













TECH BRIEFS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

-  **Technology Focus**
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-  **Software**
-  **Materials**
-  **Mechanics/Machinery**
-  **Manufacturing**
-  **Bio-Medical**
-  **Physical Sciences**
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-  **Books and Reports**

INTRODUCTION

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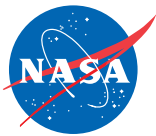
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Ka-Band TWT High-Efficiency Power Combiner for High-Rate Data Transmission

Two-way combiner waveguide circuit can be concatenated for 2^n -way combining.

John H. Glenn Research Center, Cleveland, Ohio

A four-port magic-T hybrid waveguide junction serves as the central component of a high-efficiency two-way power combiner circuit for transmitting a high-rate phase-modulated digital signal at a carrier frequency in the Ka-band (between 27 and 40 GHz). This power combiner was developed to satisfy a specific requirement to efficiently combine the coherent outputs of two traveling-wave-tube (TWT) amplifiers that are typically characterized by power levels on the order of 100 W or more. In this application, the use of a waveguide-based power combiner (instead of a coaxial-cable- or microstrip-based power combiner, for example) is dictated by requirements for low loss, high power-handling capability, and broadband response. Combiner efficiencies were typically 90 percent or more over both the linear and saturated output power regions of operation of the TWTs.

Figure 1 depicts the basic configuration of the magic-T hybrid junction. The coherent outputs of the two TWTs enter through ports 1 and 4. As a result of the orientations of the electromagnetic fields, which also provides a needed high port-to-port isolation, of these two input signals and the interior design of the magic-T junction, the input powers are divided so as to add in phase at one output port (port 2), and to be opposite in phase and hence cancel each other at the opposite coplanar output port (port 3). The net result is that the output power at port 2 is essentially double that of the output of one TWT, minus the power lost in the magic-T hybrid junction. Optimum performance as a high-efficiency power combiner thus requires a balance of both power and phase at the input ports of the magic-T.

Replicas of this two-way combiner can be arranged in a binary configuration to obtain a 2^n -way (where n is an integer) combiner. For example, Figure 2 illustrates the use of three two-way combiners to combine the outputs of four TWTs.

In data transmission tests at the Deep

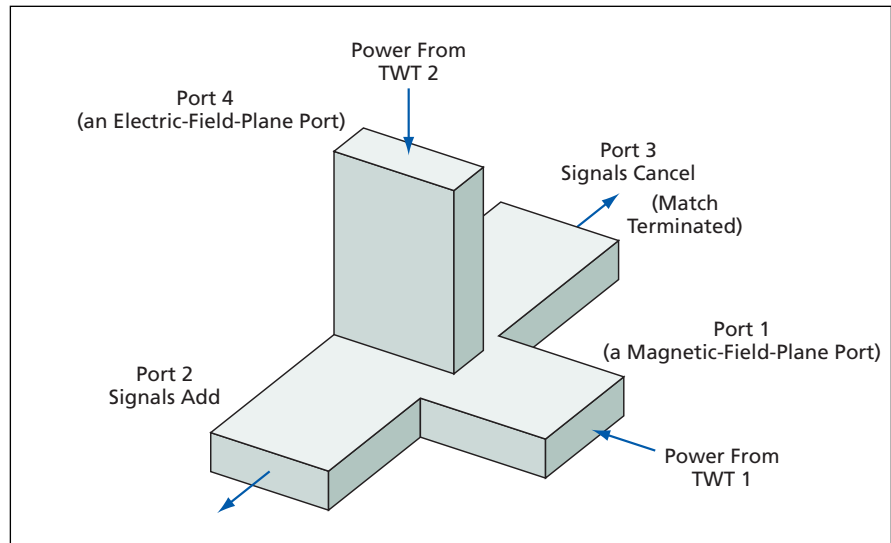


Figure 1. Basic configuration of a four-port **Magic-T Hybrid Waveguide Junction**. In the present application, coherent signals entering via input ports 1 and 4 add at output port 2 and cancel each other at output port 3.

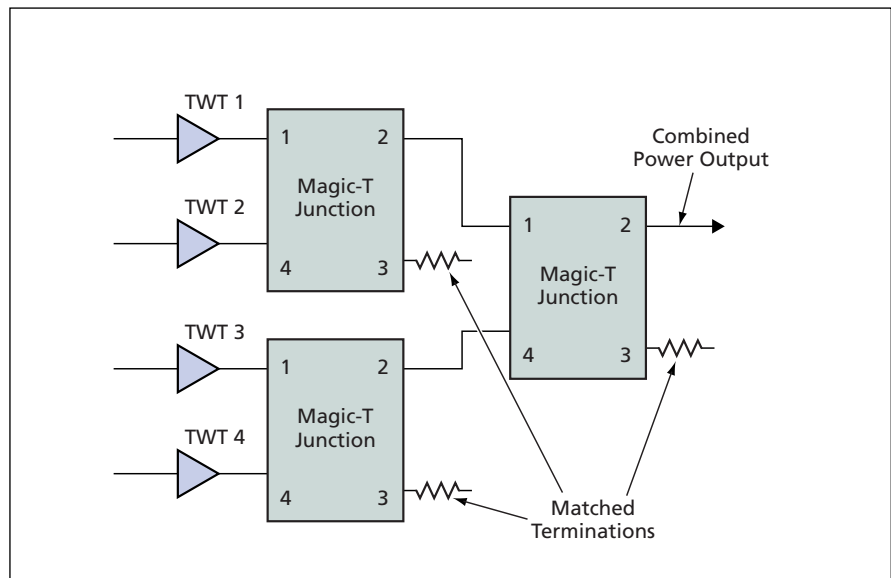


Figure 2. This **Four-Way Power Combiner** consists mainly of three magic-T junctions like that of Figure 1 in a binary configuration.

Space Network carrier frequency of 32.05 GHz, it was found that, because of the broad maximum in peak output power at the sum port, a phase-modulated narrow bandwidth data signal

could be transmitted at a rate of 8 Mb/s via this power combiner with no observable error. However, a 622-Mb/s data signal (for which a minimum bandwidth of 311 MHz was required) initially could

not be transmitted because of a large drop in signal power at the band edges. The large drop was the result of significant phase imbalance at the input ports of the magic-T hybrid junction resulting from a large difference between the rates of change of phase with frequency, which in turn was caused by a large difference between the electrical lengths of the two TWT signal paths. To correct for this disparity in electrical lengths, it was necessary to add a dispersive circuit element to one of the paths, thereby reduc-

ing the difference between the rates of change of phase by more than an order of magnitude. This correction made it possible to transmit the 622-Mb/s signal at a very low bit error rate (10^{-8}).

The helical TWTs used in the above demonstration have bandwidths of at least 9 GHz. By maintaining a balance of phase with changes in frequency at the input ports, it is thus possible to extend the operational bandwidth of the magic-T hybrid junction, which was observed to be at least 3 GHz, to that offered by the

inherently wide band individual TWTs.

This work was done by Edwin G. Wintucky, Rainee Simons, and Karl R. Vaden of Glenn Research Center; Gary G. Lesny of Alphaport Inc.; and Jeffrey L. Glass of ZIN. 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: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18092-1.

Reusable, Extensible High-Level Data-Distribution Concept

Users can optimize distributions for parallel computing, without concern for tedious details.

NASA's Jet Propulsion Laboratory, Pasadena, California

A framework for high-level specification of data distributions in data-parallel application programs has been conceived. [As used here, "distributions" signifies means to express locality (more specifically, locations of specified pieces of data) in a computing system composed of many processor and memory components connected by a network.] Inasmuch as distributions exert a great effect on the performances of application programs, it is important that a distribution strategy be flexible, so that distributions can be adapted to the requirements of those programs. At the same time, for the sake of productivity in

programming and execution, it is desirable that users be shielded from such error-prone, tedious details as those of communication and synchronization.

As desired, the present framework enables a user to refine a distribution type and adjust it to optimize the performance of an application program and conceals, from the user, the low-level details of communication and synchronization. The framework provides for a reusable, extensible, data-distribution design, denoted the design pattern, that is independent of a concrete implementation. The design pattern abstracts over coding patterns that have been found to

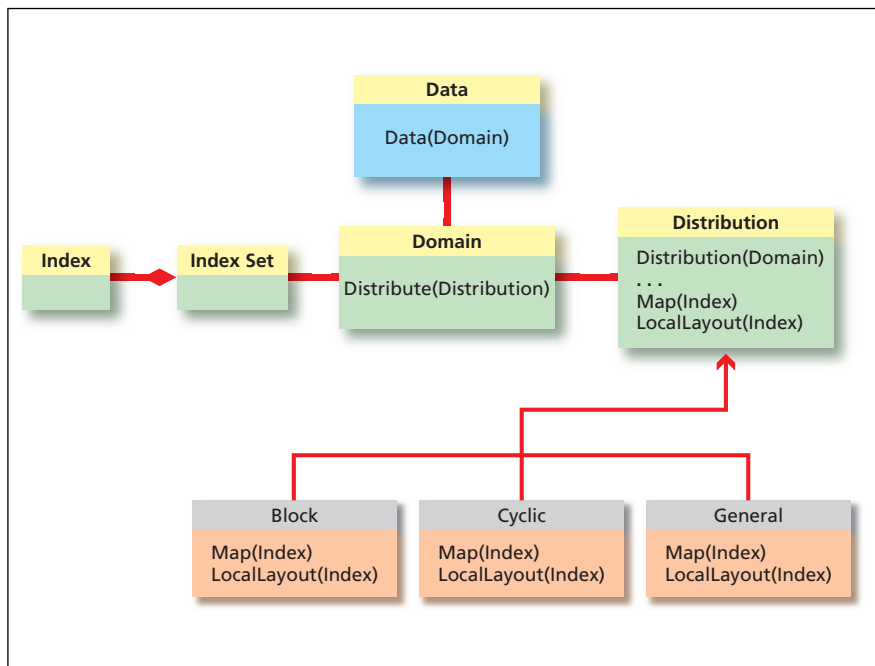
be commonly encountered in both manually and automatically generated distributed parallel programs.

The following description of the present framework is necessarily oversimplified to fit within the space available for this article. Distributions are among the elements of a conceptual data-distribution machinery, some of the other elements being denoted domains, index sets, and data collections (see figure). Associated with each domain is one index set and one distribution. A distribution class interface (where "class" is used in the object-oriented-programming sense) includes operations that enable specification of the mapping of an index to a unit of locality. Thus, "Map(Index)" specifies a unit, while "LocalLayout(Index)" specifies the local address within that unit. The distribution class can be extended to enable specification of commonly used distributions or novel user-defined distributions.

A data collection can be defined over a domain. The term "data collection" in this context signifies, more specifically, an abstraction of mappings from index sets to variables. Since the index set is distributed, the addresses of the variables are also distributed.

This work was done by Mark James, Hans Zima, and Roxana Diaconescu 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-42538.



The Items Named in the Boxes are the elements involved in defining a distribution.

▶ Processing Satellite Imagery To Detect Waste Tire Piles

Less time is needed for searching for previously unidentified piles.

Ames Research Center, Moffett Field, California

A methodology for processing commercially available satellite spectral imagery has been developed to enable identification and mapping of waste tire piles in California. The California Integrated Waste Management Board initiated the project and provided funding for the method's development. The methodology includes the use of a combination of previously commercially available image-processing and georeferencing software used to develop a model that specifically distinguishes between tire piles and other objects. The methodology reduces the time that must be spent to initially survey a region for tire sites, thereby increasing inspectors' and managers' time available for remediation of the sites. Remediation is needed because millions of used tires are discarded every year, waste tire piles pose fire hazards, and mosquitoes often breed in water trapped in tires. It should be possible to adapt the methodology to regions outside California by modifying some of the algorithms implemented in the software to account for geographic differences in spectral characteristics associated with terrain and climate.

The task of identifying tire piles in satellite imagery is uniquely challenging because of their low reflectance levels: Tires tend to be spectrally confused with shadows and deep water, both of which reflect little light to satellite-borne imaging systems. In this methodology, the challenge is met, in part, by use of software that implements the Tire Identification from Reflectance (TIRe) model. The development of the TIRe model included incorporation of lessons learned in previous research on the detection and mapping of tire piles by use of manual/visual and/or computational analysis of aerial and satellite imagery.

The TIRe model is a computational model for identifying tire piles and discriminating between tire piles and other objects. The input to the TIRe model is the georeferenced but otherwise raw satellite spectral images of a geographic region to be surveyed. The TIRe model identifies the darkest objects in the images and, on the basis of spatial and spectral image characteristics, discriminates against other dark objects, which can include vegetation,

some bodies of water, and dark soils. The TIRe model can identify piles of as few as 100 tires. The output of the TIRe model is a binary mask showing areas containing suspected tire piles and spectrally similar features. This mask is overlaid on the original satellite imagery and examined by a trained image analyst, who strives to further discriminate against non-tire objects that the TIRe model tentatively identified as tire piles. After the analyst has made adjustments, the mask is used to create a synoptic, geographically accurate tire-pile survey map, which can be overlaid with a road map and/or any other map or set of georeferenced data, according to a customer's preferences.

This work was done by Joseph Skiles of NASA Ames Research Center and Cynthia Schmidt, Becky Quinlan, and Catherine Huybrechts of San Jose State University Foundation. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to Catherine Huybrechts at endpointenvironmental.com. Refer to ARC-15916-1.

▶ Monitoring by Use of Clusters of Sensor-Data Vectors

Incoming data vectors are compared with clustered vectors representative of normal operation.

Ames Research Center, Moffett Field, California

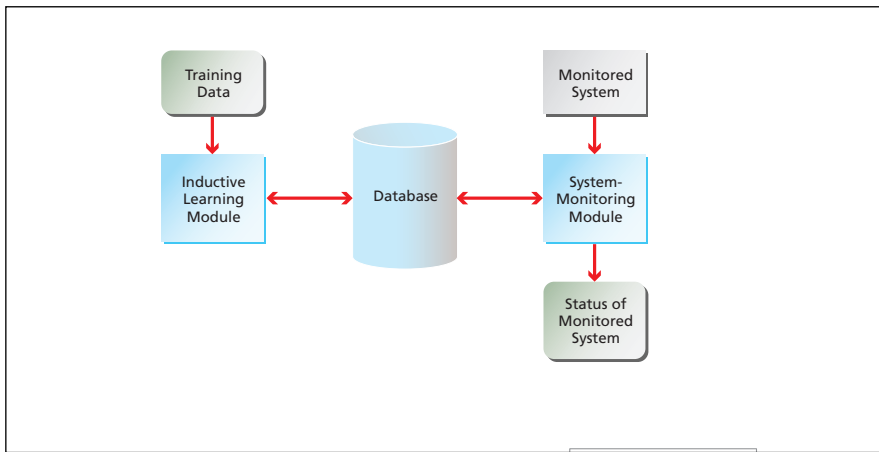
The inductive monitoring system (IMS) is a system of computer hardware and software for automated monitoring of the performance, operational condition, physical integrity, and other aspects of the "health" of a complex engineering system (e.g., an industrial process line or a spacecraft). The input to the IMS consists of streams of digitized readings from sensors in the monitored system. The IMS determines the type and amount of any deviation of the monitored system from a nominal or normal ("healthy") condition on the basis of a comparison between (1) vectors constructed from the incoming sensor data and (2) corresponding vectors in a database of nominal or normal behavior. The term "inductive" reflects the use of a process reminiscent of tra-

ditional mathematical induction to "learn" about normal operation and build the nominal-condition database. The IMS offers two major advantages over prior computational monitoring systems: The computational burden of the IMS is significantly smaller, and there is no need for abnormal-condition sensor data for training the IMS to recognize abnormal conditions.

The figure schematically depicts the relationships among the computational processes effected by the IMS. Training sensor data are gathered during normal operation of the monitored system, detailed computational simulation of operation of the monitored system, or both. The training data are formed into vectors that are used to generate the database. The vectors in the database are

clustered into regions that represent normal or nominal operation. Once the database has been generated, the IMS compares the vectors of incoming sensor data with vectors representative of the clusters. The monitored system is deemed to be operating normally or abnormally, depending on whether the vector of incoming sensor data is or is not, respectively, sufficiently close to one of the clusters. For this purpose, a distance between two vectors is calculated by a suitable metric (e.g., Euclidean distance) and "sufficiently close" signifies lying at a distance less than a specified threshold value.

It must be emphasized that although the IMS is intended to detect off-nominal or abnormal performance or health, it is not necessarily capable of perform-



The **Inductive Learning Module** builds a database containing clusters of sensor-data vectors. Each cluster in the database represents a range of normal variations of sensor data during normal operation.

ing a thorough or detailed diagnosis. Limited diagnostic information may be available under some circumstances. For example, the distance of a vector of incoming sensor data from the nearest cluster could serve as an indication of the severity of a malfunction. The iden-

tity of the nearest cluster may be a clue as to the identity of the malfunctioning component or subsystem.

It is possible to decrease the IMS computation time by use of a combination of cluster-indexing and -retrieval methods. For example, in one method,

the distances between each cluster and two or more reference vectors can be used for the purpose of indexing and retrieval. The clusters are sorted into a list according to these distance values, typically in ascending order of distance. When a set of input data arrives and is to be tested, the data are first arranged as an ordered set (that is, a vector). The distances from the input vector to the reference points are computed. The search of clusters from the list can then be limited to those clusters lying within a certain distance range from the input vector; the computation time is reduced by not searching the clusters at a greater distance.

This work was done by David L. Iverson of Ames Research Center. Further information is contained in a TSP (see page 1).

This invention is owned by NASA and a patent application has been filed. Inquiries concerning rights for the commercial use of this invention should be addressed to the Ames Technology Partnerships Division at (650) 604-2954. Refer to ARC-15058-1.



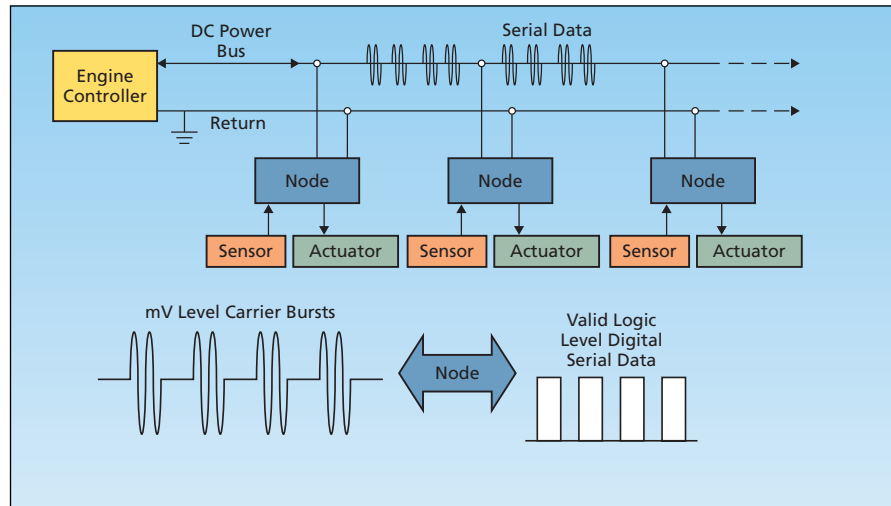
Circuit and Method for Communication Over DC Power Line

New technique usable in harsh, high-heat environments, allows for networking and smart vehicle operation with no additional wiring beyond power.

John H. Glenn Research Center, Cleveland, Ohio

A circuit and method for transmitting and receiving on-off-keyed (OOK) signals with fractional signal-to-noise ratios uses available high-temperature silicon-on-insulator (SOI) components to move computational, sensing, and actuation abilities closer to high-temperature or high-ionizing radiation environments such as vehicle engine compartments, deep-hole drilling environments, industrial control and monitoring of processes like smelting, and operations near nuclear reactors and in space. This device allows for the networking of multiple, like nodes to each other and to a central processor. It can do this with nothing more than the already *in-situ* power wiring of the system. The device's microprocessor allows it to make intelligent decisions within the vehicle operational loop and to effect control outputs to its associated actuators. The figure illustrates how each node converts digital serial data to OOK 18-kHz in transmit mode and vice-versa in receive mode; though operations at lower frequencies or up to a megahertz are within reason using this method and these parts.

This innovation's technique modulates a DC power bus with millivolt-level signals through a MOSFET (metal oxide semiconductor field effect transistor) and resistor by OOK. It receives and demodulates this signal from the DC power bus through capacitive coupling at high temperature and in high ionizing radiation environments. The demodulation of the OOK signal is accomplished by using an asynchronous quadrature detection technique realized by a quasi-discrete Fourier transform through use of the quadrature components (0° and 90° phases) of the carrier frequency as generated by the microcontroller and as a function of the selected crystal frequency driving its oscillator. The detected signal is rectified using an absolute-value circuit containing no diodes (diodes being non-operational at high temperatures), and only operational amplifiers.



In **Transmitting and Receiving OOK Signals**, each node converts digital serial data to OOK 18-kHz in transmit mode, and vice-versa in receive mode.

The absolute values of the two phases of the received signal are then summed and hard limited (digitized) by comparing them to a reference level and are then input into a microprocessor as a serial bit stream. The quasi-discrete Fourier transform is performed in high-temperature components (operational amplifiers, analog switches, resistors, and capacitors). The demodulated signal is a serial data stream that is input to the UART (universal asynchronous receiver transmitter) receiver pin of the microprocessor. The OOK of the carrier frequency uses the output of the UART pin as an enabling signal that drives the gate of the MOSFET. Logic low bits enable the carrier frequency (realized by using the 0° phase signal from the microcontroller, though either phase may be used) to be DC-coupled to the power supply bus through a current-limiting resistor mounted between the MOSFET drain and the supply rail. The presence of logic lows on the power supply rail is realized by carrier bursts while logic highs are realized by the absence of bursts.

The local power for the circuit is derived from a 5-volt regulator with the DC power supply rail as its input. The data imposed

upon the supply rail does not substantially present itself upon the local power rail of the circuit because its lower excursions are above the dropout voltage of the regulator, and are also within the regulator's power supply rejection specifications. By needing only the power bus for both power and data, this device represents a decrease in added weight to an engine system. Also, moving processing power closer to actuators and sensors makes distributed control possible by lessening the burden on a central processing element.

This device is configured from commercially available components. The commercial amplifier and analog switch used in this device also have been shown to have high ionizing radiation hardness. This technique is portable to any component grade for applications in more benign environments.

This work was done by Michael J. Krawski and Norman F. Prokop 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: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18207-1.



Switched Band-Pass Filters for Adaptive Transceivers

Switched filters could be reconfigured to conform to diverse standards.

Stennis Space Center, Mississippi

Switched band-pass filters are key components of proposed adaptive, software-defined radio transceivers that would be parts of envisioned digital-data-communication networks that would enable real-time acquisition and monitoring of data from geographically distributed sensors. Examples of sensors to be connected to such networks include security cameras, radio-frequency identification units, and geolocation units based on the Global Positioning System. Through suitable software configuration and without changing hardware, these transceivers could be made to operate according to any of a number of complex wireless-communication standards that could be characterized by diverse modulation schemes, bandwidths, and data-handling protocols.

The adaptive transceivers would include field-programmable gate arrays

(FPGAs) and digital signal-processing hardware. In the receiving path of a transceiver, the incoming signal would be amplified by a low-noise amplifier (LNA). The output spectrum of the LNA would be processed by a band-pass filter operating in the frequency range between 900 MHz and 2.4 GHz. Then a down-converter would translate the signal to a lower frequency range to facilitate analog-to-digital conversion, which would be followed by baseband processing by one or more FPGAs. In the transmitting path, a digital stream would first be converted to an analog signal, which would then be up-converted to a selected frequency band before being applied to a transmitting power amplifier.

The aforementioned band-pass filter in the receiving path would be a combination of resonant inductor-and-capacitor filters and switched band-pass filters. The

overall combination would implement a switch function designed mathematically to exhibit desired frequency responses and to switch the signal in each frequency band to an analog-to-digital converter appropriate for that band to produce a digital intermediate-frequency signal for digital signal processing.

This work was done by Ray Wang of Mobitrum Corp. for Stennis Space Center.

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:

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Silver Spring, MD 20910

Telephone No.: (301) 585-4040

E-mail: ray_wang@mobitrum.com

Refer to SSC-00260, volume and number of this NASA Tech Briefs issue, and the page number.

Noncoherent DTTLs for Symbol Synchronization

At high signal-to-noise ratios, performances would approach those of coherent DTTLs.

NASA's Jet Propulsion Laboratory, Pasadena, California

Noncoherent data-transition tracking loops (DTTLs) have been proposed for use as symbol synchronizers in digital communication receivers. [Communication-receiver subsystems that can perform their assigned functions in the absence of synchronization with the phases of their carrier signals ("carrier synchronization") are denoted by the term "noncoherent," while receiver subsystems that cannot function without carrier synchronization are said to be "coherent."] The proposal applies, more specifically, to receivers of binary phase-shift-keying (BPSK) signals generated by directly phase-modulating binary non-return-to-zero (NRZ) data streams onto carrier signals having known frequencies but unknown phases. The proposed noncoherent DTTLs would be modified versions of traditional DTTLs, which are coherent.

The symbol-synchronization problem is essentially the problem of recovering symbol timing from a received signal. In the traditional, coherent approach to symbol synchronization, it is necessary to establish carrier synchronization in order to recover symbol timing. A traditional DTTL effects an iterative process in which it first generates an estimate of the carrier phase in the absence of symbol-synchronization information, then uses the carrier-phase estimate to obtain an estimate of the symbol-synchronization information, then feeds the symbol-synchronization estimate back to the carrier-phase-estimation subprocess. In a noncoherent symbol-synchronization process, there is no need for carrier synchronization and, hence, no need for iteration between carrier-synchronization and symbol-synchronization subprocesses.

The proposed noncoherent symbol-synchronization process is justified theoretically by a mathematical derivation that starts from a maximum *a posteriori* (MAP) method of estimation of symbol timing utilized in traditional, coherent DTTLs. In that MAP method, one chooses the value of a variable of interest (in this case, the offset in the estimated symbol timing) that causes a likelihood function of symbol estimates over some number of symbol periods to assume a maximum value. In terms that are necessarily oversimplified to fit within the space available for this article, it can be said that the mathematical derivation involves a modified interpretation of the likelihood function that lends itself to noncoherent DTTLs.

The proposal encompasses both linear and nonlinear noncoherent DTTLs. The performances of both have

been computationally simulated; for comparison, the performances of linear and nonlinear coherent DTTLs have also been computationally simulated. The results of these simulations show that, among other things, the expected mean-square timing errors of coherent

and noncoherent DTTLs are relatively insensitive to window width. The results also show that at high signal-to-noise ratios (SNRs), the performances of the noncoherent DTTLs approach those of their coherent counterparts at, while at low SNRs, the noncoherent DTTLs

incur penalties of the order of 1.5 to 2 dB.

This work was done by Marvin Simon and Andre Tkacenko of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-42540

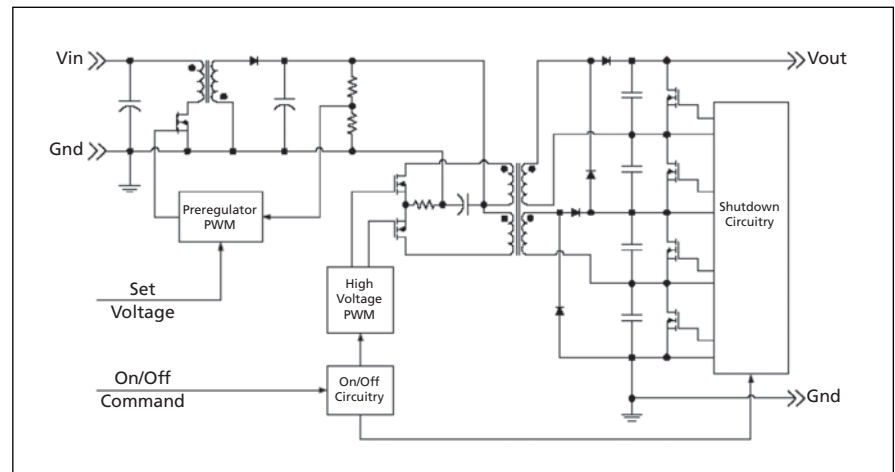
High-Voltage Power Supply With Fast Rise and Fall Times

Output is electronically programmable and electronically switchable.

Marshall Space Flight Center, Alabama

A special-purpose high-voltage power supply can be electronically switched on and off with fast rise and fall times, respectively. The output potential is programmable from 20 to 1,250 V. An output current of 50 μA can be sustained at 1,250 V. The power supply was designed specifically for electronically shuttering a microchannel plate in an x-ray detector that must operate with exposure times as short as 1 ms. The basic design of the power supply is also adaptable to other applications in which there are requirements for rapid slewing of high voltages.

The power-supply circuitry (see figure) includes a preregulator, which is used to program the output at 1/30 of the desired output potential. After the desired voltage has been set, the outputs of a pulse width modulator (PWM) are enabled and used to amplify the preregulator output potential by 30. The amplification is achieved by use of two voltage doublers with a transformer that has two primary and two secondary windings. A resistor is used to limit the current by controlling the drive voltage of two field-effect transistors (FETs) during turn-on of the PWM. A pulse transformer is



This Power-Supply Circuit features a rise time of 80 μs and a fall time of 60 μs .

used to turn on four FETs to short-circuit four output capacitors when the outputs of the PWM have been disabled. The most notable aspects of the performance of the power supply are a rise time of only 80 μs and a fall time of only 60 μs at a load current of 50 μA or less. Another notable aspect is that the application of a 0-to-5-V square wave to a shutdown pin of the PWM

causes the production of a 0-to-1,250-V square wave at the output terminals.

This work was done by Douglas B. Bear-den, Richard M. Acker, and Robert E. Kapustka of Marshall Space Flight Center. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31912-1.

Waveguide Calibrator for Multi-Element Probe Calibration

Acoustic waveguide technology produces the same acoustic field at each of the sensing elements.

Stennis Space Center, Mississippi

A calibrator, referred to as the "spider" design, can be used to calibrate probes incorporating multiple acoustic sensing elements. The application is an acoustic energy density probe, although the calibrator can be used for other types of acoustic probes. The calibrator relies on the use of acoustic waveguide technology to produce the same acoustic field at each of the sensing elements. As a result, the sensing elements

can be separated from each other, but still calibrated through use of the acoustic waveguides.

Standard calibration techniques involve placement of an individual microphone into a small cavity with a known, uniform pressure to perform the calibration. If a cavity is manufactured with sufficient size to insert the energy density probe, it has been found that a uniform pressure field can only be created at very

low frequencies, due to the size of the probe. The size of the energy density probe prevents one from having the same pressure at each microphone in a cavity, due to the wave effects.

The "spider" design probe is effective in calibrating multiple microphones separated from each other. The spider design ensures that the same wave effects exist for each microphone, each with an individual sound path. The cali-

brator's speaker is mounted at one end of a 14-cm-long and 4.1-cm diameter small plane-wave tube. This length was chosen so that the first evanescent cross mode of the plane-wave tube would be attenuated by about 90 dB, thus leaving just the plane wave at the termination plane of the tube. The tube terminates with a small, acrylic plate with five holes placed symmetrically about the axis of the speaker. Four ports are included for the four microphones on the probe. The fifth port is included for the pre-calibrated reference microphone.

The ports in the acrylic plate are in turn connected to the probe sensing elements via flexible PVC tubes. These

five tubes are the same length, so the acoustic wave effects are the same in each tube. The flexible nature of the tubes allows them to be positioned so that each tube terminates at one of the microphones of the energy density probe, which is mounted in the acrylic structure, or the calibrated reference microphone. Tests performed verify that the pressure did not vary due to bends in the tubes. The results of these tests indicate that the average sound pressure level in the tubes varied by only 0.03 dB as the tubes were bent to various angles.

The current calibrator design is effective up to a frequency of approximately

4.5 kHz. This upper design frequency is largely due to the diameter of the plane-wave tubes.

This work was done by Scott D. Sommerfeldt and Jonathan D. Blotter of Brigham Young University for Stennis Space Center.

Inquiries concerning rights for its commercial use should be addressed to:

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Refer to SSC-00248, volume and number of this NASA Tech Briefs issue, and the page number.

Four-Way Ka-Band Power Combiner

A prior X-band design has been adapted to Ka band.

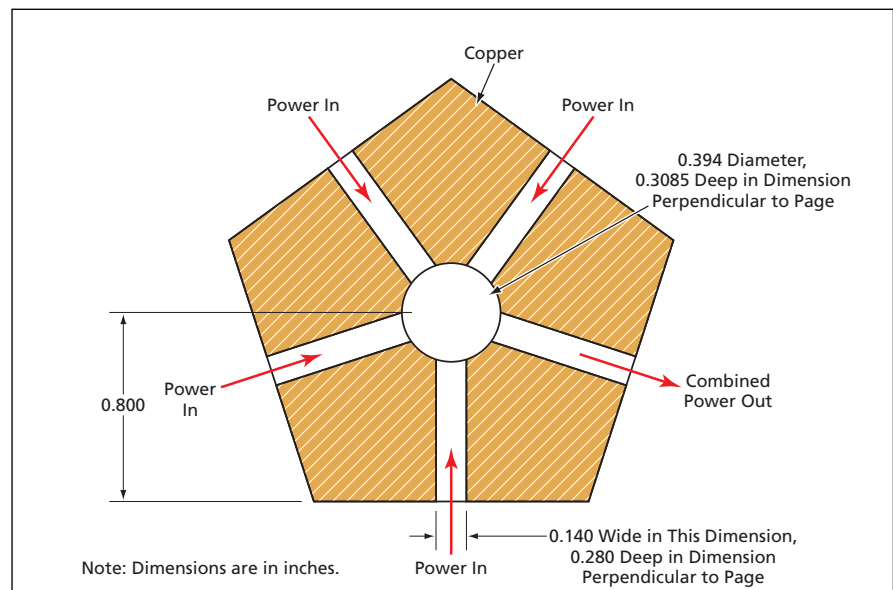
NASA's Jet Propulsion Laboratory, Pasadena, California

A waveguide structure for combining the outputs of four amplifiers operating at 35 GHz (Ka band) is based on a similar prior structure used in the X band. The structure is designed to function with low combining loss and low total reflected power at a center frequency of 35 GHz with a 160 MHz bandwidth.

The structure (see figure) comprises mainly a junction of five rectangular waveguides in a radial waveguide. The outputs of the four amplifiers can be coupled in through any four of the five waveguide ports. Provided that these four signals are properly phased, they combine and come out through the fifth waveguide port.

This work was done by Raul Perez and Samuel Li of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

NPO-41291



The **Power Combiner Structure** has five ports, of which four are used for input and one for output. This is a simplified cross-sectional view: holes for fastening and cooling are omitted for the sake of clarity.

Loss-of-Control-Inhibitor Systems for Aircraft

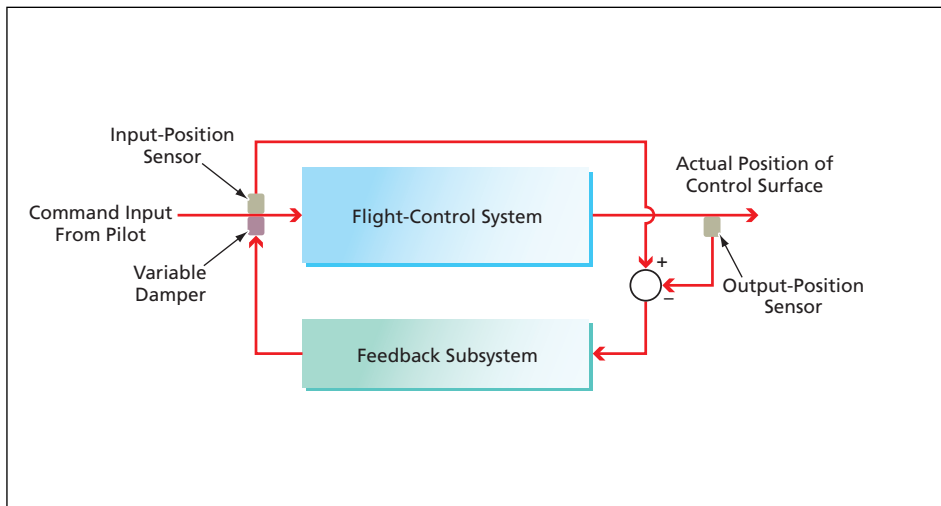
Excessive commands are resisted by feedback in the form of damping forces.

Langley Research Center, Hampton, Virginia

Systems to provide improved tactile feedback to aircraft pilots are being developed to help the pilots maintain harmony between their control actions and the positions of aircraft control surfaces, thereby helping to prevent loss of con-

trol. A system of this type, denoted a loss-of-control-inhibitor system (LOCIS) can be implemented as a relatively simple addition to almost any pre-existing flight-control system. The LOCIS concept offers at least a partial solution to

the problem of (1) keeping a pilot aware of the state of the control system and the aircraft and (2) maintaining sufficient control under conditions that, as described below, have been known to lead to loss of control.



This **Simplified Block Diagram** represents a LOCIS added to a flight-control system that includes a single control surface.

Current commercial aircraft exhibit uneven responses of primary flight-control surfaces to aggressive pilot control commands, leading to deterioration of pilots' ability to control their aircraft. In severe cases, this phenomenon can result in loss of control and consequent loss of aircraft. For an older aircraft equipped with a purely mechanical control system, the loss of harmony between a pilot's command action and the control-surface response can be attributed to compliance in the control system (caused, for example, by stretching of control cables, flexing of push rods, or servo-valve distortion). In a newer aircraft equipped with a fly-by-wire control system, the major contributions to loss of harmony between the pilot and the control surfaces are delays attributable to computer cycle time, control shaping,

filtering, aliasing, servo-valve distortion, and actuator rate limiting. In addition, a fly-by-wire control system provides no tactile feedback that would enable the pilot to sense such features of the control state as surface flutter, surface jam, position limiting, actuator rate limiting, and control limiting imposed by the aircraft operational envelope.

Hence, for example, when a pilot is involved in aggressive "closed-loop" maneuvering, as when encountering a wake-vortex upset on final landing approach, the control-surface delay can lead to loss of control. Aggressive piloting can be triggered and exacerbated by control-system anomalies, which the pilot cannot diagnose because of the lack of symptoms caused by the absence of feedback through the controls. The purpose served by a LOCIS is to counter-

act these adverse effects by providing real-time feedback that notifies the pilot that the aircraft is tending to lag the pilot's commands.

A LOCIS (see figure) includes cockpit control input-position sensors, control-surface output-position sensors, variable dampers (for example, shock absorbers containing magneto-rheological fluids such that the damping forces can be varied within times of the order of milliseconds by varying applied magnetic fields) attached to the cockpit control levers, electromagnet coils to apply the magnetic fields, and feedback control circuits to drive the electromagnet coils. The feedback control gains are chosen so that the current applied to each

electromagnet coil results in a damping force that increases in a suitable nonlinear manner (e.g., exponentially) with the difference between the actual and commanded positions of the affected control surface. The increasing damping force both alerts the pilot to the onset of a potentially dangerous situation and resists the pilot's effort to command a control surface to change position at an excessive rate.

This work was done by Ralph C. A'Harrah of NASA Headquarters. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center, at (757) 864-3521. Refer to LAR-16566.

Improved Underwater Excitation-Emission Matrix Fluorometer

This is a higher-resolution, smaller, more-capable successor to a prior instrument.

Stennis Space Center, Mississippi

A compact, high-resolution, two-dimensional excitation-emission matrix fluorometer (EEMF) has been designed and built specifically for use in identifying and measuring the concentrations of organic compounds, including polluting hydrocarbons, in natural underwater settings. Heretofore, most EEMFs have been designed and built for installation in laboratories, where they are used to analyze the contents of samples collected in the field and brought to the laboratories. Because the present EEMF can be operated

in the field, it is better suited to measurement of spatially and temporally varying concentrations of substances of interest.

In excitation-emission matrix (EEM) fluorometry, fluorescence is excited by irradiating a sample at one or more wavelengths, and the fluorescent emission from the sample is measured at multiple wavelengths. When excitation is provided at only one wavelength, the technique is termed one-dimensional (1D) EEM fluorometry because the resulting matrix of fluorescence emission data (the EEM)

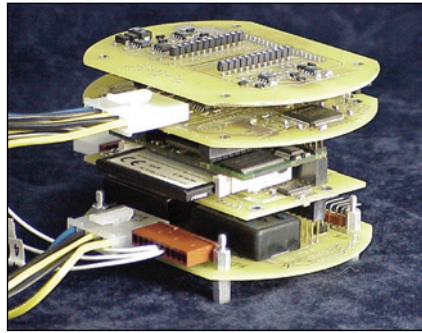
contains only one row or column. When excitation is provided at multiple wavelengths, the technique is termed two-dimensional (2D) EEM fluorometry because the resulting EEM contains multiple rows and columns.

EEM fluorometry — especially the 2D variety — is well established as a means of simultaneously detecting numerous dissolved and particulate compounds in water. Each compound or pool of compounds has a unique spectral fluorescence signature, and each EEM is rich in information

content, in that it can contain multiple fluorescence signatures. By use of deconvolution and/or other mixture-analyses techniques, it is often possible to isolate the spectral signature of compounds of interest, even when their fluorescence spectra overlap.

What distinguishes the present 2D EEMF over prior laboratory-type 2D EEMFs are several improvements in packaging (including a sealed housing) and other aspects of design that render it suitable for use in natural underwater settings. In addition, the design of the present 2D EEMF incorporates improvements over the one prior commercial underwater 2D EEMF, developed in 1994 by the same company that developed the present one. Notable advanced features of the present EEMF include the following:

- High sensitivity and spectral resolution are achieved by use of an off-the-shelf grating spectrometer equipped with a sensor in the form of a commercial astronomical-grade 256x532-pixel charge-coupled-device (CCD) array.



This Assembly of Electronic-Circuit Boards takes up significantly less room than would a conventional assembly containing circuits that perform the same variety of functions. The CCD, shown here, is mounted onto pins on the top board.

- All of the power supply, timing, control, and readout circuits for the illumination source and the CCD, ancillary environmental monitoring sensors, and circuitry for controlling a shutter or filter motor are custom-designed and mounted compactly on three circuit boards below a fourth circuit board that holds the CCD (see figure).

- The compactness of the grating spectrometer, CCD, and circuit assembly makes it possible to fit the entire instrument into a compact package that is intended to be maneuverable underwater by one person.
- In mass production, the cost of the complete instrument would be relatively low — estimated at approximately \$30,000 at 2005 prices.

This work was done by Casey Moore, John da Cunha, Bruce Rhoades, and Michael Twardowski of Western Environmental Technology Laboratories, Inc. for Stennis Space Center.

Inquiries concerning rights for its commercial use should be addressed to:

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 620 Applegate St.
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 (541) 929-5650

Refer to SSC-00235, volume and number of this NASA Tech Briefs issue, and the page number.

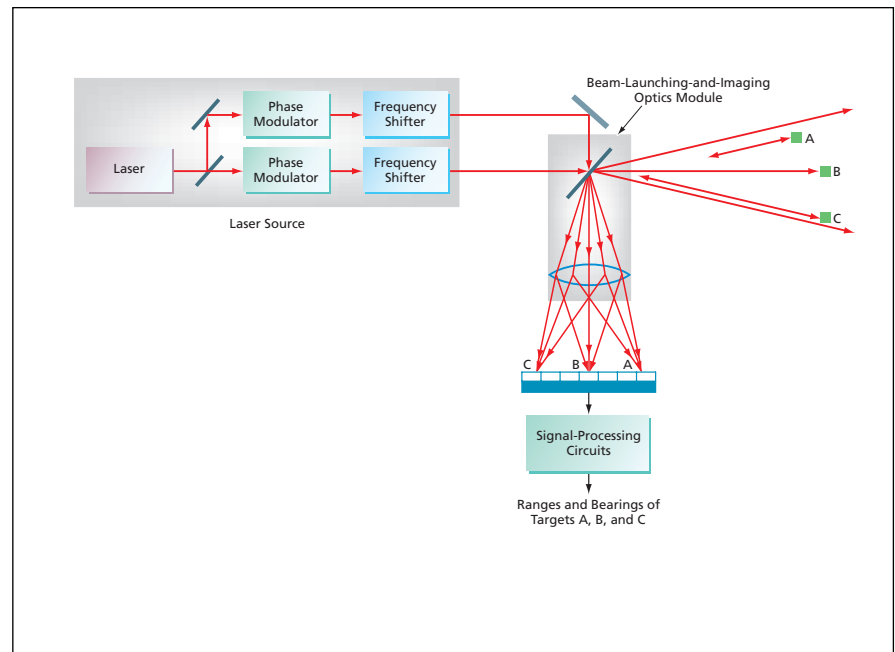
Metrology Camera System Using Two-Color Interferometry

3D locations of multiple targets are determined without mechanical scanning.

NASA's Jet Propulsion Laboratory, Pasadena, California

A metrology system that contains no moving parts simultaneously measures the bearings and ranges of multiple reflective targets in its vicinity, enabling determination of the three-dimensional (3D) positions of the targets with submillimeter accuracy. The system combines a direction-measuring metrology camera and an interferometric range-finding subsystem. Because the system is based partly on a prior instrument denoted the Modulation Sideband Technology for Absolute Ranging (MSTAR) sensor and because of its 3D capability, the system is denoted the MSTAR3D. Developed for use in measuring the shape (for the purpose of compensating for distortion) of large structures like radar antennas, it can also be used to measure positions of multiple targets in the course of conventional terrestrial surveying.

A diagram of the system is shown in the figure. One of the targets is a reference target having a known, constant distance with respect to the system. The system comprises a laser for generating local and target beams at a carrier frequency; a frequency shifting unit to introduce a frequency shift offset between



The MSTAR3D measures the bearings of targets in the manner of a star tracker and the ranges of targets by use of heterodyne interferometry.

the target and local beams; a pair of high-speed modulators that apply modulation to the carrier frequency in the

local and target beams to produce a series of modulation sidebands, the high-speed modulators having modulation

frequencies of F_L and F_M ; a target beam launcher that illuminates the targets with the target beam; optics and a multi-pixel photodetector; a local beam launcher that launches the local beam towards the multi-pixel photodetector; a mirror for projecting to the optics a portion of the target beam reflected from the targets, the optics being configured to focus the portion of the target beam at the multi-pixel photodetector; and a

signal-processing unit connected to the photodetector.

The portion of the target beam reflected from the targets produces spots on the multi-pixel photodetector corresponding to the targets, respectively, and the signal-processing unit centroids the spots to determine bearings of the targets, respectively. As the spots oscillate in intensity because they are mixed with the local laser beam that is flood illuminating the focal

plane, the phase of oscillation of each spot is measured, the phase of sidebands in the oscillation of each spot being proportional to a distance to the corresponding target relative to the reference target A.

This work was done by Serge Dubovitsky, Carl Christian Liebe, Robert Peters, and Oliver Lay of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-42187

Design and Fabrication of High-Efficiency CMOS/CCD Imagers

Economical production of back-illuminated CMOS/CCD imagers should soon become possible.

NASA's Jet Propulsion Laboratory, Pasadena, California

An architecture for back-illuminated complementary metal oxide/semiconductor (CMOS) and charge-coupled-device (CCD) ultraviolet/visible/near infrared-light image sensors, and a method of fabrication to implement the architecture, are undergoing development. The architecture and method are expected to enable realization of the full potential of back-illuminated CMOS/CCD imagers to perform with high efficiency, high sensitivity, excellent angular response, and in-pixel signal processing. The architecture and method are compatible with next-generation CMOS dielectric-forming and metallization techniques, and the process flow of the method is compatible with process flows typical of the manufacture of very-large-scale integrated (VLSI) circuits.

The architecture and method overcome all obstacles that have hitherto prevented high-yield, low-cost fabrication of back-illuminated CMOS/CCD imagers by use of standard VLSI fabrication tools and techniques. It is not possi-

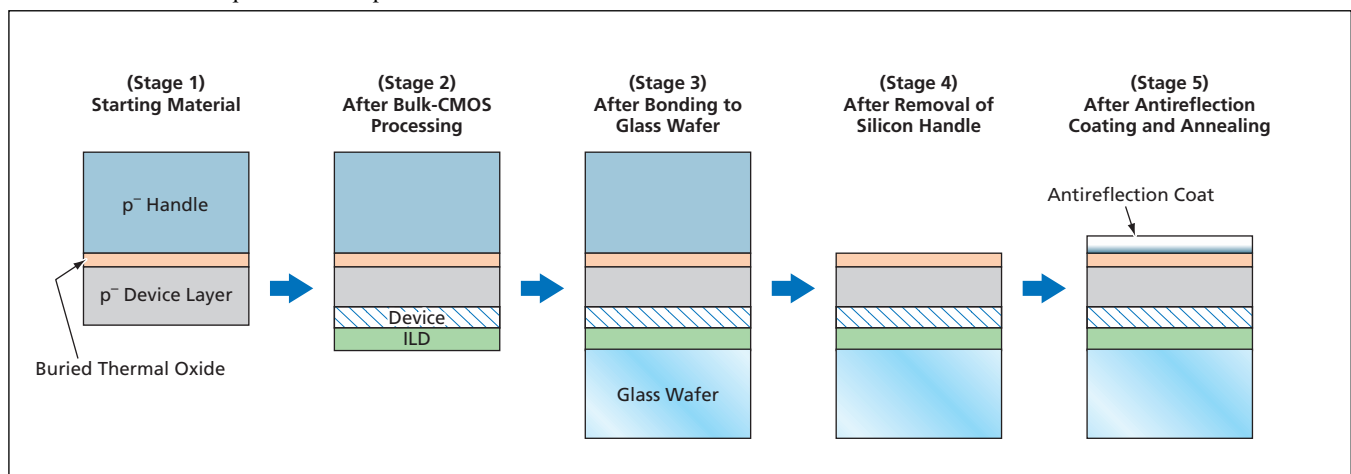
ble to discuss the obstacles in detail within the space available for this article. Briefly, the obstacles are posed by the problems of generating light-absorbing layers having desired uniform and accurate thicknesses, passivation of surfaces, forming structures for efficient collection of charge carriers, and wafer-scale thinning (in contradistinction to die-scale thinning).

A basic element of the present architecture and method — the element that, more than any other, makes it possible to overcome the obstacles — is the use of an alternative starting material: Instead of starting with a conventional bulk-CMOS wafer that consists of a p-doped epitaxial silicon layer grown on a heavily-p-doped silicon substrate, one starts with a special silicon-on-insulator (SOI) wafer that consists of a thermal oxide buried between a lightly p- or n-doped, thick silicon layer and a device silicon layer of appropriate thickness and doping. The thick silicon layer is used as a handle: that is, as a mechanical

support for the device silicon layer during micro-fabrication.

Although one starts with an SOI wafer, one uses a conventional bulk-CMOS process to fabricate the CMOS imager. The process includes implantation, oxidation, deposition of inter-layer dielectrics [ILDs (dielectric layers interspersed among metal and semiconductor structures)], and deposition and patterning of metals. Any bulk-CMOS process can be used, but it is more appropriate to use a bulk-CMOS process that has been optimized for fabrication of imagers. The bulk-CMOS process yields the structure depicted at stage 2 in the figure.

In order to prepare for back-side illumination, the CMOS structure is bonded to a glass wafer for mechanical support, as shown at stage 3. The silicon handle is then removed through a combination of wet and/or reactive-ion etching, yielding the structure shown at stage 4. The buried SiO_2 layer serves as a built-in etch stop, making it possible to form a uniformly planar back surface. In addition, the resultant



Partly Schematic Cross Sections of a wafer are shown at selected stages of processing for manufacturing CMOS imagers.

structure is self-passivated, since the device silicon layer is not exposed during etching and is protected by a high quality thermally grown oxide layer. Termination of silicon by the high quality buried oxide provides a Si-SiO₂ interface with very low interface state-density. Therefore, no additional processing is necessary, a processing step that would not only be difficult but would also be incompatible with standard VLSI processing. Inasmuch as there exists a high-selectivity etch-stop and the post-etching passivation is automatic, the process represented by the figure is fully CMOS-compatible and can be carried out at the wafer level.

Furthermore, because the device silicon is separated from the handle

through the buried oxide, no unintentional doping of the device silicon occurs during CMOS fabrication. Thus, it becomes possible to start with an SOI wafer with an appropriate doping of the device silicon layer to optimize imaging performance (e.g. high quantum efficiency, high modulation transfer function, low cross-talk, and low dark current).

The final step in the process is anti-reflection coating to increase optical coupling. Since the resultant structure is fully planar and includes only a single SiO₂ layer, one has freedom to deposit anti-reflection layer in ways that would not be possible if light were required to travel through multilayer, nonuniform ILD as in the front-illumination case.

This work was done by Bedabrata Pain of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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:

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Pasadena, CA 91109-8099
(818) 354-2240*

E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-41190, volume and number of this NASA Tech Briefs issue, and the page number.



Foam Core Shielding for Spacecraft

NASA's Jet Propulsion Laboratory, Pasadena, California

A foam core shield (FCS) system is now being developed to supplant multi-layer insulation (MLI) systems heretofore installed on spacecraft for thermal management and protection against meteoroid impacts. A typical FCS system consists of a core sandwiched between a face sheet and a back sheet. The core can consist of any of a variety of low-to-medium-density polymeric or inorganic foams chosen to satisfy application-spe-

cific requirements regarding heat transfer and temperature.

The face sheet serves to shock and thereby shatter incident meteoroids, and is coated on its outer surface to optimize its absorptance and emittance for regulation of temperature. The back sheet can be dimpled to minimize undesired thermal contact with the underlying spacecraft component and can be metallized on the surface

facing the component to optimize its absorptance and emittance. The FCS systems can perform better than do MLI systems, at lower mass and lower cost and with greater volumetric efficiency.

This work was done by Marc Adams of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-43066

CHEM-Based Self-Deploying Planetary Storage Tanks

NASA's Jet Propulsion Laboratory, Pasadena, California

A document proposes self-deploying storage tanks, based on the cold elastic hibernated memory (CHEM) concept, to be used on remote planets. The CHEM concept, described in previous *NASA Tech Briefs* articles, involves the use of open-cell shape-memory-polymer (SMP) foam sandwich structures to make lightweight, space-deployable structures that can be compressed for storage and can later be expanded, then rigidified for use.

A tank according to the proposal would be made of multiple SMP layers

(of which at least one could be an SMP foam). The tank would be fabricated at full size in the rigid, deployed condition at ambient temperature, the SMP material(s) having been chosen so that ambient temperature would be below the SMP glass-transition temperature (T_g). The tank would then be warmed to a temperature above T_g , where it would be compacted and packaged, then cooled to below T_g and kept there during launch and transport to a distant planet.

At the assigned position on the planet, the compacted tank would be heated above T_g by the solar radiation making it rebound to its original size and shape. Finally, the tank would be rigidified through natural cooling to below T_g in the planetary ambient environment.

This work was done by Witold Sokolowski and Kaushik Bhattacharya of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-43479

Sequestration of Single-Walled Carbon Nanotubes in a Polymer

The nanotubes would be solubilized for incorporation into lightweight composites.

Lyndon B. Johnson Space Center, Houston, Texas

Sequestration of single-walled carbon nanotubes (SWCNs) in a suitably chosen polymer is under investigation as a means of promoting the dissolution of the nanotubes into epoxies. The purpose of this investigation is to make it possible to utilize SWCNs as the reinforcing fibers in strong, lightweight epoxy-matrix/carbon-fiber composite materials. SWCNs are especially attractive for use as reinforcing fibers because of their stiffness and strength-to-weight

ratio: Their Young's modulus has been calculated to be 1.2 TPa, their strength has been calculated to be as much as 100 times that of steel, and their mass density is only one-sixth that of steel.

Bare SWCNs cannot be incorporated directly into composite materials of the types envisioned because they are not soluble in epoxies. Heretofore, SWCNs have been rendered soluble by chemically attaching various molecular chains to them, but such chemical attachments

compromise their structural integrity.

In the method now under investigation, carbon nanotubes are sequestered in molecules of poly(m-phenylenevinylene-co-2,5-dioctyloxy-p-phenylenevinylene) [PmPV]. The strength of the carbon nanotubes is preserved because they are not chemically bonded to the PmPV. This method exploits the tendency of PmPV molecules to wrap themselves around carbon nanotubes: the wrapping occurs partly because there ex-

ists a favorable interface between the conjugated face of a nanotube and the conjugated backbone of the polymer and partly because of the helical molecular structure of PmPV. The constituents attached to the polymer backbones (the side chains) render the PmPV-wrapped carbon nanotubes PmPV soluble in organic materials that, in turn, could be used to suspend the carbon nanotubes in epoxy precursors.

At present, this method is being optimized: The side chains on the currently available form of PmPV are very non-polar and unable to react with the epoxy resins and/or hardeners; as a consequence, SWCN/PmPV composites

have been observed to precipitate out of epoxies while the epoxies were being cured. If the side chains of the PmPV molecules were functionalized to make them capable of reacting with the epoxy matrices, it might be possible to make progress toward practical applications.

By bonding the side chains of the PmPV molecules to an epoxy matrix, one would form an PmPV conduit between the epoxy matrix and the carbon nanotubes sequestered in the PmPV. This conduit would transfer stresses from the epoxy matrix to the nanotubes. This proposed load-transfer mode is similar to that of the current practice in which silane groups are chemically

bonded to both the epoxy matrices and the fibers (often glass fibers) in epoxy-matrix/fiber composites.

This work was done by Richard A. Bley of Eltron Research Inc. for Johnson Space Center. Further information is contained in a TSP (see page 1).

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:

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4600 Nautilus Court South
Boulder, CO 80301-3241*

Refer to MSC-23257, volume and number of this NASA Tech Briefs issue, and the page number.



▶ PPC750 Performance Monitor

The PPC750 Performance Monitor (Perfmon) is a computer program that helps the user to assess the performance characteristics of application programs running under the Wind River VxWorks real-time operating system on a PPC750 computer. Perfmon generates a user-friendly interface and collects performance data by use of performance registers provided by the PPC750 architecture. It processes and presents run-time statistics on a per-task basis over a repeating time interval (typically, several seconds or minutes) specified by the user.

When the Perfmon software module is loaded with the user's software modules, it is available for use through Perfmon commands, without any modification of the user's code and at negligible performance penalty. Per-task run-time performance data made available by Perfmon include percentage time, number of instructions executed per unit time, dispatch ratio, stack "high water" mark, and level-1 instruction and data cache miss rates. The performance data are written to a file specified by the user or to the serial port of the computer.

This program was written by Donald Meyer and Igor Uchenik 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-35237.

▶ Application-Program-Installer Builder

A computer program builds application programming interfaces (APIs) and related software components for installing and uninstalling application programs in any of a variety of computers and operating systems that support the Java programming language in its binary form. This program is partly similar in function to commercial (e.g., Install-Shield) software. This program is intended to enable satisfaction of a quasi-industry-standard set of requirements for a set of APIs that would enable such

installation and uninstallation and that would avoid the pitfalls that are commonly encountered during installation of software. The requirements include the following:

- Properly detecting prerequisites to an application program before performing the installation;
- Properly registering component requirements;
- Correctly measuring the required hard-disk space, including accounting for prerequisite components that have already been installed; and
- Correctly uninstalling an application program. Correct uninstallation includes (1) detecting whether any component of the program to be removed is required by another program, (2) not removing that component, and (3) deleting references to requirements of the to-be-removed program for components of other programs so that those components can be properly removed at a later time.

This program was written by Paul Wolgast and Martha Demore of Caltech and Paul Lovvik of Sun Microsystems 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-30778.

▶ Using Visual Odometry to Estimate Position and Attitude

A computer program in the guidance system of a mobile robot generates estimates of the position and attitude of the robot, using features of the terrain on which the robot is moving, by processing digitized images acquired by a stereoscopic pair of electronic cameras mounted rigidly on the robot. Developed for use in localizing the Mars Exploration Rover (MER) vehicles on Martian terrain, the program can also be used for similar purposes on terrestrial robots moving in sufficiently visually textured environments: examples include low-flying robotic aircraft and wheeled robots moving on rocky terrain or inside buildings.

In simplified terms, the program automatically detects visual features and

tracks them across stereoscopic pairs of images acquired by the cameras. The 3D locations of the tracked features are then robustly processed into an estimate of overall vehicle motion. Testing has shown that by use of this software, the error in the estimate of the position of the robot can be limited to no more than 2 percent of the distance traveled, provided that the terrain is sufficiently rich in features. This software has proven extremely useful on the MER vehicles during driving on sandy and highly sloped terrains on Mars.

This program was written by Mark Maimone, Yang Cheng, Larry Matthies, Marcel Schoppers, and Clark Olson of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-41886.

▶ Design and Data Management System

The Design and Data Management System (DDMS) was developed to automate the NASA Engineering Order (EO) and Engineering Change Request (ECR) processes at the Propulsion Test Facilities at Stennis Space Center for efficient and effective Configuration Management (CM). Prior to the development of DDMS, the CM system was a manual, paper-based system that required an EO or ECR submitter to walk the changes through the acceptance process to obtain necessary approval signatures. This approval process could take up to two weeks, and was subject to a variety of human errors. The process also requires that the CM office make copies and distribute them to the Configuration Control Board members for review prior to meetings. At any point, there was a potential for an error or loss of the change records, meaning the configuration of record was not accurate.

The new Web-based DDMS eliminates unnecessary copies, reduces the time needed to distribute the paperwork, reduces time to gain the necessary signatures, and prevents the variety of errors inherent in the previous manual system. After implementation of the DDMS, all EOs and ECRs can be automatically checked prior to submittal to ensure that

the documentation is complete and accurate. Much of the configuration information can be documented in the DDMS through pull-down forms to ensure consistent entries by the engineers and technicians in the field.

The software also can electronically route the documents through the signature process to obtain the necessary approvals needed for work authorization. The workflow of the system allows for backups and timestamps that determine the correct routing and completion of all required authorizations in a more timely manner, as well as assuring the quality and accuracy of the configuration documents.

This program was written by Elizabeth Messer and Brad Messer of Stennis Space Center, Judy Carter of Computer Sciences Corp., Todd Singletary of Lockheed Martin, Colby Albasini of SAITECH, and Tammy Smith of ERC Incorporated.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager at Stennis Space Center (228) 688-1929. Refer to SSC-00208-1, volume and number of this NASA Tech Briefs issue, and the page number.

Simple, Script-Based Science Processing Archive

The Simple, Scalable, Script-based Science Processing (S4P) Archive (S4PA) is a disk-based archival system for remote-sensing data. It is based on the data-driven framework of S4P and is used for data transfer, data preprocessing, metadata generation, data archive, and data distribution. New data are automatically detected by the system.

S4P provides services such as data access control, data subscription, metadata publication, data replication, and data recovery. It comprises scripts that control the data flow. The system detects the availability of data on an FTP (file transfer protocol) server, initiates data transfer, preprocesses data if necessary, and archives it on readily available disk drives with FTP and HTTP (Hypertext Transfer Protocol) access, allowing instantaneous data access. There are options for plugins for data preprocessing before storage. Publication of metadata to external applications such as the Earth Observing System Clearinghouse (ECHO) is also supported.

S4PA includes a graphical user interface for monitoring the system operation and a tool for deploying the system. To ensure reliability, S4P continuously

checks stored data for integrity. Further reliability is provided by tape backups of disks made once a disk partition is full and closed. The system is designed for low maintenance, requiring minimal operator oversight.

This work was done by Christopher Lynnes, Mahabaleshwara Hegde, and C. Wrangle Barth of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15040-1

Automated Rocket Propulsion Test Management

The Rocket Propulsion Test-Automated Management System provides a central location for managing activities associated with Rocket Propulsion Test Management Board, National Rocket Propulsion Test Alliance, and the Senior Steering Group business management activities. A set of authorized users, both on-site and off-site with regard to Stennis Space Center (SSC), can access the system through a Web interface. Web-based forms are used for user input with generation and electronic distribution of reports easily accessible.

Major functions managed by this software include meeting agenda management, meeting minutes, action requests, action items, directives, and recommendations. Additional functions include electronic review, approval, and signatures. A repository/library of documents is available for users, and all items are tracked in the system by unique identification numbers and status (open, closed, percent complete, etc.). The system also provides queries and version control for input of all items.

This program was written by Ian Walters of SaiTech and Cheryl Nelson and Helene Jones of Computer Sciences Corporation for Stennis Space Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center, (228) 688-1929. Refer to SSC-00250, volume and number of this NASA Tech Briefs issue, and the page number.

Online Remote Sensing Interface

BasinTools Module 1 processes remotely sensed raster data, including multi- and hyper-spectral data products, via a Web site with no downloads and no plug-ins required. The interface provides standardized algorithms designed

so that a user with little or no remote-sensing experience can use the site. This Web-based approach reduces the amount of software, hardware, and computing power necessary to perform the specified analyses. Access to imagery and derived products is enterprise-level and controlled. Because the user never takes possession of the imagery, the licensing of the data is greatly simplified.

BasinTools takes the "just-in-time" inventory control model from commercial manufacturing and applies it to remotely-sensed data. Products are created and delivered on-the-fly with no human intervention, even for casual users. Well-defined procedures can be combined in different ways to extend verified and validated methods in order to derive new remote-sensing products, which improves efficiency in any well-defined geospatial domain. Remote-sensing products produced in BasinTools are self-documenting, allowing procedures to be independently verified or peer-reviewed. The software can be used enterprise-wide to conduct low-level remote sensing, viewing, sharing, and manipulating of image data without the need for desktop applications.

This program was written by Joel Lawhead of NVision Solutions, Inc. for Stennis Space Center.

Inquiries concerning rights for its commercial use should be addressed to:

NVision Solutions, Inc.

Stennis Space Center

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Stennis Space Center, MS 39529

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E-mail: jlawhead@nvis-inc.com

Refer to SSC-00251, volume and number of this NASA Tech Briefs issue, and the page number.

Fusing Image Data for Calculating Position of an Object

A computer program has been written for use in maintaining the calibration, with respect to the positions of imaged objects, of a stereoscopic pair of cameras on each of the Mars Explorer Rovers Spirit and Opportunity. The program identifies and locates a known object in the images. The object in question is part of a Mössbauer spectrometer located at the tip of a robot arm, the kinematics of which are known.

In the program, the images are processed through a module that extracts edges, combines the edges into line segments, and then derives ellipse centroids

from the line segments. The images are also processed by a feature-extraction algorithm that performs a wavelet analysis, then performs a pattern-recognition operation in the wavelet-coefficient space to determine matches to a texture feature measure derived from the horizontal, vertical, and diagonal coefficients. The centroids from the ellipse finder and the wavelet feature matcher are then fused to determine co-location. In the event that a match is found, the centroid (or centroids if multiple matches are present) is reported. If no match is found, the process reports the results of the analyses for further examination by human experts.

This program was written by Terrance Huntsberger, Yang Cheng, Robert Liebersbach, and Ashitey Trebi-Ollenu 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 Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-43470.

Implementation of a Point Algorithm for Real-Time Convex Optimization

The primal-dual interior-point algorithm implemented in G-OPT is a relatively new and efficient way of solving convex optimization problems. Given a prescribed level of accuracy, the convergence to the optimal solution is guaranteed in a predetermined, finite number of iterations. G-OPT Version 1.0 is a flight software implementation written in C. On-board application of the software enables autonomous, real-time guidance and control that explicitly incorporates mission constraints such as control authority (e.g. maximum thrust limits), hazard avoidance, and fuel limitations.

This software can be used in planetary landing missions (Mars pinpoint landing and lunar landing), as well as in proximity operations around small celestial bodies (moons, asteroids, and comets). It also can be used in any spacecraft mission for thrust allocation in six-degrees-of-freedom control.

This program was written by Behçet Açıkmış, Shui Motaghedi, and John Carson of Caltech for NASA's Jet Propulsion Laboratory.

This software is available for commercial licensing. Please contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-44352.

Handling Input and Output for COAMPS

Two suites of software have been developed to handle the input and output of the Coupled Ocean Atmosphere Prediction System (COAMPS), which is a regional atmospheric model developed by the Navy for simulating and predicting weather. Typically, the initial and boundary conditions for COAMPS are provided by a flat-file representation of the Navy's global model. Additional algorithms are needed for running the COAMPS software using global models. One of the present suites satisfies this need for running COAMPS using the Global Forecast System (GFS) model of the National Oceanic and Atmospheric Administration. The first step in running COAMPS — downloading of GFS data from an Internet file-transfer-protocol (FTP) server computer of the National Centers for Environmental Prediction (NCEP) — is performed by one of the programs (SSC-00273) in this suite. The GFS data, which are in gridded binary (GRIB) format, are then changed to a COAMPS-compatible format by another program in the suite (SSC-00278). Once a forecast is complete, still another program in the suite (SSC-00274) sends the output data to a different server computer.

The second suite of software (SSC-00275) addresses the need to ingest up-to-date land-use-and-land-cover (LULC) data into COAMPS for use in specifying typical climatological values of such surface parameters as albedo, aerodynamic roughness, and ground wetness. This suite includes (1) a program to process LULC data derived from observations by the Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard NASA's Terra and Aqua satellites, (2) programs to derive new climatological parameters for the 17-land-use-category MODIS data; and (3) a modified version of a FORTRAN subroutine to be used by COAMPS. The MODIS data files are processed to reformat them into a compressed American Standard Code for Information Interchange (ASCII) format used by COAMPS for efficient processing.

These programs were written by Patrick Fitzpatrick, Nam Tran, Yongzuo Li, and Valentine Anantharaj of Mississippi State University for Stennis Space Center.

Inquiries concerning rights for its commercial use should be addressed to:

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Mississippi State University
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(228) 688-4218

www.gri.msstate.edu

Refer to SSC-00273/4/5/8, volume and number of this NASA Tech Briefs issue, and the page number.

Modeling and Grid Generation of Iced Airfoils

SmagglIce Version 2.0 is a software toolkit for geometric modeling and grid generation for two-dimensional, single- and multi-element, clean and iced airfoils. A previous version of SmagglIce was described in "Preparing and Analyzing Iced Airfoils," *NASA Tech Briefs*, Vol. 28, No. 8 (August 2004), page 32. To recapitulate: Ice shapes make it difficult to generate quality grids around airfoils, yet these grids are essential for predicting ice-induced complex flow. This software efficiently creates high-quality structured grids with tools that are uniquely tailored for various ice shapes.

SmagglIce Version 2.0 significantly enhances the previous version primarily by adding the capability to generate grids for multi-element airfoils. This version of the software is an important step in streamlining the aeronautical analysis of ice airfoils using computational fluid dynamics (CFD) tools. The user may prepare the ice shape, define the flow domain, decompose it into blocks, generate grids, modify/divide/merge blocks, and control grid density and smoothness. All these steps may be performed efficiently even for the difficult glaze and rime ice shapes. Providing the means to generate highly controlled grids near rough ice, the software includes the creation of a wrap-around block (called the "viscous sublayer block"), which is a thin, C-type block around the wake line and iced airfoil. For multi-element airfoils, the software makes use of grids that wrap around and fill in the areas between the viscous sub-layer blocks for all elements that make up the airfoil. A scripting feature records the history of interactive steps, which can be edited and re-played later to produce other grids.

Using this version of SmagglIce, ice shape handling and grid generation can become a practical engineering process, rather than a laborious research effort.

This program was written by Mary B. Vickerman, Marivell Baez, Donald C. Braun, Anthony W. Hackenberg, James A. Pennline, and Herbert W. Schilling 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: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18187-1.

Automated Identification of Nucleotide Sequences

STITCH is a computer program that processes raw nucleotide-sequence data to automatically remove unwanted vector information, perform reverse-complement comparison, stitch shorter sequences together to make longer ones to which the shorter ones presumably belong, and search against the user's choice of private and Internet-accessible public 16S rRNA databases. ["16S rRNA" denotes a ribosomal ribonucleic acid (rRNA) sequence that is common to all organisms.] In STITCH, a template 16S rRNA sequence is used to position forward and reverse reads. STITCH then automatically searches known 16S rRNA sequences in the user's chosen database(s) to find the sequence most similar to (the sequence that lies at the smallest edit distance from) each spliced sequence.

The result of processing by STITCH is the identification of the most similar well-described bacterium. Whereas previously commercially available software for analyzing genetic sequences operates on one sequence at a time, STITCH can manipulate multiple sequences simultaneously to perform the aforementioned operations. A typical analysis of several dozen sequences (length of the order of 10^3 base pairs) by use of STITCH is completed in a few minutes, whereas such an analysis performed by use of prior software takes hours or days.

This program was written by Shariff Osman and Kasthuri Venkateswaran of Caltech; George Fox of Dept. of Biology and Biochem-

istry, University of Texas, Houston; and Dianhui Zhu of Dept. of Computer Sciences, University of Texas, Houston for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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:

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Refer to NPO-44785, volume and number of this NASA Tech Briefs issue, and the page number.

Balloon Design Software

PlanetaryBalloon Version 5.0 is a software package for the design of meridionally lobed planetary balloons. It operates in a Windows environment, and programming was done in Visual Basic 6. By including the effects of circular lobes with load tapes, skin mass, hoop and meridional stress, and elasticity in the structural elements, a more accurate balloon shape of practical construction can be determined as well as the room-temperature cut pattern for the gore shapes. The computer algorithm is formulated for sizing meridionally lobed balloons for any generalized atmosphere or planet. This also covers zero-pressure, over-pressure, and super-pressure balloons. Low circumferential loads with meridionally reinforced load tapes will produce shapes close to what are known as the "natural shape."

The software allows for the design of constant angle, constant radius, or constant hoop stress balloons. It uses the desired payload capacity for given atmospheric conditions and determines the required volume, allowing users to design exactly to their requirements. The

formulations are generalized to use any lift gas (or mixture of gases), any atmosphere, or any planet as described by the local acceleration of gravity.

PlanetaryBalloon software has a comprehensive user manual that covers features ranging from, but not limited to, buoyancy and super-pressure, convenient design equations, shape formulation, and orthotropic stress/strain.

This program was written by Rodger Farley of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).GSC-15112-1

Rocket Science 101 Interactive Educational Program

To better educate the public on the basic design of NASA's current mission rockets, Rocket Science 101 software has been developed as an interactive program designed to retain a user's attention and to teach about basic rocket parts. This program also has helped to expand NASA's presence on the Web regarding educating the public about the Agency's goals and accomplishments.

The software was designed using Macromedia's Flash 8. It allows the user to select which type of rocket they want to learn about, interact with the basic parts, assemble the parts to create the whole rocket, and then review the basic flight profile of the rocket they have built.

This program was written by Dennis Armstrong of Space Gateway Support and Deborah Funkhouser and Donald DiMarzio of Kennedy Space Center. For further information, contact:

Teresa L. Kinney

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Phone: (321) 867-5060

Refer to KSC-12942, volume and number of this NASA Tech Briefs issue, and the page number.



Creep Forming of Carbon-Reinforced Ceramic-Matrix Composites

Langley Research Center, Hampton, Virginia

A set of lecture slides describes an investigation of creep forming as a means of imparting desired curvatures to initially flat stock plates of carbon-reinforced ceramic-matrix composite (C-CMC) materials. The investigation is apparently part of a continuing effort to develop improved means of applying small C-CMC repair patches to reinforced carbon-carbon leading edges of aerospace vehicles (e.g., space shuttles) prior to re-entry into the atmosphere of the Earth.

According to one of the slides, creep forming would be an intermediate step in a process that would yield a fully densified, finished C-CMC part having a desired size and shape (the other steps would include preliminary machining, finish machining, densification by chemical vapor infiltration, and final coating). The investigation included experiments in which C-CMC disks were creep-formed by heating them to unspecified high temperatures for time intervals of the order of 1 hour while they were clamped into single- and double-

curvature graphite molds. The creep-formed disks were coated with an oxidation-protection material, then subjected to arc-jet tests, in which the disks exhibited no deterioration after exposure to high-temperature test conditions lasting 490 seconds.

This work was done by Wallace L. Vaughn and Stephan J. Scotti of Langley Research Center, Melissa P. Ashe of Swales Aerospace, and Liz Connolly of General Electric Co. Further information is contained in a TSP (see page 1). LAR-17289-1

Dog-Bone Horns for Piezoelectric Ultrasonic/Sonic Actuators

Relative to other shapes, the dog-bone shape offers better performance.

NASA's Jet Propulsion Laboratory, Pasadena, California

A shape reminiscent of a dog bone has been found to be superior to other shapes for mechanical-amplification horns that are components of piezoelectrically driven actuators used in a series of related devices denoted generally as ultrasonic/sonic drill/corers (USDCs). The first of these devices was reported in "Ultrasonic/Sonic Drill/Corers With Integrated Sensors" (NPO-20856), *NASA Tech Briefs*, Vol. 25, No. 1 (January 2001), page 38. The dog-bone shape was conceived especially for use in a more recent device in the series, denoted an ultrasonic/sonic gopher, that was described in "Ultrasonic/Sonic Mechanisms for Drilling and Coring" (NPO-30291), *NASA Tech Briefs*, Vol. 27, No. 9 (September 2003), page 65. The figure shows an example of a dog-bone-shaped horn and other components of an ultrasonic gopher.

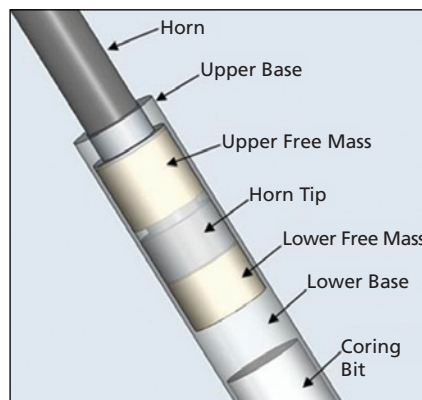
Prerequisite to a meaningful description of this development is an unavoidably lengthy recapitulation of the principle of operation of a USDC and, more specifically, of the ultrasonic/sonic gopher as described previously in *NASA Tech Briefs*. The ultrasonic actuator includes a stack of piezoelectric rings, the horn, a metal backing, and a bolt that

connects the aforementioned parts and provides compressive pre-strain to the piezoelectric stack to prevent breakage of the rings during extension. The stack of piezoelectric rings is excited at the resonance frequency of the overall ultrasonic actuator. Through mechanical amplification by the horn, the displacement in the ultrasonic vibration reaches tens of microns at the tip of the horn.

The horn hammers an object that is denoted the free mass because it is free to move longitudinally over a limited distance between hard stops: The free mass

bounces back and forth between the ultrasonic horn and a tool bit (a drill bit or a corer). Because the longitudinal speed of the free mass is smaller than the longitudinal speed of vibration of the tip of the horn, contact between the free mass and the horn tip usually occurs at a phase of the vibration favorable to transfer of momentum from the horn to the free mass. Therefore, the free mass picks up momentum and is accelerated back to the tool bit. Upon impact of the free mass on the tool bit, momentum is transferred to the tool bit. The impacts of the free mass on the tool bit repeat at a sonic frequency that can range from tens of hertz to about 1 kHz. The shock waves caused by the impacts of the free mass propagate to the interface between the tool bit and the medium (typically, rock, ice, or other brittle material) to be drilled or cored. The medium becomes fractured when its ultimate strain is exceeded at the medium/tool-bit interface. This concludes the description of the principle of operation.

The performances of several ultrasonic/sonic gophers containing horns of different shapes were analyzed in a computational-simulation study. The computational simulation was based on



These Components of an Ultrasonic/Sonic Gopher include an ultrasonic horn shaped as a rod with widened ends — a "dog-bone" shape.

a mathematical model that took account of interactions (1) between the piezoelectric stack and the driving circuit, (2) between the horn tip and the free mass, (3) between the free mass and the tool bit, and (4) between the tool bit and the medium to be cored or drilled. Inasmuch as it is necessary to keep the neutral plane of an actuator at the piezoelectric-stack/horn boundary to prevent breakage, the lengths of the horns and other parts of the actuators were ad-

justed accordingly. The equations of the model were solved numerically by finite-element analysis. The results of the analysis showed that relative to the other horn shapes, the dog-bone shape offers greater transfer of power to the medium to be drilled or cored.

Relative to the other horn shapes in the study, dog-bone shape offers a larger front area and a larger hammering mass that enhance actuation capability. The dog-bone shape also affords additional

degrees of freedom for design and additional parameters for control. Yet another potential advantage of the dog-bone shape is that it lends itself readily to the addition of a second, upper free mass that would enable reverse hammering.

This work was done by Stewart Sherrit, Yoseph Bar-Cohen, Zensheu Chang, and Xiaoyi Bao of Caltech for NASA's Jet Propulsion Laboratory. For further information, contact iaoffice@jpl.nasa.gov. NPO-40949



Benchtop Detection of Proteins

This process is relatively rapid and simple.

John H. Glenn Research Center, Cleveland, Ohio

A process, and a benchtop-scale apparatus for implementing the process, have been developed to detect proteins associated with specific microbes in water. The process and apparatus may also be useful for detection of proteins in other, more complex liquids. There may be numerous potential applications, including monitoring lakes and streams for contamination, testing of blood and other bodily fluids in medical laboratories, and testing for microbial contamination of liquids in restaurants and industrial food-processing facilities. A sample can be prepared and analyzed by use of this process and apparatus within minutes, whereas an equivalent analysis performed by use of other processes and equipment can often take hours to days.

The process begins with the conjugation of near-infrared-fluorescent dyes to antibodies that are specific to a particular protein. Initially, the research has focused on using near-infrared dyes to detect antigens or associated proteins in solution, which has proven successful vs. microbial cells, and streamlining the technique in use for surface protein detection on microbes

would theoretically render similar results. However, it is noted that additional work is needed to transition protein-based techniques to microbial cell detection. Consequently, multiple such dye/antibody pairs could be prepared to enable detection of multiple selected microbial species, using a different dye for each species. When excited by near-infrared light of a suitable wavelength, each dye fluoresces at a unique longer wavelength that differs from those of the other dyes, enabling discrimination among the various species.

In initial tests, the dye/antibody pairs are mixed into a solution suspected of containing the selected proteins, causing the binding of the dye/antibody pairs to such suspect proteins that may be present. The solution is then run through a microcentrifuge that includes a membrane that acts as a filter in that it retains the dye/antibody/protein complexes while allowing any remaining unbound dye/antibody pairs to flow away.

The retained dye/antibody/protein complexes are transferred to a cuvette, wherein they are irradiated with light

from a miniature near-infrared laser delivered via a fiber-optic cable. The resulting fluorescence from the dye(s) is measured by use of a miniature spectrometer, the output of which is digitized, then analyzed by laptop computer. The software running in the computer identifies the protein species by the wavelengths of their spectral peaks and determines the amounts of the proteins, and thus, one day, microbes of the various species from the intensities of the peaks. The above-mentioned removal of the unbound dye/antibody pairs during centrifugation prevents false positive readings. The process proves successful in detecting proteins in solution and thus can now be employed for use in microbe detection.

This work was done by Maximilian C. Scardelletti and Vanessa Varaljay of Glenn Research Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18148-1.

Recombinant Collagenlike Proteins

These proteins can be tailored to have specific biological properties.

Lyndon B. Johnson Space Center, Houston, Texas

A group of collagenlike recombinant proteins containing high densities of biologically active sites has been invented. The method used to express these proteins is similar to a method of expressing recombinant procollagens and collagens described in U. S. Patent 5,593,859, "Synthesis of human procollagens and collagens in recombinant DNA systems."

Customized collagenous proteins are needed for biomedical applications. In particular, fibrillar collagens are attractive for production of matrices needed for tissue engineering and drug delivery. Prior to this invention, there was no way of producing customized collagenous proteins for these and other applica-

tions. Heretofore, collagenous proteins have been produced by use of such biological systems as yeasts, bacteria, and transgenic animals and plants. These products are normal collagens that can also be extracted from such sources as tendons, bones, and hides. These products cannot be made to consist only of biologically active, specific amino acid sequences that may be needed for specific applications.

Prior to this invention, it had been established that fibrillar collagens consist of domains that are responsible for such processes as interaction with cells, binding of growth factors, and interaction with a number of structural proteins

present in the extracellular matrix. A normal collagen consists of a sequence of domains that can be represented by a corresponding sequence of labels, e.g., D1D2D3D4. A collagenlike protein of the present invention contains regions of collagen II that contain multiples of a single domain (e.g., D1D1D1D1 or D4D4D4D4) chosen for its specific biological activity. By virtue of the multiplicity of the chosen domain, the density of sites having that specific biological activity is greater than it is in a normal collagen. A collagenlike protein according to this invention can thus be made to have properties that are necessary for tissue engineering.

For example, deoxyribonucleic acid (DNA) encoding the D4 domain has been used to create a DNA construct that encodes for a collagenlike protein that consists of multiples of the D4 domain. From previous research, it was known that the D4 domain is critical for interaction of collagen II with chondrocytes. Hence, this multiple-D4 protein is supe-

rior to natural collagen for use as a scaffold material for repair of cartilage or for growth of cartilage *in vitro*.

This work was done by Andrzej Fertala of Thomas Jefferson University for Johnson Space Center. Further information is contained in a TSP (see page 1).

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:

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Philadelphia, PA 19107*

Refer to MSC-24151-1, volume and number of this NASA Tech Briefs issue, and the page number.

Remote Sensing of Parasitic Nematodes in Plants

Stennis Space Center, Mississippi

A method and apparatus for remote sensing of parasitic nematodes in plants, now undergoing development, is based on measurement of visible and infrared spectral reflectances of fields where the plants are growing. Initial development efforts have been concentrated on detecting reniform nematodes (*Rotylenchulus reniformis*) in cotton plants, because of the economic importance of cotton crops.

The apparatus includes a hand-held spectroradiometer. The readings taken by

the radiometer are processed to extract spectral reflectances at sixteen wavelengths between 451 and 949 nm that, taken together, have been found to be indicative of the presence of *Rotylenchulus reniformis*. The intensities of the spectral reflectances are used to estimate the population density of the nematodes in an area from which readings were taken.

This work was done by Gary W. Lawrence, Roger King, Amber T. Kelley, and John Vickery of Mississippi State University for Stennis Space Center.

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:

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Refer to SSC-00249, volume and number of this NASA Tech Briefs issue, and the page number.*



Direct Coupling From WGM Resonator Disks to Photodetectors

NASA's Jet Propulsion Laboratory, Pasadena, California

Output coupling of light from a whispering-gallery-mode (WGM) optical resonator directly to a photodetector has recently been demonstrated. By "directly" is meant that the coupling is effected without use of intervening optical components. Heretofore, coupling of light into and out of WGM resonators has been a complex affair involving the use of such optical components as diamond or glass prisms, optical fibers, coated collimators, and/or fiber tapers. Alignment of these components is time-consuming and expensive.

To effect direct coupling, one simply mounts a photodetector in direct me-

chanical contact with a spacer that is, in turn, in direct mechanical contact with a WGM resonator disk. The spacer must have a specified thickness (typically of the order of a wavelength) and an index of refraction lower, by an adequate margin, than the indices of refraction of the photodetector and the WGM resonator disk. This mechanically simple approach makes it possible to obtain an optimum compromise between maximizing optical coupling and maximizing the resonance quality factor (Q).

This work was done by Anatoliy Savchenkov, Lute Maleki, Makan Mohageg, and Thanh Le

of Caltech for NASA's Jet Propulsion Laboratory.

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:

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Refer to NPO-43178, volume and number of this NASA Tech Briefs issue, and the page number.

Using Digital Radiography To Image Liquid Nitrogen in Voids

X-ray motion pictures show draining and filling caused by cryopumping.

Marshall Space Flight Center, Alabama

Digital radiography by use of (1) a field-portable x-ray tube that emits low-energy x rays and (2) an electronic imaging x-ray detector has been found to be an effective technique for detecting liquid nitrogen inside voids in thermal-insulation panels. The technique was conceived as a means of investigating cryopumping (including cryoingestion) as a potential cause of loss of thermal insulation foam from space-shuttle external fuel tanks. The technique could just as well be used to investigate cryopumping and cryoingestion in other settings.

In images formed by use of low-energy x-rays, one can clearly distinguish between voids filled with liquid nitrogen and those filled with gaseous nitrogen or other gases. Conventional film radiography is of some value, but yields only non-real-time still images that do not show time dependences of levels of liquids in voids. In contrast, the present digital radiographic technique yields a succession of images in real time at a rate of about 10 frames per second. The digitized images can be

saved for subsequent analysis to extract data on time dependencies of levels of liquids and, hence, of flow paths and rates of filling and draining. The succession of images also amounts to a real-time motion picture that can be used as a guide to adjustment of test conditions.

This work was done by Dwight Cox and Elana Blevins of Lockheed Martin Corp. for Marshall Space Flight Center. Further information is contained in a TSP (see page 1). MFS-32443-1

Multiple-Parameter, Low-False-Alarm Fire-Detection Systems

Compact, low-power systems detect fires reliably.

John H. Glenn Research Center, Cleveland, Ohio

Fire-detection systems incorporating multiple sensors that measure multiple parameters are being developed for use in storage depots, cargo bays of ships and aircraft, and other locations not amenable to frequent, direct visual inspection. These systems are intended to

improve upon conventional smoke detectors, now used in such locations, that reliably detect fires but also frequently generate false alarms: for example, conventional smoke detectors based on the blockage of light by smoke particles are also affected by dust particles and water

droplets and, thus, are often susceptible to false alarms. In contrast, by utilizing multiple parameters associated with fires, i.e. not only obscuration by smoke particles but also concentrations of multiple chemical species that are commonly generated in combustion, false

alarms can be significantly decreased while still detecting fires as reliably as older smoke-detector systems do.

The present development includes fabrication of sensors that have, variously, micrometer- or nanometer-sized features so that such multiple sensors can be integrated into arrays that have sizes, weights, and power demands smaller than those of older macroscopic sensors. The sensors include resistors, electrochemical cells, and Schottky diodes that exhibit different sensitivities to the various airborne chemicals of interest. In a system of this type, the sensor readings are digitized and processed by advanced signal-processing hardware and software to extract such chemical indications of fires as abnormally high concentrations of CO and CO₂, possibly in combination with H₂

and/or hydrocarbons. The system also includes a microelectromechanical systems (MEMS)-based particle detector and classifier device to increase the reliability of measurements of chemical species and particulates.

In parallel research, software for modeling the evolution of a fire within an aircraft cargo bay has been developed. The model implemented in the software can describe the concentrations of chemical species and of particulate matter as functions of time.

A system of the present developmental type and a conventional fire detector were tested under both fire and false-alarm conditions in a Federal Aviation Administration cargo-compartment-testing facility. Both systems consistently detected fires. However, the

conventional fire detector consistently generated false alarms, whereas the developmental system did not generate any false alarms.

This work was done by Gary W. Hunter, Paul Greensburg, Robert McKnight, and Jennifer C. Xu of Glenn Research Center; C. C. Liu of Case Western Reserve University; Prabir Dutta of Ohio State University; Darby Makel of Makel Engineering, Inc.; D. Blake of the Federal Aviation Administration; and Jill Sue-Antillio of Sandia National Laboratories. 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: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18067-1.

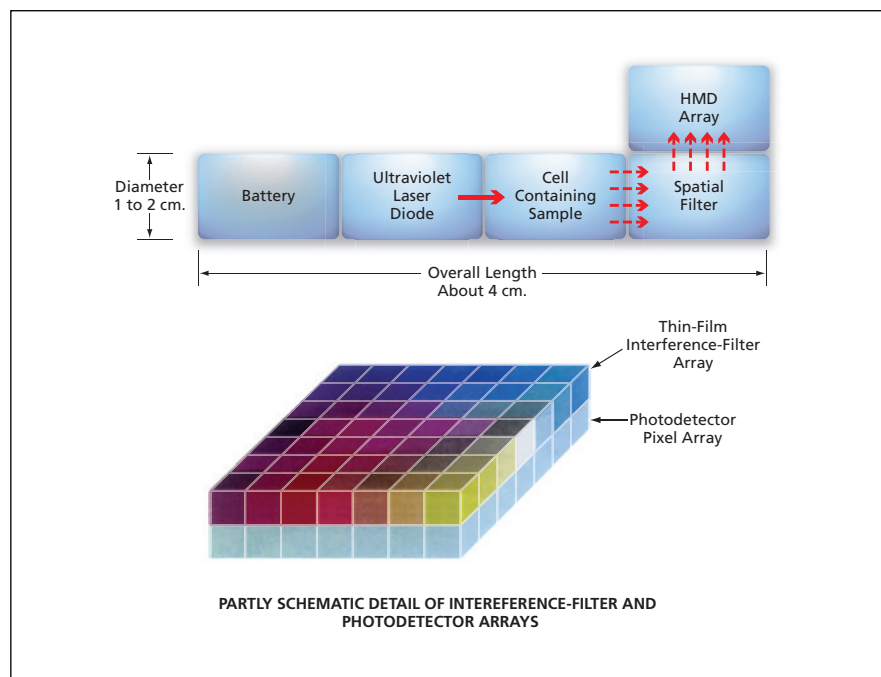
Mosaic-Detector-Based Fluorescence Spectral Imager

This portable instrument would perform comparably to larger laboratory instruments.

NASA's Jet Propulsion Laboratory, Pasadena, California

A battery-powered, pen-sized, portable instrument for measuring molecular fluorescence spectra of chemical and biological samples in the field has been proposed. Molecular fluorescence spectroscopy is among the techniques used most frequently in laboratories to analyze compositions of chemical and biological samples. Heretofore, it has been possible to measure fluorescence spectra of molecular species at relative concentrations as low as parts per billion (ppb), with a few nm spectral resolution. The proposed instrument would include a planar array (mosaic) of detectors, onto which a fluorescence spectrum would be spatially mapped. Unlike in the larger laboratory-type molecular fluorescence spectrometers, mapping of wavelengths to spatial positions would be accomplished without use of relatively bulky optical parts. The proposed instrument is expected to be sensitive enough to enable measurement of spectra of chemical species at relative concentrations <1 ppb, with spectral resolution that could be tailored by design to be comparable to a laboratory molecular fluorescence spectrometer.

The proposed instrument (see figure) would include a button-cell battery and a laser diode, which would generate the monochromatic ultraviolet light needed to excite fluorescence in a sample. The sample would be held in a cell bounded



This **Pen-Sized Instrument** would measure the fluorescence spectrum of a sample with high resolution and sensitivity.

by far-ultraviolet-transparent quartz or optical glass.

The detector array would be, more specifically, a complementary metal oxide/ semiconductor or charge-coupled-device imaging photodetector array, the photodetectors of which would be tailored to respond to light in

the wavelength range of the fluorescence spectrum to be measured. The light-input face of the photodetector array would be covered with a matching checkerboard array of multilayer thin-film interference filters, such that each pixel in the array would be sensitive only to light in a spectral band narrow

enough so as not to overlap significantly with the band of an adjacent pixel. The wavelength interval between adjacent pixels (and, thus, the spectral resolution) would typically be chosen by design to be approximately equal to the width of the total fluorescence wavelength range of interest divided by the number of pixels. The unitary structure comprising the photodetector array overlaid with the matching filter array would be denoted a hyperspectral mosaic detector (HMD) array.

To maximize the spatial resolution achievable by use of interference filters, it is necessary to ensure perpendicular incidence of light on the filters. In the proposed instrument, perpendicular inci-

dence would be ensured by incorporation of a spatial filter between the sample cell and the HMD array. To minimize potential contributions of scattering of laser light, the HMD array would be oriented at a right angle to the ultraviolet laser beam.

To enable identification and characterization of molecules by use of the proposed instrument, it would be necessary to create a data library representing the HMD image outputs corresponding to fluorescence spectra of molecular species. A fully developed version of the instrument would include, as integral parts, an electronic memory containing the library and a processor for analyzing measurement data with reference to the data in the library.

This work was done by Kyung-Ah Son and Jeong Moon of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

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:

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Refer to NPO-43539, volume and number of this NASA Tech Briefs issue, and the page number.



Books & Reports

⚙️ **Plasmoid Thruster for High Specific-Impulse Propulsion**

A report discusses a new multi-turn, multi-lead design for the first generation PT-1 (Plasmoid Thruster) that produces thrust by expelling plasmas with embedded magnetic fields (plasmoids) at high velocities. This thruster is completely electrodeless, capable of using *in-situ* resources, and offers efficiencies as high as 70 percent at a specific impulse, I_{sp} , of up to 8,000 s. This unit consists of drive and bias coils wound around a ceramic form, and the capacitor bank and switches are an integral part of the assembly. Multiple thrusters may be ganged to inductively recapture unused energy to boost efficiency and to increase the repetition rate, which, in turn increases the average thrust of the system.

The thruster assembly can use storable propellants such as H_2O , ammonia, and NO , among others. Any available propellant gases can be used to produce an I_{sp} in the range of 2,000 to 8,000 s with a single-stage thruster. These capabilities will allow the transport of greater payloads to outer planets, especially in the case of an I_{sp} greater than 6,000 s.

This work was done by Peter Fimognari of the University of Alabama in Huntsville and Richard Eskridge, Adam Martin, and Michael Lee of Marshall Space Flight Center. Further information is contained in a TSP (see page 1). MFS-32364-1

🔍 **Analysis Method for Quantifying Vehicle Design Goals**

A document discusses a method for using Design Structure Matrices (DSM), coupled with high-level tools representing important life-cycle parameters, to comprehensively conceptualize a flight/ground space transportation system design by dealing with such variables as performance, up-front costs, downstream operations costs, and reliability. This approach also weighs operational approaches based on their effect on upstream design variables so that it is possible to readily, yet defensibly, establish linkages between operations and these upstream variables.

To avoid the large range of problems that have defeated previous methods of

dealing with the complex problems of transportation design, and to cut down the inefficient use of resources, the method described in the document identifies those areas that are of sufficient promise and that provide a higher grade of analysis for those issues, as well as the linkages at issue between operations and other factors. Ultimately, the system is designed to save resources and time, and allows for the evolution of operable space transportation system technology, and design and conceptual system approach targets.

This work was done by Edgar Zapata of Kennedy Space Center and A.C. Charania and John Olds of Spaceworks Engineering. Further information is contained in a TSP (see page 1). KSC-12797

📷 **Improved Tracking of Targets by Cameras on a Mars Rover**

A paper describes a method devised to increase the robustness and accuracy of tracking of targets by means of three stereoscopic pairs of video cameras on a Mars-rover-type exploratory robotic vehicle. Two of the camera pairs are mounted on a mast that can be adjusted in pan and tilt; the third camera pair is mounted on the main vehicle body. Elements of the method include a mast calibration, a camera-pointing algorithm, and a purely geometric technique for handing off tracking between different camera pairs at critical distances as the rover approaches a target of interest.

The mast calibration is an extension of camera calibration in which the camera images of calibration targets at known positions are collected at various pan and tilt angles. In the camera-pointing algorithm, pan and tilt angles are computed by a closed-form, non-iterative solution of inverse kinematics of the mast combined with mathematical models of the cameras. The purely geometric camera-handoff technique involves the use of stereoscopic views of a target of interest in conjunction with the mast calibration.

This work was done by Won Kim, Adnan Ansari, and Robert Steele of Caltech for NASA's Jet Propulsion Laboratory.

The software used in this innovation is available for commercial licensing. Please

contact Karina Edmonds of the California Institute of Technology at (626) 395-2322. Refer to NPO-42756.

⚙️ **Sample Caching Subsystem**

A paper describes the Sample Caching Subsystem (SCS), a method for storing planetary core and soil samples in a container that seals the samples away from the environment to protect the integrity of the samples and any organics they might contain. This process places samples in individual sleeves that are sealed within a container for use by either the current mission or by following missions.

A sample container is stored with its sleeves partially inserted. When a sample is ready to be contained, a transfer arm rotates over and grasps a sleeve, pulls it out of the container from below, rotates over and inserts the sleeve into a funnel where it is passively locked into place and then released from the arm. An external sampling tool deposits the sample into the sleeve, which is aligned with the funnel. After the sampling tool leaves the funnel, the arm retrieves the sleeve and inserts it all the way into the sample container. This action engages the seal. Full containers can be left behind for pick-up by subsequent science missions, and container dimensions are compatible for placement in a Mars Ascent Vehicle for later return to Earth.

This work was done by Paul G. Backes and Curtis L. Collins of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-44154

⚙️ **Multistage Passive Cooler for Spaceborne Instruments**

A document describes a three-stage passive radiative cooler for a cryogenic spectrometer to be launched into a low orbit around the Moon. This cooler is relatively lightweight and compact, and its basic design is scalable and otherwise adaptable to other applications in which there are requirements for cooling instrumentation in orbit about planets.

The cooler includes multiple lightweight flat radiator blades alternating with cylindrical parabolic infrared re-

flectors. The radiator blades are oriented at an angle chosen to prevent infrared loading from the Moon limb at the intended orbital altitude and attitude. The reflectors are shaped and oriented to position their foci outside the radiator surfaces. There are six radiator-blade/reflector pairs — two pairs for each stage of cooling. The radiator blades and reflectors are coated on their front and back surfaces with materials having various infrared emissivities, infrared reflectivities, and solar reflectivities so as to maximize infrared radiation to cold outer space and minimize inadvertent solar heating. The radiator blades and reflectors are held in place by a lightweight support structure, the components of which are designed to satisfy a complex combination of thermal and mechanical requirements.

*This work was done by Jose I. Rodriguez of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-44960*

GVIPS Models and Software

Two reports discuss, respectively, (1) the generalized viscoplasticity with potential structure (GVIPS) class of mathematical models and (2) the Constitutive Material Parameter Estimator (COMPARE) computer program. GVIPS models are constructed within a thermodynamics- and potential-based theoretical framework, wherein one uses internal state variables and de-

rives constitutive equations for both the reversible (elastic) and the irreversible (viscoplastic) behaviors of materials. Because of the underlying potential structure, GVIPS models not only capture a variety of material behaviors but also are very computationally efficient.

COMPARE comprises (1) an analysis core and (2) a C++-language subprogram that implements a Windows-based graphical user interface (GUI) for controlling the core. The GUI relieves the user of the sometimes tedious task of preparing data for the analysis core, freeing the user to concentrate on the task of fitting experimental data and ultimately obtaining a set of material parameters. The analysis core consists of three modules: one for GVIPS material models, an analysis module containing a specialized finite-element solution algorithm, and an optimization module. COMPARE solves the problem of finding GVIPS material parameters in the manner of a design-optimization problem in which the parameters are the design variables.

This work was done by Steven M. Arnold of Glenn Research Center and Atef Gendy, Atef F. Saleeb, John Mark, and Thomas E. Wilt of the University of Akron. Further information is contained in a TSP (see page 1).

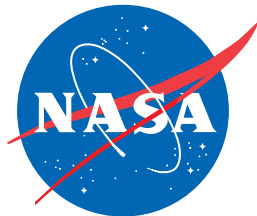
Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17999-1/8000-1

Stowable Energy-Absorbing Rocker-Bogie Suspensions

A report discusses the design of the rocker-bogie suspensions of the Mars Exploration Rover vehicles, which were landed on Mars in January 2004. Going beyond the basic requirements regarding mobility on uneven terrain, the design had to satisfy requirements (1) to enable each suspension to contort so that the rover could be stowed within limited space in a tetrahedral lander prior to deployment and (2) that the suspension be able to absorb appreciable impact loads, with limited deflection, during egress from the lander and traversal of terrain.

For stowability, six joints (three on the right, three on the left) were added to the basic rocker-bogie mechanism. One of the joints on each side was a yoke-and-clevis joint at the suspension/differential interface, one was a motorized twist joint in the forward portion of the rocker, and one was a linear joint created by modifying a fixed-length bogie member into a telescoping member. For absorption of impact, the structural members were in the form of box beams made by electron-beam welding of machined, thin-walled, C-channel, titanium components. The box beams were very lightweight and could withstand high bending and torsional loads.

*This work was done by Brian Harrington and Christopher Voorhees of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov.
NPO-40967*



National Aeronautics and
Space Administration