03-07 March 2007

Tech Briefs

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTRODUCTION

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Requests for individual Tech Briefs or for Technical Support Packages (TSPs) announced herein should be addressed to

National Technology Transfer Center

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Please reference the control numbers appearing at the end of each Tech Brief. Information on NASA's Innovative Partnerships Program (IPP), its documents, and services is also available at the same facility or on the World Wide Web at **http://ipp.nasa.gov**.

Innovative Partnerships Offices are located at NASA field centers to provide technology-transfer access to industrial users. Inquiries can be made by contacting NASA field centers listed below.

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Tech Briefs

National Aeronautics and Space Administration

Advanced Systems for Monitoring Underwater Sounds

Versatile units can be deployed at depths as great as 1 km.

John F. Kennedy Space Center, Florida

The term "Passive Acoustic Monitor–ing System" (PAMS) describes a developmental sensing-and-data-acquisition system for recording underwater sounds. The sounds (more precisely, digitized and preprocessed versions from acoustic transducers) are subsequently analyzed by a combination of data processing and interpretation to identify and/or, in some cases, to locate the sources of those sounds. PAMS was originally designed to locate the sources such as fish of species that one knows or seeks to identify. The PAMS unit could also be used to locate other sources, for example, marine life, human divers, and/or vessels.

The underlying principles of passive acoustic sensing and analyzing acoustic-signal data in conjunction with temperature and salinity data are not new and not unique to PAMS. Part of the uniqueness of the PAMS design is that it is the first deep-sea instrumentation design to provide a capability for studying soniferous marine animals (especially fish) over the wide depth range described below. The uniqueness of PAMS also lies partly in a synergistic combination of advanced sensing, packaging, and data-processing design features with features adapted from proven marine instrumentation systems. This combination affords a versatility that enables adaptation to a variety of undersea missions using a variety of sensors.

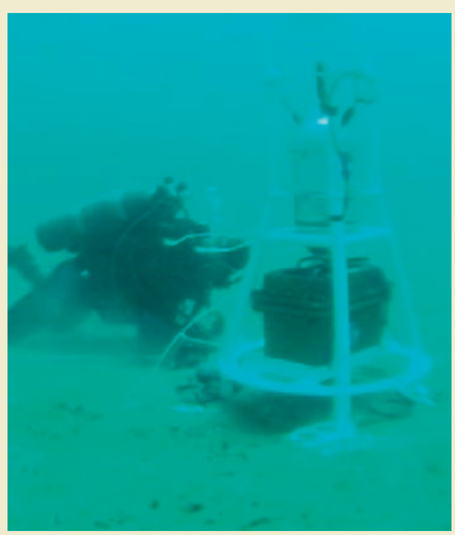
The interpretation of acoustic data can include visual inspection of power-spectrum plots for identification of spectral signatures of known biological species or artificial sources. Alternatively or in addition, data analysis could include determination of relative times of arrival of signals at different acoustic sensors arrayed at known locations. From these times of arrival, locations of acoustic sources (and errors in those locations) can be estimated. Estimates of relative locations of sources and sensors can be refined through analysis of the attenuation of sound in the intervening water in combination with water-temperature and salinity data acquired by instrumentation systems other than PAMS.

A PAMS is packaged as a battery-powered unit, mated with external sensors, that can operate in the ocean at any depth from 2 m to 1 km. A PAMS includes a pressure housing, a deep-sea battery, a hydrophone (which is one of the mating external sensors), and an external monitor and keyboard box. In addition to acoustic transducers, external sensors can include temperature probes and, potentially, underwater cameras. The pressure housing contains a computer that includes a hard drive, DC-to-DC power converters, a post-amplifier board, a sound card, and a universal serial bus (USB) 4-port hub.

Typically, a PAMS is lowered into the water by use of a deck hoist, then guided to its assigned position by divers for a shallow deployment (see figure) or by crew members in miniature submarines for deployment at a greater depth. Alternatively, if great precision is not required, a PAMS can be simply allowed to sink to the selected location. The PAMS is then left in place to record data for a predetermined time or until it exhausts battery energy or data-storage capacity. Currently, the PAMS can be deployed at sea for four days, but the deployment time and sampling are battery and hard-drive dependent. For example, at a sample rate of 22,050 Hz, the data acquired was 3.5GB per 24 hours using a 40GB hard drive. However, at 44,100 Hz

PAMS on Deck

PAMS on Hoist



PAMS and Diver on Ocean Floor

A **PAMS Is Hoisted** into the water, then guided into position by a diver.

sample rate, the data acquired was 7.1GB per 24 hours.

The PAMS is subsequently retrieved and its recorded data are downloaded to a computer, which can be used to either process the data or record the data on a disk for transfer to another computer for processing. The PAMS can then be prepared for another deployment.

This work was done by Michael Lane and Steven Van Meter of Kennedy Space Center; Richard Grant Gilmore, Jr., of Estuarine, Coastal and Ocean Science, Inc.; and Keith Sommer of the United States Air Force. For further information, contact the Kennedy Innovative Partnerships Office at (321) 861-7158. KSC-12634.

Wireless Data-Acquisition System for Testing Rocket Engines

Time-consuming, error-prone wiring tasks are eliminated.

Stennis Space Center, Mississippi

A prototype wireless data-acquisition system has been developed as a potential replacement for a wired data-acquisition system heretofore used in testing rocket engines. The traditional use of wires to connect sensors, signal-conditioning circuits, and data acquisition circuitry is time-consuming and prone to error, especially when, as is often the case, many sensors are used in a test.

The system includes one master and multiple slave nodes. The master node communicates with a computer via an Ethernet connection. The slave nodes are powered by rechargeable batteries and are packaged in weatherproof enclosures. The master unit and each of the slave units are equipped with a time-modulated ultra-wide-band (TM-UWB) radio transceiver, which spreads its RF energy over several gigahertz by transmitting extremely low-power and super-narrow pulses. In this prototype system, each slave node can be connected to as many as six sensors: two sensors can be connected directly to analog-to-digital converters (ADCs) in the slave node and four sensors can be connected indirectly to the ADCs via signal conditioners. The maximum sampling rate for streaming data from any given sensor is about 5 kHz. The bandwidth of one channel of the TM-UWB radio communication system is sufficient to accommodate streaming of data from five slave nodes when they are fully loaded with data collected through all possible sensor connections. TM-UWB radios have a much higher spatial capacity than traditional sinusoidal wave-based radios. Hence, this TM-UWB wireless data-acquisition can be scaled to cover denser sensor setups for rocket engine test stands. Another advantage of TM-UWB radios is that it will not interfere with existing wireless transmission.

The maximum radio-communication range between the master node and a slave node for this prototype system is about 50 ft (15 m) when the master and slave transceivers are equipped with small dipole antennas. The range can be increased by changing to larger antennas and/or greater transmission power. The battery life of a slave node ranges from about six hours during operation at full capacity to as long as three days when the system is in a “sleep” mode used to conserve battery charge during times between setup and rocket-engine testing. Batteries can be added to prolong operational lifetimes. The radio transceiver dominates the power consumption.

The software running in the computer enables users to do any or all of the following:

- Remotely controls the sleeping/awakening schedule of the slave nodes.
- Manage the sampling rates and latencies of readings of specific sensors to satisfy specific requirements and maximize utilization of the system.
- Synchronize the operations of all nodes.

This work was done by Chujen Lin, Ben Lonske, Yalin Hou, Yingjiu Xu, and Mei Gang of Intelligent Automation, Inc. for Stennis Space Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to:

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Refer to SSC-00231, volume and number of this NASA Tech Briefs *issue, and the page number.*

Processing Raw HST Data With Up-to-Date Calibration Data

Goddard Space Flight Center, Greenbelt, Maryland

On-the-Fly Reprocessing (OTFR) is a collection of data-processing routines that work within the context of the Hubble Space Telescope (HST) pipeline data-flow system. The purpose served by OTFR is to generate, on demand, scientifically useful data products from raw HST data stored in an archive. First, on the basis of the requested final data products, OTFR retrieves the corresponding sets of raw data from the archives. Next, OTFR processes the raw data sets to remove artifacts and to establish proper header and other template information. Finally, the calibration routines appropriate to the specific data sets are invoked to produce the requested data products, and the data products are released to an archive distribution system for transmission to the requesting party. OTFR offers two notable advantages: (1) Inasmuch as calibrated data occupy about 8 times as much storage space as do raw data, by obviating storage of calibrated data, OTFR reduces the storage capacity needed by the archive; and (2) the calibration routines can be updated to give requesters the benefit of the most recent calibrations.

This work was done by Warren Miller of Space Telescope Science Institute for Goddard Space Flight Center. Further information is contained in a TSP (see page 1).

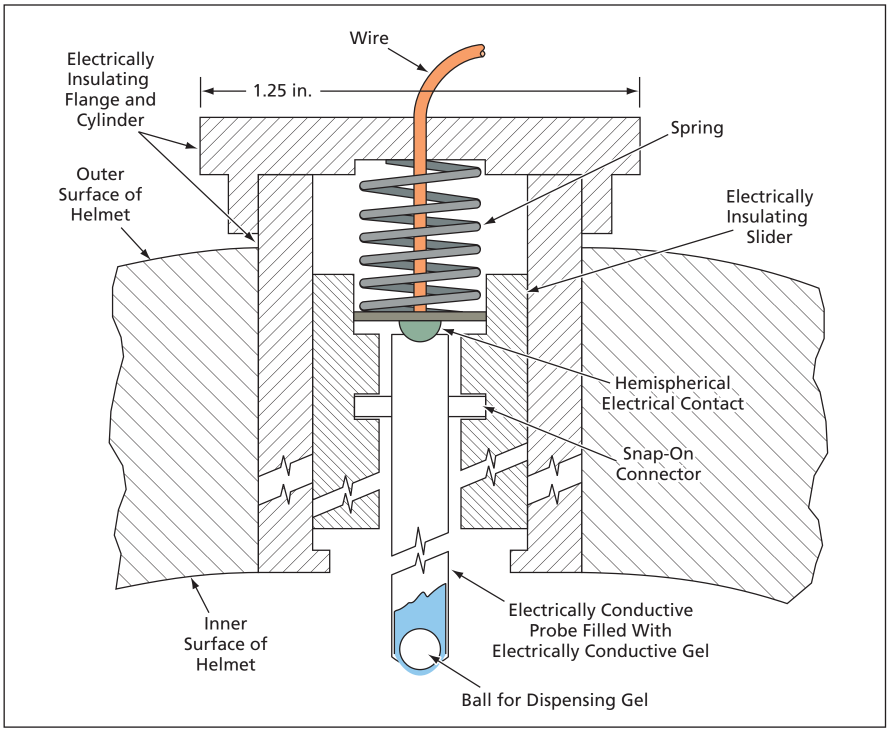
Mobile Collection and Automated Interpretation of EEG Data

Diagnoses could be performed while subjects engaged in ordinary activities.

NASA's Jet Propulsion Laboratory, Pasadena, California

A system that would comprise mobile and stationary electronic hardware and software subsystems has been proposed for collection and automated interpretation of electroencephalographic (EEG) data from subjects in everyday activities in a variety of environments. By enabling collection of EEG data from mobile subjects engaged in ordinary activities (in contradistinction to collection from immobilized subjects in clinical settings), the system would expand the range of options and capabilities for performing diagnoses.

Each subject would be equipped with one of the mobile subsystems, which would include a helmet that would hold "floating electrodes" (see figure) in those positions on the patient's head that are required in classical EEG data-collection techniques. A bundle of wires would couple the EEG signals from the electrodes to a multi-channel transmitter also located in the helmet. Electronic circuitry in the helmet transmitter would digitize the EEG signals and transmit the resulting data via a multidirectional RF patch antenna to a remote location.



This **Probe Assembly** would be one of several mounted in a helmet. Each such assembly would hold an EEG electrode in one of the required positions on the wearer's head.

At the remote location, the subject's EEG data would be processed and stored in a database that would be auto-administered by a newly designed relational database management system (RDBMS). In this RDBMS, in nearly real time, the newly stored data would be subjected to automated interpretation that would involve comparison with other EEG data and concomitant peer-reviewed diagnoses stored in international brain data bases administered by other similar RDBMSs.

This work was done by Frederick Mintz and Philip Moynihan 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-42386, volume and number of this NASA Tech Briefs *issue, and the page number.*

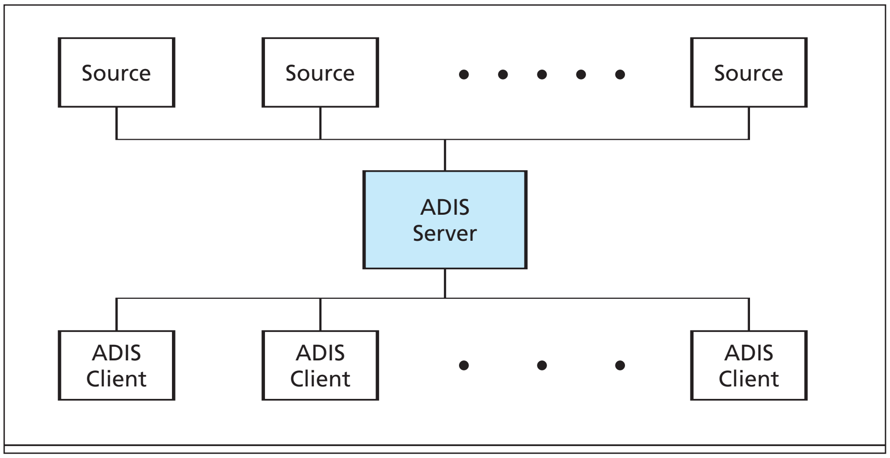
System for Secure Integration of Aviation Data

Data can be analyzed without compromising security or anonymity.

Ames Research Center, Moffett Field, California

The Aviation Data Integration System (ADIS) of Ames Research Center has been established to promote analysis of aviation data by airlines and other interested users for purposes of enhancing the quality (especially safety) of flight operations. The ADIS is a system of computer hardware and software for collecting, integrating, and disseminating aviation data pertaining to flights and specified flight events that involve one or more airline(s). The ADIS is secure in the sense that care is taken to ensure the integrity of sources of collected data and to verify the authorizations of requesters to receive data. Most importantly, the ADIS removes a disincentive to collection and exchange of useful data by providing for automatic removal of information that could be used to identify specific flights and crewmembers. Such information, denoted sensitive information, includes flight data (here signifying data collected by sensors aboard an aircraft during flight), weather data for a specified route on a specified date, date and time, and any other information traceable to a specific flight. The removal of information that could be used to perform such tracing is called "de-identification."

Airlines are often reluctant to keep flight data in identifiable form because



The **ADIS Server** receives aviation data from multiple sources, integrates the data, and provides the integrated data in de-identified forms to authorized (ADIS client) end users.

of concerns about loss of anonymity. Hence, one of the things needed to promote retention and analysis of aviation data is an automated means of de-identification of archived flight data to enable integration of flight data with non-flight aviation data while preserving anonymity. Preferably, such an automated means would enable end users of the data to continue to use pre-existing data-analysis software to identify anomalies in flight data without identifying a specific anomalous flight. It would then also be possible to perform statistical analyses of integrated data.

These needs are satisfied by the ADIS, which enables an end user to request aviation data associated with de-identified flight data. The ADIS includes client software integrated with other software running on flight-operations quality-assurance (FOQA) computers for purposes of analyzing data to study specified types of events or exceedences (departures of flight parameters from normal ranges). In addition to ADIS client software, ADIS includes server hardware and software that provide services to the ADIS clients via the Internet (see figure).

The ADIS server receives and integrates flight and non-flight data pertaining to flights from multiple sources. The server accepts data updates from authorized sources only and responds to requests from authorized users only. In order to satisfy security requirements established by the airlines, (1) an ADIS client must not be accessible from the Internet by an unauthorized user and (2) non-flight data as airport terminal information system (ATIS) and weather data must be displayed without any identifying flight information. ADIS hardware and software architecture as well as encryption and data display scheme are designed to meet these requirements.

When a user requests one or more selected aviation data characteristics associated with an event (e.g., a collision, near miss, equipment malfunction, or exceedence), the ADIS client augments the request with date and time information from encrypted files and submits the augmented request to the server. Once the user's authorization has been verified, the server returns the requested information in de-identified form.

This work was done by Deepak Kulkarni, Yao Wang, Rich Keller, Tom Chidester, and Irving Statler of Ames Research Center; Bob Lynch of Flight Safety Consultants; Hemil Patel and May Windrem of SAIC; Naveen Ashish of USRA-RIACS; and Bob Lawrence of Safe Flight.

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-15036-1.

Electronics/Computers

Servomotor and Controller Having Large Dynamic Range

A lightweight, compact, mechanically simple system offers high performance.

Marshall Space Flight Center, Alabama

A recently developed micro-commanding rotational-position-control system offers advantages of less mechanical complexity, less susceptibility to mechanical resonances, less power demand, less bulk, less weight, and lower cost, relative to prior rotational-position-control systems based on stepping motors and gear drives. This system includes a digital-signal-processor (DSP)-based electronic controller, plus a shaft-angle resolver and a servomotor mounted on the same shaft. Heretofore, micro-stepping has usually been associated with stepping motors, but in this system, the servomotor is micro-commanded in response to rotational-position feedback from the shaft-angle resolver.

The shaft-angle resolver is of a four-speed type chosen because it affords four times the resolution of a single-speed resolver. A key innovative aspect of this system is its position-feedback signal-conditioning circuits, which condition the resolver output signal for multiple ranges of rotational speed. In the preferred version of the system, two rotational-speed ranges are included, but any number of ranges could be added to expand the speed range or increase resolution in particular ranges. In the preferred version, the resolver output is conditioned with two resolver-to-digital converters (RDCs). One RDC is used for speeds from 0.00012 to 2.5 rpm; the other RDC is used for speeds of 2.5 to 6,000 rpm. For the lower speed range, the number of discrete steps of RDC output per revolution was set at 262,144 (4 quadrants at 16 bits per quadrant). For the higher speed range, the number of discrete steps per revolution was set at 4,096 (4 quadrants at 10 bits per quadrant).

In the preferred version, there are position-feedback signal-conditioning circuits that generate two separate outputs. The electronic controller is used to select the rotational-speed range along with whichever of the two position-feedback outputs is appropriate to that range. The controller also receives a speed command through an RS232 serial interface. This rate command is converted to a position command updated at a set frequency — that is, the position is commanded at so many steps per unit time to obtain rotation at a desired speed. Finally, the controller takes the position command and the selected position feedback and implements a proportional + integral + derivative (PID) control law with a current-command output. The current-command output is fed as input to a current amplifier that provides power to the motor. The motor can be a brushless or a standard brush-type DC motor.

The main innovative aspect of this system is the use of the multiple signal-conditioning circuits with the single resolver in generating micro-rotation commands for the motor. The use of the multiple signal-conditioning circuits increases the rotational resolution and the dynamic range for speed control. The speed-control dynamic range of this system is 5×10^7; a greater dynamic range could be obtained by adding signal-conditioning circuits for additional speed and position ranges.

This work was done by Dean C. Alhorn, David E. Howard, and Dennis A. Smith of Marshall Space Flight Center, Ken Dutton of Madison Research Corp., and M. Scott Paulson of Mevatech. Further information is contained in a TSP (see page 1).

This invention has been patented by NASA (U.S. Patent No. 7,081,730). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31529-1.

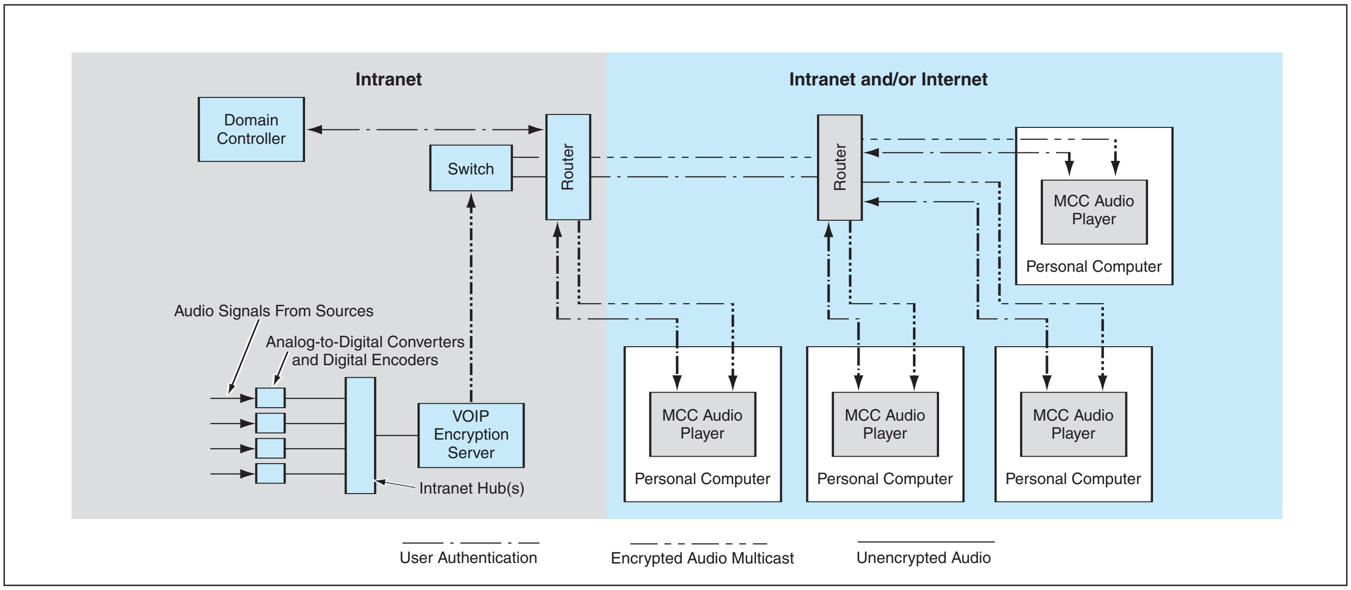
Digital Multicasting of Multiple Audio Streams

Authorized listeners can hear any or all streams in nearly real time.

Lyndon B. Johnson Space Center, Houston, Texas

The Mission Control Center Voice Over Internet Protocol (MCC VOIP) system (see figure) comprises hardware and software that effect simultaneous, nearly real-time transmission of as many as 14 different audio streams to authorized listeners via the MCC intranet and/or the Internet. The original version of the MCC VOIP system was conceived to enable flight-support personnel located in offices outside a spacecraft mission control center to monitor audio loops within the mission control center. Different versions of the MCC VOIP system could be used for a variety of public and commercial purposes — for example, to enable members of the general public to monitor one or more NASA audio streams through their home computers, to enable air-traffic supervisors to monitor communication between airline pilots and air-traffic controllers in training, and to monitor conferences among brokers in a stock exchange.

At the transmitting end, the audio-distribution process begins with feeding the audio signals to analog-to-digital converters. The resulting digital streams are sent through the MCC intranet, using a user datagram protocol (UDP), to a server that converts them to encrypted data packets. The encrypted data packets are then routed to the personal computers of authorized users by use of multicasting techniques. The total data-processing load on the portion of the system up-



The **MCC VOIP System** distributes audio streams, in the form of encrypted data packets, to the personal computers of authorized listeners.

stream of and including the encryption server is the total load imposed by all of the audio streams being encoded, regardless of the number of the listeners or the number of streams being monitored concurrently by the listeners.

The personal computer of a user authorized to listen is equipped with special-purpose MCC audio-player software. When the user launches the program, the user is prompted to provide identification and a password. In one of two access-control provisions, the program is hard-coded to validate the user's identity and password against a list maintained on a domain-controller computer at the MCC. In the other access-control provision, the program verifies that the user is authorized to have access to the audio streams.

Once both access-control checks are completed, the audio software presents a graphical display that includes audio-stream-selection buttons and volume-control sliders. The user can select all or any subset of the available audio streams and can adjust the volume of each stream independently of that of the other streams. The audio-player program spawns a "read" process for the selected stream(s). The spawned process sends, to the router(s), a "multicast-join" request for the selected streams.

The router(s) responds to the request by sending the encrypted multicast packets to the spawned process. The spawned process receives the encrypted multicast packets and sends a decryption packet to audio-driver software. As the volume or muting features are changed by the user, interrupts are sent to the spawned process to change the corresponding attributes sent to the audio-driver software. The total latency of this system — that is, the total time from the origination of the audio signals to generation of sound at a listener's computer — lies between four and six seconds.

This work was done by Mitchell Macha of Johnson Space Center and John Bullock of LiCom. For further information, contact the Johnson Technology Transfer Office at (281) 483-3809.

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, Johnson Space Center, (281) 483-0837. Refer to MSC-23349.

Software

Translator for Optimizing Fluid-Handling Components

A software interface has been devised to facilitate optimization of the shapes of valves, elbows, fittings, and other components used to handle fluids under extreme conditions. This software interface translates data files generated by PLOT3D (a NASA grid-based plotting-and-data-display program) and by computational fluid dynamics (CFD) software into a format in which the files can be read by Sculptor, which is a shape-deformation-and-optimization program. Sculptor enables the user to interactively, smoothly, and arbitrarily deform the surfaces and volumes in two- and three-dimensional CFD models. Sculptor also includes design-optimization algorithms that can be used in conjunction with the arbitrary-shape-deformation components to perform automatic shape optimization. In the optimization process, the output of the CFD software is used as feedback while the optimizer strives to satisfy design criteria that could include, for example, improved values of pressure loss, velocity, flow quality, mass flow, etc.

This program was written by Mark Landon and Ernest Perry of Optimal Solutions Software, LLC 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-00190, volume and number of this NASA Tech Briefs *issue, and the page number.*

AIRSAR Web-Based Data Processing

The AIRSAR automated, Web-based data processing and distribution system is an integrated, end-to-end synthetic aperture radar (SAR) processing system. Designed to function under limited resources and rigorous demands, AIRSAR eliminates operational errors and provides for paperless archiving. Also, it provides a yearly tune-up of the processor on flight missions, as well as quality assurance with new radar modes and anomalous data compensation.

The software fully integrates a Web-based SAR data-user request subsystem, a data processing system to automatically generate co-registered multi-frequency images from both polarimetric and interferometric data collection modes in 80/40/20 MHz bandwidth, an automated verification quality assurance subsystem, and an automatic data distribution system for use in the remote-sensor community. Features include Survey Automation Processing in which the software can automatically generate a quick-look image from an entire 90-GB SAR raw data 32-MB/s tape overnight without operator intervention. Also, the software allows product ordering and distribution via a Web-based user request system.

To make AIRSAR more user friendly, it has been designed to let users search by entering the desired mission flight line (Missions Searching), or to search for any mission flight line by entering the desired latitude and longitude (Map Searching). For precision image automation processing, the software generates the products according to each data processing request stored in the database via a Queue management system. Users are able to have automatic generation of co-registered multi-frequency images as the software generates polarimetric and/or interferometric SAR data processing in ground and/or slant projection according to user processing requests for one of the 12 radar modes.

This program was written by Anhua Chu, Jakob Van Zyl, Yunjin Kim, Scott Hensley, Yunling Lou, Soren Madsen, Bruce Chapman, David Imel, and Stephen Durden of Caltech, and Wayne Tung of Columbus Technologies and Services, Inc. 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-40998.

Pattern Matcher for Trees Constructed From Lists

A software library has been developed that takes a high-level description of a pattern to be satisfied and applies it to a target. If the two match, it returns success; otherwise, it indicates a failure. The target is semantically a tree that is constructed from elements of terminal and non-terminal nodes represented through lists and symbols. Additionally, functionality is provided for finding the element in a set that satisfies a given pattern and doing a tree search, finding all occurrences of leaf nodes that match a given pattern. This process is valuable because it is a new algorithmic approach that significantly improves the productivity of the programmers and has the potential of making their resulting code more efficient by the introduction of a novel semantic representation language. This software has been used in many applications delivered to NASA and private industry, and the cost savings that have resulted from it are significant.

This program was written by Mark James 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-42732.

Reducing a Knowledge-Base Search Space When Data Are Missing

This software addresses the problem of how to efficiently execute a knowledge base in the presence of missing data. Computationally, this is an exponentially expensive operation that without heuristics generates a search space of $1 + 2^n$ possible scenarios, where n is the number of rules in the knowledge base. Even for a knowledge base of the most modest size, say 16 rules, it would produce 65,537 possible scenarios. The purpose of this software is to reduce the complexity of this operation to a more manageable size. The problem that this system solves is to develop an automated approach that can reason in the presence of missing data. This is a meta-reasoning capability that repeatedly calls a diagnostic engine/model to provide prognoses and prognosis tracking. In the big picture, the scenario generator takes as its input the current state of a system, including probabilistic information from Data Forecasting. Using model-based reasoning techniques, it returns an ordered list of fault scenarios that could be generated from the current state, i.e., the plausible future failure modes of the system as it presently stands. The scenario generator models a Potential Fault Scenario (PFS) as a black box, the input of which is a set of states tagged with priorities and the output of which is one or more potential fault scenarios tagged by a confidence factor. The results from the system are used by a model-based diagnostician to predict the future health of the monitored system.

This program was written by Mark James 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-42818.

Ground-Based Correction of Remote-Sensing Spectral Imagery

Software has been developed for an improved method of correcting for the atmospheric optical effects (primarily, effects of aerosols and water vapor) in spectral images of the surface of the Earth acquired by airborne and spaceborne remote-sensing instruments. In this method, the variables needed for the corrections are extracted from the readings of a radiometer located on the ground in the vicinity of the scene of interest. The software includes algorithms that analyze measurement data acquired from a shadow-band radiometer. These algorithms are based on a prior radiation transport software model, called MODTRAN™, that has been developed through several versions up to what are now known as MODTRAN4™ and MODTRAN5™. These components have been integrated with a user-friendly Interactive Data Language (IDL) front end and an advanced version of MODTRAN4™. Software tools for handling general data formats, performing a Langley-type calibration, and generating an output file of retrieved atmospheric parameters for use in another atmospheric-correction computer program known as "FLAASH" have also been incorporated into the present soft-ware. Concomitantly with the soft-ware described thus far, there has been developed a version of FLAASH that utilizes the retrieved atmospheric parameters to process spectral image data.

These programs were written by Steven M. Adler-Golden, Peter Rochford, Michael Matthew, and Alexander Berk of Spectral Sciences, Inc. for Stennis Space Center.

Inquiries concerning rights for the commercial use of this invention should be addressed to:

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Refer to SSC-00226, volume and number of this NASA Tech Briefs *issue, and the page number.*

State-Chart Autocoder

A computer program translates Unified Modeling Language (UML) representations of state charts into source code in the C, C++, and Python computing languages. ("State charts" signifies graphical descriptions of states and state transitions of a spacecraft or other complex system.) The UML representations constituting the input to this program are generated by using a UML-compliant graphical design program to draw the state charts. The generated source code is consistent with the "quantum programming" approach, which is so named because it involves discrete states and state transitions that have features in common with states and state transitions in quantum mechanics. Quantum programming enables efficient implementation of state charts, suitable for real-time embedded flight software. In addition to source code, the autocoder program generates a graphical-user-interface (GUI) program that, in turn, generates a display of state transitions in response to events triggered by the user. The GUI program is wrapped around, and can be used to exercise the state-chart behavior of, the generated source code. Once the expected state-chart behavior is confirmed, the generated source code can be augmented with a software interface to the rest of the software with which the source code is required to interact.

This program was written by Kenneth Clark, Garth Watney, Alexander Murray, and Edward Benowitz 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-41951.

Pointing History Engine for the Spitzer Space Telescope

The Pointing History Engine (PHE) is a computer program that provides mathematical transformations needed to reconstruct, from downlinked telemetry data, the attitude of the Spitzer Space Telescope (formerly known as the Space Infrared Telescope Facility) as a function of time. The PHE also serves as an example for development of similar pointing reconstruction software for future space telescopes. The transformations implemented in the PHE take account of the unique geometry of the Spitzer telescope-pointing chain, including all data on relative alignments of components, and all information available from attitude-determination instruments. The PHE makes it possible to coordinate attitude data with observational data acquired at the same time, so that any observed astronomical object can be located for future reference and re-observation. The PHE is implemented as a subroutine used in conjunction with telemetry-formatting services of the Mission Image Processing Laboratory of NASA's Jet Propulsion Laboratory to generate the Boresight Pointing History File (BPHF). The BPHF is an archival database designed to serve as Spitzer's primary astronomical reference documenting where the telescope was pointed at any time during its mission.

This program was written by David Bayard, Asif Ahmed, and Paul Brugarolas 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-43374.

Mechanics/Machinery

Low-Friction, High-Stiffness Joint for Uniaxial Load Cell

Friction and hysteresis are minimized.

Lyndon B. Johnson Space Center, Houston, Texas

A universal-joint assembly has been devised for transferring axial tension or compression to a load cell. To maximize measurement accuracy, the assembly is required to minimize any moments and non-axial forces on the load cell and to exhibit little or no hysteresis. The requirement to minimize hysteresis translates to a requirement to maximize axial stiffness (including minimizing backlash) and a simultaneous requirement to minimize friction. In practice, these are competing requirements, encountered repeatedly in efforts to design universal joints. Often, universal-joint designs represent compromises between these requirements.

The improved universal-joint assembly contains two universal joints, each containing two adjustable pairs of angular-contact ball bearings. One might be tempted to ask why one could not use simple ball-and-socket joints rather than something as complex as universal joints containing adjustable pairs of angular-contact ball bearings. The answer is that ball-and-socket joints do not offer sufficient latitude to trade stiffness versus friction: the inevitable result of an attempt to make such a trade in a ball-and-socket joint is either too much backlash or too much friction.

The universal joints are located at opposite ends of an axial subassembly that contains the load cell. The axial subassembly includes an axial shaft, an axial housing, and a fifth adjustable pair of angular-contact ball bearings that allows rotation of the axial housing relative to the shaft. The preload on each pair of angular-contact ball bearings can be adjusted to obtain the required stiffness with minimal friction, tailored for a specific application. The universal joint at each end affords two degrees of freedom, allowing only axial force to reach the load cell regardless of application of moments and non-axial forces. The rotational joint on the axial subassembly affords a fifth degree of freedom, preventing application of a torsion load to the load cell.

This work was done by James L. Lewis of Johnson Space Center, and Thang Le and Monty B. Carroll of Lockheed Martin Corp. 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, Johnson Space Center, (281) 483-0837. Refer to MSC-23876.

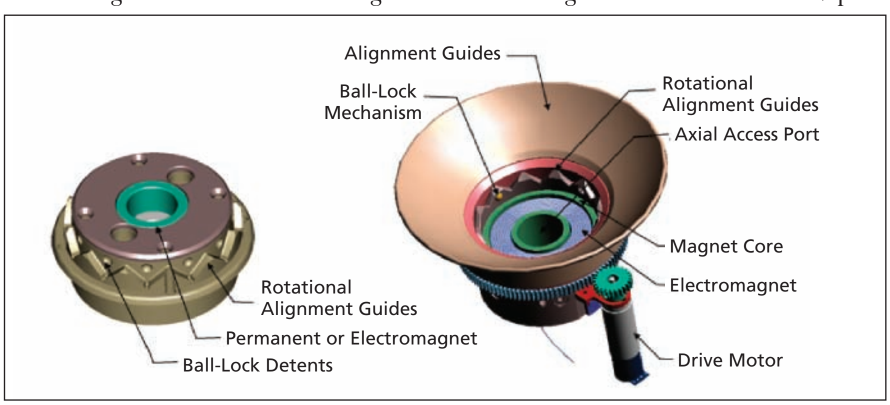
Magnet-Based System for Docking of Miniature Spacecraft

The capture envelope for this system is approximated by a 5-in. (12.7-cm) cube.

Lyndon B. Johnson Space Center, Houston, Texas

A prototype system for docking a miniature spacecraft with a larger spacecraft has been developed by engineers at the Johnson Space Center. Engineers working on Mini AERCam, a free-flying robotic camera, needed to find a way to successfully dock and undock their miniature spacecraft to refuel the propulsion and recharge the batteries. The subsystems developed (see figure) include (1) a docking port, designed for the larger spacecraft, which contains an electromagnet, a ball lock mechanism, and a service probe; and (2) a docking cluster, designed for the smaller spacecraft, which contains either a permanent magnet or an electromagnet.

A typical docking operation begins with the docking spacecraft maneuvering into position near the docking port on the parent vehicle. The electromagnet(s) are then turned on, and, if necessary, the docking spacecraft is then maneuvered within the capture envelope of the docking port. The capture envelope for this system is approximated by a 5-in. (12.7-cm) cube centered on the front of the docking-port electromagnet and within an angular misalignment of <30°. Thereafter, the magnetic forces draw the smaller spacecraft toward the larger one and this brings the spacecraft into approximate alignment prior to contact. Mechanical alignment guides provide the final rotational alignment into one of 12 posi-



The **Magnetic Capture Mechanism** includes a docking cluster on the left and a docking port on the right.

tions. Once the docking vehicle has been captured magnetically in the docking port, the ball-lock mechanism is activated, which locks the two spacecraft together. At this point the electromagnet(s) are turned off, and the service probe extended if recharge and refueling are to be performed. Additionally, during undocking, the polarity of one electromagnet can be reversed to provide a gentle push to separate the two spacecraft. This system is currently being incorporated into the design of Mini AERCam vehicle.

This work was done by Nathan Howard of **Johnson Space Center** *and Hai D. Nguyen of Lockheed Martin Corp. For further information, access http://aercam.nasa.gov/index.htm.*

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, Johnson Space Center, (281) 483-0837. Refer to MSC-23997.

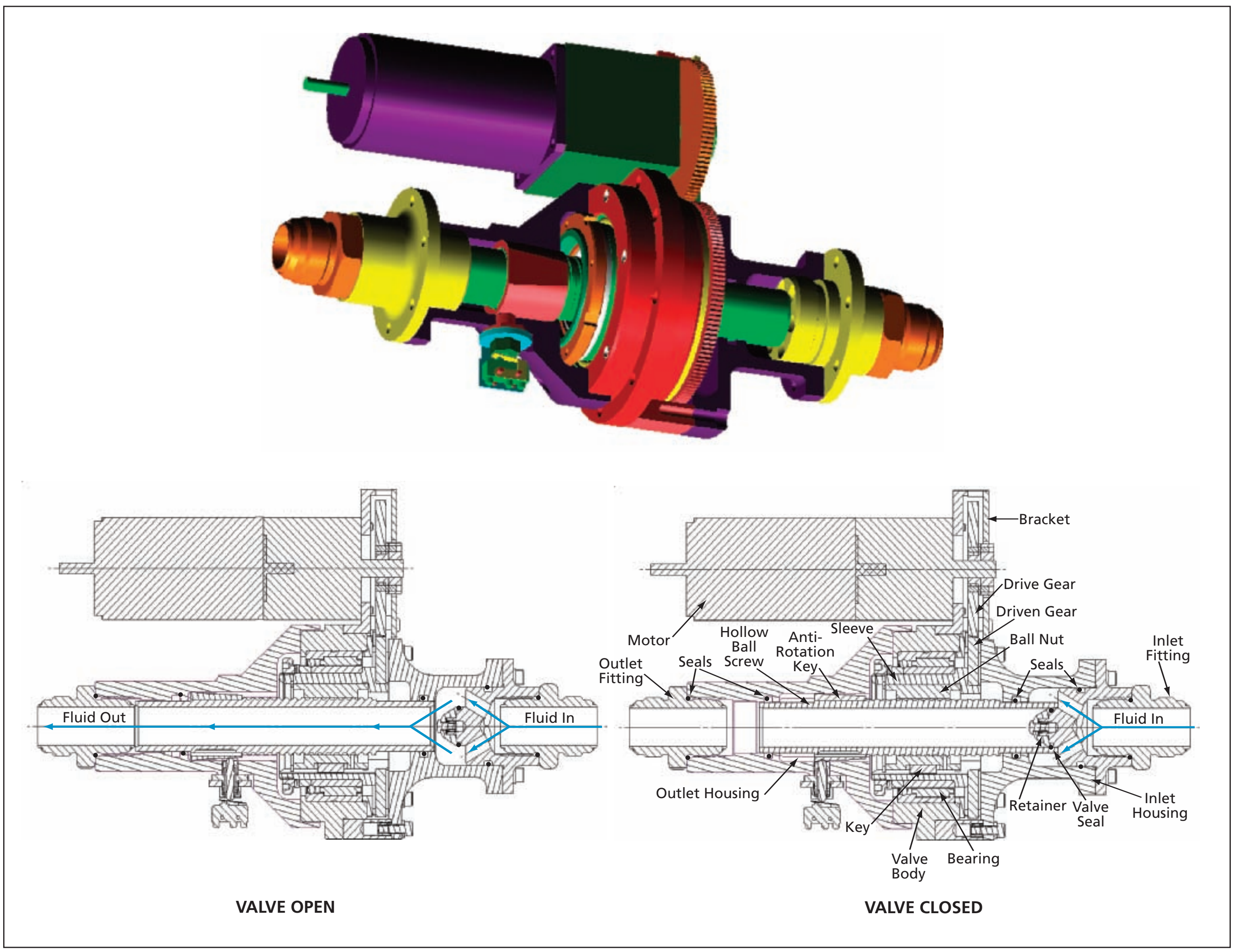
Electromechanically Actuated Valve for Controlling Flow Rate

A ball screw would be both an actuator and a flow-control component.

Marshall Space Flight Center, Alabama

A proposed valve for controlling the rate of flow of a fluid would include an electric-motor-driven ball-screw mechanism for adjusting the seating element of the valve to any position between fully closed and fully open. The motor would be of a type that can be electronically controlled to rotate to a specified angular position and to rotate at a specified rate, and the ball screw would enable accurate linear positioning of the seating element as a function of angular position of the motor. Hence, the proposed valve would enable fine electronic control of the rate of flow and the rate of change of flow.

The uniqueness of this valve lies in a high degree of integration of the actuation mechanism with the flow-control components into a single, relatively compact unit. A notable feature of this integration is that in addition to being a major part of the actuation mechanism, the ball screw would also be a flow-control component: the ball screw would be hollow so as to contain part of the main flow passage, and one end of the ball



The **Rate of Flow Through This Valve** would be determined by the axial position of the hollow ball screw relative to the valve seat.

screw would be the main seating valve element.

The relationships among the components of the valve are best understood by reference to the figure, which presents meridional cross sections of the valve in the fully closed and fully open positions. The motor would be supported by a bracket bolted to the valve body. By means of gears or pulleys and a timing belt, motor drive would be transmitted to a sleeve that would rotate on bearings in the valve body. A ball nut inside the sleeve would be made to rotate with the sleeve by use of a key.

The ball screw would pass through and engage the ball nut. A key would prevent rotation of the ball screw in the valve body while allowing the ball screw to translate axially when driven by the ball nut. The outer surface of the ball screw would be threaded only in a mid-length region: the end regions of the outer surface of the ball screw would be polished so that they could act as dynamic sealing surfaces. The inlet end (the right end as depicted in the figure) of the ball screw would be the main seating valve element: in the fully closed position, it would be pressed against the valve seat, as depicted in the upper part of the figure.

A retainer would hold the valve seat in an inlet fitting. In addition, the retainer would be contoured to obtain a specified flow rate as a function of axial position of the ball screw.

In the fully closed position, little force would be needed to press the ball screw against the seat because the push bore area upon which the upstream pressure would act would be small. The motor would position and hold the ball screw against the seat, providing the force necessary for sealing.

To open the valve to a particular position, the motor would be commanded to rotate to a particular angular position (equivalently, a particular number of revolutions) at a particular rate of rotation within its torque limitations. Once the valve was open, fluid would flow through the inlet fitting and the chamber in the inlet housing, past the seat and its retainer, along the hollow core of the ball screw, and through the outlet housing and outlet fitting. The net force generated from fluid pressure in the open position would be small because the pressure exposed to the push bore areas at the inlet and outlet are nearly equal and the forces generated would be in opposing directions.

This work was done by Paul Patterson of Marshall Space Flight Center. Further information is contained in a TSP (see page 1).

This invention has been patented by NASA (U.S. Patent No. 6,802,488). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-31761-1.

Plumbing Fixture for a Microfluidic Cartridge

Lyndon B. Johnson Space Center, Houston, Texas

A fixture has been devised for making the plumbing connections between a microfluidic device in a replaceable cartridge and an external fluidic system. The fixture includes a 0.25-in. (6.35-mm) thick steel plate, to which the cartridge is fastened by two 10-32 thumb screws. The plate holds one plumbing fitting for the inlet and one for the outlet of the microfluidic device. Each fitting includes a fused-silica tube of 0.006-in. (≈0.15-mm) inside diameter within a fluorinated ethylene-propylene (FEP) tube of 0.0155-in. (≈0.39-mm) inside diameter and 0.062-in. (≈1.57-mm) outside diameter. The FEP tube is press-fit through the steel plate so that its exposed end is flush with the surface of the plate, and the silica tube protrudes 0.03 in. (≈0.76 mm) from the plate/FEP-tube-end surface. The cartridge includes a glass cover plate that contains 0.06-mm-wide access ports. When the cartridge is fastened to the steel plate, the silica tubes become inserted through the access ports and into the body of the cartridge, while the ends of the FEP tubes become butted against the glass cover plate. An extremely tight seal is thereby made.

This work was done by Kevin Francis of Johnson Space Center. For further information, contact the Johnson Innovative Partnerships Office at (281) 483-3809. MSC-23335

Camera Mount for a Head-Up Display

Langley Research Center, Hampton, Virginia

A mounting mechanism was designed and built to satisfy requirements specific to a developmental head-up display (HUD) to be used by pilots in a Boeing 757 airplane. This development was necessitated by the fact that although such mounting mechanisms were commercially available for other airplanes, there were none for the 757. The mounting mechanism supports a miniature electronic camera that provides a forward view. The mechanism was designed to be integrated with the other HUD instrumentation and to position the camera so that what is presented to the pilot is the image acquired by the camera, overlaid with alphanumeric and/or graphical symbols, from a close approximation of the pilot's natural forward perspective. The mounting mechanism includes an L-shaped mounting arm that can be adjusted easily to the pilot's perspective, without prior experience. The mounting mechanism is lightweight and flexible and presents little hazard to the pilot.

This work was done by Wayne Geouge, Monica Barnes, Larry Johnson, and Kevin Shelton of Langley 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 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-16380-1.

Core-Cutoff Tool

Damage and waste are reduced.

John F. Kennedy Space Center, Florida

A tool makes a cut perpendicular to the cylindrical axis of a core hole at a predetermined depth to free the core at that depth. The tool does not damage the surrounding material from which the core was cut, and it operates within the core-hole kerf.

Coring usually begins with use of a hole saw or a hollow cylindrical abrasive cutting tool to make an annular hole that leaves the core (sometimes called the "plug") in place. In this approach to coring as practiced heretofore, the core is removed forcibly in a manner chosen to shear the core, preferably at or near the greatest depth of the core hole. Unfortunately, such forcible removal often damages both the core and the surrounding material (see Figure 1). In an alternative prior approach, especially applicable to toxic or fragile material, a core is formed and freed by means of milling operations that generate much material waste. In contrast, the present tool eliminates the damage associated with the hole-saw approach and reduces the extent of milling operations (and, hence, reduces the waste) associated with the milling approach.

The present tool (see Figure 2) includes an inner sleeve and an outer sleeve and resembles the hollow cylindrical tool used to cut the core hole. The sleeves are thin enough that this tool fits within the kerf of the core hole. The inner sleeve is attached to a shaft that, in turn, can be attached to a drill motor or handle for turning the tool.

This tool also includes a cutting wire attached to the distal ends of both sleeves. The cutting wire is long enough that with sufficient relative rotation of the inner and outer sleeves, the wire can cut all the way to the center of the core.

The tool is inserted in the kerf until its distal end is seated at the full depth. The inner sleeve is then turned. During turning, frictional drag on the outer core pulls the cutting wire into contact with the core. The cutting force of the wire against the core increases with the tension in the wire and, hence, with the frictional drag acting on the outer sleeve. As the wire cuts toward the center of the core, the inner sleeve rotates farther with respect to the outer sleeve. Once the wire has cut to the center of the

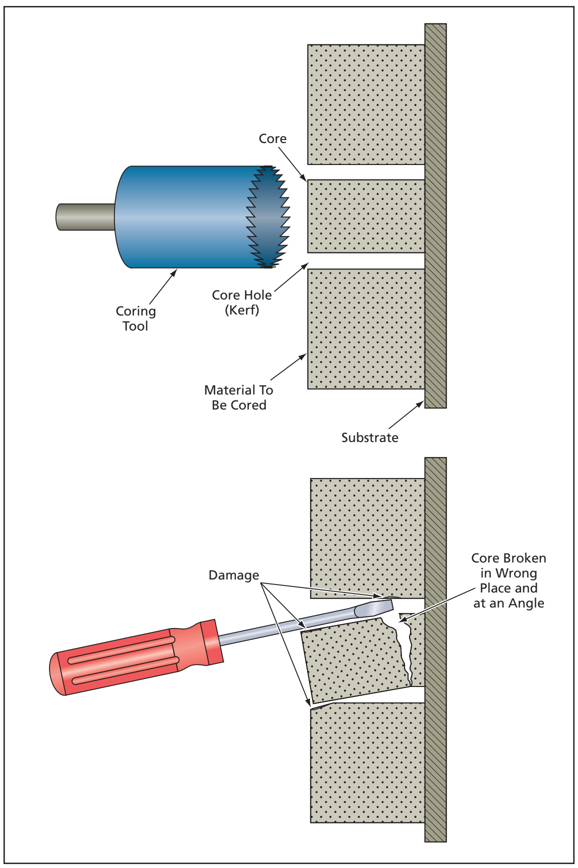


Figure 1. A **Core Remains in Place** after cutting a hole around it. Forcible removal of the core (in this case, by prying with a screwdriver in the kerf) can damage both the core and the surrounding material.

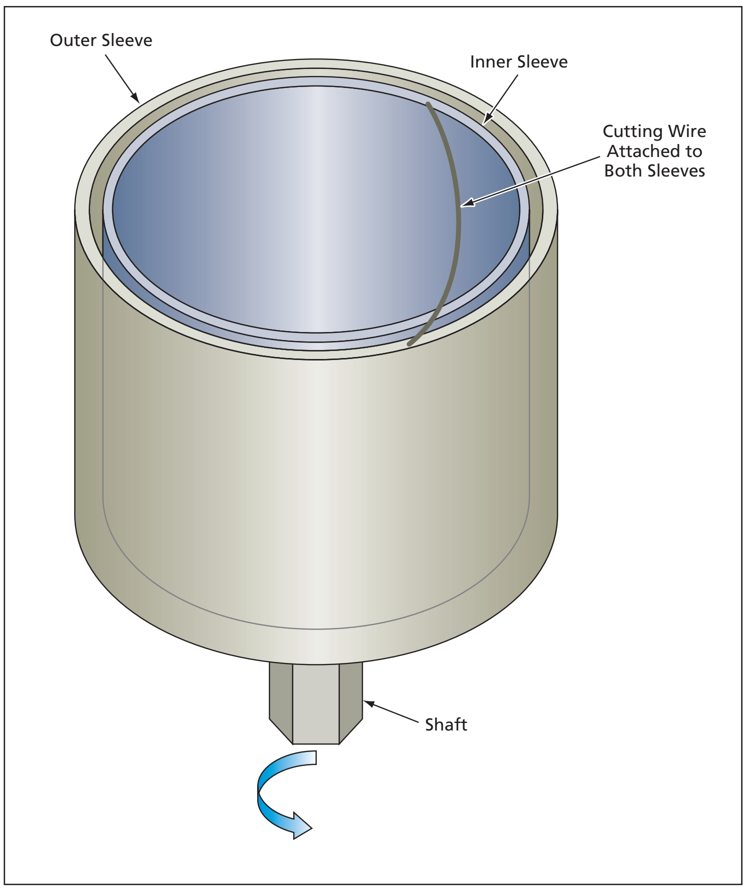


Figure 2. The **Core-Cutoff Tool** is designed to operate entirely within the kerf so as to free the core while generating minimal waste and not damaging either the core or the surrounding material.

core, the tool and the core can be removed from the hole.

The proper choice of cutting wire depends on the properties of the core material. For a sufficiently soft core material, a nonmetallic monofilament can be used. For a rubberlike core material, a metal wire can be used. For a harder core material, it is necessary to use an abrasive wire, and the efficiency of the tool can be increased greatly by vacuuming away the particles generated during cutting.

For a core material that can readily be melted or otherwise cut by use of heat, it could be preferable to use an electrically heated cutting wire. In such a case, electric current can be supplied to the cutting wire, from an electrically isolated source, via rotating contact rings mounted on the sleeves.

This work was done by Darrell Gheen of United Space Alliance LLC for Kennedy Space Center. For further information, contact the Kennedy Innovative Partnerships Office at (321) 861-7158.
KSC-12600

Physical Sciences

Recirculation of Laser Power in an Atomic Fountain

Optical and electronic subsystems of a frequency standard can be simplified.

NASA's Jet Propulsion Laboratory, Pasadena, California

A new technique for laser-cooling atoms in a cesium atomic fountain frequency standard relies on recirculation of laser light through the atom-collection region of the fountain. The recirculation, accomplished by means of reflections from multiple fixed beam-splitter cubes, is such that each of two laser beams makes three passes. As described below, this recirculation scheme offers several advantages over prior designs, including simplification of the laser system, greater optical power throughput, fewer optical and electrical connections, and simplification of beam power balancing.

A typical laser-cooled cesium fountain requires the use of six laser beams arranged as three orthogonal pairs of counter-propagating beams to decelerate the atoms and hold them in a three-dimensional optical trap in vacuum. Typically, these trapping/cooling beams are linearly polarized and are positioned and oriented so that (1) counter-propagating beams in each pair have opposite linear polarizations and (2) three of the six orthogonal beams have the sum of their propagation directions pointing up, while the other three have the sum of their propagation directions pointing down.

In a typical prior design, two lasers are used — one to generate the three "up" beams, the other to generate the three "down" beams. For this purpose, the output of each laser is split three ways, then the resulting six beams are delivered to the vacuum system, independently of each other, via optical fibers.

The present recirculating design also requires two lasers, but the beams are not split before delivery. Instead, only one "up" beam and one oppositely polarized "down" beam are delivered to the vacuum system, and each of these beams is sent through the collection region three times. The polarization of each beam on each pass through the collection region is set up to yield the same combination of polarization and propagation directions as described above.

In comparison with the prior design, the present recirculating design utilizes the available laser light more efficiently, making it possible to trap more atoms at a given laser power or the same number of atoms at a lower laser power. The present design is also simpler in that it requires fewer optical fibers, fiber couplings, and collimators, and fewer photodiodes for monitoring beam powers. Additionally, the present design alleviates the difficulty of maintaining constant ratios among power levels of the beams within each "up" or "down" triplet.

This work was done by Daphna G. Enzer, William M. Klipstein, and James D. Moore of NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-41202

Simplified Generation of High-Angular-Momentum Light Beams

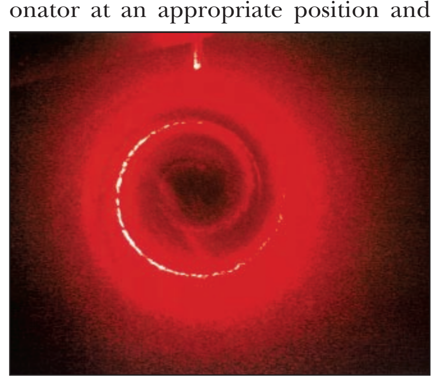
Inherent properties of a WGM resonator and optical fiber are exploited.

NASA's Jet Propulsion Laboratory, Pasadena, California

A simplified method of generating a beam of light having a relatively high value of angular momentum (see figure) involves the use of a compact apparatus consisting mainly of a laser, a whispering-gallery-mode (WGM) resonator, and optical fibers. The method also can be used to generate a Bessel beam. ("Bessel beam" denotes a member of a class of non-diffracting beams, so named because their amplitudes are proportional to Bessel functions of the radii from their central axes. High-order Bessel beams can have high values of angular momentum.)

High-angular-momentum light beams are used in some applications in biology and nanotechnology, wherein they are known for their ability to apply torque to make microscopic objects rotate. High-angular-momentum light beams could also be used to increase bandwidths of fiber-optic communication systems. The present simplified method of generating a high-angular-momentum light beam was conceived as an alternative to prior such methods, which are complicated and require optical setups that include, variously, holograms, modulating Fabry-Perot cavities, or special microstructures.

The present simplified method exploits a combination of the complex structure of the electromagnetic field inside a WGM resonator, total internal reflection in the WGM resonator, and the electromagnetic modes supported by an optical fiber. The optical fiber used to extract light from the WGM resonator is made of fused quartz. The output end of this fiber is polished flat and perpendicular to the fiber axis. The input end of this fiber is cut on a slant and placed very close to the WGM resonator at an appropriate position and



A **Vortex** is shown as it is generated by the apparatus. The red glowing stick at the top edge of the photo is a fused silica horn.

orientation. To excite the resonant whispering-gallery modes, light is introduced into the WGM resonator via another optical fiber that is part of a pigtailed fiber-optic coupler.

Light extracted from the WGM resonator is transformed into a high-angular-momentum beam inside the extraction optical fiber and this beam is emitted from the polished flat output end. By adjusting the geometry of this apparatus, it is possible to generate a variety of optical beams characterized by a wide range of parameters. These beams generally have high angular momenta and can be of either Bessel or Bessel-related types.

This work was done by Anatoliy Savchenkov, Lute Maleki, Andrey Matsko, Dmitry Strekalov, and Ivan Grudinin 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:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-42965, volume and number of this NASA Tech Briefs *issue, and the page number.*

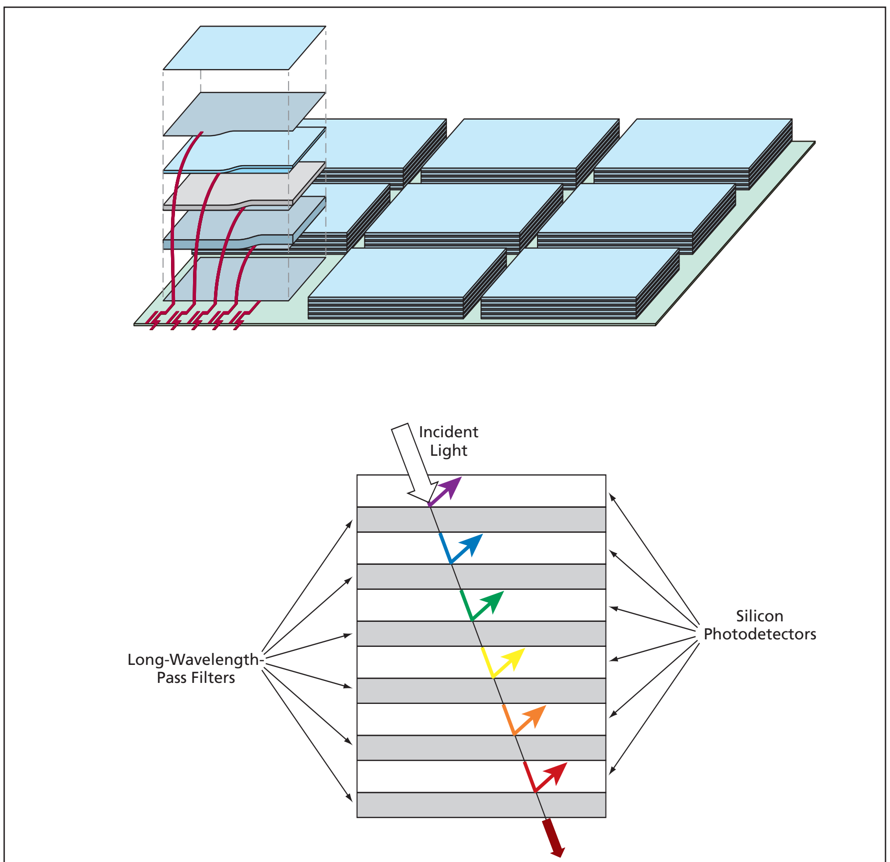
Imaging Spectrometer on a Chip

One integrated circuit would perform the functions of a conventional several-kilogram spectrometer.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed visible-light imaging spectrometer on a chip would be based on the concept of a heterostructure comprising multiple layers of silicon-based photodetectors interspersed with long-wavelength-pass optical filters. In a typical application, this heterostructure would be replicated in each pixel of an image-detecting integrated circuit of the active-pixel-sensor type (see figure).

The design of the heterostructure would exploit the fact that within the visible portion of the spectrum, the characteristic depth of penetration of photons increases with wavelength. Proceeding from the front toward the back, each successive long-wavelength-pass filter would have a longer cutoff wavelength, and each successive photodetector would be made thicker to enable it to absorb a greater proportion of incident longer-wavelength photons.



Each Pixel of an Active-Pixel Sensor would contain multiple photodetector/filter pairs operating at successively longer wavelengths.

Incident light would pass through the first photodetector and encounter the first filter, which would reflect light having wavelengths shorter than its cutoff wavelength and pass light of longer wavelengths. A large portion of the incident and reflected shorter-wavelength light would be absorbed in the first photodetector.

The light that had passed through the first photodetector/filter pair of layers would pass through the second photodetector and encounter the second filter, which would reflect light having wavelengths shorter than its cutoff wavelength while passing light of longer wavelengths. Thus, most of the light reflected by the second filter would lie in the wavelength band between the cutoff wavelengths of the first and second filters. Thus, further, most of the light absorbed in the second photodetector would lie in this wavelength band. In a similar manner, each successive photodetector would detect, predominantly, light in a successively longer wavelength band bounded by the shorter cutoff wavelength of the preceding filter and the longer cutoff wavelength of the following filter.

This work was done by Yu Wang, Bedabrata Pain, Thomas Cunningham, and Xinyu Zheng of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-41125

Interferometric Quantum-Nondemolition Single-Photon Detectors

These detectors would function independently of frequency.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two interferometric quantum-nondemolition (QND) devices have been proposed: (1) a polarization-independent device and (2) a polarization-preserving device. The prolarization-independent device works on an input state of up to two photons, whereas the polarization-preserving device works on a superposition of vacuum and single-photon states. The overall function of the device would be to probabilistically generate a unique detector output only when its input electromagnetic mode was populated by a single photon, in which case its output mode would also be populated by a single photon.

Like other QND devices, the proposed devices are potentially useful for a variety of applications, including such areas of NASA interest as quantum computing, quantum communication, detection of gravity waves, as well as pedagogical demonstrations of the quantum nature of light. Many protocols in quantum computation and quantum communication require the possibility of detecting a photon without destroying it. The only prior single-photon-detecting QND device is based on quantum electrodynamics in a resonant cavity and, as such, it depends on the photon frequency. Moreover, the prior device can distinguish only between one photon and no photon. The proposed interferometric QND devices would not depend on frequency and could distinguish between (a) one photon and (b) zero or two photons.

The first proposed device is depicted schematically in Figure 1. The input electromagnetic mode would be a superposition of a zero-, a one-, and a two-photon quantum state. The overall function of the device would be to probabilistically generate a unique detector output only when its input electromagnetic mode was populated by a single photon, in which case its output mode also would be populated by a single photon.

The input mode would first be divided by a 50:50 beam splitter. The two resulting modes would be directed into two separate Mach-Zehnder (MZ) interferometers, each of which would contain elements that would produce a phase shift of $\pi/2$ radians between its two arms. At the same time, single-photon probes would enter through secondary input ports of the MZ interferometers. Whenever a single-input photon entered through the primary port of either interferometer, the single-pho-

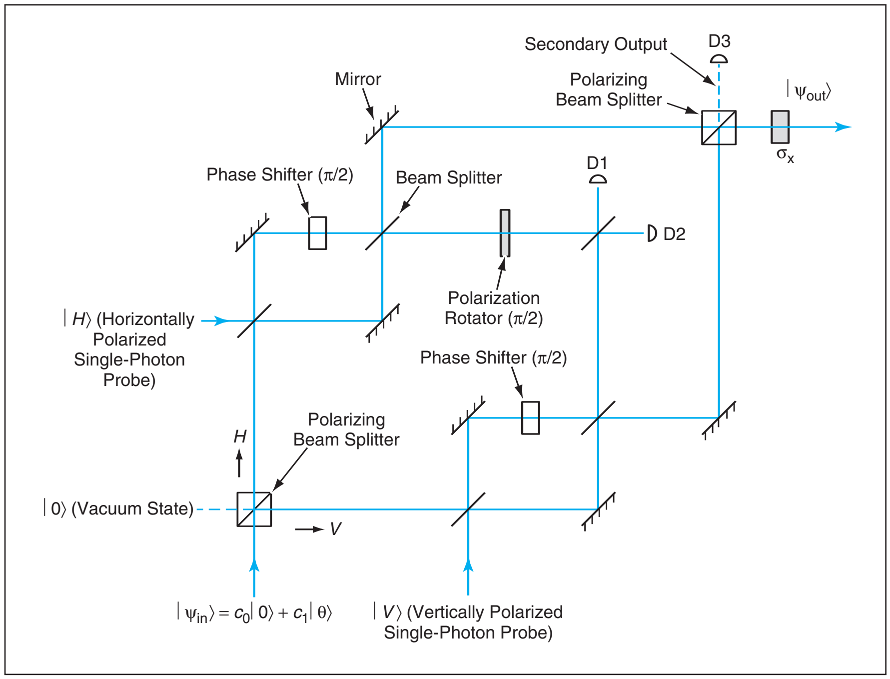


Figure 2. In this **Interferometric QND Device**, a D1/D2 coincidence accompanied by zero output from D3 would signal the presence of a single photon of arbitrary polarization, which would be preserved.

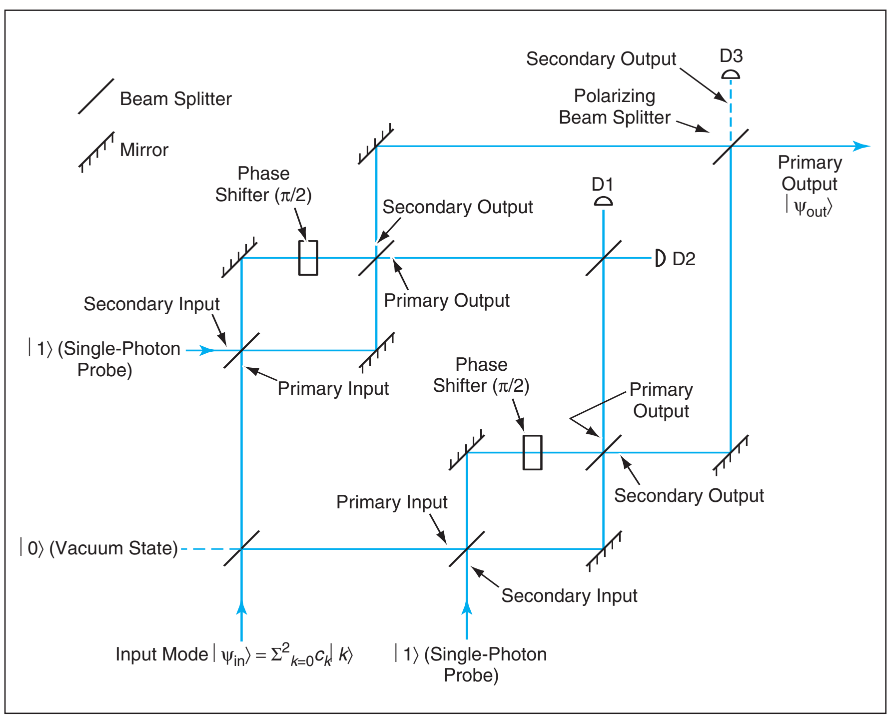


Figure 1. A **Single Photon in the Input** of this interferometric QND device would be indicated by coincident outputs of photodetectors D1 and D2 and no output of photodetector D3.

ton probe would effect a relative-phase change. The primary outputs of the MZ interferometers would be mixed in a beam splitter and detected by photodetectors D1 and D2. A coincidence in the outputs of these photodetectors could signal the presence of one or two photons in the input mode. The interferometers would be balanced in such a way that a vacuum input could not result in a coincidence in detectors D1 and D2.

The remaining outgoing modes would be combined in another beam splitter. The secondary output of this beam splitter would be sent to photodetector D3, while the primary output of this beam splitter would be the desired output mode of the device. D3 would be used to rule out a two-photon input state. The net result would be that an absence of output of detector D3 simultaneous with a coincidence in detectors D1 and D2 would signify that both the input and output modes of the overall device were single-photon states. The probability that a single-photon input state would give rise to a D1/D2 coincidence would be 1/8. If one were to repeat the QND measurement *ad infinitum*, the probability of a successful measurement would be

$$\sum_{n=1}^{\infty}(1/8)^n = 1/7$$

If the photodetectors were capable of resolving single photons and operated with efficiency η, then the overall efficiency for repeated measurements would be $\eta^2/7$.

The second proposed device, depicted in Figure 2, is designed to signal the presence of a single photon with arbitrary polarization state $|\theta\rangle = \alpha|H\rangle + \beta|V\rangle$, (where α and β are complex numbers and $|H\rangle$ and $|V\rangle$ signify the horizontal and vertical polarization states, respectively) and to preserve the input polarization in the output. The second proposed device is similar to the first proposed device except as follows:

- The initial and final beam splitters would be of the polarizing type.
- The single-photon probes would be in the same polarization as those of the primary inputs to their respective MZ interferometers.
- The secondary output of the horizontal-polarization MZ interferometer would be rotated by $\pi/2$ radians (in other words, made vertical) in order to prevent any polarization/path information from affecting the outputs of D1 and D2.
- The output beam would be subjected to a polarization flip σ_x: $\{|H\rangle\rightarrow|V\rangle, |V\rangle\rightarrow|H\rangle\}$ to recover the input state.

The single-photon input that one seeks to detect would result in a D1/D2 coincidence accompanied by zero output of D3. In this device, a D1/D2 coincidence accompanied by zero output from D3 could also indicate a two-photon input state $\alpha|H^2\rangle_{in} + \beta|V^2\rangle_{in}$ and a corresponding output state of $(\alpha - \beta)|HV\rangle_{out}$. One could suppress this undesired condition by applying the appropriate SU(2) transformation to make $\alpha = \beta$ upstream of the interferometer and then applying the inverse of the transformation downstream of the interferometer.

This work was done by Pieter Kok, Hwang Lee, and Jonathan Dowling of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).
NPO-30551

Ring-Down Spectroscopy for Characterizing a CW Raman Laser

Parameters of operation can be obtained from a single ring-down scan.

NASA's Jet Propulsion Laboratory, Pasadena, California

A relatively simple technique for characterizing an all-resonant intracavity continuous-wave (CW) solid-state Raman laser involves the use of ring-down spectroscopy. As used here, "characterizing" signifies determining such parameters as threshold pump power, Raman gain, conversion efficiency, and quality factors (Q values) of the pump and Stokes cavity modes.

Heretofore, in order to characterize resonant-cavity-based Raman lasers, it has usually been necessary to manipulate the frequencies and power levels of pump lasers and, in each case, to take several sets of measurements. In cases involving ultra-high-Q resonators, it also has been desirable to lock pump lasers to resonator modes to ensure the quality of measurement data. Simpler techniques could be useful.

In the present ring-down spectroscopic technique, one infers the parameters of interest from the decay of the laser out of its steady state. This technique does not require changing the power or frequency of the pump laser or locking the pump laser to the resonator mode.

The technique is based on a theoretical analysis of what happens when the pump laser is abruptly switched off after the Raman generation reaches the steady state. The analysis starts with differential equations for the evolution of the amplitudes of the pump and Stokes electric fields, leading to solutions for the power levels of the pump and Stokes fields as functions of time and of the aforementioned parameters. Among other things, these solutions show how the ring-down time depends, to some extent, on the electromagnetic energy accumulated in the cavity.

The solutions are readily converted to relatively simple equations for the parameters as functions of quantities that can be determined from measurements of the time-dependent power levels. For example, the steady-state intracavity conversion efficiency is given by $\Gamma_1/\Gamma_2 - 1$ and the threshold power is given by $P_{in}(\Gamma_2/\Gamma_1)^2$, where P_{in} is the steady-state input pump power immediately prior to abrupt switch-off, Γ_1 is the initial rate of decay of the pump field, and Γ_2 is the final rate of decay of the pump field. Hence, it is possible to determine all the parameters from a single ring-down scan, provided that the measurements taken in that scan are sufficiently accurate and complete.

This work was done by Andrey Matsko, Anatoliy Savchenkov, and Lute Maleki of Caltech for NASA's Jet Propulsion Laboratory. 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, NASA Management Office–JPL. Refer to NPO-42281.

Complex Type-II Interband Cascade MQW Photodetectors

Multiple active subregions, each optimized for a different color, would enable multicolor operation.

NASA's Jet Propulsion Laboratory, Pasadena, California

Multiple-quantum-well (MQW) photodetectors of a proposed type would contain active regions comprising multiple superlattice subregions. These devices would have complex structures: The superlattice of each subregion would be designed for enhanced absorption of photons in a desired wavelength band (typically in the infrared) and multiple subregions of different design would be cascaded for multicolor operation.

The designs of these photodetectors would take advantage of the characteristic alignment of the edges of the electron-energy bands in type-II quantum-well structures: Within each finite superlattice, interband transitions would be used for detecting photons, and between finite superlattices, intraband relaxation and interband tunneling would be used for transport of charge carriers, all such as to enable detection of normally incident photons.

Absorption of photons in the active region of a photodetector according to the proposal could be significantly enhanced by designing the superlattice/MQW structures to contain closely spaced energy states. The photodetector could be operated with a small bias to facilitate transport of charge carriers. The superlattices could be somewhat chirped, with a preferred transport direction.

This work was done by Rui Yang 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-41976, volume and number of this NASA Tech Briefs *issue, and the page number.*

Information Sciences

Single-Point Access to Data Distributed on Many Processors

NASA's Jet Propulsion Laboratory, Pasadena, California

A description of the functions and data structures is defined that would be necessary to implement the Chapel concept of distributions, domains, allocation, access, and interfaces to the compiler for transformations from Chapel source to their run-time implementation for these concepts. A complete set of object-oriented operators is defined that enables one to access elements of a distributed array through regular arithmetic index sets, giving the programmer the illusion that all the elements are collocated on a single processor. This means that arbitrary regions of the arrays can be fragmented and distributed across multiple processors with a single point of access. This is important because it can significantly improve programmer productivity by allowing the programmers to concentrate on the high-level details of the algorithm without worrying about the efficiency and communication details of the underlying representation.

This work was done by Mark James 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-42505.

Estimating Dust and Water Ice Content of the Martian Atmosphere From THEMIS Data

NASA's Jet Propulsion Laboratory, Pasadena, California

Researchers at JPL and Arizona State University conducted a comparative study of three candidate algorithms for estimating components of the Martian atmosphere, using raw (uncalibrated) data collected by the Thermal Emission Imaging System (THEMIS). THEMIS is an instrument onboard the Mars Odyssey spacecraft that acquires image data in five visible and nine infrared (IR) wavelength bands. The algorithms under study used data collected from eight of the nine IR bands to estimate the dust and water ice content of the atmosphere. Such an algorithm could be used in onboard data processing to trigger other algorithms that search for features of scientific interest and to reduce the volume of data transmitted to Earth.

The algorithms studied were based on regression models. In the study, the optical depths estimated by these algorithms were compared with optical depths estimated in ground-based processing using fully calibrated data from both THEMIS and the Thermal Emission Spectrometer (TES). TES is an instrument onboard the Mars Global Surveyor spacecraft that also observes the planet at infrared wavelengths, but at a lower spatial resolution than THEMIS does. Of the algorithms studied, the one that performed best was based on a Gaussian Support Vector Machine regression model. The test results indicated that this algorithm, operating on the raw data, had error rates that were within the uncertainty associated with the estimates obtained by the ground-based analysis of the fully calibrated data. This level of fidelity demonstrates that these algorithms are sufficiently accurate for use in an onboard setting.

This work was done by Kiri Wagstaff, Rebecca Castaño, and Steve Chien of Caltech for NASA's Jet Propulsion Laboratory and Joshua Bandfield of the Arizona State University. 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-43590.

Computing a Stability Spectrum by Use of the HHT

Unlike in the predecessor method, the mathematical sign of the damping is retained.

Goddard Space Flight Center, Greenbelt, Maryland

The Hilbert-Huang transform (HHT) is part of the mathematical basis of a method of calculating a stability spectrum. This method can be regarded as an extended and improved version of a prior HHT-based method of calculating a damping spectrum. In the prior method, information on positive damping (which leads to stability) and negative damping (which leads to instability) becomes mixed into a single squared damping loss factor. Hence, there is no way to distinguish between stability and instability by examining a damping spectrum. In contrast, in the present stability-spectrum method, information on the mathematical sign of the damping is retained, making it possible to identify regions of instability in a spectrum. This method is expected to be especially useful for analyzing vibration-test data for the purpose of predicting vibrational instabilities in structures (e.g., flutter in airplane wings).

A brief summary of the HHT is prerequisite to a meaningful brief summary of the present method. The HHT has been a topic of several prior *NASA Tech Briefs'* articles, the first and most detailed being "Analyzing Time Series Using EMD and Hilbert Spectra" (GSC-13817), *NASA Tech Briefs*, Vol. 24, No. 10 (October 2000), page 63. To recapitulate: The HHT method is especially suitable for analyzing time-series data that represent nonstationary and nonlinear physical phenomena. The method involves the empirical mode decomposition (EMD), in which a complicated signal is decomposed into a finite number of functions, called "intrinsic mode functions" (IMFs), that admit well-behaved Hilbert transforms. The HHT consists of the combination of EMD and Hilbert spectral analysis.

An unavoidably lengthy description of the mathematical basis of the prior damping-spectrum method is also prerequisite to a meaningful brief summary of the present method. The instantaneous amplitude of a vibration signal at time t is given by

$$x(t) = \sum_{j=1}^{n} c_j(t) + r_n$$

where n is an integer, $c_j(t)$ is an IMF, and r_n is a residue signal.

For each IMF (for example, the kth one), a Hilbert transform is performed to obtain a complex time-dependent function: $z_k(t) = c_k(t) + id_k(t)$.

The time-dependent amplitude $[a_k(t)]$, phase $[\theta_k(t)]$, and frequency $[\omega_k(t)]$ of the kth IMF are then given by

$$a_k(t) = \left[c_k^2(t) + d_k^2(t)\right]^{1/2};$$

$$\theta_k(t) = \tan^{-1}\frac{d_k(t)}{c_k(t)}, \text{ and}$$

$$\omega_k(t) = -\frac{d\theta_k(t)}{dt}.$$

The damping of the kth IMF is given by

$$\gamma_k(t) = -\frac{2}{a_k(t)}\frac{da_k(t)}{dt}.$$

The damping loss factor of the kth IMF is then given by

$$\eta_k(t) = -\frac{2}{a_k(t)}\frac{da_k(t)}{dt}\frac{1}{\omega_{0k}},$$

where

$$\omega_{0k} = \left[\omega_k^2(t) + \left(\frac{\gamma_k(t)}{2}\right)^2\right]^{1/2}.$$

Then summing all the squared damping loss factors as functions of time and frequency and letting frequency become a continuous variable ω, one obtains the damping spectrum $\eta^2(\omega,t)$, which is related to an amplitude spectrum $a(\omega,t)$ via the equation

$$\eta^2(\omega,t) = \frac{\left[\frac{-2}{a(\omega,t)}\frac{da(\omega,t)}{dt}\right]^2}{\omega^2 + \left[\frac{1}{a(\omega,t)}\frac{da(\omega,t)}{dt}\right]^2}$$

This concludes the description of the prior method.

In the present method, one computes a damping loss factor $\eta_k(t)$ or $\eta\ (\omega,t)$ by use of equations similar to those shown above, but with the following notable differences:

- Instead of using the Hilbert transform to compute a complex function and then using the complex function to compute the amplitude function, one uses a cubic spline to compute the amplitude function. The reason for this change is that in a practical implementation, a Hilbert transform can introduce spurious oscillations that can mask true damping or anti-damping, whereas any spurious oscillations introduced by a cubic spline are much smaller.
- The instantaneous frequency $\omega_k(t)$ or $\omega(t)$ is not calculated as indicated above. Instead, it is calculated by use of the normalized HHT. This change is necessitated by a limitation of the Hilbert transform — too complex to discuss here — that has been a topic of prior publications.
- One retains the sign of the damping by simply refraining from squaring the damping loss factor: in other words, $\eta\ (\omega,t)$ becomes the stability spectrum. Areas of positive and negative damping can be readily distinguished on a plot of the spectrum. To make areas of negative damping even more readily apparent, it could be desirable, in some cases, to place areas of positive damping and areas of negative damping on separate plots.

This work was done by Norden E. Huang of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).
GSC-14833-1

Books & Reports

Theoretical Studies of Routes to Synthesis of Tetrahedral N_4

A paper [Chem. Phys. Lett. 345, 295 (2001)] describes theoretical studies of excited electronic states of nitrogen molecules, with a view toward utilizing those states in synthesizing tetrahedral N_4, or T_d N_4 — a metastable substance under consideration as a high-energy-density rocket fuel. Several *ab initio* theoretical approaches were followed in these studies, including complete active space self-consistent field (CASSCF), state-averaged CASSCF (SA-CASSCF), singles configuration interaction (CIS), CIS with second-order and third-order correlation corrections [CIS(D) and CIS(3)], and linear response singles and doubles coupled-cluster (LRCCSD). Standard double zeta polarized and triple zeta double polarized one-particle basis sets were used.

The CASSCF calculations overestimated the excitation energies, while SA-CASSCF calculations partly corrected these overestimates. The accuracy of the CIS calculations varied, depending on the particular state, while the CIS(D), CIS(3), and LRCCSD results were in generally good agreement. The energies of the lowest six excited singlet states of T_d N_4 as calculated by the LRCCSD were compared with the energies of possible excited states of $N_2 + N_2$ fragments, leading to the conclusion that the most likely route for synthesis of T_d N_4 would involve a combination of two bound quintet states of N_2.

This work was done by Timothy J. Lee of Ames Research Center and Christopher E. Dateo of Eloret Corp.

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-15125-1.

Estimation Filter for Alignment of the Spitzer Space Telescope

A document presents a summary of an onboard estimation algorithm now being used to calibrate the alignment of the Spitzer Space Telescope (formerly known as the Space Infrared Telescope Facility). The algorithm, denoted the S2P calibration filter, recursively generates estimates of the alignment angles between a telescope reference frame and a star-tracker reference frame. At several discrete times during the day, the filter accepts, as input, attitude estimates from the star tracker and observations taken by the Pointing Control Reference Sensor (a sensor in the field of view of the telescope). The output of the filter is a calibrated quaternion that represents the best current mean-square estimate of the alignment angles between the telescope and the star tracker. The S2P calibration filter incorporates a Kalman filter that tracks six states — two for each of three orthogonal coordinate axes. Although, in principle, one state per axis is sufficient, the use of two states per axis makes it possible to model both short- and long-term behaviors. Specifically, the filter properly models transient learning, characteristic times and bounds of thermomechanical drift, and long-term steady-state statistics, whether calibration measurements are taken frequently or infrequently. These properties ensure that the S2P filter performance is optimal over a broad range of flight conditions, and can be confidently run autonomously over several years of in-flight operation without human intervention.

This work was done by David Bayard 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-43375.

Antenna for Measuring Electric Fields Within the Inner Heliosphere

A document discusses concepts for the design of an antenna to be deployed from a spacecraft for measuring the ambient electric field associated with plasma waves at a location within 3 solar radii from the solar photosphere. The antenna must be long enough to extend beyond the photoelectron and plasma sheaths of the spacecraft (expected to be of the order of meters thick) and to enable measurements at frequencies from 20 Hz to 10 MHz without contamination by spacecraft electric-field noise. The antenna must, therefore, extend beyond the thermal protection system (TPS) of the main body of the spacecraft and must withstand solar heating to a temperature as high as 2,000 °C while not conducting excessive heat to the interior of the spacecraft.

The TPS would be conical and its axis would be pointed toward the Sun. The antenna would include monopole halves of dipoles that would be deployed from within the shadow of the TPS. The outer potion of each monopole would be composed of a carbon-carbon (C-C) composite surface exposed to direct sunlight (hot side) and a C-C side in shadow (cold side) with yttria-stabilized zirconia spacers in-between. The hot side cannot view the spacecraft bus, while the cold side can. The booms also can be tilted to minimize heat input to spacecraft bus. This design allows one to reduce heat input to the spacecraft bus to acceptable levels.

This work was done by Edward Charles Sittler, Jr., of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15052-1

Improved High-Voltage Gas Isolator for Ion Thruster

A report describes an improved high-voltage isolator for preventing electrical discharge along the flow path of a propellant gas being fed from a supply at a spacecraft chassis electrical potential to an ion thruster at a potential as high as multiple kilovolts. The isolator must survive launch vibration and must remain electrically nonconductive for thousands of hours under conditions that, in the absence of proper design, would cause formation of electrically conductive sputtered metal, carbon, and/or decomposed hydrocarbons on its surfaces.

The isolator includes an alumina cylinder containing a spiral channel filled with a porous medium made from alumina microbeads fired together with an alumina slurry. Connections to gas-transport tubes are made at both ends of the alumina cylinder by means of metal caps containing fine-mesh screens to prevent passage of loose alumina particles. The outer surface of the alumina cylinder is convoluted to lengthen the electrical path between the metal caps and to afford shadow shielding to minimize the probability of formation of a continuous deposit that would electrically connect the ends. A flanged cylindrical metal cap that surrounds the alumina cylinder without touching one of the ends provides additional shadow shielding.

This work was done by Bruce Banks 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-18016-1.

Hybrid Mobile Communication Networks for Planetary Exploration

A paper discusses the continuing work of the Mobile Exploration System Project, which has been performing studies toward the design of hybrid communication networks for future exploratory missions to remote planets. A typical network could include stationary radio transceivers on a remote planet, mobile radio transceivers carried by humans and robots on the planet, terrestrial units connected via the Internet to an interplanetary communication system, and radio relay transceivers aboard spacecraft in orbit about the planet. Prior studies have included tests on prototypes of these networks deployed in Arctic and desert regions chosen to approximate environmental conditions on Mars. Starting from the findings of the prior studies, the paper discusses methods of analysis, design, and testing of the hybrid communication networks. It identifies key radio-frequency (RF) and network engineering issues. Notable among these issues is the study of wireless LAN throughput loss due to repeater use, RF signal strength, and network latency variations. Another major issue is that of using RF-link analysis to ensure adequate link margin in the face of statistical variations in signal strengths.

This work was done by Richard Alena of Ames Research Center; Charles Lee of QSS Group, Inc.; Edward Walker and John Ossenfort of Foothill-De Anza; and Thom Stone of Advanced Management Technology, Inc.

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-15245-1.

National Aeronautics and
Space Administration