

EXPLORATIONS



Engineering Solutions to Problems of National Significance

SPRING 2003



LAUNCHING INTO THE COSMIC WEB:
Developing the Spacecraft Bus for the SPIDR Mission

THE INERTIAL STELLAR COMPASS:
Attitude Determination for Future Spacecraft

TIMELINER SOFTWARE:
Automating Spacecraft Operations

DRAPER 
LABORATORY



MESSAGE FROM THE PRESIDENT

To help our sponsors and other members of the engineering community keep up to date on our work, Draper Laboratory has begun publishing this periodical, *Explorations*. Each issue will highlight a selection of Draper's current activities in engineering solutions to problems of national significance. This first issue is focused on space programs. Future issues will feature

Draper's work in autonomy technology, strategic deterrence, and biomedical engineering. Readers can look forward to a new issue of *Explorations* in summer.

As an independent engineering laboratory engaged in leading-edge research and development focused on real-world applications, Draper continues to be a vital link between basic research at one end of the spectrum and production at the other. By focusing long-term on advancing key technologies—guidance, navigation, and control; autonomous operations; highly accurate and precise sensors; and custom microelectronics—Draper has built a set of versatile core competencies. We apply these to solving both the nation's strategic and tactical defense problems and to challenges posed by future space systems.

Our role as an engineering research and development laboratory means that readers will find something new, either technologies or applications, in each issue. I hope that you find *Explorations* informative.

Vincent Vitto
President & Chief Executive Officer

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TABLE OF CONTENTS

Building on a Legacy: Draper's Space Program Is Breaking New Ground	1
Inertial Stellar Compass: Attitude Determination for Future Spacecraft	2
Draper-JPL Strategic Partnership	3
Launching into the Cosmic Web (SPIDR)	4
Timeliner Software: Automating Spacecraft Operations	6
Technology Leaders Join Draper's Board	8
New Business Development Head Named	8
Draper Hosts Technology Exposition 2002	9

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BUILDING ON A LEGACY:

Draper's Space Systems Are Reaching for the Stars



From the earliest days of the Apollo program, Draper Laboratory has pioneered the development of first-of-a-kind space systems to meet the needs of the nation. For more than four decades, we have developed highly reliable sensors, software, and computing systems to navigate, guide, and control an increasingly complex and diverse collection of advanced space vehicles. Our pioneering technical achievements include the guidance, navigation, and control (GN&C) system for the Apollo lunar missions, the first implementation of digital fly-by-wire, development of many of the GN&C algorithms for the Space Shuttle (the nation's first reusable launch vehicle), and the command and data-handling system for the International Space Station.

In the last decade, Draper has expanded beyond manned space flight to take on many of the challenges associated with the nation's full spectrum of space systems. It has done this by contributing to the development of experimental autonomous space vehicles, commercial and military satellites, and planetary exploration missions.

This issue of *Explorations* highlights just a few of our current programs in small scientific satellites, innovative space sensors, autonomous satellite inspection, autonomous space operations, and planetary exploration. Notably, each program culminates in either a flight demonstration or a first-of-a-kind system that will advance the development of the nation's future space systems.

Draper is building a small scientific spacecraft for Boston University (B.U.) called SPIDR, which is a NASA Small

Explorer mission that will image and quantify the highly ionized diffuse intergalactic medium where much of the mass of the universe is believed to reside. Draper is building the spacecraft bus and will integrate a set of six ultraviolet spectrometers built by the B.U. Center for Space Physics into a small Earth-orbiting observatory. This is Draper's first complete satellite, and its innovative and efficient design allows the spacecraft to obtain a very high-altitude elliptical orbit. SPIDR will be the first mission to achieve this kind of orbit in a low-cost space mission.

The Inertial Stellar Compass is a new stellar inertial attitude determination system that Draper will build, test, and flight validate for NASA's New Millennium program. This system combines an advanced imaging detector, a powerful miniature flight processor, and miniature inertial sensors into a very low-mass and low-power sensor system. It will be the first use of microelectromechanical systems (MEMS) in an operational space system.

Autonomous Satellite Inspection is being demonstrated for the first time on the XSS-11 mission for the Air Force. This mission will rendezvous autonomously with several non-cooperating Resident Space Objects and then will conduct a detailed visual inspection of them. Draper is developing the autonomous GN&C algorithms and autonomous mission manager for the spacecraft bus that is being built by Lockheed Martin. Draper also is developing the mission management system for Boeing on DARPA's Orbital Express program. This system incorporates Draper's autonomous sequencing language, called Timeliner,

currently in use for the automation of operations and experiments onboard the International Space Station.

Once completed, these systems will significantly advance the state of space vehicle technology, enabling future space systems to operate autonomously or with very minimal interaction with ground controllers. Indeed, the development and flight validation of enabling technologies for autonomous operations has been a major thrust for Draper's Space Systems directorate. Our ultimate goal is to develop systems with sufficient onboard intelligence to sense their external environment, assess their own state of health, develop alternative courses of action, decide upon a course of action, and implement those actions to complete the mission successfully. If mission success is not possible, the system will place the vehicle and all of its systems in a safe configuration so that it is able to conduct future missions.

Achievement of this level of autonomy presents a significant technical challenge, but recent advances in sensor technology, computational speed, and algorithmic efficiency for complex GN&C problems provide the basis for turning this vision into a reality. The innovative technical solutions and flight demonstrations described in this issue represent a major step toward the achievement of this goal.

-Darryl Sargent
Director, Space Systems

INERTIAL STELLAR COMPASS

Attitude Determination for Future Spacecraft

Attitude determination is a critical function needed by all spacecraft in order to accomplish any mission that requires attitude control. Current spacecraft typically use a combination of inertial measurements with Earth sensing, sun sensing, or star tracking to accomplish this function. However, the size, weight, and power requirements for current attitude determination systems place a very large burden on the spacecraft bus, effectively reducing the amount of payload for small (<500 kilogram) and micro-spacecraft (<100 kilograms).

To further reduce size and power impact, the ISC design also offers the possibility of using its Data Processor as the spacecraft's primary processor.

In order to expand the mission capabilities of these small spacecraft, they need to be able to determine their attitude with high accuracy using a low-power and low-mass system.

Draper is developing the Inertial Stellar Compass (ISC) to answer this need for high accuracy, low-power, real-time attitude determination for micro-spacecraft. The ISC, developed under NASA's New Millennium Program's Space Technology 6 Project, is an enabling technology that utilizes Draper's expertise in both micro-electromechanical (MEMS) sensor technology and active pixel sensor (APS) imagers. It integrates a wide field-of-view star camera, MEMS gyros, and associated processing electronics into a 2.5-kg two-piece attitude sensor that consumes less than 3.5 watts of power, compared to 4.5 kg and 25 watts for a comparable conventional sensor suite.

Smart Sensor Offers Simple Integration into User Spacecraft

The ISC consists of two separate components, the Data Processor Assembly and Camera Gyro Assembly, allowing for separate installation of the components within the spacecraft. As a "bolt-on" smart sensor, the ISC reduces complexity by tightly integrating the gyros and APS star camera within the Camera Gyro Assembly to simplify alignment and calibration. Integration costs are reduced since

the Data Processor Assembly performs all the attitude determination and filtering, rather than the spacecraft software itself. The spacecraft receives its attitude information from a simple serial interface in the form of an Earth-Centered Inertial (ECI) attitude quaternion and attitude rates, which it can use to modify its position. To further reduce size and power demands and their impact on the spacecraft, the ISC design also offers the possibility of using its Data Processor as the spacecraft's primary processor to run both the ISC and spacecraft software.

MEMS Gyros and Star Camera Marriage Is Key to ISC Performance

During normal operation, the ISC's MEMS gyros provide continuous attitude information, which is input to a Kalman filter for determination and output of the inertial attitude quaternion at a 5-Hz rate. To compensate for the gyros' bias and scale factor errors, the star camera is used periodically (every few minutes) to provide an attitude "truth" reference which bounds the error growth due to the gyros. This fusion of star camera and MEMS gyro data provides improvement in the performance of both devices: the gyros provide information continuously, during periods when the spacecraft



Tye Brady (left) and Clemens Tillier use star simulator to test sensitivity of active pixel sensor imager.

may be undergoing high slew rates such that the camera cannot obtain good star images, and also during periods when the camera is occluded by the sun, moon, Earth, or satellite appendages. The camera also provides periodic updates to support gyro compensation.

Draper-JPL Strategic Partnership

A new strategic partnership between Draper and the Jet Propulsion Laboratory (JPL) was formed recently to address the critical space needs of the nation. The combination of Draper's expertise in autonomy and guidance, navigation, and control with JPL's spacecraft design and development experience has the potential to produce great innovations in advanced space systems for both planetary exploration and military space.

The organizations jointly have developed a framework to facilitate technical exchange of information and collaboration on new projects. Significant activities are focused on NASA's current programs to perform detailed exploration of Mars, and the team is examining possible missions to other planetary bodies in our solar system.

The coming decades will involve detailed, in-situ investigations of planetary surfaces and atmospheres. A new set of miniaturized instruments and sensors coupled with fully autonomous landing, orbiting, and roving vehicles will be needed to enable this exploration program.

Robotic exploration remains the only affordable way to gather science data about this solar system for the next decade and beyond, and the need for precise targeting of landers and autonomous operation of exploratory vehicles has become a primary design driver. The vast distances between planets mean that even at the speed of light, radio signals will take hours to reach their target; the only

Image provided courtesy of Jet Propulsion Laboratory, California Institute of Technology



realistic way to maneuver a robot into difficult (and therefore scientifically interesting) locations will be through the use of advanced guidance, navigation, and autonomy.

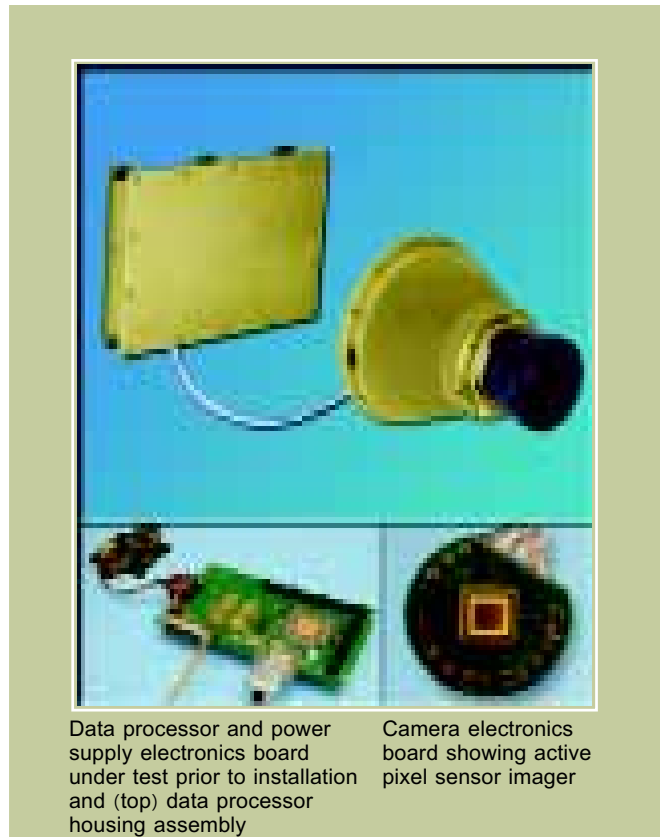
Together, Draper Laboratory and JPL are a team uniquely capable of meeting these needs and taking the nation's space program beyond the current phase of reconnaissance spacecraft that perform imaging and remote sensing activities, into detailed, in-situ exploration and analysis, using levels of autonomy never before achieved.

Lost-in-Space Capability Allows ISC Initialization

The ISC is self-initializing using the star camera. Star field images taken by the ISC's camera electronics are processed to provide a camera quaternion. Stars in the image are identified using a lost-in-space attitude determination algorithm, which analyzes the image against a catalog of 1,500 known stars to identify the camera's line of sight, requiring no prior knowledge of spacecraft attitude. Once initialized, the gyros are used to maintain attitude knowledge until the next stellar update occurs. This capability helps the spacecraft to overcome difficulties during transients, high slew rates (up to 50 deg/s), or periods of star camera occlusion.

Summary

Completion of the ISC and its flight validation, scheduled for 2004 as a Hitchhiker payload on the Space Shuttle, will represent a breakthrough in low power, low mass, real-time attitude determination for future space and Earth science missions. In addition to its direct application as an enabling technology for power-challenged micro-spacecraft, its ability to operate during high slew rates and perform lost-in-space attitude determination make it an attractive choice as a backup "safe hold" system to help faulty or damaged spacecraft control large rates and recover a safe, power-positive attitude.



Data processor and power supply electronics board under test prior to installation and (top) data processor housing assembly

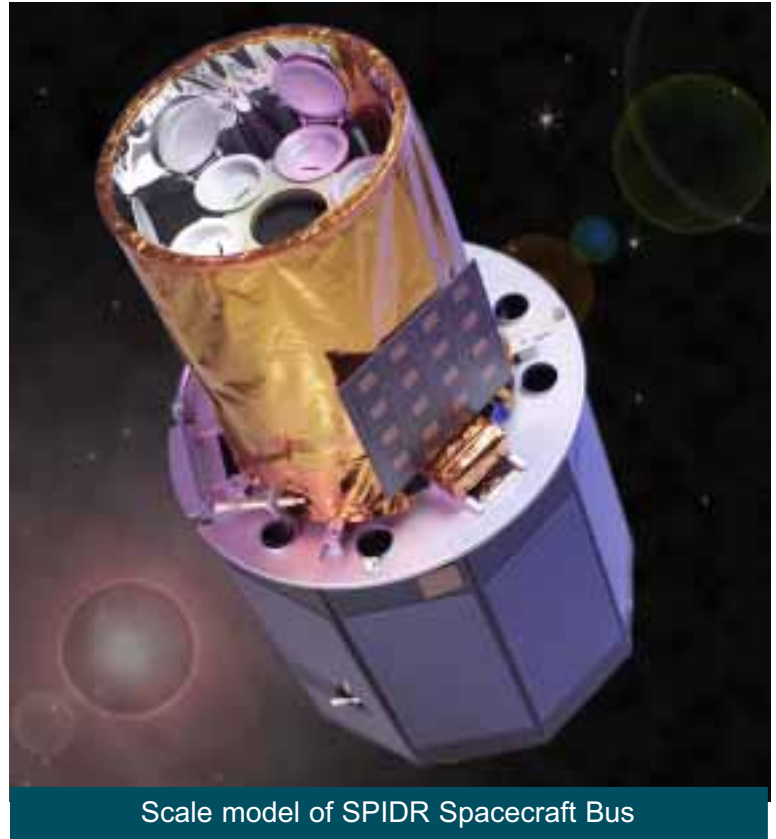
Camera electronics board showing active pixel sensor imager

LAUNCHING INTO THE COSMIC WEB

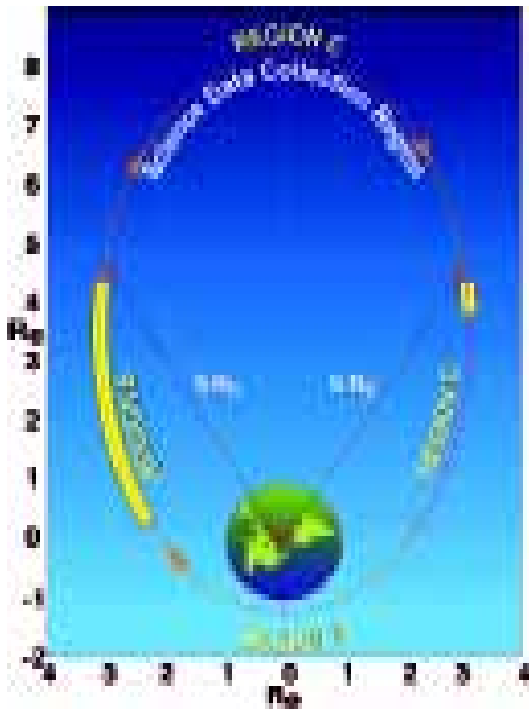
Developing the Spacecraft Bus for the Spectroscopy and Photometry of IGM's Diffuse Radiation (SPIDR) Mission

Draper recently expanded beyond its traditional role in guidance, navigation, and control systems to embark on new challenges for NASA's Space Science Program. As a member of a team headed by Boston University (B.U.), Draper is designing and will build a complete small scientific spacecraft called SPIDR which will perform Spectroscopy and Photometry of the Inter-galactic Medium's Diffuse Radiation (SPIDR).

The B.U. team was selected earlier this year to execute NASA's eighth Small Explorer (SMEX) mission, a category of relatively low-cost scientific endeavors. Draper's primary roles in the project are to design the mission – the orbit and basic sequence of operations that allow the required scientific data to be collected – and to design and build a spacecraft bus (SCB) to carry B.U.'s scientific instruments.



Scale model of SPIDR Spacecraft Bus



The SPIDR science orbit

The Mission

The SPIDR mission aims to answer fundamental questions about the “Cosmic Web” (see sidebar) by collecting measurements of warm/hot (10^5 to 10^7 K) gas in the Oxygen VI and Carbon IV lines in the ultraviolet (UV) spectrum. Taking these measurements at the required sensitivity and resolution is only possible if B.U.'s instruments – six UV imaging spectrographs – can reach a sufficient distance from the Earth's surface, approximately 32,000 km, so that all observations are taken without the influence of Earth's atmosphere. Previous SMEX missions all have been in low Earth orbit at an altitude between 500 and 800 km. Furthermore, the signals from the Cosmic Web are faint; achieving a meaningful map requires an exposure time of about 100 hours. So the SPIDR mission orbit must be above the minimum distance for a significant period of time, or else very few complete exposures can be taken.

Due to cost constraints and NASA's limitations on using foreign launch vehicles, Pegasus, a launch vehicle developed by Orbital Sciences and launched from a jet aircraft at 38,000 ft., is the only viable choice for a SMEX mission. Because Pegasus is a small vehicle, it cannot lift the SPIDR spacecraft to the necessary high orbit for data collection on its own. Draper's solution is to design the spacecraft bus around a STAR-24C solid rocket motor built by ATK. When the spacecraft is launched, the Pegasus will lift the SPIDR observatory to a low-altitude parking orbit. Some time later the STAR-24C will ignite and push SPIDR into a highly elliptical orbit. From there, SPIDR will use its monopropellant hydrazine propulsion system to tune the transfer orbit's apogee and perigee until a repeat ground-track orbit is achieved that provides 14.5 hours of science observation time per day. The result is that 1 103-hour exposure can be taken each week, totalling 150 exposures during the course of the 3-year mission.

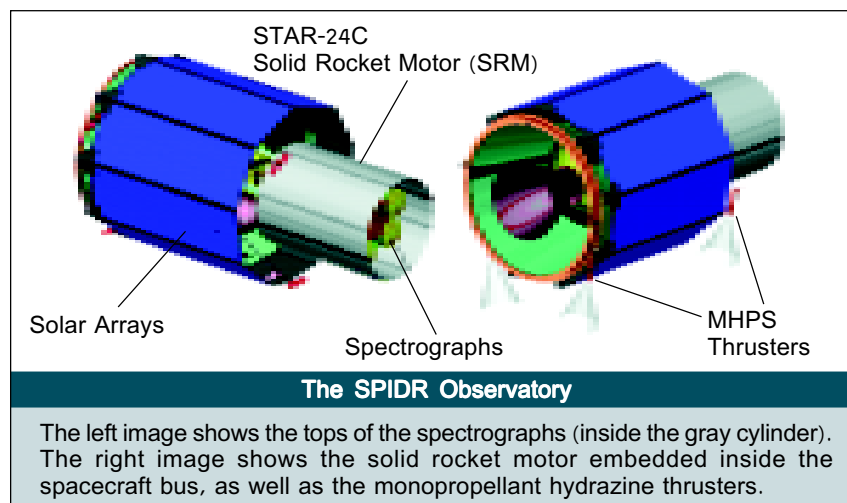
An extremely short timeframe from conception to launch makes the mission even more challenging. The project began officially in December 2002, the Draper Spacecraft Integration and Test Facility will be completed one year later, and the scheduled launch date is in May 2005.

The Spacecraft Bus

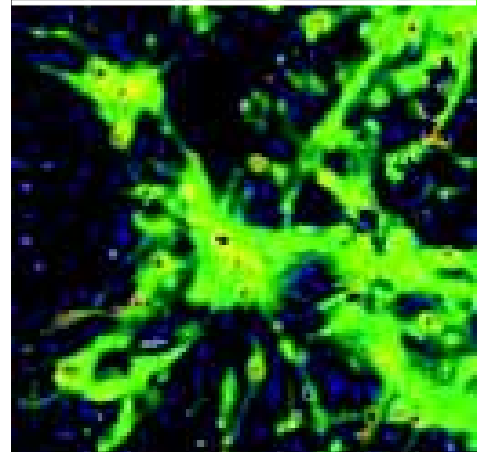
Draper's SCB needs to fulfill specific design requirements, including supporting SPIDR's six spectrographs during the Pegasus launch and the STAR-24C burn. In addition, it needs to point the instruments accurately over a multi-orbit exposure and to return the 22 gigabytes of data collected from each exposure to the ground station for processing. A limiting factor in the design is structural mass. The Pegasus launch vehicle can deliver only a total of 370 kg to SPIDR's parking orbit; after including the 245-kg STAR-24C, 4 kg of hydrazine fuel, and the 28-kg science payload, only 93 kg is left for the SCB. In order to account for unforeseen needs which may arise during development, the design target for Draper's engineers is actually 80 kg.

The task is challenging – all required SCB functions must fit within the allotted 80 kg, including structural support, power generation and storage, power management and distribution, computation, telecommunications, attitude determination and control, thermal control, and the hydrazine propulsion system. The resulting bus design features fixed solar arrays, an electronics deck on which most

see SPIDR, pg. 7



What is the Cosmic Web?



The Big Bang Theory is the accepted basis for modern cosmology. What is not well understood is exactly how galaxies and stars evolved from this fundamental event. Of particular interest is the fact that the motion of today's universe – which results from gravity and time – cannot be explained by the quantity of matter that can be observed. The phrases “missing matter” or “dark matter” are often used to describe this issue.

One theory is that much of the matter in the primordial universe resides in the form of warm-hot gas in the temperature range of 105 to 107°K. Gravity collected this gas into filaments, and then where the filaments crossed, into stars and galaxies. This collection of filaments is referred to as the “Cosmic Web” and is the focus of SPIDR observations.

Although current space missions have seen hints of this warm/hot interstellar matter (WHIM), SPIDR is the first mission designed to observe the WHIM directly. Using measurements of the Oxygen VI and Carbon IV emission lines in the mid and far ultraviolet spectrum, SPIDR will obtain deep spectral maps of the filamentary structure of the Cosmic Web. These maps will be used to shed light on many of the problems in cosmology and astronomy, including the question of how much dark matter lies in this form of hot gas. In addition, SPIDR will provide valuable measures of the location and properties of hot gas in this galaxy and its impact on cycles of matter and energy.

Image source: Cen, Renyue; Ostriker, Jeremiah “Where Are the Baryons?” *The Astrophysical Journal*; Vol. 514, Issue 1, pp. 1-6; March, 1999. Reproduced with permission from the AAS.



Photo courtesy of National Aeronautics and Space Administration

TIMELINER SOFTWARE: AUTOMATING SPACECRAFT OPERATIONS

To help bridge the large gap between man-in-the-loop operations and full autonomy, Draper has developed a man-machine interface language called Timeliner that enables spacecraft automation. Future systems will need to be highly automated to reduce the training and manpower requirements of today's spacecrafts. Timeliner is an important step toward that goal; it now is being used on

subsystem performance. In each case, even relatively simple and routine tasks require an operator to schedule the activity, issue the appropriate commands, and observe the results.

Timeliner has been developed as a tool to automate the activities that are necessary for the operation of space vehicles. These activities may be sequential tasks that typically would be

systems. The execution environment provides real-time monitoring and control based on the commands and conditions defined in the Timeliner language.

Historically, Timeliner was created by Draper to emulate the actions taken by the astronauts in the Laboratory's simulations of the Space Shuttle. This version of Timeliner has been in use since 1982. This system was extended for use in other

The language was specifically designed to allow easy definition of scripts that provide sequencing and process control of complex systems.

the International Space Station (ISS) for the command and control of the space station subsystems, for the control and monitoring of space station payloads, and for the command and control of the Kibo Japanese Experiment Module.

Currently, manned space vehicles require extensive crew training and time to execute complex flight procedures or onboard experiments, and unmanned crafts require a large number of ground controllers to operate the vehicle or satellite and to react to failures or changes in

performed by a human operator or they may be precisely ordered sequencing tasks that allow autonomous execution of a control process.

The Timeliner system is both a specialized computer language and an execution environment. The system includes elements for compiling and executing sequences that are defined in the Timeliner language. The language was specifically designed to allow easy definition of scripts that provide sequencing and process control of complex

applications, and it was enhanced to provide real-time sequence execution and to support interactive control commands from the operator. Beyond its current uses, possible future applications of Timeliner onboard the ISS include vehicle control, performance of preflight and post-flight subsystem checkouts, and handling of failure detection and recovery.

Timeliner also is being incorporated as a key component of the autonomous mission manager for Defense Advanced Research Projects Agency's Orbital

Timeliner cont'd.

Express mission, which will conduct a flight demonstration of autonomous satellite servicing. Timeliner will be used to control the execution of the servicing operations, including fuel transfer from one vehicle to another, as well as the replacement of spacecraft avionics using a robotic servicing vehicle called ASTRO. It also will monitor the vehicle and subsystem operations. Able to recognize faulty conditions, Timeliner will take appropriate action under such circumstances to terminate the experiment and place the subsystems and the vehicle in a safe configuration until ground controllers can issue a new set of commands.

Such a diversity of uses is enabled by the generalized design of Timeliner, which makes it very flexible and versatile. It features an English language syntax that does not require specialized computer programming skills. It is a modular system that can operate on a variety of computational platforms, consisting of a kernel containing the core functionality and adaptors that allow the kernel to run on a variety of operating systems (for example, UNIX and Solaris).

Timeliner works by executing programmed sequences of activities either autonomously or through interactive control with the astronauts or ground operators. It can run predefined “scripts”

of procedures and allows intervention by system operators in real time through commands to install, remove, start, stop, step ahead, or resume scripts. It can execute multiple simultaneous sequences of operations, running up to 40 scripts in parallel. Timeliner also can execute scripts that are triggered by events in the system or complex dynamic conditions.

Through the use of sub-sequences, Timeliner scripts can implement complex decision logic, making it an ideal platform for the introduction of automation into current systems or as the basis for implementing various levels of autonomy in new systems.

SPIDR cont'd.

electronic components are mounted, and an upper structure holding the science instruments.

An Ingenious Structure

The biggest design driver for Draper’s SCB structure occurs when the Pegasus is dropped from the jet aircraft that carries SPIDR to the launch point. The 245-kg STAR-24C, the other SCB subsystems, and the science instruments all must be supported through the shock of the drop while cantilevered from the Pegasus interface ring. Structural support must be accomplished with a smaller fraction of the available observatory mass than is usual for similar spacecraft. Draper’s design features a

thin-walled support cone, comprised of a series of clockwise and counterclockwise helical ribs, that connects the Pegasus interface ring to the STAR-24C. An electronics deck is supported above the STAR-24C by another thin-walled structure, while the science payload assembly is supported by a truss that provides easy access to the electronics during the integration phase of the project. The science payload assembly mounts a star tracker in the center of the cluster of six UV spectrographs, ensuring that each science instrument points along the axis measured by the star tracker.

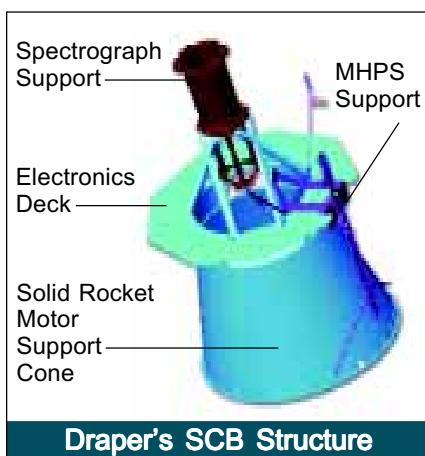
Autonomous Spacecraft Control

A consequence of the highly elliptical high-altitude science orbit is that the SPIDR observatory is out of view of its Las Cruces, N.M., ground station for most of its flight. Therefore the spacecraft must be largely autonomous. Autonomy reduces the cost of ground operations, a significant benefit to a SMEX mission with limited funds. The spacecraft software and operations will be relatively simple in nature because of the deliberate pace of the observations and the repeatable nature of the orbit and communications cycles. Once the

STAR-24C burn is completed, the observatory slowly cycles through its science orbit and transmits the stored data only when the observatory is too low for clear observations.

New Possibilities

The unique nature of explorer mission spacecraft fits perfectly within Draper’s charter to develop first-of-a-kind systems. Not only is SPIDR an exciting project for Draper because the Lab is able to take on the new challenge of building a spacecraft, but also because it has created a stimulating new working relationship with B.U. and NASA’s Space Sciences Program, a division of NASA focusing on questions relating to astronomy, the solar system, and the sun and its interaction with Earth. With such a relationship, Draper has moved beyond its traditional roles in NASA’s human spaceflight programs of Apollo, the Space Shuttle, and the International Space Station. This has opened up new possibilities in the unmanned space arena, positioning the Laboratory to make significant contributions to the study of cosmology and astronomy, as well as answering fundamental questions about our universe.



Technology Leaders Join Draper's Board



C. Bruce Tarter

C. Bruce Tarter joined the Board in October 2002. He has been a member of Draper's Corporation since 1999. Director of Lawrence Livermore National Laboratory since 1994, Tarter is also an adjunct professor in the Department of Applied Science at the University of California at Davis. Tarter has a Ph.D. in theoretical physics from Cornell University and a bachelor's degree in physics from MIT.

Tarter has served on the Army Science Board, California Council on Science and Technology, University of California President's Engineering Advisory Council, Pacific Council on International Policy, Nuclear Energy Research Advisory Committee, and Council on Foreign Relations. He is a fellow of the American Physical Society.



Maxine L. Savitz

Maxine L. Savitz, who joined in October 2002, is a retired general manager of Honeywell Technology Partnerships. She earned a Ph.D. in organic chemistry from MIT in 1961 and completed the Executive Program in Management at UCLA in 1992. In 1974 she joined the U.S. Department of Energy; she completed her service in 1983 as deputy assistant secretary for conservation. She subsequently made a career in the corporate world.

Savitz is a member of the National Science Board, Secretary of Energy Advisory Board, Laboratory Operations Board, and Advisory Board for the High Temperature Materials Laboratory. She serves on the board of directors for the Electric Power Research Institute and the American Council for an Energy Efficient Economy.



Kenneth C. Malley

Kenneth C. Malley joined the Board in February. A retired Vice Admiral of the U.S. Navy and former director of the Strategic Systems Program Office, he has been a member of Draper's Corporation since 1995. He retired from the Navy in 1994 as Commander, Naval Sea Systems Command, and became president of Malley Associates. He then joined ARINC, Inc. in 1995 as a vice president. He left in 2001 to work as a private consultant.

Malley has a bachelor's degree in Naval Science from the United States Naval Academy and a master's degree in electrical engineering from United States Naval Postgraduate School.

He serves on the Advisory Board of the Naval Submarine League and is a member of the American Society of Naval Engineers and of the United States Naval Institute.

New Members of the Corporation

Elected as members of the Corporation were Robert Caren, former corporate vice president of science and engineering at Lockheed Corp.; Vincent Chan, a professor in MIT's Dept. of Aeronautics and Astronautics and director of MIT's Laboratory for Information and Decision Systems; Vice Admiral (ret.) George Nanos, Jr., interim director of Los Alamos National Laboratory; Admiral (ret.) William Studeman, vice president and deputy general manager for intelligence and information superiority at TRW Systems; and Delores Etter, professor at the U.S. Naval Academy.

New Business Development Head Named

Paul Blasche became Draper Laboratory's principal director of new business development and strategic planning on Jan. 1, succeeding James Harrison, who retired. Blasche, while director of Hardware Design and Development for the past four years, worked closely with Harrison on the Lab's biomedical engineering initiative, independent research and development planning, and the patent committee, responsibilities that Blasche now performs. Additionally, Blasche assesses Draper-developed technologies as candidates around which to build spin-off companies through the Laboratory's subsidiary venture capital firm, Navigator Technology Ventures, LLC.

Blasche has been with Draper for most of the past two decades, with the exception of four years at Boston University as



Paul Blasche

deputy director of the Center for Photonics Research and associate professor in the Electrical, Computer, and Systems Department (1994-98), as well as a one-year stint at the Defense Advanced Research Projects Agency through the Inter-governmental Personnel Act (1991-92).

Blasche joined Draper in 1980 as a technical staff member after receiving his doctorate in electrical engineering from Ohio University. His bachelor's and master's degree, also in electrical engineering, were earned at University of Texas at Arlington. He became a section chief, division leader for the Communications and Signal Processing Division, and then division leader for the Sensor and Communication Electronics Division. Blasche returned to Draper from Boston University as director of Hardware Design and Development before attaining his current position.

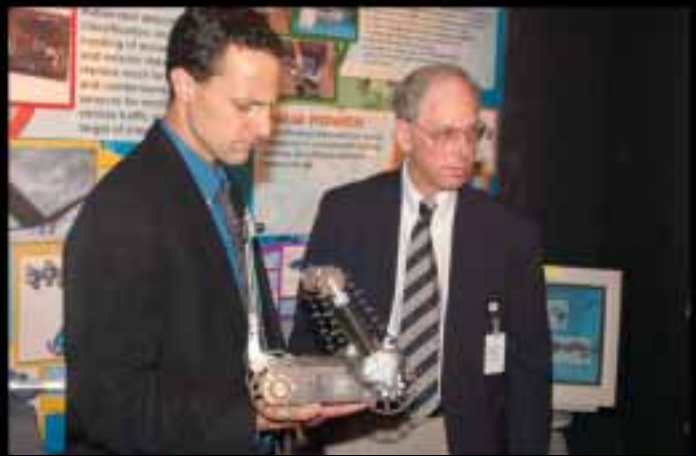
DRAPER HOSTS TECHNOLOGY EXPOSITION 2002

Draper Laboratory held its 2002 Technology Exposition on Oct. 2 and 3 to coincide with the fall meeting of Draper's Board of Directors and the Annual Meeting of the Corporation. In addition to employees and Corporation members, the Expo welcomed students from local universities and Cambridge's public high school, as well as interested journalists and sponsors. The Expo presented an excellent opportunity to learn about Draper's core competencies: strategic guidance sensors and systems; robust, integrated Global Positioning System/inertial navigation system; autonomous control systems; micro-electromechanical devices and systems; custom electronics design and packaging; information management and dissemination; reliable real-time software; fault-tolerant systems design and evaluation; robotic systems design and prototyping; radiation-hard electronics; systems test and evaluation; networking and communications; and systems architecture design.

Attendees saw exhibits featuring demonstrations of technologies under development at Draper from across the Laboratory's program areas, including strategic, tactical, space systems, special operations, biomedical engineering, and independent research and development. A number of the projects included graduate or undergraduate students on their teams, whose participation is coordinated through Draper's Education Office.

Draper's subsidiary venture capital fund, Navigator Technology Ventures, LLC (NTV), displayed information about its portfolio companies, Sionex Corp., Sand Video, Actuality Systems, and Polychromix, at the Expo. This year's Expo included an open house for local venture capitalists sponsored by NTV to show the venture capital community the types of technologies produced at Draper and possibly available for licensing through Draper's Technology Licensing Office.

Pictured, left to right, top to bottom: Member of Technical Staff George Costa and Chairman of the Board John Kreick; Program Manager Rob Larsen and Member of the Corporation Jeffrey Shapiro, director of MIT's Research Laboratory of Electronics; Member of the Corporation Ruth David, president and chief executive officer of ANSER, Inc., and Member Emeritus Robert Monroe, senior counselor of Bechtel National, Inc.; Bioengineering Center Director Jeff Borenstein with students from Cambridge Rindge and Latin High School





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