NASA Facts

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

Center for Space Microelectronics Technology

Future space travel means small spacecraft. In today's constrained budget environment, large space missions can no longer be afforded. At the Jet Propulsion Laboratory, planners have adjusted the size of missions and spacecraft to be more moderate, primarily by taking more risks and asking the spacecraft to do less. In the future, they will be using very advanced technology in order to reduce the spacecraft size even more, while retaining the functionality of today's spacecraft. The spacecraft of the future will provide world-class science in focused areas for an affordable price, making it possible for many of these microspacecraft to be launched, perhaps as many as one per month.

JPL's Center for Space Microelectronics Technology (CSMT) concentrates on innovative, high-risk, high-payoff concepts and devices that hold the potential to enable new space missions or to enhance current and planned space missions. The center conducts research and development in microsensors and microinstruments, advanced detectors and high performance computing. Once the concepts are proved through demonstrations, the successes are transferred to mission applications or to industry for commercialization.

The center focuses on areas of microelectronics and advanced computing that are unique to space applications. This includes sensors studying objects in space in portions of the electromagnetic spectrum that can not be readily studied from Earth because of atmospheric interference, as well as high-performance ground computing for mission data analysis and visualization.

In 1987, NASA and several Department of Defense agencies with space responsibilities established CSMT in order to create a program in space microelectronics with world-class facilities, equipment and staff.

Microdevices Laboratory

Much of CSMT's research and development work takes place in the

Microdevices Laboratory, a unique 38,000-square-foot facility at JPL.

It includes clean rooms for thin-film material deposition, lithography, device processing and optical characterization.

Work at the Microdevices Laboratory encompasses a wide range of sensors designed for use on future spacecraft, including passive optical instruments, dust detectors and a variety of spectrometer instruments. A mass spectrometer, for instance, is used to identify and measure gases. An X-ray fluorescence spectrometer would be used to measure the absolute abundance of elements at the surface of an airless body, such as an asteroid. The center also is developing new micro instruments for Earth remote sensing.

Other sensors measure infrared radiation. The intensity of infrared radiation in our environment is second only to that of visible light. All objects produce radiation, most of which is emitted in the infrared waveband of the electromagnetic spectrum. Infrared extends from just beyond red light to the beginning of microwaves. NASA has a significant interest in space instruments that map in the infrared. The agency is developing instruments that look upward into the universe as well as downward to observe Earth.The center has developed a gallium arsenide-based quantum well infrared photodetector (QWIP) that has been made into large arrays and packaged into camcorder sized portable cameras. QWIP detectors have a narrow bandwidth (~1µm) and have been made in various wavelength responses from 6 µm to 22 µm. Because gallium arsenide is a mature and producible technology, 256 by 256 and 640 by 480 element arrays can be routinely made.

In addition, scientists are currently working to improve spacecraft "eyes." Wireless digital imaging cameras the size of two sugar cubes are being developed which can operate in the ultraviolet, visible and near-infrared realms. The active pixel sensor, a compact, solid-state image sensor technology, makes possible a veritable "camera on a chip." In many imaging applications, such sensors may ultimately replace charge-coupled devices (CCDs), which measure light digitally and are used in many still and video cameras. An active pixel sensor camera uses 100 times less power than the standard CCD camera, has superior resolution, is less susceptible to radiation damage in space, and can be made in a standard semiconductor factory. The camera features automatic exposure control and electronic pan and zoom. In addition, it comes with a built-in transmitter that can send images more than a mile. These "cameras-on-a chip" will be used in orbiters, landers and rovers.

Still, CCDs will be used on many future space missions, and a new process has been developed at the center to build CCDs to image at ultraviolet wavelengths. That enhancement will allow a new set of NASA space instruments for ultraviolet astronomy and other remote sensing projects.

In the area of microinstruments, scientists are developing highly sensitive, light, compact, robust, low-power microaccelerometers and seismometers for planetary, cometary, microgravity and terrestrial applications. Conventional seismometers are ill-suited for space applications; despite good sensitivity, they require careful deployment and are delicate, heavy and power-hungry. The miniature seismometer weights less than 200 grams (about 7 ounces); normal seismometers are about the size of an overnight bag and weigh about 50 times more. To understand if Mars has a molten core, scientists want to measure Mars quakes with seismometers capable of measuring one billionth the acceleration of gravity, all within a package the size of a message pager. A prototype of a microseismometer has successfully measured earthquakes in laboratory demonstrations.

Several microdevices needed for future space missions have been developed by the center, including instruments for a microweather station that may go to Mars. Imagine fleets of nearly autonomous microlanders dispersed by one small spacecraft, each with a weatherstation aboard. A network of these stations could be established to supply information about the humidity and wind and the composition and temperature of the planetary atmosphere. Because of the importance of water to the atmospheric science of both Earth and Mars, the microhygrometer is the most scientifically important component of the micro weather station. A microhygrometer for direct dew-point measurements has been developed and successfully tested on NASA's DC8 for upper troposphere measurements of humidity. It has demonstrated superior performance compared to conventional, large, chilled-mirror hygrometers. Other instruments being developed in the program include micromachined silicon sensors for wind, pressure and air temperature, a radiation densitometer to measure radiation and a micro laser Doppler anemometer to measure wind speed and direction. Surface micro weather stations also have applications in military tactical situations as tools for gathering critical information on surface conditions on land or sea. This effort has resulted in the world's first demonstration of single mode lasers suitable for spectroscopy applications that operate at ambient temperatures.

To enable scientists to learn more about the role water played in Mars' past and its impact on the planet today, the Microdevices Laboratory has developed and delivered space-qualified tunable diode lasers to detect water, as well as a variety of other gases. Measurement of water in the martian atmosphere will be done by near-infrared diode lasers the size of pencil points. These lasers can be assembled with their electronics into instruments the size of a roll of pennies. Any data attained could help answer questions regarding the possibility of life on the planet.

One of the most innovative projects at the Microdevices Laboratory has been the development of the ballistic electron emission microscope

(BEEM). Scientists working in solid-state physics must know the conditions existing at the interface of two separate materials. The BEEM method uses a scanning tunneling microscope to inject an electron tunnel current into a structure with one or more buried interfaces between different materials.

Electrons injected into the structure are sent ballistically -- that is, without scattering or loss of energy -- for distances as small as tens of billionths of a meter (nanometers). The stabilized microscope tip is scanned over the surface as the electron current is detected crossing the buried interface. The transmission of ballistic electrons gives information on the material and interface quality.

High Performance Computing

High-performance computers are needed onboard spacecraft to enable spacecraft autonomy and to analyze and compress scientific data prior to transmission to Earth. High-performance computers are also needed on the ground to analyze and visualize data as part of the process of turning data into knowledge. Ground-based computers are also used for space mission and spacecraft design and simulation, and for theoretical studies and modeling of physical phenomena.

The center's activities in on-board computing have focused on developing a miniature flight computer using advanced technologies, including multichip modules and three-dimensional chip and module stacking.

Although the initial emphasis has been on system miniaturization, the limited power onboard deep space missions has made low-power consumption a major new R&D direction. Under NASA's High Performance Computing and Communications program, the center is developing a scalable, low-power flight computer architecture that relies on commercial microprocessors and implements the fault tolerance needed for space applications in software. A single mode of the computer could be used for a simple microlander application, whereas a 50-processor parallel machine can do onboard processing of hyperspectral science imagery.

Other scientists at the center are developing innovative magnetic and optical data storage techniques and optical processing. A major thrust is directed toward electronic neural networks modelled on the human brain, capable of pattern recognition and vehicle control in real time.

JPL and the California Institute of Technology have been pioneers in developing technologies for massively parallel computing. A dozen years ago, the Center was building parallel supercomputers because there was no industry. Caltech/JPL partnerships with Intel, Cray Research and, most recently, Hewlett Packard have been instrumental in turning high performance parallel supercomputing into the industry known today.

The center concentrates on software and applications of high performance parallel supercomputers for NASA and Defense Department applications. These include ocean modeling, data visualization, mission design and radar processing. The new 256-processor Hewlett Packard Exemplar system has a peak performance of 184 billion operations per second, with a memory of 64 gigabytes. This is 700 times faster than the JPL's CRAY X-MP supercomputer of a decade ago. The memory is 4,000 times larger than that of a typical desktop system. The large memory allows huge problems to be tackled. For example, all the data NASA has from previous missions can fit into the machine's memory and can be processed and visualized in real time.

Microspacecraft

In the future, we will be using more and more very advanced technology in order to reduce spacecraft size, all the while retaining the functionality of today's spacecraft.

By the year 2010, second-generation microspacecraft the size of toaster ovens that weigh 5-1/2 kilograms (about 12 pounds) and use 5 watts of power will travel a billion miles away and send data back to Earth. They will be able to figure out their location and navigate autonomously, all by the position of the stars.

These microspacecraft will be enabled by advances in space technology. Many of the key technologies will be derived from those in such commercial products as cell phones, low-power palm top computers and pagers. Others are being developed specifically for space. These include a micromachined gyro, accelerometer and other micro-electro-mechanical systems, microthrusters, neural networks and spacecraft autonomy software.

The center is developing ground-based micro-spacecraft prototypes that include many of the above components to begin to investigate the systems issues that will arise when building these new miniature spacecraft.

Management

Dr. Carl Kukkonen is director of the Center for Space Microelectronics Technology. Policy guidance and program oversight are provided by a board of governors. Board members include the major sponsors of the center, together with the JPL director, Caltech president and Caltech provost.

The center's scientific advisory board, composed of seven world-renowned scientists, reviews the technical program and provides advice to the board of governors and the center's director.

Programs

Many of the center's technologies have commercial as well as government mission applications. The U.S. Department of Commerce joined the center in 1991 and urged the center and its sponsors to emphasize technology applications for business. As a result, the center has initiated programs with a strong emphasis on dual-use technologies and partnerships with industry.

Currently there are 39 cooperative agreements with U.S. industry in the areas of electronics, computing, communications, automotive and health care. Those collaborations are with companies both large and small, as well as minority- and women-owned businesses.

- ❑ Key programs under the center include:
- ❑ Low- and high-temperature superconductors
- ❑ Semiconductor lasers
- ❑ Microsensors and microinstruments
- ❑ Microelectro-mechanical systems
- ❑ Infrared, visible and ultraviolet detectors
- ❑ Submillimeter receivers
- ❑ Advanced flight computer
- ❑ High-performance computing
- ❑ Advanced networking
- ❑ Neural networks
- ❑ Vertical Bloch line memory

For more information, visit the CSMT web site at http://csmt.jpl.nasa.gov .

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