OCEAN explorer

For the Young Associates of Woods Hole Oceanographic Institution

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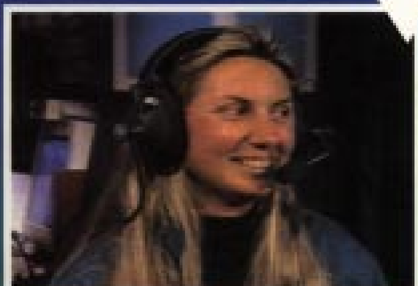
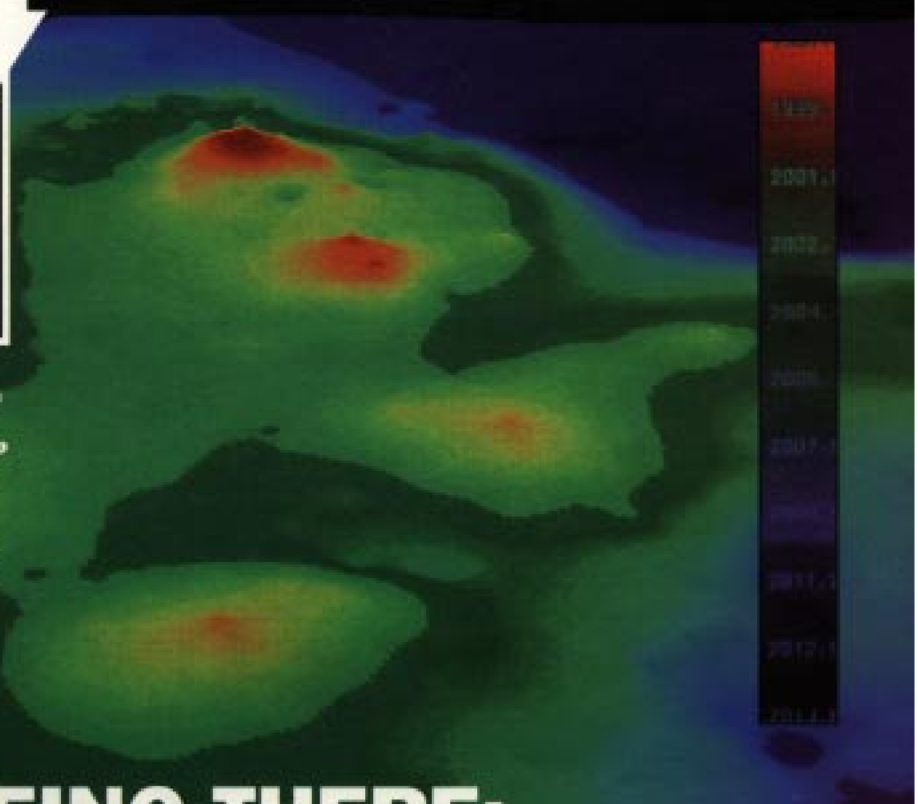


"The audience will have to excuse the grin on my face," says Veronique Robigou, at sea on the *Laney Chouest*, as she gets her first glimpse of the 3-D "fly-through" seafloor map *(right)* created in a computer-satellite-computer relay with a land-based group led by WHOI's Ken Stewart. "I just saw the map that Ken produced. When I look at it, I can't help being excited. We've all been working so hard for the last two weeks.... I'm really pleased with the results."



BEING THERE:

Telecommunications, Remote-sensing and Oceanography

It was a sunny Saturday in March, 1993 in the Sea of Cortez. The Research Vessel *Laney Chouest* cruised over hydrothermal vent fields that lay thousands of feet below. On deck in a van crammed with computers, video monitors, and people, geologist Veronique Robigou of the University of Washington at Seattle smiled broadly. She was getting her first glimpse of a very realistic three-dimensional map of the seafloor that lay beneath her. *[The map is shown on this page.]*

In earlier years, making such a map might have required as many as twenty-five submersible dives. Collecting the data could have taken months, or even years. The data used to make this map was collected in just two weeks by the Remotely Operated Vehicle *Jason*, as part of the 1993 JASON Project.

The data was then sent by a computer-satellite-computer relay to a land-based team from WHOI, lead by Ken Stewart. They used the data to create the image you see above. Within hours, they sent this image back to Veronique.

The map arrived at the *Laney Chouest* just in time. Veronique was on camera, taking part in a videoconference with thousands of scientists from North America and Great Britain.

Telecommunications and remote-sensing are changing the way oceanography is done. In this issue, *Ocean Explorer* describes more experiments that combine these techniques to help us unravel more of the mysteries of the deep, dark ocean.

HERE, THERE AND EVERYWHERE

Computer Networks Pool Information, Spread News

Far out to sea, a herd of hundreds of dolphins is hunting. At the easternmost edge of the group, a dolphin discovers a large shoal of fish. It shares the news with dolphins near it. Instantly, they relay the information to others further away. As one, the group dashes eastward to join the chase. This pooling of information, called "sensory integration," helps dolphins survive.

Scientists around the world pool information too — within institutions where they work, at conferences they attend, in scientific journals and books they read and write, and increasingly, via computer networks, such as Internet, the "network of networks" that links four million scientists around the world. Networks shrink the distance between people, letting them practice "mental integration," as they share resources, swap information, and work together.

A WORLD-WIDE WEB

Use of Internet (also called "the Net") is growing by leaps and bounds. It's changing the way scientists do their work. The Net's electronic mail capability lets a scientist in Vladivostok stay in daily communication with another in Mexico City, despite a sixteen-hour time difference. It allows both of them to browse through almost all of the university libraries on earth to research a given topic. It lets interested scientists read the results of experiments within days of their conclusion, instead of waiting months, or even years, for results to be reported in technical journals.

SCIENCENET LINKS MANY OCEANOGRAPHERS

Most scientists have access to Internet and use it for many different purposes. There are also specialized networks that serve scientists in certain fields. For example, many oceanographers use a network that is called SCIENCEnet, run by Omnet of Newton, MA.

Omnet was begun twelve years ago by Bob Heinmiller, who was then at the Massachusetts Institute of Technology. Bob was managing a big research project, called PEQUOD (Pacific Equatorial Ocean Dynamics Experiment). Forty scientists living in the United States, Australia and Canada needed to be in constant communication for the project to succeed.

The prospect of keeping forty different people living in five different time zones up to date on all aspects of a complex project was daunting, even though it was not necessarily unfamiliar. Many oceanographic projects require scientists in different countries to work together. Often oceanographers are far from their home laboratory, at sea, or at a remote field station.

Where some might have seen a nightmare, Bob saw an opportunity. He set up a computer network that would allow the forty oceanographers to communicate via electronic mail. They could stay in touch, even though they couldn't work together in real time. A scientist in Boston, stumped on a problem at the end of a work day, could leave a message for a colleague in Australia. The Australian could read the message while the Bostonian slept, and have the answer ready when the Bostonian arrived at work the next morning.

Long technical papers, which were once laboriously photocopied and placed in the mail, sometimes arriving weeks later, could now zip around the world at the speed of light. Data could be transmitted as soon as it was collected.

Having access to this network shrank the size of the world for these scientists. Soon word of the project spread, and other scientists were knocking at Bob's door, hoping to gain access to this invaluable hook-up.

Today the forty-scientist "experiment" has grown into SCIENCEnet, which links thousands of scientists in 50 countries around the world. SCIENCEnet also can make itself available to researchers in surprisingly remote locations. For example, it is the communications network for research stations in Antarctica and on the Greenland ice sheet. In 1989, SCIENCEnet made it possible for a climbing party on top of Mt. Everest to receive specialized up-to-the-minute weather forecasts from the University of Pennsylvania.

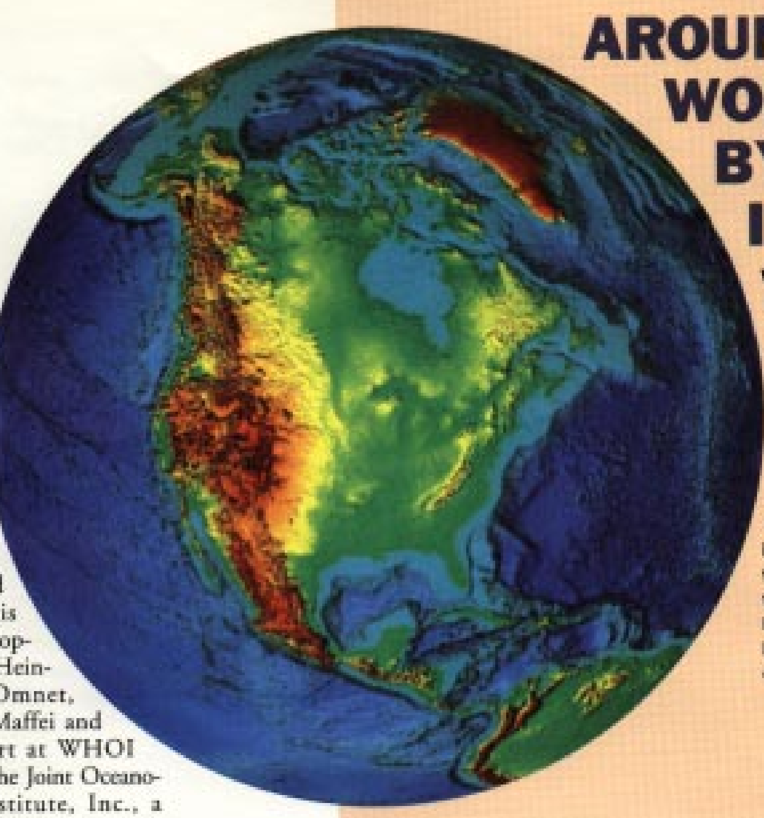
For about the last ten years, oceanographers at sea have been able to access SCIENCEnet as well, via hookups to two satellites: the Applications Technology Satellite (ATS) and Inmarsat.

MORE INFORMATION, PLEASE

This ship-to-shore capability is very valuable, though it has shortcomings. Ships must be within range of the satellites, which limits the times of day they can transmit data, the amount of data they can transmit, and the areas they can travel to and still be able to access the network.

Oceanographers would really like to be able to gather much more data from the sea than they can today, at the instant it is being recorded. They'd like to be able to receive continuous data from devices, such as research buoys, that they have moored at locations around the world *(see pages 4-5)*. A real-time, low-cost, continuous communications link with the ocean is a long-held dream of many.

AROUND THE WORLD IN 80 BYTES, VIA INTERNET



With Internet access it's possible to find written information on almost any topic imaginable. With the proper software, it's also possible to see hundreds of thousands of different images, such as this one of the earth's topography *(left)* including the ocean floors. The data used to make this single image was collected by researchers all over the world.

SEANET: THE NEXT WAVE

New possibilites are offered by an experiment called SeaNet. It is being developed by Bob Heinmiller at Omnet, and Andy Maffei and Ken Stewart at WHOI along with the Joint Oceanographic Institute, Inc., a group of oceanographic institutions that works together. Its purpose is to connect vessels and research devices at sea to Internet, eventually quite inexpensively. *[The first test of this new idea produced the 3-D map shown on page 1.]*

"Any ship doing research out in the ocean should be connected to Internet," says Andy, network manager at WHOI. "We're trying to provide some common networking capabilities to connect ships at sea back to shore." SeaNet also hopes to provide a continuous data link for buoys and other devices at sea.

As connections like SeaNet become reality, oceanographers around the world will be able to monitor data in real-time from remote ocean locations, allowing them to share information, to react instantly to what they observe, and to change experiments, working as a team — like a fast-moving herd of dolphins hunting on the open sea.

With Internet, you can probe a subject that interests you. By connecting with a computer at the University of Michigan, you can call up an hours-old satellite image that shows the U.S. weather. Do you see that storm over Florida? Let's get a closer look at it. *(See below.)*

Pressing a few more keys brings a close-up image of the storm. Can you locate the counterclockwise swirl of the storm system? By looking carefully, you may also see the large, isolated thunderstorm just at the center of the swirl. It doesn't look like a very good beach day in Miami!

IMAGES OF GLOBE ON THESE PAGES COURTESY PETER SLOSS/NOAA/NGDC.

SATELLITE IMAGES COURTESY NOAA. SPECIAL THANKS TO PETER SLOSS/NOAA/NGDC AND DAVID GALLO AND JON HOWLAND/ WHOI FOR THEIR HELP IN ASSEMBLING THIS MATERIAL.

SOUND AND SENSE:

Remote-Sensing Lets Oceanographers Reach Out and Touch the World

BY TOM GIDWITZ

Turn on the television news any evening, and you're likely to see a weather map showing temperature and precipitation in dozens of cities, warm and cold pressure fronts, and satellite pictures of cloud cover. This detailed information is made possible by World Weather Watch, a system that has been in place since 1963.

Oceanographers wish they could have as clear an idea of conditions beneath the sea as we have of weather on land. They are working hard to achieve that goal, using communications technology and remote sensors to discover what's happening throughout the ocean.

THE WORLD'S LARGEST THERMOMETER

How would you measure the temperature of the Pacific Ocean? One way might be to have each of the 4,500 working oceanographers around the world dunk thermometers in the water in different places at the same time. That's pretty impractical. And the readings would only tell you the temperatures at the moment they were taken. To study the condition of the ocean over time, measurements need to be made over and over again.

Physical oceanographers John Spiesberger of Pennsylvania State University, and Dan Frye, manager of WHOI's Advanced Engineering Laboratory, have a more efficient way to take the ocean's temperature. They're using sound.

"We know that sound travels great distances over the ocean," says Dan. "By looking at the way that sound propagates [travels], we can learn something about how the temperature changes."

The sea absorbs 97% of the heat that the earth receives from the sun. Scientists suspect that if the amount of heat in the sea changes, then our climate might change, too. Scientists will better be able to make long-term weather predictions if they can come up with a way to monitor the ocean's temperature changes over time. An acoustic (sound-using) thermometer seems to be an excellent tool to do just that.

"Everybody thought it would be more expensive to map temperatures in the ocean than the atmosphere. Just the opposite is true," says John, who developed the thermometer in the 1980s.

SOUND AND SEA TEMPERATURE

Sound can travel thousands of miles underwater. It changes its speed according to the water's temperature. In warm water, the sound waves speed up slightly. In cold water, sound moves more slowly. When scientists know the precise distance from a sound source to a receiver, and the time it takes for a sound pulse to travel between them, they can tell the temperature of the water along the way.

Later this year, Dan, John and others will begin an experiment called GAMOT, short for Global Acoustic Mapping of Ocean Temperature. GAMOT is a two-year project using sound to measure the temperature of the North Pacific.

GAMOT's sounds will be made by a device that dangles down 1500 feet into the ocean, suspended from a buoy off the coast of Hawaii. Every few hours, the device will give off a very brief low-frequency pulse. Within an hour, the sound will reach ten floating receivers scattered across the Northeast Pacific basin.

Precise clocks on the transmitter and receiver will record the instant the sound is made and the instant it arrives. The receivers will also have instruments to record their position to within 90 feet. The receivers will be able to beam their data to orbiting satellites. The satellites will send the information to a land station, which will relay the findings to participating scientists. Since the scientists will know the exact distances between the transmitter and receivers, they'll be able to figure out the sound's speed. With this data they can calculate the water temperature along the sounds' paths.

Interpreting the data to decide whether the ocean is warming or cooling is not complicated. "If the travel time comes in sooner, that means the ocean's warming," says John. But the measurements are critical. Even though the sound is travelling thousands of miles, at speeds of over 3,000 miles per hour, its arrival has to be measured to within a millisecond, much less than the time it takes you to blink your eyes.

If GAMOT is successful at collecting deep-sea temperature data, more such transmission systems may be set up at other locations, increasing the amount of knowledge we have about temperatures beneath the sea. "Nature has decided that sound is the best way to communicate underwater," says Dan. "That's why we're using it."

MEASURING WAVES AND WIND

In a winter storm on the open sea near Bermuda, white caps heave and crash, and blustery winds whip the water into foam. These waves and wind set currents into motion that can stir as much as the top 100 feet of the ocean's surface. Suddenly, a rogue wave, 42 feet tall, twice as high as those around it, sweeps the area.

"Nature has decided that sound is the best way to communicate underwater. That's why we're using it."

PHOTOGRAPH BY [illegible]

Normally, such a wave would pass through the seas unobserved. But this wave was noticed—first by a floating buoy at sea, then by a passing satellite that picked up a signal from the buoy, and finally by a group of scientists at Woods Hole Oceanographic Institution, who received the satellite's transmission.

"What we're trying to do is understand how the wind moves the surface water," says WHOI physical oceanographer Bob Weller. "We're learning little pieces of information all the time."

The scientists want to know the height and direction of passing waves and weather conditions, such as wind speed, air temperature and humidity. These measurements are difficult to make on the open ocean during storms. And it's expensive to keep a research ship in one spot day after day to record data. So instead, Bob and others use buoys to make their observations.

HIGH TECH BUOYS ON THE JOB

This past winter, oceanographers on the research ship *Knorr* deployed two buoys near Bermuda. One buoy measures waves while the other monitors the weather and currents. Both buoys record their data on tape cassettes. In the spring, the scientists will return and pick the buoys up. Back in the lab, they'll analyze the recorded data.

But in the meantime, the buoys are beaming some of their data to satellites. The satellites in turn relay the data to an earth station which passes the data to the scientists.

Bob's buoys take weather measurements every few minutes. Though there are not enough available satellites for the buoys to send all of their data to shore, what they do send is of enormous value. Bob can start analyzing the data without having to wait for the buoys to be retrieved. He will know within hours if a buoy breaks or is destroyed, taking with it years of work. And he'll have a back-up archive of the weather data in case the recorders on the buoy break down.

"We sweat bullets as to whether a ship's going to run over a mooring and destroy the data," says Bob. "We check every day. If it breaks free we know. Then we launch a rescue effort."

Last year, the satellite data showed that one of Bob's buoys in the South Pacific was beginning to malfunction. "We sort of pushed the panic button," Bob says. Four WHOI engineers were soon on on a plane to New Caledonia. A French research ship brought them to the troubled buoy. They were able to make a quick repair.

Bob looks forward to the day when new satellites and cellular phone networks will make it possible for every person to have a portable phone with a unique number, reachable anywhere, anytime. Even objects at sea, like buoys, will have their own phone numbers. "Then we can call our buoys directly," says Bob. "This technology will enable us to do better science."

The top photo shows the deployment of the Surface Suspended Acoustic Receiver, which will receive signals in the GAMOT experiment and will transmit results to satellites overhead. The bottom photo shows one of the high-tech buoys recently deployed near Bermuda to make long-term measurements of the movement of water. For four months, it will record every rise and fall of the waves on which it rides.

LEO-15, PHONE HOME

Dream Becomes Reality as Seafloor Research Station Begins Construction

Before the end of this century, students in the Midwest who can't get access to the ocean, will be able to conduct seafloor experiments and drive underwater robots off the coast of New Jersey, without leaving their classroom. These explorations will take place with a computer and video hook-up to an underwater research station called LEO-15.

LEO-15 is the brainchild of a team of twenty-five scientists and engineers led by biologist Fred Grassle, Director of the Institute of Marine and Coastal Sciences at Rutgers University, and Chris von Alt, who heads up the Oceanographic Systems Laboratory at WHOI.

PHOTO BY J. FREDERICK GRASSLE/RUTGERS UNIVERSITY

Every day that weather permits, biologist Rose Petrecca *(above, left)* and her team dive near the site of LEO-15. With still and video cameras, current meters, sample collectors and other devices, they keep a close watch on the area. When LEO-15 is fully up and running, these daily dives won't be as necessary. "We'll need divers to clean off the windows of the sensors," says Rose. She's glad LEO-15 will be on the scene taking measurements even on days when diving is impossible.

"Personally, I would prefer being there underwater, as opposed to looking at a video screen. But there are a lot of people involved in the project who are not divers. The link is going to open up a whole new world for them."

LONG TIME COMING

It was back in 1971 that Fred first started to dream about a long-term research station on the seafloor. Then based at WHOI, Fred and others would conduct deep-sea research from the submersible *Alvin*. "We'd set up experiments and revisit them on a later cruise," Fred remembers. Usually the return cruise would be a year later, or more.

Though much was learned from this method, the system was far from perfect. Once an experiment was set up, it couldn't be changed, or even examined, until it was collected. The time lapse between an experiment's beginning and end was often quite long, making the pace of discovery somewhat slow. Also, in recent years, simply getting back to the same place has gotten harder and harder, as funding for deep-sea research cruises has become much scarcer.

Fred knew that for a long-term underwater site to be useful, it needs to be as flexible and as accessible as a field laboratory on land. Ideally, it needs to be in constant communication with land-based scientists who can keep track of the progress of their experiments, or make changes as the need arises.

DREAM COMES TRUE

Fred's long-held dream will soon become reality, thanks to the support of the National Science Foundation. Work has begun on LEO-15, a research station that will lie on the seafloor a few miles off the coast of New Jersey.

The facility, whose name stands for Longterm Ecosystem Observatory — Fifteen Meters, will be the ocean's first link in a chain of environmental monitoring facilities that will someday extend from the inland Pinelands Reserve on the Mullica River near Atlantic City, past an old Coast Guard life-saving station at Tuckerton that serves as the Institute's field station, into the ocean, across the continental shelf, and finally out into the deep sea.

"We want to extend the kind of information that people routinely get on the terrestrial environment out into the ocean," says Fred.

LEO-15'S REACH TO EXCEED ITS GRASP

LEO-15 will be a fixed site, tied into the Institute's lab and also to satellites looking down from space. By monitoring the satellite images, scientists may detect an event they want to explore that is taking place just beyond LEO-15's sensor reach. For that reason, Chris von Alt's lab is also developing a set of untethered vehicles, singly and collectively called REMUS (Remote Environmental Measuring UnitS) that can travel up to 15 nautical miles away from LEO-15, as needed.

"REMUS can go on excursions, looking for information," says Chris. "It will bring the information back to the LEO-15 site, dock, and download information over the network."

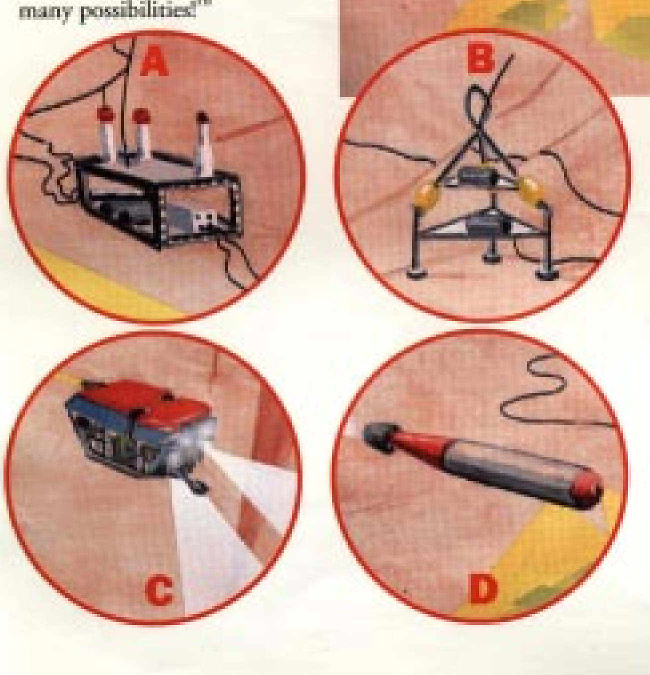
LEO-15: IN TOUCH

When LEO-15 is up and running, the research station will be linked by fiber optic cable to schools throughout New Jersey, as well as the Camden Aquarium and the Liberty Science Center in Jersey City. The link will extend to Internet as well, eventually making video images sent back from LEO-15 accessible to people around the world, like that classroom in the Midwest.

Students will be able to operate winches, gather data, control sampling, move instrument panels up and down to study water density, and calibrate information that will go to satellites "We're not just trying to create a new generation of marine scientists," says Mike De Luca, in charge of the educational thrust of LEO-15. "Our aim is to make young people more environmentally aware. If students are better prepared to understand these issues and discuss them intelligently, we will all be better off."

Fred gets excited when he talks about LEO-15. He says, "Chris and I keep asking each other, 'Why didn't somebody think of this a long time ago? There are so many possibilities!'"

WELCOME TO THE WORLD OF LEO-15



This artist's rendering explains some of the components of the LEO-15 obervatory. The main station (A) will operate instruments that will continuously measure the environment in the area. It will also be linked up to other, smaller observatories (B), each of which is linked directly to the fiber-optic cable that travels back to the laboratory. LEO-15 will also operated a tethered, remotely operated vehicle (C) that can collect samples and perform other work around the station. It will communicate acoustically with other experiments and explorers. LEO-15 will also communicate acoustically with vehicles, such as REMUS (described in the article) (D). LEO-15 will operate an underwater docking system for REMUS and other vehicles, at which they can dock, recharge their batteries, transfer data, and be reprogrammed. It will maintain a link with space-based and land-based satellite and tracking facilities. Finally, it will maintain interactive contact with educational and research institutions, via Internet.