MARSBUGS:

The Electronic Astrobiology Newsletter

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The purpose of this newsletter is to provide a channel of information for scientists, educators and other persons interested in exobiology and related fields. This newsletter is not intended to replace peer-reviewed journals, but to supplement them. We, the editors, envision *Marsbugs* as a medium in which people can informally present ideas for investigation, questions about exobiology, and announcements of upcoming events.

Astrobiology is still a relatively young field, and new ideas may come from the most unexpected places. Subjects may include, but are not limited to: exobiology and astrobiology (life on other planets), the search for extraterrestrial intelligence (SETI), ecopoeisis and terraformation, Earth from space, the biology of terrestrial extreme environments, planetary biology, primordial evolution, space physiology, biological life support systems, and human habitation of space and other planets.

CONTENTS

Page 2 GEOCHEMISTS FIND EVIDENCE THAT FLOWERS MAY HAVE EVOLVED 250 MILLION YEARS AGO
By Mark Shwartz

Page 3 THE THERMOSYNTHESIS MODEL FOR THE ORIGIN OF LIFE: IMPLICATIONS FOR SOLAR SYSTEM EXPLORATION
By Anthonie W. J. Muller

Page 6 LEAFY GREEN ASTRONAUTS
By Patrick L. Barry

Page 8 LIFE'S CHEMICAL FINGERPRINTS
By Lee Siegel

Page 9 TWENTY THOUSAND LEAGUES UNDER THE SEA
By Henry Bortman

Page 11 SCIENTISTS DETERMINE HOW CHEMISTRY KEEPS WEIRD WORMS "OUT OF HOT WATER" AT STEAMING DEEP-SEA VENTS
University of Delaware release

Page 12 ASTROCHEMISTRY OF LIFE
Symposium announcement

Page 13 LIFE AS WE *DIDN'T* KNOW IT
By Patrick L. Barry

Page 15 SETI: SEARCHING FOR GIANT PLANETS ON ASTRONOMY DAY
By Edna DeVore

Page 15 SHUTTLE EXPERIMENT LAUNCHES TO U.S. CLASSROOMS
By Brian Mattmiller

Page 15 RESEARCHERS STUDY MUSCLE CELL DAMAGE THAT OCCURS WHEN ASTRONAUTS RETURN FROM SPACE
Medical College of Georgia release

Page 16 FABRICATION BEGINS ON MARS DESERT RESEARCH STATION
Mars Society release

Page 16 SPRING RECCONAISANCE EXPEDITION RETURNS FROM FLASHLINE ARCTIC STATION
Mars Society release

Page 17 HAKYLUYT PRIZE CONTEST OPEN FOR 2001
Mars Society release

Page 17 RED PLANET SCOUTS: SEEKING UNEXPECTED DISCOVERIES ON MARS
By Leonard David

Page 17 THE AUSTRALIAN MARS EXPLORATION CONFERENCE
Mars Society Australia release

Page 18 NEW ADDITIONS TO THE ASTROBIOLOGY INDEX
By David J. Thomas

Page 18 CASSINI WEEKLY SIGNIFICANT EVENTS
JPL release

Page 19 THIS WEEK ON GALILEO
JPL releases

Page 19 ISS STATUS REPORT
NASA/JSC release

Page 20 MARS GLOBAL SURVEYOR STATUS REPORT
JPL release

Page 20 MARS ODYSSEY MISSION STATUS
JPL release

Page 21 STARDUST STATUS REPORT
JPL release

GEOCHEMISTS FIND EVIDENCE THAT FLOWERS MAY HAVE EVOLVED 250 MILLION YEARS AGO
By Mark Shwartz
Stanford University release

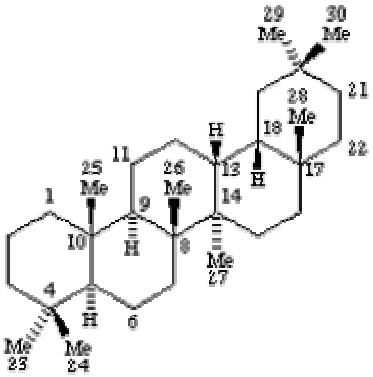
4 April 2001

Daffodils, tulips, roses and other flowers are so much a part of our daily lives that we take them for granted. But to evolutionary scientists, the question of how and when flowering plants appeared on Earth has gone unanswered for more than a century. Mosses were the first plants to emerge on land some 425 million years ago, followed by firs, ginkgoes, conifers and several other varieties. According to the fossil record, flowering plants abruptly appeared out of nowhere about 130 million years ago. Where did they come from, and how could they have evolved so suddenly without any transitional fossils linking them to other ancient plant species?

"An abominable mystery" is how 19th-century naturalist Charles Darwin referred to the origin of flowering plants, and the puzzle remains as controversial today as ever. Now a team of Stanford geochemists has entered the debate with evidence that flowers may have evolved 250 million years ago—long before the first pollen grain appeared in the fossil record.

"Our research indicates that the descendants of flowering plants may have originated during the Permian period, between 290 and 245 million years ago," says J. Michael Moldowan, research professor of geological and environmental sciences. "We based our findings on an organic compound called oleanane, which we found in the fossil record," he adds.

Moldowan and his collaborators, research associate Jeremy Dahl and graduate student David A. Zinniker, presented their findings at the annual meeting of the American Chemical Society (ACS) in San Diego on April 2, during a symposium titled "Biogeochemistry of Terrestrial Organic Matter."



The chemical stucture of oleanane. Moldowan and his colleagues have detected Oleanane in oily rock deposits that are hundreds of millions of years old.

Oleanane

Oleanane is produced by many common flowering plants as a defense against insects, fungi and various microbial invaders. But the chemical is absent in other seed plants, such as pines and gingkoes. Using gas chromatography and mass spectroscopy, Moldowan and his colleagues have been able to extract molecules of oleanane trapped in oily rock deposits that are hundreds of millions of years old.

"Our work has shown that oleanane is lacking from a wide range of fossil plants," he notes, "but the chemical is found in Permian sediments containing extinct seed plants called gigantopterids."

That makes gigantopterids the oldest oleanane-producing seed plants on record—an indication that they were among the earliest relatives of flowering plants, concludes biologist David Winship Taylor of Indiana University Southeast, a co-author of the ACS study.

"This discovery is even more significant because we recently found gigantopterid fossils in China with leaves and stems that are quite similar to modern flowering plants," Taylor notes—further evidence that flowering plants and gigantopterids evolved together roughly 250 million years ago.

Molecular fossils

Moldowan and his colleagues point out that the chemical fossil record can be an important tool for studying the history of life on Earth.

"In our research we use molecular fossils, or biomarkers, such as oleanane to provide evolutionary and paleoenvironmental information from sediments and petroleum," he says. Perhaps one day this technique will help solve Darwin's "abominable mystery" once and for all.

Additional information on this story is available at http://www.stanford.edu/dept/news/report/news/april4/acsflowers-44.html.

Additional articles on this subject are available at:
http://nai.arc.nasa.gov/index.cfm?page=flowers
http://science.nasa.gov/headlines/y2001/ast17apr_1.htm?list52260

THE THERMOSYNTHESIS MODEL FOR THE ORIGIN OF LIFE: IMPLICATIONS FOR SOLAR SYSTEM EXPLORATION
By Anthonie W. J. Muller

8 April 2001

Thermosynthesis

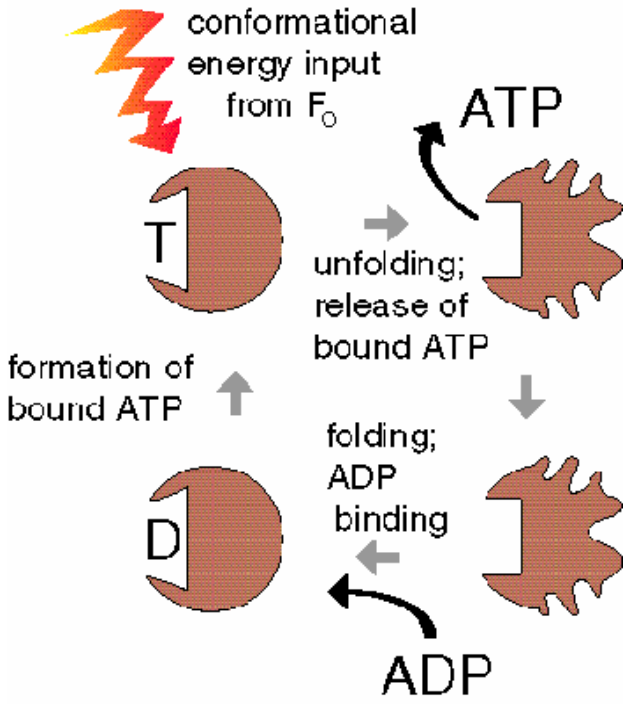
A model has been proposed for the origin of life and the evolution of biological energy conversion based on the chemiosmotic mechanism for ATP synthesis. Chemiosmosis itself was first proposed 40 years ago, and although it is now known to play a crucial role in the energy supply of all organisms, origin of life researchers still give scant attention to it. It involves ATP synthesis by a voltage difference across a biomembrane. Because of this perceived complexity, it is generally considered to must have emerged late during evolution. Many builders of models of early biochemistry implicitly assume that the first biological energy source was fermentation. Other builders consider special redox chemistry, and look for special reduction reactions. Such models for early metabolism require however a large set of enzymes, which seems implausible during origin of life conditions.

In contrast, the thermosynthesis theory gives a stepwise model for the emergence of the chemiosmotic machinery, and of life, that starts with only one enzyme, ATP synthase. This enzyme functions according to the distinct "binding change mechanism":

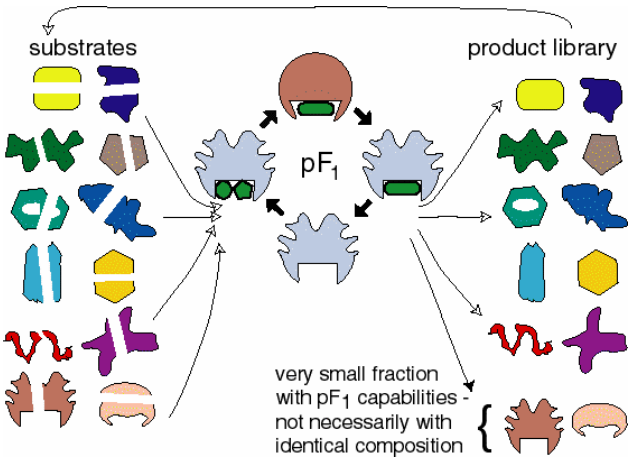
(a) binding ADP and phosphate in the local dehydrated enzyme cleft;
(b) forming the high-energy compound ATP in the cleft, which does not cost energy during the local anhydrous conditions, and
(c) using the energy associated with the membrane voltage for opening the cleft and releasing the ATP.

The thermosynthesis theory makes two assumptions for a similar 'thermally regulated binding change mechanism' for the very first ATP synthase:

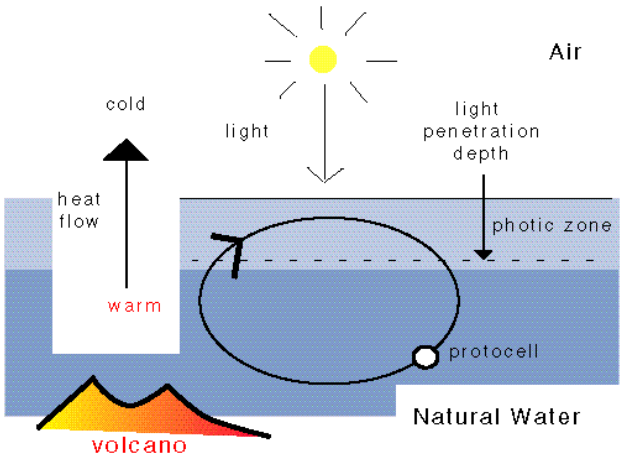
(1) The opening of the cleft (step c) occurred by a thermal unfolding.
(2) Similar to phosphorylation, peptide bond formation does not cost free energy during dry conditions. It is assumed that the enzyme also created peptide bonds during thermal cycling. More generally, during thermal cycling other condensation and dehydration reactions could occur as well.



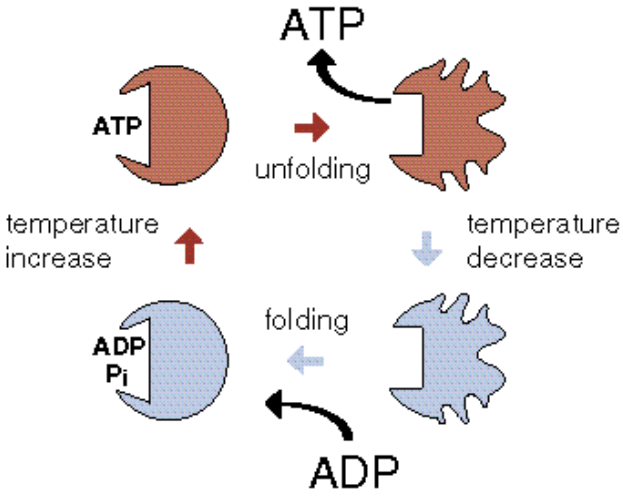
With small peptides as reactants and larger peptides as products, a simple model for the origin of life is easily constructed: the first ATP synthase synthesizes a library of polypeptides, in which a very small fraction has itself the assumed capabilities. Life starts with a functional replication. The genetic code emerges as a mechanism for increasing the fraction of functioning ATP synthases in the product library by information carrying helper molecules that themselves are synthesized by ATP synthase as a byproduct.



In the model the first organisms work on thermal cycling, being essentially heat engines. The thermal cycling is the result of dragging along by convection currents in volcanic hot springs. Another mechanism for thermal cycling, on a small scale, is circulation within a cell spanning a thermal gradient, the prime example being the palisade cell that spans the leaf, with the protoplasm stream circulating the chloroplasts between the hot sunny and the cold shade side. Many examples of thermal gradients over a small distance at interfaces can be given: soil-air, rock-air, water-air, ice or snow-air, volcanic rock-water, water-ice. Even nowadays, organism presence is often conspicuous at these interfaces.



Almost all order in the inanimate world is ultimately due to convection: plate tectonics, volcanism, sea currents, the weather, the hydrological cycle, even ore formation, are all driven by convection. The thermosynthesis model similarly accounts for the self-organization required for the origin of life in terms of convection.



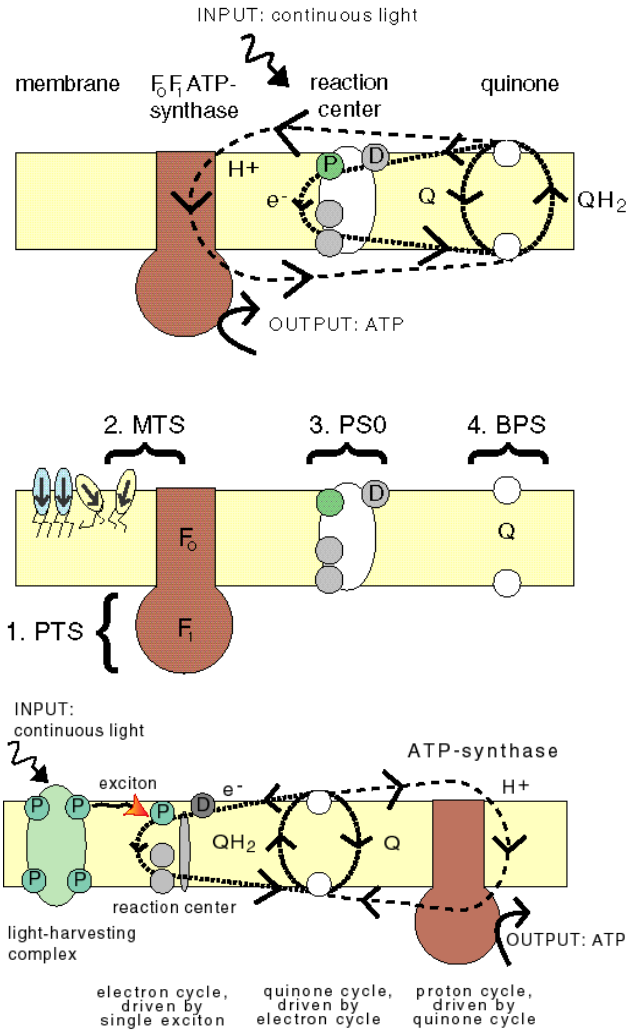
The present day chemiosmotic machinery is obtained during evolution by:

(1) first invoking protein unfolding with product release during a temperature cycle (protein thermosynthesis, PTS);

(2) next invoking membrane dipole potential changes during thermotropic phase transitions (membrane thermosynthesis, MTS). Across lipid monolayers a dipole potential is present that is normally screened off by counterions. During the thermotropic phase transition the associated change in dipole potential is not instantaneously screened off, and is assumed to be able to drive ATP synthesis;

(3) invoking membrane dipole changes due to light-induced metastable dipoles (photosystem 0, PS0) during light fluctuations in natural waters (it concerns the same light intensity fluctuations that one can observe at the bottom of swimming pools with waves at the surface). The first photosynthetic reaction centers are assumed to have been very small, and are assumed not to have spanned the membrane;

(4) adding quinones. After the growth during evolution by the stepwise addition of charge carriers the reaction centers span the membrane. Quinones can donate electrons to and accept electrons from the reaction centers while pumping protons across the membrane. This proton gradient then permits bacterial photosynthesis (BPS) as we know it.



Thermosynthesis gives new viewpoints on the origin of many physiological processes. For instance, the ubiquitous protein phosphorylation reaction can be interpreted as a method acquired later in evolution to mimic PTS during constant temperatures; regulation by calcium, by its effect on membrane thermotropic phase transitions, as a method to mimic MTS. The two states that photosynthesizing organisms can assume are naturally interpreted as relics of the hot and cold states of thermosynthesis. Many more biochemical phenomena are similarly explained. Many physiological phenomena still depend on thermal cycling: cell division, seed and spore germination, budding, flowering. Even the temperature of our own bodies still cycles during the day, that of women during their monthly cycle.

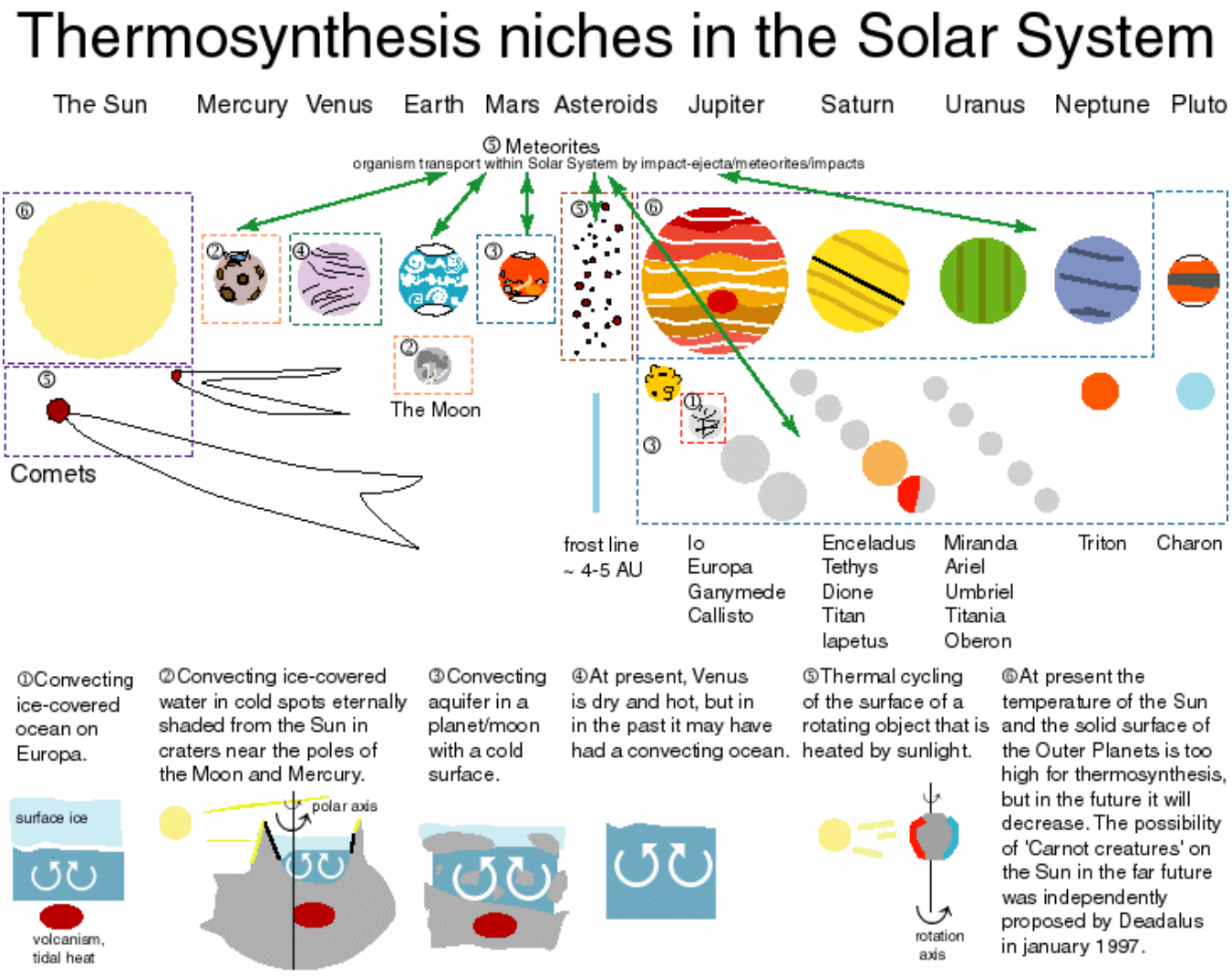
The power of thermosynthesis is much smaller than the power of photosynthesis or respiration, but its machinery is also much simpler. It does not require food or light. Thermosynthesizers could live everywhere where water circulates by convection, even where this water is covered by surface ice. An organism on an object rotating in the sunlight could also make use of thermosynthesis. Surprisingly, inspection shows that on all bodies of the Solar System thermosynthesis could occur at present, may have occurred in the past, or may occur in the future!

Implications for solar system exploration

Convection currents in fluids and thermal gradients with water present constitute possible niches for thermosynthesizers that

abound in the Solar system. During exploration one should especially be aware of its possibility on the following sites.

Mercury
The surface of Mercury is very hot because of its short distance to the Sun. At the poles, however, the interior of craters is shielded from the sun and is in eternal shadow. These interiors constitute cold traps, where water and other volatile substances can condense. Radar observations have indeed demonstrated the presence of ice. As the ice may be heated from below by volcanism, liquid convecting water is plausible underneath this ice.



Venus
In the past Venus carried an ocean, but it has now boiled away. Until it evaporated, this ocean could have carried thermosynthesizers, especially because it must have been strongly convecting. Carl Sagan has proposed life in the clouds of Venus that would make use of cyclic wetting and drying, a mechanism resembling thermosynthesis.

The Moon
Ice has been observed in shaded lunar craters on the Moon. Just as for Mercury, these craters constitute possible niches for thermosynthesizers.

Mars
The evidence for the presence of liquid water near the surface of Mars steadily increases. At present the surface is too cold, but in volcanic areas the surface ice may have melted, and convection would be plausible. Subsurface aquifers can also contain convecting water. In the past Mars had an ocean, which may have locally convected by volcanism as well. The same would be true for lakes, hot springs, etc.

Asteroids, meteorites and comets
While these objects rotate, the surface will be cyclically heated by the Sun. In outer space the state of being strongly heated in this manner has been called "barbecue mode" by engineers. Just under the surface of these objects, shaded from the Sun's UV light by rock or ice, thermosynthesis may therefore occur. For organisms on meteorites consisting of ejecta from impacts on a planet, a biological energy source can thus be given, which makes interplanetary transport of organisms by meteorites even more plausible.

The large outer planets
The surfaces of the outer planets are at present far too hot to permit any life. In their cooler clouds, life in the form of floating microorganisms has been proposed. Again, thermosynthesis is a plausible energy source for organisms in convecting atmospheres. In the future these planets may cool sufficiently to permit an ocean at the surface. Organisms in this ocean could live on thermosynthesis.

The moons of the large outer planets
Several moons of the big outer planets are covered with ice. Liquid water underneath this ice would constitute an environment that could permit thermosynthesis. A prime candidate niche for thermosynthesizers is constituted by the Jovian moon Europa, which contains an ocean covered with ice that is intensely heated by tidal friction.

The Sun
Obviously the present Sun is far too hot to permit any stable molecules, and there can be no question of Solar life. In the very far future the Sun will cool, however. The possibility of "Carnot creatures" in convection cells on the cooling Sun has independently been proposed by Nature's columnist, Daedalus in 1997.

How could thermosynthesis be demonstrated? The most simple way would be (a) to add small radioactive tracer molecules to a medium in which thermosynthesizer presence is suspected, (b) apply thermal cycling in the absence of food and light, and (c) detect high energy elongated molecules, formed from the small molecules that contain the tracer. For thermal cycling reliable machinery exists. It is commonly used during nucleic acid amplification by PCR. Detection of large molecules is easily done using standard chromatography. Another possible experiment is to add ADP and phosphate, and detect formed ATP by the sensitive luciferase luminometry method. The described methods could be applied to samples of lunar dust, meteorites, including the meteorites from Mars. Obviously, contamination by terrestrial thermosynthesizers should be avoided.

Conclusion

Thermosynthesis is a physical model for the origin of life based on mechanisms from many scientific disciplines. The combination is the novelty, not the mechanisms themselves, which are well-established. Thermosynthesis is not life as we know it, but life based on thermosynthesis can easily be imagined, and may be quickly found now one knows where to look. In the universe it may occur almost anywhere. The entire solar system is a zone habitable for hermosynthesizers.
Thermosynthesis yields a model for our very first ancestors that is simple, straightforward, and without mystery.

The following documents give more details and references.

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LEAFY GREEN ASTRONAUTS
By Patrick L. Barry

9 April 2001

Every year around this time northern school children begin sowing seeds and tending classroom gardens. It's a familiar springtime tradition. But if NASA scientists have their way, this annual gardening ritual could turn into something much more—astronaut training! For future spacefarers gardening will be a matter of survival. Not only will plants provide food when deliveries from Earth aren't possible, but plants will also work to make air breathable and water drinkable. Plants and people—two very different kinds of astronauts—will eventually live together in balanced, sustainable habitats where contact with Earth is a luxury, not a necessity.

When building a "greenhouse" in space, the light source needs to be as efficient as possible to reduce energy demands. This picture shows wheat growing under LEDs (Light Emitting Diodes) —the same technology used for indicator lights in consumer electronics. LEDs save energy by only releasing light in frequencies that plants can use for photosynthesis.

This vision of self-contained colonies in space—or even on other planets—has existed for decades in the pages of countless science-fiction novels. The growing International Space Station (ISS) brings that vision closer to reality, but the ISS isn't self-sufficient. Its life support systems are strictly mechanical so food must be ferried from Earth.

"In order to have affordable—and even doable—long-term exploration (of space), you need to incorporate biology into the life support system," said Chris Brown, director of space programs at the Kenan Institute for Engineering, Technology & Science at North Carolina State University.

NASA researchers at the Kennedy Space Center (KSC) and the Johnson Space Center (JSC) are figuring out how to do just that. They're exploring technologies that could wed people, plants, microbes, and machines into a miniature "ecosystem" capable of supporting space travelers indefinitely. This type of life support system—called "bioregenerative"—would be fully self-contained, creating an ecologically sound microcosm where each element supports and is supported by each of the others.

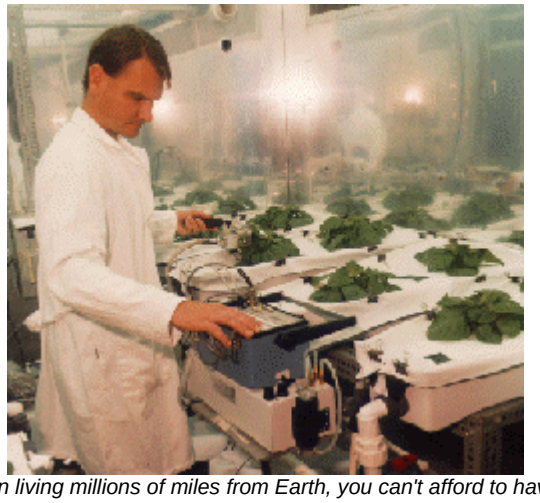
"If we really want to leave (the Earth) on a permanent basis, we need to figure out how this blue ball in space supports all of us, and somehow replicate the parts that are necessary so that we can move on," said Jay Garland, principal scientist for the Bioregenerative Life Support Project at Dynamac, Inc., at KSC.

Humans and plants are ideal space traveling companions. Humans consume oxygen and release carbon dioxide. Plants return the favor by consuming carbon dioxide and releasing oxygen. Humans can use edible parts of plants for nourishment, while human waste and inedible plant matter can—after being broken down by microbes in tanks called "bioreactors"—provide nutrients for plant growth. Plants and microbes can also work to purify water, possibly with help from machines. The only input needed to keep such a system going is energy in the form of light.

This is a simplified portrayal, of course. For scientists and engineers who are trying to design a real system, the devil is in the details. For example, finding just the right plant varieties for the "space garden" is a painstaking process.

"Plants are going to be central linchpins of the life support system—or at least the biological part of the life support system," Brown said.

The ideal space-plant would have short stalks to save room, would have few inedible parts, would grow well in low light, and would be resistant to microbial diseases. Research is underway at KSC to choose varieties of wheat, rice, lettuce, potatoes and other plants that meet these criteria.



When living millions of miles from Earth, you can't afford to have a bad crop! Scientists are using high-tech methods to find the right plant varieties and growing system to ensure reliable and efficient harvests.

Researchers are also working to develop a "greenhouse" that will function properly in space. In an orbiting greenhouse, freely-falling plants don't feel the constant downward pull of gravity. As a result, water spreads out evenly in the soil-like material around their roots, which makes it harder for both air and water to reach the roots. Researchers had to choose the size of the granules in the "soil" very carefully. If the grains are too big, the roots won't get enough water; if they're too small, not enough air. (The right size turns out to be 1 to 2 millimeters; for more information, see the editor's note at the end of this article.) Also, there is less natural air circulation in an orbiting outpost—plants can therefore suffocate on their own "exhaled" oxygen! Designers have to provide fans to keep the air moving. Researchers caution that ironing out these sorts of details won't guarantee a working system when all the pieces are assembled.

"There's a question of how the complete system will develop with time," Garland said. "On top of the ecological concerns of how the various microbe species will undergo succession (i.e., a sequence of replacements of one species by another species), you've got evolutionary effects. For microbes, with their short generation times, you're talking about real evolutionary time scales for prolonged missions."

To test how the humans, plants, and microbes fare when sealed together for extended periods of time, JSC is building a test chamber called BIO-Plex. This facility will incorporate all of the elements of a bioregenerative life support system—including the people. And just in case self-contained bubbles of life outside Earth's atmosphere aren't "sci-fi" enough for you, NASA researchers are also considering how biotechnology and nanotechnology could be used to improve such "bubbles" in mind-boggling ways.

For example, foreseeable advances in biotech and nanotech could make it possible to alter plants' genes so that their cells produce little molecular sensors, transmitters, and receivers. These would monitor the plants internally and report on their health to ensure a good crop, and could even make the plants controllable, sprouting and flowering on cue. Another idea is to engineer plants to produce chemicals that protect them from the increased radiation in space and on planets with thin atmospheres, such as Mars. Brown also suggested that nanotech devices in the plants' cells could deliver light directly to the cell parts that perform photosynthesis, making the plants more efficient.

"There are feasibility issues, but... none of them should stop us completely," said Brown, who wrote a study on the potential uses of nanotechnology for these life support systems. "Maybe we can't quite do it now, but nothing we are considering is against the laws of physics or chemistry or nature," he said.

A bioregenerative life support system will probably never fully replace the mechanical one on the International Space Station, Garland added. At most, a small crop might be grown there to provide fresh food. But eventually, with the help of plants and microbes, future space stations—or outposts on the Moon or Mars—will truly become worlds unto their own.

Note: Why does the size of grains in soil matter to orbiting plants? A fine-grained soil like clay would be an effective sponge, holding lots of water and not much air. A coarse-grained soil like gravel wouldn't be much of a sponge at all, containing lots of air but little water. Here on Earth the precise "graininess" of soil isn't too important because water percolates downward—a process that aerates soil around a plant's roots. In a free-fall environment (equivalent to zero-G), there is no downward percolation. It's essential to tweak the grain size so that capillary action draws water to the roots while leaving space for air.

For more information on this story, see http://science.nasa.gov/headlines/y2001/ast09apr_1.htm?list52260.

LIFE'S CHEMICAL FINGERPRINTS
By Lee Siegel
From the NASA Astrobiology Institute

9 April 2001

Perhaps in 2008, a rover on Mars will press its robotic arm against a rock. A probe at the end of the arm will scan the rock, repeatedly zapping the surface with a microscopically thin laser beam, probably green or ultraviolet. As the laser light hits the rock, it will "scatter" (be deflected) in random directions. Most of that light will stay the same color, but a tiny fraction will be shifted just slightly to a different color, a phenomenon called the Raman effect. That slight shift will reveal whether the rock harbors the chemical signatures of life, either microbes now alive or the remains of organisms that lived in the past. The "Raman-shifted" light also can detect any minerals indicating whether Mars once was conducive to life.

In the more distant future, a spacecraft hardened against Jupiter's intense radiation may land on the icy moon Europa, then melt its way downward to a vast ocean below. The interplanetary submarine will activate a Raman probe, analyzing the water for mineral evidence of seafloor hot springs and life that might thrive there.

Thanks to miniaturization of devices that once were as big as beds, researchers are developing "Raman spectrometers" small enough to look for evidence of life on Mars and Europa. They hope green or ultraviolet Raman instruments—or perhaps both—might be launched toward Mars in 2007. Prototypes of the green-laser Mars Microbeam Raman Spectrometer—which excels at identifying minerals—were built by a team led by Larry Haskin, a professor of Earth and planetary sciences at Washington University in St Louis. His team includes researchers from the University of Alabama at Birmingham, Cornell University and NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California.

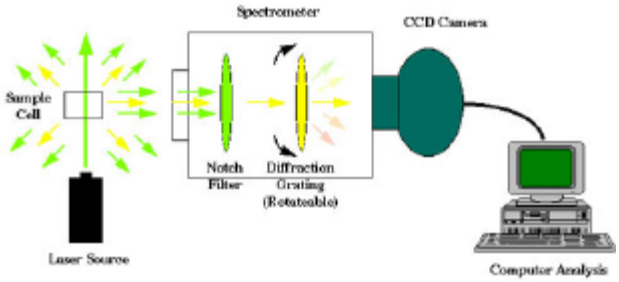
Dr. Alian Wang of Washington University, a member of Haskin's team, first conceived and designed the miniature instrument. Michael Storrie-Lombardi, a member of the NASA Astrobiology Institute, works at JPL's Center for Life Detection. He is principal investigator of a second team, which builds devices that use ultraviolet lasers to perform Raman spectroscopy highly sensitive to organic materials. Scientists believe Raman spectroscopy is more likely to find minerals indicating conditions conducive to life than it is to find unambiguous evidence of life itself, past or present.

"No instrument can tell you life—yes or no—so you can be sure about it," said Tom Wdowiak, a member of the Haskin group and a physicist at the University of Alabama at Birmingham. But a Raman spectrometer "is the best instrument we have in the pipeline for selecting samples on Mars to answer the question of whether or not life ever could have existed on that world-or if conditions are such that life could exist there now."

"If there were life forms or residues of life and we encountered them with the [Raman] instrument, of course we would see them," Haskin said. "But our chances of running into it [life] are extremely low."

Raman spectroscopy was named for Chandrasekhra Venkata Raman, a University of Calcutta physicist who won the Nobel Prize in physics in 1930 for his discovery of the Raman effect. When a laser beam of a specific wavelength or color hits a target material, most of the light that bounces off the material stays the same wavelength, or color. But a small portion of the laser light, from one-in-one-thousand to one-in-one-trillion photons (light particles), changes wavelength. The precise shift in wavelength is determined by the molecular makeup of the targeted material. Each different type of molecule has a unique signature.

As a result, Raman spectroscopy-determining the wavelengths of Raman-shifted light-can characterize minerals, detect trace amounts of organic substances and identify biological substances such as proteins, DNA, amino acids and plant pigments. The method often is used in medicine, for tasks that range from analyzing genes to detecting microbes, Storrie-Lombardi said.



The basic process of Raman spectrometry. The mineral sample to be studied is illuminated by a laser beam. Scattered light is collected by the spectrometer. A filter removes any light that is the same color as the laser beam, letting only the light that has changed color (Raman-shifted light) pass through. The diffraction grating separates the light by color (wavelength). The different wavelengths are collected by a charged couple device (CCD) camera. A computer creates a graph showing the intensity of light at each wavelength. Image credit: University of Utah, Center of Excellence for Raman Technology.

A planetary Raman spectrometer would press a probe against a sample, or perhaps plunge a fiber-optic cable into the soil, then fire the laser repeatedly as the probe scanned the sample. A special filter would remove scattered light that had not changed color. Raman-shifted light would pass through the filter, then pass through a grating and bend according to wavelength. The light would hit an electronic camera. A computer would convert the data collected by the camera into graphs showing the "spectra" or wavelengths of the Raman-shifted light. Organic substances and minerals can be identified by the "peaks" they create at certain wavelengths on these graphs.

Wdowiak said a Raman spectrometer could look not only for life and organics, but also for minerals in which organisms might have fossilized. The Raman device also could detect minerals that formed in the presence of water, which is needed for life, and minerals that indicate energy use in living organisms. Haskin and Wdowiak said the green laser Raman spectrometer was bumped from NASA's 2003 Mars launch program when the mission evolved into a pair of rovers.

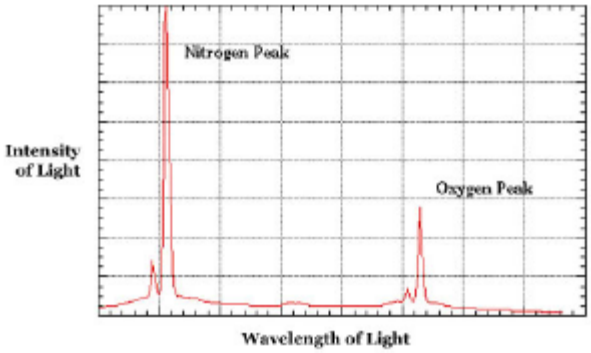
"The best prospect now for the Raman spectrometer to go to Mars," Wdowiak said, "is in 2007, because the 2005 mission is going to be an orbiter."

The Haskin team's latest green Raman spectrometer is an L-shaped device that fits in an outstretched hand. Storrie-Lombardi's most recent ultraviolet Raman spectrometer is "about the size of a carry-on suitcase," he said. "Were aiming to get it down to a tenth of that size" or smaller.

Storrie-Lombardi said the green laser Raman device is first in line for Mars. But he also would love to send his ultraviolet instrument, which is more sensitive for detecting signs of life. William Hug of Photon Systems in Covina, CA, developed the miniaturized ultraviolet laser used in Storrie-Lombardi's Raman instrument, which can identify DNA (the genetic material of life) and detect three of the 20 amino acids that build proteins in living organisms. Not only could the ultraviolet device use the Raman effect to look for those signs of life, it also could make "black-light" and visible-light photographs of extraterrestrial samples. Protein glows fluorescently in ultraviolet light, Storrie-Lombardi said, just as blood glows under black lights used by crime-scene investigators. Storrie-Lombardi's prototype has detected bacteria,

DNA, protein and other organic materials in laboratory experiments.

"The first thing we scanned was coffee grounds. Clearly organic," he joked. "We'll be able to tell if there is Starbucks on Mars."



When illuminated by a laser, chemicals and minerals scatter light. The specific wavelengths of the light identify the composition of the chemical or mineral. This Raman spectrograph of ordinary room air shows that air is composed of nitrogen and oxygen. Image credit: University of Utah, Center of Excellence for Raman Technology.

Haskin said that as his Raman device scanned a 1.1-billion-year-old volcanic basalt from Minnesota, "all of a sudden, we got a beautiful organic spectrum, which turned out to be a wax," produced by microscopic lichens on the rock. Wdowiak used Raman spectroscopy to detect 2-billion-year-old fossilized bacteria in rock. Storrie-Lombardi's ultraviolet light illuminated algae and fungi when it was tested on rocks from Antarctica. According to D. D. Wynn-Williams of the British Antarctic Survey, modern cyanobacteria in harsh Antarctic deserts produce chlorophyll and other pigments detectable by Raman spectroscopy. The pigments have been found in 3.5-billion-year-old fossilized cyanobacteria. Wynn-Williams suggested a spacecraft could use a fiber-optic cable to extend a Raman probe into Martian soil to look for such pigments, which would provide "evidence of former surface life on Mars."

Wdowiak doubts such "biomarkers" will be found on Mars, however, because the surface environment is so harshly oxidizing it destroys any life.

Haskin said he hopes a Raman device on Mars will "find minerals that require water and warm conditions for their formation." Finding such minerals on Mars would indicate conditions hospitable to life once existed there. A Raman spectrometer on Europa's icy surface could identify any minerals or organic material that welled up from the moon's purported ocean and broke or percolated through the ice, he added.

Darcy Gentleman and colleagues at Arizona State University have suggested using a submersible Raman instrument to look for organic materials around undersea hot springs on Earth and Europa. Earth life may have begun near undersea hydrothermal vents, which "might be places to look elsewhere in the solar system for life," Gentleman said. According to Storrie-Lombardi, though, such a mission is unlikely before the 2020s.

What next?

Beyond Mars and Europa, he said he would like to see a Raman device look for signs of life on Jupiter's moon Callisto. Storrie-Lombardi said Raman spectrometers not only can explore other worlds, but also can screen spacecraft to ensure they are not carrying Earth microbes to other planets. They also can be used to protect Earth from extraterrestrial contaminants hitchhiking on returning spacecraft.

Additional information on this story is available at http://nai.arc.nasa.gov:8080/index.cfm?page=raman.

TWENTY THOUSAND LEAGUES UNDER THE SEA
By Henry Bortman
From the NASA Astrobiology Institute

11 April 2001

Miles below the ocean surface exist some of the most fascinating habitats for life on Earth. Here, where sunlight never reaches, live complex ecosystems that can appear and disappear within a matter of decades. What provides the thermal and chemical energy that fuels these ecosystems are deep-sea hydrothermal vents, one of the unofficial wonders of the natural world. These vents occur at oceanic "spreading centers," mountainous ridges where magma from deep within the Earth's crust forces its way up to the ocean floor, creating new ocean crust and pushing the old crust out of the way. This is the engine that drives apart the Earth's tectonic plates, moving continents about and causing volcanic eruptions and earthquakes.

From time to time, hydrothermal vents, known as "black smokers," occur along these ridges. They are underwater geysers. At these vent sites, cold ocean water seeps down through cracks in the seafloor to hot spots underground. The water gets superheated to several hundred degrees Celsius and is spit back up in a mineral-rich broth of scalding fluid. And in this bizarre environment, life flourishes.

Until a little over 20 years ago, no one knew that deep-sea hydrothermal vents existed, much less that they were teeming with life. The first such vent was discovered in 1977 east of the Galapagos Islands. Since then, dozens of vents have been discovered and explored along ridges in the Atlantic and Pacific. Active vents are inhabited by a complex ecosystem of organisms containing both microbial and more complex animal life. (There is no plant life in the deep ocean, because sunlight cannot reach down that far to drive the process of photosynthesis on which plants depend.) The animal life includes tube worms, shrimp, clams, mussels and crabs.

Most hydrothermal vents are found at mid-ocean ridges along the edges of tectonic plates. The Dive and Discover expedition is currently exploring a point in the Indian ocean where three plates meet. Image credit: Woods Hole Oceanographic Institute.

Last year scientists discovered a vent along a ridge in the Indian Ocean. (It's located south of the southern tip of India and east of the African island nation of Madagascar.) An expedition is

currently underway to explore this vent. Japanese scientists visited this vent in August, 2000, but spent only four days there. The new expedition plans to spend several weeks at the new vent. Cindy Lee Van Dover, of the College of William and Mary in Williamsburg, VA, is chief scientist on the research cruise. Van Dover has been exploring ocean vents for many years.

Samples of adult (above) and juvenile vent shrimp returned by the Jason vehicle. Ruler shows scale. Image credit: Woods Hole Oceanographic Institute.

"I really never thought that one could be an explorer in this day and age. But in the ocean, it's absolutely true. You're going places that nobody's ever been before."

Van Dover studies the morphology (body shape) of vent animal life. Mussels are her specialty. Bob Vrijenhoek, a senior scientist at the Monterey Bay Aquarium Research Institute in Moss Landing, CA, takes a different approach. He studies vent animals, as well as the bacteria that inhabit the vents, by analyzing their DNA. Members of Vrijenhoek's research group are participating in the Indian Ocean expedition.

The study of how animal populations evolve and disperse geographically is known as "biogeography." Hydrothermal vents offer a unique opportunity for biogeographers because the underwater environment is affected by fewer factors than are land environments.

"People study biogeography on land and it's always got superimposed on it the effects of latitude and climate," says Van Dover. Hydrothermal vents, in contrast, are "largely decoupled from climate. They are isolated from what goes on above."

Most vent organisms, scientists believe, can exist in their adult form only near an active vent site (although many of these organisms have swimming larval stages, which can travel for great distances). Individual vents remain active for anywhere from a few decades to a few thousand years. When a vent shuts off, the adult animals living there die. Yet as soon as a new vent emerges, it is rapidly colonized. Within a few years, a new vent undergoes a complete transformation from uninhabited to fully populated. By studying the similarities and differences among the animals that live at different vents, scientists have begun to piece together a picture of how organisms move from one vent to another, what are the natural barriers to such movement, and how the geography of the deep ocean affects the evolution of the species that inhabit it.

Swarms of Rimicaris exoculata*—a vent shrimp—dart about the vent, feeding on bacteria. Image credit: Magnus Johnson.*

Most of the research into the fauna (animal life) that inhabit hydrothermal vent systems has been done in the northern region of the Mid-Atlantic Ridge and along the East Pacific Rise, which runs roughly parallel to the west coast of South America. Although similar types of animals can be found at both Atlantic and Pacific vent sites, there is more similarity among the vent ecosystems along the same ridge than there is between the two ridges. For example, shrimp are found at both Atlantic and Pacific sites, but one particular type of shrimp, known as "swarming shrimp," is found only in the Atlantic.

The Pacific is a very old ocean, while the Atlantic is relatively young, having fully formed only about 120 million years ago. One question scientists are interested in is how the animals that inhabited the Pacific ridge system made their way to the younger Atlantic ridge. One theory is that some of the organisms may have arrived by way of the Tethys Sea. Don't look for it on a map, unless it's a map of what Earth looked like 100 to 200 million years ago. All that's left of it today is the Mediterranean. The Tethys Sea was a much larger body of water, which once connected the Indian Ocean to the Atlantic. Scientists theorize that animals could have migrated along ocean ridges from the Pacific to the Indian Ocean, and from there through the Tethys Sea to the North Atlantic.

Some vent organisms, for example, vent shrimp, haven't been around all that long. They are thought to have evolved only 20 million years ago. So they couldn't have arrived by way of the Tethys Sea, because by 20 million years ago it had closed up. Another possible route for organisms to have traveled is through the Indian Ocean around the Cape of Good Hope to the South Atlantic. In either case, the Indian Ocean vents may provide a "missing link" between Atlantic and the Pacific vent ecosystems. Early photographs from the Indian Ocean site taken by Japanese scientists show shrimp and mussels that appear very similar to those found at Atlantic vents.

"If you had shown me one of those pictures and asked me where that picture came from," says Vrijenhoek, "I'd have told you it came right from the mid-Atlantic ridge." But, he cautions, "we could get fooled just by superficial appearance." He is looking forward to the results of the DNA analysis that his colleagues will perform on these animals.

Recently developed, highly efficient DNA-based tools have dramatically changed the way scientists study evolution. Scientists like Vrijenhoek use these tools to determine the similarities and the slight mutational changes between the genes in organisms found at different vent sites. Using this information leads to a better understanding how the life cycle of an organism

interacts with the changing typography of the seafloor to affect both the geographic dispersal and evolution of that organism.

"We do the same thing that a forensic scientist would do," Vrijenhoek explains. "We basically extract DNA from the organism and then we use that DNA to look at the degree of relationships within populations, and then between populations."

For example, Vrijenhoek and his colleagues have found what he calls "genetic discontinuities" among populations of vent amphipods (small crustaceans) that don't appear among populations of other vent organisms. This is due, he explains, to the fact that there is no swimming larval stage in the amphipods' life cycle. As a result, one population of organisms can easily be cut off from another, causing the two populations to drift apart genetically.

Says Vrijenhoek, "The amphipods probably just ride up and down these ridge axes like a corridor. So if there's a disruption in that corridor, through a transform fault or lack of habitat, or something like that, they simply can't get from point A to point B." The isolated populations then evolve along separate pathways.

Genetic isolation is less likely to occur among populations of animals that have do have a swimming larval stage, because they can more easily cross such physical barriers. This is just what is seen in mussels, clams and tube worms.

What next?

Although there is plenty of work yet to be done in the Indian Ocean, Van Dover and Vrijenhoek are also excited about taking a look at other vent sites that remain completely unexplored. The southern Atlantic is one such region. But if given a choice (and funding), Van Dover would head for the Arctic Ocean, because of its isolation.

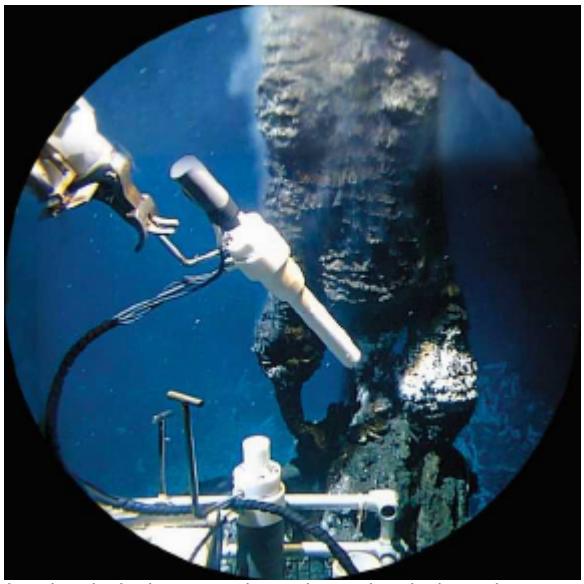
"The Arctic Basin's been separated from the Atlantic and the Pacific since the Arctic Ocean was formed by shallow fill. So the deep fauna of the Atlantic and the Pacific, the ones that occur at the vents, may not have gotten up into the Arctic. If you wanted to pick the place to go find the most unusual vent organisms, I'd have to choose the Arctic."

Additional information on this article is available at http://nai.arc.nasa.gov/index.cfm?page=expedition_story.

SCIENTISTS DETERMINE HOW CHEMISTRY KEEPS WEIRD WORMS "OUT OF HOT WATER" AT STEAMING DEEP-SEA VENTS
University of Delaware release

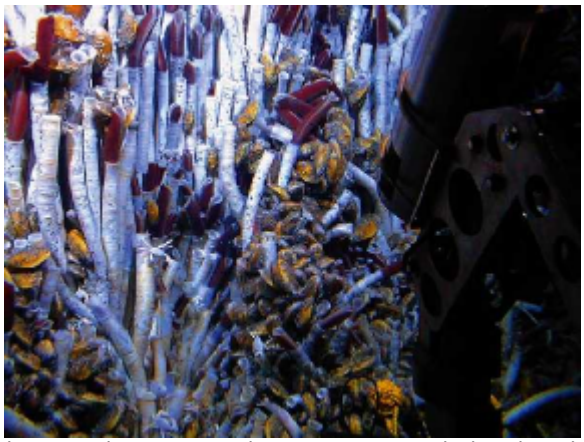
11 April 2001

Using a novel detector attached to a submarine, a research team led by University of Delaware marine scientists has determined that water chemistry controls the location and distribution of two species of weird worms that inhabit deep-sea hydrothermal vent sites. The study, which is the first to demonstrate through real-time measurements how different chemical compounds control the biology at the vents, is reported in the April 12 edition of *Nature*. The interdisciplinary research team included chemists, biologists, and marine engineers from the UD Graduate College of Marine Studies, Woods Hole Oceanographic Institution, Rutgers University, and Analytical Instrument Systems, Inc. The National Science Foundation, the National Oceanic and Atmospheric Administration's National Sea Grant College Program, and the National Aeronautics and Space Administration supported the research.



This chemical detector—the "electrochemical analyzer"—was built by scientists at the University of Delaware and Analytical Instrument Systems, Inc., in Flemington, New Jersey. It houses electrode sensors for taking chemical measurements at hydrothermal vents. The wand also is equipped with a thermometer. Image credit: University of Delaware Graduate College of Marine Studies.

UD's George Luther, a marine chemist, and Craig Cary, a marine biologist, worked with Don Nuzzio, president of Analytical Instrument Systems in Flemington, New Jersey, to develop a chemical detector capable of withstanding the harsh conditions at the vents. Their "electrochemical analyzer" consists of a foot-long wand that houses several needle-like, gold-tipped electrodes, which are coated in super-tough plastic to protect them from heat. The wand, which resembles a large, hand-held hairdryer, is connected to a 3-foot-long, 8-inch-diameter tube that houses the system's electronics. The tube is mounted to the bottom of the submarine Alvin. Once attached to one of Alvin's highly maneuverable arms, the analyzer's wand can be placed near a vent to instantaneously reveal the ingredients in the sulfur-rich stew rocketing out of the Earth's crust.



Tubeworms have no mouth, eyes, or stomach ("gut"). Their survival depends on a symbiotic relationship with the billions of bacteria that live inside of them. These bacteria convert the chemicals that shoot out of the hydrothermal vents into food for the worm. This chemical-based food-making process is referred to as chemosynthesis. Image credit: University of Delaware Graduate College of Marine Studies.

"One of the analyzer's greatest benefits is its ability to detect a number of sulfur compounds simultaneously, such as iron

monosulfide, hydrogen sulfide, thiosulfate, polysulfide, and others," says Luther. "Previous techniques could not identify these compounds, which are the lifeblood of the vents."

Previous University of Delaware research confirmed that the Pompeii worm is the most heat-tolerant animal on Earth, able to survive an environment nearly hot enough to boil water. Covering this deep-sea worm's back is a fleece of bacteria. These microbes may possess heat-stable enzymes useful in a variety of applications, such as pharmaceutical production, food processing, paper and textile manufacture, and others. Image credit: University of Delaware Graduate College of Marine Studies.

During the past two years, the research team tested the analyzer at vent sites in the Gulf of California and in the Pacific Ocean. They examined the microhabitats of two different vent worms: the tubeworm (*Riftia pachyptila*), which looks like a giant lipstick and can grow to 9 feet tall, and the hairy, 5-inch Pompeii worm (*Alvinella pompejana*), which currently holds the record as the "hottest" animal on Earth. The tubeworm lives on the seafloor near hydrothermal vents. It has no eyes, mouth, or stomach. Instead, this worm relies on the billions of bacteria that live inside it to make food. Using the analyzer in a tubeworm colony, the scientists confirmed that this animal resides in waters up to 30°C (86°F), and its bacteria require hydrogen sulfide for survival. If the chemical is not present, the tubeworms die.

Unlike the tubeworm, the Pompeii worm eats helpful microbes. "A fleece of bacteria also occupies this worm's back," says UD marine biologist Craig Cary. In 1998, Cary and his team confirmed that the Pompeii worm is the most heat-tolerant animal on Earth, capable of surviving nearly boiling water.

"The Pompeii worm forms tube-dwelling colonies on the sides of certain vent chimneys," says Cary. By replacing the analyzer's hairdryer-like wand with a more slender attachment, the scientists were able to insert the device right into the Pompeii worm's home. They found that the Pompeii worm resides in much hotter water than the tubeworm, with temperatures fluctuating from 40°-90°C (104°-194°F).

According to Luther, this hot water causes an important chemical reaction critical for the worm's survival. "The higher temperatures allow for the formation of soluble iron monosulfide, a compound that reduces the toxicity of the hydrogen sulfide in the surrounding water," he notes. "So figuratively speaking, you might say the worm's hot-water home helps keep it out of 'hot water.' "

While this research demonstrates how differences in chemical compounds control the unique ecology of vent environments, Luther says the study also may aid astrobiologists.

If you look closely at the lower right-hand quadrant of this photo, you can see a Pompeii worm extending its dark-red feathery head and paler body from its tube home. The worm is about 13 centimeters (5 in) long. Image credit: University of Delaware Graduate College of Marine Studies.

"The interplay of oxygen, iron, and sulfide compounds in controlling biology in primordial environments on Earth could provide a paradigm for the detection of life on other planets," he says. "Europa, one of Jupiter's moons, is covered in ice. But recent findings suggest that portions of the ice move, which is strong evidence that liquid water lies beneath it, maintained by hydrothermal vents. If hydrothermal vents exist on Europa, there's a possibility that ancient microbes could live there, too."

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Additional information on this story is available at
http://www.ocean.udel.edu/newscenter/weirdworm.html.

An additional article on this subject is available at
http://nai.arc.nasa.gov/index.cfm?page=keeping_cool.

ASTROCHEMISTRY OF LIFE
Symposium announcement
http://www.bham.ac.uk/Astrochemistry/APCGroup/AofL/

12 April 2001

This Multidisciplinary Symposium will be held as part of the Royal Society of Chemistry (RSC) 2001 Annual Conference. The Conference will take place at the splendid International Convention Centre (ICC) in Birmingham (UK) from 30 July - 2 August, and the Symposium itself runs from Wednesday lunchtime (1st August) to the end of Thursday afternoon (2nd August). It is being organized by the Astrophysical Chemistry Group of the Royal Society of Chemistry and the Royal Astronomical Society. It is planned that in addition to being a benchmark meeting in its own right, the Symposium will provide a forum that will increase debate with and amongst chemists and

biochemists, and encourage involvement in this very exciting area. All titles given below are provisional.

Wednesday 1st August 2001

From molecular clouds to planets

? Pascale Ehrenfreund, Formation and Evolution of Organics (in particular amino acids) in Space
? Yuri Aikawa, Chemistry in Protoplanetary Disks
? Didier Queloz, Extrasolar Planets: Discoveries and Questions for Tomorrow
? Tobias Owen, The Formation of Habitable Planets: Sources of Water, Carbon and Nitrogen

Thursday 2nd August 2001

Life in the solar system

? Monica Grady, Carbon in Meteorites
? David Wynn-Williams, Photosynthetic Microbial Life on Mars—are Pigments the Clue?
? Jim Ferris, Catalysis and Prebiotic Synthesis: The Formation of RNA
? John Sutherland, Recent Studies in Prebiotic Chemistry
? Mike Russell, The Onset of Life at an Alkaline Seepage in an Acidulous Ocean

Life on extrasolar planets

? Alan Penny, Plans for Looking for Signs of Biological Activity on Extra-solar Planets

Poster session

There will be a poster session on the Wednesday evening. Please submit abstracts on-line. The closing date is 1st June 2001.

General details and registration

Further general details are given on the Annual Conference web page (http://www.rsc.org/lap/confs/annconf2001.htm) and this includes a self-registration email update facility. All registration, payment of registration fees, accommodation details etc. are to be made through the Royal Society of Chemistry Annual Conference web page and not through the Astrophysical Chemistry Group. Some information on fee levels for the Symposium and information for students is given here.

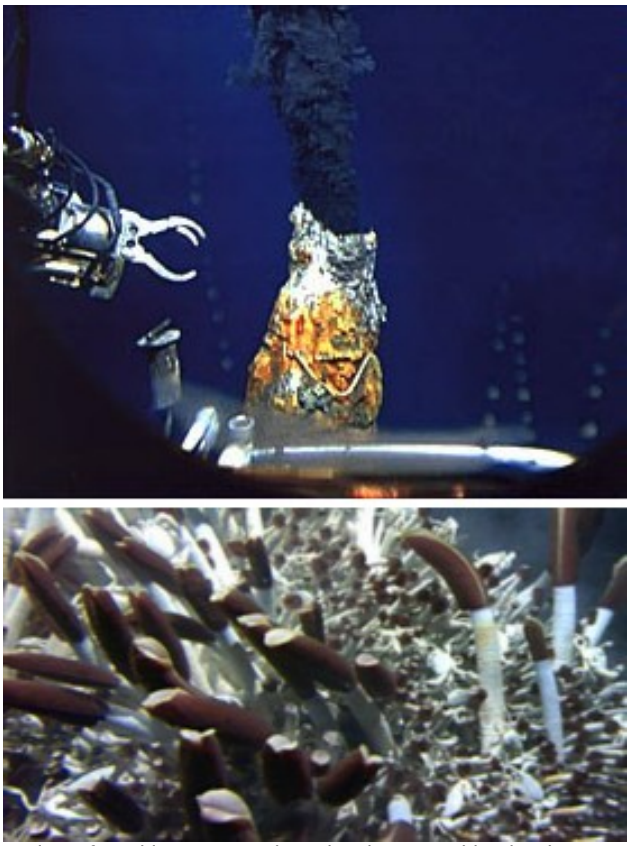
Bursaries

There will be a substantial number of travel bursaries for UK and International Participants for this Multidisciplinary Symposium.

LIFE AS WE *DIDN'T* KNOW IT
By Patrick L. Barry
From *NASA Science News*

13 April 2001

Dr. Cindy Van Dover maneuvers her robotic craft closer to the strange, rocky landscape below. It's totally dark, except for lonely circles of light where she points her flood lamps. Back on the mother ship her monitor reveals tall, thin towers of craggy rock billowing black smoke from their peaks. Very strange! All around the towers stand dozens of red-and-white, tube-like organisms. These bizarre, 3-foot-long, wormish creatures have no mouth, no intestines, and no eyes. Stranger still, they derive their energy from the planet itself, not from the light of the nearby star—a feat most biologists didn't believe possible until these creatures were found. She steers toward the worms and uses the robotic arm to reach out and take a sample for later examination.



A view of a "chimney" vent (top photo) captured by the deep-sea submersible JASON. The superheated black water pouring from the vent provides high-energy chemicals that sustain the tubeworms (bottom photo) and other organisms that thrive in this unlikely habitat. Image credits: Woods Hole Oceanographic Institution.

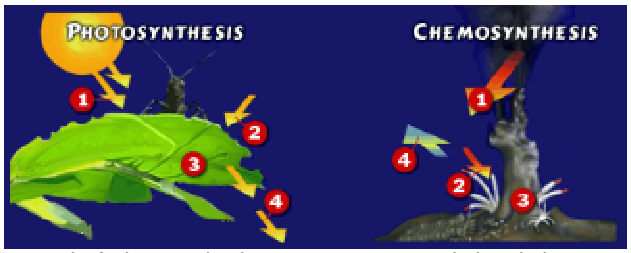
Is this a science fiction tale? No. Is the intrepid Dr. Van Dover truly exploring another world? Yes! Van Dover is as real as is the alien world she's discovering. And both are right here are Earth! Cindy Van Dover, a marine biology professor at the College of William and Mary in Williamsburg, Virginia, is one of some 60 scientists, technicians and sailors currently sailing the Indian Ocean aboard the research vessel Knorr from the Woods Hole Oceanographic Institution. The 40-day expedition, from March 27th through May 5th, is sending a 1-ton robotic submarine named JASON 2,000 meters down to explore the peculiar sunless world of deep-sea hydrothermal vents.

"I really never thought that one could be an explorer in this day and age," said Van Dover, chief scientist for the expedition and a member of NASA's Astrobiology Institute. "But in the ocean, it's absolutely true," she added. "You're going places that nobody's ever been before!"

The hydrothermal vents—which are essentially geysers on the sea floor—support exotic chemical-based ecosystems. Some scientists think the vents are modern-day examples of environments where life began on Earth billions of years ago. And the vents might also hold clues to life on other planets. The thriving communities of life that surround these hydrothermal vents shocked the scientific world when the first vent was discovered in 1977.

Before 1977, scientists believed that all forms of life ultimately depended on the Sun for energy. For all ecosystems then known to exist, plants or photosynthetic microbes constituted the base of the food chain. In contrast, these vent ecosystems depend on microbes that tap into the chemical energy in the geyser water that billows out from the sea floor—energy that originates within

the Earth itself. Because they offer an alternative way for life to meet its fundamental need for energy, these vent ecosystems have piqued the interest of astrobiologists—scientists who study the plausibility of life starting elsewhere in the universe.



Instead of photosynthesis, vent ecosystems derive their energy from chemicals in a process called "chemosynthesis." Both methods involve an energy source (1), carbon dioxide (2), and water to produce sugars (3). Photosynthesis gives off oxygen gas as a byproduct, while chemosynthesis produces sulfur (4). Image credit: Woods Hole Oceanographic Institution.

"It's the only system we know of on Earth where life can thrive in the complete absence of sunlight," said Bob Vrijenhoek, senior scientist at the Monterey Bay Aquarium Research Institute in Moss Landing, California. Vrijenhoek will conduct DNA analysis on the samples gathered by the expedition.

One chore that astrobiologists have struggled with for years is to define the range of conditions (temperature, salinity, irradiation, chemical composition, etc.) in which "life as we know it" could exist. The discovery of hydrothermal vent ecosystems expanded that range.

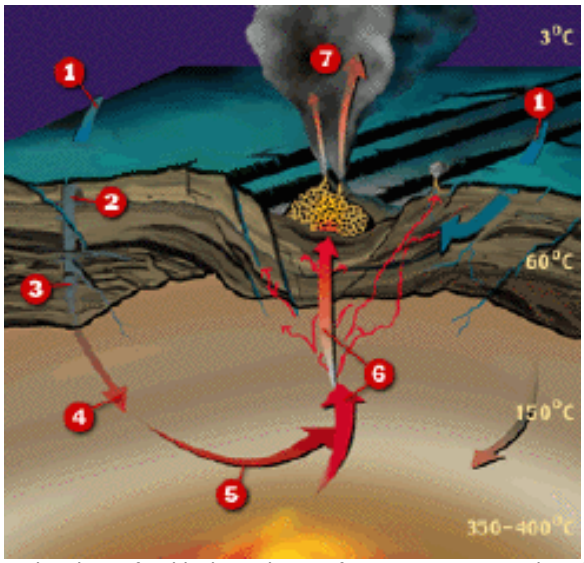
"It (the life around the vents) was the first discovery of 'life as we don't know it,'" Vrijenhoek said.

Hydrothermal vents form along mid-ocean ridges, in places where the sea floor moves apart very slowly (6 to 18 cm per year) as magma wells up from below. (This is the engine that drives Earth's tectonic plates apart, moving continents and causing volcanic eruptions and earthquakes.) When cold ocean water seeps through cracks in the sea floor to hot spots below, hydrothermal vents belch a mineral-rich broth of scalding water. Sometimes, in very hot vents, the emerging fluid turns black—creating a "black smoker"—because dissolved sulfides of metals (iron, copper, and several heavy metals) instantaneously precipitate out of solution when they mix with the cold surrounding seawater.

A variety of animals live near these hydrothermal vents, including the shrimps, crab, and anenome in this picture taken at the Indian Ocean vent. So far, the hallmark red and white tubeworms have not been spotted at this vent. Image credit: Woods Hole Oceanographic Institution.

Unlike plants that rely on sunlight, bacteria living in and around the dark vents extract their energy from hydrogen sulfide (H_2S) and other molecules that billow out of the seafloor. Just like plants, the bacteria use their energy to build sugars out of carbon dioxide and water. Sugars then provide fuel and raw material for the rest of the microbe's activities.

Deep-sea bacteria form the base of a varied food chain that includes shrimp, tubeworms, clams, fish, crabs, and octopi. All of these animals must be adapted to endure the extreme environment of the vents—complete darkness; water temperatures ranging from 2°C (in ambient seawater) to about 400°C (at the vent openings); pressures hundreds of times that at sea level; and high concentrations of sulfides and other noxious chemicals. The ability of life to tap such geothermal energy raises interesting possibilities for other worlds like Jupiter's moon Europa, which probably harbors liquid water beneath its icy surface. Europa is squeezed and stretched by gravitational forces from Jupiter and the other Galilean satellites. Tidal friction heats the interior of Europa possibly enough to maintain the solar system's biggest ocean. Could similar hydrothermal vents in Europa's dark seas fuel vent ecosystems like those found on Earth? The only way to know is to go there and check.



The chemistry of a "black smoker." After sea water seeps into the crust (1), oxygen and potassium (2) and then calcium, sulfate, and magnesium (3) are removed from the water. As the water begins to heat up (4), sodium, potassium, and calcium dissolve from the crust. Magma superheats the water, dissolving iron, zinc, copper, and sulfur (5). The water then rises back to the surface (6), where it mixes with the cold seawater, forming black metal-sulfide compounds (7). Image credit: Woods Hole Oceanographic Institution.

Astrobiologists are increasingly convinced that life on Earth itself might have started in the sulfurous cauldron around hydrothermal vents. Vent environments minimize oxygen and radiation, which can damage primitive molecules. Indeed, many of the primordial molecules needed to jump-start life could have formed in the subsurface from the interaction of rock and circulating hot water driven by hydrothermal systems. If this idea proves true, then as Van Dover gazes through the submarine's camera at the vents on the floor of the Indian Ocean, she may be seeing both a portrait of life's genesis in Earth's distant past—and a glimpse of alien life yet to be discovered.

More information on this article is available at http://science.nasa.gov/headlines/y2001/ast13apr_1.htm?list52260.

SETI: SEARCHING FOR GIANT PLANETS ON ASTRONOMY DAY
By Edna DeVore
From *Space.com*

17 April 2001

Searching for ET involves seeking the evidence of alien technology—radio and optical—in the midst of the vast symphony of noise generated by the natural universe. When we look for life, we assume that ET has a habitable home—a safe and comfy planet where food, energy and other ETs abound. Thus, searching for ET also involves understanding the origin and prevalence of planets in our universe. A good place to start is in our own solar system.

Get the full story at
http://www.space.com/searchforlife/seti_astronomy_day_010417.html.

SHUTTLE EXPERIMENT LAUNCHES TO U.S. CLASSROOMS
By Brian Mattmiller, bsmattmi@facstaff.wisc.edu
University of Wisconsin-Madison release

17 April 2001

Thousands of elementary and middle school students will try their hand at rocket horticulture later this month when the Space Shuttle Endeavour makes its rendezvous with the International Space Station. The mission STS-100, scheduled for takeoff Thursday, April 19, will carry a payload of fast-growing mustard plants in a high-tech growth chamber, the Advanced Astroculture unit developed by the Wisconsin Center for Space Automation and Robotics (WCSAR). While that project will help demonstrate how plants grow in microgravity, gravity-bound students in hundreds of U.S. classrooms will follow the project via the Internet and run parallel studies using similar plant growth chambers and parameters in class.

"The students will take an active role in designing, preparing, and conducting the experiment," says Bratislav Stankovic, a WCSAR scientist at the College of Engineering. "It will challenge students to do science, share results online and collaborate on scientific investigations while being part of a real space project."

This experiment will be designed by groups of high school students from more than 400 public schools nationwide. The STS-100 experiment is sponsored by WCSAR's commercial partner, Space Explorers, Inc. SEI is a privately held company based in Green Bay, Wis., that develops K-12 standards-based commercial education programs delivered via the Internet.

The science and engineering data obtained from the experiment will be used by SEI to develop Orbital Laboratory, Internet-based multi-media software. The product will allow students and educators to compare ground plant experiments with space plant experiments, study microgravity effects on plant growth and to create an environment for students to design, conduct, and analyze the space experiment on Earth. WCSAR will provide the engineering and the scientific expertise for securing a successful plant growth experiment in space, whereas SEI will develop, market, and service the Orbital Laboratory. This will be the ninth space shuttle mission on which WCSAR has flown, but will be the first to test a new larger chamber designed for fully automated growth of plants, from seed to seed, aboard the International Space Station.

This first test will examine the growth and development of the plant *Arabidopsis thaliana*, a plant in the mustard family that is important to science because of its short growing cycle and relatively small genome. By comparing the space station plants with their own earth-bound plantings, Stankovic says the students will be adding important control information to the experiment. Most of the participating classrooms already have their *Arabidopsis* plantings under way in hydroponic growth chambers. WCSAR has been involved in the development of environmentally controlled technologies for space and terrestrial applications for more than a decade, and has accumulated a great deal of knowledge, experience, and know-how in this field.

"Thanks to the NASA Space Product Development and Utilization Division, WCSAR was financially able to develop the Advanced Astroculture and provide the flight opportunity to Space Explorers, Inc.," says Weijia Zhou, director of WCSAR. "This mission will not only test the functionality and robustness of the engineering technologies that WCSAR developed, but also will provide valuable information for us to refine and develop new technologies for future space-based plant biotech research platform."

For more information about the project or participating school, contact Stankovic, (608) 265-8427, bstankovic@facstaff.wisc.edu.

RESEARCHERS STUDY MUSCLE CELL DAMAGE THAT OCCURS WHEN ASTRONAUTS RETURN FROM SPACE
Medical College of Georgia release

18 April 2001

Astronauts returning from a bout of weightlessness experience painful tearing of muscle cells when they set foot on earth. But much like a punctured tire is patched, muscles cells literally ripped apart by use after even a week of disuse appear to patch themselves in a matter of seconds, according to researchers at the Medical College of Georgia.

"Nature has retained the economy of the patch," said Dr. Paul L. McNeil, cell biologist. "In nature, cells repair surface tears much like a mechanic used to repair a flat, by applying a membrane patch to the torn spot."

Dr. McNeil first identified this patching process in some of life's simplest forms: sea urchin eggs and fibroblasts. Now, with funding from the National Aeronautics and Space Administration, he's determining if the process holds up in more complex life forms.

"In space, none of the major muscle groups, the legs, hips and back, are loaded under gravity," Dr. McNeil said. "You can move yourself from one end of the spaceship to the other by just pushing on something with your little finger."

But soft muscle tissue adapts to its environment; rather than increasing in number, these cells increase in size in response to mechanical load.

"You remove load from the muscle and it shrinks," Dr. McNeil said. "That's an unfortunate fact of life. None of us is going to look like Arnold Schwartznegger unless we exercise like him."

Weightless life in space is more akin to time spent as a couch potato. When astronauts return and reload muscles—particularly with activities, such as walking down stairs or down a hill, that simultaneously stretch and contract muscles, the result is microscopic tears in the membrane of the muscle cells. Dr. McNeil suspects that the muscle soreness athletes experience is probably a consequence of this tearing; that tearing triggers an inflammatory response directly responsible for the pain. Excessive cell tearing also is a factor in the progressive, debilitating disease Duchenne's muscular dystrophy, he said.

"The cells lose their all-important external boundaries," Dr. McNeil said.

The result is that calcium—present outside these cells at concentrations 10,000 times higher than intracellular levels—rushes in to promote healing or wreak destruction.

"It's a paradox," Dr. McNeil said. Inside muscle cells, the normal, low levels of calcium signal muscle contraction. In studies first done in sea urchins and fibroblasts, Dr. McNeil documented that when extracellular calcium rushes in through a tear in the cell membrane, it can either help form the cell-saving patch or destroy the cell, possibly by prompting the cell to contract to death.

"In a sea urchin egg, you can rip off 1,000 square microns of surface, the equivalent of one-third of the surface of the egg and, within seconds, no more calcium is coming in," Dr. McNeil said. "There is complete restoration of the surface covering of the egg within seconds. The egg can then be fertilized and go on to divide; so afterward, it's healthy," he said of research findings first published in *Journal of Cell Biology* and *Journal of Cell Science*; a review article is scheduled for the May issue of *Nature Cell Biology*.

The cell-saving patch results from a fusion of vesicles, little spherical structures that normally nourish the cell, and the initial onslaught of external calcium. "The calcium that rushes in through the membrane disruption causes small vesicles or membranes inside the cells, to fuse with each other, making a bigger membrane structure that is a patch," Dr. McNeil said. "The patch then fuses with the cell surface."

But if that patch doesn't form, calcium continues to rush in, rapidly becoming the villain by killing off some of the finite number of muscle cells. "If you inhibit this (patching) process, within less than a minute, the cell will be dead," Dr. McNeil said.

With the three-year, nearly $900,000 grant from NASA, Dr. McNeil is using a laser to simulate in a mouse model the tearing that occurs when an astronaut reacquaints with gravity, then documenting the repair process.

"If we can understand at the molecular level how this resealing occurs, we might be able to promote it and, in the case of astronauts or trauma victims or other people with massive muscle damage, we might be able to facilitate the repair or healing process," Dr. McNeil said.

Images supporting this release are available at http://www.mcg.edu/news/2001NewsRel/mcneil.html.

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FABRICATION BEGINS ON MARS DESERT RESEARCH STATION
Mars Society release

19 April 2001

Fabrication has begun on the Mars Desert Research Station, the second of the Mars operations simulation stations that the Mars Society is building around the world. The first unit in this program, the Flashline Mars Arctic Research Station, a simulated Mars exploration base, was built during the summer of 2000 on Devon Island in Nunavut, Canada, and will go into operation in the high Arctic during the summer of 2001. The Mars Desert Research Station (MDRS) will be deployed in a Mars analog desert environment in the American southwest this September, and will support field operations during the fall, winter, and spring. Together, the two stations will act as laboratories supporting a year-round program for learning how to live and work on Mars, offering researchers the opportunity to conduct systematic studies of the strategies, technologies, human factors and hardware designs necessary to prepare for the human exploration of Mars.

The Mars Desert Research Station is being fabricated for the Mars Society by Built on Integrity (BOI), of Boulder City Nevada. Founded by Scott Fisher, of the Fisher Space Pen company, a longtime supporter of space exploration in general and the Mars society in particular, BOI has developed a proprietary construction technology combining a steel frame, foam core, and elastomeric skin to produce an ultra lightweight structure with extremely effective insulation properties. The MDRS will use this technology to produce a station that is the same size as the fiberglass honeycomb Flashline Station, but which weighs less than half as much. The Mars society intends to take advantage of the lightweight nature of the MDRS to make it mobile, moving it to support exploration at several different desert locations in the course of its operating lifetime.

Engineering support for the design of the MDRS is being provided by the University of Nevada in Las Vegas. Currently, fabrication is advancing rapidly, and a rollout of the structure is planned for May 3 in Las Vegas. Details of the time and place of the rollout will be posted on the Mars society web site at www.marssociety.org. Photographs of the panels of the Mars Desert Research Station in fabrication can be viewed on the BOI web site at www.spaceconstruction.com.

A Mars Society volunteer task force has been formed to examine promising locations for MDRS operations in the American southwest. Scouting trips have already been conducted in Texas, Utah, Nevada, Arizona, and California. A downselect to determine the initial station site is expected before summer.

An in depth discussion of plans for operation of the Mars Desert Research Station will occur at the Fourth International Mars Society Convention, which will be held at Stanford University, August 23-26, 2001. See www.marssociety.org for details.

SPRING RECCONAISANCE EXPEDITION RETURNS FROM FLASHLINE ARCTIC STATION
Mars Society release

19 April 2001

A Mars Society spring reconnaissance expedition to Devon Island to assess the condition and effect improvements in the Flashline Mars Arctic Research Station has just returned. Led by Project Scientist Pascal Lee and Project Manager Frank Schubert, the team landed on snow-covered Devon in Twin Otter aircraft equipped with skis for landing gear, and found the station to be in excellent shape after being left alone for an Arctic winter. They then stayed on the island for seven days, installing airlocks, and new electrical and plumbing systems in the hab in preparation for this summer's field season.

Both Lee and Schubert kept journals of the trip. In the introduction to his journal, Lee writes:

"The April, 2001 early deployment to the Mars Society's Flashline Mars Arctic Research Station has just been completed. Six of us, Frank Schubert, Matt Smola, Leonard Smola, Greg Mungus, Joe Amarualik and I spent a week on Devon Island configuring the interior of the habitat in preparation of the upcoming summer field season. It was a week of relatively intense work and an interesting experience for us all. For this one week we were the only inhabitants of Devon Island, otherwise the largest uninhabited island on our planet. The FMARS was both our home and our work place, our base and our lifeboat. The exterior environment, while not as lethal as that on Mars, was in many ways more hostile than that prevailing in the summer. The outside temperature oscillated between -27°C and -35°C, and the Arctic ozone hole was at a maximum as is the case at this time every year. The stay gave us all a flavor of some of the great experiences to come, when crews will be spending increasing amounts of time in isolation in the FMARS, living and working as if they were on Mars. Properly managing our power resources and supplies, and using adequate clothing for all outdoor activities was critical to our survival. Luckily, winds remained close to calm throughout our stay, a true blessing given all the materials and equipment we had to move from the runway (a snow strip) to the habitat 0.5 mile away."

Describing the arrival of the crew at the station, Schubert writes; "The landscape just fades into the sky here. Still the white hab sticks out. We circle several times, then the pilot does a couple of touch and go passes. I felt pretty safe. Temperature at Devon International Airstrip is -50 with the wind chill. We land on skis and unload the snowmobile. Then we head for the hab. The doors to the hab are frozen shut. I bang on the door and a ton of snow falls on my head. Inside the hab, temp is about -30. The condensation of my breath makes it hard to see. Pascal, Greg and Joe arrive shortly after we get the door open. The heaters are fighting a losing battle downstairs, so we move all heat upstairs and decide to go for it and stay the night. IT IS COLD."

Photographs from the trip and the complete expedition journals of both Schubert and Lee are posted on the Mars Society web site at www.marsociety.org.

HAKYLUYT PRIZE CONTEST OPEN FOR 2001
Mars Society release

19 April 2001

Students, there is still time to enter the Hakluyt prize contest! This year, as always, the Mars Society is conducting a contest for the best student letter to world leaders advocating a humans to Mars program. The letters should be no more than 500 words long, and will be judged on the basis of both the quality of the letter and the number of world leaders to whom it was sent. Students 22 years old and younger are eligible. The winner will receive an all expenses paid trip to the Mars Society Convention at Stanford, California, and a fine Bushnell telescope. Winners in past years have included Adrian Hon, 15, of Liverpool, England; Katie Harris, 17, of Georgetown, Ontario; and Felix Dance, 16, of Brisbane, Australia.

Entries should be sent to Mars Society headquarters by no later than May 31, 2001. Letters, including the list of leaders to whom they were delivered, may be sent by email to info@marssociety.org or via post to Hakluyt Prize, Mars Society, Box 273, Indian Hills, CO, 80454.

The Hakluyt prize is named after Richard Hakluyt, the tireless pamphleteer whose writings convinced Queen Elizabeth I and the circle around her to take the policy decisions that made possible the British settlement of North America. If Mars is to be settled, future Hakluyts will be needed. Perhaps one of them could be you. For further information see our web site at www.marssociety.org or contact info@marssociety.org

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RED PLANET SCOUTS: SEEKING UNEXPECTED DISCOVERIES ON MARS
By Leonard David
From *Space.com*

20 April 2001

Mars needs spacecraft! That's the call from NASA as it seeks to populate the Red Planet with a new class of robot explorer—the Mars Scout. These probes are envisioned as being able to reconnoiter Mars via any number of ways—from orbit, the planet's surface and subsurface, as well as by floating or flying at low altitude over Martian terrain. NASA has kicked off the Mars Scout effort, with the agency on the lookout for innovative ways to investigate Martian biological, chemical and physical phenomena and processes. The first Mars Scout mission could take flight in the late 2006 to mid 2007 time frame.

Get the full story at
http://www.space.com/missionlaunches/missions/scouting_mars_010419.html.

THE AUSTRALIAN MARS EXPLORATION CONFERENCE
Mars Society Australia release
http://www.marssociety.org.au/amec/index.shtml

21 April 2001

Introduction

The Mars Society Australia presents the first annual Australian Mars Exploration Conference (AMEC) in Melbourne on the weekend of 12th & 13th May, 2001 as part of National Science Week. The program includes a range of speakers on the Saturday, with a conference banquet in the evening and a program of workshops on Mars Society technical projects on the Sunday including a question and answer session (by telephone) with Dr Robert Zubrin, author of *The Case for Mars*.

When: 8.30 AM Saturday May 12th, 2001.
Where: The Earth Sciences Building, University of Melbourne.

Registration

Registration for the Saturday conference and banquet is *essential*. Download a registration form at http://www.marssociety.org.au/amec/RegistrationForm.html and send it in to the address shown to secure your seat. Registration for a limited number of delegates only may be available on the day.

The program

The Saturday program will feature presentations on topics ranging from Martian geology, robotic exploration and the search for life to the lessons of Antarctica for Mars exploration. Speakers include leading experts on Mars exploration and related science:

(1) Prof. Malcolm Walter of Macquarie University, author of *The Search for Life on Mars*,
(2) Dr. Nick Hoffman of Latrobe University,
(3) Dr. Philippa Uwins of The University of Queensland,
(4) Mr. Gerard de Valence of The University of Technology, Sydney,
(5) Prof. Ray Jarvis, Monash University,
(6) Dr. John Webb of La Trobe University,
(7) Mr. Jason Hoogland of The University of Queensland.

This will be followed by a three-course conference banquet to be held on campus beginning at 7:30 PM.

The Sunday program will consist of a series of workshops focussing on the Mars Society Australia's technical program. There will be a question and answer session with Dr Robert

Zubrin, author of *The Case for Mars* and founder of Pioneer Astronautics (by telephone hookup). Further details to be announced.

Media information

Contact Dr. Nick Hoffman (AMEC media liaisons), phone: 0438 397 366, fax: 03 9479 1272.
Conference inquiries may be directed to enquiries@marssociety.org.au.

NEW ADDITIONS TO THE ASTROBIOLOGY INDEX
By David J. Thomas
http://www.lyon.edu/webdata/users/dthomas/astrobiology/astrobiology.html

23 April 2001

Articles about astrobiology, exobiology and terraformation
http://www.lyon.edu/webdata/users/dthomas/astrobiology/online_articles1.html

L. David, 2001. Red planet scouts: seeking unexpected discoveries on Mars. *Space.com*.

Articles about the biology of extreme environments (on Earth)
http://www.lyon.edu/webdata/users/dthomas/astrobiology/online_articles2.html

P. L. Barry, 2001. Life as we didn't know it. *NASA Science News*.

J. Copley, 1998. Going for a spin. *New Scientist*.

S. Simpson, 1999. Life's first scalding steps. *Science News*.

Articles about human space exploration and the microgravity environment
http://www.lyon.edu/webdata/users/dthomas/astrobiology/online_articles3.html

P. L. Barry, 2001. Leafy green astronauts. *NASA Science News*.

Articles about the search for extraterrestrial intelligence (SETI)
http://www.lyon.edu/webdata/users/dthomas/astrobiology/online_articles4.html

E. DeVore, 2001. SETI: searching for giant planets on astronomy day. *Space.com.*

CASSINI WEEKLY SIGNIFICANT EVENTS
JPL release

5-11 April 2001

The most recent spacecraft telemetry was acquired from the Goldstone tracking station on Wednesday, April 11. The Cassini spacecraft is in an excellent state of health and is operating normally. The speed of the spacecraft can be viewed on the "Present Position" web page http://www.jpl.nasa.gov/cassini/english/where/.

Recent spacecraft activities included a Reaction Wheel Assembly (RWA) unload and a High Water Mark clear. The Imaging Science Subsystem (ISS) observations continued this week. Additional Instrument activities included a Magnetospheric Imaging Instrument (MIMI) Ion and Neutral Camera (INCA) Positive Collimator high voltage test, Flight Software (FSW) checkout for the Composite Infrared Spectrometer (CIRS), conclusion of the Radio and Plasma Wave Science (RPWS) Periodic Instrument Maintenance, and an RPWS HFR calibration. The Cosmic Dust Analyzer (CDA) performed a checkout of their existing Version 7.2 FSW then powered off. Later in the week Version 8 FSW was uplinked with checkout to be scheduled for a later date.

The Radio Science Subsystem (RSS) Operations Interface Test/Mission Verification Test (OIT/MVT) was performed this week in preparation for the Gravitational Wave Experiment (GWE). A comprehensive series of tests spanning three days was executed. The main objectives were three-fold:
1) Consistently lock the KaT to the Ka-band uplink.
2) Stay locked to the Ka-band uplink.
3) Characterize the phase stability of the locked KaT.

The first day of testing saw the KaT locking on several occasions. In a unique event, with the regular X-band uplink also operating, Cassini became the first spacecraft ever to handle dual uplinks from a single DSN station. RSS personnel also observed the longest stable uplink to the KaT since the original checkout over a year ago. The nominal plan for day two of the test included sending real-time commands to cycle the power to the KaT for each uplink attempt. The "normal" wait time between power OFF/power ON cycles has been 30 minutes. One opportunity was used to cut that time to 5 minutes. The result was that the KaT reset itself and came up in the expected frequency region. On the final day of testing, eleven different Ka-band uplinks were transmitted, with the KaT power cycled between each uplink. The KaT was seen to lock ten out of eleven times. With the test now concluded, the RSS team and the Italian Space Agency (ASI) will analyze the compiled data. Further testing is scheduled for next week.

RADAR's results from the January measurements of Jupiter's synchrotron radiation were recently presented at two conferences in Europe, the European Geophysical Society meeting and the International Workshop on Planetary Radio Emissions V. These data were the first ever obtained of the Jupiter synchrotron emission in the 2 cm wavelength range. This wavelength is unattainable from Earth-based telescopes. Cassini's radiometer data, which were able to tie down the previously unexplored upper limit, are being combined with new data acquired simultaneously in the 20 cm and 90-cm wavelength ranges by ground-based partners in this experiment (the DSN, the Very Large Array, and the Goldstone-Apple Valley Radio Telescopes). These combined data sets are being used to create new maps of the Jovian energetic particle distribution within Jupiter's radiation belts. Instrument Operations and the Multi Mission Image Processing Laboratory processed and delivered 702 Imaging Science Subsystem (ISS) Wide-Angle Camera (WAC) asteroid dustband images this week.

The Spacecraft Operations Office (SCO), Cassini Program Manager and Project Scientist supported the fourth Huygens Recovery Task Force (HRTF) meeting held at the Alcatel facility in Cannes, France. This was the first joint meeting with the Huygens Science Working Team participating. The purpose of the meeting was to review the HRTF work done so far and to select the recovery scenarios that will be subjected to a detailed study in the next months. The HRTF has established a very good understanding of the receiver performance as a function of the three main parameters: signal-to-noise ratio, received frequency, and data bit transition probability. Additional technical work that must be done has been identified to allow a complete evaluation of the respective values of the recovery scenarios.

A team of FSW and spacecraft experts from SCO reviewed the Saturn Orbit Insertion (SOI) system mode test plan. This is a series of Integrated Test Lab (ITL) system mode tests that will examine the interaction of flight software fault protection with the critical SOI sequence. The plan calls for weekly tests through next fall. The team suggested a re-ordering of the test cases and made a few refinements to the tests.

A peer review of the Solid State Recorder (SSR) Management Tool requirements was held, which looked into possible scenarios for data return. Science instrument teams submitted their files for the first input port for the development of the C27 sequence.

Cassini is a cooperative project of NASA, the European Space Agency and the Italian Space Agency. The Jet Propulsion Laboratory, a division of the California Institute of Technology in Pasadena, CA, manages the Cassini mission for NASA's Office of Space Science, Washington, DC.

THIS WEEK ON GALILEO
JPL releases

16-22 April 2001

The pace of activity onboard Galileo picks up a bit this week. On Wednesday, routine maintenance is performed on the spacecraft propulsion system. On Friday, routine maintenance is performed on the tape recorder. Both of these activities are done periodically during the relatively quiet cruise portion of an orbit in order to maintain the health of the thrusters and of the tape recorder for when they are needed the most—during the intense activities of the close satellite encounters.

On Sunday, some special science instrument calibrations are performed. Because of the limits on the amount of data that Galileo can return in a given orbit, calibrations, though very important, are rarely done. The preferred data to return are the detailed science observations made during the close flybys. However, because of the intense radiation environment the spacecraft has been living in over the years, and the simple fact that the spacecraft has been in space for over 10 years, the science instruments have slowly been degrading with age. In order for the science data to accurately measure specific physical quantities (100 photons, for example), we must calibrate the instruments so that we know how they respond to a given input signal (the instrument receives 100 photons, but only reports 85 of them). Also, even in the absence of input signals (looking at black sky, for example) most instruments will report seeing some signal, mostly as a result of electrical noise in the control circuits.

The Solid State Imaging camera (SSI) will be taking pictures through different color filters of two star fields with stars of known intensity, which have been measured before by the Galileo instrument. By comparing these pictures with those taken earlier in the mission, scientists can see how the sensitivity of the camera at different wavelengths may have changed. Also, pictures taken without opening the camera shutter will determine how much noise there is in the camera's electronic circuits. The Near Infrared Mapping Spectrometer (NIMS) will be looking at dark sky, and at the star Sirius, the brightest in the sky.

This is the last time in the mission that we plan on calibrating SSI and NIMS in this way. These measurements will be stored on the spacecraft tape recorder and played back over the next month, prior to the next flyby of Callisto near the end of May. Leading up to this activity, playback of data recorded during the last flyby of Ganymede in December will continue. At this point, the data are mostly a replay of data that were lost in transit during an earlier playback attempt.

SSI will be filling gaps in an observation of Ganymede taken when that satellite was in Jupiter's shadow. These images were looking for the glow of an aurora on the satellite, which was the highest priority observation for this instrument on this orbit. Bits of other pictures to be returned are from Ganymede's polar cap boundary, and the Dardanus Sulcus region of this largest of Jupiter's moons. Also expected are pictures of a stormy area near the Great Red Spot on Jupiter itself, and of Jupiter's ring.

NIMS will be completing some mapping of Ganymede, both at a global scale, and at somewhat higher spatial resolution. An observation of Io will also be returned, keeping track of the volcanoes and hot spots on this satellite. On Jupiter itself, an observation of hot spots in the atmosphere near 7 degrees North latitude will be played back, as well as measurements taken of the North Temperate Zone and of the aurora in the south polar region of the planet.

23-29 April 2001

This week sees the continuation of the set of instrument calibrations that began on Sunday. On Monday, the Near Infrared Mapping Spectrometer (NIMS) views a calibration plate mounted on the spacecraft. Since NIMS is sensitive to thermal emissions (heat), this Radiometric Calibration Target plate is warmed to a known temperature, and the instrument measures the signal it sees. By comparing the signal from this known source with those from observations of Jupiter's atmosphere or of the surfaces of the satellites, scientists can determine the correct temperatures of those features.

The Solid State Imaging camera (SSI), which imaged Saturn on Sunday, today views its largest satellite Titan. The observations are made through three filters that are sensitive to wavelengths of light characteristic of absorption by methane gas. Since both Saturn and Titan have prominent methane atmospheres, these bodies make excellent calibration targets.

Following these activities, Galileo will be turned approximately nine degrees so that the spin axis of the spacecraft will be pointed directly at the Sun. This allows the Sun to shine directly on another calibration plate on the spacecraft, the Photometric Calibration Target. When this plate is evenly illuminated, and not shadowed by any other parts of the spacecraft, nor varying in brightness as the spacecraft spins, both NIMS and SSI can view a flat field of known, uniform intensity. This allows the instruments to determine if their sensitivities vary across their respective fields of view, or have changed since the last calibration of this type in 1997.

This is the last time in the mission that we plan on calibrating SSI and NIMS in this way. These measurements will be stored on the spacecraft tape recorder. Late Monday night playback of the data will begin, and this will continue over the next month, completing prior to the next flyby of Callisto near the end of May.

After the calibrations are complete, the spacecraft is again turned to point the communications antenna towards Earth. Then a special engineering test of the SSI electronics will be done. During the last encounter with Ganymede in December of 2000, there were several times when an intermittent problem in the instrument electronics saturated the signal received from the imaging CCD sensor. This had the same effect as shining a bright light into the camera, washing out the pictures taken. Tests have shown that turning the instrument power off and on again clears up the problem. However, when the instrument is turned off, the software that governs the camera operations must be reloaded into its computer memory. This test exercises a new technique to reload that software more quickly and using fewer commands. This technique will make it easier to restore camera operations if the problem should recur.

For more information on the Galileo spacecraft and its mission to Jupiter, please visit the Galileo home page at one of the following URL's:
http://galileo.jpl.nasa.gov
http://www.jpl.nasa.gov/galileo

ISS STATUS REPORT
NASA/JSC release

12 April 2001

The International Space Station's Expedition Two Crew spent this week loading the Progress supply craft with trash and unneeded items in preparation for its undocking next week to clear the aft

port on the Zvezda module for the relocation of the Soyuz capsule. This air traffic control activity clears the way for the arrival next week of Space Shuttle Endeavour and the STS-100 crew delivering the Canadian built station robot arm and another high tech moving van full of supplies.

Remaining fuel and oxidizer from the Progress vehicle was transferred into tanks on the Russian Zvezda module yesterday and today, and plans call for final fuel and oxidizer transfer to the Zarya module tomorrow and Friday. The Progress engines were fired earlier this week in a small reboost maneuver that verified for the first time a command link of the thrusters through the Zvezda module's computer.

The Progress is scheduled to be remotely undocked from Zvezda's aft docking port about 3:30 AM CDT Monday after which it will be deorbited to burn up harmlessly in the Earth's atmosphere. The relocation of the Soyuz spacecraft that delivered the first expedition crew to the station is planned for 7:30 AM April 18. The 35-minute procedure calls for the three crewmembers to climb aboard the Soyuz, undock from a docking port on Zarya and fly-around to the aft docking location on Zvezda. This will provide the necessary clearance for the Raffaello Multi Purpose Logistics Module's (MPLM) attachment to the Unity module's nadir port during STS-100. The resident crew of the International Space Station—Commander Yury Usachev and Flight Engineers Jim Voss and Susan Helms—is nearing the end of its first month aboard the complex, having begun its increment work on March 18.

The activation of the station's Ku-Band communication system is essentially complete and several television downlinks this week have shown the crew in its daily routine of experimenting, housekeeping and maintenance aboard the station. One of the major tasks accomplished is a complete checkout of two Robotic Work Stations, which will serve as the command and control locations for the station Remote Manipulator System, known as Canadarm2.

The high-tech robot arm and the second Italian Space Agency-built MPLM are the major cargo aboard Endeavour. The seven-person crew will fly to Florida Monday morning for the final three days of the countdown to launch. The countdown is set to begin at 5 PM CDT Monday leading toward liftoff at 1:41 PM CDT April 19. An on time launch will see Endeavour dock to the station at about 8:36 AM CDT April 21.

In and around preparations for the Progress departure, the Soyuz fly-around and upcoming shuttle arrival, the Expedition crew continues to conduct science investigations aboard the ISS. With the station's Ku-band television system working, experimenters are working to activate the Human Research Facility (HRF) rack in the Destiny Laboratory and are preparing for the arrival of new racks of experiments on the upcoming shuttle visit. The HRF is managed and operated by a team in the Telescience Support Center at the Johnson Space Center. All station payloads are overseen from NASA's Payloads Operations Center in Huntsville, Alabama. For details on the science investigations ongoing aboard the ISS, visit http://www.scipoc.msfc.nasa.gov.

The International Space Station continues to orbit the Earth in good shape at an altitude of 240 statute miles (386 km). The next ISS Status Report will be issued following Endeavour's mission, unless developments warrant.

MARS GLOBAL SURVEYOR STATUS REPORT
JPL release

18 April 2001

Launch / Days since Launch: November 7, 1996 / 1624 days
Start of Mapping / Days since Start of Mapping: April 1, 1999 / 748 days
Total Mapping Orbits: 9,444
Total Orbits: 11,127

Recent events

The spacecraft continues to operate nominally in performing the beta-supplement daily recording and transmission of science data. The mm128, mm129, and mm130 sequences executed successfully from 01-095 (4/05/01) through 01-104 (4/14/01). The mm131 sequence has performed well since it started on 01-105 (4/15/01). It terminates on 01-108 (4/18/01). The mm132 sequence, successfully uplinked on 01-107 (4/17/01), begins executing on 01-109 (4/19/01). MGS successfully performed twelve Radio Science Occultation Egress Scans on 01-095 (4/5/01) and 01-096 (4/6/01). They were contained in the mz085 mini-sequence. MGS has performed 65 Roll Only Targeted Observations to date.

Spacecraft health

All subsystems report nominal health.

Uplinks

There have been 30 uplinks to the spacecraft during the past two weeks, including new star catalogs and ephemeris files, instrument command loads, the background sequences cited above, a thruster accumulator reset command, and ROTO mini-sequences mz086 through mz090. Commands were uplinked to modify the Reaction Wheel Assembly fault protection software and associated scripts. The modified response will allow a quicker recovery should another reaction wheel fail.

The first of three solar array position management scripts was modified to offset the commanded solar array positions by 25 degrees. Our goal is to extend the life of the Partial Shunt Assemblies by reducing the amount of excess power generated by the solar arrays. We will update the other two scripts after verifying the expected spacecraft performance under the first script. There have been 5,258 command files radiated to the spacecraft since launch.

Upcoming events

The mm133 background sequence will be uplinked on 01-110 (4/20/01). On 01-115 (4/25/01) of that sequence, MGS will transmit high frequency spacecraft body rate data to Earth. The data will provide insight into the health of the -Y solar array hinge and the effects of solar array motion on TES data. MOC Defocus Calibration Scans will be performed by the mm134 and mm135 sequences between 01-116 (4/26/01) and 01-123 (5/02/01). Radio Science Occultation Egress Scans are scheduled for 01-132 (5/12/01) and 01-133 (5/13/01). ROTO mini-sequences mz090 and mz091 will execute this next week.

MARS ODYSSEY MISSION STATUS
JPL release

12 April 2001

Due to a favorable launch trajectory on Saturday, flight controllers for Mars Odyssey have decided that they can postpone the first maneuver to fine-tune the spacecraft's flight path. All systems on the spacecraft are in excellent health. The first trajectory correction maneuver had been scheduled for Monday, April 16, but after analyzing the current spacecraft trajectory, spacecraft

engineers have decided to wait until later in the cruise phase to perform the first maneuver. The navigation team is currently evaluating dates in late May for a potential mid-course correction.

Flight controllers will now concentrate on turning on and calibrating the science instruments. On Monday, they will send commands to Odyssey that tell the spacecraft to position itself in its cruise attitude and point both the medium and high gain antennas toward the Earth. On Tuesday, they will turn on the thermal infrared imaging system (THEMIS) and then on Thursday, THEMIS will take both a thermal infrared and a visible image of the Earth.

Odyssey is currently 1,488,556 kilometers (924,944 miles) from Earth and traveling at a speed of 3.3 kilometers per second (7,455 miles per hour) relative to the Earth. The Mars Odyssey mission is managed by the Jet Propulsion Laboratory for NASA's Office of Space Science, Washington, DC. JPL is a division of the California Institute of Technology, Pasadena, CA. The Odyssey spacecraft was built by Lockheed Martin Astronautics, Denver, CO.

STARDUST STATUS REPORT
JPL release

13 April 2001

There was one Deep Space Network (DSN) tracking pass this week and all subsystems are performing normally. The spacecraft has flight sequence SC029g active and was not impacted by the recent solar flares. Two additional Navigation Camera images were taken while the CCD and mirror motor heaters are still on. Both images verify that the camera image quality remains good; the second contamination accumulated after Earth flyby has been removed. The heaters will remain on for the foreseeable future, giving the highest probability that any contaminate within the camera might be driven out of the camera into deep space. The Cometary and Interstellar Dust Analyzer (CIDA) instrument continues to observe the interstellar dust stream with optimal spacecraft attitude when not in communications with the Earth.

A blizzard, power outage and fire alarm interrupted the flight team at Lockheed Martin Astronautics during a non-contact time with the Stardust spacecraft. Reserve power to key computers, consoles and lighting worked well; however, this event gives an opportunity to review all fall-back systems for potential improvement.

The excellent Stardust launch video taken from aboard the Delta launch vehicle was outdone by the Mars Odyssey launch, which had both forward and aft looking cameras providing video of this near-perfect launch. The Science Times section of the *New York Times* has used a drawing of the Stardust spacecraft with mission and spacecraft facts as part of the newspaper's ad campaign.

For more information on the Stardust mission—the first ever comet sample return mission—please visit the Stardust home page at http://stardust.jpl.nasa.gov.

End *Marsbugs*, Volume 8, Number 15.