The PLANETARY REPORT

Volume VIII Number 1 January/February 1988

Earth or Mars?

A Publication of
THE PLANETARY SOCIETY

The Planetary Report (ISSN 0736-3680) is published six times yearly at the editorial offices of The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106, (818) 793-5100. It is available to members of The Planetary Society. Annual dues are $20 in the US, $25 in Canada, and $30 outside the US or Canada.

Editor, CHARLENE M. ANDERSON; *Technical Editor,* JAMES D. BURKE; *Assistant Editor,* DONNA STEVENS; *Art Director,* BARBARA SMITH

In Canada, Second Class Mail Registration Number 9567

COVER: This enhanced false color mosaic of* Landsat *images covers a portion of the eastern Sahara. The Uweinat Mountain, 40 kilometers across, is the largest topographic prominence, and causes a vast spindle-shaped, sand-free zone. The mountain rises at the borders of Egypt, Libya and Sudan. Smaller features also cause a dark, sand-free zone in their lee. Similar features have been imaged by spacecraft orbiting Mars.

Photograph courtesy Farouk El-Baz

Letters to the Editor

We encourage our members to write to us on topics related to the goals of The Planetary Society: Continuing planetary exploration and the search for extraterrestrial life. Address them to: Letters to the Editor, 65 N. Catalina Avenue, Pasadena, CA 91106.

It is very disheartening to read that the leadership of our Society is lobbying Congress to kill the space station program. ("A Space Station Worth the Cost: The Planetary Society Proposal," Senate Appropriations Committee testimony of Carl Sagan, Bruce Murray and Louis Friedman, reported in the July/August *Planetary Report.*)

As the originator of the dual-keel concept and the one who first presented it to NASA in May 1985, I know why this configuration was proposed and its capabilities. The primary reason to have two widely separated vertical keels was to provide the acreage necessary to assemble large spacecraft and to house upper stages for geosynchronous, lunar and interplanetary missions. This is precisely what is needed to outfit and launch a manned Mars mission.

Life science experiments on the station will provide the understanding of long-term, microgravity impacts on human and plant physiology necessary to design manned vehicles for 400- and 1,000-day manned Mars missions. The nearly closed-loop environmental control and life support system on the space station will probe the technology issues and systems needed for either a lunar base or a manned Mars mission.

The easiest way to kill a program is to study it to death. Serious station studies have been performed several times in the last 20 years. You can never develop a design that will fully satisfy all possible station users. Waiting for a new launch system or re-examining the requirements will not result in a better design; it will just mean more delay.

We have waited too long already. I believe that the membership of The Planetary Society, despite its leadership, would like to see a permanently manned US station before the end of this century.
CARL M. CASE, *Boeing Aerospace Company, Huntsville, Alabama*

After reading Drs. Sagan, Murray and Friedman's testimony, I found myself with thoughts on their arguments concerning the goals and implementation of the US space station. True, the US should adopt Mars exploration as a primary goal of our endeavors in space. False, the currently proposed space station, even with its weak definition and disturbing lack of public commitment, is not worth the cost.

The Planetary Society leaders seem to be vocalizing an adage that a space station designed for everyone satisfies no one. Such a philosophy is indicative of the inability of the participants to compromise on a design. While this problem is not unique to the scientific community, I feel that if we, as Society members, cannot be enlightened with the wisdom of compromise, then no one else will be willing to negotiate either. Advocating a "Mars or no space station" position is preposterous.

Justifying the space station has been difficult given its $18 billion price tag. Justifying a Mars program that could cost more than $100 billion will be even more difficult. We should adopt a divide and conquer strategy of space station, lunar settlement, then Mars exploration. To make real progress, you have to make hard decisions, even if a few of us don't like those decisions.
CARLOS H. PEREZ, JR., *Houston, Texas*

Now that the Ride Report *(Leadership and America's Future in Space)* has affirmed that a Moon base should be America's next step into space, it is time for The Planetary Society's leadership to abandon its self-destructive Mars-or-nothing policy. I find it greatly disturbing that the Society's Directors have spoken out strongly and harmfully against the space station and a Moon base in the far-fetched hope of going to Mars first. The Mars-first initiative is inadequate as a goal for America's space program.
GREG URBACK, *North Hollywood, California*

Let's Reinvigorate the US Space Program

by Carl Sagan and Louis D. Friedman

The current status of the United States' space program greatly concerns all who feel that exploration of the solar system is among the most exciting and inspiring undertakings of our time. As the largest space interest group in the world, The Planetary Society has led the call for the country to set a goal that can help reinvigorate that program. Through congressional testimony, newspaper and magazine articles, and lectures, the Society's officers have suggested that the human exploration of Mars is a goal that could focus NASA's energy and imagination and pull it out of its current morass.

In the July/August *Planetary Report,* Carl Sagan, Bruce Murray and Louis Friedman, the Society's officers, presented their view of NASA's space station program. A sampling of letters from members who do not share their opinion is printed on the opposite page.

The Society's officers are delighted with this outpouring of concern for the space program, irrespective of whether members agree, disagree or just view the issues differently. The Planetary Society is a membership organization and we care about and are influenced by our members' opinions, suggestions and ideas about the future of the space program and of The Planetary Society.

We encourage our members to continue to write and to create a dialog with the Society's officers on such topics as the space station, the lunar base and the exploration of Mars. We will carefully consider your opinions and will use your ideas to help form The Planetary Society's positions. To continue the dialog, we print here an Op-Ed piece by two of our officers that appeared in the November 21, 1987 issue of the *Los Angeles Times.*

Send your letters to: Members' Dialog, The Planetary Society, 65 N. Catalina Avenue, Pasadena, CA 91106.

Has NASA lost its way? The space agency has been severely criticized by friends and foes, by insiders and outsiders, for a string of unprecedented launch disasters—but also for lack of purpose and for the absence of a coherent, readily understandable, compelling exploratory objective. Part of this criticism is misdirected.

NASA is responsible for reliable launches and for trailblazing scientific exploration. It is not in the business of setting its own goals. The nation must do that, through Congress, and especially through the President. NASA is a mission-oriented agency; tell it what to do—even ask it for the Moon and the planets—and frequently it has delivered on time and on budget.

But part of the criticism is justified. It *is* NASA's business to know what goals should drive the US space program, what steps should be taken to reach those goals, and how to get its perspective understood by the President and Congress. Its feeble response to the Paine Report of the National Commission on Space is illuminating. The report, which recommends a bold series of steps moving toward human exploration and settlement of the solar system, was requested by the President, and was submitted to him more than a year ago. He has yet to say a word about it.

Neither has NASA. Instead, the agency selected a popular astronaut and let her issue the response, as a recommendation to the agency's Administrator. This way NASA takes no stand that might offend the distracted occupants of the White House.

The astronaut, Sally Ride, and her team issued a forthright and incisive study, critical of the present condition of the US space program—and recommending a range of new initiatives for the nation consistent with the Paine Report: systematic study of Earth from space; robotic exploration of the solar system; an outpost on the Moon; and a program of Mars exploration culminating in the first landing of humans on another planet. The report cites Mars as the "ultimate objective of human exploration." We concur.

But there is a curious and revealing incongruity in the report. Despite this "ultimate objective," Dr. Ride found the Mars goal premature and claimed it would lead to a "wasteful space race" if undertaken now. How did this incongruity come about? Reading the charge to the Ride panel, we find two unusual constraints on its deliberations: Do not consider US-Soviet cooperation (or any other international cooperation) on a mission of humans to Mars; and consider only quick (so-called sprint) missions. As nearly as we can tell, these are the only two mission-particular constraints imposed on the Ride panel from above. They are precisely the opposite of what makes prudent space policy, and they straitjacket the possible recommendations.

International cooperation, especially between the two superpowers, is one of the principal justifications for a voyage of humans to Mars. Congressional resolutions have cited it as a rationale; it has been a major topic of every symposium held on Mars exploration in the last several years; it broadens the scope of available technical talent and decreases costs; and the Soviet Union appears to be amenable to the proposal. Prohibiting the Ride panel from even considering joint missions to Mars severely undercuts the reason for going. Similarly, a "quick" mission (by 2005) of humans to Mars requires an expensive and perilous leap in technology inconsistent with prudent, steady evolution of flight programs, and forces a pessimistic assessment.

Why the incongruity? Because of the constraints from above. And why the constraints? Since they make no technical sense they must be political; perhaps they are a way to scuttle joint Mars missions without taking explicit responsibility for so doing—perhaps by those fearful that cooperative work on a great exploratory endeavor will make perpetual strategic confrontation a less viable way of life for the United States and the Soviet Union. But these political constraints are likely to change as the present administration prepares to leave office.

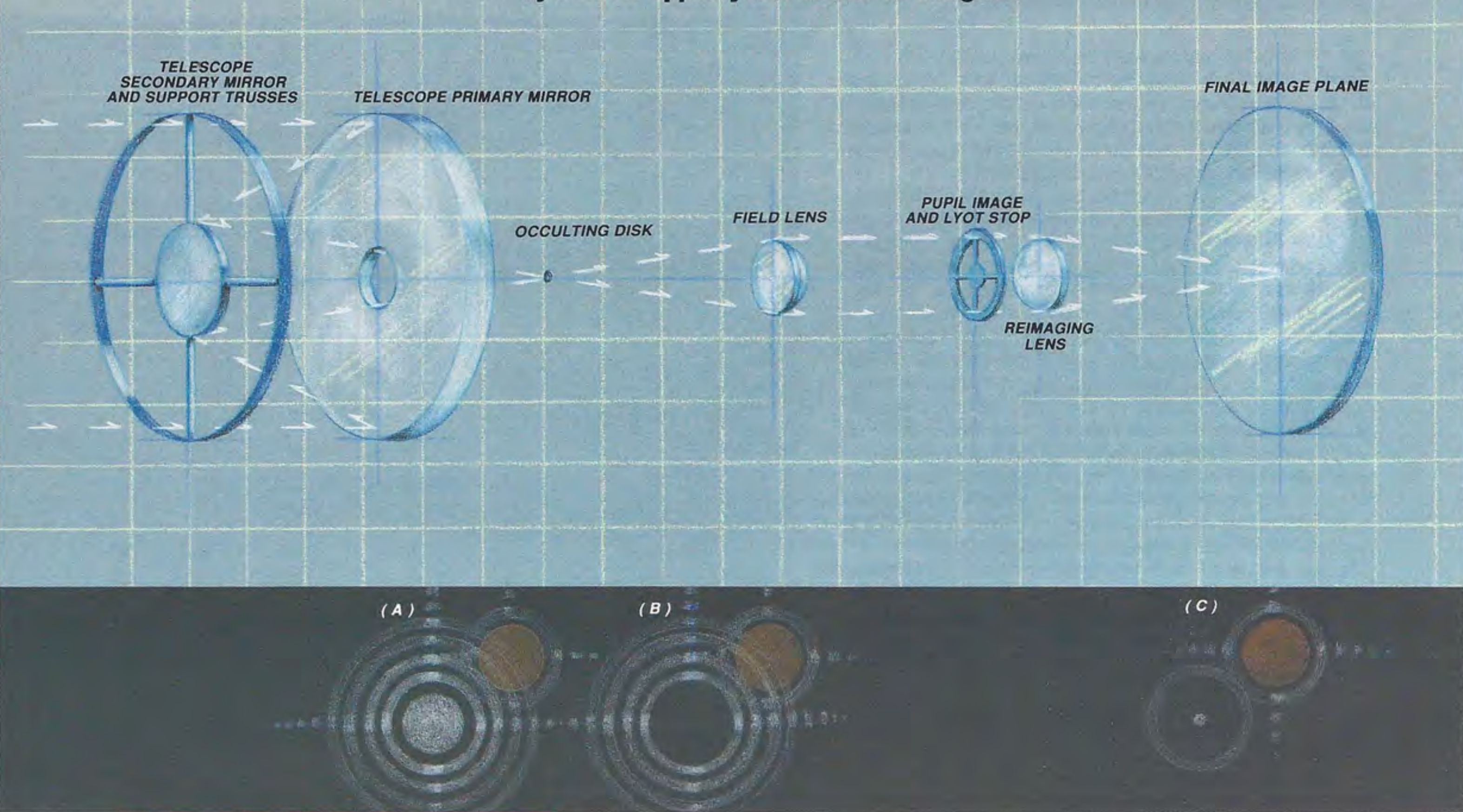
The planet Earth and the solar system exploration focus of the Ride report will serve us well.

However, the lunar outpost—neither as exciting as robotic planetary exploration nor as practical as observing Earth as a planet, and far more expensive than either—is more problematical. We've been to the Moon; it neither stimulates public imagination nor provides the impetus for international cooperation in space nearly as well as Mars does. The Ride report justifies a lunar base as a stepping stone to Mars. We're not so sure: Earth and Earth orbit are better and far easier places to test the engineering systems, and the Moon's surface (with no atmosphere and no water) is so different from Mars that science testing there is of limited relevance. But this will get sorted out as technologies and capabilities are developed by a reinvigorated NASA.

The goal of multinational exploration of Mars by humans is the best way to achieve such a reinvigoration. We agree with Dr. Ride's conclusion that human exploration of Mars should take place early in the next century, after renewal of American capabilities in robotic exploration of the solar system and long-duration human flight. NASA now seems to recognize the need for such a revival. We look forward to the time when it will be able to lift its head—and again look to the frontiers.

Detecting and Studying Extrasolar Planets

by John F. Appleby and Arthur H. Vaughan



How a coronagraph works . . .

If you look closely at a star's image formed by a typical astronomical telescope, you see that it resembles the picture at the lower left (A)—it has a very bright core, surrounded by successively fainter rings. If the telescope's aperture is partly blocked by secondary mirror support trusses as shown, the image will have bright "spikes" extending out from the core perpendicular to the shadows of the trusses. If you look carefully enough, you'll notice that these "spikes" are bright only where they cross bright rings. Both the rings and the spikes are the result of the diffraction, or bending, of light passing near an obstruction or close to the edge of the telescope's primary or secondary mirror.

A coronagraph does the trick of removing these unwanted features. First, an occulting disk in the telescope's focal plane blocks out the bright core of the star's image. What's left are the rings and the spikes—and the feeble light of a planet, if there is one, circling the star (B).

To remove the diffracted light (the rings and the spikes), we next create, with a field lens, an image of the telescope's aperture in which the diffracted light is now concentrated in bright lines along the edges that produced the diffraction. Here, in the "pupil" image, a stop is placed so as to mask off those bright edges.

When the star (and its planets) are again brought into focus, only a trace of the star's light remains, while the brightness of any nearby planet is undiminished (C).

Illustration: S.A. Smith

The discovery of an Earth-like planet orbiting another star would capture our imaginations and expand our scientific frontiers. It would also foment new speculation on the existence and nature of extraterrestrial life. We know little enough about the relationships that may exist among stars, planets and life. Once revealed, however, this knowledge will change our view of the universe. As David Black of NASA's Ames Research Center has noted in these pages (*The Planetary Report*, September/October 1984), we will never fully understand the origin and evolution of our planetary system—and of life on Earth—until our knowledge is imbued with a galactic perspective. Only then could we describe star systems in general—and our solar system in particular.

We may be on the verge of detecting large, Jupiter-like extrasolar planets. Several years ago, observers using the Infrared Astronomical Satellite (IRAS) discovered infrared radiation from extensive shells or disks of material encircling at least a dozen stars within 80 light years of Earth. Scientists later imaged one of these systems, Beta Pictoris, at visible wavelengths. When coupled with two theoretical considerations, these data become very interesting: First, star formation models suggest that planets form naturally with the collapse of a protostellar nebula (the cloud of dust and gas from which a star forms). Thus we believe that the circumstellar shells and disks could be directly related to planet formation. Second, our Sun is an ordinary star, like countless others in the galaxy. Lacking evidence to set the Sun apart in some fundamental way, it's reasonable to proceed on the assumption that planets have formed about many solar-type stars. (See Eugene Levy's article in the September/October 1984 *Planetary Report.*)

Ultimately, we want to answer several fundamental questions: Are there Earth-like planets that could support life as we know it? Is the mix of terrestrial (rocky) and jovian (gas giant) planets in our system the rule or the exception? What determines the distribution of planets around a star? How old are planetary systems? Are they always about the same age as the parent star? How are they created, and how do they evolve? What types of stars have planetary systems, and why?

The search for extraterrestrial intelligence (SETI), supported by The Planetary Society through Project META (see the July/August 1987 *Planetary Report*) would benefit from even partial answers to these questions.

Owing to technical limitations, the prospects merely for detecting extrasolar planets used to be poor. Today the outlook is far more promising. Many scientific and engineering approaches now under serious scrutiny may someday carry us far beyond the first stages of detection. Let's consider some of the basic technical issues.

In the visible spectrum (the wavelengths most strongly emitted by the Sun and Sun-like stars) planets shine by reflected light. A planet is not very bright. Earth would have a visual magnitude of 28 if seen from 33 light-years away, a distance that encompasses roughly 240 stars and provides a good "search volume." (Magnitude is a measure of stellar brightness; the higher the number the lower the brightness. With the unaided eye we can see only stars brighter than the fifth magnitude.) A single object of magnitude 28 is just barely detectable by the 200-inch Hale Telescope on Mount Palomar.

But our parent star shines enormously brighter—by about 13 billion times, and the Sun and Earth are separated by only 150 million kilometers. Using special techniques, we can distinguish astronomical sources 33 light years away separated by less than 150 million kilometers, but only if the sources are about equally bright. Even a large planet such as Jupiter is only about one-billionth as bright as its parent star. With planets close to their central star, and given the enormous brightness differences, the detection of an Earth—or even a Jupiter—becomes a major technological challenge.

When we contemplate observations at infrared wavelengths, the situation changes. At sufficiently long wavelengths, the radiation we receive from a planet is dominated, not by reflected light from its parent star, but by its own incandescence, with an infrared brightness that depends on the planet's temperature and composition. The peak radiation for Earth and for Jupiter occurs at infrared wavelengths 40 to 80 times longer, respectively, than the wavelengths of visible light, where the Sun's output is most intense. So, in the infrared, the star-to-planet brightness ratio is much more favorable. For example, at 25 microns (a wavelength about 50 times longer than that of visible light), the star-to-planet brightness ratio for an Earth would be 800,000 to 1, and only 100,000 to 1 for a Jupiter.

Our solar system contains a potentially competing source of radiation—interplanetary dust concentrated in the ecliptic (the plane defined by Earth's orbit about the Sun). This material is the source of the zodiacal light, which is simply sunlight reflected by the dust. It is visible on very dark, clear nights just before sunrise or just after sunset. Like the planets, this dust not only scatters the light of the Sun, it emits infrared radiation. For certain measurements, this weak zodiacal glow from our own system will limit the faintest objects that we can detect with an Earth-orbiting telescope.

Researchers have advanced many ideas for detecting extrasolar planets (see the September/October 1984 *Planetary Report*). Some would use imaging systems to make pictures of the planets. Jim Elliott of the Massachusetts Institute of Technology has examined how an image might be obtained using the edge of our Moon to block the central star's light. Other concepts would take measurements from which the existence of planets might be inferred. For example, consider the transit of a planet across the disk of its central star. If the planet's orbital plane happened to lie edge-on to Earth, we could detect the slight dimming of the star's brightness as the planet passed in front of it.

New instruments designed to search for extrasolar planets will have to contend with the zodiacal light, seen here as the faint band of light running from lower right to top left. (The bright, familiar band of light competing with the zodiacal light in this image is the Milky Way.) Dust concentrated in the ecliptic plane (defined by Earth's orbit about the Sun) reflects visible sunlight, which can be seen in dark, clear skies just after sunset or before sunrise. Since the zodiac is made up of constellations that lie along the line of the ecliptic, the glow from this dust is called the zodiacal light. This dust also gives off infrared radiation, and so it will interfere with instruments—even those placed in Earth orbit—that are searching for faint extrasolar objects. *Photo: Dennis DiCicco*

Another indirect approach makes use of the observable fact that a massive planet will cause its star to move in a circle in response to the planet's motion: Both the planet and the star move in orbits about their common center of mass. If our solar system were seen from stellar distances, the Sun's wobble in reaction to Jupiter would be just detectable by an instrument like the Hubble Space Telescope (HST). This objective was used to define one of the telescope's performance specifications. Using the HST's Wide Field/Planetary Camera, researchers will try to make such astrometric detections of extrasolar planets.

The perturbations in a star's motion caused by the gravitational pull of a massive planet would be detectable as a shift in frequency (doppler shift) of spectral lines due to the absorption of light by atoms in the star's atmosphere. Pierre Connes of France's Centre National de la Recherche Scientifique has devised an elegant spectrographic approach to exploit this phenomenon. His concept involves measuring changes in a star's velocity induced by planetary motions, using a laser for a frequency reference.

After a six-year observing program, Canadian astronomers Bruce Campbell, Gordon Walker and Stephenson Yang recently announced tentative detections of extrasolar planets around two (and possibly more) stars based on their ability to measure stellar velocities as small as 10 meters per second.

The most convincing demonstration on the existence of extrasolar planets would come from actual images. At the Jet Propulsion Laboratory, scientists and engineers are studying several promising techniques. To discriminate between an exceedingly faint planet and its much brighter parent star raises some problems, each calling for a special solution.

The first problem is simply the very bright central core of a star's image. If we had a large, optically perfect telescope, the image core would be very small, perhaps smaller than a planet's orbit. Still, the light from the core would be so great that it would hide any nearby fainter image. So we would have to get rid of the core image.

We can do this by introducing an opaque occulting disk into the telescope's focal plane, making it just large enough to block the image core, and leaving the rest of the field-of-view undisturbed. However, a faint halo of starlight will remain due to diffraction—the bending of light around the edges of the telescope's mirror. We can reduce these effects with a Lyot stop, named after its inventor, Bernard Lyot. This ingenious device works by blocking much of the light entering the telescope near its aperture's edge. Originally used to study our Sun's corona, a stellar coronagraph of this design (a telescope equipped with an occulting disk and a Lyot stop; see illustration) was successfully used to image the vast circumstellar dust shell around Beta Pictoris (see the November/December 1984 *Planetary Report).*

Recently, scientists working at the Perkin-

Elmer Corporation and at JPL developed mathematical tools to compute accurately the behavior of a stellar coronagraph and to optimize it for planet detection. Their work has shown that, in principle, most diffracted light from a circular aperture can be removed, although perhaps one part in a million will get through to compete with the feeble planetary images that we seek. This estimate is optimistic because it assumes that the occulting disk, the Lyot stop and any optical elements in the system are perfect.

But, as we know, nothing is perfect. For example, the surface of a telescope's main mirror will only approximate the shape the designer intended. One effect will be that some light that should have been directed into the core of the star's image (where an occulting disk would have blocked it) will instead appear as a halo of scattered light. Normally, skilled manufacturers can control residual errors well enough that the scattering is negligible compared to the diffraction, which is what we mean when we say that a certain telescope is diffraction-limited. This often requires that an optical surface not depart from the ideal by more than one-twentieth the wavelength of visible light, or around 100 times the diameter of an aluminum atom. (This factor of one-twentieth was the design specification for the primary mirror of the Hubble Space Telescope.)

However, even in a stellar coronagraph where the diffracted light is greatly reduced by a Lyot stop, starlight scattered by the telescope's imperfections would still obscure a very faint planet. Calculations show that, to reduce the effect of imperfections, the mirror must be 15 times smoother than the HST mirror. With the Perkin–Elmer Corporation, Rich Terrile of JPL is studying the building of such a telescope about 1.5 meters in diameter. It could detect the brighter planetary companions of our nearest stellar neighbors and could image circumstellar material. But to detect and characterize Earth-like planets out to 33 light years, we will need a much larger and more exotic telescope.

A JPL group headed by Dave Diner is studying several advanced telescope concepts. The team is developing a method to image both jovian and terrestrial planets out to at least 33 light years, and to make multispectral observations for determining planetary temperatures and compositions. (Of the 240 known stars within 33 light years, 58 are similar to our Sun.) Diner's team is evaluating a variety of system trade-offs. For example, to form direct images of planets at visible wavelengths, using the low-scatter-coronagraph approach, we would need a mirror about 12 meters in diameter. To place it in Earth orbit, such a large telescope would have to consist of individual segments, like the Keck Telescope being built in Hawaii, or the orbiting Large Deployable Reflector under study at JPL. Positioning the segments to the extremely high precision required to detect extrasolar planets would be a formidable challenge.

However, as we have seen, direct imaging in the infrared has some advantages. It would require an even larger segmented mirror—about 50 meters in diameter—but due to the longer wavelengths and the more favorable star/planet contrast, the positioning of the segments need not be as precise. In this case, one technical challenge concerns cooling: The optics would have to be cooled to about -190 degrees Fahrenheit throughout the observations, otherwise heat from the telescope itself would block faint planetary signals.

An alternative to a large reflector is interferometric imaging. An image of an extrasolar planetary system would be constructed by combining data from a set of paired telescopes. Each pair contributes part of the image. This technique has been used successfully to image many astronomical sources at radio wavelengths with the Very Large Array (*left*) in New Mexico. The advantage of this approach is that the total collecting area of the telescope can be smaller, thus reducing the system's mass and the area to be cooled. One concept under study is a rotating array of telescopes in which the light from each element of a given pair is combined so as to cancel the star's radiation. The quality of the result is determined, among other things, by the number of paired telescopes, the quality of the mirrors, and by how accurately each element can be pointed, stabilized and controlled. Again, detailed trade–off analyses are in progress to determine whether the merits of this approach will result in a practical design.

The technical challenges for detecting and characterizing Earth-like and Jupiter-like extrasolar planets out to 33 light years are formidable, but not insurmountable. Our recent progress suggests that we can mount a program that someday will tell us about the origin and evolution of planetary systems, their relationships to stars, and the factors governing extraterrestrial habitats in our galaxy.

John F. Appleby works in the Earth and Space Sciences Division of the Jet Propulsion Laboratory. His research interests include atmospheric modeling, remote sensing science and extrasolar planets. Arthur H. Vaughan is a Senior Scientist and Supervisor of Optical Sciences at JPL and Institute Associate in Astronomy at the California Institute of Technology.

The Very Large Array in New Mexico (above) is a group of radio telescopes that can be used simultaneously to observe an astronomical object. By carefully combining the radiation collected by each individual dish, researchers can reconstruct an image as if the entire area enclosed by the array were a single, giant aperture. This technique has many advantages for detecting and characterizing extrasolar planets.

Photograph: JPL/NASA

In this painting (right), NASA's Large Deployable Reflector, now being studied at the Jet Propulsion Laboratory, is constructed in Earth orbit. This type of telescope uses a segmented primary mirror to produce direct images of the source. This telescope is one possible approach to the problem of finding and studying extrasolar planets.

Painting: JPL/NASA

Questions & Answers

I know that ocean tides are generated by the gravitational pull of the Moon and the Sun. It's easy to visualize a tidal bulge under the Moon, but what causes the bulge on the opposite side of Earth?
—Dale S. Smith, Ashland, OR

The tidal bulge under the Moon is easy to visualize because you probably have a mental picture of the Moon pulling gravitationally on Earth itself; if it's going to raise the tidal bulge on the side of Earth facing the Moon, then it must pull harder on the water than on the Earth. Why? Distance is the key. The Moon is closer to the water in the oceans than it is to the solid Earth itself. If we ignore the fact that neither the Earth nor the Moon is perfectly spherical, we can think of the gravitational force that the Moon exerts on the entire Earth as being concentrated at the center of the planet, which is about 4,000 miles further away from the Moon than the water at its surface. So, the Moon pulls harder on the water at the surface than on Earth itself, raising a tidal bulge. Such a force, which is different at two separate points in a body and thereby can cause a distortion of the body, is known as a differential force or (sensibly enough) a tidal force.

Now the explanation of the second tidal bulge on the opposite side of Earth is fairly straightforward. Since the Moon is closer to Earth's center than to the water on the far side, it pulls harder on Earth than on the water. In effect, the Moon pulls Earth out from under the water on the far side of the planet, producing the second tidal bulge.
—ALMA C. ZOOK, *Pomona College*

Galileo* *will use a Venus-Earth-Earth gravity assist trajectory to gain the necessary speed to reach Jupiter. What is the necessary speed to reach Jupiter?
—Jeffrey S. Buch, Costa Mesa, CA

The motions of objects in orbit about the Sun are governed by Kepler's First Law of Planetary Motion: Objects orbiting the Sun travel in ellipses. When a spacecraft is launched from Earth, it becomes, in effect, a planet orbiting the Sun. Following Kepler's law, spacecraft travel on elliptical paths from point to point in the solar system. To get from Earth to Jupiter, *Galileo* must travel an ellipse whose perihelion (closest point to the Sun) is near Earth and aphelion (farthest point from the Sun) is near Jupiter.

The spacecraft's velocity at perhelion will be determined by another of Kepler's Laws: Orbiting bodies sweep out equal areas of their ellipses in equal times. For *Galileo* to reach Jupiter, its speed at perihelion (speed is magnitude of velocity; velocity is speed and direction) should be about 39 kilometers per second. Earth goes around the Sun at about 30 kilometers per second. To gain the additional 9 kilometers per second, *Galileo* will need a push from a rocket. This was to be the job of the *Centaur* upper stage that would have launched *Galileo* from the shuttle. When the *Centaur* was canceled, *Galileo* was left without a rocket powerful enough to provide that extra 9 kilometers per second. Mission analysts came up with another technique to supply the needed velocity. *Galileo* would be launched toward Venus (the required two or three kilometers per second velocity can be provided by the Inertial Upper Stage) so that when it swings by that planet, its trajectory will be bent into a more elongated ellipse—it will be given a "gravity assist" from Venus (see the March/April 1982 *Planetary Report*). That ellipse will be targeted for Earth, where the spacecraft can receive another gravity assist. *Galileo* will swing by Earth once again, and with that final push, it will have the 39 kilometer per second speed that it needs to reach Jupiter.
—WILLIAM J. O'NEIL, *Jet Propulsion Laboratory* and LOUIS D. FRIEDMAN, *The Planetary Society*

I have noticed on maps of the Moon that the side facing Earth has many more large maria and fewer craters than the "far" side. Is this a result of the forces that caused the Moon to become gravitationally locked with Earth?
—Ronald Mallory, Huntington Beach, CA

There are fewer craters on the maria because the great floods of lava that formed them occurred after the ancient bombardment that made the myriad craters on the highlands. During that bombardment, some very large impacts left what are called basins: depressions hundreds of kilometers in diameter surrounded by rings of mountains. The basins on the Moon's near side are largely filled by mare lavas, while those on the far side remain mostly empty. Whether this was a cause or an effect, during the tidal braking of the Moon into its current lock facing Earth, is unknown.
—JAMES D. BURKE, *Jet Propulsion Laboratory*

The surface pressure of Venus' atmosphere is about 90 times that of Earth, yet Venus and Earth are about the same size and mass. Did Earth once have a thicker atmosphere? Where did the excess go? Did it react chemically with the oceans?
—Robert Casey, Oradell, NJ

Earth and Venus have similar abundances of volatile (easily evaporated) elements and hence, they have the potential for similar atmospheres. In fact, if Earth had formed a few million miles closer to the Sun, its climate might now resemble that of Venus. Luckily for humans and similar life-forms, Earth is far enough away from the Sun that liquid water can form and persist on our planet's surface. As you correctly surmised, the oceans have been very important to Earth's atmospheric evolution. They have helped keep Earth's atmosphere relatively thin and its surface relatively cool by allowing the removal of atmospheric gases such as carbon dioxide (CO_2). The carbon dioxide can dissolve in the ocean, where it forms carbonate rocks such as limestone. It can then be incorporated into Earth's crust.

Carbon dioxide makes up over 95 percent of Venus' atmosphere, but only about 0.03 percent of Earth's present atmosphere. This carbon dioxide, together with a small amount of water (H_2O), gives Venus a very effective "greenhouse," leading to high surface temperatures of about 460 degrees Celsius —hot enough to melt lead.

Earth's atmosphere seems to have varied greatly over its history. One of many pieces of evidence of this variation made the news recently. Researchers discovered that an 80-million-year-old piece of amber contained air bubbles that hold 50 percent more oxygen than does our present atmosphere. If these air bubbles do indicate the state of the air 80 million years ago, then Earth's atmosphere had more oxygen, and presumably a higher overall pressure, during the Cretaceous period—the era of the dinosaurs. This discovery, along with other studies indicating a warmer, thicker atmosphere at that time, have led to the suggestion that large reptiles could fly more easily in the thicker atmosphere.

With our recently acquired ability to dump large amounts of pollution into our environment, humans have a chance to make Earth a little more like Venus. We cannot increase substantially the atmospheric pressure, but we can change the abundance of minor elements that can have major effects on climate and life. The burning of fossil fuels at its projected rate may cause the carbon dioxide abundance to double in the next century. This addition could raise Earth's average temperature a couple of degrees and so significantly affect such things as agriculture and sea level.
—JULIANNE MOSES,
California Institute of Technology

ALIEN LIFE—FORMS AN

by James

When we find "others" or they find us, and we begin exchanging snapshots, what will they look like? In a delightful reverie the human mind can range over the splendid diversity of life on Earth and can create imaginary beings that go beyond even the bizarre creatures seen in the open sea, along a coral reef, or in a good aquarium. Life's molecular architectures have enough intrinsic complexity that they can be, and are, arranged successfully by evolution into millions of different forms—even here on Earth, where fundamentally all life is one.

On another planet (or even on this one, as evolution slowly remodels animals and plants), endless further varieties of shape are possible; for example, land locomotion is here practiced with two, four, six, eight and "many" legs, but nothing now known prevents the use of three (kangaroos), five (spider monkeys) or nine. Science-fiction authors have had and have disseminated great fun with such possibilities, and even some scientists have speculated on the subject—on occasion going so far as to say that evolution anywhere would naturally lead to a bipedal creature about two meters high with a brain at the top, two ears and two eyes!

A wonderful monograph on the myriad shapes of life, with a down-to-Earth perspective and no nonsense about alien possibilities, is D'Arcy Thompson's classic, "On Growth and Form." Thompson, a natural philosopher of the old school, simply tells us what he sees. But in the process he advances irresistibly the theme that certain laws do govern plant and animal shapes.

In this article, let us consider one regime where physical law reigns absolutely; namely, the realm of fast motion through fluids. It is no accident that everything fast in the ocean, past or present, looks like a fish. Engineers know why: There is but one certain family of shapes, permitted by fluid mechanics, that gives minimum drag, hence lowest energy consumption, for a given speed. In water at animal speeds, and in air at speeds up to those of most airliners, these shapes are distinctly fishlike; rounded in front, tapered at the rear, and a few times as long as they are wide, with fair, "streamlined" curvatures all along their length. (Microorganisms, whose world is dominated by the viscosity, or stickiness, of water, have a different drag problem, but even there a form of streamlining can be observed.)

Thus, any animal whose competitive success is aided by fast movement underwater tends to be shaped by evolution into a streamlined form. On Earth (see illustration) this has happened again and again. A half billion years ago, creatures appeared that began the long and as yet unending story of the shark. A hundred and fifty million years later, the first bony fish entered the fossil record; their descendants today are the swift, elegant tuna, swordfish and other teleost predators of the sea. Meanwhile, life began its ascent onto the land. By the end of another hundred and fifty million years some air-breathing dinosaurs had returned to the sea. Of these, one family, the icthyosaurs, resumed the classic streamlined shape, while others with less need for speed made more modest adjustments.

In the wonderfully plastic habit of life, this whole cycle was repeated by the mammals and even, with limitations, by birds. Whales, dolphins, seals, otters and penguins all display the same adaptation forced by hydrodynamic law.

Then came the thinker and builder, man. For the first time in all the long ages, the adaptation began to be extrasomatic. Instead of streamlining their own gawky bodies, which would have entailed the atrophy of other useful functions, humans invented boats. But wait: A boat is pointy at the bow and broad near the stern, very unlike a fish. This is because it travels on the water surface, where wave drag and other considerations such as stability and dryness dominate over classical underwater hydrodynamics. To an engineer, the problem of shape for a surface ship, a sailing yacht or a speedboat is immensely more complicated than that for a submarine. Fast submarines do look like sharks, fish, icthyosaurs and whales and, as do these animals, they perform superbly when

D FUNCTIONS IN FLUIDS

D. Burke

deeply submerged. The long history of seagoing vessels in some ways parallels the Darwinian evolution of life. Better-adapted forms have gradually made earlier ones extinct, while a few "living fossils" hang on in parts of the world where they can survive, either because they can compete or because they are loved.

What does all this suggest to us about the life forms of another planet? Wherever there is an ocean with creatures in it, if speed confers an evolutionary advantage, any fast-moving inhabitants of the deep will have the shapes of fish. If the ocean is not water, but some other liquid with different density and viscosity, these alien fish may display different combinations of size and speed. Their shapes may differ slightly from those of fish on Earth, but the governing physical laws will still have forced them into the universal mold. (The Victorian physicist, Osborne Reynolds, elucidated the relevant similarities; in his honor, hydrodynamicists refer to the Reynolds number as a descriptor of differing flow regimes.) This tendency of beings with different ancestry to assume similar shapes is called convergent evolution; in the endless shuffling of life's possibilities it is a trend counter to the divergent evolution that causes animals and plants to radiate out and occupy every possible niche.

If we expect to find fish, whales, possibly even brain-built submarines in some far-distant ocean, it is natural to speculate on the subject of dirigibles. Again, science-fiction writers have led the way, imagining great shimmering argosies of soft, sentient beings cruising in alien atmospheres. Indeed, no physical law forbids the existence of such creatures, and with the aid of Reynolds and other aerodynamicists we can even figure out what they should look like, given knowledge or assumptions about the atmospheres in which they might live. However, biological law may condemn such lovely creatures to oblivion. Faster-flying animals, alien birds, might eat them. Otherwise, we have to imagine the blimp-beings protecting themselves as jellyfish do, which makes them rather less attractive.

Birds. Just as in the case of fish, but with complications due to landing and roosting, here evolutionary adaptation is forced by physical law. Time and again on Earth, evolution has made an ornithopter: at least two kinds of pterosaurs, endless varieties of birds and insects, and bats. Finally, evolution yielded up a brain powerful enough to imagine, analyze, design, build and fly the airplane. No known law of nature prevents all this from happening elsewhere, but aerodynamic laws do govern bird and airplane shapes. Therefore, if heavier-than-air flying creatures or artifacts are discovered in other atmospheres, we may find them startlingly familiar.

What about natural analogs of human inventions such as the screw propeller, the planing hull, the jet engine? Well, some bacteria have corkscrew tails driven by electric motors, various animals make use of hydrodynamic lift at the water surface, and squids and octopi employ pulsed jet propulsion. But there is not, and apparently never has been on Earth, a true animal equivalent of the wheel or of the jet boat as used for towing water skiers. Perhaps Darwinian evolution has no use for such energy–guzzling frivolities...but who is to assert this as a universal fact? On the surface of some strange lake or ocean, maybe nature, red (or some locally more fashionable color) in tooth and claw, has yielded up, for flight or for pursuit, the planing hull—a frightening prospect to be sure, but if such things do exist and we ever come to know them, we will see at once how their function follows from their form.

As we continue to seek the origins of the phenomenon we call life, we marvel at the results, past and present, of opposing divergence and convergence as Earth's age-old stochastic game goes on. Imagine the richness that would be added by the discovery, anywhere, of another game in progress! Or even of one that ended long ago . . . .

James D. Burke, our Technical Editor, is a member of the technical staff at JPL. These same ideas have been elegantly woven into the texture of Arthur C. Clarke's new book, "2061: Odyssey Three."

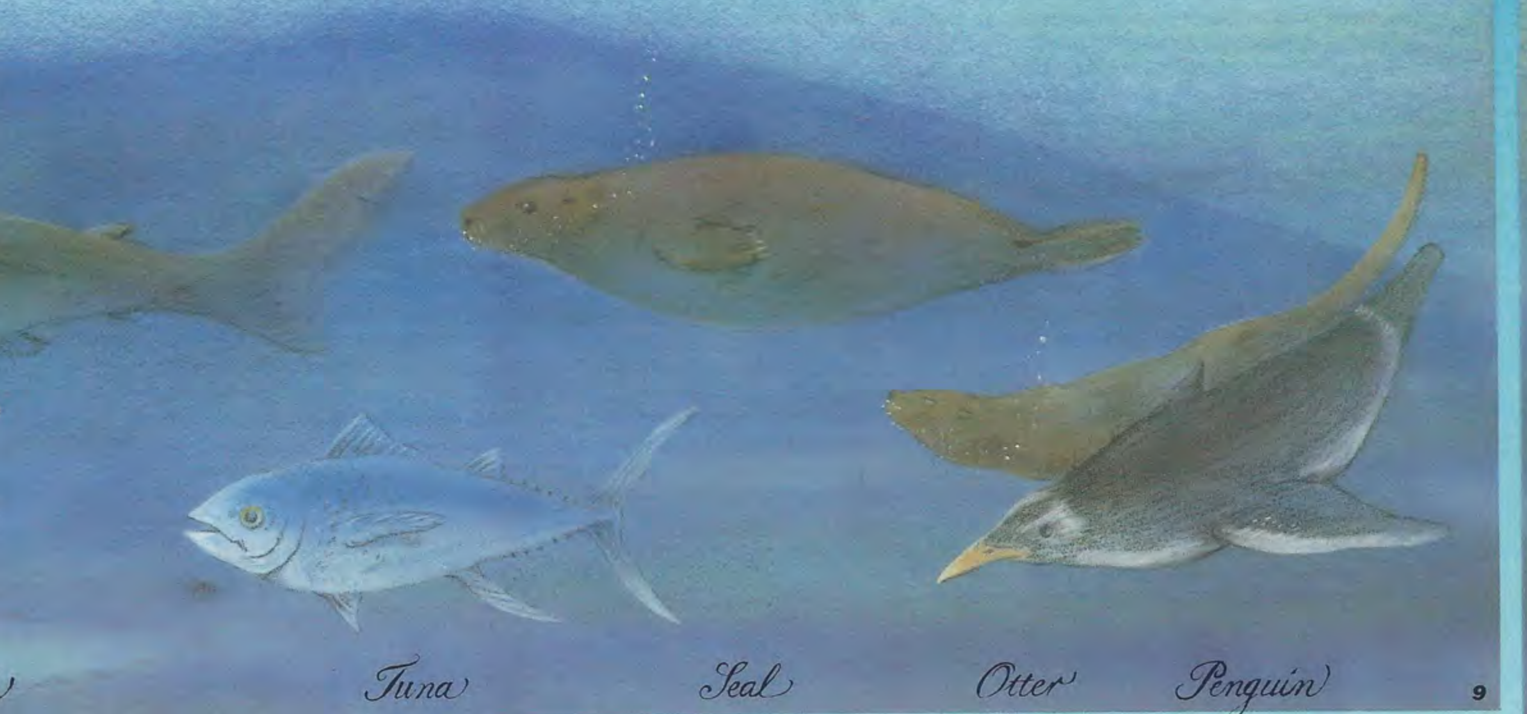


ILLUSTRATION: S. A. SMITH

Is It Earth... or Is It Mars?

by Farouk El-Baz

Our eyes were fixed on the display screens at NASA's Jet Propulsion Laboratory, while we anxiously awaited the first photographs of the planet Mars. The excitement quickly disappeared with the arrival of the first images, because they showed nothing! Details of the martian surface remained veiled as image after blank image was transmitted by the *Mariner 9* spacecraft in its approach to the Red Planet. For nearly two months, an intense global dust storm raged in the atmosphere of Mars and shrouded its surface. Only the highest volcanic peaks would peer through the dust to be revealed by the vidicon cameras aboard the automated probe.

Then, as *Mariner 9* became the first spacecraft to orbit another planet on November 13, 1971, the dust settled and unveiled a desert-like surface. Dunes littered the surface of Mars, particularly in polar regions. They occured in groups forming dune fields or as individual, crescent-shaped or barchanic forms. Thus, the similarities between the wind-blown features of Earth and Mars were first revealed. Five years later, two *Viking* orbiters would bring surface features of Mars into sharper focus. Then, on July 20, 1976, the first of the two *Viking* landers arrived on the martian surface, seven years to the day after the *Apollo 11* astronauts first set foot on the Moon. On arrival at Chryse Planitia, the "Golden Plain," the lander transmitted amazingly clear and sharp views of the martian surface. Several experiments searched for traces of life or organic molecules, with negative results. Images from both orbiters and landers confirmed the *Mariner 9* conclusion that the heretofore ambiguous seasonal color changes on Mars are not due to biological but rather to meteorological causes.

Photogeologic interpretations by numerous investigators confirmed two basic characteristics of the surface of Mars: 1) It appears to have hosted surface water in its past, and in some cases valleys were formed by fluvial erosion; and 2) under today's climatic conditions, wind is the major agent of erosion, transportation and deposition of particulate materials.

These two characteristics can also describe the hyper-arid deserts of Earth. The shuttle imaging radar has revealed the now sand-buried courses of great rivers that once carried much water in the eastern Sahara. Archaeologic and geologic evidence nearby in the Western Desert of Egypt supports the presence of much surface water during several wet episodes in the geologic past. Today, however, the area is bone-dry, where the sunlight falling on the sands is capable of evaporating 200 times the amount of rainfall. As on Mars, only the wind reigns.

Dunes are only one of the many features that are common to the deserts of Earth and Mars. Other analogies were confirmed by field checking. For example, in the eastern Sahara, there is a group of mountains, with the largest called Uweinat. There are spindle-shaped dark zones behind these topographic prominences. The mountains occupy the upwind part of the dark areas and the spindle shapes are bordered by light-colored material on either side.

The field checks allowed the comparison of analogs of features in this desert to those on the surface of Mars. In the case of Hagar El-Garda, (**Figure 1, left**) like the Uweinat Mountains it has a spindle-shaped sand-free zone in its lee. Sand forms the light-colored pattern on either side. In the lee of the hill, where there is no sand, the exposed ground is dark.

Figure 1, right, is an almost identical situation on Mars. In the same way, the wind distributes the particulate material on either side of topographic impediments, in this case, two craters. The dark areas in the lee represent the original surface and are surrounded by light-colored dusty deposits.

Another case is illustrated in **Figure 2**, where on the left is part of the desert southeast of the Uweinat Mountain. As the wind moves across the knobby terrain, it leaves sand-free lanes behind individual knobs and a streaked pattern develops. On the right is an area in the Cerberus region of Mars, which displays the same kind of pattern.

A further illustraton of similarities is shown in **Figure 3**. In photographs of Mars, mixtures of rock sizes were believed to be the result of catastrophic events such as a flood or meteorite impact. However, in the Western Desert of Egypt we find similar mixtures that result from the natural decomposition of rocks in the hyper-arid environment.

A fourth example of similarities between the Western Desert of Egypt and the surface of Mars is even more instructive. When vesicles (small pits in the rocks) were first revealed by the *Viking* lander cameras, geologists immediately thought of vesicular basalt. This is a type of volcanic rock that occurs in many places on Earth, including the vast tracts of the northwestern United States. It is also among the rocks that were returned from the Moon by the *Apollo* astronauts. It is vesicular because, as the lava extrudes to the surface and very quickly chills, its gases have no time to escape and so get trapped in pockets. Thus, the rock acquires a spongy appearance.

A similar rock fabric that has nothing to do with volcanic activity occurs in the Western Desert of Egypt (**Figure 4**). Its pits were formed by persistent wind erosion. Thus, the rocks on Mars did not have to be volcanic, but could be any type of rock pitted by the wind.

These comparisons between the features of the hyper-arid Western Desert of Egypt and parts of the surface of Mars suggest that aeolian processes such as wind erosion and deposition act similarly on the surfaces of both planets. This is but one illustration of the many uses of comparative planetology to better understand the environment of Earth.

Farouk El-Baz is Director of the Boston University Center for Remote Sensing.

Figure 1

Spindle-shaped, sand-free zones 27 kilometers long in the lee of a hill in eastern Libya (left) and a similar 115-kilometer long zone in the lee of a crater in the Cerberus region of Mars (right).

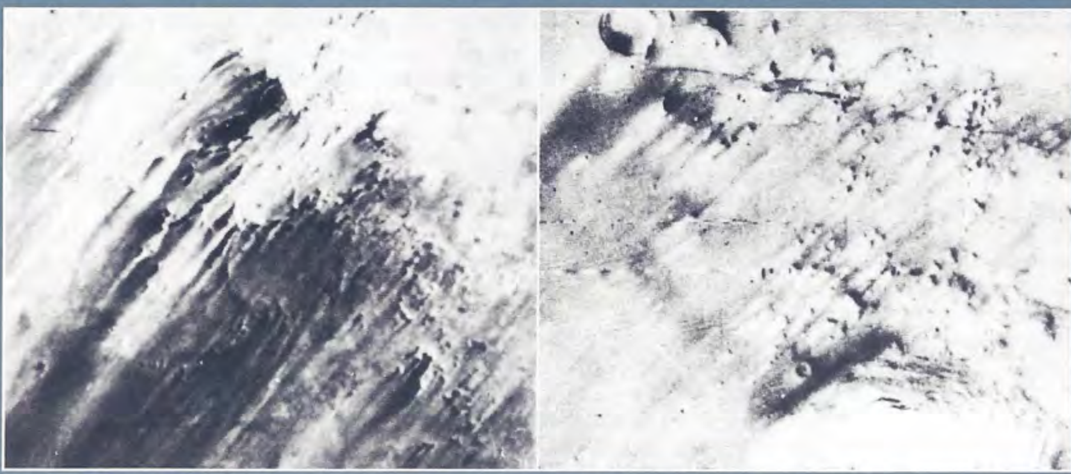


Figure 2

Dark-colored streaks, the largest 15 kilometers wide, in the lee of knobs in north-western Sudan (left), and in a similarly rugged terrain on Mars. The crater in upper left is 20 kilometers in diameter (right).

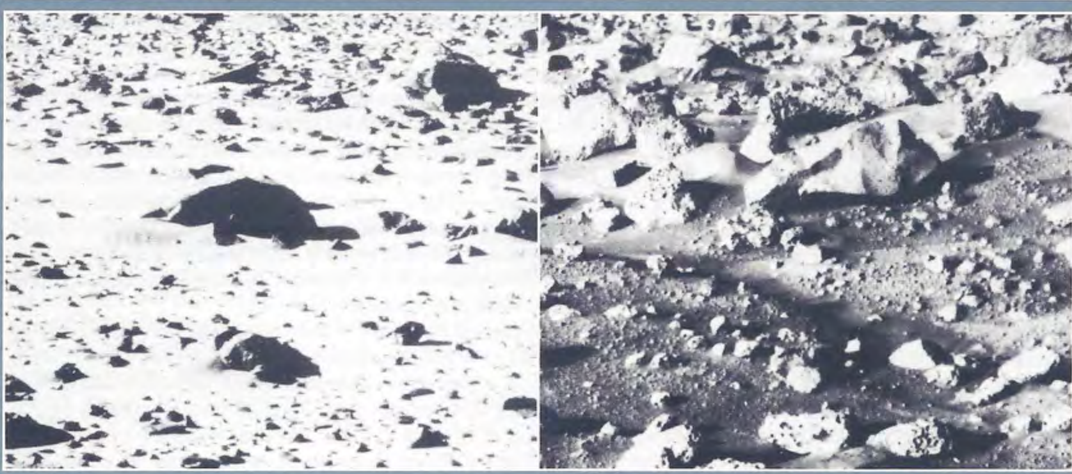


Figure 3

A mixture of angular blocks of varying sizes on the desert surface in southwestern Egypt (left) and in the Viking 2 landing site on Mars (right). The largest block in both cases is about one meter across.

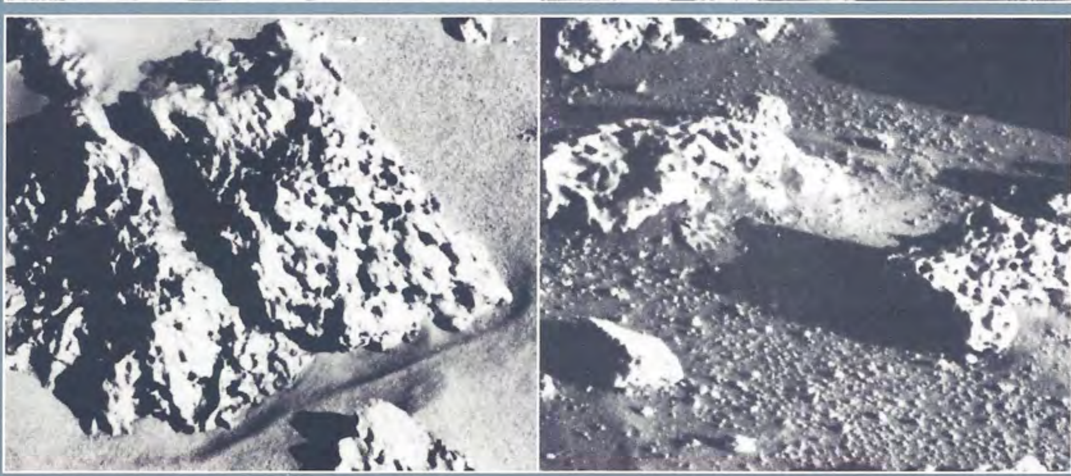


Figure 4

Wind-pitted quartzite in the Gilf Kebir region in the Western Desert of Egypt (left) and vesicular rocks from the Viking 2 landing site. The largest blocks are about 30 centimeters across.

PHOTOS:
Courtesy Farouk El-Baz

News & Reviews

by Clark R. Chapman

I believe that the most profound discovery of planetary science during the Space Age has been our recognition that interplanetary space is a shooting gallery and that we, on Earth, are the targets, just like the other planets. Since *Sputnik* turned serious scientific attention toward space, it has been proven that the Moon's craters were created by collisions with comets and asteroids. We have recognized hundreds of impact craters on our own planet. And we have found that the solid surfaces of every body in the solar system (except those subject to extremely active geological processes that erase even recent geological formations) are covered with impact craters. Finally, we have realized that comets and asteroids, and their unseen smaller cousins, the meteorites, are bombarding us all the time; they may have caused extinctions of species and threaten catastrophe in the future. One single scientist is responsible for most of this new perception of our planet and our solar system: Eugene M. Shoemaker.

A particularly delightful article about Gene Shoemaker appeared in the October 26th issue of *The New Yorker*, excerpted from a new book of essays, *First Light* by Richard Preston, on the general theme of the Mount Palomar Observatory. Shoemaker thinks of himself chiefly as a geologist, but he will do practically anything to pursue his passion of learning about the cratering process. In this essay, Preston finds Gene Shoemaker playing the role of astronomer, shivering in a mountain-top observatory, taking photographic plates of distant asteroids.

As a young man wanting to travel to the Moon, while it was still the stuff of science fiction, Gene Shoemaker was attracted to the crater south of Winslow, Arizona; he proved that it was truly due to an asteroidal impact. Nowadays it is difficult to imagine that Meteor Crater's origin was ever in dispute—you can still pick up meteorites scattered on its slopes—but that just exemplifies the changed *gestalt* for which Gene Shoemaker is largely responsible. He later led the research about lunar craters photographed by *Rangers* and *Surveyors*, and about craters imaged on outer-planet satellites by *Voyager*. In the early 1970s, he turned his attention to the skies, to the asteroids and comets that are responsible for the bombardment. He, his wife Carolyn, and their associates have been responsible for discovering most of the Earth-approaching asteroids known today. How they do it is chronicled in Preston's essay.

Preston writes about the origin of the asteroids, the Alvarez mass-extinction hypothesis, the Trojan asteroids out near Jupiter, and the significance of planetary cratering, all within the context of late-night conversations with the Shoemakers on Palomar Mountain. Preston has the feel of an astronomer's existence exactly right: The cold, the piercing starlight, the red glow of LED numbers on the instrument panel, and the disorienting rotation of the dome following the stars. The significance of Gene Shoemaker's scientific research comes through strongly.

The Soviets in Space

Sputnik began a continuing effort in the Soviet Union to become the leading spacefaring nation. While the United States embarked on its manic-depressive approach to space (landing a man on the Moon only to abandon the whole *Apollo* program), the Soviets have kept a steady pace. Little is known in the United States about the impressive scientific and technical achievements of the USSR. In 1987, for example, while the US was grounded, cosmonauts accumulated more than 7,500 hours in space, chiefly in the *Mir* space station. After years of frustrations, Soviet scientists now have a string of successful planetary missions to point to, and are about to embark on a series of impressive future missions that make the United States' modest *Mariner Mark II* and Planetary Observer missions seem relatively mundane.

For years, lack of knowledge in the West of the Soviet space program was due to Russian secrecy. But for several years now, they have been nearly as open as the Americans, announcing launches in advance, broadcasting them live, and finally reporting some of the tragedies that occurred in earlier years. The continuing ignorance in America about the Soviet space program is now due mostly to lack of coverage in the American news media. A recent, highly readable summary of the present state of "glasnosting space" is Peter Pesavento's article in the October issue of *Technology Review*, published by the Massachusetts Institute of Technology.

Where Do We Go From Here?

NASA, of course, has been mired in inactivity. Apart from the obvious problems of getting the shuttle working again, there has been little movement toward adopting long-range goals and beginning to take concrete steps to meet them. Around the time of the *Challenger* disaster, the National Commission on Space attempted to set a future agenda for NASA, but nothing much was done about it. More recently, Sally Ride was commissioned to outline some bold new initiatives; she issued her report in the late summer before leaving the space agency. This time NASA has taken at least a few small steps towards trying to implement her recommendations. The real proof of serious intentions, however, will be in the President's budget, to be released about the time you are reading this. A first test will be whether or not the Comet Rendezvous Asteroid Flyby (CRAF) mission is in the budget, which it must be if it is to meet the time schedule of Sally Ride's recommendations.

For a quick overview of the Ride Report, see the January 1988 issue of *Astronomy* magazine. The report is excerpted, including summaries of the four major initiatives: Mission to planet Earth, exploration of the solar system, outpost on the Moon, and humans to Mars. The Ride Report is a bit ambiguous about whether these are to be regarded as competing alternatives or as a unified program. I believe that America's response to the challenge of space requires all four initiatives to be undertaken: It is inconceivable that we should not augment our nearly moribund planetary exploration program, and we must also apply similar techniques to studying our own planet. These are the least costly of the initiatives, and they need to be started *now*. The lunar outpost, which makes use of the space station, is a natural (if not essential) precursor to a piloted mission to Mars, as are the Mars missions within the solar system exploration option. Since I believe that we must embark on all four approaches to our future in space, I am a bit disappointed in the divisive questions posed in *Astronomy*'s readers' poll.

Clark R. Chapman is a founding member of The Planetary Society.

World Watch

by Louis D. Friedman

WASHINGTON—"For want of a horse...." In the United States' space program, the horse is a launch vehicle. With some six months before space shuttle flights are said to resume, the United States is poised to reclaim its role in the exploration of space. The first launch since the *Challenger* tragedy is scheduled to lift a Tracking and Data Relay (TDRS) satellite into Earth orbit in 1988. With the Hubble Space Telescope, *Magellan* (a Venus-orbiting imaging radar), *Ulysses* (the European mission to fly over the north pole of the Sun) and *Galileo* (the Jupiter orbiter and probe) all figuratively on the launch pad and ready to go, the United States is hoping that the next 18 months will rejuvenate space science. If all goes well, 1989 could be the "year of space science" that we had hoped for in 1986.

If shuttle flights resume smoothly, and NASA acquires expendable launch vehicles for its space science program, the future of space exploration will brighten. NASA's space science program has used the three-year delay productively to lay the groundwork for an exciting decade in the 1990s. The missions now scheduled include:

Mars Observer—Unfortunately delayed from 1990 to 1992, the mission is now better defined, ensuring that NASA will obtain valuable information about Mars. The *Mars Observer* will be a precursor to landing and sample return missions by robotic vehicles, and later human missions. A second spacecraft has been added as a backup. If this mission goes well, that spacecraft could be used as a *Lunar Observer.*

Comet Rendezvous Asteroid Flyby (CRAF)—This important next step following the Halley's Comet encounters will be the first rendezvous with a comet. CRAF will make detailed remote and on site measurements of a comet and its environment. This mission will be the first of the *Mariner Mark II* series, a new class of modern spacecraft that will be suitable for outer planet missions. CRAF is scheduled for a new start in fiscal year 1989. We'll know if it gets this new start after the President's budget is sent to Congress at the end of January. This would be the first planetary new start in four years.

New Observatories—The Advanced X-Ray Astronomical Facility (AXAF) will observe the universe at non-visible wavelengths, complementing the deep-space investigations of the Hubble Space Telescope. AXAF was submitted to the administration for a new start this fiscal year, and its fate will be unknown until after the President's budget is revealed.

Advanced Technology Development for the Mars Rover and Sample Return—Such an unmanned mission will probably not be launched until 1998 or 2000, but NASA has been organizing advanced development and study team efforts to prepare for this milestone mission. A well-coordinated, cooperative study at the Jet Propulsion Laboratory and NASA's Johnson Space Center has a team of NASA personnel, industry contractors and university scientists laying out the specifications and requirements.

An expendable launch vehicle plan, finally announced by NASA, now permits a greater flexibility in planetary mission planning. Since the 1970s, all launches had been restricted to the shuttle. Now backup launch vehicles and spacecraft are being prepared for *Galileo,* CRAF and other future missions so that they will not be as vulnerable to single-point failures or vagaries in launch scheduling. A *Titan 3* is being planned as backup for the Planetary Observers (a proposed series of spacecraft based on Earth-orbiting satellite designs) and a *Titan 4-Centaur* could boost the Comet Rendezvous Asteroid Flyby. Such resiliency has been sorely needed since the decision to abandon expendable launch vehicles and to rely solely on the shuttle.

Clouds on the Horizon

However, there are clouds on the horizon. Of most concern, of course, is the shuttle schedule itself. Many independent analysts still think that NASA is too optimistic in its predicted rate of launchings. *Magellan,* scheduled for April 1989, will be only the fourth launch of the revamped shuttle, and delays with the new system are to be expected. *Galileo* and *Ulysses* can hardly afford to be delayed again if their constrained launch windows (October of 1989 and 1990, respectively) cannot be met. Thanks, in part, to efforts by Planetary Society members in support of the *Mars Observer,* Congress urged NASA to make future planetary missions "dual compatible"—that is, able to fly on either the shuttle or an expendable launch vehicle. However, such dual compatibility does not come cheaply, and the *Mars Observer* remains in a precarious position since NASA is reluctant to commit resources for an expendable *Titan* rocket to launch it. The House Science and Technology Committee, under the leadership of Congressman Robert Roe (D-NJ), has been particularly active in support of the *Mars Observer.*

The Reagan administration's budget difficulties also form a dark cloud looming over the future. Some Washington observers of space policy believe that the Office of Management and Budget cares little for the US planetary program and would willingly cut it out entirely. While this is not likely, it does appear that OMB is giving it very low priority and trying to forestall any new initiatives in the 1990s.

The United States has not launched a planetary mission since *Pioneer Venus* was sent on its way in 1978. If no decisions are made now to fund new programs, then the decade of the 1990s will be just as empty. The United States will not enter the 21st century as a deep-spacefaring nation. Planetary missions require very long lead times and decisions being make in Washington today will affect planetary encounters in the next century. Whether or not any US spacecraft are launched to visit other worlds in the next decade will be known when the President submits his budget to Congress. Without a new start for CRAF and support for future exploration, such as the Mars rover and sample return mission, we can assume that there will be no American planetary encounters for a very long time.

Louis Friedman is the Executive Director of The Planetary Society.

Into the Computer Age

As you no doubt noticed, the last issue of *The Planetary Report* was a little late in getting to our members. With the November/December 1987 issue, we tried two new things: We converted to a computerized page-makeup system, and we expanded our special issues from 24 to 32 pages. We did not plan to do both things at once, but with equipment delays and the inexorable march of deadlines, we managed to prove that Murphy's Laws do control the universe.

We hope to have better luck with future issues. Once we learn its idiosyncracies, the new computer system should speed up production and help us remain on schedule.

The expanded special issues will allow us to bring our members even more features on planetary exploration and the search for extraterrestrial life. We will soon be making some format changes to make the magazine more readable, to bring you even more information, and to display more spectacular spacecraft images and illustrations inspired by our exploration of the planets.

So stick with us. While others shrink or withdraw, we expand!

SOCIETY *Notes*

DISTINGUISHED SCHOLARS JOIN SOCIETY'S ADVISORS

The Planetary Society is proud to announce the addition of two distinguished new members to the Board of Advisors: John Logsdon of George Washington University and Marvin Minsky of the Massachusetts Institute of Technology.

John Logsdon is Director of the Space Policy Institute at the University, where he is also a professor of Political Science and Public Affairs. In his letter accepting the Society's invitation, Dr. Logsdon wrote: "I am convinced that it is exploration and consequent discovery that are the most important reasons for going into space for most men and women, and I am gratified to be associated with an organization that has done so much to support the exploratory urge that defines our species."

Marvin Minsky is Donner Professor of Science in the Department of Electrical Engineering at MIT. A member of the National Academy of Sciences, Dr. Minsky is a former president of the American Association for Artificial Intelligence, Logo Computer Systems, Inc. and Thinking Machines Corporation, and founder of MIT's Artificial Intelligence Laboratory.

We welcome Drs. Logsdon and Minsky to the Board and look forward to working with them on projects promoting the Society's goals.

NEW COLLEGE SCHOLARSHIPS ANNOUNCED

The Planetary Society has announced a new scholarship program for American and Canadian university students who are Society members or the nominees of members. Five $1,000 awards will be given to students who major in engineering or science, and who plan a career in planetary science. Scholarships will be based on merit and requirements include a written essay on a relevant topic. For more information, write: The Planetary Society, Department ED, 65 N. Catalina Avenue, Pasadena, CA 91106. The deadline for completed applications is April 15, 1988.

NEW MILLENNIUM COMMITTEE SCHOLARSHIPS OFFERED

Each year the New Millennium Committee of The Planetary Society awards a total of $5,000 in scholarships to high school seniors planning careers in planetary science. (The committee was formed to provide major financial support for educational programs and research projects that will extend into the 21st century.) The amount of each award depends on the qualifications of applicants. To be eligible for this scholarship, a student must be a member of The Planetary Society or the nominee of a member. Scholarships are given on the basis of SAT or ACT scores (or the equivalent), scholastic achievement, letters of recommendation, accomplishments, and a written essay. The deadline for completed applications is April 15, 1988. For more information, write: The Planetary Society, Department ED, 65 N. Catalina Avenue, Pasadena, CA 91106.

Each year The Planetary Society also supports a National Merit Scholarship, which is administered by the National Merit Scholarship Corporation. For more information on this program, talk to your high school counselor.

"TOGETHER TO MARS?" VIDEOTAPE AVAILABLE

The Public Broadcasting System television special on The Planetary Society's historic Spacebridge meeting between American and Soviet space scientists, engineers and policy leaders is now available on videotape.

Linked by satellite during the Spacebridge, participants covered a wide range of topics related to the human exploration of Mars. (See the September/October 1987 *Planetary Report.*) Among the fascinating ideas discussed were: the Soviets' plans to continue the search for life on Mars; proposals to place navigational beacons on the martian surface; and the prospects for international cooperation on future missions to Mars.

For information on ordering the videotape, see page 15.

ENTHUSIASTIC MEMBERS SUPPORT SPACEBRIDGE

Thanks to our members' enthusiasm and generosity, we were able to raise the $84,000 that we needed to fund the Spacebridge meeting held last July in Boulder, Colorado and Moscow. We believe that this meeting, and the resulting television special—broadcast in the US, the USSR and Japan—were important steps toward the eventual cooperative human exploration of Mars.We are grateful to all who donated for making this event so successful, with special thanks to New Millennium Committee member Sam Karayusuf whose $12,000 challenge grant inspired members to contribute.

LOMBERG JOINS SOCIETY AS SENIOR CONSULTANT

Artist Jon Lomberg has recently accepted the post of Senior Consultant to The Planetary Society. Mr. Lomberg designed the Society's logo—the ship sailing out into space—and produced our slide show, "Exploring Other Worlds." A well-known space artist, Mr. Lomberg also helped create the record carried by the *Voyager* spacecraft and co-authored *Murmurs of Earth.* Mr. Lomberg has produced radio shows for the Canadian Broadcasting Corporation.

UPCOMING EVENTS

February 7—"Mars Watch '88" public symposium to be held at the University of California at **Berkeley,** co-sponsored by the Lawrence Hall of Science and The Planetary Society. The program will feature presentations by Christopher McKay of NASA/Ames Research Center and coordinator of the Society's Mars Institute; Baerbel Lucchitta of the United States Geological Survey in Tucson; and Stephen Edberg of the Jet Propulsion Laboratory and Mars Watch '88 coordinator. An educators' workshop and a volunteer network meeting will follow the symposium. San Francisco area members will receive more information in the mail.

February 11-15—The American Association for the Advancment of Science will hold its annual meeting in **Boston** at the Hynes Convention Center. The Planetary Society will have a booth in the Science and Information Exhibition. Members will be able to enter the exhibit hall for free. Details will be mailed to Boston area members.

March 26—"Exobiology and Future Mars Missions," a conference at **NASA/Ames Research Center.** A public symposium sponsored by The Planetary Society will follow this two-day scientific conference.

October 7-9—"International SETI Conference" co-sponsored by The Planetary Society and the Ontario Science Center, **Toronto.** A two-day scientific conference will be followed by a day of public sessions.

The Solar System in Pictures and Books

• Books

ORDER NUMBER	Books	PRICE (IN US DOLLARS)
108	**Beyond Spaceship Earth: Environmental Ethics and the Solar System** edited by Eugene C. Hargrove. 336 pages.	$20.00
110	**Comet** by Carl Sagan and Ann Druyan. 398 pages.	$20.00
115	**Cosmic Quest: Searching for Intelligent Life Among the Stars** by Margaret Poynter and Michael J. Kelin. 124 pages.	$ 9.00
124	**Entering Space** by Joseph P. Allen. 239 pages.	$15.00
127	**Flyby — The Interplanetary Odyssey of Voyager 2** by Joel Davis. 237 pages.	$18.00
129	**Living in Space — A Manual for Space Travellers** by Peter Smolders. 160 pages.	$13.50
130	**Mercury — The Elusive Planet** by Robert C. Strom. 197 pages.	$18.00
135	**Nemesis: The Death-Star and Other Theories of Mass Extinction** by Donald Goldsmith. 166 pages.	$14.00
137	**New Worlds: In Search of The Planets** by Heather Couper and Nigel Henbest. 144 pages **Soft Cover**	$11.50
140	**Out of the Cradle: Exploring the Frontiers Beyond Earth** by William K. Hartmann, Ron Miller and Pamela Lee. 190 pages.	$11.00
145	**Pioneering the Space Frontier** by the National Commission on Space. 211 pages.	$12.00
150	**Planetary Exploration through Year 2000: An Augmented Program.** Part two of a report by The Solar System Exploration Committee of the NASA advisory council. 239 pages.	$10.00
154	**Rings — Discoveries from Galileo to Voyager** by James Elliot and Richard Kerr. 209 pages. NEW In Soft Cover	$ 8.00
156	**Saturn** by Seymour Simon. Age 8-11. 28 pages.	$12.00
157	**Starsailing: Solar Sails and Interstellar Travel** by Louis Friedman. 146 pages. NEW	$ 9.00
158	**Space — The Next 25 Years** by Thomas R. McDonough. 237 pages.	$16.00
159	**The Case for Mars** edited by Penelope J. Boston. 314 pages.	$18.00
160	**The Case for Mars II** edited by Christopher P. McKay. 700 pages. **Soft Cover**	$26.00
165	**The Grand Tour: A Traveler's Guide to the Solar System** by Ron Miller and William K. Hartmann. 192 pages.	$10.00
175	**The Mars Project** by Senator Spark Matsunaga. 215 pages.	$15.00
178	**The Nemesis Affair** by David M. Raup. 220 pages.	$ 6.25
180	**The Planets** edited by Byron Preiss. 336 pages.	$22.00
183	**The Search for Extraterrestrial Intelligence: Listening for Life in the Cosmos** by Thomas R. McDonough. 256 pages.	$18.00
185	**The Surface of Mars** by Michael Carr. 232 pages.	$16.00
187	**To Utopia and Back — The Search for Life in the Solar System** by Norman H. Horowitz. 168 pages.	$11.00
188	**The Voyage of the Ruslan** by Joshua Stoff. Age 9-13. 103 pages.	$11.50

• Videotapes

ORDER NUMBER		Videotapes	PRICE (IN US DOLLARS)
410 411	VHS BETA	**Comet Halley** (60 min. videotape)	$15.00
420 421 422	VHS BETA PAL	**Mars, the Red Planet** (30 min. videotape)	$30.00
430 431 432	VHS BETA PAL	**The Voyager Missions to Jupiter and Saturn** (28 min. videotape)	$30.00
440 441 442	VHS BETA PAL	**Universe** (30 min. videotape)	$30.00
450 451 452	VHS BETA PAL	**Uranus — I Will See Such Things** (29 min. videotape)	$30.00
460 461 462	VHS BETA PAL	**Together to Mars** (60 min. videotape) NEW	$15.00

• Color Reproductions

ORDER NUMBER	Color Reproductions	PRICE (IN US DOLLARS)
305	**Apollo** — photograph of Earth / full disk (16"x 20" laser print)	$ 8.00
308	**Earth at Night** — 23'x 35" poster	$ 6.00
310	**Earthprint** — photograph of North America (8"x 10" laser print)	$ 4.00
315	**Earthrise** — photograph of Earth from the Moon (16"x 20" laser print)	$ 8.00
320	**Halley Encounter** — 2 pictures from Vega and Giotto missions.	$ 2.50
321	**Uranus Encounter** — 4 pictures from Uranus and its moons.	$ 4.50
322	**Jupiter** — photograph of southern hemisphere (16"x 20" laser print)	$ 8.00
323	**Mars** — landscape from Viking Orbiter (16"x 20" laser print)	$ 8.00
325	**Other Worlds** — 23"x 35" poster	$ 7.00
330	**Planetfest '81** — Saturn and the F-ring (two 23"x 35" posters)	$ 5.00
333	**Saturn** — photograph of full view (16"x 20" laser print)	$ 8.00
334	**Solar System Exploration** — 35"x 35" map with booklet	$ 9.00
335	**Voyager 1 at Saturn** — set of five posters	$16.00
336	**Solar System in Pictures** — 9 pictures	$10.00
337	**Uranus — Sunlit Crescent** — 16"x 20" laser print	$ 8.00
340	**"You Are Here"** — 23"x 29" poster	$ 5.00

• 35mm Slide Sets

ORDER NUMBER	35mm Slide Sets	PRICE (IN US DOLLARS)
205	**Chesley Bonestell's Vision of Space** (40 slides with sound cassette)	$15.00
210	**Remember Halley's Comet** (20 slides with description)	$10.00
213	**Mars** (20 slides with description)	$10.00
220	**Viking 1 & 2 at Mars** (40 slides with sound cassette)	$15.00
225	**Voyager 1 & 2 at Jupiter** (40 slides with sound cassette)	$15.00
230	**Voyager 1 Saturn Encounter** (40 slides with sound cassette)	$15.00
231	**Voyager 2 Saturn Encounter** (40 slides with sound cassette)	$15.00
235	**Voyager Mission to Uranus** (20 slides with description)	$ 7.00

• Other Items

ORDER NUMBER	Other Items	PRICE (IN US DOLLARS)
505	**An Explorer's Guide to Mars** (color map of Mars)	$ 4.00
510	**Back Issues** of *The Planetary Report* — each volume contains six issues (Vol. I-5,6; Vol. II-1,6; Vol. III-2,6; Vol. IV-2; Vol. VI-1,4; Vol. VII-4,5 have been sold out.) Specify the issues you are ordering by volume and number. **Each**	$ 2.00
515	**The Planetary Society Logo** — bookmark (6"x 2")	$ 1.00
516	**We're Saving Space for You** — bookmark (6"x 2")	$ 1.00
520	**Exploring the Universe** — 1988 calendar	$ 7.00
526	**Hugg-A-Planet-Earth** — 14" diameter pillow	$14.00
530	**"I Love Mars, That's Why I Joined The Planetary Society" T-Shirt** burnt orange. S M L XL	$ 8.00
535	**Mars Model** by Don Dixon and Rick Sternbach.	$65.00
540	**Men's T-Shirt** — white with blue logo. S M L XL	$ 9.00
541	**Women's T-Shirt** — navy with white logo. S M L XL (sizes run small)	$ 9.00
545	**Planetary Report Binder** — blue with gold lettering (2 for $16.00)	$ 9.00
550	**TPS Buttons** — blue with logo	$ 1.00

IF YOU NEED MORE ROOM, JUST ATTACH ANOTHER SHEET OF PAPER

NAME ______________________

ADDRESS ______________________

CITY, STATE, ZIP ______________________

COUNTRY ______________________

DAYTIME TELEPHONE NUMBER ( ) ______________________

☐ CHECK OR MONEY ORDER FOR $ ____________ (Sorry, no C.O.D.'s)

☐ VISA ☐ MC ☐ AM/EXP EXPIRATION DATE / ___ / ___ / ___ /

COMPLETE ACCOUNT NUMBER ______________________

SIGNATURE ______________________

ITEM NUMBER	QUAN	DESCRIPTION	PRICE EACH	PRICE TOTAL

For faster service on credit card orders:
Phone: 8 A.M. – 5 P.M. (Pacific Time)
(818) 793-5100

Sales Tax: California residents add 6%. Los Angeles County residents add an additional ½% transit tax.

Shipping and Handling: All orders add 10% (maximum $10.00) Non-US add an additional $4.00

Total Order:

Officers of The Planetary Society do not receive any proceeds from sales of books of which they are authors and contributors.

MAIL ORDER AND PAYMENT TO: ***THE PLANETARY SOCIETY, 65 N. CATALINA AVE., PASADENA, CA 91106***

"VISTA GALACTICA" is a view of a typical spiral galaxy seen from a hypothetical desert planet 20,000 light years distant. This painting was inspired by landscapes at Death Valley, California and the Painted Desert in Arizona.

Kim Poor is a professional space artist from Tucson, Arizona and is current president of the International Association of Astronomical Artists.

THE PLANETARY SOCIETY
65 North Catalina Avenue
Pasadena CA 91106

NONPROFIT ORG.
U.S. POSTAGE
PAID
LONG BEACH, CA
PERMIT NO. 786