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Cover: The violent eruption of Mount St. Helens was a deadly reminder of the power of volcanic processes on Earth. Our exploring spacecraft have revealed that volcanism is a relatively common process on the worlds we have visited thus far.
PHOTO: HARRY GLICKEN, U.S.G.S.

On Leaving JPL—A Personal Perspective
by Bruce Murray

Planetary Society Vice-President Bruce Murray, Director of the Jet Propulsion Laboratory since April, 1976, officially announced he will be leaving that post later this year.

Recently I did something special with my wife, Suzanne. We *visited* Washington, D.C.!

As a courtesy, we were permitted to enter the Smithsonian National Air and Space Museum one hour before the public opening. We had it almost entirely to ourselves. (This is the most heavily visited museum in the world, with over 10 million visitors annually.) Displayed there are *Explorer 1, Ranger, Surveyor, Mariner 2,* and my special favorite, *Mariner 10. Voyager* is now hanging there conspicuously among the proudest trophies of our nation's history. Special exhibits featured some of the pictures and other products of these JPL missions; indeed, the Air and Space Museum magnificently showcases 25 years of outstanding JPL achievements.

It was quite an emotional trip down memory lane for Suzanne and me. But, by the time we left, we had been reminded once again what a remarkable technological country we are. America has led the world first into aviation, then on to the Moon and finally to the planets. Even now, each day *Pioneers 10* and *11* and *Voyagers 1* and *2* expand humankind's reach still deeper into the outer reaches of our solar system.

The last several years have been especially hard on dreamers and visionaries like so many of us at JPL. But I strongly recommend a personal visit to the Air and Space Museum as a fine antidote to discouragement. It reminds us how this country has continually renewed itself in response to challenges both from within and from without. Those marvelous American flying machines and spacecraft in the Air and Space Museum are the bittersweet fruits of war and peace, of economic success and business collapse, and of the hopes and disappointments, and even the very lives, of tens of thousands of Americans over this past century. JPL is in very distinguished company there, and we must remind ourselves that times of high achievement are very often also times of great challenge and some despair.

Last December, we won the decisive political victory for the *Galileo* mission, for the future of the Deep Space Network, and for the *Voyager* mission continuation on to Uranus and even Neptune. The extraordinary U.S. exploration of the outer planets will continue through this decade, with JPL as its heart and brain.

But the setbacks last year were very great. Our plans and preparations for new missions to explore Venus, to observe the Sun from its polar directions, and to encounter Halley's Comet were all swept away in an unprecedented trauma of budget cutbacks that affected every civilian federal program. Thus, JPL and NASA must now rebuild an inner planets and solar-terrestrial program for the late 1980's and beyond, with new, more affordable concepts and implementation modes, such as our new Venus Mapper concept and our innovative new low-cost concept to fulfill many of the objectives of the cancelled U.S. International Solar Polar Mission spacecraft. Fortunately, Jim Beggs, the NASA Administrator, and Burt Edelson, the new head of the combined Space Sciences and Applications Office, are deeply committed to that rebuilding process. I'm sure they will support it to the limits of their ability.

When I came to JPL as Director in April, 1976, it was to be for a period of five to ten years duration, because I believe strongly in both personal and institutional evolution and renewal. Last year, I began to realize that the proper time for the transition to a new Director was approaching. Even while *Voyager 2* was triumphantly passing Saturn last August, Suzanne and I were making personal plans for some long-overdue travel. I have a good deal of writing that I am eager to get started, once I'm free of the demands of being Director. And, finally, of course, I'll be able to continue to give special attention to one of the brightest accomplishments of the last six years—The Planetary Society. □

Volcanism in the Solar System

by Michael H. Carr

Eruptions of ammonia, water and sulfur—these are now concerns of planetary volcanologists as they try to understand volcanic processes on other worlds. As exploration of the solar system progresses, we are confronted with ever more exotic forms of volcanism, and now realize that the types of volcanic activity observed on the Earth represent only a small fraction of the possible volcanic phenomena. While some volcanic features of other planets have close terrestrial counterparts, others are strikingly different and appear to have formed from materials not normally associated with volcanism here.

Much of the Earth's volcanic activity is controlled by plate tectonics. The outer, rigid rind of the Earth is divided into several large plates that move laterally across the planet's surface. Volcanic activity concentrates along plate margins. Where the plates diverge, as along mid-oceanic ridges, a fluid basalt called tholeiite erupts, creating new ocean floor between the diverging plates. Most of these eruptions take place underwater and only occasionally (as in Iceland) do they result in discrete volcanos that reach above the ocean surface.

Where plates converge, one plate is usually subducted; that is, it dips under the opposing plate. As the subducted plate descends into the hotter rocks below, it is partially melted, giving rise to magmas which work their way to the surface and form volcanos. These magmas are more viscous than those erupted at divergent plate boundaries and the resulting volcanic activity tends to be more explosive, as seen at Mount St. Helens and Krakatoa. Cones of volcanic ash and lava typically are created, and strings of these volcanos form the Circle of Fire around the Pacific Ocean. Not all terrestrial volcanos form at plate margins, however. Some, such as the shield volcanos of Hawaii, grow far from plate boundaries over "hot spots" in the underlying mantle.

We have no evidence of plate tectonics on other planets. Venus may be an exception; it does show evidence of volcanism but we do not yet know the cause. Lunar volcanism was dominated by huge floods of erupted basalt which formed the lunar maria between 3.9 and 3.2 billion years ago. The lunar lava flows are vast by terrestrial standards, many being tens of kilometers across and hundreds of kilometers long. Many flows were fed by rivers of very fluid lava which cut channels we now call sinuous rilles. The sizes of these flows and their feeder channels imply large eruption rates—several cubic kilometers per day, many times greater than that which flows from Hawaiian volcanos during typical eruptions. The only terrestrial eruptions approaching lunar volumes were the lava floods that formed the Columbia River basalts of the northwestern United States and the Deccan basalts of India.

As on the Moon, extensive lava plains stretch across Mars, cut by numerous lava flows. Broad individual flows extend for hundreds of kilometers down shallow slopes, again suggesting high rates of eruption of low-viscosity lava. But the most spectacular volcanic features on Mars are the large shield volcanos. The now familiar Olympus Mons soars 25 kilometers above the surrounding plain, encircled by an outward-facing cliff 550 kilometers in diameter and, in places, over 6 kilometers high. Actually, the volcano extends beyond the foot of the cliff, for numerous flows moved down the flank, over the cliff, then across the plains beyond. Olympus Mons closely resembles terrestrial shield volcanos such as those in Hawaii. However, most of the Martian features are 10 to 100 times larger than their earthly equivalents, possibly because of high eruption rates.

Martian volcanos can grow to such great sizes partly because the planet lacks plate tectonics. The Hawaiian shield volcanos form over a magma source, or hot spot, beneath the Pacific Plate. As the volcano grows, the plate carries it away from the hot spot, and it ultimately becomes extinct. A new volcano starts to grow over the hot spot, repeating the cycle. A chain of extinct volcanos stretches across the Pacific from Hawaii to Midway Island, enabling us to trace the activity of the Hawaiian hot spot back 70 million years. On Mars, a volcano remains over its hot spot and continues to grow as long as magma can be pumped to the sur-

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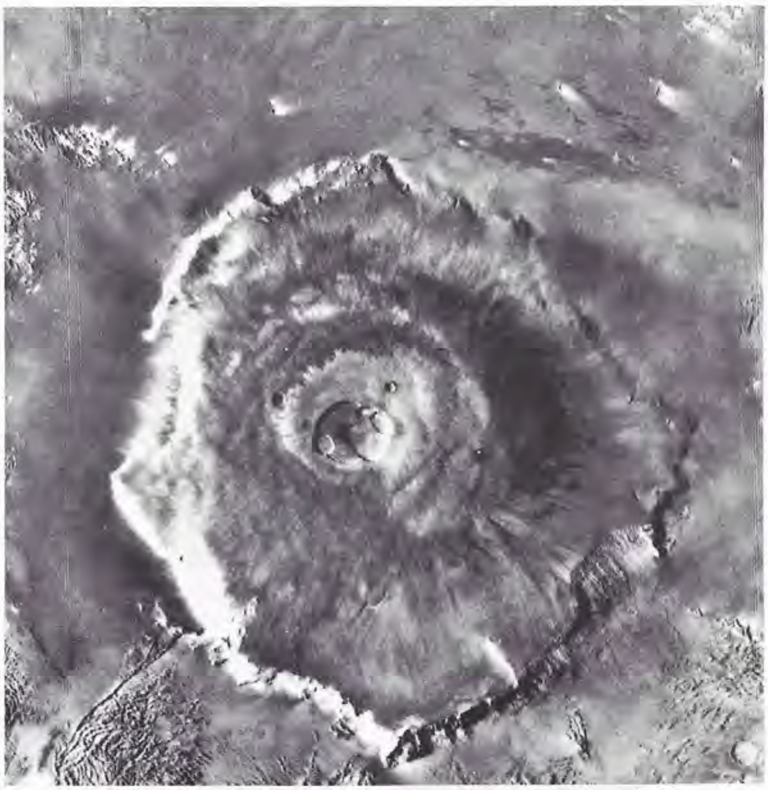

PHOTO: JPL/NASA

ABOVE: The great Martian volcano Olympus Mons stretches 550 kilometers across the planet's surface; the summit caldera lies 25 kilometers above the plain. The faint radial texture on the volcano's flanks results from lava flows.

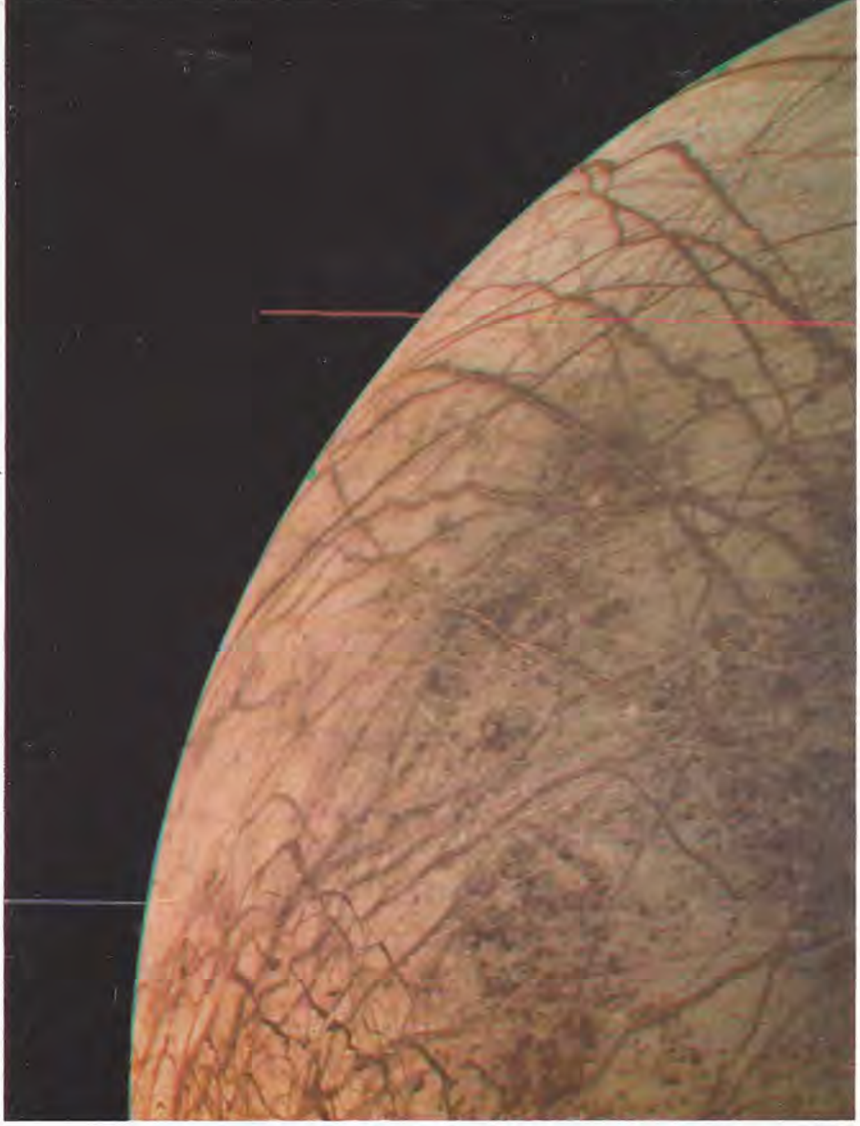

PHOTO: JPL/NASA

PHOTO: *APOLLO 15*/NASA

face. Some may remain active for a billion years, so Martian volcanos can become enormous.

Not all Martian volcanos are shields. Some, called *paterae*, are broad but have little surface relief. Alba Patera, for example, is over 1,500 kilometers across but is probably under 10 kilometers high. Large, beautifully preserved flows mark its gently sloping flanks, so it appears to be built of very fluid lava. Other Martian volcanos may be composed largely of ash. Tyrrhenna Patera is surrounded by deeply eroded, bedded deposits, whose poor preservation suggests that they are friable and easily eroded. In addition to the large volcanos, numerous small ones only a few kilometers across are scattered across the Martian surface. Thus, volcanism on Mars has been varied, forming extensive lava plains, huge shield volcanos and smaller cones, and depositing thick layers of volcanic ash.

Volcanic eruptions on the terrestrial planets are almost entirely of silica-rich melts. This volcanism is driven by heat left over from the formation of the planets and by the decay of radioactive elements such as uranium, thorium and potassium. On the Moon and Mercury, volcanism ceased early because their small bodies cooled rapidly. As we go farther out in the solar system, we encounter quite different forms of volcanism, in both the materials involved and the driving forces.

We now know that Io, the innermost of the large Jovian satellites, is the most volcanically active body in the solar system. Vast plumes of volcanic debris shoot hundreds of kilometers above the surface; calderas and flow fields are everywhere, and dark warm spots on the surface suggest lava lakes. Impact craters are totally absent, indicating that flows and plume debris rapidly resurface the satellite. The surface color, its temperature and the presence of sulfur in the neighborhood of Io all indicate that sulfur is the erupted material, in contrast to the predominantly silicate eruptions of the terrestrial planets. However, sulfur eruptions are not unknown on Earth. In rare cases, sulfur deposits, previously formed by condensation from volcanic gases, have been melted into sulfur flows which may extend for several kilometers.

We understand the cause of the intense activity on Io reasonably well; it is alternately pulled and released by the gravity of Jupiter and its accompanying satellites. These tidal forces continually flex Io's surface, heating it up and driving the volcanism. This mechanism for the volcanism on Io was predicted by Stanton Peale before the *Voyager* discovery.

Europa, the Galilean satellite second closest to Jupiter, also shows evidence of volcanism, but of a totally different type from Io's. Few impact craters pit Europa, indicating that its surface is continually reworked by tectonic and volcanic processes. Its density suggests that it is largely silicate covered with an ice-rich layer tens of kilometers thick. Criss-crossing dark lines mark its surface; many have bright central ridges, suggesting recent eruptions of water or slush, followed by rapid freezing. These eruptions appear to have been concentrated along fractures. There are no slush flows or slush volcanos, only ridges of ice over the fissures. This form of volcanism is not found on Earth, although analo-

TOP: Criss-crossing lines mark the surface of the Jovian satellite Europa. Faint bright ridges at the center of some of the dark markings may represent recent eruptions of water ice onto the satellite's surface. (The red and blue horizontal lines are artifacts of computer processing.)

BOTTOM: Meandering valleys, called sinuous rilles, wriggle for hundreds of kilometers across the surface of the Moon. In the upper right of this photograph is the great impact crater Aristarchus, which can be easily seen from Earth as a bright spot at about ten o'clock on the face of the full Moon.

gous processes may occur in pack ice. These repetitive eruptions may be due to tidal heating, although tidal effects on Europa are much smaller than on Io because of the greater distance from Jupiter.

Ganymede, the next satellite out from Europa, shows no sign of recent volcanism, although it may have been active in the distant past. An older, dark, densely-cratered region is crossed by belts of sparsely-cratered terrain with closely packed, sub-parallel ridges and valleys. Corrugated belts formed across the older dark terrain early in the satellite's history, probably over 3 billion years ago. As the heavier silicates settled into a core, the volume of the satellite changed, "wrinkling" the icy crust. This process probably drove ice eruptions analogous to those postulated for Europa, but the evidence is indirect. Fewer craters mark the corrugated regions, but we can't determine whether they were destroyed by deformational processes or were buried under erupted material. Probably both processes were involved. Callisto, the Galilean satellite most distant from Jupiter, shows no evidence of volcanism; its entire surface is saturated with impact craters.

Because most of the Saturnian satellites are small, a few hundred kilometers or less in diameter, we did not expect to find evidence of volcanism on them. Any heat from radioactive decay would dissipate rapidly and tidal effects would be negligible because of the small masses of the satellites. Most of the satellites were thought to be mainly water ice and there seemed no plausible combination of radioactivity and tidal heating that could raise temperatures to the melting point of water after the first billion years of the planet's history. The *Voyager* spacecraft surprised us by finding clear evidence of resurfacing on several of Saturn's satellites. The clearest evidence is on Enceladus, where some regions are so sparsely cratered that material must have erupted onto the surface late in the planet's history, perhaps within the last billion years. Most likely, the erupted material is not water, but something else with a considerably lower freezing point. Possibly the melts were mixtures of ammonia and water, which could melt at 173° Kelvin, 100° Kelvin lower than the melting point of water. Another possibility is a methane-water mixture. In both cases the melting points are so low that a combination of radioactivity and tidal heating could cause melting on a body as small as Enceladus, about 250 kilometers in diameter.

As we travel outward in the solar system we encounter stranger and stranger forms of volcanism. Most volcanologists would feel they were on familiar ground as they traversed the younger lava plains of Mars, although the sizes of the flow fronts and lava channels would be rather intimidating. Even the sulfur eruptions of Io and the ice-filled fissures of Europa have some remote terrestrial equivalents. But in the Saturnian system we find truly alien worlds, and our terrestrially-biased geologic intuition is of little use in attempting to understand them. Presumably we will find yet other exotic forms of volcanism when we encounter Uranus in 1986.

Michael Carr is with the Branch of Astrogeologic Studies within the United States Geological Survey. From 1970 to 1980 he was leader of the Viking *Orbiter Imaging Team.*

PHOTO: JPL/NASA

PHOTO: JPL/NASA

TOP: A volcanic plume shoots above the surface of Io, the most volcanically active body yet visited in the solar system. Scientists believe the ejected material is primarily sulfur.

BOTTOM: Scientists were surprised by the surface of Enceladus, a small Saturnian satellite. Its ancient, cratered surface has been reworked in some regions, indicating that erupted material buried some of the impact craters in the recent geologic past.

A Talk with George Keyworth

President Reagan appointed Dr. George Keyworth to be his Science Advisor and to head the Office of Science and Technology Policy (OSTP). Dr. Keyworth, a nuclear physicist, had been the Leader of the Physics Division at the Los Alamos Laboratory in New Mexico. The OSTP is currently conducting a comprehensive review of the space policy of the United States.

Early last December, the Washington Post reported that Dr. Keyworth had recommended to the President that all new planetary space missions be halted for at least the next decade. Dr. Keyworth had also indicated that he regards planetary exploration as low-priority science. Planetary scientists and advocates of exploration of the solar system were greatly upset by his opinions.

Dr. Keyworth agreed to the following interview with The Planetary Society's Executive Director, Dr. Louis Friedman, as a chance to clarify his views and the position of the Reagan administration on space exploration.

Louis Friedman: Dr. Keyworth, does solar system exploration support or benefit policies of the United States?

George Keyworth: Basically, that comes down to the question: why should we support space exploration? Let's look at what the overall space program means to this country and why we supported it with one of the largest increases in any area of the federal budget for the next fiscal year. For the American people and possibly the entire world, the space program has long been and continues to be the clearest, best-defined symbol of American technology and curiosity. One of the beauties of space exploration is that it is the part of space sciences most readily comprehensible to the American public and the rest of the world.

We have only a little laboratory here on Earth, and it's tiny compared to the size of the universe. We have the opportunity, unique in history, to explore in tremendous detail the other planets of this solar system, to understand how this particular system evolved, and from that to learn much more about fundamental science, terrestrial geology and, perhaps most importantly, about the universe in general. So, considering the universe as a gigantic, near-infinite laboratory, we now have a microscope with which we can study a small element of it in great detail. That's the way I see space exploration.

LF: Yet I've seen some quotes attributed to you that suggested that you considered this particular area as low-priority science.

GK: Planetary science is rare in that it has two values: one is the science and one is the symbol of technology. I believe we should clearly distinguish between exploration and science. I will use the analogy of the distinction between Newton and Columbus. They made different contributions, both of them enormous, but they were fundamentally different.

Planetary science, in itself, is very rich. However, I do not think that planetary science is so rich as to preclude emphasis upon astronomy, astrophysics and solar-terrestrial physics at a time when we have offered to us a capability with the shuttle that allows us to take enormous steps forward in those areas of science. Let me explain this with an example. You know I have been rather outspoken on the subject of the Space Telescope. We have an opportunity to take a step forward in astronomy that perhaps is only exceeded by the invention of Galileo's first telescope. I think it is terribly exciting. And the opportunity wouldn't be there if we didn't have the shuttle. We could not put up such a thing with an expendable launch vehicle.

I think we should build a gamma ray observatory, because of the richness of the past eight, nine, and ten years of gamma ray astronomy and what we are learning about the universe, black holes and pulsing stars. I also believe that we should maintain a rich program of planetary exploration and planetary science. I have discussed, with people like Frank Press, President of the National Academy of Sciences, Bruce Murray, Director of JPL, and others, the wisdom of trying to develop a planetary program on the *Explorer* [a series of small, near-Earth spacecraft] model that would have relatively lower-scope missions. Let me explain why. It's not just because of budgetary issues. There's another problem. When you start having missions every six, eight or ten years and you are trying to draw dynamic, vital young people into the program to keep it vital and dynamic, it's going to be very hard to do when missions are separated by a period that appears to be almost infinitely long. I contend that to a young scientist, it might as well be every fifty years. We need to get a higher frequency of missions.

LF: Would you then say that your statements that upset the planetary community were misconstrued?

GK: I made a statement at one point that I didn't see any new missions for this decade. In fact, we had *Galileo*. At that time, early last December, we were also looking carefully at VOIR [Venus Orbiting Imaging Radar] and had not made a firm decision on that. We had those two major missions for this decade spelled out; they weren't new missions.

LF: But that's a different interpretation than many placed on your quoted statements at the time.

GK: That's why I'd rather talk only through scientific journals and not to newspapers.

LF: You might now back up a little and support smaller-scale missions like the reduced Venus [radar] mapper, and maybe a lunar orbiter and Mars orbiter?

GK: Yes, but let me introduce a caveat. We cannot just go ahead and say, "Well, we had a good mission planned for a billion dollars, so we'll halve everything and make it a half-billion dollar mission." We've got to define missions that may be narrower in scope but still reap the very best science that is appropriate for the size of our space program.

When I constantly hear these fears that we are being put in a non-competitive position by the European Space Agency's *Ariane* [a booster rocket being developed for scientific and commercial launches], for example, I might remind you that NASA alone (let alone the military commitment, which could also support some pertinent developments) spends about $6½ billion a year, and the entire European combine spends about $1 billion a year. What I expect to see is science whose richness is commensurate with the enormous magnitude of that investment, and not compromised missions because we want higher frequency. We still want good missions even though they are narrower in scope.

One thing the scientific community is going to have to do now, focusing upon a reduced VOIR, is to provide surface resolution that will give better information than can be obtained using Earth-based radar.

We can't compromise to the point that we don't make major scientific advances. Quality and excellence of mission must be preserved.

LF: Space science has had a large increase in the budget this year; planetary science has not. These increases resulted from [*Galileo* and Space Telescope] decisions that were made in the late 1970's by the previous administration. How do you plan to encourage, if not giant growth, at least moderate growth and vitality in planetary sciences and exploration?

GK: It is a fact that in real dollars our present commitment to NASA is much less than it was at the peak of the *Apollo* period. I think the increase in real dollars that we have suggested to Congress for fiscal year 1983 is large with respect to the economic climate today, and it's also substantial compared to recent years. The total NASA budget, as I recollect—I don't have a perfect memory for numbers—is up by something like 12 percent and the scientific part is up about 18 percent.

LF: But planetary science is considerably decreased, especially its research base. And, although space science is up 17 percent, most of that is for the Space Telescope which is, as I said, a previous administration's commitment.

GK: No question. The support of non-planetary space science is up more than 40 percent, so I'm not trying to hide any facts. I'm trying to point out that we have put all our emphasis in this program because we believe it is rich. The scientific and engineering communities have got to look now at the richest possible missions and activities. There will be a strong correlation between the amount of funding and the quality of those programs. A commitment to a guaranteed growth rate in science is not commensurate with investing your money in excellence. You do not stimulate excellence when you make a guarantee. We want to stimulate the most creative thinking we can possibly get.

Let me raise an example. I cannot, with my emphasis upon excellence, support a major initiative at this time on the space operations center [SOC]. I have not seen a coherent package on what could be done in the space operations center. There's no question of our ability to put large modules in space. The shuttle is natural for that and that's one of the reasons that there's so much emphasis on the SOC. But we have to not only emphasize the engineering to do it, but also the science and applications. That's what I'm trying to stimulate at this time.

LF: Let me ask you about international cooperation in space exploration. There have been suggestions that the administration discourages such cooperation. Do you feel that this is a promising area to pursue?

GK: Well, I am a member of the administration. I have most enthusiastically encouraged it, and have discussed such cooperation with Hubert Curien, the director of the French space agency [Centre National d'Etudes Spatiales], as well as with people in Germany, the Japanese and the British. The U.S. is the world leader. If we rest upon that, we won't retain it. We should look to the major advances that can be made in our understanding of nature. And we can do more in cooperation with the Europeans and the Japanese, for example, than we can alone.

We have had a number of discussions about whether the United States can afford to put its entire space investment in the shuttle, or whether we should also maintain an expendable launch vehicle fleet. Well, we aren't sure what we will have to do and we aren't sure when what we will do will be appropriate. But we know this: the European community is committed to developing an extensive expendable launch vehicle capability. Some experiments are more appropriate for that; lots of others are more appropriate for the shuttle. A cooperative approach between the U.S., western Europe and Japan is going to be much more fruitful for space exploration and for the development of space and space science. We should look at it from a fully pragmatic point of view.

LF: So the administration would not put up barriers to the discussion of combined efforts to explore the asteroids, for example, and do assays of extraterrestrial resources, or to look toward future exploration of Mars with different types of vehicles?

GK: I won't be specific but I will say this: the administration is certainly not opposed to looking at international cooperation—rather, we encourage it. There may be vestiges of isolationism in this country, but I do not think there are vestiges of isolationism in this administration.

LF: There's a very strong feeling that there's a crisis in the planetary program. We have gone from dozens of missions in the last decade to the six or seven that were planned for this decade to one, *Galileo*, that is barely hanging in there. In the last year we've seen two U.S. solar system missions cancelled. We've seen a tremendous blow to planetary research that will, to save $40 million, cut back things we've already invested $14 billion in, like the Hawaii Infrared Telescope, the Lunar Curatorial Facility, the tracking of all the *Pioneers*, cuts in *Viking* and *Voyager* data analysis, and so forth. There's a real feeling of crisis.

GK: I don't have that feeling. Let's look at what has happened. The problem is not unique to planetary science, nor to space science. The problem is simple. The scientific community has had a very difficult time adapting to transition from an economy that was in very rapid growth to an economy that is near zero-growth. I read a paper some months ago, written in Europe, on how to conduct science in a zero-growth economy. It was thoughtful and particularly interesting to me in that Europeans have been thinking about this problem for some time while we Americans have not. We've built more and more expensive missions during a period of rapid growth and continued it into a period of low growth. And now we are in a state of shock, when we realize that 25–30 percent increases are very difficult to sell to Congress and to the American people.

(continued on page 14)

PANORAMAS FROM THE LATEST S

OVIET CRAFT TO LAND ON VENUS

Venera 13 (top and bottom) landed on March 1, 1982; Venera 14 (center) landed on March 5. Each lander transmitted images and other data to Earth via its flyby spacecraft bus. The temperature at the *Venera 13* landing site was 457° C, with a pressure 89 times that of Earth's atmosphere at sea level; at the *Venera 14* site the figures were 465° C, 94 atmospheres.

Each lander carried two cameras, scanning from horizon to horizon on opposite sides of the craft. The nearest portion of each picture is about a meter and a half away, and objects as small as a few millimeters across can be seen. Filters were used to permit color reconstruction from successive scans, and the color images show Venus's orange sky and brownish, apparently oxidized soil. The landing sites were selected in cooperation with American scientists, using *Pioneer* Venus mapping data. *Venera 13* landed on the flank of Phoebe Regio, an upland region; the terrain appears to be volcanic. *Venera 14* landed in the lowlands on a basaltic plain. The x ray chemical-composition data confirmed the generally volcanic nature of the surface rocks.

Dr. Valeriy Barsukov, Soviet Director of the Institute of Geochemistry and Analytical Chemistry, presented these panoramas and described other investigations carried out by the spacecraft, including sample collection, an experiment to measure surface physical properties (whose sensors are on the spring-driven, ladderlike arm which on *Venera 14* landed atop the ejected camera cover), and instruments that measured atmospheric and cloud properties during the landers' descent to the surface. The *Venera 14* panorama is a later computer-enhanced version provided to us by Dr. Roald Z. Sagdeev, Director of the Soviet Institute for Space Research. —JAMES D. BURKE

News & Reviews

by Clark R. Chapman

Groundbased astronomical telescopes have been used to study the planets since the time of Galileo. You might imagine that observing from a distance has been supplanted, since the early years of the Space Age, by the close-up examination and direct measurements possible from spacecraft. But you would be wrong. If anything, the rate of discoveries about the solar system from ground-based telescopes has *increased* as more powerful instruments and analytical techniques are used by astronomers. Ground-based observing complements spacecraft approaches; years of monitoring from the ground can help place data obtained during a brief encounter in a temporal context.

Telescopes, Voyager, and Titan

In the February, 1982, *Scientific American*, Tobias Owen describes a particularly good example of synergism between astronomers and spacecraft experimenters. Telescopic observations paved the way for *Voyager 1* to uncover some of the mysteries of one of the most significant bodies in the solar system—Titan. Larger than some planets, Titan is the dominant moon in the Saturn system. Owen describes how telescopes nearly forty years ago revealed that Titan has a substantial atmosphere with methane in it. Later, unusually warm temperatures and an astonishing layer of haze high in Titan's atmosphere were found. Yet, astronomers were confused about whether the high temperatures are at the surface or high above, within the haze. And they could not tell whether Titan's atmosphere is denser than that on Earth or more tenuous than the thin air on Mars.

This evidence for an interesting chemical environment was Titan's prime attraction for *Voyager*. A variety of spacecraft instruments analyzed the atmospheric haze and probed down to the satellite's remarkable surface. Evidently, Titan has been so cold that oxygen remains trapped in water ice deep within its body. Thus, Titan's air is unoxidized, or *reducing*, and composed mostly of nitrogen, argon, and methane.

Let's Imagine a Planet

Tobias Owen takes us on a mind's-eye boat tour atop Titan's frigid oceans of liquid methane. He notes that the hazy, dimmed sunlight might seem more like a moonlit night, even at high noon. Our boat would be propelled across a sea of abundant fuel (the methane), but its motor would require an oxidant, perhaps oxygen mined from the buried ice. On Earth, as we all know, oxygen is abundant, and fuel is expensive to acquire.

Our planetary imaginations must soar to greater heights if we are to visualize as-yet-undiscovered planets about other stars. That presented no problem for a group of writers, artists and scientists who not only dreamed up an imaginary planet, Thraxisp, but populated it with a bestiary of strange life forms—all supposedly scientifically "possible." This creative enterprise has been written up by one of the participants, planetologist William K. Hartmann, in the March, 1982, issue of *Smithsonian* magazine.

Voyager Saturn Encounters

Often it is our *real* solar system, rather than worlds of the imagination, that astounds us. As David Morrison writes in the November/December, 1981 issue of *Mercury*, "What scientist or poet or artist had ever imagined the awesome complexity of the tens of thousands of rings that we now recognize circling Saturn?" Nearly that whole issue of *Mercury* is devoted to Morrison's readable account of results from the two *Voyager* encounters with Saturn. It is based on the summary chapter in Morrison's new book, *Voyage to Saturn*, which is now available from The Planetary Society (see page 15). Beyond Titan and the wonderful rings, the *Voyagers* studied an intriguing variety of smaller moons, Saturn's symmetrical magnetic field and resulting magnetosphere, and the weather patterns of the planet's pastel-colored clouds. Morrison puts it all in perspective in twenty of *Mercury's* pages.

For readers with the greatest technical interest in *Voyager*, the January 29, 1982 issue of *Science* presents the first comprehensive series of scientific reports from last August's *Voyager 2* encounter. The cover of *Science's* February 26, 1982 issue carries a unique, first-ever portrayal of a comet colliding with the Sun. According to the accompanying technical article, the comet was discovered by a coronagraph aboard an Air Force satellite in August 1979. Within a matter of hours, the nucleus was vaporized in the Sun while the headless tail remained visible for a time.

Galileo and the Future

While the basic research efforts in planetary science remain in jeopardy pending the final action of Congress on the fiscal year 1983 budget, it now looks as if the *Galileo* project will remain alive. Since *Galileo* is all that is left of the American planetary exploration program, it is interesting to look ahead and see what it is expected to accomplish when it reaches Jupiter in 1990. In a colorfully illustrated article in the February, 1982 issue of *Astronomy*, Clayne Yeates and Theodore Clarke outline the *Galileo* mission. It includes the probe, which will penetrate the giant planet's atmosphere for the first time. After relaying data from the probe to Earth, the orbiter will take a flower-petal-like tour of the Galilean satellites. *Galileo* carries advanced instruments, which should enable us to investigate some of the most fundamental physical, chemical and geological questions posed by *Voyager*.

Clark Chapman writes about recent magazine articles and new books about space exploration for each issue of The Planetary Report. *He is Vice-Chairman of the Division for Planetary Sciences of the American Astronomical Society.*

Society Notes

by Louis Friedman

The Planetary Society receives a great deal of mail, from 100 to 1000 pieces every day. Most of it is routine—the processing of new memberships and renewals. We processed 100,000 new memberships during our first year alone, and now we are concentrating on handling our renewals—already at the very high rate of over 60 percent—and the steady stream of new members. In addition to the memberships, we deal with thousands of picture and book orders, and the many generous donations from members. Our error rate in all these transactions is between one and two percent, but even this low percentage can result in hundreds of problems per month, and we are attempting to reduce that rate by an order of magnitude.

Those members who may be experiencing difficulties—please let us know. But before you do, consider the following: do we have your present and correct address and zip code? Nearly three-quarters of all membership problems result from address changes. It is not sufficient to simply notify the Post Office about address changes because most of the Society's mail is sent at third-class rates and, even when we guarantee return postage, we do not usually learn about the address change. Third-class mail is rarely forwarded.

Although it is slower and is not forwarded, we must use third-class mail because of its low cost. Since the founding of the Society, mail rates have risen an average of 50 percent for the different types of mail we use. We have not raised dues, nor do we intend to. But we must economize with our bulk mail. Despite a measure of uncertainty and occasional delays (we have found that mail can take from one to forty days to reach members), we see no alternative to third-class mail.

If you are on the membership list correctly—as shown on your address label—then missing issues of *The Planetary Report* may have been properly sent out, but were not properly handled at their destination. Often colorful high-quality magazines get "lost in the mail." It may help to speak to your mail carrier.

If you have eliminated these two possibilities and still have a problem with your membership listing and/or mail, then write to us and include your address label, or your name, address, zip code and, if possible, membership number (the first six digits above your name). If you have changed your address since you joined, include your complete previous address and membership number or we may not be able to locate you on our membership list. Please keep mail about membership problems separate from picture or book orders.

The Society's lecture and public events program is particularly active this spring. We are holding events and lectures in Los Angeles, Chicago, Sacramento, Baltimore, New Britain, Connecticut and Vancouver, British Columbia. Local organizations are cosponsoring several of these events. Although the formats will differ, in each event we will present films, slides and lectures on the exploration of the solar system. Planetary Society members will have an opportunity to get together while we publicize the Society and recruit new members.

If you wish to help organize an event in your immediate area, contact us with your proposal for a program. The proposal should describe the location, facilities, time and, if applicable, a previously organized event we may join.

The Planetary Society is supporting a major scientific search to planets around other stars as part of its continuing policy toward the Search of Extraterrestrial Intelligence (SETI). Along with other organizations, the Society has provided funds for a project headed by Dr. George Gatewood, Director of the Allegheny Observatory of the University of Pittsburgh. These funds were provided by donations from thousands of Society members.

Dr. Gatewood's group is building a telescope that will be the most sensitive instrument capable of detecting planets outside our solar system. "Tests have shown that the precision of a one-hour observation is more accurate than the average of an entire year's photographic exposures. This will give humanity its first significant system capable of detecting extrasolar planetary systems," Dr. Gatewood said.

Much of the work building the instrument is being done by Ronald Hilliard of Optomechanics Research, Inc. in Tuscon, Arizona. The figuring of the lens will be done at the University of Arizona by Robert Parks, Richard E. Sumner and Steven Lang. Observations are expected to begin in about one year.

In other Society news, we have expanded the Board of Directors to include Mr. Henry Tanner, Assistant Treasurer of the California Institute of Technology, and Mr. Joseph Ryan of the law firm, O'Melveny & Myers. They will help direct Society management and finances. And lastly, the Society has taken its first steps to organize internationally. Dr. Sagan gave lectures on May 17 and 18 in Toronto, and we are now planning a Canadian membership drive. □

Back Issues Now Available

We have reprinted Volume I, Number 1 of *The Planetary Report* and can now offer all issues from our first year of publication. Members may obtain copies by writing: Back Issues, *The Planetary Report*, P.O. Box 3599, Pasadena, CA 91103. Please specify the issues requested by number; Number 1 covered December 1980/January 1981, and Volume I closed with Number 6 for October/November 1981. The suggested donation for back issues is $1.50 each, which will help defray printing, postage and handling costs.

NEW SOCIETY INFORMATION LINE

Planetary Society members will now be able to keep up-to-date with Society programs and other events sponsored by the space community with our new telephone information line. A recorded message detailing upcoming events can be reached 24 hours a day at (213) 793-4328 for areas east of the Mississippi and (213) 793-4294 for areas west of the Mississippi. (A five minute call at night rates costs about $1.00; at evening rates $1.60; and at day rates $2.45.) The information line is now in operation, and includes the latest information about Spaceweek, July 19–23, 1982.

Soviets Host International SETI Conference

by Jon Lomberg

An international conference of scientists has reaffirmed that SETI—the Search for Extraterrestrial Intelligence—is "an activity of great philosophical, scientific and social significance." Held in Tallinn, Estonia from December 8–11, 1981, the conference was organized by the Soviet Academy of Sciences. Two hundred participants from the Soviet Union, the United States, Bulgaria, Hungary, Poland, France and Japan met to discuss strategies and techniques of observation, and the limited searches for alien signals that have been carried out since the early 1960's.

Soviet scientists revealed plans for several new groundbased and spaceborne instruments useful for SETI research. A Japanese astronomer reported on a new, large radio telescope being built in Japan, and on the burgeoning Japanese interest in SETI. American researchers, who have recently seen all SETI funding cut from the NASA budget, discussed their reduced program and the few small projects still underway.

In 1959, physicists Philip Morrison and Giuseppe Cocconi pointed out that radio is the most reasonable way for civilizations to contact one another across the great gulfs between the stars. Radio waves travel at the speed of light, are cheaper than spaceships, can easily carry large amounts of information, and are probably generated fairly early in the lifetime of any technological civilization. Soon after developing radio, Earth's civilization announced its presence to the universe. An expanding sphere of radio waves from radio, television and radar transmitters has been traveling out from Earth for the past 30 to 40 years. These electromagnetic waves may already have been detected by astronomers on planets of other stars. Morrison and Cocconi, therefore, urged Earth's radio astronomers to listen for signals that might be traveling our way from other civilizations. Deliberate beacon signals could be broadcast by other species to attract the attention of anyone listening. These beacons, if detected, might open the door to a flood of scientific and cultural information beamed across space and time.

Dr. Frank Drake, former Director of the giant radio telescope observatory at Arecibo, Puerto Rico, and the first American scientist to actually search for extraterrestrial signals, led the U.S. delegation to the SETI conference. The delegation included Dr. Bernard Oliver and other engineers and scientists who have done SETI research or designed equipment intended to scan the vast radio spectrum for sharp, narrow-band signals—"needles in the cosmic haystack," in Dr. Drake's words.

The conference was held at a time when western SETI researchers have been struggling against political and scientific opposition. Senator William Proxmire of Wisconsin, a long-time opponent of SETI, last year attached an amendment to a Congressional appropriations bill making it illegal for NASA to sponsor SETI. NASA had been asking for about $2 million to design and build a signal-processing multichannel spectrum analyzer (MCSA). It was to have been built at Stanford University by a team led by people from NASA's Ames Research Center and the Jet Propulsion Laboratory. The device would have allowed astronomers to monitor 8 million channels at once while listening to any particular celestial object. The project will be ended unless government-supported work can be reinstated in the fiscal year 1983 budget.

Within the scientific community, a different sort of opposition to SETI has been appearing. Some scientists take the lack of evident aliens in our solar system as proof that no advanced societies have evolved elsewhere in our galaxy. They argue that if there are beings on other planets, at least some of them would have discovered efficient interstellar travel and set out to colonize the galaxy. Since we haven't observed any aliens, these scientists conclude that no other technological civilizations have evolved contemporary with ours.

These arguments have convinced as eminent a SETI proponent as I. S. Shklovskii, the Russian astrophysicist who coauthored *Intelligent Life in the Universe* with Carl Sagan. At the Tallinn conference, Shklovskii argued that intelligent life is extremely rare, if not unique to Earth. SETI supporters respond that absence of evidence is not evidence of absence, and also point out that, given the small number of limited searches to date, we are not even in a position to assert that there is absence of evidence.

The American delegates were struck by the enthusiasm with which the Soviets regard SETI. "The SETI concept has been sold at a much higher level in their government than in our government," Dr. Oliver said. The conference itself indicated that Soviet SETI is well-financed, well-respected and well-publicized. Soviet participants included some of the U.S.S.R.'s leading space scientists. Four cosmonauts attended the sessions, including three-time space veteran Vitaly Sevastyanov, who participated attentively in many of the sessions. Sevastyanov hosts a nationwide television program about science for which he conducted an extensive interview with Frank Drake.

The Soviets demonstrated that their SETI efforts have substance as well as show. In the U.S., new radio astronomy instruments, such as the Very Large Array in New Mexico, are not being used for any SETI work. In the U.S.S.R., time on some of the most advanced astronomical instruments will be allocated for SETI. N. S. Kardashev of the Space Research Institute in Moscow described a new radio telescope being constructed near the city of Samarkand. This telescope will have a steerable dish 70 meters in diameter and will be sensitive to millimeter wavelength radiation. Dr. Kardashev said that a significant portion of the new observatory's work will involve the search for alien signals.

Kardashev also described plans for a new Soviet satellite that will make observations at infrared wavelengths, which are blocked out by our atmosphere. He wants to use this satellite to search around the center of our own galaxy for evidence of the activities of very advanced civilizations, whose "astro-engineering" projects might be leaking infrared radiation. Kardashev, a prominent astrophysicist, is a spokesman for one Soviet viewpoint that SETI should concentrate on strange objects, such as quasars or the centers of galaxies, rather than upon individual stars.

V. S. Troitskii, another Soviet radio expert, outlined plans for a network of receivers capable of listening to the whole sky at once for omni-directional (as opposed to tightly-beamed) signals. G. S. Tsarevskii described a study for a huge orbital radio telescope with a dish three kilometers in diameter, which could be "infinitely expandable" by the addition of new panels to the dish. The large collecting surface would provide sensitivity 10,000 times greater than that of any existing radio telescope. The instrument could also be linked to a telescope on the ground via Very Long Baseline Interferometry, which allows two widely spaced radio telescopes to act as one. The greater the spacing of the two components, the finer the angular resolving power of the telescope. Since the space radio telescope could be placed in an orbit one million kilometers from Earth—two and one-half times more distant than the Moon—very compact radio sources could be detected and pinpointed. In addition, the great sensitivity might allow detection of natural radio emission from large, Jupiter-like planets orbiting other stars.

Japanese interest in SETI was expressed by Professor Jun Jugaku of Tokyo Observatory who described a 45 meter radio telescope, sensitive to millimeter wavelengths, nearing completion in Japan. This instrument will study the huge, dark clouds of dust, rich in organic molecules, that line the spiral arms of the Milky Way. These clouds will be observed at the 4.83 Gigahertz absorption line of formaldehyde, a molecule plentiful in such clouds. This frequency might be an ideal place to look for artificial signals since there is very little radio noise there. If any civilizations are transmitting messages at the formaldehyde frequency, they might be detected by the new telescope's survey of the Milky Way, so the Japanese are planning to do SETI in tandem with their observations.

Despite their current funding problems, the American delegates were able to contribute substantially to the conference. (Several participants received grants from The Planetary Society and the Sloan Foundation that enabled them to attend.) Dr. Paul Horowitz of Harvard University described his "suitcase SETI" instrument, funded by The Planetary Society. This small, portable multichannel receiver can monitor several thousand channels at once and could be taken to various observatories for SETI observations. Dr. George Gatewood of the Allegheny Observatory in Pittsburgh described his work with optical instruments, also partly funded by The Planetary Society, in trying to detect planetary systems around other stars. Dr. Sam Gulkis of JPL described the proposed NASA program which includes both a targeted search and all-sky survey, looking for signals in the microwave region of the radio spectrum. Dr. Robert Dixon reported on a private program of all-sky monitoring at Ohio State University.

Some of the Soviets have a very different strategy for SETI. N. S. Kardashev put it bluntly: "[The strategy of] searching for individual stars will lead nowhere and will not be followed." Kardashev believes that we cannot reasonably put any upper limits on the prowess and abilities of highly advanced civilizations and that they will go where the greatest amount of energy is available for their use. Those places would be the centers of peculiar galaxies, like Seyfert galaxies or quasars, that burn brightly far across the universe. In our own galaxy, the same logic would dictate looking at the center, where Kardashev wants to look with the planned Soviet infrared satellite and the new Samarkand radio telescope. Troitskii represents the other major line of Soviet strategy—it makes more sense to listen to the whole sky at once for pulsed or radar-like signals.

The Soviets seem prepared to commit themselves to decades of patient observation. In Dr. Tsarevskii's words, "We must search, search and search." He and his colleagues are fired by the staggering implications of a successful SETI program. Soviet leaders appear to understand the enormous prestige that would result from detecting extraterrestrial life, and they fund the search projects. But Soviet scientists are also eager to work with their western colleagues. At the close of the Tallinn conference, Troitskii, Kardashev and a few other Soviet astronomers met with the American delegation to discuss the possibility of joint SETI researches. Although the Soviet Union has outstanding theoreticians and a firm commitment to the search, the United States can draw upon superior computer and electronic technology. An ideal combination might be, for example, data collection by Soviet telescopes and data analysis by American computers.

The Soviet astronomers, set for the long haul, wanted to know how much support they could count on from their western counterparts. But the American SETI workers, lacking government support, could express only vague and unspecific interest. Frank Drake summed up the meeting: "Whereas these leading Soviet astronomers were in a position to offer concrete plans and tentative commitments, we could only indulge in wishful thinking. We had to leave these possibilities up in the air, to be taken up seriously at such time as SETI becomes an American endeavor again."

The Tallinn conference did not achieve as much as might have been hoped for, but still it may have been a significant milestone. By calling attention to the progress and seriousness of the international searches, it may have helped toward the resumption of the American SETI program.

Jon Lomberg is a free-lance artist and journalist working in Toronto, Ontario.

PAINTING: JON LOMBERG

THE GALAXY SPEAKS, ARECIBO LISTENS —

This painting shows the antenna feed structure of the Arecibo radio telescope, silhouetted against the Milky Way.

WASHINGTON WATCH

by Louis Friedman

The NASA budget for the fiscal year 1983, which begins in October, 1982, is now being considered by Congress. The budget submitted by President Reagan was up 11 percent from 1982, primarily due to increases in the space shuttle program. The budget for space science activities was up 17 percent as the Space Telescope project reached its year of peak funding. The planetary exploration program, however, was hit with a major decrease—a cut of more than 20 percent.

Hardest hit were a group of activities that get little public attention but are the basis of new discoveries about the solar system. NASA has indicated that the proposed cuts would require:

—Irreversibly shutting off the *Pioneer* Venus Orbiter that, as its orbit evolves, is penetrating previously unexplored regions around Venus;

—Irreversibly shutting off the *Pioneer 10* and *11* spacecraft; *Pioneer 10* is heading down the heliotail, the "wake" of the solar system, and will eventually enter the interstellar medium to become the first artifact of humanity to leave the solar system;

—Eliminating the Mars Data Analysis program, which will end analysis of the highest resolution pictures from the *Viking* mission—thousands of which have still not been processed;

—Closing the Lunar Curatorial Facility, which holds the moon rocks from the *Apollo* missions, a collection of pristine meteorites from Antarctica and aircraft-collected dust samples that may be cometary debris;

—Closing the Hawaii Infrared Telescope, opened just two years ago;

—Reducing research funding, making it impossible for some planetary scientists to continue work in their field.

The nation has already invested $14 billion in these programs. The savings to the NASA budget is only $40 million, or two-thirds of one percent. The Congressional committees involved with NASA have all listened to a great deal of testimony opposing these cuts. Planetary Society President Carl Sagan testified to the Senate Government Affairs Subcommittee, chaired by Senators Charles Percy and John Glenn, and also addressed the newly formed Congressional Space Caucus.

Planetary Society members may wish to write in support of these programs to their Congressmen or members of the relevant House and Senate subcommittees, listed on page 21 of the March/April 1982 issue of *The Planetary Report.*

The Society has been encouraging reinstatement of the Search for Extraterrestrial Intelligence (SETI) program that was cut last year by Congress. Dr. Sagan met with Senator William Proxmire, who has opposed SETI in the past, and gave him a technical briefing on the present SETI plans. The Senator was interested and offered us some hope that a modest research and development effort would be permitted in the NASA program.

And finally, a vacancy in the NASA management was filled. Dr. Burt Edelson, formerly vice-president of COMSAT, was appointed NASA Associate Administrator for Space Science. Dr. Edelson is a charter member of The Planetary Society and has expressed a great deal of enthusiasm for our goals of continued solar system exploration and the search for extraterrestrial life. □

George Keyworth

(continued from page 7)

LF: I deliberately phrased my concerns not in terms of bottom-line dollars, but in terms of things ending. We will no longer track the *Pioneer* spacecraft, which will be the first spacecraft to reach interstellar space; we're going to close the Lunar....

GK: You must carefully distinguish between NASA's priorities and the total amount of funds available. I do not manage NASA, nor do I wish to manage NASA. There will always be decisions with which many people will disagree. But the question of cutting programs, in which $14 billion has already been invested, to save $40 million is not because the program did not have $40 million; it had to do with establishing priorities.

LF: If we argue with those priorities, you say we are not arguing with you, but with those managing the programs.

GK: I'm saying that arguing with priorities is very different from arguing if there's $40 million available in a half-billion-dollar program. But let me be upbeat for a second because I only answered part of the question. I'm trying to be realistic, but I don't see, at the moment, any justification for explaining to the American people why we should have massive increases, from 25–30 percent, that have often been proposed. But I also do not want to say that we cannot foresee any major advances in the future. It depends entirely upon the kind of programs that are proposed by the scientific and engineering community. Go back to my excellence argument. Excellent programs get excellent support. I would encourage the entire space community, most of all the planetary community, to go away and be thoughtful, and come up with the most imaginative, creative and high-quality programs that they possibly can.

Railing at the administration is not support for space science. Pick up any newspaper and see the kind of economic problems this country faces. This administration *is* supporting science. The community of planetary scientists should use their imaginations to come up with the best possible programs and we will do our very best to support them.

LF: Neither The Planetary Society nor the space science community has called for 25 percent increases. But have cuts gone so deep that soon there may be no one left to do that creative work you suggested?

GK: Well, I said that we are supporting *Galileo* and that we would like to encourage a family of smaller scope missions at higher frequency. That's a transition. Such a proposal has *not* been made in any concrete fashion yet. We have a discontinuity between the former way and the future way of doing planetary science. This does not imply that there will not be richness or excitement in the future, nor should any planetary scientist decide that it's a field to abandon. There's a lot in the future, but it's not only dependent upon the administration supplying money without asking questions. It's dependent upon the quality of the proposals. □

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VENUS ATMOSPHERE PROBES—In this fanciful rendering of the sulfuric acid clouds of Venus, several small superpressure balloons float at various altitudes, carrying sampling instruments. Precise radio tracking from Earth or from Venus orbiters and landers would permit measurement of the planet's atmospheric dynamics as the balloons circle Venus every four days. The balloon probe idea was developed by the Centre National D'Etudes Spatiales, the French space agency. A future French-Soviet Venera mission may carry similar probes to Venus.

M. E. Vicary-Diddams is a freelance artist and scientific illustrator working in Toronto. Her work has been shown by the Canadian Broadcasting Corporation and she is a member of the Royal Astronomical Society of Canada.

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