

Where Do We Go Next In Space?

by Bruce Murray



From the Moon, Apollo 8 views the rising Earth in 1968 — a preview of the “golden decade” of planetary exploration.

VIEWS from an intellectual perspective, the decade between 1971 and 1981 was one of the most extraordinary in recorded history. It was a golden decade, characterized by a phenomenal increase in humankind's knowledge and perception of the solar system in which our planet Earth is situated. One of the reasons for our looking back on this as a golden age is that the next decade is not going to be that way. In fact, perhaps my title should have been “The End of the Beginning.” From the apogee in the 1970s of man reaching out to explore the environment of his home planet, there is going to be at least a leveling off in the 1980s and probably a decline in some ways. Beyond that time, I don't know.

I do know, however, that we can anticipate our future to some extent by understanding our past. That past — the origin of the golden decade — really goes back in a direct line to Yuri Gagarin, the first Soviet cosmonaut to go into orbit. By virtue of an accelerated launch-vehicle development program, the Soviets were able to put a spacecraft, Sputnik, in orbit in 1957, and a man in 1961. Both achievements were earlier than we had anticipated or prepared for. In a Cold War sense they challenged us to race. It was a highly visible race, and it caused fear and consternation in this country.

Our response was the Apollo program, and with it a determination to put a man on the Moon by the end of the decade of the 1960s. That response was one of the great political, technical, and economic decisions in the stream of American history since World War II. It demanded performance at the very limit of our national capability. Apollo was the most complicated thing we could attempt, and it was beyond anything the Soviet Union could do. And, equally important, Apollo was an entirely peaceful, adventuresome, open use of advanced technology. Nothing better describes the positive and most likeable aspects of our society than Apollo, except perhaps Voyager, a lineal descendant of 1961's Apollo impetus happening some two decades later.

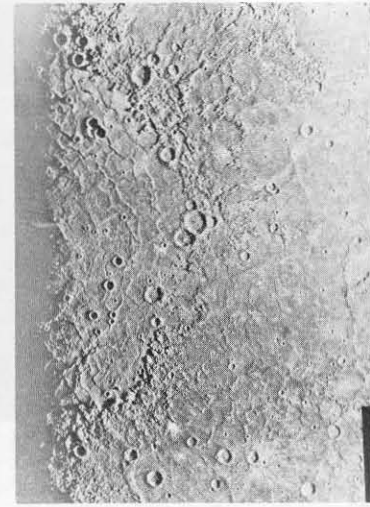
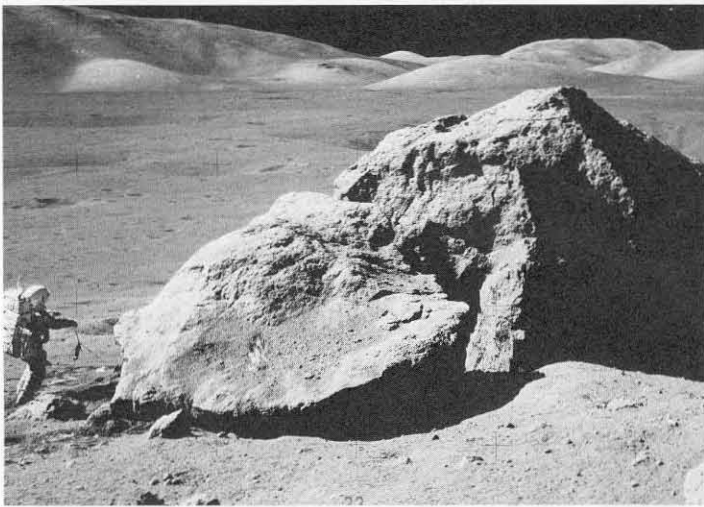
So the United States felt challenged, and we determined to respond with a big space effort, the

centerpiece of which was going to be the Apollo program. The planetary program, of which JPL became the leader, likewise arose in an environment of competition with the Russians. The principal theme in our program became a search for life on Mars — a theme that was already a part of our culture. Ever since the time of the astronomer Percival Lowell at the turn of the century, we in the United States have been fascinated with the idea of human habitation of Mars. As we became more sophisticated, we clung to the possibility that there was at least plant life on Mars.

A second theme spun off in the latter part of the 1960s. We wanted to use a rare alignment of the planets to make what we called the Grand Tour. It was an opportunity (that normally happens less than once a century) to go to Jupiter, use the gravity assist there to get to Saturn, go on to Uranus, and then on to Neptune. In fact, we didn't commit to do the whole Grand Tour because it would have involved building a very complex and expensive spacecraft, but we are doing a more moderate adventure in its place with the Voyager spacecraft. Subsidiary themes have been several missions to Venus, all of which have been of very high scientific yield, and one mission to Mercury with the Mariner 10 spacecraft.

The Russian planetary response has been much larger than that of the United States. They have invested far more in rocket launches and in spacecraft for missions to Venus and Mars. With the exception of Venus, these efforts have achieved very little. They have not been able to go either in — toward the Sun and Mercury — or out — toward the outer planets. They did some automated exploration of the Moon after the end of the manned phase there, and then focused on Venus, where they have gathered most of the important knowledge of that planet that exists.

We are all aware of the popular impact of space exploration in the decade from 1971 to 1981, but I would like to point out some of the highlights of the scientific impact of that exploration. We have, for example, learned an enormous number of things about the Moon, and one of major significance is that the Moon's surface, when



analyzed chemically, does not date back to the time of the formation of that satellite 4½ billion years ago. For the most part, the surface records the end of an enormous period of bombardment about 4 billion years ago. The Earth also formed about 4½ billion years ago, and it also shared that heavy bombardment, but no validated trace of it has been found on our planet. By looking at the Moon, then, we have learned something about our Earth that we could otherwise never have discovered.

In 1974 Mariner 10 flew by Venus and obtained the first images of its upper atmosphere, which rotates 60 times faster than the surface, and both atmosphere and surface rotate in the opposite direction from all other planets. Altogether we have recognized that Venus is the epitome of “fossil-fuel burning.” It has a naturally high greenhouse effect due to high carbon dioxide content, and there is an intense natural sulfuric acid rain. We earthlings need to learn about our kinfolk on that uninhabitable planet so we don’t tend to emulate them through unintended large-scale climatic modification of the Earth. Other discoveries came out of the Soviet landing on the surface of Venus. They learned that the atmosphere of that planet is 100 times more dense than that of Earth, that it is highly corrosive, and that the temperature is well above the melting point of lead. The surface pictures show that there are active processes going on there, amazing for an atmosphere so dense.

Mariner 10 went on to Mercury from Venus and found a surface there much like that of the Moon. We had previously thought that was not so. Furthermore, Mariner 10 found a small but surprisingly earthlike magnetic field at Mercury. So Mercury became a real place scientifically as a result of that mission.

Mars, of course, has always been an important place in our minds, but Mariner 9 and then the Viking spacecraft gave us a great deal of detailed and unexpected information about it. We were astounded at the gigantic features that characterize Mars, many of them the result of volcanism. We had once thought of Mars as perhaps the most earthlike of the planets, but we have found that though the processes that go on on Mars are similar to those on Earth, the features are totally unlike. Therefore the history and composition of Mars differ from Earth’s in profound ways. The two Viking landers found no life of a type that could be detected by any instruments we could conceive, the reason being that, because of the almost unimpeded ultraviolet radiation from the Sun, there is no organic material in the soil of Mars.

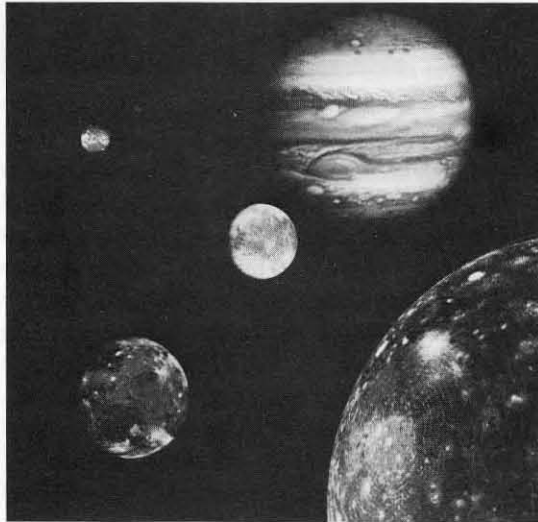
Both Voyager spacecraft were launched in 1977, and we have learned a great deal from them. We now know, for example, that the flow of energy through the atmosphere of Jupiter is quite different from what happens in the terrestrial atmosphere. Earth is heated by absorbed sunlight at the surface, and its atmosphere, which is transparent, responds to that surface heating. In the case of Jupiter, there is a significant component of internal heat as well as heat from the outside, and they combine to create very different atmospheric properties.

In flying by the Galilean satellites of Jupiter, the Voyagers discovered that they were extraordinary worlds in their own right — from Callisto, whose icy surface has probably survived from a very early time, to Ganymede, which shows evidence of internal heating at an early stage, and Europa, which has undergone heating fairly recently and is probably still undergoing it, to Io, which is dotted with active volcanoes indicating

Apollo 17 astronaut Harrison Schmitt (left) takes a walk on the Moon in 1972. Such extraordinary scenes, and the close-up views of our neighboring planets have become almost commonplace over the past decade. Mariner 10’s television cameras, for example, took 3500 pictures of Venus as the spacecraft flew by enroute to Mercury in 1974. One of these images of the planet’s upper atmosphere is shown in the center. Mercury’s pockmarked Caloris Basin (right), surrounded by a rim of mountains up to 6500 feet high, looks very much like the lunar surface in this enhanced set of Mariner 10 photos.



The Viking 1 Orbiter in 1976 provided images that formed the basis for the artist's conception (above) of the great Martian volcano, Olympus Mons. The 15-mile-high mountain, 357 miles across at the base, has a caldera (crater) 50 miles across. Jupiter and its four planet-size moons were photographed in early March 1979 by Voyager 1 and assembled into this composite picture (right). The moons are not to scale but are in their relative positions. Io is upper left, Europa at the center just below Jupiter, then Ganymede, and Callisto is at the lower right. Jupiter also has nine other satellites.



that its interior is currently boiling.

We came to understand that these four large moons orbiting Jupiter interact with each other in the same way our Moon interacts with Earth, creating tides in each other. The very powerful gravity field of Jupiter acts to place huge stress on the innermost satellite, Io, and keep it boiling; a similar but probably less strong force acts upon Europa. By the time it reaches Ganymede and Callisto, the force is probably very small.

Both Voyager spacecraft have now passed Saturn, and the biggest surprise there has been the rings. We expected to see something as simple as a three-string guitar, and we found the intricacy of an organ instead. The human perception of Saturn has forever been altered as a consequence of Voyager's findings about the complexity of the ring structure and processes. We learned a number of things about Saturn's great moon Titan as well. From ground-based telescopes we had known that Titan had an atmosphere that was composed of methane and probably hydrogen. Now we know that in a general way Titan's atmosphere is like that of Earth; it is mostly nitrogen, and methane is relatively less abundant

but far more important than we had been led to expect. It plays a role similar to that of water in Earth's atmosphere; that is, there is methane rain, ice, liquid, and vapor.

What about the future? The first thing to note about the 1980s is that there was very little reinvestment during the 1970s. That is important because of the inevitable time lag between investment in and realization of an actual mission. The things that happened in space in the 1970s were the consequences of investments, or at least decisions, in the late 1960s. Voyager was finally decided upon in 1972, and since then there has been very little reinvestment in this kind of endeavor. There are no doubt many reasons — the polarization because of Vietnam, the disillusionment of Watergate, the frustration with inflation and interest rates, and becoming dependent upon imported oil and the effects of that on foreign policy. The outcome is that as a nation we have lost our commitment — to being number one, to looking to the future and to investing in it. The result is that the course of space exploration in the 1980s is already pretty well determined.

In the case of the planet Mars, for example, the United States has no plans to follow Viking and little prospect that anything will develop. But the Soviet Union has been licking its wounds over Mars, because the Soviets have spent more on its exploration than we have, and they have virtually nothing to show for it. My guess is that they will resume that exploration; they have the technology, the launch vehicles, and the commitment. Informally, there has been some discussion of a Soviet mission to land on the Martian moon Phobos.

Since the end of the Apollo program, the United States has done nothing at all on the Moon. Maybe one of the aftereffects of the kind of effort that went into Apollo is the creation of a near-vacuum afterward. I believe the Soviets will make some efforts on the Moon, and in addition, the European Space Agency, which represents the 14 nations of western Europe, is very serious about a modest lunar polar orbiter. The Japanese also have an interest, so something is probably going to happen, but at the moment it does not seem that the U.S. will play any part in it.

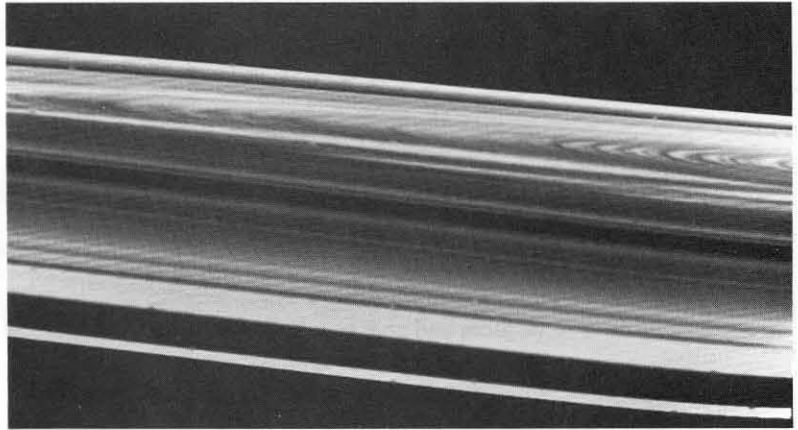
In the case of Venus, the orbiting portion of the Pioneer Venus mission launched in 1978 is still operating and is collecting some useful data. (Subject to budget cuts!), we have no further plans at present. In contrast, the Soviets have just launched two large Viking-class (in terms of weight and launch-vehicle capacity) missions to Venus. They are expected to do so again at the next opportunity, which is a little over a year

hence, and they have committed themselves to the one after that because it's a dual mission that would go on to Halley's Comet.

The international scientific community had also developed the idea that since we've been exploring the plane of the ecliptic (the plane in which the planets move about the Sun), it was important to try to explore what is in the space away from that plane. In so doing, we would get a chance to observe the Sun from a direction we can never do on Earth, namely, looking (from our point of view) up or down at its polar regions. That mission was entitled the International Solar Polar Mission. Two spacecraft were planned, one to be developed by the Europeans, one rather more ambitious by the U.S., both to be launched by the U.S. on some kind of high-energy upper stage of the Space Shuttle. The two spacecraft were to go together out to planet Jupiter and use the gravity of Jupiter like a great slingshot to toss one of them "up" to observe the Sun and its emissions from "above" the plane of the ecliptic. The other was to perform the same kind of observations simultaneously but from "below." Unhappily, one of the casualties of the last year of budgeting was the outright cancellation by the U.S. of its spacecraft for that mission.

There has been a lot of agitation for each of the spacefaring nations to do whatever possible in the way of space missions when Halley's Comet returns to the vicinity of Earth in the early part of 1986. The U.S.S.R., for example, is moving its planned two spacecraft missions to Venus in 1984 around so as to be on a trajectory that will subsequently intersect Halley's Comet. They have substantially upgraded and changed the payload for that new purpose. The Europeans are sending a smaller spacecraft with a dust shield to pass very close to the nucleus of Halley's Comet, and the Japanese are also sending a very small spacecraft (actually two of them, but one is really a test vehicle). It will not be navigated close to the nucleus of Halley or the coma, but it will provide ultraviolet observations otherwise not available. The obvious thing is, of course, that the United States will not be there, so Halley's Comet will make its once-every-76-years visit to our neighborhood without our country contributing significantly to understanding what its properties are.

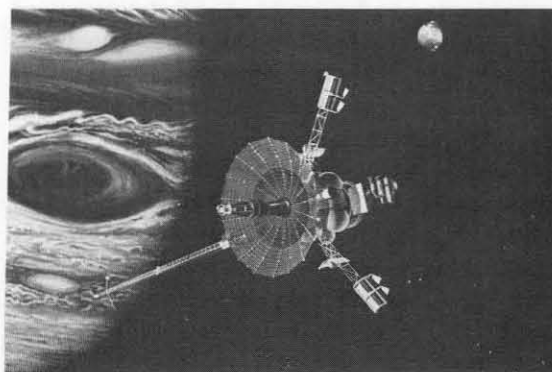
All is not lost, however. As an introduction to Voyager's trip to Uranus and to the Galileo mission, which we *will* be doing in the late 1980s, I'd like to describe to you what our strong suit really is — interplanetary navigation. When we went to Venus with Mariner 2 in 1962, the first successful interplanetary mission of any kind, the window of uncertainty in our aim was much



Voyager 2 took this wide-angle image of Saturn's rings just before the spacecraft crossed the ring plane. The enormous complexity of the planet's rings was one of the most startling surprises of the Voyager missions.

larger than the size of Venus itself. By the time we went to Mars in 1964, the area of uncertainty had been vastly reduced, to less than the size of Earth. On our mission to Mars in 1969 we were aiming at an area about the size of the United States. By 1971, the aim uncertainty of Mariner 9's orbiter amounted to roughly 100 by 100 miles, something like the size of southern California. When Voyager got to Saturn's moon Titan — the most challenging navigation feat of all — we were operating at approximately a billion miles from Earth, and the miss-distance there was 400 square miles. That is very fancy shooting, and it was the result of a combination of tracking accuracy and computing ability on the ground and of the precise maneuvering that is possible with the spacecraft. Just as navigation accuracy was once the key to circumnavigating the globe reliably, so it is the key to exploring our solar system.

The Galileo mission, which is our centerpiece for the latter part of the 1980s, has a target area smaller than the size of Pasadena. At Jupiter, where the gravity field is tremendous, Galileo will use the Jovian moons as sources of gravity to modify its orbit so as to cruise in the vicinity for nearly two years. This will require very sophisticated navigation, moving the orbit around and changing its plane (as well as its dimensions)



Galileo, the only surviving new interplanetary mission for the 1980s will demonstrate the United States' strength in sophisticated navigation as it orbits Jupiter for about two years, using the satellites as sources of gravity.

simply by close passage of each moon.

In January of 1986, Voyager 2 will arrive at Uranus, and will do an Earth and a solar occultation of both the planet and its rings in this passage. The gravity of Uranus will keep Voyager properly aimed to go over the top of Neptune and make a close passage of its large moon Triton plus another Earth and solar occultation, and then the spacecraft will move on out of the solar system. What we don't know is whether it will still be alive and able to tell us what it is sensing.

All this depends upon the navigational accuracy. It is a kind of technology, a kind of exploration, that is uniquely American. No other country has even done its first simple swingby like our 1974 Mariner 10 mission to Venus and Mercury.

What conclusions about space activities in the decade ahead — the 1980s — can be drawn from all this? My first conclusion is that the Soviet Union will be the major player in the inner solar system, that is, in the exploration of Mars, Venus, Halley's Comet, and perhaps the Moon. The major player in the outer solar system — Uranus, we hope Neptune, and certainly Jupiter — will be the United States. So we're not out of business. In some ways it's a 50/50 split.

There are some other factors we should be aware of, however. First of all, the European Space Agency and Japan, at least, will definitely be entering the scene. And that's good. It is good that more nations will be responding to their own aspirations and capabilities to reach out beyond Earth. It is a positive thing that the competitive Cold War race between just two countries that started space exploration is going to change.

But while we will still have a major (though not a dominant) role in the 1980s, we need to ask ourselves whether we will be investing in the 1990s. If we do not, we will not even be a significant player in the future. The decision we will have to make soon is how much we care about the future; it is the same decision we blew in the 1970s.

I can't predict the outcome; it's a free society that decided to go with Voyager, for example, in response to popular appeal. And that program managed to survive four Presidents and six Congresses. The representatives of the same society decided not to go to Halley's Comet, and you just have to accept that.

What is clear to me is that to the extent that we influence the future and participate in it we must do so internationally. Our period of dominance is over, and it is unlikely to return. What is more likely, and certainly more desirable on a long time scale, is that the United States will help to coordinate international efforts, not just in deter-

mining what we will do in space but in how we will deal with our neighbors on Earth. That, I think, is our challenge and our hope.

I must say that, as a country, we do not seem to be very expert at doing this at present. The way we have handled the demise of the Solar Polar mission and to some extent the Halley's Comet mission has left bitter wounds among our very best friends overseas. We have a lot to learn, and we have to want to do so, but the longer it takes us, the less likely we are to become a part of the future.

The 1990s and beyond are harder to predict than the current decade, so I'd like to bracket a range of possibilities for planet Earth. The first possible scenario is that history will repeat itself; that there will be another Apollolike nationalistic race between the United States and the Soviet Union to reach, say, Mars with men. I think that is unlikely, though the Russians may choose to go unilaterally.

Another possibility that is probably more plausible is what I call the "Antarctic Analogy." An earlier nationalistic race was to the South Pole, though it was dominated more by personalities and less by national interests. In the winter of 1911-12 it was Scott against Amundsen, and Amundsen won. Very little happened in the Antarctic for some time afterward because we had two world wars that distracted from interest in it. But a by-product of those two wars was the development of relatively cheap transportation technology. So after World War II it was reasonable for the U.S. Navy to support some Antarctic scientific exploration. From that was born the International Geophysical Year, in 1957, which launched a continuing program of low-level exploration and scientific measurements in the Antarctic by many countries.

The motivations for that are not entirely altruistic. Almost all the countries want to maintain a presence there because of potential territorial claims, or at least because resources in the Antarctic will eventually become valuable. The shrimplike krill are already beginning to be harvested in the Antarctic seas, and they are viewed as a major source of food for the Earth. And there are mineral and probably oil deposits that will be exploited in the coming three or four decades.

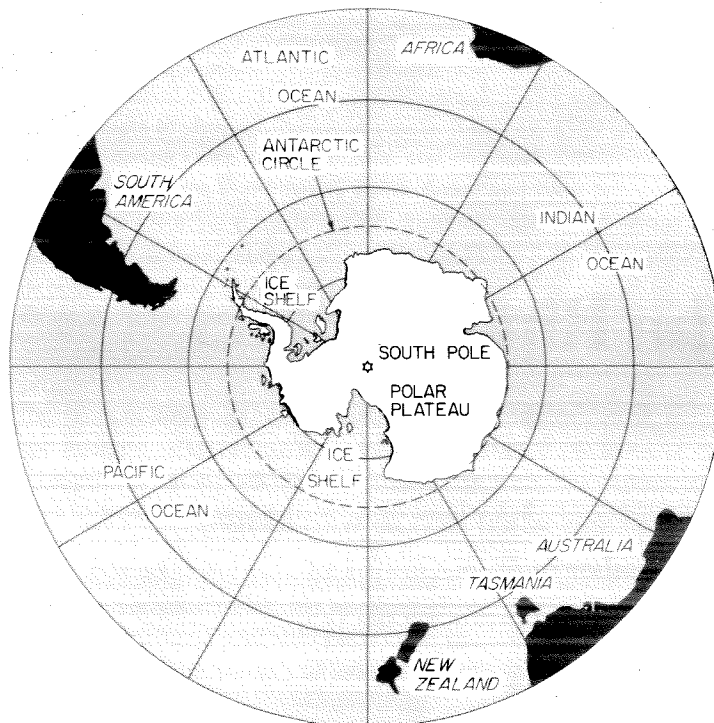
So the Antarctic parallel may be a better guide for space. In that case, the Apollo syndrome would not repeat itself, but rather there would be a lull during which space transportation technology would get cheap for reasons that had nothing to do with the solar system. Eventually it would become more affordable to do somewhat utilitarian programs.

A third possible way to go is what I call the "Look Inward and Downward" alternative. Some kind of combination of war, terrorism, and ecological disaster could so weaken the industrialized countries of the world that the reaching-out process would just stop. And the planetary exploration phase, of which we have witnessed the apex, would *really* become a historical anomaly.

Finally, the fourth of my scenarios for a possible future is what I call "Some Unforeseen Compelling Event." For example, there is a growing concern about climatic change occurring on Earth. A natural fluctuation in climate over, say, tens to hundreds of years could be driven by solar phenomena — perhaps fluctuations in both the magnitude and the kind of solar radiation and other materials with Earth. A climatic change could also be induced by human activities, especially by the burning of fossil fuels, which adds large amounts of carbon dioxide to the atmosphere, increases the self-heating capacity of Earth, raises the temperature, causes the ice caps to melt thus raising the sea level, and leads to a number of bad effects. These effects could eventually alter the sources and global availability of food and the habitability of the seacoasts. One of the responses that would make a lot of sense would be to invest in understanding solar radiation and its interaction with Earth both at present and historically. On a mission like the Solar Polar one we could measure what is going on around the Sun right now, and the best place to look for the history of solar action is probably on Mars, where (because there are no oceans) the effects of a small fluctuation in solar radiation are amplified. Given the prospect of real climatic problems on Earth, we might find scientific fact-gathering space missions observing the Sun or even to the polar areas of Mars suddenly becoming "affordable."

A second example of an unforeseen compelling event (and a very fanciful one) would be if an Earth-crossing asteroid hit the Earth. Such an event — with about ten megatons equivalent energy — actually happened early in this century in Siberia. If a search — either intentional or accidental — were to reveal the existence of an asteroid or a family of them in an Earth-encountering orbit in, say, 100 years or so, it would certainly get people's attention. There would no doubt be a sudden interest in understanding all the objects of that type that we ought to know about and where the potentially dangerous ones actually are. For the modest-sized ones, it's feasible that we might even develop the technology to change their orbits.

I don't think either of those things — climatic



change or the asteroid-impact idea — is likely to happen in just the way I hypothesized. But something might occur that would re-energize solar system exploration, not just for the U.S. but for the world. In any case, our national role will have to be part of a larger global scenario. We cannot see the future simply in American terms, because once you stop being the leader — as we are surely doing — you have to be more responsible to the rest of the system.

So whatever U.S. efforts occur beyond the 1980s they will reflect in part what is happening globally. And they will also reflect what is happening here in the United States of America. Will we decide that our destiny is to lead internationally through effective means of coordination? Will our position ten years from now still be one of confusion about our role? Or will we have decided to withdraw from the 20th century?

Regardless of which global scenario comes up, regardless of what degree of leadership, if any, we choose to exert, the phase that is drawing to an end was the beginning of *Homo sapiens* reaching out to physically understand the environment in which the species is growing up. It has been a remarkable time for all of us — the golden decade that marks the end of the beginning. My own belief is that 100 years from now the solar system will be very familiar territory. It will be utilized and internationalized intellectually in a very broad way in the human population. The men and women of that time will go to the Smithsonian of the day and look at what we did — a Viking or a Voyager spacecraft — as incredibly tiny scratchings but of tremendous import. And we will be honored very greatly for having done those things. □

The history of Antarctica provides an analogy for a possible future scenario in space. Though it was first opened up to exploration in the early 20th century, it was only after the development of relatively cheap transportation after World War II that interest in our southernmost continent gradually increased. After the initial push of the 1970s, further space exploration may also wait until transportation technology becomes cheaper.