The PLANETARY REPORT

Volume XIII Number 6 November/December 1993

Mars Observed—Then Oblivion

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 in the US or Canada are $25 US dollars or $30 Canadian. Dues outside the US or Canada are $35 (US).

Editor, CHARLENE M. ANDERSON
Technical Editor, JAMES D. BURKE
Assistant Editor, DONNA ESCANDON STEVENS
Copy Editor, GLORIA JOYCE
Production Editor, MICHAEL HAGGERTY
Art Director, BARBARA S. SMITH

Canadian Publications Mail Sales Product Agreement Number 87424

***COVER:* Mars Observer *didn't leave us much, just this "postcard" taken 5.8 million kilometers from Mars on July 26, just 27 days before it lost contact with Earth. From this distance, the planet displays the face familiar to telescopic observers on Earth. The dark feature in the center is Syrtis Major, a region of volcanic plains and sand dunes. At the top is Nilosyrtis, a region of buttes, mesas and box canyons similar to the southwestern deserts of the United States. Near the bottom is the Hellas basin, a circular impact crater some 2,000 kilometers across.* Image: JPL/NASA**

FROM THE EDITOR

Events in planetary exploration are unfolding faster than at any other point in the lifetime of The Planetary Society. As most of you know, on August 21 all contact was lost with *Mars Observer*.

There is also important news on the political front. Vice President Al Gore and Prime Minister Viktor Chernomyrdin signed a groundbreaking agreement to merge the space station programs of the United States and its international partners with Russia's *Mir* program. The Planetary Society has fought long and hard to see the principles laid out in this agreement implemented.

Now the Society is deeply involved in efforts to recover from the *Mars Observer* failure and ease the way to true cooperation among the spacefaring nations. You can be sure that our voices are being heard in discussions about the human future in space.

In this issue we begin our coverage of these breaking developments.

What Happened to *Mars Observer*?—Page 4—The investigation continues as to what caused the spacecraft to go silent, but here is a summary of what we know so far.

Triumph and Failure: The Way of Planetary Exploration—Page 5—The loss of one spacecraft is a blow to our ambitions, but the exploration of the solar system will go on. Here is a brief status report on planetary missions.

Return to the Wonder World: *Mars Observer* in Perspective—Page 6—Planetary Society President Carl Sagan reflects on the unexpected end of the *Mars Observer* mission.

The Space Station: In the Beginning . . . Page 8—Few people can claim to have been present at the birth of the American space station, but Hans Mark is one who can. He was there when President Reagan decided that NASA should build it. He watched it grow into something very different from what he had dreamed of. This is his story of the space station.

World Watch—Page 16—Here are the details of the agreement signed on September 2 by Vice President Gore and Prime Minister Chernomyrdin. It will fundamentally change the space programs of both Russia and the US.

Awaiting the First Explorers: Society Members' Names to Be Archived on Mars—Page 17—This is perhaps the ultimate benefit of membership in The Planetary Society: If you were a member as of October 15, 1993, your name will be archived on Mars. This special announcement replaces Society Notes in this issue.

A Planetary Readers' Service—Page 18—We return to planet Earth in this issue's selection.

News & Reviews—Page 19—Our faithful columnist reports on Biosphere 2, which recently completed its first experiment in living in a closed environment.

Questions & Answers—Page 20—We discuss disasters—asteroid impacts and ozone holes—in this column.

—Charlene M. Anderson

About That MarsLink Appeal . . .

It was a disturbingly unfortunate coincidence: The special appeal requesting help for our MarsLink education project was dropped into the mail on the same day JPL lost contact with *Mars Observer*. As you know, MarsLink was designed to give students a hands-on opportunity to work with data from the mission. The Society found itself asking for money for a project tied to a dead spacecraft.

Many of you recognized that we face a greater challenge than ever before in trying to make planetary exploration accessible to schoolchildren and sent in donations despite the loss. We appreciate these generous gestures of support.

And with your support, MarsLink will go on. We are now revamping our plans, to include newly processed data from the *Viking* missions, and we are investigating other ways to involve students in the excitement of planetary exploration. We will keep you posted on our progress.
—CMA

Members' Dialogue

As administrators of a membership organization, The Planetary Society's Directors and staff care about and are influenced by our members' opinions, suggestions and ideas about the future of the space program and of our Society. We encourage members to write us and create a dialogue on topics such as a space station, a lunar outpost, the exploration of Mars and the search for extraterrestrial life.

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

I am writing concerning the very sad news of the loss of the *Mars Observer*. I was so looking forward to new science and in-orbit pictures of the Red Planet. With all the problems of the highly complicated and very expensive space projects that have completely failed or become partially disabled, I believe that the space exploration system should go toward smaller, less expensive projects. Maybe microelectronic projects weighing about 90 to 140 kilograms (200 or 300 pounds) that can be launched by cheaper rockets or even high-flying aircraft. Something has to be organized and done toward this goal *now* or Congress and the taxpayer will wreck all exploration and we will have nothing.

Could Earth-type satellites now in inventory possibly be modified to fit the *Atlas* and be sent to Mars? Maybe even on the new private rockets?
—KENNETH S. JETT, *Salem, Oregon*

My kids' Nintendo game and my VCR get banged around enough, surely more times than an interplanetary spacecraft. They still work and they're cheap. I know the *Mars Observer*, Hubble Space Telescope and *Galileo* spacecraft are more sophisticated than any Nintendo game, but what are we doing here?

Dan Goldin's vision of days gone by when spacecraft were simpler and inexpensive and returned their intended results makes more sense than ever before. We need to see results again if the space program is going to remain in the public's eye as more than a bunch of money-wasting, glory-seeking, scientific nerds. The Hubble Space Telescope, as far as the taxpaying public is aware, is nothing more than a billion-dollar Celestron with a screwed-up mirror. It has returned fantastic results, even in its crippled condition. Who sees this? Maybe the person who reads *Sky & Telescope* or *The Planetary Report,* but the nightly news and the press are always eager to discuss the "Hubble Billion Dollar Blunder." If it didn't blow up, break down, kill people, waste money, crash in the ocean or have someone sleeping with someone else who pocketed funds allocated for telescope usage time, it will never sell on the news. This has got to change.

NASA, get your act together or give the job to someone else. Planetary Society, keep pushing for a global space system. Let's try to make space and science something more than a 30-second filler at the end of the evening news.
—DAVID C. BUDDA, *West Hazleton, Pennsylvania*

I'm writing in response to Walker Rideout's letter in the September/October issue of *The Planetary Report*. The planet Mercury may appear to be a solved puzzle, nothing more than another heavily cratered, Moon-like body. Yet Mercury remains one of the great enigmas of the solar system, keeping secrets more than 4 billion years old.

We have not even imaged *half* the surface of Mercury. The half we have mapped leaves us with maddening clues to both its formation and the formation of the solar system itself. On Mercury we can see half the largest impact basin in the solar system. This basin has much in common with lunar basins, but some striking differences. Examination of the basin as a whole would offer insight into basin formation here and on other planets. Tiny Mercury also has a magnetic field. This implies that part of the interior is liquid, but such a small planet should have solidified to its center long ago.

I hope that The Planetary Society continues to support *all* planetary research to the best of its ability, especially the investigation of, and missions to, asteroids, the Moon, Mercury and other, more nondescript rocky entities, whose critical scientific importance it is so tempting to underestimate.
—JENNIFER A. GRIER, *Tucson, Arizona*

At first glance, it would appear that we on Earth will miss seeing one of this era's great catastrophes when comet Shoemaker-Levy 9 hits Jupiter next July. I was thinking that it was too bad that *Galileo* will be too late, when it occurred to me that there might still be a way.

Voyagers 1 and *2* are, as I understand, still operational. A little old, a little cold, but still operating in cruise mode. I believe that their cameras were shut down for lack of targets and to conserve power. I don't know where the spacecraft are in relation to Jupiter, but even so, useful data may be obtainable if Jupiter can be targeted with *Voyager*'s instruments.

How often does anyone get a chance to see a series of gigaton bombs go off? Since it will be such a rare event, I thought I'd plant the seed in case this idea has a chance of success.
—DAVID J. BOYLE, *Fox River Grove, Illinois*

The Jet Propulsion Laboratory is already working on it.
—Editor

On August 28, 1993, *Galileo* captured a series of image frames of the main-belt asteroid 243 Ida as it flew past. The five frames that comprise this mosaic of Ida were captured when the spacecraft was three and a half minutes from its closest approach of 2,400 kilometers (1,500 miles). The encounter took place about 441 million kilometers (274 million miles) from the Sun.

Theories about Ida's surface being geologically youthful may be dispelled by its plethora of craters, and this view seems to rule out the idea that it is a double body. Ida's south pole is believed to be on the dark side, near the middle of the asteroid.

Image: JPL/NASA

What Happened to *Mars Observer*?

by Louis D. Friedman

The mission advisory from the Jet Propulsion Laboratory was brief, but chilling. It began:

"On Saturday evening, August 21st, communications were lost with the Mars Observer spacecraft as it neared to within 3 days of the planet Mars. Engineers and mission controllers at NASA's Jet Propulsion Laboratory (JPL), Pasadena, California, responded with a series of backup commands to turn on the spacecraft's transmitter and to point the spacecraft's antennas toward Earth. As of 11:00 a.m. EDT on Sunday, August 22nd, no signal from the spacecraft had been received by tracking stations around the world."

As I write this, several weeks after communications ceased, there is still no signal from *Mars Observer*. Nearly everyone has given the spacecraft up for lost.

We may never know what went wrong with *Mars Observer*. The core of the problem is that we have no data. We only know what events were supposed to have taken place as the spacecraft neared its target planet.

At 9:00 p.m. EDT on Saturday, August 21, *Mars Observer* began a sequence of actions to pressurize its fuel tanks. This had to be done to prepare the braking thrusters to fire in a maneuver that would have slowed the spacecraft enough for it to enter orbit about Mars. Orbital injection was scheduled for the following Tuesday.

The tank pressurization began by opening valves by setting off a small pyrotechnic device. To protect the sensitive electronic equipment from the effects of the shock, the onboard computer was programmed to shut down the spacecraft transmitters during the event. After it was over, the transmitters were supposed to be turned back on automatically and communication with Earth was to resume. It never happened.

Mars Observer never again sent a signal that was received on Earth and, so far as we know, the spacecraft did not receive the signals sent from Earth. People began to speculate that the pressurization procedure had led to an explosion that destroyed the spacecraft. However, the type of small pyrotechnic device used to open the valves should not have triggered a full-scale explosion. Although nothing can be ruled out, an explosion is not now considered the most likely scenario.

In the agonizing days that followed, project engineers tried sending all kinds of command sequences. They listened for telemetry, cycled through computer sequences, simulated potential failure modes. The most hopeful speculated that the onboard computer might still be working and that it would take *Mars Observer* into orbit.

But the project team received no indication of what was happening out near Mars. Speculation began to center on a set of transistors in the clock circuits of the spacecraft. These transistors were part of a manufacturing batch that had experienced an unusually high number of failures in spacecraft. Unfortunately, this was not discovered until after *Mars Observer* had been launched.

It is possible that the transistors in both the master and backup clocks failed. The one in the backup could have failed earlier without having been detected. The one in the master clock could have failed at the time of the pyrotechnic firing. If both clocks did indeed fail, the spacecraft computer would have shut down completely and it could not be reactivated.

As we go to press, the culprit in the loss of *Mars Observer* is still unknown. Two investigating committees are now meeting behind closed doors, discouraging speculation before they complete their work. One group is an internal JPL committee; the other is an external committee appointed by NASA Administrator Daniel S. Goldin and chaired by Timothy Coffey, director of the Naval Research Laboratory.

Even if the problem is identified as most likely due to faulty transistors purchased from an outside contractor, there will be questions raised about testing procedures and systems design. Queries will focus on what actions could have been taken to prevent the failure or to enable the spacecraft to overcome its problems.

We await the results of the official inquiry. The lessons learned will help future spacecraft designers in planning other planetary missions.

One lesson that I believe should be learned is that planetary missions should be designed with two spacecraft. Early in the history of planetary exploration, this was the accepted practice for both the United States and the Soviet Union. *Mariners, Pioneers* and *Vikings* were sent in pairs to explore their targets. The Soviet Union routinely launched spacecraft in pairs to both Mars and Venus. Several of their Mars vehicles failed, and in the recent *Phobos* mission, only one spacecraft returned good data before it, too, failed.

With the loss of *Mars Observer* and with the problems of the *Galileo* spacecraft, the weaknesses of the single, large spacecraft strategy become apparent. It's time to learn from the past to preserve our future in exploring the planets.

Louis D. Friedman is Executive Director of The Planetary Society.

Triumph and Failure: The Way of Planetary Exploration

by Louis D. Friedman

The loss of *Mars Observer* is a severe blow to all who care about the exploration of the solar system and the search for extraterrestrial life. The endeavor of planetary exploration is more than three decades old, and during that relatively short time we have experienced both great triumphs and disheartening failures.

The spacefaring nations of Earth have sent robotic explorers to every planet from Mercury to Neptune, and they have lost many spacecraft in the process. But it is one of the better aspects of robotic exploration that we can risk much in the pursuit of great achievement and still avoid risking human lives.

Despite the setback dealt by the loss of *Mars Observer*, planetary exploration will continue. Data from this mission would have made planning for subsequent missions easier, but they will go on nevertheless. Global climatological and geological maps produced from the data would have helped mission planners in choosing landing sites for the Russian *Mars '94* and *'96* missions and NASA's MESUR Pathfinder. The Mars Balloon Relay carried by *Mars Observer* would have enabled these robots to return data to Earth at a higher rate. Still, all these missions will continue.

Here's a brief rundown on planetary missions still in progress or planned:

- *Magellan:* launch, May 1989; arrival at Venus, August 1990; still in operation about the planet.
- *Galileo:* launch, October 1989; arrival at Jupiter, December 1995.
- *Ulysses:* launch, October 1990; passage over the Sun's south polar region, June–November 1994; passage over the Sun's north polar region, June–September 1995.
- *Clementine:* launch, January 1994; arrival at Moon, February 1994; arrival at asteroid Geographos, August 1994.
- *Mars '94:* launch, October 1994; arrival at Mars, September 1995.
- *Mars '96:* launch, November 1996; arrival at Mars, September 1997.
- MESUR Pathfinder: launch, November 1996; arrival at Mars, November 1997.
- *Cassini/Huygens:* launch, October 1997; arrival at Saturn, June 2004.
- Planet-B: launch, August 1998; arrival at Mars, spring 1999.

NASA hopes to have a new class of missions under way later in this decade, with the proposed Discovery program. MESUR Pathfinder is the first in the series of relatively small, quick, low-cost missions. It could be followed by the Near-Earth Asteroid Rendezvous (NEAR) mission. NASA is also considering submitting a Pluto fast flyby mission to Congress for "new start" funding in the near future.

Meanwhile, attention is focused on how to recover from the *Mars Observer* catastrophe. NASA Administrator Daniel S. Goldin has directed the Jet Propulsion Laboratory to establish three study teams, under the overall direction of JPL Assistant Director Charles Elachi, to explore the possibilities for a return mission to Mars in either 1994 or 1996. These teams will evaluate candidate spacecraft from industry; military satellites from the Ballistic Missile Defense Organization, such as *Clementine* or MSTI (for Miniature Seeker Technology Integration); or a reflight of *Mars Observer*. The teams will also consider using a Russian launch vehicle for the mission. Planetary Society President Carl Sagan, Vice President Bruce Murray and consultant Gene Giberson have been named members of yet a fourth team, which will be reviewing all of the proposals.

Among the principal criteria for the review will be the ability of candidate spacecraft to accommodate instruments that can meet most of *Mars Observer*'s scientific objectives. The ability of the replacement craft to serve as a communications relay for planned Mars lander missions will also be an important detail.

Interest in the exploration of Mars—and the rest of the solar system—has not died with the first *Mars Observer* spacecraft. Our hopes of studying and understanding this most Earth-like of planets and, eventually, of seeing human beings walk its surface remain alive. □

Loss of Mars Balloon Relay Will Affect Mars '94 and '96 Missions

When Mars Observer disappeared, it took with it a critical communications relay that was to have transmitted data from the Russian Mars '94 and '96 missions back to Earth. Project scientists are now evaluating what the loss of this Mars Balloon Relay (MBR) will mean to those missions.

Both Russian missions involve orbiters that can still relay the data to Earth but, because of their long, looping orbits about Mars, they will not be as ideally positioned to receive transmissions as Mars Observer would have been in its nearly circular orbit.

Conceived by Planetary Society Advisor Jacques Blamont, the MBR would have more than doubled the rate at which data from the Russian landers would have reached Earth. It was originally devised to work with the Mars Balloon, but, as the Russian projects developed, other landing craft planned for the 1994 and 1996 missions also tied their data return to the MBR. The rover, small landers and penetrators will all be affected by the loss.

However, spacecraft engineers and scientists are used to exercising their ingenuity, and they are now studying ways to get around the problem. The Russians were already building a spare transmitter for the Mars '94 orbiter, and this may help compensate for the loss of Mars Observer. If there is a 1994 Mars Observer follow-on with an MBR, much of the problem will of course be alleviated. *—LDF*

Return to the Wonder World:

Mars Observer in Perspective

by Carl Sagan

"M.O. Call Home" was the plaintive message on a banner hung outside the Jet Propulsion Laboratory's Mission Operations Facility in late August 1993. The failure of the United States' *Mars Observer* spacecraft at the very moment it was to insert itself into orbit around Mars was a great loss. It was the first mission failure of an American lunar or planetary spacecraft in nearly three decades. Many scientists and engineers had devoted a decade of their professional lives to *M.O.* It was the first US mission to Mars in 17 years—since *Viking*'s two orbiters and two landers in 1976. It was also the first real post–Cold War spacecraft: Russian scientists were on several of the investigator teams, and *Mars Observer* was to act as an essential radio relay link for landers from the Russian *Mars '94* mission and for a daring rover and balloon mission for *Mars '96*.

The scientific instruments aboard *Mars Observer* would have mapped the geochemistry of the planet and prepared the way for future missions, guiding landing site decisions. It might have cast a new light on the massive climate change that seems to have occurred in early martian history. It would have photographed some of the surface of Mars with detail better than 2 meters across. Of course, we do not know what new wonders *Mars Observer* would have uncovered. But every time we examine a world with new instruments and in vastly improved detail, a dazzling array of discoveries emerges—just as it did when Galileo turned the first telescope toward the heavens and opened up the era of modern astronomy.

The cause of the failure remains a mystery. A commission of inquiry has been appointed and the answer may be forthcoming soon. Perhaps it was avoidable. Or perhaps it was an unlucky accident. But it's important to keep this matter in perspective. Let's consider the full range of missions to the Moon and the planets attempted by the US and the former Soviet Union.

In the beginning, our track records were poor. Space vehicles blew up at launch, missed their targets or failed to function when they got there. As time went on, we humans got better at interplanetary flight. There was a learning curve. The adjacent figures show these curves (based on NASA data with NASA definitions of mission success). We see that it wasn't until about its 30th launch to the Moon or the planets that the US mission success rate got as high as 50 percent. The Russians took about 50 launches to get there. Averaging the shaky start and the better more recent performance, we see that both the US and Russia have a cumulative *launch* success rate of about 80 percent. But the cumulative *mission* success rate is still under 70 percent for the US and under 60 percent for the USSR/Russia. Equivalently, lunar and planetary missions have failed on average 30 or 40 percent of the time.

Missions to other worlds were from the beginning at the cutting edge of technology. They continue to be so today. They are designed with redundant subsystems, and operated by dedicated and experienced engineers, but they are not perfect. If they were anything like perfect, we would be doing the same thing over and over, instead of trailblazing the future.

We don't yet know whether the *Mars Observer* failure was due to incompetence or just statistics. But we must expect a steady background of mission failures when we explore other worlds. No human lives are risked when a robot spacecraft is lost. Even if we were able to improve this success rate significantly, it would be far too costly. It is much better to take more risks and fly more spacecraft.

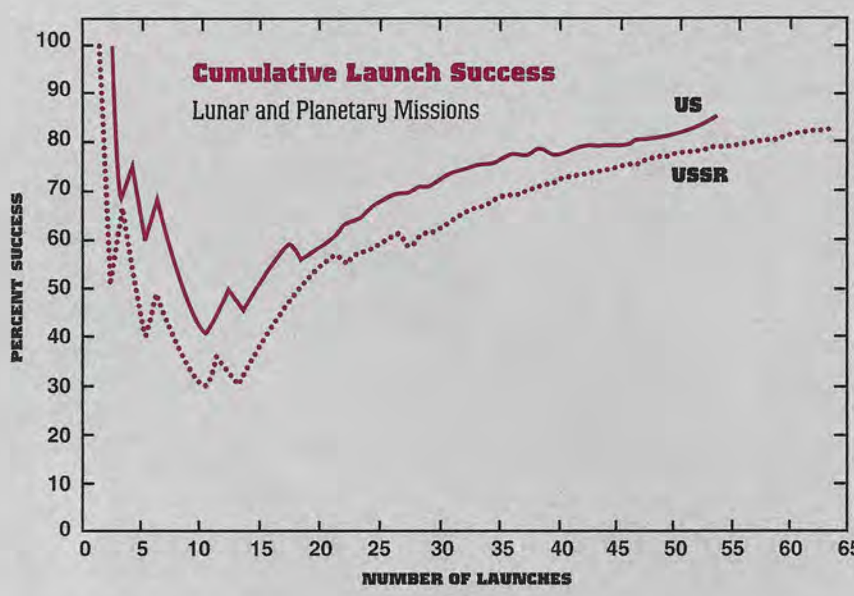
Knowing about irreducible risks, why do we these days fly only one spacecraft per mission? In 1962 *Mariner 1* fell into the Atlantic; *Mariner 2* to Venus became the human species' first successful planetary mission. *Mariner 3* failed, and *Mariner 4* became, in 1964, the first spacecraft to take close-up pictures of Mars. Or consider the 1971 *Mariner 8/Mariner 9* dual launch mission to Mars. *Mariner 8* was to map the planet. *Mariner 9* was to study the enigmatic seasonal and secular changes of surface markings. The spacecraft were otherwise identical. *Mariner 8* fell into the ocean. *Mariner 9* flew on to Mars and became the first spacecraft in human history to orbit another planet. It discovered the volcanoes, the laminated terrain in the polar caps, the ancient river valleys and the eolian nature of the surface changes. It disproved the "canals." It mapped the planet pole to pole and revealed all the major geological features of Mars known to us today. It provided the first close-up observations of a whole class of small worlds (targeting the martian moons, Phobos and Deimos). If we had only launched *Mariner 8*, the endeavor would have been an unmitigated failure. Launching *Mariners 8* and *9*—despite the failure of *Mariner 8*—made the endeavor a brilliant and historic success.

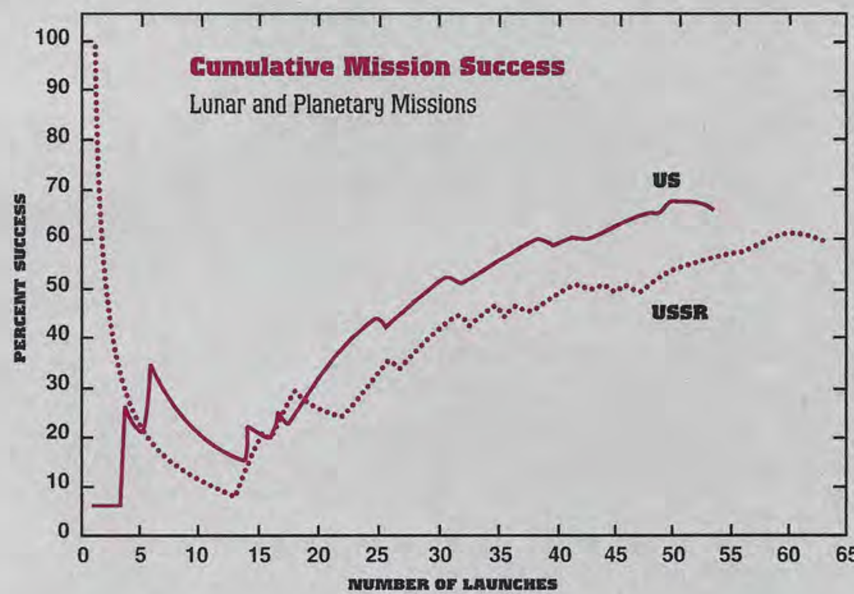
Why was only one *Mars Observer* flown? The standard answer is cost. Part of the reason it was so costly, though, is that it was planned to be launched by shuttle, which is an almost absurdly expensive booster for planetary missions —in this case too expensive for two launches. After many shuttle-connected delays and cost increases, NASA changed its mind and decided to launch *Mars Observer* on a *Titan* booster. This required an additional two-year delay and an adapter to mate the spacecraft to the new launch vehicle. If NASA had not been so intent on providing business for the increasingly uneconomic shuttle, we could have launched a couple of years earlier, maybe with two instead of one spacecraft.

These remarks are meant not as recriminations, but as lessons for the future. There are several possible options. We could return to Mars in the October 1994 launch window, or wait until the 1996 window. We could launch a complement of instruments very like *Mars Observer*'s on a shuttle, or on the Russian workhorse *Proton* booster. Or we could split the payload onto two smaller boosters—*Deltas*, for example. We could send lighter, riskier and less comprehensive instrumentation of the sort that will be tested out next year in the *Clementine* mission to the Moon and the asteroid Geographos. We would certainly want to send another radio relay. The attractiveness of *two* launches is, I think, clear.

There's also a further option: Do nothing. Some commentators see the *Mars Observer* failure as part and parcel of a much broader problem with NASA—a problem that includes the *Challenger* shuttle disaster, the nearsighted Hubble Space Telescope and the stuck high-gain antenna on *Galileo*—a feeling that American genius can no longer deliver the goods. Let's abandon the space program, they say.

But the missions to Mars are an excellent example of why we need the space program. Mars is a planet where Earth-like climate conditions somehow transformed themselves into a deep Ice Age planet. Shouldn't we, who are thoughtlessly altering our planetary environment, learn more about what happened on ancient Mars? The martian surface is bathed in solar ultraviolet light, because its atmosphere has no ozone layer. Shouldn't we, who have until lately been heedlessly destroying our own ozone layer, learn more about ultraviolet light and Mars?



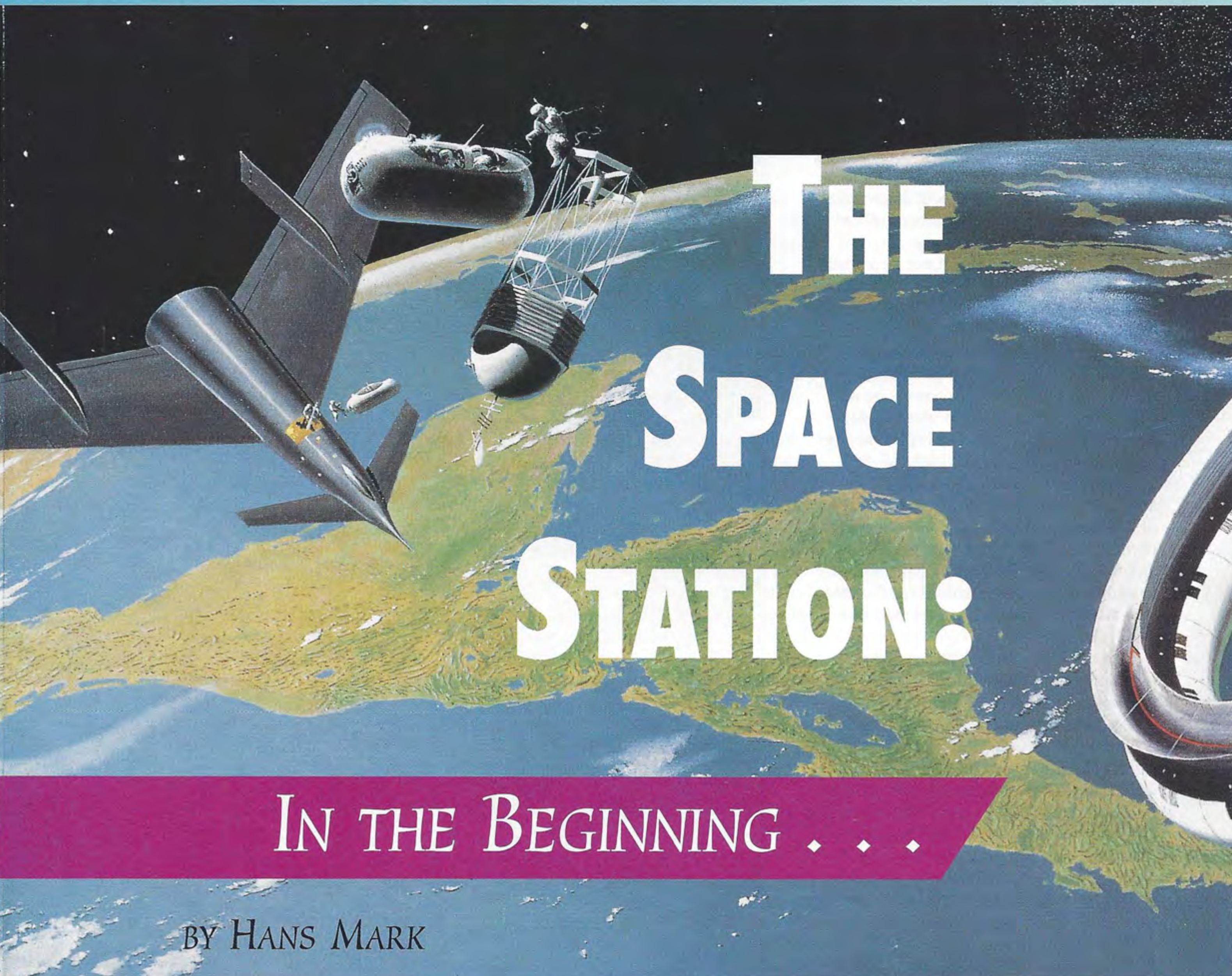


Note: Data through mid-1980s, supplied by NASA. Magellan, Vega 1 *and* Vega 2 *are counted as mission successes;* Mars Observer, Phobos 1 *and* Phobos 2, *as mission failures. The ongoing* Galileo *and* Ulysses *missions are counted as launch successes but not yet as mission successes.* *Charts: Carl Sagan; drawn by B. S. Smith*

Mars is the nearest planet to which human explorers could someday go. Mars is the nearest world on which life, past or maybe even present, is possible. Mars is a world that excites the exploratory spirit and presents young people with a vision of a hopeful future. A much more vigorous program of Mars exploration than we've committed to lately could be bought for about 0.1 percent of the US defense budget—and less if performed jointly with the Russians, the Europeans and the Japanese. Isn't this something we should be doing?

We continue to learn from our mistakes. President Clinton and NASA Administrator Goldin are addressing the problem of an ossified bureaucracy in the space program. Cheaper, quicker, smarter spacecraft are being developed. The US and Russia have signed a historic agreement for cooperative ventures in space, both robotic and human. This is the time to stand up, shake ourselves off, learn from the past and return to the wonder world.

Carl Sagan is the David Duncan Professor of Astronomy and Space Sciences and Director of the Laboratory for Planetary Studies at Cornell University.



The Space Station:

In the Beginning . . .

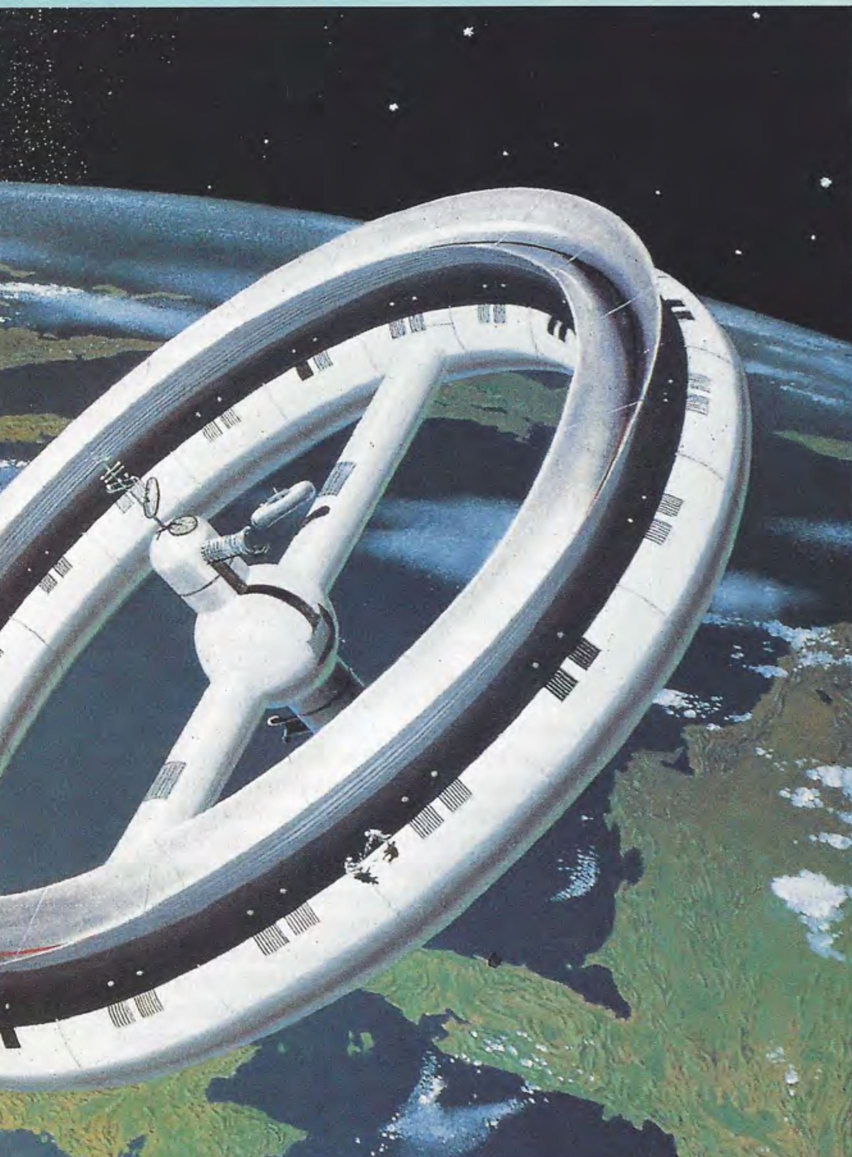
By Hans Mark

The idea of constructing an orbiting station in space is not a new one. It was mentioned in the seminal writings of Konstantin Tsiolkovsky and Hermann Oberth in the early years of this century, and the concept was fully developed by Austrian engineer Count Guido von Pirquet in the journal *Die Rakete* in 1928. I first ran across the idea in a book called *Rockets Through Space*, published in 1936. Its author, Philip E. Cleator, recounts the ideas of von Pirquet and others:

"They envision the construction of an artificial moon, an outward station in space, specifically designed for the purpose of refueling spaceships. . . . this tiny man-made world would describe an orbit around the earth in the plane of the ecliptic, that is the apparent path of the sun around the earth, actually the plane of the earth's orbit. Located at a height of some 600 miles and traveling with the speed of 4 1/2 miles a second, it would no more stray from its appointed path than does the moon itself. Details of the proposed outward station have been fully worked out, even to the cost, which is reckoned at no more than $10 million. . . . Count von Pirquet is of the opinion that the achievement of interplanetary travel must depend upon the construction of such a station."

This is a very complete description of one of the major functions a space station would perform, even if the cost estimate was wildly optimistic! Von Pirquet and his successors understood that direct trips to Mars or to the Moon would require rockets so large that they were beyond the ability of existing technology to create. With a staging base, interplanetary travel could be achieved with much smaller rockets.

These ideas were elaborated in *Rockets and Space Travel*,



The concept of an Earth-orbiting space station reached a broad popular audience through a series of articles in Collier's *magazine in the early 1950s. Here a winged supply rocket arrives at the rotating space station.*
Painting: Chesley Bonestell, Space Art International

and look back at Earth. These are to this day the two major points made by advocates of the space station program.

Serious Planning

All of the works I have cited so far were essentially speculations because the rockets necessary to achieve the objectives of the authors were not available. However, during World War II the technology of rocketry was developed to a point where one could think seriously about orbiting spacecraft. The first time these ideas were put down on paper was in a report issued in 1946 by a unit of the Douglas Aircraft Company that was later to become the Rand Corporation. The report, *Preliminary Design of an Experimental World-Circling Spaceship*, concluded that the rockets that would soon be available could, in fact, place artificial satellites in Earth orbit, and that these satellites would have the capability of carrying interesting and valuable scientific instruments. The report also speculated on putting humans in space and traveling to other bodies of our solar system.

Ideas similar to those put forth in the Rand report were popularized a few years later by a series of articles that appeared in *Collier's* magazine from March 1952 to April 1954. These articles were authored by Wernher von Braun, Fred L. Whipple, Joseph Kaplan, Heinz Haber, Willy Ley and Oscar Schachter, and illustrated by the great space artist Chesley Bonestell.

Here for the first time the technical difference between spaceships designed to get from the surface of Earth to the space station and those designed to go from the space station elsewhere in the solar system was fully developed. The former—"winged rockets," as they were called in the *Collier's* articles—are essentially aircraft that can fly in space: our space shuttles. They must have an aerodynamic shape and the necessary thermal protection systems to allow them to fly through the atmosphere at high speed. For the true spaceships that would then go from the space station to the Moon and elsewhere, such "baggage" would not be necessary.

A little more than three years after the last of these articles was published, the Soviets put *Sputnik 1* into Earth orbit, and thus began the space race that eventually led to the initiation of the *Apollo* program by President John F. Kennedy in May 1961 and the first landing of people on the Moon in July 1969. Staging from Earth orbit was considered, but the decision was made to stage from lunar orbit instead, and thus the command and service module of the *Apollo* spaceship became a de facto temporary space station in orbit around the Moon. While this facilitated the lunar landing, it unfortunately did not leave any permanent residue of the *Apollo* program. There were many of us at the time who regretted the decision to adopt what was called the "lunar orbit rendezvous method." However,

a book written by Willy Ley in 1947. Ley discusses the construction of a "terminal in space" that would include a laboratory where biologists could "investigate tissue growth and other biological phenomena under zero gravity conditions," and where "astronomical observations could be carried out with an efficiency impossible from the surface of the earth." He goes on to say that "naturally, observers on the station would also have an excellent view of the earth," and that "a trained observer could greatly assist weather bureaus all over the earth and he could provide warnings of icebergs and storms all over the world."

Thus, by the time Ley published his book, shortly after World War II, the principal reasons for building a space station were in place: It would facilitate interplanetary travel, and it would serve to study how people could survive and work in space, perform astronomical observations

President Reagan describing the space station to world leaders at the June 1984 economic summit in London.
Photo: NASA

given President Kennedy's timetable, there was no other choice.

The idea of a space station was revived in 1971 when George Low and James Fletcher (the deputy administrator and administrator of NASA, respectively) persuaded the Nixon administration to use leftover *Apollo* hardware to initiate the *Skylab* program. *Skylab* was the first US space station, and the idea was considered to maintain it permanently in Earth orbit and to revisit it periodically to perform various experiments.

In the meantime, planning continued with what was then called the post-*Apollo* program. I remember participating in this planning in early 1969 as a member of a committee chaired by then NASA Associate Administrator George E. Mueller. Wernher von Braun was the dominant member of this committee and the program he proposed closely followed what had been published in the *Collier's* magazine series more than 15 years earlier. A space station would be created either through the *Skylab* program or in some other way and then a space shuttle vehicle to get back and forth would be built. I remember von Braun arguing that we would have a space station (*Skylab*) to be launched four years hence (in 1973) and that we would then have the shuttle to resupply this space station.

Unfortunately, *Skylab* was in an orbit that would not be permanent because it was too low. Calculations showed that *Skylab* would return to Earth in 1979 or 1980. In 1972, when the space shuttle program was initiated, the schedule called for the first flight in 1978. Therefore, if everything went according to plan, the shuttle could pull *Skylab* into a safe orbit and we would then have the system envisioned in the *Collier's* articles, a space station with a space shuttle to get back and forth.

Things did not turn out this way. The schedule of the space shuttle was delayed and *Skylab* returned to Earth on July 11, 1979. Thus the opportunity to deploy a space station early on was lost. *Skylab* would not have had the same capabilities that we now consider essential but it would have been a first step.

At the same time, the Soviets were developing the *Soyuz–Salyut* space station. (The first *Salyut* was placed in Earth orbit in 1971.) This system was a relatively small but workable orbital base from which much useful information has been obtained regarding the ability of humans to work in space for extended periods of time. In 1975, a linkup between an *Apollo* command and service module and a Soviet *Soyuz* spacecraft was executed. This "handshake in space" was the first US–Soviet collaborative project involving people in space.

Initiation of the Space Station Program

It was recognized when the space shuttle program was approved by President Nixon in early 1972 that building the shuttle would be a technically difficult proposition. (We had for that reason elected in 1970 to delay the space station until the shuttle was flying.)

As things turned out, there were delays and cost overruns in the shuttle program. After an overrun of over a billion dollars was encountered during the Carter administration, Secretary of Defense Harold Brown and Undersecretary of Defense for Research and Development William Perry saved the program by pointing out its national security applications. The space shuttle *Columbia* flew for the first time on April 12, 1981, and the shuttle has been generally a technical success. There have been operational problems and as I see it the shuttle is much too expensive to fly, primarily because a workable operational organization has not yet been established.

The next step after this was to persuade the Reagan administration to initiate a space station program. At the time, I was serving as the deputy administrator of NASA. All of the old arguments were revived and polished; we provided a new one that we felt would be important. This was to have the space station become a "maintenance base" for deployed satellites.

To demonstrate this capability, we decided to use the space shuttle to repair a satellite that had failed while in Earth orbit. This satellite was a scientific vehicle called the Solar Maximum Mission, later popularly known as Solar Max. In April of 1984, the satellite was rescued, repaired and redeployed so it could continue on what became a very successful scientific mission. We also thought that large and valuable spacecraft, such as the Hubble Space Telescope, might be designed from the beginning to be repaired and maintained by periodic visits from astronauts, either from a shuttle or from a space station using a suitable orbital transfer vehicle to move such spacecraft from their orbits to the space station and back again.

It was during the planning for the Solar Max mission that I first ran across the extreme reluctance on the part of the people at the Johnson Space Center to perform extravehicular activity (EVA). There is no doubt that EVA entails some risks, but the assessment of these risks was and is a matter of judgment. My own feeling has been all along that we should do much more EVA and build the space station around performing many of the functions with astronauts outside the spacecraft.

The issue of EVA would continue to dominate the debate over the space station configuration. The concept that I favored was one that emerged in early 1982 from numerous conversations with members of the scientific community and other knowledgeable people led by Daniel H. Herman, who was a leading member of the space station planning office at NASA headquarters at the time.

The baseline architecture we had in mind was to have central habitation and laboratory modules with several co-orbiting platforms flying "in formation" with them. The co-orbiting platforms were to be uninhabited by people; there would be periodic visits by the astronauts from the habitation modules to do experiments or maintenance work. Each of the co-orbiting platforms would have a different purpose: astronomy, materials research in microgravity, biological experiments and so forth.

By operating in this manner several advantages would accrue. The experiments on a co-orbiting platform that required accurate pointing would not be harmed by people moving around in habitation modules since there was no rigid connection between the modules and the platform. The experiments requiring cryogenic cooling would not be adversely affected by effluents from the habitation modules since the co-orbiting platform could be positioned far enough away to avoid the problem. (A picture of the space station configuration developed at this time is shown in the illustration below.)

Obviously, this configuration would require relatively extensive EVA and this factor turned into a major bone of contention. The configuration as presented also included the development of appropriate orbital transfer vehicles to perform the "maintenance" function that I have mentioned.

In July 1983 the American Institute of Aeronautics and Astronautics (AIAA) sponsored a symposium in which all of these issues were aired in great detail. The baseline configuration that I have described was the one we selected when we made our presentation to President Reagan on December 1, 1983. It was at this December meeting that the decision was made to go ahead with the space station program.

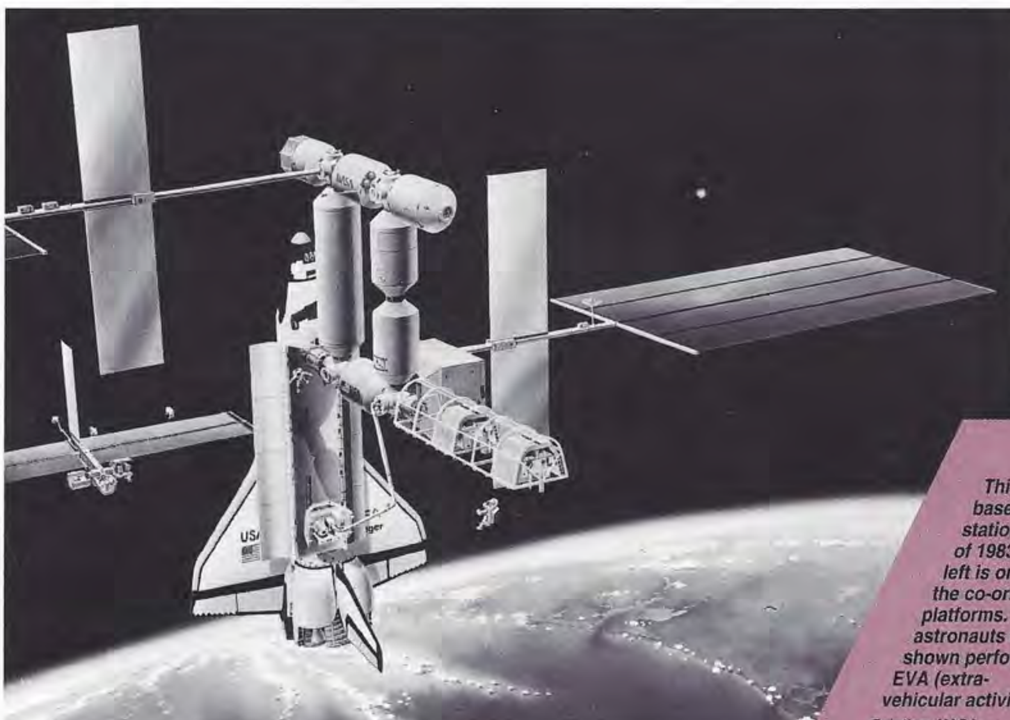
A few days later, we were told that the president wanted to make the space station an international effort. We responded that this would be very appropriate and that NASA had extensive experience in managing large international efforts of this kind. At the London Economic Summit Meeting in June 1984 the initial negotiations to develop the space station as an international effort were begun.

Three arguments were used to persuade the president to adopt the space station: First, the space station would be a laboratory in Earth orbit as envisioned more than a quarter of a century earlier by Willy Ley. Second, with an appropriate orbital transfer vehicle the space station would become a maintenance base in Earth orbit as demonstrated by the rescue and repair of Solar Max. And finally, the space station would be a staging base for more ambitious missions in the future in accordance with the ideas first developed by Count Guido von Pirquet.

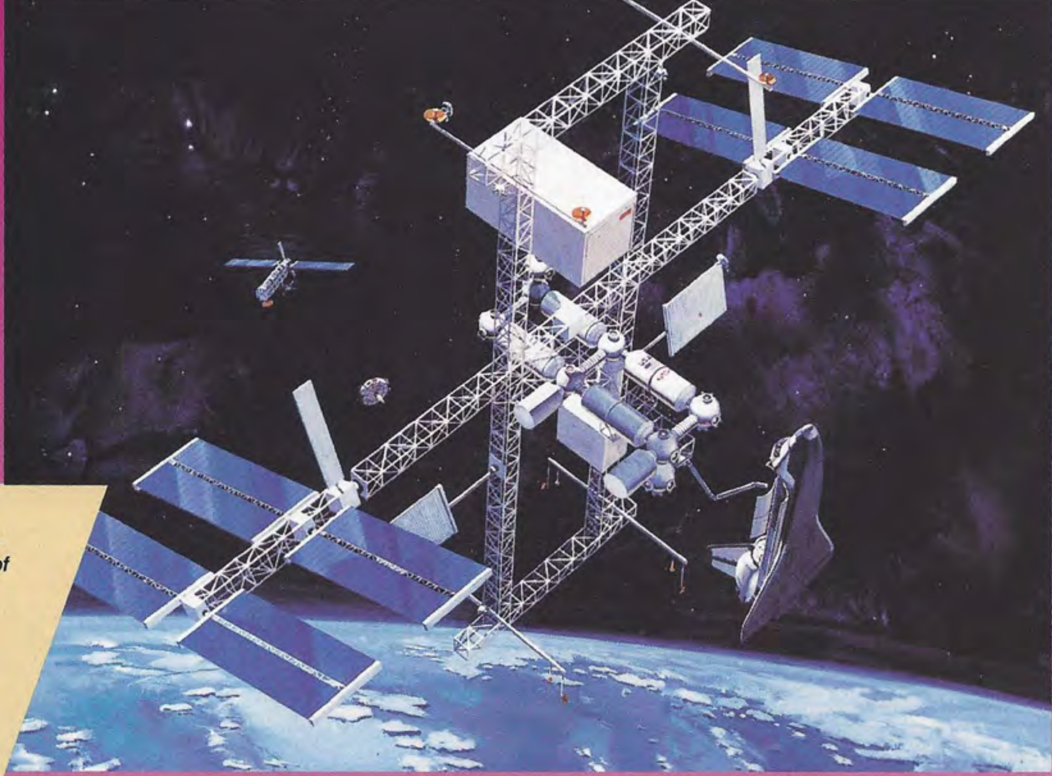
In the spring of 1984, we began the process of persuading Congress to approve the first increment of funding ($150 million in fiscal year 1985) for the space station. At the time, we told Congress that the space station would cost something like $8 billion and that we would deploy it in 1992. This would be the first step and capability would be added as funds became available. I remember then NASA Administrator James Beggs telling a congressional committee that the space station should and could be built "by the yard." What he meant was that the configuration we had selected could be expanded as new capabilities were desired and he was right. This was one of the major positive features of the baseline configuration. Congress approved our request in June 1984.

In the summer of 1984, I made the decision to leave

(continued on page 14)

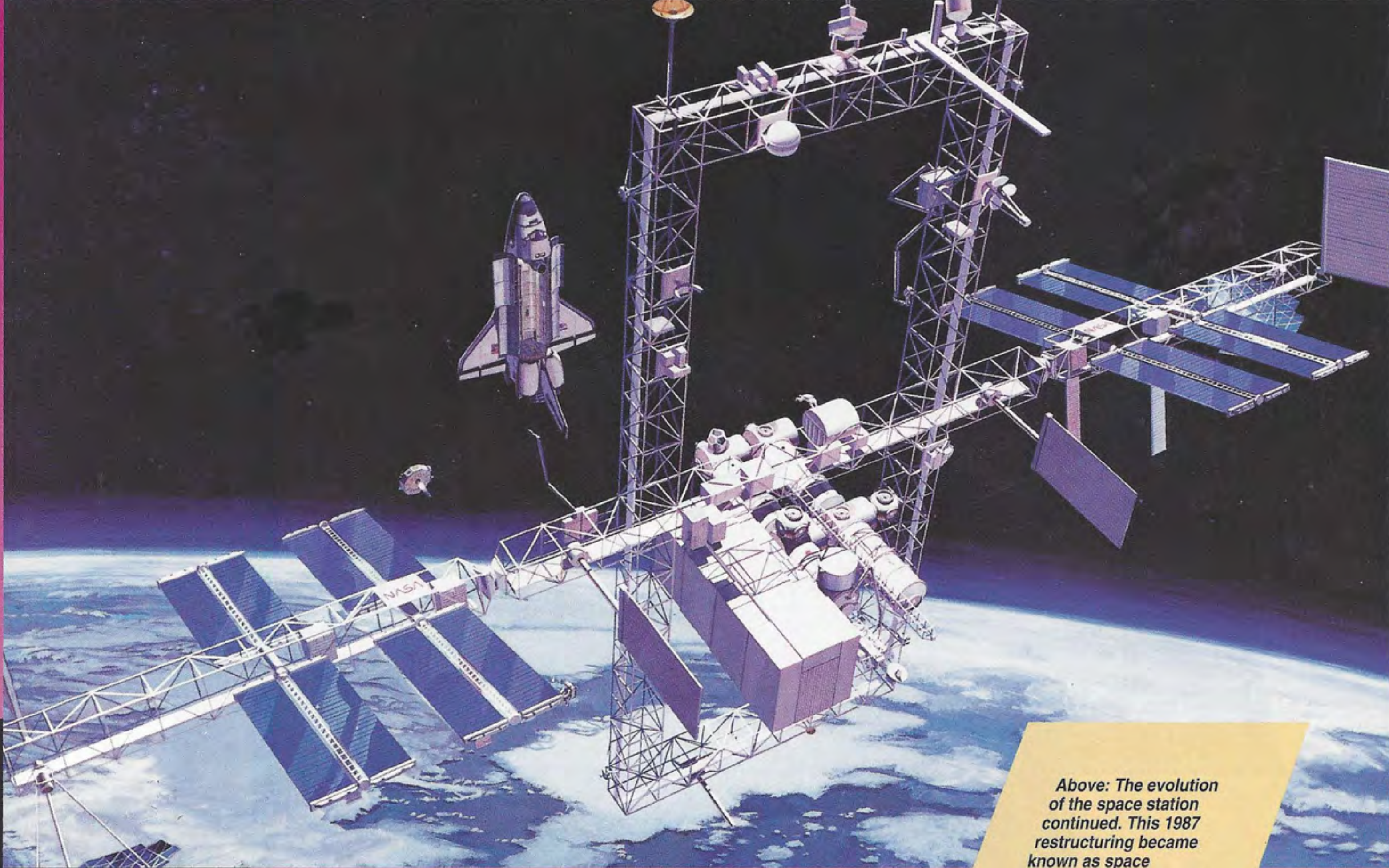


This is the baseline space station concept of 1983. At the left is one of the co-orbiting platforms. Three astronauts are shown performing EVA (extra-vehicular activity).
Painting: NASA



Right: This is the "full up" version of the space station, complete with the truss structures that were adopted after the baseline configuration was abandoned. This version dates to 1985.

Below: By 1988, the elaborate, multi-trussed structure had been simplified into a single truss design.



Above: The evolution of the space station continued. This 1987 restructuring became known as space station Freedom.

Left: Space station Freedom continued to be redesigned in response to budgetary pressures. This 1991 version is still much more complicated than the originally proposed baseline configuration.

Paintings: NASA

In 1993 the Clinton administration called for yet another redesign to simplify construction and lower cost. This illustrates the "go-slow" approach of beginning with a human-tended space station, rather than one that would be permanently inhabited.

(continued from page 11)

NASA. At the time, I thought we had accomplished our objectives and that things were in good shape. The space shuttle was on the way to becoming operational and the space station program had been initiated. It is my considered opinion that had we held to the plans that were developed in 1984 the space station would be in orbit today. Unfortunately, that was not how things turned out.

The Space Station From 1985 to 1992

Up to 1984, I was a close spectator and often a participant in the events that led to the development of the space station program. I left my post as deputy administrator of NASA in September 1984 after three and a half years in office. Therefore my knowledge of what happened after that is based not on personal experience and participation, but rather on looking at things from a distance.

In the spring of 1984, the baseline concept that had been developed in 1982 and 1983 was reconsidered. A design was studied that had a single integral structure on which the habitation modules, the power system and the experiment modules were all mounted. This created precisely the kinds of problems that Daniel Herman and his colleagues had foreseen back in 1982 when the baseline configuration was developed. Consequently, much money would have to be spent to isolate the various components of the space station from one another.

I argued against this approach, and as late as July 1984 the original baseline configuration was still NASA's official position. However, once I left NASA, the baseline concept was abandoned.

In 1985 there occurred what was essentially another major design change. My guess is that there were people in NASA who developed some unconstrained "requirements" that led to this circumstance. Many of these were quantitative "scientific" requirements (such as the maximum gravity level in the space station) that were not well justified.

The eventual outcome was what came to be known as space station *Freedom* (shown on page 13). This space station is clearly more elaborate than the one we had in mind in 1983. *Freedom* was costed out at more than twice the development cost we had given to the president and to Congress in 1984, a much different proposition from the earlier concept.

In addition to the escalation of the "requirements" for the space station program, NASA adopted a fragmented management scheme that was essentially unworkable. Instead of the single "lead center" and single "prime contractor" management method that had been traditional for large projects, a program office at NASA headquarters and a project office established in Reston, Virginia, would manage the program. The work was split into three major portions at the Marshall Space Flight Center in Alabama, the Johnson Space Center in Texas and the Lewis Research Center in Ohio. This multilayered and fragmented management structure would cause great difficulties as time went on. While I was at NASA, I argued strongly against this approach.

All of these difficulties were exacerbated by the loss of *Challenger* in January 1986. Once again, I can only speculate on what happened, but my guess is that the attention of the NASA management was so focused on making the space shuttle fly again that the space station program was left to its own devices for at least two years.

In 1989, under congressional pressure, there began a series of redesign activities in the space station program, intended to cut back the cost. None of these were really effective because they did not deal with what I felt at the time was the real problem, the management structure that had been adopted. In 1990, a committee chaired by Nor-

After the recent redesign, the Clinton administration adopted this space station design, called Option A. Note the Russian modules attached to the habitation module at the top of this picture.
Paintings: NASA

man Augustine concluded that the space station program had become unmanageable and recommended major changes. The Augustine committee did recognize the importance of continuing with the program, but criticized the way it had been conducted.

The issue of EVA was again raised during this period. My guess here is that once again people who were reluctant to conduct EVA worked out the design of the space station in such a way as to minimize EVA. This very probably added to the difficulty of deploying the space station and also added to the overall costs.

By the end of 1992, the space station program was in deep trouble. There was much criticism from Congress and from the scientific community. The general feeling was that the purpose for building the space station had been forgotten and that NASA had grossly mismanaged the program. Regretfully, I was forced to conclude that this judgment was probably correct.

The Election of President Clinton, and the Future

The advent of the Clinton administration brought some major changes to the space station program. A complete review was decided upon and a mandate was developed to reduce the run-out cost back to something close to the original $8 billion. Another external review committee was created, this time chaired by Charles Vest, president of the Massachusetts Institute of Technology.

This latest redesign attempt was more thoroughgoing than those conducted previously. NASA Administrator Daniel Goldin ordered the abandonment of the space station *Freedom* concept and a greatly reduced version of the space station was finally adopted. Most important, it was recognized by all concerned that the management method adopted by NASA was a serious contributor to the problems that had been encountered. The Vest committee was especially strong on this point, recommending that NASA select a single lead center that would manage a single prime contractor to do the job—which was the same management structure we had proposed years earlier. So after almost a decade of "work," we are essentially back to what we started with in 1984.

It is my considered judgment that what has emerged from the redesign of the space station program is the right way to go. Even so, the program is still in trouble. The House of Representatives, in its vote on June 21, 1993, approved the program by the narrowest of margins (216 to 215).

There is much work to be done to reestablish NASA's management credibility and, more important, to explain once again to the political authorities and to the general public why a space station is important. It is simply not true that there are no good reasons for building it. Too much stress has been placed on the scientific value of the work to be done there; good scientific research alone cannot justify the expenditure. The operational functions of the space station will ultimately dominate the future of our enterprise in space. That is the case that has to be made. We are making an investment here that is vital to the long-term future of the human race.

Ninety years ago, Konstantin Tsiolkovsky foresaw the real reason for building the space station: "The earth is the cradle of mankind but one cannot remain in the cradle forever."

Hans Mark is a professor in the Department of Aerospace Engineering and Engineering Mechanics at the University of Texas at Austin and a Planetary Society Advisor. He also served as secretary of the Air Force from 1979 to 1981 and as deputy administrator of NASA from 1981 to 1984.

WORLD WATCH

BY LOUIS D. FRIEDMAN

WASHINGTON, DC—A historic agreement on cooperation in space, aeronautics and Earth observation was signed by Vice President Al Gore and Russian Prime Minister Viktor Chernomyrdin on September 2, 1993.

In the agreement, which was part of a broader energy, science and missile technology control pact, the United States and Russia agreed to immediately begin cooperating in their space station programs. The Russians will in effect become full partners in the space station now being developed by US, European, Japanese and Canadian space agencies. The new plan will provide a central role for Russia's *Mir 1* and *Mir 2* stations, as well as for other Russian capability in their human spaceflight program.

Perhaps most significant was the decision announced by Vice President Gore that the new international space station would be in an orbit inclined 51.6 degrees to Earth's equator, a point whose importance was stressed in The Planetary Society's statement to Congress earlier in the year. What this decision means is that the space race is over, replaced by a joint effort centering on an international base for future human exploration and activity in space.

In recognition of The Planetary Society's 10-year advocacy of US–Russian cooperation in human and robotic space programs, Society officers were invited to the signing ceremony. Almost all of the other attendees were government officials. Society President Carl Sagan, Vice President Bruce Murray and Executive Director Louis Friedman were present, along with Advisors John Logsdon and Roald Sagdeev.

The criticisms leveled at the Society's stand on the space station over the past few years now seem a distant memory, as the new space station plan with its lower cost, modular design and international context is what we had been advocating. We believe that it will significantly bring closer the day that human exploration of the solar system can occur.

Unveiled at the signing agreement was a three-phase station approach. The first phase would be a relatively simple docking of the US space shuttle with *Mir*. This would permit early US experience with long-duration life science effects, since astronauts would be able to stay on *Mir* for longer periods of time than currently possible in the US program.

The second phase would provide an interim human-tended space science capability by using both the *Mir* module and a new US laboratory module. The third phase would see the construction of a larger structure, with a permanent human-tended capability, that would include the modules being developed in Europe and Japan, as well as the Canadian robot arm.

The agreement also included a directive to expand cooperation in environmental observation from space and in space science, calling for the initiation of joint studies. This, together with additional agreements in the aeronautical sciences, outlines a broad and comprehensive role for the new partnership.

Vice President Gore stated that in addition to lowering costs in the US, the agreement would permit earlier realization of space station objectives, including those connected with microgravity experiments by humans in space and the long-duration life sciences investigations.

The House of Representatives and the Senate have now agreed on space station funding and on most aspects of the redesign, but the cooperation agreement is being criticized by some staffers in Congress, who are trying to keep the US space station going without Russian cooperation. These staffers also fear that priority will be given to the life sciences on the space station, preferring instead the development of hypothetical commercial applications—applications we believe are better developed in a robotic laboratory in Earth orbit, without the interfering effects, costs and risks of human presence. Some American aerospace firms have been lobbying against the agreement because they fear it will lead to a short-term decline in contracts.

Watching congressional action on the station is confusing, since the administration and NASA have had to work on two simultaneous tracks—with and without a major Russian involvement. The redesign reported in the previous issue of *The Planetary Report* could not include the Russians because the agreement had not yet been made. But the redesign still had to go ahead to meet the realistic cost constraints defined by the administration.

The design selected by President Clinton this past July has been modified to fit into the three-phase approach. The new design, called *Alpha,* could use a US module should the agreement with Russia break down. But Congress has before it, in the bills submitted prior to the agreement, the older redesign.

The differences between the administration plan and the plan before Congress will be settled after the budget is passed. The role of Russia in the US program will be the subject of subsequent congressional hearings, at which The Planetary Society will testify.

Louis D. Friedman is Executive Director of The Planetary Society.

A Special Opportunity

We'd like you to join us in Washington, DC, next July for a special Planetary Society tour and celebration in honor of the 25th anniversary of *Apollo 11.*

We have several public events planned to commemorate this historic mission, as well as activities relating to the predicted impact of comet Shoemaker-Levy 9 with Jupiter.

Trips are planned to sites with special appeal for our members, like the National Air and Space Museum and NASA Goddard Space Flight Center, as well as to historic landmarks and places of interest.

Tour brochures will be available soon. For more information, call Sam Shah at Advanced Travel, 1-800-292-0650.

Awaiting the First Explorers: Society Members' Names to Be Archived on Mars

by Charlene M. Anderson

There has been an exciting development in the upcoming *Mars '94* mission. When the *Mars '94* landers touch down on the Red Planet, each one will be carrying a very special cargo: a microdot bearing the names of all Planetary Society members as of October 15, 1993.

This is a tremendous gesture of thanks to our members for the unflagging support you all have given the *Mars '94* and *'96* missions. Your name will be recorded for posterity as one who helped make human exploration of Mars possible.

The microdot will also carry the instructions for retrieving and playing a Society-created CD-ROM entitled *Visions of Mars*, which will be stowed inside each lander and will hold a collection of the best science fiction and art relating to the Red Planet. This CD is a tribute from our generation of explorers to the writers and artists whose works inspired so many of the scientists and engineers who have made planetary exploration their lifework.

Visions of Mars is also a gift to the future generation of Mars explorers, who, we hope, will one day retrieve it from the *Mars '94* craft. It will be their library to remind them of how we once envisioned Mars.

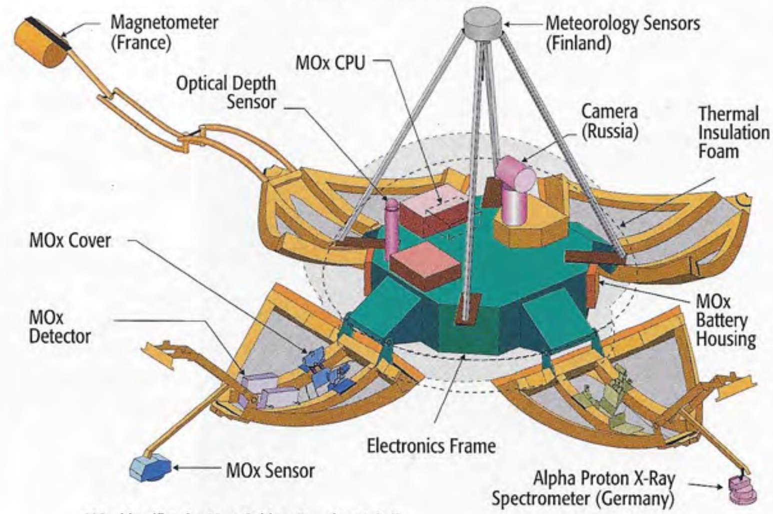
The Russian Space Agency is cooperating with the Society on the project. Viacheslav Linkin, chief lander scientist on the mission for the Russian Space Research Institute, is our liaison.

Mars '94 will send an orbiter, two penetrators and two small landing stations to Mars. *Mars '96*, carrying the Mars Balloon and the Mars Rover to the planet's surface, will follow it.

The idea for encoding our members' names on the microdot arose during discussions with the Microdevices Laboratory at the Jet Propulsion Laboratory in Pasadena. We were looking for a way to attach the instructions for the CD to the skin of the spacecraft. The JPL researchers told us that by using electron-beam lithography they could inscribe all the instructions we required on a 1-millimeter-square microdot, with room to spare—enough room for the equivalent of 100,000 names. We knew immediately which names we would want to include.

The innovative JPL team has even found a way to turn our martian library into a scientific instrument platform. Using microelectronics developed for the Strategic Defense Initiative Organization (now the Ballistic Missile Defense Organization), they may be able to attach scientific instruments to the silicon chip that holds the microdot and take measurements of the martian atmosphere and the radiation falling on the planet.

Mars '94 Lander



MOx identifies the Mars Oxidant Experiment (US)
Illustration: Sandia National Laboratories

Mars '94 Mission Scenario

Launch:	*October 1994*
Flight duration:	*315 Earth days*
Arrival at Mars:	*September 1995*
Mission components:	*One orbiter* *Two small landers* *Two penetrators*

Selected Scientific Objectives

Surface:	*Topographic mapping* *Mineralogical mapping* *Elemental composition of soil* *Structure and extent of permafrost*
Atmosphere:	*Climatic changes* *Abundance and distribution of atmospheric constituents* *Plot of temperatures and pressures* *Features near volcanoes*
Internal structure:	*Thickness of crust* *Magnetic field* *Seismic activity* *Search for active volcanoes*

If we are able to include this scientific package, the CD will be not only a repository of earthly literature and art, but also a source of valuable scientific data for whoever finds it.

The Time-Warner Interactive Group is manufacturing the CD-ROM for inclusion on the small landers. Jon Lomberg is directing production of the CD for the Society and Gene Giberson is the technical director for the project.

By the time of the *Mars '94* scheduled launch, in October of 1994, we will have replicas of *Visions of Mars* available to Planetary Society members and the general public.

In 1981, science fiction author Ray Bradbury wrote a short piece for *The Planetary Report* entitled "We Are the Martians." With *Visions of Mars* and the microdot containing Planetary Society members' names, we are beginning to prove that he was right.

Charlene M. Anderson is Director of Publications of The Planetary Society.

A Planetary Readers' Service

Our Planetary Readers' Service is an easy way for Society members to obtain newly published books about the science and adventure of voyages to other worlds.

We make these books available at the lowest possible prices. Each title is offered for six months, or three issues of The Planetary Report. *We keep rotating our stock so that the titles we offer are always fresh.*

Tales of the Earth: Paroxysms and Perturbations of the Blue Planet

By Charles Officer and Jake Page;
Oxford University Press, New York, 1993, 226 pages, illustrated.
Retail price: $24.00
Member price: $21.00

In case you hadn't noticed, the home planet's unstable. Volcanoes, earthquakes and floods wipe out thousands of livelihoods, not to mention lives, with little warning and disquieting frequency. But in between these internally generated cataclysms, Earth's a lovely place to live.

As for external threats, those asteroids that have been posited as periodic visitors, not to worry. Charles Officer and Jake Page, earth scientist and science writer, respectively, gleefully point out that all of the trendy dinosaurs lived—and died—over a 160-million-year sweep and never were exterminated by a single event, not even an extraterrestrial one. They offer climatological and geological explanations for the disappearance of *Triceratops* and take the minority position, explaining the iridium layer—a widespread rock layer with an unusually high concentration of the rare element iridium, used by catastrophists as evidence of meteoric visitation—as the product of particle fallout from volcanic eruptions.

Their *Tales of the Earth* is reader-friendly, with just the right mix of solid data, anecdote and humor. The authors are not a bit awed by a scientific establishment that "ambushed" Alfred Wegener's 1912 treatise on continental drift at a 1926 meeting of petroleum geologists.

They look askance at the conservative, turf-protective scientific elite, but they delight in the achievements of scientists who blend climate studies, atmospheric explorations and volcanology to provide fresh explanations for historical disasters as well as for potential global change, including the much-mentioned greenhouse effect and the ozone problem: "too much of the right stuff in the wrong place [the Los Angeles basin] and not enough where we need it [over Antarctica]."

They take the long view—the life history of Earth, and the Moon, too—and interpret recorded history beginning with the legend of the sinking of Atlantis and the Exodus from Egypt. They connect these events with the eruption of the volcano on the Greek island of Santorini, which triggered tsunamis (tidal waves) as far away as the Sea of Reeds, the site of the Suez Canal.

Always skeptical, they remind us that "for every complex problem, there is a solution that is simple, neat and wrong." They are also mindful that correlation is not causation. By chance, for instance, Stanford physicists noted especially loud background radio noise prior to the 1989 Bay Area earthquake. Is there a connection? The jury is still out.

Where the jury is in (and extensively documented) is the role we humans are playing in eradicating other forms of life, and perhaps even making Earth—the only planet known to support life—uninhabitable for ourselves. Officer and Page believe that, by setting priorities, people can solve the problems people created.

In an era of funding limits, they declare, we can't learn everything, so they have listed areas of scientific ignorance, including the exact series of events in the life and death of stars, what makes a sociopath, how the universe began, how to irrigate land without ruining it in a few centuries or less. A loaded list. They suggest triage, funding only life-sustaining sciences.

They implicitly challenge the timeliness of a trip to Mars or the construction of a space station. Members of The Planetary Society may well dispute their priorities, and not a few could make a good case for including planetary exploration in a program to save life on Earth.
—Reviewed by Bettyann Kevles

<u>Still Available:</u>

To a Rocky Moon: A Geologist's History of Lunar Exploration,
by Don E. Wilhelms.
A highly personal story of the Moon race, mission by mission, by a geologist who was involved from the start.
(Reviewed July/August 1993.)
Retail price: $29.95
Member price: $24.00

The Evening Star: Venus Observed,
by Henry S.F. Cooper, Jr.
One of the best space science writers of our time chronicles the Magellan *mission to Venus.*
(Reviewed September/October 1993.)
Retail price: $22.00
Member price: $19.00

To Place Your Order:

Please send a check or money order, made out to The Planetary Society, for the price of the book (in US dollars) plus, for each book, a shipping and handling charge of $2.50 for the US, Canada and Mexico, $5.00 for other countries. Address your envelope to: Planetary Readers' Service, 65 N. Catalina Avenue, Pasadena, CA 91106.

For faster service, order by telephone with your Visa, MasterCard or American Express card. Call (818) 793-1675 from 9:00 a.m. to 5:00 p.m. Pacific time.

All books sent postpaid. Please allow 4 to 6 weeks for delivery in the US, Canada and Mexico, 12 weeks for delivery to other countries.

News & Reviews

by Clark R. Chapman

In the aftermath of the *Mars Observer* tragedy, NASA is once again struggling to define itself and find a pathway to the stars. One challenge is to manage the technological complexity of space operations in a cost-effective yet reliable manner. Its other big challenge, since the heyday of the *Apollo* program, is what President Bush called "the vision thing." Despite gold-ribbon panels and glossy reports, NASA still hasn't defined the overarching themes that will shape its goals for the 21st century.

A year ago I met with NASA's administrator, Daniel Goldin, and I sense that he is a man of vision. But, after a year and a half on the job, he has been unable to translate his personal dreams into a vision that can motivate the bureaucracy he runs. Instead, NASA's energies are consumed by trying to get the shuttle to be reliable, redesigning the space station (yet again) to meet ever-changing political "realities" and recovering from past mistakes and accidents.

Biospherians Re-emerge

In contrast, there is a non-NASA enterprise that unquestionably has vision: Biosphere 2. Eight "biospherians" emerged recently after two years of encapsulation within a (nearly) closed 3-acre environment, located a scant 20 miles from my home near Tucson. The gleaming structure of glass and steel amid the Arizona chaparral is conceived by some of its builders as a precursor for a self-sustaining habitat on Mars—or elsewhere in space.

The goal is grandiose, but it is impossible to be on the grounds of Biosphere 2 and not be struck by the power of the dreams of the people who, with no taxpayer funds, built this living monument to the future. A few weeks before he emerged with his seven colleagues, I had a lengthy telephone interview with Mark Nelson, director of environmental applications for Space Biospheres Ventures, the private organization that built and operates Biosphere 2. (The passage of many important things, like food, between the interior and the outside world is strictly controlled, but other things—including "information," like telephone calls—flow freely.) Although the project has captured the imagination of enough people to make it the number two tourist attraction in southern Arizona, Nelson is most pleased by the outpouring of enthusiasm from schoolchildren.

Not all, or even most, of the public interest in Biosphere 2 has been positive, however. Following a slashing attack in *The Village Voice* two years ago, much of the local and national coverage of the project has been highly critical. The media are determined to find fraud at the Biosphere, but I think SBV's major failing was its original naïveté about press relations. Reporters have written exposés about things coming and going through the air lock. They have overlooked the more significant news about just how tightly sealed the Biosphere has proven to be: There has been less than 10 percent annual interchange with outside air, far better than has been achieved in previous facilities.

Oxygen Depletion

There *have* been surprises, of course. Biosphere 2 is a complex assemblage of ecosystems whose evolution was impossible to predict. There were conjectures, naturally, but a major purpose of the experiment was to see what happened that was unexpected. Many scenarios for disaster never materialized, and many of the elaborate biotechnologies tested in the Biosphere worked well (the waste-recycling system, for example, has "worked like a charm," according to Nelson).

But nobody thought that oxygen levels would drop continuously by 0.25 percent per month. That made necessary the injection of fresh oxygen, which couldn't be done on Mars, of course. But it neither means that there has been fraud nor that "the experiment failed." Little in science turns out as expected, and the essence of science is to try to understand why. In fact, researchers at Columbia's Lamont–Doherty Laboratory, trying to explain the oxygen loss, have developed some hypotheses about processes of carbonation involving concrete in the Biosphere, which may have much broader applications.

I have read through a pile of reprints and preprints that Nelson sent to me. It is clear that Biosphere 2 fosters an active research environment and that preliminary results are being communicated with the broader scientific community. The studies document the nutritional needs of human beings in a tightly controlled environment, describe changes in the miniature ecosystems within the Biosphere and investigate various bioregenerative technologies.

Having toured inside Biosphere 2 twice before closure, I am most impressed by Mark Nelson's descriptions of changes—and lack of changes—within the individual biomes. I would have expected weeds and bugs to proliferate during two years, at the expense of many of the 3,000 species originally represented at closure. But, with minimal intervention by the biospherians, little has been lost—only one species of 40 in the coral reefs, for example.

Biosphere 2 is only one approach and only the first step up a long staircase to living on Mars. But Nelson is optimistic, from some of the early results, about applications in space, and he notes that many of the systems within Biosphere 2 can be miniaturized. Most important of all, however, is that the biospherians have a planetary vision, and they are actually doing something about it.

Clark R. Chapman, who is on the imaging team of the Galileo *mission, has been studying the first picture recently returned of the asteroid Ida.*

Questions & Answers

Would it be better to redirect an incoming asteroid to land in the ocean or on dry land? Wouldn't an oceanic impact be the worst possible scenario, causing tsunamis (tidal waves) thousands of feet high, and wiping out coastal cities in both hemispheres?

If an asteroid about 8 kilometers (5 miles) in diameter were headed for Houston (where I live), wouldn't we be better off redirecting it to, say, Dallas instead of the Gulf of Mexico? What could we expect from either event?

—David Chisholm, Houston, Texas

If it is already too late to redirect the threatening asteroid away from our planet, it might be worse to attempt a hasty redirection than to just let the body hit. Then, at least, we could better predict *where* it would hit, and we could mitigate the consequences (by evacuating the area, for example). We would also avoid worse consequences (that is, if our attempts to change its course instead broke it into several large pieces; they might hit Dallas, Houston and, even worse, *my* house in Tucson).

The consequences of impact depend on the *size* of the body and on just *which* part of Earth's land or oceans is about to be struck. It hardly matters for a comet or asteroid as large as the Cretaceous/Tertiary (K/T) impactor, the one that struck the Caribbean 65 million years ago and caused the extinction of the dinosaurs. (It was probably at least 10 kilometers, or about 6 miles, in diameter.) The oceans would be "thin" to such an impactor, and most ejected material would be from beneath the ocean floor. The environmental consequences would be numerous and severe, any few of which would result in a global holocaust.

Even for a K/T-size impactor, however, the impact locality may affect exactly what happens. For example, the K/T impactor apparently struck an area having an unusually high concentration of carbonate rocks, liberating more carbon dioxide into the air than would normally be the case.

If the impactor is only tens of meters in diameter, similar to or smaller than the objects that made Meteor Crater or caused the Tunguska explosion in 1908, then the dangerous consequences would be entirely local; indeed, they would be catastrophic if the target happened to be a major metropolitan area. Or it could be like Tunguska in Siberia, which apparently caused not a single death. Such an impact into the ocean would mean doomsday for a nearby ship, but probably would not generate tsunamis large enough to affect distant coastlines.

An ocean impact by an intermediate-size impactor several hundred meters across, however, would generate tsunamis that could be devastating at great distances from the impact point. A land impact by such an object could—if it struck a populous country or province—produce horrifying regional consequences, even though global effects would be minimal.

FACTINOS

A group of US and French scientists has discovered that Pluto is covered by surface ices that are 98 percent nitrogen. "Rather than methane as previously thought, it appears that frozen nitrogen dominates the surface," said Ted Roush of NASA's Ames Research Center. This is the first clear indication of the element on the tiny planet and the first clear indication that its atmosphere is mainly nitrogen gas rather than methane. Carbon monoxide was also detected for the first time.

The nitrogen had not been identified before now because it is a poor absorber of sunlight and it produces very weak spectral absorptions in the light reflected from the planet.

The observations were made in Hawaii with a new instrument on the United Kingdom Infrared Telescope. The results were published in an August issue of *Science*, along with observations of Neptune's moon Triton. Because their surfaces are made of similar materials, scientists think Pluto and Triton could have formed in similar locations in the solar nebula.

—from NASA

❖

Astronomers can quit searching for Planet X because it isn't there! That is the conclusion of a new study of solar system measurements.

For 50 years stargazers have hunted for the solar system's hypothetical 10th planet. But a new study of the outer planets shows that the long chase, based on presumed wobbles in the orbits of Uranus and Neptune caused by a planet, stemmed from erroneous observations and calculations.

E. Myles Standish of the Jet Propulsion Laboratory recalculated the motions and masses of the outer planets and found that they are moving just as one would expect without another large planet's gravity tugging on their orbits. His analysis is the first to make use of an extremely accurate measurement of Neptune's mass made by *Voyager 2* in 1989.

—from Malcolm M. Browne in *The New York Times*

❖

The Solar Anomalous Particle Explorer (SAMPEX), a joint United States–German satellite launched last year, has identified a new radiation belt around Earth that holds an exotic collection of matter from outside our solar system (see illustration at right).

"What's exciting about this is that

It might seem useful, then, to divert an object from an ocean impact toward an unpopulated desert. But if we had time to do that, we would probably have time instead to completely evacuate shipping lanes and coastal regions; destruction of coastal infrastructure by the tsunamis would still be massive, but loss of life could be kept to a minimum.

Of course, we must keep a sense of perspective. The chances of a damaging impact by an intermediate- or large-size asteroid are very small. Although the frequency of impacts by Tunguska-size bodies is much greater, other natural hazards that are just as deadly (like earthquakes and floods) happen at least a hundred times more often.
—CLARK R. CHAPMAN,
Planetary Science Institute

Why can't we use satellites to send the abundant and harmful ozone from smog up into Earth's stratosphere to help plug up the ozone hole(s)? This way two problems could be solved at once.
—Terry Manion,
Yucaipa, California

The power level associated with the natural formation of stratospheric ozone by the action of solar ultraviolet radiation on the atmosphere is about 24 terawatts (a terawatt is a million million watts). The power level for *all* human activities (coal, oil, gas, nuclear, hydro, and so forth) is about 10 terawatts. The natural system is just too massive to be significantly supplemented by humankind.

The difference between creating and destroying ozone is in the energetics. Energy is required to make ozone (O_3) from molecular oxygen (O_2). However, no energy is required for the conversion of O_3 back to O_2 because that process is downhill energetically.

Ozone is formed one molecule at a time. But the chlorine chain reaction partially responsible for depleting Earth's ozone layer can destroy thousands of ozone molecules in rapid succession at no energy cost, because each reaction step actually releases energy. This happens when the chlorine atoms from chlorofluorocarbons that reach the upper atmosphere act as catalysts in a complex set of reactions that convert two molecules of ozone to three molecules of ordinary oxygen, depleting the ozone layer faster than it can be replaced by natural processes.

The ozone concentrations in the stratosphere are higher than those in the atmosphere over Los Angeles, so the actual direction of net ozone flow from the stratosphere is downward. An ozone concentration of 120 parts per billion leads to a smog alert at ground level, while normal (no hole) concentrations of 5,000 parts per billion can occur in the stratosphere. The greatest concentrations of ozone are found at altitudes near 18 kilometers (10 to 12 miles), where the atmospheric pressures and densities are about one-tenth of surface values. These pressures are still much too high for satellites to operate in, even if the proposal were otherwise satisfactory.
—F. SHERWOOD ROWLAND,
University of California, Irvine

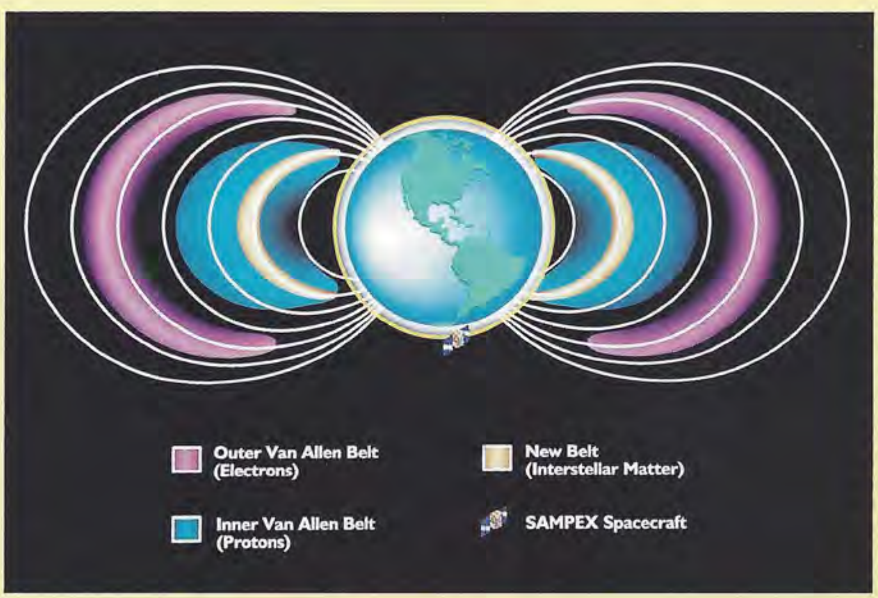
Using the solar wind as a propellant, how large would a solar sail have to be to get a space environment the size of* Skylab *to a planet like Mars?
—Clinton D. Stallings,
Ridgecrest, California

The solar wind is not the major force that propels a solar sail. The force from the solar wind is about 1,000 times weaker than that from the sunlight pressure that is created by the photons that hit the large reflective area of the sail and bounce off as reflected light. The momentum imparted to the sail by this process is what actually propels it. The solar wind is created by electrons and other atomic particles that travel much more slowly and with less energy than sunlight.

To carry a vehicle the size of *Skylab* to Mars, the sail would have to be huge—on the order of 60 square kilometers (about 25 square miles) in size. This is much larger than is practical now—but in principle such a sail could be constructed in space in the future.
—LOUIS D. FRIEDMAN,
Executive Director

it's a sample of matter from a place that we'd like to be able to study. We'll be able to do it because it's right here," says Jay R. Cummings, a space physicist from the California Institute of Technology and a member of the satellite team.

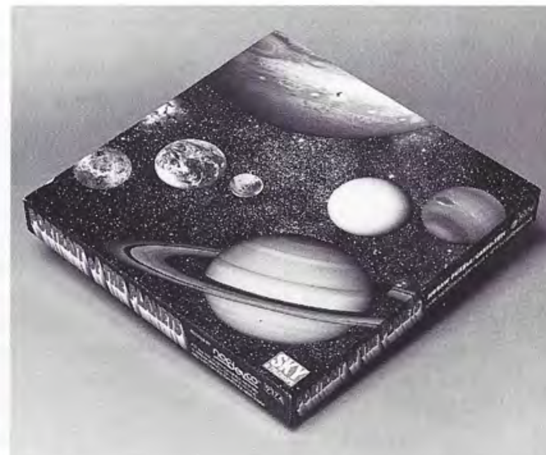
The newly discovered radiation belt joins two others discovered in 1958 by James A. Van Allen of the University of Iowa. All three belts contain electrically charged particles that have become trapped by Earth's magnetic field. The outer Van Allen belt holds mostly energetic electrons, while the inner one contains mostly fast-moving protons. The new belt sits inside the other two and stores energetic ions of oxygen, nitrogen and neon, says SAMPEX scientist Richard A. Mewaldt of Caltech.
—from R. Monastersky in *Science News*

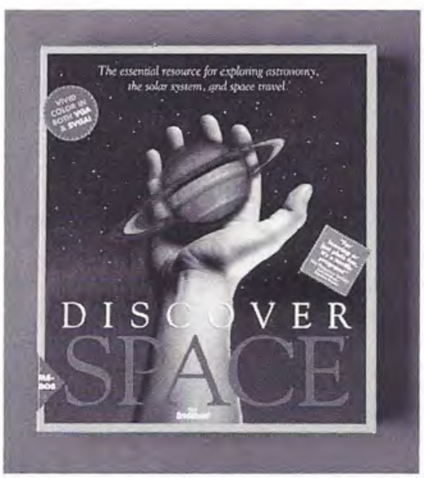


The newly discovered radiation belt (yellow) is most intense above an 8,050-kilometer (5,000-mile) strip of Atlantic Ocean between the southern tips of South America and Africa. The rays are strongest here because Earth's magnetic field is not centered perfectly, and this is where it allows the trapped particles to get closest to the planet's surface.
Illustration: NASA

Holiday Gift Guide!

Make this holiday season fun and easy by shopping with The Planetary Society. Use this gift guide and the catalog (in the September/October 1993 issue of <u>The Planetary Report</u>) to make everyone on your list happy!





Clockwise from lower left:

Galileo: Earth and Its Moon
Galileo looked back and captured this image of Earth and its Moon from 6.2 million kilometers away. 18" x 24". 2 lb. **#318 $8.50**

Discover Space
Discover Space is the essential resource for exploring astronomy, the solar system and space travel. Endorsed by The Planetary Society. IBM/Tandy-compatible software—requires 16 MHz 386SX or faster and hard disk with 7 MB hard disk space. Sound card recommended. (Please specify 3 1/2" or 5 1/4" disks.) 2 lb. **#720 $49.00**

Children's Solar System T-Shirt
Children can learn about the solar system the fun way! 50/50 heavy-weight cotton/poly. Sizes S, M, L. 1 lb. **#668 $11.00**
Now available in adults' sizes S, M, L, XL. 1 lb. **#667 $14.00**

Puzzle—Portrait of the Planets–_NEW!_
Piecing together this 18" x 24" puzzle will prove to be a truly cosmic experience. 500 pieces. 3 lb. **#556 $11.95**

Hugg-A-Planet Earth
Show your love for your native planet, or one near you. Hugg-A-Planet Mars will also be available through December 31, 1993.
Earth—14" diameter. 2 lb. **#526 $15.00**
Mars—8" diameter. 1 lb. **#528 $13.50**

Accessories
Planetary Society collectibles make it fun and easy to display your membership with pride!
Planetary Society Mug 2 lb. **#580 $7.00**
***Special Offer!* Four Mugs** (8 lb.) **for $24.00!**
Planetary Society Key Ring 1 lb. **#677 $4.75**
Planetary Society Pin 1 lb. **#670 $3.00**

The items shown on these two pages are just a selected few of the products available at The Planetary Society. Refer to your catalog for a full listing and photographs. If you don't have a catalog, phone 818-793-1675 and we will send one to you. Use the order form inserted in the center of the magazine to place your order through the mail.

Above and clockwise:

Argus Calendar–*NEW!*
In Greek mythology, Argus is the many-eyed watchman of the gods. On the *Mars '94* spacecraft, Argus is a multifunction imaging system that will investigate the martian surface. This 23 1/2" x 33" souvenir poster, printed in Russia, promotes this innovative instrument with a 1994 calendar in both Russian and English. 1 lb. **#304 $7.00**

NightStar Legend–*NEW!*
The NightStar Legend is imprinted with drawings of all 88 constellation figures. 2 lb. **#559 $26.95**

Star Theater
Star Theater projects stars, planets, constellations and their names on your ceiling and walls. Included is an exciting 56-minute audiocassette on myths and legends of the night sky, along with an illustrated activity guide. 2 lb. **#669 $32.00**

The Game of Space
A challenging, fact-filled game for ages 10 and up. Two to six people can play. Similar to Trivial Pursuit. 2 lb. **#522 $10.00**

Outta This World Magnets
Use these colorful magnets to post messages for your family on your refrigerator or just as decoration.
1 lb. **$2.50 each**
#549 Moon
#550 Earthrise, *Apollo 8*
#551 Aldrin on Moon's Surface
#552 Mother Earth
#554 Saturn
#555 Jupiter and One of Its Moons

Need More Gift Ideas?

Dance of the Planets
Dance of the Planets combines art and science to produce a unique, dynamic model of the solar system. IBM-compatible software—requires 80x86 CPU, DOS 3.X or higher, 640K RAM, EGA or VGA graphics, hard drive. Math co-processor recommended.
(Please specify 3 1/2" or 5 1/4" disks.)
2 lb. **#715**
Special Holiday Offer—**$135.00**
(Offer expires December 31, 1993.)

Spacecraft Science Kits
Build your own spacecraft and learn how it works. All models are accurate representations of the robots now exploring the universe.
1 lb. **$14.00 each**
#525 Hubble Space Telescope
#538 *Magellan*
#560 *Voyager*
#524 *Galileo*

Puzzle—A View to Earth
This 1,200-piece full-color jigsaw puzzle has been produced from a photograph taken by the *Apollo* astronauts as they looked back on Earth, with the Moon in the foreground.
2 lb. **#502 $16.00**

Planetary Society Fashions
Whether you're trying to stay cool or keep warm, The Planetary Society has the fashions for you. Sizes S, M, L, XL.
1 lb. for all shirts, 2 lb. for sweatshirt.

#517 Climb Olympus $14.00
#651 Surf Titan (long sleeve, navy blue) $20.00*
#530 Mars (black) $18.00
#531 Mars Observer (black) $16.00
#568 Dive Europa (ash) $14.00*
#553 Ski Mars $14.00
#532 Mars Rover $14.00
#630 Mars Balloon $14.00
#665 Planetary Society T-Shirt (black) $16.00
#664 Planetary Society Sweatshirt (ash) $21.00
**M, L, XL only.*

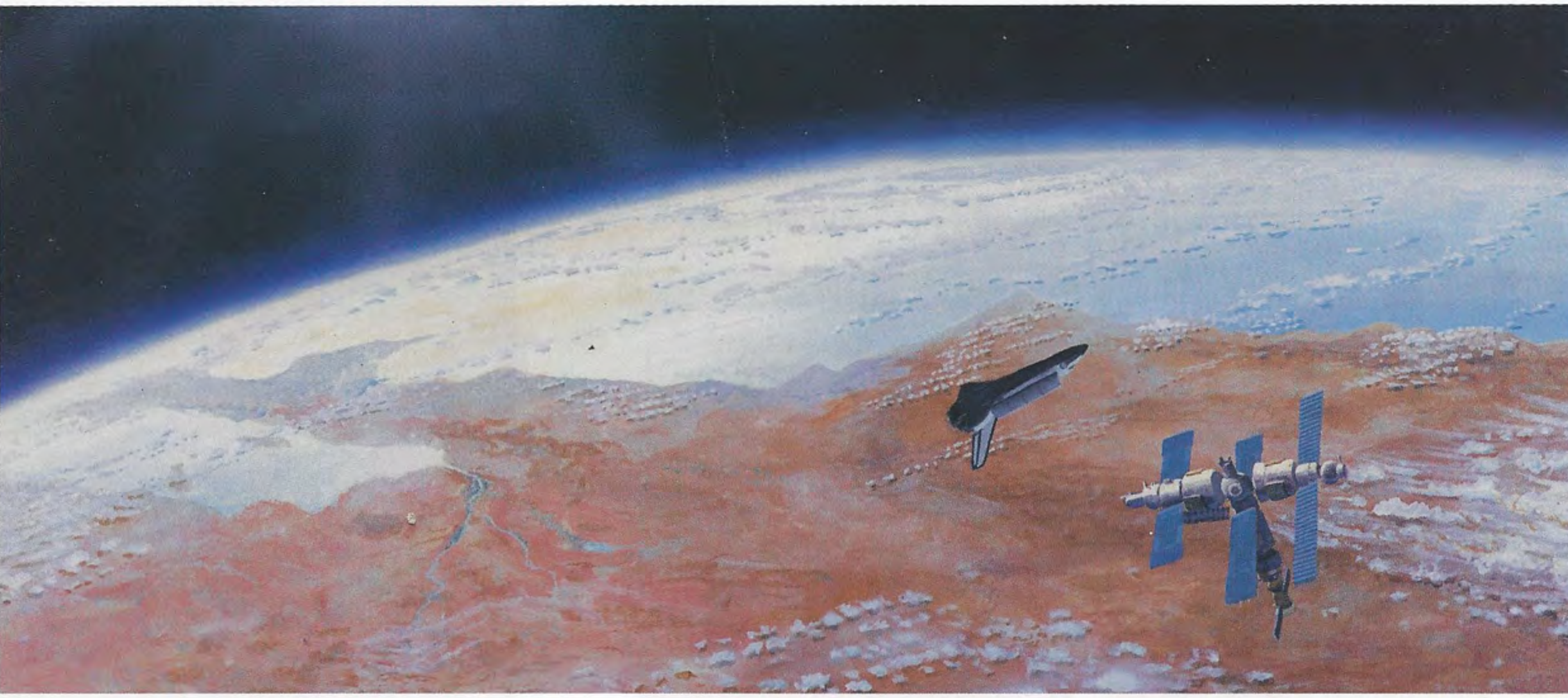
Two Faces of Mars
These images of Mars were taken in 1980 by the *Viking 1* orbiter. 22 1/2" x 29" poster.
1 lb. **#339 $5.00**

Meteorites
Perfect addition to any study or classroom shows a vivid illustration of a fiery meteor hurtling toward Earth. 22 1/2" x 29" poster.
1 lb. **#328 $9.00**

Just for the Holidays:

Selected Planetary Society merchandise will be available at the United Nations store in Pasadena. We invite our Southern California members to stop by. Be sure to bring your Planetary Society membership card to receive your member discount.

United Nations Association – USA
763 East Green Street
Pasadena, CA 91106
818-449-1795



"RENDEZVOUS AT LAST." A United States shuttle prepares to dock with Russia's Mir *space station. The scene is set over Arizona, looking southwest, with the Pacific coast, Los Angeles and Baja California in the background.*

William K. Hartmann is known internationally as a planetary astronomer, writer and painter. Asteroid 3341 is named for him in recognition of his work on planetary evolution, asteroid-comet relationships, and lunar origin. He is also a lead consultant on The Planetary Society's education initiative.

THE PLANETARY SOCIETY
65 North Catalina Avenue
Pasadena, CA 91106

NONPROFIT ORG.
U.S. POSTAGE
PAID
THE PLANETARY SOCIETY

PRINTED ON RECYCLED PAPER
Printed in USA