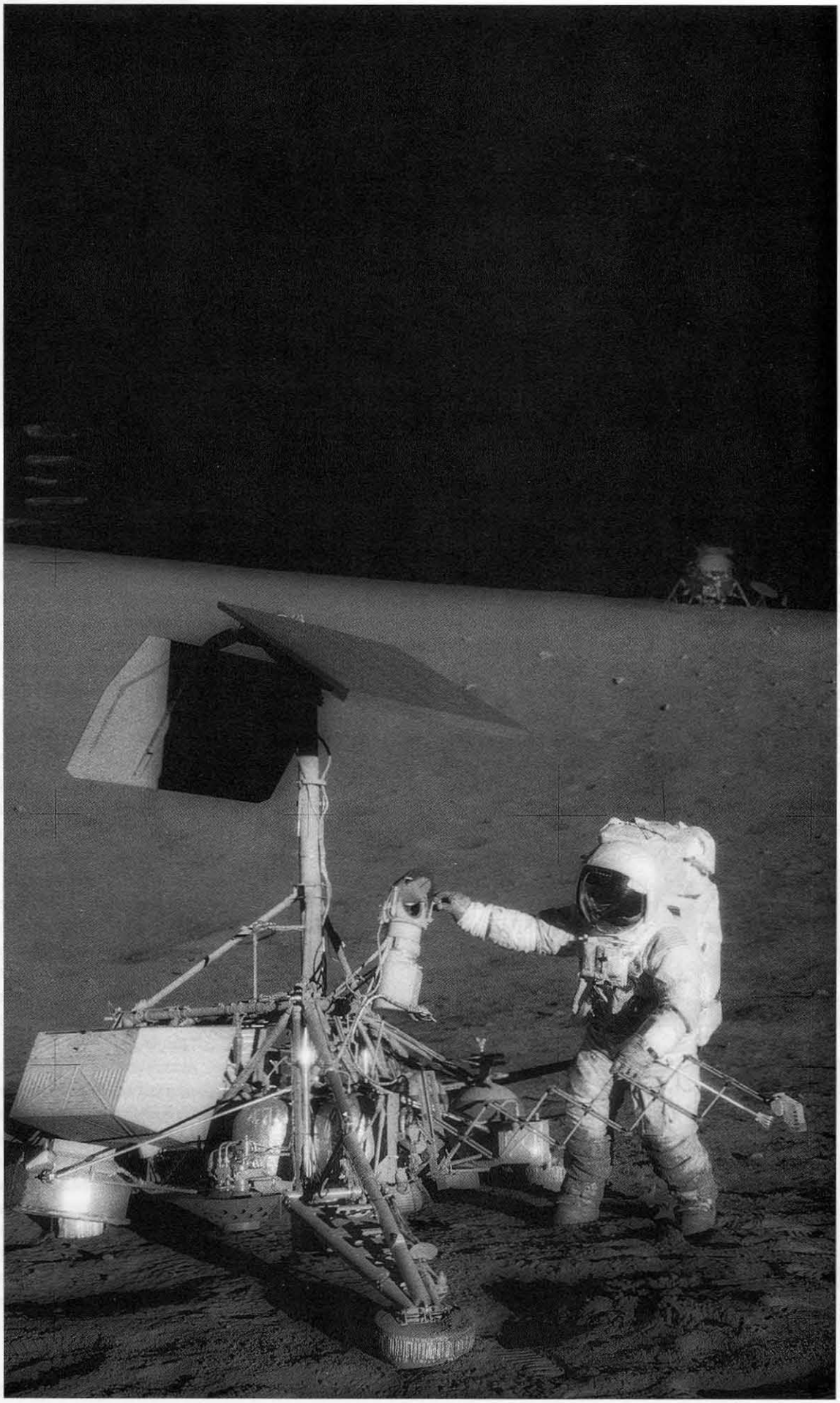


The Future of Planetary Exploration

Goldin: It's an opportune time for change because our world is changing. The Berlin Wall came down and it changed everything.

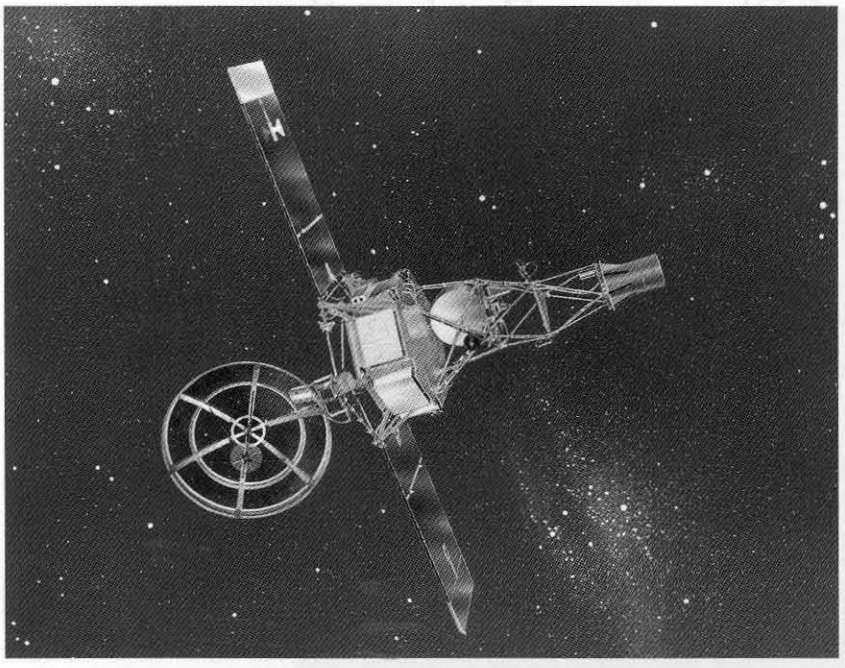
On December 4, 1992, NASA Administrator Daniel Goldin and Planetary Society President Carl Sagan, of Cornell University, debated the future direction of America's space program before throwing the floor open to questions from the audience. The program, adapted for this article, was organized by the Pasadena-based Planetary Society, of which Sagan is a co-founder, and held at Caltech's Beckman Auditorium. The venue was particularly appropriate, as Caltech manages the Jet Propulsion Laboratory (JPL), whose bailiwick includes exploring the planets using unmanned spacecraft, for NASA.

Days of future passed: Astronaut Charles Conrad, Jr., inspects the Surveyor 3 spacecraft on November 19, 1969—942 days after it soft-landed in the Ocean of Storms (Oceanus Procellarum). Apollo 12's lunar module can be seen in the background, 200 yards away. If NASA "returns to the days of Apollo," as Goldin put it, and humans follow robots to Mars, this scene may be replayed with a Viking lander.

Daniel Goldin: As I thought about what I might talk about tonight, I let my mind wander back 500 years. Columbus was having a miserable day. He was in the middle of an ocean. He knew not where the end was—maybe the edge of the world. His crew was cranky. They wanted to turn back. But he persevered and pretty soon, he made some amazing discoveries. At various times, he thought he was in India, Japan, China, and even the Garden of Eden. And what does that prove? It proves the European ignorance in the 1500s about the world, in spite of their great feats of exploration. If we extrapolate to today and look at our space program, we're in the early 1500s. Humans have been to the moon six times, but we've never returned any material from any other planetary body. We don't know if there are planets in any other solar system. We've encircled the globe with weather satellites and remote-sensing satellites, but we've yet to understand our own planet. We don't know how climate changes on other planets relate to what might happen on our own. Mars is now cold, dry, and dead, and there's a runaway greenhouse effect on Venus. We've been out to the planets, but we know so little.

Back in the days of the Mariners, we had a very robust program. I worked on Pioneers 10 and 11, which weighed 550 pounds each and were on the cutting edge of technology for their time. I think they cost $35 or $40 million each. Even converted to 1992 dollars, that's still a very modest amount of money. Since then, technology has moved at a record-breaking pace. Yet, instead of having a robust planetary program today, we have exactly one new planetary spacecraft program. Cassini is a $4 billion program. God help us if we fail. We could lose the entire planetary program. Cassini took a decade from conception to congressional approval. It'll take almost a decade to build and it will take a good fraction of a decade to get to Saturn. The participants are going to be old and gray before they get the results back. We didn't get to this point because we had bad people. We had brilliant, wonderful, enthusiastic people. But NASA only has four primary programs under development today—a shuttle, a space station, a planetary probe, and a major astronomical facility [AXAF, the Advanced X-ray Astrophysics Facility]. Something has to change.

It's an opportune time for change because our world is changing. The Berlin Wall came down and it changed everything. America for five decades was focused on the "Evil Empire." It drove our education. It drove our highway program. It drove the soul of our country. NASA is a civil space program, but our origins are in the Cold War. We had to demonstrate to the world that



JPL's Mariner 2 was launched August 27, 1962, and passed 21,648 miles from Venus on December 14, 1962.

we could throw larger things into space than they could. That isn't the case anymore. This is an opportunity that comes around once in a century. We could reach out to Russia, and instead of having two competing programs with tremendous resources going into duplicating infrastructure, we could work together. Think of the possibilities.

Instead of using 10-year-old technology because we have a multi-billion-dollar program and having to play it safe to assure success, let's get back to where we were with Pioneer, which took 11 months from inception to launch. We were inventing to schedule. We were bold. We need a complete resurgence of our space program. We have to let go of what we have in order to allow change to occur—to allow ourselves a few failures a year, instead of trying to make everything so successful that we build a bureaucracy and spend our money on paperwork instead of science and exploration. We cannot go on the way we are. We need to demonstrate again that we're not afraid to take risks.

Sagan: Mariner 2... was the first successful interplanetary mission in human history.

Carl Sagan: While I have debated all the other NASA administrators in my mind while taking a shower, and sometimes face to face, I have a very hard time arguing with Dan Goldin because I believe he is the first NASA administrator in a very long time who is willing to understand—because it takes some courage to do so—just what the problems are. In the question period, I'll try to be provocative, but I want to say here that he and I agree on many topics.

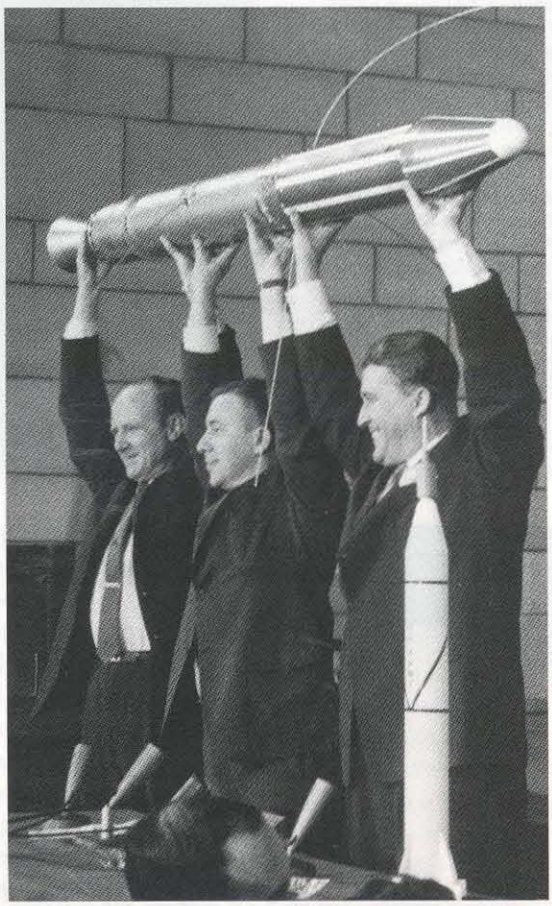
It's reasonable and appropriate to talk about anniversaries. It's also useful to remember that Columbus returned from his last voyage in chains and was thrown in jail. So there are ups and downs in exploratory programs, and it's wise to remember that, even if things seem a little gloomy on occasion, it's the long-term average that counts.

One way to look at NASA is: My goodness, we're capable of doing all these wonderful missions. Why can't Congress understand that they should give us more money? Another way to look at it is: Considering that NASA doesn't put bread on the table, it's astonishing that we've been permitted to spend so much money on what is very close to pure science.

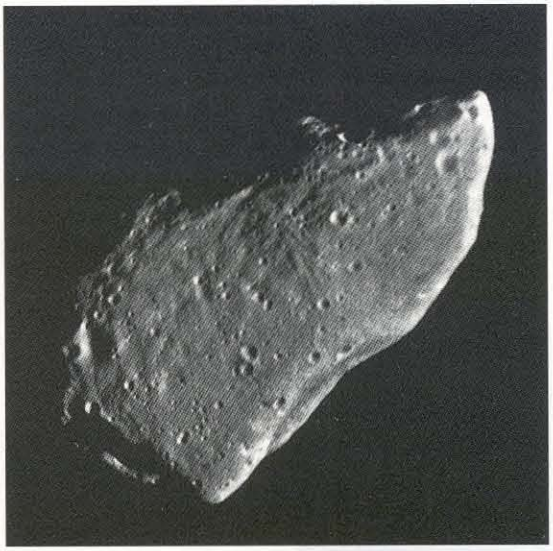
I completely agree that the space program is a creature of the Cold War. Sputnik 1—the precipitating event of the space age—was launched in the Cold War context. Mr. Khrushchev made that extremely clear. If you could launch large payloads to low Earth orbit, you could carry nuclear weapons halfway around the planet. It was a rite of national manhood, and the shape of the boosters assisted in that image. A whole generation has grown up more or less on those terms, and now that the Cold War is over, there's a loss of direction. What is the role of NASA in the post–Cold War era? What can it do that is in the national interest, in a time of pressing economic and other social problems, at a time with a painfully limited discretionary federal budget? I hope we'll get into that tonight.

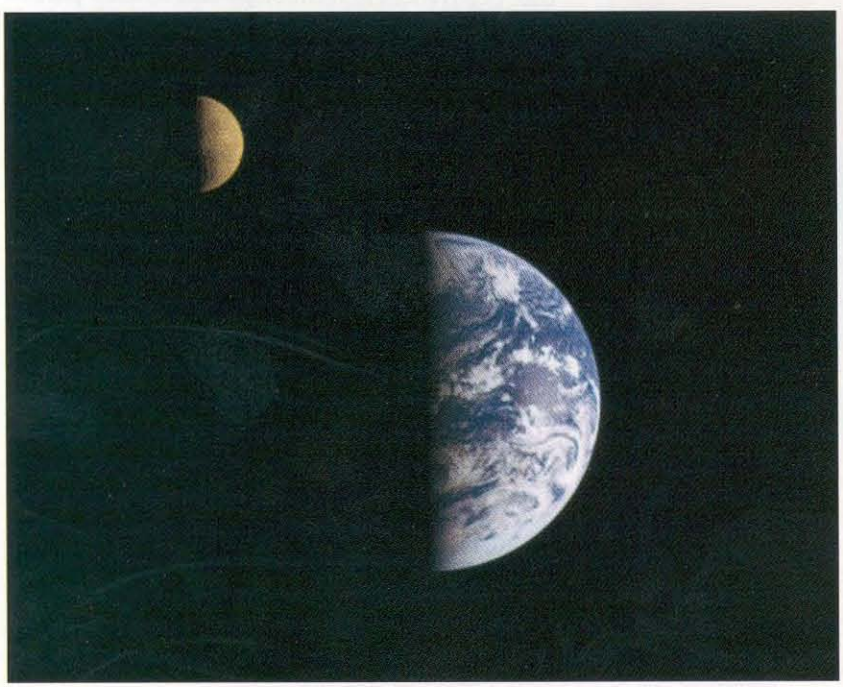
I want to add a few words about Mariner 2, in which I was involved in a peripheral way. It was the first successful interplanetary mission in human history. (As the number suggests, there was one previous failure, Mariner 1.) Mariner 2 was cheap. It was built fast. The scientists who would use the data helped build the instruments. A JPL team led by Marcia Neugebauer [and Conway Snyder, PhD '48] discovered the solar wind. There had been intimations about the solar wind from the acceleration of comet tails, but the first real measurement of it was made by Mariner 2 with an instrument that, if I remember right, was built at JPL. And Mariner 2's infrared radiometer, which gathered information about the structure of Venus's clouds, was built, at least in part, at JPL. [Caltech's Hughes Professor and Professor of Physics] Gerry Neugebauer [PhD '60] played a major role on that team. He was there only because he had been drafted, and the Army had assigned him to JPL—an event that's had momentous consequences for infrared astronomy. It's nice that there was a husband-and-wife team in those early sexist days of planetary exploration. Another instrument, the microwave radiometer, found limb-darkening—evidence

Right: (from left:) William Pickering, then director of JPL; James Van Allen, for whom the Van Allen radiation belts are named; and Wernher von Braun, the original "rocket scientist" hold aloft a model of Explorer 1, America's first successful spacecraft.



More recently, JPL's spacecraft Galileo departed on a circuitous voyage to Jupiter.
Far right: Galileo flew by the asteroid Gaspra on October 29, 1991. Taken at a range of 10,000 miles, this is the most detailed view yet of an asteroid in its native heath. Potato-shaped Gaspra is about ten miles long by six miles wide.
Below: On December 22, 1992, eight days after its second encounter with Earth, Galileo looked back over its shoulder to take this parting shot. The moon is in the foreground so we see its far side, and is moving from left to right.





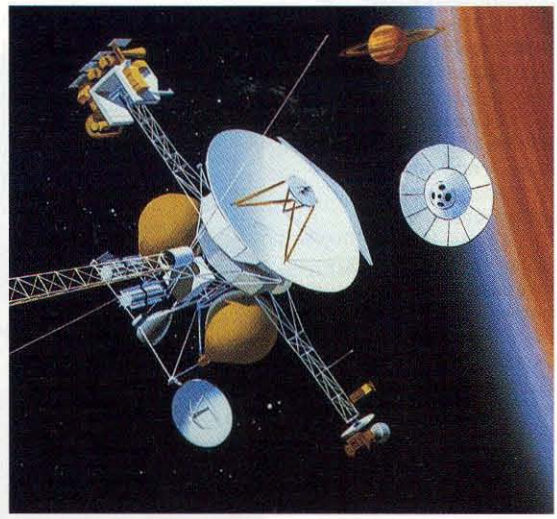
that the surface of Venus was astonishingly hot.

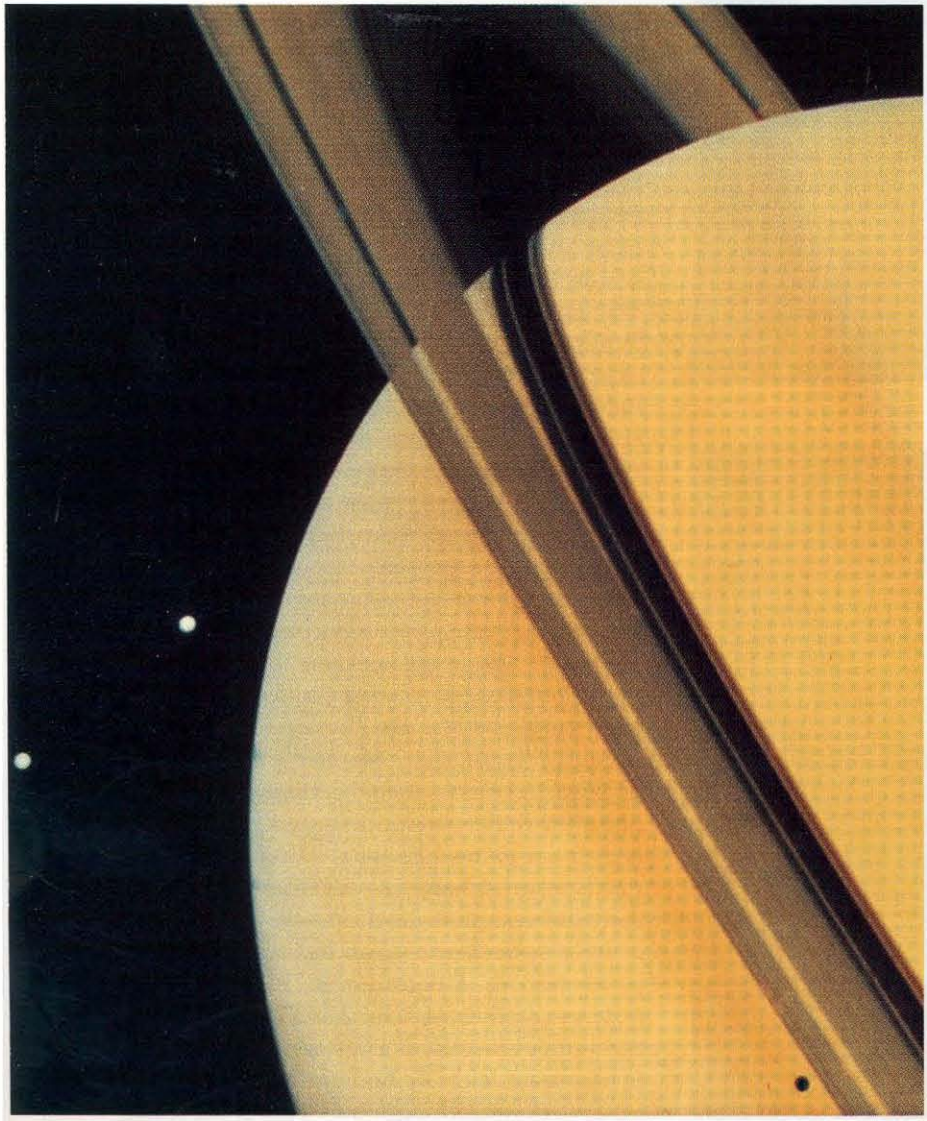
Mariner 2 didn't have a camera. I remember the debates on that. Leading figures in the scientific community said, 'It's pointless to send cameras. Cameras are unscientific. The way to do things is you pose a scientific question. Then you design an instrument to answer that question yes or no. And you proceed from that yes or no to design the next instrument for the next mission.' While that may have been a wise decision for Venus, knowing that it's covered by impenetrable clouds—although we weren't so sure of that then—the subsequent history of planetary exploration has shown that broad-gauge, multipurpose instruments that do not ask specific questions, but answer questions before we're smart enough to ask them, have been extremely productive.

Mariner 2 is still in orbit around the sun, approaching Venus's orbit once every few hundred days. Sooner or later there'll be a close encounter, like the one that Galileo has just had with Earth, and Mariner 2's trajectory will be substantially changed. Mariner 2 will make a set of such encounters, and perhaps it will be propelled to the outer solar system, as Galileo was, or out of the solar system altogether. I hope that before that happens—which will be in a few thousand years at the earliest—we go grab it and bring it to the Smithsonian Institution, or at least to von Kármán Auditorium at JPL.

If we could do Mariner 2 at a very quick pace and very low cost with a harvest of absolutely fundamental scientific findings, why is it so hard for us to do such things now? Part of the reason

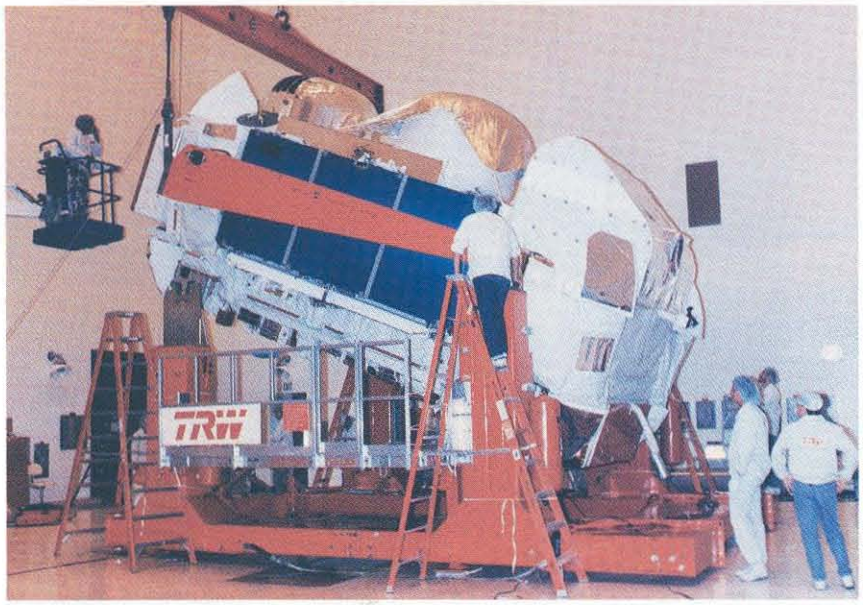
Right: Cassini, a joint JPL–European Space Agency project, will drop a probe into Titan's atmosphere to sample it. Below: Saturn and its moons Tethys and Dione at 7.8 million miles, as seen from JPL's Voyager 1. One of the moons casts its shadow on the planet just below the rings. Left: Iapetus is roughly the same size as Tethys and Dione.





is that the cream has been skimmed. Explorer 1 discovered the Van Allen radiation belts. They were waiting to be discovered—all you needed to do was fly a particle counter through them. It's inevitable that the easy discoveries are made early. Subsequent work becomes progressively harder, or you have to go farther from Earth to do it. That, in turn, means that the work becomes slower and costs more.

I pose the following question to you, Dan: You have been an eloquent proponent for what you summarized here tonight—getting cheaper missions going quickly, in order to take advantage of advances in technology and to keep pace with the human life cycle. On the other hand, there are some questions, outer-solar-system issues for example, which of necessity require larger, slower, more expensive missions. Cassini, of which you have been both an active critic and active supporter—the two are connected, of course—is a good example. You've argued that the real cost, adding in everything, is something like $4 billion. That's a heck of a lot of money. But think what it will do if it works. It will go into long-term orbit around Saturn. It will examine Saturn's rings, which are on some level a model of the solar nebula out of which the planets formed. It will make close encounters with Saturn's major moons, including Enceladus, a most peculiar object because there's no way for its surface to have melted, and yet it has been; Iapetus, which has one of the darkest materials in the solar system on one side, and one of the brightest materials on the other; and Titan, which, according to many models, has a liquid-



Workers in the Payload Hazardous Servicing Facility at Kennedy Space Center carefully position the massive Compton Gamma-Ray Observatory on a test stand. Deployed April 7, 1991 from the shuttle *Atlantis*, the 35,000-pound observatory carries four instruments to study celestial gamma-ray sources.

hydrocarbon ocean covering part of its surface. Cassini will drop a probe into Titan's atmosphere—a place where organic matter falls from the sky like manna from heaven, and is the closest model of any place in the solar system to the events that preceded the origin of life on Earth four billion years ago. That's a big return, and for a big return, it makes sense to make a big investment. Isn't there a danger that if we say small, cheap, and fast, we get small, cheap, and fast scientific results; that is, having skimmed much of the cream, we won't be able to approach the really deep issues?

Goldin: Let me take an extreme position for the sake of discussion and say that if it were up to me, I would limit spacecraft to 500 pounds. I would allow no more than four years to build them—in fact, three might be a better number. And I'd allow no more than two years for preliminary study before development, because I believe the technology is here—commercial, off-the-shelf technology. We're losing a tremendous amount of support for the current planetary program because there's not enough action for the American people. They have to wait ten years to see results. And, as a planetary scientist, if you don't get onto that one expensive spacecraft, where are you going to go? Is it right, is it fair to have such a program? There's no multiplicity or diversity.

Sometimes diversity helps bring issues into focus. I have seen a study done by a number of very bold human beings who felt that they could perform the Cassini mission much faster and just as effectively for much less money. It's still only a study, and that's symbolic of the problem. There's a very tight community that has been working together for a very long time, and they own the planetary program. They're not bad people, but they've gotten so comfortable with the program that you cannot have a divergence of opinion or you get attacked.

For example, a young man from JPL approached me about the Pluto mission. I didn't even know there *was* a Pluto mission. And he said, "Mr. Goldin, the prevailing thought says if we're going to go to Pluto, we must have the right scientific instruments. But once you put that many instruments on the spacecraft, it gets heavy." I think he said about 800 pounds. "It'll take us a decade to build. And if we put it on the biggest rocket we have, it'll take 15 years to get there. So I have a different concept—what if we make the spacecraft smaller with fewer instruments? We could get it out there in seven years. And if we do the program differently, we could build it in four or five years, so that 12 years from now, we could be at Pluto, instead of 25 years from now." I embraced the idea because I thought Pluto was such a challenging mission. If we could prove the concept of a small—he was talking about 200 pounds—spacecraft going to Pluto, we could convince everybody that there's another way to do things. A number of people attacked me in the press, "What right does the NASA administrator have to interfere with the scientific process?"

NASA's "scientific process" was pulled together because the space physicists, the astrophysicists, the planetary program, the life sciences, and the microgravity communities were arguing with each other in Congress and getting each other's programs canceled because the important thing was to get their own program going. Six years ago, they called a truce, saying, "We'll all get together at some nice place, and 500 of us space scientists will come to a consensus on America's space program." In those six years, the research and analysis money that funds university scientists has gone down 25 percent; the planetary program has dropped about 20 percent; and the physics and astronomy program has dropped 25 percent in constant fiscal 1992 dollars. The mission-operations and data-analysis budget—the money it takes to fly the spacecraft and analyze the data they send back—went up 233 percent. The space program belongs to the American people, not to the people working on the program. I submit it's not right to have the space scientists decide by consensus what the program ought to be. I'm not saying that they're bad people, but there's such a desire for survival. Why does someone have to bury a study in a

Upon settling into orbit around Jupiter, Galileo will drop a probe into the Jovian atmosphere. As the probe descends, it will analyze samples of all of the visible cloud layers, sending its findings to the orbiter for eventual transmission to Earth. The probe is expected to transmit for about an hour and a quarter before the orbiter disappears over Jupiter's horizon.

filing cabinet somewhere because it may be so controversial it'll cause a problem? We have to open up to diversity and multiplicity, and fund a technology program that makes sense.

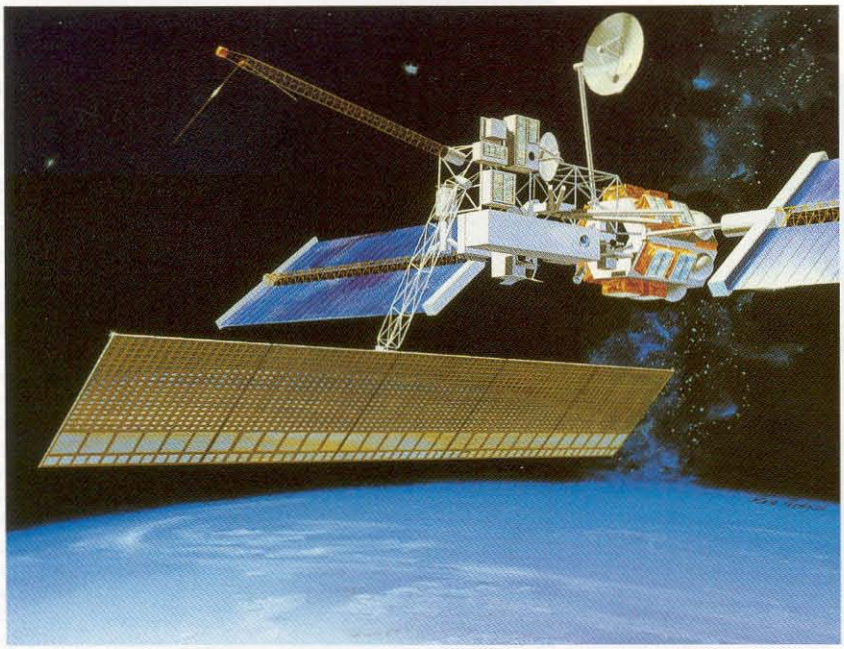
JPL's director has a discretionary budget of three-tenths of one percent. I think that's absolutely appalling. The micromanagement of NASA has gotten to the point that a fine institution has no way to use new technology. I deeply believe in my heart that my 500-pound, four-years-plus-two-years rule with robust technology funding will give us what we want. There are exceptions. Clearly if you have a large aperture requirement or need a liquid-helium dewar for cooling, like on an infrared telescope; or need bulk material for the detector, like the Compton Gamma-Ray Observatory; or have a real need for simultaneity or diversity of measurements, those conditions may dictate a large spacecraft. But just as the program has been out of balance between infrastructure and human spaceflight on the one hand, and science on the other, it's also out of balance between big and small. I know there's this desire to hold on, but I believe if we could try these things, we will have the most robust, the most wonderful science program in the world.

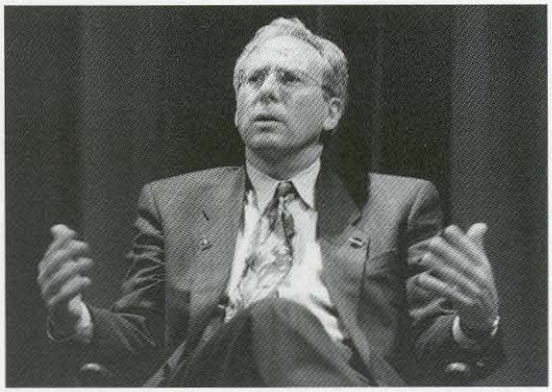
Sagan: So glad I gave you an opportunity to get that off your chest.

Goldin: I'm a little intense on the subject.

Sagan: But isn't there an excluded middle here? Surely there are many good missions that can be done by taking some risks. You can do that if you have other missions in the pipeline, so that on average you do well. In the progression of scientific exploration, there are circumstances in which the obvious next step requires something more elaborate than what preceded it. Look at the exploration of Jupiter. It starts with Pioneers 10 and 11—spacecraft like your quick Pluto mission—then Voyagers 1 and 2. And now Galileo, which is not a flyby but an orbiter. That's a logical sequence. If NASA were *really* strapped, then the conclusion would be don't go to the outer solar system. Just go nearby. You can do things quicker, for less money. And there are lots of important scientific issues to find out about near Earth. I don't consider that an absolutely hopeless position, but it loses a significant fraction of the solar system in heliocentric distance, in mass, and in many cases in scientific interest. Were you to exclude Galileo, which weighs about three tons, we'd be closing lots of options.

Goldin: In this course in creative thinking I teach, I ask people to put six lines on a piece of paper. Then I say, take those lines and arrange them into four equal-sized equilateral triangles. Most people will draw a square with two lines across it, but the sides of those triangles are 1:1: square root of 2. A few people will think for a few moments and realize the answer is a tetrahedron. What's the lesson? I tricked them. I asked them to think in two dimensions. Very few people, when asked to think in two dimensions, start thinking in three. There's a belief in the space community that you have to have "big" to accomplish what needs to be accomplished. I believe deeply that if we start thinking in three dimensions, we'll find that in three out of four





Dan Goldin

Goldin: Mission to Planet Earth started as six Battlestar Galacticas.

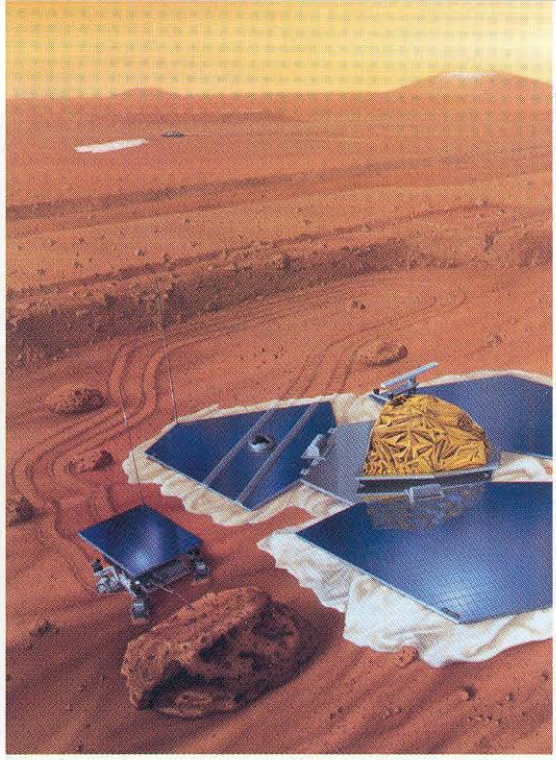
Carl Sagan

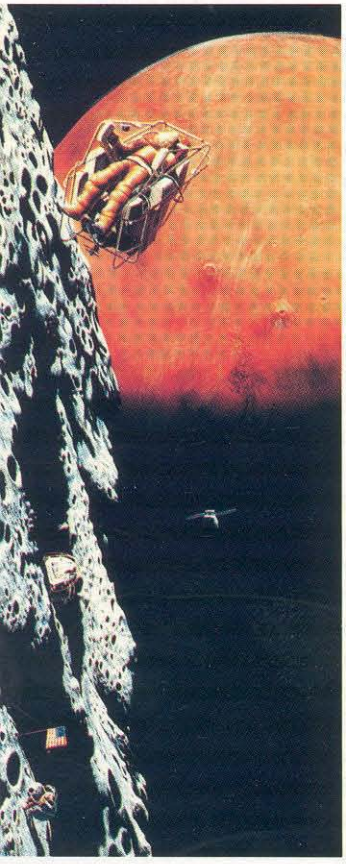
cases, we could do it small. As an example, star trackers don't have to weigh tens of pounds—they could be built for hundreds of grams. The same for inertial units. If we start using advanced technology, not even in the science, but in the bus that carries it out there, the payload mass fraction will go way up. One of the reasons I grabbed onto the Pluto mission is that I believe you should take the geniuses out here at JPL and unleash them. It's been a decade since we put technology into NASA programs. We ought to be reaching out toward technology that's two or three years away, and pulling it back so that NASA once again gets to the cutting edge. I come from a regime where we had to invent to schedule because we didn't have the luxury of debating it. I worked on a project where we designed and built dozens of integrated chips using three unique production processes in less than five years. While we reach for the planets and the stars, we will transfer technology into the American economy to create new industries and new jobs. This also meets our new president's political agenda.

Sagan: The perfect example of what you just said is in monitoring Earth with regard to global environmental issues from Earth orbit. Flying lots of small missions makes perfect sense. Then you can design each mission from what you found in the previous mission. You have quick turnaround so you can take advantage of improvements in technology. You can be responsive to presidential needs on budgets. Graduate students can work on the whole mission life cycle, from instrument construction to data analysis, before they get old and gray. But the farther away from Earth you get, it seems to me, the less true that is—after you've skimmed the cream.

Goldin: This gets back to my main message, that the space program has been run for the benefit of NASA. Mission to Planet Earth started as six Battlestar Galacticas. An enormous battle went on to try to make them smaller. The tremendous pressure not to allow them to get smaller percolated right down to where I was, in industry. Finally we went from full-blown Battlestar Galacticas to half-sized Battlestar Galacticas. That's where we are now, and God help anyone who wants to change that train as it gathers speed going down the tracks. A GAO [General Accounting Office] study says that when NASA planned this mission, most of the data-gathering requirements came from NASA researchers and not the tens of thousands of users who are going to need the data.

Let me switch the subject and say that we've now had four town-hall meetings, in general in cities where NASA does not have facilities, because we wanted to know what people thought. They've been standing-room only. In Los Angeles, at Cal State Dominguez Hills, we had an auditorium for 500 people. We had an overflow room with a video screen for 200 people. It filled up. We added a second overflow room for another 200 people, and that filled up and we had to send people away. There was a tremendous swell of opinion that we had to get back to the days of Apollo. They wanted to get humans to Mars as fast as possible. One young man spoke with such intensity that he's emblazoned in my mind.



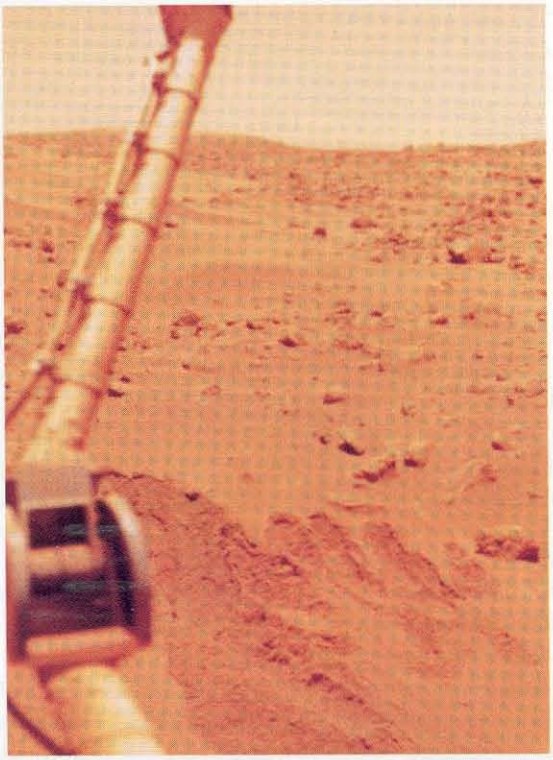


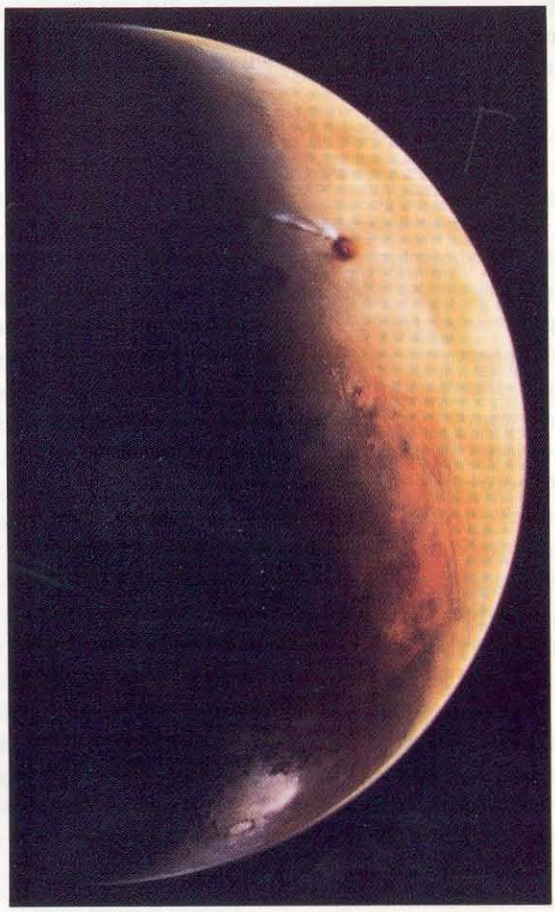
He said, "I'm 22 years old, Mr. Goldin. Tell me right now. Are we going to Mars or not? Am I going to be an old man, and gray, and walk with a cane before we get there?" He represented a lot of people. How do we get there? How do we balance economic priorities at home? How does NASA balance science versus economics, so that we don't get swallowed up in another large program? Space is more than just science. What is your sense, Carl, of how we might get to Mars and when? What ought the balance be between human and robotic space probes? And what reasons would be behind it in this new world we live in?

Sagan: That's a lot of questions. First off, we ought to acknowledge that one possible outcome of that analysis is that there isn't an economically coherent reason for sending humans to Mars, heretical as that might seem in some circles. I would say that if you cannot provide a coherent justification to the taxpayer and Congress for spending the amount of money in question, then you have no right to ask for it. Clearly, a mission that takes half a trillion dollars and 30 years to send a few people to Mars is very difficult to justify. It's as much money as the savings and loan scandal, which only benefited a small number of rich thieves. Surely going to Mars is more in the national interest. But still, the United States in its present circumstances does not have a whole lot of half-trillion-dollar checks, and 30 years is politically very difficult. We're asking a great deal of any president, no matter how farseeing, to spend a lot of political capital now for a benefit to come during some presidency two, three, four, or five presidents downstream, and—who knows?—maybe even of a different political party. John Kennedy's speech announcing the Apollo program was in 1961. Apollo 11 put humans on the moon in 1969, and had he not been assassinated, it almost would have been at the end of his second term. That makes political sense. Sending humans to Mars for, say, $50 billion and taking 10 or 12 years is a completely different kettle of fish than $500 billion and 30 years.

Arguments for going include science, although the argument that you need humans to do the science is certainly not compellingly made. If NASA were to spend anything approaching the cost of a human mission to Mars on robotic systems, artificial intelligence, and telepresence—you're wearing a virtual-reality helmet and glove and feel that you're "inside" a robot spacecraft or lander, seeing what the robot sees and using the robot's arm as if it were your own—I believe we could accomplish an enormous amount of science, including going to areas that are too dangerous to send humans, although those areas may be scientifically very exciting. Beyond that, there are arguments about education, about national prestige. But in every case, we have to ask is this the most cost-effective way to those goals? Let's say $15 billion of it is justified on the basis of education. Is that the best way to spend $15 billion on the scientific education of Americans? And it's very easy to think of activities on Earth that would earn the admiration of most nations and cost less than $15 billion. So the question is, can the sum of a fairly large number of inadequate reasons constitute

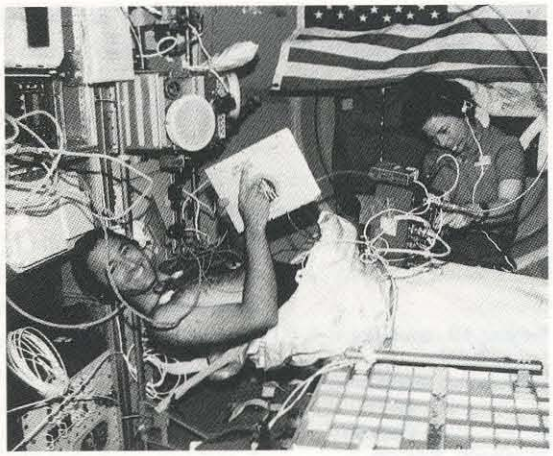
Opposite page: The possible futures of Mars exploration. Far left: An astronaut explores the surface of Phobos, Mars's larger moon, in a personal spacecraft. Top left: Rocky IV, a 16-pound microrover being developed at JPL. (The final, Mars-qualified robot explorer will be even smaller.) Rocky IV has a set of "programmed reflexes" that enable it to plot its own path through its surroundings without detailed instructions from Earth. The needle-like probe chips away weathered rock, exposing a fresh surface to the onboard spectrometer. Right: The proposed Mars Environmental Survey mission would land microrovers to emplace seismometers and collect soil samples at up to 16 sites around the Martian globe. The lander, shown sitting on the deflated air bag that cushioned its impact, doubles as a weather station.





This page: The reality of Mars, as revealed by the Viking missions. Top: The Viking 1 lander's soil scoop scrabbled at the rocky dunes of Chryse Planitia. Sadly, Viking's experiments found no signs of life. Bottom: Mars from the Viking 2 orbiter. To the north (upper right), Ascareus Mons, one of the great Martian volcanos, trails westward plumes of water-ice cloud. Valles Marineris, a canyon system almost 3,000 miles long, lies near the equator. In the south, frost dusts the lowlands of Argyre Planitia, a 480-mile-diameter impact basin, and the crater Galle in its rim.

Below: Astronaut Bonnie Dunbar monitors astronaut Lawrence DeLucas' heart in a life-science experiment aboard the shuttle *Columbia*.



an adequate reason? The answer might be yes, but how you do this arcane calculus is not clear to me.

It's fantastic that you're doing these town meetings, especially away from NASA centers. Of course you get a lot of people saying, yes, I want to go to Mars. But if you tell them, "It will cost hundreds of billions of dollars. Do you know what a small fraction of that could do for your community?" the field shifts. There's also a selection effect. The people who come to your talks are, generally speaking, already supportive of NASA. It's a mistake to draw too sweeping a conclusion from what people say at these town meetings. When I talk to members of Congress, I get a very different impression.

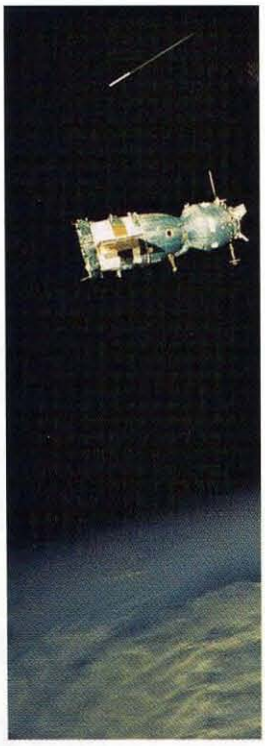
My advice would be to vigorously pursue robotic exploration, especially of Mars. There are key questions about Mars that, for perfectly good reasons, attract public interest: the reason for its past massive climate change; the search for past, or—who knows?—present life; the question of possible future human habitability. And it would clearly be prudent to examine the safety of long-duration spaceflight, including the effects of radiation in space on humans. This seems to me to be the only conceivable justification of a space station, although it is hardly optimized for that function. All this could be done without anything like the savings and loan scandal's cost. If enthusiasm develops, if the discretionary federal budget permits, if a president wishes to make a gesture that will ensure his or her place in history, then we can well imagine that we will go to Mars. But in the present situation, it's politically

unrealistic to urge endorsement, especially on a specific timetable—by the year 2019 or something like that—for sending humans to Mars.

Goldin: You're on the right track. One thing I'd like to add: 500 years ago, each individual country explored for itself, planting its flag separately for its own people. This gave rise to the most horrendous wars. We're ending a millennium just strewn with blood. Think about the possibilities of bringing nations together on a very difficult venture, under one flag planted for all humankind. I think that's a very, very positive reason for going.

Sagan: That's an argument I fervently pushed in the closing years of the Cold War. The United States and the Soviet Union working together on behalf of the human species for a change, using that same rocket technology that had put everybody on Earth at risk, was a supremely worthy goal. We found a resonant chord in some of our opposite numbers. Mr. Gorbachev was convinced and made a serious approach to Mr. Reagan, which Mr. Reagan turned down. Now, with the Soviet Union in utter collapse, the necessity seems less, although not zero. Russia, the U.S., Japan, the Europeans, and China, say, going to Mars together has a profound symbolism. Whether that's a compelling argument for people who don't have enough to eat is another question.

Soyuz 19, as seen from Apollo 18. Launched separately on July 15, 1975, astronauts Thomas Stafford, Vance Brand, and Deke Slayton and cosmonauts Alexei Leonov and Valeri Kubasov were neighbors and frequent visitors while their spacecraft flew docked for two days.



Goldin: This is a fundamental issue as NASA establishes balance in its program. Clearly I agree with your statement. You cannot send humans to Mars until you can understand how they could live and work in the hostile space environment. The interaction of cosmic rays with human tissue is yet to be resolved. We could write a book about what we don't know about humans in zero gravity. But as we perform these tasks, we can, over the next five or ten years, develop critical technologies and system designs in parallel without breaking the bank.

Sagan: [The Russian space station], Mir, is the way to do that. It's operational, although only intermittently used. Residual Cold War attitudes are decaying very slowly, and that's all that prevents us from using Mir to start to answer questions about long-duration spaceflight. A few Russian cosmonauts have already lived in Earth orbit for around a year, which is roughly the time it takes to get to Mars.

Goldin: The problem is twofold—technical and political. In the technical domain, one of the best-kept secrets has been the fact that American and Russian physicians have been working together for the last ten years, but there's a real problem with in situ measurements because of Mir's limited power and instrumentation capacity. Actually, Russia's and America's strengths are complementary. They're very sophisticated in their mechanical engineering, their propulsion, and their metallurgy. We're very sophisticated in our electronics, simulations, and computers.

Sagan: It's a marriage made in heaven, but one surprisingly difficult to consummate.

Goldin: Which gets me to the political aspect—we've only had five months to work together. There's tremendous instability in Russia, and there's a reluctance in the United States to put its program in series with the Russians. So we've decided to do some confidence-building tasks first. We'll have a cosmonaut fly in the shuttle. We'll have an astronaut fly up in the Soyuz capsule to Mir. And, finally, we'll have a shuttle rendezvous with Mir. That's a very difficult task, what with their offset centers of mass and different docking mechanisms. And we're considering changing our space station's projected orbit. Right now, it would be at 28.5°. But Mir's already up there at 51.7°. What if we put ours in the same orbit? It would be much simpler going from station to station. Think about the possibilities if our shuttle wasn't available, or vice versa. Think about lifeboats. We could build on that concept as we go along. Maybe instead of adding modules, we could start sharing them. It's not revolutionary, but it might evolve to where we could really start working together. We're going to get the best out of Mir and the best out of our space station.

Sagan: Doesn't that put off still further the day when we finish the long-term low-gravity and radiation-biology studies and so on? Does that indicate that we're not going to be sending humans to Mars in the next few decades?

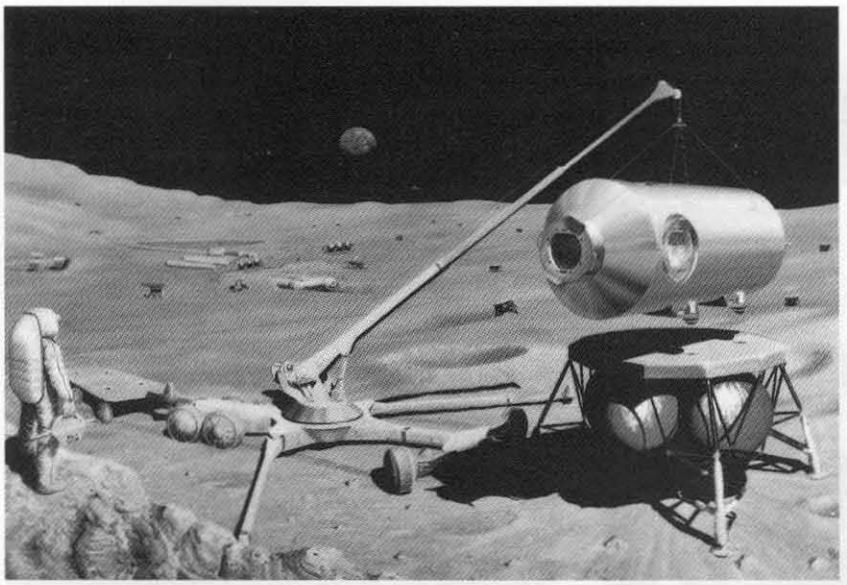
Goldin: I don't think we can in the next decade or two anyhow. For low-gravity studies, I challenge the employees at NASA Langley and NASA Johnson—and anyone in this audience—to come up with a faster, better, cheaper human centrifuge for hundreds of millions instead of billions. It can be done. I have my own design. They say I'm off base again. "Goldin, you're out of your mind."

Sagan: I like the idea of a NASA administrator designing spacecraft.

For the balance of the program, Goldin and Sagan fielded questions from the audience.

Question: Mr. Goldin, you've been to the Soviet Union three or four times in the last year and a half. Is it realistic, given what appears to be an economic black hole over there, for the United States to expect to have an equal partner in such a project?

Goldin: Is it risky? You bet. Will there be



Artist's conception of a lunar mining facility. Oxygen, silicon, iron, calcium, aluminum, and magnesium could be mined on the moon, as well as helium-3.

people who criticize it? You bet. Can we afford not to do it? We cannot. The Russians are committed to their space program. It'll be one of the last things to go. It's a matter of national pride. It does have over-capacity in overall launch capability, perhaps by a factor of three. On one trip to Russia, I visited a factory where rockets were stacked like cordwood. There are going to be terrible dislocations in their space industry, but it won't die, because the Europeans will work with them. Could there be another coup? Yes. But how can we afford not to reach out? We can't live in isolation.

Question: I have an article here dated December 7, 1988. It says, "a U.S. industry to build power satellites for all nations would tap a world market exceeding $250 billion." That's clean power from space. Have you considered building solar-power satellites, utilizing the moon's resources, to finance your other projects? I mean, that's a $250 billion potential every year.

Goldin: Think about the possibilities of bringing nations together on a very difficult venture, under one flag planted for all humankind.

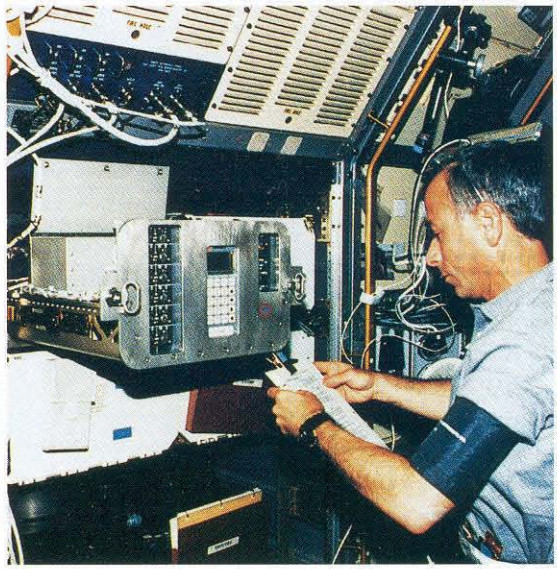
Goldin: It's clean power, with one exception—what does the microwave power that you would beam down from space do to human tissue? We don't really know. Before we start building more Battlestar Galacticas, let's understand some of the fundamentals. Once we get through that barrier, how feasible are these activities and what's the payoff? Let me give you another possibility. What if, 50 years from now, we could make a controlled thermonuclear reaction with helium-3? Helium-3 would give off almost no radioactive waste, and 20,000 pounds would power the whole United States for one year. Helium-3 comes flowing off the sun and has riddled the moon for billions of years. It shouldn't be too difficult to mine and bring back. One 20,000-pound load per year would not be very expensive, relative to what you're talking about. There's a tendency in our society to want to do everything all at once. That young man wanted to go to Mars immediately. You're proposing to rush off and get power satellites up there. Let's take our time and make the right decisions. Can we afford to spend the billions of dollars before we find out whether we're affecting human tissue? The engineers would have a jolly good time, but it gets back to the statement I made before: engineers are not the ones who should set the requirements. America should set the requirements.

Sagan: Why go into space to harvest sunlight, when you can put your sunlight-harvesting cells in the Mojave Desert at vastly less expense? It's not enough to say that it'll make $250 billion a year. You have to demonstrate that you couldn't get that $250 billion a year by making the same or lesser investment on Earth.

Question: Mr. Goldin, [at the LA town meeting] yesterday you described our space program and the aerospace contractors as having a sickness. Could you expand on that? What do you feel the cure might be? And Mr. Sagan, what is the single most important challenge to our space program, and how would you face it?

Goldin: I said that I'm terribly concerned about our credibility with the Congress. I talked about accountability and responsibility. We've built up a bureaucracy over the last 20 years. We have 24,000 NASA employees and 42,000 service-support contractors. Should we have so much help to do our job? Can't we convert NASA's bureaucratic work into science and exploration? We have a pretty full plate: Congress fully funded the space station; we have congressional approval on the Mission to Planet Earth, on Cassini, and on AXAF; and we have a number of smaller projects under way. One of Congress's biggest criticisms of NASA is that we have so much on our plate, yet we keep trying to get new things to do. So let's deliver on what we've already promised first.

Sagan: NASA does not, in my view, do a good job of explaining why it does what it does, or even what it does. The average person's sense of what NASA is about is that every few months, a few people crowd into a tin can, go up into low Earth orbit, launch a satellite that could just as well have been launched by an unmanned booster, do some experiments the significance of which we never hear about afterward—the tomatoes didn't grow, or something—and then they come



Left: Astronauts Jan Davis (left) and Mae Jemison prepare to deploy the Lower-Body Negative-Pressure apparatus aboard space shuttle *Endeavour*. The LBNP pulls blood and intercellular fluid into the legs to mimic gravity's effect on the circulatory system and, according to NASA's stock caption, should increase future astronauts' tolerance to "orthostasis"—what most folks would call standing upright—upon return to Earth. Right: Astronaut Carl Meade (MS '75) ran the Generic Bioprocessing Apparatus on Columbia. This piece of equipment can hold 132 test tubes at a time, allowing the effects of microgravity to be studied on samples ranging from molecules to small organisms.

down again. And at the same time, NASA is doing fantastic science that gets very little attention. By attention, I don't mean an occasional article in the Tuesday [Science] section of The New York Times. I mean four or five minutes—no, that's absurd—two or three minutes on the evening news, with wonderful visuals prepared by the nonexistent computer-animation laboratory devoted to public education at NASA headquarters. Orange-juice substitutes in Earth orbit we hear plenty about. But real science? Very, very little. Part of this, of course, is because of media resistance. Many people have the sense that the American public is simply too stupid to understand science. But the evidence is manifestly clear that that's not the case. I think it's important for NASA to pound on the doors of the media gatekeepers, to present the argument for science and exploration in such an appealing way that the doors are opened.

Goldin: That was one of the major comments at the town-hall meetings. The public is telling us we don't communicate, especially to schoolchildren. People talked about documents and pamphlets written in language no one understands. I agree wholeheartedly. No one's responsible for publication at NASA. It's dispersed throughout the organization, which gets back to my basic point that there must be responsibility and accountability—one task, one human being. But I do want to take issue with you relative to tomato seeds on the shuttle.

Sagan: I thought you would.

Goldin: Part of the problem is that the life sciences have been woefully underfunded relative to physics and astronomy. Yet we are doing some very sound life science and microgravity science on shuttle flights. Pharmaceutical companies are working with us as commercial participants. A shuttle is only up there for a short period of time, and life science can be performed on the space station and will be.

Sagan: If we talk about physics and astronomy, we can answer absolutely fundamental questions from space—issues like the validity of general relativity, or whether the universe will expand forever. What is fundamental to biology is the genetic code and the evolutionary process. The biology to be studied in Earth orbit is applied biology, having to do with human reactions to long-duration spaceflight, not fundamental biology. The only compelling argument, I believe, for life science in Earth orbit is to prepare for human missions to the planets. If we're not going to the planets, then there's no necessity for life science on a shuttle or space station.

Goldin: All I'm saying is that we have to have a robust life-science program to perform the basic mission of the space station. Life science, not the engineering feat, should dominate what we do on the space station, if we're to understand how humans can live and work in space.

Sagan: But no tomatoes.

Goldin: Maybe just a few.

Question: Mr. Goldin, I'm a student majoring in materials engineering. There doesn't seem to be any mechanism for NASA and JPL to handle the good ideas you get in college. What kind of proposal process would you implement for NASA to get diverse ideas for new technologies?

Goldin: Thank you for the softball. About four weeks ago, I announced a new organization at NASA—the Advanced Concepts and Technology Office. I was terribly concerned by all the people who beat a path to my door saying that NASA was resistant to new ideas, and that if someone wanted to bring a new idea, they were just sent around from organization to organization to organization. NASA had no systems-engineering team capable of analyzing, in a broad perspective, the merits of a technology. Technology by itself is not enough. It becomes a solution seeking a problem to solve. Technology applied in the broad sense of the mission is crucial. Because NASA technology gives crucial input to the American economy, we also brought in the offices where we transfer technology to industry, and commercialize activities in space. The goal is one-stop shopping. Greg Reck is the acting associate administrator. He's now traveling around the country at my request, soliciting opinions from universities and industry, professors and students, as to what's the right way to organize this. Send him a letter. He will respond.

Question: It's amazing how many Americans couldn't care less about the space program because they don't know anything about it. They don't believe that we could possibly gain anything in daily life from space exploration. They don't know about simple things, like the ball-point pen. What can NASA and The Planetary Society do to educate the American public?

Goldin: The single biggest problem may not be the lack of computer-animation capability at NASA headquarters. There's a more fundamental problem. Scientists and engineers do not write in plain English. I'm not saying that as a joke. It is a very serious problem. When I became the NASA administrator, President Bush challenged me, "On the evening news, instead of seeing a shuttle taking off or landing, can we have a minute or two of science?"

Sagan: The president said that to you?

Goldin: Yes.

Sagan: Is this the same president who boasted how he didn't understand any of his science courses at Yale?

Goldin: I will forgo discussion on that subject and answer the question. I naively set off and asked the Public Affairs Department to brief me. Now, I've spent 30 years of my career in space science and engineering. I've been involved in the AXAF program, the Gamma-Ray Observatory, and Pioneer—all cutting-edge programs. I understand the language. And I tell you, I've spent hours in meetings at NASA trying to force people to speak English. The problem has gotten so bad that we've hired science writers to sit with the engineers and scientists and translate. We cannot afford to go on like this.

Sagan: The spin-off argument seems largely spurious to me. "Spend $80 billion to send astronauts to the moon and we'll throw in a free stickless frying pan." If you want a stickless frying pan, spend money on stickless frying pans.

Sagan: I think the Planetary Society is doing a very good job. We do write in English. By the way, one of the advantages of computer animation is that it's *already* in English. You don't have to translate. It's visual. That's why no amount of talking heads would get on the evening news, but animation will. Incidentally, the ball-point pen preceded NASA. The spin-off argument seems largely spurious to me. "Spend $80 billion to send astronauts to the moon and we'll throw in a free stickless frying pan." If you want a stickless frying pan, spend money on stickless frying pans. Don't send people to the moon in order to get a stickless frying pan. You could see it in the declining days of the SDI program. "It'll be good for laser surgery." If we want laser surgery enough to make battle stations in Earth orbit, just do laser surgery. Spin-off is not a good argument. The arguments have to be fundamental to the nature of the enterprise.

Goldin: The American public is very sophisticated, in spite of what people think. They love science. They want to hear about science. We shouldn't demean them by saying they won't understand it.

Question: This idea of the evening news bringing scientific information to us is a joke. The evening news does not treat us as intelligent beings. It's a show. It's little videos that stuff us with information—not even information, just blood and guts. I don't really feel that's the avenue to be learning about what NASA and the

astronomical community are doing.

Sagan: Of course you're right. The reason is the cutthroat competition between the networks, in which a single ratings point is worth umpty-ump million dollars. What you want is specials—in fact, series. There's even empirical evidence that this works.

Question: As a consumer, I would definitely be interested in a "space channel" or something...

Goldin: Let me jump in. There is a channel, called NASA Select, that's attempting to do that. I have a vision that the American cable industry will have enough intestinal fortitude to carry NASA Select into every American home. If that happens, the second part of my vision is that NASA will rise to the occasion and communicate in plain English and visuals so that America understands the space program.

Sagan: The cable companies are talking about 200-channel technology. They're not going to fill 200 channels without NASA Select, so that time might come.

Question: Hearkening back to your Columbus analogy—aside from wiping out most of the native populations with disease, he brought on this incredible economic boom. One might expect that might happen again as a result of space exploration. For those of us interested in investing, are you considering means to fund planetary exploration such as NASA bonds, or democratized funding programs, such that we could, say, choose to finance planetary exploration versus military satellites that burn houses here on Earth?

Goldin: First, let me say that we are not involved in direct military applications. We are working to find a separation, but things don't happen overnight. We have had the last military flight on board a shuttle. I *do* believe it's necessary for NASA and the military to work together on infrastructure, because we both can't go out and build launch vehicles, and we can't have separate communications and signal-processing infrastructure. If we have a technology the military could use, we ought to give it to them, because the taxpayer paid for it. And if they have a technology NASA could use, we ought to have access to it. But mixing missions creates a problem. With regard to the other part of your question, it would be lovely if one could commercialize scientific missions. In the long run, by reaching out to the planets and the stars, there will be commercial activities in space. Let me give you an analogy. In 1915, the United States formed the National Advisory Committee on Aeronautics to help America get into the aviation business. When it first started, the Post Office was subsidizing flights, because no one could figure out what to do with the airplane. People said the airplane was useless—you can take the train and get from point to point. The government was paying for the airplane for years, trying to figure out needs for it. The government goes in for infrastructure. We have highways because the government funded them. I don't believe bonds are going to work right now because there isn't that commercial payoff in five or ten years. There are some limited commercial things happening, but it will take a long, long time before they're on their own. What we should do is transfer space technology, not as our primary mission, but as it becomes available. But that wouldn't be the driving force for why NASA exists.

Goldin: I would like to see, in my lifetime, international expeditions to Mars and to nearby asteroids (an idea Carl suggested in a phone conversation a month or so ago), and an international research station on the moon—like the one at the South Pole—where we'll be able to image nearby stars and search for terrestrial-sized planets.

Question: Mr. Goldin, what three missions would you want, if you could have them?

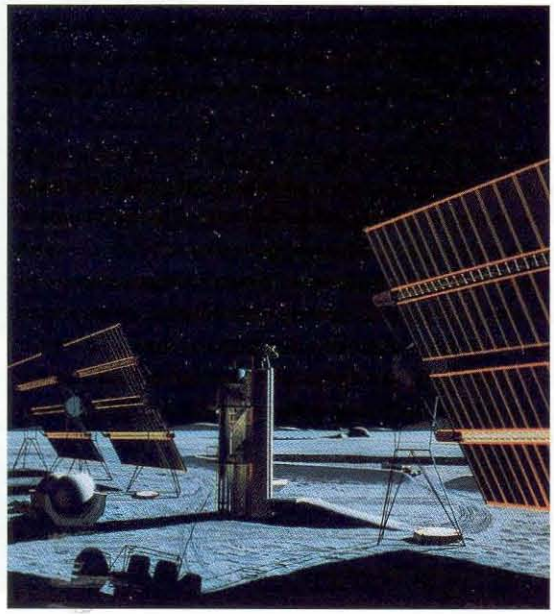
Goldin: In the planetary area, for the next 10 or 20 years, I'd like to see us darken the skies with small, low-cost, high-performance spacecraft that would be pilot pigeons if you will. I do agree with Carl that we should be sending a significant number of these spacecraft to Mars. Second, I think we ought to do all those things necessary to get us to Mars, like understanding how human beings could live and work in a hostile space environment, and getting the systems engineering right. If we devoted 10 to 20 percent of NASA's budget, we could do these things in a reasonable amount of time. Then I would like to see, in my lifetime, international expeditions to Mars and to nearby asteroids (an idea Carl suggested in a phone conversation a month or so ago), and an international research station on the moon—like the one at the South Pole—where we'll be able to image nearby stars and search for terrestrial-sized planets. That will change our view of who we are, and what we are, in the most significant manner, as would finding life, or fossilized life, on Mars.

Question: Do you want to be there?

Goldin: Of course.

Question: I'm a member of Students for the Exploration and Development of Space. What do you foresee in the way of student participation in our space program?

Goldin: Women and minorities are our future. Our engineering, scientific, and technical labor force, which was once made up exclusively of white males, must tap new pools of talent. Twenty years from now, 85 percent of those entering the national labor force are going to be females and minority Americans, and we need role models for them *now*, while they're in grades K–6. You can help them understand that they can do anything that they want to do. That could have a more profound impact on our soci-



Artist's conception of a lunar outpost.

ety than any other one task you could undertake.

NASA needs a new partnership with the universities. That's very high on my priority list. We've got to involve dedicated young people, and it can't be an exclusive club. There's a crisis right now. One need only come to California to see how state funding of higher education is being reduced. And a large degree of funding for science and technology research has come from the Department of Defense. That funding is now declining very significantly. I've had professors, department heads, and even university presidents come to me and say we have a year or two before we lose a tremendous capability. We've got to transfer some of the funds we're now spending on bureaucracy to the universities. Again, you are our future. I'll be around for some years, but you'll be around for a lot more. If we don't get national attention on this issue, I worry about the future of our society.

Sagan: It's by no means clear that the only, or the best—certainly not the most cost-effective—way of finding terrestrial planets around other stars is by establishing an extremely expensive human base on the moon.

Question: How sympathetic do you think the new administration is going to be to your projects?

Goldin: They're not my projects. They're America's projects. It's very important to understand that. I believe the new administration is very positive about the space program, because it recognizes the criticality of cutting-edge technology to America's future. Vice President Gore has been intimately involved with the space program. However, there are enormous issues facing our nation and it would be presumptive of me to say where the administration must place the space program on its priority list. I've seen a survey that shows that some 60 percent of the American people think that the NASA budget is about the size of the defense budget. It is not. We are a very small fraction of that, and I think we return a tremendous value. If you believe deeply that space exploration is important, speak out. Write letters. Pick up the phone.

Question: Earlier, you discussed the annual competition for funding among members of the planetary-science community. Has there been any thought of multi-year procurements for long-term missions? Secondly, there are similar annual competitions between advocates of the manned and the robotic programs. Has there been any thought to bringing those two communities together to stop their infighting?

Goldin: We hope to develop a shared vision with America of why NASA exists, where it's going, and how to get there. A shared vision doesn't mean 100 percent agreement. If we try to get too much of a consensus, we're going to lower the average.

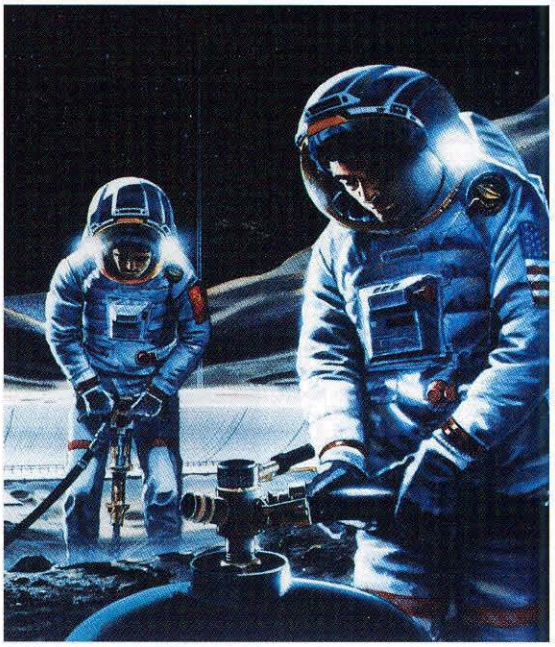
Sagan: Advocates of robotic missions and advocates of human missions should bury the hatchet and pull together. I also think that if there is not a shared, across-the-board commitment by the American people to do one or the other, then we shouldn't do it. The case for human exploration has to be made, more so than the case for robotic exploration, because human exploration is so much more expensive and also runs a risk in lives.

Question: What if a moon base is established, and you find other planets around other star systems? Isn't it disturbing to think that in order to travel to them, you would have to hand the project down several generations? The originator would never see the outcome.

Goldin: I'd love to have that frustration. To deprive ourselves of the knowledge that there might be a blue planet around another star, I think, would be the highest-level crime. Maybe we'll start working full-speed to develop warp drive. That's hokey, but...

Sagan: I agree. That's a frustration I would look forward to. But it's by no means clear that the only, or the best—certainly not the most cost-effective—way of finding terrestrial planets around other stars is by establishing an extremely expensive human base on the moon. There are other ways to do it. For example, there is a reasonably compelling case that radio astronomers have already found two planets of roughly terrestrial mass orbiting a pulsar.

Question: But is it possible to build optics strong enough to be able to see the planet's surface, or at least its color, so that you can determine what the surface might be like?



Right: In this artist's rendering, workers break ground for a lunar telescope that could look for planets in orbit around other stars.
Below: NASA's High-Resolution Microwave Survey is using this 111-foot-diameter dish at JPL's Deep Space Network facility at Goldstone, California, and a 1,000-foot-diameter dish at Arecibo, Puerto Rico, to listen for radio signals generated by other civilizations.

Sagan: Depends on the method. There are, for example, potentially very powerful occultation methods in which you use the limb of the moon, or an occulting disk, to momentarily block the light of the star around which the planet is going and then catch the planet's very faint light. You have to do it from space, but by no means would you have to do it from the moon. Or you might receive a message from the guys who live on that planet. Then they might tell you everything you wanted to know about it, much more than you could figure out from a mere optical interferometer on the moon. NASA, to its credit, has a very sophisticated search for extraterrestrial intelligence going on right now.

Question: I've never been able to see the importance of space exploration, as beautiful and fascinating as it is. Just as Dr. Sagan said, let's put the solar-power stations here in the Mojave Desert instead of going out there. Maybe you can leave me with something I could understand.

Goldin: Society, since the earliest time, has wrestled with the question of how much do we put into the present to survive, and what fraction do we use to plant the seeds for the future? Do we take the money from the space program to solve the homeless problem? As a society, we spend our money in three different areas. We pay for our debts of the past. We have a national debt that's beyond belief, because my generation has chosen to steal from the future to live in the present. Secondly, we have responsibilities in the present to make sure that people have proper education, nutrition, and health. And third, we have to invest in the future. I believe we have no right, as a society, to say that because we have problems in the present, we will walk away from the future. The civil space program is investing 10 years, 20 years, centuries ahead. NASA's budget is $14 billion. Our federal budget is $1.5 trillion. We could take the whole NASA budget and, in a feeding frenzy in the U.S. Congress, vaporize that budget in two hours. And even if we converted it into valuable things instead of pork, nine-tenths of one percent is not going to solve this nation's fundamental problems. But I would weep for our nation if we didn't have a space program.

Sagan: There's a range of justifications. People resonate differently. Let me talk a little about space in general, not just NASA programs. Communications satellites link up the planet. Meteorological satellites predict the weather, saving many billions of dollars worth of crops every year. Military-reconnaissance and treaty-verification satellites make the planet more secure. Satellites, especially those that are coming along, monitor the health of the global environment and check out the greenhouse effect, the depletion of the ozone layer, and new dangers we haven't even thought about yet. All of those are immensely practical and cost-effective.

Then there's the issue of exploration. Humans for 99 percent of our history were hunter-gatherers. We wandered. We followed the game. Exploration is built into us. And just at the moment when the planet is all explored, save perhaps for under the ocean, the planets open up as a goal for exploration. Many people feel this in a strong, emotional way—one could even call it

Sagan: The vision of the future that's offered up to young people in our society is almost universally dismal—something like guys with automatic weapons on bombed-out post-nuclear-war highways. What aspect of our society, in the natural course of doing business, offers a hopeful vision of the future? It's the space program... That's worth a whole lot.

religious in the sense that they have difficulty justifying it rationally.

And there are the deep questions that each society, one way or another, asks—the origin of life; the origin of our planet; the origin, nature, and fate of the universe. I think you'd have to be made out of wood not to wonder, at least a little, about those questions. Through folklore, religion, superstition, or science, every human culture has invested some of its resources in answering those questions. So it is reasonable for us who can, for the first time, actually find out some of the answers to make this investment as well.

If you mix those three together—the directly practical, the zest for exploration, and the answering of questions of origins—I think you'll catch a sense of what motivates a lot of people about space. And one last thing—the vision of the future that's offered up to young people in our society is almost universally dismal—something like guys with automatic weapons on bombed-out post-nuclear-war highways. What aspect of our society, in the natural course of doing business, offers a hopeful vision of the future? It's the space program. It's new worlds, new exploration. It's something that young people can be motivated by, that can help guide their lives, make them work hard and study science. That's worth a whole lot. I think NASA, despite all of its problems and its ossified bureaucracy, is a fantastic bargain. And I'd like to wrap up this evening's discussion by saying that, after listening carefully to Dan's answers to this wide variety of questions, I think that NASA headquarters finally has got a breath of fresh air. □

Ed Stone, director of JPL, introduced the speakers. "Daniel Goldin, the ninth NASA administrator, took office on April 1, 1992. Before that, he was the General Manager of TRW Space and Technology Group in Redondo Beach. He brings to NASA a long experience in developing spacecraft for NASA and for other government agencies. But even more importantly, he brings a deep conviction about the importance of the space program to both the nation and the world—a comprehensive vision and a great enthusiasm for the planetary program.

"It's hard to imagine a better-suited scientist to engage Dan Goldin in a dialogue than Carl Sagan. His career as a space scientist spans the entire 30 years of the planetary program. He was a scientific investigator on the Mariner 2 mission and has been on many planetary missions since, including Voyager's historic journey to the outer planets. He was for 12 years the editor of Icarus, the journal of the planetary science community. For the public at large, he is best known as a Pulitzer Prize-winning author, and for his masterful television series, Cosmos, *that established him as a scientific spokesman for space science."*

The Planetary Society was founded in 1980 by Sagan; Bruce Murray, professor of planetary science and geology at Caltech and then director of JPL (1976–82); and Louis Friedman, then the advanced projects manager at JPL, who had overseen Magellan, Galileo, and other spacecraft in the early stages of their development. The society was founded as a non-profit organization dedicated to the exploration of the solar system and the search for extra-terrestrial life. With approximately 100,000 members in over 100 countries, the society is the largest space-interest group in the world.