The PLANETARY REPORT

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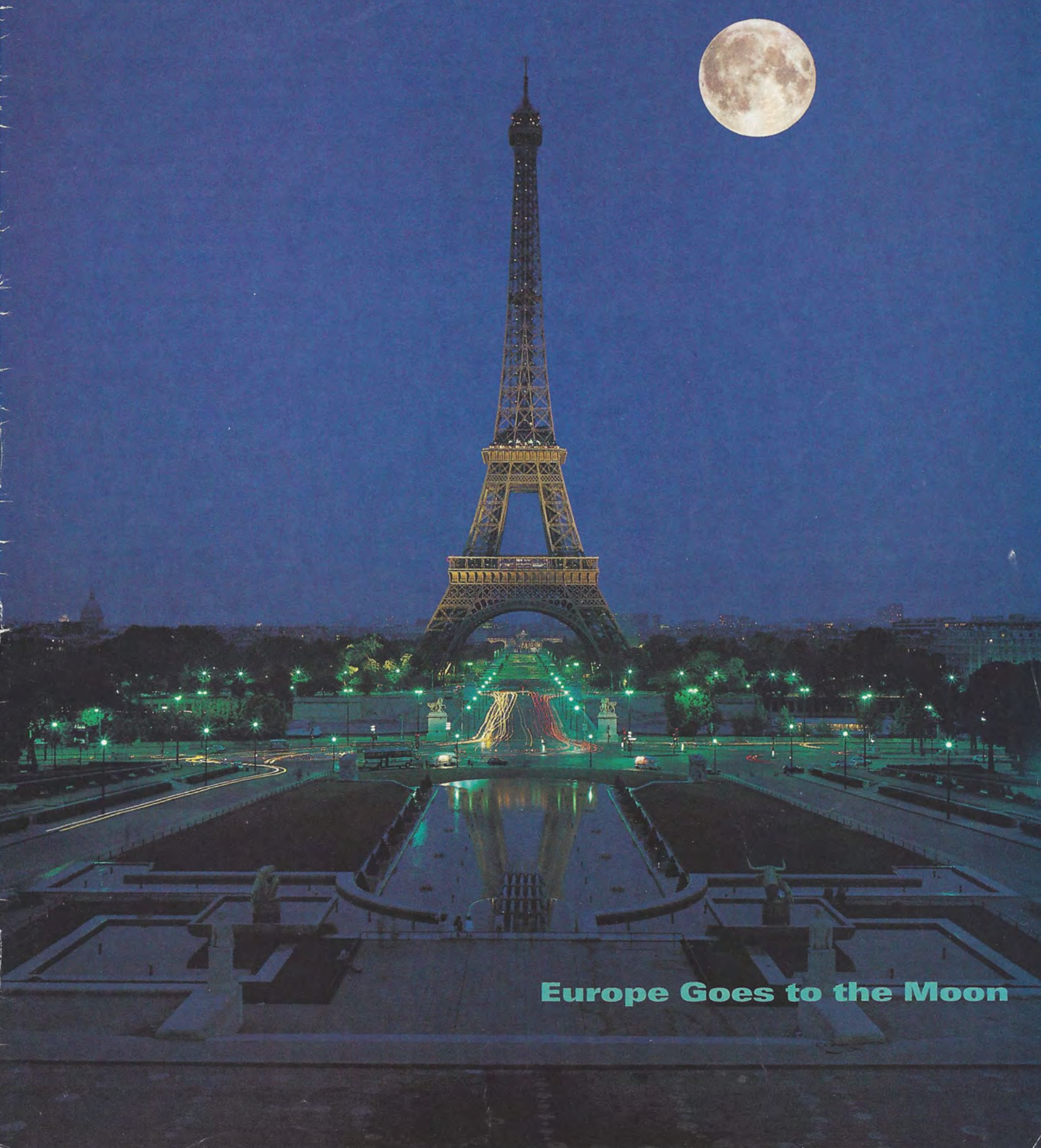

Europe Goes to the Moon

On the Cover:

We indulge in a bit of whimsy with this photomontage of the Moon over Paris, symbolizing the European Space Agency's developing interest in mounting an ambitious program to explore Earth's satellite. The Moon was the first great goal of the United States and Russian space programs, but their exploratory interests drifted elsewhere in the solar system. Only the Japanese *Hiten* spacecraft and the *Clementine* technology demonstration project have investigated the Moon lately. ESA sees it as a target of opportunity that could establish the agency as a major space power.

Eiffel Tower: Alex Bartel/Zepher Pictures
Moon: Kerry Hurd, courtesy of Dennis Milon

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From The Editor

Last year was a great one for The Planetary Society. We succeeded, perhaps as never before, in reaching out to the public and in shaping policy to support planetary exploration.

Comet Shoemaker-Levy 9's collision with Jupiter caught the attention of people around the world, and it served as a warning of what could happen to Earth should a celestial body collide with us. With our Jupiter Watch program, we focused that attention on the programs we support, and we are now working to expand research on comets and asteroids.

With Mars Together, we saw both the name and much of the content of a Planetary Society program adopted by the space programs of the United States and Russia. The dream of these former antagonists together tackling the exploration of another world never seemed closer to fruition.

But economic realities may undermine our victories. Public memory is short and it may be hard to raise funds for research. The Russian space agency may simply not have the money to fulfill its plans for Mars. We will have our work cut out for us this year if we are to see our projects succeed. *—Charlene M. Anderson*

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Members' **Dialogue**

A New Vision

Dan Goldin's call for a new NASA vision is welcome (see the November/December 1994 issue of *The Planetary Report*). The search for habitable planets elsewhere in our galaxy is one example he offered. It touches on the fundamental rationale for space exploration—the search for beings like ourselves in the universe.

But, I think that the search for habitable planets is too narrow a goal—and too passive. NASA would be just looking. It would not be reaching out to explore.

I suggest another goal: to explore and settle Mars. By searching for traces of past life on Mars, perhaps we can learn enough to answer questions about the origin, nature and evolution of life. Will humanity expand beyond our planet? Or is our future limited to staying on Earth?

These are questions that will likely be answered by 21st-century Mars exploration. Such exploration could drive our whole space program, from microdevices like Mars *Pathfinder*'s microrover to heavy-lift launch vehicles, Mars fuel factories, and robotic and human space missions. As such, I believe Mars exploration is more suitable for a NASA vision.

Goldin says that he offers his ideas to provoke discussion and other ideas. It is in that spirit that I offer this different view.
—LOUIS D. FRIEDMAN,
Executive Director

Daniel Goldin's suggestion that searching for habitable extrasolar planets should be NASA's focus is most welcome. It is an easily stated, clear goal that we can all understand and support. It would then follow that an astronomical base on the Moon, expensive though it would be, should be a priority in the near future. Regrettably, it also follows that plans for a human mission to Mars should be postponed.
—WESTON WILLIAMS,
Honolulu, Hawaii

Space Station Quarantine?

I found the July/August 1994 issue of *The Planetary Report* to be an excellent read. But while there was much discussion about the possible dangers of sample returns to terrestrial laboratories, absolutely no mention was made about the possibilities of using a space station as an isolation lab.

This seems to be an excellent compromise for the problem of contamination, allowing researchers to get their hands on the samples and devise appropriate experiments and tests, but in an isolated environment. While I would be willing to see this as an oversight, deep down I feel that it is due to the editors' and the Society's stand against the space station, since it seems to suck funding away from planetary exploration.

Nevertheless, I believe it was a disservice to your readers to ignore—both in the articles and in the included questionnaire—the possible benefits of having samples returned to a space station.
—ARNOLD G. GILL,
Nanaimo, British Columbia

Several readers commented on the possibility of using the space station as an isolation laboratory in which a Mars sample could be examined without risk of exposing Earth's environment to accidental release. Several years ago, NASA's Ames Research Center conducted a study that addressed this very question. The study, entitled "Orbiting Quarantine Facility" (edited by myself and John Bagby), concluded that there were no obvious technological barriers that would prevent this possibility, but the costs of such an isolation laboratory in orbit would be extremely high.

One possible problem with this scenario relates to the need to challenge biological systems with Mars soil to test its potential toxicity. It is conceivable that interpretation of the results could be complicated by the fact that biological systems are susceptible to significant changes when exposed to weightlessness alone, let alone any changes that might be induced by the Mars sample. However, with recent advances in cell culture techniques, with several years' worth of United States and Russian experiments on the effect of weightlessness on living systems, and with a space station becoming a reality, perhaps it is time to revisit this concept.
—Donald L. DeVincenzi,
Guest Technical Editor

In 1987, The Planetary Society testified before Congress (see "A Space Station Worth the Cost" in the July/August 1987 issue of The Planetary Report*), emphasizing our support for an international space station that focuses on long-range science and technology in preparation for human exploration of other worlds.*
—Bruce C. Murray,
Vice President

On to Pluto

Your September/October 1994 issue (see "To Pluto by Way of a Postage Stamp") convinced me that an international mission to Pluto is not only feasible, it is *worthy.* The "better, faster, cheaper" philosophy could result in an innovative, riskier mission that is enhanced by international collaboration—and in so doing might reestablish NASA's glory.
—JOEL MacAUSLAN,
Nashua, New Hampshire

Please send your letters to Members' Dialogue, The Planetary Society, 65 North Catalina Ave., Pasadena, CA 91106-2301.

BACK TO THE FUTURE:
SETI Before the Space Age

by Steven J. Dick

The modern era of the Search for Extraterrestrial Intelligence (SETI) was inaugurated some 35 years ago, with the seminal paper by Giuseppe Cocconi and Philip Morrison in 1959 ("Searching for Interstellar Communications," *Nature*) and the Project Ozma search of Frank Drake in 1960. But even many SETI enthusiasts do not realize that this era of interstellar communication (as it was originally called) was preceded by a colorful era of interplanetary radio communication—an era filled with parallels, contrasts and perhaps even some lessons for those interested in the survival of SETI in its current incarnation.

The Radio Pioneers: Tesla and Marconi

Although the idea that visual signals might be sent to the Moon or Mars was common in the 19th century, it was the idea of radio communication between Earth and these bodies in space that caught the public fancy and the early interest of several radio pioneers. Heinrich Hertz, the German physicist who first demonstrated the existence of radio waves, died in 1894, too early to see the application of his work to even terrestrial communication. But two of his contemporaries, Nikola Tesla and Guglielmo Marconi, not only foresaw the use of radio technology for communication beyond Earth, but believed they had actually detected signals of intelligent origin.

Tesla, the Serbian-born American physicist and engineer, was the first to publish this idea, in 1901—and under remarkable circumstances. During experiments at his laboratory in Colorado Springs, Colorado, in 1899–1900, Tesla observed unusual electrical disturbances that "positively terrified me, as there was present in them something mysterious, not to say supernatural."

Tesla knew of the electrical disturbances produced by the Sun, the aurora borealis and Earth itself; the new signals were more regular than any of these. "It was some time afterward," he reported in 1901, "when the thought flashed upon my mind that the disturbances I had observed might be due to an intelligent control. Although I could not decipher their meaning, it was impossible for me to think of them as having been entirely accidental. The feeling is constantly growing on me that I had been the first to hear the greeting of one planet to another."

RADIO TO STARS, MARCONI'S HOPE

Inventor Says Waves of Ether Are Eternal and Can Reach Other Planets.

GETS STRANGE SIGNALS NOW

These, He Declares, Might Conceivably Have Proceeded from Other Worlds.

Special Cable to THE NEW YORK TIMES.

LONDON, Jan. 20.—The Daily Chronicle publishes an interview which Harold Begbie had with William Marconi, in the course of which the latter discussed the possibility of communicating by wireless with the stars.

Mr. Begbie asked him if he thought that waves of ether were eternal. Mr. Marconi replied:

"Yes, I do. Messages that I sent off ten years ago have not yet reached some of the nearest stars. When they ar-

Figure 1: Radio pioneer Guglielmo (William) Marconi reported receiving signals "which seemed to come from some place outside the earth." He wouldn't rule out the possibility that the signals came from another civilization, and many reports on his work appeared in the press. This article is from The New York Times, *January 20, 1919.*

Tesla went on to a busy, and then a reclusive, life and never followed up on this idea. Astronomers were skeptical, and the revival of interplanetary radio communication in a more sustained form came not from them, but from the great Marconi himself, by now world famous for his work in radio communication. On January 20, 1919, *The New York Times* ran a front-page article with the headline "Radio to Stars, Marconi's Hope." (See Figure 1.) Asked during an interview whether he believed waves of ether were eternal, Marconi replied, "Yes, I do. Messages that I sent off ten years ago have not yet reached some of the nearest stars. When they arrive there why should they stop?"

Comparing the weakening radio signals to a repeating decimal that never comes to an end, Marconi said this property of radiation "is what makes me hope for a very big thing in the future.…Communication with intelligences on other stars…may some day be possible, and as many of the planets are much older than ours the beings who live there ought to have information for us of enormous value." Then, hesitating slightly, Marconi admitted he had often "received strong signals out of the ether which seemed to come from some place outside the earth and which might conceivably have proceeded from the stars."

These ideas were repeated in more detail in the January 27, 1920, *New York Times,* where Marconi reported that Morse code letters occurred often in these signals but no message was decipherable. Because the signals occurred simultaneously in the London and New York receiving stations and because they were of equal intensity, Marconi inferred they originated at very great distances. "We have not yet the slightest proof of their origin," he noted, saying that it could be the Sun. It was not Marconi but the press that raised the contentious question about other planets being the source, to which Marconi replied, "I would not rule out the possibility of this, but there is no proof. We must investigate the matter much more thoroughly before we venture upon a definite explanation."

For the next few weeks, *The New York Times* followed up on the story almost daily, sometimes on the front page. Radio engineers were quoted as being highly skeptical that the signals emanated from another planet, especially from intelligence, and felt that they were atmospheric disturbances induced by the Sun. The United States Navy Department, with its advanced radio communications system, was reported to be keeping an open mind, with interest manifestly outweighing skepticism. Charles Steinmetz, the famous inventor and engineer, denied that the signals came from Mars but held that "if the United States...should go into the effort to send messages to Mars with the same degree of intensity and thoroughness with which we went into the war it is not at all improbable that the plan would succeed." C.G. Abbot, director of the Smithsonian Astrophysical Observatory, suggested that Venus was a much more likely source than Mars, since Mars was too cold and lacked water. And Elmer Sperry, head of the Sperry Gyroscope Company, boasted that his company could send a message to Mars using 150 or 200 Sperry searchlights adding up to a billion candlepower.

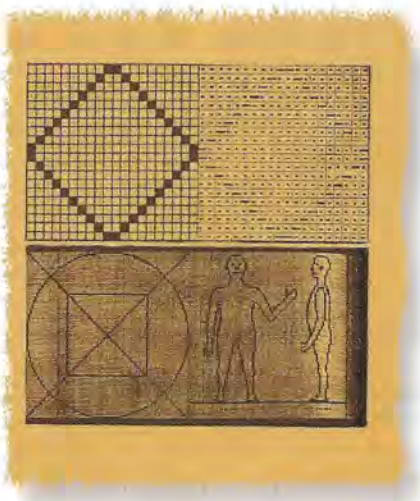

Figure 2: In 1920,* Scientific American *published this proposal for communicating by means of dots and dashes arranged in blocks. The top message uses strips of telegraph tape and graph paper. Below that, a larger number of blocks makes more complicated messages possible. This concept is similar to the later idea of formulating interstellar messages by determining blocks of pulses and spaces using prime numbers to set the dimensions of the array.

The debate reached continental Europe when the French Academy of Sciences agreed to judge a competition for a 100,000-franc prize "for the best means of making a sign to a heavenly body and the receipt of a reply." And no less a scientific icon than Albert Einstein was quoted as believing that Mars and other planets might be inhabited, but that Marconi's signals were due either to atmospheric disturbances or to experiments with other wireless systems. If intelligent beings on other planets attempted to communicate with Earth, Einstein added, he would expect them to use rays of light, which are more easily controlled. Einstein was thus an early proponent of optical SETI!

***Figure 3: In 1924, at the suggestion of David P. Todd, the United States Army directed its radio operators to listen for possible signals from Mars. The Navy also joined in the effort. This illustration appeared in the October 1924 issue of* Radio Age.**

Two weeks later, *Scientific American* argued that while Marconi's conjectures should not be dismissed, there was absolutely no proof that Martians existed; it was unlikely that they would develop a Morse code as on Earth; they could not transmit over the 80-million-kilometer (50-million-mile) distance separating Earth and Mars; and radio stations at the Eiffel Tower and elsewhere, including those of the US Navy, had not heard the Marconi signals "although they have searched for them." Suspecting even the Japanese or "the Russian Bolsheviki, who have turned to radio as a convenient means of propagating their cause at home and abroad," the editors concluded nonetheless that "this matter deserves careful study when a scientist of Mr. Marconi's standing takes it so seriously." The following month *Scientific American* featured an article entitled "What Shall We Say to Mars?," which attempted to determine how knowledge might be communicated by dots and dashes in the absence of a common language (see Figure 2).

Marconi's interest in interplanetary communication apparently peaked during a trip from Southampton, England, to New York City aboard his floating laboratory, the yacht *Elettra,* from May 23 to June 16, 1922. *The New York Times* reported that he "spent the time crossing the Atlantic performing many electrical experiments, principally by listening for signals from Mars." Marconi admitted that "they might have come from any region in the universe where electrons are in vibration." It is notable, however, that when Marconi addressed the respected Institute of Radio Engineers and the

American Institute of Electrical Engineers on the subject of radiotelegraphy a few days after his arrival in New York, he discussed long-distance radio communication but had nothing to say on the subject of interplanetary radio communication.

Of all the reactions to Marconi's statements, none was more poignant than *The New York Times'* editorial "Let the Stars Alone," which argued that "even if it could be done one doubts it would be desirable.…Quite possibly there are even yet more things in heaven and earth than are dreamed of in our philosophy, and it would be better to find them out in our own slow, blundering way rather than have knowledge for which we are unprepared precipitated on us by superior intelligences." This viewpoint also finds its parallel in the modern era.

David P. Todd, Balloon SETI and Other Schemes

In the midst of the Marconi flap, another thread of the story was developing: the idea of wireless interplanetary communication from a balloon. The prime mover in this daring enterprise, which combined an imaginative idea with a bold technology, was the well-known astronomer David P. Todd, director of the observatory at Amherst College from 1881 to 1920. As early as 1909, Todd had suggested that Martians might communicate with Earth using Hertzian waves, and that the most sensitive wireless receivers should be taken up in a balloon to diminish atmospheric effects. A skeptical *Scientific American,* anticipating in rudimentary form the problem of radio frequency interference (RFI) that frustrates modern SETI searchers, pointed out that about 2,000 wireless stations were scattered over the surface of Earth, that the Sun and Earth's atmosphere might also be sources of electrical signals and that it would thus be difficult to pinpoint the source of any supposed martian signals.

Nevertheless, in 1920 *The New York Times* reported that Todd, "after more than five years of preparation, during which time he has studied the proposition from every conceivable angle," had set the date of April 23 for a balloon ascent to try to communicate with Mars. Alas, we can only wonder what became of Todd's ambitious expedition. In subsequent days the *Times* reported only on a separate ground-based attempt at radio communication with Mars and offered a cryptic statement that while construction of Todd's balloon was progressing, the "experiment will be held in abeyance, however, until sanctioned by the U.S. Government." Once again, shades of recent SETI events!

Figure 4: In 1937, Harvard astronomer Donald Menzel proposed using number code to transmit "circle" and "dipper" to Mars. His proposal was published in the December 1937 issue of Short Wave and Television.

Though unsuccessful with his balloon experiments, by 1924 Todd pressed yet another bold project related to interplanetary communication. *The New York Times* reported that Todd had obtained informal assurances from the US Army and Navy that they would observe, as much as possible, a period of radio silence on August 22 and 23, when Mars was at closest approach. In an effort to obtain worldwide cooperation, Todd also discussed radio silence with the State Department and several embassies. In addition, Army and Navy radio operators would "listen in" for signals from Mars, and be "ready to translate any peculiar messages that might come by radio from Mars." (See Figure 3 on page 5.)

Department of Commerce officials said they too were ready to cooperate if asked. "Although officials were strongly skeptical as to success, they seemed to take the attitude that there could be no objection to giving communication with Mars a fair trial under the best possible conditions," the *Times* reported. Some experts were even more skeptical—too much so, we now know; the chief of the radio laboratory of the National Bureau of Standards declared that Earth's atmosphere would prevent any radio signals from reaching the ground!

On August 21, the Point Grey wireless station in Vancouver, British Columbia, reported having received unusual signals during the preceding week. Although the frequency was not given, "Four distinct groups of four dashes each came through the ether today," one operator had stated. The signals were in no known code, starting on a low note and ending with a "zipp," and neither a spark nor a continuous wave could have been responsible for the sounds. The following day the signals were heard again in Vancouver and reported to have been heard at the same time of day for more than four weeks. Moreover, the Associated Press reported that British wireless experts, using "a twenty-four tube set erected on a hill at Dulwich" had heard at a wavelength of 30 kilometers (18.6 miles) sounds "likened to harsh dots," but they could not be interpreted as any known code. Frank Drake and others have speculated that Tesla, Marconi and others might have been hearing "whistlers," low-frequency waves generated by lightning flashes that propagate along Earth's magnetic lines of force. These early attempts at interplanetary interpretations for unknown signals thus lend credence to the "Occam's razor" rule that mundane explanations should always be given priority over exotic ones.

Donald Menzel, Radio Amateurs and Radio Astronomy

In 1932, 10 years after Marconi's words on radiotelegraphy were published in the *Proceedings of the Institute of Radio Engineers,* Karl G. Jansky of Bell Telephone Laboratories reported in the same journal that he had detected a strange radio static that he could not attribute to any known source. This he interpreted in the following year as coming from beyond the solar system, a claim that was greeted with skepticism by most astronomers. (Occam's razor doesn't always work!)

Interest in radio communication with the planets, however, had not quite run its course. "The question of radio-communication with distant planets still holds supreme charm for all red-blooded radio experimenters," the editor of *Short Wave and Television* magazine (none other than science fiction pioneer Hugo Gernsback) wrote in the December 1937 issue. One of those radio amateurs happened to be Harvard astronomer Donald Menzel, who in the same issue wrote the article, "Can We Signal Mars by Shortwave?" Menzel noted that "the general consensus of opinion is that no very high degree of intelligent life exists in our solar system," and the thrust of his article was therefore not to propose the transmission or receipt of actual signals, but to explore the question of whether we might in principle be able to communicate information via radio signals sent from beyond Earth.

If we received a radio message from Mars, Menzel argued, radio technology implied knowledge of mathematics and physical science, and mathematics was a natural starting point for communication. Using dots and dashes, one could begin by transmitting arithmetical problems and answers, to which the Martians would reply with their own. One could then advance to abstract numbers like pi, and the relative distances of the planets from the Sun. The alphabet could be transmitted by means of a series of paired numbers, coordinates on a graph (Figure 4). Proceeding in this way to more and more complex information, Menzel saw "no obvious limit to the information that could be exchanged."

The same issue of *Short Wave and Television* included the cautious opinion of radio pioneer Lee De Forest, the more imaginative interpretations of Tesla, and a remarkable analysis by American Telephone and Telegraph (AT&T) staffer Joseph L. Richey of the optimal wavelengths and the power required to send a signal to Mars (see Figure 5). Although Richey proposed that radiation between the infrared and 10-meter radio (as well as optical) wavelengths would be optimal for penetrating Earth's atmosphere, he concluded that communication with Mars was "economically and technically not feasible with present-day equipment." Such conclusions did not dampen the enthusiasm of radio amateurs, including pioneer Hiram Percy Maxim, whose book *Life's Place in the Cosmos* (1933) gave prominent coverage to *interstellar* communication. A generation ahead of his time in this proposal, Maxim simply had faith that some day the technology would be developed.

Figure 5: On the sending end (left and center): This illustration attempted to show the enormous amount of power—about 50,000 kilowatts—estimated necessary to transmit readable messages to Mars. It appeared in the December 1937 issue of* Short Wave and Television. *At this time the first antenna for radio astronomy was being built.

***On the receiving end (top right): Hugo Gernsback gave this view of a Martian at his radio set (also in the December 1937 issue of* Short Wave and Television*). Gernsback, often called "the father of science fiction," was the founder and editor of that magazine and many others, including* Amazing Stories.**

Two Eras, Two Outcomes?

Like the modern era of interstellar communication, the era of interplanetary radio communication was led by innovative scientists with broad but practical interests. Tesla, Marconi, Todd and Menzel were all originals in their own way, not afraid to vent controversial ideas. All were well grounded in technical interests, and the interplanetary communication era was woven from those interests, though based on only the slightest of evidence. With time, the technical concerns increased in sophistication, beginning simply with unexplained signals and ending with concerns about optimal wavelengths, the effects of Earth's atmosphere, and power requirements. Prospective interplanetary communicators anticipated not only technical problems, but also philosophical, linguistic and cultural factors, only a few of which we have mentioned here.

But there are also major differences. The degree of technical sophistication is certainly one, as well as the manner in which the current debate is carried out. While a few papers appeared in *Scientific American,* debate was largely carried out not in professional journals but in newspapers. Though interplanetary listening projects were discussed and governmental cooperation was even secured in 1924, there was no real attempt to expend public funds on any project, a political process that dominated the NASA SETI program and led to its demise. Finally, we must not lose sight of the fact that despite their interesting discussions, Tesla, Marconi and others were mistaken in their interpretation of radio signals as artificial, a pattern that would-be interstellar communicators hope not to repeat. Needless to say, modern researchers would like to avoid the rather precipitous announcements of Tesla and Marconi to the media; history shows the inevitable result all too clearly. Our journey back to the future also demonstrates that while technical considerations are important, they should not act as an absolute constraint on thinking. Unbridled imagination is a dangerous thing, but it may also lead to the truth.

If we consider the era of interplanetary communication to be bracketed by Tesla in 1901 and Menzel in 1937, its life span is 36 years, almost the same duration as the current era of interstellar communication. It is true that now the entire universe awaits, rather than our own parochial solar system. But whether lack of detections, political will or funding results in a limited life span for modern SETI, and whether a century from now it will be seen as only a curious episode in the history of science like its predecessor, only the future will tell. Either way, both eras are a part of the venerable tradition of the search for humanity's place in nature.

Steven J. Dick is an astronomer and historian of science at the US Naval Observatory in Washington, DC. His book The Biological Universe: The Twentieth Century Extraterrestrial Life Debate and the Limits of Science *is currently in press at Cambridge University Press. This article is a much abridged version of a fully annotated paper given in the SETI sessions of the 44th Congress of the International Astronautical Federation, held in Graz, Austria, in October 1993.*

TAKING THE NEXT STEP:

BY R.M. BONNET

Right: The Moon orbits Earth with the same side always facing the planet. Before the space age, humans had no idea what the far side of the Moon looked like, so it was a prime target for early missions. Future missions such as those proposed by the European Space Agency will also investigate this little-known terrain. The far side is a bit different from the Moon's familiar face. It's heavily cratered, without the extensive, dark, smooth maria that mark the near side. This view of the far side was taken during the Apollo 11 *mission.* Photograph: NASA

Below: The recent Clementine *mission produced a global map of the Moon. Here we see the landing site of* Apollo 11*, where humans first walked on another world. The three craters lying in a nearly straight line above the landing site are named Collins, Aldrin and Armstrong after the crew members. The bright crater near the bottom is Moltke.* Image: Ella Mae Lee and Mark Robinson, USGS/Flagstaff

Hanging silently in the sky, beckoning for millennia to adventurous travelers, the Moon was the inevitable first target for spacefarers from Earth. In 1959, the Soviet Union flew the first spacecraft by the Moon, *Luna 1*. Ten years later, the United States landed the first humans on the Moon in *Apollo 11*. In the frenzy of the space race between the two superpowers, dozens of spacecraft were sent to explore Earth's companion. But by the mid-1970s, both countries had lost interest in the Moon, and they directed their spacecraft to other planets in our solar system.

Several of the nations of Europe had in the meantime been developing their own space capabilities, and in 1974 they joined to form the European Space Agency. While ESA does not yet rival NASA in size or budget, its abilities and ambitions are continually growing. In 1986, the ESA craft *Giotto* made the closest flyby to date of Halley's Comet. ESA has planned many other missions to explore the solar system, including *Rosetta,* which is to perform the difficult task of directly sampling a comet.

In 1989, ESA Director General R. Lüst instructed its Science Directorate to assess the interest of Europe in participating in an international Moon program. The time seemed right to consider a return to that world only briefly explored. The directorate's enthusiastic support led to the appointment of several working groups to define the objectives and requirements for such a program. We now have the outline of what could become the Moon program of Europe.

WHY THE MOON?

The Moon is a natural space platform of 38 million square kilometers (15 million square miles), one that everybody on Earth can watch, a space station that needs only to be equipped with an infrastructure to exploit its scientific potential and its resources.

Earth has been linked with the Moon since the solar system formed, more than

THE EUROPEAN MOON PROGRAM

In "Cultivating the Moon," artist Robert McCall imagines a base set up to mine the surface for its rich deposits of helium 3. This isotope is rare on Earth and, should fusion ever become a workable power source, could become an extremely valuable commodity. Painting: Robert McCall

4.5 billion years ago. Recent studies have addressed the role the Moon plays in stabilizing Earth's rotation axis, a role that ensures the long-term stability of our climate and has probably been a factor in the evolution of intelligent life on Earth. Yet even after *Apollo* and the *Luna* program, understanding the origin of the Earth–Moon system is still an elusive goal. The Moon would be a natural laboratory, a history book of the solar system and of the Sun itself.

The Moon is a unique astronomical site, offering observing conditions better than anywhere on Earth. Without a thick atmosphere to deal with, instruments placed there could have access to the entire electromagnetic, particle and cosmic ray spectrum. Its far side offers the only place in the inner solar system with a natural "clean" electromagnetic environment, making VLF (very low frequency) astronomy an appealing objective. The Search for Extraterrestrial Intelligence could be conducted without interference from earthly radio broadcasts. The next step in astronomy will be the development of more powerful instruments for imaging stars, galaxies, quasars, binary systems and, ultimately, extrasolar planets, and the Moon offers a large and stable platform for their construction.

There are problems inherent to a lunar base, such as the Moon's rotation, large temperature variation (100 to 385 degrees Kelvin, or minus 280 to plus 234 degrees Fahrenheit) except at the poles, dust pollution (both natural and the result of human activity) and sky background, micrometeorite impacts, and a long (14-day) night requiring power storage. These represent a strong incentive for new high-technology developments. The establishment of a lunar base will allow challenging projects for life scientists in the fields of exobiology, radiation biology, ecology and, eventually, human physiology.

Our satellite could also become a test bed for developing the skills necessary for interplanetary travel and planetary exploration. Using the Moon's resources to "live off the land" will place on a more realistic basis the possibility of sending humans safely to Mars.

The Moon's soil is an immense reservoir of natural resources, which could be tapped, and large power plants could then be built on its surface. The capability to locate, mine and process these resources will be essential for the development and operation of a lunar base. Little is known about the methodology that might be suitable for using them, and new technologies may well be needed. Whenever thermonuclear fusion energy production is mastered, helium 3 might become the preferred fuel. Helium 3 is scarce on our planet (there are only a few

Veering Onto the INFORMATION SUPERHIGHWAY

Presenting The Planetary Society...on Your Computer

The Planetary Society is joining the information revolution—or, to use the more familiar metaphor, we're veering onto the information superhighway. Two new electronic services, The Planetary Society On-line and The Planetary Society Home Page, give you the opportunity to communicate with us via your computer. Designed with our members' interests in mind, these services let you use a computer and modem to view articles and images, order merchandise, submit letters to the editors of *The Planetary Report* and ask questions about the planets and the search for extraterrestrial life. Here's how these services work.

LETTING THE GENIE OUT OF THE LAMP

Beginning February 1, 1995, if you have a Macintosh or Windows-based computer and a modem, you will be able to log onto The Planetary Society On-line, one of the newest additions to GEnie, the system offered by General Electric Information Services. We've designed The Planetary Society Roundtable, an area on the network where you can download images of the planets, post messages about NASA and international missions, read the latest news about spacecraft and exploration or glance at the most recent issue of *The Planetary Report.* The roundtable will also feature live conferences with planetary scientists and engineers (see sidebar).

GEnie offers you e-mail and some access to the Internet. You'll be able to send computer messages to Society headquarters and to anyone with an e-mail address. Society e-mail addresses will be posted in future issues of *The Planetary Report,* but you can also find them in our roundtable or World Wide Web page (details below).

HOW TO JOIN

To get started, make a free call to GEnie Client Services at (800) 638-9636 from 9 a.m. to 12 midnight Eastern Standard Time. The TDD number is (800) 238-9172. A GEnie representative will ask you if you need a Macintosh or Windows front end (the software that lets you connect to GEnie and move around in it easily). You can also dial into GEnie directly from a DOS-based system; just ask the GEnie representative for instructions. *Be sure to mention the special sign-up code—TPS123.* Using this code guarantees you special discount rates for the time you're logged onto GEnie and also makes sure you connect directly with our roundtable.

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The Society Home Page is the result of a collaboration with administrator Les Weber of Weber Engineering in Mankato, Minnesota. He has volunteered his computing time, expertise and space on the Internet to create this exciting way of presenting Society information. Thousands of Internet users from more than 30 countries have already read about the Society on this page.

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— Michael Haggerty

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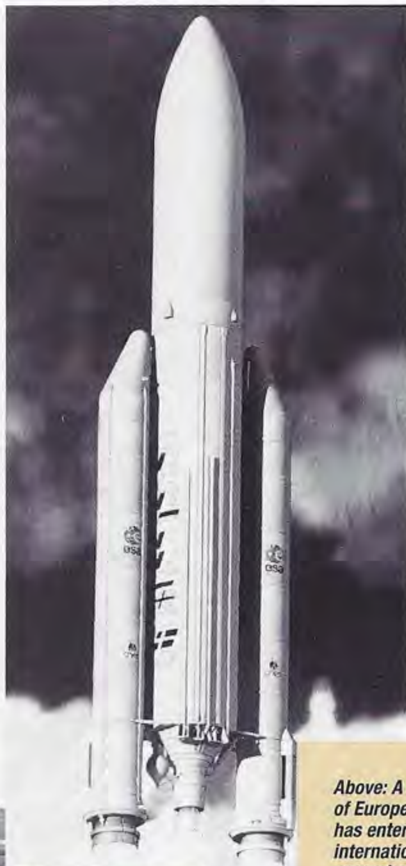
— MH



Above: A consortium of European nations has entered the international launcher market with the Ariane *family of rockets. The largest,* Ariane 5, *is still being developed. When available, it will be able to launch large payloads such as those envisioned in the proposed European lunar program.* Photomontage: ESA/D. Ducros

Left: The European Space Agency has built its launch complex for the Ariane *family in Kourou, French Guiana. This photomontage shows the* Ariane 5 *being prepared for launch.* Photomontage: ESA

TWO MISSIONS TO PREPARE THE WAY

To prepare for the first phase, ESA is studying two projects: MORO and LEDA.

MORO (for Moon Orbiting Observatory) is a scientific mission, a lunar orbiter to characterize the surface of the Moon (its geology, morphology, geochemistry, mineralogy, topography and heat flow), as well as to investigate the interior (geodesy and gravimetry). The US *Clementine* mission has demonstrated the tremendous potential of multiwavelength studies for the advancement of lunar science. MORO should be capable of filling basic gaps in lunar science left by *Clementine*. The mission has been specifically designed to address the outstanding scientific questions concerning the origin, evolution and future exploration of the Moon.

However, MORO is competing for ESA support with four other missions in the fields of astronomy, planetary science and fundamental physics, and its selection cannot be guaranteed. If selected, MORO will be launched by *Ariane 5* in 2003.

In contrast to MORO, which would be a scientific mission and part of ESA's mandatory scientific program, LEDA (for Lunar European Demonstration Approach) is seen as an optional program. (In Greek mythology, Leda is a Spartan queen, wife of Tyndareus, mother of Clytemnestra, Helen and Castor.)

The main objective of LEDA is to, using *Ariane 5*, soft-land on the lunar surface a payload to undertake investigations pertinent to the future Moon program. This payload may include a rover, a soil-processing facility and a robotic arm. Some of LEDA's technological objectives include analyzing and testing procedures for soil processing on the Moon, operating a landed system under a wide range of possible surface conditions, and preparing and demonstrating the technical capabilities leading to a permanent robotic presence on the lunar surface.

LEDA will provide information on factors crucial to the establishment of the lunar outpost: micrometeorite flux, seismic noise, soil mechanics, thermal properties of the surface, soil characterization, stereo imaging of the surface, measurements of gases and suspended dust particles, measurement of the sky background at all frequencies, and radiation doses. The landing site will be close to the lunar south pole to facilitate the search for water.

AN INVITATION TO THE WORLD

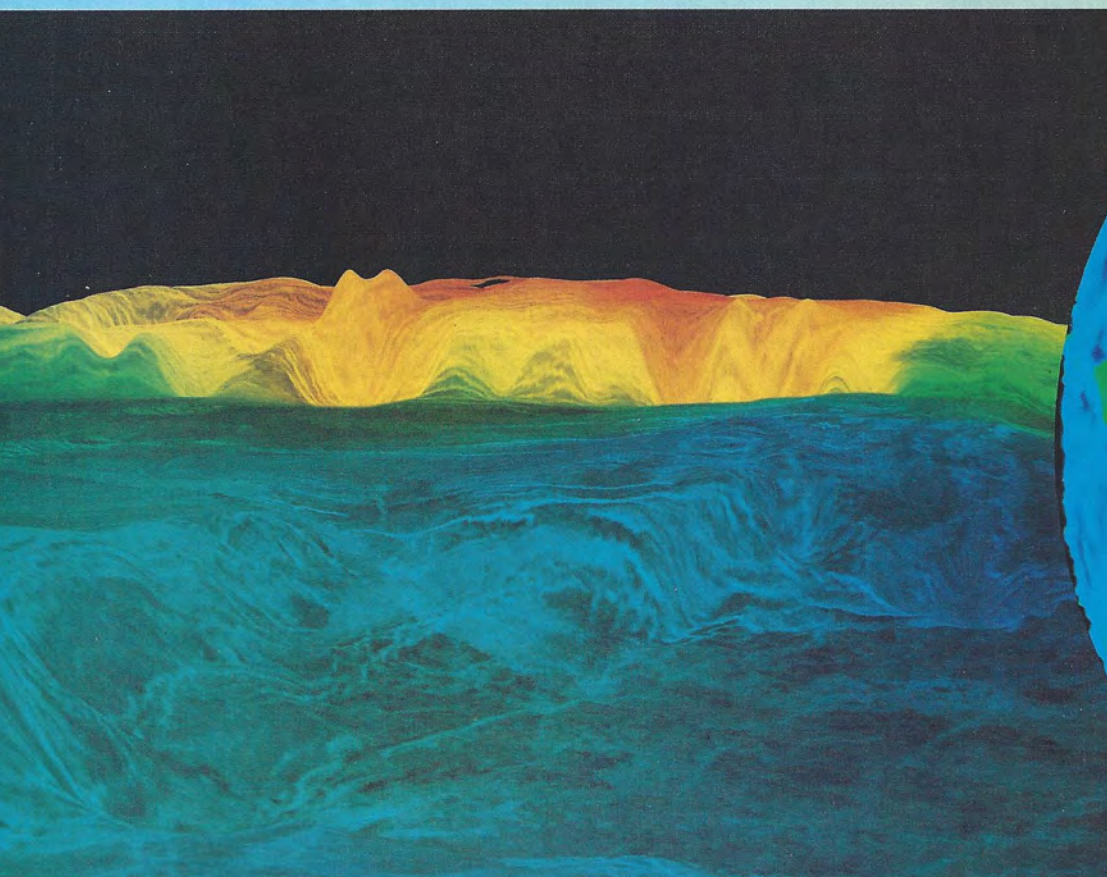
The Moon program should rest on the broadest international involvement. Via telepresence and virtual reality, it could involve everybody on Earth. But to achieve the necessary political will, we will need a worldwide initiative aimed at creating a consensus among scientists, politicians and space organizations.

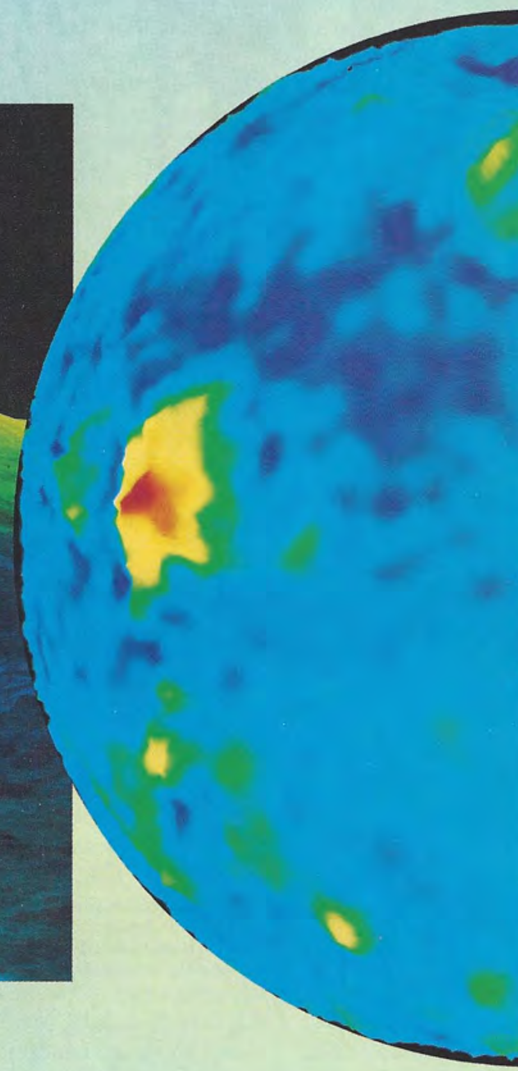
One proposal calls for the January 1, 2000, start of an International Lunar Quinquennium (ILQ), to be built around a few simple scientific missions and the testing of key technologies. The ILQ would allow all nations willing to participate to do so, and it would open the way to a renewed exploration program, offering a balance between cooperation and competition, in which nations individually or cooperatively might use the Moon and its future bases in a totally peaceful way.

R.M. Bonnet is a space scientist and presently the director of the science program at ESA. He was the chairman of the ESA committee in charge of defining the objectives and the requirements of the future Moon program.

The Mystery

by Kari Magee



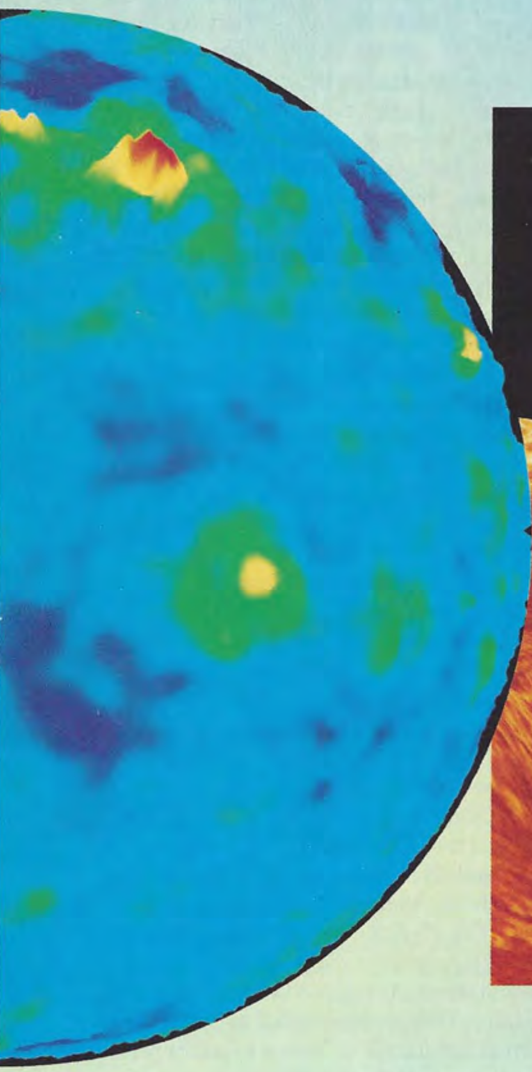


Above: In this three-dimensional oblique view, we are looking east-northeast from Lakshmi Planum and adjacent plains toward Maxwell Montes. The plateau of Lakshmi is near the center of the image, and the steep face of Maxwell rises beyond, in shades of yellow and red. Gravity data have been superposed on the local topography in this image to emphasize the correlation of high gravity with high topography, and the surface features have been exaggerated vertically 22 times.

Center: In this image, we see a portion of the global topography of Venus with gravity data superposed on it. The surface topography is shown in relief enhanced 100 times to emphasize subtle variations. Variations in gravity are shown in color (red is high, or strong; blue is low, or weak). In this hemisphere we see the highlands of Ishtar Terra at the top of the picture (the north pole corresponds to the dark blue basin above Ishtar) and Beta Regio in the central left portion of the picture. Maxwell Montes is the very prominent rise within Ishtar Terra. Immediately to the west (left) of Maxwell is Lakshmi Planum. Note the distinctive correlation between regions of high gravity and elevated topography.

Far right: This is the same view of Maxwell shown in the image above but without superposed gravity data. The orange tones are based on color images of the surface of Venus obtained by the Venera 14 *and* 15 *landers but are much more pronounced than what the colors would actually look like at the surface. As you can see here, the highest regions on Venus often appear very bright in the radar image data, a phenomenon linked to the presence of highly reflective minerals in the soil or surface rocks. This effect is slightly obscured in the other images by the superpositioning of topography and gravity data. These minerals may form as a result of chemical reactions with the atmosphere at high elevations on Venus.* *All images: JPL/NASA*

# of Maxwell



The end of *Magellan* came on October 12, 1994, as the "little spacecraft that could" entered the thick atmosphere of Venus and tumbled to its final resting place somewhere in Atalanta Planitia. Because the atmosphere of Venus is so thick, and *Magellan* entered it so slowly, the spacecraft did not entirely burn up. Mission engineers believe that pieces of it landed on the surface, unlike small meteoroids that enter the atmosphere at very high speeds and are completely incinerated. It's as if the spacecraft settled slowly through a great sea and came to rest on the ocean bottom.

Although *Magellan* is now gone, scientists will long be studying the huge amount of data returned during its four-year orbit of Venus—more data than returned by all previous planetary missions combined. We show here some of the last images to be released by the *Magellan* project. These images focus on Maxwell Montes, the highest mountains on Venus, rising some 12 kilometers (nearly 7.5 miles) above the venusian equivalent of sea level. How such a mountain range grew—and persists—is one of the mysteries of Venus still to be solved.

In these scenes, radar image data have been combined with topography and gravity data to allow scientists to study the links between surface landforms and the interior structure of Venus.

After *Magellan* completed its radar mapping mission, scientists were anxious to direct the spacecraft to gather gravity data over Venus. This is why the aerobraking maneuver to circularize *Magellan*'s orbit was so important (see the March/April 1994 *Planetary Report*). The resulting nearly circular orbit allowed scientists to obtain high-resolution gravity data over almost the entire planet and to improve upon the gravity studies done with data previously obtained by *Pioneer Venus*.

To measure the gravitational field, scientists analyzed variations in the spacecraft's orbit. Very small but detectable changes in the orbital speed of *Magellan* were correlated to specific features on the surface of the planet. Topographically elevated regions, such as mountain belts or volcanoes, contain larger masses of rocky material at the surface of the planet relative to lower-lying plains or basins. As the spacecraft crossed high above a large mountain or volcano, it experienced a slightly greater gravitational tug than it would from surrounding lowlands, causing it to accelerate in its orbit. In comparison, gravity measurements on Earth are obtained by geologists who traverse the landscape with a gravimeter, a device for measuring variations in the strength of the gravitational field. Spacecraft data are most often used to obtain gravity measurements over the oceans.

Gravity data provide clues to the interior structure and dynamics of the planet. From the data sets obtained by *Pioneer Venus* and *Magellan*, scientists have discovered a correlation between high points on the Venus landscape and regions of "high gravity" (a strong gravitational field). This correlation is very unusual compared to Earth, where topographic highs such as mountain belts are *not* always associated with high gravity. Like an iceberg, a mountain on Earth has a massive root of low-density rocks on which it floats. The gravity measured over a mountain having a large, low-density root is lower than that predicted based on its topography alone. In essence, this root counteracts a large portion of the gravity measurement associated with the mass of the mountain on Earth's surface. The strong correlation between high topography and high gravity indicates something different may be occurring on Venus.

One of the most important questions *Magellan* was to address was that of the tectonic style of Venus, a subject of heated scientific debate. Plate tectonics, a process in which large sections of the crust and upper mantle slide over the underlying mantle, has shaped the face of Earth. Plate recycling, which occurs at subduction zones where one plate dives underneath another and along mid-ocean ridges where new plates are formed, also allows Earth to rid itself of internal heat built up by the decay of radioactive elements.

Magellan image data revealed the presence of no Earth-like plate boundaries. Does this mean Venus has no plate tectonics? If so, how do we account for landforms such as Maxwell Montes? Like mountains on Earth, these mountains are orogenic belts—that is, mountains formed by the crumpling and folding of the planet's crust. Orogenic belts are rare in the solar system, as most mountains are volcanoes or the rims and central peaks of impact craters.

To form Maxwell, crustal material has been squeezed and compressed over great distances—up to 1,000 to 2,000 kilometers (about 600 to 1,200 miles). On Earth, the collision of neighboring plates drives the formation of orogenic belts. If Venus has no plate tectonics, what drives the compression we see there?

Some scientists have proposed that surface deformation on Venus may be driven by mantle convection within the interior of the planet, like the churning of surface scum in a boiling soup pot. Large regions of rising or sinking mantle underneath Ishtar Terra (the highland where Maxwell is located) may have dragged the crust horizontally, causing it to crumple in the process.

An additional puzzle associated with Maxwell is related to the nature of its root. It was originally thought that a mountain range as high as Maxwell would require a root too large to be stable unless the temperature deep in the planet's crust was much lower than expected. A low-temperature root could exist if Maxwell was formed very recently in geologic time and very rapidly—essentially, if it has not yet had time to heat up to temperatures in the surrounding mantle. However, crustal rocks may be very dry relative to similar rocks on Earth. Recent laboratory experiments indicate that, if this is so, rocks deep in the crust of Venus may be quite strong and stable. In this case, the lower root temperatures would not be necessary, and Maxwell might not be as young as some have suggested.

To solve this dilemma, scientists are looking closely at the gravity data to determine whether or not the presence of a deep crustal root is consistent with the gravity signal of Maxwell. If not, then other mechanisms (possibly related to interior convection) may be required to support such a large mountain range.

Scientists believe that tectonic events on Venus may occur episodically, rather than continuously as with plate tectonics on Earth. This is based in part on the nature of the impact record on Venus. There are considerably fewer impact craters on Venus than on the Moon or Mars, suggesting that, as on Earth, some process exists to erode or otherwise remove craters from the planet's visible surface. However, these craters are in virtually pristine condition all across the planet. Very few appear to be in any state of degradation. They are also distributed randomly. It is, therefore, difficult (if not impossible) to use crater counts to determine the relative ages of different areas on Venus, as has been done on Mars and the Moon.

Instead, an average age of about 300 million years has been estimated for the entire surface of the planet. Thus, the impact record indicates that the surface of Venus has undergone at least one major tectonic and volcanic resurfacing event that erased all previous craters. Over the past 300 million years, random impacts have been slowly re-cratering the surface. Geophysical models of Venus' evolution suggest that global catastrophic events such as these may have occurred several times throughout the planet's history (and may occur again). They may be linked to processes in which the entire crust and mantle of Venus overturn periodically to form the mountain belts and other structures seen on the surface. Scientists are now studying *Magellan*'s image data in conjunction with the gravity data to determine the nature of Venus' interior dynamics and whether or not Venus is still geologically active.

By studying Maxwell, scientists hope to gain a better understanding of mountain-building processes on Venus and on Earth. By examining the gravity data in conjunction with the other data obtained by *Magellan*, scientists hope to find the link between the origin of structures such as Maxwell and the interior dynamics of the planet. Ultimately, they may discover the reasons why two sister planets so similar in size, mass and composition should differ so remarkably in their geologic evolution.

Kari Magee is Technical Systems Manager of The Planetary Society.

Veering Onto the INFORMATION SUPERHIGHWAY

Presenting The Planetary Society...on Your Computer

The Planetary Society is joining the information revolution—or, to use the more familiar metaphor, we're veering onto the information superhighway. Two new electronic services, The Planetary Society On-line and The Planetary Society Home Page, give you the opportunity to communicate with us via your computer. Designed with our members' interests in mind, these services let you use a computer and modem to view articles and images, order merchandise, submit letters to the editors of *The Planetary Report* and ask questions about the planets and the search for extraterrestrial life. Here's how these services work.

LETTING THE GENIE OUT OF THE LAMP

Beginning February 1, 1995, if you have a Macintosh or Windows-based computer and a modem, you will be able to log onto The Planetary Society On-line, one of the newest additions to GEnie, the system offered by General Electric Information Services. We've designed The Planetary Society Roundtable, an area on the network where you can download images of the planets, post messages about NASA and international missions, read the latest news about spacecraft and exploration or glance at the most recent issue of *The Planetary Report.* The roundtable will also feature live conferences with planetary scientists and engineers (see sidebar).

GEnie offers you e-mail and some access to the Internet. You'll be able to send computer messages to Society headquarters and to anyone with an e-mail address. Society e-mail addresses will be posted in future issues of *The Planetary Report,* but you can also find them in our roundtable or World Wide Web page (details below).

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— MH

Assessing the Threat:

Notes From the Chelyabinsk Asteroid Conference

by Louis D. Friedman

It is 1:30 in the morning. The road, some 16 kilometers (10 miles) east of the Europe–Asia border, is pitch-black except for the headlights of our bus and the whirring blue light of the security car in front of us. I'm not sure why we have security—maybe because we are visitors to a high-level, closed military facility, or maybe simply as protection from the highway robbery that is rampant on Russian back roads.

After a nearly 24-hour airplane trip, we have just landed in Yekaterinburg in the southern Urals and are now en route to Chelyabinsk-70, site of the Russian hydrogen bomb development. In the front seat of our dark bus, the father of the American hydrogen bomb, Edward Teller, is in earnest discussion with our host, Vadim Simonenko. They are talking about how an asteroid might break apart in space if huge nuclear explosives are fired inside it. To me, this scene is surreal.

On that late September morning, we were on our way to a highly unusual meeting of Russian nuclear physicists. The Russians invited us to attend, together with planetary scientists Tom Gehrels (of the Lunar and Planetary Laboratory at the University of Arizona) and David Morrison (of NASA Ames Research Center) and representatives of the American nuclear weapons community. I had come to learn what the nuclear physicists proposed to do about the potential danger of near-Earth asteroids hitting Earth. The Planetary Society has long been interested in exploring these objects—indeed, for many years we funded Eleanor Helin's Planet-Crossing Asteroid Survey at Palomar Mountain Observatory in California, which led to an explosive increase in the rate of their discovery.

The weapons specialists at this meeting generally believed that conducting nuclear experiments on near-Earth objects and creating nuclear weapons to be used against them were both safe and timely endeavors. Many papers on intercept schemes and on methods for delivering explosives were presented. Most dealt with high-impact analysis, although implanting a nuclear charge from a slow rendezvous was also cited. There was widespread agreement that nuclear explosives are the only known means to deflect or destroy an asteroid. The astronomers and space scientists in attendance generally favored observation and exploratory missions, not nuclear experimentation, for the time being, and left open the question of when to initiate a deflection or intercept program.

Several papers on observation programs were presented, and there was considerable debate about whether expensive space-based observatories are needed. More debate centered on Teller's assertion that it would be cheaper and easier to get information about asteroids by conducting experiments on them with nuclear explosives than by making in situ measurements. The Russian space science community was not represented at the meeting and has shown little interest in the subject.

But the subject of asteroid and comet impacts has received worldwide popular attention as a result of the now convincing evidence that a near-Earth asteroid (or comet; the distinction is sometimes fuzzy) led to the extinction of the dinosaurs as well as to other evolutionary changes on our planet. The discovery of the nuclear winter effect—the changes in climate caused by dust and debris from a huge explosion (nuclear, volcanic or impact)—has also done its part to heighten public awareness. The impact of comet Shoemaker-Levy 9 on Jupiter last July intensified public concern. Some scientists now calculate that the risk of an individual's being killed by a near-Earth asteroid is about the same as that of dying in an airplane crash. (For more on the subject, see John Pike's "The Sky *Is* Falling: The Hazard of Near-Earth Asteroids" and Clark Chapman's News and Reviews in the November/December 1991 issue of *The Planetary Report.*)

This anxiety comes about because even though the probability of a large impact is very small (about 1 in 5,000 to 1 in 10,000 that a 1-mile-diameter object will strike Earth in any given century), the ensuing catastrophe would be global. This is what commands attention—such an impact could wipe us out, and humanity would follow the dinosaurs into extinction.

But is there really an asteroid out there that has our names on it? We don't know; this is why increased observation is needed. And if such an asteroid were to be discovered, what could we do about it? Before nuclear weapons could be used to try to destroy or deflect it, we would need to know more about the composition and structure of asteroids. Whether or not an anti-asteroid nuclear weapon program is a safe and sound idea, it needs a lot more study. The conference attendees in Chelyabinsk-70 adopted a resolution proclaiming the dangers of an impact to be significant and calling for the initiation of a global program of observation and protection.

Representing The Planetary Society, I did not sign the resolution. For now, our role is to facilitate discussion among space scientists, nuclear scientists and engineers; to encourage the gathering of more data and the intensifying of observation and exploratory missions to asteroids; and to provide information to the public.

We have taken a cautionary stand, even about labeling the potential danger to Earth a threat, simply because we believe that there is a way to gain more information rather simply. This is a 5-to-10-year program called Spaceguard, recommended to NASA by a committee of space scientists. It would detect every near-Earth object greater than 1 kilometer (0.6 mile) in diameter and obtain much better statistical data about smaller objects. We endorse this program and urge NASA and Congress to get it started.

One final note on the trip to Chelyabinsk has nothing to do with asteroids at all: We ran into *two* different Planetary Society student groups in this remote town. Both groups joined us as a result of their participation in the 1991–1992 "Together to Mars" essay contest. It was a delightful experience to meet them and talk with them. (One group expressed interest in contacting American youth groups involved in building models of ships, planes, rockets, spacecraft and the like. Members, if you're affiliated with such a group and are interested, please let us know.)

Planetary Society Executive Director Louis D. Friedman frequently travels to Russia and is no stranger to middle-of-the-night bus rides on the back roads of that country.

World Watch

by Louis D. Friedman

Washington, DC—NASA has released its draft environmental impact statement, a report on known and potential sources of environmental impact, for the *Cassini* mission. Exhaust from the solid rocket motors of the *Titan/Centaur* launch vehicle is the primary known impact. Of the potential sources analyzed in the document, an accident leading to the release of plutonium from the radioisotope thermoelectric generators (RTGs) or the radioisotope heater units (RHUs) is the most controversial possibility.

NASA also examined alternatives for the mission, including using different launch vehicles and launching at a different time on a different trajectory. For example, the nominal trajectory with a 1997 launch includes an Earth flyby, whereas a 2001 launch would not involve an Earth flyby, thus avoiding a close encounter with the spacecraft.

The document concluded that all expected environmental impacts of the nominal mission are extremely small and that "no substantial long-term environmental impacts would be associated with a normal launch of the *Cassini* spacecraft." Concerning the possibility of accident, the conclusion was that there were low-probability accident scenarios that could release plutonium in the launch phase. The health risk was estimated at less than one in a million, "small and less than many health risks faced by the public from construction and/or operation of large industrial projects." Precise comparisons with other forms of risk were not possible.

The Solar System Exploration Division at NASA released the several-hundred-page document for review by federal, state and local agencies and other interested parties. For further information, contact Peter Ulrich, chief of the Flight Programs Branch at that office.

Moscow—In early November of 1994, I accompanied NASA Administrator Dan Goldin to Russia to assess the status of the Mars Together program. (See the September/October 1994 *Planetary Report.*) The Gore–Chernomyrdin Commission initiated a study of Mars Together as a series of missions involving US and Russian launches at each opportunity, beginning in 1998. The joint Jet Propulsion Laboratory–Russian study team had come up with a mission concept involving the Russian *Proton* launch of a US Mars Global Surveyor orbiter (the next orbiter after the first one launched in 1996) and the Russian *Mars '98* descent module. That module includes the French space agency's Mars Balloon (with the Snake guiderope initiated by The Planetary Society) and the Marsokhod (Mars Rover). A 1998 US launch of a small, fixed lander on the newly commissioned Med-Lite launch vehicle was also part of that plan.

Unfortunately, during our first day of meetings in Moscow we were informed by the Russian space officials that their 1995 budget would not have enough funds to keep *Mars '98* on schedule. The only project assured of full funding was *Mars '94/'96*—the orbiter, small stations and penetrator mission planned for launch in 1994 but now slipped to 1996.

Interbol, an Earth-orbiting fields and particle satellite scheduled for launch in 1995, will receive relatively minor but adequate funding to complete its schedule. The *Spectrum* X-ray/gamma-ray satellite, a large observatory with many international instruments scheduled for launch in 1995 or 1996, was deemed the highest priority after 1996 by the Russian Academy of Sciences. But its full funding also is not assured, and it will probably have to be slipped an additional year or two. Once this priority was taken care of, it was impossible to allocate any funds for *Mars '98*.

Slipping *Mars '98* to 2001 would be the third delay in launch date for this mission. It seriously threatens the prospects of the Russian planetary program. We immediately began discussing a scaled-down version of Russian participation in a 1998 mission whereby the Marsokhod could still fly, perhaps in a US entry capsule launched by the *Proton*. This and several other options were studied by JPL and its Russian counterparts for possible inclusion in the Gore–Chernomyrdin agreement.

But the leaders of the US and Russian space agencies agreed that the basic Mars Together plan was not only the best, but the only viable, one. If the Russians cannot find the money to be ready in 1998, then a 2001 plan could and should be devised for the joint mission. Meanwhile, the US could go ahead with Mars Surveyor in 1998. The Russians could participate on Surveyor and changes to the mission design reflecting Mars Together 2001 possibilities could be considered. The Gore–Chernomyrdin commission has endorsed Mars Together, but the details of the program will depend on a Russian budget allocation, expected early in 1995. Stay tuned.

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

News and Reviews

by Clark R. Chapman

Shortly after the May 1993 prediction that comet Shoemaker-Levy 9 (SL9) would hit Jupiter, I found myself giving comet codiscoverer Gene Shoemaker some bad news. For a *Nature* article previewing the comet crash, I interviewed colleagues about what they thought might happen. Gene Shoemaker didn't yet know what I had just heard: SL9 would strike Jupiter's *back* side!

How Lucky We Were

Until then, things had been going our way. A once-in-a-century event was to happen next year. Jupiter would be high in the sky, easy to observe, not—as it sometimes is—hidden in the Sun's glare. And the fuzzy-eyed Hubble Space Telescope would be fixed in time. Moreover, good fortune had piled upon luck to give a year's advance warning. Normally, such a small, distant comet would be missed by telescopic searches. But in being torn apart by jovian tides a year earlier, SL9 became so much brighter that Gene and Carolyn Shoemaker and David Levy could find it on their search films in March 1993. Its orbit was soon calculated and the crash predicted, so astronomers around the world had a year to get telescope time, build instruments—and prepare.

Otherwise, the world's telescopes would have been trained on galaxies and other far-flung objects in the starry realm. Then an amateur Jupiter-watcher would have seen a huge, black spot with a backyard telescope. By the time the great telescopes could be outfitted with the right instruments and aimed at Jupiter, the event would have been history, and spectral evidence of jovian atmospheric turmoil would have faded away. For SL9 to be torn apart by Jupiter and then crash, two years later, is as unlikely as winning the lottery.

Cosmic Coin Flip

All we needed was for the answer to come up "heads" to a final question: "Front side or back?" But it came up tails! The only saving grace was that *Galileo,* en route to Jupiter and off to one side, could see the impacts around the planet's "edge" and radio back whatever happened, while observers on Earth would be behind the wall from the fireworks. Even that hope faded, however: By November, revised calculations placed the impacts so far around on Jupiter's nightside that even *Galileo* couldn't see them. For me, David Levy himself provided the good news in mid-December: He told my answering machine of new results indicating that *Galileo* would see the impacts after all. The news kept getting better. By March, modelers said that some impact plumes might even peek over the edge of Jupiter as seen from Earth.

Our Splendid Side View

On Halloween in Bethesda, Maryland, I joined Levy, the Shoemakers and 600 astronomers from around the world at the annual meeting of the American Astronomical Society's Division for Planetary Sciences (DPS). As everyone knows, SL9 did strike Jupiter's back side. But, as the wealth of data presented in a marathon session at the DPS meeting proved, SL9 hit in the perfect place, just beyond the morning limb. Heidi Hammel, of the Massachusetts Institute of Technology, showed Hubble's portraits of four impact plumes: What could surpass a side view? The geometry actually gave us more discriminating clues than if the fragments had plunked onto Jupiter's sunlit front side.

From Earth (but not from *Galileo*!), ground zero was just out of view. Yet, at the DPS meeting, some observers reported that they had seen faint flashes anyway. In his summary talk, Andy Ingersoll, of the California Institute of Technology, polled DPS members on seven explanations for the mystery (e.g., reflections from comet dust), but there was no consensus. Learning how light leaked around Jupiter's edge will surely be important.

Jupiter's uppermost stratosphere actually extended above Jupiter's horizon as seen from Earth, yet was in shadow. So some immediate flashes witnessed from Earth were seen where they should have been invisible—unless they were self-luminous. And, of course, the meteor entries and the early stages of erupting fireballs *were* self-luminous! Resulting Earth-based data not confused by sunlight, plus *Galileo* infrared spectra shown at the DPS meeting, permitted sizes and temperatures of the radiant fireballs to be calculated. As the plumes cooled and poked still higher into space, they crept into sunlight, providing a complementary perspective on their nature.

By the time explosion ejecta cascaded back into Jupiter's stratosphere, the impact regions had rotated into direct view from Earth. So thermal maps, spectra and measurements of waves rippling away from the impact sites—exhibited in three poster rooms in Bethesda—were obtained within tens of minutes of the actual impacts. Had SL9 struck, instead, beyond Jupiter's evening limb, *Galileo* would have been useless, there would have been no shadow zone in which to see luminous events, and the impact sites would have rotated away, not to be seen for five more hours. We would have been left with black spots and little more.

The DPS meeting was just the first chance of many for astronomers to synthesize their mountain of data and finally understand Jupiter, impacts, and comets. The data deluge was possible only because of our extraordinary luck that comet Shoemaker-Levy 9 ended its existence in precisely the way it did.

Clark R. Chapman was responsible for designing the Galileo *camera's scientific experiment for the Shoemaker-Levy 9 comet crash.*

Society News

A Tribute to Carl Sagan

On October 13 and 14, 1994, scientists, diplomats, journalists and artists gathered at Cornell University in Ithaca, New York, for a unique astronomy and space sciences symposium. The event, organized in honor of Planetary Society President Carl Sagan's 60th birthday, was Cornell's tribute to his work in science, education and public policy.

Among the speakers were NASA Associate Administrator Wesley Huntress, Jr., Jet Propulsion Laboratory Director Edward Stone and Planetary Society Advisor Roald Sagdeev, formerly of the Russian Academy of Sciences. Speakers praised Sagan's contributions and assessed the progress and goals of planetary science. Sagdeev lauded Sagan for alerting Russian scientists and political leaders to the dangers of nuclear winter, and Frank Press of the Carnegie Institution spoke on science and the social conscience.

JPL scientist Eleanor Helin and Society Executive Director Louis Friedman presented the symposium's honoree with a plaque commemorating the naming of two asteroids circling the Sun in a companion orbit—4970 Druyan and 2709 Sagan—for Sagan and his wife, science writer and producer Ann Druyan. Asteroid Druyan was specifically named in honor of Sagan's birthday.

Sagan himself discussed the Age of Exploration—along the lines of his new book, *Pale Blue Dot*. He focused on human self-centeredness, from early beliefs that Earth was the center of the universe to modern-day beliefs that it is the only planet that supports life. Referring to a *Voyager* photograph—a backward look at the solar system—he noted a small blue dot: "There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world," he said. "It underscores our responsibility to deal more kindly with one another, and to preserve and cherish the pale blue dot, the only home we've ever known."

—Diana Marquez,
Director of Development

Rover Team Refines Plans for Hawaii Tests

Plans are coming together for rover and telepresence tests near Hawaii's volcanic Mount Kilauea on February 13 through 20, 1995.

The tests will be conducted by NASA's Ames Research Center, which is developing telepresence and virtual reality software to control rovers on Mars and the Moon. Ames personnel began their program at previous Society tests with McDonnell Douglas, which will also participate in these experiments, working with a rover supplied by the Babakin Center in Russia.

The Planetary Society is coordinating its outreach program with the Jason Foundation for Education. Students at about 27 sites throughout the United States, Canada and England will teleoperate a rover in Hawaii.

Society activities include a project with Lego Dacta, the educational division of the Lego Group. Students in Hawaii, Utah, California and Ontario, Canada, will build their own rovers from Lego blocks. Using a control system like the ones being designed for the Mars Rover, children at each site will then operate the rovers built by children at other sites.

The Society will also organize linkups with engineers in Utah, California and Russia as part of its development of telerobotic control. Many of the scientists and engineers involved in the testing will discuss these experiments and other exploration efforts in live conferences on the Society's new online service (see "Veering Onto the Information Superhighway" on page 15 in this issue). Members of the test team will also speak at public events at the Volcano National Park visitors' center in Hawaii.

For the latest schedule information, write to Susan Lendroth at Society headquarters or call (818) 793-5100.

—Louis D. Friedman, Executive Director

Society Extends Paine Award Deadline

The Planetary Society has extended its deadline for applications for the second annual Thomas O. Paine Award for the Advancement of Human Exploration of Mars. The deadline is now February 1, 1995.

For a copy of the application form and nomination procedures, write to Society headquarters or call (818) 793-5100.

—Charlene M. Anderson,
Director of Publications

Planetary Events in Seattle and Birmingham

The Society's Volunteer Network continues to produce new events. Here are some of the latest ones in the Pacific Northwest and in England.

In Washington state, volunteer Michael L. Houtz has organized a series of lectures to be held at the Puget Power Auditorium, 10608 Northeast 4th Street, Seattle. Noted astronomers will speak on various topics, including the Search for Extraterrestrial Intelligence, and comets and stardust. For information on these lectures, contact Houtz at (206) 523-6032.

In Birmingham, England, volunteer Andrew Lound has scheduled an entire year of monthly lectures at the Birmingham Museum of Science and Industry. Topics include the roots of astronomy and the discovery of Pluto. For information, contact Lound at (021) 356-5446.

—Carlos J. Populus,
Volunteer Coordinator

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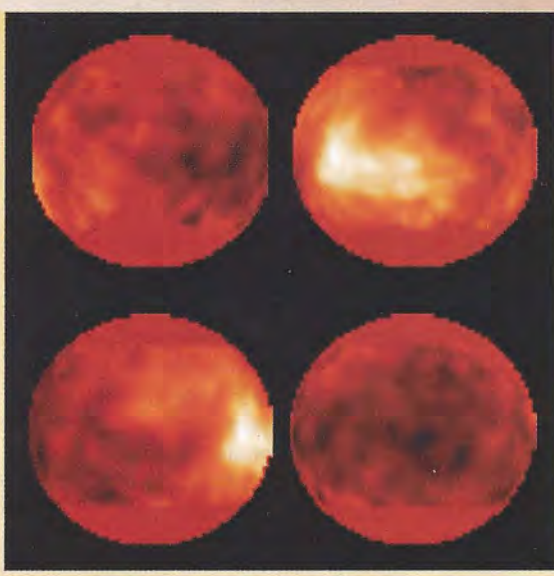
Questions and Answers

Why are Jupiter's Great Red Spot, Neptune's Great Dark Spot and their small, subdued counterparts on Saturn all in the southern hemispheres of these planets?
—Denis R. Foulem,
New Brunswick, Canada

The question really should be, "Why have no storms similar to the well-formed white ovals or the Red Spot ever been reported at latitudes between zero and 35 degrees north on Jupiter, and why are there no low-altitude 'brown barges' (storms seen in the northern hemisphere) in the south?" All of these cloud systems that you mention, along with well-formed white ovals, appear to be storm systems where the atmospheric gases are rising and expanding. As such, they are similar to storms in Earth's mid-latitudes and should not favor either hemisphere. Your question has plagued us all and is certainly one of those queries that fall into the "we just don't know" category. There are well-formed small white ovals at higher northern latitudes, but none at low latitudes.

Saturn does have a long-lived storm at high northern latitudes, and it appears to influence a peculiar six-sided wave feature that surrounds the pole. This large storm lies just south of the southern edge of the six-sided polar wave feature. If it is a large rotating system like the Red Spot, it may play a major role in

Factinos



Left: These four global projections of Titan, assembled from 14 images taken in October 1994, are separated in longitude by 90 degrees. The prominent bright area is a surface feature about the size of Australia. Scientists are still not sure whether the feature is a continent, an impact basin, an ice mass or something else.
Image: Peter H. Smith, University of Arizona Lunar and Planetary Laboratory and NASA

Right: This picture of Saturn's new storm was taken on October 18, 1994, with the 0.6-meter reflector telescope at the Tortugas Mountain Station of New Mexico State University's observatory.
Image: Reta Beebe

For the first time, scientists have produced images of the surface of Titan, Saturn's mysterious, haze-shrouded moon (see picture above). Using the Hubble Space Telescope, a team of researchers mapped light and dark features over the satellite's surface during a nearly complete 16-day rotation in October 1994. Peter H. Smith of the University of Arizona's Lunar and Planetary Laboratory announced the results of his team's work at last fall's meeting of the American Astronomical Society's Division for Planetary Sciences in Bethesda, Maryland.

To capture these images, Smith's group used the Hubble Space Telescope's Wide Field/Planetary Camera 2 at near-infrared wavelengths. Titan's haze is transparent enough in this wavelength to permit mapping of surface features according to their reflectivity.

According to Smith, it's too soon to conclude much about what the dark and bright areas in these images are—continents, oceans, impact craters or other features. Scientists have long suspected that Titan's surface is covered with a global ethane-methane ocean, but the new images show that the satellite has at least some solid surface as well.
—from the University of Arizona

A big white spot has bloomed on the face of Saturn, and scientists believe that the new feature, which may last for years, is the result of a giant storm (see picture above). The spot was first noticed last summer by astronomers at the Pic du Midi Observatory in France. The United States Naval Observatory and scientists in New Zealand have reported that the feature is several thousand miles wide. After the spot appeared last August, it began to spread eastward.

Reta F. Beebe of New Mexico State University, a specialist in planetary atmospheres, believes that the exciting and sustaining the wave structure. This feature was present in 1980 and 1981 during the *Voyager* encounters, and it has also been observed with the Hubble Space Telescope.

There is growing evidence that the large storms on Neptune, a planet with strong westward equatorial winds, are not long-lived. The Great Dark Spot seems to have disappeared (see Factinos). In addition, there is considerable new activity in the northern hemisphere.

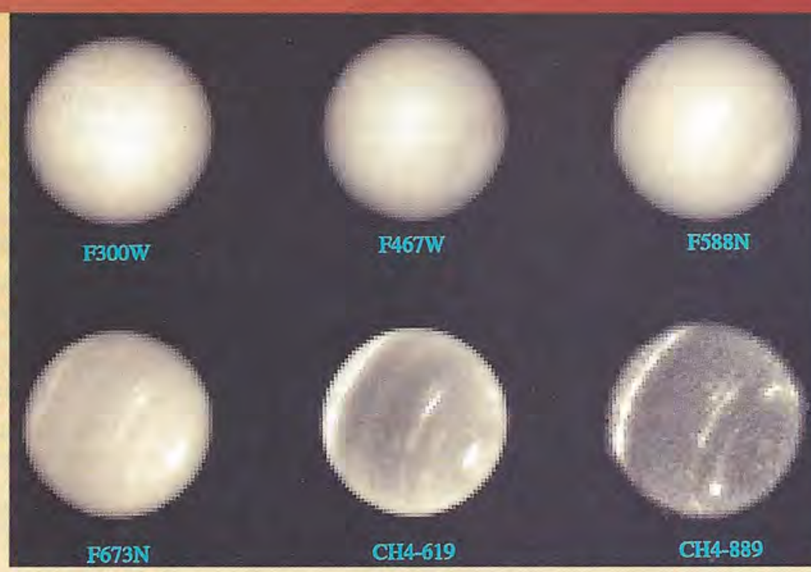
We can look forward to several very good opportunities to continue to explore these atmospheres. The Hubble Space Telescope now has an excellent camera and can be used effectively to study all four outer planets. Spectra and images from the Shoemaker-Levy 9 campaign contain a wealth of information. We will continue to use the Hubble Space Telescope for another decade, with a maintenance mission scheduled for 1997 that will install new infrared and ultraviolet instruments. *Galileo*, with its controlled entry probe, will arrive at Jupiter in late 1995, and the *Cassini* mission is being built to return to Saturn with a radar mapper to map Titan's hidden surface and an assembly of modern instruments to probe Saturn's upper cloud layers.
—RETA BEEBE,
New Mexico State University

All the talk about sample return in the July/August 1994 issue of* The Planetary Report *reminded me of a question that I have had since we first visited the Moon 25 years ago. Why hasn't there been a sampling mission to one or both of the Lagrangian points along the Moon's orbit?
—Alan Beckner,
Lompoc, California

Scientists don't think there's anything there. They could be wrong, because observations are difficult, but some years ago Joseph Bruman of the Jet Propulsion Laboratory did enough observing to show that there is no great cloud of objects orbiting near the Lagrangian points.

The American Heritage Dictionary of Science defines a Lagrangian point as "a location between heavenly bodies where centrifugal and gravitational forces neutralize each other so that an object in that location remains in stable equilibrium with respect to the other bodies." The concept of a "point" in Earth-Moon space, however, is only theoretical. Real objects, such as dust and meteoroids, in the gravity fields of Earth and the Moon move around (librate) in large regions; they do not sit in little clusters.
—JAMES D. BURKE,
Technical Editor

Right: Each of these Neptune images was taken through a different filter on the Hubble Space Telescope and the Great Dark Spot is nowhere to be seen. Even if the spot was hiding on the edges of the disks, it was wide enough (almost 40 degrees of longitude at the time of Voyager 2*'s flyby) that it would have appeared as a "bite" out of the planet's limb.*
Image: John T. Trauger and David Crisp, Jet Propulsion Laboratory



saturnian spot is probably equivalent to an earthly thunderhead cloud rising high above the lower cloud deck.

The cloud deck that masks Saturn's thick atmosphere consists of fine particles of frozen ammonia. "Every once in a while, a cloud of ammonia ice at a lower altitude warms up, rises and punches through the upper cloud deck," Beebe said. "The winds in the thunderhead are violently turbulent, just as they are in a thunderhead on Earth."
—from Malcolm W. Browne
in *The New York Times*

New Hubble Space Telescope images (see picture above) of Neptune show that the planet's atmosphere undergoes dramatic changes in just a few months, or even within a week's time. These images, taken in June and October 1994, are the highest-resolution pictures taken of the planet since *Voyager 2*'s 1989 flyby. Both sets of images confirm that Neptune's Great Dark Spot—a major storm feature seen by *Voyager 2*—has disappeared. The storm center has either dissipated or been masked by other aspects of the atmosphere, according to Heidi B. Hammel of the Massachusetts Institute of Technology.

John T. Trauger and David Crisp of the Jet Propulsion Laboratory and their colleagues analyzed the June images and found bright, high-altitude cloud features, including a cloud band in the northern hemisphere. Hammel and other scientists speculate that Neptune's variability could be linked to an interior heat source as well as to its orientation to the Sun.
—from Ron Cowen
in *Science News*

Happy New Year!

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Robert McCall was already an acclaimed aviation artist when, in the 1960s, *Life* magazine commissioned him to do a series of paintings on the future of space travel. He soon became one of a select group of artists chosen to document the United States' space program. His work is on display at Johnson Space Center, the Pentagon, the Smithsonian and the National Gallery of Art, to name a few.

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