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Diamonds from Space

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COVER: The meteorites that fall from space sometimes contain surprises that can teach us about the births and deaths of stars. Within grains from the Allende meteorite that fell in Mexico in 1969, scientists found tiny diamonds that carry the isotopic signatures of materials formed before our solar system was born.

Photograph courtesy of Roy Lewis and Edward Anders, University of Chicago

FROM THE EDITOR

Planetary exploration is an expression of the human will to understand the unknown. In earlier times, ambitious explorers sought out and investigated *terras incognitas*; today such unexplored regions lie beyond Earth. We now send robotic surrogates (and a very few humans) to do our exploring, but the drive remains the same. In this issue of *The Planetary Report* we ruminate on the role of planetary exploration in the grand historical context, talk with a leader in this endeavor, and examine bits of material that may come from a time before our solar system existed.

Page 3—Members' Dialogue—We know you're reading the magazine because we've received many letters responding to two opinion pieces we ran late last year. One asked whether Mars' moon Phobos should be exploited or set aside as a reserve. While Planetary Society members do agree that we should explore our solar system, what we should do once we get there remains an open question. Politics back on Earth also inspires debate; we print two letters debating whether The Planetary Society should take a position on "Star Wars."

Page 4—A Talk with Roald Zinnurovich Sagdeev—Probably the most influential individual in world planetary exploration is Academician Sagdeev, whose energy, skill and belief in international cooperation has transformed the Soviet program. He recently stepped down as head of the Space Research Institute of the Soviet Academy of Sciences, and in this interview Sagdeev discusses the changes in his career, in the Soviet planetary program and in the Soviet Union itself.

Page 9—The Discovery of Stardust in Meteorites—One of the most startling recent findings in planetary science is that some tiny diamonds embedded in meteorites are remnants of a time before our solar system was born. Here we learn how these bits of stardust were identified and why scientists believe them to be older than the Sun.

Page 14—Planetary Exploration—A Third Great Age of Discovery—Planetary exploration has only been possible since the development of rocket technology in this century. Yet it is still part of an exploratory process that has continued for centuries. Here an eminent scholar lays out planetary exploration's role in history.

Page 18—Continuing SETI: Scientists Share Findings at Toronto Conference—The Planetary Society's Project META (Megachannel Extraterrestrial Assay) is still the most powerful continuing search for extraterrestrial intelligence, but many other researchers are also working on this task. Last October the Society brought together SETI workers from around the world at a Toronto conference, and we report on their discussions.

Page 20—Mars Watch Chronicles—Mars Watch '88 turned out to be one of The Planetary Society's most enjoyable programs. From Mars Watch parties to gathering data on martian winds, thousands participated in activities surrounding the close approach of the Red Planet to Earth. We share with you some of the results.

Page 22—Venus After Dark—Views of the Nightside—Many spacecraft from both the Soviet Union and the United States have returned data on our sister planet, but such studies can still be augmented by telescopic research from Earth. New camera technologies enable astronomers to see unprecedented detail of our nearest planetary neighbor's atmosphere. We present some new telescopic images of Venus.

Page 24—World Watch—The Comet Rendezvous Asteroid Flyby and *Cassini* missions are up for "new starts" in NASA's budget this year. In this column, we explore the tortuous courses these missions must navigate before they are launched.

Page 28—Q & A—In this issue we examine ice on Greenland and day and night on Mercury. Take a special look at "What We Are Not About," a short essay on how we choose what topics to cover in *The Planetary Report*.

Our regular "News & Reviews" is absent this time, but your faithful columnist, Clark Chapman, will return in our next issue.
—*Charlene M. Anderson*

Members' Dialogue

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

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

I heartily agree with the opinions expressed by I. Almar, A. Horvath and E. Illes in their article "Phobos—A Surface Mine or an International Park?" (see the September/October issue of *The Planetary Report*). Far too often in our history the human race has behaved as if we had exclusive ownership of the resources of this planet. Development and exploitation of these resources have too often been seen as the only imperative. We have operated under the illusion that such exploitation could continue forever and that any concomitant environmental damage could be absorbed by the ecosystem. Now we run the risk of repeating the same mistakes in our celestial journey.

Despite the vastness of our solar system we must not be lulled into the belief that we can be even less circumspect in our use of the resources of space than we have been on Earth. Phobos (and virtually everything else in our solar system) is a place about which we know incredibly little. Before we proceed to exploit Phobos (and other bodies) we must consider the long-term impact of such short-sighted actions. It may be too late to correct some of the disastrous effects of our policies on Earth, but it is not too late to formulate even more prudent policies to guide our actions in space.
GARY ZAJAC, *N. Versailles, Pennsylvania*

I want to take issue with the article "Phobos—Surface Mine or an International Park?" I have no disagreement with the basic premise, that scientifically important sites in the solar system should be preserved. What I strongly disagree with is the stated premise that development of solar system resources and preservation are mutually exclusive, and more strongly, the unstated but implied premise that advocates of development are insensitive to environmental concerns.

The authors stated that "in just a few years of exploitation, the whole surface of Phobos would be made unrecognizable. . . ." Dr. Brian O'Leary, one of the chief advocates of Phobos development, addressed the environmental question in his book *Mars 1999*. To quote Dr. O'Leary: "What we are talking about here is a small facility about the size of a small office, a solar furnace and an excavation and reclamation area about fifty meters square and four meters deep for two years of processing." Dr. O'Leary further advocates sealing this area in a low-pressure inflated dome to prevent escaping dust from contaminating the rest of Phobos.

It would be a tragic mistake to set up a "Good Guy/Bad Guy" framework, with space development advocates portrayed as the Bad Guy—tragic because it would split the US pro-space movement into two sides working against each other. If the United States is to join the

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Calvin and Hobbes **by Bill Watterson**

NEWS BRIEFS

On a mild, windless evening in November the largest radio telescope in the nation mysteriously collapsed into a heap of rubble. The 300-foot telescope of the National Radio Astronomy Observatory at Green Bank, West Virginia, played a key role in numerous scientific discoveries, and the work of hundreds of astronomers has been curtailed by its demise.

"It's a major loss to the whole scientific community," said George A. Seielstad, director of the observatory.

Some astronomers speculated that the telescope caved in because it had been improperly maintained by an organization (the National Science Foundation) that is pinched for funds. One astronomer thought that the support structures may have been allowed to corrode.
—from Lee Dye in the *Los Angeles Times*

□

This year nine US universities will receive NASA grants totaling $4 million to establish permanent space engineering research centers. The grants are intended to "increase the number of qualified space engineers, which has been declining since the end of the *Apollo* program in the early 1970s, and to give the universities an independent opportunity to contribute (to). . . the new research and technology for the next generation of space activities."
—from the Jet Propulsion Laboratory *Universe*

□

President-elect George Bush's transition team is studying a plan to reorganize US space program management under a structure like that already being used by the nation's intelligence agencies. Under the plan,

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A TALK WITH

Roald Zinnurovich Sagdeev

Academician Roald Zinnurovich Sagdeev, one of the foremost players in international space exploration, served for 15 years as director of the Space Research Institute (called IKI after its Russian acronym) of the Soviet Academy of Sciences. Under his leadership the Soviet planetary program came of age with increasingly ambitious and imaginative missions. The spectacular *Vega* mission to Venus and Halley's Comet and the recently launched *Phobos* mission to Mars and its moon are both results of his initiative. The information returned by *Vega* and the discoveries hoped for from *Phobos* are both enriched by the participation of scientists from around the world. Sagdeev opened the Soviet planetary program to an unprecedented extent, and the hallmark of his tenure as IKI's director is the international cooperation among planetary scientists that he has fostered. In October of last year, after publicly suggesting that Soviet science would be strengthened if institute directors were limited to five-year terms, Sagdeev resigned as director of IKI. In a remarkable precedent, Alec Galeev, a corresponding member of the Soviet Academy of Sciences, was elected by his peers at IKI to succeed Sagdeev.

Sagdeev has been well recognized for his achievements. Following the *Vega* mission, the Supreme Soviet (the Soviet Union's central legislative body) bestowed on him the title "Hero of Socialist Labor"; he was awarded the Order of Lenin and the gold Hammer and Sickle medal. During 1987, he was also elected to the Supreme Soviet. The same year, American scientists honored Sagdeev and elected him an associate member of the US Academy of Sciences.

Sagdeev's efforts to internationalize planetary exploration and his outspokenness on space and defense issues have made him controversial in both Western and Soviet-bloc countries. In his capacity as scientific advisor to President Mikhail Gorbachev on the US Strategic Defense Initiative, he has often taken a position on arms-control matters. Most recently, Sagdeev has led efforts to advance *perestroika*, Gorbachev's attempt to reorganize the Soviet economy and bureaucracy.

In 1982, Sagdeev joined the Board of Advisors of The Planetary Society. Our members have heard him speak about the Soviet space program at several events across the United States, and he has helped to secure many of the articles by Soviet scientists and images from the Soviet program that have appeared in *The Planetary Report*. Following his resignation as director of IKI, Sagdeev agreed to this interview with our Executive Director, Louis D. Friedman, to inform our members of his plans, opinions and vision of future planetary exploration.

LDF: *Why did you leave the Institute for Space Research (IKI)?*

RZS: I did not leave IKI; I left my chair as director because I held that chair for more than fifteen years, and the simple formula is when somebody occupies a chair for such a long time, that is stagnation. I think rotation is essential. It is essential for an institute. It will bring fresh blood, fresh ideas. It is also essential for me personally because I need a chance to have more time for science. Maybe one day I will go back to administration, but right now I am really having a honeymoon with science.

LDF: *And so will you stay involved with space exploration?*

RZS: Yes, I will be involved in space exploration as an individual. The *Phobos* project is still going on, and I have to run it up to its conclusion. I am also the scientific director of the *Mars '94* project as it is now organized.

LDF: *You have been increasingly active politically, involved in discussions about the future of* perestroika *and about the organization of science in the Soviet Union. What issues will you work on in the next year or two, and do you think you will become a government advisor or have an official position within the Academy of Sciences?*

RZS: I have been active in a way, but not because I am attracted by political life. I thought I would have a rather good experience. During my fifteen years as director of IKI, I have had the chance to get involved in complicated interactions with the different layers of the scientific community and governmental bureaucracies, aerospace business and industry, and I wanted to use that experience in making certain recommendations. Right now we are undergoing substantial changes, especially in the field of science administration. I personally don't plan to stay in politics, to become a professional politician. I would be ready to advise the Academy or government as much as I can if such advice is required.

LDF: *What about defense issues? Do you see that as related to the space program, or is it separate?*
RZS: Probably both. I have not been involved as a researcher in the defense program, and I tried to stay away from it. It was a moral choice. But I was also director of IKI, and during the last few years I have been an active member of the arms control community. As such, I was asked to assess certain developments in the strategic area of the arms race—for example, to assess a space-based anti-ballistic missile program. This type of involvement I consider very important nowadays, and I will continue this activity. I think it is very important to provide an assessment for the public and for official circles. It's becoming increasingly important now when we understand that we have to base our battle against the military/industrial complexes on a serious, scientific approach.

LDF: *With regard to* perestroika, *global security and cooperation, are you optimistic about the next five years?*
RZS: I am optimistic. I do recognize that there are outstanding obstacles, unsolved problems in [the] internal life of our country, resistance to *perestroika*, but the country was badly managed for seventy years. Even if everyone suddenly woke up with an absolutely clear mind about the necessity of *perestroika*, you can understand how difficult it would be to change every aspect of our [lives].

We have made substantial progress on the political front of *perestroika*, but the frontline of economic changes is far behind. That's the source of most of the difficulties, and I think one can lose stability if these two fronts are separated by a big gap. I think what Gorbachev is doing is very systematic, very thoughtful and clever. On the top of such important internal changes, he always keeps in mind international issues, arms control issues, with a completely new, fresh and open-minded approach. As a scientist I feel great satisfaction when I see how deeply he understands the interdependence of military, economic and other issues with a good international human climate. He is a great supporter of international cooperation in space. So I want to be included in this.

The Phobos spacecraft is wrapped in protective material as technicians prepare it for launch to Mars and its moons. This complex mission involves three types of spacecraft: an orbiter to examine Mars, a long-duration lander that will be placed on Phobos' surface, and a "hopper" that will rove across the small moon's surface collecting data. The Phobos mission was conceived, built and launched during Roald Sagdeev's tenure as director of the Space Research Institute of the Soviet Academy of Sciences.
Photograph courtesy of A. Zakarov

LDF: *Are you optimistic too about US/Soviet relations?*
RZS: I am a realist. I don't think we should expect a sudden inflation of our relationship. Let's make it stable step by step.

LDF: *What do you think of the prospects for cooperation between the United States and the Soviet Union in space exploration? What are the inhibiting factors, the dangers that might get in the way, and do you have any recommendations about policy?*
RZS: I think we have rather good contacts now within the framework of formal cooperation between scientists of both countries. Scientists are very cosmopolitan by their natures. This is the nature of modern science, and the next task is to create a similar spirit among the aerospace engineering and technical communities. This is probably much more difficult. One difficulty is of a psychological nature because these groups are very isolated. At least on our side, our aerospace community never participated in a rich international life. If scientists are members of the big international family, I cannot describe engineering communities with the same term. The second difficulty is the problem related to military involvements of industries and trade restrictions and embargoes. We cannot ignore these difficulties. So, it is very important to pinpoint projects where we can create clean interfaces and stay away from potential military designs, hardware and so on. It would require time and a systematic approach.

LDF: *One thing that we have going for us is that the engineering people, which is where I come from, want to go home and talk about Mars missions to their families and to the people at the club and so forth. And so we're getting a lot of support from industry right now on the cooperative Mars approach because of that thinking. You find that individuals want to do it.*
RZS: I think this is an interactive process. The more you involve engineers, technicians and industrialists in that type of cooperation, the more they will be fascinated with it. They would be fascinated not only by the challenges provided by such missions, but also by a new dimension in their lives.

LDF: *Might the Soviet Union go it alone on a major Mars mission, either robotic or human, if it feels that the cooperative approach isn't working fast enough?*
RZS: In principle, yes; at least we did such things in the past. I would be terribly unhappy if we had to do it. It would be a burden to our economy. It would spoil the spirit of international scientific brotherhood, which would also be very bad. Also, we would again come back to the epoch of duplication and unnecessary competition.

LDF: *Why does the Soviet Union*
(continued on page 7)

Glasnost, the Russian word meaning "openness," is a new factor in Soviet political life. The glimpses seen in the West are evidence of enormous intellectual, social and political ferment in the Soviet Union. Our advisor, Roald Sagdeev, is a major participant in this ferment, leading the call for reform in Soviet science. Sagdeev is a member of the Supreme Soviet (the nominal governing legislative body of the Soviet Union), a member of the elite and powerful Soviet Academy of Sciences, a leader of his nation's space program, a key science advisor to President Mikhail Gorbachev, and a major force in international scientific cooperation.

This past October Sagdeev was nominated to the Presidium of the Academy of Sciences. He refused the nomination but asked that it be given to Andrei Sakharov, the internationally famous nuclear scientist and dissident. In a stunning move, the Academy accepted Sagdeev's proposal and elected Sakharov to the Presidium.

During that October meeting, Academy members openly debated many controversial topics, including the morality and ethics of scientific leadership, the internationalization of their space program and the quality of Soviet science. We present here some excerpts on topics related to planetary exploration.

From Sagdeev's speech

We have had the happy chance to witness and I hope to participate in a really revolutionary process of our society's renewal. The role of science is becoming extremely important. Those who have a scientific instrument of prediction should help humanity, which moves, like a sapper, across a minefield increasingly stuffed with mines. We face a number of political, economic, social and ecologic problems. Contemporary science is not only to lay a foundation for scientific and technological progress, but also to participate in decision making at the top political level. This is the goal that the Party and the people want us to achieve.

But how should we and the Academy [of Sciences], which currently faces stagnation, overwhelm it to become a true helping hand for our nation? As it has been said above, in this modern, changing world, science is not only to ensure an expert check-up and to insist that certain recommendations [are] to be accepted.

Perhaps some of you are familiar with this paradox. Here I am standing in front of you with my Deputy-of-the-Supreme-Soviet badge. But I must honestly admit that, as a scientist and as a physicist, as a space expert, I have been invited to testify at the hearings of the US Congress more often than at any kind of hearings at the Supreme Soviet in my native country. That well enough shows the whole importance of political reform in our country to be implemented simultaneously with restructuring of our self-awareness and the self-awareness of the scientific community.

Now I will say a few words about the space science to which I have devoted many years of my life and am going to deal with in the future. This branch of science sprang [up] 31 years ago with the launch of the first satellite. The Soviet lead in space has been formidable for a certain period of time. Such outstanding scientists as Korolyov and Keldysh dealt with space science. But to the point, the people did not know the role [these men] played in space exploration. They [were called by] anonymous names: chief designer and chief theorist of space exploration.

I would like to give one more example of command-administrative methods of work in my sphere. For the last few years, responding to Mikhail Sergeevich [Gorbachev's] appeal to work for the reconversion of military efforts, their conversion to peaceful economy, to science, I was trying to participate actively in meetings, conferences, talks on the problems of Mars exploration. It is quite probable that the joint flight to Mars, the joint program of Mars exploration, will become one of the most effective areas of reconversion. In this case there may be used more efficiently the experience of the military-industrial complex [and the] defense industry.

Comments on Sagdeev's speech by K. Ya. Kondrat'ev

Years ago when the IKI [Space Research Institute] was under development, I, a professor of the Leningrad University, witnessed how it began at that time. I and my colleagues, we were pinning our hopes on IKI. We believed that at last we should have in our country the headquarters of Soviet science in the field of space studies. Alas, not much happened.

The more time passed, the less the Space Research Institute justified itself as the head institution. And the results are sad; we are lagging behind in many fields of space studies.

Maybe planetary studies are getting on well? Not everybody is informed about this, but I know something, and I state confidently, not well. I claim some criminal thing. I think it reasonable to look back and see whether the *Venera-Halley* [the *Vega* mission to Venus and Halley's Comet] program was an outstanding achievement. Many years ago the *Venera 4* was equipped [with] Soviet instrumentation and maybe fundamental results were obtained; as to the *Venera-Halley*, it was equipped [with] instrumentation made abroad, and there were no instruments made in the USSR. And the results of the part of the program which I know about are, to put it mildly, modest. I do not understand why the proposal of French specialists to release balloons in the Venus atmosphere had to be accepted, ten observatories of the Earth had to observe their drift in order to determine the wind velocity, that is, to obtain the value which we have already known well. This experiment yielded, in essence, zero information, nothing new for science. What was all that for? You see how it is expensive, and what do we gain? It is better to invest this money in the food program. It is a serious question, and we should ponder it over. □

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seem to want to cooperate so much? Why doesn't it explore space alone or just with its Interkosmos [a Soviet-led consortium of Eastern European nations] partners?

RZS: There are so many arguments for it. I would not even put financial arguments at the top. The main argument is the importance of such cooperation as a confidence-building measure, as a measure to create an appropriate international climate for rapprochement.

This is an extremely important issue since cooperation is becoming an essential item in our life. We have to take a look at cooperation from different angles, how to avoid military confrontations, maintaining the scientific brotherhood, economic arguments and human factors. This is a very important issue, the interaction of certain areas of cooperation such as space exploration with the rest of what we are doing.

From its Moscow headquarters, the Space Research Institute of the Soviet Academy of Sciences leads the USSR's robotic exploration of the planets. Sagdeev directed the institute for 15 years. Executive Director Louis Friedman and Society Vice President Bruce Murray appear in the foreground.

Photograph: Tom Heinsheimer

LDF: *What are your impressions of the US program, of our priorities in space and in science?*

RZS: After the painful period of recovering from the *Challenger* tragedy, American space science will have a good chance to restart several outstanding programs. I think the Hubble Space Telescope is definitely going to be number one, maybe one of the greatest space science projects of the century. Then we are looking forward to seeing how *Galileo, Mars Observer* and *Magellan* will develop.

I hope very much that you will have more chances to start new projects in the next decade. I am a little bit worried about a lack of concrete steps toward Mars exploration, besides *Mars Observer*, which is a good but rather modest mission. It is not followed by projects such as a lander, a sample return and rover mission. I see a great deal of interest on the level of individual scientists, and I hope very much that my American colleagues, enthusiasts of Mars exploration, will eventually get an interesting program.

Of course I would favor a joint program. Personally, I would be happy to see as integrated a program as possible. Even with restrictions because of embargoes or political considerations, we could still have an interesting joint program, leading eventually to a joint sample return mission, which could be considered as a precursor to a manned expedition. I don't know how realistic it would be to talk about the manned flight to Mars right now, but I'm sure if both nations decided on such a goal, technology would allow us to do it in the first ten or fifteen years of the next century.

LDF: *Do you like dealing with the United States?*

RZS: Oh yes, I think this is a great country, and in my field of science, as in many other fields, it is a world leader. I like the dynamism of American life.

LDF: *Is there a relationship between the defense space program and the civilian space program, or is Glavkosmos [the primary Soviet space agency] running just the civilian space program?*

RZS: Glavkosmos is running the civilian space program.

LDF: *We were always told that the Soviet cosmonaut program was a military program, yet it seems now to be a Glavkosmos program.*

RZS: The interpretation that you heard that the cosmonaut program is a military program is wrong, but I understand why you have such an interpretation. For outsiders the very fact of military involvement, for example, that Star City [cosmonaut training center] is controlled by the Ministry of Defense, could make it seem like a military program. But in fact, very long ago at the time of Korolyov, Keldysh [leaders of the early Soviet space program] and at the time of Khrushchev, it was decided that such an outstanding program, which would require extremely complicated interagency and interdisciplinary management, should be run by the military because they have an infrastructure and they have discipline. I would rather consider the very fact of their involvement as an example of conversion from military to peaceful activities. Essentially we were using the military's potential and expertise to promote manned flights. I am sure this program has absolutely zero military significance. Even if one day the military wanted to use these results or these techniques, it would be absolutely an inefficient way.

LDF: *Senator Spark Matsunaga (D-HI), in his book* The Mars Project, *talks about organizing a human Mars mission with military people, but not as a military program.*

RZS: Somehow what we had in the manned flight program was a de facto realization of Matsunaga's concept.

LDF: *Is Glavkosmos taking the place of Interkosmos in making the arrangements for future missions?*

RZS: In the cases where we have to deal with commercial aspects. We have a gentlemen's agreement between Interkosmos and Glavkosmos on commercial issues. In that area they will act.

LDF: *How are decisions made in the Soviet Union to do, for example, a mission in 1994 to go to Mars or to launch a rover and sample return mission on an* Energia *rocket? Who makes that decision? Is it Interkosmos, Glavkosmos, both entities?*

RZS: This is a rather complicated, multi-step, interactive process. We have quite a few scientific meetings, workshops and committees, which assess the most important and changing scientific issues in space and at the same time interact with the aerospace industry, with such places as the Babikan Center. This gives an indication of which scientific issues could be treated with existing or realistic space technologies. In the

The Soviet Union now possesses a space shuttle (top), called* Buran *or "snowstorm" and very similar to that of the United States, with one crucial difference: This shuttle uses the heavy-lift launch vehicle* Energia *to boost it into orbit. Capable of flying on its own, the* Energia *(right) gives the Soviet launch vehicle stable a versatility that the US cannot yet match. Sagdeev has been critical of the Soviet shuttle program, fearing that it will travel the same path as the US program and divert money and energy from the scientific exploration of the solar system.

Top photo: Sovfoto; Right photo: Soviet Academy of Sciences

meantime, we have to interact with planning agencies to see if we could have available material resources and funds. Finally, a joint body representing the interests of the Academy of Sciences and the aerospace industry approves the program and specific projects. As the last step, we need confirmation from the government.

LDF: *At the ministry level ?*
RZS: Yes, at the level of the Council of Ministers.

LDF: *Is that where the issue of the cost of the mission and whether or not it can be afforded is decided?*
RZS: We keep in mind the costs and economic issues from the very beginning because we know the options and try to avoid science-fiction types of approaches. So, in principle, the interactive process reminds me of what you have in your country. I wouldn't even be afraid of using the word "lobbying." There are conflicts of interest and so on.

LDF: *A man at Gosteleradio [the national Soviet radio and television network] told me that there is no public support for space exploration in the Soviet Union. Do you agree? Do you think it's important?*
RZS: This is an important issue, and it is a controversial issue. As a by-product of reconsidering every aspect of our life in the process of *perestroika* and renovation, very often you hear such views that science and technology in general are enemies of humankind, that they have spoiled the life of humanity. Very often you hear that space exploration is extremely expensive or dangerous. We must find a way for the man in the street to participate in space exploration, not merely witness it, because we need the support of taxpayers. The negative reactions are a result of past policies. But now we believe that the political and international prestige is important.

LDF: *How can the Soviet Union spend so much on space science and exploration, with programs such as* Energia *[a new giant launch vehicle],* Mir *[the new, enlarged space station],* Vega *[a mission to Halley's Comet and Venus] and* Phobos *[a mission to Mars and one of its moons]?*
RZS: First realize that *Vega* and *Phobos* are much cheaper than manned programs. The prestige factors I mentioned are important, especially international prestige, but perhaps we are spending too much. *Energia* and *Buran* [the Soviet space shuttle] are often criticized. Similarly to your military/industrial complex, our industrial community argues that it needs these projects just to stay in business—an institutional necessity argument.

LDF: *What is the right mix of human and robotic missions?*
RZS: That's not an easy question. I need to understand more before I can answer. I do think that there is too much emphasis now on human missions and heavy-lift launch vehicles.

LDF: *Will the Soviet Union undertake outer planet missions?*
RZS: Not soon. There are economic and technical limitations. It is best now, during *perestroika*, not to expand too much but to keep space exploration going within limits and current defined capabilities. An international Mars sample return mission fits these criteria, but outer planet missions do not. Perhaps they will by the mid-1990s.

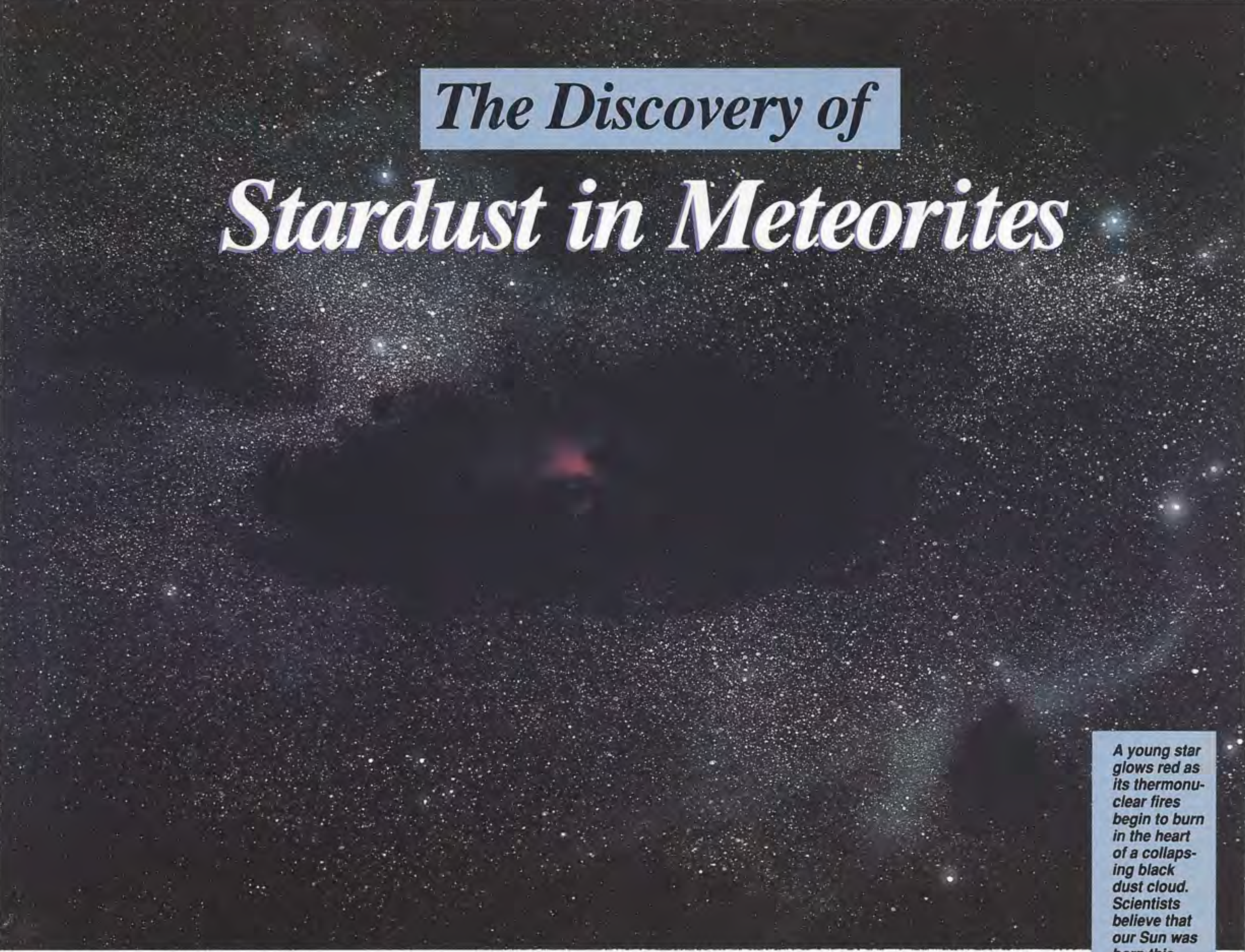
LDF: *In the United States we found that as planetary missions became more ambitious, and therefore more complex, we stopped undertaking them. Are you worried about that in the Soviet program?*
RZS: To some extent, that is already happening in the Soviet Union. In the 1960s and 1970s we sent missions to Mars and Venus at nearly every opportunity. Now our sequence of missions is to do one in 1984 [*Vega*], in 1988 [*Phobos*], and in 1994 [the planned mission to Mars].

LDF: *Is there a need for a popular organization similar to The Planetary Society in the Soviet Union? Should we try to be more active there ourselves?*
RZS: I enjoy immensely my association with The Planetary Society. It is important. There should be another Soviet on the Board of Advisors, perhaps a younger scientist. On our side, we have an interesting underground prepared to set up a similarly large public organization. I don't know if it would be a real counterpart to The Planetary Society. Some enthusiasts are talking about a kind of space explorers' federation, bringing together not only deep space programs but also near-space and astronomy missions and manned flights. This type of organization would be very important in overcoming the skepticism of the man on the street. On the other hand, it would make a bridge to promote such projects through governmental and other agencies.

LDF: *Who are the principals in that?*
RZS: There are many people: writers, artists, space engineers, scientists. I expect that such a society would be organized in the near future.

LDF: *We, of course, would like very much to cooperate with them. We do have now liaisons and working arrangements with the Union of Artists and the Union of Architects, and I hope to make arrangements soon with the Union of Writers.* □

The Discovery of Stardust in Meteorites



A young star glows red as its thermonuclear fires begin to burn in the heart of a collapsing black dust cloud. Scientists believe that our Sun was born this way, and bits of dust from before its birth may be preserved in some solar system objects, particularly the comets and asteroids.

by John W. Larimer

The term "shooting star," long used as a fanciful expression to describe a meteor, has taken on a new meaning for students of meteorites. Some meteorites appear to contain star dust, material that originated around stars that were born, lived and died before the Sun and planets formed. This exotic star dust apparently survived a lengthy journey through interstellar space before being caught up in the cloud of gas and dust that became our solar system. Having endured the trip through space, it then somehow managed to escape violent processing in the early solar system—the vaporization, melting and complex chemical reactions recorded in meteorites. And finally, after a long residence in small asteroids, the meteorite parent bodies, it survived their breakup and the trip to Earth.

Ultimately the Sun and all planetary matter came from outside the solar system and could be regarded as exotic in the broadest sense of the word. But most of this material has been so extensively processed since arriving in the solar system that it seems more appropriate to regard it as "local" in origin, reserving the term "exotic" for material that still retains some signature of a pre-solar origin. Until recently the possibility that pieces of pre-solar material might still be intact and retain a memory of their history seemed too remote to contemplate. Moreover, even if some exotic dust had survived, it was not clear how it could differ from local dust. Not surprisingly, the story of how exotic, pre-solar material has been sought and found in meteorites follows a sometimes illogical course.

Clues from Chondrites

Meteorites have long been regarded as a rich source of information about the early solar system. Roughly 85 percent of all meteorites that fall to Earth are chunks of rock known as chondrites, after the BB-sized, once-molten silicate spheres called chondrules found within them. Chondrites are old, nearly pristine samples of planetary matter. Radiometric dating (measuring radioactive decay to establish age) indicates an age of about 4.6 billion years, the accepted age of the solar system. No terrestrial or lunar rock has been found that challenges their great antiquity.

Chondrites also have a unique chemistry; they contain all the elements mixed in nearly the same proportions measured spectroscopically in the Sun. (The only exceptions are elements such as hydrogen, helium, carbon and nitrogen, which are abundant in the Sun but depleted in chondrites because they are gaseous and were not incorporated into the rocky planets.) This implies that the

Sun and chondrites formed from the same well-mixed batch of elements and that chondrites have retained this mix since forming in the early solar system.

Planetary scientists think that chondrites are pieces of asteroids, broken off during the long history of collisions in the asteroid belt. Occasionally asteroidal fragments are ejected into Earth-crossing orbits, and they eventually collide with our planet. Chondritic asteroids apparently formed early in solar system history as condensing bits of matter collided and stuck together. Afterwards, over the next several million years, they warmed up a few hundred degrees but never melted. Unlike their rocky counterparts produced by complex melting, volcanism and weathering on the lunar and terrestrial surfaces, chondrites have been little altered since they formed.

Isotopes Lend Variety to Matter

Isotopes are a variation on a theme; they reflect nature's way of adding variety to the basic building blocks of matter. The nuclei of all atoms are composed of only two kinds of particles—protons and neutrons. They have almost equal mass. All atoms of each element contain the same number of protons: hydrogen has one, helium has two, and so forth. However, not all atoms of most elements contain the same number of neutrons. Most helium atoms have two neutrons and a mass number of four (two protons + two neutrons, ^{4}He). Atoms with the same number of protons but different numbers of neutrons are called isotopes of an element: ^{3}He and ^{4}He are isotopes of helium. Both have two protons, but ^{3}He has only one neutron.

In general, the isotopes of an element are chemically identical because the small difference in mass does not affect how they interact with other elements. Light elements (^{1}H and ^{2}H or ^{16}O and ^{18}O, for example) are an exception: here the mass difference is relatively large and does somewhat affect how the different isotopes of hydrogen bond with the different isotopes of oxygen.

Occasionally, one isotope of an element is unstable; given enough time, unstable isotopes transform into other, more stable isotopes. The isotope rubidium-87 transforms into the isotope strontium-87 at a known, excruciatingly slow rate; one of two ^{87}Rb atoms becomes a ^{87}Sr atom every 47 billion years. By measuring the proportions of ^{87}Rb and ^{87}Sr in a rock, scientists can calculate the age at which it formed.—*JWL*

The first clue that exotic, pre-solar dust survived was the discovery of some unique isotopic signatures in meteoritic material. Before these isotopic "anomalies" were found, all samples of planetary material seemed to contain the various isotopes of each element in more or less the same proportions. The elements, as well as their isotopes, were thus thought to have been thoroughly mixed in the early solar system, leading to the view that matter now in planets had been totally vaporized and completely homogenized during the solar system's formation.

Of course, in some cases the isotopic composition of certain elements does vary, and we must understand these cases before we can fully appreciate the isotopic "anomalies" in meteorites. Two examples should suffice. First, unstable isotopes such as uranium-235 and -238 and potassium-40 undergo radioactive decay over time to become other isotopes. Scientists understand these cases well and commonly use the proportions of the parent and daughter isotopes to determine the ages of rocks and meteorites.

A second example is found among light elements such as oxygen, where the mass difference between ^{16}O, ^{17}O and ^{18}O is proportionately large. This mass difference, which affects the bond strength between oxygen and other atoms such as hydrogen in water (H_2O) and carbon in carbon dioxide (CO_2), leads to isotopic variations among different compounds. The effect, which increases markedly with decreasing temperature and depends on mass differences, is called mass-dependent fractionation.

A well-known study of oxygen isotopes, which has nothing to do with meteorites but illustrates the principle, involves the growth of sea shells (calcium carbonate, $CaCO_3$) from sea water (H_2O). As the shell grows, it incorporates the oxygen isotopes in proportions governed by the relative bond strength of oxygen in the water and the shell, and the $^{18}O/^{16}O$ ratio in the shell reflects the isotopic composition and temperature of the water. Isotopic measurements of fossilized sea shells have enabled scientists to trace the temperature and composition of sea water over the past few million years of worldwide glacial advances and retreats.

Discovering Nuclear Processes in Stars

The isotopic "anomalies" recently discovered in meteorites do not match any known pattern; they cannot be explained in terms of radioactive decay or mass-dependent fractionation. Instead they seem to reflect the nuclear processes by which the elements (the fundamental substances making up all matter) and their isotopes are manufactured in stars. Depending on a star's size, various nuclear reactions occur during its lifetime, leading to the buildup of heavier elements from lighter ones. Toward the end of its life, when the star becomes a red giant or explodes in a supernova, it ejects matter, including the freshly synthesized isotopes, into the surrounding interstellar medium. There the matter mixes with the debris from other stars and eventually collects to form a new star. Scientists think that most matter in our solar system is an averaged, heavily processed mix of material from many older, now-dead stars. But the new evidence raises the possibility that some dust grains that formed shortly after their constituent elements were synthesized still retain the isotopic signature of the dying star.

Until 1973 the few hints that pre-solar matter may exist in meteorites were too ambiguous to pursue seriously, but

Right: This single-crystal, x-ray diffraction study of a grain from the Allende meteorite indicates that it has a structure characteristic of a diamond.

Photograph courtesy of Roy Lewis and Edward Anders, University of Chicago

Left and above: *These scanning electron microscope images of the grains found in a dissolved sample of the Murchison meteorite reveal numerous small crystals of silicon carbide (SiC) and an occasional large one. These grains, like the diamonds, carry an isotopic signature from a time before our solar system formed.*
Micrographs courtesy of Ernst Zinner, Washington University, St. Louis

***Above:** This fanciful view of a cut diamond shows that bits of diamonds found in meteorites carry the isotopic signature of star dust, with atoms of noble gases such as krypton and xenon trapped among the carbon atoms that make up the diamond.*
Drawing: Susan Selkirk

they did plant seeds for thought. In 1973, Bob Clayton and his colleagues at the University of Chicago devised a clever model in which they would use oxygen isotopes to estimate temperatures in the solar nebula. Their idea was analogous to the study of sea shells growing in sea water; mineral grains growing in the nebular gas should preserve a record of the isotopic composition and temperature of the gas.

To estimate the isotopic composition of the gas, Clayton *et al.* studied clumps of some unusual minerals found in certain meteorites. The minerals are calculated to be the most refractory materials in a solar gas; in other words, if we imagine a gas containing all the elements in the same proportions as they occur in the Sun, then these minerals would be the last to evaporate as the gas heated or the first to condense as the gas cooled. Rich in calcium and aluminum, the minerals are clumped in small, easily resolved masses called inclusions, which are known in the meteorite literature by the acronym CAI, for calcium aluminum inclusions. The calcium- and aluminum-rich minerals are expected to grow (or evaporate) in a solar gas at temperatures of 1,500-2,000°K (1,230-1,730°C), a temperature so high that mass-dependent fractionation effects are insignificant.

Dr. Clayton and his colleagues reasoned that CAIs' oxygen isotopic composition should be the same as that of the nebular gas in which they grew. Given this information, the scientists could trace the gas as it cooled to lower temperatures where mass-fractionation effects become significant, and they could estimate temperatures at which low-temperature minerals grew, or better, ceased to grow as they agglomerated into the asteroidal parent bodies of the meteorites.

Although the first few measurements of the refractory minerals were close to those expected, there were some peculiar results from the outset, and these soon outnumbered the normal ones. In studying oxygen isotopes, the normal practice is to measure only the more abundant mass 16 and 18 isotopes because the effect is always twice as large as the 17/16 effect. As a check on what happened during the measurements, the researchers decided to measure the amount of 17 present. Much to their surprise, relative to ^{16}O, ^{18}O and ^{17}O did not vary in the usual 2:1 ratio but instead varied in nearly a 1:1 ratio.

Since there were three isotopes involved, ^{16}O, ^{17}O and ^{18}O, there were two possible interpretations: either ^{17}O and ^{18}O were varying by the same factor, or ^{16}O was varying independently. When interpreting strange results, it always seems best to adopt the simplest explanation, which in this case was that only ^{16}O was varying. But because there was no known chemical process that could cause ^{16}O to vary independently, Clayton *et al.* inferred that somewhere in the minerals there was a component with a unique isotopic signature.

Despite strenuous efforts over the past 15 years to isolate the carrier of the exotic ^{16}O-rich dust, it has not been found. Scientists increasingly suspect that the exotic dust must have been assimilated during nebular processing into grains that for the most part formed locally. Though this search proved fruitless, the discovery stimulated searches for other anomalies.

More Anomalies Spark More Questions

The CAI remained the center of focus for most of these searches because the refractory nature of the inclusions, which previously made them prime candidates for the first dust to form in a cooling nebula, now made them prime candidates for residual, and perhaps exotic, dust in a heating nebula. Much of this work was conducted at the California Institute for Technology under the direction of Gerry Wasserburg and Sam Epstein. The search involved measuring the isotopic composition of a variety of elements in inclusions with a peculiar chemistry or mineralogy. Although the team has found numerous anomalies, the search remains random since it is impossible to identify in advance inclusions with particularly interesting isotopic compositions.

Scientists still do not understand the numerous anomalies that they have discovered or the bizarre nature of the patterns. Uncertainty surrounds attempts to resolve an anomalous isotopic pattern since there is no way of knowing which, if any, of the isotopes are present in normal, solar-system amounts. Only relative amounts, or ratios, of the isotopes can be fixed with certainty. In a few cases, where many isotopes exist, we can find two or more that appear to occur in normal, solar proportions; these are then assumed to be present in normal absolute amounts. If this sounds confusing, be assured it is, even for those who study the anomalies.

Nonetheless, it appears that at least two separate processes are required. One process seems to be mass dependent; heavy isotopes are more enriched than lighter ones. The effect is more pronounced among lighter elements such as magnesium and silicon. This suggests a process such as partial volatilization, in which lighter isotopes boil off more readily than heavier ones during heating as the minerals begin to evaporate. This is consistent with the idea that these inclusions may be evaporative residues of the dust that collected to form the solar system.

At the same time the heavier isotopes of heavier elements such as strontium, barium and some of the rare earth elements are enriched more than expected from an evaporation process. The pattern among these isotopes follows one expected if the material contained freshly synthesized isotopes formed in the rapid process of stellar nucleosynthesis. This rapid or r-process occurs during stellar explosions and preferentially forms heavy isotopes. While these two processes explain much of the data, they do not explain all of the anomalies. The situation is perhaps best summed up by noting that the inclusions displaying these anomalies are referred to as FUN inclusions—Fractionated and Unknown Nuclear effects.

As in the case of the more prevalent oxygen isotope anomalies, it appears that the carriers (star dust?) of these anomalies have been assimilated into minerals of primarily local origin. These studies provide additional evidence that pre-solar dust was present in the early solar system but do not provide us with the actual pieces. Scientists discovered the minerals most likely to be actual pieces of star dust in a study that took a different tack from the beginning and represents the most recent chapter in the story.

Finding the Elusive Star Dust

As mentioned earlier, the more volatile, gas-forming elements, particularly the noble gases helium (He), neon (Ne), argon (Ar), krypton (Kr) and xenon (Xe)—which do not react or combine readily with other elements—are depleted in meteorites. The amounts of noble gases present are excruciatingly small but can still be detected and resolved into their constituent isotopes with a modern mass spectrometer. While such small amounts pose analytical problems, there are some advantages.

Several isotopes are produced by radioactive decay of less volatile, much more abundant elements. One example is argon-40, which, except on smoggy and humid days, is the third most abundant gas in Earth's atmosphere. It is produced from the decay of potassium-40. Argon-40 is abundant not because the forming Earth gathered up a lot of it but because potassium-40, its radioactive parent, is abundant on Earth relative to the other isotopes of argon. Thus, it is interesting to compare the abundances and isotopic composition of the noble gases in meteorites with Earth's atmosphere.

One long-standing question is whether noble gases in meteorites are concentrated in some special mineral or randomly trapped in all minerals. Scientists have sought clues using either of two classical procedures. In one, they physically separate and analyze the minerals. In the other, they place the meteorite sample in a furnace and heat it progressively at, for example 100° intervals, trapping and analyzing the gases evolving at each step. These studies have yielded useful information, including the discovery that different components in the meteorites contain different amounts of gas, frequently with a different isotopic composition.

Above: Scientists have found small, pre-solar diamonds in this partially dissolved sample of the Allende meteorite.

Bottom right: This sample of the Allende meteorite has been treated with acid, which dissolved away much of the organic material, leaving behind acid-resistant grains.

Photographs courtesy of Roy Lewis and Edward Anders, University of Chicago

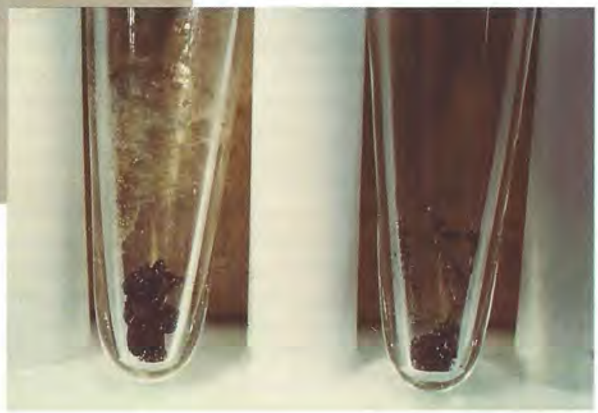
As part of an attempt in the mid-1970s to track down the mineral or component that carried a particularly unusual xenon gas, Ed Anders and his colleagues at the University of Chicago attempted to dissolve away all the minerals except one that they suspected to be the main carrier. The procedure failed: the mineral itself dissolved. Only a small residue remained, consisting largely of what looked like an insoluble organic, tar-like substance; black goo is a more descriptive if less scientific term. Its total weight was only 0.5 percent, or 1 part in 200, of the sample's weight before the dissolution procedure began. Although the mineral of interest had disappeared, Anders *et al*. analyzed the sample anyway out of curiosity. This decision was fortunate; amazingly, the sample was enriched in noble gases

Left: The Allende meteorite contains large, light-colored calcium- and aluminum-rich inclusions (CAIs). The largest, nearly spherical inclusion near the center is about one centimeter in diameter.

Photograph courtesy of the Center for Meteorite Studies, Arizona State University

Below: This is the acid-treated sample after drying. Some of the remaining acid-resistant grains are pre-solar diamonds.

Photograph courtesy of Roy Lewis and Edward Anders, University of Chicago



by a factor of nearly 200 over the bulk sample. This tiny, nondescript residue that had been boiled in acid and otherwise treated with disrespect contained virtually the entire noble gas inventory of the meteorite.

But not content with isolating nondescript residue, Dr. Anders decided to examine this residue to see if it consisted of even smaller components, only one of which might hold the gases. He subjected the residue to a variety of chemical and physical procedures in an effort to break it down further into the "Rosetta Grain" of noble gases. He followed each procedure with an isotopic analysis of the remaining gases. It rapidly became apparent that several components were present, each carrying noble gases with a unique isotopic signature.

Dust from Several Stars?

The components identified so far include carbon in a variety of crystal structures as well as amorphous (noncrystalline) carbon. In 1986, the researchers found tiny diamond crystals, and during the past year they discovered the compound SiC (silicon carbide). The isotopic patterns suggest the presence of material formed by the slow or s-process of nucleosynthesis, a process that occurs during the latter stages of a star's life and that produces most of the stable isotopes heavier than iron-56. In addition, there are a number of variations in the isotopic composition of carbon, silicon and nitrogen. The complexities are bewildering, suggesting that the dust from several stars may be represented.

Silicon carbide (SiC) has been observed in interstellar space, associated with stars containing more carbon than oxygen. These stars and their associated dust differ from the Sun, where oxygen is more abundant than carbon. Theoretical studies of the dust that would form in such carbon-rich gases indicate that silicon carbide would be one of the most refractory minerals, in contrast to the more oxygen-rich minerals found in the meteoritic inclusions.

Diamond is a well-known meteoritic and terrestrial mineral. Scientists have always thought that it formed under extremely high pressures generated by impact-induced shock in meteorites or by being buried deep within Earth. However, since the tiny diamonds carrying the isotopic signature of star dust presumably formed at the low pressures prevalent in interstellar space, then diamond formation may not always require high pressures. Exactly how these diamonds might form is a mystery, a mystery fittingly derived from studies of the most mysterious material ever studied in a laboratory, a material with an exotic, pre-solar origin.

John W. Larimer, a Professor in the Department of Geology, is also the Associate Director of the Center for Meteorite Studies at Arizona State University. His current research focuses on the chemistry of the solar nebula.

Planetary Exploration—

Thirty-two years ago, the International Geophysical Year (IGY) furnished an institutional and intellectual context for the first launch of a satellite to orbit Earth. To interpret this event—this first international mission to study Earth—most observers pointed to a continuing tradition of exploration by Western civilization that has spanned more than 500 years.

That tradition has not progressed in smooth increments. Its history has been lumpy, full of pauses and leaps reflecting changes in the geography of exploration, in its technological capabilities and expressions, in the relationship between discovery and prevailing modes of thought, and in the moral drama that gives life and social meaning to acts of discovery. For half a millennium, exploration—as an idea and as an institution—has been essential to an evolving Western civilization, a cultural phenomenon that has thrived in a vigorous cause-and-effect relationship with the civilization that it both serves and inspires. A change in one will mean a change in the other.

On occasion change has occurred on such an epic scale that distinctive ages of discovery have become apparent. IGY did more than inaugurate *Sputnik* and its successors. It announced a new epoch of exploration, a Third Great Age of Discovery.

Concept of a Third Age

In his book *Trade and Dominion* (1971), J.H. Parry traced the aftermath of Renaissance exploration and the imperial rivalries that sustained it as Europe settled into a routine of trade and a balance of colonial power. That balance was upset as Europeans spilled into the Pacific. By the middle of the 18th century a new era of circumnavigation was underway, propelled by the growing competition between France and England. Parry called this Pacific revival "A Second Age of Discovery."

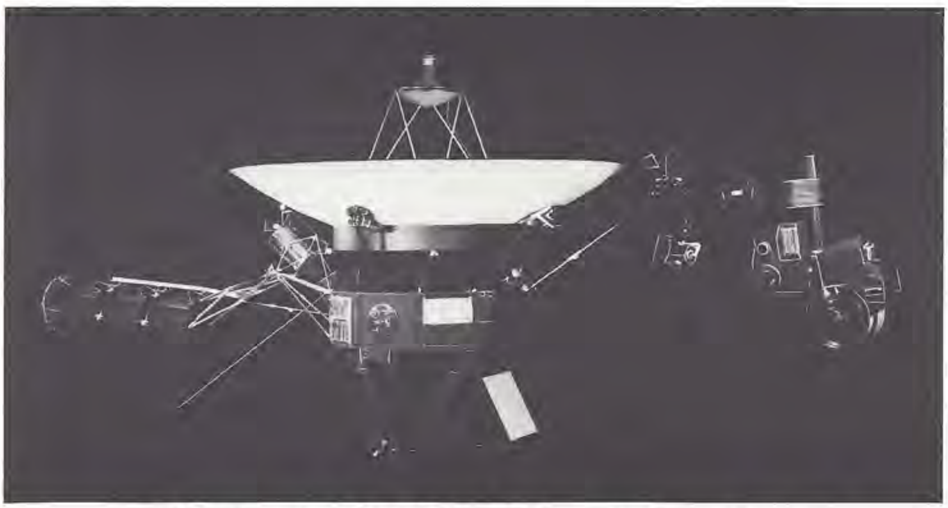
William Goetzmann, building on his masterful book *Exploration and Empire* (1967), elaborated on the phrase in *New Lands, New Men: America and the Second Great Age of Discovery* (1986), using it to describe a style of exploration that characterized a whole era of geographic discovery. The world ocean was resurveyed, and the world's continents were explored, claimed and sometimes colonized; it was an epoch of reckless European imperialism. But what made the second era different was its alliance with modern science. I have applied the same reasoning to distinguish a Third Age from the Second, ideas tested most recently in *The Ice: A Journey to Antarctica* (1986).

Geography of Discovery

Each Age has claimed a special geography. The First Age—the classic voyages of discovery—sailed the world ocean and mapped its shores. From the interior seas of Europe, pilots moved across a global sea. The grand gesture of the era was Magellan's circumnavigation of Earth. The few overland journeys, with the exception of the ancient caravan routes across Asia, were typically tied to ship-borne supplies or coastal depots.

The Second Age coincided with the serious exploration of the continents. This began with a resurvey of Europe but quickly expanded around the globe. It is no accident that this was also the great era of natural history; the scientific imperative to discover new species, new rocks and rivers, and new peoples merged perfectly with political and economic ambitions to establish wider spheres of dominance and sponsor major geographic inventories of all the lands. The great gesture of the Second Age was the overland traverse of a continent, taking a cross-section of its natural history as Lewis and Clark did for North America.

The Third Age has claimed the solar system as its geographic domain, beginning with IGY's resurvey of planet Earth—the deep oceans, the Antarctic, the near-space environment, the Moon. But the process has expanded into a marvelous new geography. This era's grand gesture is the geophysical inventory of a planet. For Western civilization, exploration has always meant geographic discovery, and the technology of interplanetary space travel has revived an institution that would otherwise have wasted into metaphor.



This doughty explorer of the Third Age of Exploration has discovered more new worlds and traveled farther than explorers of previous ages could have dreamed. The two* Voyager *spacecraft have discovered 16 new moons and trekked through the outer reaches of our solar system.* Voyager 1 *is on its way to interstellar space, heading toward the constellation Ophiuchus;* Voyager 2 *will encounter Neptune in August before beginning its journey to the stars. Photograph: JPL/NASA

A Third Great Age of Discovery

by Stephen J. Pyne

Intellectual Context of Discovery

But geography is only part of the story. For exploration to change a society in fundamental ways, it must interact with its intellectual culture, with prevailing modes of thought. It is easy to identify the First Age of Discovery with the explosive flowering of learning that passes under the label of "Renaissance." A robust curiosity spilled into new fields of inquiry much as explorers swarmed across the world ocean. Old systems of knowledge, in fact, simply crumbled under the impress of new discoveries—not only because of particular revelations, but also from the sheer volume of data accumulated.

When Goetzmann attempted to identify the defining feature of the Second Age, he pointed to the penetration of the Renaissance mode of exploration by modern science, a grand alliance that persisted into the early 20th century. But as Goetzmann himself demonstrated, the association extended beyond science. An intellectual reformation, what might be called a Greater Enlightenment, invaded and incorporated exploration as it did nearly every other dimension of Western civilization. Thus a James Cook, who voyaged to the last major islands and last unmapped region of the Pacific, can be understood as an Enlightenment explorer—practical, skeptical, inquisitive—his maps, an expression of the age's urge to codify its discoveries.

The relationship was reciprocal. As exploration oriented itself to the demands of science and other cultural reforms, it began to alter the social and intellectual dimensions of the Greater Enlightenment. The Romantic revolution was in no small way inspired by the data, experiences and exotica shipped back to Europe by the exploring expeditions that proliferated at the end of the 18th century. New sciences or vastly reconstituted older sciences—biology, geology, anthropology, archeology—emerged to handle the data. Historical painting in the dignified, formal, ceremonious Grand Manner became natural history paintings of the sublime by such artists as Thomas Moran and Frederic Church. The Grand Tour of Europe that had been almost a rite of passage for the young men and women of the previous age metamorphosed into a Grand Reconnaissance of Nature.

So it went until the Second Age ran out of new lands and new peoples. The exhaustion of continental geographies coincided with a faltering in the intellectual culture and even in the moral drama that had sustained the Second Age. The philosophical underpinnings of the Greater Enlightenment gave way to the precepts, reformed genres, perspectives and data sets of Modernism. Virtually every expression of high culture would, in time, feel this reformation—modern art in such forms as Cubism and Dadaism, modern science with the new physics and the new genetics, modern literature with the novels of Joyce and Faulkner.

The vision of the explorer as Romantic hero ended on the ice sheets of Antarctica and in the trenches of World War I. As Modernism grew, classic exploration receded; the Modernist revolution was accomplished without direct contributions from a new wave of geo-

The International Geophysical Year—A Milestone for Studies of Planet Earth

According to Homer Newell, one of the founders of American space science, it was the geophysicist Lloyd V. Berkner who, in 1950, proposed to James Van Allen and a few other colleagues that there should be a Third International Polar Year. (On two previous occasions, 1882-3 and 1932-3, scientists from many nations had collaborated in investigating polar phenomena.) Berkner argued that in view of rapid technical progress, scientists should not wait fifty years for the next such event but should stage it in 1957-8, twenty-five years after the last one.

The proposal was soon adopted by the International Council of Scientific Unions, broadened scientifically, and renamed the International Geophysical Year (IGY)—an effort to make and analyze widespread, simultaneous observations of Earth and its surroundings.

On October 4, 1954, the IGY's governing committee challenged participating nations to put up instrumented satellites as part of the worldwide measurement campaign. After much debate, in 1955 the US announced its intent to do so. In 1956 the Soviet Union followed suit, and on October 4, 1957 launched *Sputnik*, inaugurating the space age and igniting a volatile mixture of elation and consternation in the rest of the world.

Though subsequent spaceflight events overwhelmed the IGY in the news, its scientific achievements were important, and it was a pathfinder for other large, international scientific undertakings. Planning is now well underway for an International Space Year in 1992, the 75th anniversary of the Russian Revolution and the 500th anniversary of Columbus' discovery of America. During this next worldwide campaign, scientists from many nations will benefit from and extend the IGY's legacy. *—James D. Burke* graphic discovery. Instead Modernism celebrated the interior journey, more pleased to follow novelist Joseph Conrad into a "heart of darkness" or a Sigmund Freud into a murky subconscious than a Henry Stanley across tropical Africa or a John Wesley Powell through the Grand Canyon. Only recently are Modernism and the new domains of geographic discovery becoming synchronized. A full reconciliation will probably require another 50 years.

The Third Age's exploration of the solar system cannot be understood as a simple extension of the mode of exploration that carried Western civilization across the continents. The discovery of planets with no signs of life is fundamentally different from the discovery of inhabitable continents, though a planet like Mars might be made inhabitable with the use of artificial environments. The transition from an earlier mode of exploration has been awkward. The images of the Second Age are still powerful in shaping our expectations about exploration. They lead us to believe that discovery must produce the same kind of experiences to qualify as exploration. Science fiction novels and popular TV shows tend to recycle the Romance novel but set it in more far-flung places and times, to re-outfit the explorer of the Second Age with newer-model hardware; "Star Trek," for example, is the voyage of Darwin's *Beagle* at warp speed.

Modernism desperately needs to examine new information, new experiences, new images that are too alien to be interpreted with reference to ourselves and the familiar. It needs new *stuff*—new data, new tangible worlds—in great enough quantities to overwhelm its powerful analytical techniques. It needs something beyond itself, and this the exploration of the planets can provide. They insist on contrast. They force us to look *outward*. The Third Age could do for Modernism what the First did for the Renaissance and the Second for the Greater Enlightenment.

Exploration as Moral Drama

Exploration proceeds from many motives, but if it is to endure, it must share and participate in a moral universe with its civilization. The explorer becomes, intentionally or not, a moral missionary, telling others and his sustaining civilization who they are and how and why they ought to behave. The explorer evaluates one civilization against another and justifies each of them. The triumphs and failures of explorers become parables.

For Western civilization, the big story has been the saga of Western expansion, supported by a belief that this expansion has been good for the world as well as for Europe and its Neo-European counterparts, that expansion is both inevitable and desirable. This belief, too, faltered in the early 20th century. Western exploration had its dark side. It challenged the presumptions of Western religion, science and morality.

In 1910 Joseph Conrad published his damning novella *Heart of Darkness*, and Franz Boas published *The Mind of Primitive Man*. Exploration and imperialism were not ennobling but corrupting, Conrad suggested. They corrupted the discoverer. Boas contended that the West's special claims to superior intelligence and a superior moral universe were undercut by an argument for the

***Background:** Without native peoples, without a sustaining biota in its interior, Antarctica broke down the modes of exploration typical of the Second Age; after World War II, its explorers pioneered the techniques of the Third Age. The International Geophysical Year began with a special focus on the Antarctic.* Photograph by Stephen J. Pyne

Top inset: **Rainy Season in the Tropics** ***(1866) by Frederic Church. This painter shared the enthusiasms of scientists and artists for newly discovered wild lands, and landscape painting developed in tandem with natural history. Many artists accompanied scientific expeditions, and Church even traveled to South America on his own to reproduce in paintings the experiences of the explorer Alexander von Humboldt.***

Right inset: **The Oxbow** ***(1836) by Thomas Cole. This painting coincided with Ralph Waldo Emerson's classic essay "Nature," with the establishment of the Army Corps of Topographical Engineers, and with the Texas revolution. The Second Age of Exploration was shaped by the coalescence of just such events—the emergence of landscape painting, a philosophy of transcendentalism, the sciences of natural history, and the politics of expansionism.***

cultural relativity of all peoples. A society's values, ethical standards and social practices had to be understood in relation to its unique historical development. It was not fair to judge all cultures using the standards of Western tradition. It became increasingly obvious that "discovery" meant, in reality, discovery by and for the West of places and phenomena and people already known to other societies. Exploration could no longer be justified as a kind of "white man's burden," necessary in the interest of science; politically and morally, it was not a neutral act.

In the Third Age the moral dilemma of exploration only exists if we encounter life or other intelligent societies. Since this is increasingly unlikely in the solar system outside Earth, we probably won't face the kind of moral quandary that plagued the imperialism of the First and Second Ages. That's the good news.

The bad news is that exploration of lifeless worlds will look different and will lack the purposes and drama that the discovery of new lands and new peoples involved in previous centuries. There is no reason for compromise because there is no life; there is no moral dilemma because there is no Other against which to measure the Self. What will remain is an Earth-based rivalry—the kind of broad-spectrum competition that has always powered exploration by the West. Included within that rivalry is modern science, which has shown itself to be as aggressive and competitive as the civilization from which it emerged.

The US at the Crossroads

If this transfer succeeds—if the mythology of expansionism and the popular enthusiasms that it has historically rallied can be redirected to lifeless environments and robotic probes—then the essential elements for a new Age of Discovery are complete. The era will have its special geography, sustaining mode of thought, and moral vigor. All that it lacks is the inspiration of political rivalry.

The Cold War helped jump-start the new age. But the range of participants has expanded, and with or without the United States, the Soviet Union, or any other individual spacefaring nation, the Third Great Age of Discovery will go on. Apart from political, economic and military considerations—which have always contributed to nations' decisions to explore actively—the broadly cultural importance of exploration argues strenuously for participation. The benefits of planetary exploration go far beyond the usual allusions to technological spinoffs or economic multipliers; they help determine how we view the natural world, how society locates itself in that environment, and what kind of moral universe it inhabits.

Choosing to explore the solar system will not, by itself, assure any spacefaring nation's continued world status. That requires much more, a more comprehensive cultural gross national product, if you will. But choosing not to explore will guarantee loss of that status.

Stephen J. Pyne is Associate Professor of History at Arizona State University West and the author of Fire in America *and* The Ice: A Journey to Antarctica. *He was awarded a MacArthur Fellowship in July 1988.*

Continuing SETI: Scientists

On two October days in Toronto, The Planetary Society held its first international conference on the search for extraterrestrial intelligence (SETI). Hosted by the staff of the beautiful Ontario Science Centre, most of the major SETI scientists from around the world convened to discuss their current research and their hopes for future study.

META Moves South

Chaired by SETI pioneer and Society Advisor Philip Morrison, the meeting was highlighted by the announcement of META II (Megachannel Extraterrestrial Assay), the world's first permanent SETI observatory in the southern hemisphere. The Society revealed an agreement with the Argentine Institute of Radioastronomy to build a duplicate of our Harvard META SETI system, to be operated permanently in Argentina.

Built by contributions from Society members—including film director Steven Spielberg, who made a generous contribution after a discussion with Ann Druyan and Carl Sagan—META has been operating in Harvard, Massachusetts, since 1985. It searches eight million radio channels for a type of artificial signal called ultra-narrowband that could be used by another civilization to signal its existence to the rest of our Milky Way galaxy. META I is by far the most powerful SETI system operating in the world today.

Harvard professor Paul Horowitz, together with colleagues John Forster, Ivan Linscott and Brian Matthews, designed and built the sophisticated META I system. META I uses a 25-meter-diameter radio telescope located in Harvard, Massachusetts, less than an hour's drive from Harvard University, where it is jointly operated by the university and the Smithsonian Astrophysical Observatory.

If Murphy's Law ("Anything that can go wrong will go wrong") operates on a cosmic scale, the most detectable civilization in the universe might be in the southern sky, where, until now, we could have missed it completely. Only a few brief searches have been conducted in that hemisphere, so META II is a major breakthrough.

The head of the new project, Dr. Raul Colomb of the Argentine Institute of Radioastronomy, came almost halfway around the world to announce this project and to thank the Society for its members' donations of $150,000. Two Argentine specialists, Juan Carlos Olalde and Eduardo Hurrel, will travel to Harvard to study META under the supervision of Dr. Horowitz. The researchers will then return to Argentina to install the META II system at an existing radio telescope site.

Speakers Inspire and Illuminate

Among the other conference highlights were a public lecture by Society President Carl Sagan at the University of Toronto, a banquet speech by Paul Horowitz, and a panel discussion on a fundamental principle of SETI, the Drake Equation, led by Society Advisor and SETI pioneer Frank Drake. The panel also included Canadian astronomer Bruce Campbell, dolphin researcher Diana Reiss and Canadian anthropologist Richard Lee, as well as Philip Morrison and Carl Sagan. The topics ranged from the difficulties of humans communicating with dolphins to the odds that a civilization will destroy itself. The events were well attended, with crowds ranging to 1,200 people for Dr. Sagan's lecture.

David Latham of the Harvard/Smithsonian Center for Astrophysics in Cambridge, Massachusetts, described his recent breakthrough: the first *independently verified* detection of planets around other stars. Up to now, despite many claimed detections of extrasolar planets, none had been confirmed.

Share Findings at Toronto Conference

by Thomas R. McDonough

At the Toronto conference, Planetary Society President Carl Sagan, Raul Colomb of the Argentine Institute for Radio Astronomy, and Paul Horowitz of Harvard University discussed the expansion of the Society's SETI program to the skies of the southern hemisphere. The computerized signal analyzer of Project META (Megachannel Extraterrestrial Assay), now hard at work on the radio telescope at Harvard's Oak Ridge Observatory in Massachusetts, will soon be duplicated for use on a radio telescope outside of Buenos Aires, Argentina.

Planetary Society photograph

Latham's work, along with that of Bruce Campbell of Canada's University of Victoria, strongly suggests that planets are extremely common.

Ivan Linscott, who works on SETI at Stanford University and NASA Ames Research Center, announced a major breakthrough. He and Jay Duluk have founded a company, Silicon Engines, Incorporated, primarily to develop the technology needed for the NASA SETI project. Working at Stanford and funded by NASA, Mr. Duluk and James Burr have developed a powerful silicon SETI chip that could cost as little as $100 in quantities of a thousand. Researchers at these institutions and at the SETI Institute of Los Altos, California, have developed the system in which the chip will be used.

Most SETI projects such as META have been designed to look for signals at special or "magic" frequencies. These frequencies, like TV channels, would be known to other civilizations as well as ours because we have observed in studying galaxies and quasars that the laws of nature are the same everywhere in the universe. These distinctive frequencies are produced by hydrogen and other atoms abundant in interstellar space or are implied by physical constants. A signal near one of these frequencies would be easier to find than a signal hidden among the billions of possible undistinguished channels.

Among the most intriguing possibilities discussed at the conference were new "magic frequencies" much higher than the traditional Water Hole band. The Water Hole—the microwave band between the frequencies of hydrogen and hydroxyl (OH) molecules (1,400 to 1,700 MHz)—has been favored by most SETI searches up to now. As technology permits, other much higher frequencies above the microwaves may be good choices for alien transmitters.

At the Soviets' request, scientist Michael Klein of the Jet Propulsion Laboratory offered an overview of Soviet SETI research. The presentation reflected the long-term cooperation between Soviet and US SETI scientists.

With election fever running high during this period both in Canada and the US, Allen E. Goodman, Associate Dean of the School of Foreign Service at Georgetown University, presented a paper on SETI detection protocols entitled "Memorandum for the Next President of the United States," encouraging him to think seriously about SETI.

Strides and Setbacks for SETI Programs

Five scientists from NASA Ames, the Jet Propulsion Laboratory, Stanford and the SETI Institute represented NASA's SETI project. Although it did not receive the hoped-for increased funding for the new fiscal year, the project is continuing, and an operational SETI system could begin actual observation as early as 1992. Some have proposed that the NASA and Soviet SETI systems now under construction be turned on simultaneously in 1992, the 500th anniversary of Columbus' first intercontinental voyage and the 75th anniversary of the Russian Revolution. Until then, the Society's METAs will be the most powerful SETI systems in the world.

The outlook appears mixed for other SETI systems around the globe. Robert Stephens, a Canadian who built a SETI system against great odds in the frigid Northwest Territories, has had to abandon it. But he will soon begin using a 60-foot (18-meter) radio telescope in northeast Ontario for SETI. Although SETI interest remains strong in Canada, the government has unfortunately mothballed its large Algonquin radio telescope due to a cutback in government funding. Paul Feldman of the Herzberg Institute of Astrophysics in Ottawa suggested that it could be reopened for use by the NASA SETI project. Ohio State University, which had had the world's longest-running SETI system but had been off the air for several years, has just begun running an improved system called SETI Zoom.

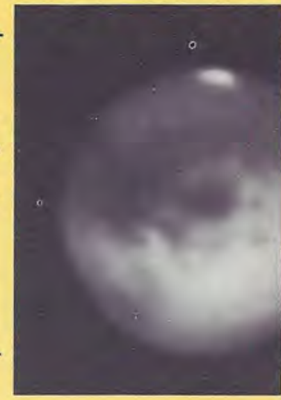
The "SETI Protocol" moved a step closer to international agreement. In this remarkable first instance of interstellar diplomacy, scientists and diplomats are working out a plan to decide how to handle the first confirmed detection of an extraterrestrial civilization. How will it be announced? Who will make the announcement? A group led by Michael Michaud of the US State Department will present the latest version of this document to other international groups for their suggestions and endorsements.

The conference also marked the opening of the Ontario Science Centre's beautiful SETI exhibit, designed by the Society's Senior Consultant Jon Lomberg. The exhibit will be in place at least through the end of January 1989, and we expect to have it on display at the Planetfest II celebration in Pasadena during *Voyager*'s Neptune encounter in August 1989.

Participants were generally agreed that the conference was a success. And I'm happy to report that despite funding problems in every interested country, SETI is moving forward vigorously.

Tom McDonough is The Planetary Society's SETI Coordinator and the author of The Search for Extraterrestrial Intelligence, Space: The Next 25 Years *and* The Architects of Hyperspace.

MARS WATCH
Chronicles



The opposition of 1988 allowed amateur astronomers to join professionals in advancing our knowledge of Mars. With good telescopes and advanced film and processing, some amateurs were able to obtain photographs equal to any taken before the age of spacecraft. We show two examples here. The south polar cap appears at the top since most astronomical telescopes invert the image. Hundreds of such photographs will give us new data on martian winds, clouds, weather and surface features affected by the transport of dust.

Photograph above: Donald C. Parker, Coral Gables, Florida; photograph right: Isao Miyazaki, Okinawa, Japan

by Susan Lendroth

September 22, 1988, marked the closest approach of Mars to Earth in 17 years, and around the world tens of thousands of people celebrated the Red Planet's bright appearance in the sky with planetarium shows, film festivals and late-night vigils with their telescopes. For many, this was their first look at Mars; others greeted the return of an old friend.

Mars Watch '88, a program developed by The Planetary Society in cooperation with the Association of Lunar and Planetary Observers (ALPO) and funded by the Norris Foundation, was the driving force behind many of these events. Astronomer Stephen Edberg served as Mars Watch Coordinator.

The Planetary Society not only publicized Mars-related activities taking place worldwide but also formally co-sponsored over 60 Mars Watch events in the United States, Canada and Great Britain. More than one-third of our membership received invitations to Planetary Society activities near their homes, and at least 15,000 people attended these slide shows, lectures and star parties. Program participants included such speakers as NASA scientist Christopher McKay, director of the Society's Mars Institute; noted US Geological Survey scientist Harold Masursky; and physicist and science-fiction author David Brin. The success of these events was primarily due to the hard work and enthusiasm of Planetary Society volunteers, who organized and staffed most of them, including over two dozen in northern California alone.

From May through September, The Planetary Society distributed several thousand Mars Watch information kits, including 1,500 educators' packets for elementary and high school teachers. Information requests ranged from short notes scrawled by school children to inquiries from serious amateur astronomers, and they came from throughout the United States as well as from at least 20 other nations, including Brazil, Ghana, Greece, Guatemala, Iran, Malaysia and the Philippines.

Many Society members also distributed Mars Watch fact sheets and star charts at private telescope parties for their friends and neighbors. And everywhere, at public and private gatherings alike, our members continued to win support for The Planetary Society's Mars goal by collecting thousands of new signatures on the Mars Declaration.

Mars Watch '88 also offered special opportunities for the serious amateur astronomer through an affiliation with ALPO's International Mars Patrol. The Planetary Society produced and distributed the *Mars Observer's Handbook*, written by Jeffrey Beish and Charles Capen of ALPO. The handbook provides amateur astronomers with detailed instructions on how to make careful scientific observations of Mars and where to contribute their martian data to a worldwide network of observers.

By the end of October 1988, the ALPO Mars Recorders had received over 500 letters from interested amateur and professional astronomers in 32 countries and US territories. Since then, 182 observers have sent in nearly 3,400 observations to date—2,490 visual observations, 705 photographs, 16 charge-coupled device images and about 180 micrometer measurements. That number could easily rise to 5,000 over the coming months.

Submitted observations not only were more numerous than in past oppositions but also were of higher quality. "I've been analyzing observations for 12 years now, and the quality is improving, perhaps because more people are following our recommendation to use color filters," said Beish. Although most observers used

These remarkable mosaics of images taken by the Viking orbiters are still far beyond the capability of any Earth-based telescope.The Syrtis Major region (right) is seen during the early northern summer of 1980. The dark blue area on the right is Syrtis Major itself, the first martian surface feature identified from Earth by Christiaan Huygens in 1659. Scientists believe it is a gently sloping volcanic shield made of dark basalts. The impact crater Schiaparelli appears at the center of the second mosaic (far right) of images taken later that summer. This feature is named for the 19th-century telescopic observer who identified "canals" on Mars.

Images: Jody Swann, US Geological Survey

At each successive Mars opposition, researchers turn new telescopic techniques on the Red Planet. These images were taken with an instrument adapted from JPL's HIRIS project (High Resolution Infrared Imaging Spectrometer) about four hours apart using an infrared camera mounted on the 200-inch telescope at the Mount Palomar Observatory. This huge instrument is usually turned on distant stellar or galactic objects, not planets, but here it reveals dark and light surface features that rotated between the two exposures.

Images courtesy of Chas Beichman, Infrared Processing and Analysis Center, California Institute of Technology

telescopes with apertures ranging from 3 to 16 inches, several astronomers employed reflectors from 20 to 90 inches and refractors from 13 to 33 inches in aperture.

Giant dust storms on Mars provided some interesting observing opportunities. Many astronomers reported a major dust storm in June that began in Hellas Planitia (the largest impact basin on Mars, lying in the southern hemisphere) and soon covered several thousand miles to the east and west. Dust clouds and haze extended to regions as far east as Electris Planitia, to the west into Argyre Planitia (another large impact basin in the south), to the north into Hesperia Planum and as far south as the south polar cap. The martian atmosphere remained dusty from the storm even through the end of August. Although large, the June dust storm was not the planetwide storm some scientists had predicted, so astronomers had several good months of observing opportunities.

Media coverage of Mars Watch '88 activities was extensive. From full-page features in major metropolitan newspapers to local stories in small-town gazettes, Mars took center stage in September. Planetary Society staff members and volunteers gave dozens of interviews to reporters from Oregon to Florida, and special press kits were sent to nearly 2,000 newspapers, magazines, and radio and television stations. Publications covering the Society's Mars Watch programs included *Astronomy*, *Sky and Telescope*, the *Detroit Free Press*, *The Los Angeles Times*, the *Baltimore Sun* and Associated Press wire stories throughout North America. Many articles not only discussed the opposition of Mars and the events planned around it but also examined future exploration of the Red Planet as a viable goal capable of rejuvenating NASA and serving as a focus for international cooperation in space.

Indeed, 1988 proved to be a landmark year for Mars in many ways: it was the most favorable opposition of the 20th century, it brought The Planetary Society and the amateur astronomical community closer together through Mars Watch '88, and it focused international media attention on Mars as a world worthy of future exploration.

Susan Lendroth is The Planetary Society's Manager of Events and Communications.

Venus After Dark —

Since *Mariner 2* reached Venus in 1962 and became the first spacecraft from Earth to visit another planet, many spacecraft from both the United States and the Soviet Union have explored Earth's sister worlds. They've orbited the planet, sampled its atmosphere and landed on its surface. The US *Magellan* radar orbiter is scheduled to be launched to Venus late this year. But despite these spacecraft efforts, we still have much to learn about our closest neighboring planet, and new telescopic technologies can help us along.

In June 1988, about 10 days after it passed between Earth and the

June 24

The researchers obtained this image in the early morning, before the Sun's heat had destroyed the good seeing of the previous night. ("Seeing" is an astronomer's term for the clarity and stillness of Earth's atmosphere.) A vertical dark band near the crescent is due to a strip of neutral filter used at the telescope to reduce the light from the brightest part of the crescent.

June 25

These images obtained over eight hours show the cloud structures to be rotating about every 6.5 days. The rotation is from right to left and is in the same direction as the much slower retrograde rotation of Venus. (The planet rotates in the direction opposite to its revolution about the Sun; a day on Venus is equal to about 117 Earth days.) This observed "superrotation" of the clouds (they rotate faster than the solid planet) corresponds to a wind velocity of 70 meters per second, significantly slower than that observed for the clouds visible in ultraviolet light that are found much higher in the atmosphere.

June

VIEWS *of the* NIGHTSIDE

Sun at a distance of about 47 million kilometers from our planet, William Sinton and Klaus Hodapp of the University of Hawaii, David Crisp of the California Institute of Technology, Boris Ragent of NASA Ames Research Center, and David Allen of the Anglo-Australian Observatory captured these images of Venus. The team used the University of Hawaii's 2.2-meter telescope and a newly available infrared camera that is similar to charge-coupled devices now being used instead of photography for visual images.

These pictures show infrared radiation from the unilluminated hemisphere, as well as the sunlit crescent of the planet. About 1,000 times weaker than the sunlit crescent, this emission is welling up through cloud structures believed to be about 20 kilometers below the enshrouding cloud cover seen in visible light.

If the *Galileo* spacecraft is launched as planned in October, it will take similar images of Venus as it flies by the planet in February 1990 on its circuitous route to Jupiter. *Galileo* should be able to see Venus with about 10 times the resolution (ability to resolve detail) shown here. At the same time a ground-based team of observers will have the opportunity to take more images similar to these.

26

The striking feature near the center of the disk, which looks somewhat like a lunar crater, is actually a cloud formation.

June 27

A very dark cloud near the right limb of the planet makes the edge of the planet appear irregular.

June 28

The dark limb feature seen on June 27 has moved to cover most of the center of the picture. However, the edge between the dark cloud and the bright region is just about to disappear into the crescent region. Viewed nearly vertically rather than obliquely, the dark cloud is not completely opaque. Because of the changing aspect of Venus, the crescent has now grown to be much broader than it was on June 24.

World Watch

As most of our members know, the numerically noteworthy date of 8/8/88 marked the tenth year without a planetary launch by the United States. Next year will, we hope, finally break this pattern with the launches of Magellan *to Venus in April and* Galileo *to Jupiter in October.* Mars Observer *will follow in 1992. No other US planetary missions have been approved.*

NASA has plans to launch the Comet Rendezvous Asteroid Flyby mission in 1995, with the Cassini *mission to Saturn and Titan close on its heels in 1996. If these missions are started now, the decade of the 1990s could once again see the US with a vigorous space program, again working closely with the Europeans and possibly exploring Mars with the Soviet Union.*

*The Planetary Society strongly supports the CRAF/*Cassini *mission and encourages the new administration and Congress to approve the project this year. —Louis D. Friedman*

NASA's Office of Space Science and Applications has given the CRAF/*Cassini* mission its highest priority for a new start in the fiscal year beginning in October 1989 (FY 90). This project combines two missions that NASA has long studied: the Comet Rendezvous Asteroid Flyby, known by the acronym CRAF, and *Cassini,* a Saturn orbiter to be built by NASA and a Titan probe to be built by the European Space Agency (ESA). Both missions will use NASA's new *Mariner Mark II* spacecraft, so combining them into a single project will greatly reduce the total cost.

This project is part of NASA's budget proposal for FY 90, now in the hands of the Office of Management and Budget (OMB). In 1989 OMB must approve it, and it must be accepted by both the President and the Congress before it officially becomes part of NASA's program.

ESA recently furnished a new incentive for OMB and presidential approval when scientific committees and its governing body selected the *Cassini* probe for a FY 90 new start. *Cassini* had been competing with three astronomy mission and another planetary mission (the French/Soviet *Vesta* mission that would have flown by several asteroids and a comet). ESA made a difficult and highly significant choice—first, simply to select a planetary mission and second, to choose the United States as a partner. This demonstrated confidence in NASA marks an important step in rebuilding European-American relations in space, which were greatly strained several years ago when the US cancelled its spacecraft for the once-joint *Ulysses* mission to study the Sun. ESA's actions should help NASA's efforts to get a new start for CRAF/*Cassini* in FY 90.

This mission will make a multi-pronged attack on understanding the distribution of organic material in the solar system. Cometary nuclei, some types of asteroids, several other moons and Titan are all rich in carbon-based compounds. (The great significance of comets and Titan to the field of exobiology was described in the November/December 1987 *Planetary Report.*) In its rendezvous with a comet, CRAF will have hundreds of days to make detailed studies far beyond those made by the *Vega* and *Giotto* craft that flew by Halley's Comet. It will send a penetrator into the comet's interior, as well as conducting remote sensing experiments.

Cassini will send an orbiting craft to spend four years studying the ringed planet Saturn, briefly visited by *Pioneer* and *Voyager* spacecraft. At Titan it will deploy a probe to make a leisurely three-hour descent through the satellite's atmosphere, measuring its structure and composition. It might even survive to land on the surface.—*Tobias Owen, State University of New York, Stony Brook*

Voyager 1 flew within 3,915 kilometers of Titan, but its cameras could see only a hazy atmosphere enshrouding this huge saturnian moon. But other instruments were able to determine that Titan is rich in organic (carbon-based) molecules useful for understanding the origin of life on Earth. We need to probe its murky atmosphere to reach its possibly liquid-ethane-covered surface. This is one goal of the *Cassini* mission.

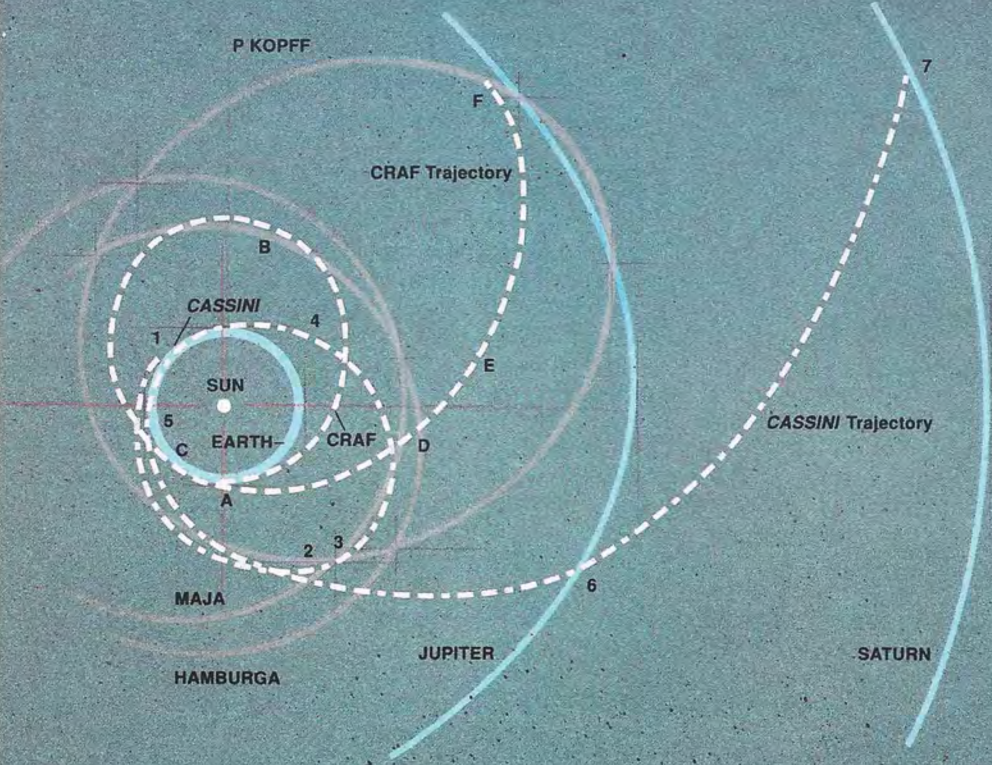
Image: JPL/NASA

NEW START—A Govern

"New Start" is the United States government's equivalent of a starter's pistol. It is the signal to government agencies and private industry to commit money, to begin work and to build hardware for a project. Every planetary mission must receive an individual new start in the federal budget before it can move forward. Since 1980 only the *Magellan* mission to Venus and the *Mars Observer* have received new starts, but both have been delayed and scaled down.

NASA may propose CRAF/*Cassini* for a new start. To receive it, the administration must propose the mission in its budget submitted to Congress. Then the mission must negotiate this tortuous path through the US Congress:

1. The Senate and House Budget Committees must accept the budget submitted by



1) Cassini Launch 4/8/96
2) Cassini Maneuver 2/13/97
3) Maja Flyby 3/14/97
4) Cassini Maneuver 1/16/98
5) Cassini Earth Flyby 6/13/98
6) Jupiter Flyby 2/1/2000
7) Arrival Saturn 10/2/2002

A) CRAF Launch 8/22/95
B) CRAF Maneuver 7/23/96
C) CRAF Earth Flyby 7/6/97
D) Hamburga Flyby 1/22/98
E) CRAF Maneuver 4/28/98
F) Arrival P Kopff 8/14/2000

If approved for new starts, the Comet Rendezvous Asteroid Flyby (CRAF) mission and Cassini will explore a broad section of our solar system and teach us much about other worlds.

Diagram: S. A. Smith

mental Starter's Pistol

NASA and give the new start high priority.

2. The Senate Committee on Commerce, Science and Transportation and the House Committee on Science and Technology must authorize the new start.

3. The Senate and House Appropriations Committees must give their approval.

4. The full Congress must approve their committees' budget, authorization and appropriation actions. If the administration fails to propose the mission, then Congress can add it as a new start.

We encourage all members to express interest in the CRAF/*Cassini* project by sending letters or mailgrams to their Representatives and Senators asking them to support the request for a new start with the Authorizing and Appropriations Committees.
—LDF

Flying by Halley's Comet at more than a quarter of a million kilometers per hour, we see only a tantalizing glimpse of what comets might be and speculate on their place in solar system evolution. We need to rendezvous with a comet and make detailed measurements of its properties. This is the goal of the Comet Rendezvous Asteroid Flyby (CRAF) mission.

Image: Ball Aerospace Corp. and ESA

SOCIETY Notes

US/USSR COOPERATION

The Planetary Society's campaign for US/Soviet cooperation in planetary exploration received an enormous boost at the recent US/USSR Planetary Working Group meeting. American scientists met with their Soviet counterparts to plan and coordinate future planetary missions. After years of the Society advocating such cooperation, NASA invited Soviet scientists to work with the US *Voyager*, *Magellan* and *Galileo* missions; the Soviets invited US scientists to assist with *Phobos* and *Mars '94;* and the two nations compared their Mars Rover and Sample Return studies with an eye to making them more international.

On November 8th, the Society hosted a reception in Washington, DC, for the Working Group to celebrate its progress as well as the prospects for increased international planetary exploration.—*Louis D. Friedman, Executive Director*

WELCOMING OUR NEW SENIOR CONSULTANT

The Planetary Society is pleased to announce the appointment of Adriana Ocampo as a Senior Consultant. Dr. Ocampo, a member of the technical staff at the Jet Propulsion Laboratory, cochaired the Society's Mexico City Workshop in September 1987, helped to lay the groundwork in her native Argentina for the Society's southern hemisphere SETI (Search for Extraterrestrial Intelligence) project, and recently helped to organize a meeting of the Pan American Space Organization in Washington, DC.—*LDF*

COME TO OUR HOUSTON EVENT

On March 16, 1989, The Planetary Society will sponsor a public presentation at NASA's Johnson Space Center in Houston, Texas. Local members will hear US and Soviet planetary scientists discuss planetary exploration. Call our events calendar telephone lines for more information.—*Susan Lendroth, Manager of Events and Communications*

DR. SAGAN URGES HUMAN MARS GOAL

In a public lecture held October 30th in Austin, Society President Carl Sagan told an overflow audience that a joint human mission to Mars can provide the cohesive goal needed to revitalize NASA and restore the US role in planetary science and exploration. The lecture was held in conjunction with the 20th annual meeting of the Division for Planetary Sciences of the American Astronomical Society.—*SL*

SPACE ART EXHIBIT

The Planetary Society, the Association of Science and Technology Centers (ASTC), The Smithsonian Institution's National Air and Space Museum, the International Association for the Astronomical Arts, and the USSR Union of Artists have joined together to sponsor a five-year space art project.

This spring the exhibit of Soviet and American paintings will highlight festivities surrounding the *Phobos* encounter with Mars and its largest moon. In August, selections from that show will travel to the Society's Planetfest '89 in Pasadena. The paintings will then go to the Reuben Fleet Space Theater in San Diego and then, under the auspices of ASTC, begin a national tour.

The Planetary Society and the Association of Science and Technology Centers are seeking corporate sponsors to join with us in the exhibit. We'll inform our members later this year when the travel schedule is set.

—*Charlene M. Anderson, Director of Publications*

MEMBERSHIP GROWS

Society membership has reached an all-time high of 125,000. This includes over 10,000 members in Canada; 1,500 in Australia, 500 in the United Kingdom; several hundred members each in Italy, Sweden, Spain, France, Switzerland, West Germany, and the Netherlands; and sizable numbers in 30 other countries. We're proud to have members in over 80 nations. Welcome aboard!

—*Cindy Oas, Data Processing Manager*

INTERNATIONAL COOPERATION CONFERENCE

On December 8-10, 1988, Washington, DC, was the site of a meeting of space policy leaders entitled "Developing the International Agenda for Space Exploration," cosponsored by The Planetary Society and the Space Policy Institute at George Washington University. Society members and the general public were invited to a symposium on the prospects for international cooperation. Society President Carl Sagan gave the keynote address. Society Vice President Bruce Murray; Roger Bonnet of the European Space Agency; Harlan Smith of the University of Texas, Austin; W. M. Evans of the Ministry of State for Science and Technology, Canada; and John McLucas of QuesTech, Inc. discussed opportunities open to the new Bush administration.

—*Tim Lynch, Director of Programs and Development*

VOLUNTEER OPPORTUNITIES

The Society's Volunteer Network enables members to participate at the local level. Over 75 enthusiastic, hardworking regional coordinators representing 38 US states and 9 other countries lead volunteers in setting up displays, distributing brochures and circulating the Mars Declaration. Some coordinators hold regular meetings. For more information and local contacts, send your name, address and phone number to me c/o The Planetary Society.—*Marshalle Wells, Volunteer Network Coordinator*

OUR MAILING ADDRESS:

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65 N. Catalina Avenue
Pasadena, CA 91106

Call for an updated events calendar:
(818) 793-4328 east of the Mississippi
(818) 793-4294 west of the Mississippi

General calls:
(818)793-5100

Sales calls ONLY:
(818) 793-1722

Soviet Union in exploring Mars, it will require a unified effort by the pro-space movement. That's an excellent incentive for advocates of development and exploration, including those concerned with environmental ethics, to work together.
TOM HUFFMAN, *Tulsa, Oklahoma*

As a member of The Planetary Society I count myself as an idealist with the hope that the exploration and eventual colonization of our solar system be undertaken as a global, non-nationalistic effort. That is why I must respond to the article "*Politics and The Planetary Society: A Personal View*" (see the September/October 1988 *Planetary Report*). To impel any space program forward on the basis of military superiority is, to my way of thinking, detrimental to this goal. While a militaristic approach is not surprising given the present ideological climate of the US, it is surprising and alarming to see The Planetary Society apathetically accepting this position. We, supposedly some of the more imaginative people of the world, must see the long-term implications and accept the responsibility of opposing the militarization of space by any nation.

To say that the deployment of armaments in space is a political issue, as you stated, is inarguably correct, but to also say that it is not an exploration issue is erroneous. The simple question of who will reap the rewards will face the spacefaring nations of tomorrow just as it did the seafaring nations of the past. If one nation's fervor for access to space is based on the desire to gain ideological dominance over another people, then conflict is historically inevitable. Space exploration will surely lead to colonization and commerce and almost certainly to tough political questions; thus, would-be explorers must consider the consequences of their quest.

To stand by apathetically simply because one's narrow, short-sighted aims are being served is selfish, unethical and wrong. The visionaries of today and the explorers of tomorrow must accept the reponsibility of voicing their concerns about the role of human beings in space and on other celestial bodies. This especially means The Planetary Society as a whole and its members individually.
R. J. LITCHFORD, *Tullahoma, Tennessee*

Louis Friedman's article concerning a more political role for the Society has me extremely concerned. The next administration will most likely be nonvisionary with respect to space exploration and could easily leave NASA wandering without purpose for another four years. We must not let that happen. If we are to prevent this we must be as united, as credible, as determined and as persistent as possible. We don't need to quarrel among ourselves or to lose favor with key politicians because we take different positions than they do on unrelated or only indirectly related issues. I understand that certain political issues affect our cause to such a degree that they cannot be ignored, but the number and extent of our involvement in these issues should be kept to a minimum. Please, let's not get caught up in politics—let's keep our unity; let's keep our focus; let's go to Mars.
BENNY J. KLEIN, *Midland, Texas*

If we as a Society and a nation hope to achieve our goal of a dynamic space program, we must support our young citizens still in school. It is disconcerting to think that these people who are too young to remember much of the *Apollo* missions and who think of space as boring or something too complex to be understood, will be the senators, Presidents and general voting population of the future. It is they who will control the funding for the space program and all space-related scientific endeavors.

We need to do more to interest and educate this age group or the space program will pay the cost in the future. The Planetary Society already recognizes this need by providing scholarships and certain educational opportunities, but I truly believe more needs to be done. Those of us who have chosen planetary science or astronomy as our careers need more places to demonstrate our ideas and ways to use our energy and enthusiasm. An outlet for ideas could be a Society newsletter, to which a member could subscribe, where new ideas and maybe informal abstracts could be published and discussed.

I hope that members will consider this and offer some suggestions to our Directors and staff. It will be effective insurance for the space program and all planetary research in the future.
JENNIFER A. GRIER, *Tucson, Arizona*

NEWS BRIEFS
(continued from page 3)

NASA's Administrator would also be given a new White House position as assistant to the President for civil space, with broad new powers for managing the total federal space effort and government support for commercial space efforts. This second job would be modeled after that of the Director of Central Intelligence, who also holds a second position as head of the Central Intelligence Agency (CIA).

The NASA Administrator would become the primary US official for coordinating all civil space actions on a day-to-day basis and would have much more power over agencies peripherally involved in space—such as the Commerce and Transportation departments. NASA's chief would also be put into a stronger position to deal with the Defense Department on space issues important to both NASA and the Pentagon.
—from Craig Covault in *Aviation Week and Space Technology*

□

In the next six years mapmaker Rex Rivolo hopes to create the first detailed map ever made of our galaxy, the Milky Way. The multi-million dollar project would show molecular clouds, reveal the galaxy's internal structure and serve as a valuable navigational tool for future astronauts. Molecular clouds, which consist mainly of hydrogen molecules, are the largest known objects in the galaxy and are important because they're the nurseries where stars are born.

Under Rivolo's proposal a team of scientists would take about five million observations of the Milky Way using specially equipped radio telescopes. The data would then be computer processed to nail down the precise location of the estimated 10,000 molecular clouds in our galaxy. Rivoli says, "When you make detailed maps you often discover great things."
—from Jim Detjen in *The Philadelphia Inquirer*

Questions & Answers

Why is most of Earth's arctic ice in Greenland?
—Bruce B. Phillips, Quinlan, Texas

Greenland is icier because of its high elevation, high albedo (reflectivity of the ice) and relatively high annual precipitation compared to other areas of the arctic.

At an average elevation of 2,000 meters (6,600 feet) above sea level, the surface of the ice sheet is so cold that little or no melting occurs. Because the albedo stays high throughout the year, there is also little summertime warming of the surface and the air near the surface. Only the edges of the ice sheet, at low elevations, do any melting.

In Siberia and arctic Canada, most of the land is low-lying, and summers are warm enough to melt all the winter snowpack so no permanent ice accumulates. There the summertime warmth is enhanced by increased absorption of solar energy as the snowpack disappears and the less reflective ground is exposed. The high elevation and continuous high albedo of Greenland are immediate consequences of its thick ice sheet, so the ice in a sense creates the climatic conditions responsible for its existence.

The precipitation that falls almost entirely as snow throughout the year adds cumulatively to Greenland's ice mass. At the Arctic Circle the average annual precipitation is 10 centimeters over central Siberia and 20 centimeters over the central Canadian arctic, but more than 50 centimeters over Greenland. This is mainly due to the warm north Atlantic Ocean, which provides a major source of atmospheric moisture. Cyclonic storms moving north from the Atlantic and east from Davis Strait and Baffin Bay carry this moisture into the interior of Greenland. Even if the ice sheet itself were somehow removed, the mountains on Greenland's east coast would still draw much snow from these storms, and ice caps would form. These might grow and ultimately merge to regenerate the ice sheet over central Greenland, even though the actual rock surface there is at low elevation, near sea level. The north Pacific Ocean is the major moisture source for the Alaskan and Canadian arctic, but most of the moisture is wrung out of the storms as they pass over the high mountains rimming the Gulf of Alaska, and little is left for the arctic. Siberia also has no good moisture source. The Arctic Ocean is not a good source of moisture because it is largely frozen over all year.

During the Ice Age, temperatures were sufficiently lower than they are today that summer melting did not eliminate winter snowfall in arctic Canada, and a large ice sheet formed there. In Siberia, however, the precipitation was so low that no ice sheet formed even then.
—BARCLAY KAMB, *California Institute of Technology*

The variance in temperature between Mercury's day and night sides is larger than that of any known body in our solar system. What are the temperatures, and how is such a large range possible considering Mercury's proximity to the Sun?
—Ivan Middlesworth, West Mansfield, Ohio

Mercury used to be thought of as both the hottest and coldest planet in the solar system. It is easy to understand why Mercury is hot since it is the closest planet to the Sun. Occasionally the Sun as viewed from Mercury is over three times as big as it looks from the Earth; imagine the heat with about 10 suns in the sky! It may seem strange that there are also very cold places on Mercury. Astronomers used to think that Mercury kept one side always facing the Sun, just as the Moon keeps one side toward the Earth. Were that true, then the other side would be in perpetual darkness. With no air to carry the dayside warmth around the planet, Mercury's nightside would be extremely cold.

As it turns out, the original observations of Mercury's rotation period were wrong. The planet spins very slowly—once every two months—so it does not keep one face always toward the Sun. Nevertheless, because the spin is so slow, parts of Mercury remain in darkness for weeks. And just like the darkside of our airless Moon, the temperatures can drop to -180° C or -300° F before the Sun again slowly rises. There are places in the outer solar system, however, that get even colder.

Neither is Mercury the hottest planet in the solar system. That honor goes to Venus, despite its greater distance from the Sun. The reason is that the deep atmosphere of Venus traps in sunlight and, rather like a greenhouse, warms up the surface to temperatures of about 465° C (860° F), which are even hotter than the hottest noontime temperatures (430° C, 805° F) on little, airless Mercury.

The distinction Mercury *can* claim is that it has the largest diurnal (daily) temperature variation. In dry desert cities on Earth, the difference between daytime high and nighttime low can be 40° F or more. There is little variation at all on Venus: the same deep atmosphere that traps in the daytime heat holds in the heat during the night. So Mercury's variation of well over 1,000°F is truly extraordinary.
— CLARK R. CHAPMAN, *Planetary Science Institute*

WHAT WE ARE NOT ABOUT

As The Planetary Society has grown to a worldwide organization and its membership has come to include people from all backgrounds, we have attempted to keep *The Planetary Report* evolving so as to inform and stimulate everyone interested in planetary exploration, the search for extraterrestrial life and the international pursuit of these objectives.

Our most successful recent additions to the *Report* are the Questions and Answers and Members' Dialogue departments. Clearly our members want to have an active interchange on subjects of mutual interest, and we shall continue to foster such communications by all available means. However, some of the letters we get are not about our main subjects. We hate to disappoint readers who seek knowledge of business satellites or black holes, but such concerns must be set aside to leave room for the central topics. Let us first consider the cosmic setting for what we are interested in and then suggest other places where readers may turn to get their non-planetary questions answered.

Planets and life are low-energy phenomena

Only in the cooler, quieter regions of the cosmos can matter condense into the stuff of rocks, trees and animals. On planets in the neighborhood of stars a narrow band of temperatures permits the existence of our kind of life. If "others" are at all like us, they will have to reside in roughly similar environments where complex molecular structures can survive and evolve.

The Planetary Society is founded on the principle that the intelligent inhabitants of Earth will reach out into the low-energy universe, investigate and understand its many splendors, travel to and perhaps settle its distant shores, seek those unfound "others" and, in the process, advance the cause of world citizenship here at home. To cover all of these things well, *The Planetary Report* must exclude many other fascinating and worthwhile endeavors. Thus we are "not about" quasars, pulsars, black holes, the astonishing gamma-ray bursts whose origin is unknown, or the many puzzles of the beautiful x-ray sky. This still leaves an enormous realm to explore: the equally strange and lovely infrared sky, the vast molecular clouds in our own and other galaxies, star birth and the ashes of star death, and finally, of course, planets—here and elsewhere.

Not only are we not about black holes—also we are not about commerce, industry and military missions in near-Earth space. The region just above Earth's atmosphere is rapidly becoming an arena for continuing many of humanity's mundane activities, with only slight connection to the pioneering outward reach that took humans to the ends of the Earth in past centuries, has taken them already to the Moon and leads onward toward the stars. True, both the economic base and the technology for these grand adventures are being developed on and near Earth, but the fundamental drive for deep space is not yet that of the builder or the merchant; it is that of the explorer.

Where to ask your other questions

If you want to inquire about the Big Bang, neutron stars, x-ray binaries, faster-than-light travel, cosmic strings, Soviet communications satellites or commercial enterprise in Earth orbit, whom should you ask?

For astronomy and astrophysics it might be good to start at the nearest science museum or planetarium. One index of worldwide hunger for knowledge of the cosmos is that thousands of such institutions exist, many of them even in smaller communities where people have assembled the needed resources as an investment in the future and an expression of civic values. Lacking a nearby planetarium, we suggest you write to the Astronomical Society of the Pacific, 1290 24th Avenue, San Francisco, CA 94122, which despite its regional origin and name, is a world-class organization.

James D. Burke, Technical Editor

FACTINOS

Ever since the 1960s and '70s, when spacecraft visited the Moon and Mars, scientists have wondered why these bodies' crusts are so much thicker than Earth's. Now Don L. Anderson, director of the California Institute of Technology's Seismological Laboratory, has discovered that our planet's "missing" crust is floating around 400 to 600 kilometers (250 to 400 miles) under the surface in the middle mantle or "mesosphere."

"The middle mantle appears to be a dumping ground for the huge slabs of crust that dive into the Earth's interior at subduction zones," said Anderson. Subduction zones are areas on Earth where tectonic plates are forced underneath other plates.
—from a California Institute of Technology news release

◇

In the laboratories of Cornell University, Bishun N. Khare, Carl Sagan and W. Reid Thompson have synthesized organic solids similar to those in the atmospheres of Titan (Saturn's largest moon) and Uranus. The experiment is like one that Harold Urey and Stanley Miller did in 1953 that duplicated Earth's ancient atmosphere. The new study, however, was enhanced with information collected by *Voyager 2* during its flybys of Saturn and Uranus.

The investigators created a plasma much like a planet's aurora, where chemical reactions abound. The Titan experiment produced a large variety of prebiotic chemicals called nitriles. Precursors of amino acids, nitriles are the basic building blocks of proteins.
—from Russell Ruthen in *Scientific American*

◇

Muscles lose more than fibers in space according to Danny A. Riley of the Medical College of Wisconsin in Milwaukee. Riley and his collaborators studied the muscle tissues of five rats flown in the Soviet *Cosmos* Biosatellite 1887 in October 1987. After twelve and one-half days in space, the rats' muscles had shrunk 40 percent. Their loss of muscle mass was 10 percent greater than that of rats flown for a week in the 1985 *Challenger* Spacelab 3—indicating that muscle atrophy in space is progressive, says Riley. The *Cosmos* rats also suffered serious damage in four to seven percent of their muscle fibers, "much worse" than that found in the Spacelab 3 rats.

Riley suggests that in space such changes may result from several things, including cosmic radiation, stress and reduced circulation as well as muscle disuse.
—from I. Wicklegren in *Science News*

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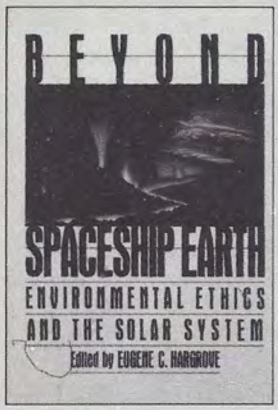

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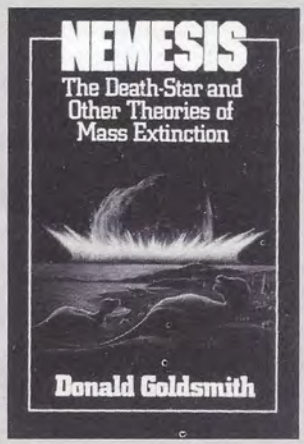

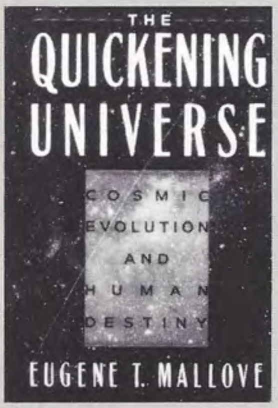

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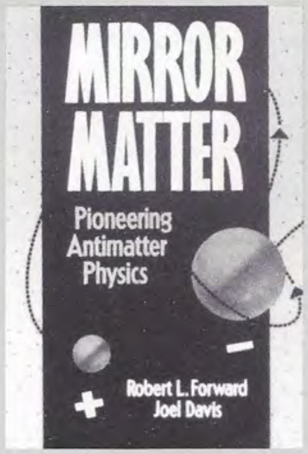

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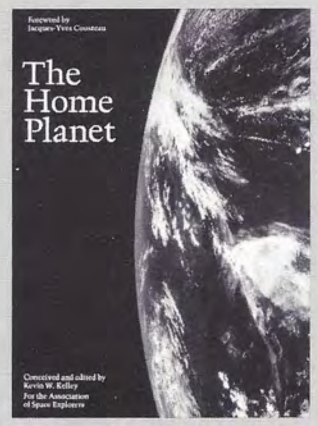

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Joe Tucciarone teaches astronomy at Daytona Beach Community College and serves as the staff artist at the Astronaut Memorial Hall Planetarium in Cocoa, Florida. He is a member of the International Association for the Astronomical Arts.

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