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The Changing Face of Earth

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COVER: This composite image clearly shows how our planet's surface is divided into plates that continually slide over, under and past one another, remaking Earth's face. Here the rift zones, where new crustal material flows up from Earth's interior, are indicated in bright yellow. New crust forming along the Mid-Atlantic Ridge (right) is pushing Africa and South America apart. The volcanic Galápagos Islands are products of the East Pacific Rise (left), marked by fractures in the ocean floor.
Image courtesy of Peter W. Sloss, National Geophysical Data Center

FROM THE EDITOR

The old cliché about not seeing the forest for the trees applies to many people when they contemplate the workings of our home planet. Earth is but one planet among nine, circling the Sun in company with uncounted smaller bodies, the moons, asteroids and comets. Taken together, all these worlds constitute our solar system, and the person who contemplates one planet without considering its relationship to the others is in the proverbial position of seeing only a tree.

One of the aims of The Planetary Society is to help enlarge the perspectives of people who don't happen to be professional planetary scientists so that they can see Earth in relation to the solar system's other inhabitants.

In *The Planetary Report*, we don't print too many articles about Earth by itself. Many other publications, such as popular scientific and environmental magazines, focus on terrestrial phenomena, so we seek to fill our own special niche. When we undertake an article about our home planet, we try to broaden the focus so that our readers can see the larger neighborhood in which humans belong.

• **Snowflakes Fallen on the Hearth: The Evolution of the Earth—Page 4**—Throughout most of its history, Earth grew, changed and nurtured life in the absence of any beings capable of appreciating it. Only recently have minds existed that could conceive of a world with a history. And only in the past few decades have those minds had the information—much of it gathered from explorations of other worlds and from bits of rock and metal that fall from space—to sketch out the story of Earth. Here Society President Carl Sagan and Ann Druyan briefly recount that story.

• **Academician Valery Leonidovich Barsukov, 1928–1992—Page 10**—The planetary science community lost one of its leaders when Valery Barsukov died. He will be remembered as one who was able to see the connections between our planet and others, and who effectively guided his nation's space program in its exploration of other worlds.

• **John Bryson Joins Planetary Society Board of Directors—Page 11**—The Society enthusiastically welcomes a new member of its governing body.

• **Roving Through Death Valley—Page 12**—We wind up our coverage of The Planetary Society's 1992 rover test program with this issue. The Death Valley project was one of the biggest we've ever undertaken, and one of the most successful.

• **A Planetary Readers' Service—Page 16**—The human drama of the race to the Moon involved some of the greatest technological achievements in history.

• **World Watch—Page 17**—While the United States reorganizes its space efforts, other nations, including Japan, are making tangible progress toward planetary exploration. Meanwhile, NASA pursues a new goal of smaller, cheaper and faster missions.

• **News & Reviews—Page 18**—A few years ago, the public saw asteroids as boring hunks of rock—then scientists began calculating the odds of one striking Earth to catastrophic effect, and these bits of interplanetary debris made the cover of *Newsweek*. Clark Chapman ruminates on this newfound notoriety.

• **Society Notes—Page 19**—It's scholarship time again at The Planetary Society, and we have some other exciting events and opportunities to report.

• **Questions & Answers—Page 20**—A mysterious shadow on the surface of Mars, seen by the Soviet *Phobos 2* spacecraft in 1989, raised a lot of speculation in certain circles that it might be evidence of an unknown spacecraft. The Planetary Society is in close contact with Russian scientists on the mission, for whom the shadow was not mysterious at all.

—Charlene M. Anderson

Members' Dialogue

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

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

Clark Chapman's column reviewing my article in *Astronomy* about the ice dwarf hypothesis was well written and provocative. [See the September/October 1992 *Planetary Report*.] I can't resist replying to two of Clark's points.

Clark asks why, if a collision between Pluto and Charon would result in binary formation, the asteroid belt is not littered with binaries. Good question; there are two reasons. First, in the asteroid belt, about 2 to 3 astronomical units (AU) from the Sun, high velocities and eccentric orbits make collisions about 20 times more energetic than they would be at 30 AU, near the orbits of Neptune and Pluto—this makes binary formation much more problematic there. Second, even if an asteroid binary is sometimes formed by a "lucky" collision, studies by planetary dynamicists have shown that the resulting system would be unstable to long-term gravitational perturbations from the Sun and Jupiter. That is, even if binaries occasionally form in the asteroid belt via collisions, they won't last long (compared to the age of the solar system). By contrast, Pluto's unique orbit keeps it far from any of the giant planets and safe from disruptive perturbations. For this reason, the Pluto–Charon binary is stable over the age of the solar system.

Clark also expresses concern that the only ice dwarf left that is close enough to see from Earth is a double one. But wait! As described in my article [see the September 1992 issue of *Astronomy*], Triton, Chiron and several other objects *inside* Pluto's orbit appear to be relics of the ice dwarf/subdwarf population. None of these are binaries.

I agree with Clark that the Pluto–Charon binary seems to be something unlikely, but the solar system is known to have other "unlikely" attributes, such as an inhabited planet, rings around all its gas giants, and no fewer than two planets that rotate backward. Unlikely or not, the Pluto–Charon binary is a datum that must be reconciled with our understanding of planetary formation. If the ice dwarf hypothesis is someday confirmed by the discovery of more Pluto-class bodies beyond Neptune, then we will be glad indeed that we were given the good fortune of the Pluto–Charon binary to spark our imaginations and spur searches for such objects.
—ALAN STERN, *San Antonio, Texas*

The September/October 1992 *Planetary Report* is one of the best issues you have ever published. "The Last of the Corsairs" moved me and gave me hope again. We at the Space Studies Institute in Princeton lost our own "dreamer" earlier this year to leukemia. In both cases, the dream goes on, fortified and inspired from the legacies of Tom Paine and Gerry O'Neill. All of the articles are equally moving. Carl Sagan's "Dreams Are Maps" touches on the mythic side of one of our human accomplishments: space exploration. With all due respect to the late Joseph Campbell, humanity doesn't need a new myth; the simple sharing of the most ancient one—humanity's destiny is among the stars—expressed throughout the centuries in all art forms, will do.

The dream goes on. At worst we can picture ourselves as ascended from our simian cousins; at best, descended from the gods. Somewhere in the middle, there is a lonely creature on a small planet, warring itself into recognition and acceptance, still circling like a lost soul, accumulating perishables and tracing territories in the sand. And yet, that frail creature is the heir of galaxies, a prince dressed in tatters through lack of vision. To that one goes the warning of Socrates, "This is why humans perish, because they cannot join the beginning to the end." As Carl Sagan asks, "Where are the visions of hopeful futures . . . where are the cartographers of human purpose?" They are still among us, despite the lethargy and souring, the predictions of extinction and the general tiredness and apathy.

If our elected leaders only mouth the vision without implementing it, our duty is to remind them forcefully of their promises and to make sure they keep them. Individual responsibility for the keeping of the vision belongs to us all, and the rest will follow.
—MARIE-LOUISE KAGAN, *Syracuse, New York*

NEWS BRIEFS

Pope John Paul II has formally proclaimed that the Roman Catholic Church was wrong in condemning Galileo for announcing that Earth was not the center of the universe. In a speech to the Pontifical Academy of Sciences, he said that Galileo's condemnation resulted from a "tragic mutual incomprehension" and became a symbol for the church's "supposed rejection of scientific progress."

The speech was the Vatican's final word on the matter nearly four centuries after the astronomer was found guilty of violating church doctrine by contending that Earth revolved around the Sun and not vice versa. Vatican experts appointed by John Paul had studied the case for 13 years.
—from the Associated Press in the Pasadena *Star-News*

Data from NASA's Total Ozone Mapping Spectrometer on board the Nimbus-7 satellite show that the 1992 Antarctic ozone hole is the largest on record. The holes of the past have usually covered about 7.7 million square miles of surface area. But in September 1992, the area covered was 8.9 million square miles, an increase over 1991 of about 15 percent.

By comparison, the surface area of the North American continent is 9.4 million square miles, and that of Antarctica is 5.1 million square miles.
—from NASA

In October 1992 NASA Administrator Daniel Goldin and Environmental Protection Agency Administrator William K. Reilly signed an agreement to increase cooperation between their two agencies. The organizations plan to work together in areas such as Earth and environmental science, pollution monitoring, technology transfer and aerodynamic and fuel efficiencies.
—from NASA

SNOWFLAKES FALLEN ON THE HEARTH: THE EVOLUTION OF THE EARTH

BY CARL SAGAN

AND ANN DRUYAN

The Earth accumulates in the dark—from rocky, icy, organic, and metallic debris in the great cloud of dust and gas out of which the Solar System forms. Although the primitive Sun is ablaze, there is so much gas and dust between the Earth and the Sun that at first no light gets through. The Earth is embedded in a black cocoon of interplanetary debris. There's an occasional flash of lightning by which you glimpse a ravaged, pockmarked, not quite spherical world. As it gathers up more and more matter, from dust to worldlets, it becomes rounder, less lumpy.

At the time agglomerations of organic molecules quickened into life, our planet was a very different world. These molecules may have been carried to Earth by infalling comets, as well as being created in the early seas by lightning strikes and ultraviolet light. Presiding over this fertile scene was the young Moon, which then orbited much closer to its parent planet. Painting: Kazuaki Iwasaki

A collision with a hurtling worldlet produces a shattering explosion, and excavates a great crater. Much of the impactor disintegrates into powder and atoms. There are vast numbers of such collisions. Ice is converted to steam. The planet is blanketed in vapor—which holds in the heat from the impacts. The temperature rises until the Earth's surface becomes entirely molten, a roiling world-ocean of lava, glowing by its own red heat, and surmounted by a stifling atmosphere of steam. These are the final stages of the great gathering in.

In this epoch, when the Earth is new, the most spectacular catastrophe in the history of our planet occurs: a collision with a sizeable world. It does not quite crack the Earth open, but it does blast a good fraction of it out into nearby space. The resulting ring of orbiting debris shortly falls together to become the Moon.

The day is only a few hours long. Gravitational tides raised in the Earth's oceans and interior by the Moon, and in the Moon's solid body by the Earth, gradually slow the Earth's rotation, and lengthen the day. From the moment of its formation, the Moon has been drifting away from the Earth. Even now, it hovers over us, a baleful reminder that had the colliding world been much bigger, the Earth would have scattered in fragments through the inner Solar System—a short-lived, unlucky world like so many others. Then humans would never have come to be. We would be just one more item on an immense list of unrealized possibilities.

* * *

Shortly after the Earth had formed, its molten interior was churning, great convection currents circulating, a world in a slow boil. Heavy metal was falling to its center, forming a massive molten core. Motions in the liquid iron began to generate a strong magnetic field.

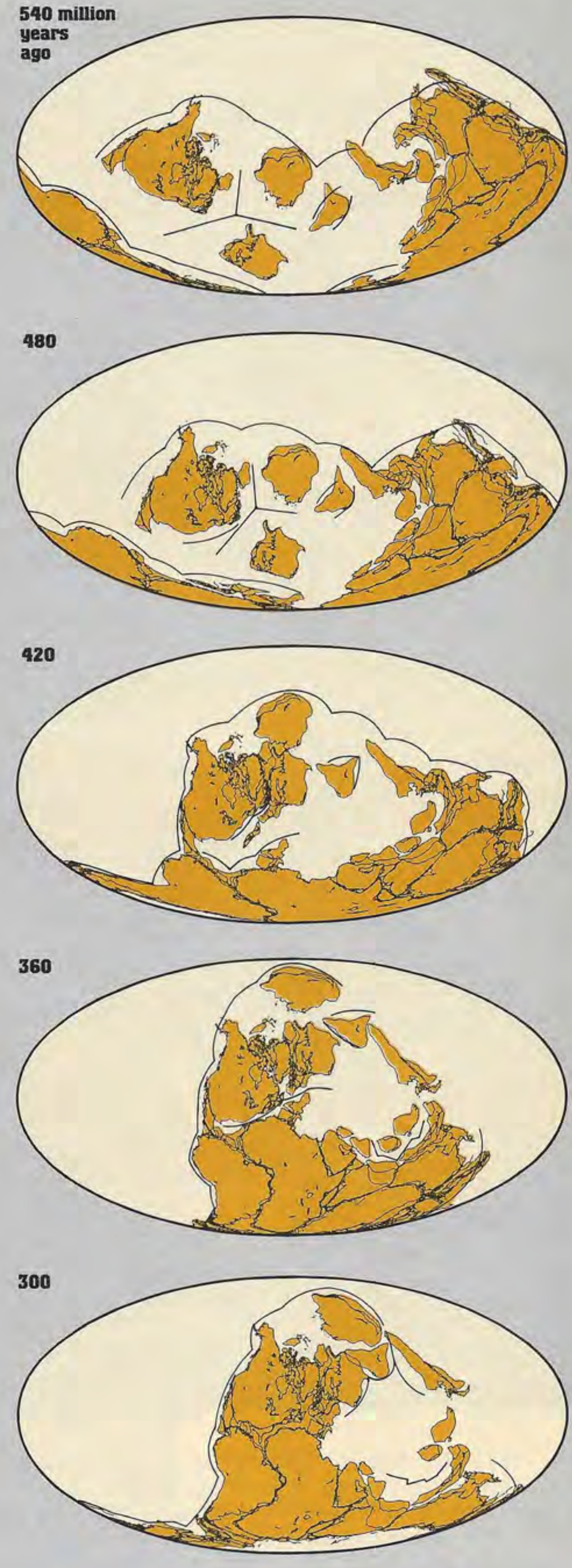
The time came when the Solar System had pretty well been swept free of gas and dust and rogue worldlets. On Earth, the massive atmosphere—that had kept the heat in—dissipated. Indeed, the collisions themselves helped to drive that atmosphere into space. Convection still carried hot magma up to the surface, but the heat from the molten rock could now be radiated away to space. Slowly the Earth's surface began to cool. Some of the rock solidified and a thin, at first fragile crust formed, thickened, and hardened. Through blisters and fissures, magma and heat and gases continued to pour out of the interior.

Punctuated by spasmodic flurries of worlds falling out of the sky, the bombardment slowed. Each large impact produced a great dust cloud. There were so many impacts at first that a pall of fine particles enveloped the Earth, prevented sunlight from reaching the surface, and in effect turned off the atmospheric greenhouse effect and froze the Earth. There seems to have been a period, after the magma ocean solidified but before the massive bombardment ended, when the once molten Earth became a frozen, battered planet. Who, scanning this desolate world, would have pronounced it fit for life? What wild optimist could have foreseen that peonies and eagles would one day spring from this wasteland?

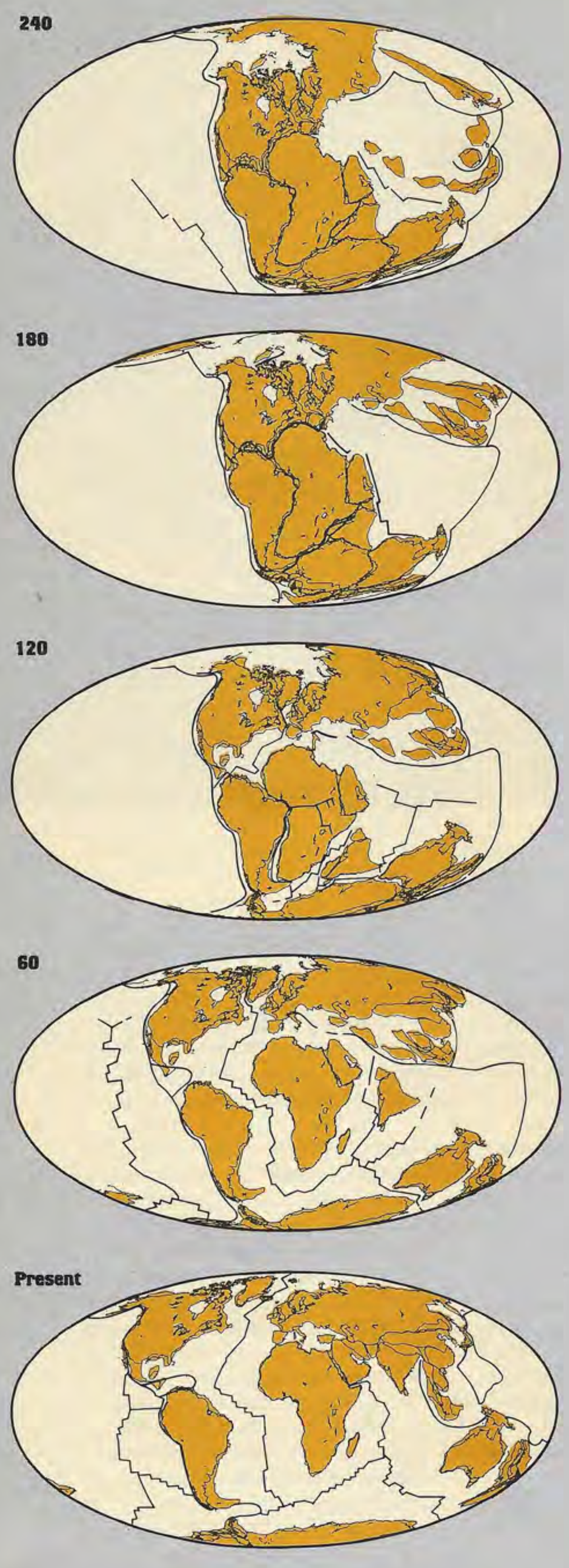
The original atmosphere had been ejected into space by the relentless rain of worldlets. Now a secondary atmosphere trickled up from the hot interior and was retained. As the impacts declined, global dust palls became more rare. From the surface of the Earth the Sun would have seemed to be flickering, as in a time-lapse movie. So there was a time when sunlight first broke through the dust pall, when the Sun, Moon, and stars could first be noticed, had anyone been there to see them. There was a first sunrise and a first nightfall.

In sunny intervals, the surface warmed. Outgassed water vapor cooled and condensed; droplets of liquid water formed and trickled down to fill the lowlands and the impact basins. Icebergs continued to fall from the sky, vaporizing on arrival. Torrents of extraterrestrial rain helped form the primeval seas.

Organic molecules are composed of carbon and other atoms. All life on Earth is made from organic molecules. Clearly they had somehow to be synthesized *before* the origin of life *in order* for life to arise. Like water, organic molecules came both from



Over the past half-billion years, the face of Earth has changed markedly. This sequence shows its evolution in steps of 60 million years. You can watch the pieces of Gondwana assemble at the South Pole (top left) and unite to become the supercontinent



Pangaea (bottom left). Then Pangaea moves northward across the equator (top right) and eventually breaks up to form the familiar continents we find today (bottom right). *Illustration: Christopher Scotese, Paleomap Project, courtesy of Sky Publishing Corporation*

down here and from up there. The early atmosphere was energized by ultraviolet light and the wind from the Sun, the flash and crackle of lightning and thunder, auroral electrons, intense early radioactivity, and the shock waves of objects plummeting groundward. When, in the laboratory, such energy sources are introduced into presumptive atmospheres of the primitive Earth, many of the organic building blocks of life are generated, and with astonishing ease.

Life began near the end of the heavy bombardment. This is probably no coincidence. The cratered surfaces of the Moon, Mars, and Mercury offer eloquent testimony to how massive and world-altering that battering was. Since the worldlets that have survived to our time—the comets and the asteroids—have sizeable proportions of organic matter, it follows that similar worldlets, also rich in organic matter but in much vaster numbers, fell on the Earth 4 billion years ago and may have contributed to the origin of life.

Some of these bodies, and their fragments, burned up entirely as they plunged into the early atmosphere. Others survived unscathed, their cargoes of organic molecules safely delivered to the Earth. Small organic particles drifted down from interplanetary space like a fine, sooty snow. We do not know just how much organic matter was delivered to and how much was generated on the early Earth, the ratio of imports to domestic manufactures. But the primitive Earth seems to have been heavily dosed with the stuff of life—including amino acids (the building blocks of proteins), and nucleotide bases and sugars (the building blocks of the nucleic acids).

Imagine a period hundreds of millions of years long in which the Earth is awash in the building blocks of life. Impacts are erratically altering the climate; temperatures are falling below the freezing point of water when the dust produced on impact obscures the Sun, and then rising as the dust settles. There are pools and lakes undergoing wild fluctuations in conditions—now warm, bright, and bathed in visible and ultraviolet light from the Sun, now frozen and dark. Out of this varied and changeable landscape and this rich organic brew, life arises.

Presiding over the skies of Earth at the time of the origin of life was a huge Moon, its familiar surface features being shaped by mighty collisions and oceans of lava. If tonight's Moon looks about as large as a nickel at arm's length, that ancient Moon might have seemed as big as a saucer. It must have been heartbreakingly lovely. But it was billions of years to the nearest lovers.

We know that the origin of life happened quickly, at least on the time scale by which suns evolve. The magma ocean lasted until about 4.4 billion years ago. The time of the permanent or near-permanent dust pall lasted a little longer. Giant impacts occurred intermittently for hundreds of millions of years after that. The largest ones melted the surface, boiled away the oceans, and flushed the air off into space. This earliest epoch of Earth history is, appropriately, called Hadean, hell-like. Perhaps life arose a number of times, only to be snuffed out again by a collision with some wild, careening worldlet newly arrived from the depths of space. Such "impact frustration" of the origin of life seems to have continued until about 4 billion years ago. But by 3.6 billion years ago, life had exuberantly come to stay.

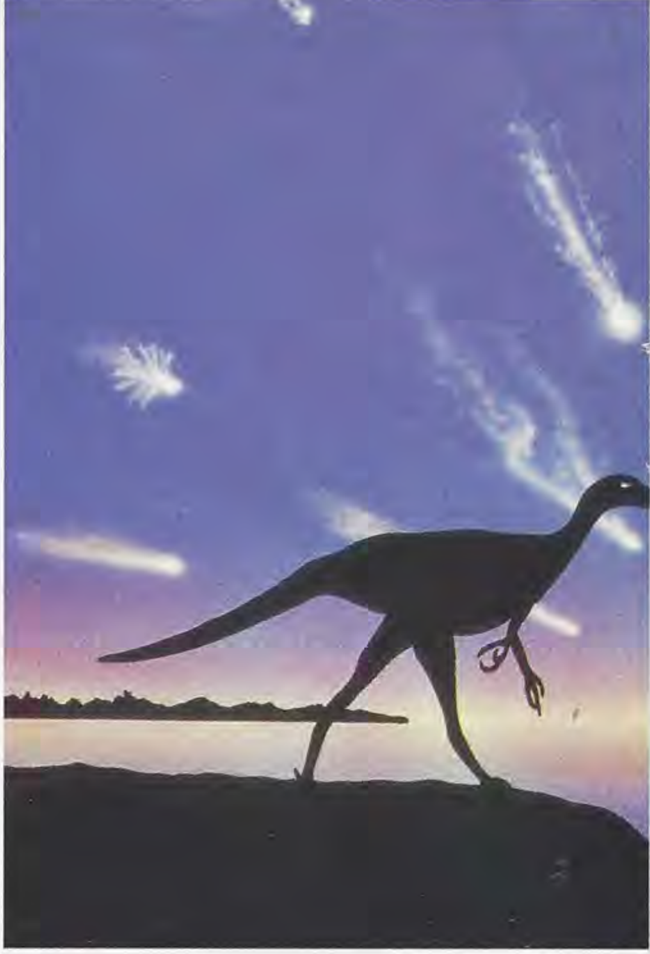
When life was first emerging, the Earth seems to have been mainly an ocean planet, the monotony broken, here and there, by the ramparts of large impact craters. The very beginnings of the continents date back about 4 billion years. Being made of lighter rock, then as now, they sat high on the moving, continent-sized plates. Then as now, the plates apparently were being extruded out of the Earth, carried across its surface as on a great conveyor belt, until plummeting back into the semifluid interior. Meanwhile, new plates were emerging. Vast quantities of mobile rock were slowly exchanged between the surface and the depths. A great heat engine had been established.

By about 3 billion years ago the continents were becoming larger. They were transported halfway around the Earth by the crustal plate machinery, opening one ocean and closing another. Occasionally, continents would crash into each other in exquisite slow motion, the crust would buckle and crinkle, and mountain ranges would be thrust up. Water vapor and other gases spewed out, mainly along mid-ocean ridges and volcanoes at the edges of plates.

Today we can readily detect the growth of continents, their relative motion over the Earth's surface (sometimes called continental drift), and the subsequent transport of the ocean floor down into the interior, in a style of motion called plate tectonics. The continents tend to stay afloat even when their underlying plates plunge down to destruction. Still, time takes its toll even on continents. Some old continental crust is always being carried to the depths and only bits and pieces of truly ancient continents have survived to our time—in Australia, Canada, Greenland, Swaziland, Zimbabwe.

Greenhouse gases and stratospheric fine particles, both generated by volcanoes, can, respectively, warm or cool the Earth. The changing configuration of the continents determines rainfall and monsoon patterns, and the circulation of warming and cooling ocean currents. When the continents are all aggregated together, the variety of marine environments is limited; when they are scattered over the globe, there are many more kinds of environments, especially those near shore, where a surprising number of the fundamental biological innovations seem to have been made. Thus the history of life, and many of the steps that led to us humans, were governed by great sheets and columns of circulating magma—driven by the heat from long-gone worlds that fell together to make our planet, from the sinking of liquid iron to form the Earth's core, and from the decay of radioactive atoms originally forged in the death-throes of distant stars. Had these events gone a little otherwise, a different amount of heat would have been generated, a different pace or style of plate tectonics elicited, and, from the vast array of possible futures, a different course followed in the evolution of life. Not humans, but some very different species might now be the dominant form of life on Earth.

We know next to nothing about the configuration of the continents over the first 4 billion years. They may many times have been scattered over the oceans and reaggregated into a single mass. For at least 85 percent of Earth history, a map of our planet would have seemed wholly unfamiliar—as if of another world. The earliest well-substantiated reconstruction we can manage dates to as recent a time as 600 million years ago. The Northern Hemisphere then was mostly ocean; in the south, a single massive continent, plus fragments of future continents, drifted across the face of the Earth at about an inch a year—much slower than a snail's pace. Trees grow vertically faster than continents move horizontally, but if you have millions of years to play with, this is quite sufficient for continents to collide and wholly alter what's on the maps.



For hundreds of millions of years, what are now the southern continents—Antarctica, Australia, Africa, and South America—plus India, were joined in a common assemblage that geologists call Gondwana. What were later to be North America, Europe, and Asia were adrift, sailing in pieces through the world ocean. Eventually, all this floating continental debris gathered itself together into one massive supercontinent. Whether we describe it as a landlocked planet with an immense saltwater lake or an ocean planet with an immense island is only a matter of definition. It might have seemed a friendly world: At least, you could walk anywhere; there were no distant lands across the sea. Geologists call this supercontinent Pangaea—"all Earth." It included, but of course was considerably larger than, Gondwana.

Pangaea was formed about 270 million years ago, during the Permian Period, a trying time for Earth. Worldwide, conditions had been warming. In some places the humidity was very high and great swamps formed, later to be supplanted by vast deserts. About 255 million years ago Pangaea began to shatter—because, it is thought, of the sudden rise of a superplume of molten

A dinosaur stands silhouetted against a twilight sky filled with comets. A leading hypothesis for the disappearance of dinosaurs is that one or more comets struck Earth 65 million years ago and the resulting climatic disruption killed off most of the species on the planet. From the ruins of the dinosaurs' world, their mammalian successors and eventually humans arose.

Painting: Jon Lomberg

lava through the Earth's mantle from its deep, seething core. Texas, Florida, and England were then at the equator. North and South China, in separate pieces, Indochina and Malaya together, and fragments of what would later be Siberia were all large islands. Ice ages seem to have flickered on and off every 2.5 million years, and the level of the seas correspondingly fell and rose.

Towards the end of the Permian Period, the map of the Earth seems to have been violently reworked. Whole oblasts of Siberia were inundated with lava. Pangaea rotated and drifted north, moving mainland Siberia towards its present position, near the North Pole. "Megamonsoons," torrential seasonal rains on a much larger scale than humans have ever witnessed, drenched and flooded the land. South China slowly crumpled into Asia. Many volcanoes blew their tops together, belching sulfuric acid into the stratosphere and perhaps playing an important role in cooling the Earth. The biological consequences were profound—a worldwide orgy of dying, on land and at sea, the likes of which have never been seen before or since.

The breakup of Pangaea continued. By 100 million years ago South America and Africa, which even today fit together like two pieces of a jigsaw puzzle, were just barely separated by a narrow strait of ocean—receding from one another at about an inch a year. North and South America were then separate continents, with no Isthmus of Panama connecting them. India was a large island headed north away from Madagascar. Greenland and England were connected to Europe. Indonesia, Malaysia, and Japan were part of the mainland of Asia. You might have strolled from Alaska to Siberia. There were great inland seas where none exist today. This time, at a glance from orbit you would have recognized it as the Earth—but with the configuration of land and water strangely altered, as if by a careless, slapdash cartographer. This was the world of the dinosaurs.

Later, the continents drifted farther apart, pulled by their underlying plates. Africa and South America continued to recede from one another, opening up the Atlantic. Australia split off from Antarctica. India collided with Asia, raising the Himalayas high. This is the world of the primates.

* * *

Each of us is a tiny being, permitted to ride on the outermost skin of one of the smaller planets for a few dozen trips around the local star. The great internal engine of plate tectonics is indifferent to life, as are the small changes in the Earth's orbit and tilt, the variation in the brightness of the Sun, and the impact with the Earth of small worlds on rogue orbits. These processes, which alter the climate and life, have no notion of what has been going on over billions of years on our planet's surface. They do not care.

The longest-lived organisms on Earth endure for about a millionth of the age of our planet. A bacterium lives for one hundred-trillionth of that time. So of course the individual organisms see nothing of the overall pattern—continents, climate, evolution. They barely set foot on the world stage and are promptly snuffed out—yesterday a drop of semen, as the Roman Emperor Marcus Aurelius wrote, tomorrow a handful of ashes. If the Earth were as old as a person, a typical organism would be born, live, and die in a sliver of a second. We are fleeting, transitional creatures, snowflakes fallen on the hearth fire. That we understand even a little of our origins is one of the great triumphs of human ingenuity and courage.

Who we are and why we are here can be glimpsed only by piecing together something of the full picture—which must encompass aeons of time, millions of species, and a multitude of worlds. In this perspective it is not surprising that we are often a mystery to ourselves, that, despite our manifest pretensions, we are so far from being masters even in our own small house.

Carl Sagan of Cornell University is President of The Planetary Society. Ann Druyan is Secretary of The Federation of American Scientists in Washington, DC. This article is taken from their Shadows of Forgotten Ancestors: A Search for Who We Are *(Random House) and is copyrighted*

Academician Valery Leonidovich Barsukov 1928–1992


Photo: Jim Head

by Jim Head

On July 22, 1992, with the untimely death of Academician Valery Leonidovich Barsukov, planetary science and exploration lost a dear friend and invaluable colleague. Academician Barsukov had achieved many of the highest scientific honors in the Soviet Union and Russia, and he was truly dedicated to international cooperation in scientific research and in the exploration of the planets. His efforts in these areas benefited us all.

Valery Leonidovich developed an interest in science and especially geology in high school, when he was drawn to the romantic and exciting side of the discipline as an assistant on geological field excursions. In 1951 he graduated from the Moscow Institute of Geological Prospecting and soon developed an excellent reputation for his work in the geochemistry of ore deposits. His early work carried him to field sites in South Yakutia, the Soviet Far East and the eastern Baikal region.

In 1971 he received a doctorate in geology and mineralogy; a few years later, he was elected a corresponding member of the Academy of Sciences. His professional interests were undergoing a metamorphosis that led to the study of the metallogenic aspects of Earth's mantle, and then to the geochemistry and geology of the planets and their satellites. At the same time he was a protégé of Academician A.P. Vinogradov, and he developed a strong interest in the political aspects of science, spending part of his career serving on the scientific staff of the Central Committee of the Communist Party. Upon Vinogradov's death, he succeeded him as director of the V.I. Vernadsky Institute of Geochemistry and Analytical Chemistry in Moscow and actively participated in the Soviet Union's missions to the Moon, Venus and Mars.

As director of this institute, which employs more than 1,200 scientists, engineers and technicians, he had considerable influence on the formulation of plans for space exploration, both within his country and in the international arena. He also showed his enthusiasm for the study of comparative planetology. Indeed, he once said that "the only way to predict what lies ahead for the Earth, for geologists and for the whole human race, is to study the planets."

His outstanding career led him to be elected first an Academician and later a member of the Presidium of the Russian Academy of Sciences. Throughout the later years of his life, his activities permitted him to develop another of his interests, international cooperation in scientific research and planetary exploration. He was a leader in numerous international professional organizations and held many important positions, including the vice presidency of the International Union of Geological Sciences. He was active in Intercosmos and in the Committee on Space Research (COSPAR) of the International Council of Scientific Unions and was a well-known figure at the annual Lunar and Planetary Science Conference in Houston.

Upon the renegotiation of a joint agreement between the United States and the Soviet Union in the mid-1980s, Valery Leonidovich was named the Soviet chair of the Joint Working Group on Solar System Exploration. In this position he continued his advocacy of international cooperation. He was also active in the restructuring of Soviet robotic space efforts and their incorporation into the Russian Space Agency. He worked tirelessly with our group at Brown University to develop joint meetings and scientific exchange visits. Even in the worst periods of the Cold War, his efforts in this area contributed to the education and personal development of many young and aspiring scientists in several countries.

Any of the accomplishments set forth here would be a highlight in the career of most people, and all of them would seem to leave no time for any other activity. Those who knew Valery Leonidovich Barsukov understood that the enthusiasm and intensity he had for his work extended into his personal life. His concern for his friends and loved ones came from great depths within his soul. His legendary musical talents, most often expressed in guitar playing and the singing of Russian folk songs, were too an expression of his unique personality. Whether in a Cajun restaurant in Texas, with students at Brown University, or in his apartment in Moscow, sharing in a serenade of Russian and Gypsy songs was an experience that signaled to everyone that Valery Leonidovich Barsukov was someone whom you wanted to get to know better. He made all of us who came in contact with him a little bit more Russian. That is one of his many wonderful legacies.

The words of Boris Pasternak seem very fitting to describe Valery Leonidovich Barsukov's passionate living of life and his personal pursuit of an understanding of the solar system:

> Live on through life without imposture,
> Live so as in the final end
> To hear the love-call of the future,
> Expanse and distance to befriend.
>
> * * *
>
> Just be alive, in thought and action,
> Alive and always to the end.

Jim Head is a professor of geological sciences at Brown University and has worked with Russian scientists on planetary missions for 20 years.

John Bryson Joins Planetary Society Board of Directors

The Planetary Society's Board of Directors has welcomed a new member to its ranks: John E. Bryson, chairman and chief executive officer of SCEcorp and its subsidiary Southern California Edison, the second largest utility in the United States. Bryson's expertise in public policy and experience in the environmental movement will add a new dimension to the Board.

"John brings to The Planetary Society a vision about Earth and its possibilities and a strong belief in the importance of discovery to society as a whole," commented Bruce Murray, Planetary Society Vice President.

Bryson began his career in public policy in 1970, when he and a few colleagues from the Yale Law School founded the Natural Resources Defense Council. By fighting its battles in the courts, the NRDC helped turn the environmental movement—once derisively considered the domain of "bird-watchers"—into an effective political force.

Following his success with the NRDC, Bryson distinguished himself by his service on such regulatory bodies as the California Water Resources Board and the California Public Utilities Commission. In 1984, he was recruited for SCE by Howard Allen, then chairman of the utility, to serve as senior vice president for legal and financial affairs. In 1990, he took over the utility and its parent corporation.


Photo: Southern California Edison

John E. Bryson

It may seem a bit paradoxical that an ardent environmentalist was chosen to lead a major utility. As Peter Nulty wrote in *Fortune*, a year after Bryson took over SCE, "It's almost as if Robin Hood had taken over Nottingham Castle—and faced the need to reconcile his duties to shareholders with his loyalties to that band in the forest."

But, as Murray put it, "There is nothing paradoxical at all about it. It was his commitment to progress that guided Bryson's appointment. He had a record of finding solutions to thorny problems, and proved himself capable of leading an organization like SCE into the future."

Bryson has been unusually creative in finding workable solutions to environmental conundrums and balancing the wants of the utility's shareholders with the need for sustainable electrical production.

"John is one of the most interesting and energetic young leaders in the business community. His contribution to the Society will be considerable," commented Joseph Ryan, attorney and long-standing Board member.

The Board of Directors is the governing body of The Planetary Society. Its members set policy, oversee finances, approve research projects and represent the membership to the public and to governments. Its President is Carl Sagan, the Vice President is Bruce Murray and the Secretary is Louis Friedman. The other Board members are Joseph Ryan and Steven Spielberg.

Apollo 11 astronaut Michael Collins and financial consultant Henry Tanner recently retired from the Board after years of dedicated service. We will miss their experience and guidance, but their influence on Planetary Society policy will last for years to come.

The appointment of John Bryson will begin to fill the gaps left by the death of Thomas O. Paine and the departures of Collins and Tanner. The recent changes in the spacefaring nations have presented the Society with new challenges, and the Board of Directors is preparing to meet them.
—Charlene M. Anderson

Buzz Aldrin — New Society Advisor

Buzz Aldrin, lunar module pilot for the *Apollo 11* mission to the Moon, has joined the Board of Advisors of The Planetary Society. Aldrin brings to the Society nearly three decades' experience with the space program, as well as 290 logged hours of spaceflight. He will add a unique perspective to the advisory body.

Aldrin is an honors graduate of West Point and received his doctorate in astronautics from the Massachusetts Institute of Technology. In 1963, he was selected for astronaut training and became one of the first of that select group of spacefarers. In November 1966, he set a record for extravehicular activity in space during the *Gemini 12* flight. On July 20, 1969, he and Neil Armstrong became the first humans to set foot on the Moon.

Since his retirement from NASA and the United States Air Force, Aldrin has continued his lifelong commitment to the exploration of the solar system. He has proposed a plan for sustained exploration based on his concept of a system of spacecraft following cycling orbits between Earth and Mars.

Aldrin is a member of the National Space Council's Space Policy Advisory Board and is also chairman of the Board of Directors of the National Space Society.

His experience and imagination will be great assets to The Planetary Society.—*CMA*

Roving Through Death

1992 Test Program Wrap-up

by Alexander Kemurdjian

When Lou Friedman first suggested testing the Mars Rover in California, I didn't quite understand what he was talking about. And why was it necessary? We had already tested the mobile Mars Rover chassis in Kamchatka, on a fairly young volcanic landscape. Tests had also been carried out in the sands of the Kara Kum Desert in Turkmeniya.

But Friedman developed his idea, and it gradually became clear that such tests could be both interesting and useful, for several reasons.

First of all, it made sense to accumulate information on the motion of the Mars Rover under a wide variety of conditions.

If it were possible to find a location on Earth about which one could say, "This is Mars," everything would be much simpler. But we can only say, of each location selected for testing, "This is a little bit like Mars." Testing in several places that are "a little bit like Mars" should give a mosaic of the reliability with which the rover will move on Mars, while providing much information needed for planning and designing the motion controls. Each such test provides additional verification of the ideas incorporated in the rover and of the rover design itself.

Moreover, the moment was approaching for us to assemble the individual systems involved in the motion of the rover so we could test them as a unit. This would require gathering a large number of participants from various countries and providing conditions under which they could live and work.

We would have had problems with all of this.

In addition, visiting another country would provide opportunities for establishing contacts (personal as well as business and scientific), opportunities not only for us to find out something useful for ourselves about the Americans, but also for American scientists, engineers, businesspeople and the general public to find out about us.

The actual test results confirmed, and in many respects exceeded, my expectations. The scientific and technical findings will be presented in a special report, but a little bit can be mentioned here as well.

To begin with, we were quite pleased that the self-propelled chassis of the Mars Rover (including the movement-control unit) operated flawlessly. However, this was not just a characteristic of the design; among the specialists who kept the rover operating were Valery Gromov, head of the laboratory where the current design of the self-propelled chassis was developed; Valery Ivashkin, mechanical engineer and experienced Mars Rover driver; Nikolai Kuznetsov, electrical engineer, responsible for the electrical and electronic parts of the self-propelled chassis; and Alexander Popov, metal worker and mechanic, who fabricated many parts of the chassis and assembled it.

On the first day of testing, the rover's adeptness at moving up a steep incline on free-flowing sand was verified at Dumont Dunes. Its ability to keep to a specified course, the true speed of motion over sand, the adequacy of the power produced by the batteries and drive motors, and the accuracy with which the rover executed maneuvers were also subjects of analysis. The processes of debugging the television and radio-control systems operated in parallel.

The work at the dunes was brief, but intense. What took place on this day was of extreme importance. This was the first test of the equipment, the overall organization of the work (and us as well) under field conditions.

Yes, we were also tested by the heat, and it was far from easy.

It was instructive for us to see how the entire operation was organized by The Planetary Society. Everything was thought out, down to the smallest detail.

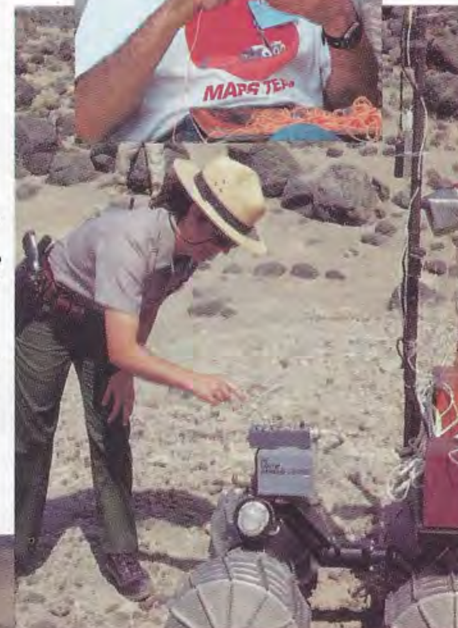
Each person knew his or her place in the overall ensemble, and knew precisely what to do. The expedition was deployed rapidly. The brilliant organization of work enabled us to start the morning of the testing, completely execute the program, strike camp and arrive at the next work site—Death Valley—by evening.

We saw how Americans are capable of working; we caught a glimpse of the American style.

The support group made a great contribution here, but I would especially like to take note of the women from The Planetary Society.

We have a saying in Russia, "Women are a great force." It seems that this holds true in America as well. Charlene, Cindy, Sarah, India and Susan were confident, sharp and

Valley:



Opposite page: The Mars Rover clambers up Mars Hill, a volcanic formation on the floor of Death Valley that closely resembles the Viking *landing sites. On this most Mars-like of terrains, the little Russian robot proved itself capable of surmounting—or avoiding—rocky obstacles that might prevent it from carrying out its mission of exploration.*

Above right: The author, Alexander Kemurdjian, sits in the shade of the command trailer and untangles the string used to calibrate distance for an experimental panoramic camera developed by Ball Aerospace of Boulder, Colorado.

Right: Nancy Hagerman, a ranger at Death Valley National Monument, stayed with the Mars Team throughout our tests. On the last day, team members invited her to drive the little robot, and Kemurdjian presented her with an official Mars Rover driver's license.

Below: Evidence of the Mars Rover's amazing maneuverability could be seen in the sands of Dumont Dunes. In the foreground is a perfect circle created by the rover as it pivoted to make a turn. Then it set off in a straight line toward the horizon.

Photographs: Charlene M. Anderson

businesslike; it's a shame I don't remember the names of all of these wonderful coworkers.

The subsequent tests in Death Valley enabled us to examine the operation of the rover under different conditions on a hillside with randomly distributed rocks of various sizes. We were also able to perform a series of tests on the television systems and on the control of the rover.

The American, French and Hungarian equipment operated successfully.

The tests were an encouraging first step in an extensive program of integrated experimental development. They provided us with food for thought as far as improving the design, and we got a better handle on several weak points. We have something to work on before the next tests.

We also developed a methodology and acquired some experience in carrying out joint tests. The international group that was assembled turned out to be a success and may serve as the basis for further work and the addition of new creative participants.

Also, the Americans showed us some of their work on microrovers. The first Soviet microrovers were sent to Mars in 1971 and 1973, and we are currently carrying out research in this direction—so we found it interesting to see what the Americans have done. An attempt to have the microrovers and the Mars Rover work together was also interesting.

Not everything proceeded as expected. However, it should be remembered that these were like the first steps of an infant in public; we expect these steps to become stronger and more confident, so that the microrovers will eventually move consistently and reliably.

I believe that research in this direction should proceed immediately, and our collaboration in designing microrovers for future planetary research will be useful to both Russia and the United States.

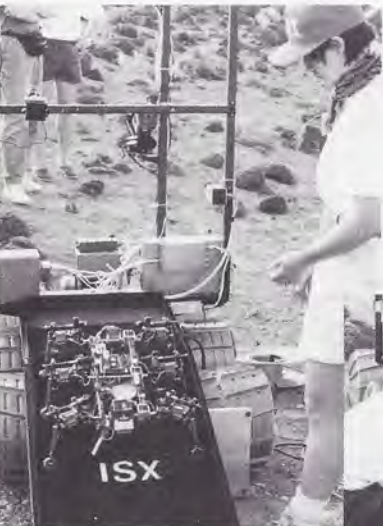
One of the important outcomes of the tests in the California desert was the expansion of contacts for us. This was greatly facilitated by the well-organized propagation of information about the tests by The Planetary Society. As a result, the tests were observed by representatives from the aerospace industry, meetings were subsequently held with representatives from several firms and universities in the US, and NASA Administrator Daniel Goldin came to see our rover at the Pasadena staging area. All this led to a better understanding of our technical capabilities and lent credence to the idea that our partnership might be mutually beneficial.

We see the results of this even today in the steps being taken by the American side in organizing a partnership with us.

As far as magazine and newspaper reporters and television and radio journalists are concerned, many were present, and, of course, this helped a significant number of Americans find out about us. In one article, however, I was quoted as saying that the previous year's testing on Kamchatka was unsuccessful. This was a distortion of my words. What I meant to say was that during the August 1991 visit by Friedman's group, the weather was unfavorable, which interfered with the flights to the test area. The testing of the self-propelled chassis of the Mars Rover on Kamchatka in 1991 was successfully carried out by our institute. And it was precisely the results of these and earlier tests that enabled us to prepare the Mars Rover for its successful operation in California.

On the whole, the Death Valley tests were beneficial for the future of planetary research, for both Mars and the Moon, and will, it seems to me, go down in history as the first joint tests between the US and Russia in the field of planetary rover construction. *—Translated by Paul Makinen*

Alexander Kemurdjian is chief designer of Russian lunar and planetary rovers.



Microrovers for Mars

by Bruce Bullock

Above: Attila the microrobot scrambles up a specially built ramp to join up with the Mars Rover.

Right: Members of the ISX team tinker with Attila as the insect-like robot is tested against the desert conditions.

Photographs: Charlene M. Anderson

At the invitation of The Planetary Society, ISX Corporation agreed to provide a microrover to ride piggyback on the Mars Rover during the Death Valley tests. The microrover could leave the big rover, take television pictures of the surrounding terrain and help the rover negotiate obstacles. The little robot could also explore risky areas and serve as a remote "arm" to collect samples. Moreover, the microrover's television camera could provide "eyes" to help ground controllers find a way to free the rover if it became stuck.

ISX Corporation had been working since 1988 with Rodney Brooks and Colin Angle at the Massachusetts Institute of Technology in developing microrobot technology. The MIT microrobots Genghis and Attila, resembling mechanical insects about a foot long, demonstrated that such machines could make their way around such obstacle-filled terrains as university offices. Attila was selected by the Russians to try the terrain of Mars Hill. In addition, we decided to test a more robust, environmentally sealed microrobot named Pebbles, which moved on tracks and carried a soil scoop.

ISRobotics in Cambridge, Massachusetts, completed Pebbles in less than a month and shipped it to ISX in California only days before we were to leave for Death Valley. We worked almost around the clock to integrate the new robot with our mission management workstation (a laptop computer). Then, on the day before we were to leave, we discovered that a newly designed circuit board in Pebbles' computer was missing some traces, leaving Pebbles unable to communicate by radio with the controlling workstation. At midnight we made the sad decision to scrap the robot's tiny computer. We would have to replace it with a simple radio control system and manually guide the robot during the tests.

Attila, the walking microrobot, had arrived the night before, and with it and the brain-dead Pebbles we left for Death Valley. Along the way we searched through hobby shops for the parts we needed to revive Pebbles, finally finding them in Lancaster.

When we reached Death Valley, our team focused on mounting a ramp on the Russian rover for the microrobots. Armed with some quickly drawn pencil sketches, the Russian technicians drilled holes in the rover frame and attached the ramp. Attila slowly made its way up and down the ramp and clambered over a few rocks, to the delight of the assembled spectators.

Pebbles came next. It was able to climb up and down the ramp, collect a soil sample and return a television image of the larger rover's wheels—all before its batteries ran out, which happened all too quickly in the intense heat.

We believe that we succeeded in demonstrating the potential for microrovers for Mars exploration—and we did it for less than the major aerospace companies spend on a single trade show. We are continuing to develop microrover technology. After NASA pioneers the use of microrovers in space, and when the time is right for commercial rovers to explore the planets, we hope to be ready with the best system.

Bruce Bullock is chief executive officer of ISX Corporation in Westlake Village, California.

Young Explorers Remember the Mars Rover Tests

Friends Peter Zorin (left) and Andy Carroll pose in front of the rover's van.

The 1992 Mars Rover tests attracted people of all ages to the California desert. We asked a few of the younger participants to share their remembrances with the Society members who couldn't attend.

I really liked the Mars Rover tests because we had cereal and watched the Mars Rover. The Mars Rover was very smart, and it was very interesting to watch. At our motel, we had a big swimming pool. Me and Peter liked to swim and dive in it. We saw a lot of toads. Peter is a boy who came all the way from Russia to see the Mars Rover. The Mars Rover's job is to take pictures of Mars. I want to do it again.
—Andy Carroll, age 8, San Diego, California

It was very hot in the desert. In the morning everybody went to the testing place: Brian with his motorhome; Michael with his cowboy hat; Lou with his little toy Marsokhod; Lu, Charlene and Susan from The Planetary Society. It was a real Death Valley, without trees, grass, animals, only dry land and mountains and rocks. The testing place was the hill like a planet without life. Everybody worked together. I have friends: German and Andy. We drove the Mars Rover and pushed the buttons: "Forward," "Back," "Turn." We have Mars Rover driver's licenses.
—Peter Zorin, age 8, Moscow, Russia

What the Mars Rover tests mean to me—three different countries working together, partnership, cooperation. Underneath the three languages the thoughts are equal: to send a space probe to another planet, helping to make a dream come true. We are never going to get anywhere just looking at each other. We need to work together. That's what counts. So the Mars Rover tests show how three countries are working together. There should be more of these projects. It doesn't matter what race you are or what your heritage is. All of this means we can go sooner to Mars. I enjoyed the desert, the people and the pool.
— German Alonso, age 11, South El Monte, California

Peter Zorin and German Alonso tested their mobility on Dumont Dunes.

Photographs: Charlene M. Anderson

Help Name the Mars Rover

In 1997, 20 years after the two *Viking* spacecraft landed on Mars, another spacecraft from Earth will land on the Red Planet. The *Viking* landers were stationary craft, unable to move and see what lay just over their horizons. But this time, the robotic spacecraft will be a rover, able to creep slowly over the surface of Mars and discover what lies beyond the next hill or across the dry riverbed.

The Mars Rover, part of the Russian *Mars '96* mission, will be able to investigate rocks and soil, monitor the martian weather and televise to Earth images of its journey. With six cone-shaped wheels and a belly that nearly touches the ground, the rover is a strange-looking vehicle. But this design will help keep the rover from tipping over as it crawls across fields of boulders or creeps up steep sand dunes.

The Russian rover will blaze a trail some 50 kilometers (about 30 miles) long during its planned year of exploration. Its top speed is only 100 meters (about 330 feet) per hour, so it will explore slowly, but thoroughly, as it completes its mission on Mars.

But before it goes to Mars, this amazing robot rover needs a name. Three Russian organizations are conducting the mission: the Space Research Institute, the Mobile Vehicle Engineering Institute and the Babakin Center. With the help of The Planetary Society, they are inviting children born from 1980 to 1984 to name the rover.

The names entered in the contest will be judged by an international panel of engineers and scientists working on the *Mars '96* mission. The final selection of the name will be up to the Russian space organizations, and The Planetary Society cannot guarantee that the winning name will ultimately be used for the rover.

The child who suggests the winning name will receive a $500 cash prize. A second prize will be a globe of Mars.

Ten finalists will each receive a copy of An Explorer's Guide to Mars. All children who enter the contest will receive an image of Mars taken by an earlier robot explorer.

So, if you qualify, enter the contest and become a part of a great planetary mission of discovery! *—CMA*

Contest Rules

1. Any child born between January 1, 1980, and December 31, 1984, is eligible to submit a name. Each entry must include proof of the child's age.

2. The entrant's name, address, telephone number and native language must be provided on the entry.

3. The suggested name must have something to do with the rover or its mission.

4. Each entry must consist of no more than two paragraphs. The first paragraph must give the name chosen and the entrant's reason for choosing the name, in no more than 100 words. The second paragraph must describe, in no more than 150 words, why the rover's mission is important.

5. The contest entry must be neatly and clearly handwritten. Drawings and other materials will not be accepted.

6. The entry must be received no later than October 1, 1993, at Planetary Society headquarters, 65 North Catalina Avenue, Pasadena, CA 91106.

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Angle of Attack: Harrison Storms and the Race to the Moon

By Mike Gray; W.W. Norton,
New York, 1992, 304 pages.
Retail price: $22.95
Member price: $19.95

There was a time when McDonnell, Douglas and Martin were people, not segments of the compound names of giant corporations, and companies like North American Aviation worked 24-hour shifts. In the first decades after 1945, engineers who had built airplanes for the war against Germany and Japan had the Cold War to keep them busy.

These men—and they were all men, Mike Gray points out in *Angle of Attack*, an exciting tale of the engineers who built *Apollo*—were in the right place when the Soviets launched *Sputnik* in October of 1957.

The media, the public and Congress went haywire at the perceived humiliation and demanded that something be done to beat the Soviets. Gray tells us that President Eisenhower knew that the United States wasn't actually running a distant second in rocketry, but military secrecy prevented him from speaking out.

In response to the public outcry, Congress rapidly pieced together the National Aeronautics and Space Administration (NASA), borrowing where it had to from the military and the old National Advisory Committee for Aeronautics (NACA). In 1961, President John F. Kennedy came into office, having stressed the "missile gap" in his campaign. After the fiasco of the Bay of Pigs rubbed salt in America's wounded pride, Kennedy rallied the nation by announcing that America would land a man on the Moon before the end of the decade. With both Congress and the president whipping up enthusiasm, the aircraft companies zoomed into the aerospace age.

Harrison Storms, North American Aviation's chief engineer, responded by going all out to win the contract for the mission dubbed *Apollo*. Gray explains how Storms got the contract, and how hundreds of engineers competed and worked within NASA's constantly changing specifications to build the ship that made the rendezvous, as promised. Storms' story, the saga of a feisty, opinionated man whom his employees "would have followed barefoot over broken glass," is the spine of the book.

Gray sustains an atmosphere of tension from the first page, bringing to life the nation's capital in that bygone era before joggers took to the streets and real men started drinking Perrier. As the pressure builds, Gray chronicles broken marriages and broken hearts—myocardial infarctions brought on by hard drinking and lack of sleep.

The author paints his American heroes as vivid individuals. In contrast, "the Germans," led by Wernher von Braun, seem a single unit. Self-consciously separate, members of the German crew had delivered themselves to the American army after escaping from Peenemünde in late 1944, fresh from sending V-2 rockets to London.

The story has its villains, too, including Kennedy's science advisor, Jerome Weisner, a constant naysayer, and Richard Nixon, who as president canceled the flights after *Apollo 17*, leaving two ready-to-fly rockets to become museum artifacts and their "irreplaceable components to rust in technological graveyards."

Angle of Attack tells an inspiring tale of teamwork, and tragedy—Gray tracks Gus Grissom into *Apollo 1*, unaware that the addition of strips of the newly invented Velcro to cabin surfaces would fuel the oxygen-fed fire soon to kill him. A lesser tragedy is Storms' own; he was the man tapped to take the fall as investigators sought a culprit for the disaster.

The human exploration of space began 30 years ago, with the Moon the first port of call. Mars awaits our visit. As we embark on that mission, the drama and determination of the *Apollo* team will likely be echoed in the lives of these next explorers.

—Reviewed by Bettyann Kevles

Still Available:

Five Billion Vodka Bottles to the Moon: Tales of a Soviet Scientist, *by Iosif Shklovsky. Relive the exciting days of the Space Race through the eyes of one of the Soviet Union's leading astronomers, a pioneer in the Search for Extraterrestrial Intelligence.*
(Reviewed September/October 1992.)
Retail price: $19.95
Member price: $17.95

From Stone to Star: A View of Modern Geology, *by Claude Allègre. Clues to the origin of Earth are found in rocks from space in this adventure tale of modern science.*
(Reviewed November/December 1992.)
Retail price: $39.95
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World Watch

by Louis D. Friedman

TOKYO—The Japanese planetary program has been steadily increasing in vitality: The Institute of Space and Astronautical Science (ISAS) has set a launch date of August 1996 for its first mission to Mars. Called Planet-B (Planet-A, renamed *Suisei*, studied Halley's Comet in 1986), this mission will focus on aeronomy and study the interactions of Mars' upper atmosphere with interplanetary space.

ISAS had originally planned to launch the Lunar-A mission to the Moon before the Mars mission, but delays in the development of the M-V rocket have forced a change in plan. Lunar missions can be launched almost anytime, but launch windows to Mars occur only once every two years. So to make use of the precious 1996 Mars window, Planet-B will go first. Lunar-A will follow in 1997.

Planet-B will carry a magnetometer, a plasma wave detector and sounder for the upper atmosphere, a plasma particle detector, a neutral particle sensor and a system for imaging in ultraviolet light.

Lunar-A will deliver the first penetrators to the surface of the Moon. ISAS has tested its design extensively, and although other spacefaring nations have studied similar technology the Japanese appear to be the most advanced in this area. The three planned penetrators will carry accelerometers, seismometers and heat-flow probes. A polar orbiter will complete the mission hardware.

The Japanese have several other planetary missions under study, including a near-Earth asteroid rendezvous, a sample return from a comet's coma, a Venus probe and a Mars lander. Some of these missions are being planned in cooperation with the United States.

The budget for space science increases modestly each year, and the ISAS researchers are hopeful that at least one, if not two, of these proposed missions will be accomplished before the end of the century.

SAN JUAN CAPISTRANO—This small California town hosted a remarkable gathering of planetary researchers from around the world, who came here to present proposals for missions for NASA's new Discovery program. These missions are to cost less than $150 million each and are to be completed in less than three years. Innovation and creativity will be needed to overcome shrinking space budgets and keep planetary missions flying, and the Discovery program is planned to encourage such thinking.

Proposals for missions to nearly every solar system body from Mercury to Pluto received a hearing, and a committee of distinguished planetary researchers is trying to select the 10 best to receive study money from NASA.

Meanwhile, planners at the Jet Propulsion Laboratory are working hard on the Mars Environmental Survey (MESUR) Pathfinder mission, which may launch in 1996. This mission would be a technology demonstration for the full MESUR mission, which would send 16 landers to the martian surface between 1998 and 2003.

MESUR Pathfinder is planned to be the first Discovery mission. It would place one or two landers on the surface, perhaps carrying a microrover such as JPL's Rocky IV.

The second planned Discovery mission is NEAR, the Near-Earth Asteroid Rendezvous, being developed by the Applied Physics Laboratory of Johns Hopkins University.

ROME—The Italian space agency, ASI, has begun studying a communications orbiter to support several missions to Mars now planned for the late 1990s. The European Space Agency is developing a Mars network (see the May/June 1990 *Planetary Report*) for that time period, and the Russian *Mars '96* mission, if all goes well, should have placed a spacecraft in orbit as well as a lander and rover on the surface. (The Mars Balloon portion of the mission will last no more than 10 days.) The Italian orbiter could also provide a communications relay for NASA's proposed MESUR mission.

While Italian scientists and engineers have played important roles in both European and American planetary missions, this would be the first planetary mission conducted by their space agency.

WASHINGTON, DC—NASA Administrator Daniel Goldin has begun to reorganize the bureaucracy at NASA headquarters. His stated goal is to enable a revitalized agency to carry out more frequent, lower-cost missions, characterized by the slogan "faster, cheaper, better."

The Office of Space Science and Applications was split into two divisions, following the recommendations of the Augustine committee (the Advisory Committee on the Future of the US Space Program, chaired by Norman R. Augustine). One will focus on the Mission from Planet Earth (solar system exploration, astrophysics and planetary astronomy), while the other will handle the Mission to Planet Earth (the Earth Observing System and other applications).

Goldin may form a third science office to handle life sciences and microgravity research. This office would oversee the research to be conducted on NASA's planned space station.

The Space Exploration Initiative, to send humans to the Moon and Mars, is currently without a home. Congress refused to fund it for fiscal year 1993, and Goldin has not yet reassigned it to a new office. He is seeking a rationale for human exploration in hopes of garnering political support in the budget battles to come.

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

News & Reviews

by Clark R. Chapman

Last autumn, the venerable *New Yorker* magazine changed its stodgy format. It began running scented perfume ads and risqué photographs. Now it even includes the titles of articles in its table of contents. (*Vanity Fair* it still is not.)

The oldest popular astronomy magazine, *Sky & Telescope*, has also "gone slick." *Sky & Telescope* has long been the preferred choice for serious amateur astronomers. And its reliable, technically sound news notes about astronomy have informed generations of professional astronomers too busy to wade through the complexities in *The Astrophysical Journal*.

The January 1993 *Sky & Telescope* is glossy and colorful. It is thicker, too, with new departments and freshly conceived sky charts. *Sky & Telescope* editor Leif Robinson tells his readers that they can expect the same reliable, meaty content, even if it is now packaged in a fluffier style. I hope so.

The January issue has some solid material, emphasizing telescopic observations of Mars, which is particularly close to Earth this winter and is a gleaming orange beacon in the night sky. There is a good article by Paul Weissman on the hypothetical Kuiper belt of comets, located beyond the orbit of Neptune. An unusual object discovered last August, designated 1992 QB_1, may be the first member of the Kuiper belt to be observed.

Killer Comet?

But I am worried about the January *Sky & Telescope* cover story. Renowned space artist Don Davis depicts comet Swift-Tuttle flying ominously low over France in the year 2126. Huge red letters cry out from the cover: "Target Earth." Beneath, smaller red type asks, "What will be the 'impact' of comet Swift-Tuttle?"

As readers of the November 23 cover story in *Newsweek* know, there has been much agitation about Swift-Tuttle of late. Passing harmlessly through the inner solar system this winter, Swift-Tuttle will return again long after we all are dead—and not because the comet ran into us! Despite astronomer Brian Marsden's estimate, given to *The New York Times* (and repeated in *Sky & Telescope*'s cover caption), that the comet has one chance in 10,000 of actually striking Earth when it comes back, there is nothing for our great-great-grandchildren to worry about. (Marsden is the author of the *Sky & Telescope* cover story.)

I was in Costa Rica soon after the *Times* article appeared, participating in The Planetary Society's outreach program to developing nations. A tour van driver asked me what I did. When I replied that I was an astronomer, he immediately queried whether it was true that the world would end in 2126. He told me that the Costa Rican newspaper failed to indicate that a Swift-Tuttle impact was extremely unlikely. (Swift-Tuttle is the source of the Perseid meteors, visible for two weeks in early August each year.)

Newsweek is an inappropriate forum for astronomers to use to debate the fine points of cometary orbit calculations. Nevertheless, Marsden and comet expert Don Yeomans slugged it out in the magazine's pages. During subsequent weeks, electronic mail messages between Marsden and Yeomans finally resulted in a more sober consensus: There is no meaningful chance that Swift-Tuttle will have strayed so far from its path as to endanger Earth.

Or Terrifying Toutatis?

The sensational implications of *Sky & Telescope*'s cover pale in comparison with the wholly irresponsible journalism of the October 1992 issue of the popular French science magazine *Sciences et Avenir*. That publication carried a good article by astronomer Anny-Chantal Levasseur-Regourd on Toutatis, the asteroid that came fairly close to Earth in December and was the subject of a worldwide observational campaign by astronomers.

Unfortunately, the magazine's editors wrote sensationalistic and wholly erroneous sidebars implying that Toutatis might strike Earth and wipe out the human species on September 26, 2000. The magazine's cover actually depicted the asteroid cracking Earth into pieces. In fact, the 1-to-2-mile-wide asteroid would make a crater only perhaps 20 miles across, although dust raised into the stratosphere by such an impact might play havoc with our planet's fragile ecosphere. And the magazine's editors simply goofed: Toutatis has no chance at all of striking Earth anytime soon. Indeed, Toutatis' closest approach to Earth in the year 2000 will be in late October, when it will miss by 7 million miles. Levasseur-Regourd, angry with the magazine publisher's treatment of her article, had to go on national French television to calm the fears of worried schoolchildren about the end of the world.

It distresses me to see *Sky & Telescope* starting down the same path. While Brian Marsden's article is good enough, as far as it goes, in discussing the history of his own thinking about comet Swift-Tuttle, Don Davis' otherwise fine cover painting of a threatening but wholly fictional event has no place on the cover of a serious science magazine.

Clark R. Chapman, who wrote about the asteroid impact hazard in his 1989 book Cosmic Catastrophes *(coauthored by David Morrison), has lately been trying to quell the rising tide of exaggeration about the seriousness of the hazard.*

SOCIETY *Notes*

MARSLINK LAUNCHED

A talented team of educators, engineers and scientists is now hard at work developing the Society's MarsLink education program. MarsLink will bring data from *Mars Observer*, scheduled to enter martian orbit in 1993, directly into classrooms around the world.

There has never before been an opportunity for science classes to work with data being collected from another planet. MarsLink lessons will enable students to apply these data to the concepts they study in general science, physics, chemistry, geography and Earth science classes.

If you are a teacher and would like to receive a free preview package this spring, please write to MarsLink, at Society headquarters. *—Carol Stadum, Education Manager*

EXPLORE KAMCHATKA WITH THE PLANETARY SOCIETY

Photo: Bud Schurmeier

The Planetary Society is planning a tour of the rugged Kamchatka Peninsula, where the Russian rover has been tested over volcanic terrain similar to the surface of Mars. For more information, contact Susan Lendroth at The Planetary Society, 65 North Catalina Avenue, Pasadena, CA 91106, or call 1-800-WOW-MARS.

PAINE MEMORIAL FUND ESTABLISHED

To push forward the date when people from Earth will walk on the Red Planet, The Planetary Society has established the Thomas O. Paine Memorial Award for the advancement of human exploration of Mars.

The Paine award will be presented to the group or individual doing the most to bring about the exploration of Mars. The Society has appointed an international selection committee to oversee the presentation of the first award.

This award grows out of a tradition Tom initiated at the triennial Case for Mars conferences. There he awarded a Mars flag of his own design to those who had made a significant contribution to Mars exploration. The Planetary Society won the flag in 1987. Just before his death in May 1992, Tom asked that the Society continue his tradition. (See the September/October 1992 *Planetary Report*.)

We are now actively raising funds for the endowment. If you would like to make a contribution in Tom's memory, or would like more information about the fund, please contact me at Society headquarters.
—Louis D. Friedman, Executive Director

PLANETARY BIOLOGY INTERNSHIPS NOW AVAILABLE

Each year, NASA funds several internships that provide opportunities to explore scientific questions of global scale about planet Earth. The planetary biology internships (PBIs) are open to graduate students and to college seniors accepted to graduate school.

Past interns have tackled studies of mineral precipitation by bacteria, models of global elemental cycles, and experimental studies of the origins and evolution of life.

If you are interested in applying for an internship, contact Lorraine Olendzensky, PBI Administrator, at the Department of Biology, University of Massachusetts, Amherst, MA 01003; telephone (413) 545-3223; fax (413) 545-3243.
—Charlene M. Anderson, Director of Publications

LET THE COMPETITIONS BEGIN!

Grab your pen and paper, find your transcripts and get set to think: The 1993 Planetary Society scholarship competitions are now officially under way.

All Planetary Society scholarships are awarded on the basis of original essays or research projects that demonstrate a student's promise in fields related to planetary exploration. Grades and test scores are also considered.

We offer cash awards to students across a range of ages:

- New Millennium awards, for high-school students embarking on college careers.
- College fellowships, for undergraduate students enrolled in a United States or Canadian college or university.
- The Mars Institute student contest, open to any high-school or college student.

To receive an application or more information, write to The Planetary Society, Attention: Scholarship Department. The deadline for entries is May 17, 1993. *—Carlos J. Populus, Contest Coordinator*

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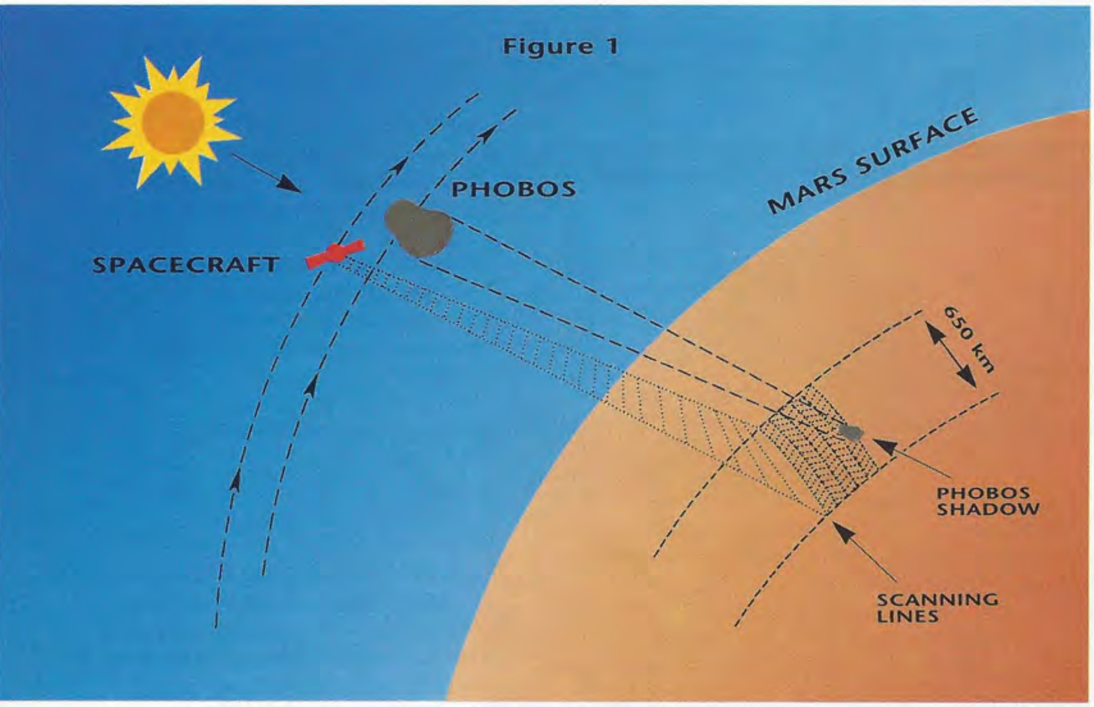
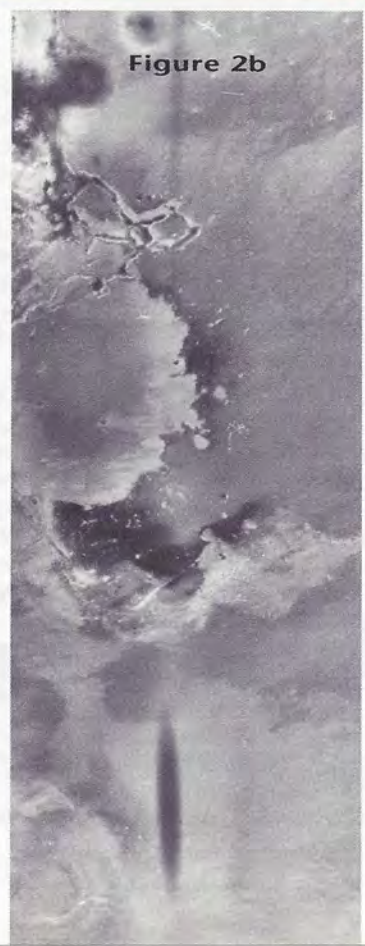


Above: This chart illustrates how the positions of the spacecraft, the moon Phobos and the planet Mars lined up to create the "Phobos Mystery Shadow."
Chart: B. S. Smith



Right: Figure 2a is a thermal, or far-infrared, image of the moon's shadow.

Far right: The Termoscan also produced a visible, or near-infrared, version of the same image, as seen here in Figure 2b.

Images: Institute of Space Device Engineering, Moscow

Last year I noticed more than one mention in the media of a "mystery object" that appeared in the last images returned by the Russian spacecraft* Phobos 2. *It was suggested that aliens were responsible for the object and perhaps even for the demise of the mission. What actually happened?

—Len Seymour, Elko, Nevada

The "mystery object" was actually the shadow of one of Mars' moons. The spacecraft *Phobos 2* reached Mars orbit and began to approach the martian satellite Phobos in February 1989. In the middle of March, Phobos and the spacecraft were several hundred meters apart, and they moved synchronously in the same orbit. At that time there were several surveys of the martian surface by the Termoscan equipment on board the spacecraft.

Termoscan is a two-channel scanning radiometer that can receive images in the visible and near-infrared region of the spectrum and at the same time in the thermal, or far-infrared, region. A Termoscan image is produced by a scanning mirror moving perpendicular to the spacecraft trajectory with a frequency of one scan line per second. Thus a picture is generated by the motion of the spacecraft in its orbit.

The survey of the martian surface was made with a constant Sun-to-spacecraft orientation. The centerline of the image is in the anti-Sun direction to an accuracy of one to two scan lines. Since the spacecraft was near Phobos and the Sun-Phobos direction was approximately the same as the Sun-spacecraft direction, the Phobos shadow on the Mars surface can be seen in the Termoscan field of view (Figure 1).

The length of this shadow was about 21 kilometers (13 miles). Termoscan's field of view on the martian surface was 650 kilometers (400 miles) wide, and resolution was 1.8 kilometers (about 1 mile). The moonlet's shadow came into Termoscan's field of view when the spacecraft was 200 kilometers (about 120 miles) away from Phobos. At this point the Termoscan instrument was pointed at Mars' surface in the same direction as the Sun's rays. On March 26, 1989, the shadow appeared as shown in Figure 2.

The factors that influenced the form and dimensions of the shadow included Phobos' orientation (Phobos has an irregular shape); distortion from Mars' surface curvature, especially near the planet's limb (the edge of its disk as seen from the *Phobos* spacecraft); and dispersion of radiation and other atmospheric processes.

Another factor—and probably a more important one—was deviation of the axis caused by the spacecraft's instability. The spacecraft's axis moved about 40 minutes of arc during the experiments.

If the spacecraft's orientation and the distance from it to Phobos had been perfectly constant, Phobos' shadow would have been an even line. But because of the deviation of the spacecraft's axis, Termoscan's lines moved ahead of the shadow or dropped behind it as the shadow moved on the planet's surface. The scanning line overtook the shadow, going through its center, then passed it (see Figure 2).

This process caused 250-to-300-kilometer (155-to-185-mile) motion on the Mars surface in the direction of motion, and the shadow was elliptically stretched in the resulting picture.

Figure 2 shows images from two different spectral regions. Figure 2a, taken in the infrared part of the spectrum, shows Phobos' shadow. In Figure 2b, a visible image, the shadow image drops behind. This image indicates that the shadow lowered the local surface temperature 4 to 6 degrees Celsius.

The temperature variation depends on how fast Mars' thin surface layer (several millimeters) cools. After analyzing the results from the two spectral channels, we were able to calculate the thermal inertia (the measure of an object's resistance to changes in temperature) of the surface layer and draw conclusions about its physical characteristics.

The calculations showed that almost all of the observed surface is covered with a layer of dust. The thermal inertia is two to three times lower than it would be without the dust. Further analysis will tell us more about Mars' surface processes.

The death of *Phobos 2* resulted from a failure in the control system of its onboard computer. This caused reorientation of the solar cells such that they did not receive sunlight power. The storage battery was drained of its charge, and all the spacecraft's subsystems lost power. *Phobos 1* went out of control earlier when its control lock with Earth was lost after an operator's error.

—A.S. SELIVANOV and U.M. GEKTIN, *Institute of Space Device Engineering, Moscow*

FACTINOS

A newly reported study shows that in December 1990 Mars' atmosphere contained the smallest concentration of water vapor ever recorded there. If all the water vapor then present in the atmosphere had condensed on the planet's surface, it would have formed an ocean only 3 micrometers deep—less than the thickness of a human hair.

The study marks the first time researchers have used a ground-based instrument—in this case the Very Large Array radio telescope near Socorro, New Mexico—to measure the thermal radio emissions of water in a planetary atmosphere other than Earth's. Past surveys, notes study coauthor R. Todd Clancy of the University of Colorado at Boulder, used near-infrared detectors to calculate martian water vapor by measuring how much sunlight the vapor absorbs. Infrared instruments aboard the *Viking* spacecraft in the 1970s found twice as much water vapor during the same season, Mars' early northern spring, as the 1990 study found. A 1988 infrared study from the ground found four times as much.

Bruce M. Jakosky, also of the University of Colorado, warns that scientists have not yet rigorously compared the infrared absorption and radio emission methods. But if the apparent variation in water vapor proves accurate, he says, the concentration of water in the atmosphere may vary as much from year to year on Mars as it does from season to season.

—from R. Cowen in *Science News*

❖

A half-mile-wide meteorite crashed into the ocean off New Jersey 35 million years ago, reports C. Wylie Poag of the United States Geological Survey. Drilling and seismic readings indicate that it left a crater which is now buried about 1,000 meters (3,000 feet) beneath the ocean floor and is about the size of New Orleans.

A University of Kansas team led by geologist Wakefield Dort says it has found a site in Nebraska where a mile-wide meteorite appears to have landed around 1000 BC. If confirmed, this would be the most recent known impact of a significantly sized meteorite in the US.

—from John Nolan for the Associated Press in *The Philadelphia Inquirer*

Mars still experiences frequent small quakes, according to a study recently published in *Science* magazine. David Tralli, a seismologist at the Jet Propulsion Laboratory, and his colleagues Matthew Golumbek and Bruce Banerdt examined high-resolution *Viking* photos of Mars' vertical fault lines and concluded that the planet has several small quakes a day. Larger quakes, equivalent to a magnitude 5.8 on Earth, probably occur every four and a half years, and those of magnitude 6.7 may happen every 350 years.

"The fact that we know Earth has a solid inner core was determined by seismology," Tralli said. "This is how we get early knowledge of the interior structure of a planet." With a similar project planned for Venus, Tralli added, "We can investigate the evolution of planets and how they're similar and how they're different. Understanding other planets helps us to understand Earth better."

—from Elizabeth Wilson in the Pasadena *Star-News*

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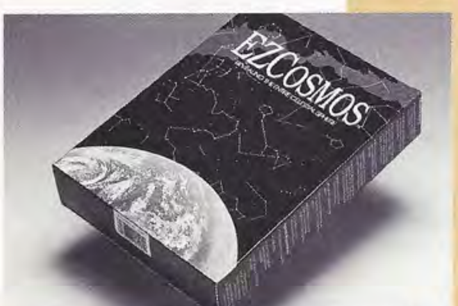

Computer software pictured at left:

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"3 May 2106" started out as an illustration of lava cascades in Mauna Ulu, Hawaii, for David Hardy's latest book, The Fires Within. *But then he and a group of other space artists went to Hawaii in July 1991 to watch the solar eclipse. David was so impressed that on his return to England he added an eclipse to the painting, saying that "next time an eclipse is seen from Hawaii—on the date in the title—there could be an eruption."*

David A. Hardy, who produced his first space art in 1950, is the European Vice President of the International Association for the Astronomical Arts. He is the author and compiler of Visions of Space, *a collection of work by over 70 international space artists. His work has also appeared on TV and in films.*

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