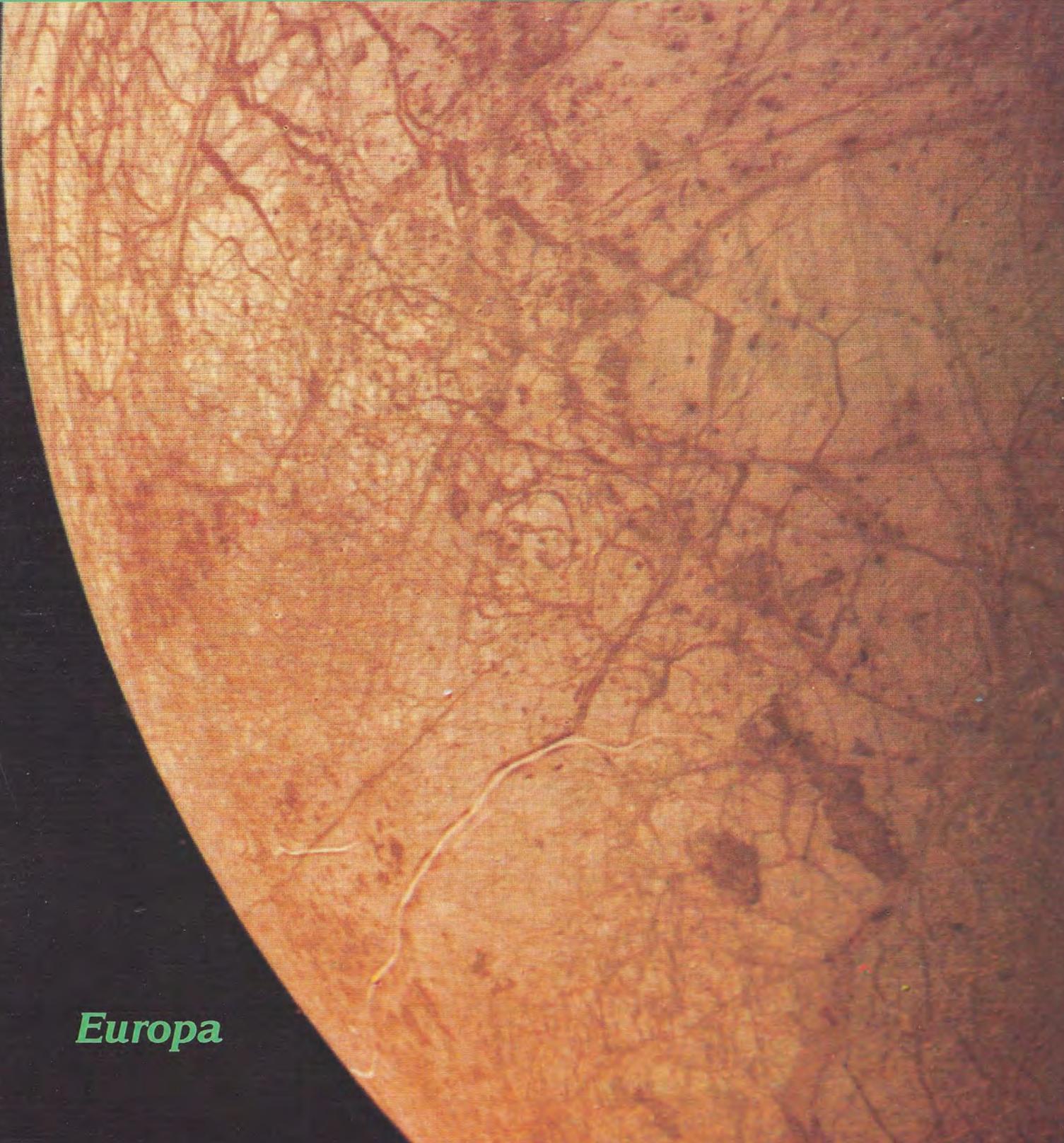


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Cover Photograph: An intricate network of dark lines covers the bright, smooth surface of Europa. This satellite of Jupiter is only one of the strange and beautiful ice worlds orbiting the giant outer planets of our solar system.

PHOTO: JPL/NASA

On March 21, 1981, Dr. Bruce Murray, Vice-President of The Planetary Society and Director of the Jet Propulsion Laboratory, testified before the Subcommittee on Space Science and Applications of the House Committee on Science and Technology at JPL. The following is excerpted from that testimony:

Mr. Chairman and Members of the Subcommittee:

I appreciate the opportunity to discuss with you the status and future of the U.S. deep space exploration program and the closely related future of the Jet Propulsion Laboratory.

Frankly, Mr. Chairman, the U.S. deep space program is in jeopardy and even may face extinction. Despite the widespread popularity and national significance of our remarkable deep space effort, this nation's unique capability to explore the solar system is fast eroding and approaching collapse.

The *Galileo* Jupiter orbiter and probe has been delayed three years by shuttle orbiter and upper stage development problems. It remains vulnerable even now to any delay in initiating serious development of the planned *Centaur* upper stage. The Venus Orbiting Imaging Radar (VOIR) has again been slipped from the planned 1986 opportunity until 1988. It is farther from realization now than it was four years ago. There is no Mars program to follow *Viking*, although extensive studies have investigated roving vehicle and sample return possibilities. Only the United States, among those nations with even a modest space exploration capability, has no plans to mount a Halley's Comet mission. And finally, for the first time since NASA was formed 22 years ago, a well-managed, well-established scientific and exploratory mission—the U.S. part of the International Solar Polar Mission (ISPM)—is being cancelled outright, international agreements notwithstanding.

It is ironic that such a list of negatives should be the issue at this hearing in this place. Today, in other rooms nearby, JPL engineers are preparing *Voyager 2* by remote control for its upcoming encounter with Saturn on August 25. Last November, *Voyager 1* held the attention of the world as it made its dramatic excursion through the Saturn system. People everywhere responded to the adventure and to the splendor of the discoveries and admired the United States' technological excellence. Not since *Apollo*, a decade ago, have U.S. citizens and the people of the world been more captivated by a space expedition. *Voyager* truly is an example of how America's deep space exploration program can properly earn the world's respect and admiration, as well as symbolize to our own people their aspirations for our nation's future. Exploratory missions like *Voyager* not only have unquestioned value to U.S. prestige around the world, but are among the most important scientific endeavors of this century. As a byproduct, such endeavors can have broad space technology applications.

Yet *Voyager* could go into the history books as the last grand achievement of a once-vigorous U.S. civilian space exploration program which contributed so heavily to our country's scientific and technological base, provided an economic stimulus for a number of U.S. industries and enhanced our national spirit and international respect. We're running out of time to preserve the rapidly diminishing NASA/industry capability for solar system exploration.

I believe that what is happening to the deep space exploration program in the United States and its supporting institutions is inconsistent with the priorities and processes that lead to such missions as *Voyager*; it is inconsistent with the stated policy of all currently concerned. If taken at face value, it would seem that some recent actions were a conscious effort to dismantle the deep space capability of this country. But I know that it is no one's intent or policy for America to quit the exploration of the solar system.

Congressman John H. Roussetot asked Dr. Murray to comment on the argument that it is more important to "put bread on the table" than to explore the planets:

There are many answers to that kind of question, and there should be. But my personal view is that man does not live by bread alone. Surely, this country has not reduced its own expectations of itself, becoming solely and completely concerned with the manufacture and consumption of day-to-day living implements. America has to have a purpose which goes beyond today and it has to create a legacy that goes beyond tomorrow. In my view, the most important "people" values are the uplifting of spirits, the stimulation of the intellect and the sharpening of our technological tools.

(continued on page 15)

Deep Space Exploration and The Space Shuttle

The successful first flight of the orbiter *Columbia* was justly hailed as a next step in the human penetration of the cosmos. Launched on the twentieth anniversary of Yuri Gágarin's pioneering flight and flawlessly recovered two days later, *Columbia* vindicated America's commitment to a future in which human access to low earth orbit will become routine.

What does this event mean to deep space exploration? By itself, the shuttle orbiter cannot propel payloads away from Earth; to do that it must carry an upper-stage rocket still to be developed (see illustration) and even then it will take five shuttle launches to equal the lunar payload mass of one *Saturn V Apollo* mission. Starting in 1985, the shuttle/*Centaur* will be able to launch automated deep-space missions, but manned ones are farther in the future.

If it is viewed as just another launch vehicle, the shuttle is much inferior to what we had some years ago. In the post-*Apollo* retreat, NASA's people settled for what they could get from a reluctant government—not the space station of their desires, but a vehicle that can go to and from the space where they believed the station would someday be. In its development the shuttle has gobbled up NASA's resources, causing the demise of the reliable *Titan-Centaur* that launched the *Vikings* and *Voyagers*, and delaying and dislocating numerous other programs. The shuttle cannot support human life for more than a few weeks in orbit. In comparison, the American *Skylab* and the Soviet *Salyut* craft could do so indefinitely. (*Salyut 6*, with its *Soyuz* and *Progress* resupply vehicles, has been occupied by relays of cosmonauts since 1977.)

Thus, in the short run there are some negative aspects of the shuttle, and its new capabilities have been attained at a major cost to other programs. However, it is not just another launch vehicle. Because it is reusable, it can indeed bring human orbital flight into the realm of everyday affairs. The economics of this are controversial—many flights must be made before the investment in reusability begins to pay off—but in the long run it will pay off, and then routine Earth-orbital operations may lead to renewed public support for ventures farther out. Multiple shuttles, each carrying a thirty-ton payload, could then assemble and fuel a large departure vehicle in low Earth orbit, enabling us once again to fling astronauts into deep space.

In the years since the collapse of *Apollo* and its Soviet manned-lunar competitor, we humans have been confined to the neighborhood of Earth, just as the ancient Phoenicians were confined to coastal sailing by a navigation technology that seldom took them out of sight of land. Nevertheless, the Phoenicians achieved remarkable discoveries, and so shall we—through the use of space telescopes, the European *Spacelab* and other instruments in the shuttle. Experiments in life support, orbital manufacturing, energy conversion and off-Earth agriculture are all possible in low Earth orbit. The great *Apollo* vehicles, resembling some ancient ships that boldly and unexpectedly crossed oceans to leave mysterious artifacts and legends upon far-distant shores, are extinct. But their traces

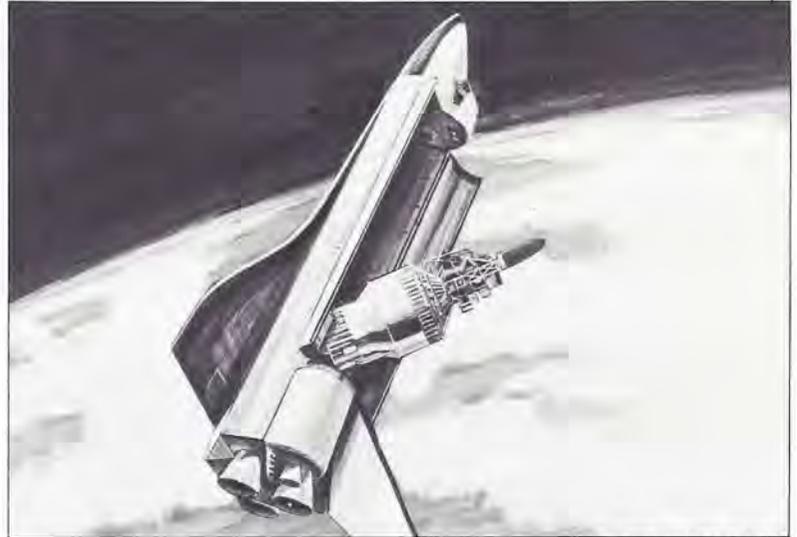


Photo: JPL/NASA

Space shuttle orbiter with a high-energy upper stage (to be derived from the Centaur) and a spacecraft destined for a planetary voyage. When fully operational, this system will provide performance comparable to that of the Titan-Centaur that launched the Vikings to Mars and the Voyagers to Jupiter, Saturn and beyond. The first planned use of the shuttle/Centaur is the Galileo mission to Jupiter, now scheduled for launch in 1985.

rest silently on the Moon and the spirit that put them there is alive. All in good time we shall pass from the age of the Phoenicians to the age of Magellan, Columbus, Hudson, Drake and Cook. As the versatile space shuttles and their Soviet counterparts spread our culture along the coastline of this island Earth, brave little expeditions will once more set out upon the great ocean beyond. Then the true promise of the shuttle for deep-space exploration will begin to be fulfilled.

Konstantin Tsiolkovsky wrote, "Earth is the cradle of reason, but one cannot live in the cradle forever." Perhaps America's failure to build a large, low Earth orbiting space station will prove fortunate, for it leaves open the possibility that our first permanent habitat off Earth could be designed and located to use the resources of the Moon. In future issues of the *The Planetary Report*, we shall discuss that prospect.—JAMES D. BURKE

SOLAR SAILING: A Frontier Transportation System

by Chauncey Uphoff

Low-cost transportation is essential for the development of a new frontier. To be truly effective, the transportation system should be capable of using local fuel—that available at the frontier. A recent example is the wood-burning steam locomotive used in the expansion and development of the American West. When the trains ran out of fuel, the operators had only to stop and cut more wood. A more elegant example is the sailing ship used to obtain access to the resources and elbow-room of the New World.

Recognizing this essential element in the development of a new frontier, Robert Staehle founded the World Space Foundation, an organization dedicated to the exploration and development of space, the largest

frontier. The basic requirement of frontier transportation forms the rationale for the Foundation's Solar Sail Engineering Development Mission, a project to demonstrate the viability of solar sailing as a low-cost, deep space propulsion system.

When sunlight is reflected from a shiny surface, there is a tiny reaction force, not noticeable in our everyday life, but persistent and plentiful enough in deep space to supply the energy and reaction mechanism for a propulsion system that requires no on-board fuel. A solar sail is basically a mirror in space capable of collecting and redirecting the momentum of light from the nearest star to change the velocity of the sail and its attached payload.

Light sails are not exactly the same

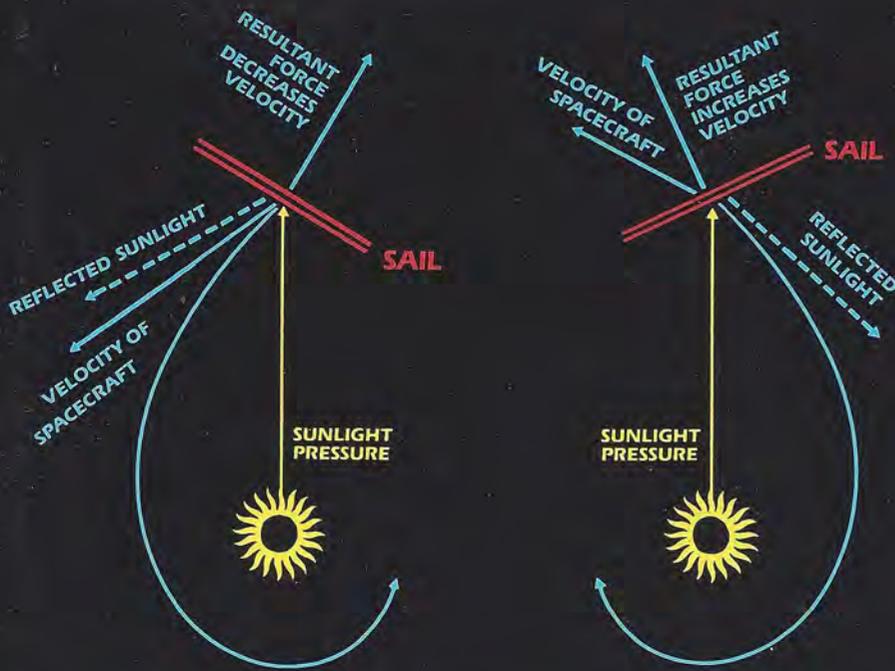
as wind sails because photons (little bundles of light) are not like air and because there is no water in space for the keel of a ship to react against. Even so, the analogy between wind sailing and light sailing is pretty close. While a wind sailing ship can direct a sizeable proportion of its thrust into the wind, a solar sail cannot get any component of its thrust directed toward the sun. However, as we shall see, because of orbital mechanics it can travel either toward or away from the sun. Neither type of sailing requires that fuel be carried along with the ship.

The thrust developed by a solar sail, even a large solar sail, is so small as to seem insignificant until it is realized that the tiny force can be applied constantly during the trip. Thus, a solar sail



HOW A SOLAR SAIL WORKS

A solar sail is a mirror that uses sunlight to obtain a propulsive thrust. As each photon bounces off the sail, the reversal of its momentum shows up as a reaction force perpendicular to the sail. To go inward toward the sun, the operator sets the sail to reflect sunlight along the sail's velocity vector (direction of motion) in its orbit around the sun. The thrust is then opposed to the motion around the sun and the sail slows down. Solar gravity then pulls the spacecraft inward and the sail spirals in toward the sun. The process is reversed to sail outward to Mars, the asteroids, and the outer planets. It is theoretically possible to build a sail so light that it would "feel" no gravity from the sun and go off in a straight line away from the solar system.



developing an acceleration of only one millimeter per second each second can change its speed by 31.6 kilometers per second during a one-year trip because it has 31.6 million seconds to apply the thrust. The application of that much impulse per unit of payload mass would be more than enough to reduce the orbital speed of a spacecraft in Earth's orbit around the sun—enough to drop the spacecraft into the sun. If such a feat were attempted using ordinary chemical propulsion, it would require over 55,000 tons of fuel per ton of payload.

But the thrust of a solar sail cannot be directed just anywhere; it must be pointed, by changing the orientation of the sail, to get the maximum change in the spacecraft energy. Only about 38 percent of the full thrust of a sail can be directed against or along the orbital velocity vector for a sailing spacecraft in circular orbit around the sun. Typical sailing trajectories to the inner solar system would use the transverse component of solar pressure to slow down the spacecraft in orbit. The solar gravity, acting as a distant analog to the keel of a wind sailing ship, pulls the spacecraft inward, even though no component of thrust was ever directed inward. The ship then spirals inward toward the source of its energy.

Using this elegant propulsion system, it is possible to deliver remarkable payloads to most objects in the inner solar system. During studies at the Jet Propulsion Laboratory several

years ago, it was shown that a square sail 800 meters (about one-half mile) on a side was capable of delivering itself and a 1500 kilogram (about 3300 pounds) payload to rendezvous with the comet named for Edmond Halley. The same sail, taking a slow trajectory to Mercury, could deliver payloads of 20 to 40 tons into close Mercury orbit in only a few years.

But the best part is yet to come. Once the payload has been delivered, the sail can pick up an equal cargo and return to Earth. This capability is a direct result of the lack of need for fuel. When a rocket runs out of fuel in deep space, it must stay in its final orbit; when a sail delivers its payload, it can turn around and come home. This continuous thrust aspect of the solar sail also led Jerome Wright to suggest its use as an interplanetary shuttle, a deep space vehicle that can have a regular "run" from Earth to Mars or Venus or both, sunward to Mercury, or outward to the asteroids, and return with valuable scientific samples or, ultimately, with cargos of minerals and chemicals for the expansion of our civilization into the cosmos.

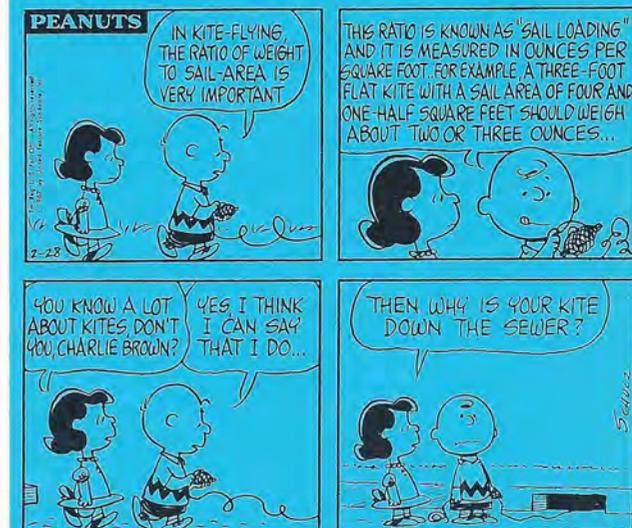
It is the simplicity of the solar sail that makes it so attractive as a long-term transportation system. Once deployed, the sail requires few moving parts for attitude control. Studies have shown that a single sail sheet of ultrathin aluminized plastic film can be expected to survive for many years in space and that refitting a solar sailing

craft with new sails will be relatively easy and inexpensive if done in space near Earth.

These advantages are the major reasons why the World Space Foundation is committed to the development and demonstration of the first solar sail in this part of the galaxy. Many individuals and organizations are now providing funding and engineering knowhow for one of the most exciting developments since the invention and demonstration of the Wright brothers' 1903 flyer.

Chauncey Uphoff is a senior member of JPL's Mission Design Section and a consultant for the World Space Foundation. Members who would like more information should write to: Solar Sail Project, World Space Foundation, P.O. Box Y, South Pasadena, CA 91030.

LEFT: The miles-long blades of the heliogyro, one solar sail concept, are kept rigid by the slow spinning of the spacecraft. Other sail concepts include a simple square sheet or a spinning disc.



THE SPECIAL CASE OF

When the theologians of the Roman Curia forced Galileo Galilei to abjure his belief in a heliocentric (sun-centered) universe in 1633, they may have thought that a long and difficult case had been put to rest. Little did they know that Galileo's case would still be debated nearly three and one-half centuries later. Because it posed one of the major philosophical quandaries of the modern era—the relationship between faith and science—Galileo's case is brought up from time to time and discussed in scholarly and popular circles. Recently it has been resurrected by the Catholic Church itself.

On October 22, 1980, the Vatican announced that Galileo's trial will be reopened. This move was the culmination of a long campaign by Swiss and French scientists spearheaded by a French scholar, Father Dominique Dubarle, a member of the Dominican Order. The Dominicans were much involved in the Inquisition, the organization within the Church which prosecuted Galileo. It seems poignant that a member of that same order now leads the movement to reopen Galileo's trial; *Newsweek* called it "a certain symmetry that might have appealed to Galileo himself."

Dubarle began his appeal in the early 1960's. Pope John XXIII—who is credited with updating the teaching, discipline and organization of the Church in the twentieth century—died before taking action on Dubarle's request, and his more cautious successor, Pope Paul VI, was unreceptive to Dubarle's plan.

John Paul II, however, has enthusiastically supported Dubarle's plea. At a session of the Pontifical Academy of Science held November 11, 1979, the Pope spoke on the case of Galileo: "I hope that theologians, scientists and historians, imbued with the spirit of sincere collaboration, will more deeply examine Galileo's case, and by recognizing the wrongs, from whatever side they may come, will dispel the mistrust that this affair still raises in many minds, against a fruitful harmony between science and faith, between the Church and the world." The Pope discussed a number of Galileo's beliefs, indicating the direction to be taken for an "honorable solution" of the problem.

Galileo's case began in 1616 after he spoke out decisively for the Copernican system, which posited the Sun as the center

of the universe rather than the Earth (as was held in the Ptolemaic system). A committee of eleven theologians ruled that the Sun-centered universe was "philosophically foolish and absurd and formally heretical." Copernicus' book describing the new system was "suspended until corrected," and Galileo was admonished not to hold or defend the Copernican view.

After Pope Gregory XV died and Cardinal Maffeo Barberini became Pope Urban VIII in 1623, Galileo requested permission to write a book discussing the Copernican system, giving the geocentric Ptolemaic system fair and equal treatment. Pope Urban, a good friend of Galileo, had opposed the actions of the Holy Office of the Inquisition in 1616 and now granted permission for Galileo to write the book. Galileo produced *The Dialogue Concerning the Two Chief World Systems*, published in Florence in March, 1632. It stirred great controversy, as it appeared that Galileo had attempted to prove the Copernican system and make a fool of Pope Urban VIII. A special commission of theologians was appointed to investigate the work and Galileo was called to Rome.

He was charged with treating the Copernican system as a true description of nature rather than an hypothesis and with being "fraudulently silent" about a command given to him in 1616 not to "hold, teach or defend the new astronomy in any way, either verbally or in writing." This latter charge was based on a document produced by the Holy Office of the Inquisition which, though technically irregular (it was initialed, not signed), was not a forgery as some scholars have thought.

Galileo refused to admit that he had tried to prove the Copernican system, and was found guilty. *The Dialogue* was banned, Galileo was condemned as being vehemently suspected of heresy, forced to kneel and abjure the Copernican system and sentenced to prison. Although he was never imprisoned, Galileo did remain under house arrest for the rest of his life.

The case quickly became a symbol of freedom of inquiry quashed by authority. John Milton cited the fate of Galileo in his *Areopagitica*, in which he pleaded for uncensored publication and liberty of conscience. In the works of French writers of the Enlightenment, Galileo was a symbol of religious persecution. In twentieth century iconography, his case remains an

example of freedom of thought versus authority and dogma.

The recent steps taken by the Church to reconsider Galileo's trial are not the first attempt to make amends. In 1724, under the pontificate of Clement XII, the Holy Office of the Inquisition authorized the construction of a monument over Galileo's tomb. Though Galileo died with the Pope's special blessing and was buried in consecrated ground (in the church of Santa Croce in Florence), Urban VIII had not allowed a memorial to be erected over his grave. In 1757, under Benedict XIV, the Sacred Congregation of the Index removed the ban on the works of Copernicus and others espousing the heliocentric system. In the twentieth century, works by Catholic authors have been conciliatory. In an article in the *New Catholic Encyclopedia*, J. J. Langford says of the treatment of Galileo, "however it might be explained, it cannot be defended."

Some Galilean scholars, especially in this century, have reservations about reopening the Galileo case. "I'm not at all sure," Ernan McMullin, chairman of the philosophy department at the University of Notre Dame, said in an interview, "if it makes any difference to rake all this up again." McMullin feels that the recent emphasis on Galileo himself "is drawing attention in the wrong way." The important issues to address, according to McMullin, would not be Galileo's trial, but the condemnation of the Copernican system in 1616 and the human predicament of a scientist faced with two sources of "truth."

According to William A. Wallace of the Catholic University in Washington, D.C., no actual retrial is planned. Members of the Pontifical Academy of Sciences are planning a conference on Galileo's case for either 1982 or 1983. The former would mark the 350th anniversary of the publication of *The Dialogue* and the latter would mark the 350th anniversary of Galileo's trial. [EDITOR'S NOTE: Today scientists still must deal with the issues raised by the trial of Galileo. The conflict between the Ptolemaic and Copernican systems echoes in the debate over differing theories of the evolution of the universe and life.]

Maureen Miller begins graduate school in Fall, 1981, at Catholic University, Washington, D.C., to study medieval history.

GALILEO GALILEI

by Maureen Miller



BLOCK PRINT: S. A. SMITH

ICE WORLDS

Science fiction writers describing imaginary planets use recurring themes: desert worlds like Tatooine (*Star Wars*) and Arrakis (*Dune*), and jungle planets like Dagobah (*The Empire Strikes Back*). A third type is often the most striking—ice-bound planets with severe, stark-white landscapes with glistening highlights, scenes of utter desolation swept by bone-chilling winds. Hoth (*The Empire Strikes Back*) is one such place. There are, however, real worlds in the Earth's neighborhood as strange and wonderful as these fantasy planets. These are the icy moons of the giant outer planets.

Galileo discovered the four large satellites of Jupiter in 1610, and, with good binoculars or a small telescope, they are easily seen as starlike points

of light that vary their position around Jupiter from night to night. Modern telescopic observations have revealed much about these satellites, and those of Saturn as well. In some cases, sunlight reflected by them is diminished in certain wavelengths (or colors). These subtle variations, called absorption features, are the compositional fingerprints of water in its various forms and indicate surfaces rich in snow and ice.

There is other evidence of the composition of these satellites. By carefully measuring satellite positions, the gravitational effects of each satellite on its companions have been determined. From these determinations, the mass of each satellite has been calculated. By studying how light intensity varies as a satellite moves into Jupiter's or

Saturn's shadows (eclipse), behind a bright edge of a planet (occultation), as the Earth's Moon blocks light from a satellite, or as the satellite moves in front of a distant star, the diameter and volume of the satellite can be crudely determined. The ratio of mass to volume then gives the satellite's density.

Many earth materials have densities of 2.5 to 3.5 grams per cubic centimeter (gm/cm^3). Water has a density of $1.00 \text{ gm}/\text{cm}^3$ as a liquid and $0.92 \text{ gm}/\text{cm}^3$ as ice. Iron has a density of $7.9 \text{ gm}/\text{cm}^3$. Mixing various quantities of these materials, thought to be the most abundant building blocks of solid planets and satellites, can produce a wide range of planetary densities. Scientists use these numbers to construct models that they compare against observed satellite densities. Using this



LEFT: Callisto's dark surface is marked by craters surrounded by light-colored material excavated from the satellite's surface by small bodies like asteroids and comet debris. The large impact basin (top) was probably formed by a collision with a large body that may have come close to penetrating the icy crust. Concentric rings spreading out from the central crater, like waves around a stone thrown in a pool, suggest the feature was formed when the ice was softer and more flexible.

ABOVE: Ridges, grooves and rayed impact craters mark the face of Ganymede, the largest satellite explored so far. The bright rays extending from the crater in the lower left are probably composed of icy materials scattered about by a collision with cosmic debris. Fractures in the crust, releasing water or ice sludge onto the surface, may have formed the ridges and grooves.

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method, three of the four largest Jovian satellites (Europa, Ganymede and Callisto) were found to have densities so low that these moons must possess large amounts of water and/or ice, unlike Earth and Mars, which contain rock-forming materials and significant amounts of iron. The bodies of these satellites are probably mixtures of frost and dust.

What sorts of worlds are these? Let us examine them from the perspective afforded by the *Voyager* spacecraft. Europa, about the size of the Earth's Moon, has a bright, nearly white surface of unusually low relief, crisscrossed by dark lines. They appear to have been formed through internal processes driven by the loss of heat generated in the satellites' formation and by torques due to enormous

tides raised by the giant planet Jupiter. Europa is most likely watery only to a depth of maybe 100 kilometers (about 61 miles) — beneath that may lie a body not unlike our own Moon. A buried ocean of liquid water could exist beneath a thin (about 20 kilometers) ice layer to a depth of perhaps 80 kilometers. But it is more probable that the crust is ice all the way to the surface of the buried, moon-like body. An alternative conceptual model of Europa spreads the water throughout the entire satellite, making it a well-stirred mixture of rock-forming materials with a slight component of water. This model, applied to Europa and other satellites, could be termed the "icy mudball model."

Ganymede and Callisto, two other Jovian satellites, are also probably ice

worlds. Callisto, about the size of the planet Mercury, has a dark, heavily cratered surface spotted by bright white ejecta patterns of the youngest craters. Large, multiple-ringed craters suggest that when they were formed the ice of Callisto was soft and could spread out more easily. Large impact craters on Ganymede, Callisto and Europa show evidence of modification by the creep of ice, much as glaciers creep on Earth. Because of "relaxation" of the ice, they are now shallower than when originally formed.

Callisto's density suggests a composition of nearly 50 percent water. If it contains so much ice, why is its surface so dark? Either the dark material is dust gathered from space by Callisto over billions of years, or the ice is
(continued on next page)



ABOVE: Ganymede's complex patterns of ridges and grooves show clearly in this photograph covering an area about the size of Pennsylvania. Resembling a mountain system, the ridges are about ten to twenty kilometers apart and approximately one kilometer high. A craters (left, center) is crossed by ridges, indicating it predates crustal deformation that created the ridged and grooved terrain.

RIGHT: Polar frost caps were revealed by *Voyager 2* as it photographed the dark side of Ganymede that faces away from the sun. Regio Galileo, the dark area in the upper right, is the largest remnant of the ancient, heavily cratered crust of the satellite. The bright white spots are craters, partially buried in the underlying, cleaner ice.



PHOTOS: JPL/NASA

(continued from page 9)

mixed throughout the satellite (an "icy mudball"), and we're seeing the top of this dust and ice mixture.

Ganymede, the largest of Jupiter's satellites, also has a dark, cratered surface in places, probably for the same reasons. Two other features are of interest: broad, bright bands of grooves and ridges that cut across the dark regions, and polar frost caps. The surfaces of Ganymede and the other icy satellites of Jupiter are very cold (-120°C, -190°F). Water vapor blasted from the surface by meteorite impact will migrate to the polar regions and condense, because those regions are even colder. Owing perhaps to a difference in the abundance of ice in their uppermost crusts, Ganymede shows the results of this polar condensation while

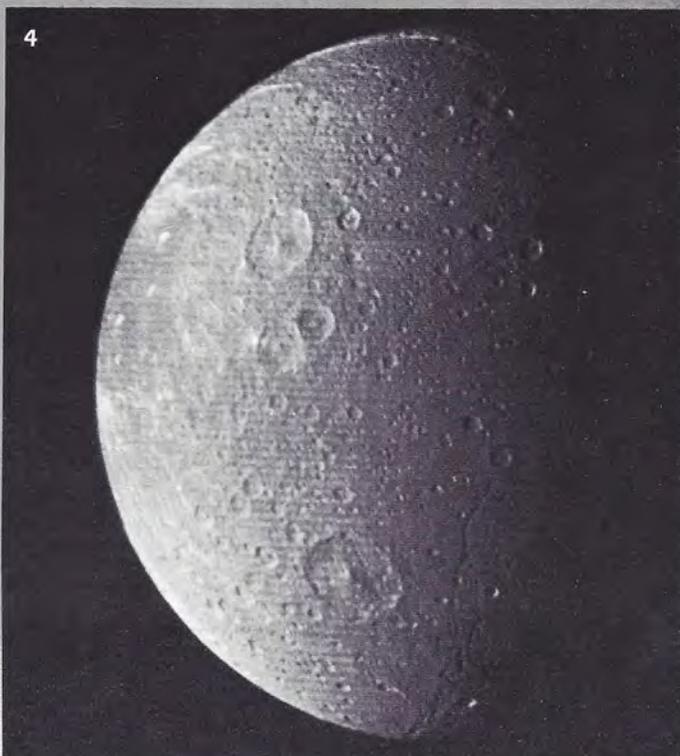
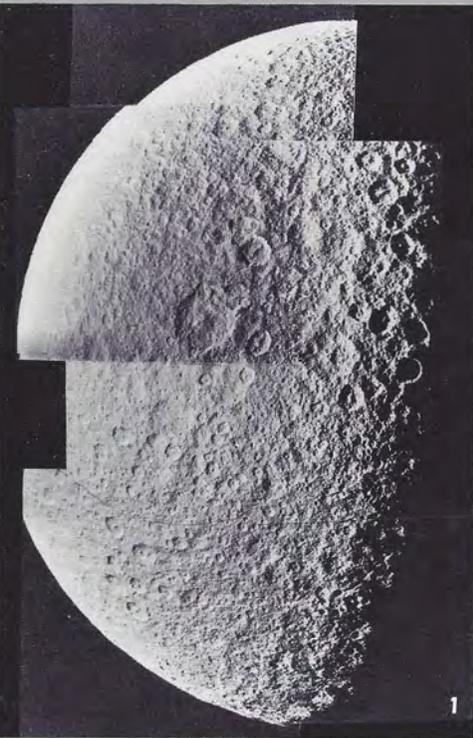
Callisto does not. Ganymede's unique ridged and grooved terrain probably results from fractures opening in its crust and torrents of water or ice sludge flowing out onto the surface.

Many of Saturn's satellites also appear to be composed of water, ice and dirt mixtures. Most are bright and have low densities (between one and two grams per cubic centimeter). However, these satellites look very different from Jupiter's. Those seen close up by *Voyager 1* all appear heavily cratered. Mimas, for example, has many craters, including one at least 100 kilometers in diameter. This crater, like many large ones on Rhea and Dione, does not appear to have experienced relaxation as have similar craters on Ganymede and Callisto. Scarps (as seen on Dione) and troughs (as seen on

Tethys) have greater relief and are much larger than the most comparable features on satellites of Jupiter. What causes these differences? Perhaps a differing amount of ice or the 50°C colder temperature make Saturn's satellites stronger — we just don't know.

In any case, these satellites are certainly among the most exotic worlds in our solar system. Though they lack atmospheres and the blowing, icy winds of Hoth, their surfaces are at least as unusual as any imagined by science fiction writers. But these are real places; places that, even as they become more familiar through exploration, will never quite lose their alien complexities.

Dr. Michael C. Malin is an Assistant Professor of Geology at Arizona State University, Tempe.



- 1) Icy Rhea is one of the most heavily cratered bodies in the solar system.
- 2) The long trench crossing Tethys may have been created by a fracture in the small, icy moon.
- 3) The collision which formed the giant "eyed" crater on Mimas may have come close to breaking apart the small, icy satellite.
- 4) The sinuous valley (top) running across Dione has greater relief and is much larger than similar features on the Galilean satellites of Jupiter.

WASHINGTON WATCH

by Louis Friedman

President Reagan announced his intention to nominate Dr. James Beggs of General Dynamics Corporation as Administrator of NASA, and Dr. Hans Mark, former Secretary of the Air Force and, prior to that, Director of NASA's Ames Research Center, as Deputy Administrator. Dr. Mark was one of our Board Advisors and a charter member of The Planetary Society. As Deputy Administrator of NASA, he will not be able to continue on our Advisory Board, but has assured us that he will continue his interest in the Society and its goals of encouraging a vigorous program of exploration of the solar system. Just before he resigned from our Board, I had a candid interview with Dr. Mark which may be presented in a future issue of *The Planetary Report*.

In previous discussions in this column we explained the Congressional budget process which is now underway. It is during these months that the final reconciliation of the Budget Committee, Authorization Committee and Appropriations Committee actions is made so that the real content of the program can be planned. While no new starts were proposed for NASA, there is still considerable interest in a Halley's Comet mission. In reading the large amount of mail that we receive, and in giving many public talks, I have been extremely impressed with the popularity of a Halley's Comet mission. Fortunately, the option to do a mission to Halley's Comet is not completely closed. In the next few weeks we will be conducting a major public information campaign about the mission and how citizens can take effective action if they want to see it launched. The imaging capability of the mission is described in the box below.

There was considerable enthusiasm and, of course, a great deal of elation over the success of the first manned orbital flight of the space shuttle. This enthusiastic reaction to the flight, not only in

America but around the world, was a surprise to some people in Washington. Once again, there was an opportunity for people to express pride for a job well done. Ironically, recent budget actions have threatened the utilization and exploration of space as promised by the shuttle.

The Reagan Administration is interested in stimulating the private sector to play a greater role in developing space opportunities. Most of this interest centers around the programs in space applications rather than deep space exploration, which is usually understood to be a government endeavor. The formation and rapid growth of The Planetary Society is, we believe, a manifestation of the great interest that people have to themselves be part of the space program rather than to have it completely run by the federal government. The missions themselves, of course, should be carried

out by our nation and others in the international community. But we are discussing a greater role for private organizations in sharing the results of exploration. The Pasadena Planetary Festival, described on page 12 of this issue, is one such effort, as was "The Case for Mars" conference we co-sponsored in May. We recently participated in a Washington meeting to discuss private sector involvement in the Halley's Comet mission. There may well be a positive role for such involvement and, if developed, it could be a great stimulus to space exploration—as long as it does not weaken the resolve for a NASA mission to Halley's Comet.

Louis Friedman, Planetary Society Executive Director, spent one year as a Congressional Fellow with the Senate Committee on Commerce, Science and Transportation.

CALENDAR OF EVENTS

VOYAGER 2 Encounter with Saturn

August 23-25

PLANETFEST '81, THE PASADENA PLANETARY FESTIVAL. See announcement on page 12 for details. August 23: Tours of JPL, space music concert; August 24, 25: Tours, exhibits, films, panel discussions. Reservations are mandatory.

August 24-28

LIVE BROADCASTS OF ENCOUNTER EVENTS. Time has been reserved on the SATCOM 1 communications satellite for live broadcasts of encounter events from JPL. Broadcast times are 8:00-9:00 pm (EDT) each night, plus 9:00-9:30 pm (EDT) August 25, the day of closest approach. Many cable services and educational stations are able to receive and broadcast these shows. Ask your local station about its planned encounter coverage.

August 25-26

CLOSEST APPROACH TIMES (EDT) of *Voyager 2*:

(Times are for the reception of the spacecraft's signal at Earth.)

TITAN: 7:21 am, August 25	SATURN: 12:51 am, August 26
DIONE: 10:32 pm, August 25	TETHYS: 3:39 am, August 26
MIMAS: 12:02 am, August 26	RHEA: 3:55 am, August 26

Halley's Comet Mission

Of the several planned or proposed missions to Halley's Comet, only the United States' Halley Intercept Mission features an Observatory Phase. By observing the comet for two months prior to closest approach, the U.S. spacecraft would provide information not presently available about any comet nor otherwise obtainable during the apparition, including the two- to three-week period around the perihelion when the comet is not observable from Earth because of its proximity to the Sun. The U.S. spacecraft's cameras, shielding and navigation would enable us to obtain higher resolution pictures of the nucleus than those obtainable by either the European Space Agency's *Giotto* spacecraft or the U.S.S.R.'s spacecraft. Japan's *Planet A* mission, designed for a distant flyby, will not carry a camera. The cameras aboard the U.S. spacecraft would be able to resolve features the size of a basketball court on Halley's nucleus from a distance of over 500 miles! None of the other missions has this capability. More than 8,000 pictures would be obtained by the U.S. spacecraft during the mission.

News & Reviews

by Clark R. Chapman

The most significant of NASA's scientific enterprises during the past two decades was the return and analysis of rocks from the Moon. The moonrocks are not the only samples of extraterrestrial materials being studied in research laboratories. Now the procedures and facilities developed to catalog and preserve moonrocks, and allocate them to scientists around the world, are being used for another collection of unearthly rocks that may prove as important for understanding the origin of the solar system as were the *Apollo* samples: meteorites and cosmic dust particles that continually fall to Earth.

I recommend the special supplement of six articles, celebrating the new Arthur Ross Hall of Meteorites at New York's American Museum of Natural History, published in the April, 1981 issue of *Natural History*. In the two centuries since meteorites were recognized to be rocks from interplanetary space, only about ten per year have fallen and been recovered from all around the world, writes Brian Mason. But the snow-swept landscape of Antarctica has yielded more meteorites during the past few years than had been collected in the previous two centuries. Polar explorers from America and Japan have brought over three thousand well-preserved meteorites back to the moonrock facilities at the Johnson Space Center in Houston.

The past decade has also seen remarkable progress in

Celebration of a Milestone in Space Exploration

Planetfest '81, the Pasadena Planetary Festival sponsored by The Planetary Society, will be held August 23-25, 1981, in conjunction with the *Voyager 2* spacecraft encounter with Saturn. The Festival will commemorate completion of the initial reconnaissance, begun in 1962, of that part of the solar system—the Moon, Mercury, Venus, Mars, Jupiter and Saturn—known prior to the invention of the telescope in the 17th century. Festival activities will take place at The Pasadena Center in Pasadena, California, near the California Institute of Technology and the Jet Propulsion Laboratory.

The Festival's program of events will be centered around the live transmission of pictures from *Voyager 2* as it passes Saturn and its rings and satellites, and will include exhibits, demonstrations, films and large screen video projections, presentations, a space music concert conducted by John Williams, lectures, panels, seminars and discussion groups. Festival participants will get a first-hand look at the vast range of scholarly disciplines necessary in planning and carrying out successful space exploration, and tours of area facilities will offer a glimpse of the scientific community at work. Winning students of The Planetary Society's national essay contest will be honored at an evening show emphasizing the Festival's theme of a celebration of youth, achievement, and science.

Blocks of rooms have been reserved at the Holiday Inn and the Hilton Inn in Pasadena for Festival participants. Other motels and hotels are also available. Reservations for the Festival and for lodging will be the responsibility of each individual and should be made as soon as possible. Advance registration for the Festival and further information may be obtained by writing to PLANETFEST '81, The Planetary Society, 110 South Euclid Avenue, Pasadena, CA 91101.

Admission to all Festival events will be open only to participants holding pre-purchased tickets. Planetary Society members will receive discounts and priority to tickets for the public events.

collection and analysis of the extraterrestrial dust that settles through the Earth's atmosphere. These rare cosmic dust grains are overwhelmed by billions of times as much common dust near the Earth's surface, but far less terrestrial dust reaches the ocean depths. So, with a magnetic rake, tens of thousands of tiny meteoritic spherules, ranging from near-invisibility to about a millimeter in size, have been collected from ocean-floor sediments. Donald Brownlee, author of the *Natural History* article on cosmic dust, has collected more than 500 pristine extraterrestrial particles from U-2 airplanes flying high in the stratosphere. His analysis suggests that these bits of interplanetary debris come mainly from comets and differ in important respects from the larger rock fragments that are recovered as meteorites. Lawrence Grossman describes a huge but rare type of meteorite that crashed in 1969 in the Valle de Allende in Mexico. It contains clues about the pre-solar supernovae that contributed heterogeneous material to our forming solar system. John Wood writes about the evidence recorded in meteorites concerning the early history of "planetesimals", which accumulated into large planets, and of asteroids, which failed to do so.

There are some new ideas that asteroids orbiting between Mars and Jupiter may be double or have one or more satellites orbiting about them. According to journalist Richard A. Kerr, writing in the March 20, 1981 issue of *Science*, the observational evidence for asteroidal satellites remains controversial, but some theoreticians are taking this new view of asteroids seriously.

Another object that was presumed to be a single body, but has been found to be double, is Pluto. Its eccentric orbit has now brought it temporarily closer to the sun than Neptune. Judging from some of the articles in the special Pluto issue of *Icarus* (dated October, 1980), there is some argument about whether this small double world, whose larger component is smaller than our Moon, even qualifies as a planet. Brian Marsden, in his *Icarus* article, "Planets and Satellites Galore," suggests that Pluto is more properly lumped with the outer solar system "asteroids" Chiron and Hidalgo, due to its size and orbital characteristics. But a group of University of Arizona astronomers, who have discovered beyond any doubt that Pluto possesses a thin atmosphere of methane, disagree: "We feel that the recent discovery of its satellite, and the present detection of an atmosphere, will do much to enhance its image and establish Pluto as a more regular and respectable member of the planetary community."

Earth-based activities will continue to be a major focus of planetary research during the 1980's—until plummeting budgets for NASA space science programs get reversed and new spacecraft missions are approved—and until the space shuttle becomes operational. Planetary scientists have had a love/hate relationship with the shuttle during its troubled development. It has gobbled up funds, leaving none for new planetary missions, and its delays have postponed the launch of the *Galileo* Jupiter mission until at least 1985. Yet the shuttle will be our only bridge to the planets during the foreseeable future. Planetary Society members can learn more about the shuttle in a two-part article by Henry S. F. Cooper, Jr., in the February 9, 1981 and February 16, 1981 issues of *The New Yorker*. Cooper tells you everything you ever wanted to know about the shuttle and about Spacelab experiments planned for the future—if they are ever restored to the budget.

Clark Chapman, of the Planetary Science Institute in Tucson, Arizona, is a member of the Galileo Imaging Team.

BY CONWAY SNYDER

This mosaic of pictures taken by Orbiter 1 early in the *Viking* mission is one of the best views that we have of a portion of the great complex of canyons that *Mariner 9* discovered, named Valles Marineris. It was taken on July 3, 1976, from a range of 2000 kilometers, looking south at a side canyon called Ganghis Chasma, situated at 10° south, 48° west, about 1900 kilometers south of the spot where Lander 1 touched down three weeks later.

At the upper right and lower left is a fairly smooth, lightly cratered plain into which the canyon was cut. (The small dark doughnut is a diffraction pattern from a speck of dust on the camera's faceplate.) In the upper left the surface seems to have been eaten away from beneath, collapsing into chaotic depressions. This process, called "sapping," results from the removal of underground water or ice. Its effect appears to have been widespread in altering and eroding the canyons, which were originally formed by tectonic activity; i.e., the motion of faults in a gigantic series of "Marsquakes" long ago, causing the ground to sink.

Ganghis Chasma is at the eastern end of the Valles Marineris, which extends for about 4500 kilometers. At the point shown it is about 50 kilometers wide. A landslide extends from the south rim 20 kilometers across the canyon floor, leaving an indentation in the wall. To its right and partially covering it, a much larger slide, or series of slides, shows striations marking the direction of flow. The debris from a small slide on the north rim nearly meets that from the southern slides.

In the canyon bottom between the slides are numerous little hillocks, some of which have long bright tails produced by the wind. At the lower left are still larger hills, some of which appear almost perfectly conical.

The widespread evidence of sapping here and in many other places is one of several lines of evidence that have convinced geologists of the presence of great quantities of underground ice on Mars, perhaps almost everywhere. Ground-based radar and spectroscopic data have been interpreted to indicate the presence of liquid water near the surface in the region called Solis Lacus (Lake of the Sun). The interpretation is controversial, as it appears to conflict with the data from the water-vapor measurements of the *Viking* orbiters.

Dr. Conway W. Snyder, of the Jet Propulsion Laboratory, was the Project Scientist on the Viking Mars Missions.

GIANT LANDSLIDES IN THE MARINER VALLEYS ON MARS



PHOTO: JPL/NASA

Society Notes

by Louis Friedman

ONE GOAL OF THE PLANETARY SOCIETY is to support selected areas of research and space activity where limited "seed" money can be used, both for technically sound research and to stimulate a rational, orderly program of government and/or industry research and development. One such selected area is the Search for Extraterrestrial Intelligence (SETI). The relevant NASA technology program has been curtailed and groups working on different aspects of SETI are underfunded or in danger of disbanding. Despite very broad popular support for SETI, we may see this exciting enterprise of humanity abandoned.

Would any event of our — or our children's — lifetimes mean more to our species than detection of life elsewhere?

Book Sales

THE PLANETARY SOCIETY was formed to enhance public awareness and share the results of America's exploration of the solar system. NASA frequently publishes special reports and books on our space missions, available to the public only through a relatively obscure process of ordering from the Government Printing Office. We are pleased to offer five of these NASA publications to members of The Planetary Society. In addition, two other books on the solar system are available. Other books and brochures will be offered in the future. With this service, we hope to help disseminate the results of space exploration.

■ **Voyage to Jupiter**—200 pages—A beautiful description of the results of *Voyager* flybys of Jupiter with many full color photographs. **\$8.00**

■ **PIONEER: First to Jupiter/Saturn and Beyond** 400 pages—A complete description of the two *Pioneer* missions, profusely illustrated. **\$13.00**

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■ **VOYAGER 1 Encounters Saturn**
An illustrated booklet with many of the best pictures from the Saturn encounter. **\$4.00**

■ **VOYAGER Encounters Jupiter**
A colorfully illustrated booklet describing the *Voyager* mission to Jupiter. **\$4.00**

■ **Mars and the Mind of Man**—Hardcover, 125 pages—illustrated results of the *Mariner 9* mission with commentary and discussion by Ray Bradbury, Arthur C. Clarke, Bruce Murray, Carl Sagan and Walter Sullivan. (Out-of-print, only a few hundred copies remaining.) **\$10.00**

■ **The Planets: A Cosmic Pastoral**
by Diane Ackerman. A collection of poems on each of the planets in our solar system. ("Saturn" appeared in the April/May, 1981 issue of *The Planetary Report*.) **\$4.00**

To order books, write to: THE PLANETARY SOCIETY, Book Sales, P.O. Box 3599, Pasadena, CA 91103. Please enclose the full amount indicated after each item (which includes shipping and handling). California residents please add 6% sales tax.

A civilization of even our own level of technological development can transmit a signal thousands of light years. The Search for Extraterrestrial Intelligence is a practical scientific objective, especially the examination of cosmic radio signals. That examination will further radio astronomy research and contribute to discoveries about our universe. We intend that money applied to SETI through the Society be used to support such a search.

The Society's program starts with the formation of an advisory team to recommend areas of funding, the planning of an international conference on SETI to be held within 18 months, a national SETI fund-raising project and the development of a SETI public information program. Details and progress of all of these will be announced in *The Planetary Report*. The fund-raising has begun with a June mailing to members, and will be enlarged with fund-raising events, benefits, advertisements, and the like.

SETI will not, of course, be our only area of research. We have been putting considerable effort into the Halley's Comet program — both to encourage a U.S. mission to the Comet and to promote observations from the ground and Earth orbit. Specific fund-raising for advertising for the U.S. mission has begun. We have co-sponsored *The Case for Mars* conference and are in the process of forming task teams to consider funding important areas currently ignored or needing revitalization — returning to the Moon and Mars, investigating asteroid mineralogy and utilizing celestial resources.

Our first anniversary was observed June 1. Since we announced ourselves and our goals in June, 1980, and since we began membership solicitation in August, 1980, we have grown to more than 65,000 members, making us the largest space interest group in the world. Your continued support — financially and in membership growth and maintenance — will prove it is not a fad but an earnest desire of people everywhere to explore the unknown and discover new worlds.

On our first anniversary, it is appropriate to thank some very special people who have helped The Planetary Society: Mr. Joseph Ryan, and the law firm of O'Melveny and Myers, in Los Angeles, who have donated considerable professional and personal time to us; Mr. James Burke, Technical Editor of *The Planetary Report*, and those who have contributed to our publication; Ms. Linda Beek, Coordinator of the Pasadena Planetary Festival, and the many people working on the Festival.

Many volunteers regularly and significantly have helped us at the Pasadena office in a myriad of ways, especially: Norvin Armstrong, Blythe Bennett, Angela Brown, Lu Ann Coffing, Dave Hagie, Bob Hill, Jeanie Jones, Sue Kovach, Terry Martin, Bonny Lee Michaelson, Ken Savary, R. J. Trembley, Joan Tuzzolino, and Ken Wong; thanks to our Board of Advisors, who have helped us with advice and direction, and Mr. Peter Tagger, our direct mail consultant who has worked with us day and night from the Society's beginning.

And, of course, I must mention the devotion of our two staff members who have contributed a great deal to the Society beyond the call of our duty: Charlene Anderson, Managing Editor of our publication, and Pamela Fields, our secretary and, more often than not, the Membership Representative in our office. □

Murray (continued from page 2)

Another aspect of space exploration is for youth. The young people of this country have got to believe in our future, and there are many signs that they are having problems with that. They mirror the adults; they are too concerned with the "now" sense. But space, and our leadership there, is a way of projecting ourselves into the future and providing an image and leadership symbol for them. And they love it. They really want to believe in it.

In terms of the bread and butter arguments, of course it should be remembered that the money is spent

on Earth. It is not spent in space. The money appropriated is spent on high technology which, by most people's assessment, improves the productivity of the country as a whole. When one is cutting budgets in a general way, one has to worry about the significance of the dollars the federal government spends. However, one argument I subscribe to is that the federal government should try to spend dollars, especially in technology, which are leverage dollars to create an industrial base and a capability to greatly magnify technology, and therefore productivity, in the future.

This has surely been the case in space. Examples are computers and information systems which are revolutionizing our whole economy and contributing significantly to it. We see this in the balance of trade. It is with the high-technology items and in agriculture that we have a positive balance of trade. In the lower-technology items we are losing our shirts, and when we get into oil, we are in deep trouble.

Thus, the results of space exploration provide food for our spirit, carrying it out strengthens our country's economy and its capability. I rest my case! □

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LOMBERG

EARTHFISH—According to artist Jon Lomberg, this painting “symbolizes the major evolutionary leap Earth life is now making. Life appeared in the oceans of Earth and is now moving out into the oceans of space. In another sense, the intricate marbling of clouds and water that appears so exquisite from space illustrates the hypothesis that the biosphere of Earth acts, in some ways, like a single organism, trying to maintain its highly ordered equilibrium.”

Jon Lomberg, astronomical artist and journalist, was the chief artist on Carl Sagan’s television series, Cosmos. He helped design the Voyager Interstellar Record and his artwork has appeared in numerous books and magazines. His radio documentaries about planetary exploration appear regularly on the Canadian Broadcasting Corporation’s program, Ideas.

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