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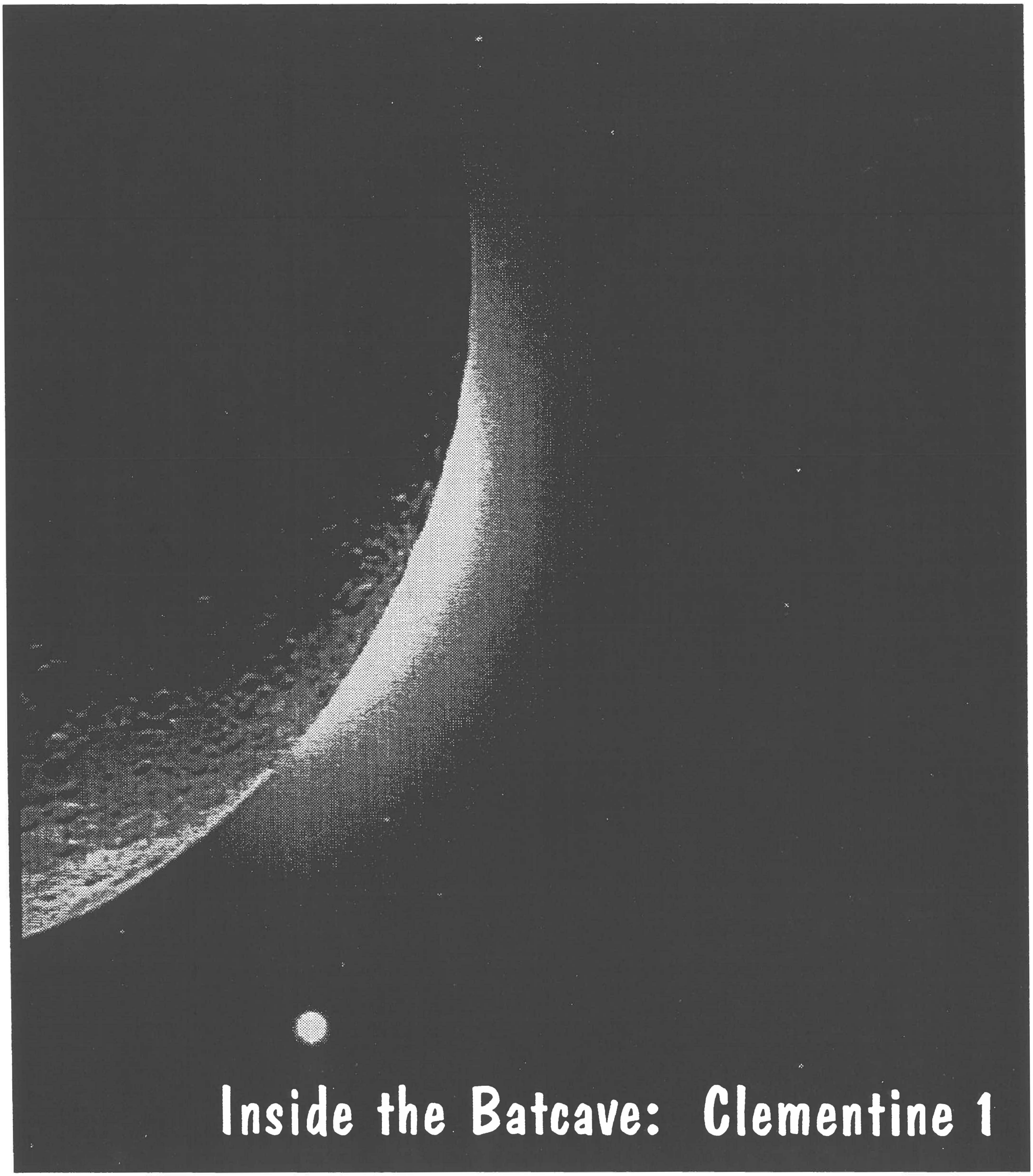
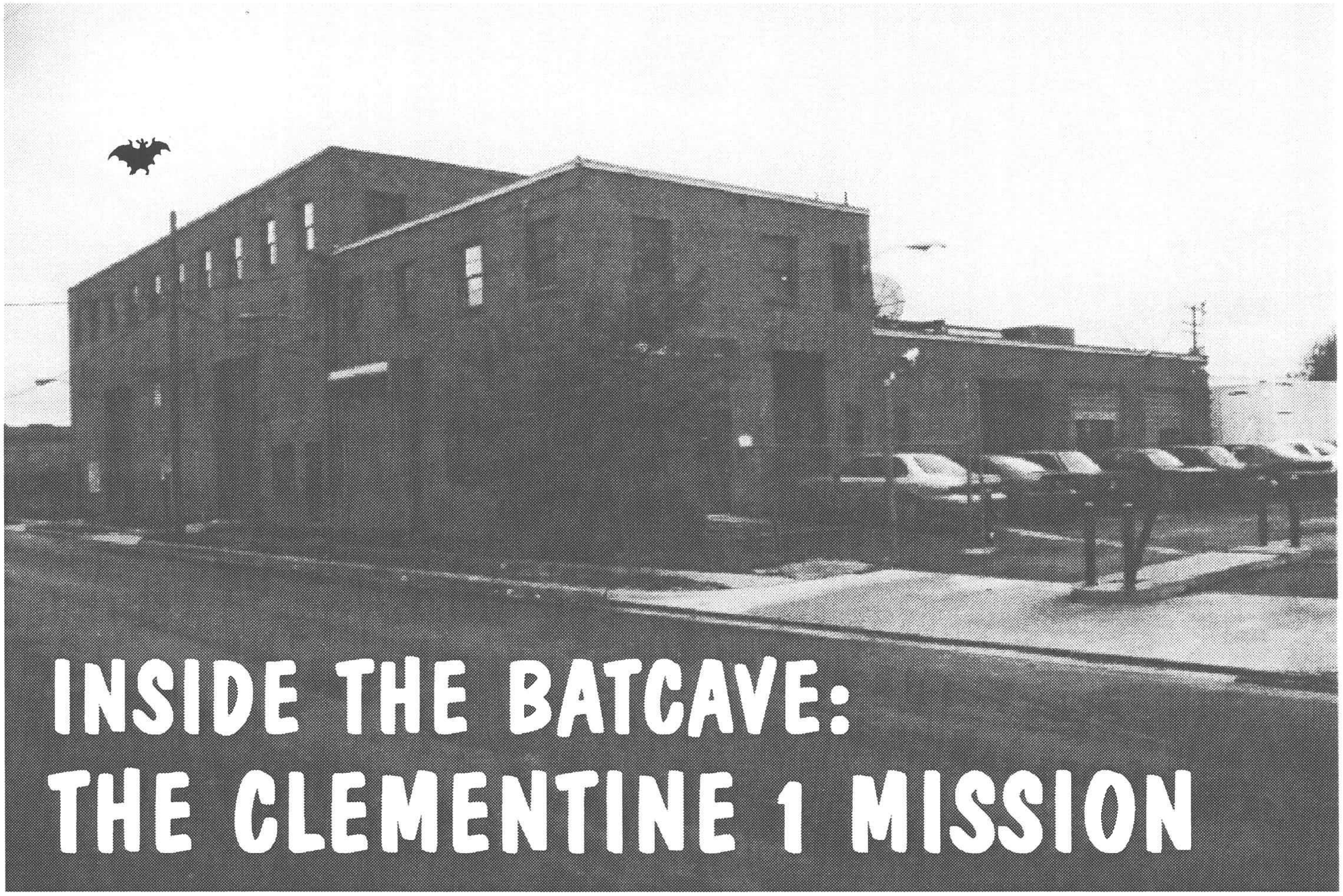




INSIDE THE BATCAVE: THE CLEMENTINE 1 MISSION

LUNAR IMAGES: CLEMENTINE 1; MISSION CONTROL PHOTOS: ANNE SPUDIS

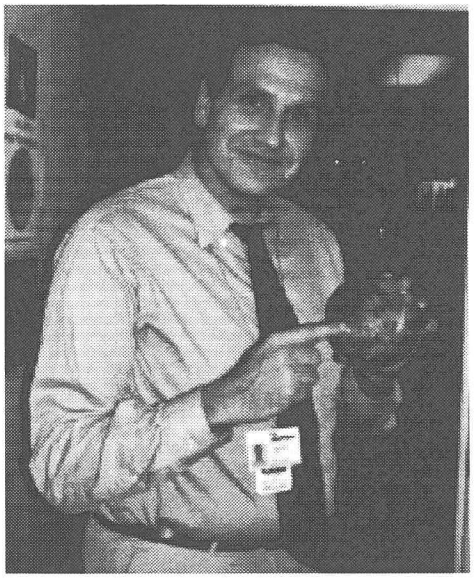
by Jeff Gillis

Here in the suburbs of Alexandria, Virginia, I have been fortunate to experience the meaning behind "faster, cheaper, better" as applied to planetary exploration. My expectations of Clementine were shaped largely by two things. My first impression was formed by word of mouth. I had been told by some that "faster, cheaper, better" gives you science that is boring, second rate, and not any better than we already have. My second impression was formed when I saw the outside of the mission control center for the first time. It is an old brick warehouse that sits across the street from an undistinguished row housing complex. In the movie *Batman,* the corrupt darkness of Gotham City contrasts with the high-tech power inside the Batcave; hence the nickname "Batcave" for Clementine's mission control. I am more than happy to report that as dissimilar as the earthy surroundings outside are to the extraterrestrial pictures on display screens inside, so is truth separated from the concept that "faster, cheaper, better" is not good enough.

Mission control here in Alexandria looks similar to mission control at the NASA Johnson Space Center, except that it's much smaller and has a staff of only 55 people. It has the same quality of high-tech equipment and bright engineers, just a smaller quantity. The people who put Clementine together for the two years prior to launch are now flying her. They definitely have pride and excitement in what they are doing, because I don't know what else would carry them through their 12-hour-plus workdays, and they never tire in their efforts to better the spacecraft's performance. Mission control is always compliant to special requests by the science team to perform unscheduled maneuvers. In fact, they often query the scientists for any input on how a particular maneuver can be optimized to maximize scientific return.

Many members of the science team have worked on mission studies in the past. Clementine, by contrast, has provided them an opportunity to work on a flying spacecraft. Even though they are "fancy Ph.D. scientists," as Lt. Col. Pedro Rustan, the Ballistic Missile Defense Organization program manager, has called them, it is remarkable to see the degree of enthusiasm that lights up these scientists when they are looking at Clementine data and contemplating information they've never had before. The richness of the data can be understood when you consider that the team has examined only 1% of the total dataset and have seen many new things emerge from this drop in the bucket.

It is truly a labor of love, this sifting through the data to figure out what it is telling us about Clementine and her lunar mapping mission. I have seen Dr. Paul



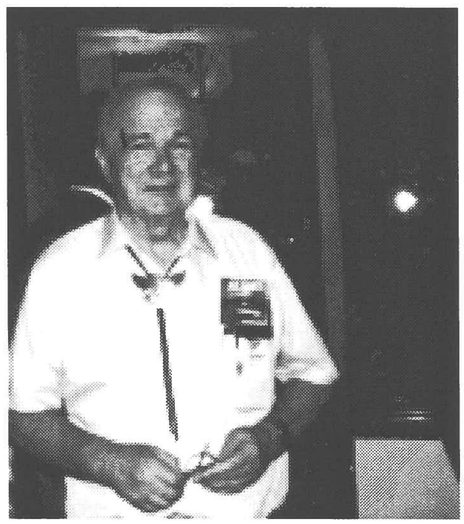
Dr. Paul Spudis

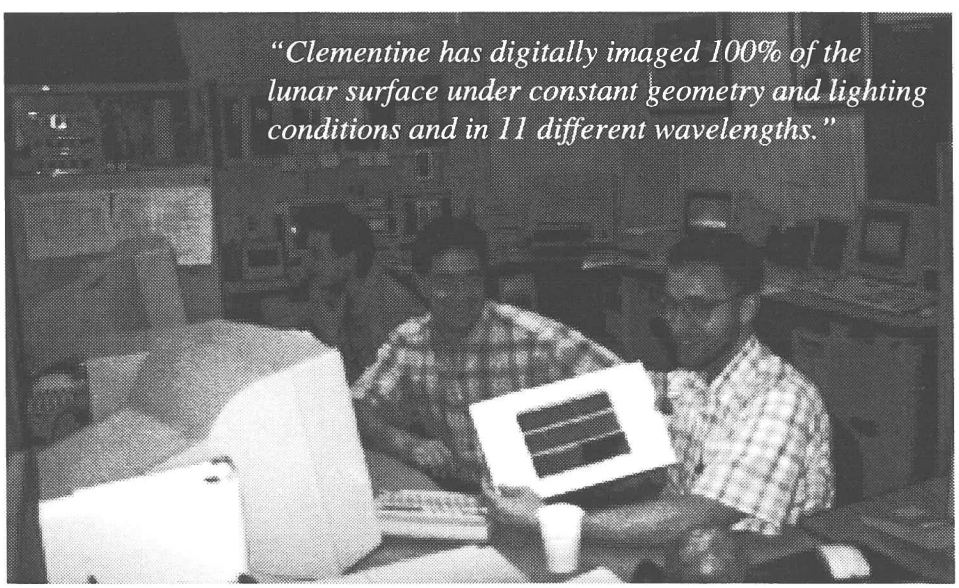
Spudis, with childlike glee, sit and paste strips of images onto a globe. With each step toward completion he grows more excited as he can read what the information is telling him. The bug has even bitten Dr. Alfred McEwen, who is reported to be happy only 10 seconds a day. He is delighted to show his work on Aristarchus Plateau and give an in-depth explanation of the information revealed in the color mosaic.

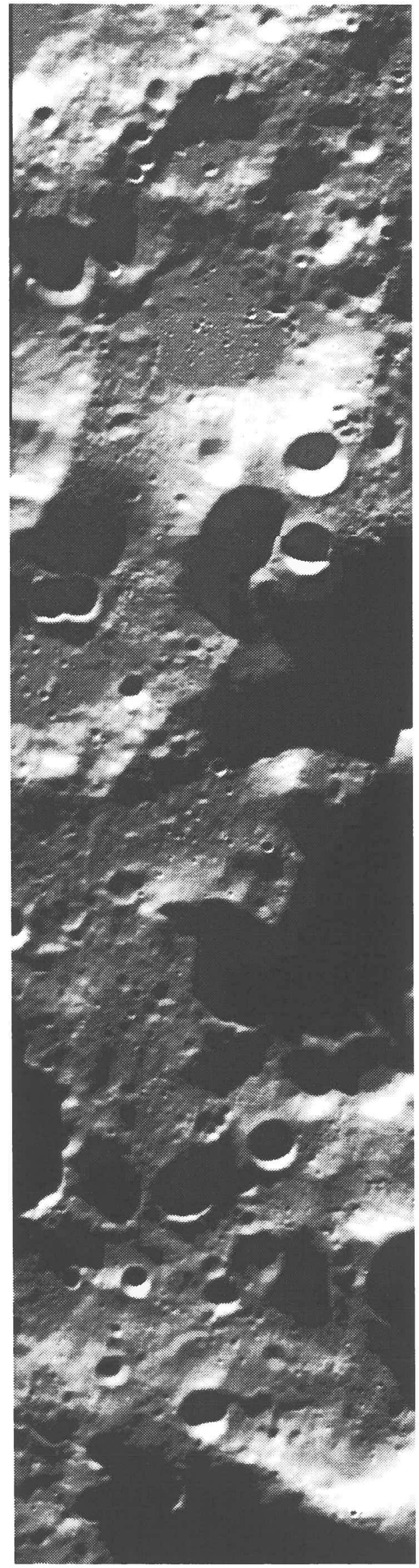
A big thrill for me, that rivals the fact that this is the first time in my life I can experience the United States at the Moon, is the chance to work with the father of planetary geology, Dr. Eugene Shoemaker, and some of the top planetary scientists in the world. Many of us only get to read about the great people who make major advances in their fields, but I have been fortunate enough to work with them, learn from them, and get to know them personally. For instance, I have seen Dr. Shoemaker sit on the floor staring at a 7 × 7-foot south polar mosaic, seemingly entranced by it. I can see him figuring, calculating, and resolving problems that my untrained eyes have not even picked up.

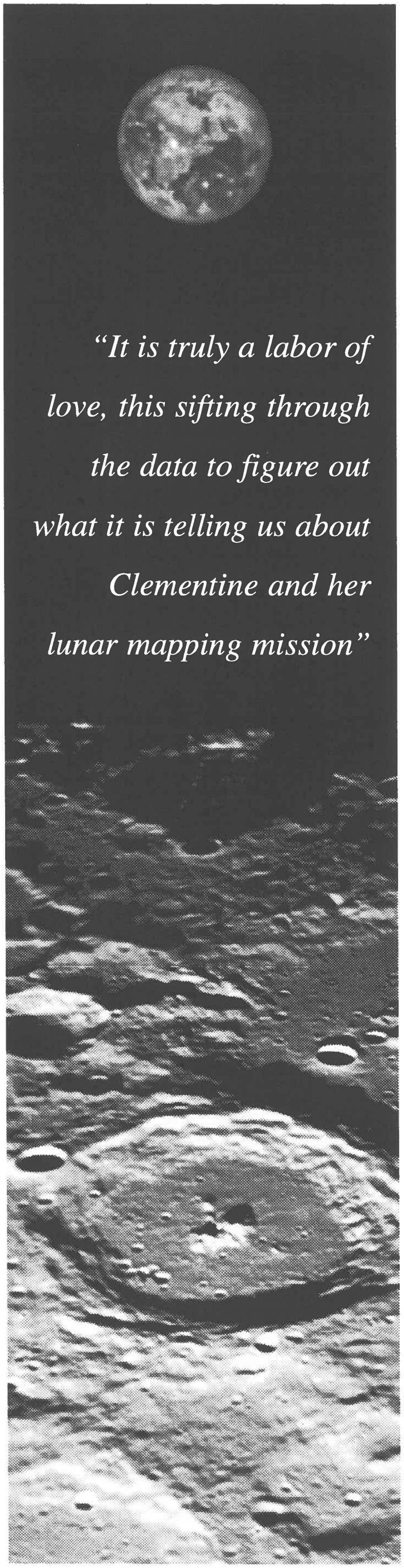
As the scientists and mission control staff prepare for Clementine to leave lunar orbit on May 3, it is evident that her mission at the Moon has been (nothing but) a complete success. Although Clementine's scientific return is a byproduct of her military mission, it has

Science Team Leader Eugene Shoemaker









given scientists a rich harvest of more than two million images collected over two months of systematic global mapping that will greatly increase our knowledge of the Moon. Clementine has digitally imaged 100% of the lunar surface under constant geometry and lighting conditions and in 11 different wavelengths. This has never been done before, for the Moon or for any other planet.

After a mapping orbit is completed, from 90° south to 90° north on the periselene side of the Moon, the spacecraft rotates using inertial forces generated by spinning wheels within the craft. This maneuver points the high-gain antenna toward Earth so that Clementine can download the data stored in its solid- state memory recorder. During the aposelene part of the orbit, the satellite downloads data gathered on that orbit to one of four groundstations that make up the Deep Space Tracking Network back on Earth. Each location, Madrid, Spain, Canberra, Australia, Goldstone, California, and Pomonkey, Maryland, has a 26–34-meter dish that receives the spacecraft's signal. The receiving groundstation sends the data to the Jet Propulsion Lab in California via underground lines. JPL in turn sends it to Goddard Space Flight Center in Maryland, which relays it to the Batcave in Arlington.

In order for the images from Clementine to be useful to the scientists, they have to be mosaicked together. A computer program called ISIS is used to calculate how each frame fits with its neighbors, using information about spacecraft altitude, camera angle, and position of the Moon at the time the image was taken, and to place the image into a specified cartographic projection. The south pole mosaic put together by Eric Eliason of the U.S. Geological Survey in Flagstaff, for instance, covers 90° to 70° south latitude and contains 1500 UV/VIS images from one color filter. This mosaic gives us our first look at features of the south pole and has revealed what appears to be a major depression near the pole, evident from extensive shadows around the pole. This depression is probably an ancient basin formed by impact of an asteroid or comet. A significant fraction of the dark area near the pole may be in permanent shadow and would be sufficiently cold to preserve water of cometary origin as ice.

Alfred McEwen, also from U.S.G.S.

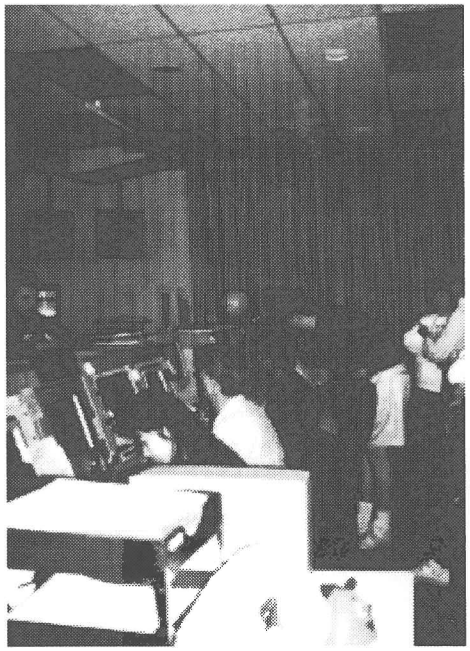
This page: left, *Clementine composite image of Earthrise over the lunar north pole;* below, *Deputy Science Team Leader Spudis discusses the mission with an interested reporter.* Facing page: center, *The compact Clementine Mission Control Center;* right, *Clementine UV/VIS camera image of the lunar crater Plato.*

Flagstaff, has processed a mosaic of 500 images acquired through three spectral filters (415, 750, and 100 nm) and has combined them into a multispectral mosaic of the Aristarchus Plateau region. Color ratios serve to cancel out the dominant brightness variations in the scene, which are caused by albedo variations and topographic shading, thus isolating the color differences related to composition or mineralogy. The Aristarchus mosaic covers only 0.4% of the lunar surface and is only 0.1% of the entire Clementine image database. Such data will be invaluable for mapping the geology of the Moon and planning future exploration and utilization of lunar resources.

One of the fascinating products made with Clementine data so far is a preliminary map of global mineral distributions put together by Paul Lucey of the University of Hawaii and Eric Malaret of ACT Corporation. They have extracted the average brightness from each image and plotted it as an individual pixel on a cylindrical map projection, enabling the reconstruction of low-resolution global color ratio images. Using the same color principles to determine mineralogy as in the Aristarchus mosaic, we have found new heterogeneities in the composition of the lunar crust. The more we can find out about compositional variations, the better we can piece together the genesis and evolution of the early lunar crust.

Another important return is from the laser altimeter (LIDAR). From this we will be able to constrain the global shape of the Moon. Three-dimensional plots of the altimetry data have been used by Paul Spudis to identify old impact basins whose existence was previously uncertain and, in one instance, previously unknown. The altimetry data has allowed us to measure the depth of many old basins. The amount of topographic relief is surprising: the South Pole-Aitken Basin is up to 12 km deep. Altimetry data combined with gravity data should shed light on crustal geology and isostasy.

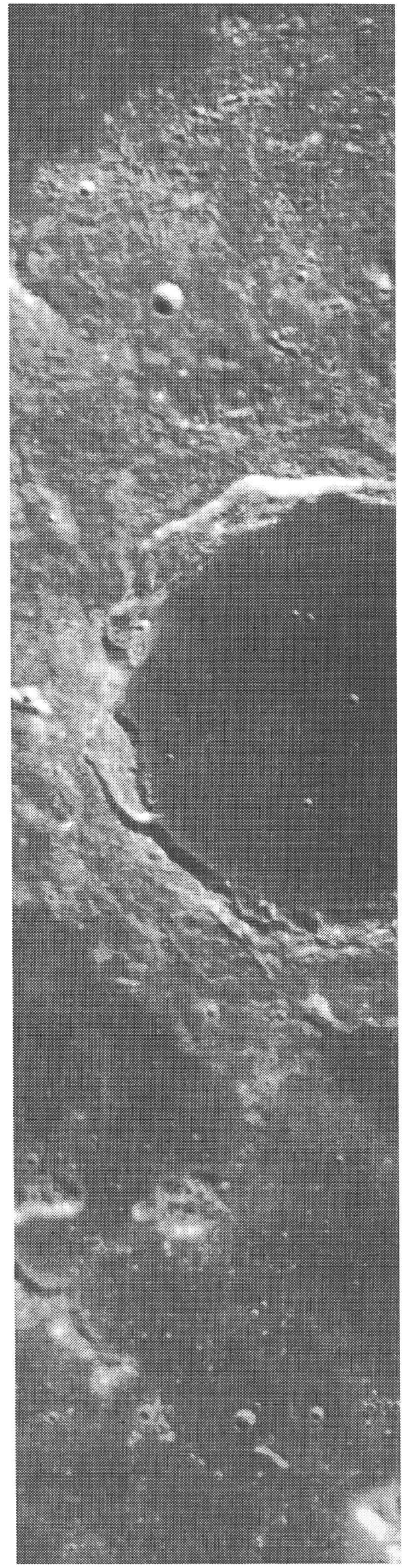
Clementine has also performed a bistatic radar test in which the spacecraft sends a radar signal from its transmitter to the Moon's pole and the reflection is received by Earth-based groundstations. Scientists are looking for a high backscattering of the reflected signal that is



characteristic of an icy surface. Ice would be a major discovery and could provide water for lunar bases.

Working on the Clementine mission is a dream come true for me. Where else can you work and every four out of five hours see images live from the Moon? As I watch a new orbit of images being dumped from Clementine, I realize that buried somewhere deep in this enormous, scientifically rich dataset exists my Ph.D. thesis. With the Clementine dataset, we are redefining scientific frontiers that were thought to be settled. I hope the lesson that space exploration can be affordable and provide first-rate science will be learned from Clementine before the lesson is lost and gone forever.

(Jeff Gillis worked on structural and stratigraphic mapping of the Moon's nearside under the direction of Dr. Paul Spudis in the LPI Summer Intern Program in 1992. He is currently a Visiting Graduate Fellow at LPI, where he has worked with Dr. Spudis on selecting geologically interesting features for Clementine's HIRES camera to target. He will pursue graduate study at Rice University. For the last two months, Jeff has been a resident of the Batcave, processing Clementine images and data.)



NEWS FROM SPACE

NASA MAPS OUT MARS SURVEYOR EXPLORATION PROGRAM

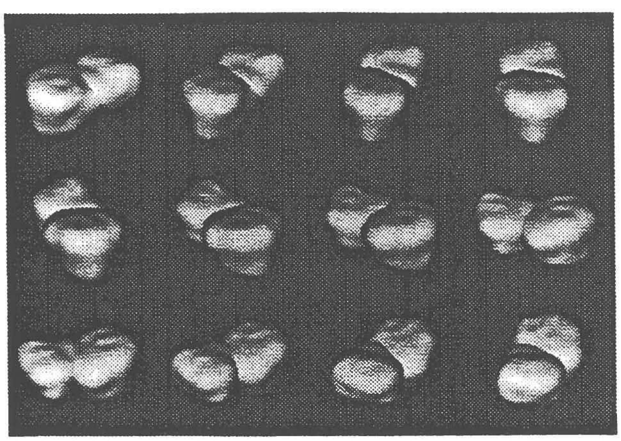
NASA is developing a new Mars exploration strategy in fiscal year 1995. The Mars Surveyor program calls for start of development of a small orbiter that will be launched in November 1996 to study the surface of the red planet. The Mars Surveyor orbiter will lay the foundation for a series of missions to Mars in a decade-long program of Mars exploration. The missions will take advantage of launch opportunities about every two years when Mars comes into alignment with Earth. NASA requested $77 million in development costs in FY 1995 for the new Mars orbiter. The 1995 fiscal year runs from October 1, 1994, to September 30, 1995.

The Mars Surveyor program will be conducted within the constraints of a cost ceiling of approximately $100 million per year. The orbiter will be small enough to be launched on a Delta expendable launch vehicle and will carry roughly half of the science payload that flew on Mars Observer, which was lost on August 21, 1993. The specific instruments will be selected later.

NASA's Jet Propulsion Laboratory issued a request for proposals to industry in March to solicit potential spacecraft designs. Selection of a contractor to build the spacecraft will be made by July 1. NASA envisions an orbiter/lander pair of spacecraft as the next in this series of robotic missions to Mars. The orbiter planned for launch in 1998 would be even smaller than the initial Mars Surveyor orbiter and would carry the remainder of the Mars Observer science instruments. It would act as a communications relay satellite for a companion lander, launched the same year, and other landers in the future, such as the Russian Mars '96 lander. The U.S. Pathfinder lander, set to land on Mars in 1997, will operate independently of the Mars orbiter. The 1998 orbiter/lander spacecraft would be small enough to be launched on an expendable launch vehicle about half the size and cost of the Delta launch vehicle. JPL will manage mission design and spacecraft operations of the Mars Surveyor for NASA's Office of Space Science, Washington, DC.

MODEL OF RADAR DATA FROM CASTALIA SHOWS DOUBLE OBJECT

Two NASA-sponsored scientists have produced the first-ever detailed, three-dimensional reconstruction of one of the thousands of near-Earth asteroids, those whose orbits bring them extremely close to Earth. Scott Hudson of Washington State University and collaborator Steven Ostro of the Jet Propulsion Laboratory created the computer model of the double-lobed asteroid 4769 Castalia from radar data obtained in 1989 by Ostro and others, using the Arecibo Observatory in Puerto Rico. The asteroid was discovered by Eleanor Helin of JPL at the Palomar Observatory in 1989.



"This computer model of Castalia represents the first detailed, three-dimensional reconstruction of a solar system body from radar data," Hudson said. The effective resolution in the reconstruction is about 100 meters. At just under 2 kilometers across, Castalia is smaller than any solar system object that has been imaged by spacecraft, including the two asteroids, Gaspra and Ida, recently imaged by Galileo.

Ostro said that previously it was very difficult to interpret radar images of small, irregularly shaped bodies. But with the development of this new reconstruction technique, the scientific value of radar observations has been dramatically increased. "I hope that the Castalia model will enhance interest in a program of exploration of these small bodies, including both Earth-based observations and spacecraft missions," he said. "A radar-derived model of a target asteroid would make close maneuvering easier, and the mission easier and cheaper."

Ostro also noted that the Castalia model verifies the suspicion of many astronomers that the near-Earth asteroids would prove to be the most irregularly shaped worlds in the solar system. "Understanding the origins of those shapes, especially the detailed role of collisions, is an important theoretical challenge," he said. The scientists believe that the double-lobed shape of Castalia shown by the model resulted from a gentle collision between two separate asteroids some time in the past.

Nearly 300 near-Earth asteroids are currently known. It is estimated that more than 1000 as large as Castalia, plus 100 million as large as a house, remain to be discovered. Most of them are thought to have been thrown into the inner solar system from the main asteroid belt, between Mars and Jupiter, by long periods of gravitational interaction with the planets. With unstable orbits, they eventually might be thrown out of the solar system by the same forces or possibly collide with planets. The scientists believe that continuing improvements in radar telescopes, expanded optical programs to search for near-Earth asteroids, and modeling techniques like this one will provide greatly increased knowledge of the properties and histories of these strange, nearby worlds.

GALAXY DRIFT CHALLENGES IDEAS ABOUT UNIVERSE'S EVOLUTION

Two astronomers have discovered that our Milky Way galaxy and most of its neighboring galaxies, contained within a volume of the universe one billion light-years in diameter, are drifting with respect to the more distant universe. This startling result may imply that the universe is "lumpier" on a much larger scale than can be readily explained by any current theory. "The new observations thus strongly challenge our understanding of how the universe evolved," says Dr. Tod Lauer of the National Optical Astronomy Observatories (NOAO).

This surprising conclusion comes from the deepest survey of galaxy distances to date, conducted by Dr. Lauer and Dr. Marc Postman of the Space Telescope Science Institute. The two astronomers used NOAO telescopes at Kitt Peak National Observatory, Arizona, and Cerro Tololo Inter-American Observatory, Chile, to study galaxy motions over the entire sky out to distances of over 500 million light years. They explored a volume of space about 30 times larger than had been surveyed previously.

The expansion of the universe causes all the galaxies in the volume surveyed to be moving away from us. Galaxies at the edge of the volume are receding from us at 5% of the speed of light. The large "flow" of neighboring galaxies that Postman and Lauer discovered comes from looking at residual galaxy motions after the expansion of the universe has been accounted for. The flow means that the nearby universe, as well as expanding, appears to be drifting with respect to the more distant universe.

Astronomers generally assume that the diffuse glow of microwave radiation left over from the Big Bang provides the backdrop or rest frame of the universe. In the mid 1970s, astronomers found that temperature of this radiation is slightly hotter toward the direction of the constellation of Leo. This effect has been interpreted to mean that the Milky Way is drifting with respect to the rest of the universe at about 380 miles per second in this direction. It has also been assumed that most of this motion is caused by the gravitational attraction of more distant galaxies; however, these galaxies have never been positively identified.

In the mid 1980s a group of astronomers surveyed the motions of galaxies out to about one-third the distance studied by Lauer and Postman, finding the galaxies to be flowing as a group with respect to the more distant universe. This team postulated that this flow was due to the gravitational pull of a large concentration of galaxies dubbed "The Great Attractor." However, these galaxies are located deep *within* the volume surveyed by Postman and Lauer and are not massive enough to cause the observed rate of drift.

In fact, the new result implies that the Milky Way and its neighbors are affected by much larger concentrations of mass at much larger distances than can be easily explained by popular theories of how the universe is organized. Lauer and Postman started their project in 1989 to measure the drift of the Milky Way with respect to 119 clusters of galaxies located all over the sky at distances as far as 500 million light years. If the motion of the Milky Way was caused by galaxies closer to us than the distant clusters, as was then presumed to be the case, then its motion with respect to the clusters should have been essentially identical to that with respect to the microwave background radiation.

Because the galaxy clusters are at a variety of distances from us, galaxies in the more distant clusters appear dimmer than the ones more nearby. However, once the various distances are accounted for, the brightest galaxy in each cluster is always found to give off roughly the same amount of light. Astronomers refer to such objects as "standard candles." The distances to the clusters are estimated from how fast they are moving away from us as the universe expands.

If the Milky Way Galaxy is drifting, however, its motion makes measurement of the expansion speeds dependent on which direction we are looking. If the drift is not corrected for, then the cluster galaxies will appear to vary slightly in brightness in a smooth pattern across the sky. Postman and Lauer used images of the cluster galaxies to detect this pattern and determine the motion of our own galaxy.

The motion of the Milky Way that Postman and Lauer measured from the distant clusters is in a completely different direction from that inferred from the microwave background. The most likely solution to this dilemma is that the clusters themselves are moving with an average velocity of 425 miles per second toward the constellation of Virgo. Because of the enormous size of the volume containing the clusters, however, this implies the existence of even more distant and massive concentrations of matter.

Most theories explaining the structure of the universe predict that the universe should be nearly uniform on the scale of the Lauer and Postman cluster sample. The motion of the Milky Way and its neighbors would then be due to concentrations of mass relatively close by.

If, instead, the portions of the universe as big as a billion light years in diameter are still drifting with respect to the larger universe, then the universe has structure or "lumps" of matter on much larger scales than predicted by most theories. The detection of galaxy flows across large volumes of space should improve our understanding of how the universe came to be organized the way we see it today.

A more provocative but probably less likely interpretation of the Postman and Lauer result is that the large volume of clusters really is at rest, with the temperature variation of the microwave background around the sky being a relic of the conditions of the Big Bang, rather then being caused by the motion of our galaxy. In this case, the microwave temperature variation would tell about the properties of the very early universe rather than about large-scale motions of galaxies.

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SUMMER INTERN PROGRAM 1994

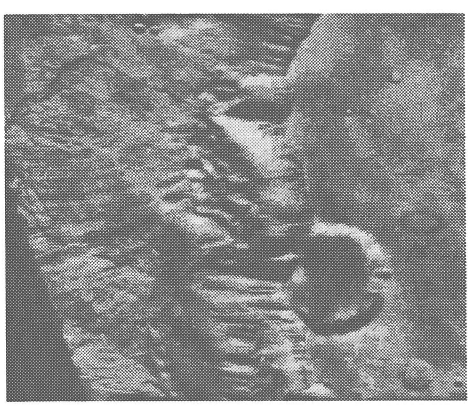
In its eighteenth year, the LPI Summer Intern Program offers selected undergraduate students an opportunity to participate in lunar and planetary science research at the Institute and the NASA Johnson Space Center. The 1994 program begins on June 13 and ends August 19. For more information or to apply for internship next year, contact LPI Summer Intern Program, 3600 Bay Area Boulevard, Houston TX 77058-1113.

KOOROSH ARAGHI, University of Arizona
Advisors: Carlton C. Allen and Tom Sullivan, NASA Johnson Space Center

Mars sample return, piloted Mars missions, and advanced life support systems on long-duration spacecraft will all need technologies to process CO_2 into needed materials such as oxygen, water, methane, etc. For planetary missions, using the resources already in space can lower the launch mass (and thus cost) more dramatically than any other technology. The objective of this project is to build and operate a reactor (breadboard) to convert CO_2 and H_2 into CH_4 and O_2. Existing membranes can process CO_2, the major component of the martian atmosphere, to O and CO. The production of CH_4 using similar membranes was recently demonstrated at Stanford University. The basic components of the system already exist and will be assembled into a working unit. Parameters such as temperature, flow rate, and pressure will be optimized to understand how the process can contribute to Mars missions by producing the propellant required for the trip home. An advantage of this technology is that a single reactor could replace three separate systems: a Sabatier reactor, and water and CO_2 electrolysis units. There are also potential uses at a lunar outpost.

KRISTIN M. BURGESS, Wesleyan University
Advisors: Fred Hörz and Michael Zolensky, NASA Johnson Space Center

The aim of this project is to characterize the size frequency distribution of all penetration holes in LDEF thermal blankets for the three cardinal viewing directions: leading, trailing, and space facing. These blankets are some 200 μm thick and penetration holes smaller than target thickness occur, but they are rare. Instead, one observes mostly craters at diameters <200 μm. It is necessary to measure the "large" members of this crater population because the transition from cratering to penetration, at constant target thickness, is velocity dependent. Exact observations related to this transition may lead to improved estimates for mean encounter velocities, a novel approach that would complement the otherwise strictly theoretical considerations based on orbital dynamics.

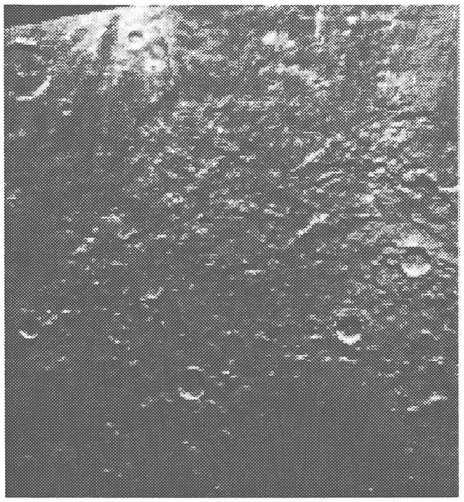


KELLY H. FUKS, Georgia State University
Advisors: Allan Treiman and Scott Murchie, Lunar and Planetary Institute

The walls of the Valles Marineris canyons on Mars are steep scarps up to 8 km high, and provide a unique view of the subsurface geology of the planet. In the uppermost 1 km of the scarps are horizontal layers of resistant rock. There are up to eight successive layers, and some layers seem to reach for hundreds of kilometers. The layers might be basalt flows, erosional terraces, or "caliche" layers from ancient groundwater or ground ice. In this research project, the intern would try to discover the origin of the layers by detailed mapping from Mariner and Viking spacecraft images. Products of the research will include maps, geological cross sections, and a written paper.

TERESA HOLLOWAY, Brown University
Advisors: Michael J. Golightly, NASA Johnson Space Center, Mark D. Weyland, Space Systems Division, Rockwell International, and Gautam D. Badhwar, NASA Johnson Space Center

This project will seek to determine the drift rate of the South Atlantic Anomaly (SAA). The SAA is a region of space over the southern Atlantic ocean where geomagnetically trapped protons extend down to altitudes characteristic of shuttle missions. The SAA is an important source of radiation exposure for astronauts and payloads in low Earth orbit; accurate knowledge of the SAA's location is essential for flight planning and payload operation purposes. The drift rate of the SAA will be determined by analyzing measurements made with the Radiation Monitoring Equipment III during 14 shuttle missions. The measurements will be mapped and smoothed into a geographic coordinate system. The location of the maximum flux will be determined by fitting the smoothed data with a two-dimensional Gaussian fit. The location of the maximum SAA flux in 1970 will be calculated from the AP8 solar maximum trapped proton model. The drift rate will then be determined based on the difference between the measured and calculated maximum flux locations and the epoch of the datasets and the AP8 model.



FRANKIE IAQUINTA-RIDOLFI, Carleton College
Advisor: Paul Schenk, Lunar and Planetary Institute

Cratering is one of the most dominant geologic processes in the solar system. The icy satellites represent (among other things) a natural laboratory in impact mechanics and the role of gravity and composition. This study will investigate the importance of gravity in controlling the ejection of material out of craters onto the surface. One theory suggests that the extent of ejecta deposits is proportional to crater diameter, but that this relationship varies inversely with the surface gravity of the planets. We will test this hypothesis. The extent of continuous ejecta deposits will be mapped, based on criteria developed as a result of terrestrial planet studies, and their dimensions measured. Satellites for which data exist include Ganymede, Callisto, Rhea, Ariel, Dione, Miranda, and perhaps Callisto. This represents a factor of 100 in variation in surface gravity. Correction will also be made to account for the widening of the original transient crater diameter due to slumping. These results will then be compared with similar measurements for the Moon and Mercury to determine the "impact" of the icy vs. rocky composition on this process. We will then use the scaling relationships to determine the diameters of palimpsests and other poorly preserved impact features on Ganymede.

MICAH SHANE JOHNSON, Indiana University
Advisor: Walter S. Kiefer, Lunar and Planetary Institute

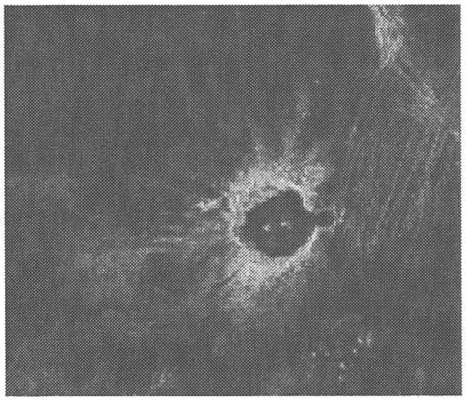
The Tharsis province of Mars contains many extensional features that are related to the uplift of the province, but there is considerable regional variation in the amount and style of this extension. These variations probably reflect regional variations in the lithosphere's vertically integrated strength and hence may be due to regional variations in crustal thickness and thermal gradient. The intern will model the relationship between extension and lithospheric strength and use the results of the model to constrain the allowed crustal thickness and thermal gradient. The results of this study will be compared with estimates of these quantities as derived from an inversion of gravity and topography data in order to determine if a self-consistent model can be found.

TRACY JOHNSTON, Wellesley College
Advisor: Gary Lofgren, NASA Johnson Space Center

The intern will examine the petrography of the chondrules in several type 3 and type 4 enstatite chondrites. The chondrule texture types will be determined, described, and classified. The natural chondrules will be compared to already completed experiments (*Lofgren and Lanier,* 1991). The results of these comparisons will be used to (1) formulate a formational history for enstatite chondrite chondrules and (2) compare enstatite chondrites to ordinary chondrites.

KARLA E. KUEBLER, University of Kansas
Advisor: Graham Ryder, Lunar and Planetary Institute

Lunar sample 72255 was broken from a boulder that had rolled down the slopes of the South Massif at the Apollo 17 landing site. It is a fine-grained impact melt containing a wide variety of small rock fragments. Subsets of these fragments have already been selected for chemical analysis and geochronological studies. The intern will contribute to our understanding of the origin of these fragments by making petrographic observations and microprobe analyses of mineral phases within them and making comparisons among the fragments and with other known lunar lithologies. Instruction in the necessary microscope, microprobe, and data presentation techniques will be provided.



SUZANNE N. LYONS, Texas A&M University
Advisor: Robert Herrick, Lunar and Planetary Institute

Several properties of complex impact craters (e.g., onset of central peaks, crater depth, etc.) have a strong dependence on target characteristics such as gravity, density, and target strength. Previous approaches to determining the nature of this dependence involved creating a forward model and demonstrating that its predicted results fit within the error tolerances of existing data. Recent compilations of morphometric data from Venus and the icy satellites have greatly expanded the range of target conditions, and it is now possible to let the data themselves determine the functional relationship of crater properties with target properties. The student will synthesize existing morphometric datasets and use standard inversion techniques to determine the dependence of complex crater formation on target gravity, density, and strength, and the relative strengths of planetary crusts.

KIMIYASU SATO, University of Tokyo
Advisor: Michael Zolensky, NASA Johnson Space Center, and Clyde Sapp, Lockheed Engineering & Science Co.

We propose to (1) obtain backscattered SEM images of thin-sectioned chondritic interplanetary dust particles (IDPs), (2) digitize each image, and (3) use the images and existing image software to determine the modal percentage of important mineral constituents and pores. This information will enable us to search for correlations between physical properties of the IDP parent bodies and their mineralogy.

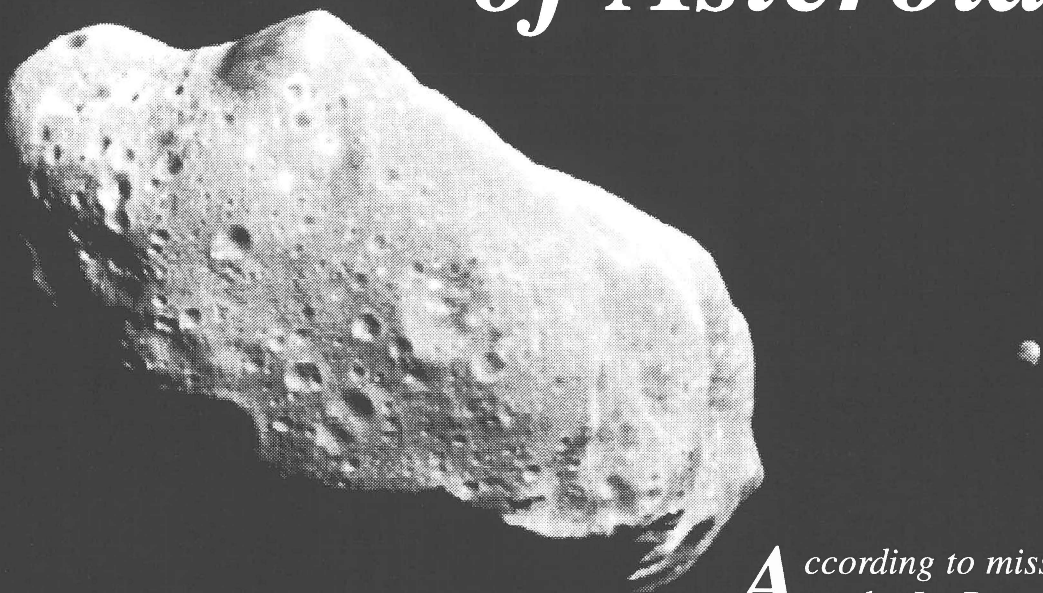
KAREN R. STOCKSTILL, Ohio Wesleyan University
Advisor: Faith Vilas, NASA Johnson Space Center

C-class asteroids probably underwent aqueous alteration during their history in the solar system. Spectral reflectance studies in the visible and near-infrared have identified absorption features similar to those seen in laboratory reflectance spectra of phyllosilicates. This project will require the study of a large number of telescopic narrowband CCD reflectance spectra of asteroids, identifying and removing effects on the data, identifying trends within the data, and studying these trends in the context of solar system compositional formation.

PATRICK VALAGEAS, Paris University
Advisor: Tomasz F. Stepinski, Lunar and Planetary Institute

This project will examine the aerodynamics of solids in viscous protoplanetary disks. The seeds of the planetary system architecture are to be found in the radial distribution of solids in an accretion protoplanetary disk. The distribution of solid particles undergoes global time evolution, which accompanies, but is not identical to, the global time evolution of the gaseous component of the disk. This project concentrates on calculating space-time distribution of relative velocities of solids with respect to the gas. The evolution of the gas is calculated using the numerical code developed for viscous accretion disks. The result of the project will be a computer program that will start from given initial conditions and compute the time evolution of relative velocities between the gas and solid particles of different sizes. Such a program could be later incorporated into solid evolution models.

Galileo Detects a Moon of Asteroid Ida



According to mission scientists at the Jet Propulsion Laboratory, this image, together with data from Galileo's near-infrared mapping spectrometer, is the first conclusive evidence that natural satellites of asteroids exist.

The photo, of asteroid 243 Ida and its newly discovered natural satellite, was taken by Galileo as the spacecraft flew past Ida last August 28. It was not transmitted to Earth until recently because the spacecraft is sending back data at a very slow rate via its low-gain antenna because the high-gain antenna never completely deployed.

The discovery gives scientists an intriguing new clue in deciphering the origins and evolution of these ancient, rocky bodies, most of which orbit the sun in the main asteroid belt between Mars and Jupiter. Even so, many pieces of information on the newly found moon—where it came from, how it came to be orbiting Ida, and the details of that orbit—are still unclear.

"It was previously thought that natural satellites of asteroids could form, but they probably weren't common," said Dr. Torrence Johnson, Galileo project scientist. "Having found one fairly quickly, we can say that they're probably more common than previously thought."

From the photo and spectrometer data, team scientists estimate that the natural satellite is about 1.5 kilometers (1 mile) across in this view, and appears to be at a distance of about 100 kilometers (60 miles), plus or minus 50 kilometers (30 miles), from Ida's center. The position will be more accurately determined as new data are analyzed. Ida itself is about 56 × 24 × 21 kilometers (35 × 15 × 13 miles) in size.

As yet they do not know the parameters of the object's orbit—critical information that can reveal Ida's mass. Combined with measurements of Ida's size and volume, that can tell scientists the asteroid's density, offering more clues to what it is made of.

The data from Galileo's near-infrared mapping spectrometer, which scans space objects at a variety of wavelengths to reveal their chemical composition, suggest that Ida's moon is made more or less from the same kind of material as Ida. An S-type asteroid, Ida is composed mostly of silicate rocks. Scientists are certain, in any event, that the moon's surface is not composed mostly of carbonaceous material, as are the many asteroids that are termed C-type asteroids. More information on the object's composition will become available as color pictures and more detailed data from the spectrometer are transmitted to Earth over the next few months.

Galileo scientists believe the moon may have been created at the same time as Ida, when an older, larger asteroid was shattered in a collision with another asteroid, giving birth to dozens of smaller asteroids.

Ida is a member of the Koronis family of asteroids, which scientists believe was created when a larger body perhaps 200–300 kilometers in diameter was smashed relatively recently or at least considerably after the solar system formed some 4.5 billion years ago. (The family was named for Koronis, one of the asteroids that belongs to it.)

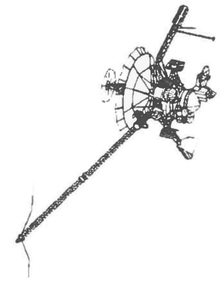
Alternatively, it is possible that Ida was hit by a smaller object even more recently, leaving a crater on the asteroid and throwing off the material that became the small moon.

"Ida's age is baffling, because the craters visible on its surface suggest that it is old, but being a part of the Koronis family suggests it is younger," said Johnson. "In any event, we don't believe that Ida and its moon could go back to the formation of the solar system," he added. "It's generally thought that a small object like that moon could not survive this long; sooner or later it would itself be broken up in a high-speed collision with an even smaller object."

Galileo scientists also believe it is virtually impossible that the moon is a captured object, something created completely separately from Ida that happened to wander near the asteroid and was caught by its gravitational field. According to the laws of celestial mechanics, such an event would deflect the smaller object, but it would not be captured into orbit unless a third force of some kind slowed it down. "Once we have determined the object's orbit, we can estimate timescales and make better guesses as to where it came from," said Johnson.

Launched in October 1989, Galileo made its closest approach to Ida at a distance of 2400 kilometers (1500 miles) last August while flying through the asteroid belt en route to its final destination, the giant planet Jupiter, where it will go into orbit in December 1995.

Because Galileo is sending data back to Earth through its low-gain radio antenna, it must transmit at slow rates. One portrait of Ida, a mosaic of five separate frames, was received shortly after the flyby, but later pictures had to wait because telecommunications conditions became unfavorable as Galileo's distance from Earth increased. In the meantime they were stored on Galileo's onboard tape recorder, awaiting playback this spring. The newly found moon was outside the boundaries of the picture of Ida received last September. Ground controllers instructed Galileo to send back more portions of photos and other data beginning in February as the spacecraft's distance from Earth decreased and radio communications with the spacecraft improved.



In preparation for complete playback, they commanded the spacecraft to transmit strips of each image—called "jail bars" by the project's engineers and scientists—so that they could locate Ida accurately in images stored on Galileo's recorder. Later, portions of an image containing Ida could be selected for playback in their entirety.

On February 17, a day after the first of these "jail bars" was sent back from Galileo, evidence of the natural satellite was noticed in one set of image strips by Ann Harch, a Galileo imaging team associate at JPL. It took several days to verify that what appeared to be a moon was not, in fact, an artificial effect of some kind. On February 23, scientists examining similar preliminary data from a chemical map obtained by the near-infrared mapping spectrometer discovered an unusual object in their data. By February 28, scientists from both the camera and spectrometer teams concluded that they had a moon.

Amateur astronomers for many years have observed the light of stars blinking off and on as objects such as asteroids pass in front of them in events called stellar occultations. Some have reported "blinkouts" that suggest that some asteroids have moons, but such reports have never been confirmed by definite second sightings. Galileo's discovery is thus the first unambiguous evidence of an asteroid moon.

Other images that may show the asteroid moon are still stored on Galileo's tape recorder and will be played back later this spring. Among them is an image that is expected to be at least three times sharper than the first image received.

The newly found moon has been provisionally designated "1993 (243) 1," the first natural satellite discovered in 1993 at Ida, which was the 243rd asteroid discovered over the past two centuries. The moon will be formally named later by the International Astronomical Union.

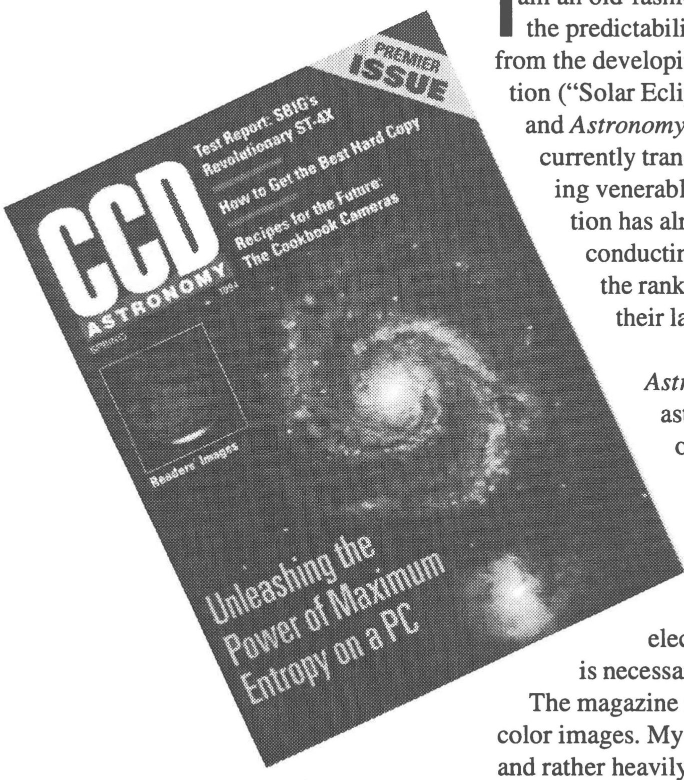
NEW IN PRINT

These publications are available from the publisher listed or may be ordered through local bookstores.

REVIEW

CCD ASTRONOMY

Premier Issue
Spring, 1994
Sky Publishing Corporation



I am an old-fashioned astrophotographer. I appreciate the precision of a Nikon body, the predictability of "Great Yellow Giant" film, and the magic of pulling the wet print from the developing drum. I've even had a photograph grace the cover of this publication ("Solar Eclipse," July 1991). But I, like many regular readers of *Sky & Telescope* and *Astronomy* magazines, am aware of the revolution in imaging technology that is currently transforming astronomy. Charged Coupled Devices (CCDs) are challenging venerable film technology for mastery of astrophotography. The CCD revolution has already swept silver halide emulsions from the great observatories conducting "real" scientific astronomy. The same technology is now threatening the ranks of amateur astronomy. My Nikons and Leicas are gloomily awaiting their layoff notices!

The editors of Sky Publishing Corporation's latest magazine, *CCD Astronomy,* are addressing the publication toward hard-core amateur astrophotographers who already have or are ready to delve into the realm of chips and image processing. Novice amateur astronomers may be impressed by the pretty pictures but confused by the somewhat esoteric subject matter. Given the audience for which it is intended, however, the publication is well written and should be of great interest. The articles did not require a high level of technical knowledge to understand (I understood it and I'm hardly an electronics wizard), but a solid familiarity with astronomy and computers is necessary.

The magazine is printed on high-quality glossy stock, which enhances the superb color images. My only complaint is that *CCD Astronomy* seems rather thin (40 pages) and rather heavily advertised (10 full page ads) for a $20.00/year quarterly publication. Of course, this is the premier issue. I hope the next issue has more user articles. In all, it is a tasteful, well-produced magazine.

If the goal of *CCD Astronomy* is to win new recruits to electronic imaging from the ranks of old-guard photographers, it has succeeded with me. I just called Sky Publishing Corporation and ordered a subscription for myself. Sorry, Nikon. You're obsolete.

—Edward Malewitz

(Edward Malewitz is a longtime amateur astronomer and photographer and an active member of the Johnson Space Center Astronomical Society. He leads the Society's Film Photography Special Interest Group.)

NEW FROM LGI

Two new technical reports are available free from the Lunar Geotechnical Institute: "Bibliography of Lunar Geotechnical Literature" TR94-01 and "Trafficability of Lunar Microrovers (Part 1)" TR94-02. Order from LGI, P.O. Box 5056, Lakeland FL 33807-5056. Phone: 813-646-1842; fax: 813-644-5920.

NEW FROM THE ASTRONOMICAL SOCIETY OF THE PACIFIC

NEW CATALOG

The nonprofit Astronomical Society of the Pacific has published a new catalog of materials for teaching and enjoying astronomy. The illustrated, color catalog includes video and audio tapes, books, computer software, CD-ROMs, slides and videodisks, observing aids, posters, and charts. New items include a 20-slide set with images from the newly repaired Hubble Space Telescope; multimedia astronomy programs on CD-ROM; an updated version of *The Planets* narrated by Patrick Stewart; an affordable, hand-held spectrometer; electronic PictureBooks for Macintosh computers; the videotape A Private Universe, one of the most influential critiques of science teaching versus science learning; an oversize print of a rendering of the Milky Way; a 32-slide set on the Sun; a variety of classroom activity books for astronomy teachers and planetarium educators; and a rotating illuminated globe that illustrates the seasons as well as Earth's relation to the celestial sphere. The catalog is free from Catalog Requests Department, A.S.P., 390 Ashton Avenue, San Francisco CA 94112. Phone: 415-337-1100.

BETTER, CHEAPER, FASTER. . .

LPI Director David Black recently completed a 173-mile, 2-day mission from Houston to Austin, Texas, on a personal roving vehicle. The two-wheel, single-seat rover employed proven, off-the-shelf technology. Helmet and suit design were also off-the-shelf in the spirit of the "better, cheaper, faster" missions of today. The mission was part of "MS 150," an annual event to benefit the Southeast Chapter of the National Multiple Sclerosis Society. Now in its tenth year, it has become the largest such event in the country. More than 4700 entrants took part in the trek, underwritten by sponsors who contribute by the mile. Dr. Black's mission alone raised more than $1400.

ABSTRACT DEADLINE FOR 26TH LPSC

The deadline for submitting abstracts for the 26th Lunar and Planetary Science Conference will be 6:00 p.m., **December 23, 1994**. The Program Committee will meet during the first week of January 1995. The Conference itself will be held March 13–17, 1995, in Houston.

CALENDAR 1994

JUNE

5-10
8th International Symposium on Solar Terrestrial Physics, Sendai, Japan. Contact: A. Morioka, Symposium Secretary, Department of Astronomy and Geophysics, Tohoku University, Aramaki, Aoba, Sendai 980, Japan. Fax: 81-22-262-6332.
Internet: morioka@stpp.geophys.tohoku.ac.jp

5-11
ICOG-8: Eighth International Conference on Geochronology, Cosmochronology, and Isotope Geology, Berkeley, California. Contact: ICOG-8, Krebs Convention Management Services, 555 De Haro Street, Suite 200, San Francisco CA 94107-2348. Phone: 415-255-1297; fax: 415-255-8496.

6-8
International Conference on Comparative Planetology, Pasadena, California. Contact: Neil L. Nickle, Jet Propulsion Laboratory, Mail Stop 180-703, 4800 Oak Grove Drive, Pasadena CA 91109-8099. Phone: 818-354-8244; fax: 818-354-1492.

6-10
Conference on Physics of the Moon and Planets, Kharkov, Ukraine. Contact: Irina Belskaya, Astronomical Observatory, Sumskaya Str. 35, 310022 Kharkov, Ukraine. Phone: 0572-43-24-28.
Internet: irina@astron.kharkov.ua

19-24
Solar Terrestrial Physics Gordon Research Conference: Collisionless Dissipation in Space Plasmas, Wolfeboro, New Hampshire. Contact: Martin Lee, SSC-Morse Hall, University of New Hampshire, Durham NH 03824. Phone: 603-862-3509; fax: 603-862-1915.
Internet: m_lee@unhh.unh.edu

25-30
106th Annual Meeting of the Astronomical Society of the Pacific, Flagstaff, Arizona. Contact: ASP at Universe '94, 390 Ashton Avenue, San Francisco CA 94112. Phone: 415-337-1100.

28-30
ASP Scientific Symposium: Completing the Inventory of the Solar System, Flagstaff, Arizona. Contact: Robert Millis, Lowell Observatory, 1400 W. Mars Hill Road, Flagstaff AZ 86001. Phone: 602-774-3358; fax: 602-774-6296.
Internet: rlm@lowell.edu

JULY

16-22
Jupiter Watch, Washington, DC. Contact: Susan Lendroth, The Planetary Society, 65 North Catalina Avenue, Pasadena CA 91106. Phone: 818-793-5100.

21-22
Workshop on Meteorites from Hot and Cold Deserts, Nördlingen, Germany. Contact: Michael Zolensky, Mail Code SN2, NASA Johnson Space Center, Houston TX. Phone: 713-483-5128; fax: 713-483-5347.
Internet: zolensky@curate.jsc.nasa.gov

25-29
57th Meeting of the Meteoritical Society, Prague, Czech Republic. Contact: Publications and Program Services Department, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113. Phone: 713-486-2166; fax: 713-486-2160.

AUGUST

1–6
Vernadsky Institute-Brown University Microsymposium 20 and Workshop on Large Impact Craters, Moscow, Russia. Aug. 1–2: Multi-topic Comparative Planetology Conference; Aug. 3: Mars 94 Long-Wavelength Radar Experiment Workshop; Aug. 4–6: Workshop on Large Impact Craters, Fieldtrip to Puchezh-Katunsky Crater. Contact: Alexander T. Basilevsky, Vernadsky Institute, 117975, Moscow, Russia. Phone: 7-095-137-4995; fax: 7-095-938-2054. James W. Head, Brown University, Providence RI 02912. Phone: 401-863-2526; fax: 401-863-3978.
Internet: basilevsky@glas.apc.org
head@pggipl.geo.brown.edu

6-11
Small Bodies in the Solar System and Their Interactions with the Planets, Uppsala-Turku, Sweden. Contact: Hans Rickman, Uppsala Astronomical Observatory, Box 515, S-75120, Uppsala, Sweden. fax: 46-18-527583.

21–26
Gordon Research Conference: Origin of Life, Newport, Rhode Island. Contact: David Des Marais, Mail Stop 239-4, NASA Ames Research Center, Moffett Field CA 94035-1000. Phone: 415-604-3220; fax: 415-604-1088.
Internet: david_desmarais@qmgate.arc.nasa.gov

AUGUST (CONTINUED)

28-30

Meteoroids, Bratislava, Slovakia. Contact: Anton Hajduk or Vladimir Porubcan, Astronomical Institute SAV, Dubravska 9, 84228 Bratislava, Slovakia. Phone: 42-7-375157; fax: 42-7-375157.
Internet: astropor@savba.savba.cs

SEPTEMBER

21–23

Space Debris course, University of Kent at Canterbury, UK. Contact: The Space Debris Course Organiser, Unit for Space Sciences, Physics Laboratory, The University, Canterbury, Kent CT2 7NR, UK.

21-24

Conference on Deep Earth and Planetary Volatiles, Pasadena, California. Contact: Publications and Program Services, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113. Phone: 713-486-2166; fax: 713-482-2160.
Internet: simmons@lpi.jsc.nasa.gov

OCTOBER

13-15

Chondrules and the Protoplanetary Disk, Albuquerque, New Mexico. Contact: Publications and Program Services Department, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113. Phone: 713-486-

OCTOBER (CONTINUED)

2166; fax: 713-486-2160.
Internet: simmons@lpi.jsc.nasa.gov

16-19

1994 Hypervelocity Impact Seminar, Santa Fe, New Mexico. Contact: Jeanne Southward, Department 1433, Sandia National Laboratories, Albuquerque NM 87185-5800.

30

Sixth International Conference on Laboratory Research for Planetary Atmospheres, Bethesda, Maryland. Contact: Kenneth Fox. Phone: 301-314-9124 or 301-262-5481.

31-Nov 4

26th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society, Washington, DC. Contact: Publications and Program Services, LPI, 3600 Bay Area Boulevard, Houston TX 77058-1113. Phone: 713-486-2166; fax: 713-482-2160.
Internet: simmons@lpi.jsc.nasa.gov

DECEMBER

6-10

American Geophysical Union, Fall Meeting, San Francisco, California. Contact: AGU Meetings Department, 2000 Florida Avenue NW, Washington DC 20009. Phone: 202-939-3203; fax: 202-328-0566.

1994 Dwornik Student Awards Announced

The Stephen E. Dwornik Planetary Geoscience Student Paper Awards, given for the best student presentations at the 25th Lunar and Planetary Science Conference, have been announced by the Planetary Geology Division of the Geological Society of America, which sponsors the competition.

The winner for oral presentation is Lauren B. Browning, University of Tennessee, for "Alteration and Formation of Rims on the CM Parent Body." Honorable mentions were given to Maribeth Price, Princeton University, for "Young Tectonism and Volcanism on Venus: Age Estimates from Crater Densities," and Robert Pappalardo, Arizona State University, for "Extensional Tectonics of Arden Corona, Miranda: Evidence for an Upwelling Origin of Coronae."

For poster presentation, the winner is Tracy K. P. Gregg, Arizona State University, for "Ratio of First and Second Generation Fold Wavelengths on Lavas May Indicate Flow Composition." Honorable mention was given to Melissa L. Wenrich, Arizona State University, for "Detectability of Carbonate in Unconsolidated and Indurated Sediments."

The cash award of $500 presented at NASA Headquarters is to provide encouragement, motivation, and recognition to outstanding future planetary scientists. Students who are U.S. citizens enrolled at any degree level in planetary geosciences are eligible to enter abstracts of which they are the senior author.

Cover—*Clementine star tracker image captures the Moon lit by Earthshine. The bright dot is Venus.*

The *Lunar and Planetary Information Bulletin* is published quarterly by the Lunar and Planetary Institute, 3600 Bay Area Boulevard, Houston TX 77058-1113.

Pam Thompson, Editor

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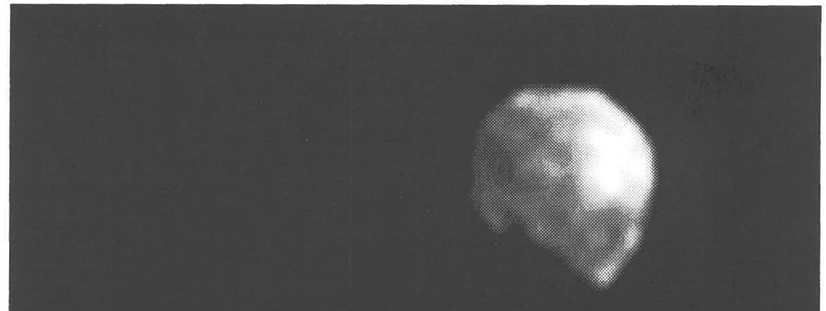
Please send articles or announcements to:
P. Thompson, 3600 Bay Area Boulevard, Houston TX 77058-1113.

Phone: 713-486-2175, fax: 713-486-2162
E-mail: (NSI DECNET) LPI::THOMPSON
(Internet) thompson@lpi.jsc.nasa.gov

INSIDE



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