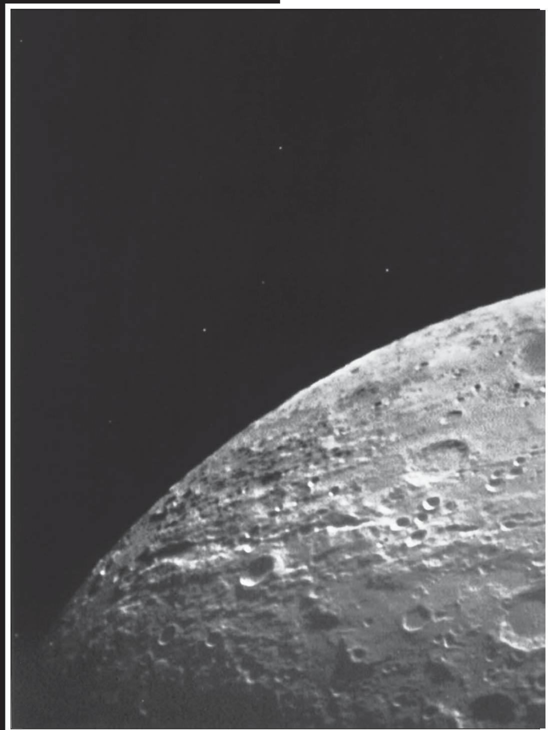
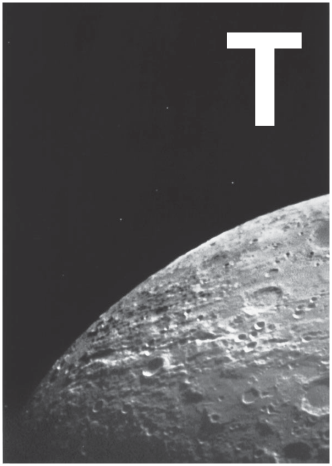
# A CLEMENTINE COLLECTION



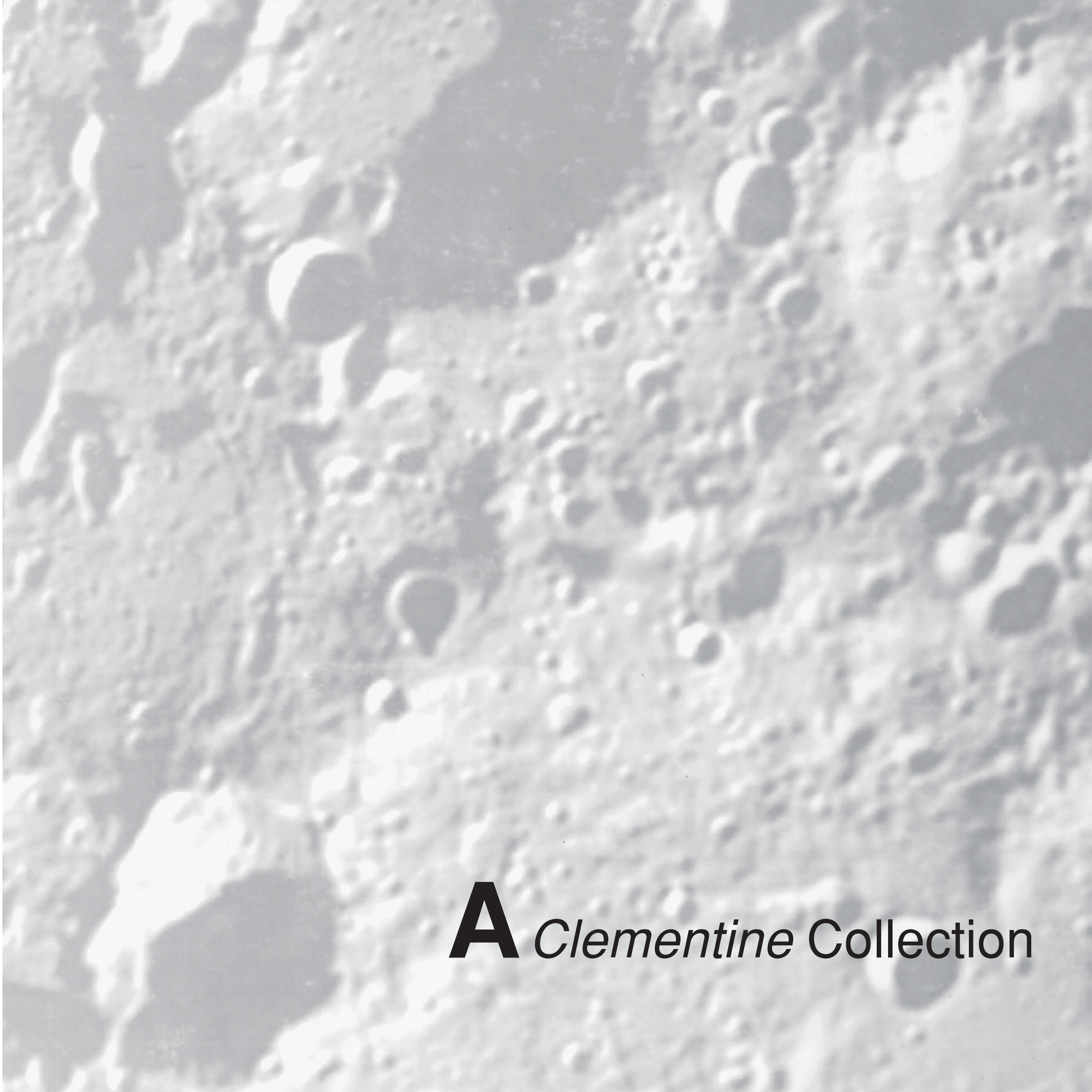
# MOON GLOW

Naval Research Laboratory
Washington, DC



This collection is an early sampling of the 1.8 million images acquired by the *Clementine* spacecraft. The mosaics and data shown in this collection are the first of many to come in the ongoing analysis and processing of images that will continue for the next five years.

# Contents



# A *Clementine* Collection

# The *Clementine* Story

The *Clementine* story began in 1990 when NASA administrator Richard Truly asked the Department of Defense to consider a joint NASA/DoD mission that would pursue goals mutually beneficial to both organizations. That request was given to the then Strategic Defense Initiative Organization (SDIO) to investigate. A mission was conceived to test the latest in space-based imaging components using the Moon as the subject. The *Clementine* mission is the result of those early investigations.

In January 1992, SDIO selected the Naval Research Laboratory (NRL) to begin a concept study to lay out an approach to implement the *Clementine* mission. SDIO and NRL investigated the latest technologies ready for flight testing and selected a camera suite from the Lawrence Livermore National Laboratory (LLNL). SDIO and NRL worked out the details of tracking support with NASA's Deep Space Network (DSN). NASA provided a science team to help select camera filters of interest to the planetary science community, while maintaining filters of interest to SDIO. The *Clementine* team was beginning to be formed.

In February 1992, SDIO informed NRL of its intent to proceed with the implementation of *Clementine*. Funding was provided to both NRL and LLNL in March 1992. The 22-month odyssey from concept to launch began.

By December 1992, SDIO, NRL, and LLNL had selected the best available components and technical support from the United States aerospace industry. One missing piece of hardware was even required from outside the United States and was provided by the French Space Agency, CNES. The team, though small, was now complete.

The spacecraft assembly began in May 1993 and was completed in early September. System-level testing was completed near the end of December, and *Clementine* was shipped to Vandenberg AFB, California, on December 30,1993, to prepare for launching. A sophisticated, deep-space spacecraft had been put together in an astonishingly short period of time. *Clementine* was tested and integrated into the Titan II vehicle and launched on January 25, 1994, as planned 2 years previously.

*Clementine* was placed in lunar orbit on February 19, 1994, completing its highly successful lunar mapping mission. *Clementine* left lunar orbit in early May 1994, but not before amassing a collection of 1.8 million lunar images.

On December 3,1996, DoD officials announced that *Clementine* data, under analysis since the mission ended, showed that deposits of ice existed in permanently dark regions near the Moon's South Pole. More recently, NASA's LUNAR PROSPECTOR mission has confirmed the presence of ice, actually at both lunar poles. These exciting discoveries suggest that a series of more aggressive missions to the lunar poles should be designed and undertaken. These deposits could be used for rocket propellant and for life-support consumables to a self-sustaining lunar colony.

The *Clementine* Program, which consisted of a small team from the Ballistic Missile Defense Organization (BMDO, formerly SDIO), NRL, LLNL, NASA, AFRL, and industry, demonstrated the capability for low-cost, high-value space exploration missions. *Clementine* represented a new class of small and capable spacecraft that enabled long-duration deep-space missions at low cost and provided significant advances in lightweight satellite technology.

*Clementine* offered many benefits to the U.S. space program. Along with its primary military mission to qualify lightweight technology, it returned valuable lunar data for the international civilian scientific community that exceeded mission science objectives. Its scientific observations have built the most comprehensive lunar multispectral geological map to date. It has also demonstrated near-autonomous spacecraft operations, showing a pathway for reduced flight operations costs on future DoD/NASA space missions.

A key element of the advanced technology demonstration was to obtain data on the performance of emerging technologies and their applicability to the space environment. *Clementine*'s findings during its mission were important for building a foundation for future small satellite operations.

*Clementine* showed the capability of the national laboratories, working in conjuction with DoD, NASA, industry, and international space organizations, to integrate, execute, and operate meaningful space missions at low cost. These organizations comprised dedicated professionals who had an almost impossible challenge in front of them. Many long days and nights were worked to achieve the results that this mission has produced. *Clementine* is living proof that the U.S. can still achieve great things in space.

*Clementine* is the first satellite to embody the concept of “faster, cheaper, better,” and represents the beginning of a new era of cooperation in space.

NRL has placed the *Clementine* imagery on the Internet:

http://www.nrl.navy.mil/*Clementine*

# The *Clementine* Team

**Ballistic Missile Defense Organization (BMDO)—**

concept, financial sponsorship, and overall program direction.

**Naval Research Laboratory (NRL) —**

design, integration, testing, construction, and operation of the spacecraft, mission planning, trajectory analysis, and data processing.

**Lawrence Livermore National Laboratory (LLNL) —**

lightweight imaging sensors and software algorithms, including especially the algorithm for determining spacecraft attitude through the LLNL Startracker.

**National Aeronautics and Space Administration (NASA) —**

tracking through the DSN; orbit determination and maneuver planning support by Goddard Space Flight Center (GSFC) and Jet Propulsion Lab (JPL); and two science teams—one to acquire and archive science data, and later a second to analyze science data.

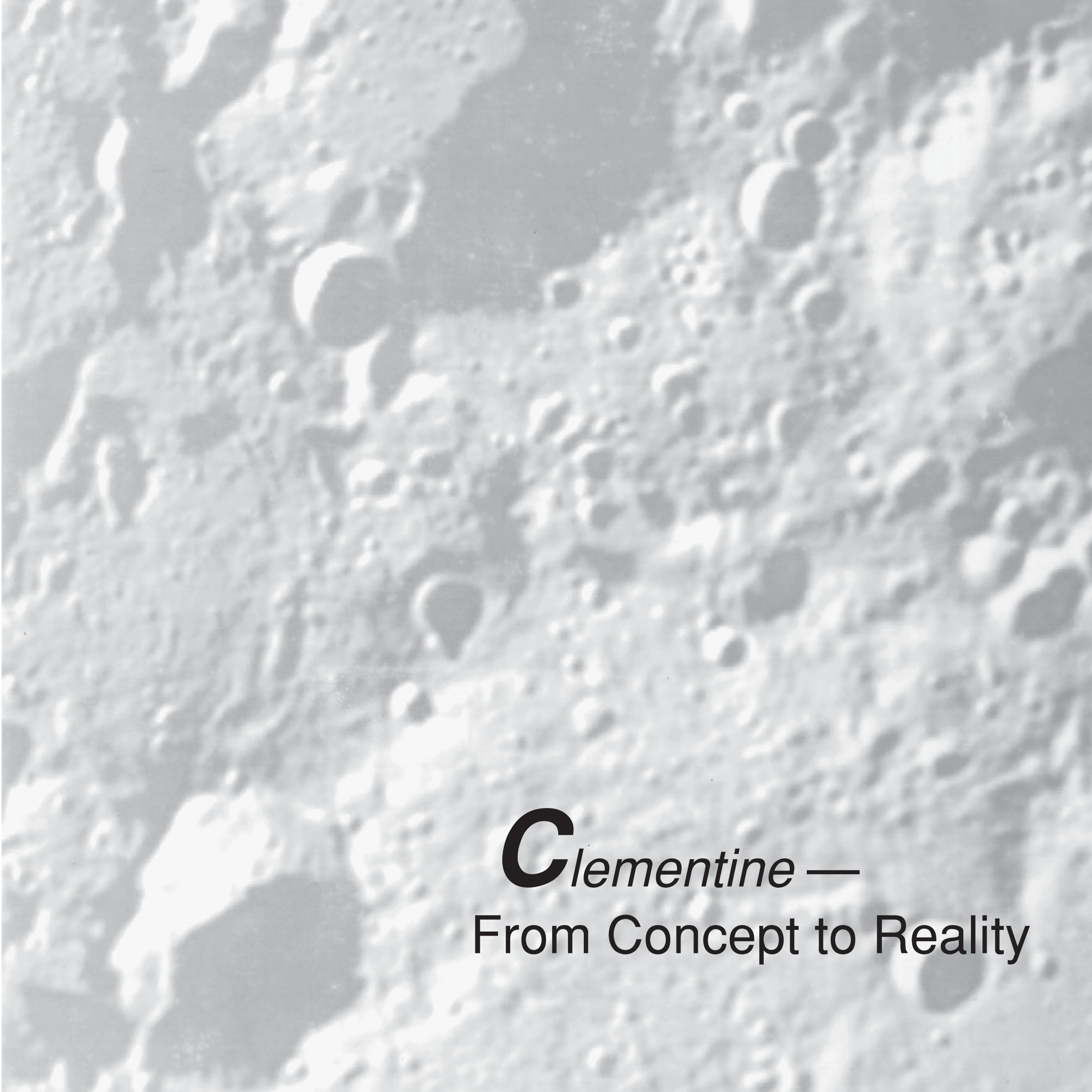
**Air Force —**

Philips Laboratory, Titan II, AFSCN

composite structures and materials, launch site and launch vehicle integration support, ground tracking, and command and control.

**Private Industry —**

significant partner with Government in all aspects of the program (see list on page 84).

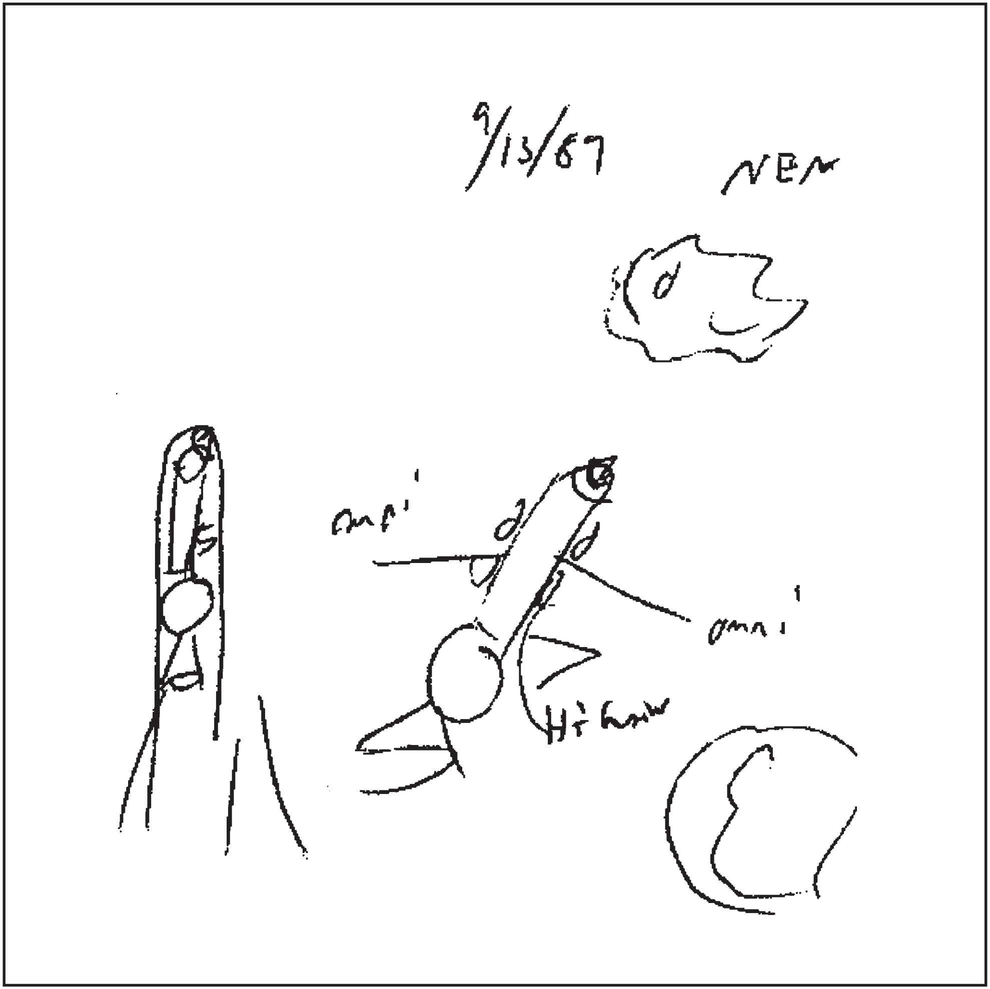


# Clementine — From Concept to Reality

# Concept on a Napkin

Stuart Nozette
*Clementine* Deputy Mission Director

*Clementine* originated in a bar on Eye Street in Washington, DC, in September 1989. I was talking to Pete Worden (working at that time at the White House National Space Council) and Geoff Tudor (then a Congressional staffer). We were discussing NASA's approach to the Space Exploration Initiative (SEI) over drinks, when *Clementine* emerged as a way to flight-qualify recently developed technology and, at the same time, demonstrate to the civilian community the great strides made by the Department of Defense and SDIO in lower cost advanced space technology. I outlined the concept on a handy bar napkin and suggested the name as a way to discuss the concept. Soon after this, I joined Lawrence Livermore National Laboratory to pursue the idea.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# The *Clementine* Concept

This artist's concept for the *Clementine* mission illustrates the final mission plan—to use the spacecraft's interstage adapter, the Moon, and a near-Earth asteroid as targets to demonstrate lightweight component and sensor performance.

# Into the Domain of *Clementine*

*Clementine* fires its kick motor and heads off for the Moon. Following a polar orbit trajectory, the spacecraft has completed the second perigee of its flight path. The sensors' cover will open after the interstage kick motor is jettisoned.

This painting is by Brian Sullivan, a production designer at the Hadyn Planetarium in New York City, and a *Clementine* fan. The painting is done with acrylic paints; images are painted with a Paasche AB airbrush brush.

# *Clementine* — designed and built by the Naval Research Laboratory

BMDO assigned prime responsibility for the *Clementine* spacecraft design, manufacture, integration, and mission execution to NRL in March 1992. The construction and integration of the spacecraft was completed in 22 months. This photograph shows the spacecraft, on top of its interstage adapter, being prepared for testing in NRL's anechoic chamber. *Clementine* is essentially completed and undergoing one of the final tests before transport to Vandenberg Air Force Base in California.

Richard Bussey
NRL Photographer

# A Fortune Cookie Says It All

Late one evening in November, while the *Clementine* spacecraft was being prepared for testing, a small group of NRL engineers and technicians ordered dinner from a nearby Chinese restaurant. After a well deserved but brief dinner break, Bob Bauldauff, an NRL thermal engineer, opened his fortune cookie before returning to work:

"You will soon take a very pleasant and successful trip."

Knowing that a vacation was not in his immediate future, due to the demands of the *Clementine* schedule, he knew that this prediction was intended for the spacecraft itself. The words were taped to the spacecraft handling dolly, where they remained for the rest of the spacecraft processing, both at NRL and at the launch site at Vandenberg AFB, California. Prior to stacking the spacecraft atop the Titan 11 launch vehicle, the words were carefully transferred to the spacecraft, where they remain today.

Michael Savell
NRL Photographer

# A Farewell to *Clementine*

This is a final look at the *Clementine* spacecraft, which is mated to its launch vehicle, the Titan 11G. Here, the nose fairing is being lowered to enclose *Clementine* in her new home during launch.

Michael Savell
NRL Photographer

# *Clementine* Heads for the Moon

*Clementine* was launched at 8:34 a.m., PST, from Vandenberg Air Force Base, on January 25, 1994.

William Raynor
NRL Mechanical Engineer

# Pomonkey Tracks *Clementine*

Bernard Kaufman
NRL Astrodynamicist

The NRL satellite ground tracking station, located in Pomonkey, MD, is the principal communications and tracking support site for the *Clementine* space mission. This site provided critical support for spacecraft orbit maneuvers providing command, telemetry, and tracking data. The antenna used at the Pomonkey site is a 100-ft-diameter dish and operates in the necessary S-Band radio frequency needed for *Clementine*. Ground equipment modified for this mission included: new receivers, command encoders, transmitters, Doppler extractors, data formatters, an uninterruptible power system, an image processing system, data recorders, telemetry decommutation systems, voice and data communication systems, computers, and software upgrades to control antenna movement and equipment configuration. The modifications were made in about four months prior to spacecraft launch. This site was operated around the clock seven days per week by a staff of six. Pomonkey has provided uninterrupted service throughout the mission, from launch through the lunar orbit phase and the continuous Earth orbit phase.

This photo of the Moon was taken at the Pomonkey site at 9 p.m on February 19, the night of the first rocket burn for lunar insertion.

Bernard Kaufman

# The BATCAVE

Donald M. Horan
Chief Scientist, NIRL *Clementine* Program

Bendix Field Engineering Corporation (BFEC) maintained offices on King Street In Alexandria, VA, for NRLs Low-power Atmospheric Compensation Experiment (LACE) Program. By 1989 the King Street spaces were too small, and BFEC was directed to find larger accommodations that could continue to provide office space and also be used as a control center for the LACE satellite. Real estate agents identified a building at Wythe and N. Fayette Streets as a good possibility. The building had been used by the Virginia National Guard, but had been vacant for several months.

On our tour of the building, we entered an open bay area whose high ceiling had exposed steel trusses. The room was dimly lit. Large cobwebs hung from the steel trusses and the overhead lighting fixtures. The floor and other flat surfaces were covered with a significant accumulation of dust. One of the group (several people claim this honor) exclaimed, “This looks like a real bat cave,” and the name stuck. There was no evidence of bats at this time.

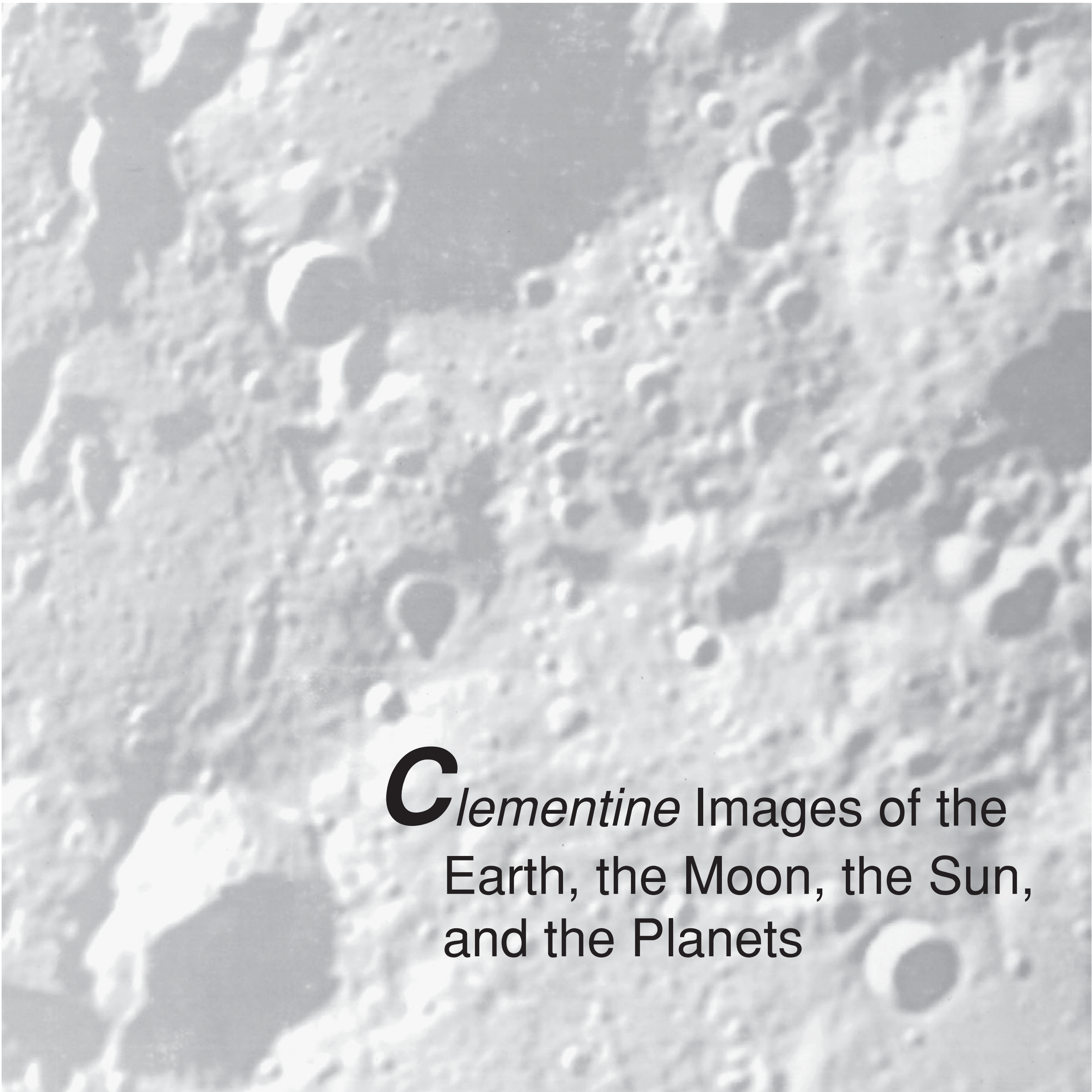
After extensive cleaning and remodeling, the Fayette Street facility came into use for the LACE Program. The name “BATCAVE” was displayed on cover sheets for the facsimile machine. Reportedly, BFEC higher headquarters said that “BATCAVE” could not be used in this manner because it was not a meaningful acronym. In rebuttal, the words Bendix Alexandria Technical Center for Aerospace Vehicle Experiments (BATCAVE) were quickly assembled to justify the acronym and the BATCAVE name attained some degree of legitimacy.

The BATCAVE was used as a mission planning, spacecraft control, and data processing center for the LACE satellite. Several months after the launch of LACE in February 1990, a real bat was discovered flying in the building late one night. The few occupants of the building panicked and chased the bat with brooms, breaking a window in the process. Unfortunately, the BATCAVE’s only bat did not survive the encounter.

Presently, the BATCAVE is the mission planning, spacecraft control, and data processing center for the *Clementine* Program.

William Griffith
NRL Photographer

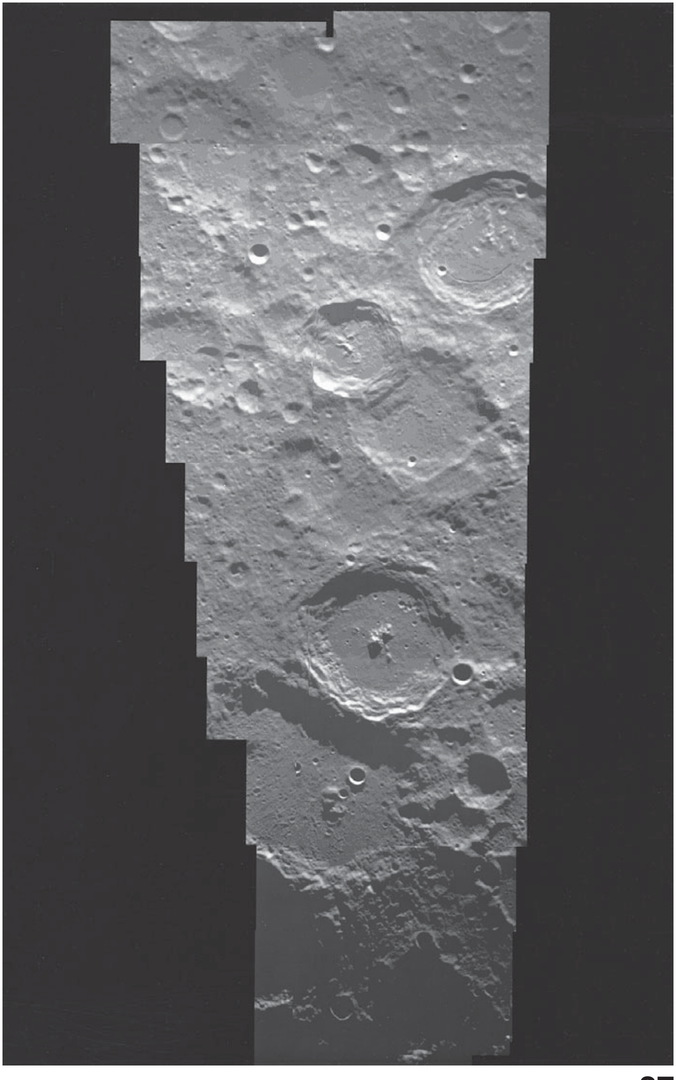

Enhanced with *Clementine* imagery



# *Clementine* Images of the Earth, the Moon, the Sun, and the Planets

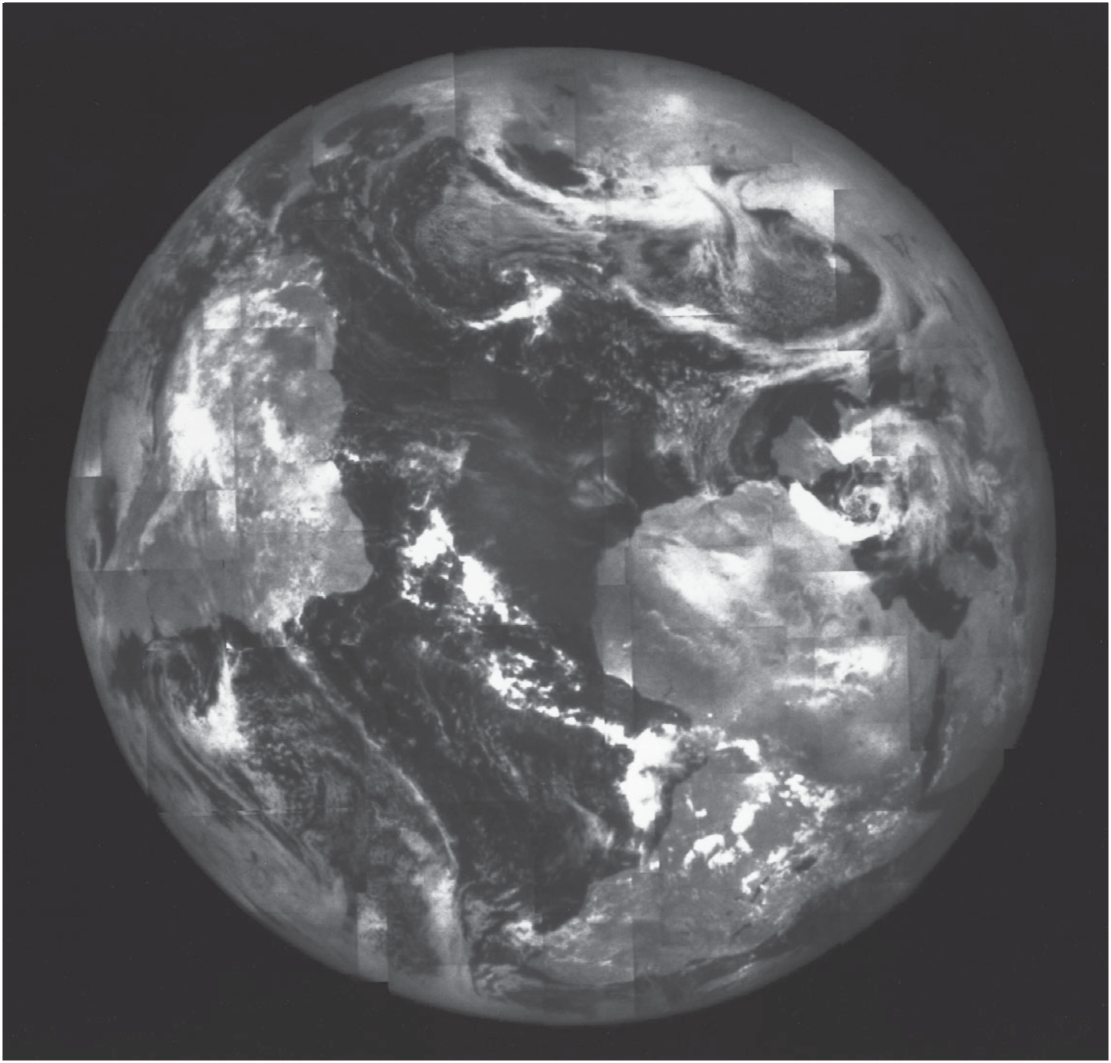
# Lunar North Polar Region

This shows a 630-km-long mosaic of the northern polar region along the 180° West longitude line from 69°N to 90°N. Imaged by the UV/VIS camera.



# Mosaic of a Full Earth

This was imaged by the High Resolution Camera at 750 nm on April 11, 1994, during lunar orbit 242. This mosaic was put together from over 70 high resolution images as the *Clementine* spacecraft's attitude was adjusted to scan the sensor across the Earth in strips. The image shows a $2 \times 2$-degree field of view and has a resolution of 6 km from a distance of 380,000 km. Africa and the Middle East are clearly visible on the right, with South and Central America visible on the left. The Caribbean, Florida, and the Eastern U.S. (mostly under cloud cover) are visible near the top of the image. North is to the upper right.

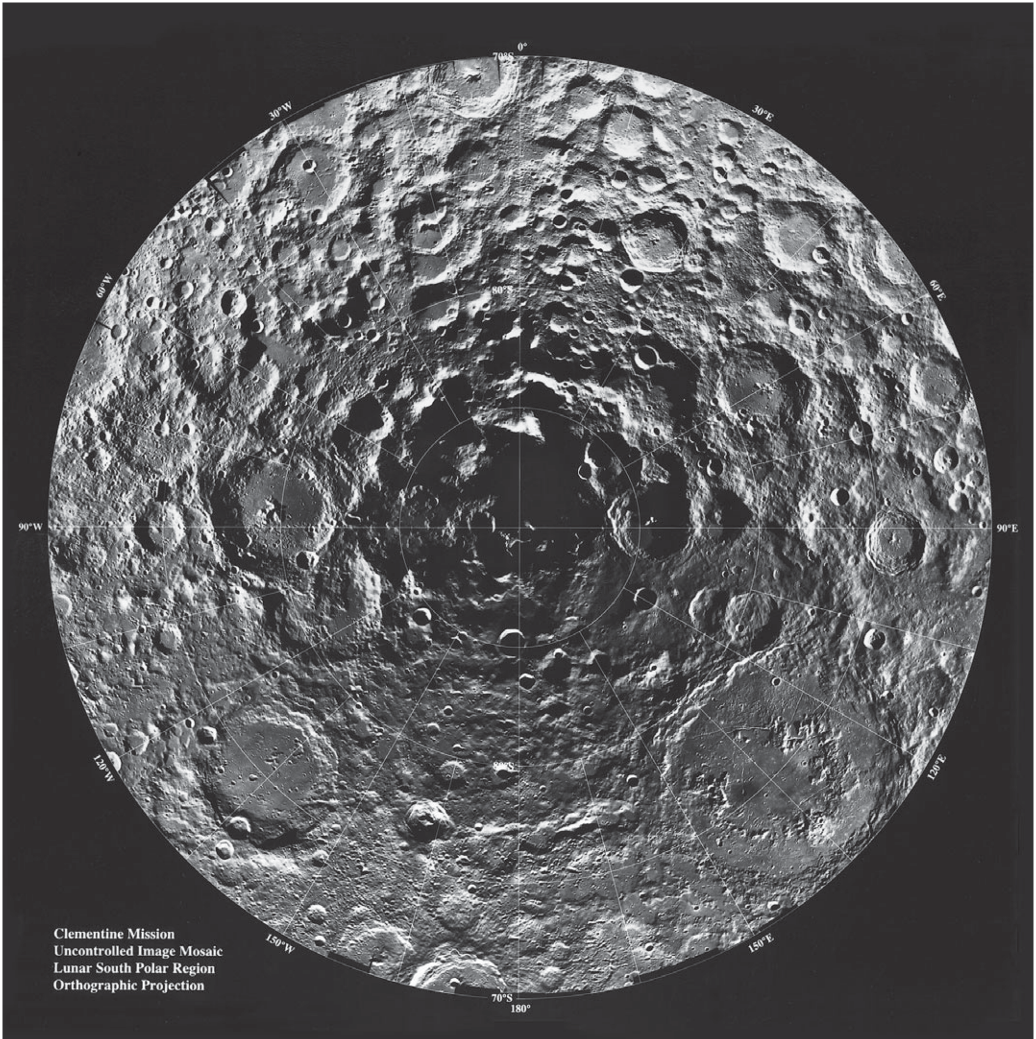


# Mosaic View of the Lunar South Pole

This mosaic is composed of 1500 *Clementine* images, taken through a red filter, of the south polar region of the Moon. These images were taken during the first month of systematic mapping. The top half of the mosaic faces Earth. *Clementine* has revealed what appears to be a major depression near the lunar south pole (center), evident from the presence of extensive shadows around the pole. This depression probably is an ancient basin formed by the impact of an asteroid or comet. A significant portion of the dark area near the pole may be in permanent shadow, and sufficiently cold to trap water of cometary origin in the form of ice.

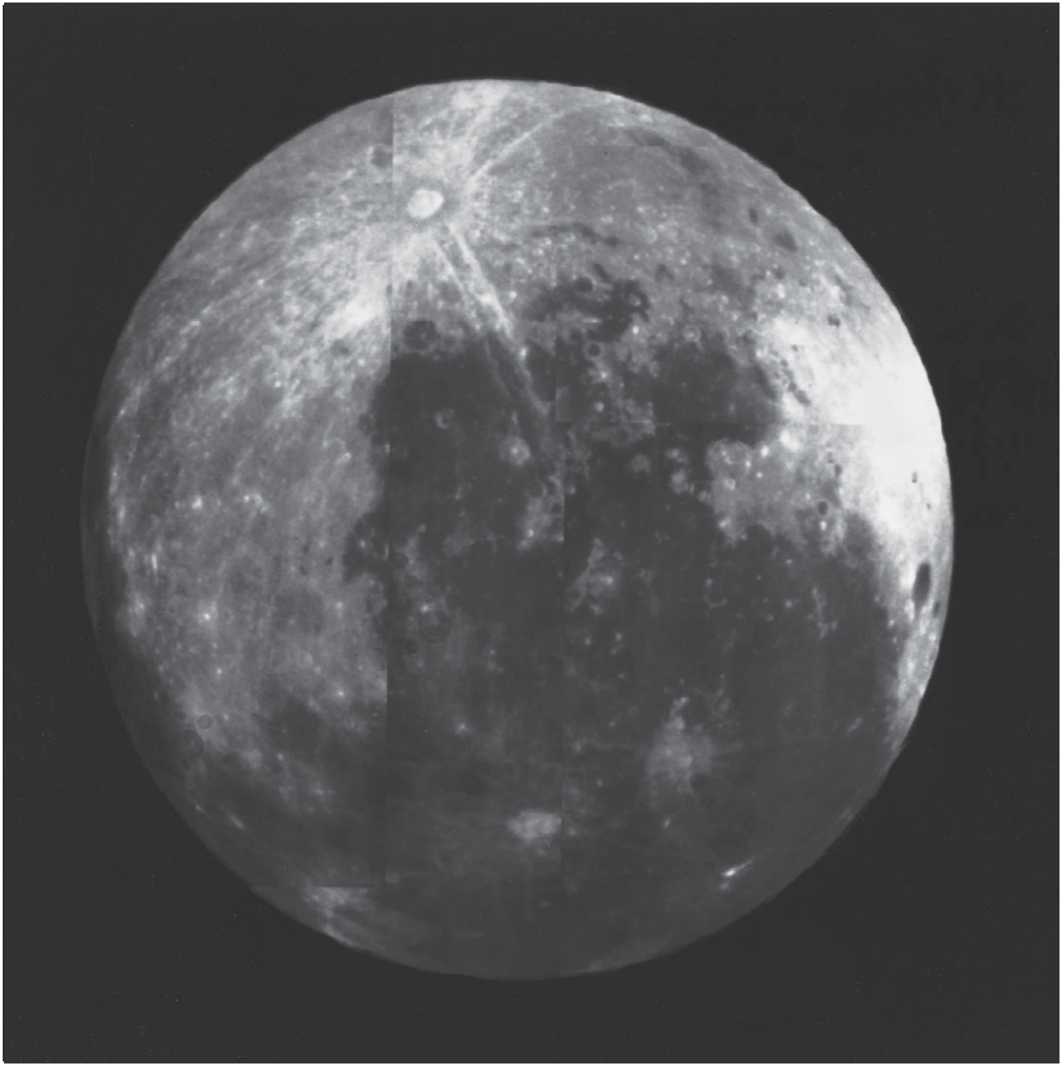
The impact basin Schrödinger (75°S, 134°E, at mosaic edge near the 4 o'clock position) is a two-ring basin, about 320 km in diameter. *Clementine* images have clarified the geological relations of Schrödinger. It is now recognized to be the second youngest impact basin on the Moon, younger than the great *Imbrium* basin on the near side, but older than the *Orientale* basin, as shown by the occurrence on Schrödinger of secondary craters formed by flying debris from the *Orientale* impact. The center of Schrödinger is flooded by lavas; these lavas are older than the crater Antoniadi (69°S, 172°W; 135 km diameter, at mosaic outer edge near the 6:30 position), as shown by the scoring of the lava surface by Antoniadi secondary craters.

Finally, a volcanic vent seen in the floor of Schrödinger is one of the largest single explosive volcanoes on the Moon; its dark ash deposit overlies the secondary craters of Antoniadi, thus indicating that it is significantly younger than lavas filling the basin. The mosaic displays a rich variety of geological relations, the deciphering of which will take lunar scientists many years.


0°
70°S
30°E
60°E
90°E
120°E
150°E
180°
150°W
120°W
90°W
60°W
30°W
80°S
Clementine Mission
Uncontrolled Image Mosaic
Lunar South Polar Region
Orthographic Projection

# Moon Lit by Earthshine

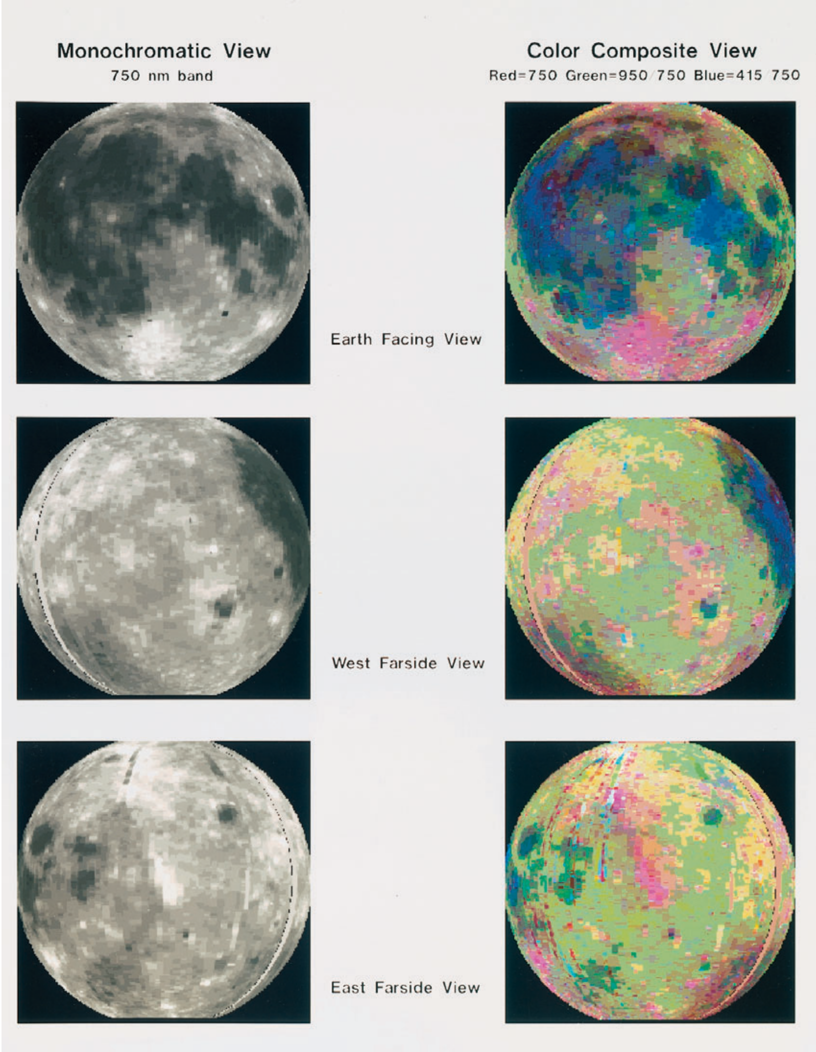
Mosaic of the near side of the Moon lit by Earthshine, as imaged by a Startracker camera on March 15, 1994. The southern hemisphere is up. The bright crater toward the top of the image is Tycho.



# *Clementine* Global Color Images of the Moon

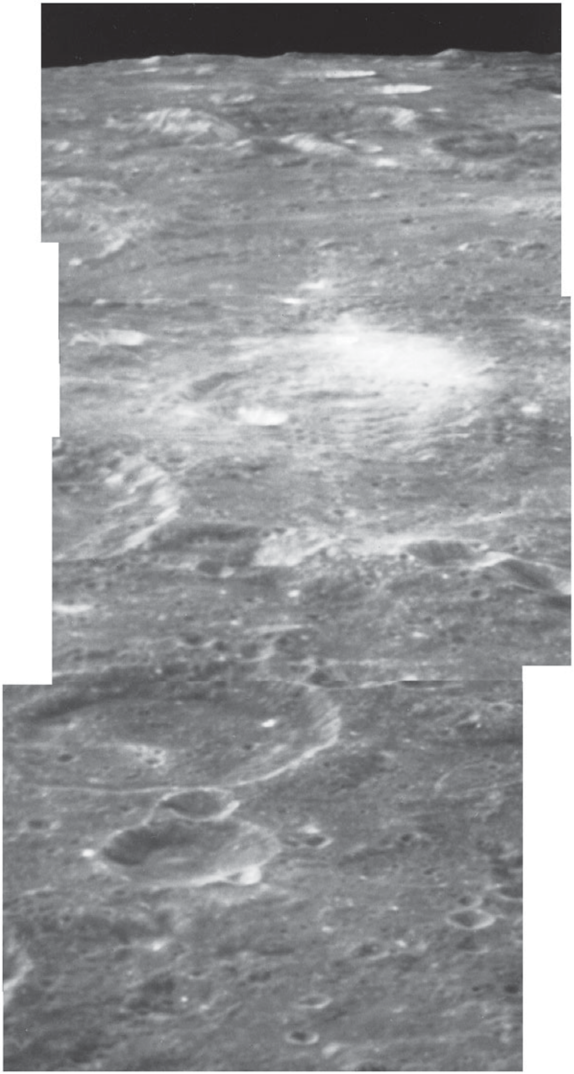
One of the major scientific goals of the *Clementine* mission is to map the Moon in 11 different wavelengths in the visible and near-infrared parts of the spectrum. The filter colors of the *Clementine* cameras were carefully chosen to differentiate types of lunar surface material. In our first look at the global color, each *Clementine* image made by the UV/VIS camera has been reduced to its average value, producing a picture of the Moon at low resolution (about 50 km per pixel). These pictures show the albedo (brightness) and color of the Moon from three aspects: the Earth-centered view (nearside) with a 0° central longitude, and two farside views with 120° East and 120° West central longitudes. These images have been made by assigning colors to the relative reflectance values obtained through various filters, resulting in a map showing the compositional variation of the Moon.

Major compositional provinces in the highlands are evident. The large dark red-gray region on the far side is the South Pole-Aitken basin, an ancient impact feature that apparently contains rocks of distinct composition. A newly discovered compositional anomaly on the east limb of the Moon (pink area near center of 120° East image) may be related to ancient flows of lava. The color picture shows that very high titanium lavas (deep blue and cyan colors) appear to be largely confined to the *Oceanus Procellarum*, *Mare Imbrium*, and *Mare Tranquillitatis* areas (nearside). These views of the Moon in three colors only hint at the scientific richness contained within the *Clementine* global data, which will be investigated for years to come.


Monochromatic View
750 nm band
Color Composite View
Red=750 Green=950/750 Blue=415/750
Earth Facing View
West Farside View
East Farside View

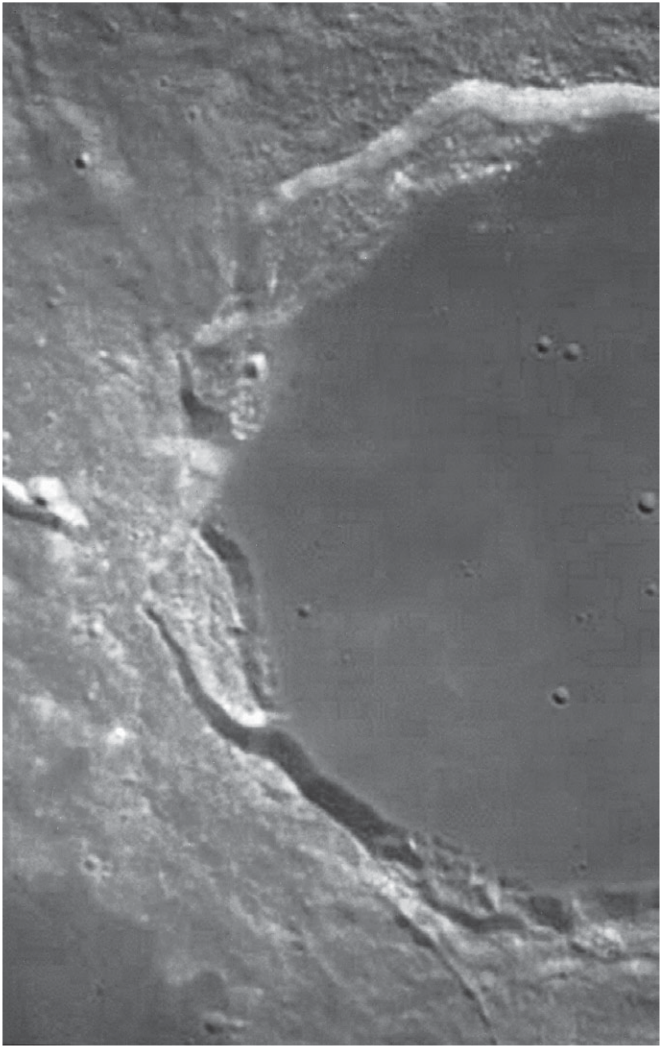
# View of Apollo 16 Landing Site Using UV/VIS Camera

This spectacular oblique mosaic is composed of five *Clementine* images. The Apollo 16 landing site is located between the two small bright craters just above the brilliant white patch in the center of the mosaic



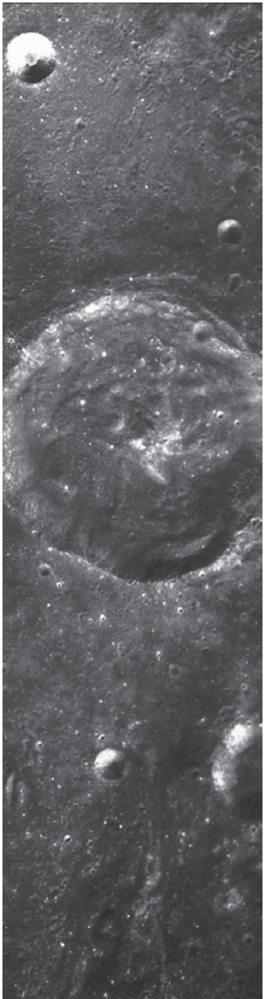
# Plato Crater

Plato crater imaged by the UV/VIS camera at 1 micron, from an altitude of 485 km. Plato is at 51°N, 9°W; North is up. The strip width of this mosaic is about 90 km. The smallest craters visible are 600 meters across.



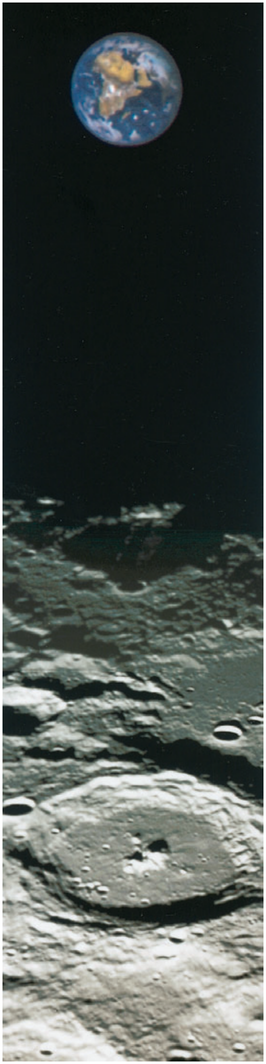
# Rydberg Crater

Rydberg crater mosaic imaged by the UV/VIS camera from an altitude of 485 km. Rydberg is at 47°N, 97°W. Strip width is about 50 km. The field of view of the UV/VIS camera is 4.2° by 5.6°.



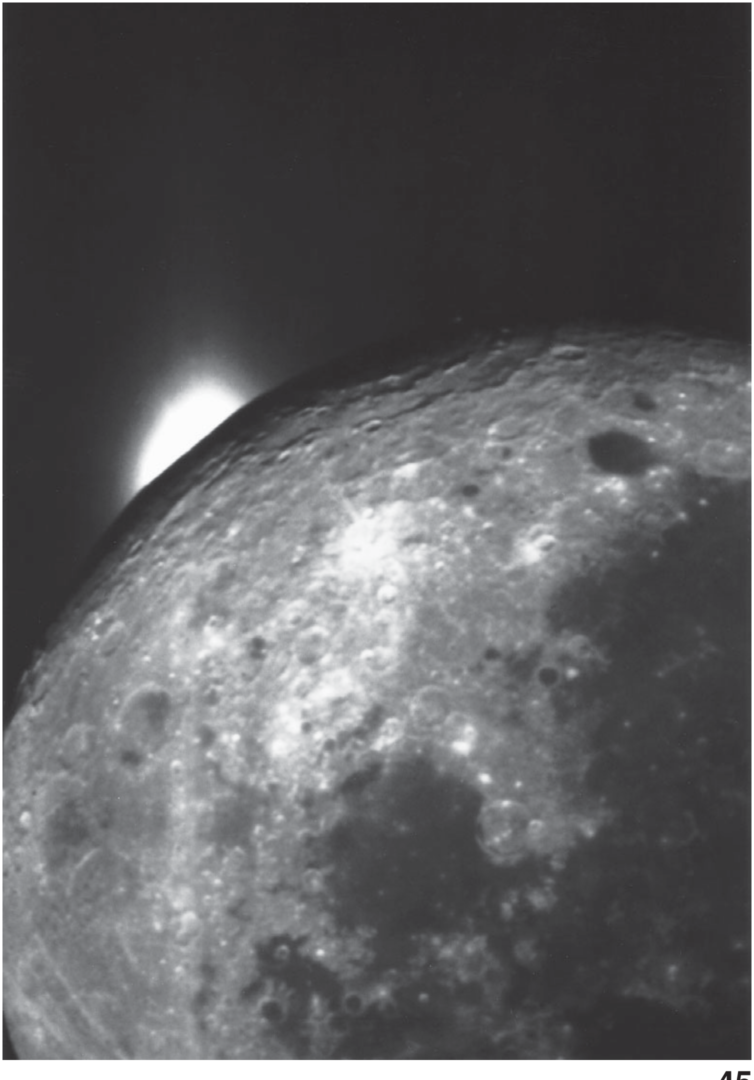
# Full Earth over Moon

This colorized image shows the full Earth over the lunar north pole as *Clementine* completes mapping orbit 102 on March 13, 1994. It is a clear day over Africa and the Arabian Peninsula. The angular separation between lunar horizon and Earth has been reduced for illustration purposes. The large crater at the bottom of the image is Plaskett at 180° West, 82° North.



# *Orientale* under Earthshine and the Solar Corona

This fantastic view of the Moon was acquired by the attitude determination camera (Startracker) on board the *Clementine* spacecraft. The Moon is illuminated only by Earthshine—that is, sunlight reflected from the Earth to the Moon. The Sun is actually behind the Moon, though the outer portion of the Sun, the solar corona, is visible over the limb. The ringed basin disappearing into the darkness is the *Orientale* basin. The deep shadows cast by its steep walls give a dramatic emphasis to its classic multi-ring morphology.

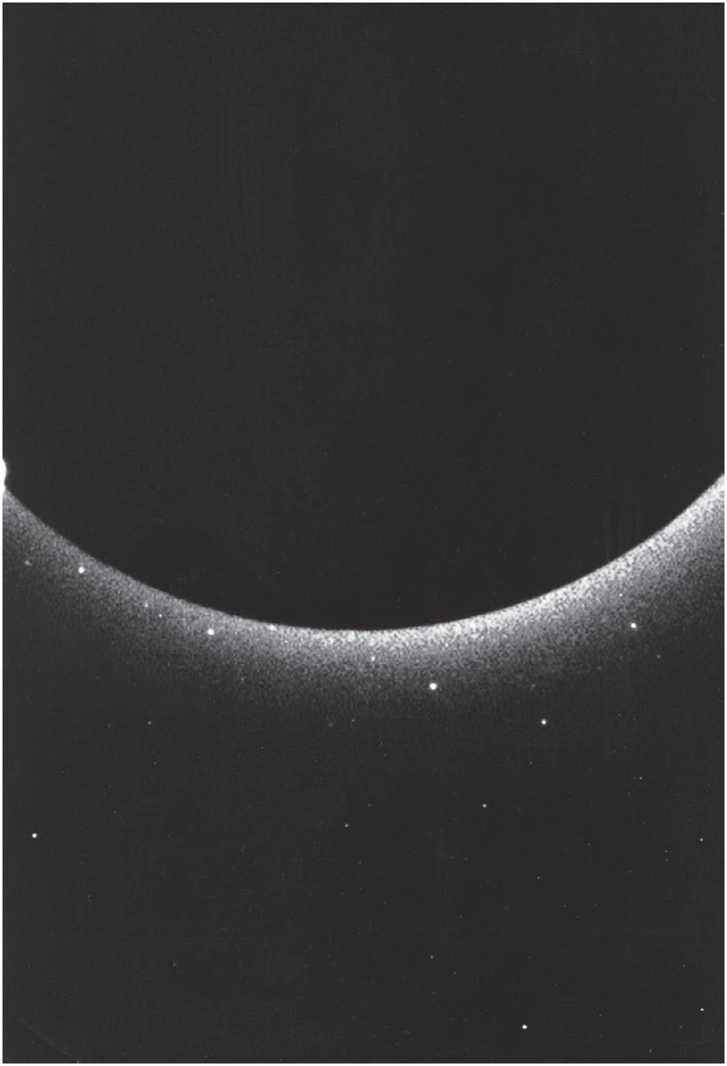


# Venus over Earth-lit Moon

Startracker image, taken during orbit 194 on April 1, 1994, of the dark Moon lit only by Earthshine. Venus is smaller than it appears in this image, as it saturates the CCD. The field of view of the image is $28° \times 42°$.

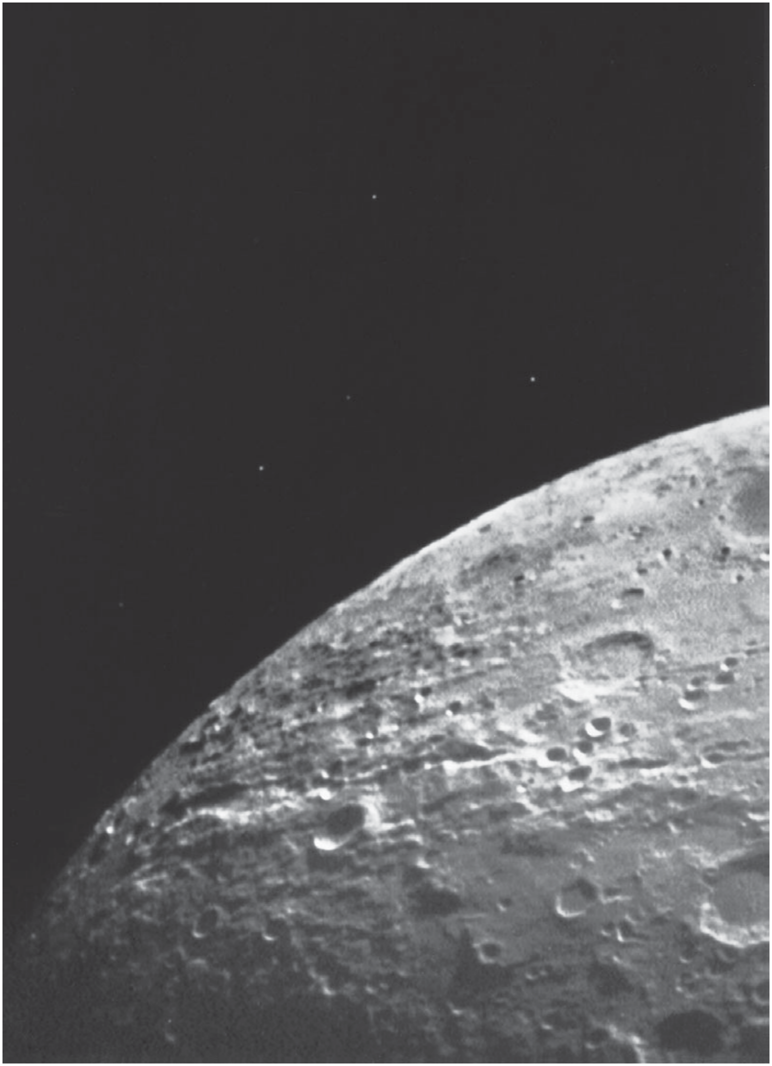
# *Clementine* View of Moon Limb Eclipsing the Sun

This Startracker image shows the Moon eclipsing the Sun. The bright crescent Earth is partially visible at left, saturating the sensor. The image was captured during orbit 164, on March 26, 1994, halfway through Moon mapping at a distance of 3500 km. The field of view of the image is 28° x 42°.



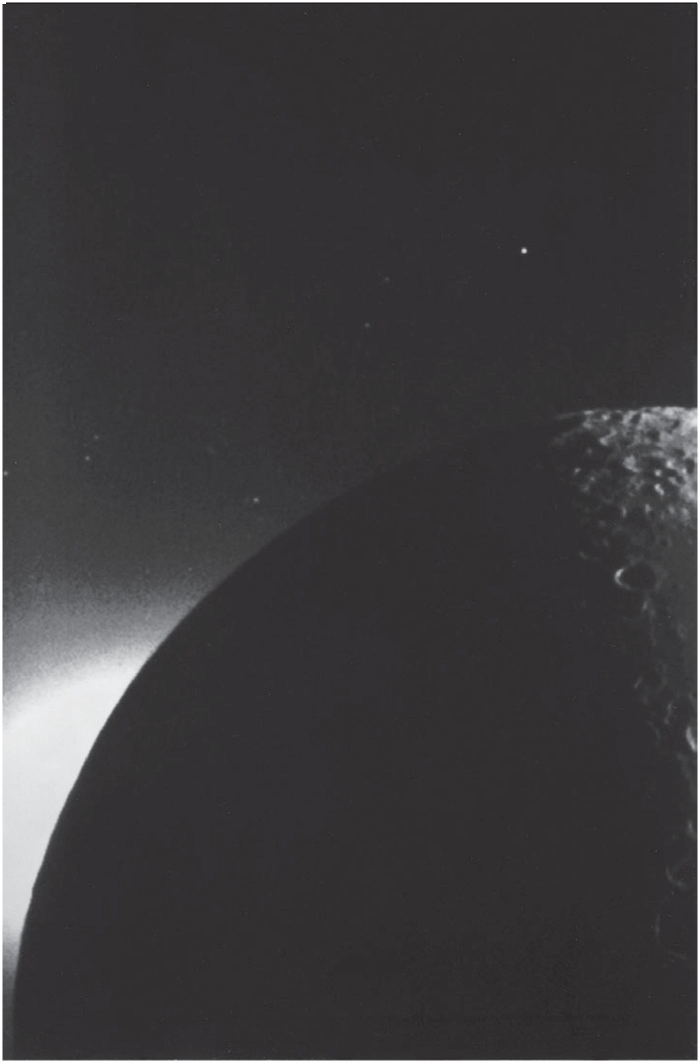
# Moonglow from Earthshine

The *Clementine* Startracker acquired this image of the Moon glowing from the reflected light of the Earth.



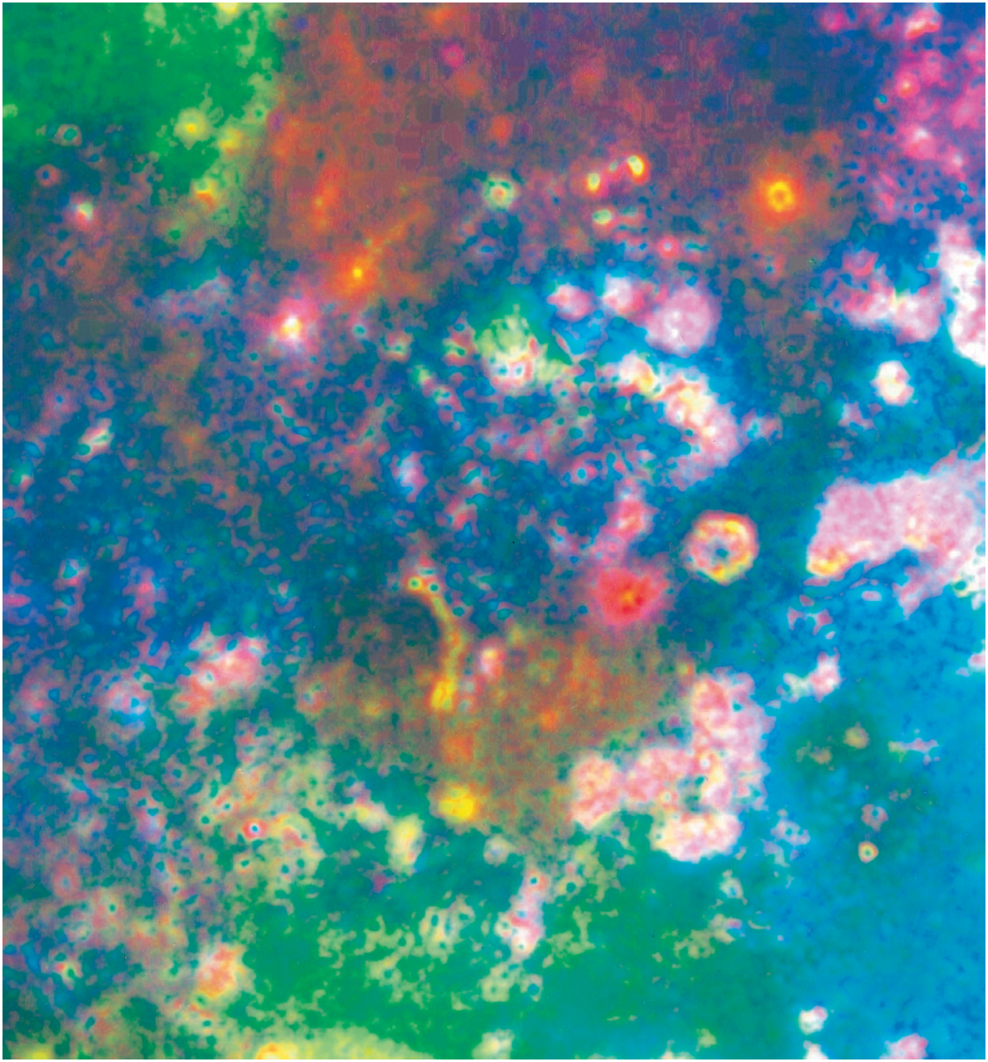
# *Clementine* View of the Sun and Moon

This presunrise Startracker image shows the solar corona, stars in the background, and the terminator between the dark side of the Moon and the area on the right, which is illuminated by light reflected from the Earth.



# West of Apollo 17

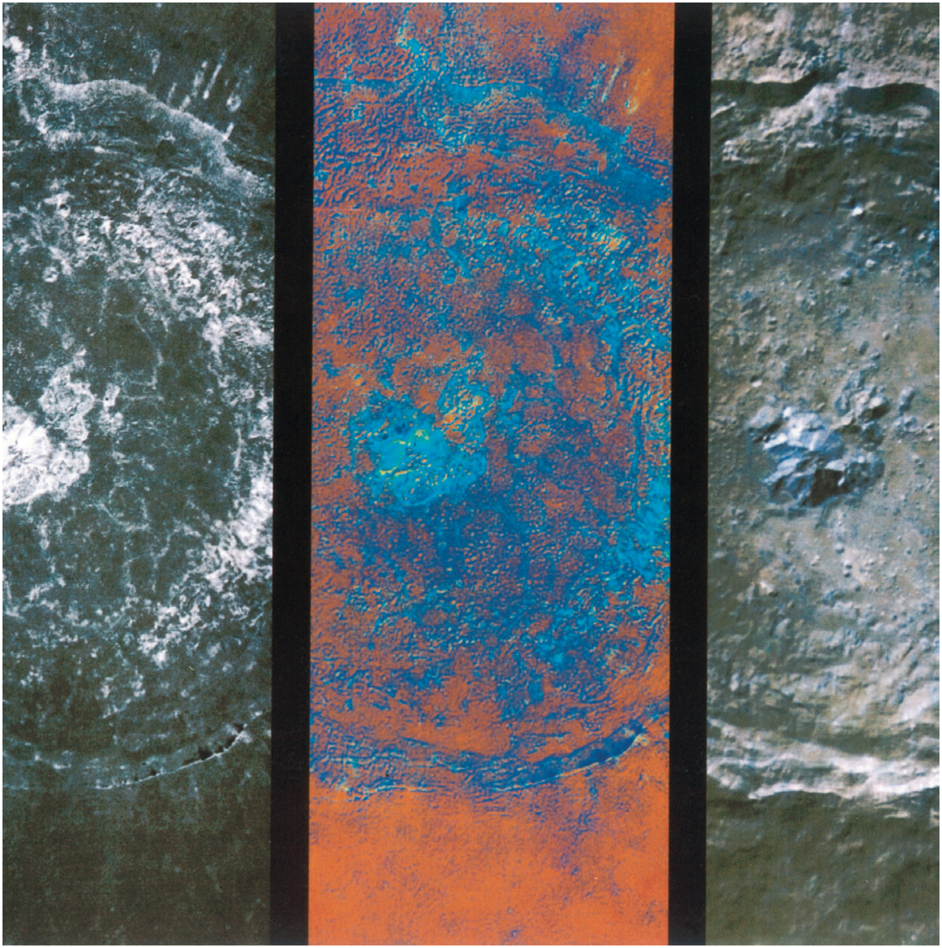
This image, captured by the *Clementine* UV/VIS camera, dramatically shows the unique capability of the *Clementine* image data to discriminate actual changes in mineralogy of the lunar surface. The colors in this mosaic are the result of a decorrelation color stretch of images at 415 nm, 750 nm, and 1000 nm. The color differences shown here result from varying rock types and “maturity” (relative age of exposure). Using similar methods, combining both image data of the NIR and UV/VIS cameras, many of the Moon's geologic secrets will be revealed for the first time. These color image data are a unique data set in the annals of planetary exploration. The width of the area in the image is about 45 km.



# Tycho Crater

These UV/VIS images were formed from a mosaic of five image cubes, each consisting of spectral bands (415 nm, 750 nm, 900 nm, 950 nm, and 1000 nm). These data were acquired during orbit 40 on February 28, 1994.

| | |
|---|---|
| Left: | Ratio of wavelengths 750 nm/1000 nm, which is useful for evaluating the amount of mafic materials. In this ratio the unusual polygonal pattern in the floor of the crater is greatly enhanced relative to the simple color composite on the right |
| Middle: | Color composite formed with ratio images<br>Red = 750 nm/415 nm<br>Green = 750 nm/1000 nm<br>Blue = 415 nm/750 nm |
| Right: | Color composite<br>Red = 1000 nm<br>Green = 900 nm<br>Blue = 415 nm |

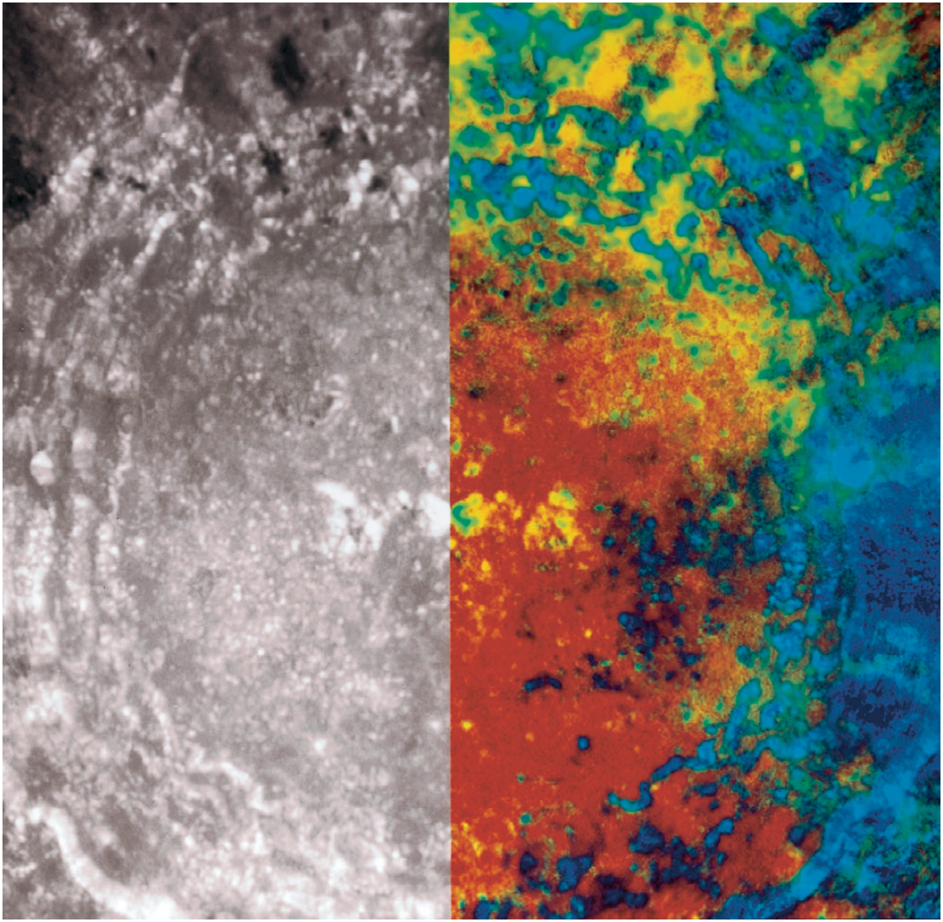


# Copernicus Crater Mosaic

Mosaic of the lunar crater Copernicus produced using images obtained by the *Clementine* UV/VIS camera. This 95-km crater, believed to be approximately 800 million years old, is located near the center of the lunar nearside and exhibits prominent rays extending in all directions. The right section of the image is a color composite mosaic of the eastern half of Copernicus. This color mosaic was prepared using images obtained through filters of three different colors chosen to allow small lunar color differences to be mapped in a geologic context. In this image, the color assignments are: red (750/415 nm), green (750/950 nm), and blue (415/750 nm). The left section of the image is a mosaic of the same area prepared using frames obtained through a single filter (750 nm). This mosaic is displayed as a mirror image to the color composite to allow easy comparison of geologic features and their color.

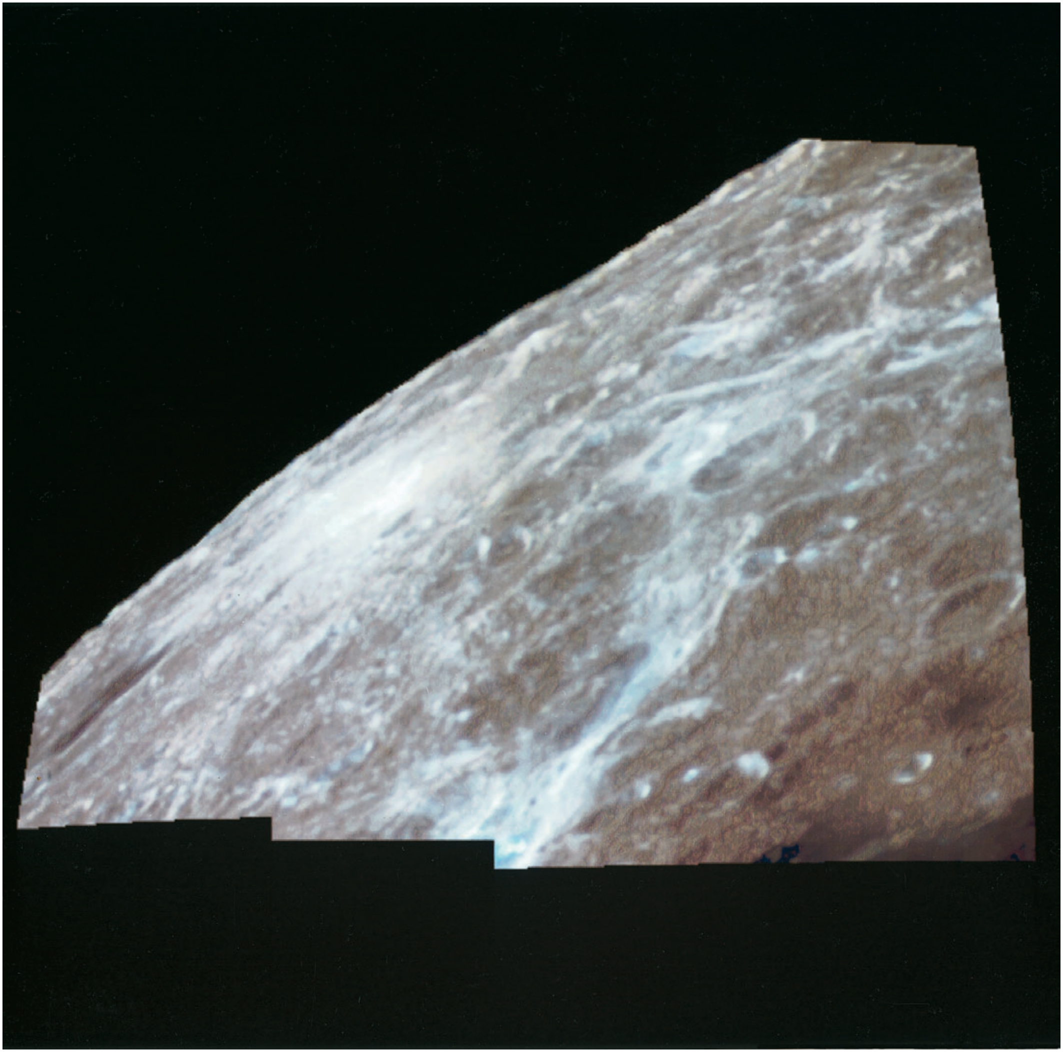
Extensive large- and small-scale heterogeneity of materials excavated by this large crater is readily evident from the color composite mosaic. Bright blue tones typically suggest fresh material similar to Apollo 16 rocks and breccias, mottled red-orange tones indicate material similar to Apollo 16 soils, vivid red is associated with deposits of impact melt (seen most prominently in the northwestern part of the crater floor), and green-yellow tones along the southern wall imply a higher abundance of iron-bearing materials.

Impact craters can be used as windows into the interior, and this multispectral image of Copernicus provides dramatic new information about how materials are excavated, melted, mixed, and deposited in a major impact event. The extensive heterogeneity around the wall of the crater indicates materials are not intimately mixed in spite of the huge energy involved during crater formation. Similarly, impact melt (target rock melted during the impact event) is not distributed uniformly, but can be seen to be concentrated in large sections of the floor and in small areas along ledges of the walls.



# Limb of Gargarin

This series of oblique images was acquired by *Clementine* during orbit 255. The images used to form this color composite were taken with the UV/VIS camera at wavelengths of 415, 750, and 1000 nm. In the lower right are seen *mare* materials (flood lavas) in the floor of the impact crater Jules Verne. To the left, near the Limb of Gagarin, is another *mare* unit in the floor of Tsiolkovsky.

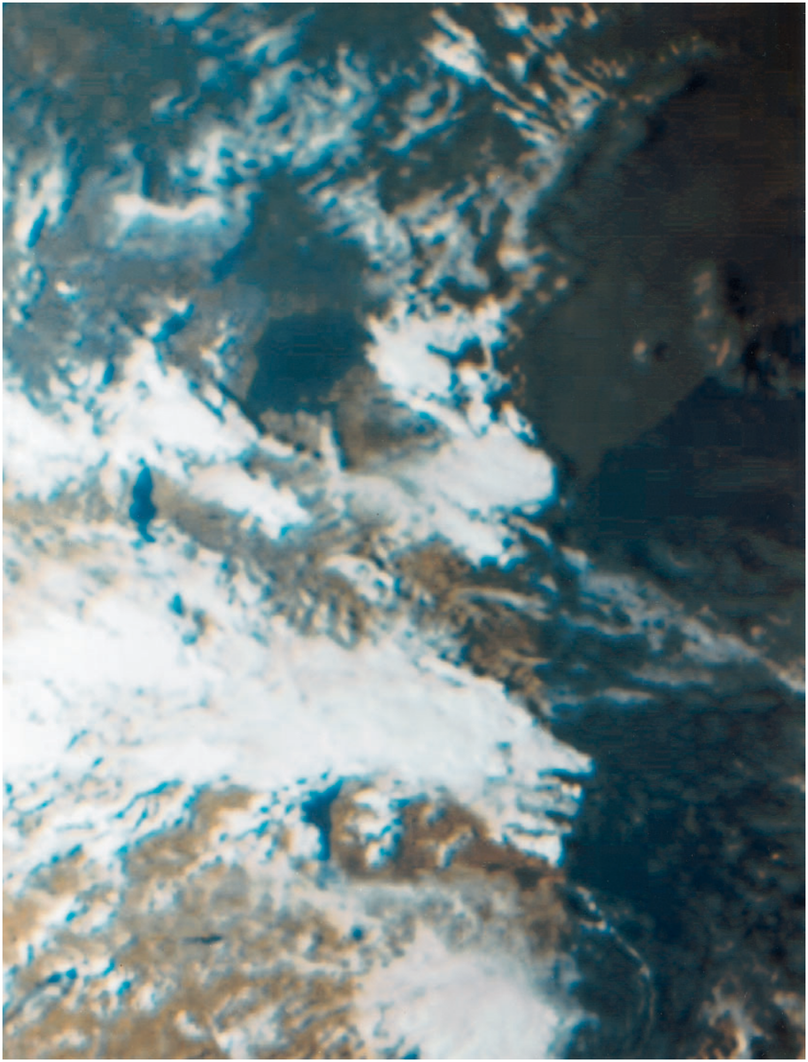


# Night and Day

Earth as seen from 78,000 km with the UV/VIS camera on February 11, 1994. India is visible toward the top of the image, with south roughly toward the left.

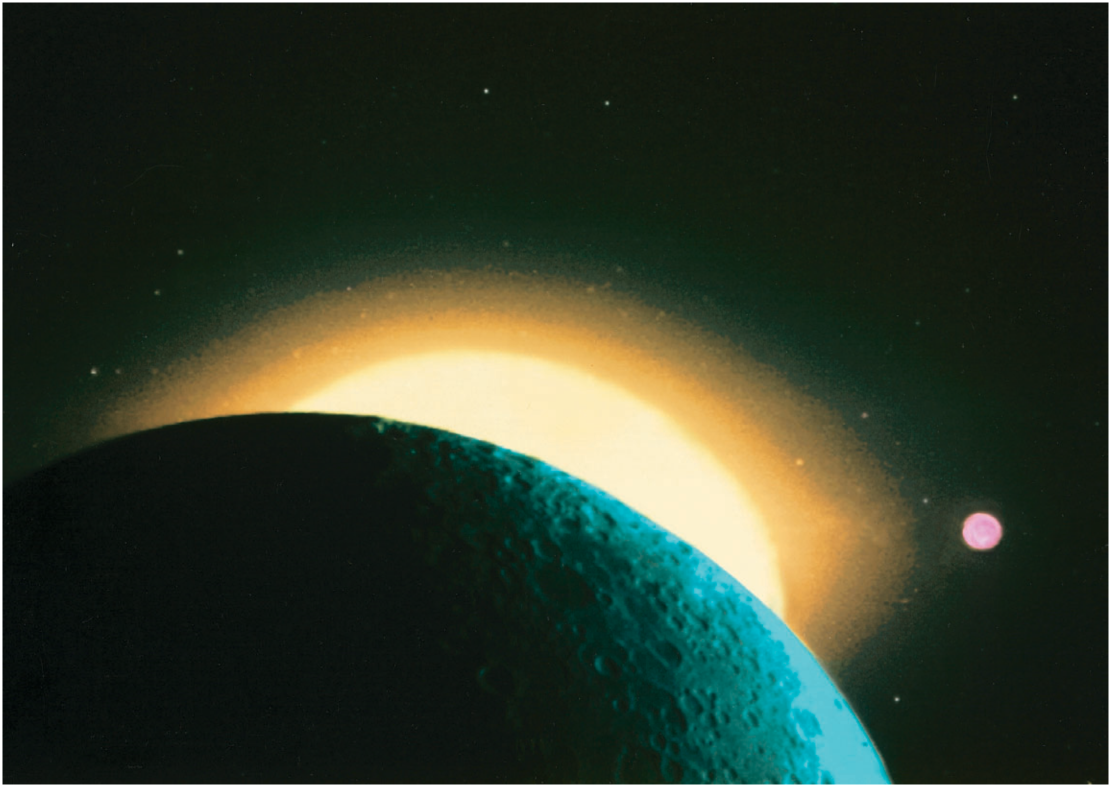
# Lake Victoria

This UV/VIS camera image shows the cloudy continent of Africa, with Lake Victoria appearing through the clouds just above the image center.



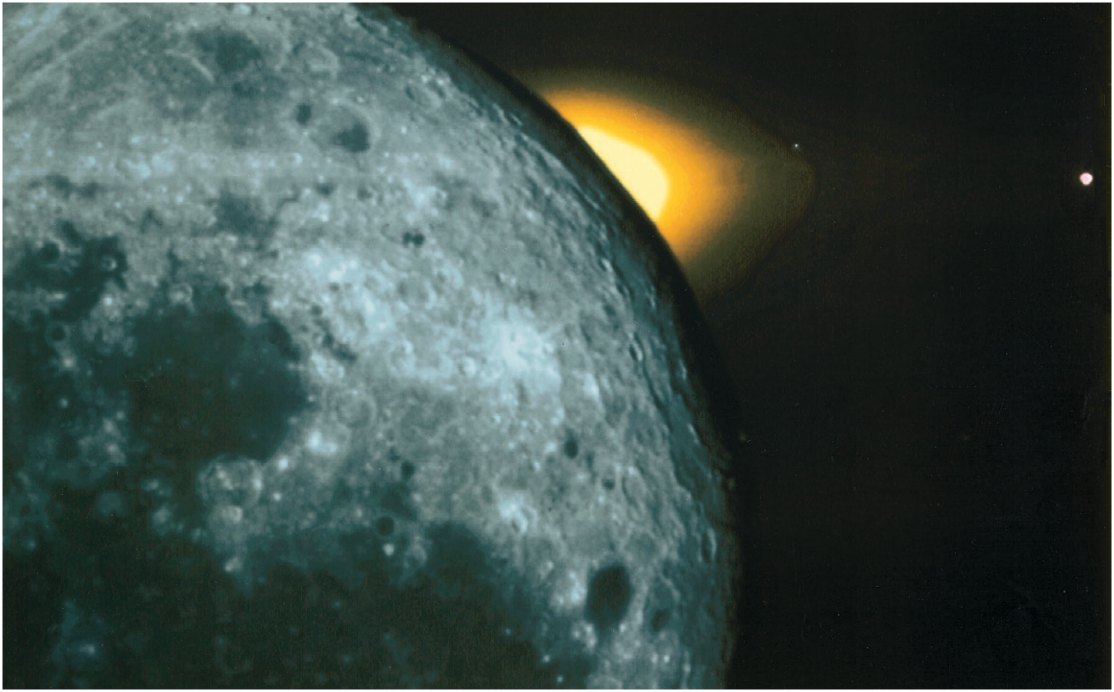
# Sunrise and Venus over the Moon

This color-enhanced image of Venus, the solar corona, and the Moon was acquired by the Startracker. The terminator between the dark side of the Moon and the Earth-lit side can also be seen.



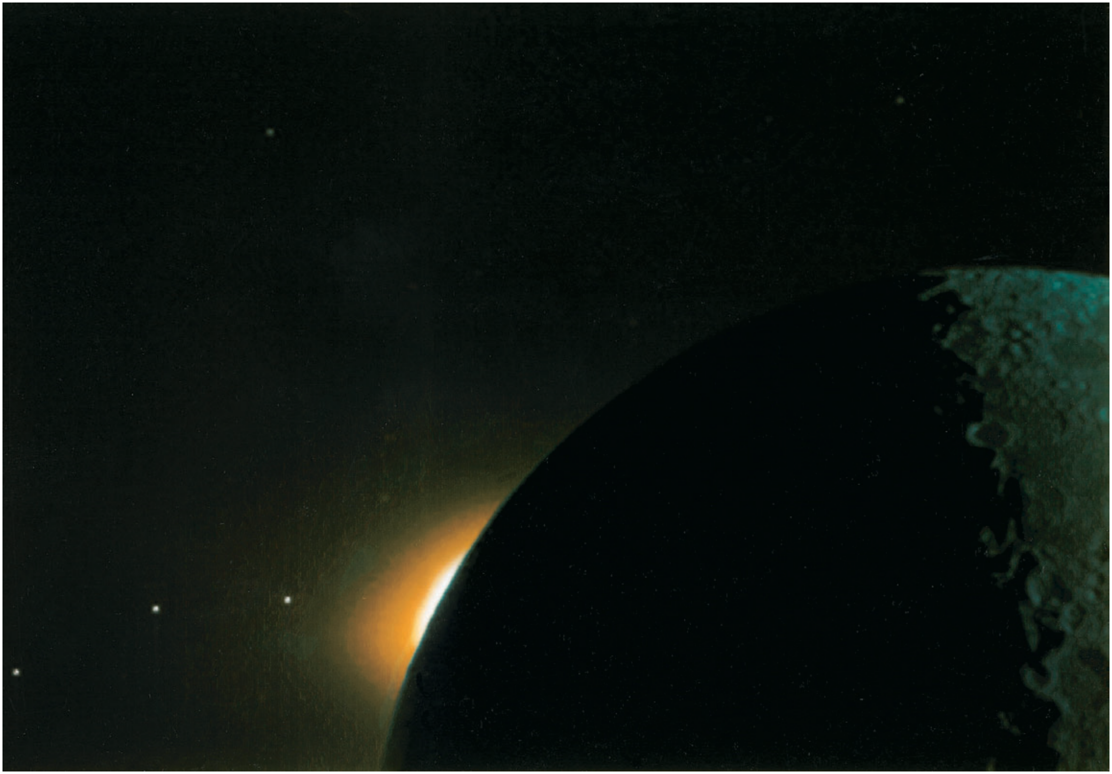
# Earth-lit Moon

The Earth-lit Moon, the Sun's corona, and—to the far right—Venus, are visible in this color-enhanced Startracker image. The *Mare Humorum* is the dark circular *mare* at the center of the lunar disk.



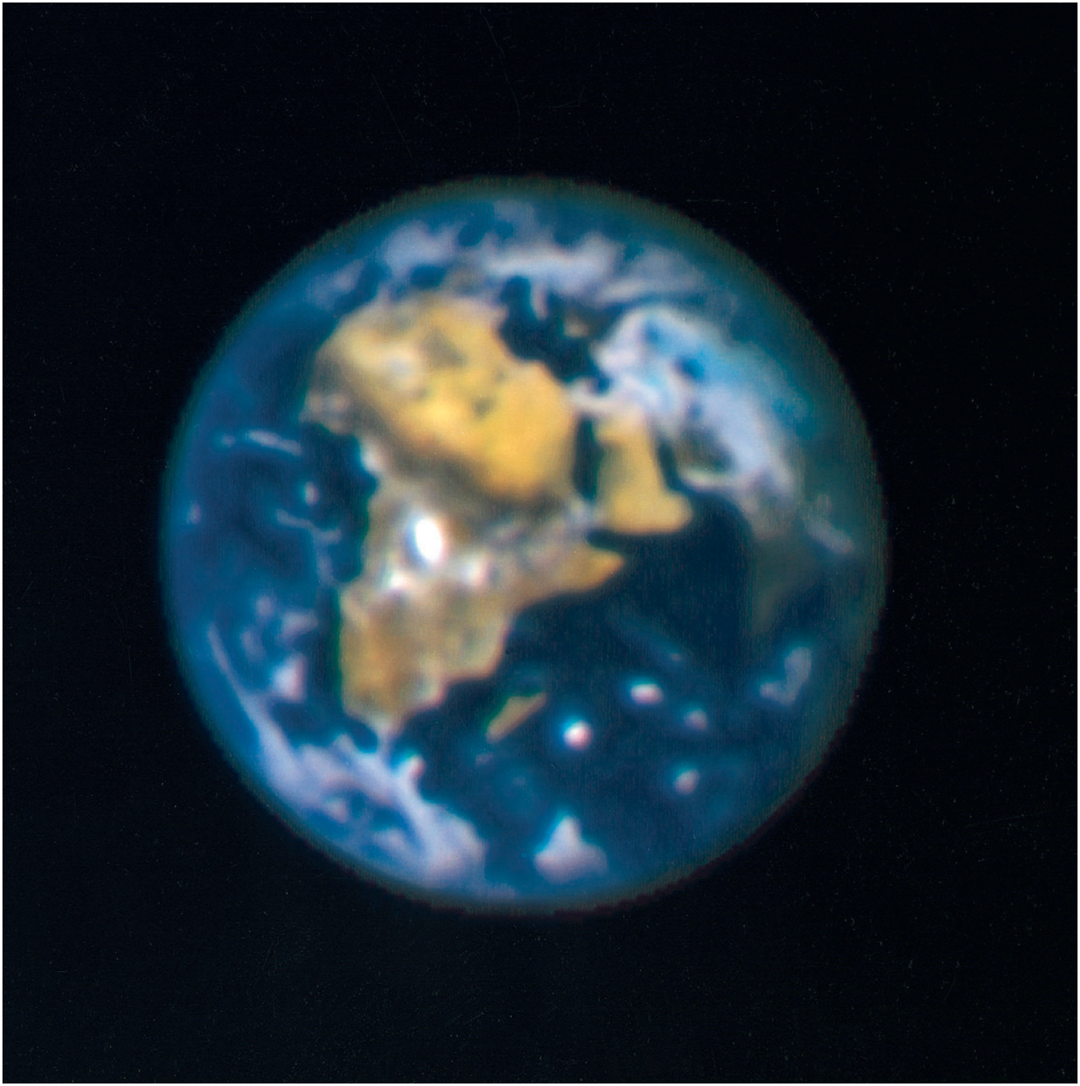
# The Moon, Sun, and Planets

The Startracker imaged this spectacular shot of the sunrise, planets, and Moon. This color-enhanced image shows, from right to left, the Moon lit by the Earth, the terminator—or boundary between light and dark—into the dark side with the solar corona just rising over the limb, and the bright planets Saturn, Mars, and Mercury. Several dimmer stars can also be seen. The Startracker algorithm achieved a star match, realizing that the Sun and planets were not in the correct position to be stars, and ignored them.



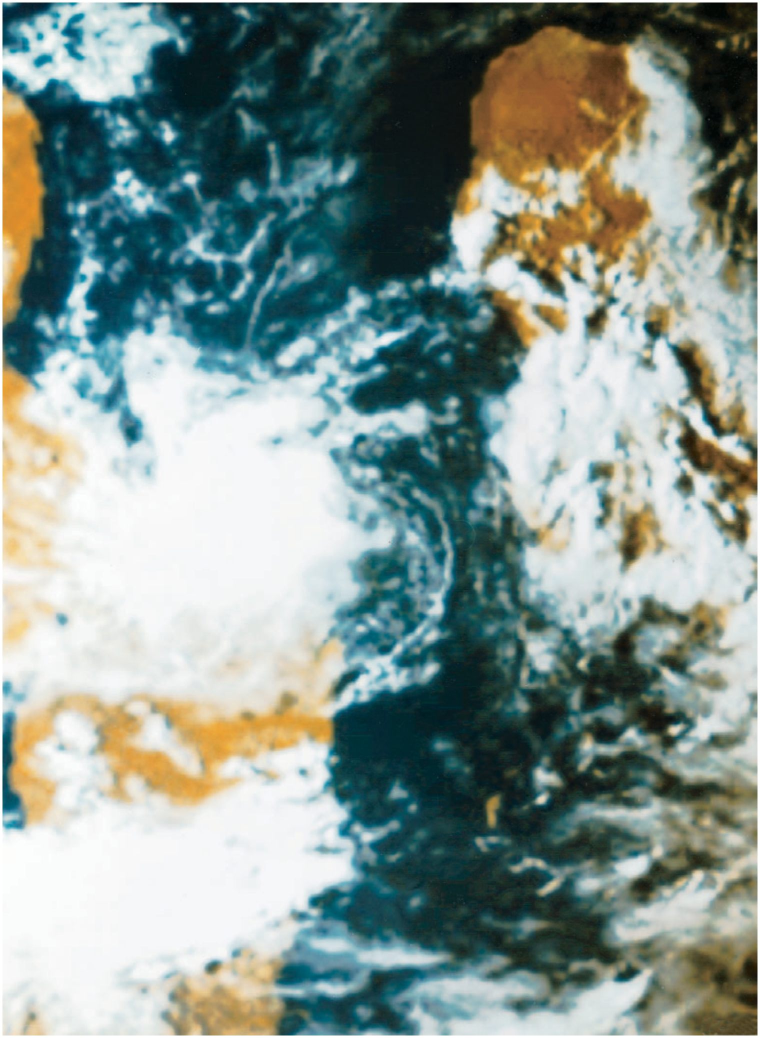
# The Full Earth

During a farside mapping orbit, this UV/VIS image of Earth was acquired. It is an unusually clear day over Africa and the Arabian Peninsula.



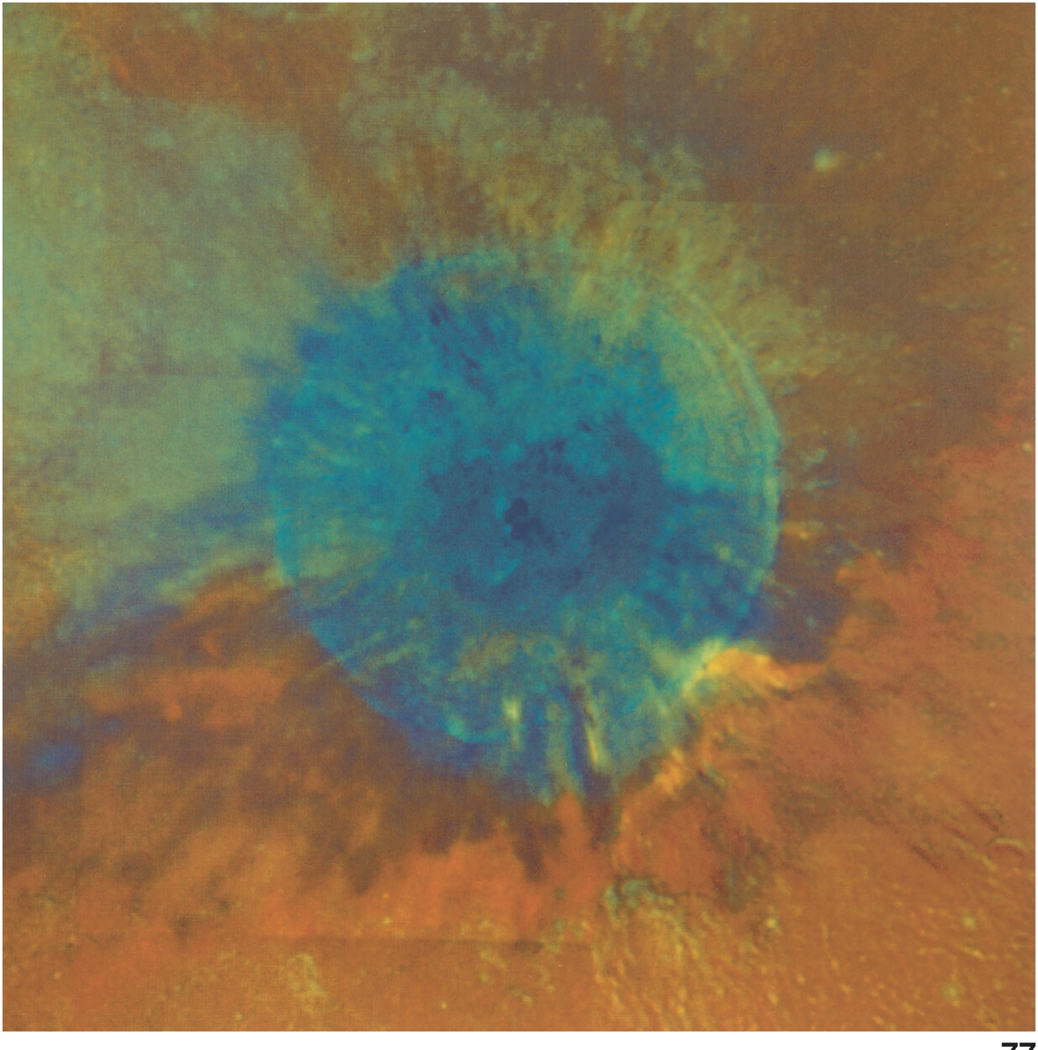
# Madagascar

This UV/VIS camera image shows the island of Madagascar, under clouds but still visible, in the right half of the photo.



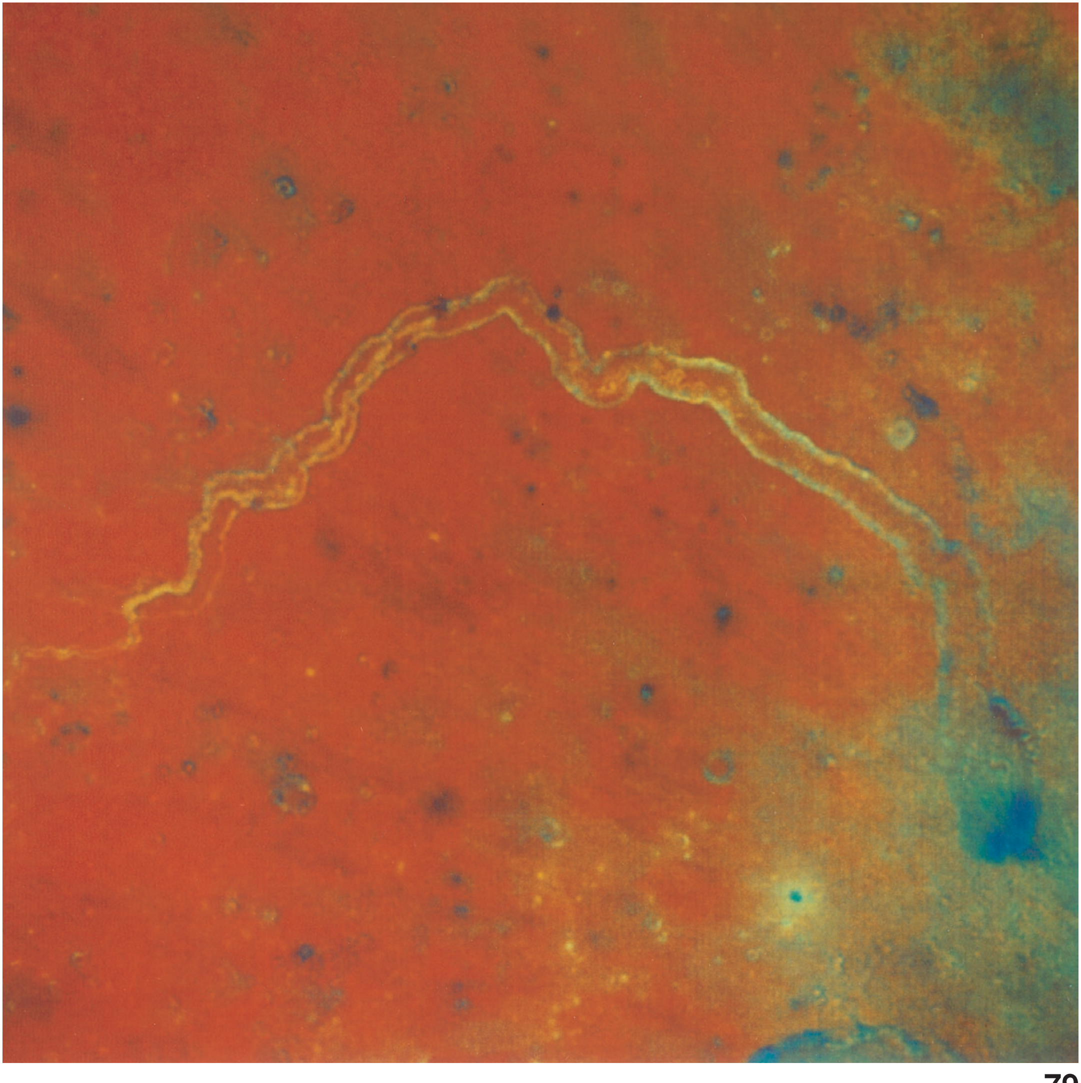
# Multispectral Mosaic of the Aristarchus Crater and Plateau

The Aristarchus impact occurred relatively recently in geologic time, after the Copernicus impact but before the Tycho impact. The 42-km-diameter crater and its ejecta are especially interesting because of the location on the uplifted southeastern corner of the Aristarchus plateau. As a result, the crater ejecta reveal two different stratigraphic sequences: that of the plateau to the northwest, and that of a portion of *Oceanus Procellarum* to the southeast. This asymmetry is apparent in the colors of the ejecta as seen in this image, which is reddish to the southeast, dominated by excavated *mare* lava, and bluish to the northwest, caused by the excavation of highlands materials in the plateau. The extent of the continuous ejecta blanket also appears asymmetric. The blanket extends about twice as far to the north and east as it does in other directions, approximately following the plateau margins. These ejecta lobes could be caused by an oblique impact from the southeast, or it may reflect the presence of the plateau during ejecta emplacement.



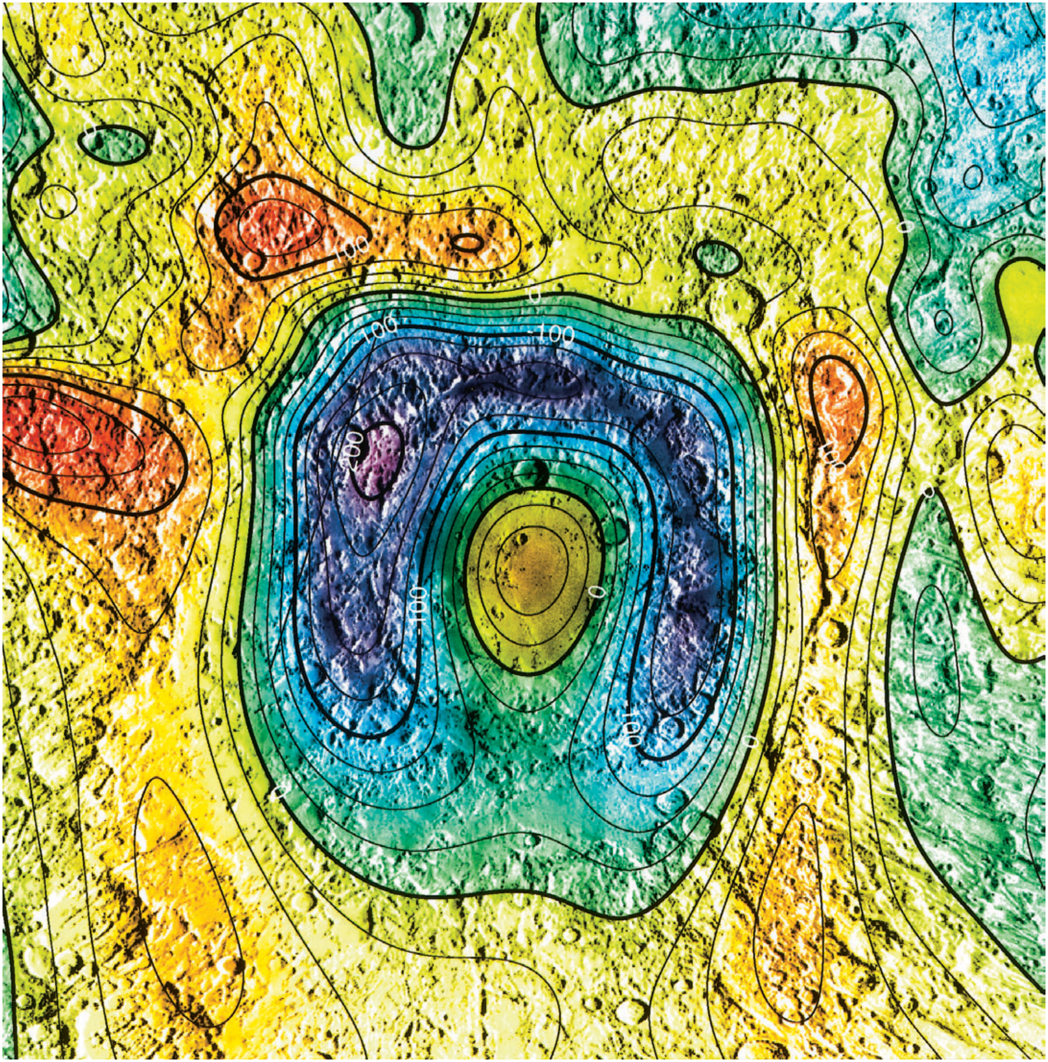
# Aristarchus Crater — *Vallis Schroteri*

The plateau of the Aristarchus crater has experienced intense volcanic activity, both effusive and explosive. It includes the densest concentration of lunar sinuous rilles (snakelike valleys) including the largest known, *Vallis Schroteri*, which is about 160 km long, up to 11 km wide, and 1 km deep. The rilles in this area begin at “cobra-head” craters, which are the apparent vents for a “dark mantling” deposit covering the plateau and nearby areas to the north and east. This dark mantling deposit probably consists primarily of iron-rich glass spheres (pyroclastics or cinders) and has a deep red color on this image. Rather than forming cinder cones as on Earth, the lower gravity and vacuum of the Moon allows the pyroclastics to travel much greater heights and distances, thus depositing an extensive regional blanket.



# GLM-1 Gravity over *Mare Orientale*

This figure shows the gravity signature of *Mare Orientale* and its surroundings from the Goddard Lunar Module-1 (GLM-1). The gravity information was derived from spacecraft tracking observations from *Clementine* as well as Lunar Orbiters 2, 3, 4, and 5, and the Apollo 15 subsatellite. The map shows a gravity high (yellow) at the center of the basin that indicates a mass concentration, or “mascon.” Also visible is a major gravity low (purple) associated with one of the basin rings that indicates a significant mass deficit beneath the surface.


100
0
100
100
200
100
0
100
0

# Bistatic Radar Image

This color image shows three perspectives of some interesting Bistatic Radar Doppler Image data created by the *Clementine* spacecraft and recorded at the DSN. The top view shows a “waterfall” plot of the Fourier-transformed raw data, in which the S-Band Carrier appears as the narrow diagonal line sloping down to the left. The lunar reflected radar signal is the rainbow-colored, broad, diagonal band sloping down to the right. The middle view is a processed image that has been realigned using the S-Band Carrier as the left-hand border. In the bottom view, the Moon’s south pole appears in the radar signal as the vertical dark blue band. Horizontal bands represent thermal noise, and are due to receiver gain changes at DSN during the data collection. These data are being analyzed for the possible presence of ice on the Moon.

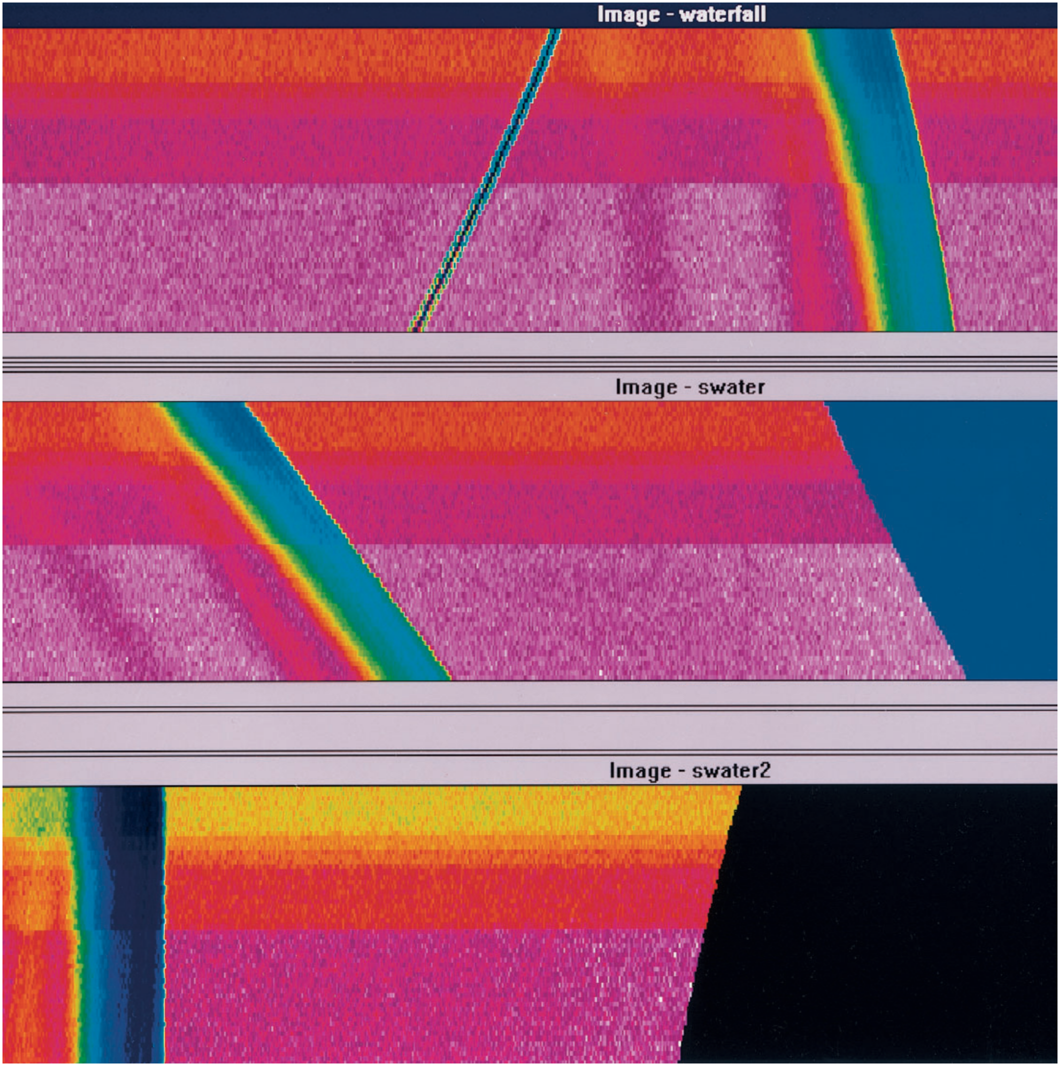


Image - waterfall
Image - swater
Image - swater2

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***Advanced Composite Structures***

Allied Signal Technical Services
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***Spacecraft Engineering and Mission Operations Technical Assistance***

Amber Engineering, Inc.
Goleta, CA
***NIR & LWIR Focal Plane Arrays, Dewar & Cryo-cooler Assemblies, & Camera Electronics Designs***

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***Provided HgCdTe Crystal for LWIR***

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***Intensifier Modules for HiRes***

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