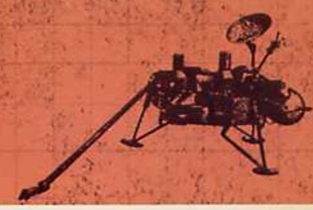
DECEMBER, 1976 VIKING PROJECT BULLETIN SPECIAL ISSUE

VIKING PROJECT
mission to mars!

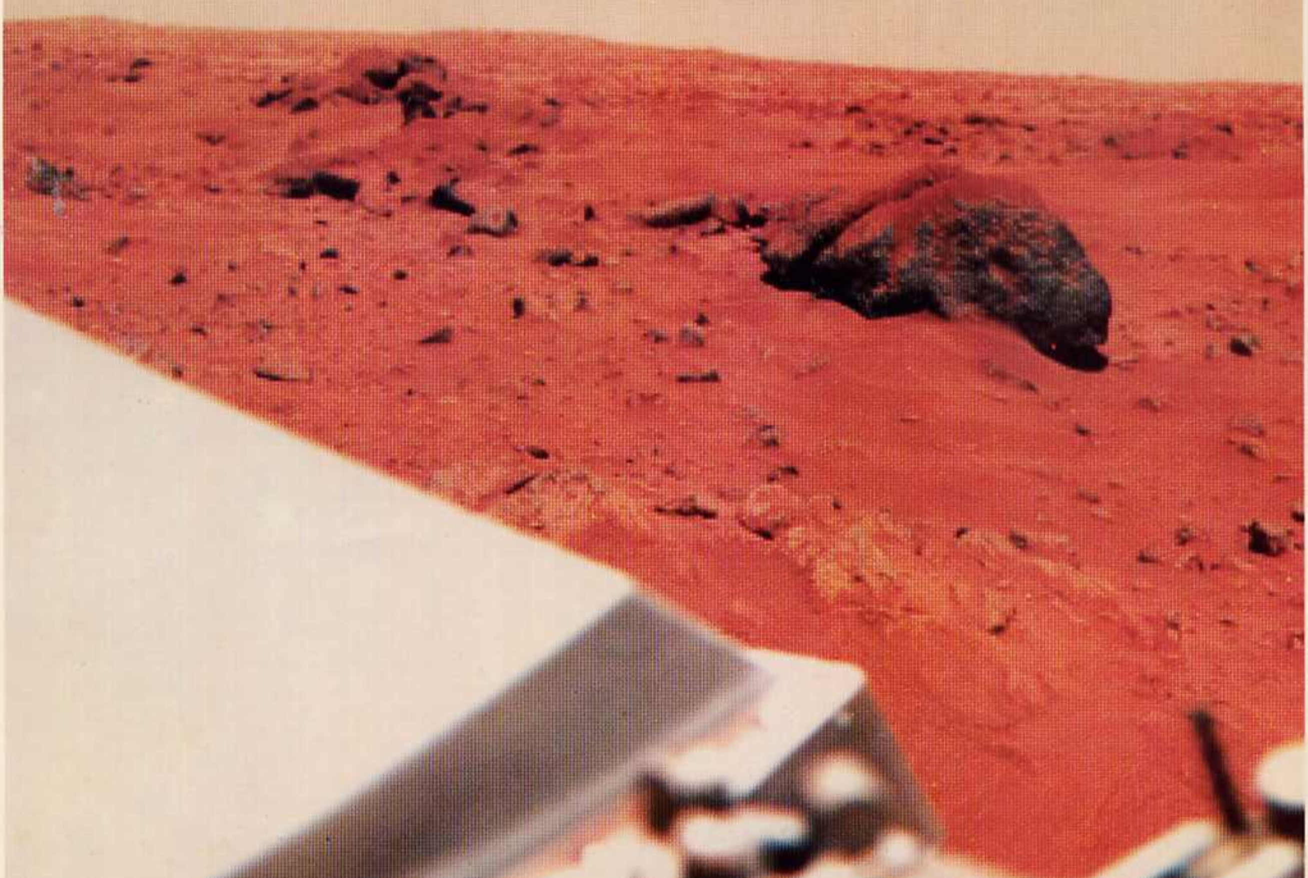
An Educational Publication of the National Aeronautics and Space Administration

The Colors Of Mars



THE HISTORIC INFLUENCE OF THE COLOR OF MARS

Nergal. . . Ares. . . Mars, legendary names for a pinpoint of reddish light in the night sky, observed to move relative to the star field even in ancient times. Because of its color, Mars was an important part of the mythology of early civilizations, serving as an abode for gods of fire, war and terror in the minds of many populaces up through the centuries. These people couldn't see the universe as we understand it today, nor could they provide causal explanations for the environment and human motivations that so profoundly affected their daily lives. Complex myths and specialized gods evolved and were associated with elements of the unknown. Today mythology is no longer necessary – though its quality of imagination remains as a tool of science in the quest for new knowledge about the universe. In the unique case of Mars, color no longer suggests aspects of mythical violence. Why then the persistent interest in its color? Science. The implications of the planet's color relate directly to Mars' chemistry, its environment, and to its physical/environmental history. Turn these pages now and sample the red planet in all of its colorations. Leave myth behind and be prepared to "think in color" about the science of Mars.



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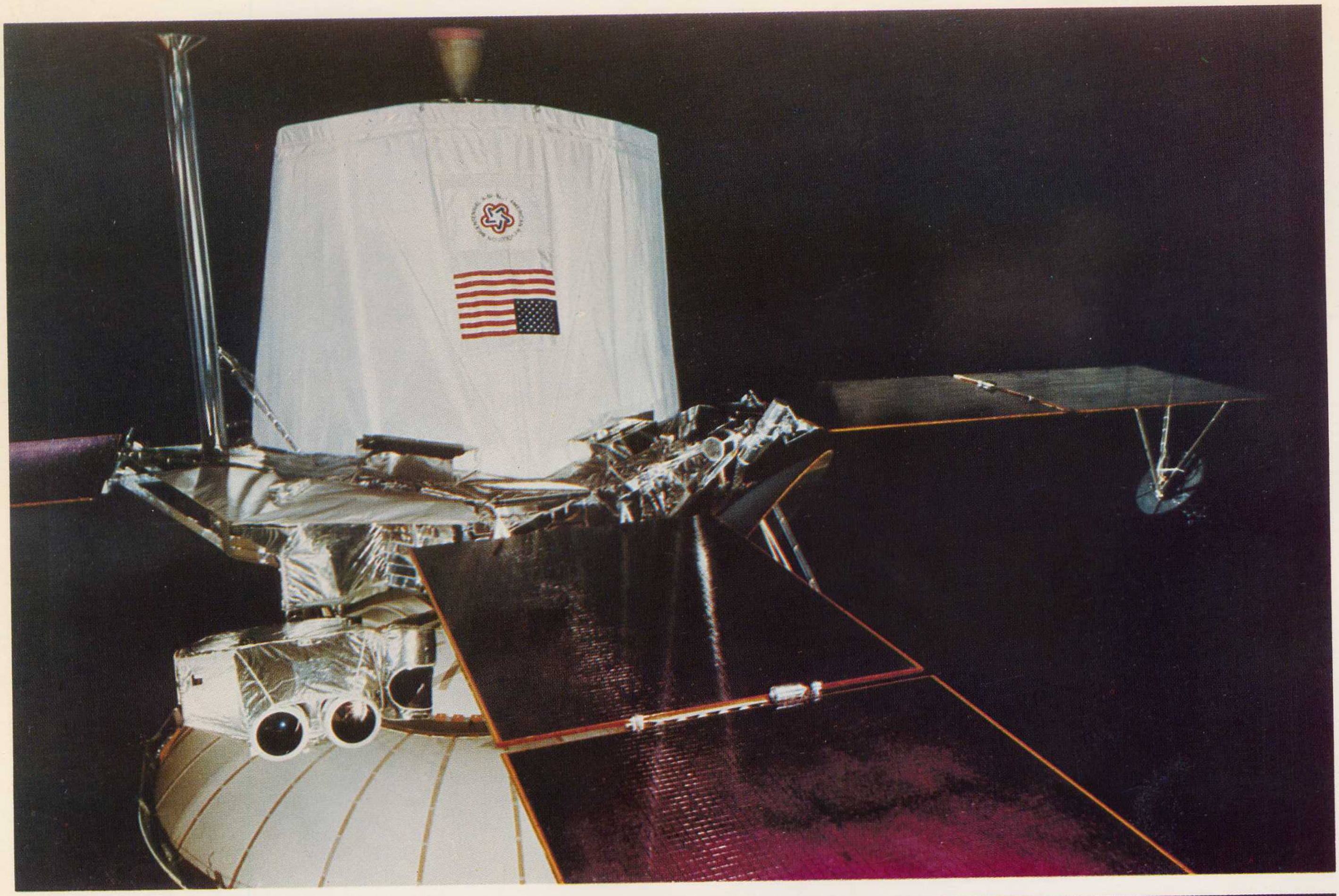
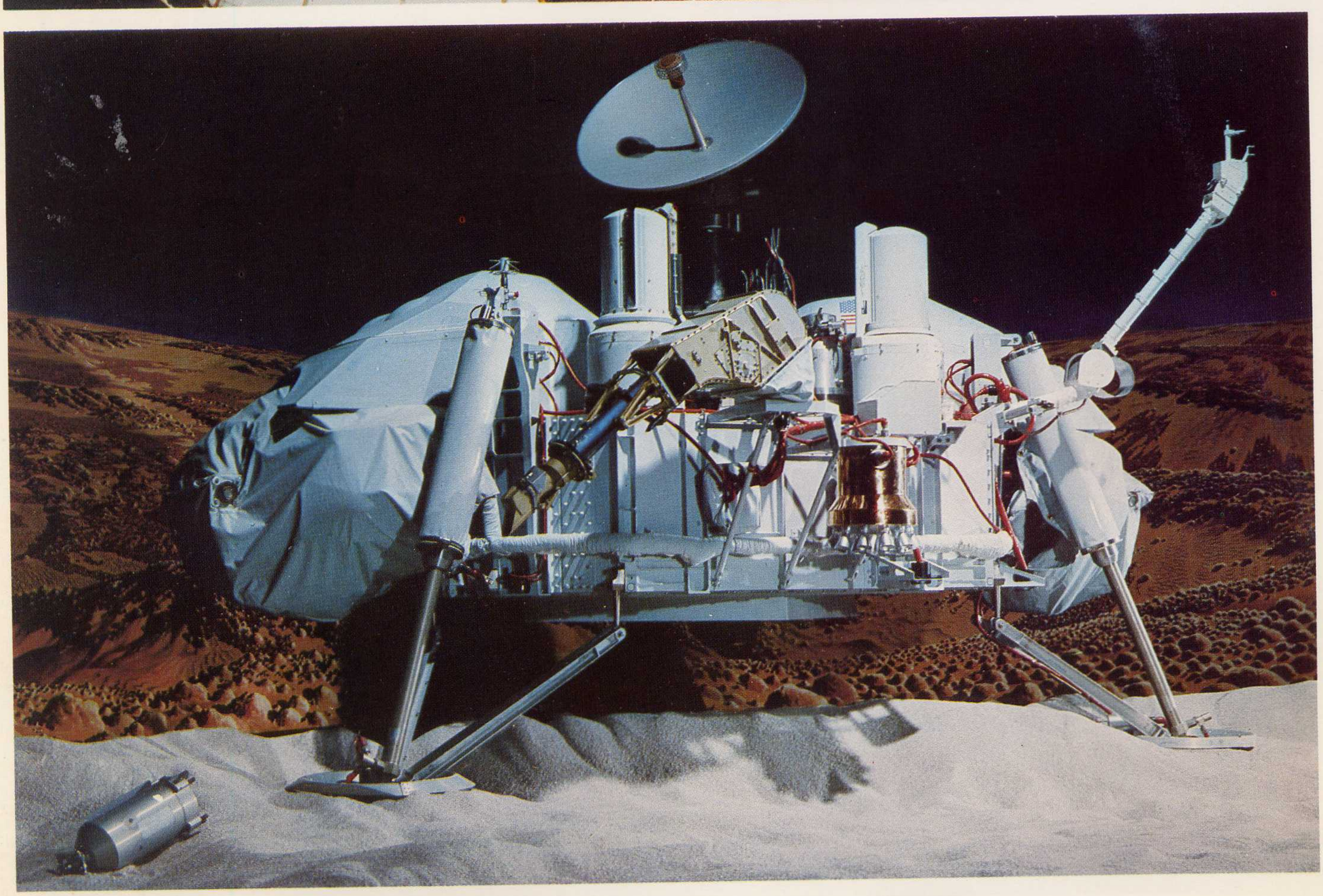
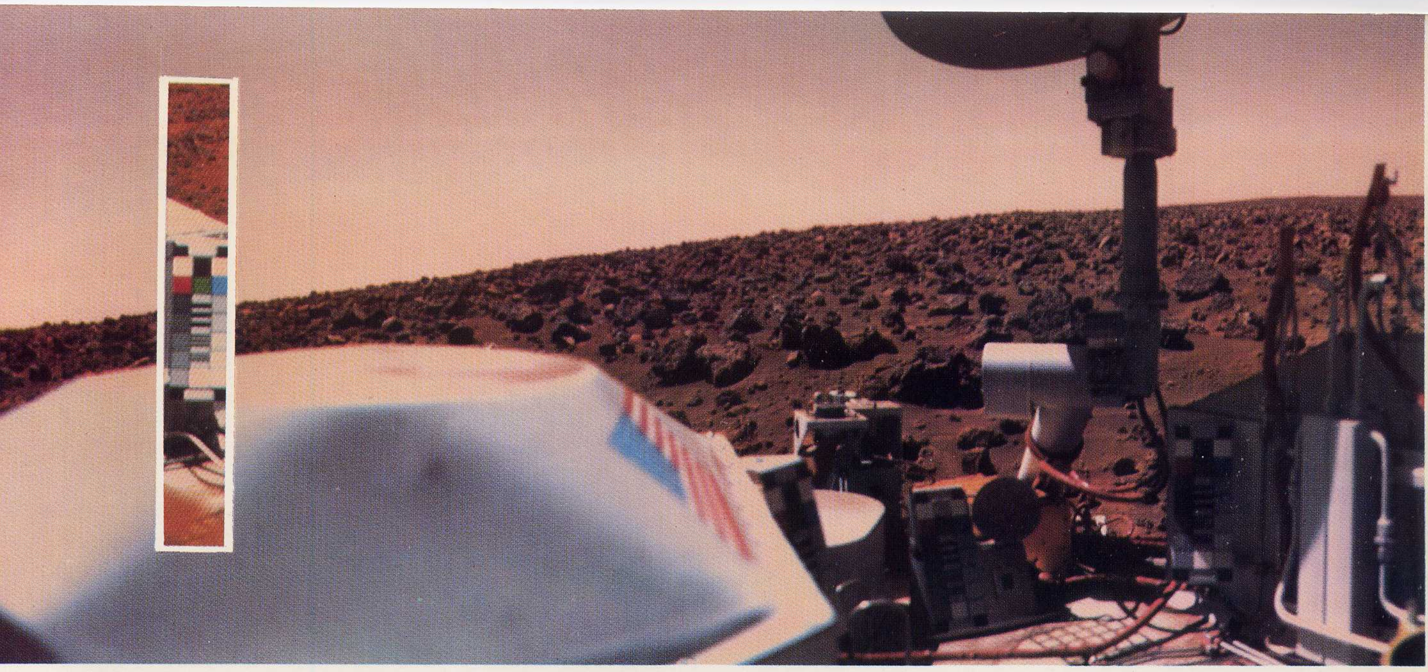
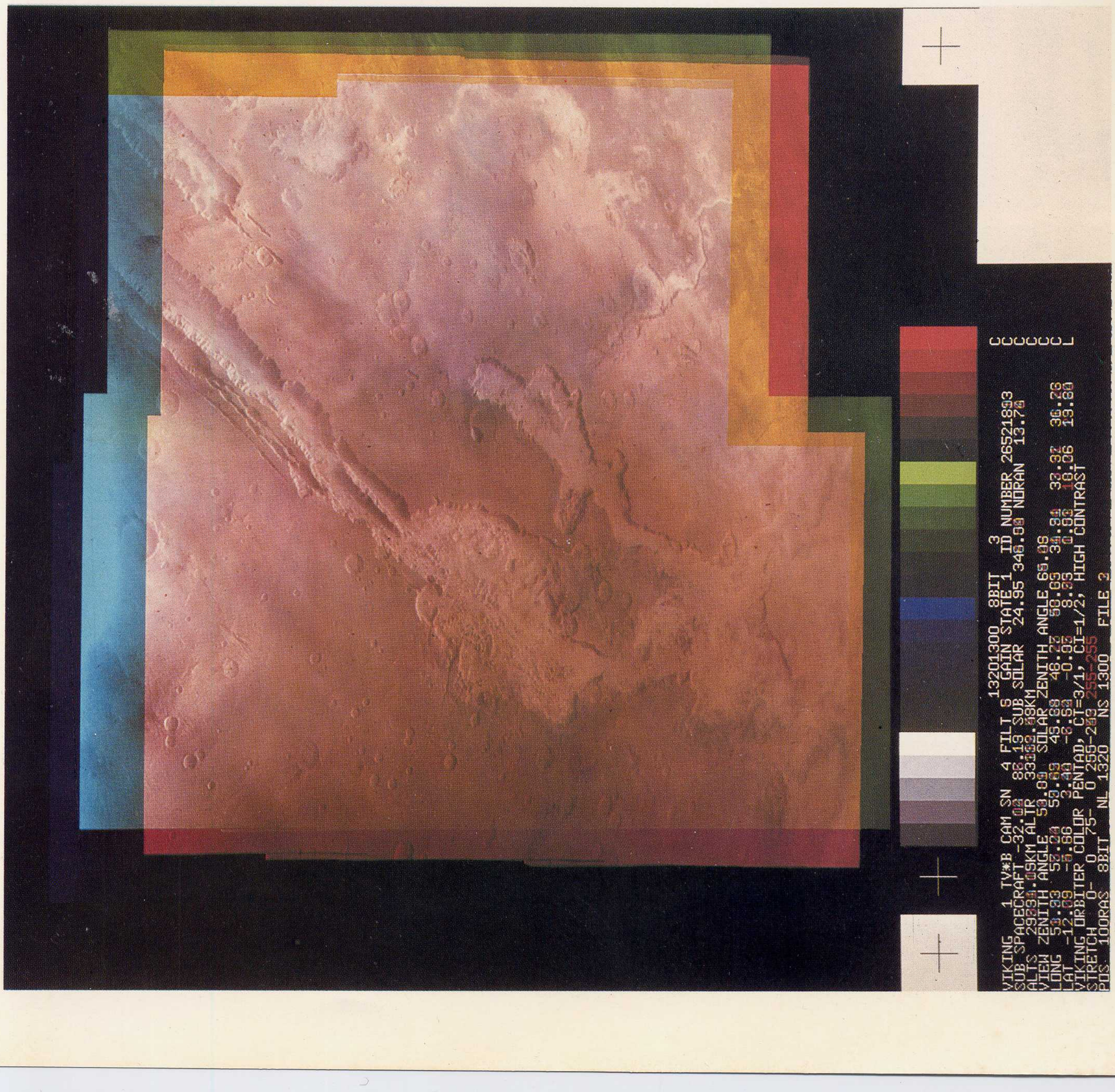






The picture above is a good representation of true color at the surface of Mars, and illustrates the location of the camera reference targets. The inset target (sunlit) shows the color patches which facilitate a rough balance of color. Below, a multi-frame pentad (grouped mosaic) shows how a large orbital color picture is assembled. All Viking pictures are initially produced with technical information about the acquisition of the image data.



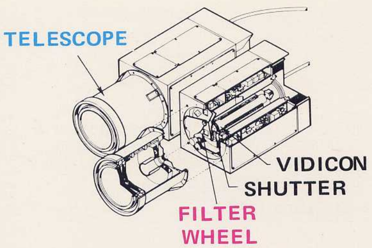
Color from Mars . . . How it's Done

While Viking Orbiter and Lander cameras produce pictures which can be reconstructed in full color at the control center by equipment common to both systems, the means of acquiring the data differ in ways that must be factored in when producing color photos.

Fundamental principles of photographic color are involved through the integration of three primary colors to produce full-color pictures. However, there are many subtle factors which can make the task of resolving completely accurate color very difficult, and this has not yet been fully accomplished to the satisfaction of the two photographic science teams.

Orbiter Cameras and Pictures

The Orbiter uses twin slow-scan vidicon cameras (relatives of the television cameras used by your local stations), but acquire only single frames by utilizing a shutter. The vidicons record the image on a photosensitive plate which is then scanned a line at a time to convert the image to digital data for transmission (1056 lines per frame, each made up of 1182 tiny picture elements). The cameras' 475 mm telescopic lenses can resolve features no smaller than a football field from the minimum orbital altitude of 940 miles. The cameras alternate, and each can recycle in 4.5 seconds.

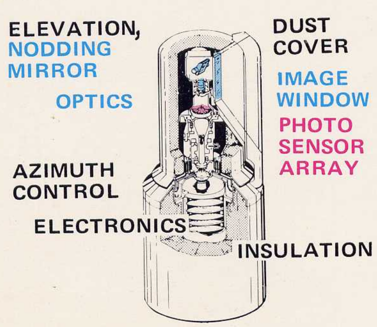


Each camera contains a filter wheel fitted with six filters: a clear filter to provide broad sensitivity across the near-ultraviolet and visible wavelengths; a violet filter sensitive only to the near-ultraviolet and violet (for cloud and ice enhancement); a minus-blue filter to yield a reverse effect to that of the violet filter; and three filters for color reconstruction (red, green, blue).

A color picture is made here on Earth, not on the spacecraft. The camera simply acquires three individual pictures in quick succession, each utilizing one of the color filters. The three pictures are combined here as individual frames, enhanced as needed to improve contrast and color balance, and mosaicked if required as seen in the pentad on the facing page.

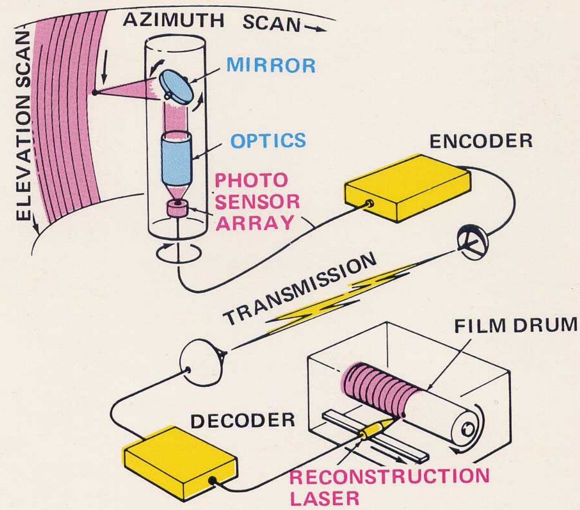
Lander Photography and Image Reconstruction

The Lander cameras are technically classified as facsimile cameras. The principle of operation is similar to that of equipment used to transmit wire photos and literature by radio or telephone, particularly in newspaper and business applications, and is quite a bit slower than vidicon photography.



The operation is not unlike that of the Orbiter vidicons in that a scanning technique is used. However, the scene is scanned directly rather than via a photosensitive plate before the lines and picture elements (pixels) are encoded as digital information for radio transmission.

The reconstruction equipment at the control center essentially reverses the camera process by converting the digital data back into an image on film with a unique artificial light beam produced by an argon/krypton laser. The sketch below illustrates the fundamental principle involved in both cases, but it should be remembered that the reconstruction process is also used for the preparation of Orbiter pictures and for the visual presentation of data that are not imagery produced. Orbital thermal mapping and water-vapor mapping data can also be illustrated as color imagery (see back cover).



The camera's spectral sensitivities and the means of recording them are described on the page titled *Light Values and the Spectrum.*

SEQUENCE OF OPERATION — MARS

- Nodding Mirror Vertically Scans Martian Scene
- Reflects Scene through Lens onto Photo Sensors
- Sensors Generate Signal Directly Proportional to Density of Incident Light
- Signal Output Sampled at Rate Synchronized with Mirror
- Samples Spaced Vertically as Picture Elements (Pixels), Each Pixel One Resolution Size on a Side (Square), 512 Pixels per Line
- Mirror Completes Elevation Scan, Returns to Start Position
- Camera Revolves One Line in Azimuth, Starts Next Line (or rescans line two more times for 3-color)
- Digitized Pixels Relayed to Lander Transmitter
- Data Transmitted to Earth (Direct or Orbiter-Relayed)

SEQUENCE OF OPERATION — EARTH

- Data Processed, Recorded on Magnetic Tape
- Data for Complete Scene Played into Reconstruction Equipment via Digital Computer, Laser Initiated
- Red, Blue, Green Beams Separated Out of Laser Beam
- Individual Beams Reflected into Light Modulators
- Modulators Computer Controlled to Alter Beam Intensities According to Digitized Pixel Intensity Data
- Three Color Beams Recombined into Laser Beam, Focused on Rotating Mirror
- Duplicates Action of Camera Mirror, Puts Image on Conventional Color Film — Unit Moves One Line Width as Each Line Completed

The Ground Reconstruction Equipment used to construct color negatives for both Orbiter and Lander pictures is shown here in operation. The laser beam originates at the lower left and the three primary colors are then separated into single-color beams — red at the far side, green in the center, and blue at the near side. These beams are modulated by the pictorial data, recombined at the right, and focused onto color negative film (see story). This kind of laser beam contains 12 colors, each so precisely focused that they can be combined in a single beam.

Welcome to Sunny, Colorful Mars!

The planet Mars may not be a tourist haven, and there are no travel brochures (yet) expounding its salient features. But color it has! A salmon colored sky, surface materials that vary from medium warm-umbers to brighter shades of orange and reddish yellows, and rocks that range from nearly black breccia-type blocks to the more characteristic reddish-yellow rocks of recognizable volcanic origin. From orbit the colors are even more diverse and include color-shaded values of white from clouds, fogs and surface ice, and many brightness variations of the reddish color that was noted of Mars some 3000 years ago.

These colors and their spectral data have a story to tell that is important to the overall science product of the Viking mission. That story is just beginning to unfold, for only a portion of the spectral data have been reduced and much remains to be done in the months ahead. *The Colors of Mars* is therefore only an early introduction and preview, but it will hopefully convey the understanding that color is more than visual aesthetics – it is science. We think you'll find it interesting in both respects.

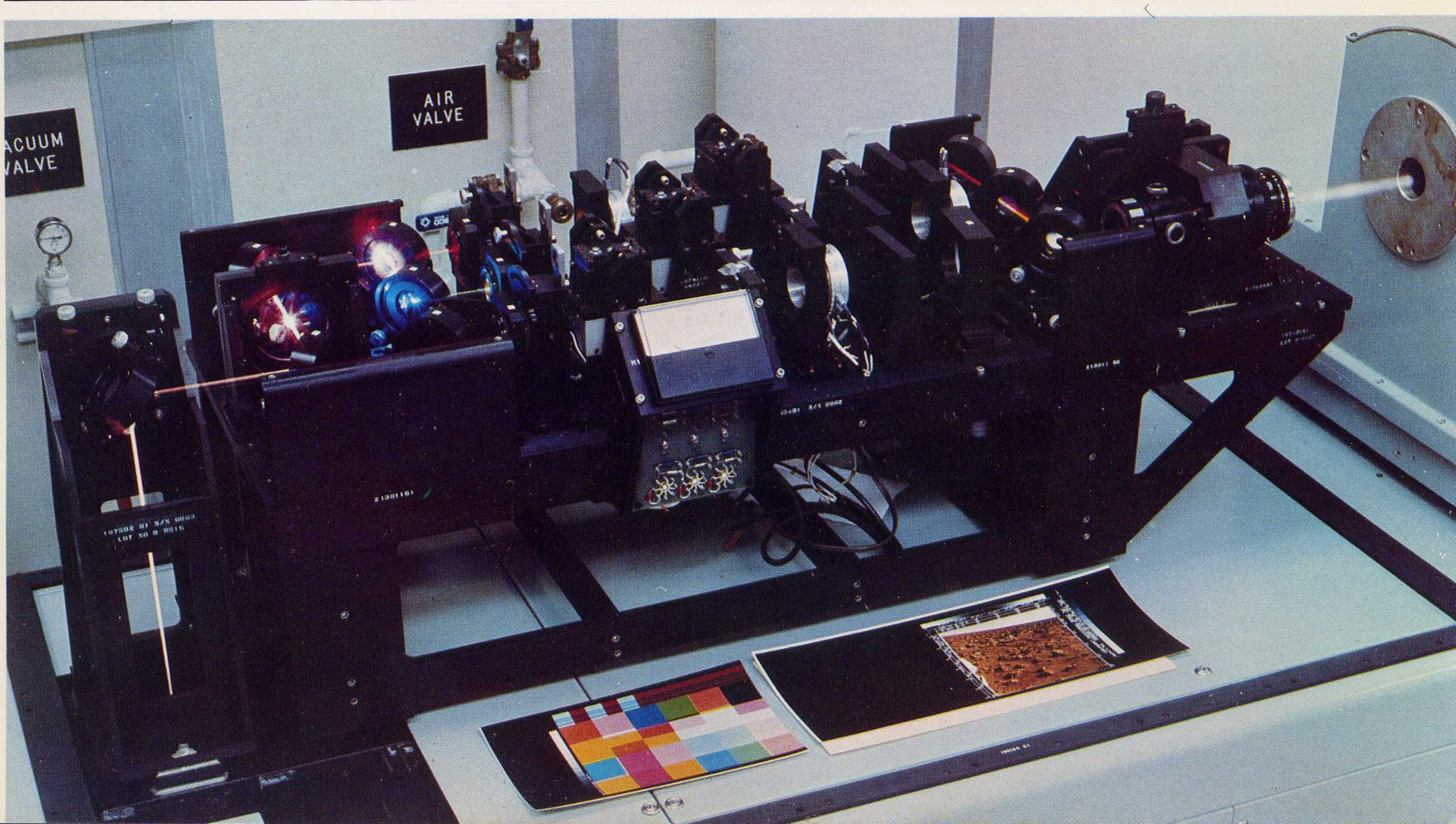
Turn the spacecraft picture flap out after reading the description below. The exposed pages will provide a simplified understanding of how the spacecraft and Earth-based photographic systems work. It will help the reader to understand some of the characteristics of the pictures to be viewed in The Colors of Mars.

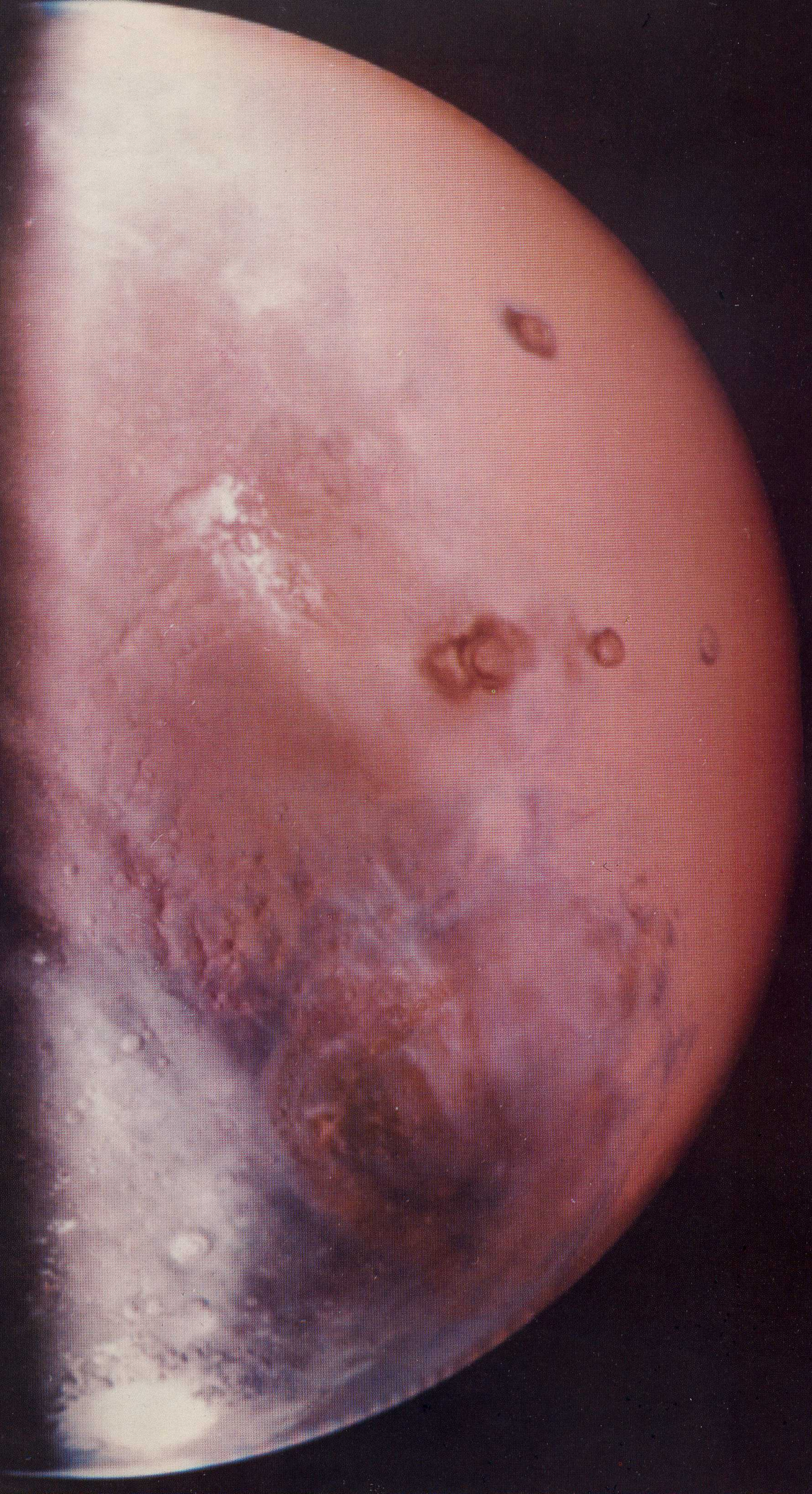
Pictorial Notes. . .

The picture on the cover was taken at VL-1's landing site on Mars' "Gold Plain" – Chryse Planitia. The boulder in the picture has been given the simple name "Big Joe" by Flight Team members – it's only about 25 feet from the Lander. Big Joe and several other substantially larger boulders farther away from the Lander are partially buried in a large drift of fine, reddish silt-like material. The drift, which extends to the visible horizon in one direction only, seems to be at or near its terminus where the Lander came to rest – and the #2 footpad is buried in it while the #3 footpad is on hard ground with little penetration. The general belief is that the drift is gradually being removed by wind erosion and that Big Joe was once buried (reason for its red cap), but this is not certain. The drift and the boulders will be watched carefully as the Martian wind season develops next year. In the meantime, the "redheaded" boulder may well become one of the most photographed boulders in the solar system.

The two Viking spacecraft systems are illustrated on the facing page. At the top, the Orbiter's science scan platform peers out from behind a solar panel – its twin vidicon cameras easily recognizable in between the water vapor mapper (left) and the thermal mapper. Half of the big S/X-band antenna that transmits both Orbiter and relayed Lander data to Earth can be seen at the right, and the antenna with the curled cone seen near the end of the solar panel at the right is the UHF antenna that receives relay data from the Lander.

The Lander seen here is the Science Test Lander. It has operational cameras and surface sampler, and all camera/sampler command sequences being prepared for the Landers on Mars are designed and tested using this Lander at JPL – its "sandbox" has been carefully modeled to the exact detail of each Lander's local terrain on Mars. Only one Lander camera can operate at a time, and after it has completed an imaging sequence it returns to its neutral position under a protective cover. Its window can also be dusted, though dust has not been a problem to date (wind velocities are slowly increasing).





Viking 1 acquired its first color picture of Mars from 348 000 miles in June, 1976.

Key Features In Picture:

The four giant Tharsis-region volcanoes. . . darker than expected.

Stable albedo and coloration differences between known surface regions.

Frost-brightened Argyre basin in the south, possible near-surface ice fogs.

Atmosphere much clearer than 1971. . . exhibits strong brightening towards limb.

Broad, thin cloud fields near poles, particularly during early morning.

Heavier cloud fields in north very encouraging on question of water. . . early water vapor mapping confirms higher northern concentrations.

Orbital Color

From orbit colors are more diverse than at the surface, because significant albedo differences and atmospheric effects can be seen on a global scale — including the bright contrasts of clouds, fogs, frost and ice. The cameras were calibrated before launch, and their technical performance is monitored constantly for variations that must be factored for color balance. Pictures shown represent improved — but not necessarily final — color-balanced products.

Visibly, however, the variations and differences are not as strong as one might expect, and because they are important they must be aided by special enhancement programs during processing. Some of these significantly alter color hues to produce dramatic false colors. Others are designed to have a minimal effect on the hues, but to effect their values (intensities) by increasing contrast. This kind of processing is done by the Image Processing Laboratory during the preparation of the magnetic tape digital data before the images are reconstructed. Other adjustments must be made to correct for artifacts of the imaging process such as artificial, uneven shading effects in each frame, and for correcting sun angles, orthographic perspective and curvature distortions.

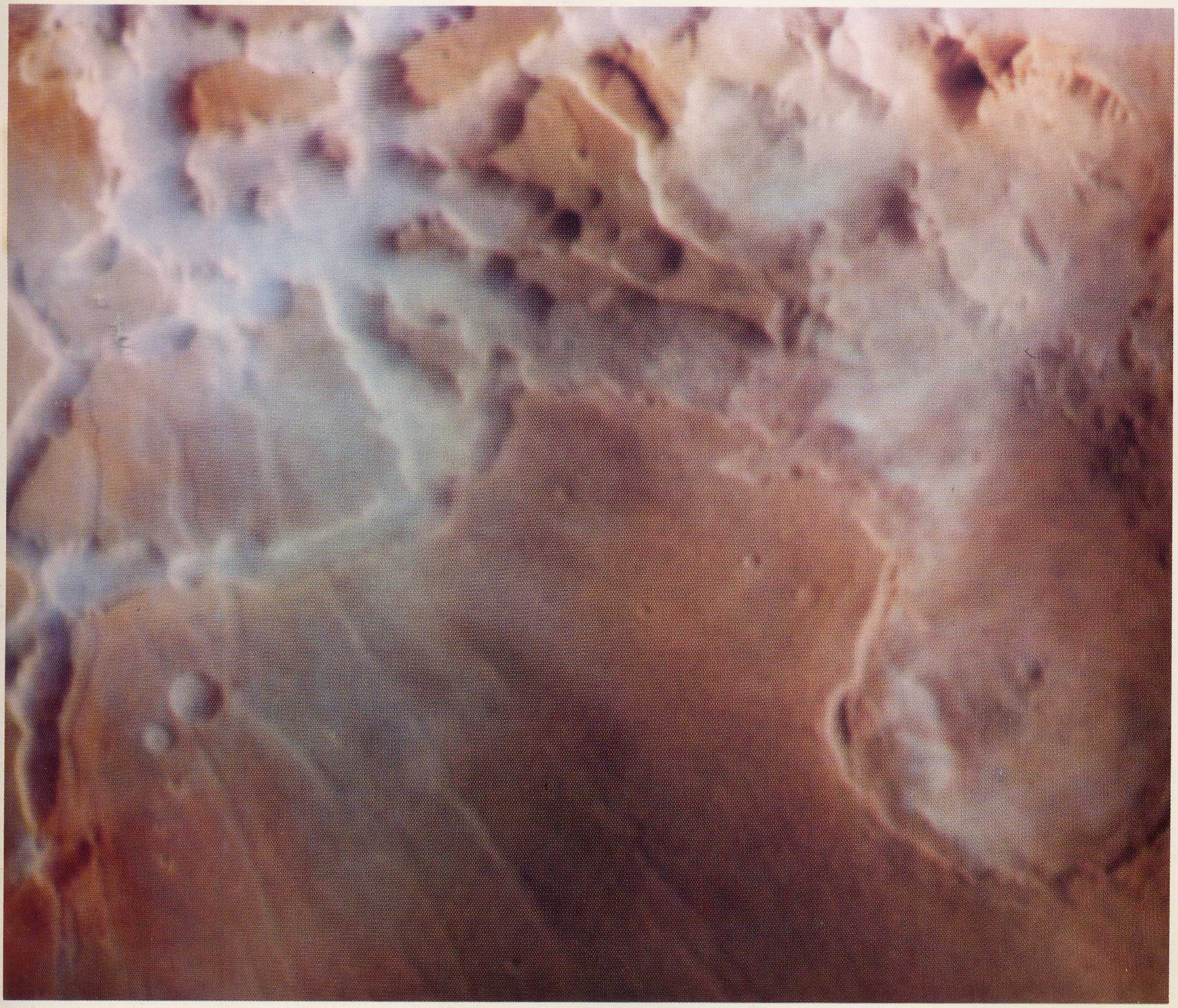
The orbital picture below illustrates the value of cloud contrasts wherein water ice clouds are seen clinging to canyon walls, creating a puzzle as to why they spill out onto the plateau only in certain areas. The probable answer must consider sun angles at different times of day, creating afternoon shading for condensation and morning radiation for evaporation.

Color photography, at its best, is still only a rough visible representation of the spectrum. The digital data is really the scientist's most important representation of light because it numerically separates color (visible or invisible) into very precise spectral positions. However, there are ways to illustrate certain aspects of spectral analysis visually, and false color is the visual tool applied.

Two other orbiter color products are illustrated on the back cover — one a color-contrast sequence, and the other a false-color rendering of thermal data acquired by the infrared thermal mapper.

The first Viking color picture of Mars was an approach-science picture taken at a range of 350 000 miles.

Bright clouds of water ice can be seen in and around the canyon network of Noctis Labyrinthus (the labyrinth of the night) during early morning hours.



STEREO PICTURES. . .
Top: Lander 1 Site; Middle & Bottom: Lander 2 Site

Mars in Stereo (3-D)

One of the dramatic products of the Viking mission has been the generation of stereo pictures. While stereo is not a specific color topic (most readily available in black and white), the addition of color provides an element of realism that is indeed exciting to view. It's like looking out your kitchen window at Mars.

The stereo pairs presented on the back of this flap are arranged in proper vision perspective (right-eye image at the right) so that they can be used in two conventional ways. Regardless of which is used, you should concentrate initially on an object on or near the horizon to obtain stereo fusion because the Lander cameras have strong separation and produce increased difficulty for stereo fusion in the near field of view. Precise focus need not be attempted until fusion is easily achieved. Vision should be allowed to relax as though looking through the picture into the distance.

Using a Stereo Viewer

The easiest technique to use is the old standby hard-copy stereo viewer. Most modern hard-copy viewers accept a card the size of the broken-line box bordering each of these stereo pairs. Paste the picture pairs cut from the reverse side of this flap to a piece of thin cardboard and cut out each pair to the dimensions of the broken-line box. These should fit viewers available at your local libraries and at many schools.

Free-Vision Fusion

The second technique is more difficult to learn but has the advantage of not requiring special viewing equipment or preparations. *Fusion* is the term used for the process of visually merging the left-eye image and the right-eye image into a single 3-dimensional image. When using a viewer, as described above, most of the work of achieving the needed abnormal convergence for stereo viewing is done by the optics and design of the stereo viewer — little extra effort is needed to develop the ability to fuse the images.

Contrary to this, free-vision fusion requires patient practice because your willpower and eyes must do the work of the stereo viewer. As an aid, a special practice stereo pair is included (a pair of solid-black circles positioned within an outer ring). When fused, the solid black circle will appear 3-dimensionally above the paper and outer ring. The practice pair can also be used in a viewer.

The instructions for free-vision stereo fusion follow. Once you have succeeded, continue to practice with the circles several times to imprint the technique experience firmly in your mind.

a) Place or hold a stereo pair at your normal reading distince, wearing reading glasses if needed.

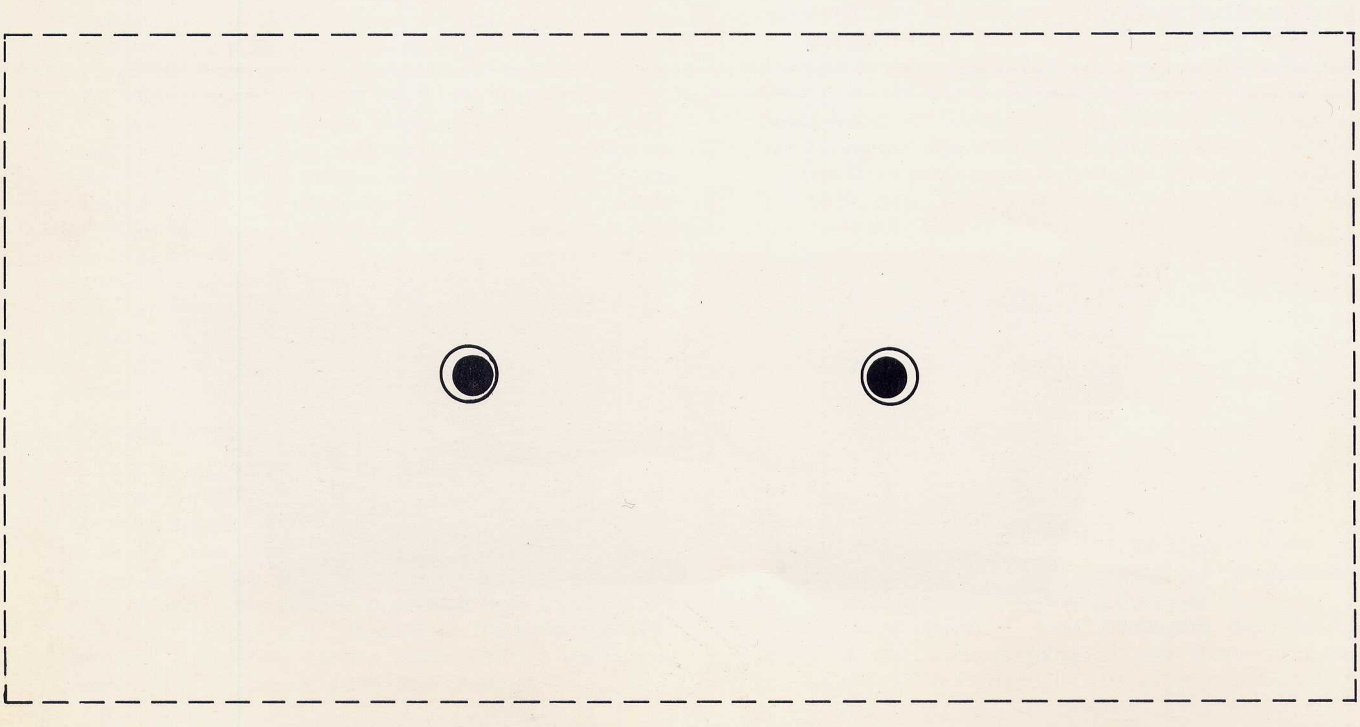
b) Focus initially on black dots.

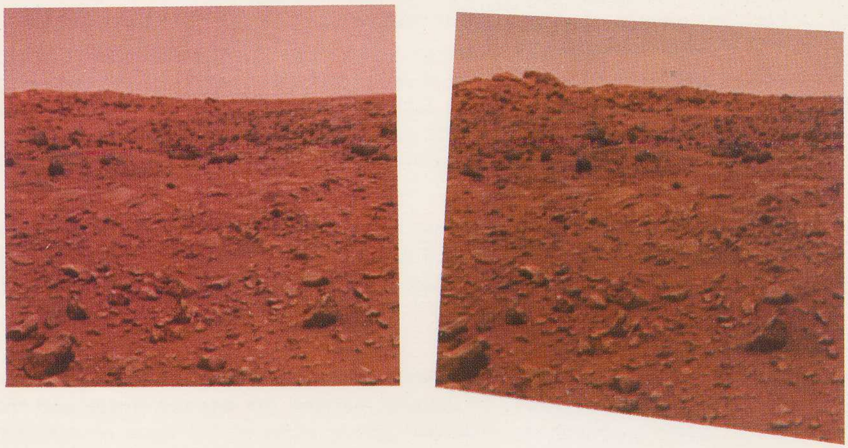
c) Allow vision convergence to relax until double images are seen — one pair at the far left of the other. (The horizontal alignment of the card can be varied to make both pairs line up as well as possible on a horizontal plane.)

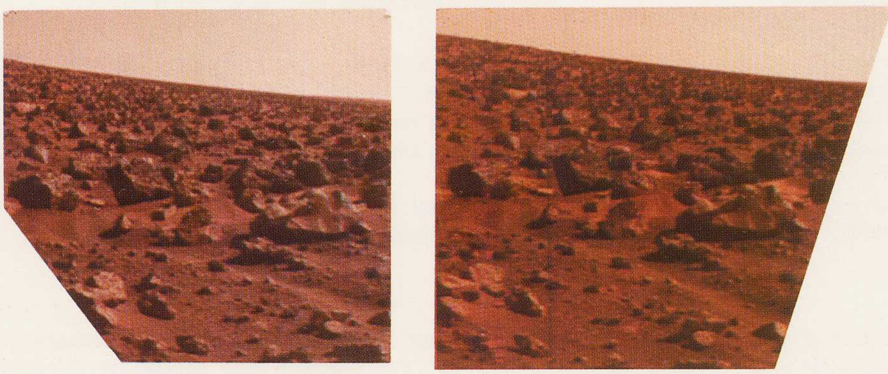
d) Concentrate on slowly allowing the two inside spots to come together as one (fusion), disregarding the two remaining spots at either side of the fused image (you will now see only three spots instead of four, and the middle one will be in stereo).

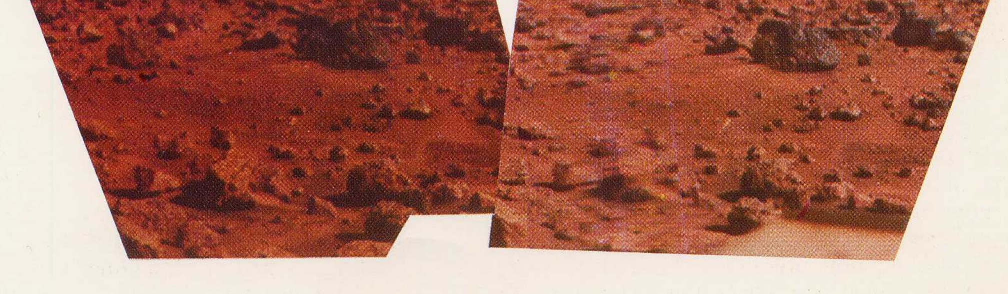
c) If focus is not sharp, concentrate on the solid circle rather than the ring. You will find it is at first difficult to hold the fused images together as one, but practice will rapidly improve your ability to do so.

Note: Because the stereo pairs are on the back of this flap and must be cut out if used in a viewer, you may wish to copy this instruction page in some manner first. In a like manner, the practice card should be duplicated for practice use as a cutout — this one cannot be cut without destroying one of the stereo pairs on the reverse side.









Color Role in Chemical, Physical and Magnetic Properties

The basic color of Mars provides clues to its chemical/physical characteristics, even without the detailed analytical potential of the spectral data. The reddish color of the planet has long suggested the probability of an oxidizing process in an iron-rich soil, and indeed Viking findings support both the visual and the chemical hypotheses.

The geological chemical properties are being studied in depth via surface-sample analyses, and the iron abundance is in the neighborhood of 15% – making it second only to silicon in the Martian inorganic-chemical inventory. In addition, unusual chemical responses in both the biology and organic chemistry instruments during soil sample analyses support the theory of oxidation.

Color information can support this science only in a limited sense. Though many mineral species can be detected normally by their specific spectral reflectance values, the weathering process on Mars seems to be extremely homogeneous. Fine, reddish material is seen everywhere, either as a thin veneer or as deposits in small pockets or large drifts and dunes – probably given global distribution by atmospheric dynamics. Because spectral data are produced by reflectance, this coating inhibits full knowledge of what it covers.

Physical Properties

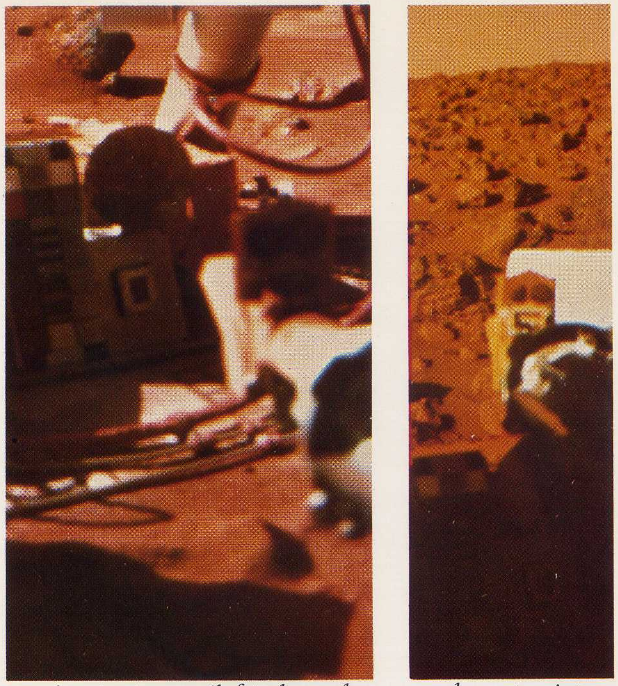
In this respect, the physical properties experiments are important from a spectral and color viewpoint because they involve the study of activities that disturb the soil material. The bulk of the physical properties work is really done with the cameras – taking pictures of sample trenches, pushed rocks, footpads, and near-Lander surface effects caused by the landings. These features are studied in extreme detail to determine various characteristics of the materials at the surface and to determine what day-to-day changes might be occurring.

Because surface color is so consistent, the interest in color is to look for changes as a result of the disturbances – in reference to the passage of time. Currently, little or no spectral or visible color differences have been detected as a result of sampling and rock moving, and this supports the theory that there is great homogeneity of the general surface material. New experiments are being planned which include the digging of a deeper hole, and the possibility of some rock pushing or scraping experiments (using the surface sampler).

The large mosaic on the foldout page lacks the latest color refinement, but illustrates the consistency of Martian color. The picture at the upper right shows "Badger" rock, which was pushed into an upright position to expose protected soil for sampling. The trenches to the right were dug in a crustal area called Bonneville, where samples were acquired from under a layer of "duracrust." The picture at the top left was taken at the Lander 1 location, of sample trenches dug in a drift near the Lander – one footpad was buried out of sight in the drift while another was on hard ground.

Magnetic Properties

It is in the area of magnetic properties that spectral analysis and color have produced a primary component of information. This science study has proved to be generally more interesting than anticipated on the basis of the highly magnetic properties (as much as 4%) of the Martian soil. The pictures presented here illustrate the placement of "bullseye" magnets on the surface sampler backhoe and center camera target – which are heavily coated with magnetically attracted material.

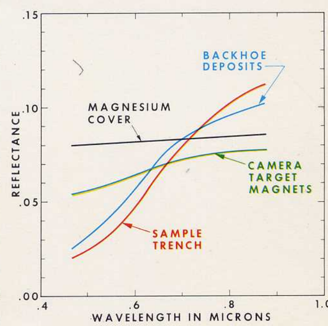


Lander 1 picture (left) shows how sampler gets picture taken from two directions at once, via round mirror. Dark rings on backhoe and top center of target indicate accumulations of magnetically attracted material. Note pile of fine reddish material dumped on Lander camera grid to aid physical properties studies – some movement seen with passage of time. Picture at right is Lander 2 image of sunlit magnets. In both pictures sampler is upside down.

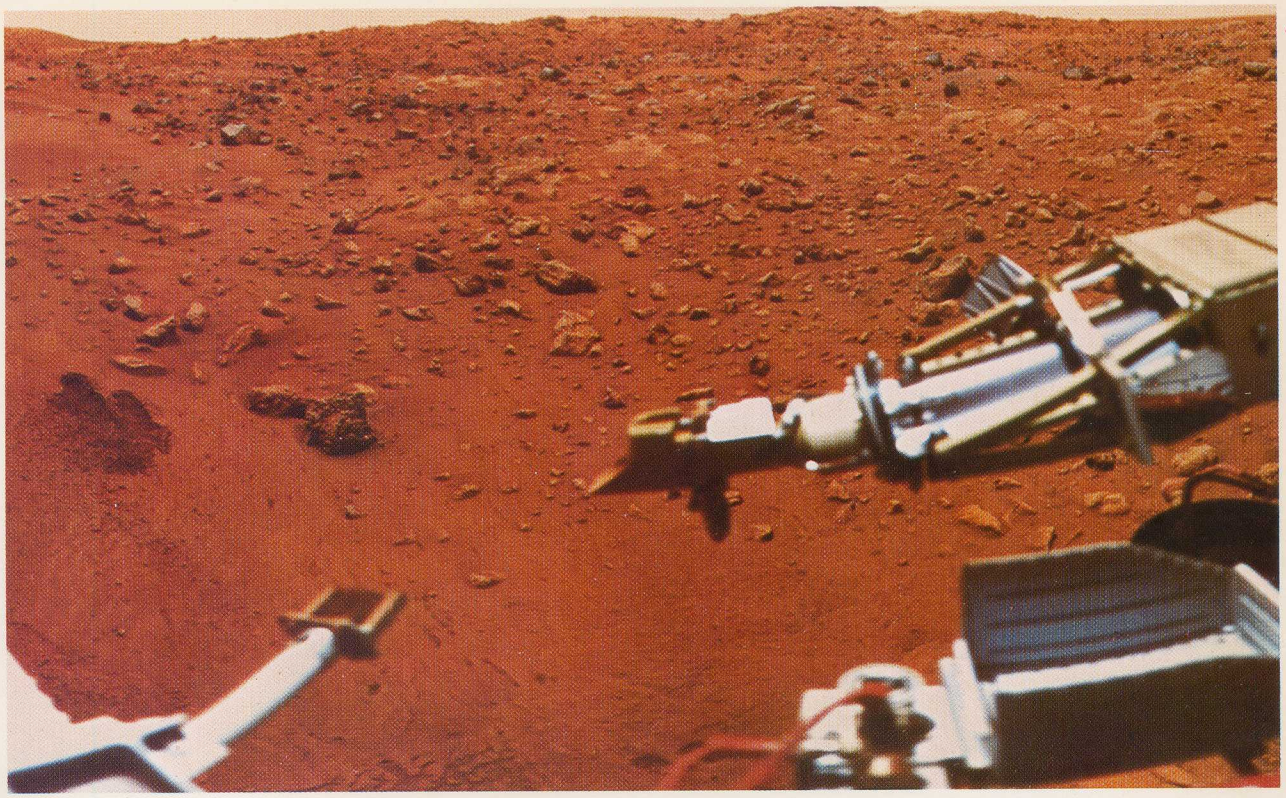
On Earth, the four iron products that tend to be magnetically attractable are iron metal, magnetite (Fe_3O_4) maghemite (Fe_2O_3) and pyrrhotite. Iron and magnetic particles tend to be black in color, maghemite is a yellowish brown and pyrrhotite is a brassy grey. Color is not a true tip-off on Mars however, because of the reddish veneer or rind that appears to coat about everything.

Actually, the oxidation progress of iron passes through a magnetite stage and becomes nonmagnetic hematite (or limonite, a hydrated oxide). Maghemite is an unusual product of the process and probably needs magnetite as a predecessor. It isn't well known because it is usually found with magnetite, and it is unusual because it can exist in both magnetic and nonmagnetic forms. It is unlikely that the material on Mars is either iron metal or pyrrhotite. The choice between the remaining two materials is difficult to make.

The next problem is to evaluate and understand the spectral data illustrated here, which suggests two different spectral responses for the backhoe magnets and target magnets. The target magnets attract their accumulation as airborne particles, and the backhoe magnets attract their deposits directly from the soil. It is possible the airborne material has been "cleaned" of its coating or that two different kinds of magnetic materials are being acquired via the two different sampling techniques.

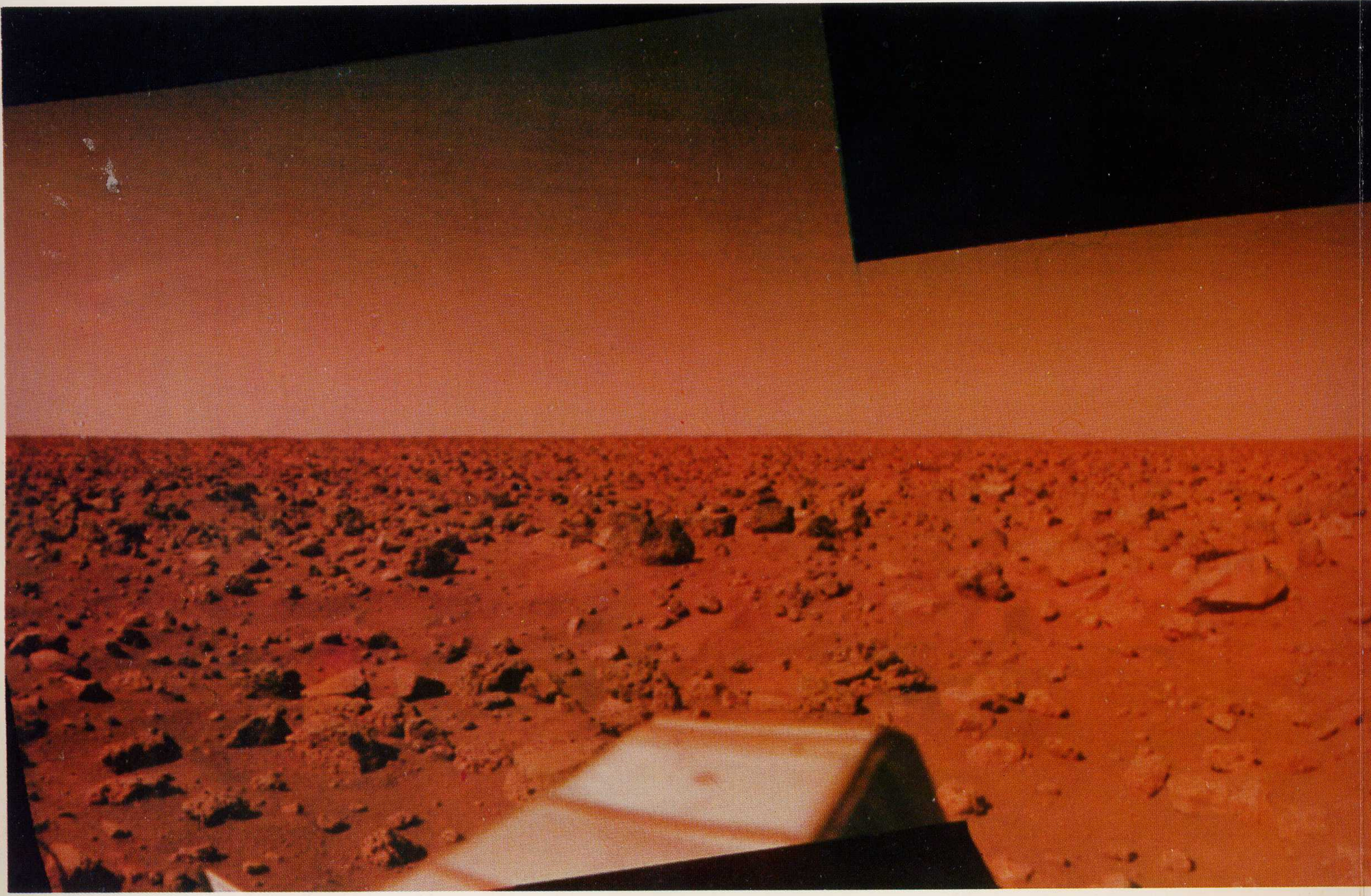


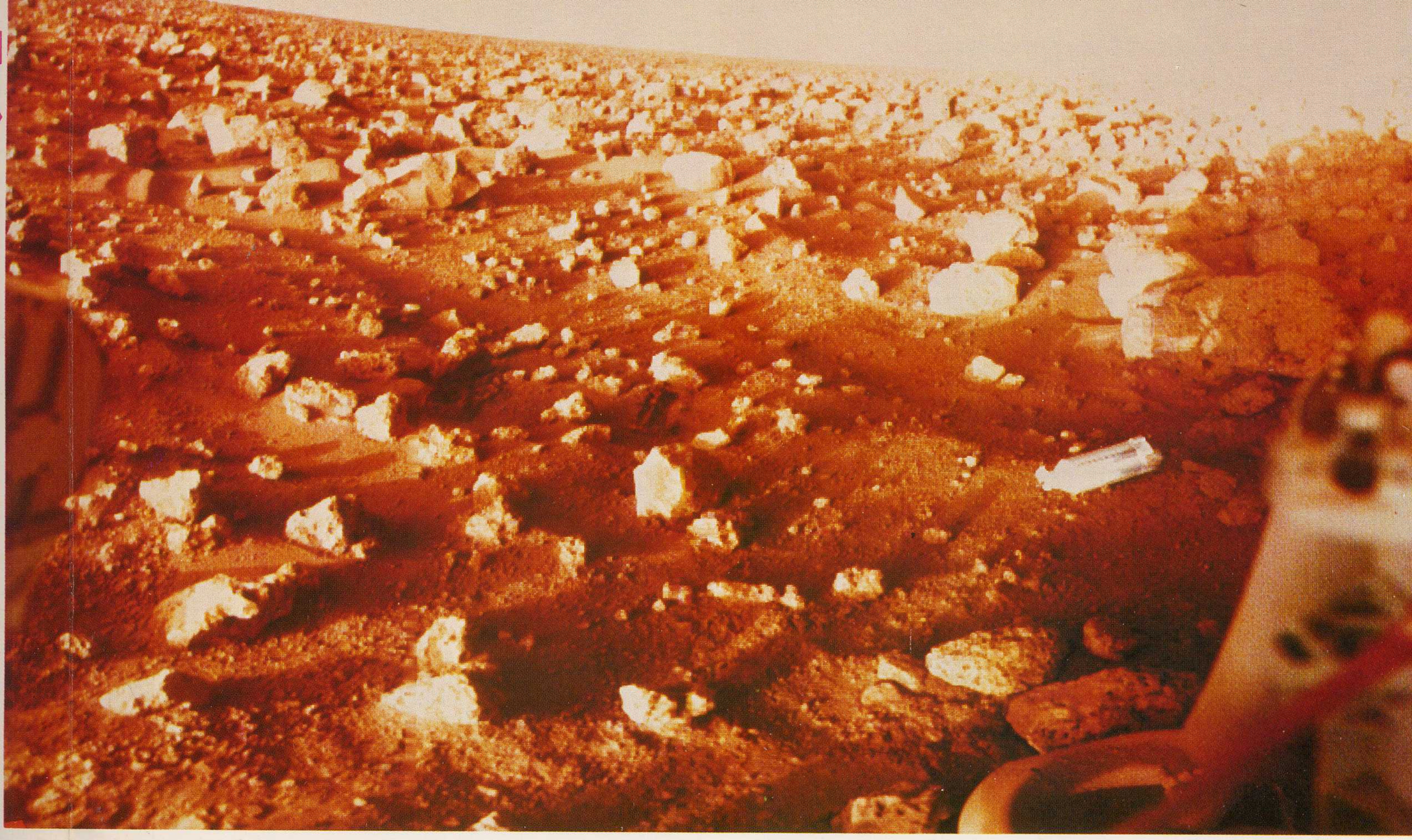
The final results, if more conclusive, have implications in the understanding of the stage of general oxidation and the effects of ultraviolet radiation.

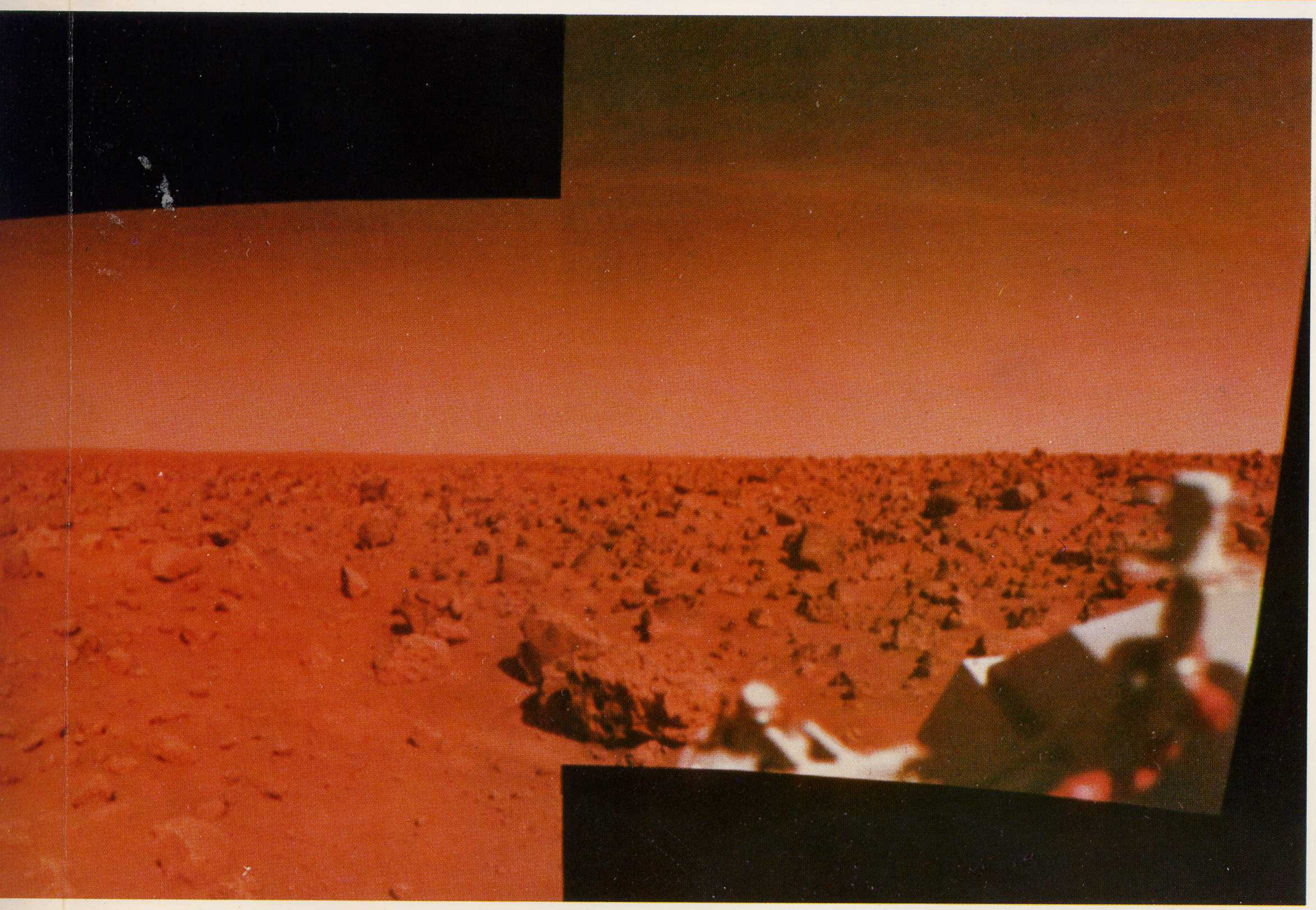


VL-1, Chryse

1) Sample trenches and sample collector at Lander 1 site; note distinct small pits and craters in drift made by materials dropped during sampling or disturbed during landing. "Wings" on boom reel are mirrors used to take pictures of areas normally not visible to cameras. 2) Picture at sunrise at Lander 2 site causes long shadows, warm coloration and excessive brightness contrasts. Note upturned Badger rock and Bonneville trenches. 3) Color mosaic from Lander 2 site; false hills created by Lander's 8° tilt computer-corrected to true horizon perspective in this picture only.







VL-2,
Utopia

Light Values and the Spectrum . . . The Story they Tell

The sunset picture seen below, in spite of its lack of detail, has been one of the most popular Lander pictures. The reasons for its aesthetic popularity are admittedly false, for the sun is not really visible — it is 4-10° below the horizon, and the halos are an artifact of how depreciating light values are imaged and reconstructed.

Falsehoods aside, it is an interesting — if not accurate — picture to use to introduce the subject of spectral analysis and photometry as applied through Lander imagery.

The heart of the camera is a disk about the size of a half dollar called the Photo Sensor Array — a marvel of microelectronics. It incorporates 11 microamplifiers and a control module around the perimeter of the disc, and 12 tiny photosensitive diodes grouped on a small chip in the center. These diodes give off a small current that is modulated by light (much like the cell in a photographer's light meter). Only the diode desired is amplified to produce the signal to record a given element of light. Four of the diodes are used for high-resolution black-and-white photography, three for infrared, one for general survey photography, one for direct solar observations, and three for color (each filtered to yield one of three primary color wavelength bands needed for full-color reconstruction — blue, green and red). There are 750 lines to 90° in a color picture, and each line is scanned three times (once in each color) before the camera steps to the next line. A 90° color picture takes about 10 minutes to record.

Because the near-infrared wavelengths (0.85, 0.95 and 0.98 microns) are invisible, they are reproduced in false color for the scientists' use. Though invisible however, these wavelengths have dramatic effects on the visible wavelengths and must be factored into the formula for the reconstruction of full-color photographs. This is one aspect that is still being evaluated to learn what adjustments must be made to provide truly accurate color pictures of Mars. Most pictures in *The Colors of Mars* are earlier products and have not been fully corrected for these infrared values.

The color graph presented here is a simple representation of the spectral sensitivity of the camera's photosensitive diodes, principally in the wavelengths of the three primary colors and the near-infrared. The specific colors of blue, green and red are each technically restricted to narrow wavelength bands, but are broadened visually when optically filtered and reproduced — such that they mix with one another at intermediate wavelengths. This is one of the reasons that roughly accurate color pictures produced using the three color filters are not true representations of Martian surface color, and must be factored into the formula along with the "leaking" infrared values and the effects of equipment performance variations.

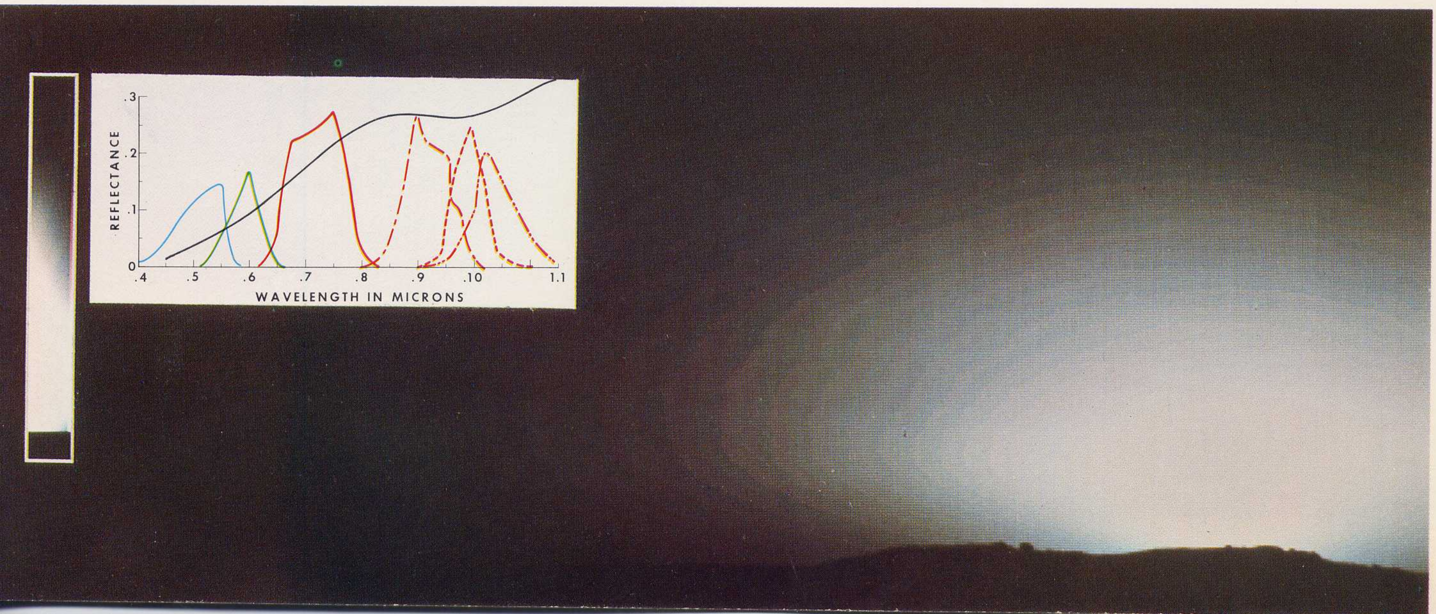
The thing to remember however, is that the precise, digitized spectral and value data can be analyzed scientifically without being seen in mixed form as an image, and can be used for detailed mineralogical and atmospheric-properties studies.

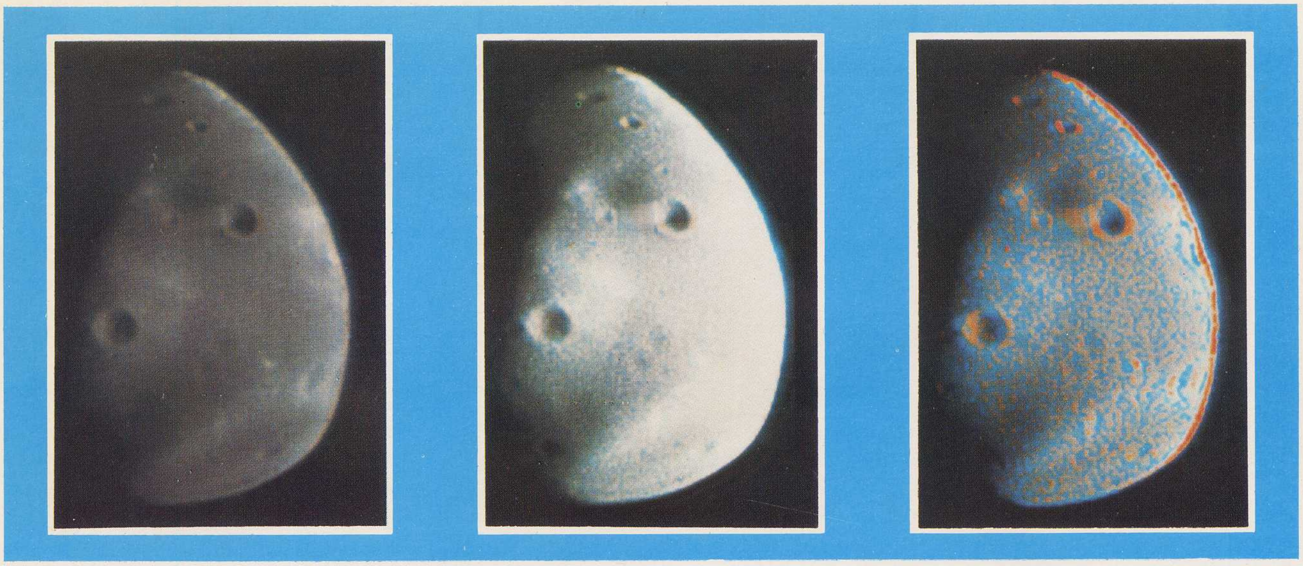
The plotted curve running through the color wavelength is a preliminary spectral curve reduced from Viking data representing a sample of an average Martian scene. It shows a distinct weakness in the "cool" wavelengths and strength in the "warmer" wavelengths. This compliments the visible color warmth that is characteristic of the surface, and the dip in the near-infrared wavelengths is representative of a typical iron-rich soil.

A "rescan" technique is employed to study the atmosphere. The camera does not step in azimuth, but slowly continues to scan the same vertical image line repeatedly. The filtered sun diode is used for solar rescans to record the changing light intensity of the sun with time (see inset on sunset picture) when it is still above the horizon.

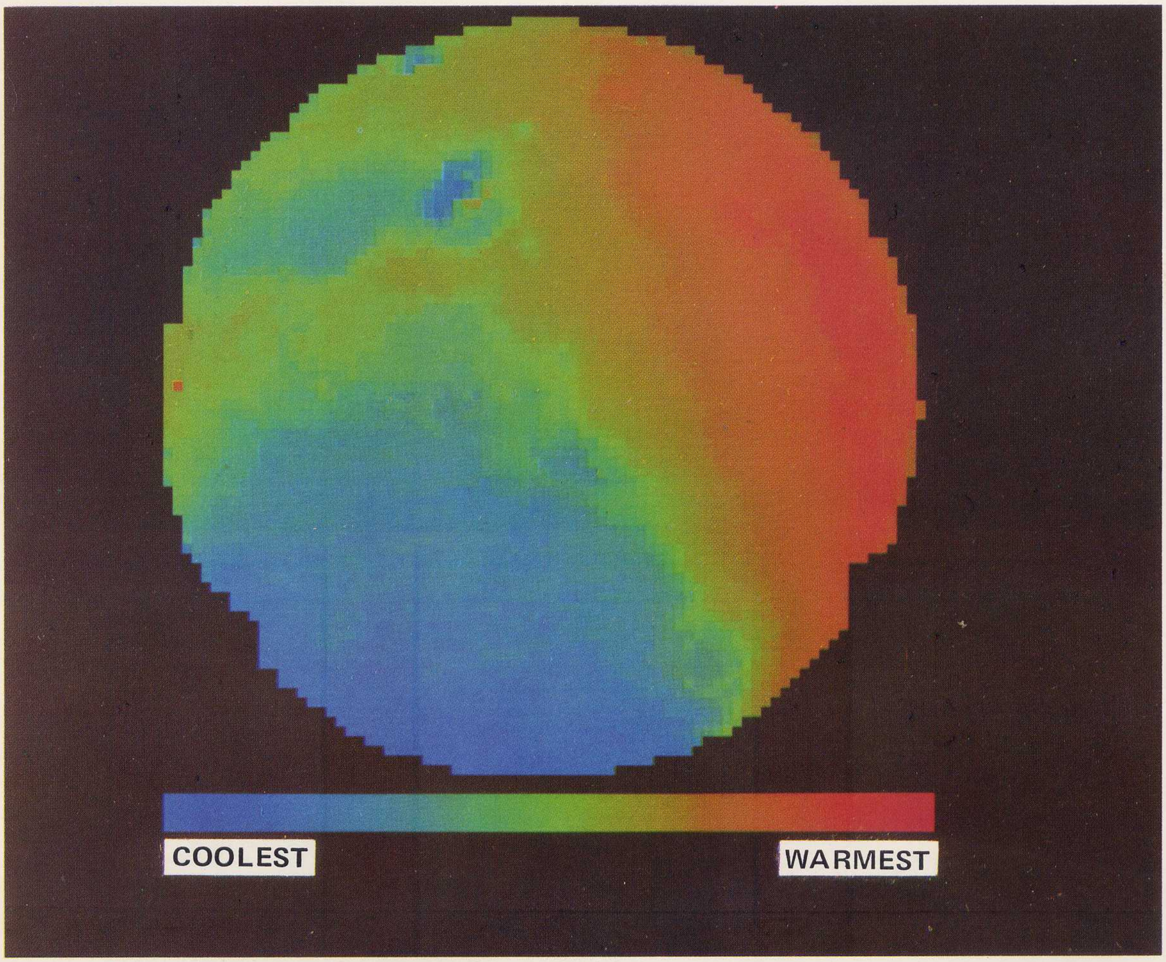
However, the filtering retards some of the needed spectral and photometric data, which is then acquired via another diode by rescan-imaging of Phobos (Mars' largest moon). One important product of all this is information about the particles suspended in the atmosphere — their size, volume, distribution and height. There is a substantial suspension of extremely small (at the micron scale) particles in the Martian atmosphere, causing color value variations and atmospheric brightness towards the limb from orbit, and this knowledge provides clues to atmospheric cycles and meteorology and the part these processes play in the global distribution of elements and moisture.

This "sunset" picture was actually taken after sunset, the camera recording the diminishing light saturation in the sky above the point where the sun went down. The "halos" are an artifact of the imaging process and are not a real characteristic of the Martian scene.





Above is a trio of color images representing different contrast enhancements of the same picture of Deimos – Mars' smallest and most distant moon (orbits approximately 12 000 miles from the planet). Contrast enhancements bring out extremely subtle albedo and color variations. The picture below was not recorded with a camera, but is a visual representation of infrared thermal mapping data. The daylight terminator extends from about the 11:30 position to 5:00 at the lower right, and the left side is the night side. All four major Tharsis volcanoes appear. Olympus Mons is the smaller blue spot at the upper limb, Arsia Mons is the prominent blue feature below Olympus, Pavonis Mons is the stronger green spot above Arsia, and Ascraeus Mons is seen on the daylight side in line with Arsia and Pavonis as a slightly stronger orange spot. The frigid south pole is seen in the dark at the lower left, the weakly yellow-ringed feature on the terminator at the lower right is the Argyre basin, and the lighter streak feature at center-right in the orange region is the giant canyon, Valles Marineris. The colors are false and stretched. The data were acquired during a single 35-minute scan program from a distance of 6200 miles.



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