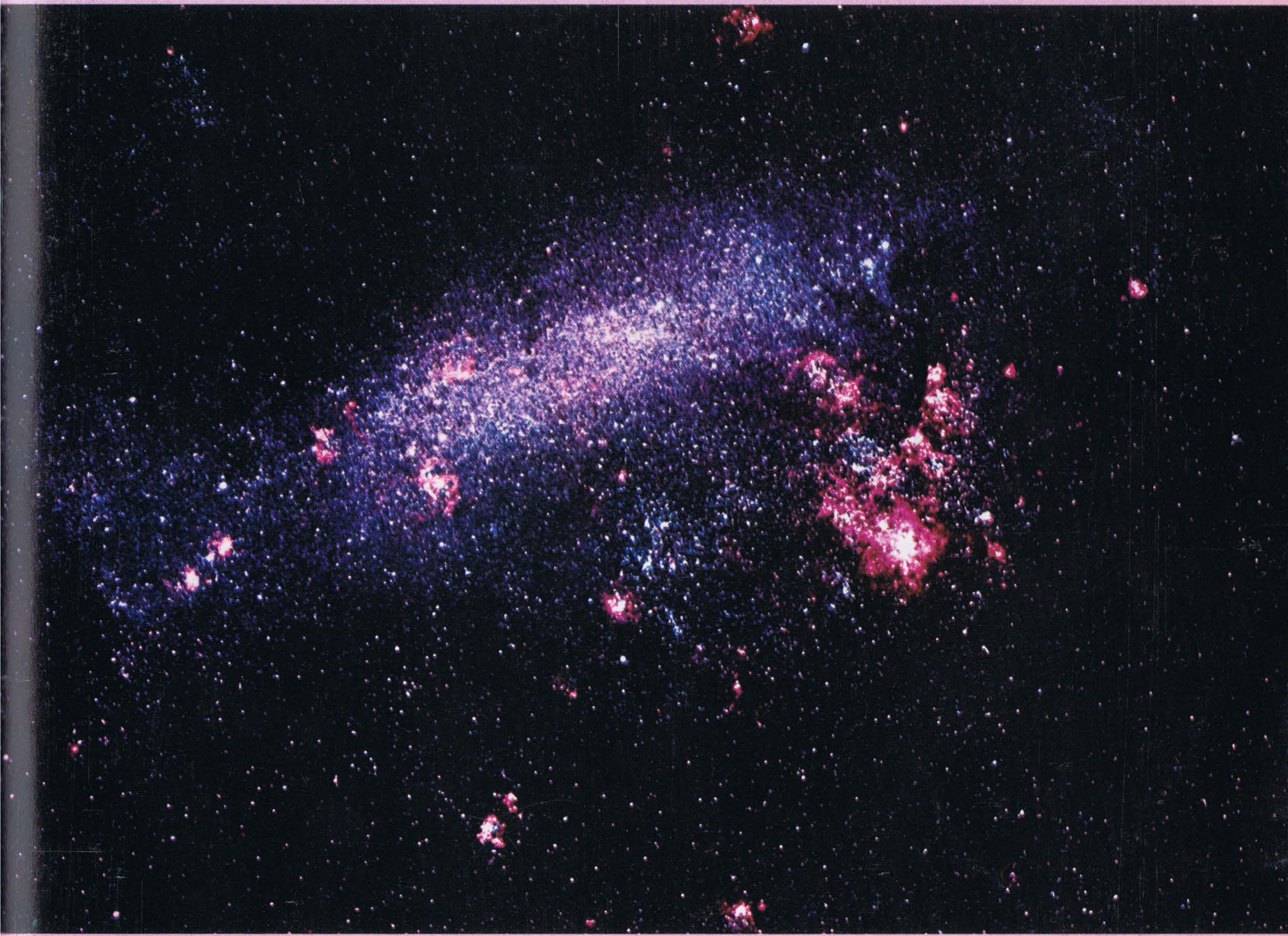
Sky and TELESCOPE



rge Magellanic Cloud

★

Vol. 55, No. 2

FEBRUARY, 1978

$1.25

★

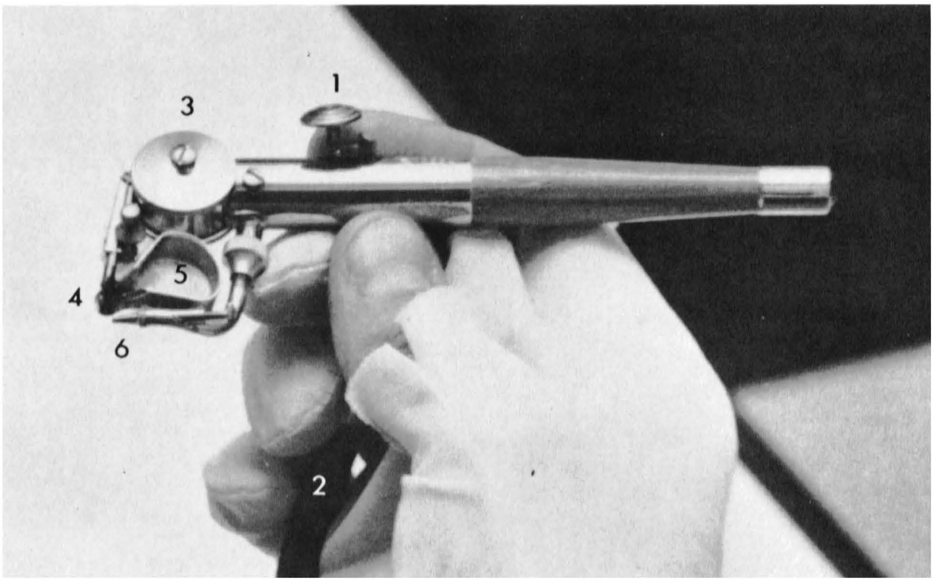
Planetary Mapping with the Airbrush

RAYMOND M. BATSON, *U. S. Geological Survey, Flagstaff, Arizona*

MAPPING is an essential activity in the planetary exploration program of NASA. Maps are required to evaluate and select landing sites for vehicles like the Viking landers. They are also the basic illustrations used by geologists to derive and evaluate relationships between surface materials. Different map products also show how various kinds of remote-sensing data (radar traces, spectroscopic observations, gravity measurements, and the like) relate to a planet's surface and to each other. NASA has entrusted the responsibility for its mapping program to the U. S. Geological Survey's Branch of Astrogeologic Studies in Flagstaff, Arizona.

The portrayal of landforms in a clear, uncluttered fashion has been a challenge to cartographers since scientific mapping began. Surface features are usually shown by symbols or are portrayed in ways that can be precisely described or defined, although this has been done with varying degrees of success. Contour lines are often added to define mathematically the third dimension of relief. Most readers are already familiar with the shaded-relief or "hill-shaded" map, which has an aesthetic appeal when well drawn and can be understood without special training.

For our purposes, mosaics of spacecraft photographs, whatever their quality, are usually not acceptable as maps. Albedo and illumination variations, haze, clouds, and camera-induced imperfections (artifacts) cannot be represented in a map legend and often obscure or obliterate the very details the map is designed to portray.



A close-up of the Paasche model AB airbrush used by planetary cartographers at the U. S. Geological Survey in Flagstaff, Arizona. The double-action trigger (*1*) controls both air flow from a high-pressure feed line (*2*) and the speed of a tiny air turbine (*3*). The latter drives a reciprocating needle (*4*) past the paint supply (*5*) and into the airstream from a small nozzle (*6*).

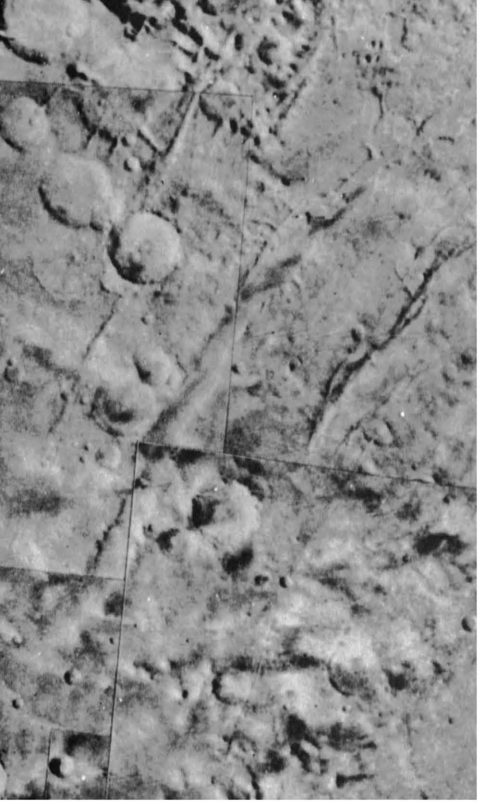
PROGRAM HISTORY

It was not until NASA initiated a program of lunar mapping in the 1960's that a technique was developed for making shaded-relief maps based on a variety of photographic information. Previous hill-shading efforts utilized topographic measurements or contour lines to define slope and, hence, shading. The new technique was developed by Patricia M. Bridges, then employed by the Air Force's Aeronautical Chart and Information Center (ACIC) in St. Louis, Missouri.

Her approach was to develop a detailed mental image of the landform to be drawn, based on meticulous examination of lunar photographs taken under a wide range of illumination and on personal observations of the moon through telescopes at Lowell Observatory. The feature was then drawn to scale with a tiny spray gun called an airbrush, shown above, which can be controlled precisely by a skilled operator. Although other methods of drawing shaded relief were tried, only the airbrush exhibited the versatility and control necessary to draw fine lines, tint large areas quickly, and allow all degrees of artistic freedom between these extremes. She accentuated highlights by removing dark tones with an electric eraser.

Using this method, each shaded-relief drawing was actually a composite of information from a wide variety of source material, yet with landforms portrayed as if illuminated consistently throughout the map. Studies have shown that illumina-

Patricia Bridges adds final touches to a map section of Mars that includes the original landing site for Viking 1.



The face of Mars, before and after. At left is part of the Syrtis Major photomosaic prepared from Mariner 9 images. At right is an airbrush drawing of the same region, showing both landforms and shading. Many different photographs were examined before rendering the drawing.

tion from the west (left) gives users the least trouble with the image reversal that makes craters appear to be domes or ridges to be canyons.

The Bridges technique was used by ACIC throughout the 1960's to make the Lunar Aeronautical Chart (LAC) map series that aided the Surveyor and Apollo programs and geologic mapping of the moon. Many cartographers and illustrators participated in the program, including Jay L. Inge, who was responsible for many refinements of the technique. By making extensive use of the electric eraser and adjusting the airbrush mechanism, he was able to extend the representation of fine details found in Lunar Orbiter photography. Several of Inge's maps have also been published by the National Geographic Society.

The program entered a new phase in 1970, when the U.S.G.S. was asked to prepare maps of Mars and Mercury from the television pictures expected to be returned by forthcoming Mariner spacecraft. These images presented problems similar to those encountered with telescopic photographs of the moon. Many pictures may cover a given area, each containing information not visible in the others. Unfortunately, only one version can be used in a photographic mosaic. In such situations, the airbrush appears to be the best and most economical way to make detailed maps of planetary surfaces. An example of cartography based on Mariner 9 imagery is shown here.

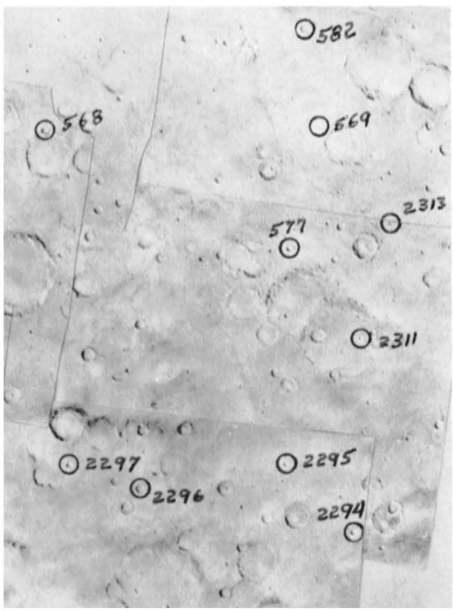
PRELIMINARY MAP PRODUCTS

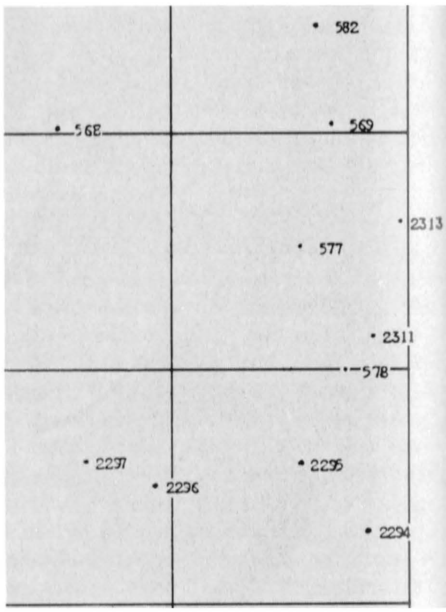
Careful cartographic planning is necessary throughout all phases of a mission, from the initial design of the spacecraft through actual acquisition of the data used in map compilation. For flights to Mars and Mercury, the initial design of map formats, quadrangle layouts, and scale determinations were made by the author in consultation with the Mariner imaging teams.

When a spacecraft begins to return its pictures, U.S.G.S. mappers are present at Jet Propulsion Laboratory in Pasadena, California, to make catalogues and photomosaics. These products are used to verify that the photographic coverage is both complete and adequate. If more data are needed, team members work with those who design the photographic sequences, reprogramming the spacecraft to fill gaps or replace unsatisfactory coverage. Scientists also use these mosaics to aid and illustrate their preliminary scientific investigations.

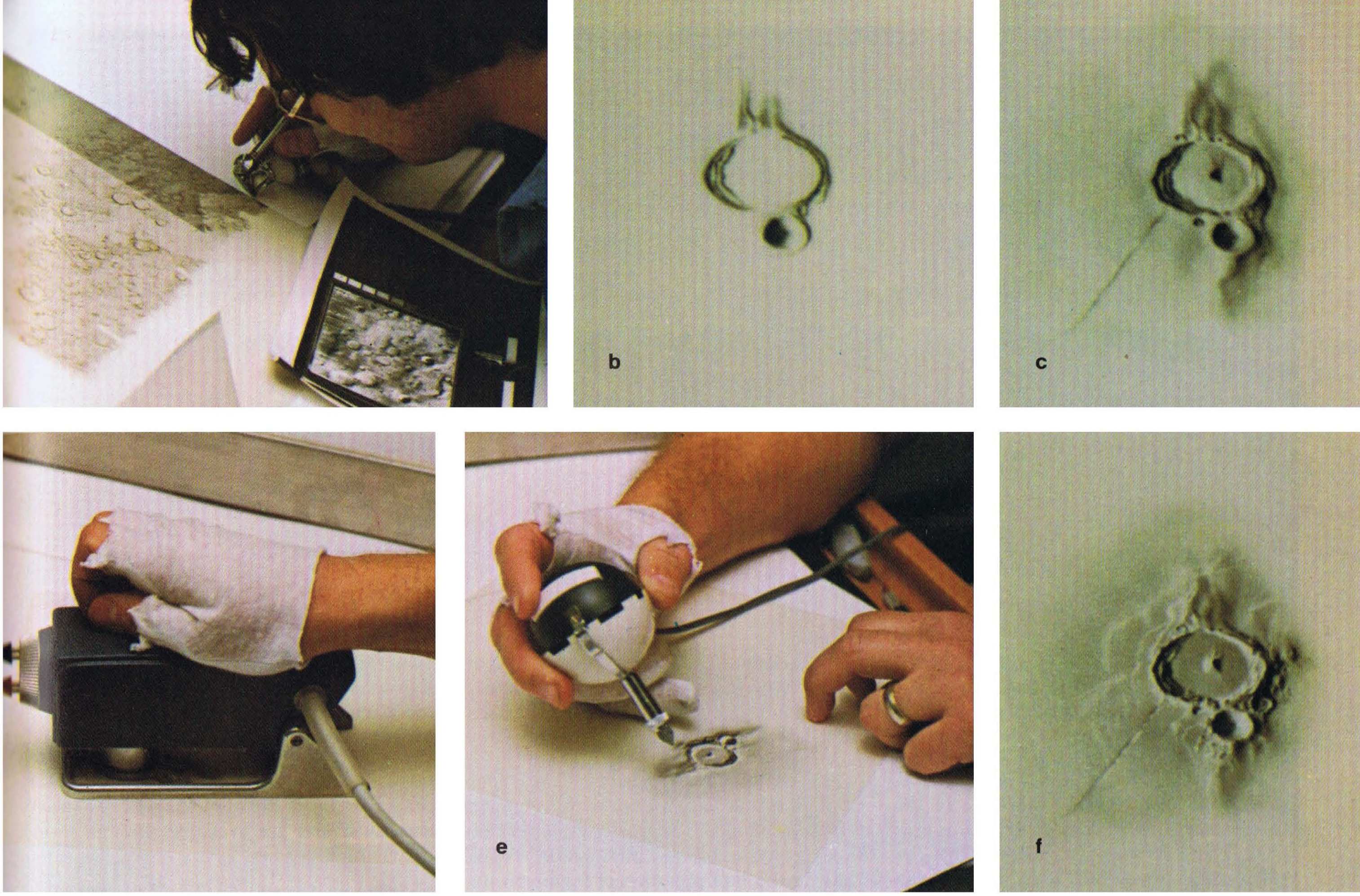
Formal mapping begins by using analytical photogrammetry to derive a network of *control points.* For Mars and Mercury this has been performed by Merton E. Davies of Rand Corporation in California. Here precise latitudes and longitudes for a well-distributed set of surface features are found by comparing overlapping images of the planet's surface with spacecraft tracking data. As shown in the accompanying illustrations, the control points are first plotted on a grid of the desired map projection, then identified on selected spacecraft photographs.

When the "best" set of pictures for a mosaic has been found, each photograph is transformed to the correct projection by manipulating the individual picture elements within the computer. In doing so, the shape of the original picture is distorted so that locations of the control points on the photograph can be placed directly on their corresponding grid positions. Both JPL and the U.S.G.S. office in Flagstaff, Arizona, perform these computer operations. Final mosaics are usually made by hand, although recently developed techniques allow the pictures to be combined electronically into a single image. The latter process has a higher initial





Control points circled at left will be used to correct the photograph's geometry prior to mosaicking. The points' positions correspond to the computer plot at right. Illustrations on this page are from the author.



This sequence of photographs illustrates the principal steps in airbrush cartography. First, details from a photographic mosaic are traced onto the map manuscript (*a*), as demonstrated by the example in (*b*). Next, other details are added (*c*) after thorough examination of all other available spacecraft pictures of the area. Uniformity of tone is checked with a densitometer (*d*), and highlights are accentuated by an electric eraser (*e*). The completed drawing (*f*) shows every feature that can be reliably derived from spacecraft data.

cost, but enhancing the resulting composite as one picture is much less expensive than treating each frame separately.

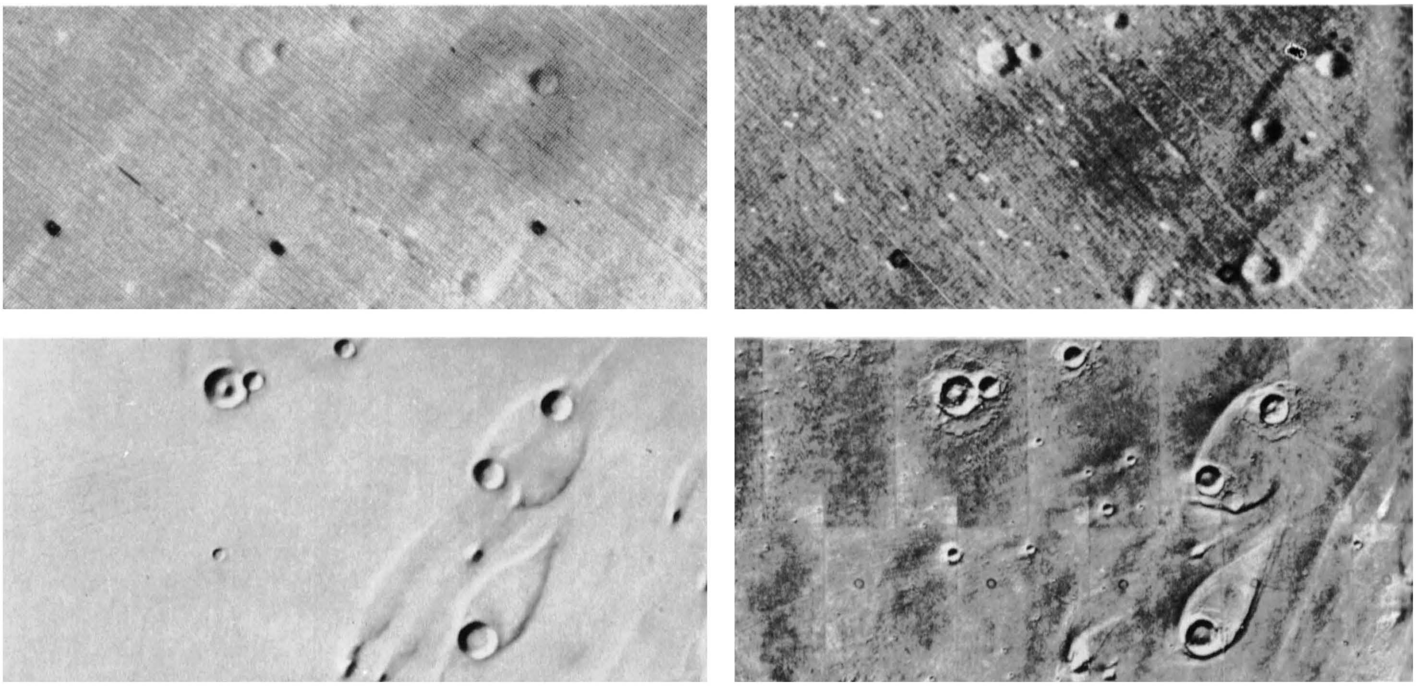
The quality of such mosaics varies enormously, depending on the quality of the original spacecraft pictures, the amount of digital processing applied to them, and the nature of landforms in the region. Some photomosaics are acceptable as maps without the airbrush stage, particularly when the number of pictures involved is small, the surface is illuminated by an early morning or late afternoon sun, and transmission noise and blemishes are not a serious problem. However, as the number of elements increases or the quality decreases, the cost of computer enhancement rises rapidly and the airbrush method becomes the only feasible way to complete the mapping economically.

The airbrushing staff at the U. S. Geological Survey's Branch of Astrogeologic Studies in Flagstaff, Arizona. From left to right, Anthony Sanchez, Sue Davis, Pat Bridges, and Jay Inge. Not pictured is Barbara Hall. Photograph by the author.

AIRBRUSH COMPILATION

The first step in the making of an airbrush map is the "lay-in," where features from geometrically corrected photomosaics are traced with the airbrush onto a translucent plastic manuscript, as seen above. After all usable details have been gleaned from the mosaic, a white backing sheet is placed between it and the manuscript, and all other available data are examined to add further detail to the drawing. Finally, an electric eraser is used to modify tones and to bring out highlights.

Uniformity and consistency are essential in portraying landforms with the airbrush. In our program, this is maintained by intensive review of each drawing. That is, a completed drawing is carefully examined and criticized by one or two other members of the airbrushing team. Differences in style exist between the artists that are readily apparent to them but rarely detected by people using the maps. Tonal



Four views of Chryse Planitia, as seen through the eyes of Mariner 9 (top left), the enhancement computer (top right), Mrs. Bridges (bottom left), and the Viking 1 orbiter (bottom right). The Viking photography verifies details seen in the airbrushed version, which was used to evaluate potential landing sites. Note that the direction of sunlight is from the right in the Mariner 9 views, but from the left in the bottom ones. These photographs were supplied by the author.

densities are rigidly controlled and corrected when necessary. The last stage in the compilation process is a technical review by at least one scientist familiar with the region. His comments may indicate the need for further modifications.

People associated with the airbrush program were gratified to learn that renditions of Mars based on relatively low-resolution images from Mariner 9 were substantiated by the better-quality photographs returned by the two Viking orbiters. One example, shown here, is from the Chryse region, near the Viking 1 landing site. Even though only small portions of the maps can be verified by higher-resolution pictures from later missions, these "field checks" lend credibility to the technique nonetheless. They demonstrate rather clearly that airbrushing can offer a dramatic improvement over any single version of a photograph, while keeping the interpretation of features within the limits of available data. Perhaps a stronger point can be made: however sophisticated the technology available for planetary mapping, the addition of human skill and craftsmanship is still an essential ingredient.

CURRENT PRODUCTION AND FUTURE PLANS

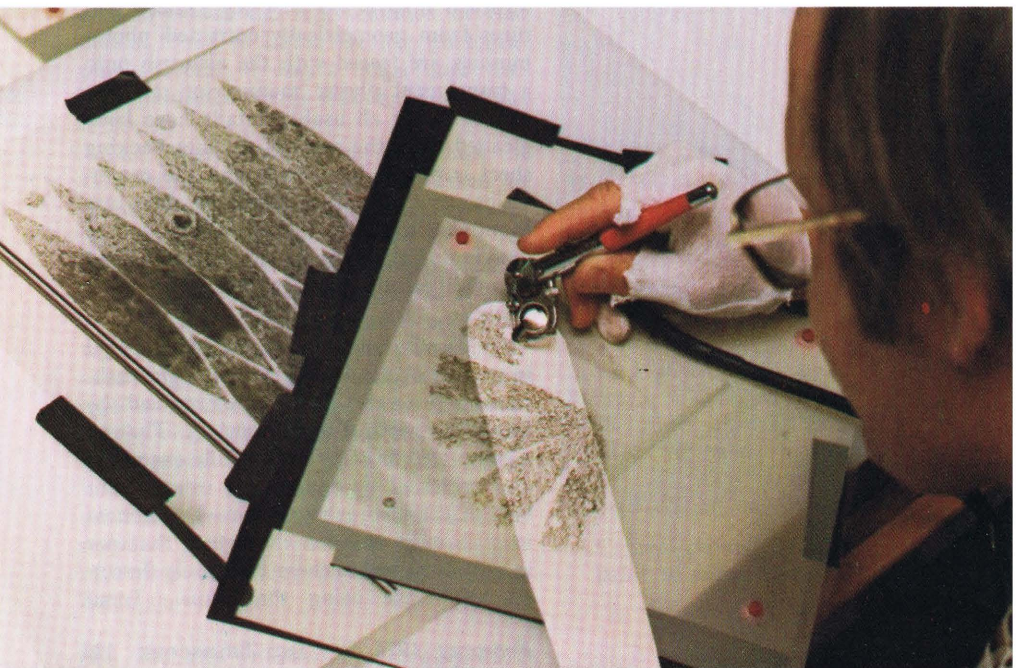
The Geological Survey's program now consists of five airbrush cartographers (including Bridges and Inge), three general cartographers, and a group for drafting and camera work. Many of the planetary maps produced by the Survey have been published and are available through these distribution centers:

U. S. Geological Survey Branch of Distribution Denver Federal Center Denver, Colo. 80255	U. S. Geological Survey Branch of Distribution 1200 South Eads St. Arlington, Va. 22202

These include shaded-relief maps and topographic maps of Mars and Mercury at the scales of 1:25,000,000, 1:5,000,000, and 1:1,000,000.

A series of shaded-relief globes showing the lithospheres, or solid surfaces, of the terrestrial planets is in preparation. Although their production is expected to be limited for research use only, they may eventually be produced in sufficient numbers for sale to the general public. Work is also proceeding on maps of Phobos, and planning is underway for mapping the surface of Venus in 1979 by both spacecraft and ground radar stations.

Finally, should the Voyager mission prove successful, we are looking forward to the preparation of maps for Jupiter's Galilean satellites and for seven of Saturn's moons. The first of these should be completed sometime in 1980.



Jay Inge, who refined many of the techniques used in airbrush cartography, works on the polar sections of a 1:32,000,000 moon globe. When completed, it will be added to similarly scaled globes of the terrestrial planets for use in comparative studies. Unless otherwise credited, photographs in this article were taken for *Sky and Telescope* by J. Kelly Beatty.