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Technical Memorandum 33-445

Revision 1

The Surveyor Experimental Test Laboratory

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Preface

The work described in this report was performed by the Space Sciences Division of the Jet Propulsion Laboratory.

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Abstract

This report covers the physical description and the various applications of the *Surveyor* Experimental Test Laboratory (SETL). Developed as an answer to the need for obtaining design and analytical information about the *Surveyor* spacecraft and its mission to the moon, SETL applications include simulation, training, instrument development, and the use and handling of mosaics. Several unique and specialized instruments and techniques for their use are covered. Hundreds of television and soil mechanics experiments gave invaluable information for the analysis of the data from the moon. The overall success of the *Surveyor* program points out the SETL potential for future missions.

The *Surveyor* Experimental Test Laboratory

I. Introduction

The capabilities of the spacecraft and operational test simulation laboratory that operated during the *Surveyor* lunar project are described in this report in the belief that the information contained herein could be of value for future lunar and possibly planetary exploration.

The *Surveyor* Experimental Test Laboratory (SETL), during the *Surveyor* program, provided valuable data which was sometimes the determining factor in decisions made before, during, and after each of the *Surveyor* missions. The SETL, although intended initially only for science payload interpretation purposes, also provided invaluable real-time capability for engineering functional operation decisions.

II. History

There was an urgent need, early in 1963, for a test laboratory in which members of the *Surveyor* science experiment teams (engineering and scientific) could study and determine the capabilities and limitations of science experiment operations using a full-scale spacecraft model. At that time, the Jet Propulsion Laboratory (JPL) did not have hardware available for use in spacecraft simulation. Therefore, it was necessary to design and build a full-scale spacecraft model that had the necessary capabilities for simulating actual spacecraft configurations and/or conditions. This, of course, meant that such a model would have to have operational slow-scan television cameras and working mock-ups of other science instrumentation and equipment.

With these requirements set forth, the SETL came into being and its members set about the tasks of building the working laboratory.

III. Test Facility Description

The first SETL full-scale spacecraft model was fabricated at JPL. It was of welded frame construction and was a close approximation in dimensions and configuration. Two slow-scan TV cameras with ground display and monitoring equipment were designed to *Surveyor* scan rates with all electrical characteristics the same as the actual *Surveyor* system. The physical characteristics, except for shape and size, were only approximations of the flight cameras. The lens and mirror assemblies, however, were close representations.

Everything that was necessary to simulate actual television pictures was accomplished. The cameras were hard wired and mounted to the space frame in the proper location and attitude for the *Surveyor* A21 configuration.

A completely automated control system for the cameras was designed and fabricated as was a control system for the operation of a prototype surface sampler, which was mounted on the space frame. These systems had built-in time delays for simulating real-time operation of command and readout.

With the spacecraft model and its control system operational, it was a relatively simple task to make television surveys in and around the spacecraft.

During and following the *Surveyor I* mission, it became evident that a more accurately scaled model of the *Surveyor* spacecraft was needed. Simulations that were made with the first system were good but not adequate for detailed study. Pictures received from *Surveyor I* revealed a number of *Surveyor* test model inaccuracies when it came to simulating impressions or disturbances in the lunar surface and simulating spacecraft obscurations.

By the time *Surveyor III* had landed, it was decided that if SETL were to support the science teams during mission operations to the fullest capability, a new full-scale *Surveyor* spacecraft model would have to be built.

The construction of the new model was accomplished using as many actual *Surveyor* spacecraft spare parts as could be obtained. A model 4.2.2 spacecraft television camera, a prototype surface sampler, and a mock-up of the alpha scattering instrument were used, as were vernier engines, attitude control jets, footpads, crushblocks, and various solenoid and squib firing valving. The antenna and mast assembly from an antenna test model were also utilized. All of these were finished to the latest paint and surface finish configurations of *Surveyor V*. The spacecraft was subsequently upgraded to the latest configurations throughout the rest of the missions.

Concurrent with the completion of this new *Surveyor* model, a sun simulator was added to the facility (see Fig. 1). The simulator was to provide a convenient, quick

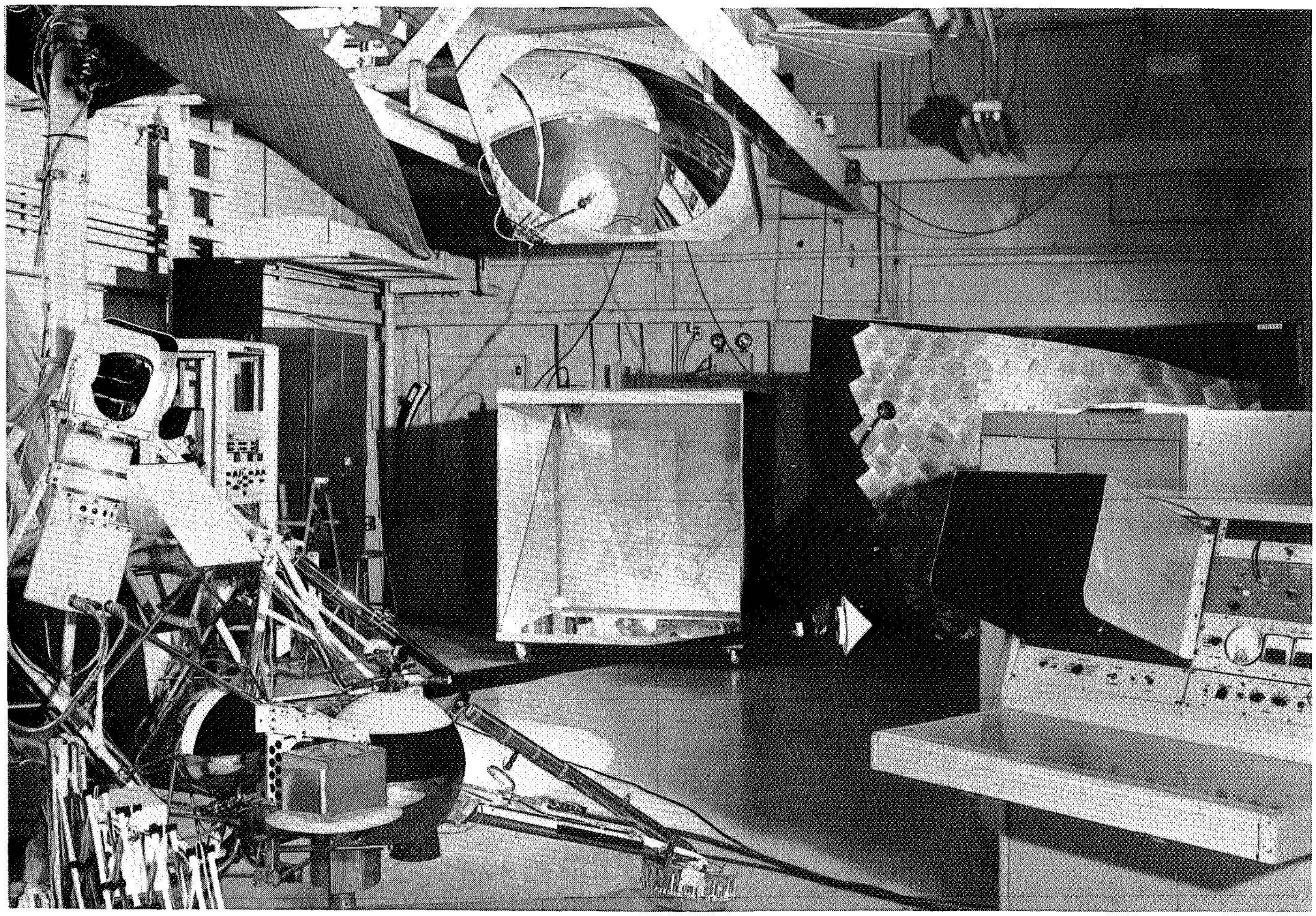

Fig. 1. Test facility with full-scale model spacecraft under collimated light source and, directly below light, 45-deg mirror for sun angles below 7 deg

and accurate method to simulate shadows cast on the lunar surface by the spacecraft and/or objects in the field of view of the spacecraft camera. The simulated sunlight source emitted a 5-ft diam collimated beam of light. It was mounted about 15 ft above the floor and was capable of being adjusted for a desired sun elevation angle from 7 to 90 deg. Azimuth angles were accomplished by rotating the spacecraft in place. Sun angles below 7 deg were made by directing the light down into a 45-deg-angle mirror (see Fig. 2). The use of both full and 1/5 scale spacecraft models along with the light source and mirror made possible accurate determinations of illumination

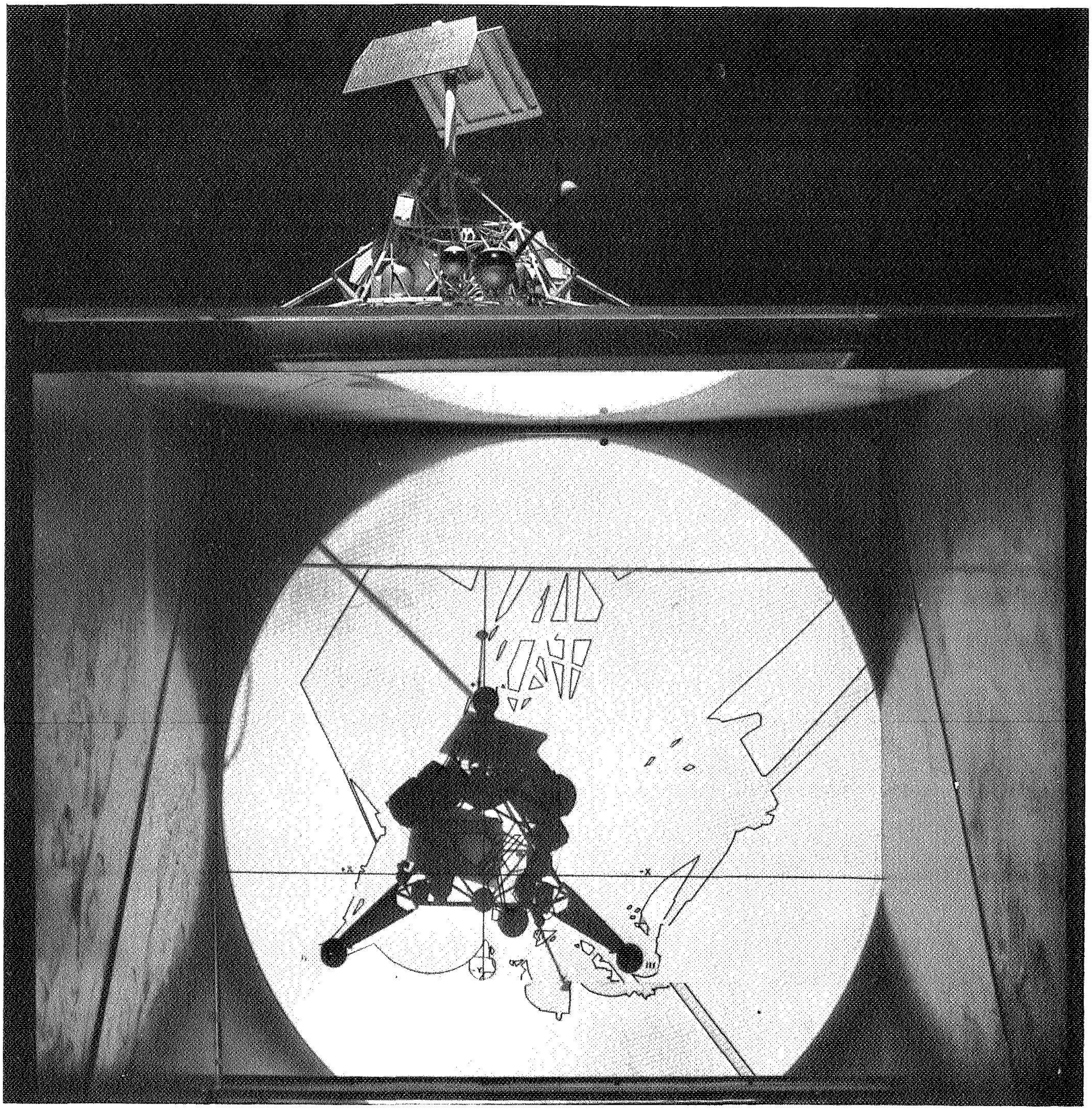

Fig. 2. *Surveyor* 1/5-scale model shadow projection with simulated 90-deg overhead sun angle; lined-in shaded area, never seen by camera, is camera's obscuration pattern

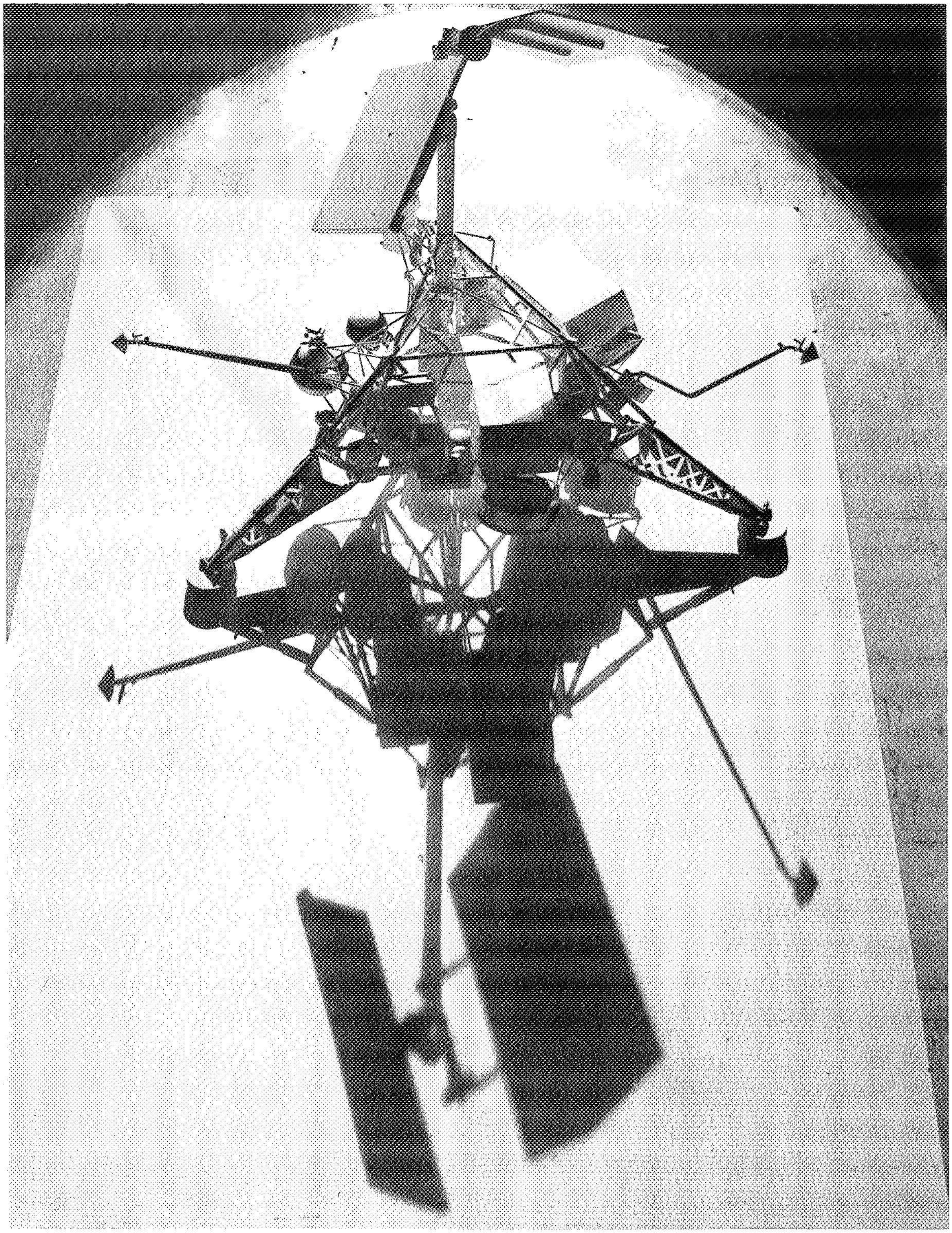

Fig. 3. Spacecraft shadow projection with low sun angle; method was used in predicting shadow angle at various times of lunar day

and shadow conditions on spacecraft components for improved temperature predictions during mission operations. Figures 2 and 3 show the shadow projected by the 1/5 scale model under simulated lighting conditions.

IV. Facility Applications

A. Simulation

The test system as described before was specifically designed for spacecraft simulations and/or surface conditions around the spacecraft. Uses in simulation were:

(1) Early in the *Surveyor* program, the SETL spacecraft was used in determining proper camera tilt for optimum visual field of view of the surface sampler and its working area.

(2) Auxiliary mirrors, magnets and other scientific aids that were added to the spacecraft as the project progressed were also located, fitted, and tested at SETL.

(3) Footpad, footpad imprints, crushblock, crushblock imprints and any other surface disturbances or conditions could be readily simulated in a *Surveyor* TV picture. Throughout the mission and post-mission data analysis, extensive studies to obtain such measurements as footpad and crushblock penetrations were made. Figures 4 and 5 are prime examples of this type of simulation.

(4) Soil samples of different types were used for determining reflective qualities of the lunar surface.

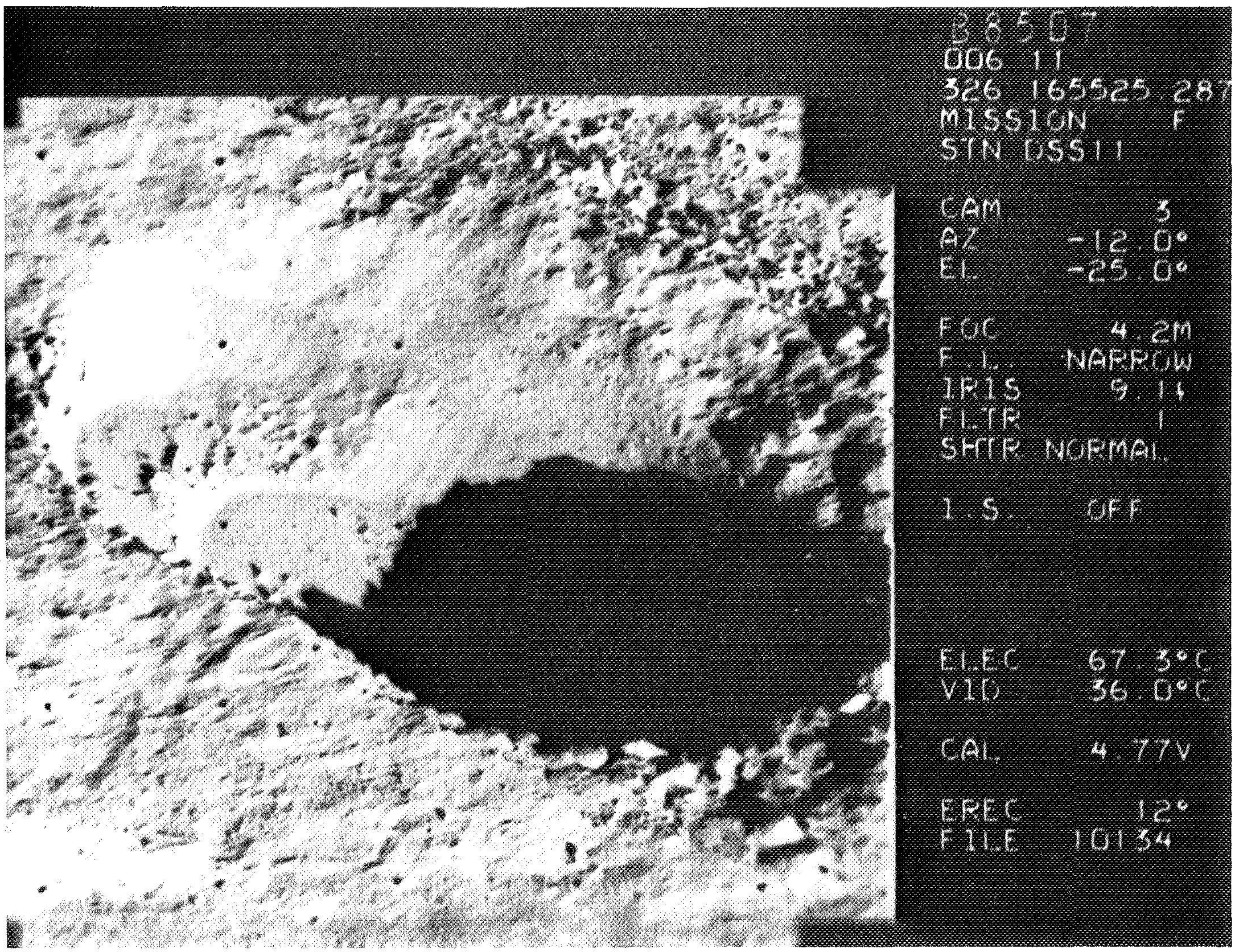

Fig. 4. Real-time photo of imprint of *Surveyor VI* footpad No. 2, made on initial landing

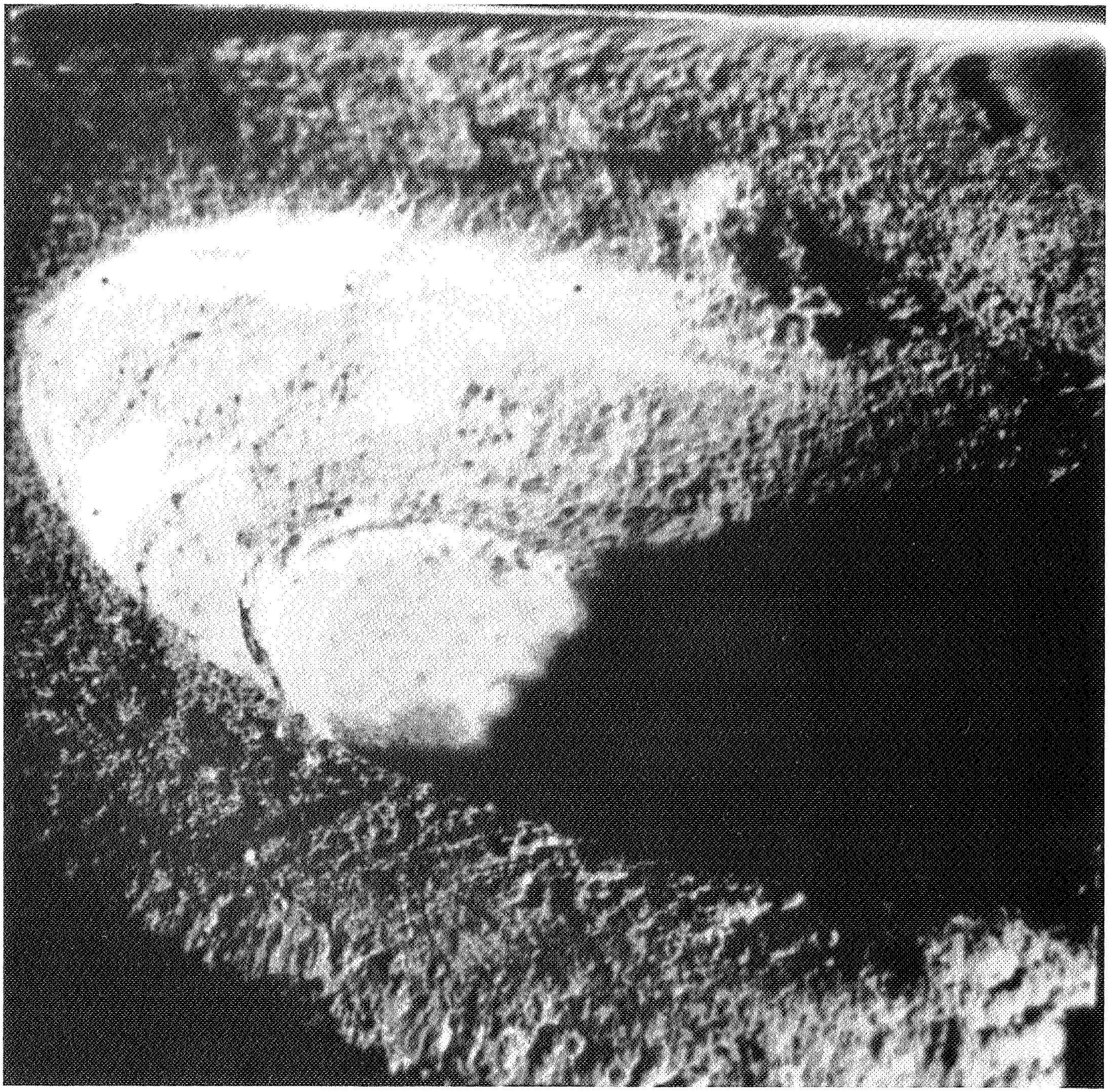

Fig. 5. TV picture of model of Fig. 4, showing simulation technique for depth-of-penetration measurement

These and many other simulations were made to determine lunar surface properties.

(5) Extensive studies to determine those areas in and around the spacecraft that would be obscured from view of the television camera by the spacecraft itself were carried out.

(6) Shadow plots before and during mission operations proved to be a tremendous aid. This allowed us to predict the spacecraft shadow at any time during the lunar day. With this information, mission operations could orient antennas for optimum shadow cover of instrumentation on board thus making it possible sometimes to operate instruments for longer periods during high sun angles when temperatures were at their peak.

B. Training

The SETL proved useful in the training of personnel in mission operations who were responsible for commanding surface sampler sequences. A mock mission operations was set up at SETL and surface sampler and camera sequences were carried out as would be done in real time. In some respects this was an invaluable aid for those responsible for carrying out these tasks during a mission. These are only two of the many training applications of SETL. Experience demonstrates that this type of test laboratory as can be seen has tremendous possibilities in all types of lunar or planetary spacecraft landers.

To cite a particular case which will exemplify the need and usefulness of this type of test facility for emergencies, we have only to go to a time during the *Surveyor VII* mission in which the alpha scattering instrument failed to deploy to the lunar surface on command. Since the instrument's latching mechanism was apparently malfunctioning, it was decided that possibly it could be freed with a little help from the surface sampler. However, before such an attempt was made, it was all simulated and practiced using the SETL spacecraft. There is the possibility that had it not been for this test facility and the knowledge gained from it, the plan to free the alpha scattering instrument would have failed, thus leaving the instrument uselessly dangling and the attempt even may have damaged the surface sampler.

Figure 6 illustrates the SETL spacecraft with deployed surface sampler displayed on its video monitor. It was basically this type of test setup that was used for simulating the alpha scattering instruments predicament.

C. Instrument Development

Although SETL was primarily a test facility, it proved useful in other areas of mission support. It developed what was called *the paper camera.*

A need developed prior to the *Surveyor* missions for a camera which would photograph, in real time, pictures taken by the *Surveyor* TV camera. Such a camera was designed and built for this purpose through the efforts of the SETL team. This camera made available in literally seconds a film positive of the scene just photographed by the spacecraft. Almost the only delay in the system was the signal transit time from the moon to earth. From these pictures real time pictures, mosaicking of the lunar surface was accomplished.

Two paper camera systems were fabricated and interfaced with mission operations and were used constantly without breakdown throughout all *Surveyor* missions.

SETL also assembled a 35mm negative film camera for similar use. Of course, this film had to be processed conventionally.

D. Mosaics

Another area in which SETL was very active was the one of mosaicking pictures taken during the *Surveyor* missions. SETL developed a unique and practical way of mounting and presenting these mosaics. Mosaic mounting boards were designed as spherical segments. Each segment was 36-deg wide and 75-deg high with a scale factor of 1 deg equaling 1.0 in. Each *Surveyor* mission was presented at least once in 360-deg panoramic mosaic form. Each pictorial scene contained about 800 to 900 individual pictures which recreated a camera-eye view of the lunar surface around the spacecraft.

Since these mosaics were composites of many pictures taken during a mission, it was necessary to go through the *Surveyor* film library and select pictures of the best quality possible so that the mosaic, when completed, would give a good photographic representation of all surface features in the field-of-view of the spacecraft camera. The spherical segments were lined with a grid system which was used as a guide for locating and positioning the individual frames. This positioning was done by the grids and by the TV camera's azimuth and elevation. At the same time, corrections were made for camera and spacecraft tilt which thus gave 360 deg of picture with an average horizon which was level.

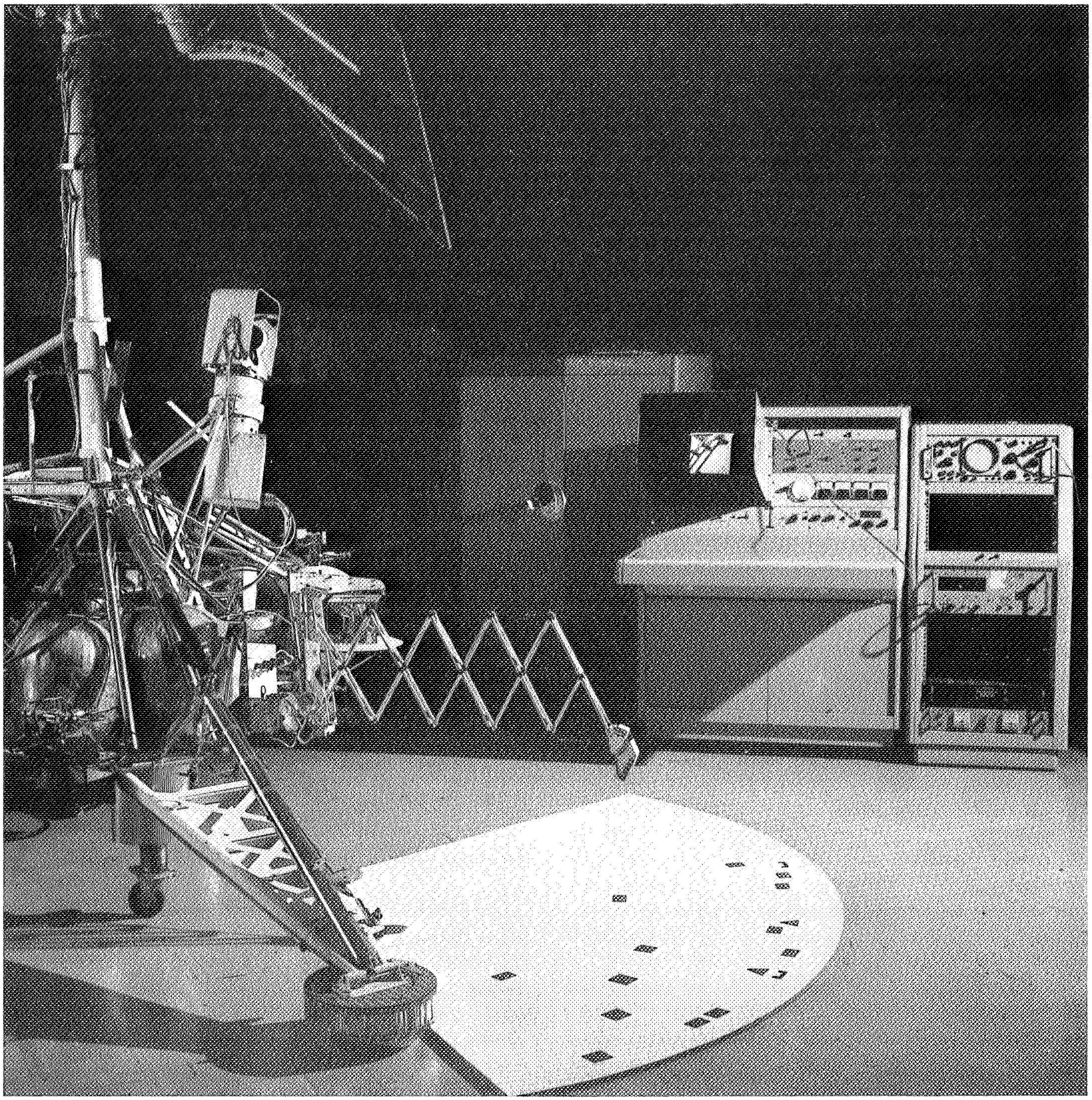

Fig. 6. Basic test system for determining use of surface sampler to free *Surveyor VII* alpha scattering instrument; video monitor displays narrow-angle view of surface sampler

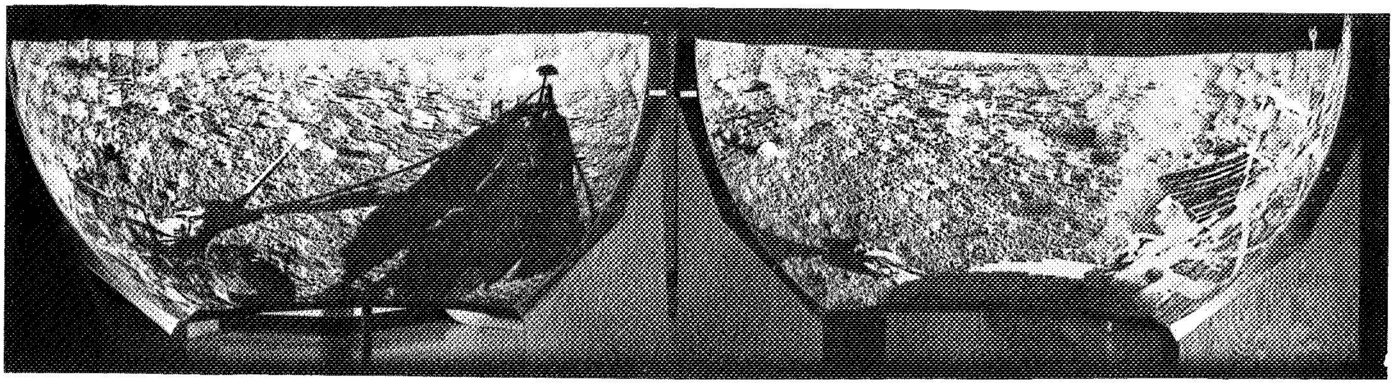

Fig. 7. *Surveyor I* landing site; five mosaic segments required for each 180-deg spherical section shown

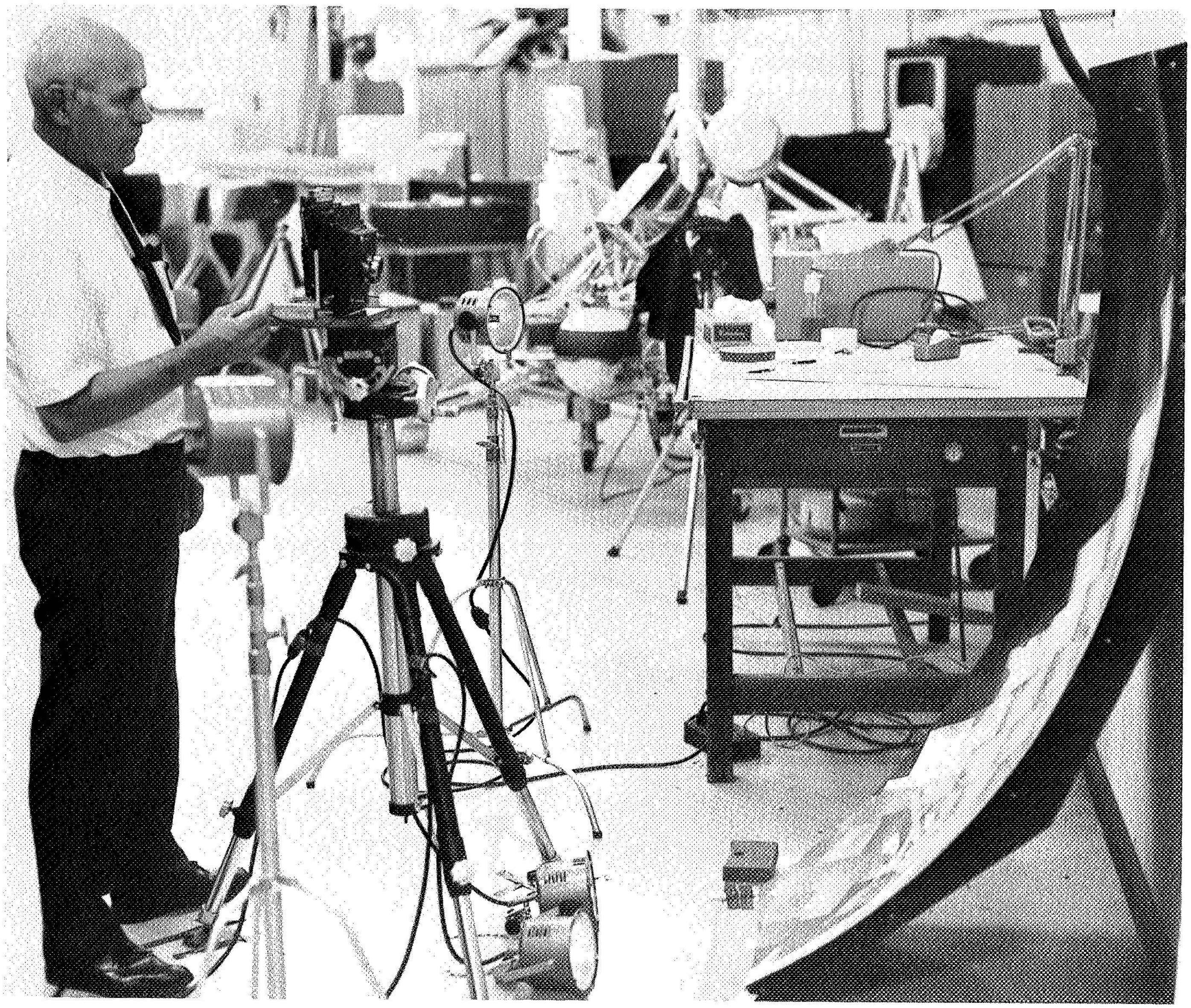

Fig. 8. Setup for photographing mosaics

When all pictures for a particular mission were selected they were printed to scale size (approximately a 6-in.^{2} picture) for mounting on 10 spherical segments. These segments when attached (bolted together) formed a 360-deg surface to which the pictures were mounted (see Fig. 7).

This type of presentation is not only spectacular to view but is very useful in the study of the lunar surface.

In order that these panoramic mosaics could be studied in a somewhat more convenient form, SETL designed a special 4 × 5 film camera to photograph them.

When each of the mosaics were completed, that is to say when 360 deg of picture had been mounted, it was then cut up into the 10 individual segments and photographed a segment at a time with the special wide-angle camera (see Fig. 8). Photographing was done in such a way that when the photographs were matched together on a flat surface a rectangular picture was obtained with a 360-deg field-of-view with a mean horizon level (see Fig. 9). The lunar surface could then be studied either on the spherical boards or in a flat rectangular picture form.

Hundreds of smaller special-area type mosaics, together with large panoramic type pictures, were prepared by SETL for mission analysis.

V. Conclusion

The SETL throughout the *Surveyor* program functioned in a manner which added significantly to the overall success of the project in general. Its ability to simulate and perform specific tests and/or conditions of spacecraft and surroundings time and again proved to be a valuable asset. Much was learned by its use on *Surveyor* and much could be learned from it or one like it on future missions, particularly landing missions.

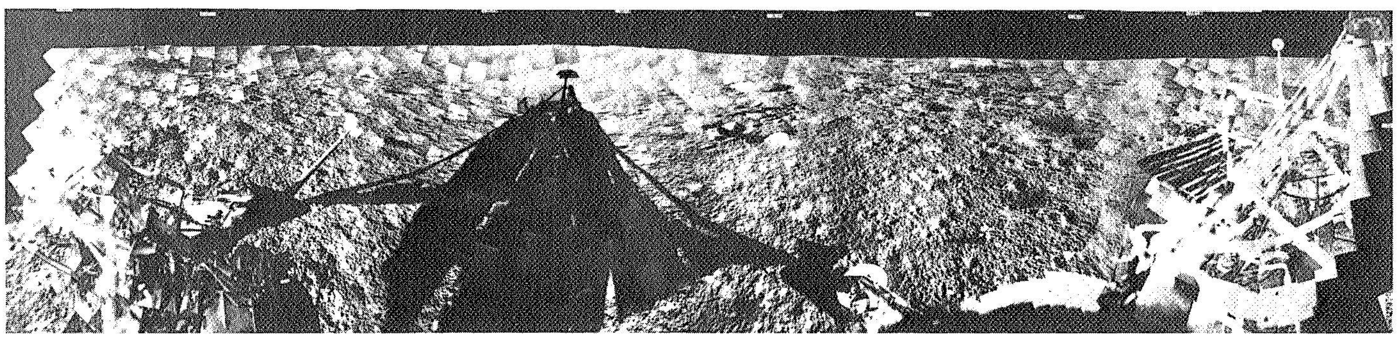

Fig. 9. Assembled segments of Fig. 7 spherical panorama in which Fig. 8 technique was employed