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Large-Scale Lunar Photogrammetry

Terrestrial mapping and television offer an initial basis for the design of a Lunar system.

ABSTRACT: *With the advent of the Ranger VII pictures of the lunar surface, a new area with its challenges and problems is being opened to the photogrammetry profession. Large scale photography and the resulting mapping tasks are bringing forth some new problems to the attention of photogrammetrists. Investigation of the lunar surface from the lunar surface is a realistic possibility. Utilization of modified terrestrial type camera systems are being considered. Accurate results for interpretation and mapping are being demanded. The problems and solutions being considered are complex and new when compared with conventional photogrammetry. Primary problems lie in areas of:* (1) *utilization of television presentations;* (2) *multi-purpose imaging systems;* (3) *techniques and procedures of calibration;* (4) *data reduction and mapping techniques for large scale analysis. Definitive data are needed in maximizing terrestrial types of camera systems in order to obtain the best photogrammetric utilization of coming space exploration projects.*

A RELATIVELY NEW ERA for photogrammetry is underway. The exploration of space has introduced a new application of the basic photogrammetric operations. The success of the Ranger VII and VIII in obtaining large scale pictures of the lunar surface has shown the capability of remote systems to obtain visual information once thought to be beyond the capability of man. With the development of these highly sophisticated systems, it becomes necessary to re-evaluate the photogrammetric methods and procedures required for the analysis of the information.

The portion of this new photogrammetric era which will be emphasized here is that part which pertains to large scale mapping and exploration of the lunar surface. This discussion excludes the work currently being done with lunar photography from earth and the future investigations which will probably be done from lunar orbiting vehicles. Emphasis is upon scales which are greater than 1:1000 and for special purpose studies may be at 1:1.

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Such programs involve obtaining imagery of the lunar surface, from the lunar surface. The specific endeavor which is anticipated to accomplish this task is the Surveyor Project which is a NASA program managed by the

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Jet Propulsion Laboratory in Pasadena, California. Part of the objective of this program is to obtain large scale television pictures, and subsequent photogrammetric data and scientific interpretative information so that a better understanding of the configuration of the lunar surface may be known.

The specific design and engineering characteristic of the imaging system to be used on Surveyor is not discussed; emphasis is directed towards the photogrammetric problems encountered, and some of the prospective solutions. It should be pointed out that, as in most space efforts, we are forced to utilize systems designed for several purposes. Surveyor is no exception. The difficulty of the overall task requires that maximum image information be obtained, so a system is selected to satisfy the scientific interpretation tasks as well as serve as the source for photogrammetric data. Until an optimum photogrammetric system can be utilized, we must provide maximum information with the more flexible systems currently anticipated for our first real detailed exploration of the moon.

IT IS FIRST NECESSARY to review some of the basic differences between the conventional, earth oriented mapping concepts and the large scale lunar photogrammetric tasks. The two most important basic differences are the utilization of fixed camera positions and the application of television as the image medium. Emphasis of the photogrammetric tasks is on terrestrial type of analysis procedures. These procedures in turn are complicated by use of convergent systems, as well as systems characterized by parallel camera axes, for collection of stereoscopic imagery. This may even include averted systems, where camera axes are practically parallel but not perpendicular to the base line between camera stations.

Scientific and engineering constraints have forced use of lenses with smaller fields of view than conventional mapping lenses where the trend has been towards increased field of view. This results in many more pictures to cover the area of interest. However, advantageous television resolution criteria can be thus obtained. The problem introduced by pictures of small angular coverage is not only a function of the large number of frames to cover the scene, but also involves the mode for presentation of the data.

Simulation tests and evaluation of the significant geologic features of a terrestrial scene indicate that individual pictures of the surface taken via narrow angle lenses (less than 10° field angle) may not be meaningful until some evaluation has been done whereby the context of the overall scene can first be appreciated (Figure 1). High frequency details may be of little value until the larger features are identified and correlated. The importance of a composite picture, the mosaic (Figure 2) is obvious. To provide a better concept of the overall scene, a shorter focal length lens and, consequently, wider angle of view may be utilized. With the current Surveyor system, this is accomplished with a zoom lens.

The application of terrestrial type camera systems is primarily limited to the immediate vicinity of the camera station. Basic objectives are related to providing reliable data within a few tens of meters of the spacecraft. With the advent of advanced capabilities for the lunar missions, it is probable that some type of roving vehicle may provide data over a greater area. Until such a capability is available, it must be anticipated that our major source of detailed information about the moon's surface will come from a series of "spot" investigations. It is this large scale "spot" mapping which will probably provide much of the basic information to support the manned lunar missions, especially relative to establishing the surface characteristics of the moon.

THE VALUE OF THE photogrammetric data cannot be over emphasized. Before this data can be most effective, it is necessary to have accurate and meaningful calibration data of the imaging system used. The calibration of conventional photogrammetric cameras is a well developed and exact science. However, the calibration of cameras which are to perform photogrammetric tasks in a hostile environment such as the moon's, is an entirely different story. The temperature variations and physical forces related to just placing the camera carrying vehicle on the lunar surface are extreme themselves. Lighting conditions and the ranges at which it is desired to obtain information require variations in camera characteristics (filters, aperture settings, shutter speeds, etc.) in order to maximize the operational output of the imaging system.

The requirement for using a selected imaging system for multiple purposes also complicates most photogrammetric calibration requirements. Application of zoom type lenses, with their attendant features such as moving nodal points, planes of best focus, etc., are difficult to calibrate. This is only a minor part of the problem. Calibration is one

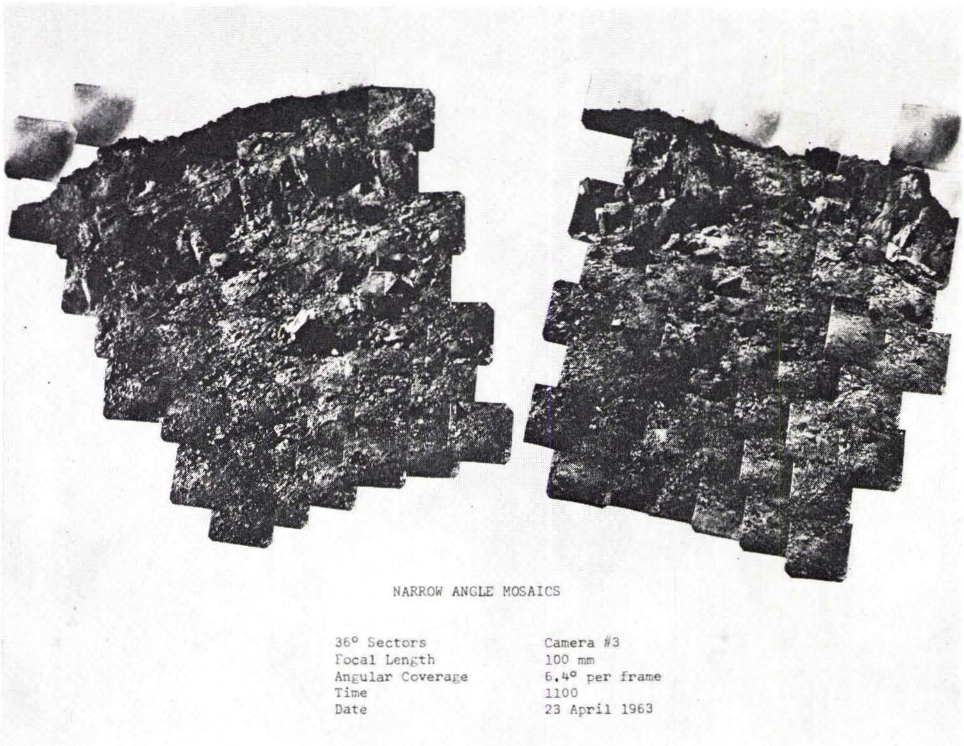

FIG. 1. Narrow angle mosaics.

thing, but another is to "calibrate" errors which will allow reasonable photogrammetry. It may be said that the application of these unconventional photogrammetric lenses to photogrammetry is not reasonable from the very beginning. The accuracy which is currently desired from these systems, as far as photogrammetry is concerned, may be an order of magnitude less than the common mapping accuracies accepted today. However, as better systems are developed and as operational techniques are improved, it may be anticipated that more accurate results will be obtained from the lunar and planetary exploration programs.

The photogrammetric calibration procedures and techniques required for these investigations obviously are not independent of the hardware being developed. As improved results are demanded, it will become imperative that the more rigid photogrammetric requirements be taken into consideration early in the system design. It may be a long time before a space borne imaging system can be selected according to purely photogrammetric considerations. Multi-purpose systems will be with us for sometime to come. In order to optimize future systems in terms of photogrammetry, it will be necessary to develop design criteria for these "unconventional" lenses which will be applicable for the development of better calibration characteristics for photogrammetry.

Generally, the standard factors which are calibrated in conventional photogrammetric systems are the same elements which require calibration in space systems. However, in these new systems the characteristics which were avoided in conventional photogrammetric systems, in order that they could be precisely calibrated, are required. How to handle this problem and still satisfy most of the multi-purpose imaging requirements is probably the major task currently facing space oriented photogrammetry.

THE SECOND MAJOR DIFFERENCE between lunar photogrammetric tasks and the normal, earth oriented applications is the introduction of television and its problems into the system. It should be remembered that this discussion is directed towards remote unmanned systems located on the lunar surface and therefore application of television type

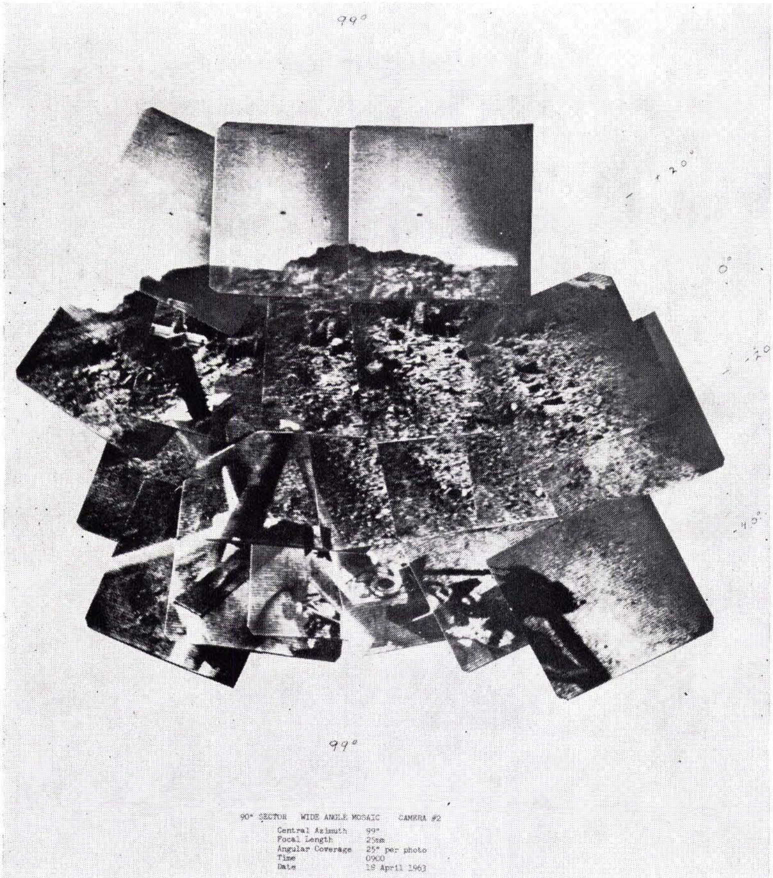

FIG. 2. Wide angle mosaic showing area imaged in Figure 1.

transmissions are required for the immediate future plans.

The application of television, as a photogrammetric media, is just beginning. Consequently there are many problems to be evaluated and eventually solved. The utilization of pictures transmitted by television, in the Surveyor program, involves the photorecording of the transmitted signal on a small format, 70 mm, film (Figures 3 and 4). The final output which will be used is hard copy photography, either positive or negative; but it will not only have characteristics determined by the film process, but also the inherent characteristics of the television receiver and transmitting-ground receiving system. It is these last characteristics which require evaluation relative to the photogrammetric tasks at hand. The evaluation of these pictures is not merely a function of the image resolution, regardless of how you define this item, but consideration must be given to the unique characteristics of television itself.

The image quality capability of television systems applied to a space environment is illustrated in Figure 3 which shows one of the Ranger VIII pictures with some basic noise removal and image enhancement techniques applied for image improvement. Figure 4 shows the same picture after application of sine wave response correction technique to maximize the image quality. These techniques basically involve the pre-flight calibration data of the television cameras, applied after completion of the mission. It is not the purpose of this discussion to describe these enhancement techniques but rather to demonstrate the general quality of imagery which can currently be obtained by space borne television systems, especially after application of computer techniques for image quality improvement.

One of the basic considerations relative to evaluating the photogrammetric potential of a television system is a determination of its parallax recording capability. With conven-

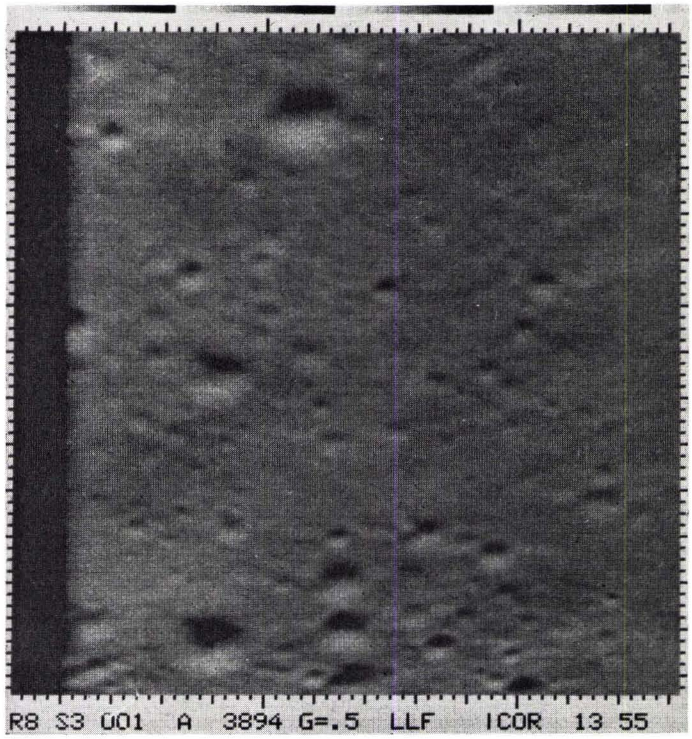

FIG. 3. A Ranger VII frame after preliminary image improvement using ground based system and pre-flight calibration data.

tional photogrammetric systems, the parallax recording capability is a function of various camera, objective, and film characteristics. These characteristics include camera focal length, base distance between camera stations, object distance plus the film recording capability. These same factors are involved in the determination of the television concept as described here; however, this is not all. Various other television parameters now must be introduced into the evaluation program. For simplicity, this discussion emphasizes vidicon type of television systems.

THESE "NEW" FACTORS include scan rates, television resolution or the number of scan lines per format, size of the scanning spot, etc. The effect of these parameters on the parallax recording capability of the system may not be fully appreciated at the first glance. Complications arise when considerations of horizontal versus vertical resolution criteria are introduced. This factor can pose a major problem especially when one considers vertical as well as horizontal base line configurations. Under these conditions, the orientation of the television raster could be very important, as far as maximizing the potential of the system for photogrammetry is concerned.

Some theoretical discussions have included minimum parallaxes recordable by television systems in general. This would obviously involve consideration of the signal to noise problems. Assuming that the signal to noise ratio is very high, say for example, equal to that found in a high resolution, conventional aerial photograph, then the parallaxes in the television presentation may be a function of the parameters previously mentioned. It has been said by various highly competent individuals that obviously a televison system can only record parallaxes down to the width of a television line. Unfortunately, other equally competent persons have stated that a "good" television system would naturally have a parallax recording capability of a fraction of a television line. Such unsupported facts emphasize the need for some basic photogrammetric investigations with television systems.

Stereoscopic models have been established by viewing cathode raytube presentations and the feasibility and utilization of stereoscopic television pictures has been established. The problem that is emphasized here relates to the actual photogrammetric capability of optimized television systems. Once

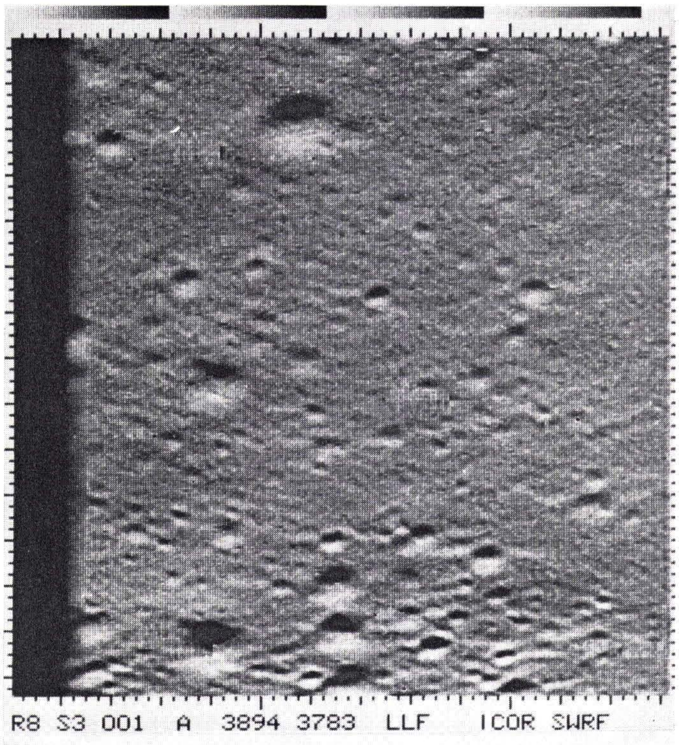

FIG. 4. Same frame as Figure 3, but after application of sine wave response correction.

this capability is established, then specific systems, including their individual components, can be evaluated.

A very basic approach to this problem could be through the analysis of imagery obtained by an optimum photogrammetric system and similar data collected through a television system. By utilizing a well controlled object field, controlled lighting (contrast) conditions such as could be established in a laboratory environment, and similar high quality, essentially distortion-free optics for both systems, a meaningful comparison of data could be made. Utilization of the same data reduction equipment and techniques, plus determination of overall system quality through application of accepted frequency response concepts, would increase the usefulness of the data obtained from such a program. This type of investigation is planned at the Jet Propulsion Laboratory.

Obviously the evaluation of this basic concept is not the whole story as far as photogrammetry and television are concerned. The electronic distortions of the viewed scene will most probably be much greater than those associated with the optics and required film recording media. For the most part, the image distortions resulting from the latter sources can be calibrated "out" of the system prior to its actual employment. The electronic distortions can be estimated prior to the system's use, but actual image distortions must be established in the data obtained during the mission operation. Both the current Ranger and Surveyor systems utilize a matrix of reseau points to establish the actual distortion characteristics of the received data.

THE PROBLEMS OF APPLYING television in the currently conceived photogrammetric systems for lunar exploration are not limited to techniques for determination of the mapping potential of such systems. For example, if we assume that it has been established that television is a satisfactory media for the lunar photogrammetric investigations desired, then what is the next step in the overall program? Obviously it concerns the data reduction and analysis phase of the operation. This problem cannot be solved easily. The pictures obtained will not be compatible with any conventional plotting equipment because of unusual focal lengths, uncommon formats, high degrees of convergency, and for some photos, large variances from a normalized orientation.

Scale differences between stereoscopic pairs may be significant. Special analytical plotters and some automated plotting equipment may be closer to a realization of applicable data reduction for production of some maps.

The development of automated, analytical plotters has slowly been making significant gains in the mapping field. The flexibility of these devices as far as input material, is highly desirable for application in the new space age. However, there still exists a requirement for viewing devices and plotting equipment which allow cognizant scientific personnel to study a stereoscopic model and to make a few selected measurements in the model.

Previously, the utility of mosaics was emphasized because of the narrow angle viewing constraints of the individual frames. Careful mosaic construction techniques may quite likely provide secondary material which will contain significant scientific data to merit sterescopic investigations. To accomplish this, it may be anticipated that requirements for modification of existing equipment or development of new viewing devices will come into existence. The problems related to establishing specifications for these types of devices are directly related to the characteristics of the imagery to be utilized, the range of angles of convergency, scale differences, and above all, accuracies desired for the resulting analytical efforts. It is anticipated that as experimentation and testing continues, answers to these problems will be provided to the photogrammetric community.

ONE RATHER SIGNIFICANT PROBLEM which has been overlooked so far in this discussion is not directly related to the type of imaging system to be used for the planned large scale photogrammetric investigations of the lunar surface. This is the problem of control points. For the present and the immediate future, the concept of control points as applied in conventional photogrammetry is not possible. The deployment of targets or known geometric shapes from the spacecraft to assist in scale determinations and serve as pseudo-control points is considered beyond the scope of this presentation. It is planned that correlation of lunar photos made from the lunar surface, with vertical or near vertical pictures made from orbiting vehicles or taken during the approach phase of the lunar landing will assist in establishing some of the necessary control data for use with the surveys from the lunar surface.

The lack of control data for the lunar surface places a great deal of importance on the camera position as determined from trajectory analysis and various spacecraft parameters which can be used to determine camera orientation. It may develop that these factors will become the primary ones for relating specific features to a common datum. Correlation and transfer of control data from previous photos would depend upon the quality of these photos plus the capability of locating recognizable features. Indirect techniques for establishing any degree of control will most probably have to be employed in the first large scale explorations of the lunar surface.

As this fairly new era of photogrammetry gets under way, it becomes imperative that extensive research and development effort be directed towards advancing the technological capability of space oriented, scientific imaging systems. However, the development of any system is of little value unless the information can be utilized. Advances in electronic imaging, in general, have been remarkable and it seems quite logical that the day will come when good photogrammetric imagery will be obtained from these systems.

THE REAL KEY to these new developments for photogrammetry seems to lie in the area of the data reduction. It will be necessary for advances to be made in various types of photogrammetric equipment which can handle the unconventional input material regardless of the specific program that will serve as the image collector. Capabilities for the imaging systems currently seem well ahead of the data reduction activities. Perhaps, the answer lies in the area of analytical techniques, but a need does exist for the less complex, analog form of instrument for scientific investigations which will utilize photogrammetric data. This challenge to photogrammetry is just underway and as the problems of today are solved, perhaps they will become the photogrammetric technique for the future.