ESTABLISHMENT OF A SELENODETIC SYSTEM, Lawrence A. Schimerman, USAF Aeronautical Chart and Information Center, 2nd & Arsenal Streets, St. Louis, Mo. 63118

The unique characteristics of the Apollo 15 Metric Camera System provide an opportunity for establishment of an improved selenodetic system. Existent lunar coordinate systems related to the center of lunar mass were developed in support of circumlunar navigation and mapping of sites of scientific or mission interest. Their area of coverage is restricted and the Lunar Orbiter and Apollo 8-14 photographic mission data on which they are based has inherent accuracy limitations.

As a first step in development of an improved selenodetic system, the USAF Aeronautical Chart and Information Center (ACIC) has undertaken the analytical photogrammetric reduction of Apollo 15 Metric Camera photography for NASA. A prime objective of this project is the establishment of a consistent system of lunar positions and elevations throughout the area of coverage. This new positional data will enable improved geodetic-cartographic support of the lunar scientific community. Also, intermediate results reflecting the photogrammetric solutions' measure of the effects of uncertainties in lunar geodetic and geophysical parameters will provide new data for investigators involved in these specialties.

The analytical photogrammetric solution under development employs NASA's generation of a spacecraft ephemeris for initial orbital position, measures of some 900 vertical terrain photos to project and extend lunar surface positions, measurement of companion stellar photographs for determination of terrain camera orientation and the first direct measurement of lunar orbit to surface distances through laser altimetry. Reduction of this mass of data is scheduled for completion in 1973 and this paper's primary concern is presentation of test results achieved to date.

A photogrammetric test was designed to provide a miniaturization of the total photogrammetric triangulation, enabling evaluation of the Apollo 15 Metric Camera System results, identification of problem areas caused by data variations and definition of attainable accuracies. Twenty-one terrain and related stellar exposures accomplished during Apollo 15's 22nd, 27th and 60th orbital revolutions were selected for generation of test data. (Figure) They cover an area of approximately 80,000 square kilometers surrounding the Apollo 15 landing site and provide a sample of the unique pattern of photography provided by a lunar photographic mission constrained to land astronauts at 26°N lunar latitude.
Analytical photogrammetric computer programs LOSAT and LOBAT providing computation of orbitally constrained photo strip and block assemblies, are the basic testing tools. Weighted input data for these programs includes terrain photo measurements, camera orientation components and spacecraft state vectors (position and velocity), as well as time of exposure. The resulting computation provides the projected positions of measured lunar surface points as well as an updating of the initial orbital and orientation data based on a best fit of these data. While information produced to date is based on a small sample, and testing of basic camera calibration and compatibility of spacecraft positions with other data is continuing, some conclusions and comparisons may presently be drawn.

a. Measurements of terrain photo images show standard errors of 5-9 micrometers, with range of error being dependent upon the sun angle of photography and its effect on precise identification and transfer of image points.

b. The process of deriving terrain camera orientation through measurement and reduction of stellar photography reflects a standard error of 20 seconds of arc in derived orientation.

c. An uncertainty of approximately 3 micrometers exists in relating terrain photo measurements to the camera fiducial system due to the combined effect of the camera's image motion compensation system and residual film distortion. It is anticipated that this displacement will become inseparable from definition of camera position in the photogrammetric solution, resulting in an error of approximately 5 meters in defining distance between successive exposure stations. The 1 millisecond accuracy of time information would otherwise have limited error in this dimension to 2 meters.

d. Comparison of Spacecraft Inertial Measurement Unit (IMU) orientation values with those obtained from reduction of stellar photography shows a bias of approximately 8 minutes of arc. The lesser accuracy inherent in the onboard sextant star sightings upon which IMU values are based, necessitates acceptance of base orientation values derived from stellar photography. However, comparison of rate of orientation change between the two methods showed good correlation and a standard deviation of 46 seconds of arc.

e. Present photogrammetric solutions have not been able to exploit the laser altimeter's one meter accuracy in defining camera station to lunar surface distance. As the point of reflection is not imaged on the photography, an approximate point identification can only be defined by establishing its photographic location with reference to camera calibration information. Measurement and transfer of this ill defined image has incorporated increased error. Not surprisingly, 7 altimeter observed distances from orbital revolution 22, show a mean difference of 35 meters.
(maximum 63 meters) with respect to photogrammetric distance determinations. Three comparisons of laser to photogrammetrically determined distance on revolution 27 show systematic 82-105 meter differences. The systematic nature and magnitude of these latter differences are inconsistent with evaluated error of the preliminary photogrammetric solution and are indicative of an editing role for laser altimetry data in this project.

Extrapolation of observed residual photographic errors to orbital and lunar surface positional determinations, defines these components at a 20 meter and lower level. Based on this limited sample, it appears that the acquired materials are adequate for fulfillment of the Apollo Orbital Photographic Science Team's concept of developing an improved selenodetic system and providing a basis for evaluation of presently accepted lunar geodetic and gravimetric values.