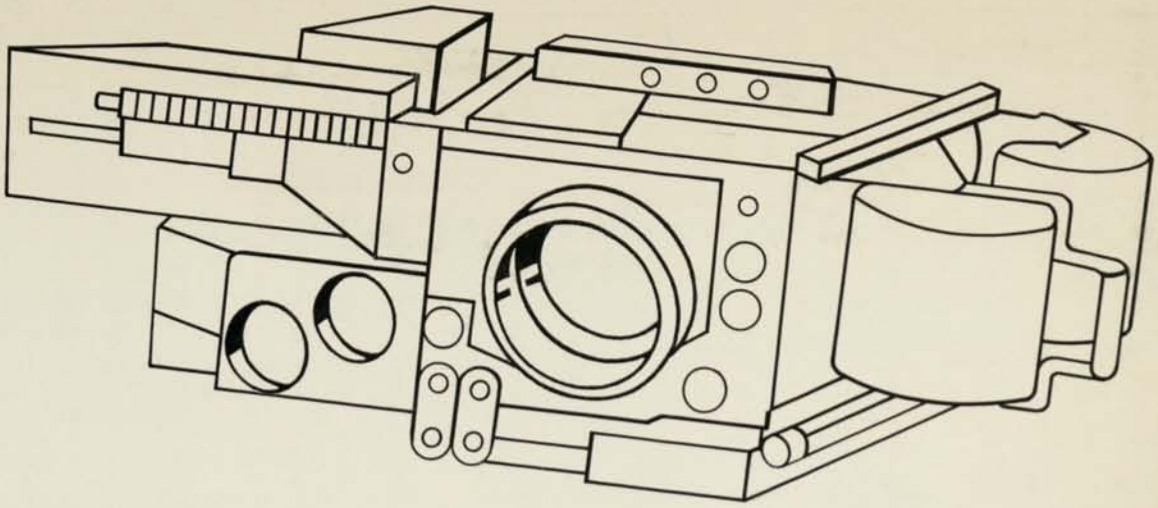

LUNAR MAPPING CAMERA

NASA APOLLO PROGRAM

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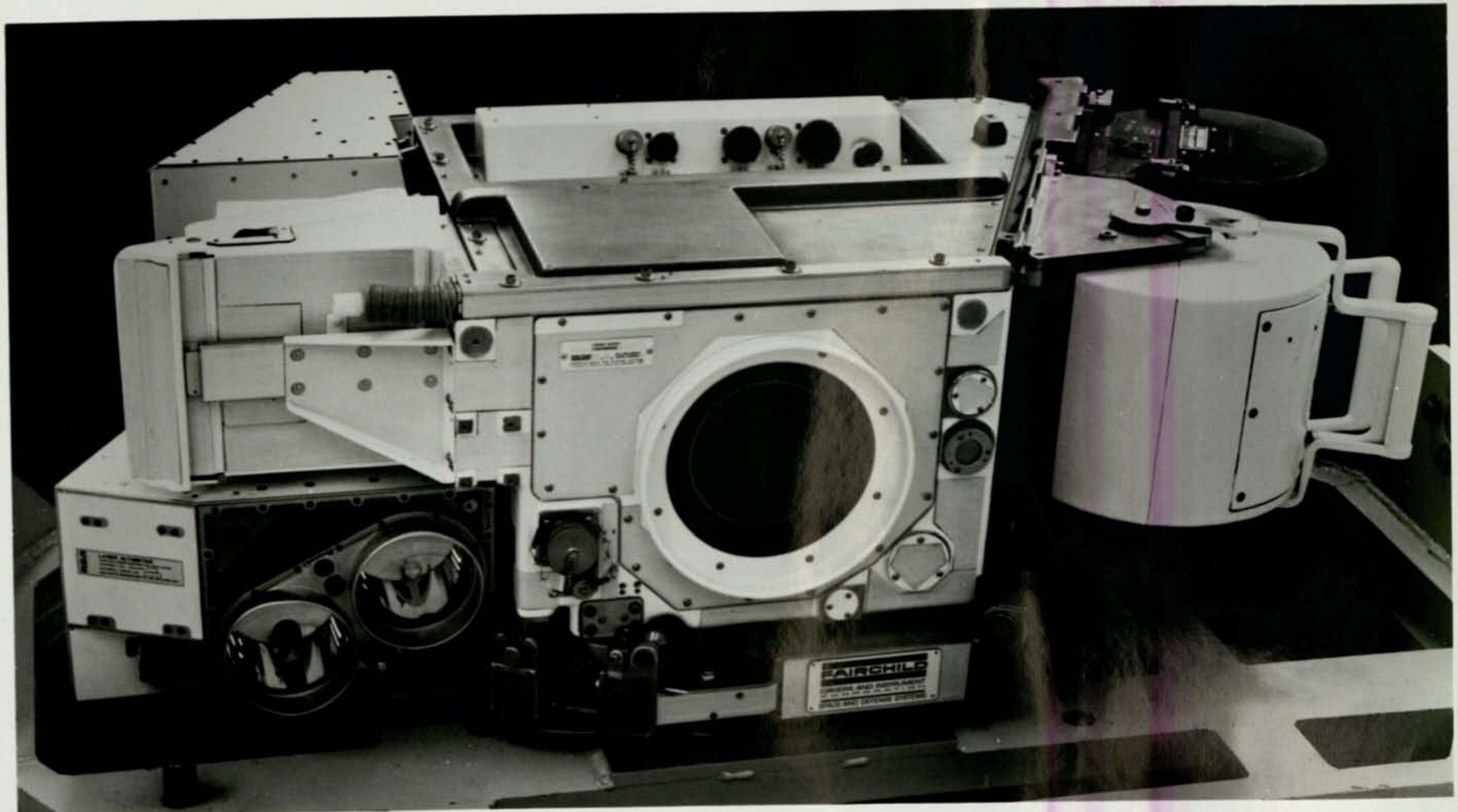

LUNAR MAPPING CAMERA

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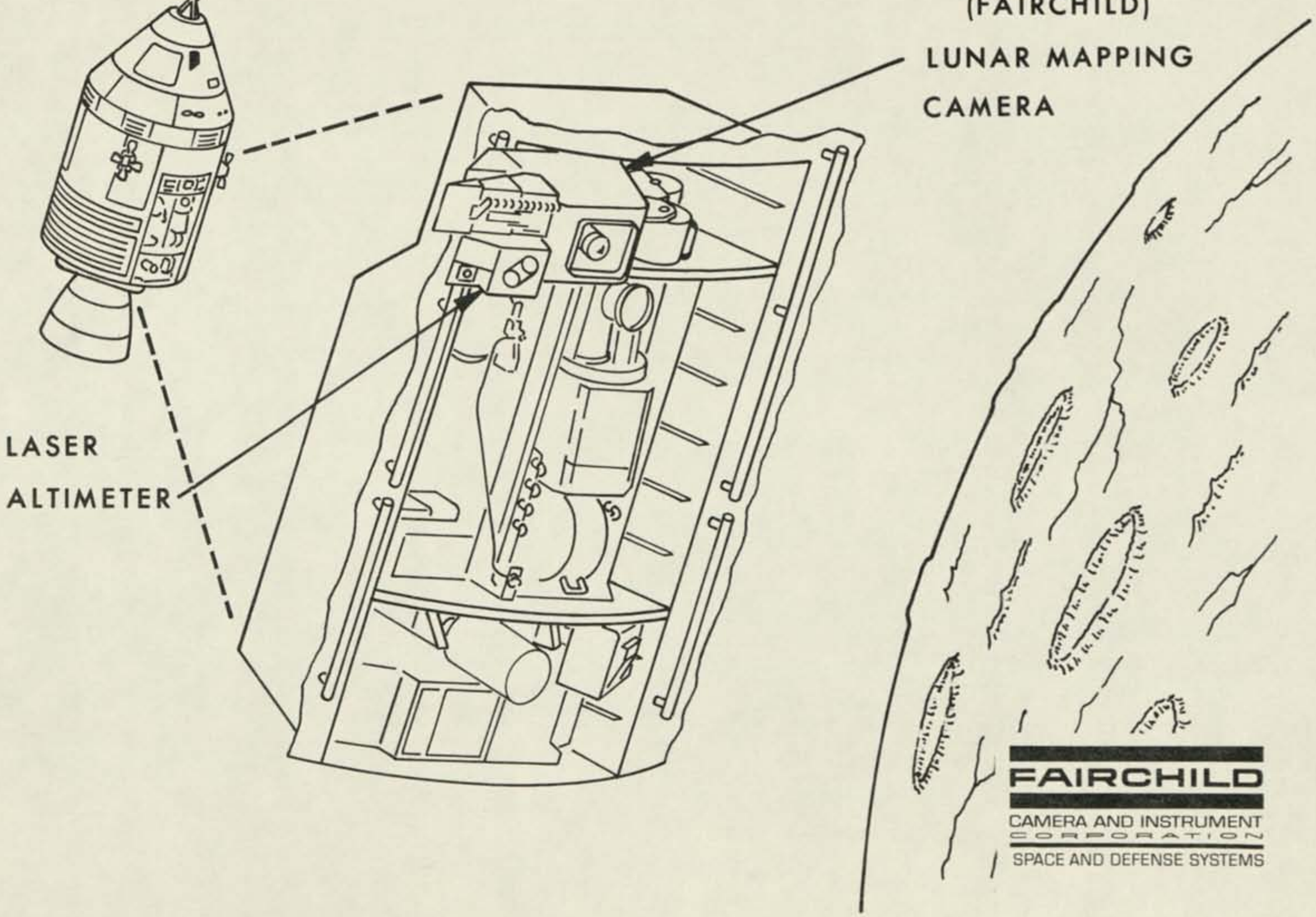

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FAIRCHILD
CAMERA AND INSTRUMENT
CORPORATION

SPACE & DEFENSE SYSTEMS DIVISION
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FOR IMMEDIATE RELEASE

FIRST PRECISION MAPPING PHOTOGRAPHY OF MOON TO BE TAKEN DURING APOLLO 15 MISSION -- ASTRONAUT TO RETRIEVE FILM DURING EVA

SYOSSET, N. Y., July 26 -- Astronaut Alfred M. Worden is scheduled to retrieve film containing the first precision cartographic photography taken from lunar orbit during his scientific extra vehicular activity on the Apollo 15 mission.

The Lunar Mapping Camera Subsystem, which will be housed in the Scientific Instrument Module (SIM) of Apollo 15's Command Service Module has been developed by the Space & Defense Systems division of Fairchild Camera & Instrument Corp. for NASA. The Fairchild camera is one of several orbital scientific experiments to be conducted on Apollo missions 15, 16 and 17.

Under a program awarded by the NASA Manned Spacecraft Center, Houston, Texas, the system is designed to provide additional and improved scientific information on selenodesy, as well as data on landing site definition/analysis and topographic map compilation and updating. Four flight mapping camera subsystems, plus a prototype and qualification unit, are being developed by Fairchild for the Apollo Experiments Program.

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The Lunar Mapping Camera Subsystem housed on Apollo 15 consists of two precisely oriented frame cameras. One is designed to provide metric photography of the lunar surface, while the other will be used for simultaneous time-correlated stellar photography. This stellar camera is designed for post-flight camera system attitude determinations. A laser altimeter (developed by RCA) provides altitude information coincident with the center of exposure and will be recorded on each frame of terrain photography.

The subsystem's interlocking metric and stellar cameras have their optical axes and orientation fixed and calibrated relative to one another. The metric camera has a 3-inch focal length, f/4.5 lens. The format is 4-1/2 x 4-1/2 inches on 5-inch wide film and the angular coverage is 74^{o} x 74^{o}. The stellar camera has a 3-inch focal length, f/2.8 lens. The format is 1-1/4 inches x 1 inch on 35 mm film and the angular coverage is 24^{o} cone with flats. Film capacity for the metric camera is 1500 feet, as compared to the 500-foot film capacity for the stellar camera.

The cameras also provide dynamic auxiliary data which are recorded on each of the photographic frames. This data block contains coded time, photographic exposure (metric camera only) and laser altimeter information.

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(71-153)

GROUND SUPPORT FOR LUNAR MAPPING MISSION

Harold Sigler and Angelo D. Beccasio
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Syosset, New York

Gerald F. Pels
NASA Manned Spacecraft Center
Houston, Texas

BIOGRAPHICAL SKETCH

Harold Sigler is a Principal Engineer in the Photographic Systems Department of Fairchild Space and Defense Systems. Mr. Sigler is presently assigned to the NASA Mapping Camera Project serving in the capacity of Interface Manager. He is directly responsible for formulating technical decisions and agreements with the Apollo Prime Contractor as well as providing technical liaison with NASA. Mr. Sigler was previously Program Manager for the KA-82 Panoramic Camera. He was also involved in the development of electronic color separation scanners. Mr. Sigler received an M. E. and an M. S. degree in Chemical Engineering from Stevens Institute of Technology.

A. D. Beccasio is a Principal Engineer in the Photographic Systems Department of Fairchild Space and Defense Systems. Mr. Beccasio received a B.S. degree in Geology from City College of New York and an M. S. degree in Geology from New York University. He is presently engaged in the evaluation and analysis of advanced concepts for reconnaissance image interpretation, mapping and photographic data processing systems. In addition to his efforts in the Apollo Lunar Mapping Program, Mr. Beccasio has also participated in various research programs relating to the military and geoscientific exploitation of advanced remote sensor image data. He was previously involved in conducting numerous aerial photographic and field projects relating to natural resources exploration.

G. F. Pels is an Aerospace Technologist at the NASA Manned Spacecraft Center in Houston, Texas. He is the NASA Experiment Manager for the Lunar Mapping Camera program. He has worked on the MSC Earth Resources program with responsibility for mapping camera systems and infrared instrumentation. He also has experience in high speed cine photographic systems. He received a B.S. in Physics from the University of Texas and a M.S. in Physics from the University of Houston.

ABSTRACT

The Lunar Mapping Camera is a multiple camera system consisting of a terrain camera, a stellar camera and a laser altimeter. This precision photographic instrument provides high quality metric photography of the moon from lunar orbit. In order to insure for the maximum accuracy and useability of the lunar mapping photography, a considerable amount of planning with regard to pre-and post-mission ground support is required. This support consists of stellar field calibration, pre-launch and ground control assistance and post-flight data reduction and analysis of the mission film.

INTRODUCTION

Fairchild Space and Defense Systems is currently developing the Lunar Mapping Camera under contract to NASA Manned Spacecraft Center. The Lunar Mapping Camera is a photographic instrument consisting of two precisely oriented frame cameras which will be mounted in the forward portion of the Apollo Scientific Instrument Module (SIM) of Apollo Missions 15 through 17. It will be remotely operated from the Command Module. One frame camera is designed to provide metric lunar photography, and the other will be used for simultaneous time correlated stellar photography. The stellar photography will be used for post-flight camera system attitude determination, since the optical axis of each frame camera and their orientation relative to one another are fixed and calibrated. Directly mounted and aligned to the Lunar Mapping Camera is the laser altimeter which provides altitude information which will be coincident with the center of exposure and will be recorded on each terrain frame. The viewing spot of the laser altimeter will be calibrated within the terrain format.

The Lunar Mapping Camera will be deployed from the Apollo spacecraft when ready for use so that the stellar camera has a clear field of view. Figure 1 depicts the deployed configuration of the camera system in the SIM bay. After the photographic mission is completed, the Mapping Camera will be retracted and the astronaut will perform an EVA to retrieve the film record container that contains the exposed lunar and stellar imagery. The resulting photography will be processed on the ground and subsequently used by the scientific community to derive and improve the knowledge of selenodesy as well as provide data on landing site definition/analysis and topographic map compilation and updating.

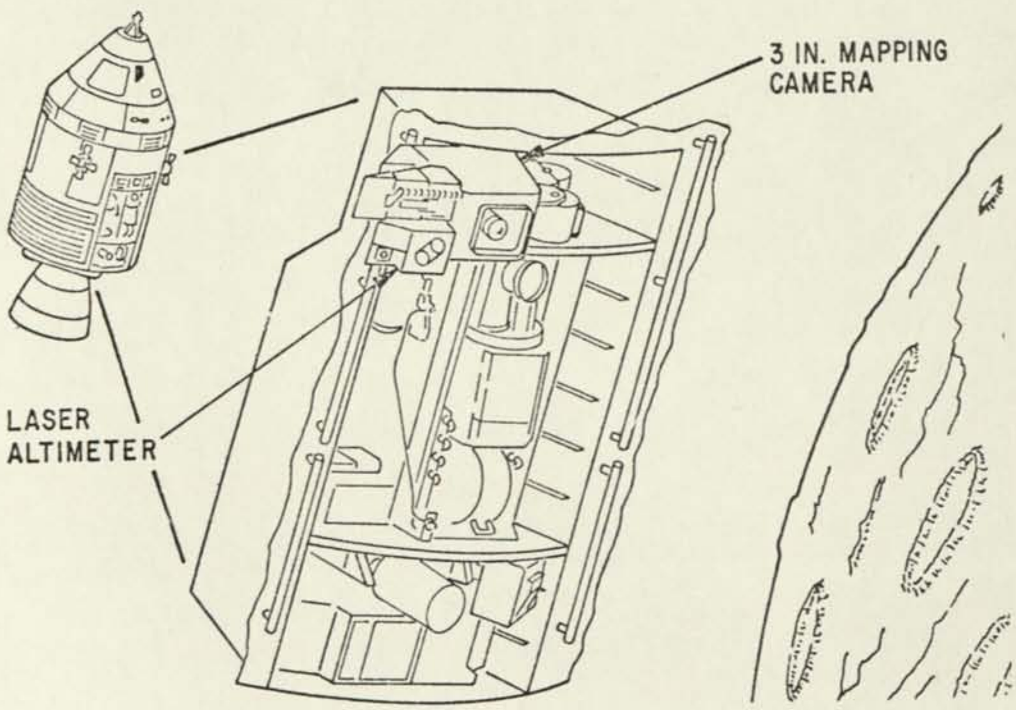


FIGURE 1 LUNAR MAPPING CAMERA DEPLOYED

DESCRIPTION OF LUNAR MAPPING CAMERA

The Mapping Camera Subsystem consists of an interlocking metric camera and stellar camera whose optical axes and orientation relative to one another are fixed. Figure 2 shows the basic configuration of the Mapping Camera Subsystem.

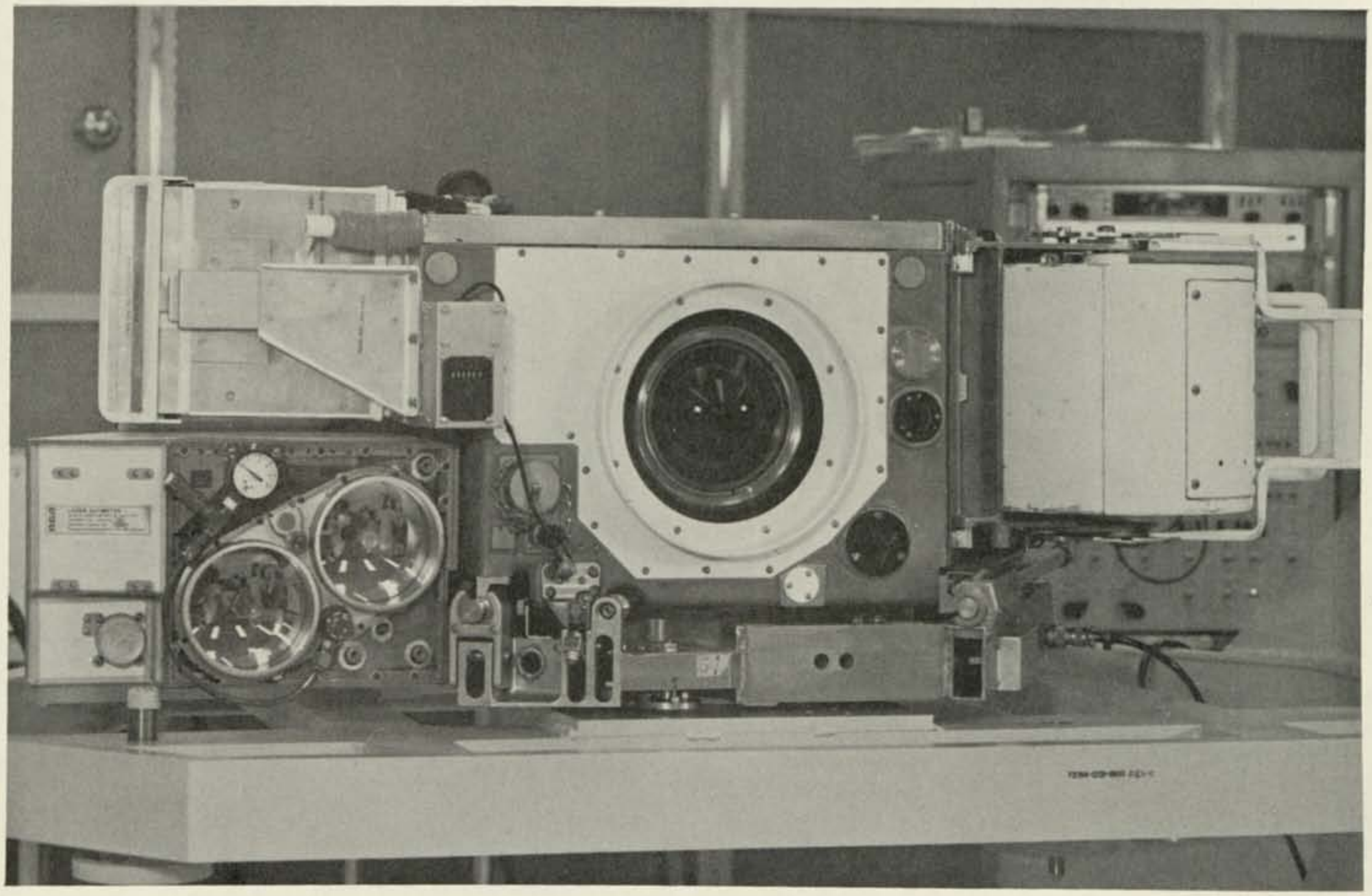


FIGURE 2 LUNAR MAPPING CAMERA SUBSYSTEM

The metric camera has a 3-inch focal length, f/4.5 lens. The format is 4-1/2 x 4-1/2 inches on 5-inch wide film and the angular coverage is 74° x 74°. The exposure time is AEC-controlled and ranges from 1/15 to 1/240 second. The endlap, which is critical for stereo mapping is 78%. FMC accuracy is 3% and film flattening is accomplished by glass plate. The stellar camera, on the other hand, has a 3-inch focal length, f/2.8 lens. The format is 1-1/4 inches x 1 inch on 35 mm film and the angular coverage is a 24° cone with flats. Exposure time for the stellar camera is 1.5 seconds fixed. Film capacity for the stellar camera is 500 feet as compared to the 1500 feet film capacity for the metric camera. The critical interlock angle between metric and stellar cameras is 96°. Correspondingly, the laser altimeter is mounted with its transmission and receiving optical axes parallel to those of the metric camera.

The metric and stellar cameras also provide reference and dynamic auxiliary data which are recorded on each of the image frames. Reference data consists of fiducial marks and reseau crosses. The fiducial marks on the metric camera are both naturally and artificially illuminated whereas the fiducials on the stellar camera are artificially illuminated. The array of naturally illuminated reseau crosses on the metric camera are spaced 10 mm apart whereas the artificially illuminated reseau array on the stellar camera has a 5 mm spacing. Reseau crosses are pertinent to the determination of post-flight film shrinkage. Dynamic auxiliary data for both metric and stellar cameras consist of binary coded time and altitude words which are recorded on each frame. The metric camera also provides a record of exposure time for each photographic frame as well as indicating the presence or absence of FMC motion.

STELLAR FIELD CALIBRATION

Since there will be relatively few lunar mapping missions, it is essential that great care be taken to insure that the pertinent performance capabilities of each camera unit (i.e., calibrated focal length, radial, tangential distortion parameters, defined principal point, relative orientation, etc.) are well defined prior to flight and subsequent data reduction of the mission film. This is particularly important in a multiple camera system, such as the Mapping Camera Subsystem, which requires the need for a precise stellar calibration in order to insure for the maximum useability of the photography in photogrammetric data reduction by the user community.

Prior to performing the stellar calibration task it was first necessary to develop the stellar calibration ground support plan for handling the Lunar Mapping Camera in the field. Figure 3 shows the flow relationships of the overall stellar calibration test plan. Included is the definition of test area requirements, test area selection and development, logistics/handling, mission observation (data acquisition) and data reduction and analysis support plans. Note that the output of the data reduction phase is the Final Calibration Report which presents the results of the calibrated internal and external geometric parameters of the Lunar Mapping Camera.

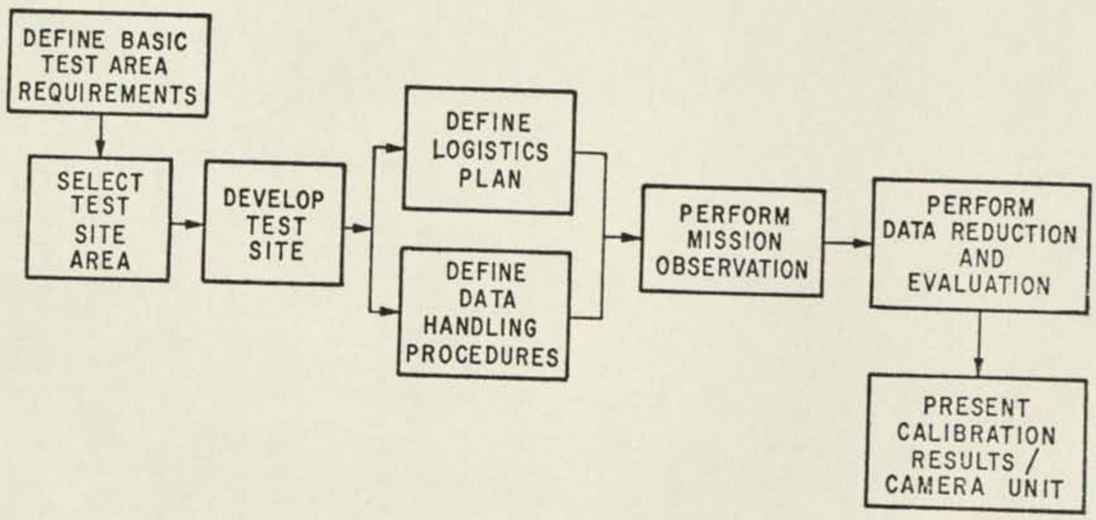


FIGURE 3 STELLAR CALIBRATION TEST PLAN

The site that was selected for Lunar Mapping Camera stellar calibration was NASA White Sands Test Facility (WSTF) near Las Cruces, New Mexico. A small observatory building was constructed on the WSTF site. This building houses the equatorial mount and associated observation equipments in addition to affording maximum protection to the camera during data acquisition. The observatory building is designed so that its roof slides back on tracks, thus providing the nearly horizon to horizon clearance which is required for the calibration of an interlocked multiple camera system such as the Lunar Mapper. Correspondingly, the axis of the equatorial mount is oriented along the meridian and mount tracking is, in turn, accomplished by sidereal clock drive. During actual mission observation, the Lunar Mapping Camera is positioned on the mount in such a manner that its optical axes are aligned along the meridian, with the stellar lens pointing north and the metric lens south. With proper stellar tracking at sidereal rate, the resulting stellar images recorded on the photographs will be uniformly distributed point sources which will provide for the optimum data reduction and subsequent precise calibration of the Lunar Mapping Camera flight hardware.

PRE-MISSION GROUND SUPPORT

After stellar field calibration is completed the Lunar Mapper is returned to the factory for final assembly and cleaning. The next step in the Ground Support Plan is to ship the Lunar Mapping Camera flight hardware to Kennedy Space Center (KSC) for a series of prelaunch checkouts prior to installation and integration into the Apollo SIM. Included is the site activation, operation and integration of all related ground support equipments and facilities. In addition, test and checkout operations are performed on the Lunar Mapping Camera to insure that all interfaces are compatible including possible interactions with other experiments in the SIM. If required, design and engineering changes will be initiated to insure interface compatibility. Correspondingly, all preventive maintenance and repairs will be performed within the field site capability on an as required basis. Major repairs will be done at the factory.

Lunar Mapping Ground Support also entails the servicing of the flight hardware, including film loading and unloading as well as the laboratory calibration of measuring devices unique to the camera. Technical consultation and data inputs are provided to support NASA flight readiness reviews and operations planning. Correspondingly, technical guidance is provided during the installation of the flight hardware into the SIM. Technical monitoring continues during the critical periods of pre-launch, launch and post-launch operations to insure that all Lunar Mapping Camera components and interfaces are functioning properly. This monitoring will, in turn, insure for the acquisition of optimum lunar mapping photography.

ASTRONAUT TRAINING

Since an extra vehicular activity (EVA) is involved in this mapping mission, additional measures were taken to fully acquaint the astronauts with the Lunar Mapper's physical characteristics.

A high fidelity wooden mockup of the camera system was constructed for use both as a fit check device and a ground training unit. This allowed the astronauts to gain familiarity with the external aspects of the camera.

As the training progressed, a special EVA mockup was provided. This training model was not only a physical representation of the Lunar Mapper but also provided two special record containers for training use under simulated weightless conditions. One record container was made of a lightweight material and balanced so that it would float underwater in a neutral bouyancy tank. The other record container was loaded with a mass simulator for use in zero "g" airplane tests. In these latter tests a specially fitted airplane makes inverted parabolic dives so that the passengers and contents are in free fall at the apex of the dive for about 10 seconds.

The final bit of training will occur sometime during the countdown when the astronauts will practice removing the record container from the flight camera for a confidence check.

HANDLING AND DATA REDUCTION OF MISSION FILM

Assuming a successful lunar mission, the next step in the Ground Support Plan involves the handling of the post mission flight film. The generalized flow for handling the Mapping Camera image data acquired from the Apollo Lunar Mapping Mission is shown in Figure 4. As shown in this diagram, the film undergoes photo processing and reproduction at the Manned Spacecraft Center immediately upon its return. The master and duplicate copies which are generated from the original negative roll are sent to the various user agencies for subsequent data reduction. Typical tasks to be accomplished during data reduction include stellar coordinate mensuration, mensuration of photo control points and map compilation. A pertinent offshoot in the data reduction process is the interpretation and analysis of specific image frames for purposes of lunar scientific investigations.

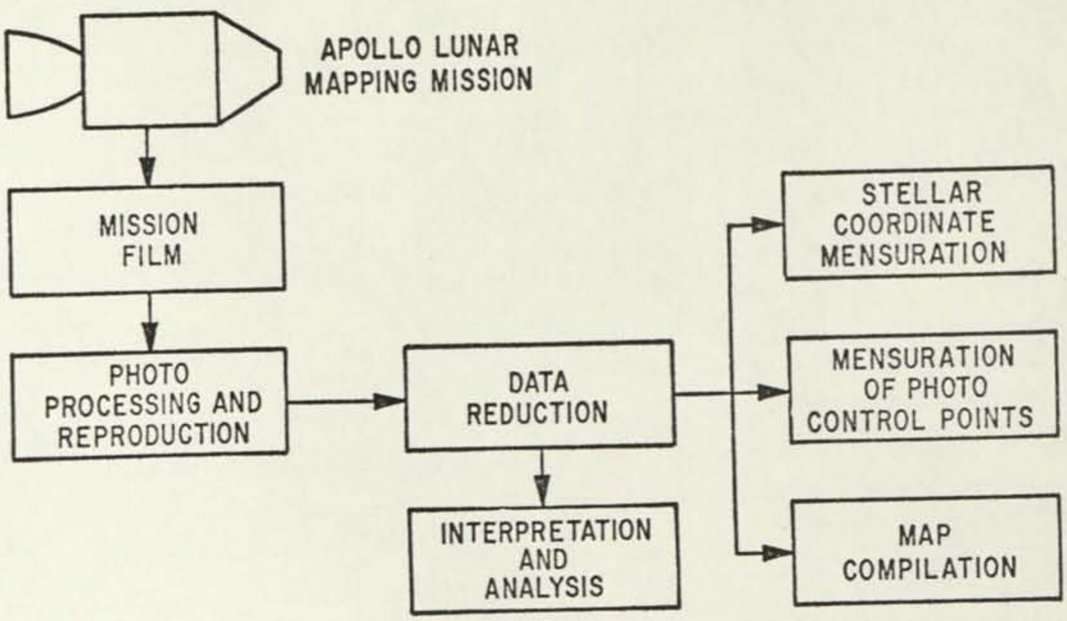


FIGURE 4 GENERALIZED LUNAR MAPPER DATA HANDLING FLOW

Photographic Processing and Reproduction

The functional flow outlining the tasks to be performed during photographic processing and reproduction is shown in Figure 5. The primary system inputs include the exposed frames of both the terrain and stellar roll film photography. The basic system output products consist of master positive copies of both terrain and stellar roll film photography. Upon completion of the reproduction phase, copies of the output photography are transmitted to the user agencies. The original negative terrain and stellar roll film photography is, in turn, placed in controlled archival storage at the Manned Spacecraft Center.

Data Reduction

As shown in Figure 6, the three primary tasks to be performed during the data reduction phase are: (1) reading of the terrain and stellar data blocks; (2) stellar photography coordinate mensuration; and (3) data processing and terrain photography control point mensuration and data processing. The results obtained from these individual tasks will be used in a variety of photogrammetric/selenodetic applications such as to provide the required control and triangulation for the subsequent compilation of the lunar metric photography and to provide the means for transferring control points from the metric photography to other non-metric photographic data obtained from the lunar mission.

SUMMARY

The various operations that are required to insure for the optimum handling and support of the Lunar Mapping Camera during the pre- and post-flight phases of the Apollo photographic mission have been concisely described herein. It is evident that a great deal of planning must be accomplished prior to achieving the required end results; namely, the acquisition of optimum lunar metric and stellar photography, and the subsequent photogrammetric data reduction and analysis of the image data by the scientific user community.

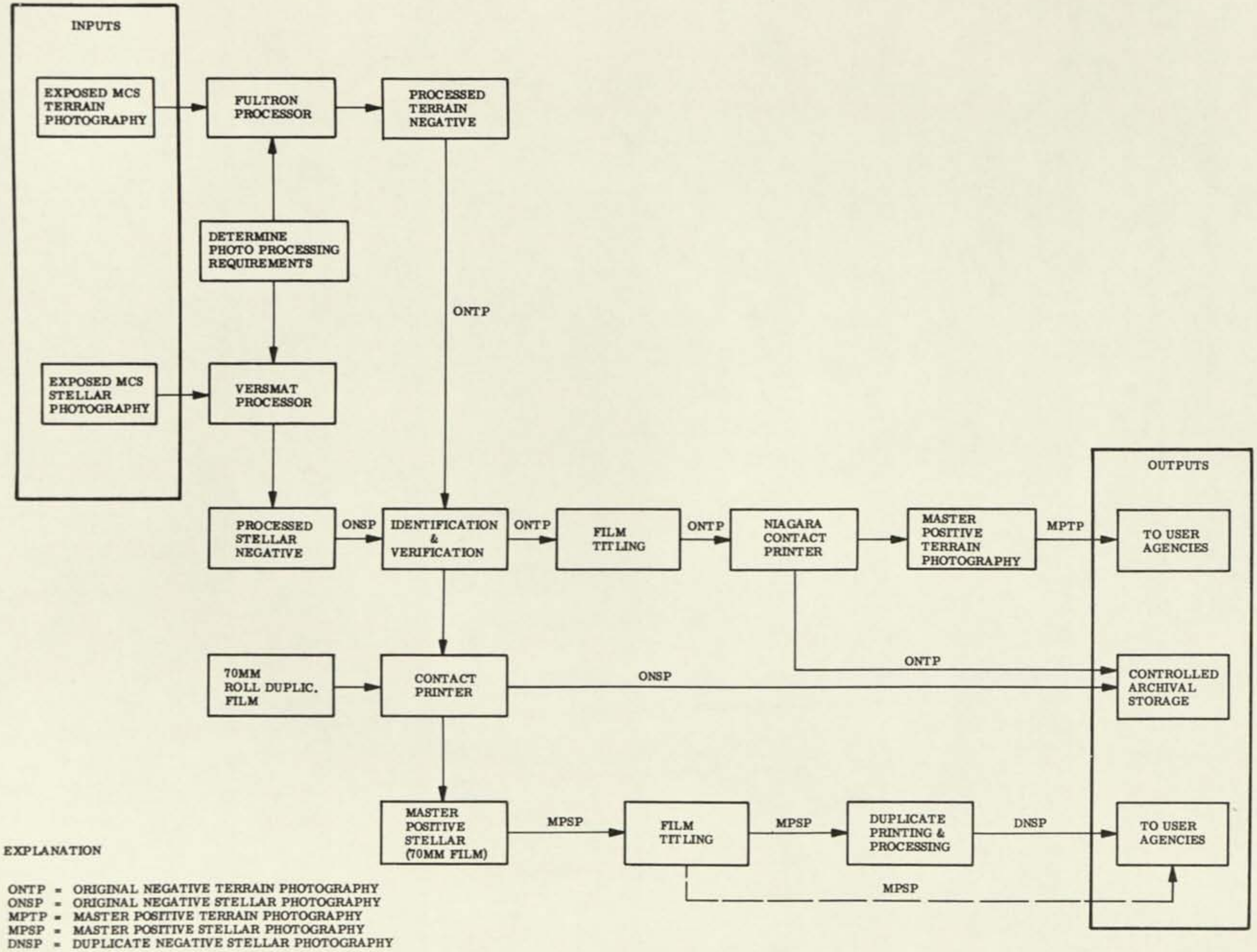


FIGURE 5. LUNAR MAPPER PHOTO PROCESSING AND REPRODUCTION

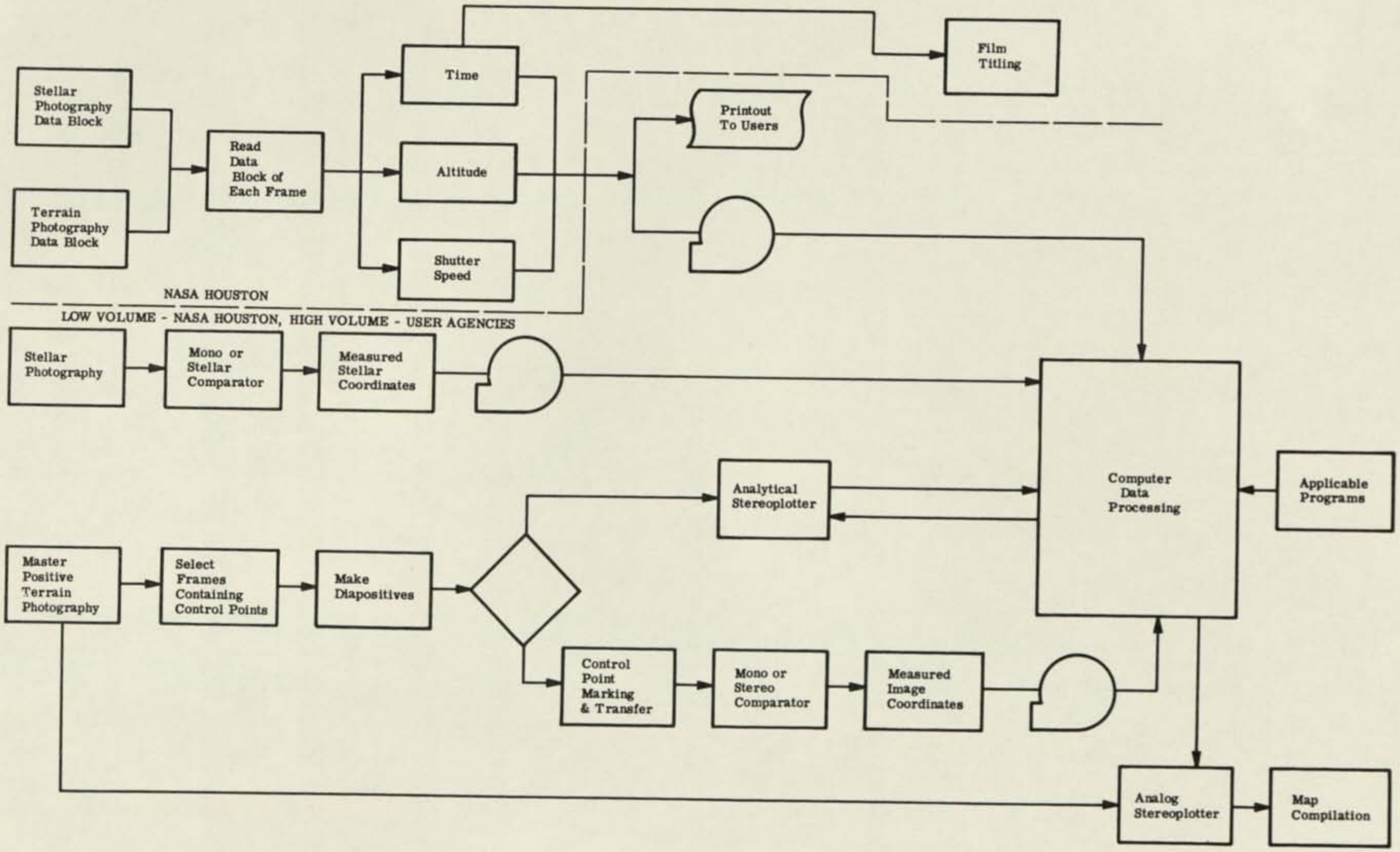


FIGURE 6. LUNAR MAPPER DATA REDUCTION

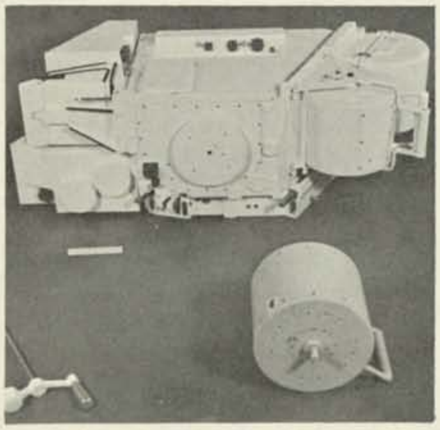
ACKNOWLEDGEMENT

Fairchild Space and Defense Systems (FSDS) is indebted to Mr. R. Dickerson of the NASA Manned Spacecraft Center for his guidance and general assistance during the preparation of the Lunar Mapping Camera Ground Support Plans. The authors are also grateful to the following personnel who contributed to the results presented in this paper: Messrs. A. G. Hutchins and C. H. Jirak of FSDS.

TRAINING FOR THE MOON

As FSDS goes ahead manufacturing the moon mapping camera subsystem (MCS) for operation in August 1971, astronauts are learning how to operate the camera, and how to recover the film after the mission. The camera will be installed in the Apollo Service Module, and the film must be removed and stored in the Command Module for the return trip to earth.

The astronauts practice EVA (Extra Vehicular Activities) with a mockup of



Mapping Camera retracted *Laser Altimeter*

Fairchild's MCS containing a take-up cassette similar to the real one. The take-up cassette has a removable portion called the record container which holds the five-inch mapping film and the 35mm film from stellar photography.

The film in the take-up cassette must be cut, and certain switches and locks be maneuvered under weightlessness by the astronaut in order to remove the record container.

There are two ways of training: in the air and underwater.

Practice sessions for the astronauts include using the lunar camera mockup in a specially fitted aircraft which performs inverted parabolic dives. At the end of the plane's upward sweep it poises for 30 seconds before making the downward descent of the dive. Everything is weightless in the aircraft for those 30 seconds. The astronaut tries to recover the film, but it is not nearly enough time. These sessions are called "zero g" tests.

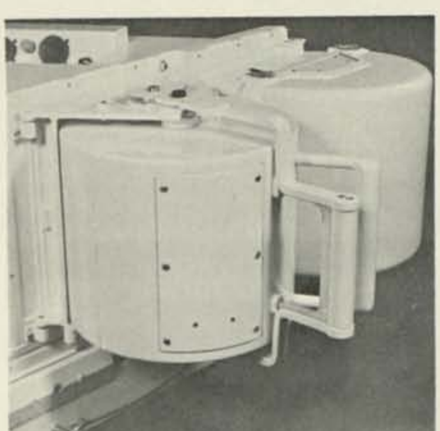
Other training sessions are held in a special underwater tank to simulate weightlessness. The astronauts wear space suits which have an air supply to permit long testing times. A different take-up cassette that has neutral buoyancy to simulate weightlessness is used in these EVA practice sessions.

A final high fidelity mockup, identical in configuration to the camera that will be aboard Apollo 15 is being delivered to NASA for astronaut ground training in January. Astronaut James Erwin visited FSDS last month to view the Hi Fi mockup.

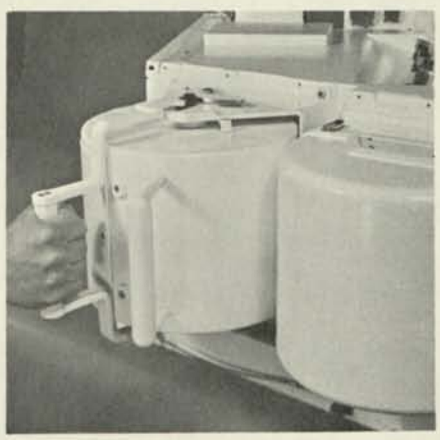
To be a contractor for NASA requires mandatory specifications and qualifications. One specification is that hand soldering must be of exceptional grade. This necessitated an FSDS in-house special soldering course for electrical technicians. They had to gain a higher degree of proficiency and pass a qualifying examination given by NASA.

Engineers and technicians working on the MCS will be taking a course at NASA Safety School in Cape Kennedy this year to permit them to enter the Apollo '15 Service Module atop Pad #38 during preparations for launch. One of the final things during countdown is loading the camera!

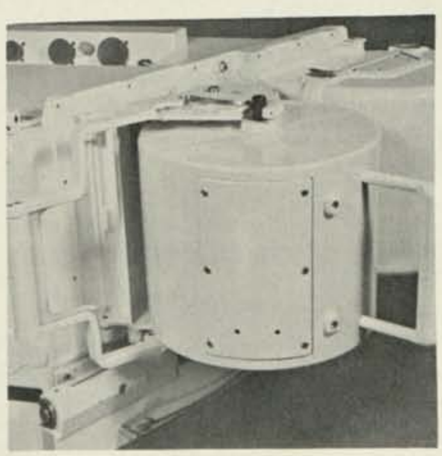
Some FSDS personnel will also take an additional course in QLDS (Quick Look Data System) so they can monitor testing activities prior to launch and also keep watch during the flight.



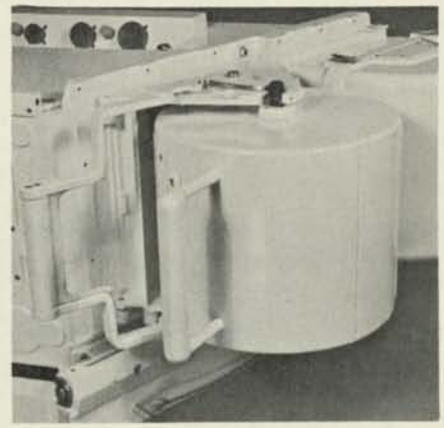
Film record container installed and locked.



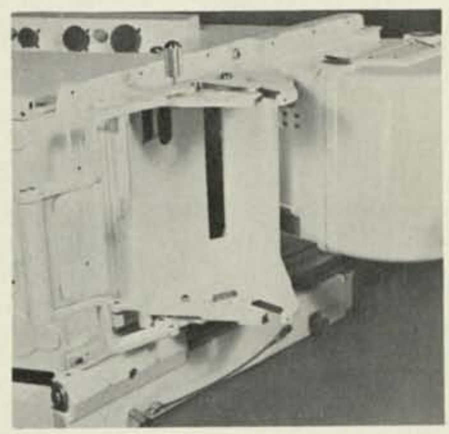
Actuating the release handle



The release handle in locked open position.



The record container ready for release



Record container removed

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