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ENGINEERING STUDY FOR PALLET ADAPTING THE APOLLO LASER ALTIMETER AND PHOTOGRAPHIC CAMERA SYSTEM FOR THE LIDAR TEST EXPERIMENT ON ORBITAL FLIGHT TESTS 2 AND 4

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Final Report

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16. Abstract

A Laser Altimeter and Mapping Camera System was included in the Apollo Lunar Orbital Experiment Missions. The back-up system, never used in the Apollo Program, is available for use in the Lidar Test Experiments on the STS Orbital Flight Tests 2 and 4.

Studies were performed to assess the problems associated with installation and operation of the Mapping Camera System in the STS. They were conducted on the photographic capabilities of the Mapping Camera System, its mechanical and electrical interface with the STS, documentation, operation and survivability in the expected environments, ground support equipment, test and field support.

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PREFACE

OBJECTIVE

This is the Final Report of engineering studies performed to investigate the adaptation of the Apollo Laser Altimeter and Mapping Camera System to an STS pallet to allow a Lidar test experiment to be carried out on OFT-2 and OFT-4.

The studies were conducted to yield results in keeping with the austere atmosphere of the Lidar Program.

SCOPE

The studies were performed in areas of photographic capabilities, structure, thermal environment, data and system control, STS interface testing, and OFT support.

CONCLUSIONS

The MCS, with very minor changes, can be used to the fullest extent of its photographic capabilities when provided with the ancillary equipment described in this report.

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1.0 GENERAL

The Mapping Camera Subsystem designed and built for the Apollo Lunar Missions together with its companion Laser Altimeter makes an ideal combination to carry out Lidar Test Experiments.

1.1 BACKGROUND *

The laser altimeter and mapping camera system, Figure 1, was one of the instruments included in the Apollo Lunar Orbital Experiments Missions to acquire new or refined lunar data. The function of the altimeter was to provide precise measurements of Apollo Command Module height above known positions on the lunar surface. This data was directed to the spacecraft's Scientific Data System for transmission, recording, and observation. When the mapping camera is operating, the altimeter supplies altitude data to the camera for recording on the film. The mapping camera supports the altimeter mechanically and a deployment mechanism was provided to move the units from their stowed position by about 18 inches. This permitted the orthogonal camera system to photograph a star field for accurate determination of pointing direction.

The measured altitudes, camera photographs, timing, and spacecraft tracking data were analyzed after the mission. Mapping camera film was accurately scaled and rectified by means of altitude and stellar field photographic data. Lunar navigational points were precisely located and variations in lunar shape and gravitational

*Extracted from the GSFC Proposal for the Lidar Test Experiment(LITE) for OFT-2 and OFT-4, December 1976

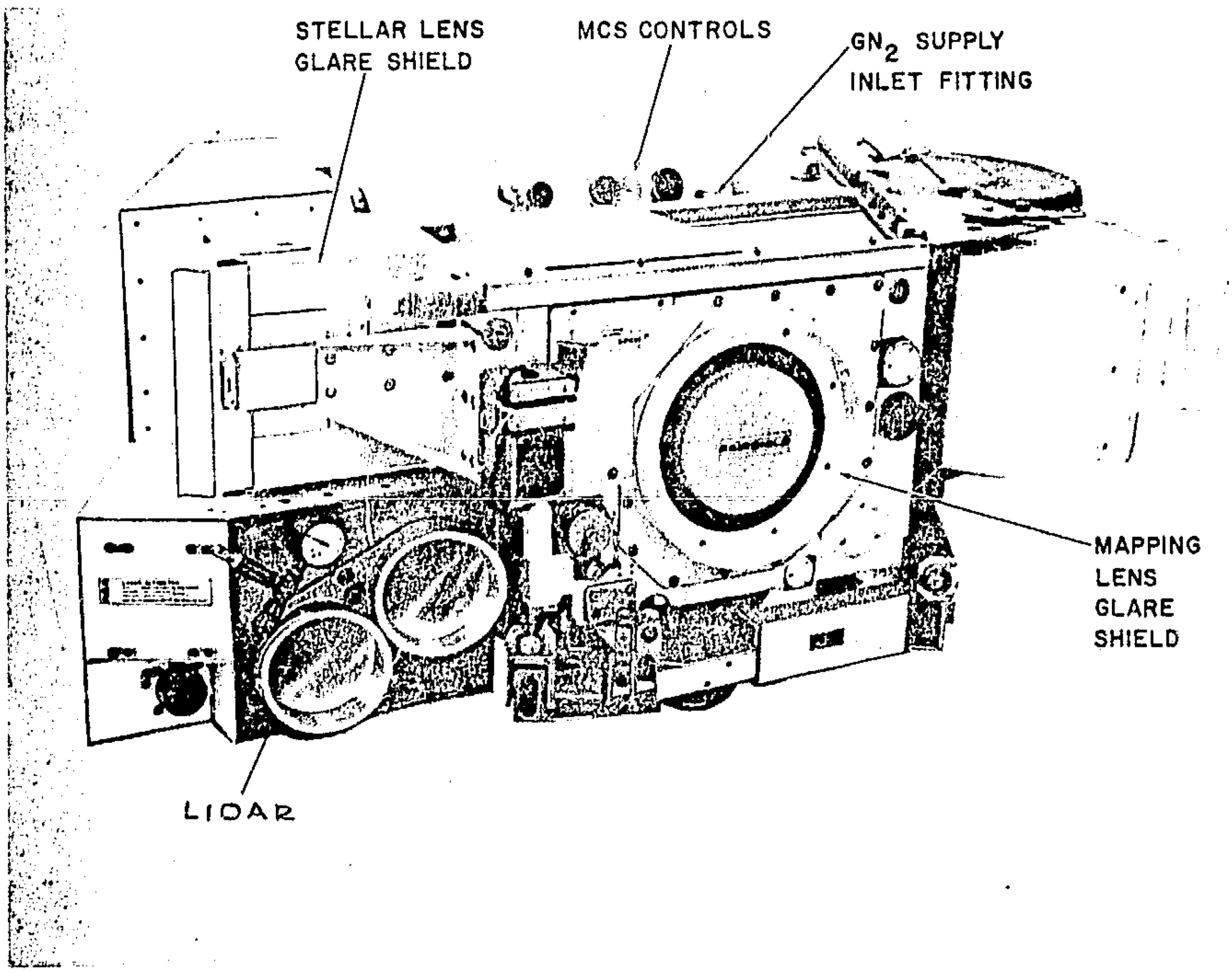

Figure 1 . Mapping Camera Subsystem, Part No. 1231AA1

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field were sought. The position of the lunar center of mass relative to the earth and the characteristics of lunar librations relative to the center of mass were more accurately defined.

1.2 LIDAR SYSTEM

The installation described in the Lidar Test Proposal consists of the MCS attached to a pallet supporting structure and electrically interfaced with the GFSC Electrical Canister for power and control. Camera outputs normally telemetered to ground control will be recorded in the canister.

The Laser Altimeter mounted on the Mapping Camera is powered from the GFSC canister while receiving triggering impulses from the Mapping Camera. Its return beam will be recorded on tape in the canister for later analysis.

The Mapping Camera is a photographic instrument designed to obtain high quality metric photographs of the lunar or earth surface from orbit combined with time-correlated stellar photography for selenodetic/cartographic control. Figure 1 and Table 1 shows the Mapping Camera System (MCS) and leading particulars.

Involvement of the astronauts for experiment photography will be at an absolute minimum requiring only preflight actuation of the standby function and switch to "operate" to initiate photography during orbit. The system will run to expiration of film and shut down automatically.

TABLE 1

MAPPING CAMERA SYSTEM
LEADING PARTICULARS

Type	Stationary film, mapping
Mode of Operation	Autocycle
Lens	
Stellar	3-inch f/2.8
Mapping	3-inch f/4.5
Format	
Stellar	1.25 in. diameter with 0.96 in. flats
Mapping	4½ x 4½ in.
Coverage (Mapping)	74° by 74°
Film	
Stellar	35mm, 2.5 mil base non-perforated
Mapping	5 in., 2.5 mil base non-perforated
Altitude	
Lunar	30 to 80 nautical miles
Earth	105 to 200 nautical miles
Film Capacity	
Stellar	510 feet
Mapping	1,500 feet
Cycle Time	
Stellar	8.25 to 33.0 sec/cycle
Mapping	8.25 to 33.0 sec/cycle
Exposure Time	
Stellar	1.5 sec (fixed)
Mapping	1/15 to 1/250 sec
Aperture	
Stellar	Fixed
Mapping	Fixed

TABLE 1

MAPPING CAMERA SYSTEM
LEADING PARTICULARS
(continued)

Exposure Control	
(Mapping Only)	Automatic between lens shutter
Forward Motion Compensation	
(Mapping Only)	12.1 to 16.1 milliradian/second
Resolution	
Stellar	80 lines/mm AWAR, 1000:1 contrast target, EK 3400 film
Mapping	90 lines/mm AWAR, 2:1 contrast target, EK 3404 film
Distortion	
Stellar	±10 microns radial 5 microns max tangential
Mapping	±50 microns radial 5 microns max tangential
Overlap	
(Mapping Only)	78 pct, 67 pct, or 56 pct
Fixed Data Recording	
Stellar	Reseau Fiducial Lens Serial Number
Mapping	Reseau Fiducial Camera serial number
Auxiliary Data Recording	
Stellar	Index Coded Time Altitude
Mapping	Index Coded Time Altitude Shutter Speed FMC On/Off

TABLE 1

MAPPING CAMERA SYSTEM
LEADING PARTICULARS
(continued)

Size	33 in. high by 45 in. wide by 15 in. long
Weight (with film)	225 lbs.
Power	28V DC, Operating wattage 50W average to 150W maximum

1.3 MCS DESCRIPTION

The MCS consists of a Mapping Camera, a Stellar Camera, detachable Supply and Takeup Cassettes. The Mapping Camera film format is shown on Figure 2 and the stellar film format is shown on Figure 3.

Mounted adjacent to the lens assembly, but not part of, is an automatic exposure cell which measures scene brightness. An AEC cell filter to match the film being used can be added preflight.

The film drive mechanism includes a rectilinear platen motion arrangement to provide compensation for image motion during photographic exposure. This forward motion compensation is a function of velocity/height (V/H) and setable preflight to the particular mission V/H expected. It can be disabled when not required for the mission.

The capability also exists to vary the photography overlap to any of 78, 67, or 56 percent forward overlap settings to provide stereoscopic imagery. This is done preflight by addition of the proper one of three available cams.

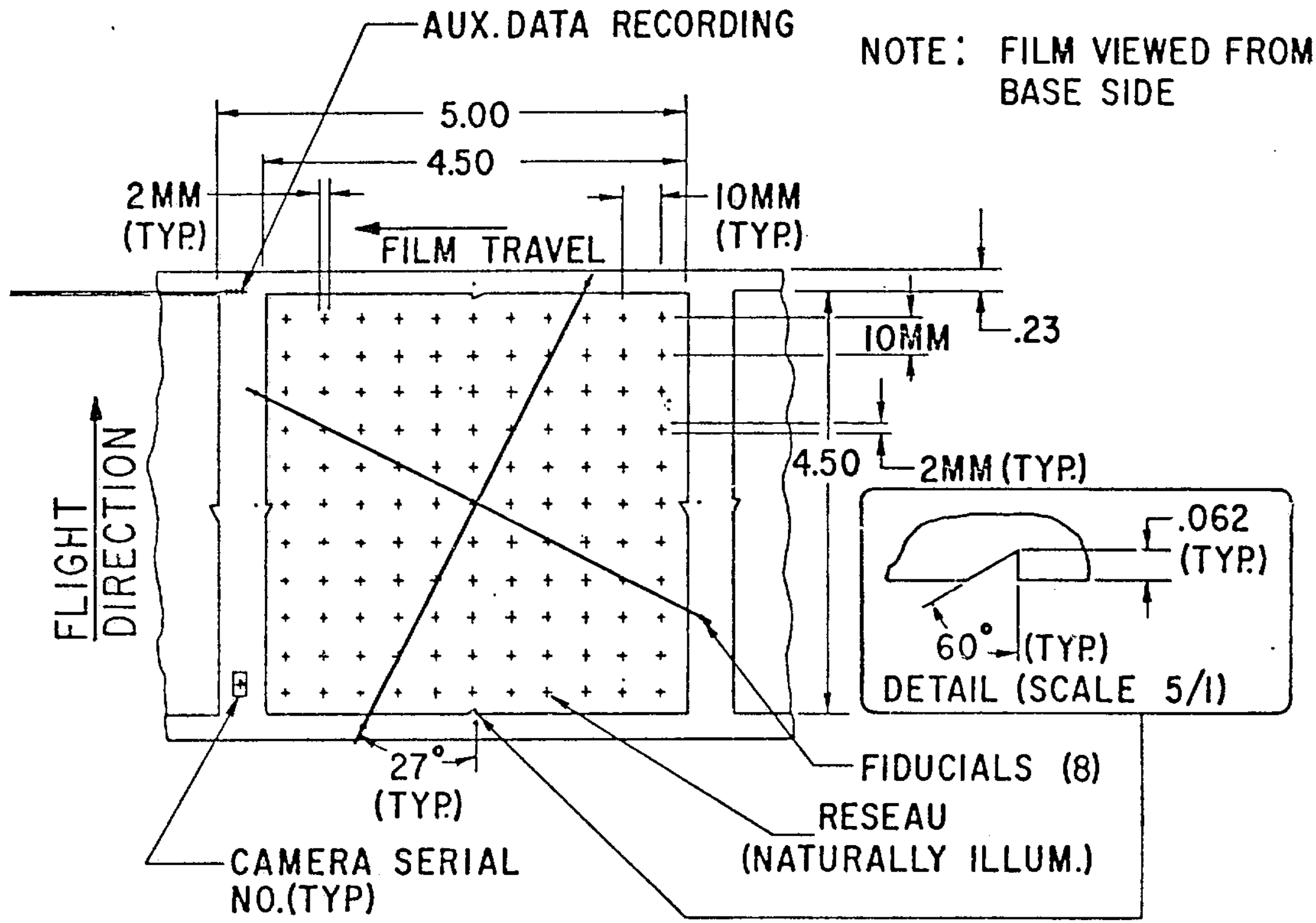

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Figure 2 - Mapping Camera Film Format

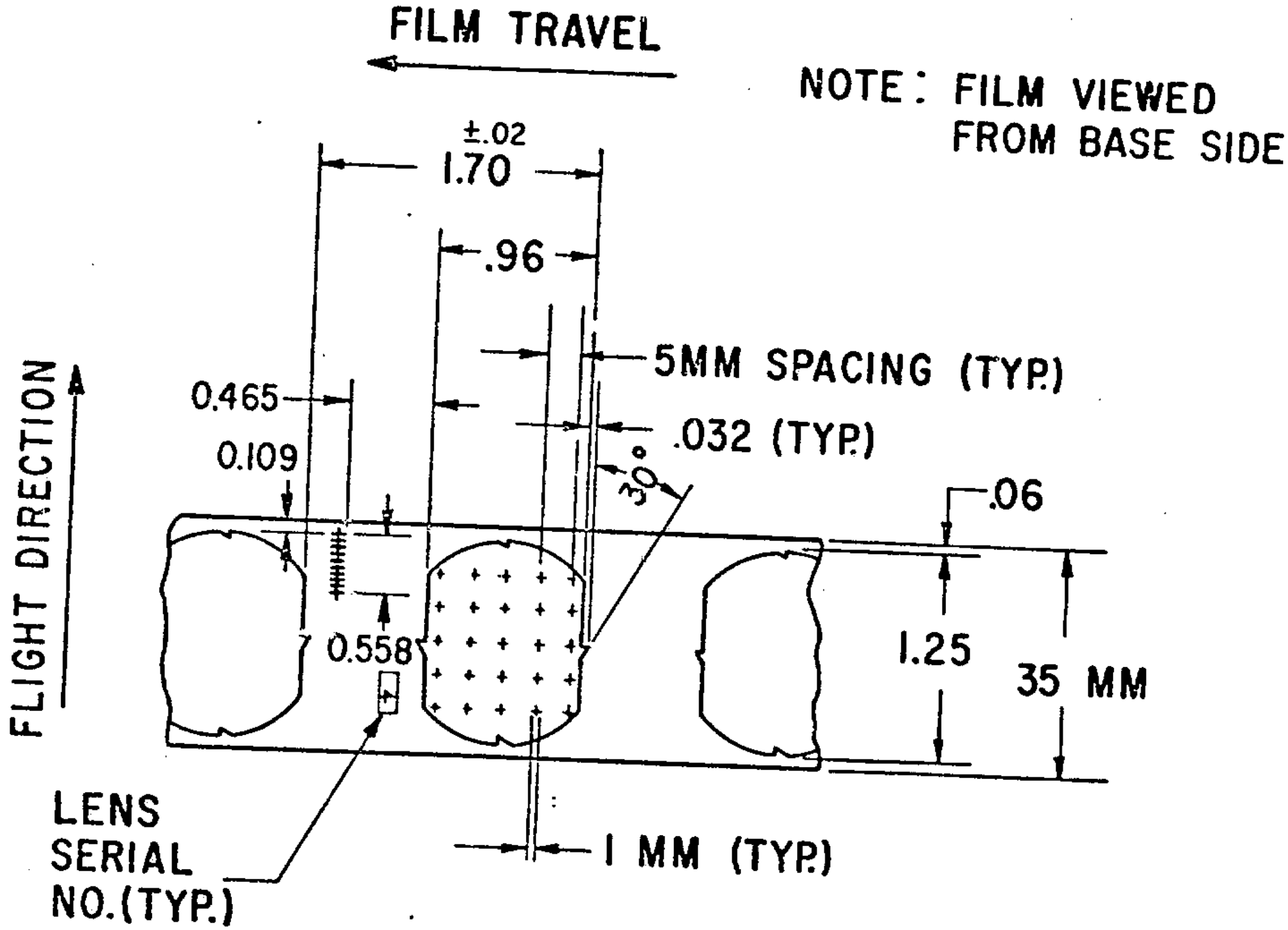


Figure 3 - Stellar Camera Film Format

2.0 MCS OPERABLE STATUS

The MCS available for this study, Serial No. 006, was operated in the laboratory and its performance observed.

While no measurements were made,all of the functions were observed to be operating. Observations made were:

2.1 AUTOMATIC EXPOSURE CONTROL

The AEC action was checked to observe the operation of the diaphragm when light was directed into and removed from the AEC photocell aperture.

2.2 FORWARD MOTION COMPENSATION

Forward Motion Compensation is obtained by pressure on the film against the platen which moves during exposure to provide image motion cancellation. This motion was observed during various camera cycling rates.

2.3 SHUTTER OPERATION

Audible clicks and shutter speed variations in phase with the cycling rate were heard indicating that both shutters were operating.

2.4 CYCLING RATE

Changes in V/H setting were observed to have caused noticeable changes in camera frame rate indicating V/H response.

2.5 DATA RECORDING

Data laydown on the film corresponded to test set inputs which verified that data recording was functioning properly.

2.6 PHOTOGRAPHY

Exposures were made in the laboratory which when developed showed the scenery photographed with the reseau patterns for each lens. The stellar lens was capped so that the reseau pattern would appear on the film.

3.0 STUDIES

Studies were conducted to assess the problems associated with the installation and operation of the MCS in the STS environment. They were performed on the photographic capabilities of the MCS,its mechanical and electrical interface with the STS, documentation, operation and survivability in the expected environments, ground support equipment, test and field support recommended.

3.1 PHOTOGRAPHIC CAPABILITIES

The camera photographic capabilities in the two proposed orbital test flights follow:

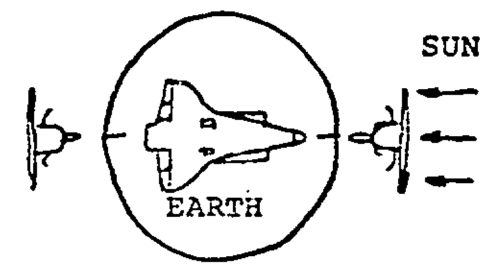
3.1.1 Orbital Flight Test-2

During OFT-2, the STS will fly an orbit within 90 to 150 nautical miles of earth in an attitude with the STS top at local vertical, (Figure 4). This attitude with relation to the sun provides an excellent opportunity for photographic data acquisition since the earth's surface will be in the camera field-of-view throughout the test flight.

In order to provide proper image motion compensation, the V/H will have to be set to some one particular value based on an orbital altitude which will be known before the mission. If the orbit is elliptical from 90 to 150 N.M., the V/H could be set at some optimum ratio representing a best-performance compromise. For example, if the resolution at any single setting is 80 l/mm and the V/H is set to a flight altitude of 130 N.M. resolution at both altitude extremes along the flight path would be 70 l/mm. Cross-track resolution would remain at 80 l/mm.

PHOTOGRAPHY

OFT 2



ALTITUDE 90 - 150 N. M.

$$\frac{V}{H} = 45.6 \text{ TO } 26.0 \text{ MILLI-RADIANS/SECOND}$$

MCS NOW SET FOR 16.1 TO 12.1 MILLI-RADIANS/SECOND

FIGURE 4

3.1.2 Orbital Flight Test-4

Since OFT-4 involves 3 different attitudes at 225 N.M. (Figure 5), only, the second attitude will provide any earth-surface photographic possibilities. In the first attitude, the lens would be looking continuously into deep space. In the third attitude, the lens would be looking continuously into the sun. Obviously, there will be no photography during these attitudes.

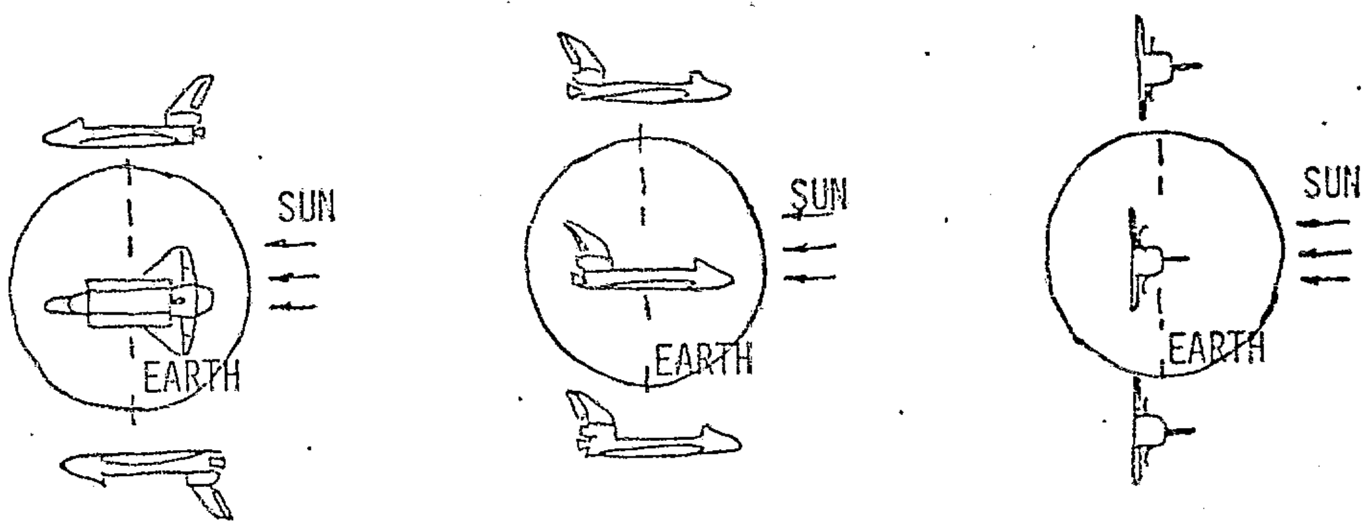
While the second orbital attitude is far from ideal, from a photographic data acquisition standpoint, it does offer some possibilities. Photography will show the earth only during the lower half of orbit where the STS payload bay position provides this earth view.

When the camera mounted in the same fashion as for OFT-2, the FMC would be in cross-track direction and will be disabled. The in-flight line resolution, as of result of image smear, will be at least 45 l/mm while the cross-track resolution will remain at better than 80 l/mm.

In-flight resolution could be improved by rotating the MCS 90^{O} so that the built-in FMC will be in the correct attitude. This will provide optimum resolution. The trade-off, however, will be loss of stellar photography which is occluded by payload bay ends or the D.F.I. installed in the payload bay.

PHOTOGRAPHY

OFT 4



ATTITUDE 1 — NO PHOTOGRAPHY

ATTITUDE 2 — PHOTOGRAPHY

ATTITUDE 3 — NO PHOTOGRAPHY

FIGURE 5

Figure 6 shows the stellar field of view with the Mapping Camera mounted at station 1237.5. If the stellar view is forward over 60% of the field is occluded by the D.F.I. (view of Section Y-Y) and most of the remainder cut off by the forward bulk head and payload bay door hinge area (view of section X-X).

If the camera is arranged with the stellar view aft, the stellar camera would be looking entirely into the aft bulkhead (view of section Z-Z).

Because of the continually changing attitude of the MCS to the earth, the overlap (Figure 7) will continually change from that selected to 100% at which time only deep space will be in view.

The MCS will continually view the twilight equator and will yield photographs with long shadows.

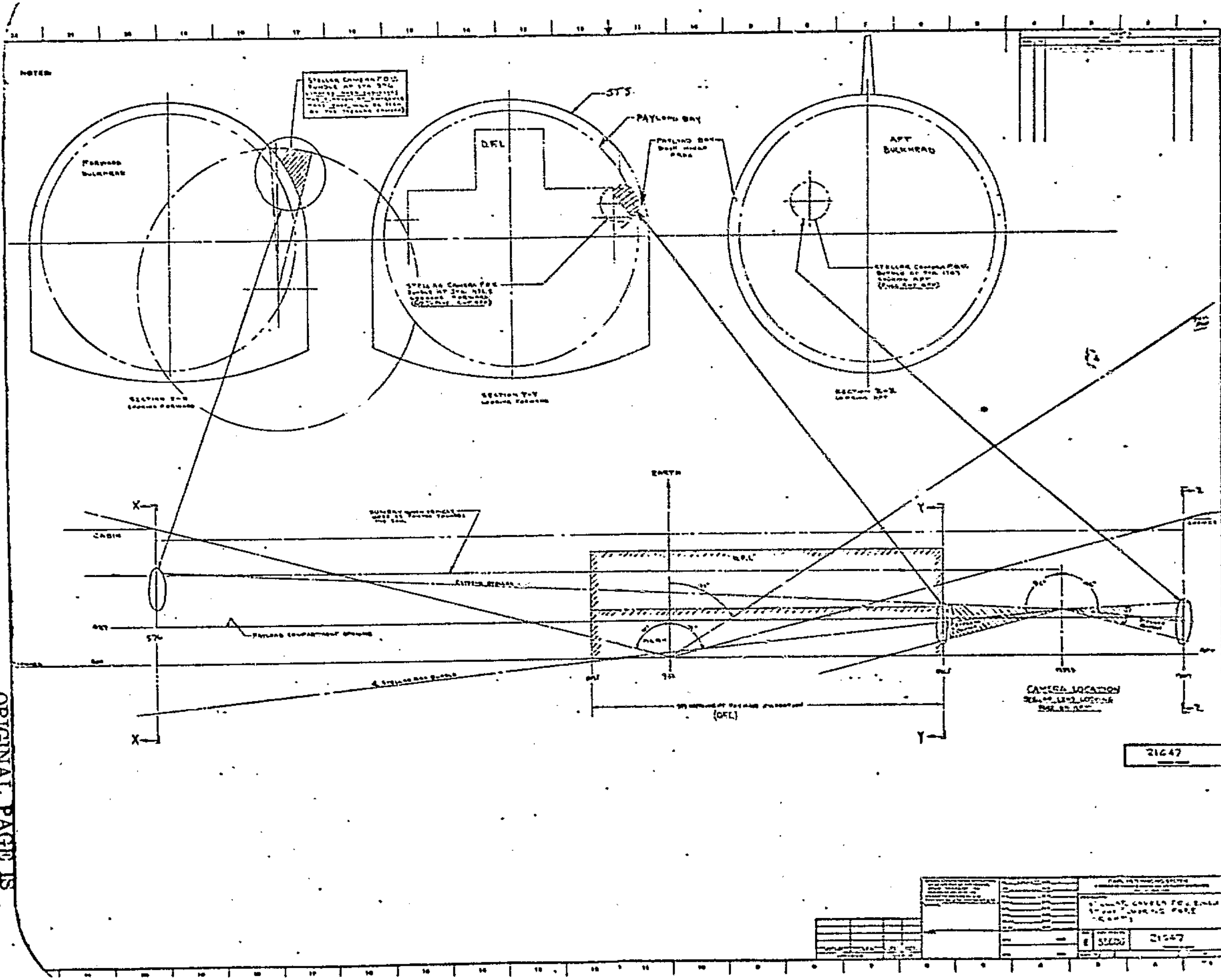


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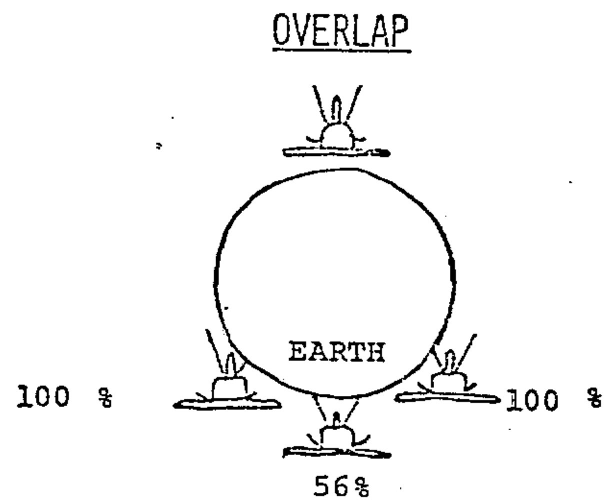
FIGURE 6

PHOTOGRAPHY

MISSION 4 -ATTITUDE 2



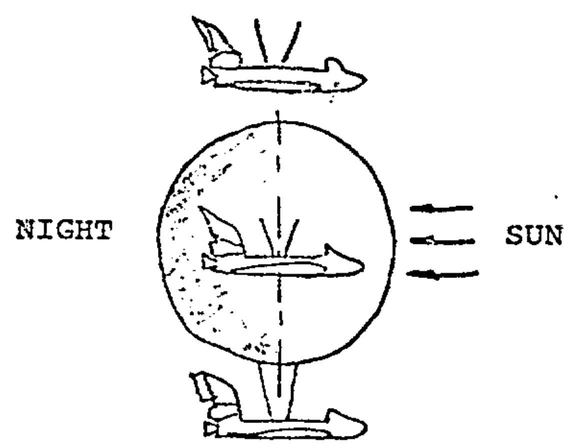


FIGURE 7

3.1.3 Effects of STS Crab Angles

If the attitude of the STS varies so that the flight path is not in line with the long axis of the vehicle, there will be some resolution degradation because of image smear. This degradation will be in both axes of the photographs and vary with the crab angle and shutter speed used. For example, a crab angle of 5° and 1/100 sec shutter speed at 150 N.M. will degrade resolution from 80 l/mm to 79 l/mm in the flight direction and to 75 l/mm cross-track. For a 10° crab angle, the resolution in the flight direction would degrade to 78 l/mm and cross-track to 72 l/mm.

3.1.4 Sensitometric Considerations

For the Apollo Lunar Mapping flights, every precaution possible was taken to obtain maximum photographic image information.

The procedure followed by NASA,Houston involved photographing gray scale wedges on sample lengths cut from each roll and after development selecting the rolls with the highest gamma.

The selected rolls then were exposed to gray scale wedge images for about 12 ft of length back some 30 ft from the leading end. The 30 feet was adequate for camera loading and checkout pre-flight after which a total of 50 feet was wound through the camera into the takeup cassette. Lens caps covered the lenses during these operations.

This procedure allowed processing of the first 50 feet to determine the best processing characteristics.

In this way, maximum advantage was taken of the particular sensitometric film properties to get the best result.

Since these procedures were all handled within NASA, they could be applied to this program.*

3.1.5 Light Reflections

Studies were performed to determine how detrimental light reflections will be eliminated or attenuated in the Stellar Camera. These are documented by layouts described below.

3.1.5.1 Earth Reflection Ray Clearance

Figure 8 depicts the probable reflection angles of rays from upper level of earth's atmosphere. The stellar glare shade will be extended part way and locked to avoid these reflections.

3.1.5.2 Sun Ray Bounce

Figure 9 shows probable reflections from earth's upper atmosphere and if during OFT-2 the STS attitude changes to $B = 45^{\circ}$. With the stellar glare shade extended as shown reflections will be avoided.

3.1.5.3 Payload Bay Door Hinge Reflections

Figure 10 shows the extent of the glare shade extension and baffle additions necessary to avoid reflections from STS payload door hinge and from top of atmosphere.

*For processing at Houston, Contact: Mr. Noel T. Lamar, Photo Science Office, Bldg. 8, Room 252, Mail Code JL-12; Telephone: (713)-483-4141

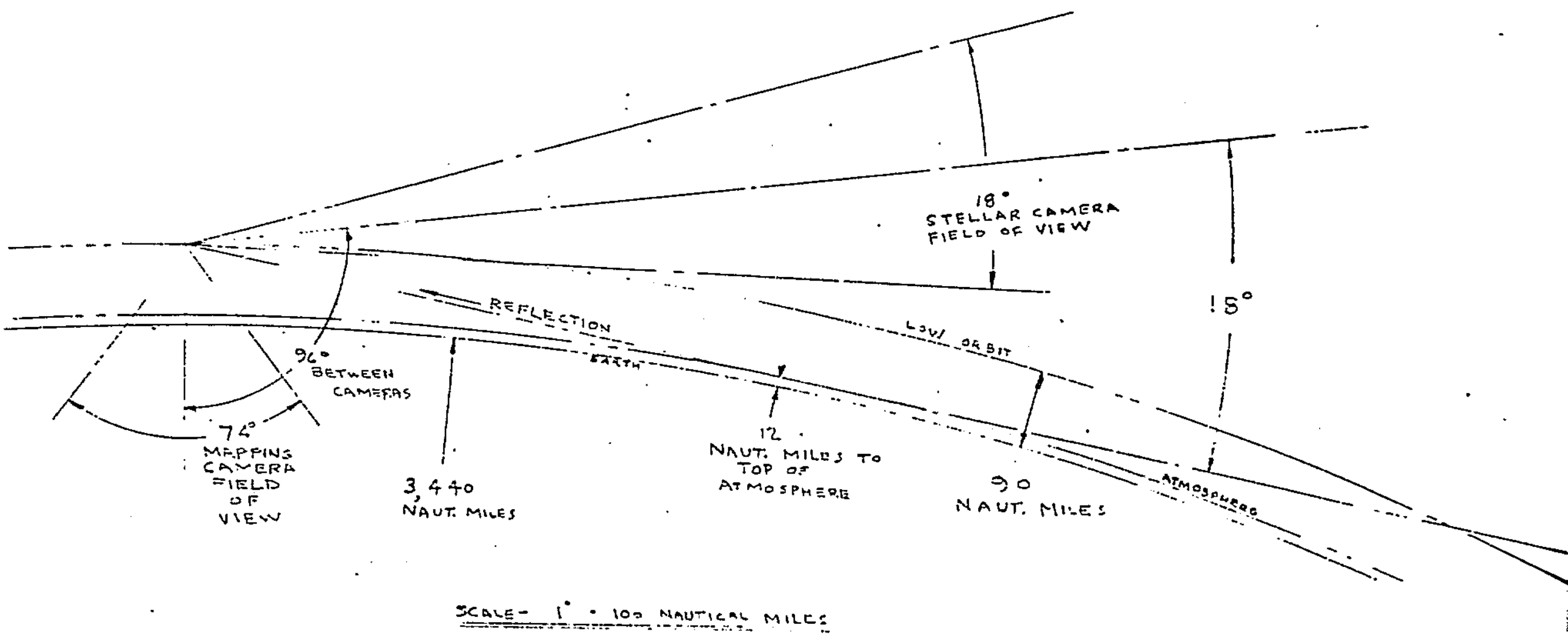


FIGURE 8 - EARTH REFLECTION STUDY

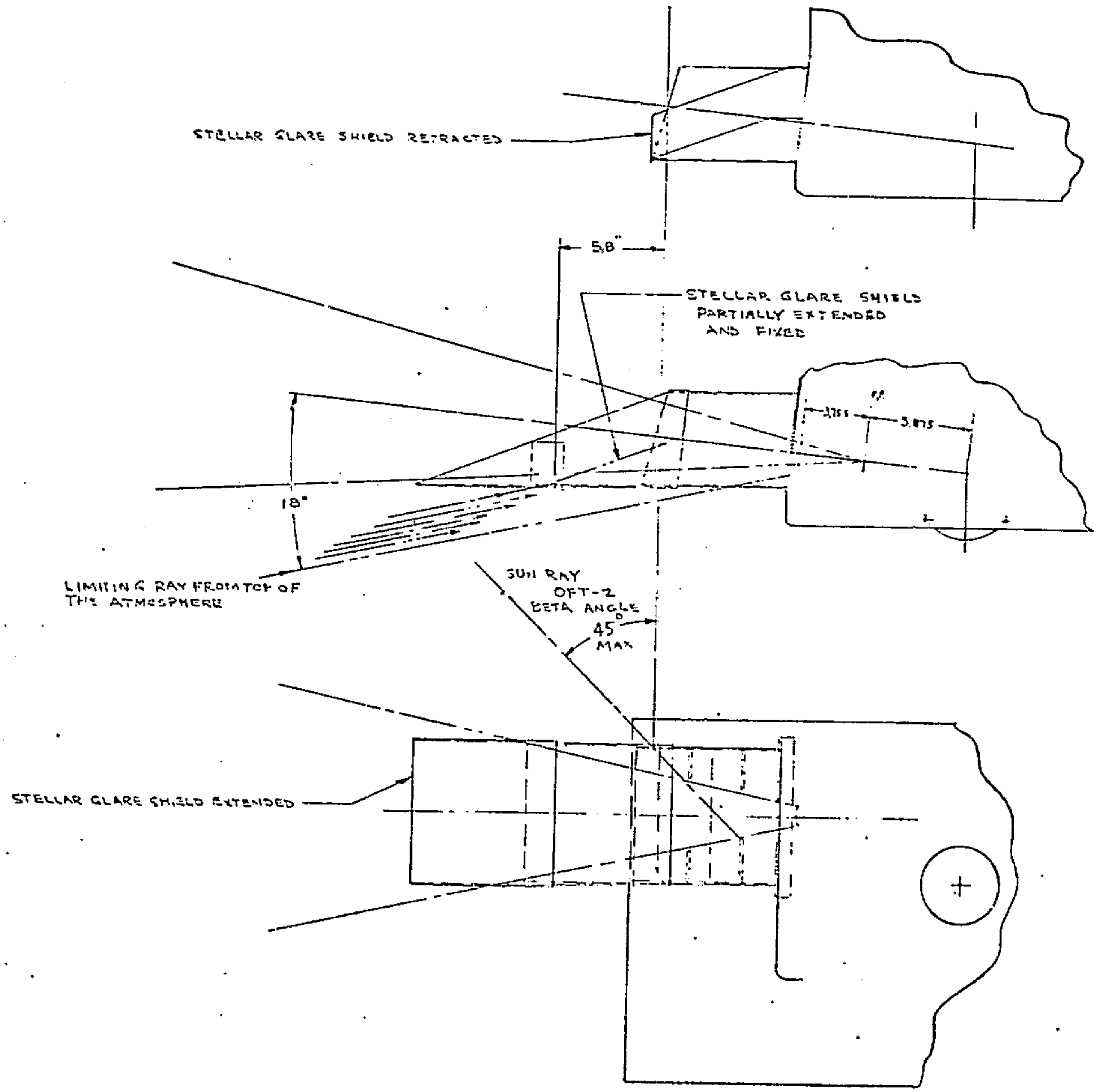


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FIGURE 9 - REFLECTION STUDY

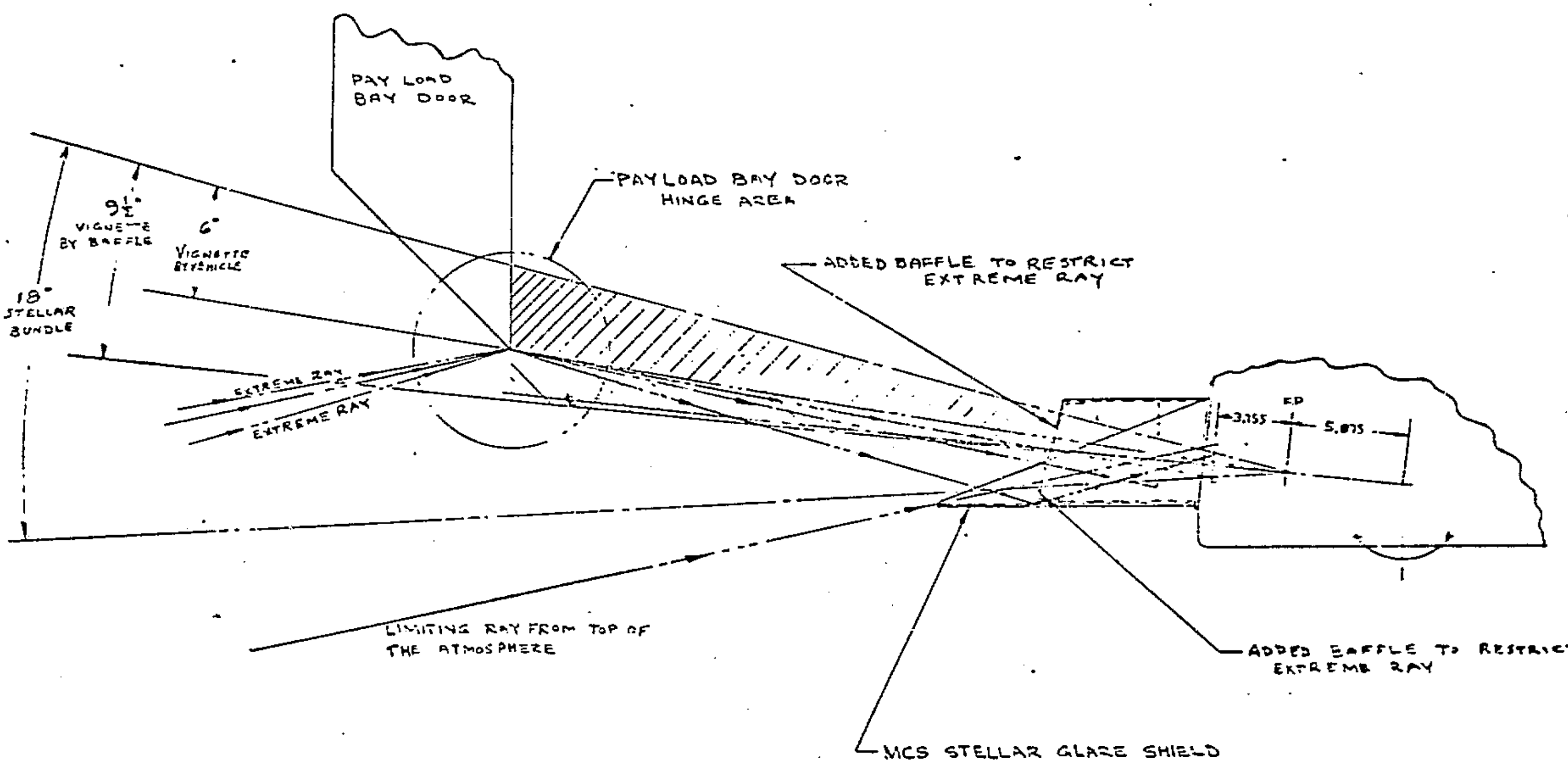


FIGURE 10 - PAYLOAD DOOR HINGE REFLECTION STUDY

3.1.6 Automatic Exposure Control

The Automatic Exposure Control feature built into the Mapping Camera provides for interchange of filters to accommodate various available aerial films. These are:

Film Type	AEI No.	Neutral Density No.
EK-3404	6	1.125
SO-397	16 (12)	0.742
EK-3400	20	0.602
EK-3401	64	0.097

For SO-397 the AEI No. 16 filter which is part of the existing set will closely approximate the recommended N.D. filter (12) for the color film. This substitution will be within one-half aperture stop and have little effect on the photography.

3.1.7 Color Film

Resolution of the photography will be degraded from 80 l/mm at 2:1 contrast obtained on 3404 (3414) emulsion to approximately 60 l/mm when color film such as SO-242 is used in place of the black and white film. On a fast color film (SO-397) resolution of the order of 30 - 40 l/mm at 2:1 contrast can be expected.

This is due to many factors most important of which is the fact that the Mapping Camera's objective was not designed for use with color film, but rather with a spectrum truncated by a minus-blue filter. Also the color emulsion is made up of several layers rather than one for black and white. These layers of course shift the sensitive surface out of the plane of best focus and degrade the imagery.

The resolution estimates are not based upon measurements, but rather on the bases of general experience when lenses of this class have been used in this manner.

3.2 INTERFACE WITH THE STS

In order to accommodate the Lunar-MCS System in the STS, the mechanical and electrical interface requirements were investigated. The results of these investigations follow.

3.2.1 Mechanical Interface with STS

Installation in the STS payload bay includes:

- Primary Mount
- Rotated Mount (optional)
- Thermal Additions
- Gaseous Nitrogen
- Interconnecting Cables

3.2.1.1 Primary MCS Mount

Installation on the STS pallet must not only give full earth view but must give reasonable stellar field view while avoiding reflections off the vehicle. Figure 11 shows one possibility where approximately 1/2 the stellar view is occluded by the payload door hinge. Baffles in the stellar glare shade will eliminate any undesirable reflections. This stellar view, of course, can be improved by raising the MCS on the mount approximately 5". The trade-off involves a heavier and more pendulous mount. See reference view in center of Figure 11.

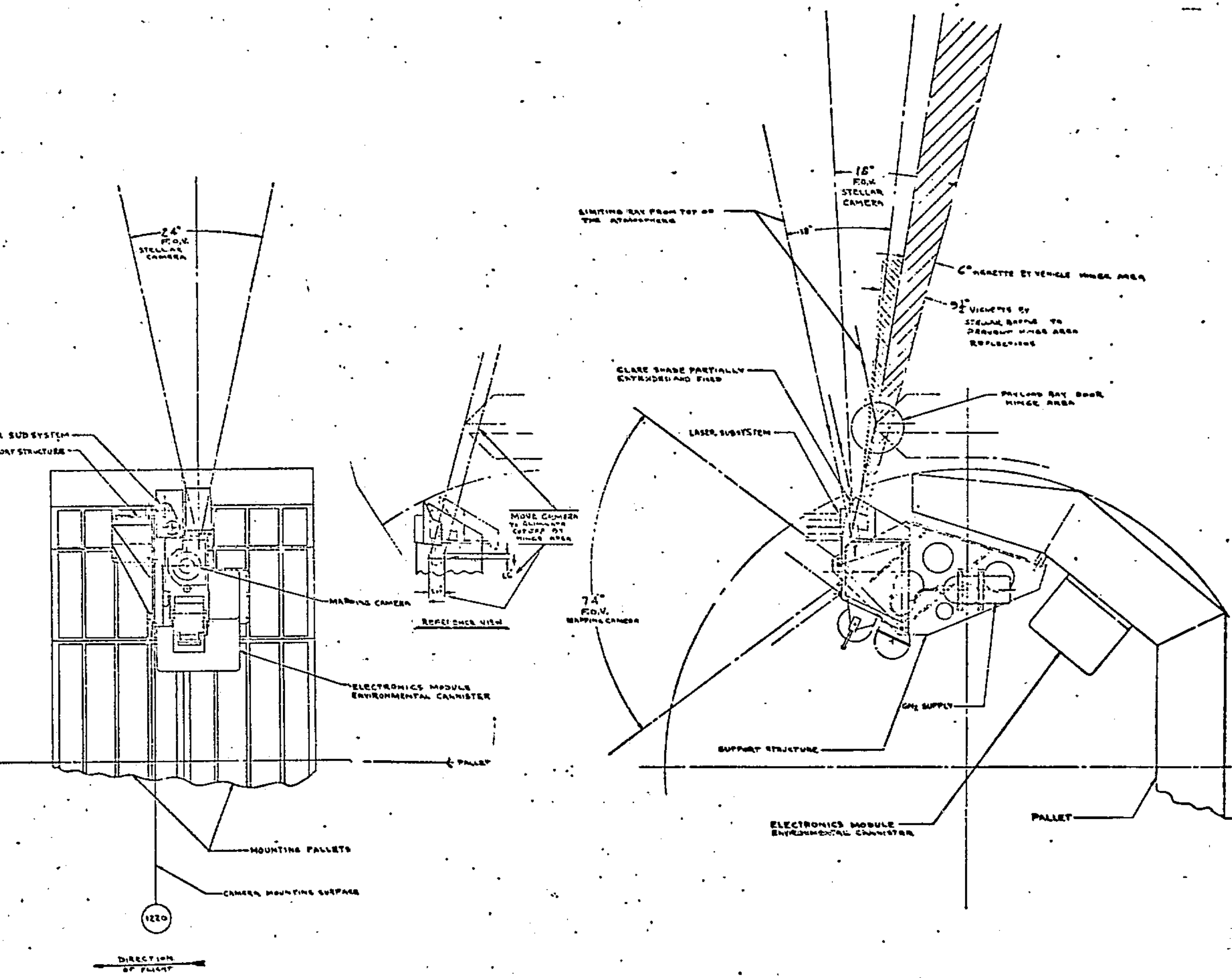


FIGURE 11 - MCS PALLET INTERFACE

Actually, when all physical characteristics of the STS door and bay area become available this feature can be accurately determined and tradeoffs considered. The MCS mount will be designed using aluminum alloy plates shaped and welded together to form the structure shown in Figure 11. It is anticipated that the configuration will be simple and straightforward with major design emphasis placed on structural integrity with very conservative load factors rather than attempting to minimize structure weight.

The MCS will be positioned in the STS either aft of station 1136.5 or forward of station 883.5 to clear possible locations of the STS development test instrumentation.

3.2.1.2 Rotated Mount

In order to allow forward motion compensation in the photography during OFT-4, an addition to the primary mount will permit the MCS to be placed in a position where the FMC will be effective. This option is shown in Figure 12.

The added structure, again of 1" aluminum plate, consists of two plates at right angles welded and gussetted for rigidity and attached to the primary mount in place of the MCS. The MCS is mounted to the right angle face of this rotation adapter, and to insure rigidity, a stabilizing bar is added for support to the pallet.

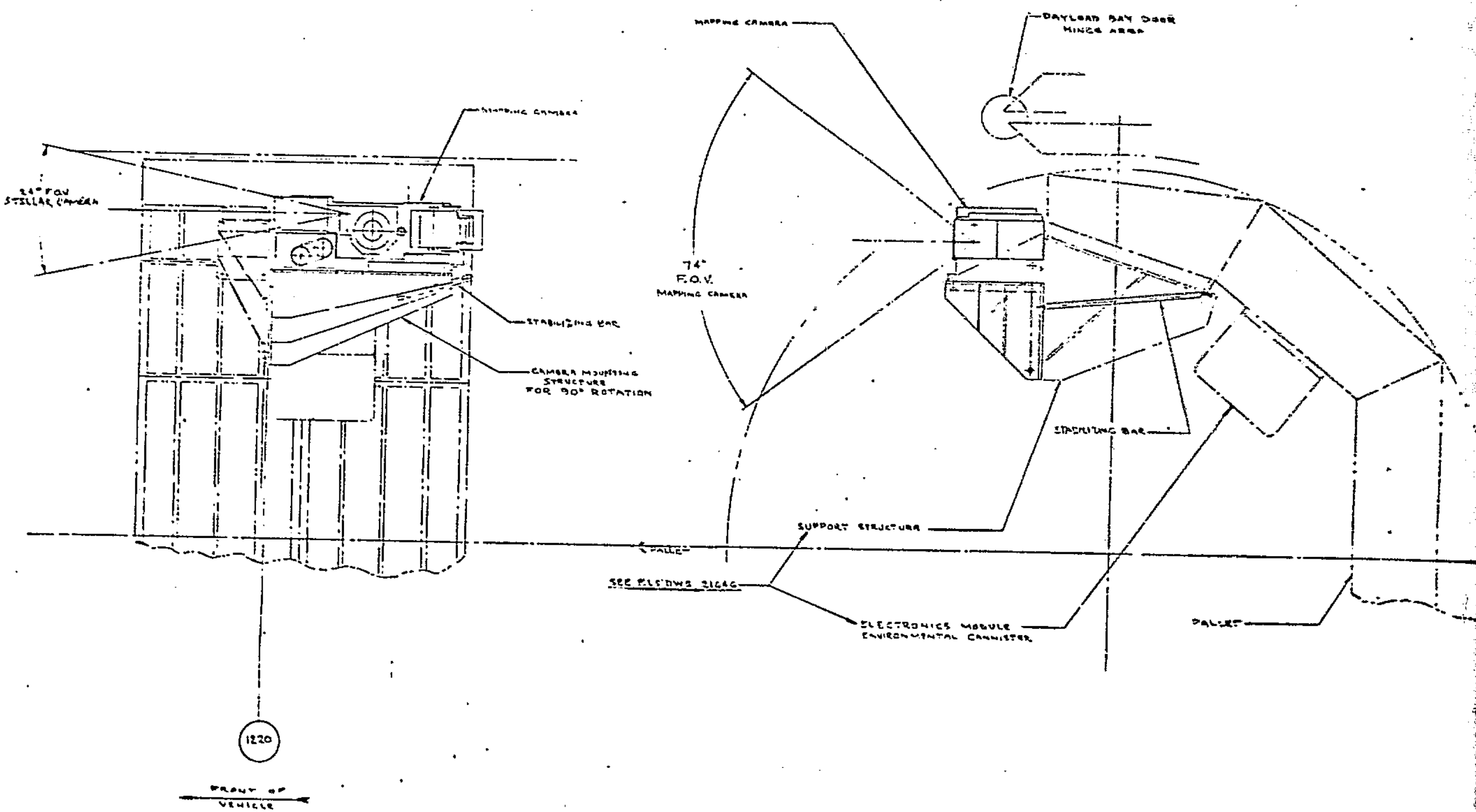


FIGURE 12 - MCS ROTATED 90°

3.2.1.3 Changes to the MCS

Changes required and work to be done on the Mapping Camera System are non functional and are summarized as follows:

- add baffles to stellar glare shade
- lock stellar glare shade
- lock deployment mechanism and disable drive servo
- drill and tap mounting feet
- clean optics and camera interior
- run acceptance test
- touch-up exterior
- install in transport case

3.2.1.4 Thermal Additions

In order for proper camera functioning and film survival during the orbital test flights, additional thermal insulation is required. See paragraph 3.4.2 for complete thermal discussion.

Orbital Flight Test 2 Thermal Additions

The attitude of the STS payload bay during OFT-2 positions the camera so that it will not be exposed to any direct solar radiation. However thermal protection will be needed during descent and landing where, for short periods of time, the temperatures in the closed payload bay will be excessive.

To insure that the temperature of the MCS and especially of the test film is tolerable, thermal insulation blankets will be used.

These blankets consist of multi-layer 1/4 mil aluminized mylar sheets in a 2 mil kapton enclosure, the same as used in the Apollo experiments.

Orbital Flight Test 4 Thermal Additions

The attitude of the payload bay during the third portion of the test flight causes constant full solar radiation to be directed at the lens side of the camera. Since this attitude will cause extremely high temperatures in the lens and camera system, additional thermal protection is necessary. Since the photography was completed in the prior attitude, the whole front lens side can be shielded from direct solar radiation by a fixed thermal shield and a thermal capping shutter.

The thermal shield, Figure 13, is arranged to prevent direct radiation from impinging directly on the Mapping Camera System. The shield will be hinged over the cassettes to allow easy access for film loading and cassette removal. The thermal insulation will be similar to that used for OFT-2 except that it will be slightly modified to expose additional camera areas for radiation of absorbed heat. If both test flights are conducted, the thermal setup for OFT-4 will satisfy OFT-2 as well.

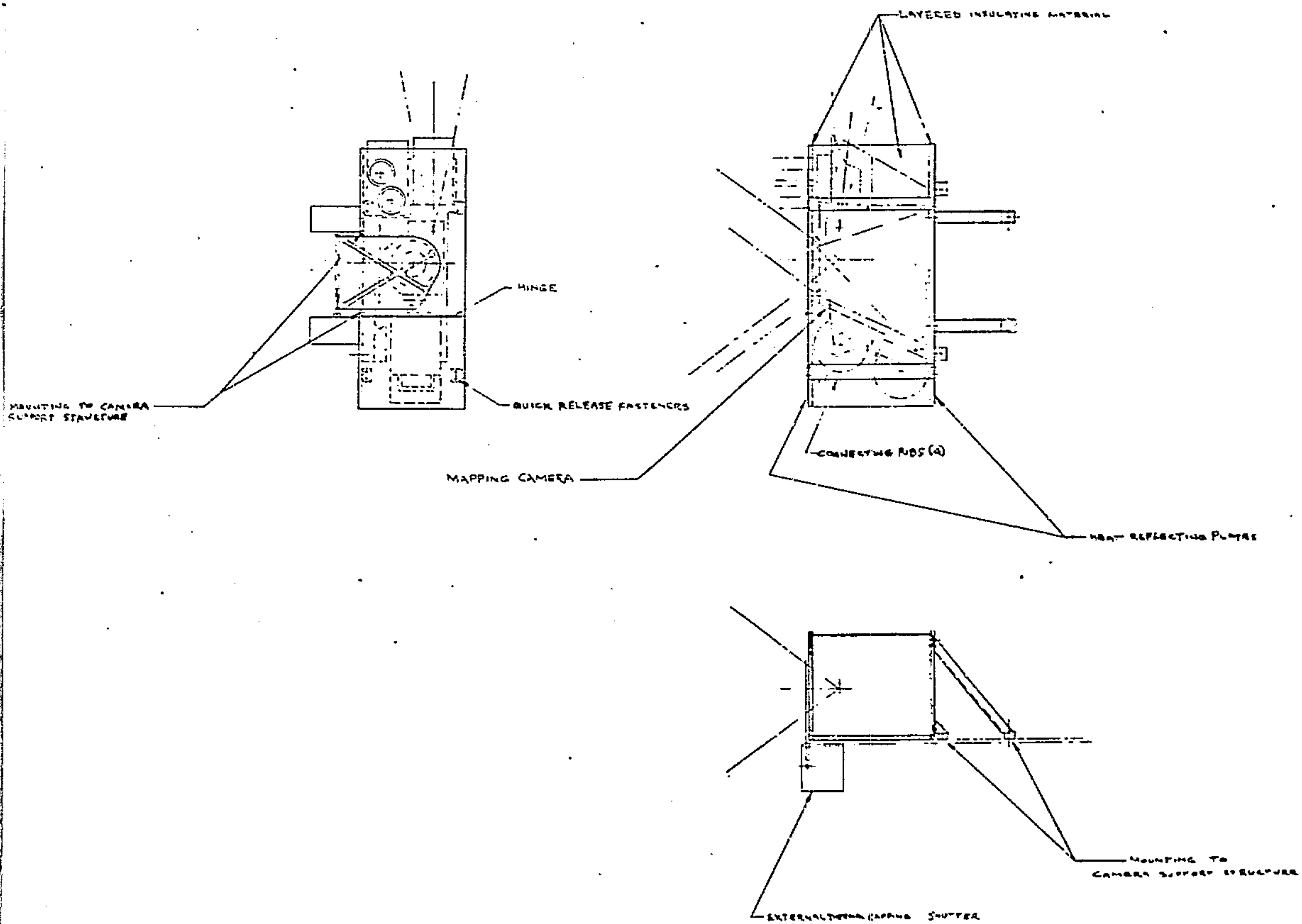


FIGURE 13 - THERMAL ADDITIONS

The thermal shutter, Figure 14, is actuated by two solenoids to insure photography if one solenoid fails. The design is self-locking by overcenter drive links which will avoid any problems during take-off and ascent vibrations. The shutter will be opened by "operate" command and closed by spring return when the film is completely run through the cameras.

The camera system will also be provided with thermal mounting insulators to minimize thermal conduction at the Camera/Support Structure mounting interface.

3.2.1.5 Gaseous Nitrogen

In order to minimize electro-static discharge and film marking, the MCS is designed to be pressurized during operation to approximately 100 microns of Hg. To implement this feature, a pressure bottle will be mounted on the pallet and connected to the solenoid valve and metering orifice in the MCS as shown on Figure 11.

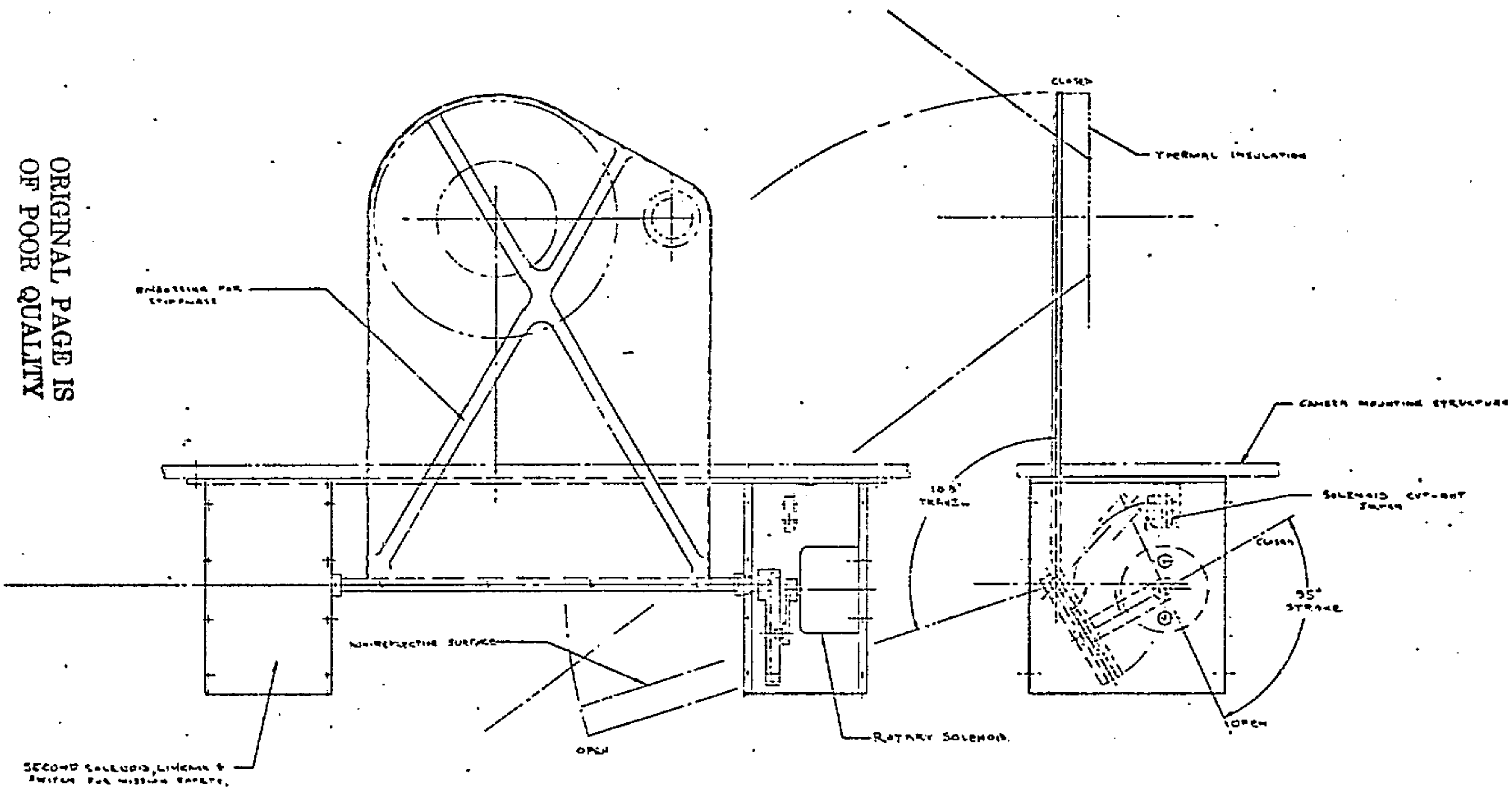


FIGURE 14 - THERMAL SHUTTER

3.2.1.6 Cables

Suitable cables will be supplied for test and operation. These interconnecting cables are shown in Figure 15.

Canister to Camera

Power Cable

Control Cable

Telemetry Cable

Test

Canister to Test Set

Control Cable

Test Cable

Canister to Thermal Shutter

Shutter Cable

3.2.2 Electrical Interface with STS

The Lidar experiment which is designed around the laser equipped Mapping Camera System includes a GSFC designed and supplied electronics canister which will supply power and control to the Mapping Camera Systems.

Instrumentation outputs from the MCS, normally telemetered to ground control, will be sent to the canister where they will be recorded on tape.

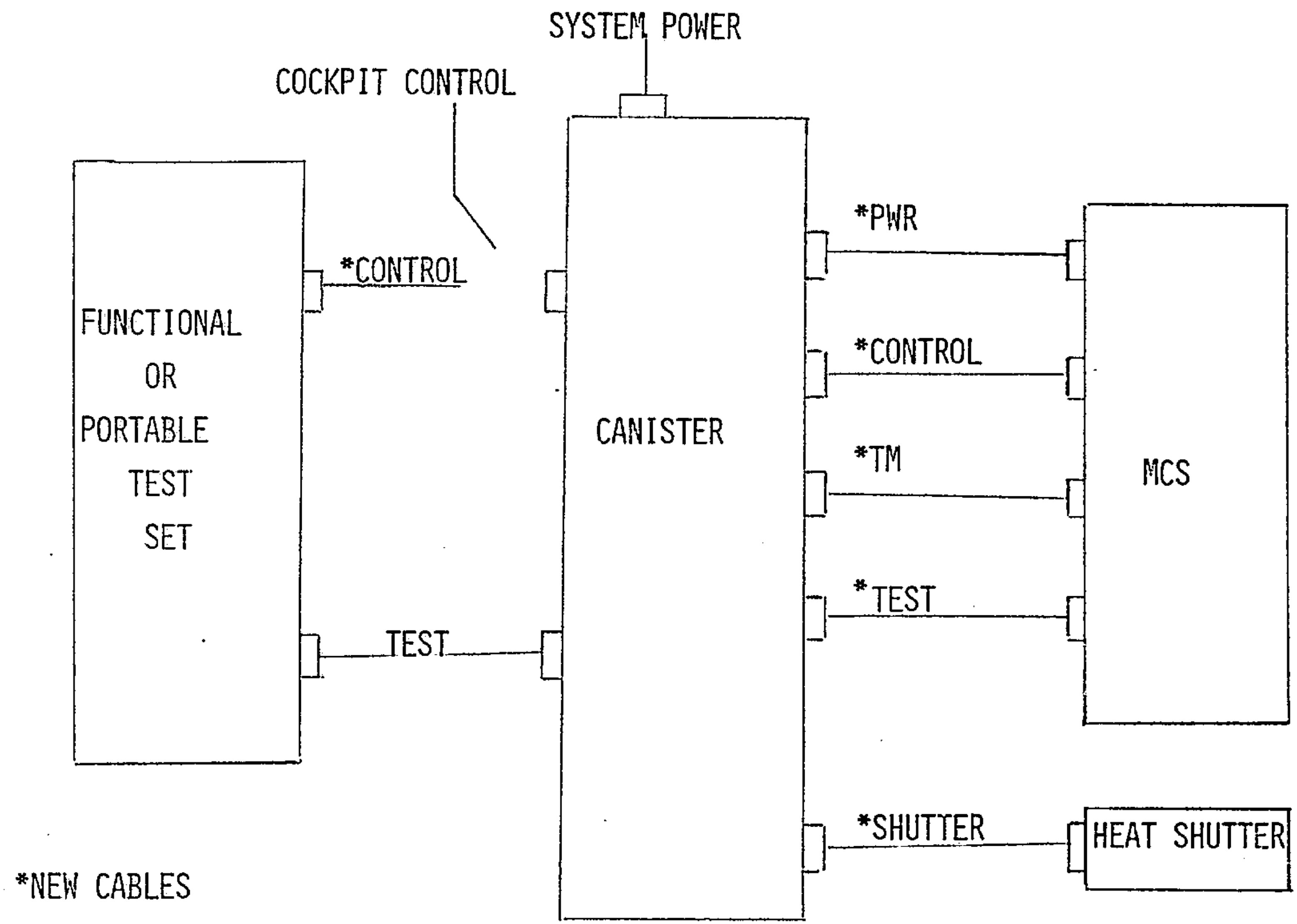


FIGURE 15 - INTERCONNECTING CABLES

The astronauts' tasks are kept to an absolute minimum consistent with mission objectives. (See paragraph 3.2.2.3).

3.2.2.1 Canister Requirements

To enable the MCS to meet its system requirements, the canister must provide standby battery power, external control circuitry and camera/test set interface connections.

3.2.2.1.1 Standby Battery Power

In order to meet both mission and MCS requirements, DC standby power and control circuitry will be required to insure that proper film tension is maintained after flight film is loaded. This DC voltage will be supplied by a sealed alkaline battery located within the canister. Its volume will be one cubic foot and weigh 20 pounds. It will supply enough power for 48 hours of standby operation. Also within the canister will be the battery control circuitry. The circuitry will sense pallet power and turn off battery power.

3.2.2.1.2 Control Circuitry

Located within the canister will be thermal shutter circuitry, which will sense the camera operate command and energize the heat shutter. Also on the canister will be the V/H control and FMC control.

3.2.2.1.3 Camera/Test Set Interface

The canister will contain the required interface connector for MCS test and operation.

3.2.2.2 DC Power (less Heaters) at MCS Interface

The average DC power required by the MCS will not exceed 100 watts. The maximum DC peak power will not exceed 300 watts. Standby power will not exceed 10 watts. Standby power will be required whenever the system requires active thermal control produced by the internal heaters.

Heater Power at MCS Interface

The DC power consumption required by the MCS heaters shall not exceed 15 watts.

Voltage Requirements at MCS Interface

Steady State Voltage Limits	25 to 30 volts DC
Transient Voltage Limits	21 to 32 volts DC, recovering in 1.0 second
Ripple Voltage (Peak-to-Peak)	1.0 volt

3.2.2.3 Astronaut Controls

The functions required of the astronaut have been minimized to one preflight (standby) and one (camera operate) during orbit.

The cockpit function switch has three positions:

OFF, STANDBY, and OPERATE

Off Position

Setting the switch to OFF position inhibits all MC functions.

If the switch was previously set to the ON position, those functions associated with the ON position will continue to occur for a maximum of one MC photographic cycle.

Standby Position (See Note 1)

Setting the switch to standby makes the following MC functions operative:

1) Thermal Control Heaters
2) Supply Cassette Back-Tension
3) Temperature Telemetry
4) IMC ON or OFF Function (See Note 2)

Operate Position

Setting the switch to operate makes the following MC functions operative:

1) Thermal Control Heaters
2) All Telemetry
3) Photographic Functions
4) Heat Shutter Activated
5) V/H Level (See Note 2)

NOTE 1 - Powered from batteries until pallet power is supplied.

NOTE 2 - Preset to mission profile.

3.2.2.4 Canister Controls

Preflight controls for mission settable camera features will be housed in the NASA canister where they will be available for preflight selection. These are:

V/H Level Control

The particular mission V/H is set to provide the proper camera cycling rate for the mission profile as discussed in paragraph 3.1.1.

FMC ON/OFF Switch

This switch will either enable or defeat the forward motion compensation as dictated by the mission profile and vehicle attitude as discussed in paragraphs 3.1.1 and 3.1.2.

This switch is enabled only when the camera control switch is in the standby position.

3.2.2.5 Data Signals

The MCS was designed to provide data signals suitable for telementry to mission control during the Apollo flights. For these orbital experiments, the signals will be stored on tape in the NASA canister. Their characteristics are:

Digital

Digital event signals are conditioned to the following:

- The amplitude of a binary zero is 0 ±0.5V DC.
- The amplitude of a binary one is +3.5 to +10V DC.

Analog

Analog signals are conditioned to 0.0 to 5.0V DC which corresponds to a zero to full scale measurement span.

Output Impedance

The data output impedance for all analog and digital events is a maximum of 5,000 ohms.

Data Serial Time Code Inputs

The experiment shall be capable of accepting the following serial time code inputs from the Central Timing Equipment with the following characteristics:

a) Format: IRIG "B", without optional final straight binary seconds count. (Ref. Figure 16).

b) Load Impedance: 50K ohms minimum.

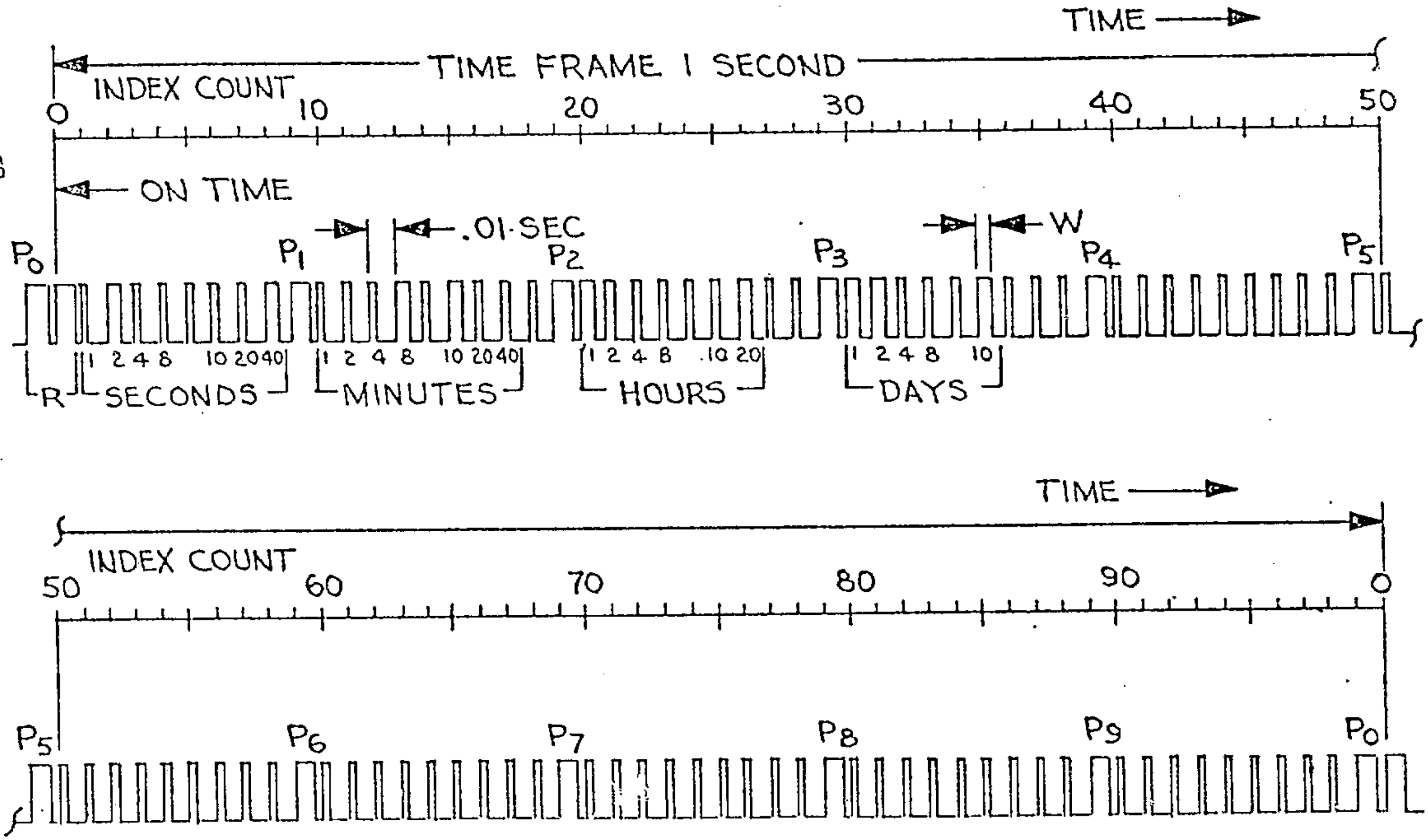
c) Output Rise Time: 50 microseconds maximum.

d) Output Fall Time: 50 microseconds maximum.

e) Output Pulse On Level: 4.0 to 10.0 volts maximum

f) Output Pulse Off Level: 0.0 to 0.5 volts maximum

g) Output Impedance: "OFF" Level 6K ohms maximum
"ON" Level 5K ohms maximum



R = 1 SEC REFERENCE MARKER
P = POSITION IDENTIFIER, 8 MS DURATION
W = WEIGHTED CODE DIGIT, 5 MS DURATION
DURATION OF INDEX MARKERS = 2 MS

SAMPLE TIME SHOWN IS 13 DAYS, 21 HOURS, 18 MINUTES, 42 SECONDS

BALANCE OF FRAME IS UNMODULATED

100 PPS CODE - MODIFIED IRIG STANDARD FORMAT B

FIGURE 1

3.3 DOCUMENTATION

In order to provide adequate design,installation, integration, operation and testing information, the following documents will be prepared:

3.3.1 Electrical Interface Document

This document will describe the canister and payload bay electrical requirements needed to satisfy the MCS.

3.3.2 Installation, Operation and Instruction Manual

A supplement to the MCS operation and installation manual will be prepared to detail the installation and test interface between the MCS and the STS.

3.3.3 Operation and Instruction Manual for Ground Support Equipment for MCS

A supplement will be prepared to accommodate the changes and additions for the STS application.

3.3.4 Acceptance Test Procedures

Supplement to accommodate changes required to suit the STS application will be prepared for the:

- Mapping Camera System
- Functional Test Set
- Portable Test Set

3.4 ENVIRONMENTAL STUDIES

The Apollo Lunar Mapping Camera System was designed and qualified for use in the Scientific Instrument Module for photographic missions from lunar or earth orbit. The following is a review of its ability to perform and survive in the environment encountered when installed in the STS in earth orbit.

3.4.1 Mechanical

3.4.1.1 Ground Handling Shock

The MCS was designed and tested to withstand 10.5g ,11ms sawtooth pulse shock in 6 directions. Reference Figure 15. In its transport case, it will withstand a 2-1/2 foot drop on edges and corners which is well in excess of 20.5g.

3.4.1.2 Pyro Shock

Requirements TBD. When this requirement is defined, its effects on the MCS will be assessed.

3.4.1.3 Flight Shock

Figure 17 shows low level g requirements at a very low application rate. The MCS will not be affected by these flight shock levels.

3.4.1.4 Ground Handling Vibration

Refer to Figure 18 which shows the ground handling vibration requirements and values to which the MCS was tested. No problem is envisioned because the g levels not tested for are low and verified by levels tested for during inflight tests.

GROUND HANDLING SHOCK

MCS 10.5g 11MS SAWTOOTH PULSE – 6 DIRECTIONS
STS 20g. 11MS SAWTOOTH PULSE – 6 DIRECTIONS

FLIGHT SHOCK

STS PYRO SHOCK – TBD

STS LANDING SHOCK g	MILLI-SEC	APPLICATIONS/100 MISSIONS
0.23	170	22
0.28	280	37
0.35	330	32
0.43	360	20
0.56	350	9
0.72	320	4
1.50	260	1

77-519

FIGURE 17

GROUND HANDLING VIBRATION

	FRQ. Hz	LEVEL g	SWEEP RATE OCT/MIN	DURATION MINUTES
MCS	35–70	0.75	1.0	15
STS	2–5	1.0 d/a (.2g – 1.3g)	4 SWEEPS @ 1/2 OCT/MIN	
	5–26	1.3g		
	26–50	0.036 d/a (1.2g–4.6g)		
	50–1000	5g		

77-520

FIGURE 18

3.4.1.5 Flight Vibration-Sine

The MCS was tested for 15 minutes at 35-70Hz varying at the rate of 1.0 oct/minute for 15 minutes at 0.75g level.

The requirement is TBD.

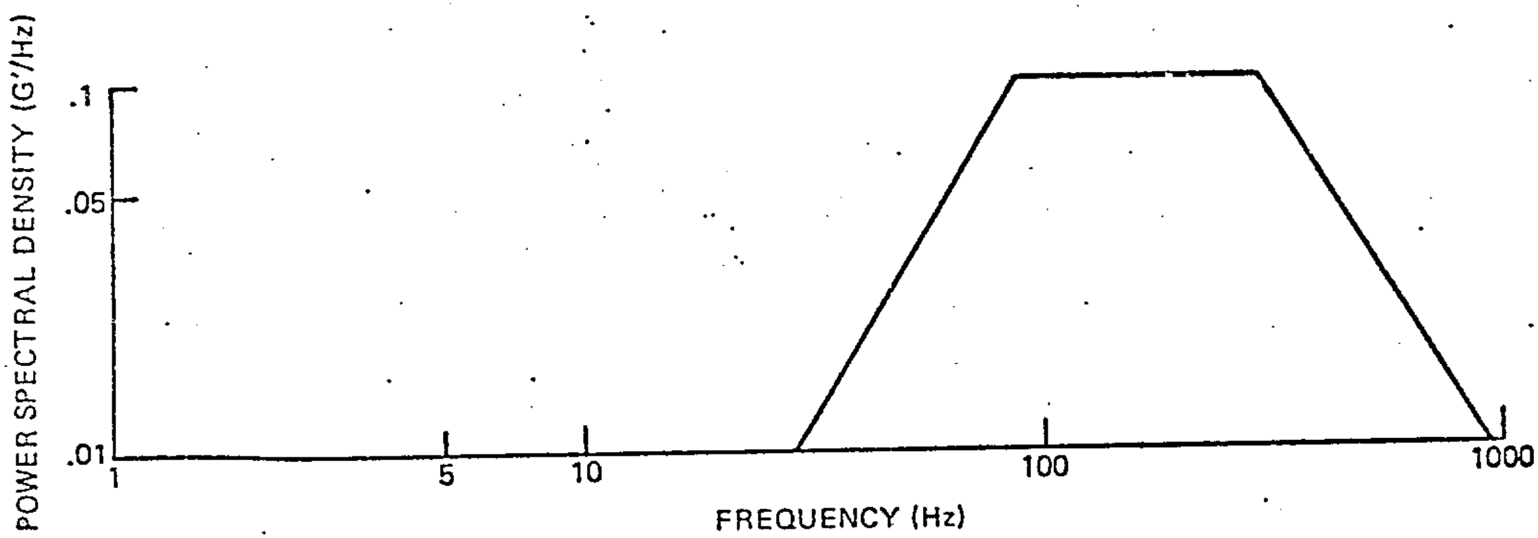
3.4.1.6 Random Flight Vibration

Figures 19, 20, and 21 show the predicted levels of random vibration expected during lift off and ascent along with the tested levels of the MCS. While the Mapping Camera tested level falls somewhat short of the STS power spectral density requirement, the frequencies are approximately the same. Since the MCS was designed to exclude or minimize resonances from the tested range of frequencies and the duration of the test significantly longer than the predicted STS levels, it is expected that no operating problems will develop in the flight vibration environment.

3.4.1.7 Acceleration

The MCS was tested in the camera X axis at levels shown in Figure 22 with the STS design levels. Since all but crash are relatively low and the MCS was tested to 10g shock in all axes, no effect is expected on MCS.

The mounting structure will be designed to accommodate crash safety requirements as well as all other environmental considerations.



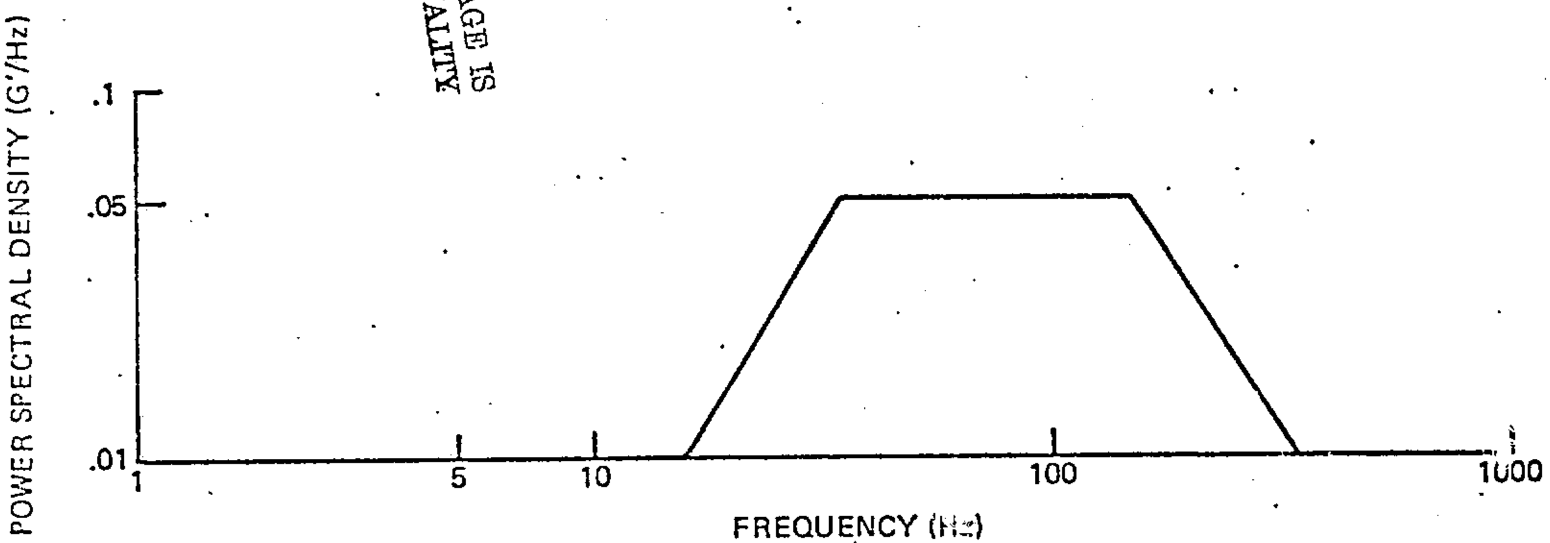
MIDFUSELAGE PAYLOAD INTERFACE - LIFTOFF

20 SECONDS PER MISSION

77-526

FIGURE 19

ORIGINAL PAGE IS
OF POOR QUALITY

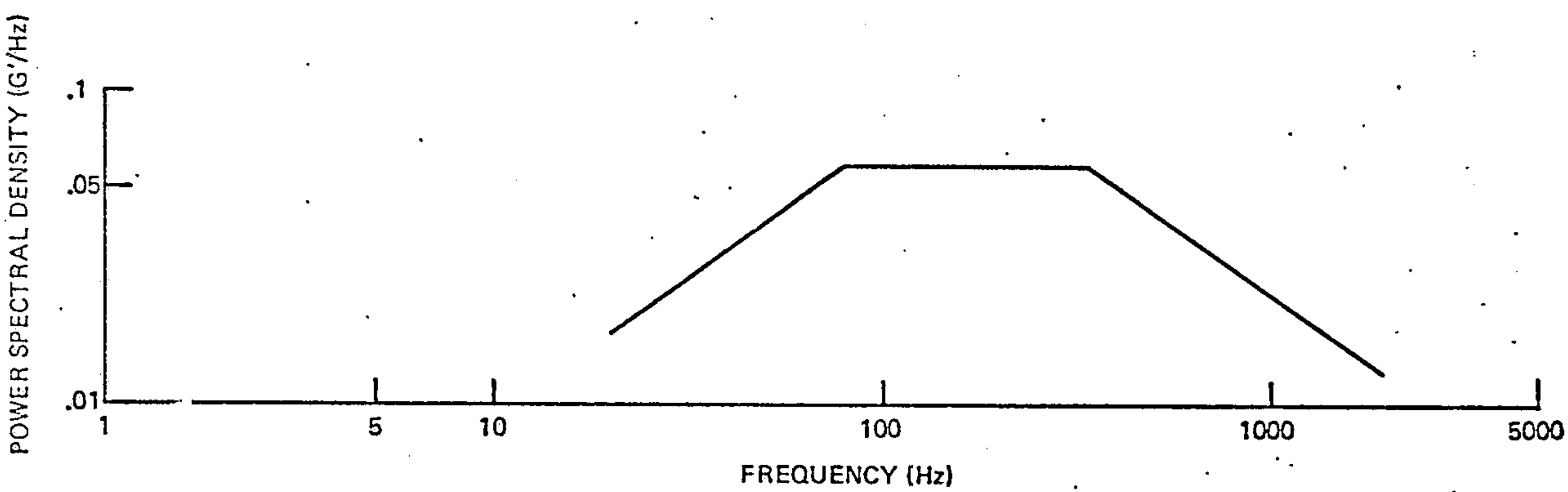


MIDFUSELAGE PAYLOAD INTERFACE - ASCENT

8.4 SECONDS PER MISSION

77-524

FIGURE 20



MAPPING CAMERA SYSTEM

150 SECONDS

77-525

FIGURE 21

ACCELERATION

MCS	1.25g INCREASING TO 6g IN 140 SECONDS HOLD AT 6g FOR 20 SECONDS – X AXIS		
STS	GROUND	2g	VERTICAL ONLY
	FLIGHT	3.3g*	VEHICLE X AXIS – MCS Z AXIS
	LANDING	2.8g*	VEHICLE Z AXIS – MCS Y AXIS
	CRASH	9.0g*	VEHICLE X AXIS – MCS Z AXIS
		4.5g*	VEHICLE Z AXIS – MCS Y AXIS

* STS LIMIT DESIGN ACCELERATIONS

77-523

FIGURE 22

3.4.1.8 Acoustics

The MCS was tested to essentially the same levels indicated in the STS requirement. From an overall acoustical standpoint, the MCS was subjected to 147db relative to a requirement of 145db. See Figure 23.

3.4.2 Thermal Considerations

The thermal considerations discussed in the following paragraphs are based on the MCS installed on a pallet in the STS payload bay using payload bay characteristics as spelled out in JSC07700, Volume XIV. The thermal environment that will eventually determine the thermal effects on the MCS will, of necessity, be influenced by the structures and equipment in the vicinity of the MCS in the actual installation.

3.4.2.1 Orbital Flight Test 2

OFT-2 involves an orbital attitude where the payload bay will continually face the earth (Figure 24) while orbiting in a plane parallel to the sun. The MCS in the payload bay will always be shaded from direct solar radiation either by the vehicle or the earth.

The combination of heat generated by the camera, heat radiated from the payload bay and that reflected from the earth will provide an environment satisfactory for continuous camera operation.

ACOUSTICS

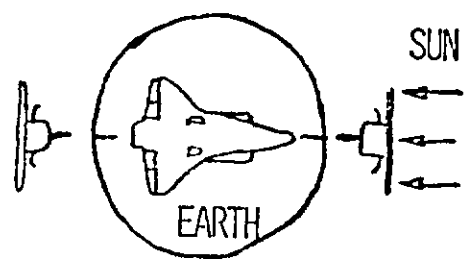
	MCS	STS
25–1000	COMPARABLE	
1250	128	130
1600	125	129
2000	122	128
2500	119	127
3150	116	126
4000	113	125
5000	110	123
6300	107	122
8000	104	120
OVERALL	147	145 FOR 120 SECONDS

FIGURE 23

77-522

THERMAL

OFT-2



MCS WILL ALWAYS BE SHADED FROM DIRECT SOLAR RADIATION

FIGURE 24

Insulation will be required to protect against the high temperatures encountered during descent and landing.

3.4.2.2 Orbital Flight Test 4

OFT-4 involves a single orbital path wherein the vehicle changes attitude twice. Figure 25 shows attitude 1 where the payload bay will continually face outer space. The camera will not be running but will be on standby where thermostatically controlled heaters will provide a protective atmosphere. Attitude 2 shows the vehicle in constant position relative to the sun with the vehicle nose continually pointed at the sun.

The lower half of this orbit does permit photography as discussed in paragraph 3.1.2. Temperatures in the camera area will be within the camera operating capability. During this attitude, all film will be transferred through the camera from the supply to the takeup cassette.

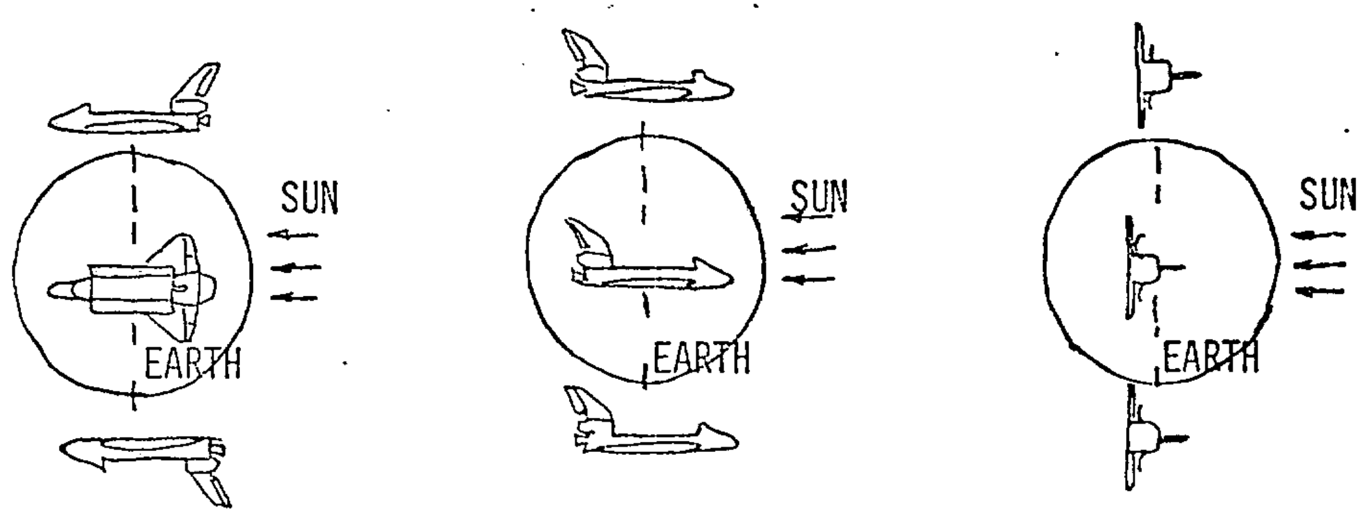
When the attitude changes to the last in the series, the lens continually faces directly into the sun for 26 hours. The camera must be protected to survive this environment and the film in the take-up cassette must not reach a destructive temperature.

No information on film characteristics is available from Eastman Kodak above 120°F so in order to be safe 100°F is set as a no risk maximum temperature.

A simple temperature model was set up which used the volume of the camera with the reflective silicone paint on its sun side (no holes for lenses)and multi layer insulation on the remaining five sides.

THERMAL-VACUUM

OFT-4



	ATTITUDE 1	ATTITUDE 2	ATTITUDE 3
PHOTOGRAPHY	NO	YES	NO
THERMAL PROBLEM	NO	NO	YES

FIGURE 25

Calculations of camera model terminal temperature showed that the MCS would reach 143°F in 26 hours and 3° higher during descent and landing.

In order to do the best job possible for least expenditure of Engineering and Factory dollars, it was decided to settle on a thermal shield and thermal shutter, which together with some thermal insulation will reduce the MCS temperature safely below 100°F.

The thermal shutter, held closed by spring pressure until photography begins at which time it will be opened by two rotary solenoids which provide reliable power. After photography is completed and the cameras turned off, the shutter will spring to the closed position. Calculation of this new model shows terminal MCS temperature after 26 hours of solar radiation to be 64°F and after landing prior to purge to be 80°F. This satisfies the 100°F goal.

3.5 GROUND SUPPORT EQUIPMENT

In order to verify the MCS capabilities and measure its performance, ground test equipment will be required at FISD and at different levels of MCS integration. The ground test equipment will be a Functional Test Set and a Portable Test Set both FISD property. Both were previously used on the MCS during the Apollo Program and will be used at no cost to GSFC on this program. They will, however, have to be refurbished and modified.

3.5.1 Functional Test Set

The Functional Test Set (FTS) part number 1231G1 consists of 11 subassemblies which are housed in a single double-door cabinet, see Figure 26. The purpose of the FTS is to exercise and measure the performance of the Mapping Camera Subsystem (MCS) through a series of operations which parallel those encountered during actual flight.

The FTS, presently at FISD, will require reconditioning and modifications to enable the test set to meet MCS/canister configuration requirements.

The FTS reconditioning will include repair or replacement of console equipment and recalibration of test equipment. The items that will require repair or replacement are the CRT of the dual trace memory oscilloscope, the pins of the eight channel Brush recorder, and all console indicators. Items that will require recalibration are two counters, one digital voltmeter, one oscilloscope, an 8 channel recorder and the camera power supply.

Modification of the FTS will be in the area of additions, modifications, and deletions of controls and associated circuitry, and the addition of new assemblies and the fabrication of new test cables. The V/H and IMC controls will require modification and the battery and shutter control will be new additions. The deployment

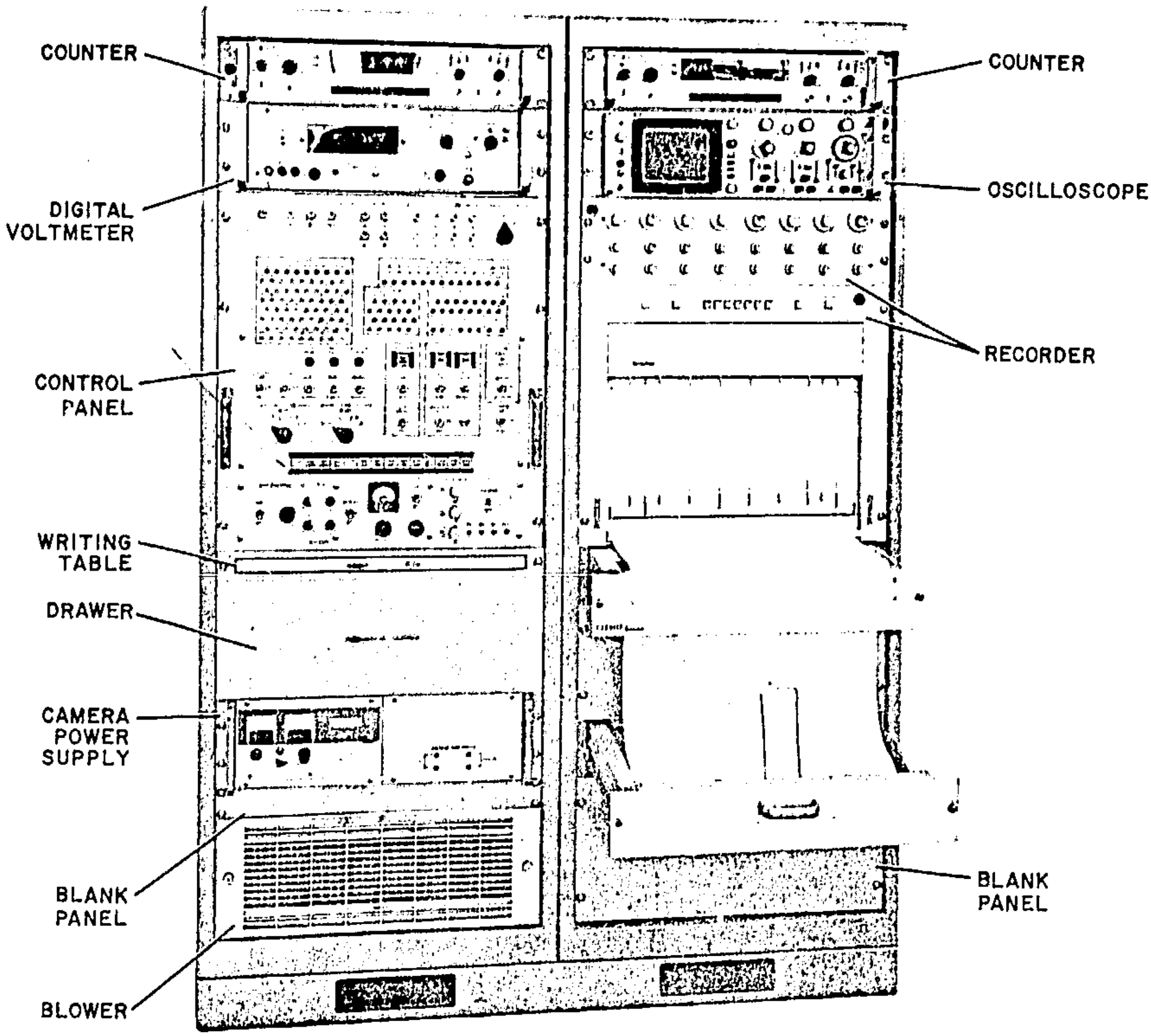


Figure 26 Functional Test Set

control will be deleted from the FTS. A battery assembly will be added, in order to operate the camera under simulated flight conditions. Two new test cables, control and heat shutter, will be required.

After completion of all reconditioning and modification, the FTS will be fully tested to an Acceptance Test Procedure (ATP) reflecting MCS/CANISTER requirements.

3.5.2 Portable Test Set

The Portable Test Set (PTS) part number 1231G80 is housed in a portable transit case, see Figure 27. The lower section of the PTS contains the operating controls and indicators, the upper section of the case houses the GN_2 Flowmeter, AEC lamp and test cables. The PTS provides a mobile and compact test facility for checking and testing the Mapping Camera Subsystem (MCS).

The PTS, presently at FISD, will require reconditioning and modification to enable the test set to meet MCS/canister requirements.

The PTS reconditioning will include replacement of defective components from large periods of non-use, repair or replacement of damaged or faulty indicators and controls, and the recalibration of the GN_2 Flowmeter.

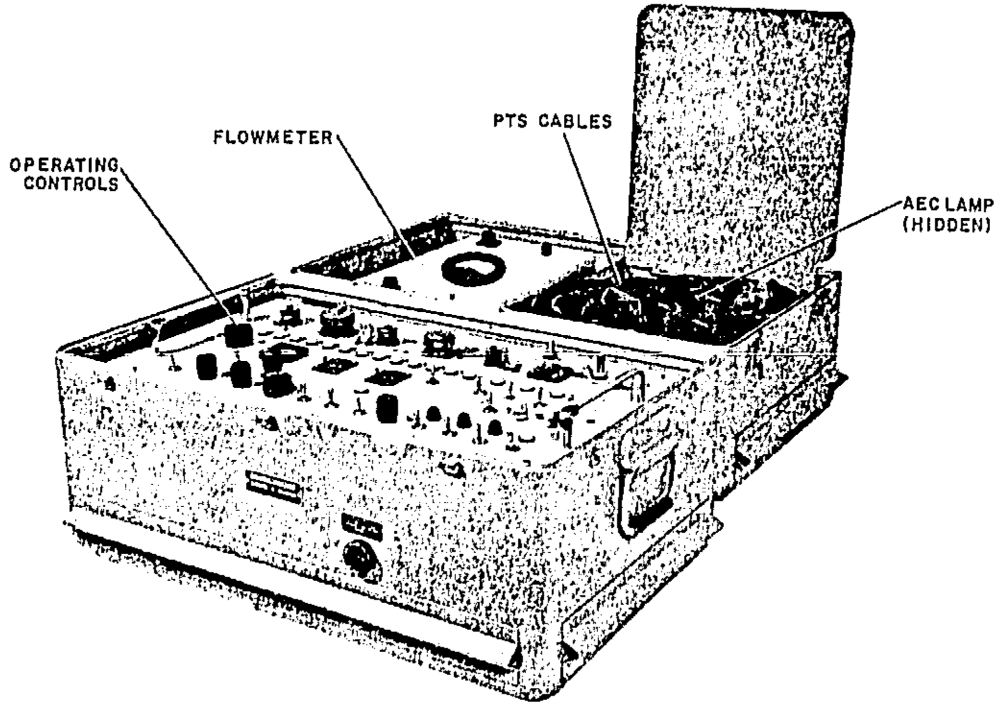


Figure 27 . Portable Test Set and Cables

Modification to the PTS will cover additions, deletions, and changes to controls and circuits. A new V/H and battery power control will have to be added. The IMC control will require modification and the deployment control will require deletions.

At the completion of all reconditioning and modification, the PTS will be fully tested to an Acceptance Test Procedure (ATP) reflecting MCS/Canister requirements.

3.6 TEST AND QUALITY ASSURANCE

3.6.1 Acceptance Test Procedure

The ATP used to accept the camera for the Apollo flights has been reviewed with the intent of elimination of non essential testing.

Verification of the stability of the stellar calibration is desirable since the MCS will be returned and post flight measurement is possible.

This was not the case in the Apollo Lunar Program because the MCS did not return to earth.

Several ways in which this measurement could be made are discussed below under "Stellar Calibration."

3.6.1.1 ATP Omissions

No acceptance data package will be prepared nor will the following other features be tested:

Grid Plate Calibration	- Not essential
Weight and C.G.	- Not essential
Deployment Tests	- Not required
Vibration	- Run at GSFC during system integration
Thermal Vacuum	- Run at GSFC during system integration
Forward Motion Compensation	- The FMC mechanism is a mechanically coupled arrangement that can be checked by observation. Since the FMC test fixture is a very involved expensive device and no longer available, the FMC function will be observed for operation but not photographically checked.

Stellar Calibration - In order to determine that the stellar calibration did not change in flight, it should be measured after the OFT runs. The original resolution test fixture could do this job but since this fixture is no longer available and would be too costly to replace other ideas are considered.

Self Stellar Calibration

The earth has been mapped and with only a few exceptions, in mid-ocean and desert areas, there are sufficient control points to provide a rigid geometric model of the earth. Where control points are missing, sophisticated bridging techniques maintain geometry of the earth to within a few seconds of arc.

The intrinsic geometry of the camera has been established at Fairchild by proven techniques on precision calibration equipment accurate to within two seconds of arc.

The camera, plus its clock, is thus its own calibrator, providing accurate angular orientation and nadir reference through standard rectification techniques.

Additional confirmation of the orientation can be obtained from the stellar camera, again established by in-flight calibration. It is emphasized that this is a corroborating procedure not essential to the basic mapping accuracy of the camera system.

Other artificial techniques could be employed as prior and post operation checks. However, they would fall far short of the accuracy obtainable from today's precision earth model.

Collimated Fixture

A new fixture could be built similar to the original equipment but simplified. This fixture would contain two accurately positioned collimators in each field of view to yield photographs that demonstrate the stellar calibration angle. Subsequent use will allow comparison and shift of the stellar view, if any, determined to within seconds of arc. This fixture would still be expensive to fabricate since the stability and accuracy of the basic structure is still required.

Laboratory Stellar Angle Measurement

Collimators could be accurately set up at the stellar angle on solid benches in a precision environmentally controlled laboratory.

Photography of the projected collimated images before and after flight will reveal any interior camera orientation shift.

3.6.2 Quality Assurance

This program, being austere, will not be covered by the normal DCAS surveillance but will be monitored directly by GSFC personnel. All work will be to military and Fairchild standard practices. The QA tasks are:

- Incoming Inspection without Disassembly
- Repair all Minor Discrepancies
- Major Repairs will be Discussed with Customer prior to Repair
- All Inspection to Military Practice
- ATP Less Tasks above in Paragraph 3.6.1.1
- Final Cosmetic Inspection after ATP

3.7 FIELD SUPPORT

Support will be provided for the various test levels and program phases as described in paragraph 4.0. In support at GSFC during Level IV verification and integration testing, the services of one qualified camera field technician and one camera engineer will be required as necessary. They will perform the following tasks during the scheduled seven month period:

- unpack and inspect the MCS and GSE
- setup and baseline test GSE
- setup and baseline test MCS

- aid in integration of data processing subsystem with MCS-LIDAR System
- Complete system test
- aid in installing LITE system on pallet
- aid in testing

  GSE Compatibility

  Thermal

  Vibration
- break down systems, pack and ship

Similar support will also be provided at the staging area during the seven month period to:

- unpack and inspect the MCS and GSE
- setup and baseline test of GSE
- setup and baseline test of MCS
- aid in integrating LITE into STS
- run operational verification test
- remove film from canister post-flight

NASA-CR-152616

ENGINEERING STUDY FOR PALLET ADAPTING THE APOLLO LASER ALTIMETER AND PHOTOGRAPHIC CAMERA SYSTEM FOR THE LIDAR TEST EXPERIMENT ON ORBITAL FLIGHT TESTS 2 AND 4

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Fairchild Imaging Systems Division
300 Robbins Lane, Syosset, New York 11791

August 12, 1977
Final Report
Appendix

Prepared for

GODDARD SPACE FLIGHT CENTER

Greenbelt, Maryland 20771

4.0 PROGRAM PLAN

The program is planned to coincide with the major milestones of the Lidar Experiment Program Plan as outlined in the Lidar Test Experiment Program for OFT-2 and OFT-4 dated December 1976. The schedule and time frame of events is depicted on Figure 28.

4.1 PROGRAM PHASES

In keeping with the austere program requirements, the interface, design, fabrication and test phases in Syosset were shortened by one month so that these activities could be completed in August 1978. In place of DCAS surveillance, GSFC personnel will monitor all phases of the program. The phases are:

4.1.1 Interface (1 October through 1 December 1977)

This two month period is allocated to finalize all the MCS Canister - STS interface information so that all needed information will be on hand by 1 December 1978.

4.1.2 Design Phase (1 December 1977 through 1 April 1978)

Design and drawings will be prepared during this phase.

4.1.3 MCS Modification (1 March 1978 to 1 July 1978)

The MCS will be modified in accordance with approved drawings and new features will be procured, fabricated and assembled.

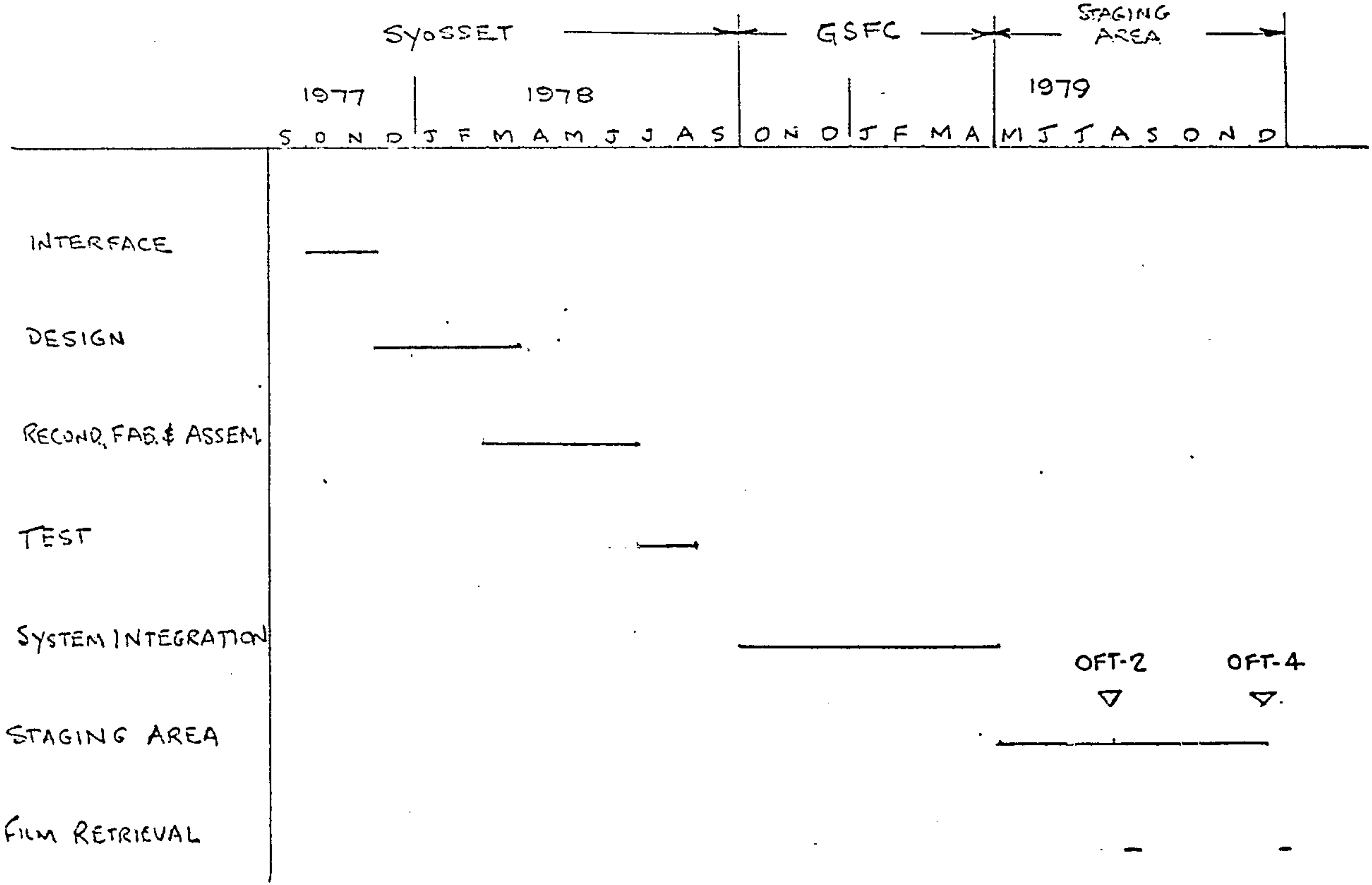
4.1.4 Test (1 July 1978 through 1 September 1978)

The MCS and added features will be tested in accordance with the ATP description in paragraph 3.6.1. GSFC personnel may witness this testing.

4.1.5 Integration at GSFC (1 October 1978 to 1 April 1979)

This period will be supported by qualified Fairchild personnel to keep the MCS equipment continually operative during the integration and test period.

SCHEDULE



MCS FOR LIDAR PROGRAM

FIG. 28

4.1.6 Flight Phase (1 April 1979 to 15 December 1979)

This phase where the MCS will be mated to the pallet and subsequently to the STS will be supported by Fairchild field personnel as necessary on an on-call basis.

4.1.7 Post Flight (23 July to 22 December 1979)

Fairchild field personnel will retrieve the film canister and deliver it for processing by NASA.

4.2 PROGRAM MANAGEMENT

The Lidar Test Experiment Mapping Camera System project will be the responsibility of the Photographic Systems Department where the camera system was originally conceived and designed. Some of the original design personnel will provide inputs and minimize the effort required.

The program will be under the control of an Engineering Program Manager who will be responsible technically as well as administratively.

4.3 PROGRAM COSTS

Program costs are based on the program schedule which will run for two years as shown on Figure 28. While only the first year will be wholly at Syosset, the program manager, who is also the program mechanical engineer, and his administration staff, will control the efforts and expenditures throughout the entire two year period.

The orbital thermal effects are much more extreme for OFT-4 so that the simpler thermal design for OFT-2 would not suffice for OFT-4. Therefore, in order to weigh this cost impact. The cost for these items have been separated rather than being provided within the total program costs.

4.3.1 Orbital Flight Test-2

The costs for OFT-2 are shown in Table 2. This unit will be satisfactory for OFT-2 only.

4.3.2 Orbital Flight Test-4

Additional thermal protection necessary to survive the OFT-4 environment is presented as add-on costs to OFT-2 costs. These are shown in Table 3.

4.3.3 Orbital Flight Test-4 with Rotated Mount

In order to accommodate the MCS built-in FMC to improve the flight resolution, an adapter to rotate the MCS is required. The cost for this feature, if provided, is indicated in Table 4.

4.3.4 Cost Summary

The summarized costs of OFT-2, OFT-4 and OFT-4 with rotation adapter are shown in Table 5.

ORBITAL TEST FLIGHT - 2 COSTS

MCS REWORK	$ 51,535
STANDARD MOUNT	$ 34,692
THERMAL INSULATION	$ 13,984
CABLES	$ 12,876
HOISTING YOKE	$ 1,596
G.S.E. REFURBISH	$ 22,109
DOCUMENTATION	$ 18,311
GN_2 SUPPLY	$ 3,309
MANAGEMENT	$ 91,491
• TOTAL HARDWARE COSTS	$249,898
FIELD SUPPORT	$ 38,689
• TOTAL OFT-2 PROGRAM COSTS	$288,587

TABLE 2

ORBITAL TEST FLIGHT - 4 Δ COSTS

THERMAL SHUTTER	$17,093
THERMAL SHIELDS	$ 8,934
MANAGEMENT	$ 6,961
• TOTAL Δ HARDWARE COSTS	$32,988
Δ FIELD SUPPORT	$14,951
• TOTAL Δ PROGRAM COSTS	$47,939

TABLE 3

ORBITAL TEST FLIGHT - 4 ROTATED MOUNT

MOUNT-ROTATED $ 27.564

TABLE 4

COST SUMMARY

	OFT-2	OFT-2 OFT-4	OFT-2 OFT-4R
HARDWARE	$249,898	$282,886	$310,450
PROGRAM	$288,587	$336,526	$364,090

TABLE 5

4.3.5 Cost Details

Find cost details to support the above program costs in the following pages.

MCS REWORK

TASK:
- ADD BAFFLES TO STELLAR GLARE SHIELD
- LOCK STELLAR GLARE SHIELD
- LOCK DEPLOYMENT MOUNT & DISABLE DRIVE
- DRILL MOUNTING FEET
- CLEAN OPTICS
- RUN A.T.P.
- TOUCH UP
- INSTALL IN TRANSPORT CASE

LABOR

DESCRIPTION	HOURS
Program Manager	120
Engineer	160
Design Leader	160
Technician	200
Machine Shop	160
Finishing	10
Mechanical Assy	250
Qual. Assurance Engr.	18
Qual. Analyst	6
Mech. Assy Insp.	38
Incoming Inspection	8
Optical Technician	232
Optical Engr.	104
Environ. Tech.	60
Environ. Engr.	30
Qual. Assurance Clerk	20

MATERIAL

DESCRIPTION	$
Raw Material	100.00
Film	2000.00

TOTAL $51,535.00

STANDARD MOUNT

TASK: FABRICATE MOUNT ELEMENT
MACHINE PRECISION SURFACE & HOLES
MACHINE FOOT INSULATORS

LABOR

DESCRIPTION	HOURS
Program Manager	120
Sr. Staff Engr. (Stress Analysis)	100
Design Leader	200
Draftsman	200
Machine Shop	200
Finishing	20
Mechanical Assy	40
Vendor Control	16
Qual. Analyst	2
Shop Inspection	20
Qual. Assur. Clerk	2

MATERIAL

DESCRIPTION	$
Engr. Material	100.00
Raw Material	400.00
Sub-Contract	3300.00
Packaging	150.00

TOTAL $34,692.00

THERMAL BLANKETS FOR CFT-2

TASK: PROVIDE FOR DESIGN AND ATTACHMENT OF THERMAL BLANKETS

LABOR

DESCRIPTION	HOURS
Program Manager	10
Sr. Staff Engr. (Thermal Analyst)	150
Engineer	40
Design Leader	100
Machine Shop	8
Mechanical Assy	8
Vendor Control	8
Shop Insp.	4
Q.A. Clerk	2

MATERIAL

DESCRIPTION	$
Engr. Mat'l	200.00
Purchased Parts	50.00
Sub-Contract	1500.00

TOTAL $13,984.00

CABLES

TASK: BUILD AND TEST CABLES FROM MCS TO CANISTER

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Engineer	160	Raw Material	1000.00
Layout Draftsman	80		
Technician	200		
Qual. Analyst	2		
Elec. Assy Insp.	8		
Incoming Insp.	6		
Q.A. Clerk	2		

TOTAL $12,876.00

HOISTING YOKE

TASK: BUY WELDMENT AND FABRICATE SOME PARTS AND ASSEMBLE

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Machine Shop	8	Purchased Parts	488.00
Finishing	2		
Mech. Assy	2		
Vendor Control	16		
Q.A. Clerk	2		

TOTAL $1596.00

G.S.E. REFURBISH

TASK: MODIFY AND REFURBISH THE FUNCTIONAL AND PORTABLE TEST SETS

LABOR

DESCRIPTION	HOURS
Engineer	220
Sr. Designer	100
Technician	180
Mech. Ass'y	40
Qual. Analyst	6
Mech. Ass'y Insp.	20
Elec. Ass'y Insp.	30
Incoming Insp.	6
Elec. Tech (Q.A.)	4
Jig & Fixture Tech (QA)	120
Q.A. Clerk	6

MATERIAL

DESCRIPTION	$
Purchased Parts	1700.00
Packaging	200.00

TOTAL $22,109.00

DOCUMENTATION

TASK: PREPARE SUPPLEMENT TO:
MCS OPERATION AND INSTRUCTION MANUAL
MCS GROUND SUPPORT EQUIPMENT OPERATION AND INSTRUCTION MANUAL
MCS A.T.P.
FUNCTIONAL TEST SET A.T.P.
PORTABLE TEST SET A.T.P.
PREPARE A NEW ELECTRICAL INTERFACE DOCUMENT

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Program Manager	100	Engr. Material	50.00
Engineer	160		
Tech. Service G.S.	50		
Tech. Writer	80		
Tech. Illustrator	80		
Photographer	40		
Clerical	200		

TOTAL $18,311.00

GN_2 SUPPLY

TASK: DESIGN, FABRICATE AND TEST A GN_2 SUPPLY SYSTEM FOR THE MCS

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Program Manager	10	Purchased Parts	150.00
Design Leader	40		
Technician	8		
Machine Shop	20		
Mech. Ass'y	5		
Qual. Analyst	1		
Shop Insp.	4		
Incoming Insp.	2		
Envir. Tech.	4		
Envir. Engr.	2		
Q.A. Clerk	4		

TOTAL $3309.00

MANAGEMENT - OFT-2

TASK: THE PROGRAM MANAGER, WHO IS ALSO THE MECHANICAL ENGINEER, WILL PROVIDE CONTINUOUS DIRECTION OF THE PROGRAM FROM START TO RECOVERY OF LAST FLIGHT FILM.

LABOR

DESCRIPTION	HOURS
Program Manager	864
Administrator	1060
Clerical	1060

MATERIAL

DESCRIPTION	$
Reproductions	500.00
Travel	4300.00

TOTAL $91,491.00

FIELD SUPPORT - OFT-2

TASK: TO SUPPLY, ON DEMAND, ONE FIELD ENGINEER AND ONE CAMERA SPECIALIST AS NECESSARY

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Program Manager	120	Air Fare - 4 trips @ $75. =	$300.
Engineer	664		
		VAFB	
		Air Fare - 4 trips @ $450. =	$1800.
		Per Diem - 98 days @ $50. =	$4900.
		Car Rental - 98 days @ $33 =	$3234.

TOTAL $38,689

ORBITAL TEST FLIGHT - 4 Δ COSTS

THERMAL SHUTTER

TASK: DESIGN, FABRICATE AND TEST A THERMAL SHUTTER

LABOR

DESCRIPTION	HOURS
Program Manager	100
Sr. Staff Engr.	20
Engineer	50
Design Leader	100
Layout Draftsman	40
Technician	20
Machine Shop	80
Finishing	8
Mech. Ass'y	30
Qual. Analyst	4
Mach. Ass'y Insp.	8
Shop Insp.	16
Incoming Insp.	4
Q.A. Clerk	4

MATERIAL

DESCRIPTION	$
Raw Material	50.00
Purchased Parts	750.00

TOTAL $17,093.00

THERMAL SHIELD AND INSULATION FOR OFT-4 Δ COSTS

TASK: ADDITIONAL COSTS REQUIRED TO CONVERT OFT-2 THERMAL INSULATION COSTS TO SATISFY OFT-4 REQUIREMENTS. DESIGN, FABRICATE, ASSEMBLE AND TEST HEAT SHIELD AND THERMAL BLANKLT.

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Program Manager	90	Purchased Parts	3 50.00
Design Leader	60		
Machine Shop	42		
Finishing	8		
Mech. Ass'y	22		
Mech. Ass'y Insp.	6		

Δ COSTS TOTAL $8,934.00

MANAGEMENT OFT-4 Δ COSTS

TASK: ADDITIONAL MANAGEMENT COSTS TO EXTEND THE PROGRAM TO COVER OFT-4

LABOR		MATERIAL	
DESCRIPTION	HOURS	DESCRIPTION	$
Program Manager	96	Travel	500.00
Administrator	40		
Clerical	40		

TOTAL $6961.00

FIELD SUPPORT OFT-4 Δ COSTS

TASK: ADDITIONAL COSTS TO EXTEND SUPPORT TO OFT-4

LABOR		MATERIAL		
DESCRIPTION	HOURS	DESCRIPTION		$
Program Manager	24	- VAFB		
Engineer	272	Air Fare		
		3 trips @ $450	=	$1350.00
		Per Diem		
		37 days @ $50	=	$1850.00
		Car Rental		
		37 days @ $33	=	$1221.00

TOTAL $14,951.00

MOUNT ROTATING ADAPTER

TASK: FABRICATE MOUNT ELEMENT
MACHINE PRECISION SURFACES
FABRICATE BRACE TO PALLET

LABOR

DESCRIPTION	HOURS
Program Manager	80
Sr. Staff Engineer	80
Design Leader	160
Layout Draftsman	160
Machine Shop	60
Finishing	10
Mech. Ass'y	40
Vendor Control	16
Quality Analyst	2
Shop Inspection	16
Q.A. Clerical	2

MATERIAL

DESCRIPTION	$
Engineering Mat'l	100
Sub Contract	5000

TOTAL 27,564.00