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FINAL REPORT

SURVEY STUDY OF THE DATA ACQUISITION POTENTIAL OF THE "ENHANCED" MOL/DORIAN BASELINE SYSTEM DURING THE BLOCK II (JULY '74 - JAN. '76) TIME PERIOD

PREPARED BY: MOL SYSTEMS DEVELOPMENT OPERATION

9 MAY 1969

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1. INTRODUCTION

This report summarizes the results of a study conducted by the MOL Systems Development Operation in response to a request from the Aerospace Corp. The study was conducted between 21 April 1969 and 9 May 1969.

The objective of the study was to provide information on the overall data acquisition potential of the "Enhanced" MOL/Dorian system during the Block II time period, considering new "add-on" sensors and new operational concepts. The flight schedule assumed for this study is as follows:

Block I (Baseline) (Manned Flights only)

DATE	FLIGHT NO.
July 1972	(2)
Jan. 1973	(3)
July 1973	(4)
Jan. 1974	(5)

Block II (Enhanced Baseline) (Manned Flights only)

DATE	FLIGHT NO.
July 1974	(6)
Jan. 1975	(7)
July 1975	(8)
Jan. 1976	(9)

The photographic technical intelligence objectives of the baseline Block I system are assumed to be carried over into Block II. Adjunct missions are assumed to be secondary, with minimum degradation of the effectiveness of the MOL/Dorian system in the photographic technical intelligence mode. The changes to the baseline (Block I) hardware are not expected to be drastic, with the major Block II deltas to be in the form of new (additional) equipment required to improve the data acquisition capability of the MOL/Dorian system/mission in Block II. Relatively small ($<$1,000 lbs.) on-orbit weight increases are assumed to be tolerable.

This report presents the results of the study in the form of "adder" options which should be considered for the Block II systems. Descriptive, cost, schedule and performance data are provided for most of the options considered valuable enough for inclusion in this report. Based on the option-data, two different "enhancement" implementation roadmaps were developed. (Section 2.0) One roadmap depicts a technology/schedule constrained implementation plan; the other a real-world, dollar-constrained implementation plan.

The "enhancement" option areas discussed in further detail in this report are as follows:

<u>Sensor Packages</u>

- Infra-red/Multispectral
- UV Astronomy
- [redacted]
- ATS Scene Recording/Transmission
- MO Scene Transmission

<u>Operational Packages</u>

- High/Medium Resolution Readout Operations
- Targetting Operations

The following items are discussed only briefly:

- Extended Duration
- EK Performance Improvements
- [redacted]
- Fly-low Mission

Extended Duration

GE's study report on Extended Duration was submitted to the AF/AS in March 1969. The study concluded that a 15-day extension to the baseline on-orbit life of 30 days would present no difficulties to the mission payload systems (GE and EK). The data presented in the subsequent sections of this report are essentially valid, regardless of any AF decision on extended duration. In one respect, an extended duration Block II mission is advantageous to "enhancement" since more mission time would be available for programming the new sensor packages and the new operations. The primary disadvantage of the longer mission is the reduction of weight available for new sensor packages and operations.

EK Performance Improvements

GE's study report on the effect of EK performance improvements on the GE hardware was submitted to the AF/AS in January 1969. The study identified the accommodation impact of the elliptical tracking mirror, relay camera, and miscellaneous optical improvements. In summary, the relay camera and miscellaneous optical improvements are readily accommodated, with little impact on the baseline system. The substitution of the elliptical tracking mirror, however, while totally feasible, does have significant impact.

The advantages of the relay camera are obvious since it improves the versatility of payload at relatively low overall cost. On the other hand, the miscellaneous optical improvements and elliptical tracking mirror produce relatively minor performance improvements at relatively high cost.

The data presented in the subsequent sections of this report is valid, regardless of any AF decision on EK performance improvements. The primary disadvantage is the reduction of weight and dollars available for new sensor packages and operations.

[redacted]

Fly-low Mission

Where the acquisition of a few "super" resolution photographs is very important, short-duration "fly-low" operations may permit the resolution objectives to be satisfied. A survey report on the "fly-low" mission was submitted to the AF/AS in mid-1968. The report concluded that nearly all of the geometric advantages of flying-low would be realized for one or two revs. For more than a couple of revs, the OV heating problems become evident and the geometric resolution gains are negated.

It may be desirable to consider relatively simple hardware mods in Block II to permit the acquisition of extra high-resolution photographs [redacted] for up to 8 revs by combining fly-low operations with Photographic Section improvements.

2.0 SYSTEM SELECTION SUMMARY

Data generated in support of the various Block II improvements has been used as a basis for a Block II system selection. Two systems have been developed; first, a technology/schedule constrained system and, second, a real-world dollar constrained system.

The dollar constraints considered for this report are shown in Table 2.0-1. The amounts shown were selected by GE personnel as being correct for the time period shown with consideration given to the present and expected fiscal situation. The dollar amounts shown are considered to be those additional dollars which would be made available to GE for Baseline MOL changes.

Selected data from the improvements covered in this report are shown in Table 2.0-2. It should be noted that the dollars shown in Table 2.0-2 are "program" dollars and include items such as:

- Design and Development Costs
- Qualification Testing
- Acceptance Testing
- One Set of Flight Hardware

Inasmuch as possible, these are considered to be non-recurring costs and are as complete as could be obtained within the time allotted. For instance, the 32.5 million estimated for Read-Out includes 16.0 million for one relay satellite.

TYPE OF PROGRAM	FISCAL YEARS										
	70	71	72	73	74	75	76	77	78	79	80
1. Studies, Minor Mods Adders	.2	1.0	3.0	10.0	12.0	15.0	10.0	10.0	10.0	10.0	10.0
2. Baseline Changes "Same" Vehicle	1.0	5.0	12.0	20.0	46.0	60.0	60.0	60.0	60.0	60.0	60.0
3. New Vehicle New Development	5.0	20.0	80.0	100.0	150.0	200.0	200.0	200.0	150.0	100.0	80.0

- GE dollars: (part of Total Dollars)
- Millions of Dollars

TABLE 2.0-1

ESTIMATED FUNDING PROJECTIONS - MOL

	WEIGHT	TIME	COST
	#	Yrs.	$\$x10^{-6}$
Far Infra-red	[redacted]	3	12
[redacted]		4.5	12.5
High/Medium Resolution Read-Out	87	3	32.5
Geodetic Targetting	90	4.5	6
ATS Scene Recording/Transmission	15	2	1.5
MO Scene Transmission	10	2	2.5
Multispectral	10	1	.3
Ultra-violet Astronomy	800	5	20

TABLE 2.0-2 BLOCK II IMPROVEMENTS

As shown in Table 2.0-2, all improvements with the exception of Ultra-violet Astronomy could meet a schedule of inclusion in Flight 6, and UV Astronomy could be scheduled for Flight 7. This assumes a start date of January 1970, and a launch date for Flight 6 of July 1974.

Table 2.0-3 provides data concerning hardware required for the preferred options of the improvements being considered. This data, plus data available from Tables 2.0-1 and 2.0-2, provided a basis for selection of the option implementation systems for Block II.

SECTION NUMBER	PREFERRED SYSTEM	REQUIRED HARDWARE (NEW OR ADDED COST)
3.1	READ-OUT	Image Formatter, Laser Scanner, A/D Encoder, Encryptor, X-Band Communications Link, Steerable Antenna, Relay Satellite
3.2	GEODETIC TARGETTING	Laser Ranging Device (Transmitter, Receiver, Power supply)
4.1	IR/MULTISPECTRAL	
	FAR IR	[redacted]
	MULTISPECTRAL	Rapid change filter package for relay camera
4.2	UV ASTRONOMY	Primary Optics, Folding Mirror Reconfiguration, Added Optics Barrel, UV/IR Detector Packages, Coax Transmitter, Broadband Tape Recorder, Read-Out System
4.3	[redacted]	[redacted]
4.4	ATS/MAIN OPTICS IMAGING	
	RELAY (MAIN) OPTICS	TV Camera, Read-Out System
	ATS OPTICS	Interior Flip Mirror, Adapter Lens, 70 MM Camera, Filter Pack, Storage Cassettes

TABLE 2.0-3 BLOCK II IMPROVEMENT SUMMARY

2.1 TECHNOLOGY/SCHEDULE SYSTEM SELECTION

Configurations selected for Block II flights are shown in Table 2.1-1. Reasons for the selection of these configurations are based on the improvements indicated in this report, are discussed below. It should be emphasized that this system selection was not constrained by questions of available resources. Rather, the constraint was "technology".

[redacted]

As an adjunct to the Dorian TI mission, IR data of the same area of coverage appeared to be next most important. Inclusion of this improvement provides an entirely new area of intelligence data without altering or degrading the basic TI mission.

[redacted]

The inclusion of the IR sensor and the read-out package required a modification to the structure of the mission module. Because of the practical reasons for. making revisions at only one time, the EK improvements (elliptical mirror and relay camera) were also included in Flight 6.

TECHNOLOGY/SCHEDULE CONSTRAINED

FLIGHT 6 (JULY 1974)		7	FLIGHT 8 (JULY 1975)		9
WT.	B/L Mission [redacted]	SAME AS FLIGHT 6	774	Flight 6 as B/L	SAME AS FLIGHT 8
605	FAR IR [redacted]		90	Geodetic Targetting 100' CEP	
62	[redacted]		15	ATS Scene Recording Off-Axis Camera Photographs	
87	High/Medium Res. Read-Out Data Link to Ground		10	Main Optics Scene Trans. TV by Data Link to Ground	
20	EK Improvements Relay Camera Photographs		10	Multispectral	
	WT. = 774 pounds			WT. = 899 pounds	

TABLE 2.1-1
BLOCK II OPTION IMPLEMENTATION

The addition [redacted] Far IR, Read-Out, and EK improvements to the baseline mission provides a technology constrained system for Flight 6.

Flight 7 has been left identical to Flight 6 in order to obtain the advantages of the"learning curve". It was not felt desirable to make revisions on each flight.

All remaining improvements with the exception of Ultra-violet Astronomy were included in Flight 8 and Flight 9. Ultra-violet Astronomy was not included in any of the Block II flights for the following reasons:

1) The Large weight delta (800 pounds) would require that other improvements be removed in order to install UV Astronomy.

2) UV Astronomy does not appear to add to the basic MOL Dorian TI mission.

3) Similar type capabilities are planned for other satellites.

4) The long development/lead time (5 years) coupled with the structural revisions required in the Mission Module lead to a decision not to include UV Astronomy in Block II vehicles.

2.2 RESOURCE CONSTRAINED SYSTEM

In order to obtain an indication of the resources available for Block II MOL vehicles, the data from Table 2.0-1 was utilized. The resources shown are considered available to GE and the GE cost of providing the various improvements was calculated. Essentially, these costs are the same as those shown in Table 2.0-2.

The dollar figures used were those listed under "Baseline Changes - 'Same' Vehicle" of Table 2.0-2, while certain of the improvements are considered to be only minor modifications, items such as Far IR, [redacted] and Read-Out are considered to be more than "minor modifications".

Based on the resources available and the estimated cost of the improvements, the system selected for the Technology/Schedule constraints was examined in order to determine whether the same system could be implemented. The results indicate that the same system could be had based on Technology constraints or on resource constraints. However, about 10 million dollars must be expended during fiscal year 1974 in order for the selected improvements to be added to Flight 6. This requires a very close scheduling between the total vehicle flow and the improvement flow. This was felt to be well within the capability of present scheduling procedures. Therefore, the system selected for technology constraints was also acceptable based on resource constraints. Table 2.2-1 reiterates the system selection.

It should be noted that a completely different system selection would be made based on the resources identified in Table 2.0-1 titled "Studies, Minor Modification, Adders". The availability of these limited funds would result in an austere system selection.

RESOURCES CONSTRAINED

FLIGHT 6 (JULY 1974)		7	FLIGHT 8 (JULY 1975)		9
WT.	B/L Mission [redacted]	SAME AS FLIGHT 6	774	Flight 6 as B/L	SAME AS FLIGHT 8
605	[redacted]		90	Geodetic Targetting 100' CEP	
62	[redacted]		15	ATS Scene Recording Off-Axis Camera Photographs	
87	High/Medium Res. Read-Out Data Link to Ground		10	Main Optics Scene Trans. TV by Data Link to Ground	
20	EK Improvements Relay Camera Photographs		10	Multispectral	
	WT. = 774 pounds			WT. = 899 pounds	

TABLE 2.2-1

BLOCK II OPTION IMPLEMENTATION

3.0 OPERATION PACKAGES

3.1 HIGH/MEDIUM RESOLUTION READ-OUT

3.1.1 INTRODUCTION

3.1.1.1 The Need for a Read-out System (Rho)

During a mission, the MOL vehicle will have access to many targets which will be of immediate intelligence value. These targets are of the event warning and crisis management types. Additionally, regularly scheduled targets with unexpected activity as well as unscheduled targets of opportunity are candidates which would be read-out if the capability existed on-board the vehicle.

Due to the nature of these targets, the intelligence value of their photographs decreases with time. It is important to deliver their information to the user in the shortest time possible.

The present MOL has a mission duration of 30 days with possible plans in Block II for an extension beyond that time. Without read-out, all photographic data remains unavailable until the end of the mission. This time lag is acceptable for the primary mission (technical intelligence) of MOL, however, it is unacceptable for the type of mission considered here.

In addition to the return of timely data, the read-out system could be used to return regularly scheduled technical intelligence photographs to provide some measure of insurance against a total loss of data should there be an unsuccessful recovery of the hard copy data.

Separate from its own performance, the read-out system, or part of it, is necessary to support several of the Block II systems. The proposed imaging sensors such as multi-spectral, ATS camera, and UV astronomy present some of their data in film form. Reading this out to the ground would utilize the entire read-out system. Other systems, such as the [redacted] TV and the ATS advanced TV will utilize the communication capability only. While some of these experiments do not require urgent delivery of data, all could be initially checked and monitored out by a read-out system.

3.1.1.2 New Missions Enabled by the Availability of Read-out

1. Crisis Management

   By frequent and timely surveillance of crisis areas.

2. Event Warning

   Missile Tests

      Launch site or downrange activity

   Satellite launches

   Nuclear Testing

   ABM site activity

3. Targets of opportunity

      Chance observation of areas of unexpected activity

4. Request support

      To provide up-to-date information on a specific target in support of a newly developed need.

3.1.2 SYSTEM DESCRIPTION AND OPTION MAP

3.1.2.1 System Description

For purposes of convenience only one of the possible development paths of the read-out system will be discussed in this section. It is not necessarily the preferred approach to the problem from the projected study point of view, however, it will serve to permit discussion of a solution. It is assumed that transmission will be only a Conus station via a relay satellite.

Figure 3.1-1 shows a block diagram of a typical read-out system.

Black and white film, after on-board development by the bimat processor, will be examined by the crew, and target areas will be selected to be transmitted. With the selected film mounted in the laser scanner, the crewman initiates acquisition of the relay satellite. The operation of the scanner will be started automatically when the link has been established. Scanning of the film will continue until completion or until relay contact is lost.

The scanner output is an analog signal which is encoded into a digital stream by a device such as a delta modulator and PCM converter. This digital stream is encrypted and then phase modulated onto a carrier for inter satellite transmission with eventual realy into a continental U.S. (Conus) receiving station. At the Conus station, decryption and data reconstruction takes place resulting in a reproduction of the source material. The entire transmission and reconstruction takes place in real time, requiring consistent bandwidth capability in the MOL, the relay satellite, and the Conus receiving equipment. Because of the problem of picture smear due to mechanical vibration, it is assumed here that the communications antenna will be steered only when the tracking mirror is being slewed.

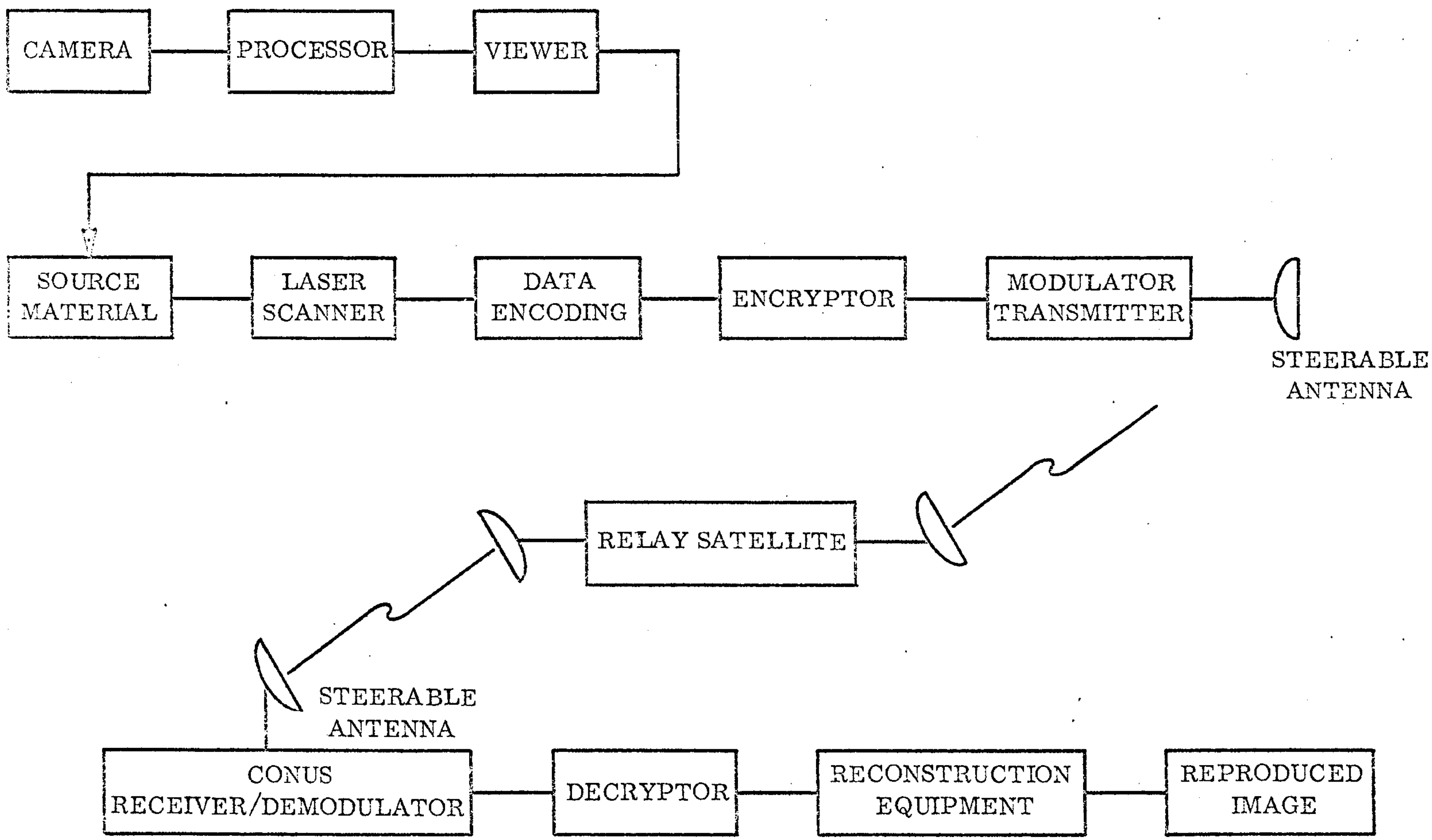


FIGURE 3.1-1. BLOCK DIAGRAM OF TYPICAL RHO SYSTEM

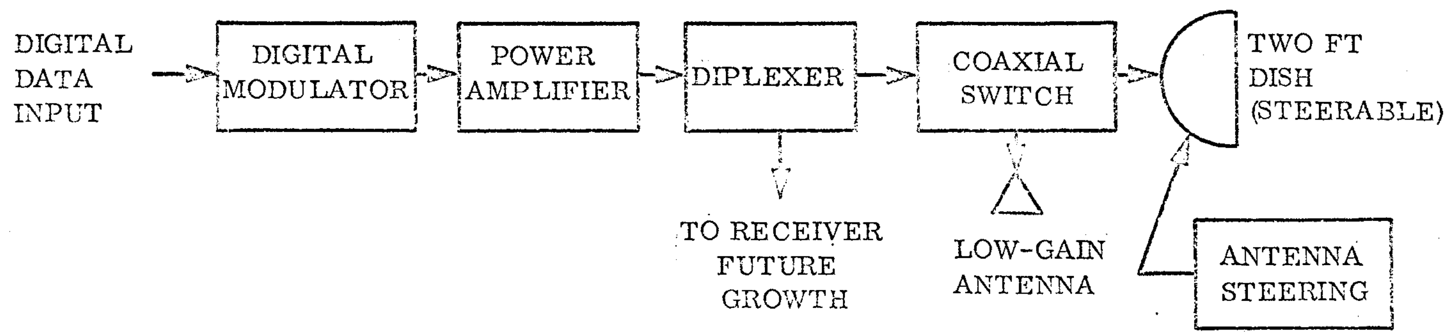


FIGURE 3.1-2. USER DATA COMMUNICATION SUBSYSTEM

Installation

Space is available in the baseline MOL to permit the installation of the read-out system. The system consists of the following fundamental units:

1. Film Processor (existing)
2. Viewing Table (existing)
3. Laser Scanner (new)
4. Digital Encoding Equipment (new)
5. Encryptor (existing, but must be modified)
6. Communication Equipment (new)
7. Steerable Antenna (new)

Items 3 and 4 can be mounted in the Laboratory Module in Console 2 Panel A. This location is a good choice for the following reasons:

- Efficient location with respect to operational requirements.
- Requires the least amount of changes in console component harnessing and plumbing installations.
- Places the film insertion opening close to the viewed in Bay 4.

Item 6 has been located in the forward end of the mission module between stations 415 and 450 half way between the +Y axis and the -Z axis. This requires the enlargement of the equipment bay in that part of the vehicle.

Item 7, the steerable two-foot antenna can be stowed within the vehicle envelope during alunch. It will be located, behind a blow-off door, between stations 415 and 450 half way between the -Y axis and the -Z axis. From this location the antenna can be deployed on a boom with sufficient length to permit viewing throughout the hemisphere away from the Earth. See Figure 3.1-3.

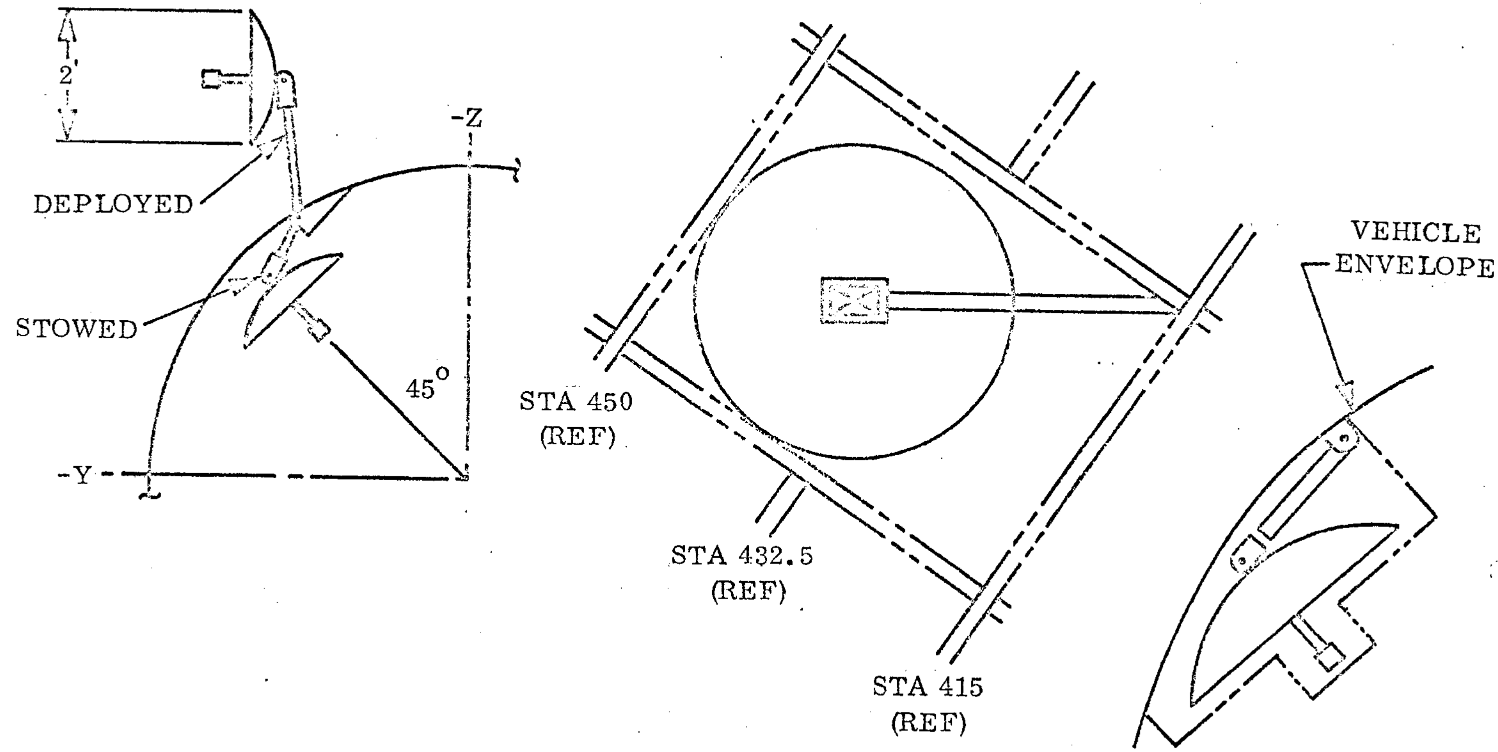


FIGURE 3.1-3. STEERABLE HIGH GAIN ANTENNA INSTALLATION FOR RELAY SATELLITE LINK

A second antenna is mounted on the vehicle as a redundant back-up to the loss of high gain antenna steering for some other interruption in the relay link.

This antenna can be located in the forward part of the mission module between stations 482.5 and 500 approximately 10 inches either side of the +Z axis. In this degraded mode downlink communications can be established with the Conus station when the orbit geometry permits.

Table 3.1-1 shows a sample link calculation for the relay link. The margin of 3.15 dB is calculated at the maximum communication range of 6,600 n.mi. and, therefore, represents worst case. The range during the transmission will always be less than or equal to this value.

TABLE 3.1-1 LINK CALCULATIONS USER TO MEDIUM ALTITUDE RELAY SPACECRAFT

	Loss (dB)	Gain (dB)	Power (dBM)
Transmitter Power (35 w)			45.45
Diplexer Loss	0.4		
Circuit Losses	0.8		
User Antenna Gain (2 ft. 8 GHz)		31.46	
Path Loss (6,600 nm)	192.2		
Medium Altitude Satellite Antenna Gain (8 ft.)		43.52	
Line Losses	0.3		
Pointing Loss	0.3		
Polarization Loss	0.1		
Power at Receiver			-74.7
Receiver Noise Density (7 dB NF)			-167 dBM/Hz
Bandwidth (30 MHz)	74.75		
Required S/N	13.4		
Link Degradation	1.0		
Power Required at Receiver			-77.85
Margin		3.15	

PHYSICAL PARAMETERS

COMPONENT	WEIGHT (POUNDS)	POWER (WATTS)
Low Gain Antenna	0.5	
Antenna Dish & Feed	4.0	
Modulator/Exciter	5.0	17.0
Travelling wave tube (includes power supply)	12.0	100.0
Diplexer	.8	
Antenna Deployment and Steering	20.0	15.0
Laser Scanner	40.0	50.0
Digital Encoding	5.0	5.0
	87.3	187.0

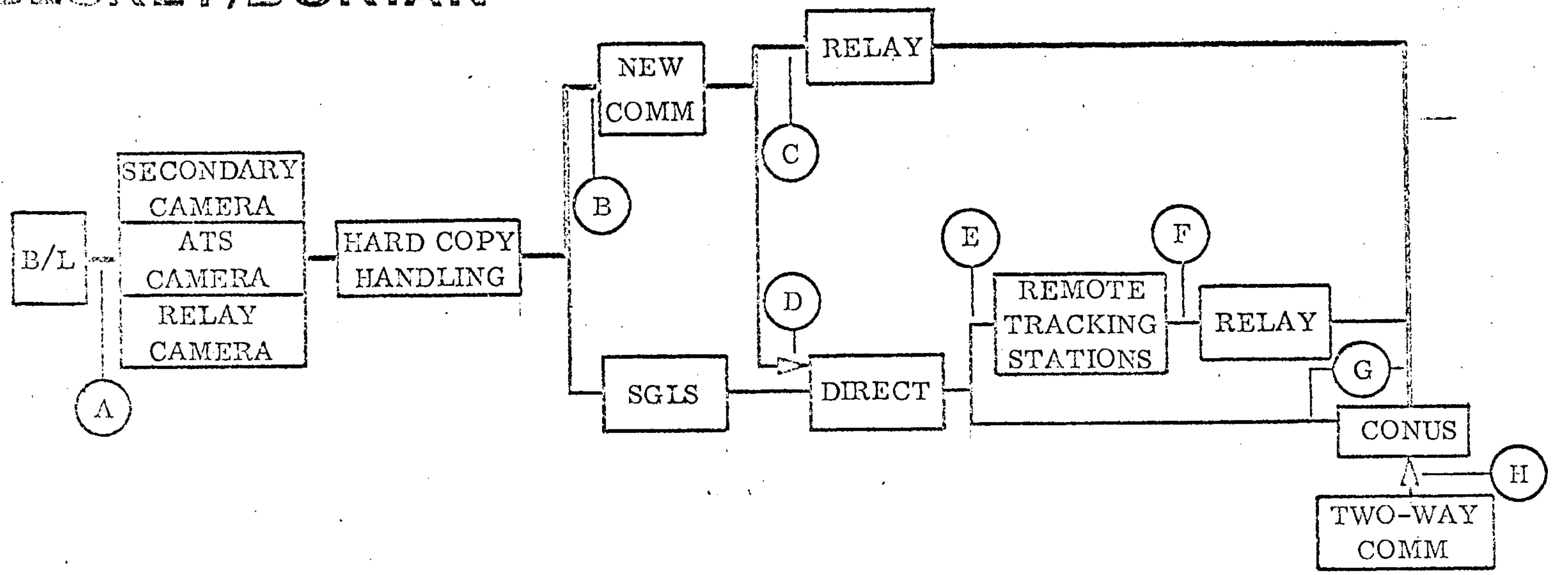
3.1.2.2 Rho System Option Map

The Rho option map is shown in Figure 3.1-4. It indicates the paths that the system could take as a means to the end result of delivering photographic data to the user. Indicated by a dotted path is a minimum cost minimum impact approach to the problem. This path, which utilizes the on-board SGLS link, and adds only minimal equipment to the AVE, requires the use of a satellite relay (similar to Compass Link) from the RTS to Conus. It has been ROM costed at about \$8.0 million.

A more advanced system would require the addition of a new MOL communications capability including possibly a steerable antenna. The development paths for this approach are shown on the option map along with technology or development areas needed for the program. From a data yield point of view, the path including the MOL to relay transmission is the desirable one. This would provide the longest contact times and, with a match of the data rate (much lower than that required for direct transmission) to the mission duration, the delivery of all photographic data to Conus throughout the mission.

The program cost for this approach is estimated to be $\$32.5 \times 10^6$ million with a development time of 30 months. Of this, $\$16.5 \times 10^6$ is the cost of the MOL AVE and ground station equipment. The remaining $\$16 \times 10^6$ is the cost of putting an operating relay satellite into a 360 x 4100 nm altitude highly inclined orbit. The costs include:

Engineering	Safety & Reliability
Design	Simulation & Training
Manufacture	Program Management
Integration	Contracts & Finance
Product Assurance	



A:
- FILM HANDLING AND SOURCE SELECTION
- LASER SCANNER
- TI AND/OR MEDIUM RESOLUTION ANALYSIS
- SUPPORTS FUTURE USE OF ELECTRONIC (TV) SCANNING OMEGA (Ω)

B:
- ENCRYPTION
- BANDWIDTH COMPRESSION
- WIDEBAND COMMUNICATION

C:
- STEERABLE ANTENNA
- INTER-SATELLITE COMMUNICATION
- MEDIUM DATA RATIO
- RELAY SATELLITE CAPABILITY

D:
- HIGH DATA RATES (STEERABLE ANTENNAS)

E:
- STORAGE EQUIPT (TAPE)
- GROUND STA DEVEL

F:
- GROUND LINK AND/OR SATELLITE LINKS

G:
- DESCRIPTION
- RECONSTRUCTION
- STORAGE EQUIPT (TAPE)

H:
- COMMAND UP-LINK

FIGURE 3.1-4. HIGH/MEDIUM RESOLUTION READOUT

3.1.3 PERFORMANCE CAPABILITY OF READ-OUT

The main optical system of MOL/Dorian is capable of delivering photographs, of 2:1 contrast ratio objects, with a resolution of [redacted] This resolution is equivalent [redacted] on the ground when viewed from an altitude of 80 miles, neglecting atmospheric conditions, and is aptly suited to the technical intelligence mission. As such, it is included as a read-out resolution. In addition, for the missions of the lower resolution nature, a second capability is included. The number 30 inches is assumed here for purposes of discussion. The system will be designed to provide two choices of resolution selectable by a switch.

Figures 3.1-5 and 3.1-6 show the possible performance of a Rho system with two resolution capabilities. The first figure is far down-link transmission only. It has vertical reference lines for a single station pass of 4 minutes and for an average day, set of passes, of 24 minutes total. The second figure shows the capability utilizing relay satellites with relay transmission into a continental U.S. station from a medium altitude satellite of the highly inclined elliptical orbit type. Each figure has horizontal reference lines to show the data content, in bits, of one square inch of a photograph with [redacted] with 30 inch resolution. The bit content is calculated, based on the assumption of a kell factor of .707, a 2 bit delta modulation, and a nadir footprint of 9,000 ft. diameter.

The transmission rates on these graphs range from 1 Mbps to 1 Gbps, and cover capability from the existing SGLS link to a projection to links of the mid 1970's.

MODEL DATE

HANDLE VIA BYEMAN SYSTEM ONLY
~~SECRET~~/DORIAN

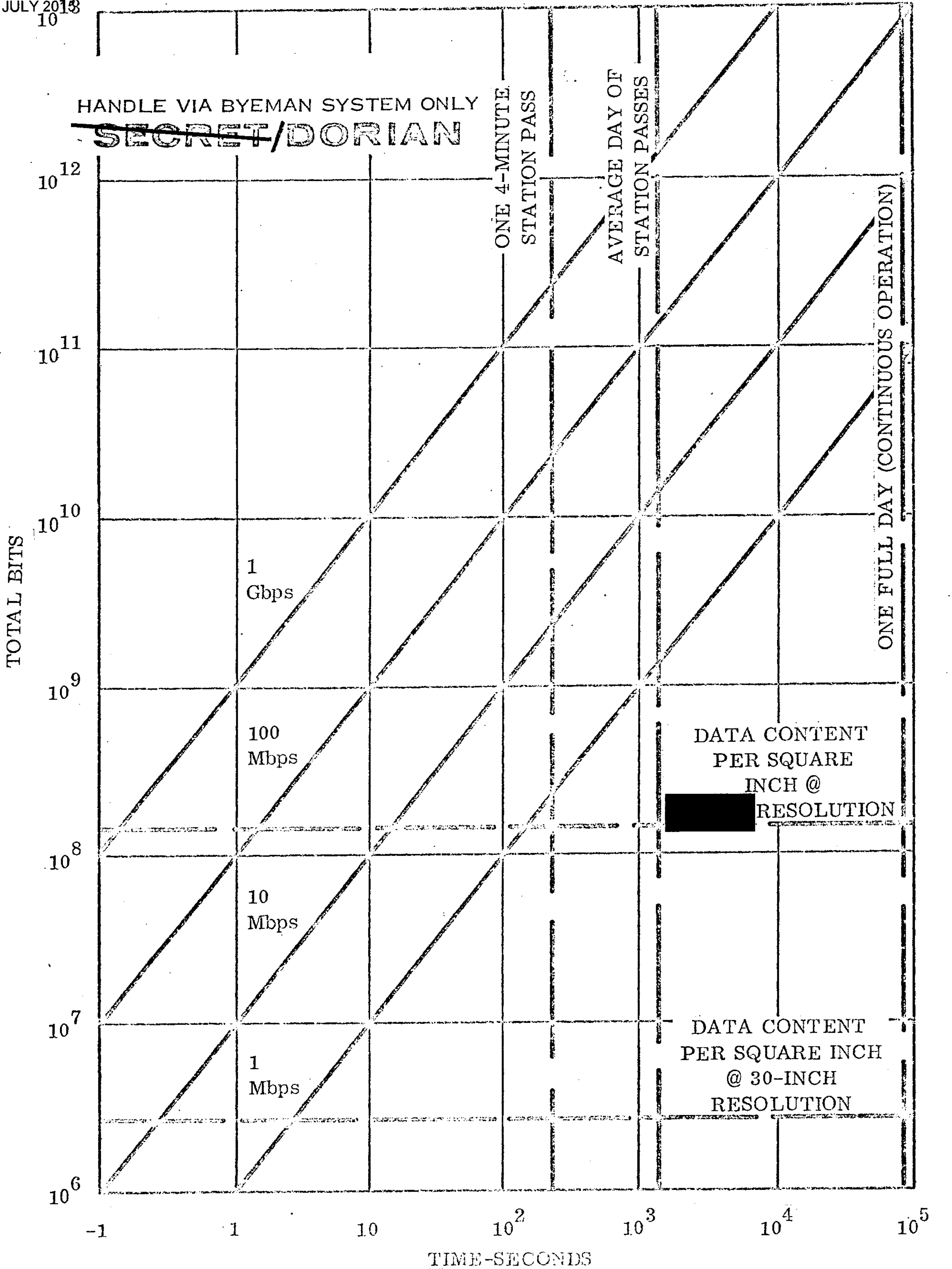


FIGURE 3.1-5. RHO SYSTEM CAPABILITY USING DIRECT DOWNLINK TRANSMISSION

~~SECRET~~/DORIAN
HANDLE VIA BYEMAN SYSTEM ONLY

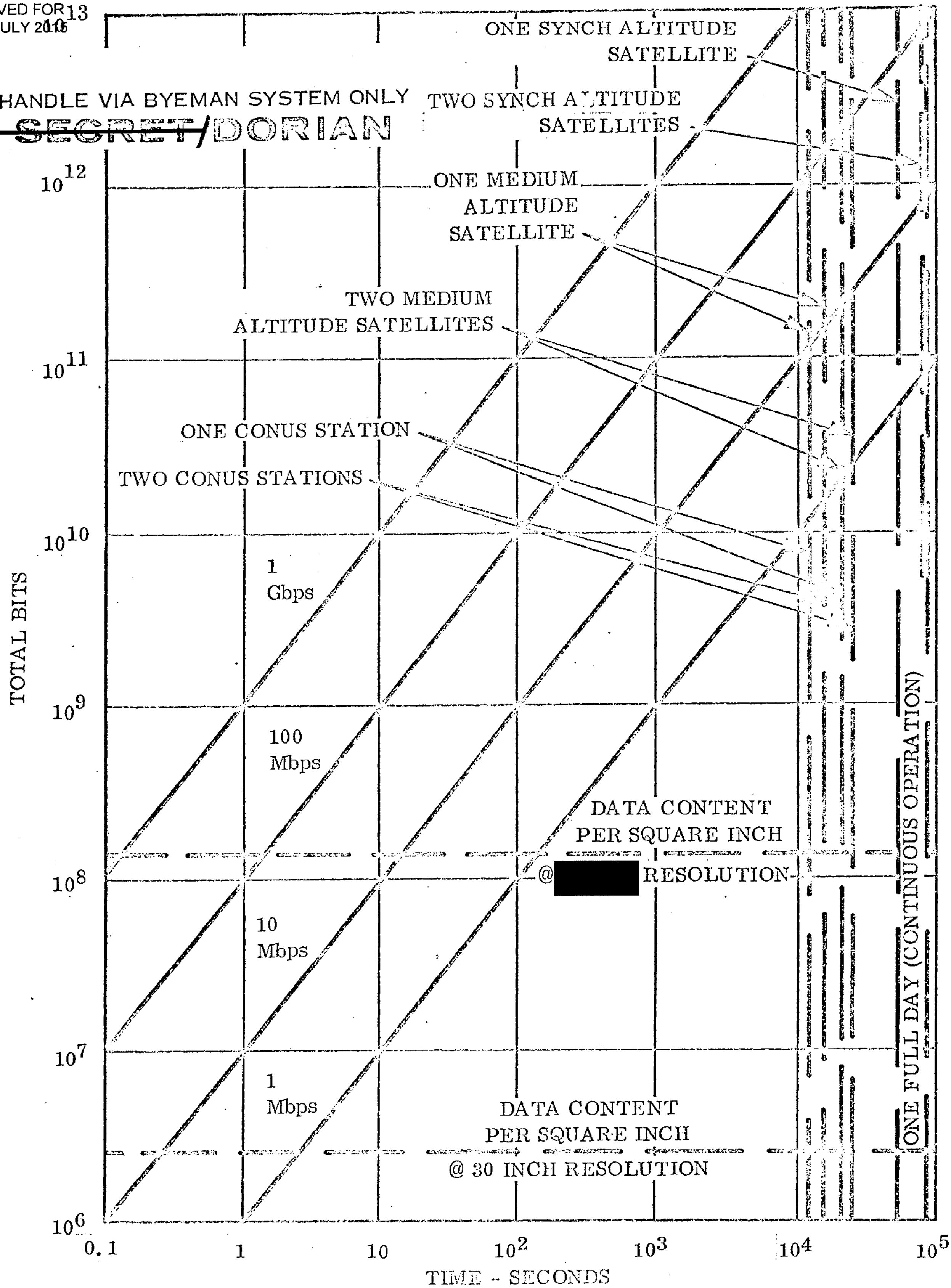


FIGURE 3.1-6. RHO SYSTEM CAPABILITY USING RELAY SATELLITE TRANSMISSION

3.1.4 CRITICAL TECHNOLOGY AREAS FOR READ-OUT

3.1.4.1 Laser Scanners

There are several potential vendors for laser scanning: 1) CBS Laboratories, 2) Sequential Information Systems, and 3) RCA, are among the leaders. The state-of-the-art at present is such that scanners of 5" wide film have been built and operated in the laboratory while development of a 9" version is underway. The bandwidth capabilities of these devices are in the tens of megacycles with growth upward, and are not expected to be the limiting factor in the development of a wideband system.

3.1.4.2 Encryptors/Decryptors

At present the encryptors operate at 1 Mbps. It is predicted that, with a high probability, by the early 70's, encryption at rates of 20 Mbps will be operational. Higher rates than 20 Mbps will be within the state-of-the-art for this time period, however, development of the devices will be necessary and should be undertaken.

3.1.4.3 Film Processing and Handling

Bimat processors are included in the baseline for processing 9" wide film, and a space qualified 70 MM wide processor, from a NASA Program, exists. Other processing methods should be investigated and/or developed in the interest of better imaging, lesser weight, lesser power, more convenient operation.

In a similar vein, image storage methods such as photoplastic recording (PPR) and thermo plastic recording (TPR) should be considered with regard to the progress of the state-of-the-art of these processes.

3.1.4.4 Communication Systems

The development of wideband communication links is in the laboratory stage at this time. Operating links at several hundred megabits have been demonstrated with error rates within several dB of theoretical. These links can be qualified for space within two years.

Work is being done utilizing various digital multiphase modulation techniques, i.e., quadriphase and octiphase. These approaches are a means of increasing the signals information bandwidth without a corresponding increase in the transmitted, or channel, bandwidth. This improvement is obtained at a cost of more transmitter power or antenna gain, however, for a bandwidth constraint this is a reasonable penalty.

Additional work in the area of bandwidth compression should be accomplished. Techniques such as the coarse-fine approach and delta-modulation show promise of significant increase of transmitted information per unit channel bandwidth. Complete analysis and development of these techniques should be undertaken to properly determine their value to the return of wideband data from an orbiting vehicle.

3.1.4.5 Technical Intelligence vs. Non-Technical Intelligence

A fundamental problem to consider in the early design of a read-out system is that of the nature of the mission to be flown. MOL basically has a high resolution capability, satisfying the most important requirement of the technical intelligence (TI) mission. However, equally important missions to fly are those of crisis management (CM) and event warning (EW). There is overlap in the needs of these missions as well as divergence. The following Table shows a comparison of some of the factors that contribute significantly to the system design.

TABLE 3.1-2 MISSION CONSIDERATIONS WHICH AFFECT THE READ-OUT DESIGN

TECHNICAL INTELLIGENCE	CRISIS MANAGEMENT OR EVENT WARNING
High Resolution	Medium to low resolution
Small area of coverage	Large area of coverage
No present requirement for quick delivery of data	Value of data depends on the timeliness of its return
Relay Satellite enables the delivery of more TR data	Relay Satellite is an important link in the data delivery path

These areas have impact on the design of the system. For example, if one chooses the TI mission, it would be logical to provide film processing only in batches of one length without the capability of handling shorter runs. This follows from no known need for rapid delivery of data. Similarly, since small, high resolution areas would be selected for transmission, it follows that the scanner would be designed to view prepared film "chips" with the capability of rapidly changing from chip to chip to enable efficient transmission of data per unit time. By contrast, a crisis management mission requiring large area coverage would dictate the utilization of a scanner which would read strip film. In support of the timeliness of the data return, processing of short sequences of pictures, would be called for, requiring more versatility in the film processing procedures.

3.2 GEODETIC TARGETTING

SUMMARY

Geodetic Targetting, or the ability to accurately determine the geodetic coordinates of selected targets, is an important function for ICBM targetting and for upgrading performance of subsequent reconnaissance flights, particularly unmanned flights.

The baseline Dorian hardware, utilizing special post-flight techniques, is capable of horizontal targetting accuracy commensurate with the 1971 ICBM targetting objective.

Baseline Dorian hardware cannot achieve vertical targetting accuracy sufficient to meet the 1971 objective. However, the addition of a ranging device, such as a laser ranger, could allow MOL (Block II) to be competitive in vertical as well as horizontal targetting. The addition of the ranging device could keep MOL/Dorian competitive in ICBM targetting through 1976.

DESCRIPTION

Several options available for the targetting mission are presented in Figure 3.2-1. Two of the approaches are discussed in detail below.

An approach based on improving the pointing accuracy of the system was rejected since only a 50 foot improvement is projected for a reduction in pointing error from [redacted]

Baseline MOL Benchmark Calibration

The baseline main optics can be calibrated to reduce the most significant targetting error, the main optics pointing error, from its nominal value of [redacted] for baseline Dorian hardware. This approach is justified because the pointing error overshadows all the other errors in its effect on geodetic targetting.

The ranging device (laser ranger) eliminates the necessity for measuring the main optics pointing vector. Instead, the ranger accurately measures slant range. To determine the coordinates of an unknown target, the slant ranges must be measured at three different geometries (different Ω and Σ). Post-flight analysis then triangulates on the target from positions based on the post-flight ephemeris. This method eliminates the need for benchmark targets and on-board calibration procedures.

PERFORMANCE ESTIMATES

The baseline MOL/Dorian system is capable of horizontal and vertical targetting accuracies of approximately 250 feet (1σ). This accuracy is sufficient for upgrading future reconnaissance missions but not for ICBM targetting. ICBM miss distances are very sensitive to target altitude (vertical targetting) errors and the baseline hardware cannot meet the required vertical targetting accuracies. (Each foot of vertical targetting error results in a two-foot ICBM miss, whereas, one-foot horizontal error causes a one-foot miss).

Advanced MOL with a ranging device could meet ICBM targetting objectives. Table 3.2-1 lists current and projected target location errors. Figure 3.2-2 is a plot of Table 3.2-1 data which has been extrapolated to 1980. It gives the expected performance of baseline Dorian hardware and advanced Dorian hardware with a ranging device. The targetting data is plotted in circular error probability (CEP) versus years. The CEP is defined such that 50% of the events will occur within the circle.

The predicted performance of advanced MOL is a reasonable assumption but lacks analysis to back it up. Block II performance (Figure 3.2-1) assumes only a vertical targetting improvement over baseline whereas Block III assumes both horizontal and vertical improvements.

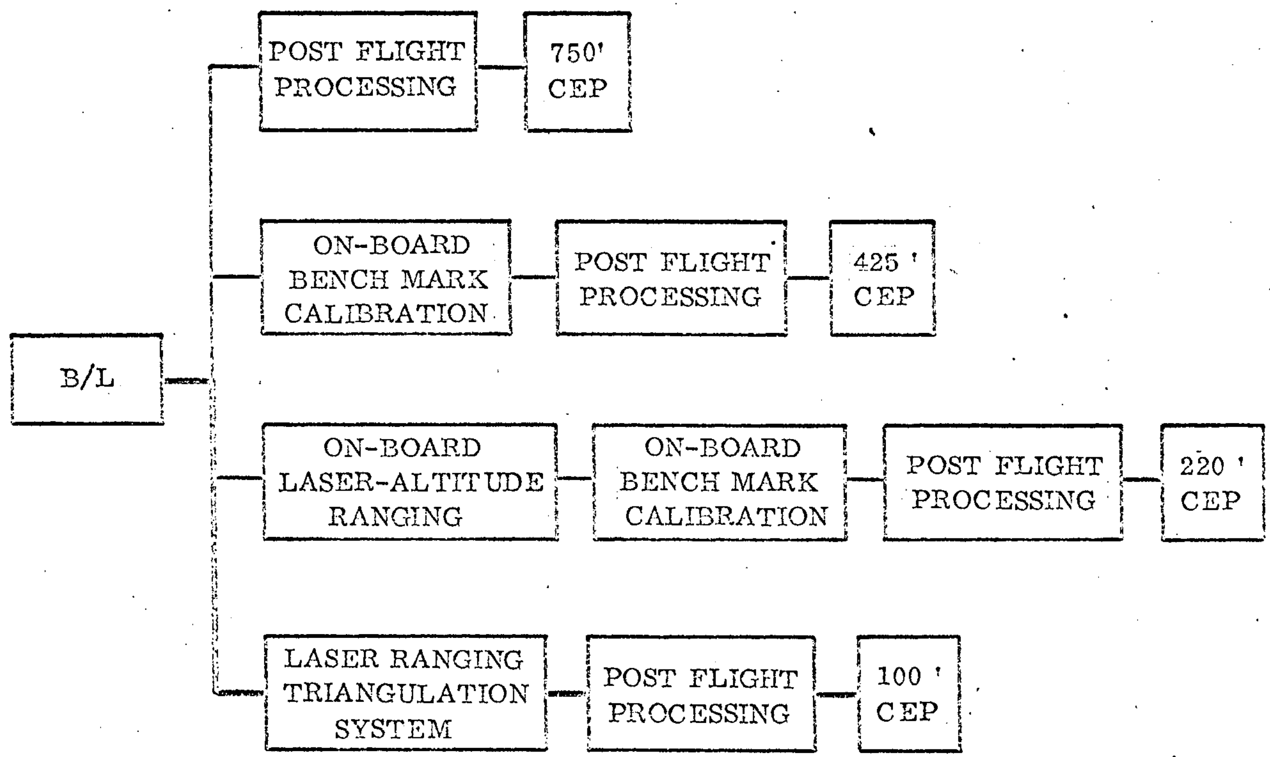


FIGURE 3.2-1 GEODETIC TARGETTING

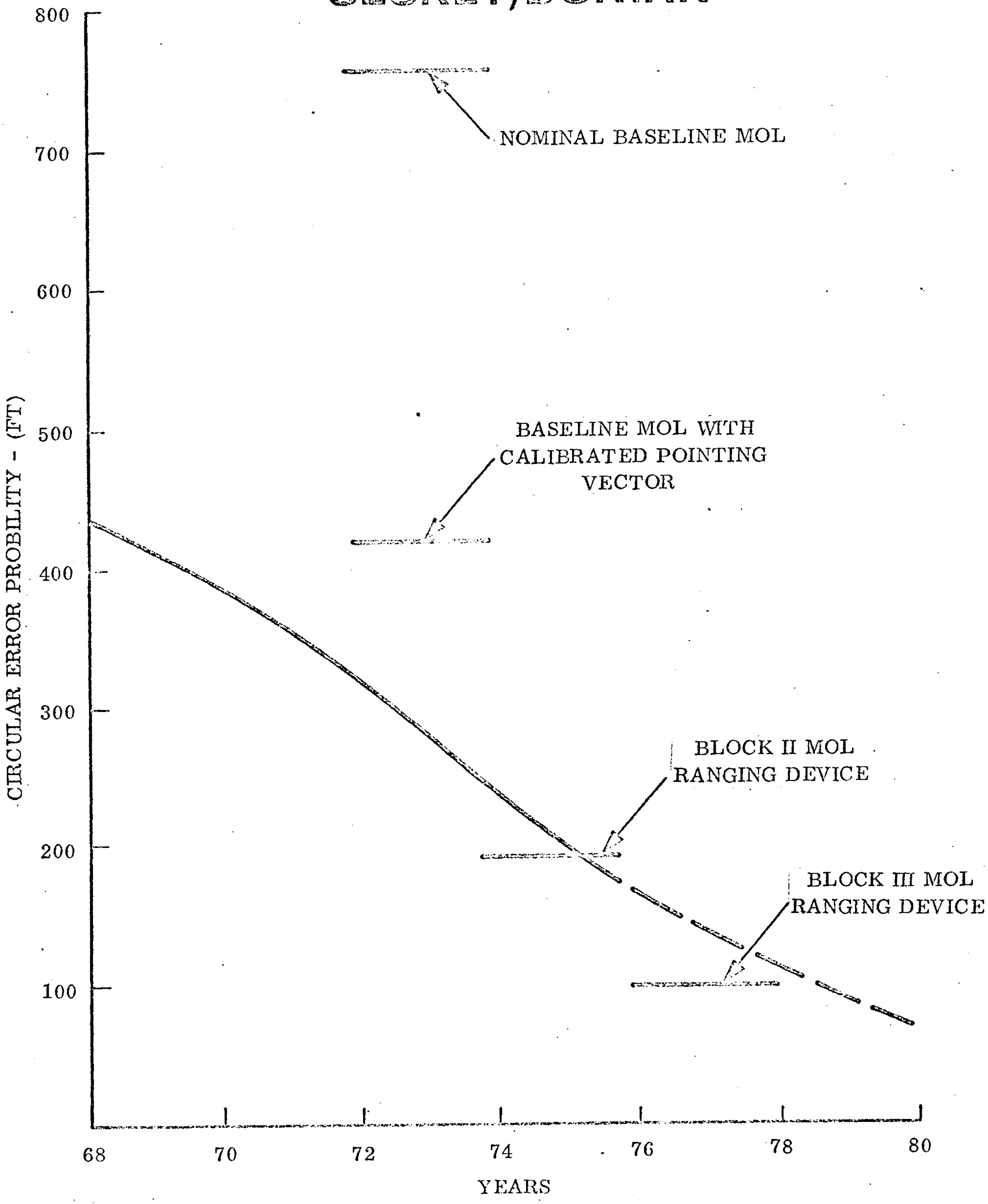


FIGURE 3.2-2. GEODETIC TARGETTING AVAILABILITY

Briefly, the calibration technique consists of photographing at least three benchmark targets (BM). Post-flight analysis of the BM photographs and ephemeris data determine the actual main optics (MO) pointing angles. The actual pointing angles, when compared with the on-board (OB) measured pointing angles for the BM photographs can be used to estimate bias in the OB measured pointing angles. This has the effect of calibrating the OB pointing vector and reducing the effective pointing error by approximately a factor of two.

To determine position coordinates of an unknown target, post-flight analysis of the target photographs utilizes the calibrated pointing vector and the post-flight ephemeris data to calculate the coordinates by relatively straight forward geometric considerations. A minimum of two photographs, at different geometries, are needed for each unknown target to provide sufficient information to calculate the three position coordinates. If the target is photographed more than twice, redundant information is available which can be used to reduce the geodetic coordinates error by standard statistical methods.

Triangulation by Laser Ranging

The baseline hardware, utilizing special post-flight techniques, is capable of accurate horizontal targetting but is insensitive to vertical targetting. Advanced MOL, with the addition of a ranging device could be competitive in vertical, as well as horizontal, targetting. Advanced MOL could be competitive in ICBM targetting through 1976.

COST ESTIMATE

An estimate of cumulative cost versus time is plotted in Figure 3.2-3.

CRITICAL AREAS

The critical areas are associated with the laser ranging schemes.

One basic assumption has been made that by the Block II time period it will be permissible to radiate electromagnetic energy from a space vehicle down to a foreign soil.

Key questions which must be answered are:

1) Can suitable space for the laser ranging system be found in the vehicle?

2) Can the hardware be limited in size to fit in the optical chain of the M/O?

3) Does the present power supply have the capacity to handle the requirements of the laser ranger?

4) Can ephemeris errors be reduced to the low level required for the G/T mission?

5) Can we accommodate the operational sequence changes with minimum impact on the TI mission?

ESTIMATED WEIGHT

Total weight of Laser System = 90 pounds.

1) Receiver = 15 pounds

2) Transmitter = 30 pounds

3) Power Supply = 45 pounds

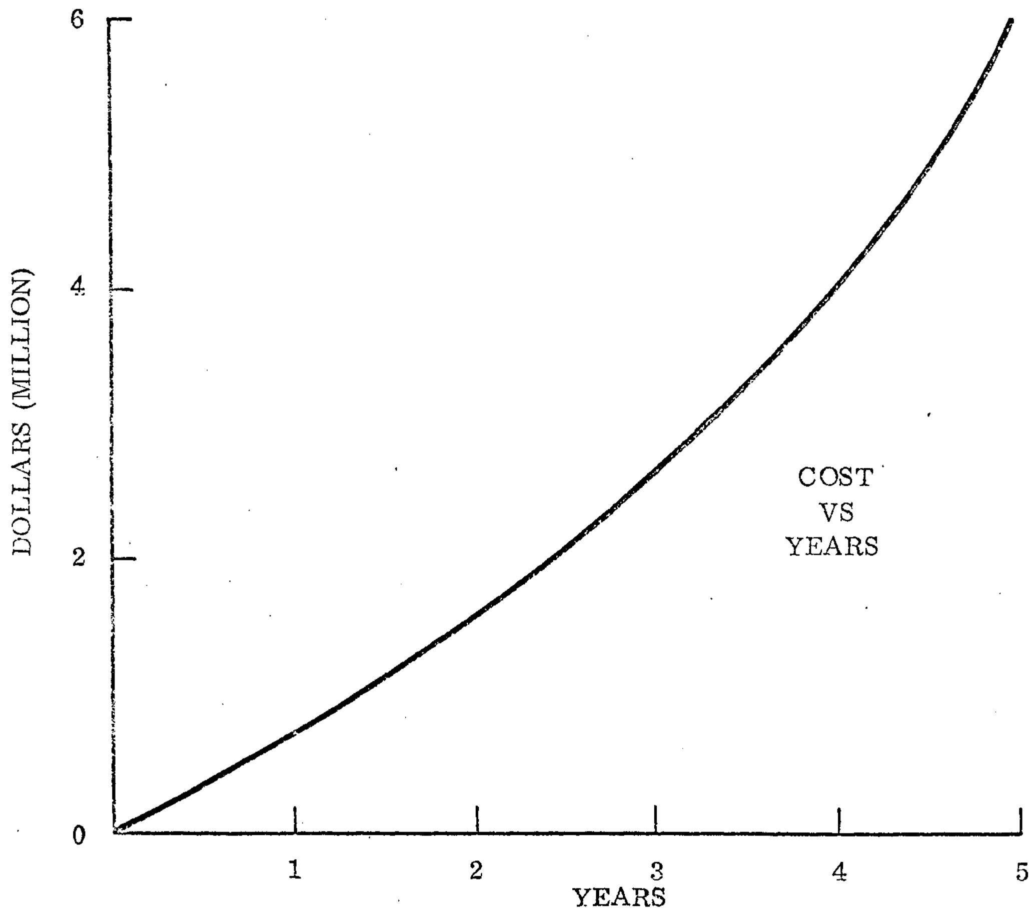


FIGURE 3.2-3. CUMULATIVE COST/TIME

COORDINATE	ICBM TARGETTING OBJECTIVE			MOL CAPABILITY (1σ)			
	1968	1971	1974	NOMINAL BASELINE MOL	CALIBRATED * BASELINE MOL	BLOCK II ** MOL	BLOCK III ** MOL
Horizontal Coordinates (1σ)	420'	210'	95'	500'	225'	225'	100'
Vertical Coordinates (1σ)	170'	182'	90'	550'	250'	100'	50'

* Utilizing special techniques and post-flight analysis

** Assumes special techniques and post-flight analysis and the inclusion of a ranging device

TABLE 3.2-1

4.0 SENSOR PACKAGES

4.1 INFRA-RED IMAGERY

4.1.1 INTRODUCTION & SUMMARY

Preliminary investigations indicate that it is possible to incorporate Infra-Red Imaging and Multispectral capabilities into the MOL mission for the 1974-75 time period. Alternate methods for obtaining Multispectral, [redacted] imagery are defined in the following material. These alternates will allow a balancing of performance against an available budget.

[redacted]

The addition of Multispectral and IR capabilities to the high resolution capability of MOL will greatly increase its mission flexibility. But in addition to this, the concurrent availability of data in several different spectra concerning a single target will have a synergistic effect and increase the total amount of technical intelligence delivered by MOL. Just as the combination of two two-dimensional stereo images creates an image in three dimensions, the combination of different spectral images can add entirely new dimensions to the information concerning a target.

Augmented MOL, plus man, will gather far better and more relevant intelligence than an automated MOL. This is because the value of man as part of a system increases as the complexity of possible functions of the system increases. Although it is possible to automate almost any system, beyond a certain complexity it becomes cheaper and more efficient to include man. This will be particularly true of a versatile system such as MOL when Multispectral and [redacted] capabilities are added.

4.1.2 IR SUB-SYSTEM OPTION MAP

[redacted]

Although there are 24 possible ways in which the identified components can be combined in a functioning system, one particular combination seems preferable for incorporation into Block II MOL.

This single recommendation is indicated by the heavier paths through the map elements. There are two paths in the one recommendation because the equipments are physically independent and non-interfering. They, nevertheless, provide images that supplement one another. Although a specific recommendation is being made, material in Table 4.1-1 of this section will allow an estimate of the costs of other possible combinations on the Option Map.

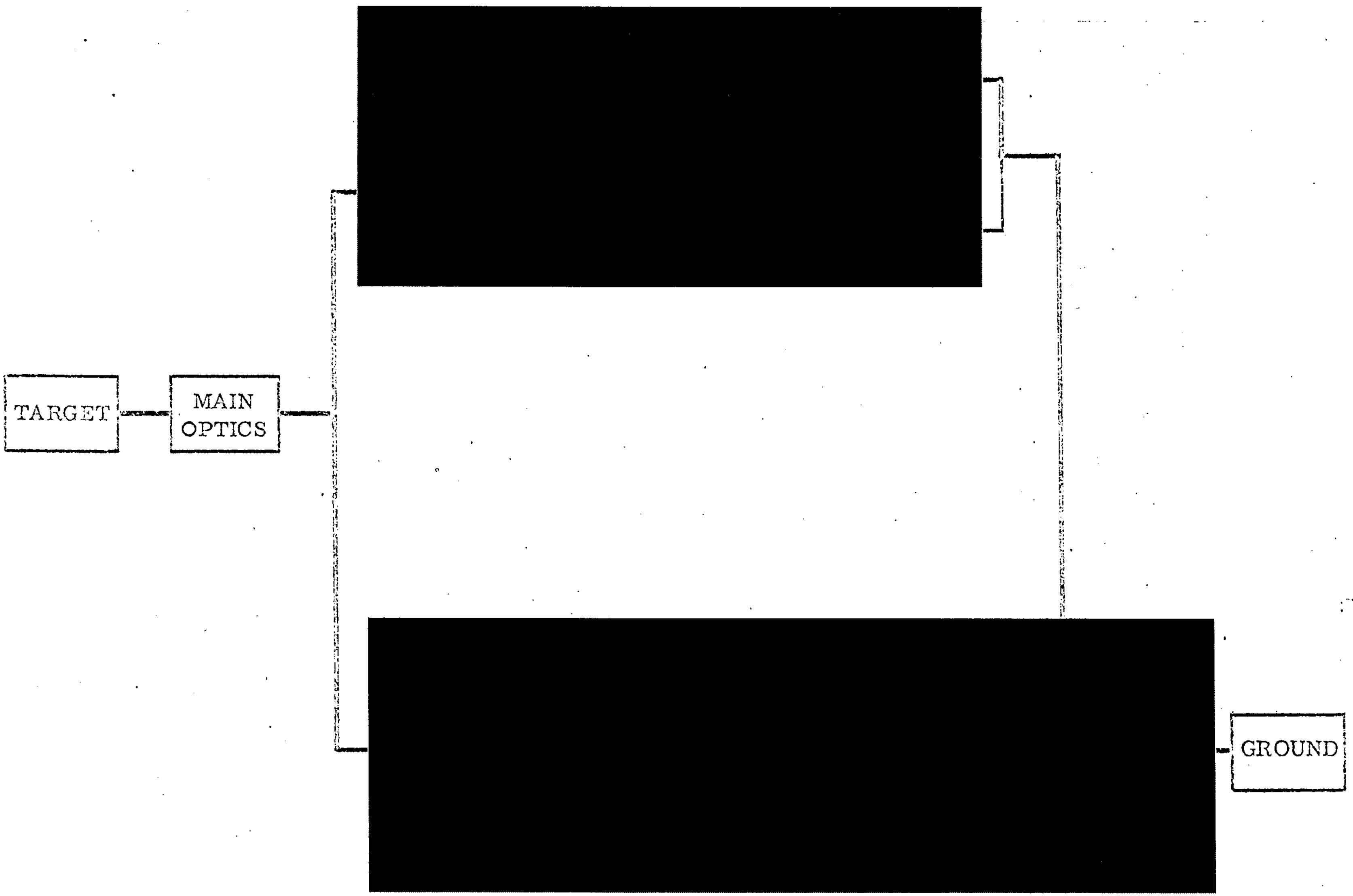


FIGURE 4.1-1 INFRARED/MULTISPECTRAL

TABLE 4.1-1 [redacted] COMPONENT DATA

ITEM	CHARACTERISTICS	USAGE	NON-RECURRING COSTS	WT. LBS.	TIME TO DELIVERY
[redacted]			$1,000K	100	24 Months
			$1,500K	100	24 Months
			$2,000K	50	24 Months
			$5,000K	30	36 Months
			$250K	25	10 Months
			$1,000K	170	24 Months
			$250K	150	10 Months
Grd. Support	Service Vehicles	Coolant service & grd. support	$1000K		24 Months
Container	Tape containers	Stored in Gemini	$100K	30 loaded	12 Months
Read-Out	See Section 3.1				

4.1.3 PERFORMANCE ESTIMATES

4.1.3.1 [redacted]

In every IR application, that part of the Main Optics consisting of the tracking mirror and the primary mirror will be used.

[redacted] Obviously, storage and flow control for the cooling agent will be required. The relationship of components is shown in Figure 4.1-2. The physical layout is shown in Figure 4.1-3.

The above comments apply to both options at the first division of the lower path of the Option Map, but the two kinds of sensing equipment are quite different. The type currently being used in operational [redacted]

The other type is currently being successfully tested in several laboratories and is expected to be ready for operations by the 1974-75 time period. A schematic diagram of this device is shown in Figure 4.1-4. In this design, [redacted]

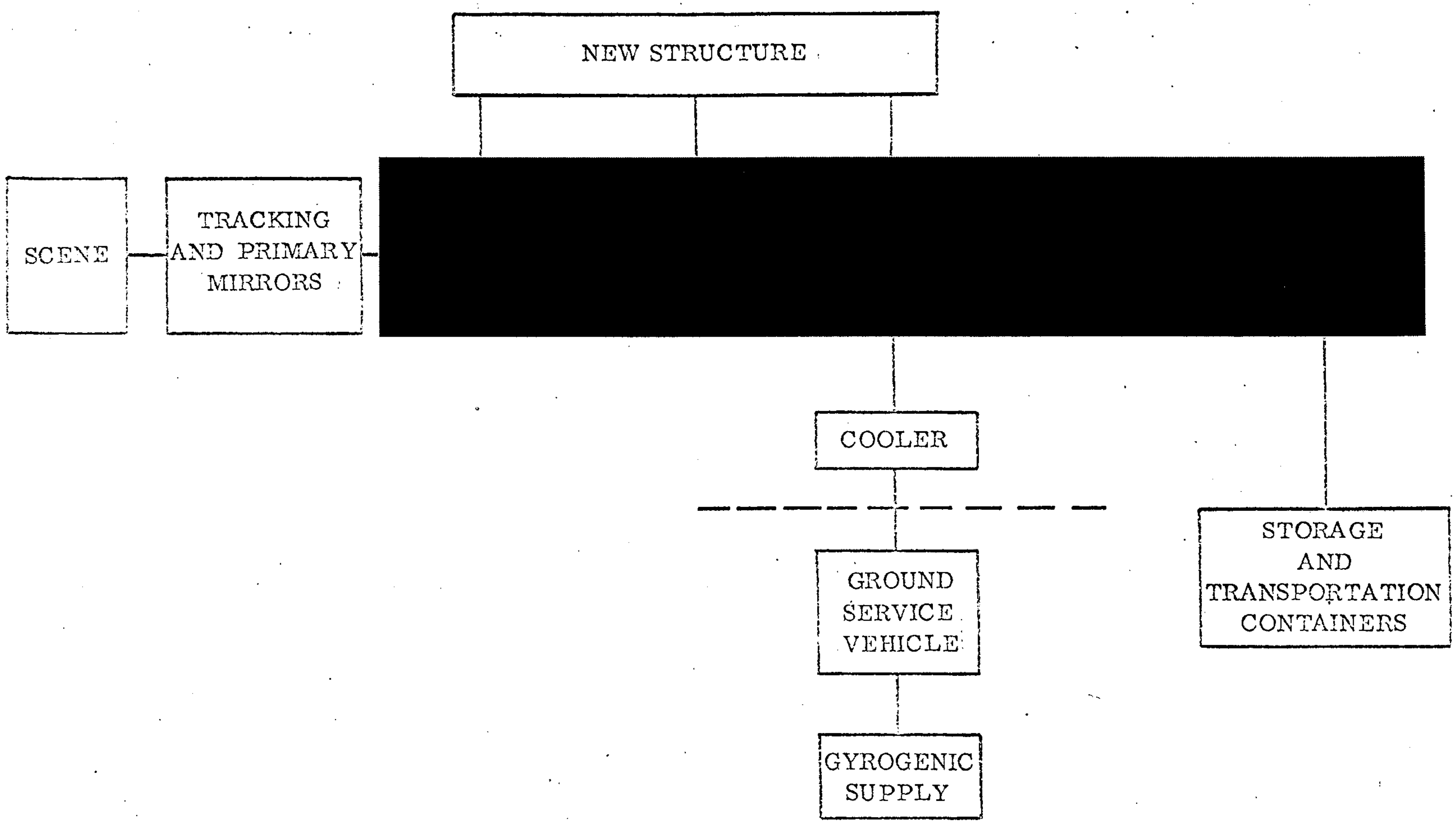


FIGURE 4.1-2 [redacted] BLOCK DIAGRAM

[redacted]

[redacted]

FIGURE 4.1-3 MOL-INFRARED MODIFICATION

[redacted]

FIGURE 4.1-4 SCHEMATIC IR SENSOR CONFIGURATION

[redacted]

[redacted] for MOL. Experience also indicates that IR resolution larger than [redacted] has limited value. This factor, as well as the obvious problems of aligning and maintaining rotating scanners for long periods of time, makes the [redacted] the less desirable of the two alternates.

[redacted] The choice of alternates again can be made without too rigorous an analytical comparison.

[redacted]

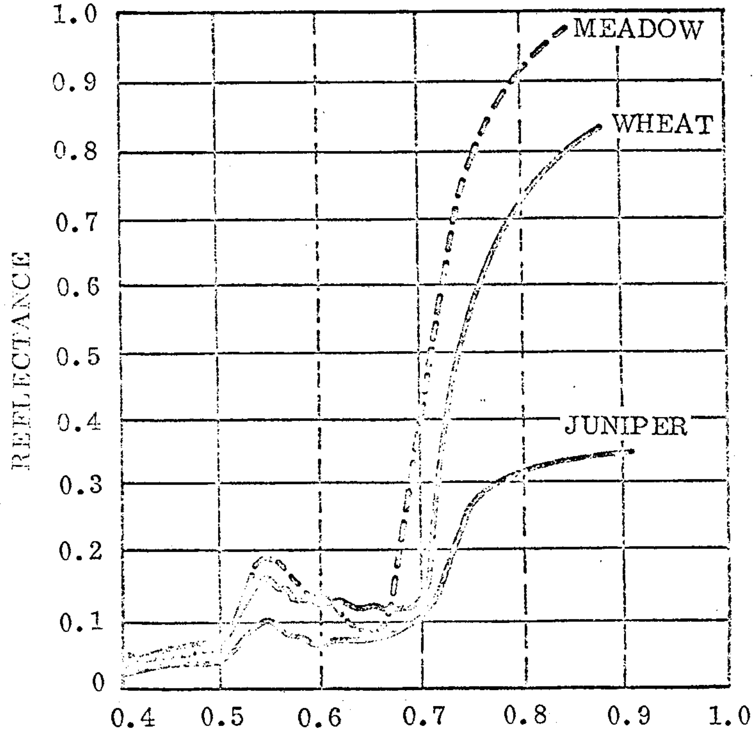
[redacted] The rationale here is quite simple and not nearly as definitive as the preceding ones. It is that it would be preferable to define a system the existence of which was not conditional upon the acceptance of another new system (i.e., Read-Out).

There are existing tape recorders (and signal processors) that can record up to one-half hour of visual data on a single tape having a [redacted] capability. [redacted] it will generate an [redacted] signal for the recorders. This will be a [redacted] quantized signal. Two recorders, of the existing type, each using two heads will be required to handle this amount of data.

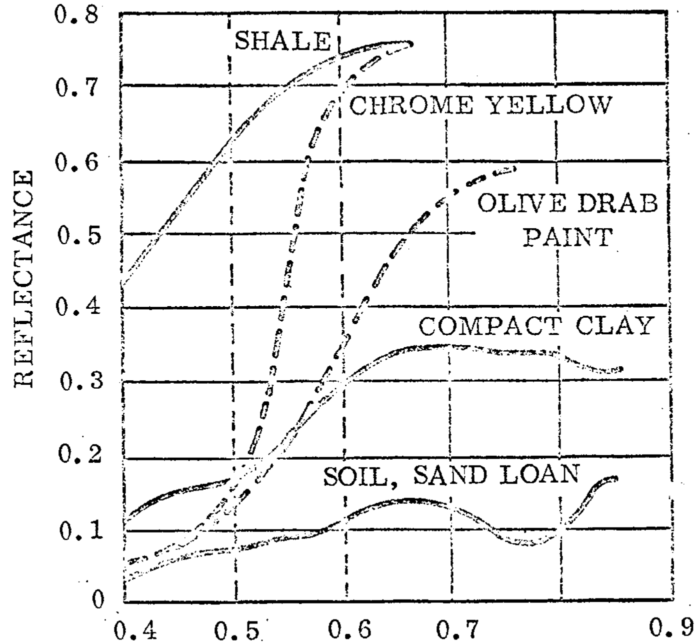
[redacted]

[redacted]

[redacted]



SPECTRAL REFLECTIVITY OF VEGETATION



SPECTRAL REFLECTIVITY OF
INERT MATERIAL AND PAINT

FIGURE 4.1-5 MULTISPECTRAL DISCRIMINATION

The choice of the upper recommended path through the Option Map has involved essentially no difficult evaluation of alternatives. Nevertheless, the other alternatives are not precluded should other considerations make one of them more desirable.

4.1.4 IDENTIFICATION OF CRITICAL AREAS

Any extensive modification of a complex system in which the physical performance of one part depends on the performance of all the other parts is of itself a critical undertaking. For example, the Mission Module structure will need to be cut into for the addition of the new IR optical barrel. This change alone will change the "hotdogging" characteristics of the Mission Module under thermal loads. It may also affect the vibration frequencies and modes which in turn will affect the image motion for the primary mission. Power usage and timeline profiles will also be affected. The criticality lies in the coordination of the system design so that the cumulative effects do not degrade the primary mission capability.

Possibly the most critical single item of the [redacted] If the volume and weight constraints are met, the structure must be of marginal rigidity. Yet the requirement for reproducible location and alignment of this mirror are exceedingly high. Location of the mirror within a small fraction of an inch is relatively easy but the angular alignment to seconds (or even minutes) of arc is difficult. No new technology is involved but this design feature will be critical.

[redacted]

In this instance, it will be the untried application of a new technology that is critical. In particular, the requirement for a [redacted] may be difficult to attain within the weight and power constraints. Only a [redacted] is mentioned in this report but there are other alternates which can be used should a design problem develop.

The recorders indicated are disproportionately heavy when compared to other components. If the weight budget is critical this weight may also be critical. However, the weight estimate is based on existing units and the available technology in 1974-75 may allow an appreciable reduction.

4.1.5 COST ESTIMATE

The costs for the components of the possible IR systems have been estimated. The ground rules are as follows:

- Only increments of cost, in addition to baseline design costs, were considered.
- Only non-recurring costs associated with the necessary changes are identified.
- Research and test costs through fabrication of the first item are included.
- Hardware directly associated with ground support is included. Indirect effects such as expanded computer storage are not included.

[redacted]

The cost estimate is $250,000 to be expended over a period of 1 year.

[redacted]

The cost estimate for the recommended configuration is $12.0 million, expended over a three-year period. Note that this value is more than the sum of component costs of Table 4.1-1. This is because the supporting functions required to integrate and evaluate a complex system must also be considered. Note also that costs for the read-out components are not included. These costs are included in Section 3.1.

4.2 ULTRAVIOLET ASTRONOMY

4.2.1 SUMMARY

A study was undertaken to ascertain if additional use could be made of the national resource provided in the Manned Orbiting Laboratory Program. In particular, the utility of the laboratory for scientific research in visible, ultraviolet and infrared astronomy was investigated. Within the many constraints imposed by the requirement not to jeopardize the basic mission and the short in-orbit life of the system with its present orbit parameters, the study indicates that astronomical observations of significant scientific value can be accomplished but at a high cost. This high cost is associated with major modifications which must be made to the Mission Payload and are estimated to be a minimum of $20 Million.

The set of astronomical observations that should be accomplished have been derived from studies funded by NASA. To facilitate discussions between NASA and the AF on the joint undertaking of such a program the results of the Orbital Astronomical Support Facility Study by McDonnell Douglas, that is the Observation Requirement Data Sheets (ORDS) have been utilized. These observation requirement data sheets identify the specific knowledge desired and the basic characteristics of the apparatus required to make the necessary observations.

The process by which these ORDS's were developed was similar to that shown in Figure 4.2.1. The procedure used to select from the total set of ORDS's, those that potentially could be accomplished by the Manned Orbiting Laboratory, is outlined in Figure 4.2.2. These ORDS's are listed in Table

In general, the observations can be accomplished by a 1.0 meter diameter or a 3.0 meter diameter optical aperture telescope and associated equipment such as spectrographs, cameras and etc. The exposure requirements are generally short but may extend to one hour. The guidance stability during exposure extends from about 1.0 arc second to 0.01 arc second. Some of the observations require data to be taken at intermittent intervals for a period as long as a year but significant data can be acquired in a much shorter time period.

The differences in the optical system in the MOL and the system discussed in the Orbiting Astronomical Support Facility Study are not sufficient to cause drastic changes in the associated measuring apparatus. It is therefore reasonable to use the cost estimates provided by McDonnell Douglas for this equipment. Additionally, the supporting research tasks that were identified in that study are also valid. It is believed that the cost of these instruments and these research tasks will be borne by NASA. The manufacture of additional units for use on MOL would probably add a cost an order of magnitude less than that incurred in developing the first space flight qualified unit. Other cost savings would accrue by the use of existing NASA facilities for data acquisition and reduction.

Observations of the planets in the visible light regime are also of value if the guidance stability is greater than 1.0 arc second since this is the atmospheric "seeing" limitation at the earth's surface. Of course, balloon borne telescopes can also achieve better guidance stability and represent an alternative instrument. However, since the use of the MOL system for this purpose would require merely to focus the film plane on infinity it should receive consideration.

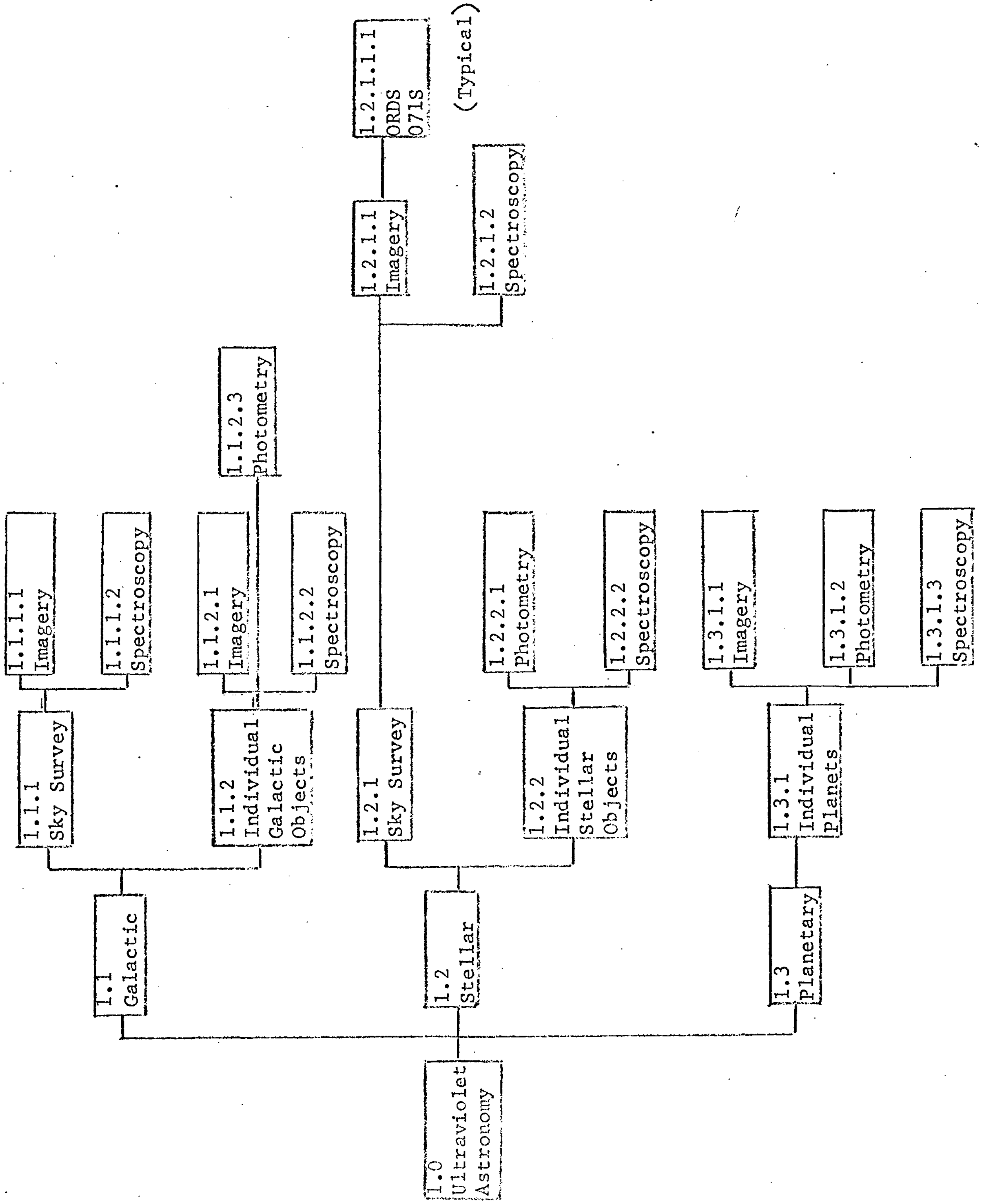


FIGURE 4.2.1 POSSIBLE UV ASTRONOMY MISSIONS

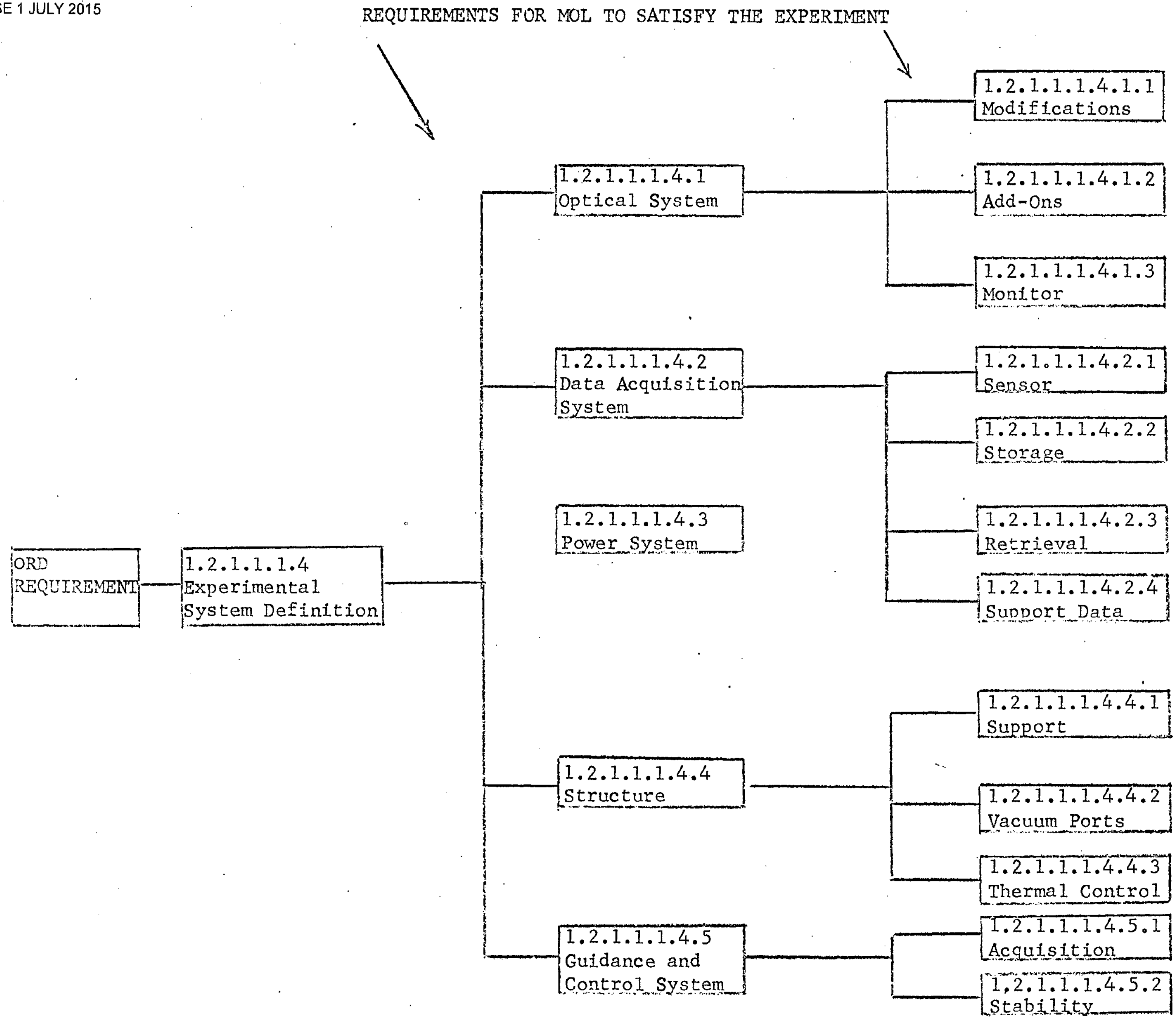


FIGURE 4.2.2 REQUIREMENTS DEVELOPMENT FOR A TYPICAL UV MISSION

TABLE 4.2.1 OBSERVATION REQUIREMENTS APPLICABLE TO MOL

ORDS NUMBER	TITLE
002	Wideband Ultraviolet Photometry of Stars
019	Resolution and Measurement of Extremely Close Binary Stars
020	Coarse Photographic Mapping of Mercury
021	High Resolution Photography of Martian Cloud Patterns (Synoptic Meteorology)
022	Synoptic High Resolution Study of Martian Surface Feature
023	Photographic Photometry of Faint Main Sequence Stars in Globular Clusters
024	Optical Structure of Galactic Nuclei on Quasistellar Objects (Quasars)
026	Photometry of Cepheids in Galaxies Beyond the Local Group
027	Ultraviolet Spectrophotometry of O and B Type Stars
028	Ultraviolet Spectroscopy of Planetary and Diffuse Nebulae
029	High Angular Resolution Radiometry of Infrared Sources
030	Absolute Stellar Spectrophotometry
031	Measurement of Large Doppler Shifts in O and B Type Stars: Giant and Supergiant
032	Measurement of Luminosity - Sensitive Ultraviolet Lines in the Spectra of O and B Stars, Giants, and Supergiants
033	Search of Star Spectra for Absorption Features from Interstellar Molecular Hydrogen (H_2)
034	Ultraviolet Spectroscopy of Stellar Chromospheres

035	Equivalent Line Widths in Ultraviolet Stellar Spectra for Abundance Determination
036	Measurement of Equivalent Widths of Interstellar Absorption Lines in Ultraviolet Stellar Spectra
037	Spectroscopic Search for Oxygen in the Atmosphere of Venus, Mars, Jupiter and Saturn
038	Ultraviolet Spectroscopy of Quasi-Stellar Objects (Quasars) with Large Wavelength Shifts
039	Ultraviolet Polarimetry of O and B Stars for Interstellar Dust Study
040	Ultraviolet Photography of Venus
071S	Ultraviolet Photographic Sky Survey
072	Infrared Spectroscopy of Planetary Atmospheres
075	Infrared Spectroscopy of Late Type Stars
077	Infrared Spectroscopy of Hydrogen II Regions
078	Spectroscopic Search for Interstellar Infrared Emission and Absorption Lines
101	Images of Galaxies in Light of Lyman Alpha and Lyman Beta Lines
107S	Ultraviolet Spectral Sky Survey
113	Ultraviolet Imagery of Extended Objects

4.2.2 MISSION OPTIONS

Fundamentally, three options are available for the astronomical observations. The first uses the present optical system with a film plane change during portions of the orbit not useful to the prime mission but acceptable to one or more of the visible light observations. The second option requires modification of the basic optical system to utilize the astronomical measuring instruments during the portions of the trajectory not useful to the prime mission. The third option requires that the modified telescope system be placed into a longer life orbit after the prime mission has been accomplished. It is conceivable that all three options could be accommodated in a single spacecraft if desired.

4.2.2.1 Option I - Photography of Planetary Objects

This mode of operation is limited to the visible and very near IR portion of the spectrum. However, it requires only a change in the camera. The focus change required to accomplish this mission seems to be within the capability of the present instrument; hence, the cost and time constraints associated with this mission arise from the need for a slower focal plane shutter, the modification required to re-orient the vehicle to point at a planet and the energy to make the change.

The problem arises in viewing the planetary objects of finding a suitable object, that is, the planet must be in the restricted view of the satellite and near opposition so that the phase may be shown. It is expected that the number of useful observations will be quite small. The observations will, however, be above the atmosphere resulting in more information than photos from balloon borne telescopes.

4.2.2.2 Option II - Astronomical Observations Within The Normal Mission Life

The MOL capability can be extended to accomplish astronomical experiments in the ultraviolet and visible portions of the spectrum by the addition of several instruments to the primary telescope (see Table 4.2.2). The experiments that could be accomplished with a modified system are defined in ORDS's which have been identified earlier. With the exception of ORDS's 038 and 039, the operational parameters defined in the ORD's were based on the use of a telescope having an aperture of [redacted] approximately [redacted]

The same type of instrumentation defined for use with these telescopes could be used with the existing MOL telescope having an aperture of 1.8 meters and a focal length of approximately [redacted]

The use of the larger aperture telescope would be advantageous for stellar observations where the target is a point source. The sensitivity of an optical collecting system relative to point source targets is a function of the collection area only. The MOL telescope with a collecting area approximately three times larger than the 1 meter units would therefore permit a reduction of the individual observation times noted in the stellar ORDS by a factor of three.

TABLE 4.2.2
ASTRONOMICAL MEASUREMENTS SUBSYSTEM

Instrument	Basic Parameters	Applicable ORDS	Estimated Cost (Instrument Only)	Remarks
Ultraviolet Spectrograph range dispersion resolution Recording Scale	 900 - 3000 A 100 A/mm 2 A at 15W A 13.8 arc sec/mm	002, 027, 028, 030 031, 032, 033, 034 037, 113	$600,000	
Echelle Spectrograph range dispersion resolution Recording scale	 900 - 3000 A 10 A/mm 0.2 A at 2000 A 13.8 arc sec/mm	031, 032, 034, 035 036	$714,000	Greater spectral range and resolution than above
Slitless Spectrograph range dispersion resolution Recording scale	 900 - 4000 A 50 A/mm 2.5 A at 2000 A 13.8 arc sec/mm	028	$500,000	
Field lens and/or image tube	photomultiplier image intensifier	002, 027, 028, 030	$200,000	
Plate Camera size FOV Recording scale	 25 x 25 mm 0.06 arc minutes 13.8 arc sec/mm	113	$699,000	
Photopolarimeter	0.5% polarization 1050 - 3000 A	039	$500,000	
Spectrophotometer	900 - 3200 A 10 - 100 A resolution	002, 027, 030	$800,000	

The same is not true for planetary observations where the target is an extended source and the sensitivity of the telescope is a function of focal ratio. In this case, the MOL system F-7 is not quite as "fast" as the 1 meter F-5 system so that planetary observations take slightly longer periods than those indicated in the ORDS.

The field-of-view of the existing system when utilizing the entire focal length is somewhat smaller than desired for the astronomical experiments. The smaller field-of-view will require more accurate pointing than shown in the ORDS.

This can be corrected, however, by either the use of a larger recording aperture than proposed by the ORDS or by using an inter-mediate focal length on the MOL telescope. The latter is attractive for planetary observations since the shorter focal length would produce a smaller F number and thus increase the speed of the system. Methods of changing the focal length are shown in Figures 4.2.6 and 4.2.7.

Changing the focal length is not unrealistic since major changes must be made to the Dorian optics to satisfy the astronomical experiment(s). Since lenses filter out essentially all of the ultraviolet, only those portions of the optics which are reflective can be retained. These are the tracking, primary, Newtonian and Ross Mirrors.

The requirement of not interfering with the primary technical intelligence mission places a severe constraint on the location of the sensor and the methods of getting the light to it. An examination of the optics configuration shows that at least one of the mirrors, the Newtonian or Ross folds, must be re-oriented or alternate mirrors must be swung into the light path during operation of the astronomical experiment. The experiment package will most likely have to be located somewhere around the periphery of the light bundle in the mission module. Sketches of typical mirror re-orientation and experiment package are shown in Figures 4.2.3 thru 4.2.7. Every effort has been made to retain present designs and configurations.

Since the sensor locations are on the mission module it will be very difficult to retrieve film or photographic plates from them without complex film chutes to the Lab Module or crew extra vehicular activity. Therefore, it is expected that the sensor will have their output data in the form of electronic signals. These signals will be routed to the LM where they will be recorded for either later transmission via the readout communication link or manual return.

It is the location of the sensors and the modifications to the optics which create the high cost of implementing an astronomical system on MOL. The sensors themselves, while not off-the-shelf, are currently within the state-of-the-art and are being developed elsewhere.

Additional star trackers will be required for this mission also. With the vehicle looking at stars the existing star trackers are on the earth pointing side of the vehicle. At least two other star trackers must be used to prevent occlusion and it should be noted that OAO used six to cover the entire sky.

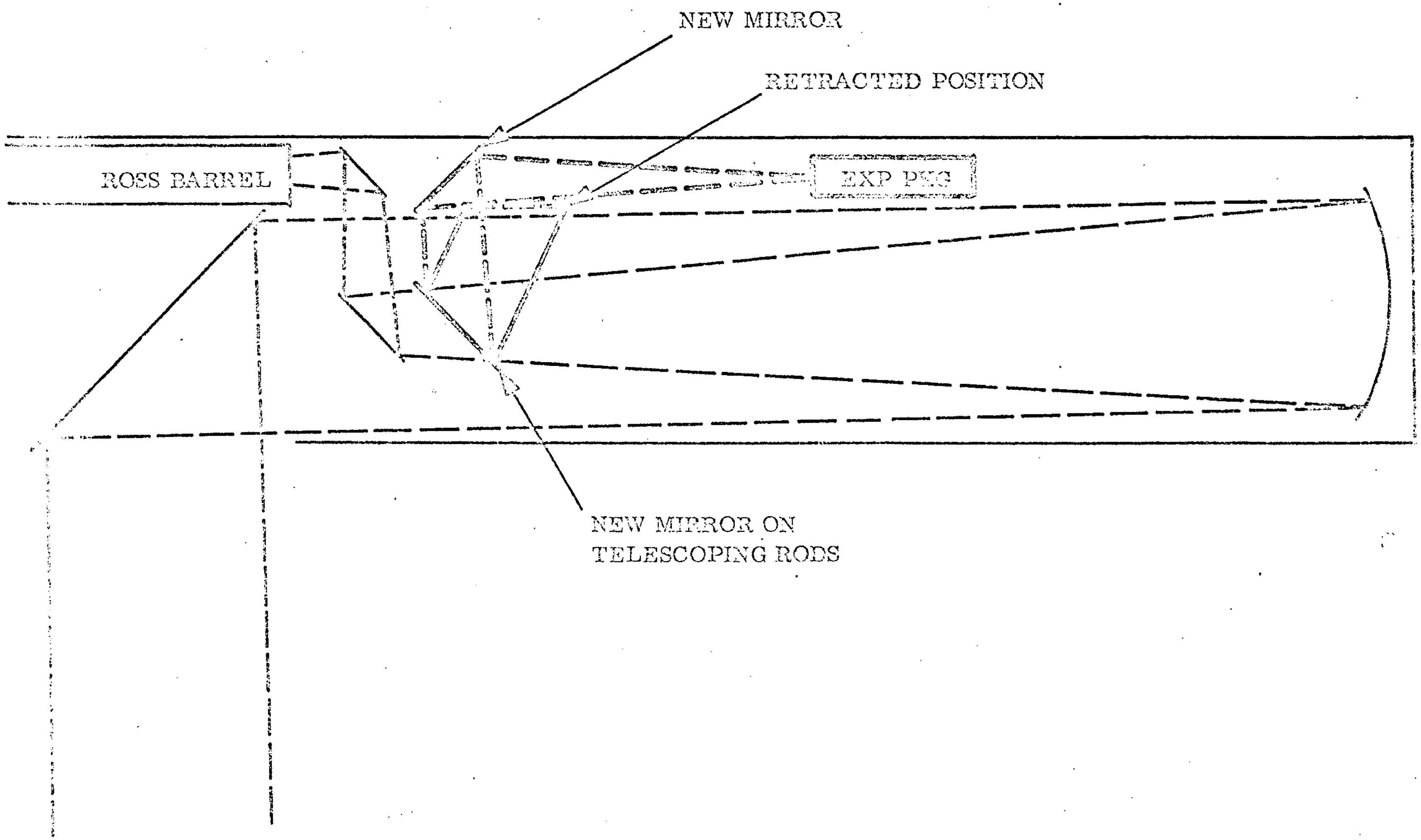


FIGURE 4.2-3 MODIFIED OPTICS - TELESCOPING ROD APPROACH

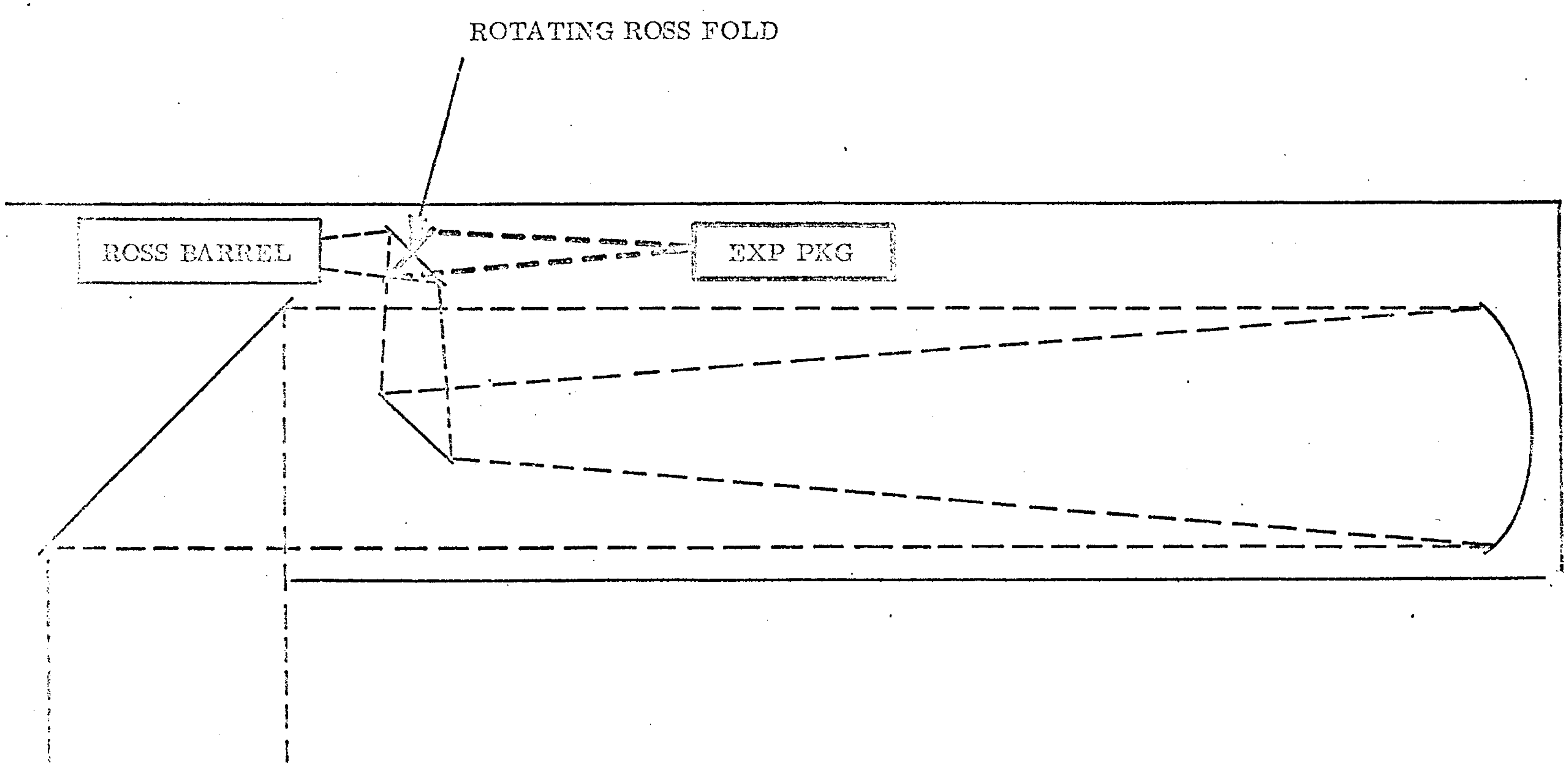


FIGURE 4.2-4 MODIFIED OPTICS - ROTATING ROSS FOLD

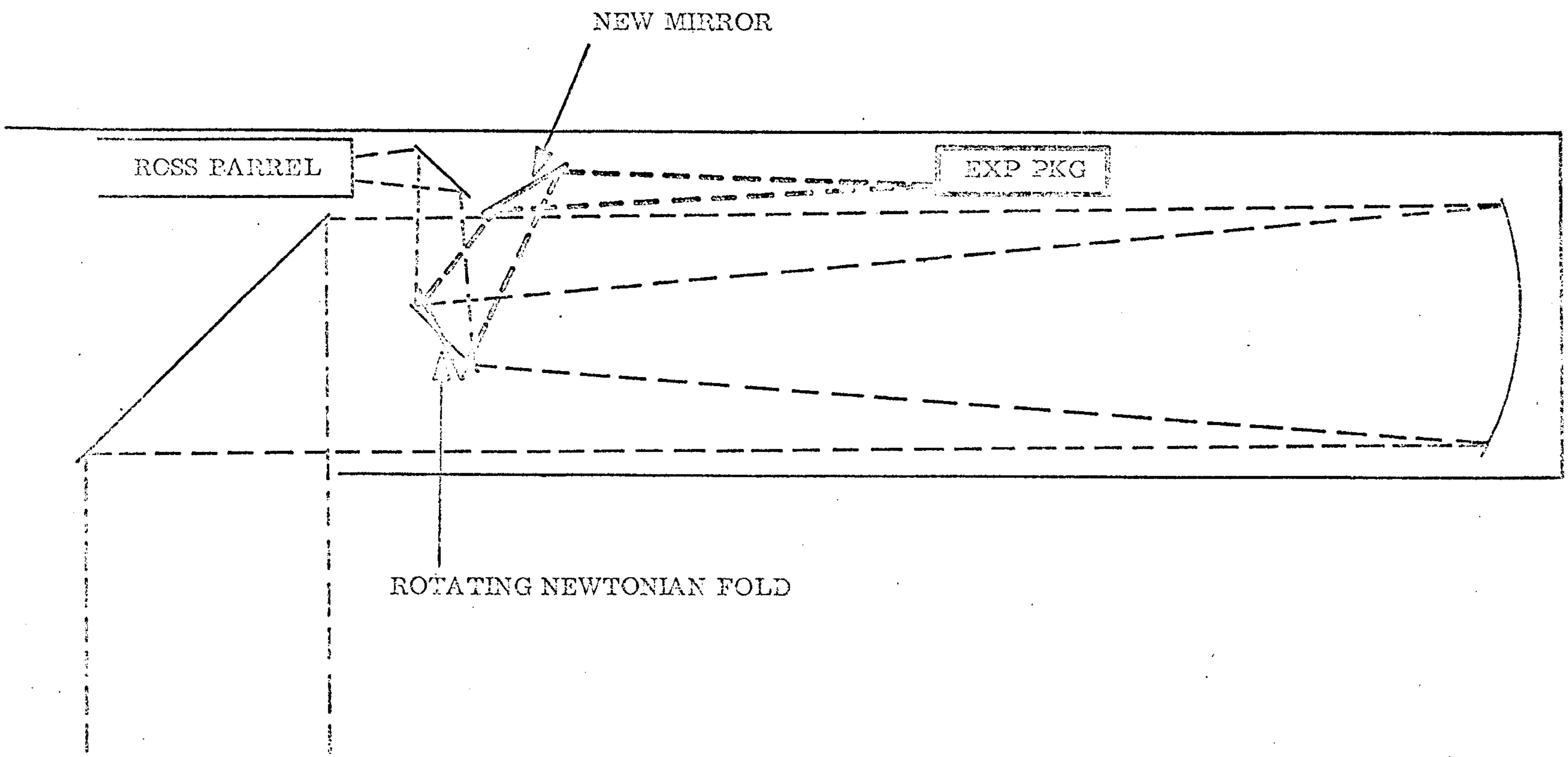


FIGURE 4.2-5 MODIFIED OPTICS - ROTATING NEWTONIAN FOLD

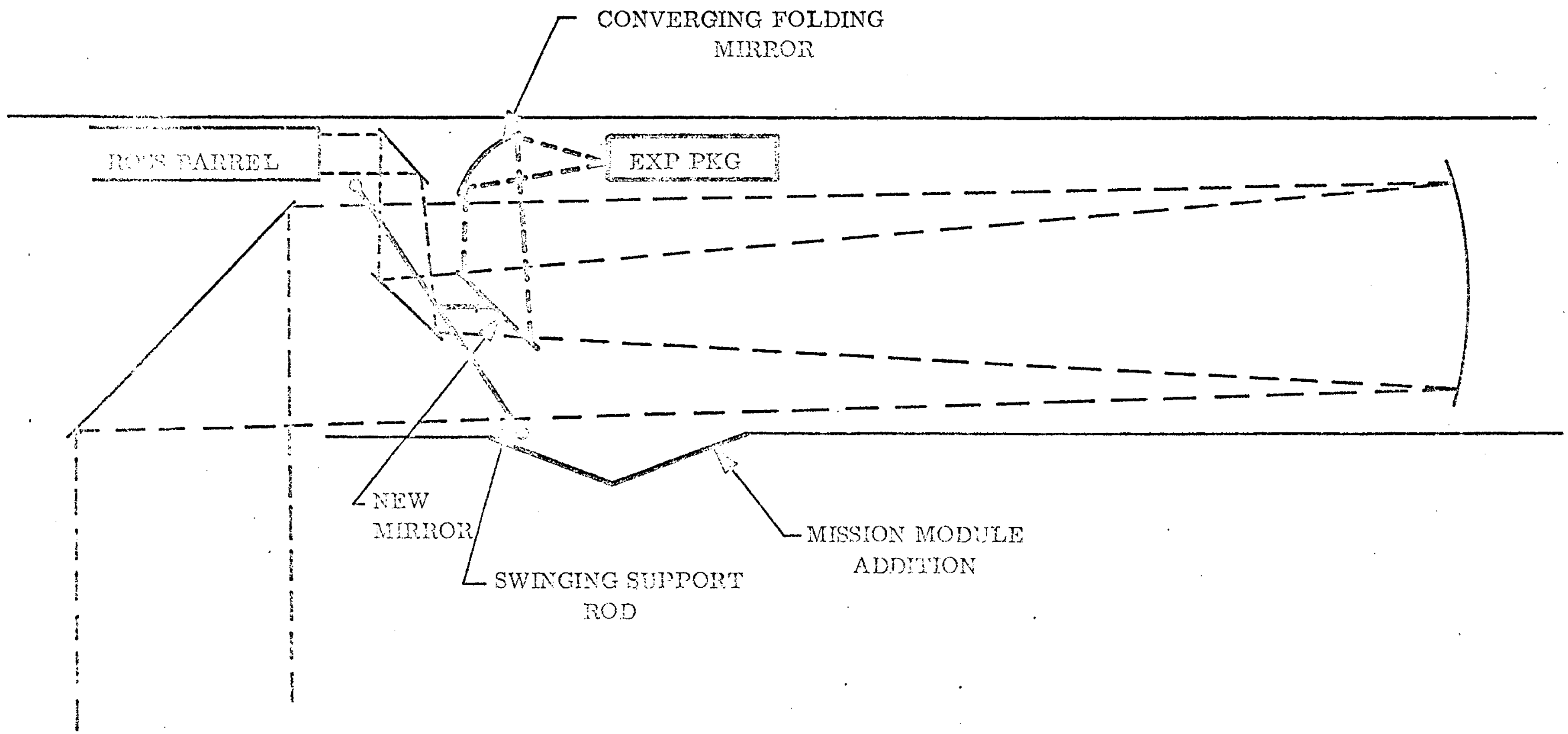


FIGURE 4.2-6 MODIFIED OPTICS - F6 SYSTEM

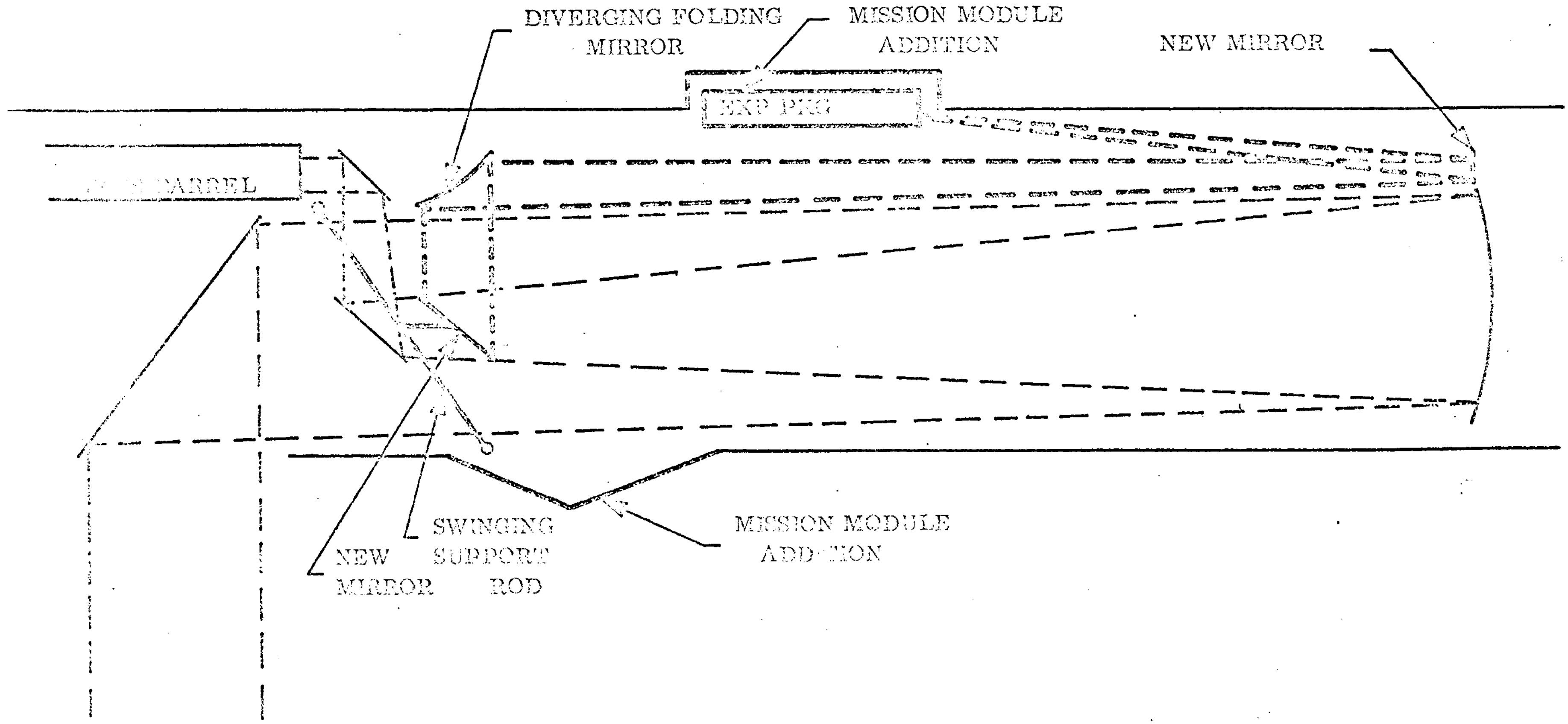


FIGURE 4.2-7 MODIFIED OPTICS F13 SYSTEM

4.2.2.3 Option III - Astronomical Observations After Completion Of The Prime Mission

There is insufficient time throughout a normal mission duration to complete many of the experiments listed on the ORDS. If, however, the spacecraft can be put into a higher orbit upon completion of the normal mission and operated in an automatic mode, then an entire series of experiments could be completed in approximately one year. The desire for a higher altitude orbit stems from the background illumination problems due to the geocorona and problems due to absorption by the residual atmosphere at the existing 80 NM orbit.

For example, most of the ORD's specify an altitude of 460Km. This requirement will provide a longer life for the satellite and raise it above the atmosphere. For an 80 N.Mi. (148Km) orbit there will be additional atmosphere to attenuate the light. In this region the gas consists principally of O_2, O, N, and N_2. The exact proportion has not been exactly measured, but it is known that it varies with the solar cycle. During the minimum sunspot portion of the cycle the proportion of atomic oxygen is greater because of the greater flux of cosmic rays. The composition also has a daily and a seasonal variation.

In the ultraviolet region the absorption depends upon the wavelength, there being a photoionization continuum for the atoms as well as broad bands for the molecules. With the data readily available one finds that at 1400 A between the altitudes of 148 and 450 Km the oxygen molecules can absorb about 1%, the nitrogen molecules less than 0.01%, and the atomic oxygen and nitrogen somewhat less.

The extended life, higher orbit option has the same problems associated with it as Option II, i.e.; the placement of the sensor and the optics modifications. Far more important, however, and perhaps the most critical problem is extending the lifetime of the MOL vehicle from 45-60 days to a one year period and equipping it to operate fully automatically.

4.2.2.4 Preferred Path

Figure 4.2.8 shows the options available for an astronomy mission. The preferred path is via Option II, astronomical observations within the normal mission life. This path was selected since it provides a significant amount of experimental data but avoids to 1 year reliability and automatic operation problems of Option III. Option I, while involving relatively simple modifications, does not provide a scientific contribution worth the added complexity of including this capability in the baseline system.

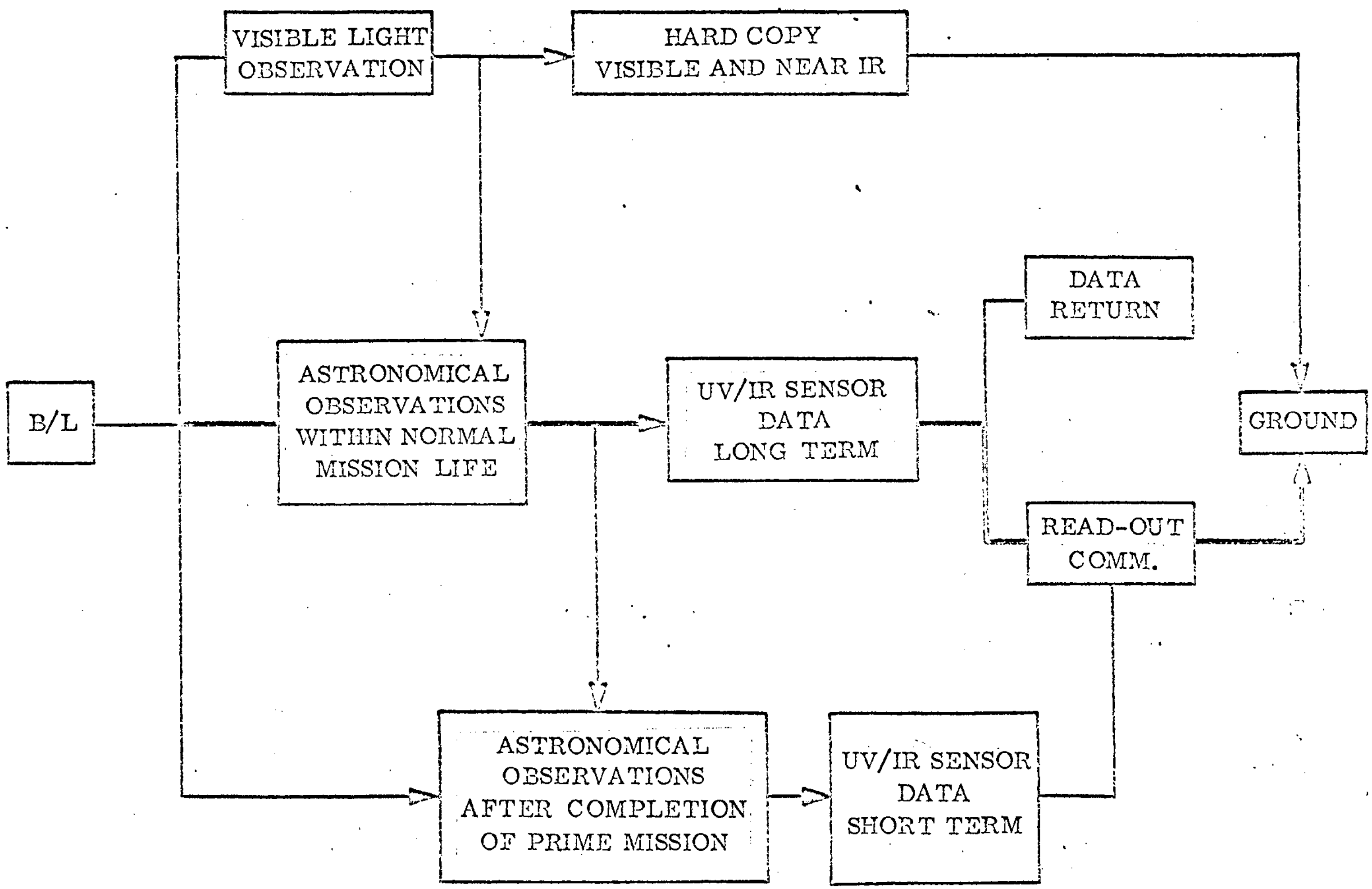


FIGURE 4.2-8. ASTRONOMY (UV/IR)

4.2.3 LIST OF CRITICAL AREAS

Option I - Planetary Photography

No critical areas identified

Option II - Astronomical Mission

Sensor Location

Modifications to the Mission Payload Optics

Mission Payload Structure to Support the Sensor

Added Star Trackers

Total Added Weight

Option III - Long Life, High Orbit Astronomical Mission

Same as Option II plus:

Long Life Reliability

Automatic Tracking and Pointing (including additional star trackers)

[redacted]

[redacted]

[redacted]

[redacted]

FIGURE 4.3-1 [redacted]

[redacted]

[redacted]

[redacted]

TABLE 4.3-1

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

4.4 ATS/MAIN OPTICS IMAGE TRANSMISSION/RECORDING

4.4.1 SUMMARY AND INTRODUCTION

Additional capability can be added to the MOL baseline design for a minimum cost through use of the existing visual optics systems in the Acquisition and Tracking System (ATS) and the Main Optics (M/O). Auxiliary cameras can be incorporated into these systems or added to their eyepiece.

A preliminary study of the performance of possible configurations indicates that simple add-on cameras for the ATS (35 MM) may provide ground resolutions (at 80 N.M., nadir) ranging from approximately 4 feet to 28 feet. Similarly special built-in camera installations for the ATS (35 MM or 70 MM) might lower the best possible ground resolution to nearly 2 feet.

The small size of the film format for these systems would minimize the requirements for film processing and readout equipment needed to provide an initial near-real-time readout and transmission capability.

The study also indicated that a simple add-on television camera (such as that used on Apollo) used with the M/O visual optics could transmit real time imagery through a modified SGLS link with a ground resolution ranging from approximately 4 feet to 60 feet. The same TV camera used with the ATS would provide ground resolution ranging from 28 feet to 225 feet. At the latter value the ground coverage would be approximately 5.6 N. Miles in diameter.

The applications for the existing visual optics for the M/O and the ATS can be increased by providing a capability for recording and/or transmitting the images seen by the crewmen. These images can either be permanently recorded on film or transmitted to the ground as a telemetered signal. Both methods are feasible. The method selected can therefore be tailored to best suit the planned customer use. The present probable uses are indicated in Table 4.4-1.

4.4.1.1 Constraints/Requirements

There are constraints imposed on a camera design by the limited space within the Laboratory Module and the tight operations schedule planned for the crewmen. These constraints are relatively severe in that the add-on capability, by definition, must have a minimum impact on other elements of the MOL system. In addition to the spaceborne system constraints there are constraints related to the ground based system. For example, the SGLS communication link has a one megabit per second maximum capability that will limit the amount of real time digitized visual data that can be transmitted. Similarly, there are only short intervals during which the spacecraft will be accessible to ground stations that can accept SGLS data.

Finally, there are the constraints imposed by the basic capabilities of the ATS and M/O optical systems and the currently available devices to record their visual images.

Consideration of these constraints leads to the identification of a preliminary list of requirements as follows:

TABLE 4.4-1 - PROBABLE USES FOR ADDITIONAL IMAGERY

1- IMAGERY FOR USE IN PUBLIC RELEASES (COVER STORY)

2- IMAGERY FOR INEXPENSIVE DEMONSTRATION OF READOUT (RHO)

3- REAL TIME READ-OUT DEMONSTRATION (TV)

4- PERMANENT RECORD OF ALTERNATE TARGETS AND GROUND CONDITIONS (TRAINING)

5- VERSATILITY (e.g., MULTI-SPECTRAL, COLOR, REDUNDANCY)

General requirements

1. The add-on features must not degrade the basic performance capability of the ATS or the M/O.

2. If add-on attachments interfere with the normal functioning of either the ATS or the M/O, it shall only be for the time the add-on capability is in use.

Camera requirements

1. The access to the film plane must be inside the Lab Module.

2. The film should be in quickly interchangeable film cassettes. The size must be standard and no more than 70 MM in width.

3. There must be direct visual access through the eyepieces to minimize smear from tracking errors. Instantaneous observation as in a reflex camera is acceptable.

4. Automatic computer control of focus in accordance with pointing and ephemeris status must be provided.

5. The nominal shutter speed for the known sun angle must be preset by the computer.

6. Rapid sequences of exposures must be possible and physical access to the film cassette may be awkward, therefore, a motor driven film advance is necessary.

7. Provision must be made for rapid insertion of special filters.

8. If possible ancillary data such as, focus and pointing data, should be directly recorded at the side of each frame. Otherwise such data must be separately recorded and coded for transmission by separate means.

9. There must be the capability for processing the black and white film on board, preferably using the same processor used by other cameras (e.g., the relay camera).

Television camera requirements

1. Quick attachment to the M/O or ATS eyepieces is required.

2. There must be concurrent viewing of the eyepiece image on a TV monitor.

3. The image transmitted must be in near real time but not necessarily in real time. There is no need for images giving the impression of motion.

4. Where the image presented by the optics far exceeds the resolution capability of a simple TV camera, the field-of-view can be restricted so that the TV image will have a nominal resolution.

Support requirements

1. The software programs to support these add-on systems should be minimized. This implies a minimum of automation.

2. There should be a film scanner which will convert the on-board processed imagery into signals suitable for transmission to the ground.

3. Both the TV camera and the film reader will require a device to digitize and encode the amplitude modulated signals for transmission to the ground.

4. The TV system may require a short term storage device having a capacity suited to a single image.

4.4.2 SUBSYSTEM OPTION MAP

4.4.2.1 Configurations Considered

The possible configurations are severely limited in number when the preceding constraints and requirements are considered. There are only three film and three television camera configurations that are directly applicable. The design options leading to these configurations are illustrated in Figure 4.4-1 These same configurations are listed in Table 4.4-2 and are discussed in more detail below.

Location At The Reticle Plane

There are essentially only two locations in the ATS optical train that allow easy access to an image plane. One is located between the derotation prism and the zoom and eyepiece optics. This location was originally reserved for access by a visual cue projection device. The target centering reticle is also located at this image plane. Because of the original plan for use of a flip mirror in this area to project the cue image through the eyepiece optics, there is still space for a flip mirror (differently oriented) to direct the image to a camera. However, the space outside the ATS structure originally reserved for the cue mechanism has been utilized by other equipment. Therefore, it must be assumed that it will be possible to relocate

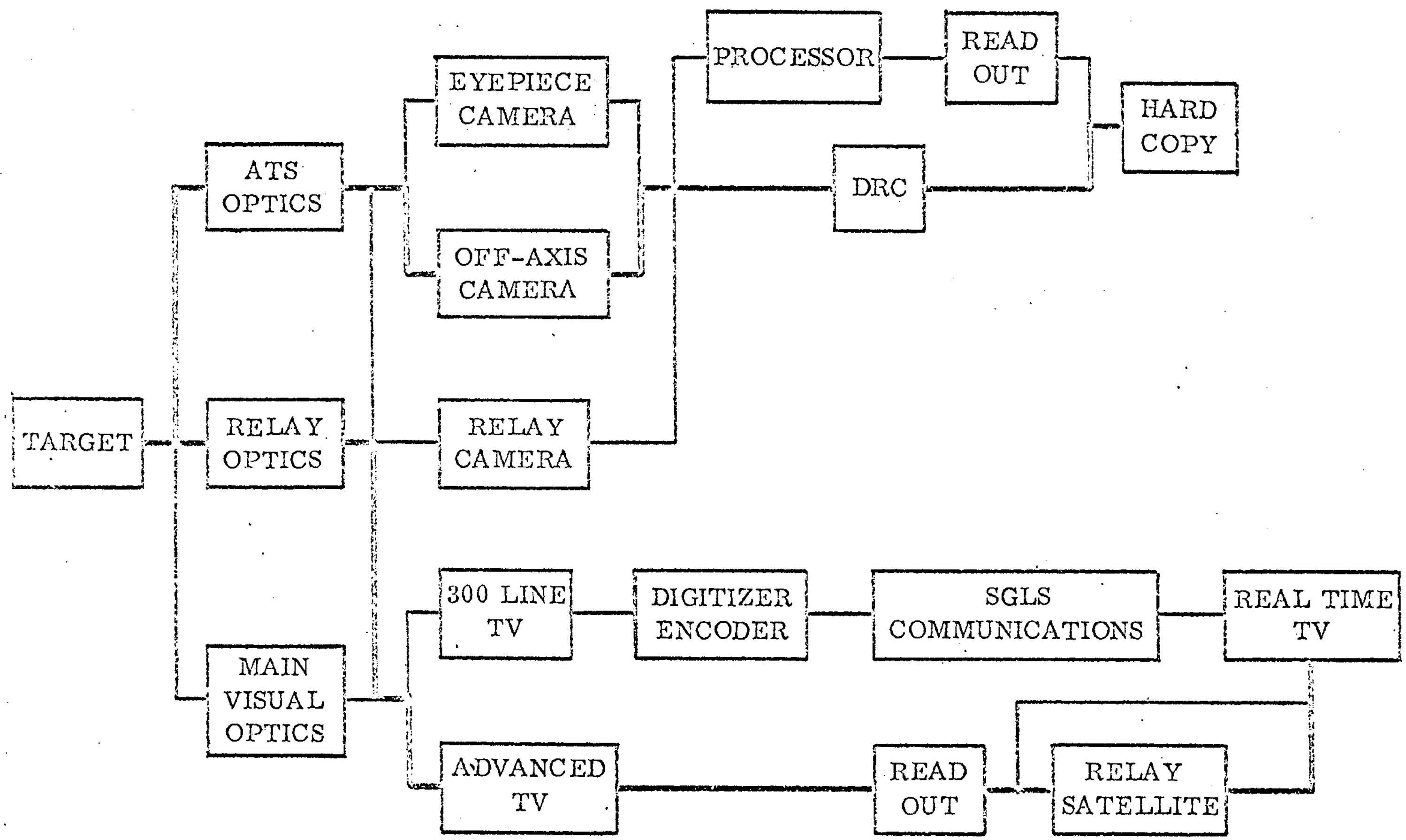


FIGURE 4.4-1 ATS/MO IMAGE TRANSMISSION RECORDING

these equipments as part of any redesign effort to install a camera at the reticle plane. The need for this modification is a negative factor in consideration of this configuration.

There must be quick and easy access to the film cassette and camera controls or the necessary functions must be automated. Access to the ATS reticle plane is below and behind a console and is possible, but only as a special activity. It cannot be part of an operational sequence during a target pass. A reticle plane camera must therefore be automated. Automation will require a larger volume and more electrical power than a simpler, manual system.

TABLE 4.4-2 - CONFIGURATIONS BEING CONSIDERED

A. FILM CAMERA

1. REMOTE CONTROL - ACCESS TO ATS OPTICAL TRAIN AT RETICLE PLANE

   a. 35 MM FILM - USE OF INSERTABLE DEFLECTING MIRROR AND MINIMUM OPTICS TO PUT COMPLETE IMAGE ON FILM.
      FILTERS, FILM ADVANCE AND CHANGES MECHANIZED.

   b. 70 MM FILM - USE OF MIRROR AND SPECIAL OPTICS TO ENLARGE IMAGE TO FILM SIZE.
      OPERATIONS MECHANIZED.

2. CARRY-ON - ACCESS AT ATS EYEPIECE FOR 35 MM CAMERA.
   FURTHER ENLARGEMENT TO 70 MM FORMAT NOT CONSIDERED BECAUSE OF VOLUME AND COMPLEXITY CONSIDERATIONS.

B. TELEVISION - VIDICON CAMERA ATTACHED TO EYEPIECE AND IMMEDIATE TRANSMISSION TO GROUND THROUGH SGLS.

1. ATS EYEPIECE - SIMPLE ADAPTER LENS AND ATTACHMENT FOR EXISTING 300 LINE TV CAMERA (e.g., CAMERA USED ON APOLLO)

2. MO EYEPIECE - AS ABOVE

3. RELAY CAMERA - ADVANCED TV CAMERA USING RELAY CAMERA ADAPTER.

Nevertheless, there are definite advantages to locating a camera at the reticle plane. Most of the available light is available at this location, possibly as much as 90% of that at the ATS objective lens. This is far better than the 30% that reaches the eyepiece. This will allow shorter exposure times with a resulting reduction in image smear.

The image plane also is relatively flat and would require the minimum of correction before exposure to the camera film thus allowing relatively constant resolution across the entire image format. The image diameter is approximately 1.2 inches and therefore is a good fit for a 35 MM film format. If interchangeability with the 70 MM relay camera was desired, this image could be enlarged to a 70 MM format but with a corresponding increase in exposure time.

The installation of a TV camera at this location would be possible but a special design and installation would be required. The easy add-on features would not exist and the design effort would approach that required for the Integrated Electronic Viewing System (Omega - the unclassified title) but with far less satisfactory resolution capability. This configuration is therefore not being considered for the Image Transmission/Recording capability.

Location At The ATS Eyepiece

The second location for a camera is at the ATS eyepiece. This location is far more accessible but less desirable relative to optical quality.

There is no "real" image outside the eyepiece so that an imaging lens for a camera (film or TV) will be needed. This lens will also need to flatten the image plane which is presently curved. The eye of an observer can accommodate a field curvature that would cause an unacceptable across-the-format image degradation in a flat film plane.

Only 30% of the light incident on the objective lens will be available to a camera through the eyepiece. A correspondingly long exposure time will be required. This is of importance because the ATS line-of-sight movement (smear) is appreciable and subject to rapid increase if not continuously monitored through the eyepiece and corrected by the crewman.

The requirement for continuous monitoring of ATS pointing requires that there be a flip mirror in the camera line-of-sight to allow the film to be exposed. The same requirement for the TV camera will require use of a pellicle (with still further reduction of light) or use of a TV monitor screen on the console face.

The zoom capability of the ATS eyepiece is a minor advantage. In particular, it would allow a rapid match of image detail to the TV resolution capability. This would be helpful since in the simple system being considered here, the optical system resolution would always exceed that of the 300 line TV camera.

The eyepiece location also has the major advantage of easy accessibility. The add-on capability can consist of small compact devices that can in effect be carried on board and quickly attached by the crewman. For example, the TV camera evaluated in the following section is assumed to have the same characteristics as the carry-on TV camera used in the Apollo flights.

An interesting variation of a carry-on camera that should be studied further might be an 8mm ATS eyepiece camera. The image would be 4 times smaller than the 35mm image thus reducing the exposure by a factor of 16 and reducing image smear. The film bulk would be reduced. The curves in a later figure indicate an effective limit of 75 lines/mm at the film, or approximately 600 line pairs across the 8mm image. This would be equivalent to a little more than 8 foot ground resolution at best and 64 foot resolution at the worst. This is surprisingly adequate performance.

Location At The Main Optics Eyepiece

The extreme magnification at the Main Optics eyepiece offers the interesting possibility of obtaining comparatively high ground resolution in near real time using a simple TV camera (300 lines). See Figure 4.4-2.

This add-on capability is further simplified because the automatic motion compensations for the M/O makes continuous monitoring through the eyepiece unnecessary. The four magnification values for the M/O will also allow some selectivity with respect to total ground coverage in such an application.

The insertion of a 70 MM format camera into the M/O optical train is already being considered as the Relay Camera installation. Therefore, there is no advantage to considering other camera additions to the M/O system.

The additional degradation in resolution caused by the adapting lens at the eyepiece and the smear during exposure must also be considered. The exposure at the reticle plane was assumed to be the same as that for the primary M/O camera (i.e., 1/200 sec.) since the object, aperture, and film are the same. But for the eyepiece only 30% of the light is available so that a longer exposure is required with a resulting increase in smear. Similarly at the reticle, if a 70 MM format is used the exposure and smear must be increased by a factor of four.

The expected resolution for the TV camera was obtained by a much simpler method. It was assumed that 2 TV lines are equivalent to one resolution line pair or that for a 300 line TV system there would be 150 resolution elements in the image. Thus, the ground resolution would be equivalent to

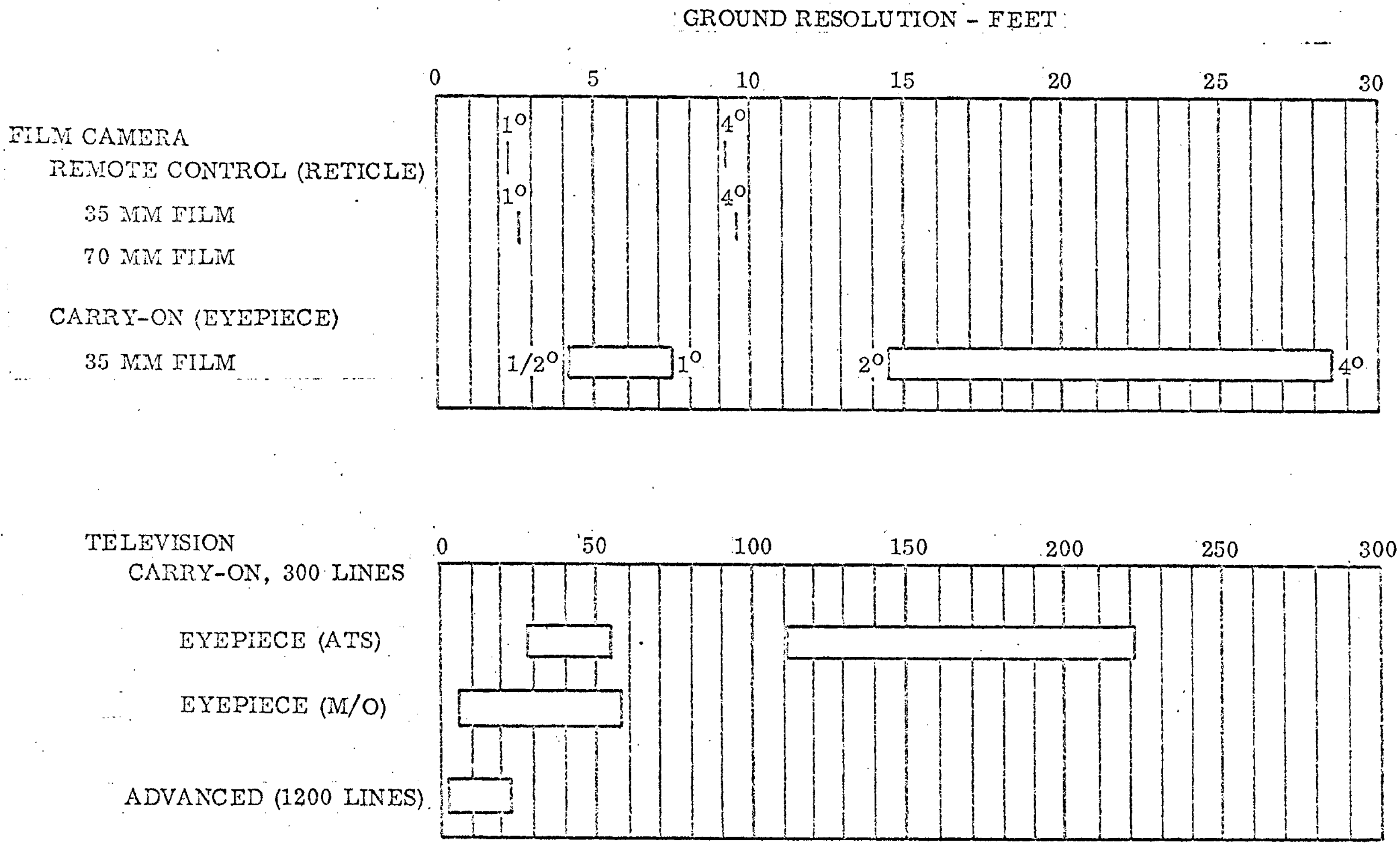


FIGURE 4.4-2. RESOLUTION COMPARISON OF POSSIBLE CONFIGURATION (PRELIMINARY)

1/150 of the diameter of the field-of-view projected onto the ground at nadir.

Location At The Relay Camera Adapter

A still more effective installation for an add-on television camera would be as an interchangeable attachment to the Relay Camera fittings. Once the Relay Camera optics were available and a real time relay link was operative -- even for limited parts of an orbit -- a high quality image of the target area could be transmitted to the command center. The ultimate quality of this image would depend upon the capacity of the relay link. A rough estimate of the resolution of a normal contrast target at nadir is shown in Figure 4.4-2.

This capability may not be directly productive of technical intelligence but it may also have significant potential for aiding mission operations. For example, the resolution on the ground is expected to approach that of the ATS for the crewman. Then in some instances, the ground command personnel can perform their own evaluation of critical ground activity. At the very least, such an installation will provide an excellent capability for testing and evaluating operating procedures for later systems making greater use of direct visual links.

4.4.3 PERFORMANCE EVALUATION

A preliminary analysis of the performance capability of the preceding configurations has been made. The results are summarized in Figure 4.4-2. The obtainable resolution at the reticle plane equals or exceeds that obtained by the crewman through the eyepiece at both magnification levels. These are, 16 power with a 4° field-of-view, and between 9 and 10 foot resolutions; and 63 power with a 1° field-of-view and between 2 and 3 foot resolution.

The attainable resolution at the eyepiece is degraded by the numerous glass elements of the zoom and eyepiece lenses. There are other sources of degradation that apply to both the reticle and eyepiece optical systems. The relationships of the more important of these factors are shown in Figure 4.4-3. The modulation transfer functions (MTF) are shown as a function of resolution in lines per millimeter for the reticle and eyepiece systems (the dashed lines); and for the type 3404 aerial reconnaissance film (dotted line). The loss of modulation because of normal haze, as seen from space, is shown as the horizontal dashed line at the top of the figure. The products of these MTF's are shown by the two solid line curves.

The resolution values at which there would be zero modulation (cut-off frequency) were assumed to be 111 lines per millimeter for the eyepiece and 251 lines per millimeter, (at the reticle, at 127 power) on the basis of information from the Alpha Subcontractor. The dashed curves are interpolations from these cutoff frequencies based on the MTF of a perfect unobstructed circular lens. The dotted curve is the published MTF for type 3404 film. The ascending straight line is descriptive of the relationship in which the dimension of film granularity at a given contrast will limit and establish

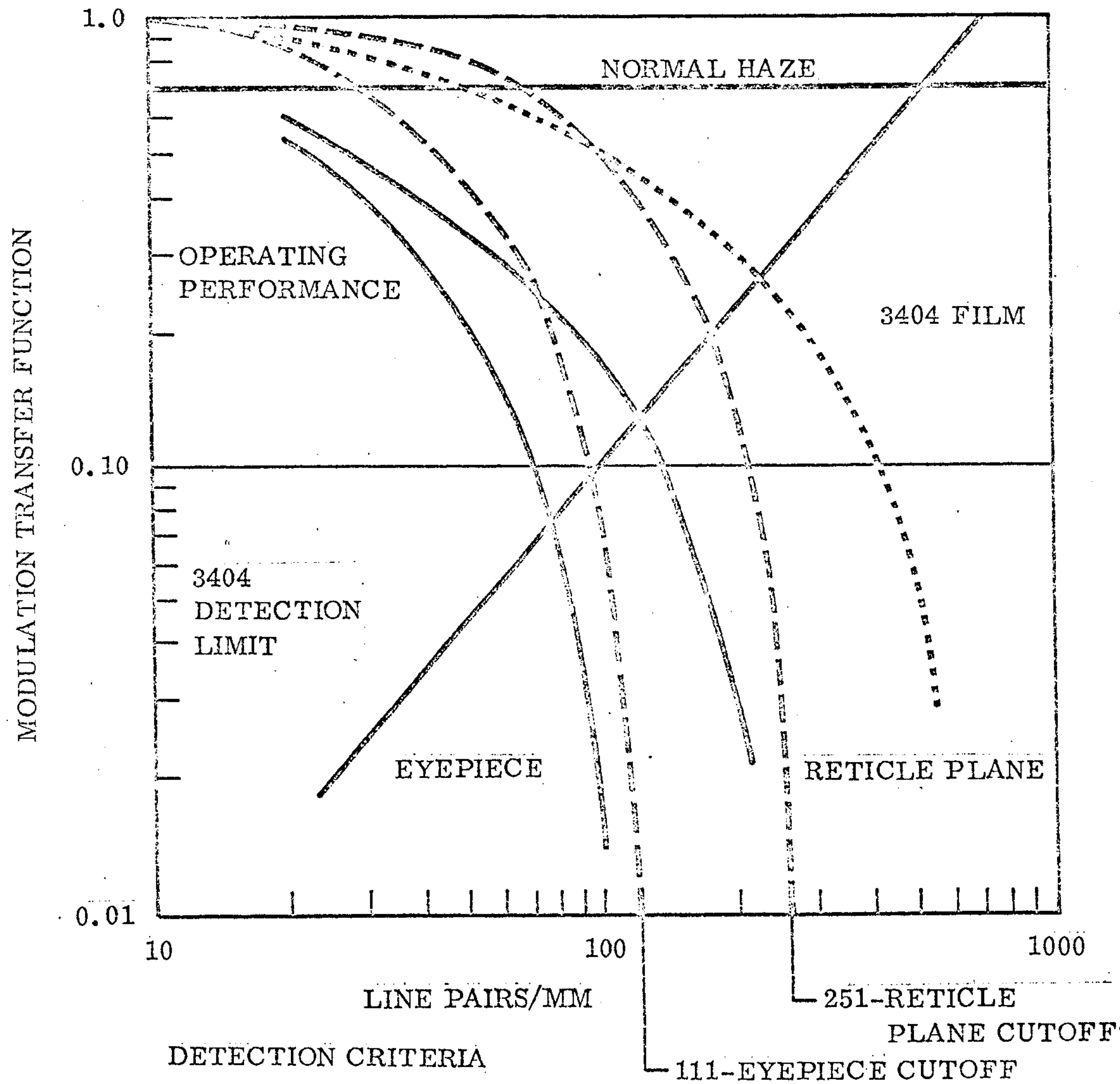


FIGURE 4.4-3 DETERMINATION OF ATS CAMERA LIMITS

the dimensions of the observable spatial frequency in the image. The intersections of the combined MTF curves (solid lines) with the line describing the detection limit establish the predicted resolution capability of the combined film-lens system.

4.4.4 CRITICAL TECHNOLOGY AREAS

The preceding material has mentioned design problems but the truly critical areas have not been emphasized. It is believed that none of the problems are insoluble - considering that most of these changes will not be implemented until the mid-seventies. However, certain assumptions must be proved by more detailed studies (or tests) before the detailed design can proceed. These assumptions and critical areas are as follows:

A) Real time (TV) image transmission by the SGLS digital link is possible. Obviously it is also assumed that the Rho system is in operation. A truly real time TV (30 frames per second) is out of the question because of band width limitations. But even at the slower frame rates used in Apollo (i.e., 10/sec), the band width exceeds the capability.

Since in every case the image will be essentially stationary because of the elaborate telescope and camera pointing controls, it may be possible to greatly increase the frame time. Possibly one second or more per frame is feasible. One limit will be the movement internal to the ground image because of its changing aspect as the vehicle passes over.

A critical limit will then become the availability of TV cameras having the capability for slow scan rates.

B) The availability of suitable space at the proper locations is not yet certain. It seems obvious that a small camera could be attached to the ATS or Main Optics eyepieces. Yet this assumes that the crewman's access to his console is not disturbed. This must be confirmed.

In the case of the ATS reticle plane location, the space once reserved for the cue projector has been used for other equipment. This space is essential to a camera installation at this location. It may be impractical to displace the equipment now in this location. A more careful investigation of the situation is necessary before a detailed design can begin.

In all camera installations there must be storage space available for the film. This is most critical for exposed film being returned to the ground. The very versatility of the simple add-on cameras suggested here will lead to a number of cassettes for different kinds of film. These cassettes may not allow an efficient packing factor for their return trip. A simple lack of space could restrict the amount of returnable data to an uneconomic level.

C) It has been assumed that relatively simple adapter lens can be made to permit a camera to image the eyepiece image. It is also assumed that little or no additional degradation results from the use of such adapters. A more detailed analysis of the performance possibilities of such systems should precede detailed design commitments.

D) The total cost of adding capability not directly related to the primary mission objective is possibly the most important constraint to be considered. The uncertainties caused by the preceding items are also cost uncertainties. Therefore, at this time any cost estimates can only indicate the relative scale of costs for the recommended addition. Since the assumed total cost for the image transmission/recording system is also very low, what would be otherwise mirror problems can alter these costs so that they are unacceptable. Studies of candidate configurations leading to specific cost estimates are therefore an additional critical area.

4.4.5 TRADE-OFF CONSIDERATIONS AND COST ESTIMATES

The foregoing analysis has made it apparent that acceptable theoretical performance can be obtained through the use of simple add-on systems. The practical problems involved in implementing any of the possible configurations have been mentioned in passing but no comparison of relative difficulty or merit has been attempted. The trade-off matrix of Table III presents a qualitative approach to such an evaluation.

The five configurations previously discussed are listed and each of them has been evaluated on a 3 valued scale. That is, for example, high, moderate, low. If arbitrary numerical values are substituted for these rankings and a weighted average value for each configuration derived, the qualitative value of each configuration is obtained. No one configuration is outstandingly good - or bad. The 70 MM camera at the reticle plane ranks slightly lower than the others, and the TV camera on the M/O and the ATS carry-on camera slightly higher. Quite probably, presently unspecified requirements of the customer could override the relatively small differential between configurations. For example, interchangeability of a 70 MM ATS camera with a 70MM M/O relay camera could make this a favored configuration. In

TABLE 4.4-4

TRADE-OFF CONSIDERATIONS

	RESOLUTION	VERSATILITY	ACCESSIBILITY	POWER WEIGHT VOLUME	EQUIPMENT AVAILABILITY	COMMENT
FILM CAMERA						
REMOTE CONTROL (RETICLE PLANE)						
35 MM FILM	GOOD	MODERATE	DIFFICULT	MODERATE	GOOD	EXISTING IMAGE FILLS FRAME SIZE
70 MM FILM	FAIR	LOW	DIFFICULT	HIGH	SPECIAL LENS	RELAY CAMERA INTERCHANGE, READ-OUT COMPATIBILITY
CARRY-ON (EYEPIECE)						
35 MM FILM	FAIR	HIGH	EXCELLENT	LOW	GOOD	LESS LIGHT AVAIL.
TELEVISION (CARRY-ON, 300 LINES)						
EYEPIECE (ATS)	POOR (RELATIVE)	HIGH	EXCELLENT	LOW	GOOD	EASY ADD-ON, ZOOM
EYEPIECE (M/O)	GOOD	MODERATE	EXCELLENT	LOW	GOOD	EASY ADD-ON, HIGH RESOLUTION IN REAL TIME

Approximations of the costs, weights, and development time for the two preferred options are listed below. Since there is no interaction between them, they are listed separately.

1) Off-axis camera, 70 MM format mounted at ATS reticle plane

   - $1.5 Million Cost
   - 15 pounds weight increment
   - 2 years to first flight

2) Advanced TV, quick attachment to fit Relay Camera fittings

   - $2.5 Million Cost
   - 10 pounds weight
   - 2 years to first flight