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TOTAL PAGES 117

MURAL SYSTEM [redacted] C[redacted]

PERFORMANCE EVALUATION

REPORT

24 January 1964

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FOREWORD

This PET Report includes an analysis of Missions 9056, 9057, 1001-1, and 1002-1. These flights occurred on 26 June, 18 July, and 24 August 1963, respectively. The several missions are incorporated into one report in order to compare one with another and to look at factors which are not universally present in all missions. For example, Mission 9056 had a yaw programmer and a Titanium/Invar Drum and Mission 1001-1 had a higher instrument temperature than the others. Mission 9057 is considered to be "typical" and the bulk of the analysis is concentrated on this mission, but loss of the Index camera on this mission precludes an analysis of system mapping capability on this mission. System mapping capability was therefore analyzed by ACIC using Stellar-Index photography from Mission 1002-1.

It should be noted that this report is to some degree after the fact and system changes have since been incorporated which influence the team's recommendations concerning system improvements.

PUBLICATION REVIEW

This report has been reviewed and is approved.

ALBERT W. JOHNSON
Captain, USAF
PET Chairman

ABSTRACT

An evaluation of the Corona M/J System was made using data from Mission 9056, 9057, 1001-1, and 1002-1. The bulk of the analysis is concentrated upon Mission 9057. Comparisons of one system with another were made, and isolated factors pertaining to individual missions were analyzed.

The evaluation was performed by representatives of AFSSD, LMSC, and ITEK assisted by personnel of the National Photographic Interpretation Center, Army Map Service, Aeronautical Chart and Information Center, and the 6594th Test Squadron (AFSPPL) (AFSC).

It is concluded that the photography collected by the M/J System is suitable for search intelligence and that it has considerable capability for mapping purposes.

Average ground resolutions were estimated to be 24 feet (12 foot object size) for Mission 9057, slightly greater than 24 feet for Mission 9056, and approximately 40 feet (20 foot object size) for Mission 1001-1.

The variations are attributed to temperature effects and to a light leak on Mission 9056. The Stellar-Index malfunctions appear to have been corrected by the changes made on the later missions.

Recommendations are included to further optimize the system performance.

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PERFORMANCE EVALUATION TEAM

PARTICIPANTS

AFSSD
[redacted]
Captain Albert W. Johnson (Chairman)

6594TH TEST SQUADRON
[redacted] Commander
Technical Staff

NPIC
[redacted]
Technical Staff

ACIC
[redacted]
Technical Staff

LMSC
[redacted]

ITEK
[redacted]
Mr. Francis J. Madden

TEAM OBJECTIVES

The objective of this evaluation is to analyze Mural System performance and the degree to which the system meets design objectives. The PET evaluation includes an analysis of system malfunctions, attempts to correlate performance indicators with the various degrading factors, and makes recommendations for system improvements.

SECTION I

MURAL SYSTEM DESCRIPTION

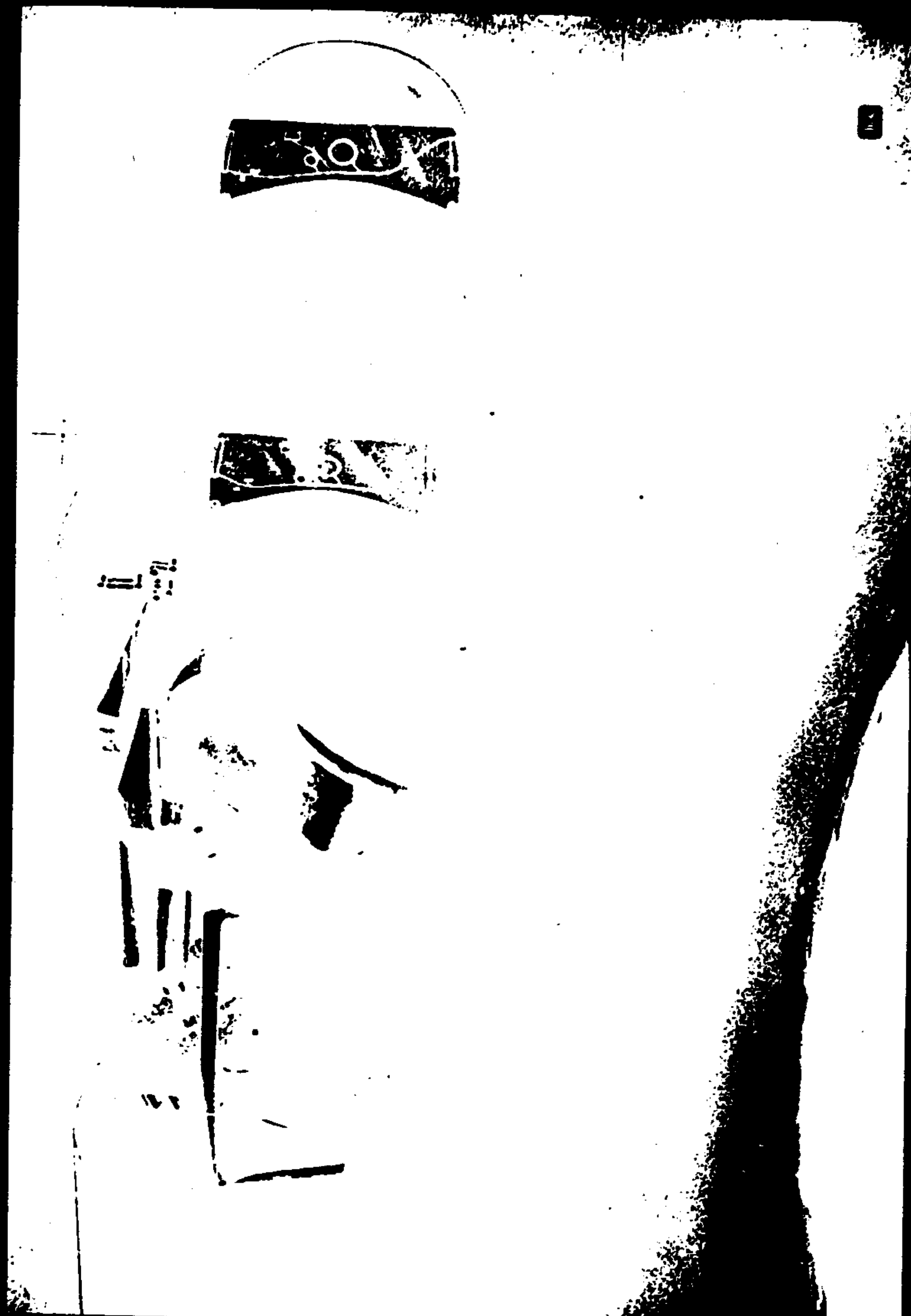
The payload section of the Mural (J) System consists of the camera subsystem, space structure subsystem and recovery subsystem. The payload section is boosted into orbit by the Thor or Improved Thor with second stage propulsion and orbit injection performed by the Agena D vehicle.

1. Camera Subsystem

The M/J Camera System consists of two high-acuity panoramic cameras aligned for 30 degree convergent stereoscopic photography (Figures 1, 2, and 3). Each camera incorporates a constantly rotating, 24-inch focal length, f/3.5, Petzval lens system, the velocity of which is matched to a reciprocating scan head during film exposure. The basic operation of both cameras is the same, with one camera acting as a "Master" instrument and the other as a "Slave." The Master camera carries the double frame camera programmer and the V/h programmer, and is the forward-looking instrument in operation.

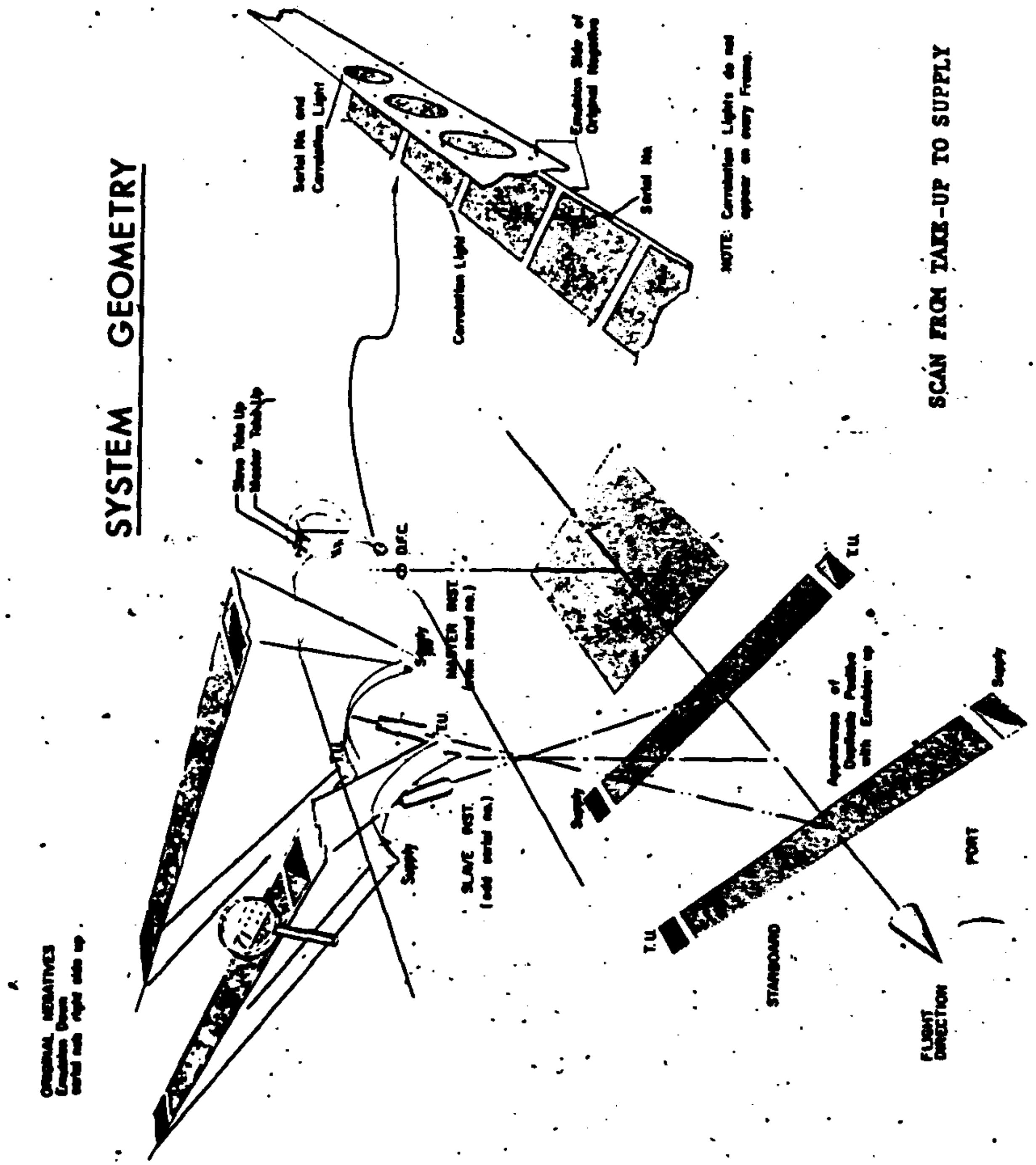
The power to operate each of the cameras is supplied by three motors; the supply and cassette torque motors, and the camera drive motor, all of which are energized simultaneously upon receipt of an "operate" signal. The M-System supply torque motor maintains constant film tension

FIGURE 1



J SYSTEM CAMERA

FIGURE 2


SYSTEM GEOMETRY
SCAN FROM TAKE-UP TO SUPPLY
Serial No. and
Correlation Light
Correlation Light
Serial No.
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Original Negative
NOTE: Correlation Lights do not
appear on every Frame.
D.F.C.
Supply
T.U.
MASTER INST.
SLAVE INST.
PORT
STARBOARD
FLIGHT
DIRECTION
ORIGINAL NEGATIVES

FIGURE

on the supply side of the transport system by attempting rotation in a direction counter to film transport, and the cassette torque motor maintains constant film tension through the camera system beyond the input metering roller and provides the power required to take film out of the camera and onto the take-up spools. Power for all other camera functions is supplied by the camera drive motor.

When the camera drive motor is energized, the lens begins to rotate (one lens rotates in counter-direction to the other), the metering roller feeds film into the camera, and the scan arm begins its reciprocating motion (Figure 4). A timing belt linkage to the camera drive motor rotates the lens 360 degrees about the lens vacuum nodal point at a constant velocity (for a given V/h). At the same time, the camera drive motor supplies power to the scan arm through sector gears, a cam and cam follower, and another timing belt linkage. The scan arm cam, which provides the proper position and velocity relationships between the lens and the scan arm, is accurate to within 0.25 percent. While the lens is rotating and the scan arm oscillating, unexposed film is fed from the supply spools into the camera through a system of metering, pressure, idler, and shuttle rollers. Camera drive motor power is transmitted to the input metering roller through a timing belt linkage and one of two alternate gear trains. The resulting tension on the film up to the input

M/J CAMERA OPERATING SCHEMATIC

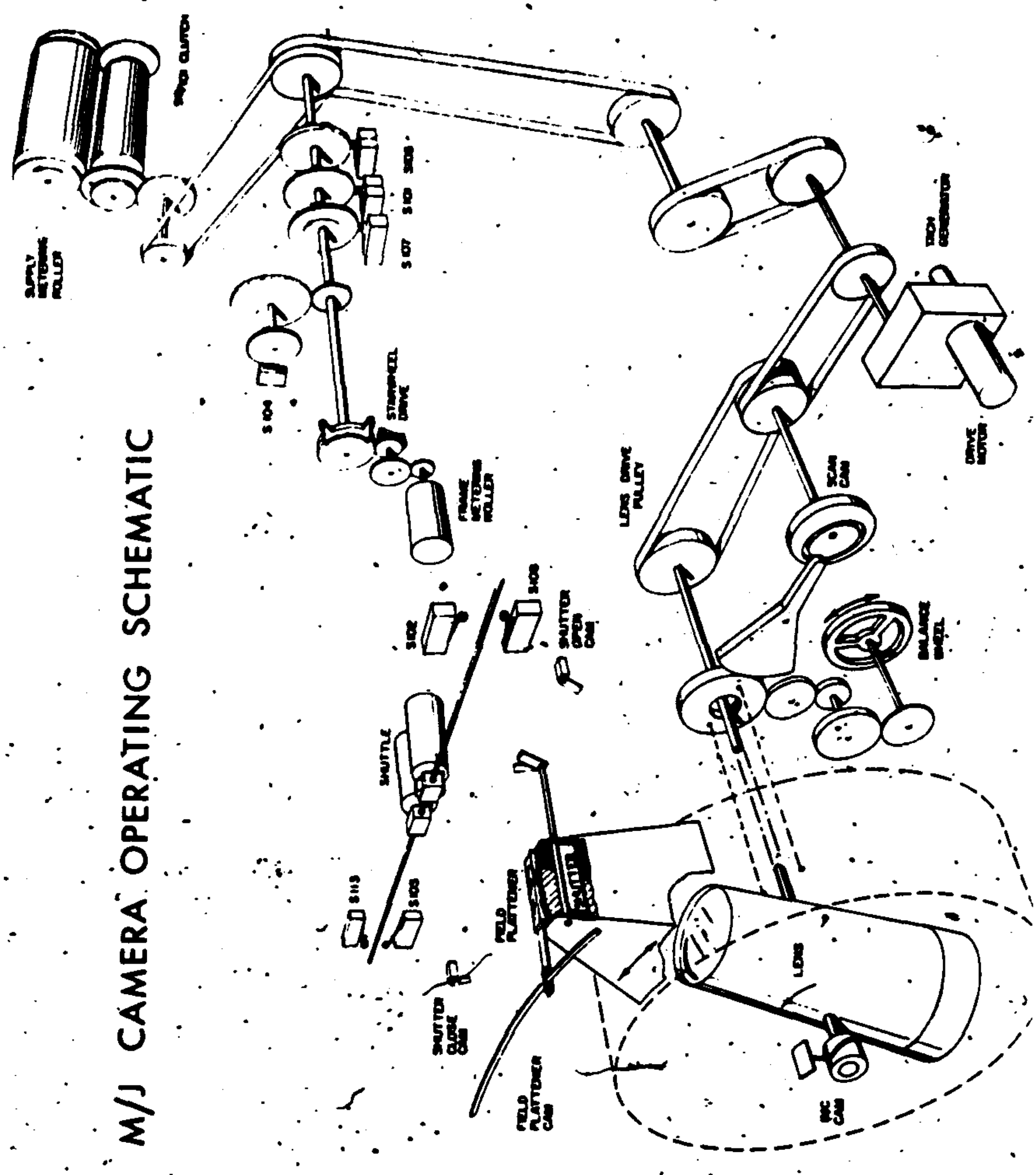
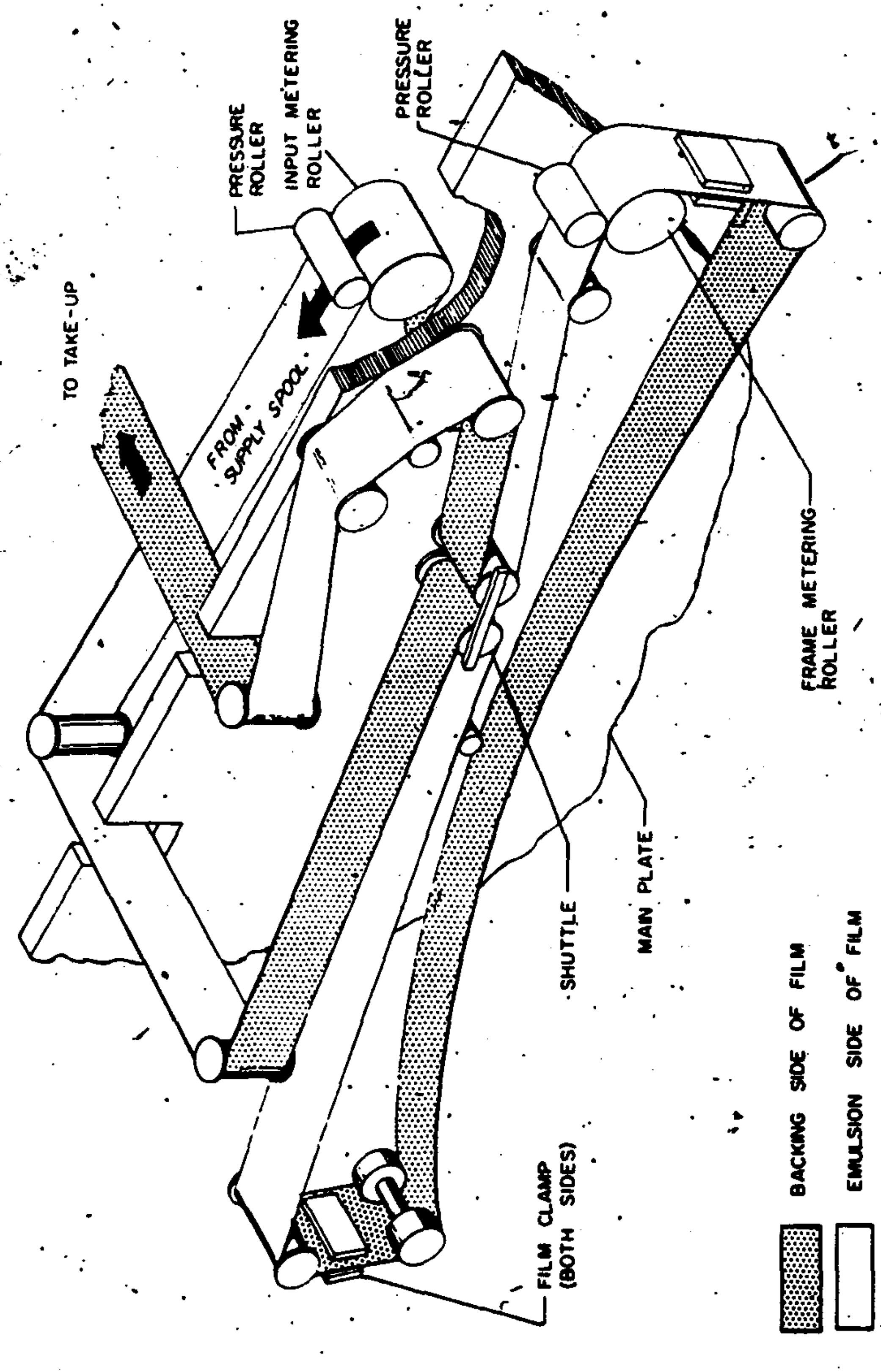


FIGURE 4

metering roller is applied by the supply torque motor, which is energized at less than full voltage throughout the operating cycle (the complete film path is shown in Figure 5). Thus, film is metered into the system while tension is maintained. Continuous input metering, as well as continuous film take-up, is made possible by the film shuttle system, which stores a "loop" of incoming film while giving up a "loop" of exposed film. The film loop is adjusted by engaging one or the other of two gear trains which drive the input metering roller. The two gear train values represent an input film speed of either 99 or 101 percent of the nominal film speed of 31-3/8 inches per lens revolution, a value established by the frame metering roller. By alternating gear trains as a function of shuttle position, the required average film speed is maintained throughout operation.

The frame metering roller is driven by the camera drive motor through a timing belt linkage and a "star-wheel" drive. This roller meters film through the guide rails; the film that is given up by the frame metering roller is transported through the remainder of the film path by the action of the take-up motor. The "star-wheel" drive imparts an intermittent rotation to the frame metering roller to limit roller rotation to the non-photographic portion of lens rotation. Slightly before, during, and slightly after the exposure portion of the cycle,



M/J CAMERA SYSTEM FILM PATH

FIGURE

the dwell period of the intermittent drive is in effect so that no film is metered; during this period, film clamps located at either end of the film guide rails are activated to ensure that there is no film "creep" over the rails.

While a frame of film is being metered, the scan arm moves in a direction counter to continuous lens rotation. When the scan arm reaches the "start-scan" position, the shutter opens, and the arm reverses direction. The scan arm, which is now moving in the same direction as the lens, accelerates until it reaches the "start-exposure position"; the scan arm and the lens reach this position simultaneously. At this point, the scan arm and lens, the velocities of which are now identical, are mechanically coupled through a latching system. The coupled scan arm and lens then sweep, at a constant velocity, to expose the film which is being held motionless, until the "end-exposure" position is reached. The resulting exposure time is a function of the scan velocity as the camera contains a single, fixed slit. At the end of scan, the lens is uncoupled and the scan arm decelerates to the "end-scan" position. Lens rotation continues at a constant angular velocity, film frame metering resumes, the scan arm reverses direction and returns to the "start-scan" position, and the next cycle begins.

The film being exposed is supported in semi-circular guide rails which approximate the sweep of the scan head. The radius of this semi-circle is 0.010 to 0.012 inches less than the lens focal length. Ball bearing rollers in the scan head lift the film slightly as the head scan and positions the film such that the film is at the exact focal distance during exposure.

Camera cycle rates are a function of the exact V/h, which is matched through the selection of pre-programmed ramp functions for the expected vehicle orbit; 121 non-linear ramps are provided to cover a wide spectrum of possible orbit characteristics. Operational cycle rates range from 6.0 seconds per cycle to 2.15 seconds per cycle; a programmer limiter circuit assures that the cycle rate will be no greater than 2.15 seconds per cycle. The V/h programmer and transducer are set such that voltages to the camera drive motor maintain camera cycle rates to within 5% of the required rates; for a given command, cycle rates of the two cameras are within 3% of each other.

Image motion compensation is achieved through the IMC cam, which is attached to the lens shaft; this cam is accurate to within 0.25%. Lens shaft rotation causes the cam to translate the lens along the line of flight axis. During the exposure portion of lens rotation, the cam translates the lens at a changing velocity as a function of scan angle in a direction counter to the direction of flight. During the film transport period, the cam completes its revolution and returns the lens to its original position. Translational IMC velocity is directly proportional to the lens rotational rate, and therefore, to the required V/h.

The momentum of the oscillating scan arm and its associated components is of sufficient magnitude to affect vehicle flight characteristics in the event that one instrument is operated while the other is not, or in the event that the two scan arms are not in exact synchronization. Compensation is achieved through a balance wheel in each instrument, the $I\alpha$ product of which is equal to that of the scan assembly. Motion is transmitted through a gear train which changes rotational direction and velocity so that the $I\alpha$ product of the balance wheel is equal to and in the opposite direction from that of the scan arm assembly.

Exposed film is taken up and stored in the cassette, which is capable of storing 7800 feet of 70mm film on each of its main take-up spools. The exposed film is pulled into the cassette with approximately the same tension at all times regardless of the diameter of the film wrap on the take-up spools. Take-up tension is maintained at a constant value by varying torque to the spool as a function of the spool core radius. The take-up motor is provided with an anti-back-up mechanism to prevent reverse rotation of the spool. This mechanism maintains the tension in the film while the camera is not operating and thereby prevents the formation of slack loops in the take-up system.

Data recorded on the film includes clock readout time (relative to the start of the mission), camera serial number, start of pass indicator, 200 cps timing track, film shrinkage markers, center of format marker, and Stellar-Index camera operate indicator (Figure 6).

Time relative to the start of the mission is imposed directly on the film by the camera binary data lamps, which are energized by a series of pulses from the vehicle clock; at the same time, the camera serial number is exposed on the film. The 200 cps timing track makes it possible to check the instantaneous scan velocity rate in effect during each exposure. The timing mark projector is mounted in the scan head so that its light strikes the edge of the format; the marker is energized and de-energized at the same time as the film clamping solenoids. Because the pulse rate is a known constant (200 cps), the number of pulses imposed on a frame indicates scan head and lens velocity. The film shrinkage markers and center of format indicator are exposed through small v-shaped cutouts on the inboard film guide track. The light transmitted through the lens is masked from the edge of the film except where the cutouts allow it to pass through. Since the distance between the markers

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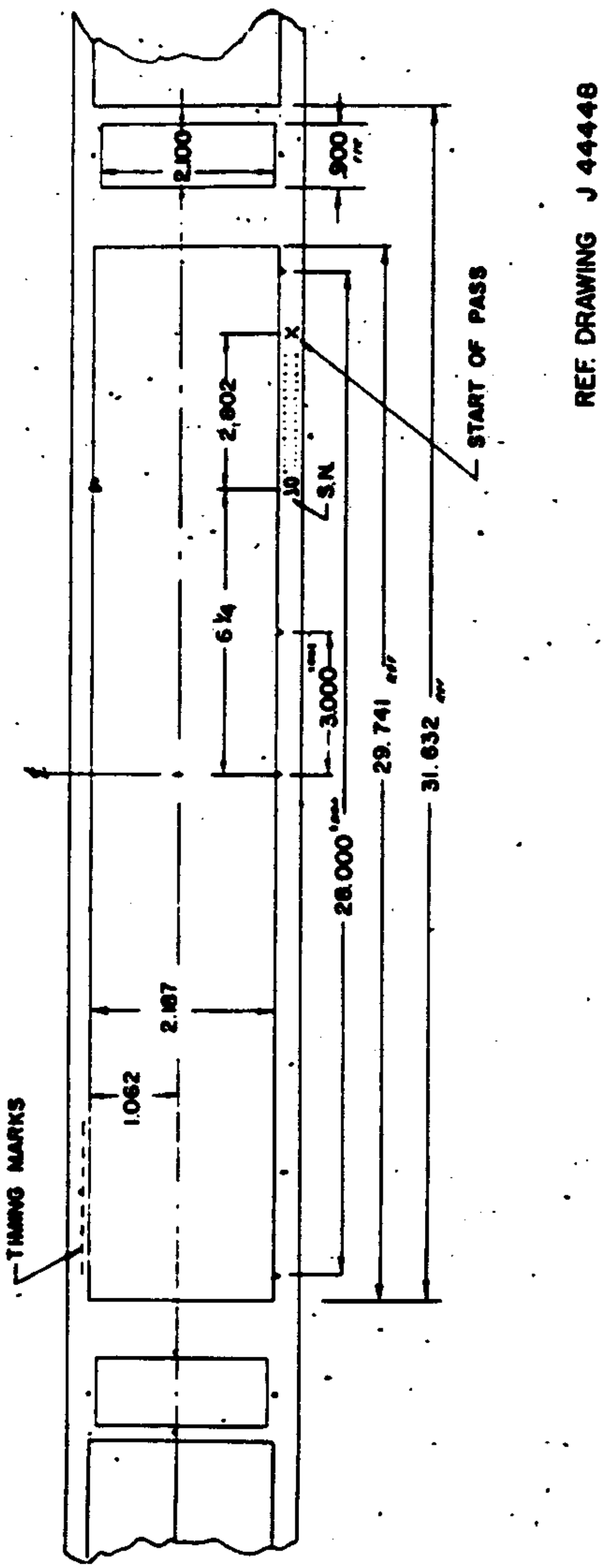

M/J SYSTEM FORMAT

FIGURE 6

on the film guide track is known, the measurement of the distance between the markers as developed on the film will indicate any shrinkage that may have occurred between time of exposure and the time of measurement. Each time the Stellar-Index camera shutters are fired, a 20 millisecond pulse is simultaneously transferred to the master panoramic camera's frequency lamp, thereby producing a smear on the Master camera film at that point.

The two Horizon cameras are mounted at either end of the film guide rails so as to focus on the port and starboard horizons when the vehicle is in the correct operational attitude. The cameras record the horizons on alternate frames during the mission, and this information is subsequently evaluated to determine the vehicle attitude at the time of eac exposure. Each of the two horizon cameras contains a 55mm f/6 Aerotar, wide-angle lens with a self-cocking shutter. Apertur and shutter speed can be varied and then set for optimum expos prior to flight. A Wratten No. 25 filter is used to penetrate haze and to improve contrast. Fiducials built into each camer expose pin-hole images at the ends of the two major axes of th horizon format. These fiducial markings, which are imposed on the film each time the horizon exposure is made, facilitate evaluation of the Horizon information. Power to energize the Horizon cameras is series-connected through two switches such that the cameras operate every other cycle. The shutters are fired through a spring connection between the shutter release lever and cam-energized solenoids. The exact relationship between the Horizon camera optics and Panoramic camera optics is determined through theodolite calibration.

For these missions, the Stellar-Index camera has been calibrated for distortion and alignment of the optical axis by photographing a stellar field and making precise measurements of the position of the recorded stellar images. This calibration is difficult and is dependent upon local weather conditions.

Itek is developing a goniometer technique to accomplish camera calibration. This approach has the virtue of providing measurement points at critical areas across the lens field and should result in improved distortion data. Cameras calibrated by the goniometer method should be available in March 1964.

In this Panoramic camera the focal distance depends upon the length of the scan arm and the distance the film rises above the scan head rollers during the scan cycle. This necessitates consideration of the dynamic effects of the scan arm rollers on the film. A technique (called the Dr. Aschenbrenner Test) has been developed which produces a contour map of the film position with relationship to the field flattener during the exposure scan.

The field flattener (optical element #6) is replaced with a glass plate having 9 transparent 25 micron wide lines in the direction of lens scan. A pair of bulbs are mounted approximately 3 inches apart, and 4 inches below the glass plate, and thus produce on the film a pair of line images corresponding to each line on the glass plate. The separation of this line pair is directly proportional to the height of the film above the field flattener. A calibration standard set of exposures are made on glass at .010 inch and .000 lift above the film lift rollers. Measurements are then made at 1/2 inch intervals of the spacing of each pair of lines on the 9 lines for each format developing the actual contour. The fundamental concepts of this technique are depicted in Figure 7, Aschenbrenner Test for Film Position.

2. <u>Space Structure Subsystem</u>

The space structure subsystem consists of the Aft conic adaptor providing the interface with the Agena D vehicle, the barrel section which provides the housing for the Panoramic camera, and the conic fairing which provides housing for the Stellar-Index camera and the digital clock, and mounting attachment for the recovery capsule. The space structure also contains cabling and junction boxes to supply electrical power and commands to the payload subsystem. The digital clock which provides system time to the Panoramic cameras is a part of the

ASCHENBRENNER TEST FOR FILM POSITION

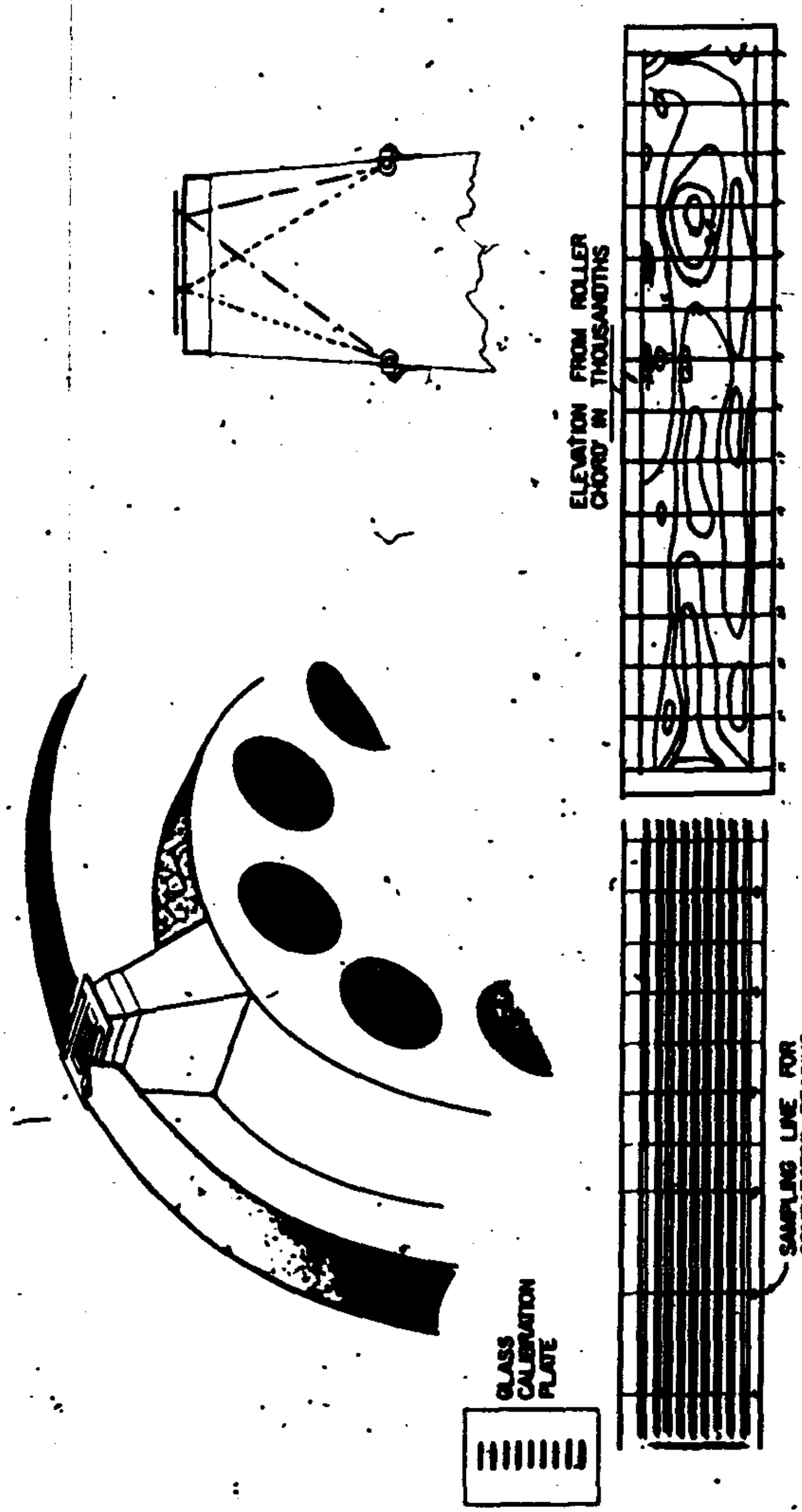

FIGURE 7

space structure. This clock is accurate to one millisecond in a 12-hour period and is related to real time by comparing telemetered system time to clocks at the tracking stations. The space structure also provides the signal conditioner to convert payload subsystem telemetry pickoff signals into the proper signal for the Agena D telemetry system and/or tape recorder. Other major functions of the space structure are to provide thermal control and light-tight housing for the cameras.

3. Recovery Subsystem

The recovery subsystem is the standard Mark 5A satellite recovery vehicle used throughout 1962 and 1963. It provides a light-tight container for the film take-up cassettes recovery aids in the form of tracking beacons and event telemetry, a parachute, and a de-orbiting rocket motor system. It also provides an ablative shield to protect the inner container from re-entry heat.

4. Vehicle System

The oribiting vehicle consists of the payload section and the Agena D vehicle modified to carry Program [redacted] peculiars The Agena D provides the second stage thrust to attain orbit, on orbit attitude control, electrical power to operate the vehicle and payload on orbit, and on-orbit programming of the payload on orbit. Initial thrust to attain the required attitu and velocity to attain orbit is provided by the Thor or improved Thor.

The attitude of the Agena vehicle is maintained by an inertial reference platform. The drift in the pitch and roll platform gyroscopes is continually corrected by infra-red horizon scanners. The yaw gyroscope is coupled to the roll attitude control segment; however, the drift cannot be actively corrected.

The error tolerances for the resulting attitude control at the time of Mission 9056, 9057, and 1001-1, based on a 90% probability, were:

Pitch Error	±	1.64°
Roll Error	±	1.64°
Yaw Error	±	2.19°
Pitch Rate	±	80°/hr
Roll Rate	±	160°/hr
Yaw Rate	±	160°/hr

Subsequent modifications and improvements to the Agena attitude control system have reduced to the allowable error tolerances, based on a 90% probability, to:

Pitch Error	±	1.0°
Roll Error	±	0.5°
Yaw Error	±	1.1°

Pitch Rate	±	10°/hr
Roll Rate	±	30°/hr
Yaw Rate	±	10°/hr

5. <u>Normal Expected Performance</u>

When the camera is considered without regard to vehicle or natural parameters, the camera-film (type 4404) combination should be capable of performing dynamically within the range shown in Figure 8. This figure also illustrates the dependence of resolution image contrast.

The capability range was arrived at by noting the relationships between static lens bench tests, static simulator tests, and dynamic simulator tests, while taking into account the degradation by the simulator collimator of the omiginal target contrast.

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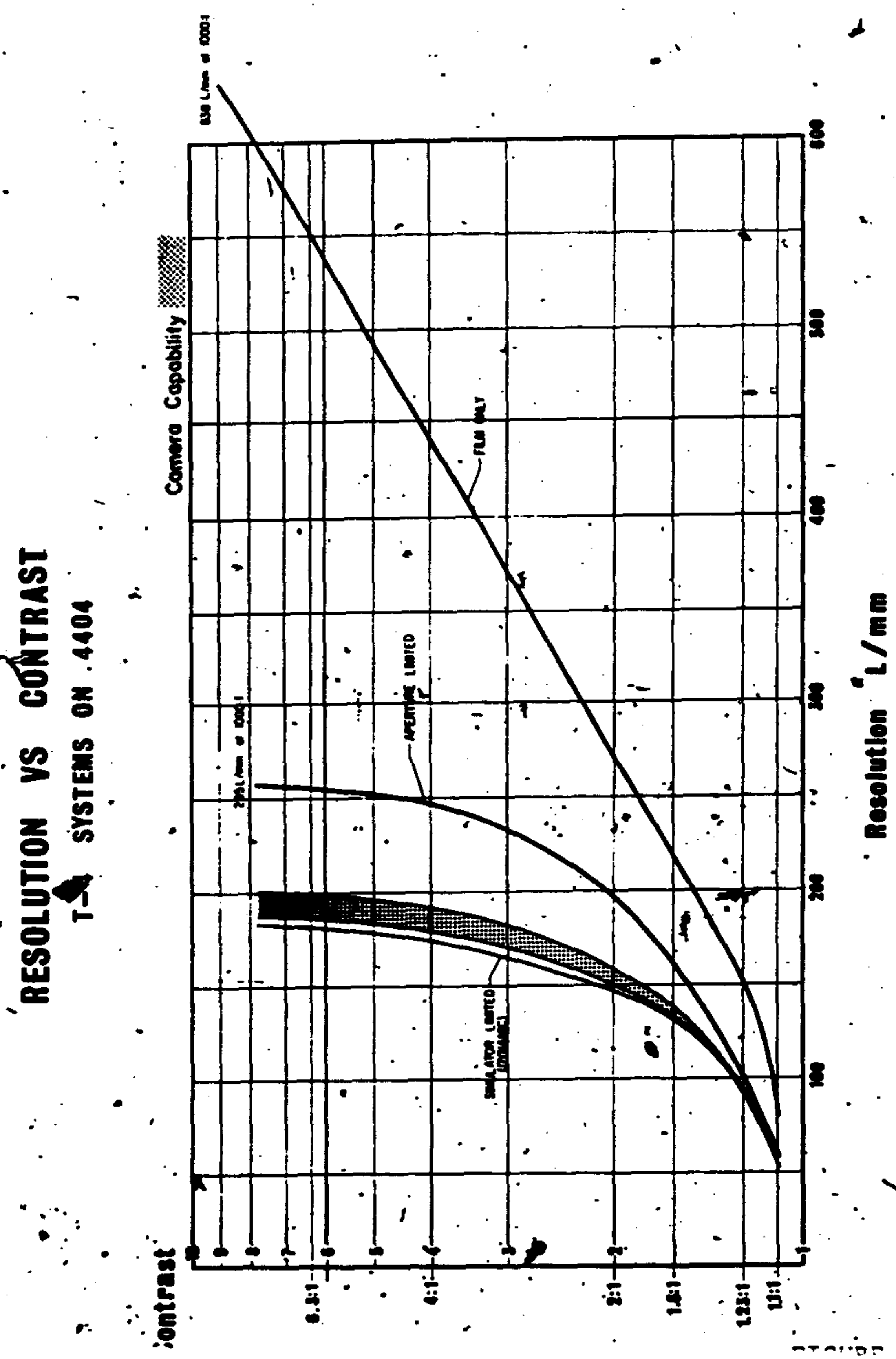

SECTION II

COMMAND SYSTEM

1. Command System Description

The Mural Command System used on Mission 9057 was the Type 7 Orbital Timer and a V/h Programmer controlling camera cycling rate. The Type 7 Orbital Timer is loaded before flight with commands as a function of elapsed time to turn the camera system on and off and to control certain system functions. The timer may be periodically reset by real time command transmitted by radio from the ground tracking stations to assure that desired operations are obtained. Real time commands are also used to select alternate programs, V/h ramps to adjust for orbit parameters, active lifeboat recovery mode, and similar functions.

Missions 9056 and 1001-1 were flown with the Type 8 Orbital Timer which replaces the Type 7. The same principles of operation are employed, but more timer tracks are provided on the tape which allows more alternate programs to be stored. This capability is particularly required for Corona J Missions where the second operation may occur a considerable time after the first operation resulting in shifts of the orbital parameters.

Inasmuch as Mural or J Systems are primarily employed for broad area coverage, targetting is not too difficult a problem. After selection of orbit parameters and designation of the areas to be photographed, the timer tape is prepared to turn the camera on at the proper time. It is standard practice to add a 25 second pad to both on and off times which reduces the need to make adjustments to the command system during flight. Recently the off time pad has been reduced to 15 seconds.

2. Command System Response

An examination of post flight records of Missions 9056, 9057, and 1001-1 shows that in all cases the command and control systems functioned satisfactorily and that desired operations were obtained. In the case of Mission 9057, a perigee shift of 18 degrees occurred which caused some difficulties in matching V/h ramps. Despite this, normal coverage was obtained.

SECTION III

ON-ORBIT OPERATIONS

The assurance of optimum satellite reconnaissance photography is dependent upon the acquisition of a quality latent image on the photographic emulsion and the ability to know where the photographed object is located on the surface of the earth. Some of the more paramount variables, beyond proper equipment operations, are exposure selection, image motion compensation and thermal control. These facets of the system as well as attitude determination are presented herein.

1. <u>Exposure Selection</u>

The exposure time for each frame of photography is, as noted in Section I, a direct function of the camera scan velocity. The width of the camera slit is selected based upon the range of solar angles that the system will be expected to be operating. Experience has shown that a 0.200 inch wide slit is optimum for operations during the major part of the year with a 0.250 inch wide slit used during operations near the winter solstice.

The camera scan velocity is controlled by the V/h programmer, hence, this velocity is essentially proportional to the latitude of the vehicle, since the vehicle altitude is usually higher over the poles than for the lower sunlit latituc for the Mural missions. The solar elevation for the day and time of launch is known for each terrestial latitude; therefore, the ephemeral parameters and launch time are selected to result in a best match of exposure time to solar elevation for the mission.

[redacted] has published curves which provide the optimum exposure time vs. solar elevation for various filter/emulsion conditions at three levels of processing time: Primary, Intermediate, and Full. The slit selection is based on the Intermediate processing curve to allow the underexposed and overexposed areas, resulting from exposure time - solar elevation mismatches, to receive proper processing.

2. Image Motion Compensation

The creation of quality photography made with a moving camera system requires some technique to stop the motion of the image during the time that the exposure occurs. This technique is called Image Motion Compensation (IMC). In Section I the method used within the camera system to accomplish IMC is described to compensate for the forward motion of the vehicle. This technique is predicted to correct IMC to a 90% probable error of 3%.

Other motion effects are, in some cases, compensated by airborne hardware. Mission 9056 contained equipment that would induce a programmed yaw error (horizontal deviation of the vehicle center line with respect to the orbital plane) to compensate for the velocity vector induced to the image by earth rotation. This feature has not been present on any mission since Mission 9056.

3. Thermal Control

Temperature variations of 30° to 40°F from nominal have been experienced during these missions. These changes from normal displace the film plane from the lens focal plane far in excess of the depth of focus. See Figure 9, Image Plane Shift with Temperature Change. The poor imagery was determined to be caused by the expansion or contraction of the magnesium drum-scan arm assembly. An invar titanium drum-scan arm assembly has been incorporated into the camera and now permits greater thermal variations before the film plane is displaced from optimum focus.

The effect of temperature variation on the resolution is shown on Figure 10, Lens System Thermal Response.

4. Attitude Determination

The post-flight determination of the geographical location of the center of each photographic frame is an established mission requirement. The Mural System contains Horizon cameras as a part of each panoramic instrument as described in Section I. The Horizon cameras photograph the

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IMAGE PLANE SHIFT WITH TEMPERATURE CHANGE

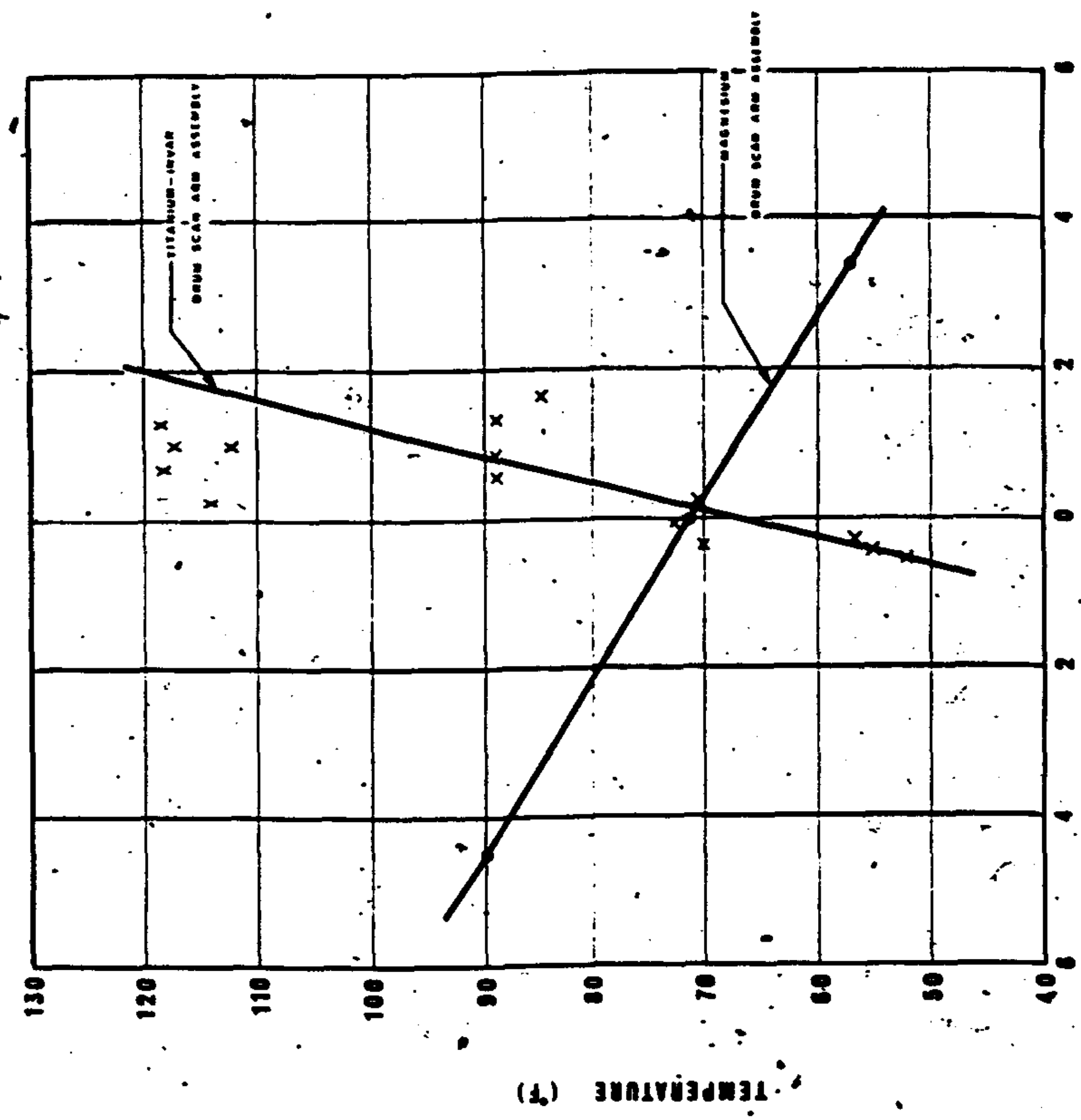

FIGURE 9

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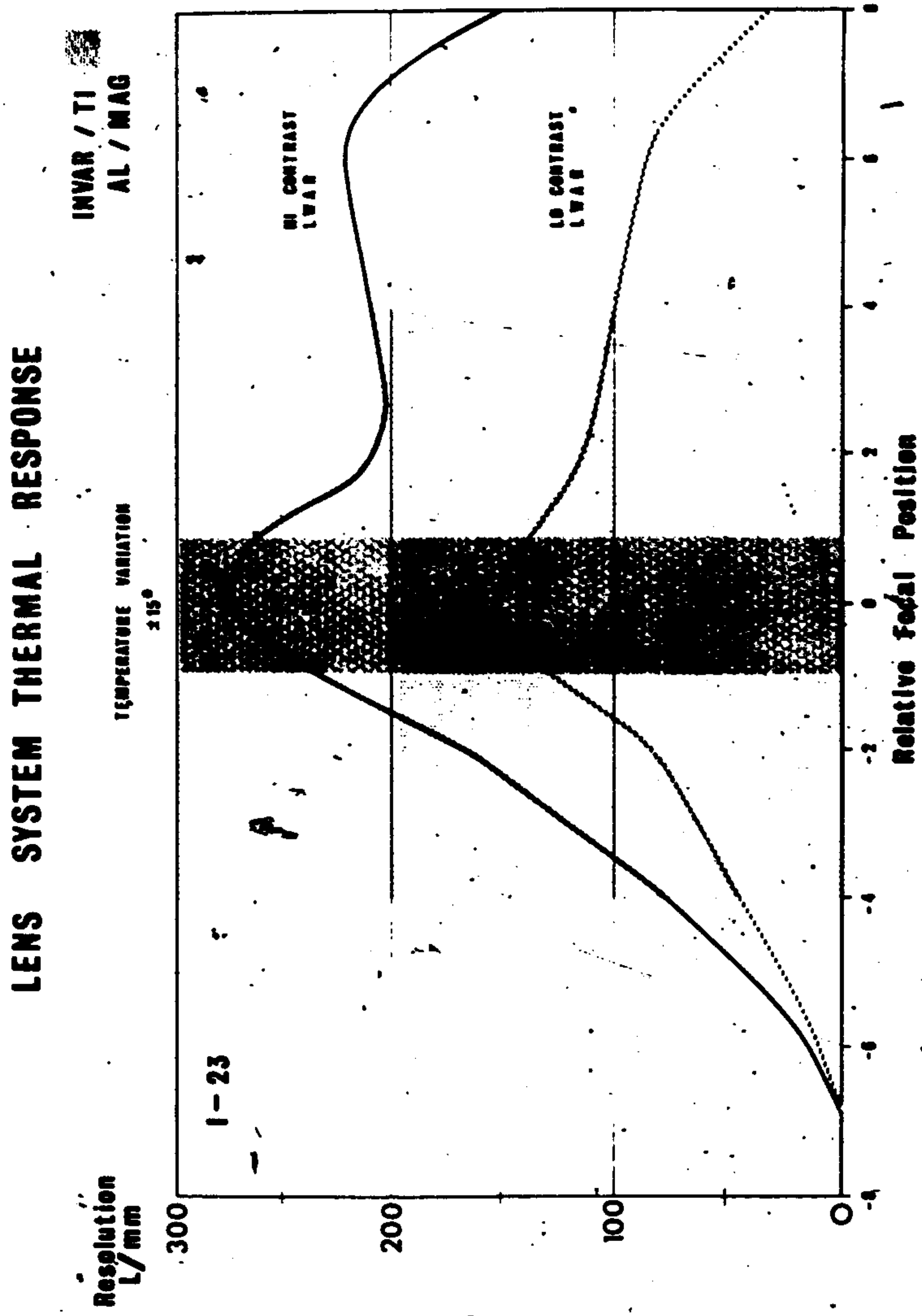


FIGURE I-10

port and starboard earth-space interface during every other cycle of the Panoramic camera. Coupled with pre-determined alignment data the pitch and roll position of the system can be determined. The center of format location of each frame is then determined with this attitude data and the normal tracking information.

A double frame (Stellar-Index) camera is installed in these systems which provides very accurate pitch and roll data and also permits measurements of the system yaw error.

SECTION IV

DATA PROCESSING AND MEASUREMENT

The quality of the intelligence information gathered by a system during operation is highly dependent upon the proper processing of the original negative as well as performance of the camera system. The evaluation of mission performance to ascertain the causes of reduction in intelligence gathering capability presents a difficult mensuration problem. Several techniques are now used to perform this evaluation.

1. <u>Original Negative Processing</u>

The control of the processing level imparted to the original negative is accomplished by a variable speed processor to achieve either the Primary, Intermediate, or Full processing conditions established as nominals by [redacted]. The original material is given Primary processing and manually viewed with infra-red equipment to ascertain the degre of further processing required to optimize the density range of the ground images.

The operator of the processor is assisted by the estimated exposure time and solar elevation at the start and end of each camera operation. This data is prepared and transmitted by TWX to the processing facility prior to the receipt of the flight material.

2. <u>Mission Information Potential</u>

Satellite photographic reconnaissance missions are launched to record intelligence information. The determination of the degree of success of any given mission in recording information is a controversial topic and may vary depending upon the user, or evaluator, his objectives, experience and expectations. However, NPIC recognizes the need for some subjective measure for determining and expressing the "success" of a mission. Based upon the experience gained from a number of Mural missions, certain feasible expectations have been established, and a set of arbitrary values adopted to express the relative "success" of each mission with respect to photographic quality, not the "success" in regard to targets covered.

The Mission Information Potential (MIP) values are determined subjectively and reflect the best apparent photographic quality found within the mission, even though this quality may be limited to a few frames. This is considered the maximum potential of the mission, hence the Mission's Informati Potential. These arbitrary values are not limited to a termina value of 100, but can be increased as the system improves. Whe plotted, these values provide a graphic picture of the potentia of each individual mission as well as the relative potential or "success" of various missions.

3. Reciprocal Edge Spread

The determination of image quality by AFSPPL is accomplished by an alternate technique called Reciprocal Edge Spread (RES). An image subject is selected which has well-defined edges, parallel and perpendicular to the line of flight. Cultural features are selected where possible; however, natural features are used as secondary selections.

The subject is viewed with a microscope containing a precision Filar micrometer. The reticule edge is located on the edge of the subject. The reticule is then moved across the width of the spread or "fuzzy" area adjacent to the subject. This width is measured in millimeters and the reciprocal of this measurement is the recorded RES value.

The mission material is examined throughout on an every tenth frame sample. Originally the sample started with the first frame of every pass, as was the case for all missions through 1002-1; however, this procedure has recently been changed to start the sample with the fifth frame of all passes. Each frame is divided into five equal areas and a measurement made in each area, thus for each frame, with no cloud cover, a total of ten measurements are made.

4. Micro-Analyzer

Several of the best images in each mission are selected for micro-densitometer traces to provide additional information about these subjects. AFSPPL uses a Micro-Analyzer to perform this measurement.

The equipment uses a 1.58 micron round spot to scan the subject. This spot is created by a 40X reduction of a 0.0025 inch aperture. The subject is scanned at a speed of 0.5 millimeters per minute and a chart speed of 101.6 millimeters per minute giving a final scale of one inch on the plot equal to 25 microns. The informational output equals 1620 bits per millimeter recorded from high resolution film.

Samples of selected areas and the Micro-Analyzer traces are in Appendix E through H.

5. Density Measurement

The measurement of diffuse density is done with a Macbeth TD-100 Densitometer in the same frames where RES values have been recorded; however, one set of values is obtained for the entire frame rather than five sets in each frame.

The instrument is equipped with a 1.0 millimeter aperture and uses a white light source. Recently, after Missic 1001-1, the spot size was reduced to 0.5 millimeters and a Wratten 39B blue transmitting filter added by AFSPPL, as their prime mission is to produce duplicate positives which are made with a blue light source. In each selected frame values are obtained for the minimum and maximum image density, the maximur density of the cloud areas and the base plus fog density.

SECTION V

PERFORMANCE EVALUATION

The overall system performance has been examined and evaluated for Missions 9056, 9057, and 1001-1. Some areas could not be evaluated in detail due to the lack of pertinent data. Discrete portions of other missions have also been evaluated in order to present a more complete appraisal of the Mural system.

1. Thermal Effects

The available in-flight temperature data from sensors 11 and 13 (stove and drum) was examined for correlation with RES measurements since two of the three missions exceeded the design objective for camera temperature. Two missions (9057 and 1001-1) employed magnesium scan arms, while 9056 employed Titanium/Invar. Laboratory data shows that significant defocussing should occur over the temperature ranges encountered on 1001-1 with magnesium scan arm.

All three missions showed marked differences in temperature between the drum and stove on Forward and Aft cameras immediately after launch (Pass 0). This difference, due to exit heating, dropped rapidly even when the temperature at both positions rose sharply as it did in 9056 and 1001-1 by Pass 9. The following table shows the temperature of drum and stove immediately after launch for all three missions:

Mission	Instrument	Sensor 11 (stove) after Launch	Sensor 13 (drum) after Launch	Difference
9056	Master (Fwd)	130°F	60°F	70°F
	Slave (Aft)	110°F	64°F	46°F
9057	M	110	72	38
	S	No Data	73	--
1001-1	M	88	62	26
	S	84	62	24

Although the drum and stove temperatures are markedly different throughout the first few passes, RES data does not show any significant improvement as this difference is reduced. Instead, significant correlation does appear between RES values and average temperature, particularly on 1001-1 (magnesium scan arm) where average temperature rose from 75°F on Pass 0 to 105°F by Pass 9 (see Figure 13). Over the same period, RES dropped from about 80 to 50. Reference to the Lens System Thermal Response data (Figure 10) shows that a 30° temperature rise causes a focus error of about .008", sufficient to account for a 50% drop in resolution.

Mission 9056 (Figure 11) experienced a similar temperat rise from 90°F to 125°F by Pass 10. However, the Titanium/Inva scan arm shows about a .002" shift in focus for a 35°F rise in temperature which is insufficient to reduce even low contrast resolution below 110 l/mm from a peak of 150 l/mm (see Figure 9 The RES data for this mission shows no significant change durir the period when temperature rose sharply, apparently substantiatir the effectiveness of the Titanium/Invar materials.

Mission 9057 employed a magnesium scan arm, as did 1001-1. However, temperatures throughout stayed close to design objective, rising only briefly after launch to 94°F on the Forward camera, 86° Aft. This mission also was rated as one of the best in both MIP ratings and in RES readings. There is a wide spread in RES readings (see Figure 11) which cannot be explained on the basis of temperature fluctuations.

In examining the data shown in Figures 11, 12, and 13, it must be remembered that temperature data is not available on each pass, that there is an uncertainty of about ± 5°F in each reading, and the degree of uncertainty in the RES evaluation technique is not fully understood.

2. Static Discharge

Table 1 summarizes the occurrence of static discharges (dendritic and corona) which were severe enough to produce a photographic record.

Dendritic static occurred on less than 0.1% of the total number of frames in the panoramic instruments for all three missions.

Corona was reported as noticeable only on the aft looking camera on Mission 1001-1, starting with Pass A34 and lasting from Frame 3 to Frame 8 on each pass until the end of the mission. A possible factor which could increase the tendency toward corona on start-up in the Aft camera is its closer proximity to venting. Thus, a lower pressure might prevail on start-up until several frames have transported. A second factor could be variations in roller resistivity.

Generally, corona is more apt to be encountered on the initial frames of later passes, and this is associated with the general trend toward a lower pressure environment as the equipment internal to the vehicle outgasses and dries out. The fact that start-up corona persisted through the seventh or eighth frame in Mission 1001-1 is explained by noting that the J configuration has a considerably longer film path between the supply spool and the camera than that in the M system.

During environmental test phases, these cameras did not show any tendency to dendritic discharge, but it has been observed when the dry material is unspooled for processing. It is likely that the discharge of this type reported occurred at this time rather than during operation.

3. Horizon Camera Operational History

The Horizon cameras on Missions 9056, 9057, and 1001-1 all employed 90mm f/6.3 lenses with Wratten 25 filters. The shutter speed was 1/100 second.

Table 2 summarizes briefly the functional history of the Horizon cameras for Missions 9056, 9057, and 1001-1.

COMPARISON OF CAMERA TEMPERATURE WITH RES READINGS

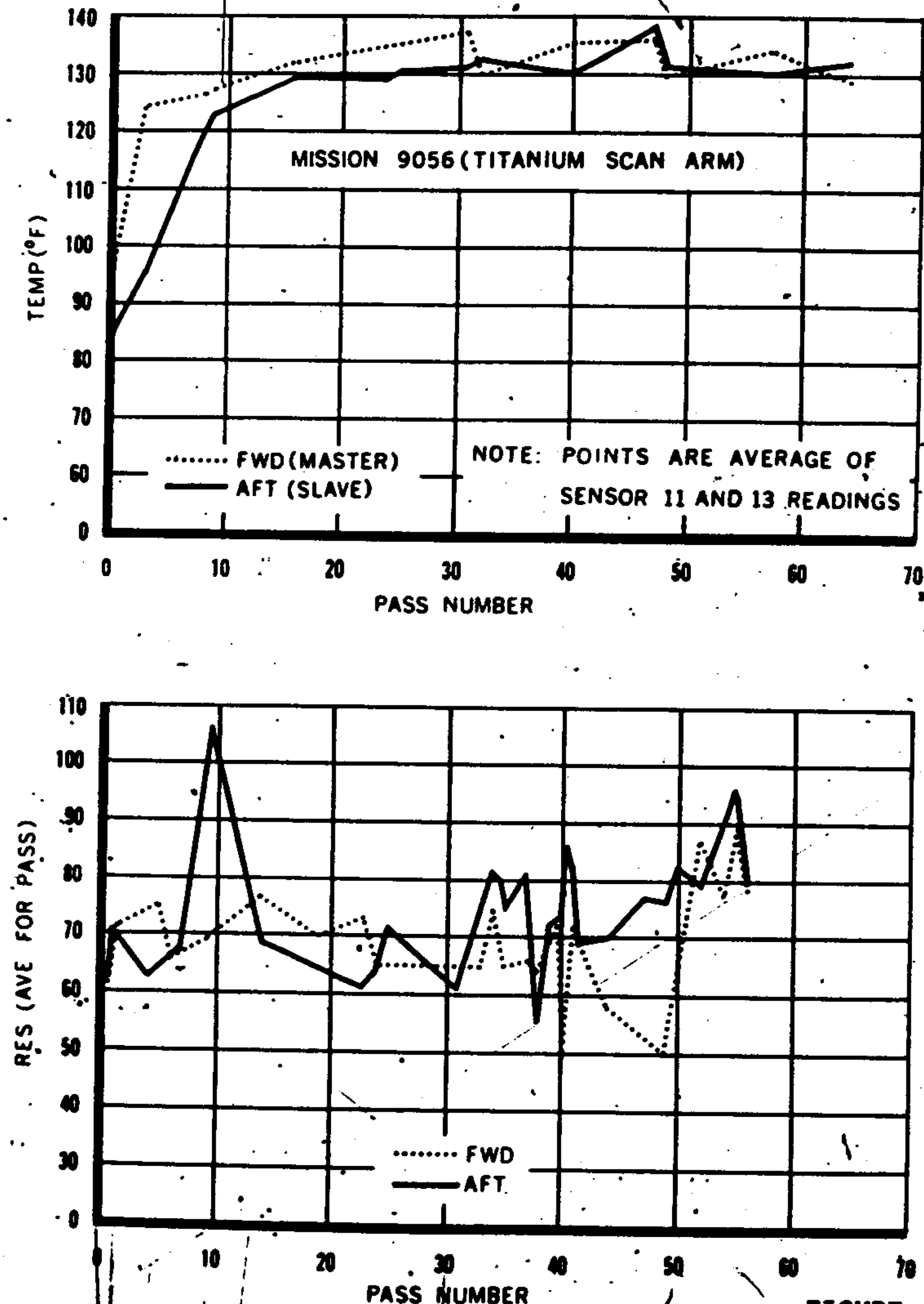


FIGURE 11

~~TOP SECRET~~ CORONA [redacted]

COMPARISON OF CAMERA TEMPERATURE WITH RES READINGS

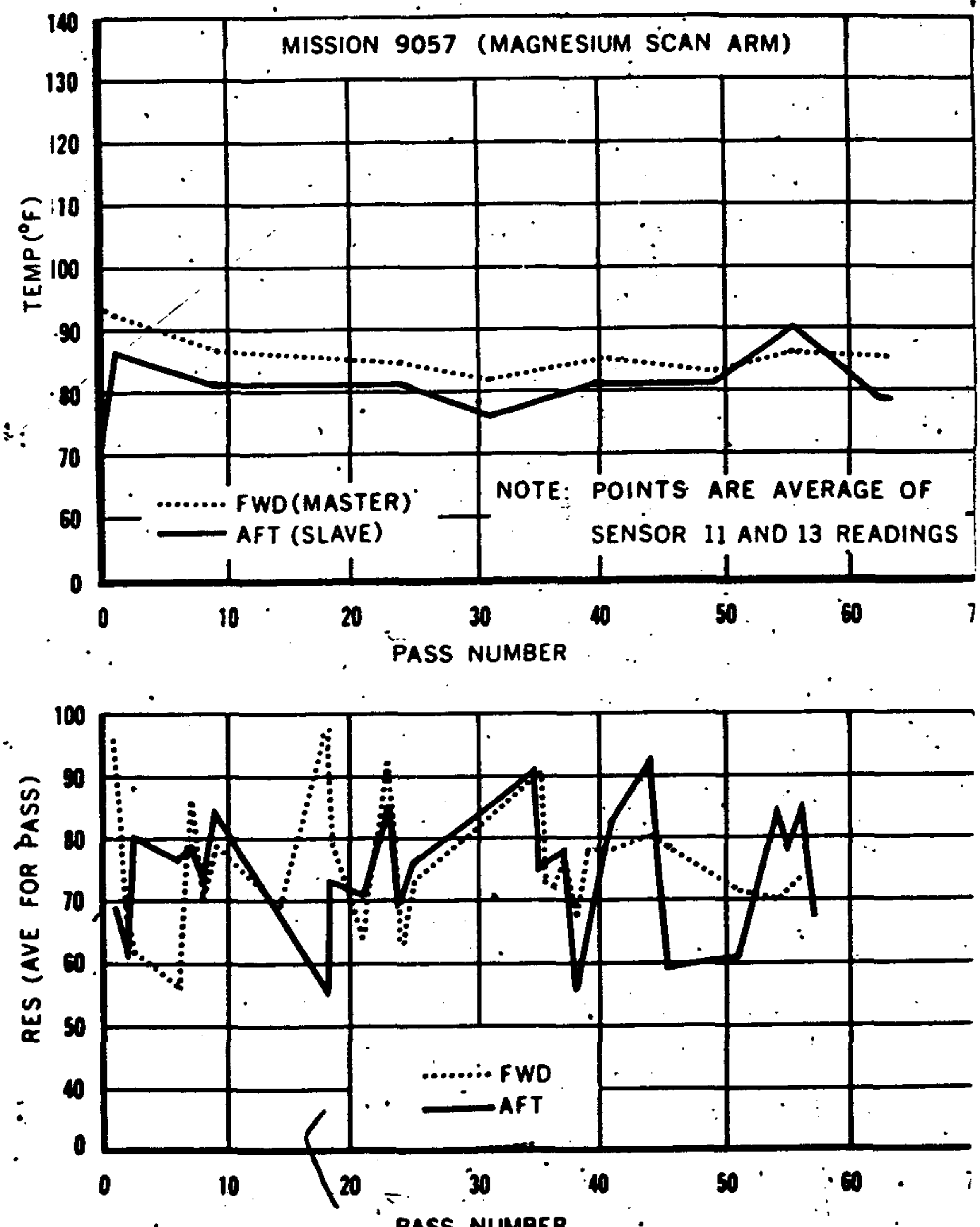
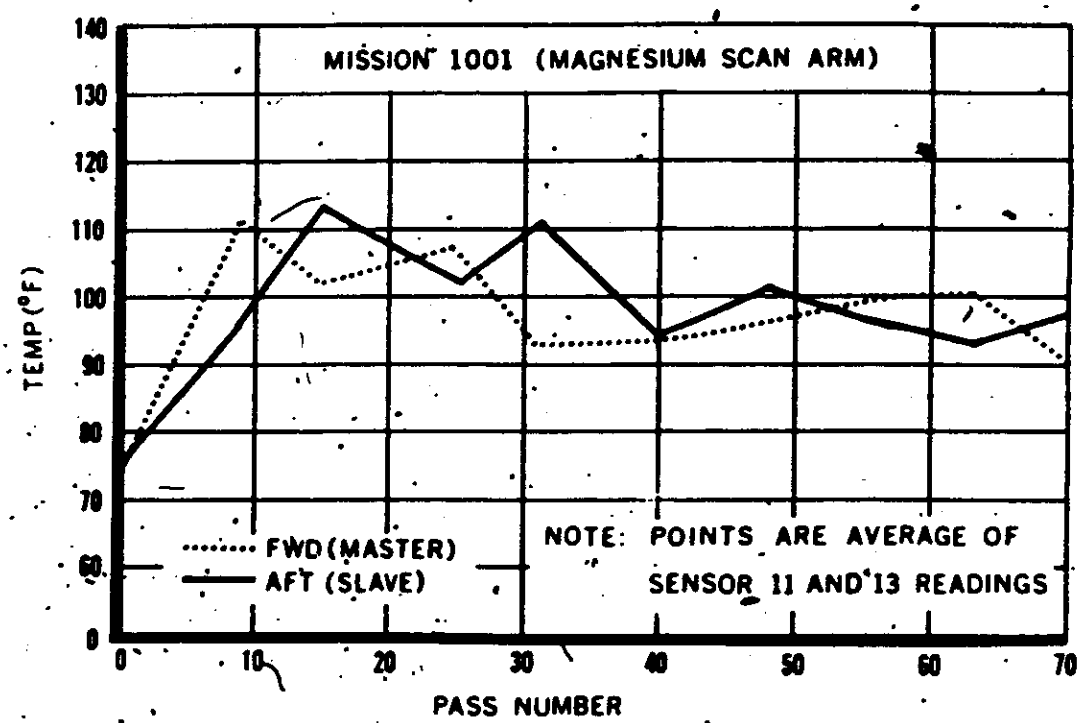


FIGURE 12

COMPARISON OF CAMERA TEMPERATURE WITH RES READINGS



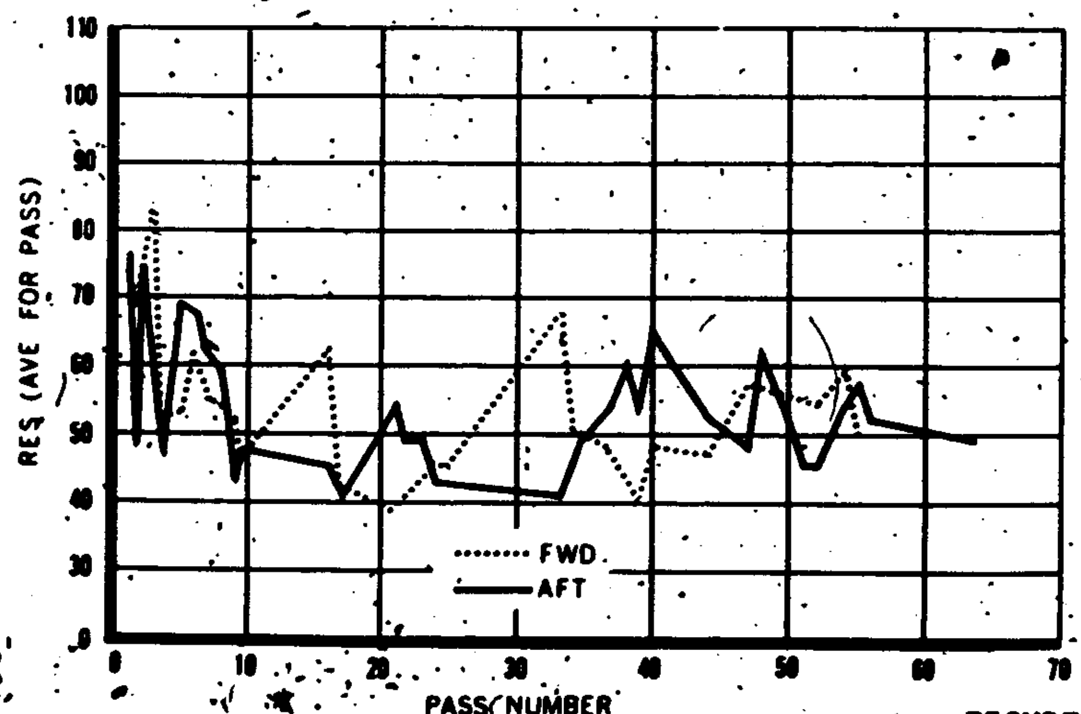


FIGURE 1.

MISSION	INSTRUMENT	OCCURRENCE
9056 No Corona Reported	MAIN - FWD	Dendritic static occurred on Pass D25, Frames 140-152; Pass A50, Frames 14-31; Pass D55, Frames 52-71.
	MAIN - AFT	Dendritic static on Passes D35, Frames 10, 36, 40, 49, 84, 85; Pass D02, Frames 3, 5, 32, 34; Pass D37, Frames 12, 27, 28, 46, 71, 84, 121, 144, 154; Pass D23, Frames 19, 26, 64, 74.
	STELLAR	Dendritic static occurred on Frames 385, 386, 390, 391, 401-409.
	INDEX	None, except possibly on edge of Frame 398.
9057	MAIN - FWD	Dendritic static occurred on Passes A01, D23, D24, D54.
	MAIN - AFT	Dendritic occurred intermittently throughout mission, occasionally extending into format.
	STELLAR	None.
	INDEX	Dendritic static occurred intermittently on both edges, more intense in last 25%.
1001-1	MAIN - FWD	Dendritic static occurred on Pass A44, Frames 1, 10. Corona appeared on Pass D64, Frames 4, 5, 35, 37.
	MAIN - AFT	Corona is present on Passes A34 through D84, starting in 3rd frame, disappearing by 7-8th frame. Static discharges occur in horizon format on Pass D38, Frames 43-45. Slight dendritic static occurs on Pass D64, Frame 37.
	STELLAR	Few static discharges randomly located.
	INDEX	Infrequent edge static, not extending into format.

TABLE 1: Occurrence of Static Discharges for Missions 9056, 9057, and 1001-1

MISSION NO.	CAMERA	OPERATIONAL STATEMENT	IMAGE QUALITY
9056	Master Serial No. 112	Port - No imagery due to shutter malfunction.	No Imagery
		Stbd - Functioned properly	Good
	Slave Ser No. 113	Stbd - Functioned properly	Good
		Port - Intermittent during Mission	Good
9057	Master Serial No. 120	Port - Functioned properly	Good
		Stbd - Functioned properly	Poor
	Slave	Stbd - Partial shutter malfunctions	Poor
		Port - Partial shutter malfunctions (The malfunctions noted were due to a faulty triggering switch)	Good
1001-1	Master Serial No. 114	Port - Failed oper. Pass A34 thru D64	Good
		Stbd - Functioned properly	Good
	Slave Serial No. 115	Stbd - Functioned properly	Good
		Port - Functioned properly	Poor

TABLE 2: Horizon Camera Operational Summary

The notes on quality refer to image sharpness rather than to the effects of exposure or development. In those cases where image quality is noted as poor, it represents a very marked loss. Laboratory attempts to simulate this poor image quality show that a focus error of at least 1/4 inch is required; however, the appearance is not attributable to an out-of-focus condition. A damaged glass filter (such as the stratified layers that occur with a severe thermal shock) produces an image which has a similar appearance as those seen on Mission 9057, Forward camera, Starboard side, and Aft camera, Starboard side.

Even in cases of poor horizon image quality, the fiducials have been sharp. This indicates the film is properly positioned during exposure.

Several changes have been incorporated into the Horizon camera system since these missions. Simulated launch environmental testing at A/P by Lockheed established that the Horizon cameras were subjected to large forces along the optical axis during ascent. This was due to the high differential pressure across the light-tight boot which connects the Horizon camera to the vehicle.

There is a possibility that the strains produced by these forces caused binding in the plunger-type shutter actuati then in use, and could be at least partially responsible for the shutter malfunctions occurring during operation. A light leak which occurred during Mission 9056 has been traced to the Horizon camera area. Separation of the boot from the camera, tearing by a broken plunger actuator, or shearing of the actuator mechanism away from the Horizon camera are possible causes. Additional venting has been added to the boot to reduce stressing of the Horizon camera in the future.

The camera itself has been modified. The lens has been changed to a 55mm f/6.3, the wider field coverage providing a greater angular segment of the horizon. The shorter focal length provides another advantage since it is further away (by 35mm) from the vehicle skin and less susceptible to flare and thermal effects. The shutter actuation is now accomplished through a tension spring which allows considerable tolerance in the alignment of shutter trip lever and tripping solenoid. Further, the actuation mechanism is now placed where it will not be stressed during ascent.

All of the changes noted above were incorporated in the last operation (9062). No mechanical malfunctions occurred and the quality of the Horizon images were considered to be the best ever obtained.

An analysis of calibration procedures applied to the Horizon instruments has revealed that all collimator positions are determined to plus or minus 6 seconds of arc. Three collimators composing a bank are coplanar to ± 6 seconds, and the angular radius of the banks can be regulated to ± 6 seconds.

The center of format calibration image location is determined to ± 15 seconds of arc in the track direction. Edge of format definition is the prime factor influencing this mensuration. Modification of the dimension for temperature disparities is unnecessary because of the compensating structure.

The position of the principal ray of an auxiliary camera is determined to ± 20 seconds.

4. <u>Center-of-Format Switch Failure; Mission 9057</u>.

During on-orbit operations, telemetry showed that the center of format switch on the Slave camera was not closing. This prevented the advance of the Slave camera cycle counter and interrogation of the clock for serial readout. This also precluded clock parallel outputs for data block recording on the film and operation of the Horizon optics on all cycles where the failure occurred. Examination of the film confirmed these conclusions. However, outputs on the Master camera were normal which permitted recovery of both time and vehicle attitude data. Since this failure, the center-of-format switch has been modified to be parallel redundant which should reduce this type of failure to a very low probability of occurrence.

5. Exposure Time; Mission 9057

The operational exposure time is, as previously noted, selected to follow the intermediate processing curve. Figure 1 plots the actual exposure times versus solar elevation for the beginning and end of each operate cycle for Mission 9057. This plot is representative of Mural program operations. The figure does show that the majority of operate cycles were exposed within the range of the Intermediate curve. The original negative, however, received full processing for the majority of the mission which is excessive based upon the published processing data. Those few areas that did receive intermediate processing are well below the nominal Intermediate curve.

The prediction error of the operation exposure time as published in the Performance Estimate is very low and well within the envelope of each processing curve. Figure 15 shows that the percentage error in exposure time is less than 18%, or about a one-eighth of a stop, 90% of the time. Figure 16 shows the frequency distribution of the prediction error. Both figures are considered representative of Mural system operation

6. Haze Attenuation

The performance of a photographic system is, as shown in Figure 7, a function of the object contrast as presented to the optics. The examination of the mission results suggested the postulate that the low light reflectivity range for the

MISSION 9057
OPERATIONAL EXPOSURE POINTS

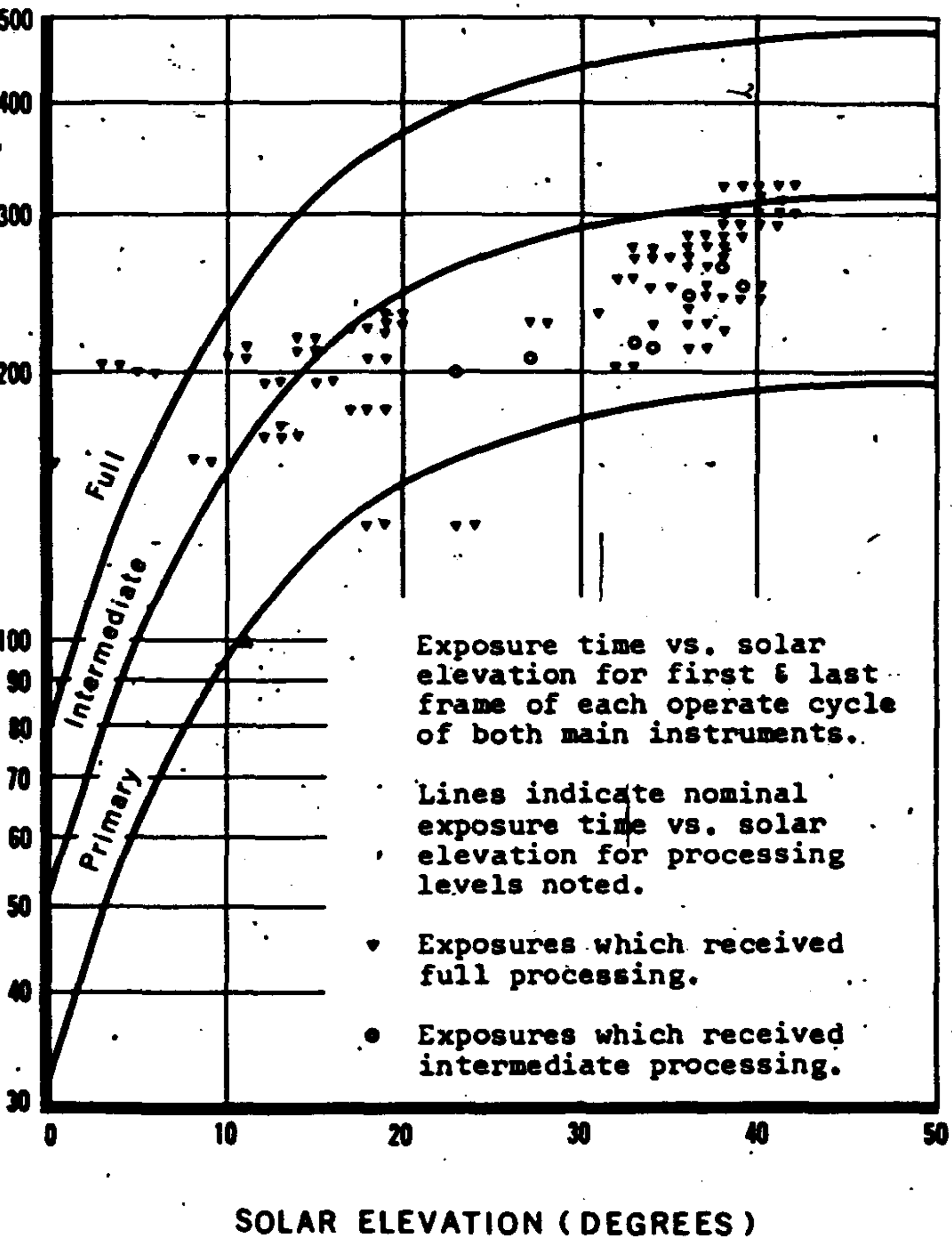


FIGURE 1

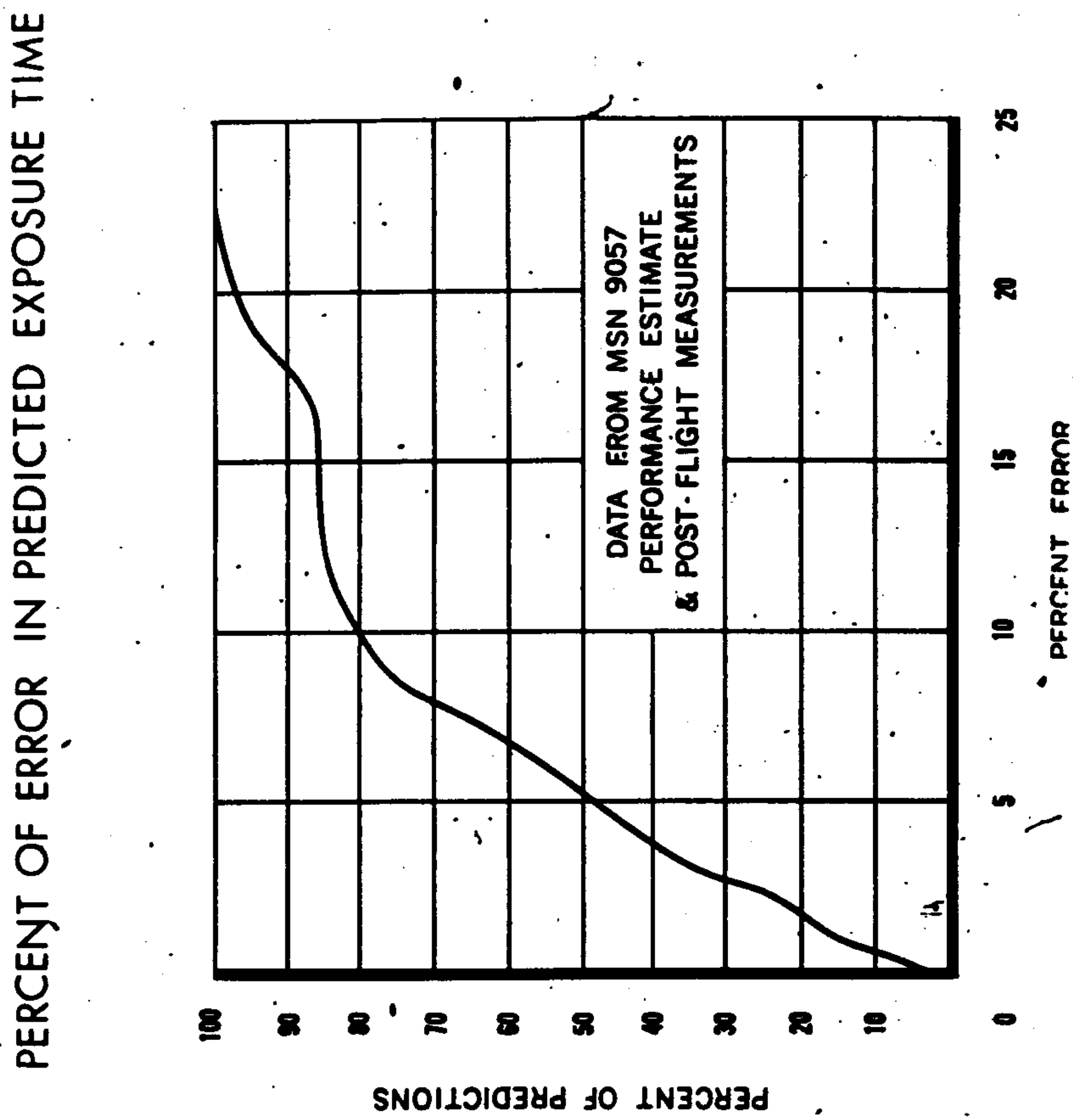

PERCENT OF ERROR IN PREDICTED EXPOSURE TIME
DATA FROM MSN 9057
PERFORMANCE ESTIMATE
& POST-FLIGHT MEASUREMENTS
PERCENT ERROR
PERCENT OF PREDICTIONS
0
5
10
15
20
25
100
90
80
70
60
50
40
30
20
10
0

FIGURE 15

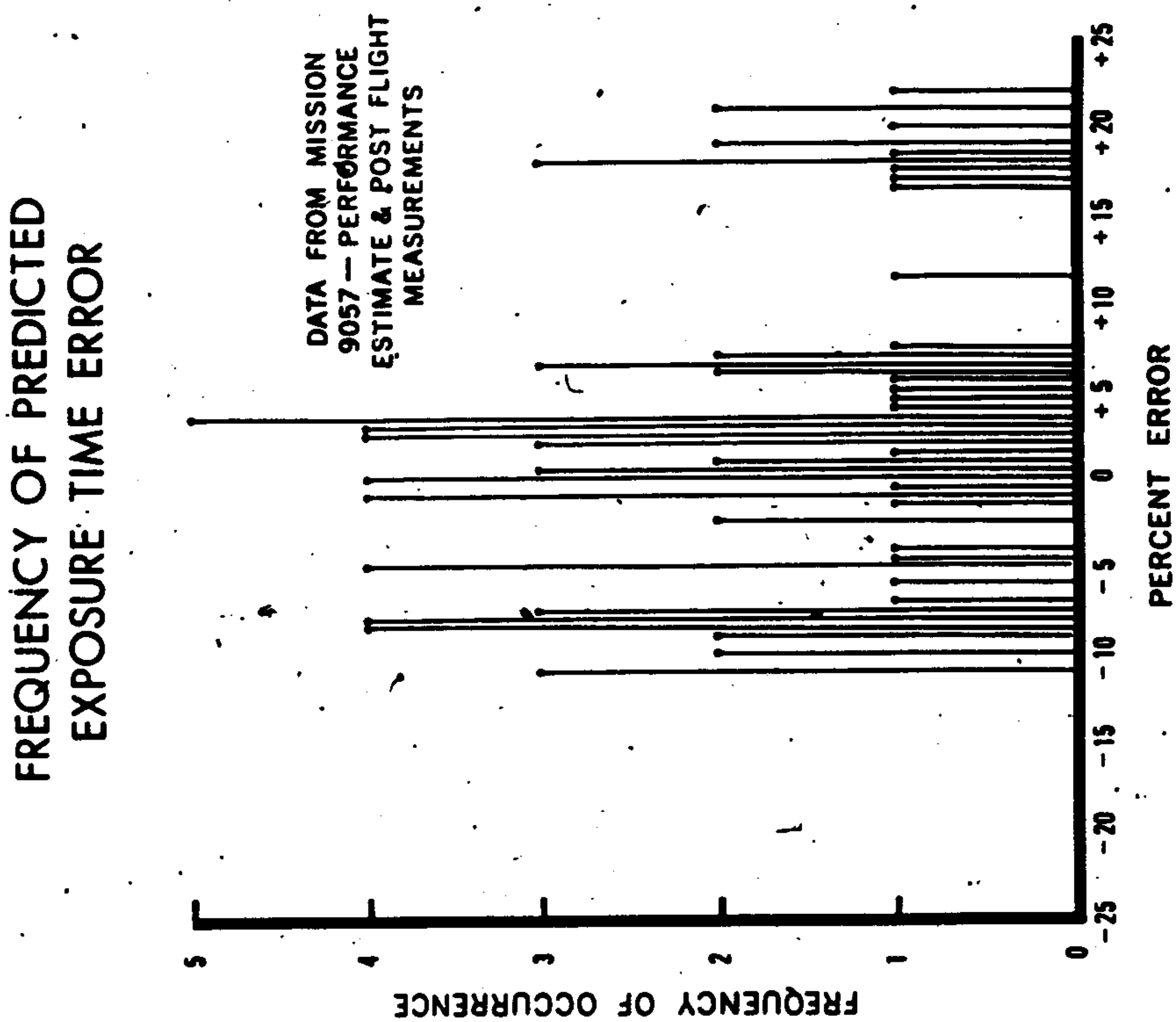

FREQUENCY OF PREDICTED
EXPOSURE TIME ERROR
DATA FROM MISSION
9057 — PERFORMANCE
ESTIMATE & POST FLIGHT
MEASUREMENTS
FREQUENCY OF OCCURRENCE
0
1
2
3
4
5
PERCENT ERROR
-25
-20
-15
-10
-5
0
+5
+10
+15
+20
+25

FIGURE 16

recorded values of Dmin was very small in all frames due to the vast area that is examined in each frame.(approximately 2000 square miles). If this were correct, then the value for the minimum density would vary as a direct function of the atmospheric attenuation and should, therefore, vary inversely with the RES value. Figure 17 displays the variation in the minimum density values and RES values for Pass D41 of Mission 9057. It shows only one isolated operation; however, the correlation with the reportes RES values is considered significant.

7. <u>Stellar-Index Camera</u>

In Mission 9057 the Index camera showed a malfunction that precluded its use in the system evaluation. The malfunction is characterized by the appearance of a boot shaped flare in the center of each format. Camera metering appeared to be normal, and the failure is thought to be associated with the shutter trip mechanisms. Since this mission, the Stellar-Index camera has been modified to include new shutters and improved shutter rewind and tripping mechanisms. These modified cameras have worked successfully since their introduction on Missions 1002-1 and 9062. An unmodified camera on Mission 1001-1 showed shutter failures traceable to the shutter rewind mechanism which caused loss of approximately 50 per cent of the possible take. For this

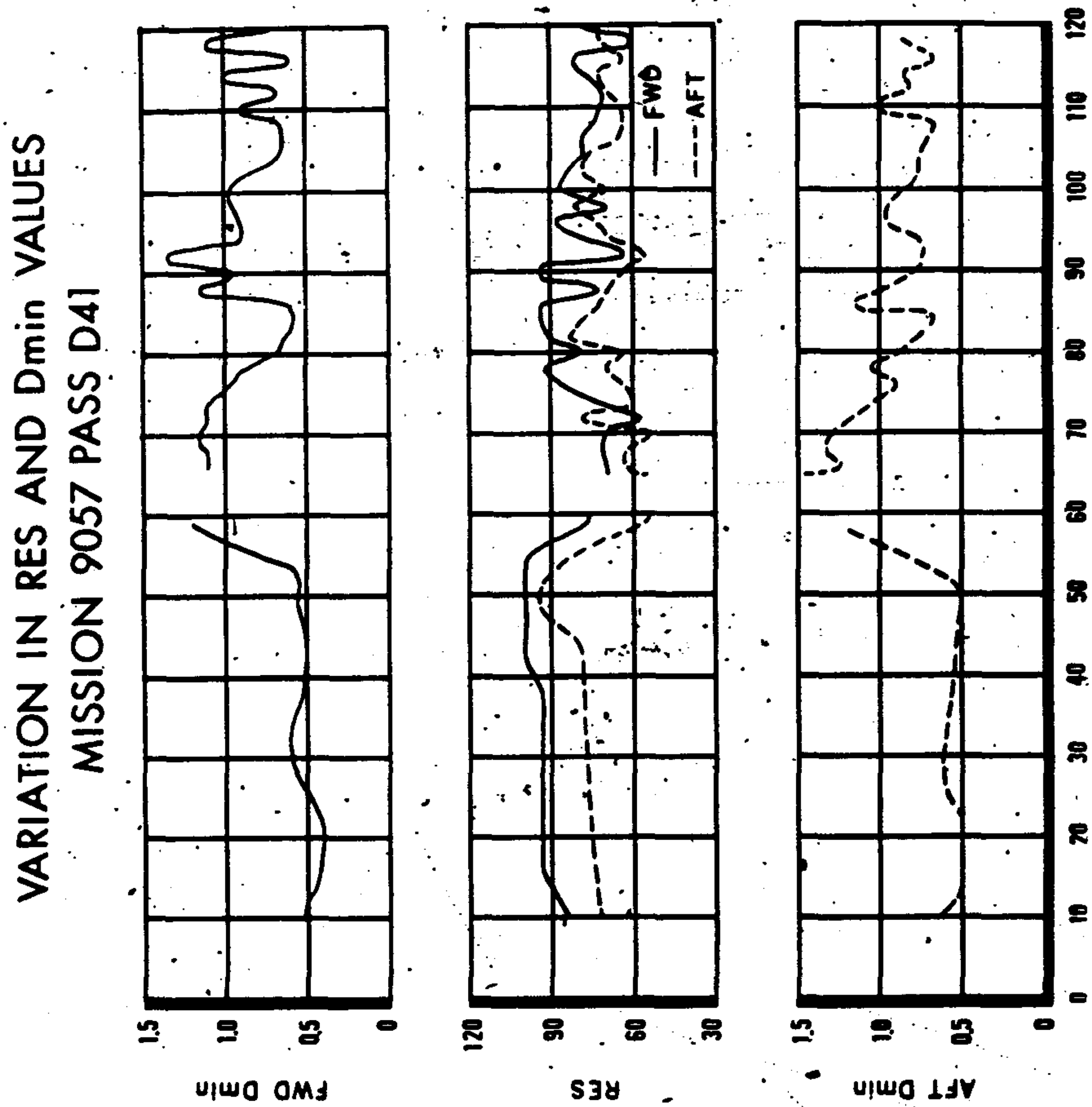

VARIATION IN RES AND Dmin VALUES
MISSION 9057 PASS D41
FWD Dmin
1.5
1.0
0.5
0
RES
120
90
60
30
FWD
AFT
AFT Dmin
1.5
1.0
0.5
0
0
10
20
30
40
50
60
70
80
90
100
110
120

FIGURE 1

reason, Stellar-Index photography from Mission 1002-1 was chosen for evaluation.

In cases examined in Missions 9057, 1001-1, and 1002-1, the Stellar camera functioned and produced usable Stellar imagery. The major degrading factors noticed in the Stellar photography are corona discharge and the appearance of flare light in the format area. The corona discharge effects are heightened by the fact that a high speed emulsion, Type 4401, is used. Despite heavy corona discharge on Mission 1002-1, sufficient Stellar images have been found to permit using the Stellar camera photography for attitude determination.

The flare from earth light reflecting from the fairing onto the end of the baffle matches pre-flight predictions and did not cause significant loss of Stellar imagery. Stars to approximately the 7th magnitude are imaged. Continued review of choice of extendable baffle (5 1/2 inch length or 11 inch length) before every mission will be necessary to insure that acceptable photography is obtained. In the case of Mission 9056, the Stellar baffle failed to deploy properly resulting in vignetting most of the field. Design changes to the deploying mechanism have been made to assure proper extension.

A detailed description of the usability of the Stellar-Index photography and Panoramic photography for cartographic purposes may be found in Appendix A and Appendix B prepared by ACIC. A short statement of cartographic suitability of Mural photography prepared by Army Map Service is also included in Appendix C.

8. V/h Programming

The performance of the V/h programming accuracy for Mural system operations was evaluated for the Forward camera of Mission 9057 only, as no other reduced data was available. The mission data for passes up to D06 was discarded as the 20° northward latitude perigee shift caused a significant V/h mismatch from the pre-launch expected values. Pass D06 was the first active pass following a ground station contact where the in-flight V/h program selection was performed.

The evaluation of V/h programming errors was divided into two areas as significant errors were found during the first six to seven frames of photography of each operate cycle. Figure 18 shows the V/h error envelope for the first ten frames of all operate cycles for Mission 9057, Forward camera. These large errors are due to the camera system start-up and the time required to achieve proper operating speed. Nominal operating speed is reached by the sixth to seventh frame which normally is with the 25 second time pad allocated to the system.

The V/h errors for Frame 10 to the end of the operate cycle are shown in Figure 19. This plot shows that the V/h error was 3.85% or less 90% of the operating time. This

[redacted]

CAMERA START-UP ERROR

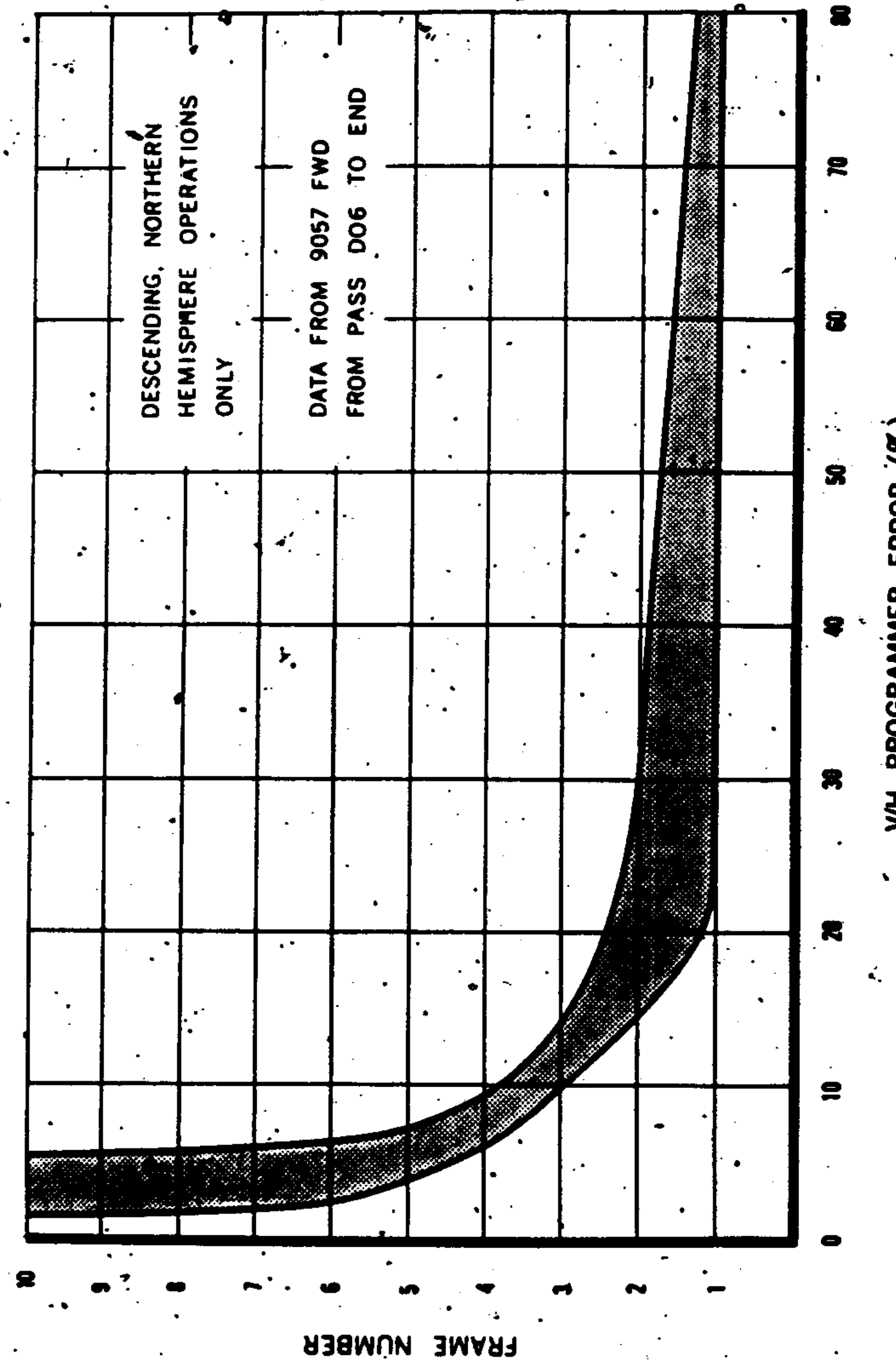
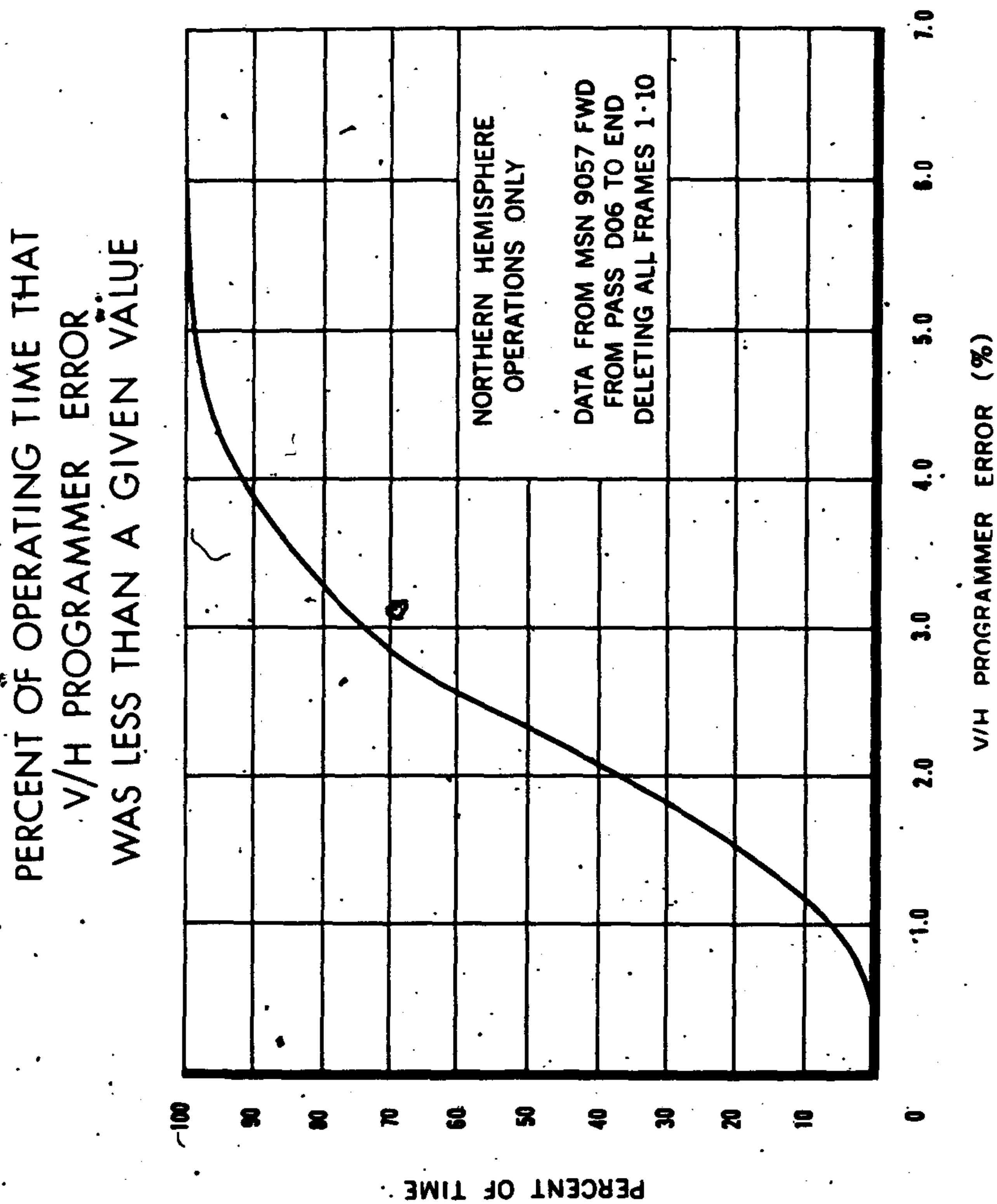


FIGURE 18


PERCENT OF OPERATING TIME THAT
V/H PROGRAMMER ERROR
WAS LESS THAN A GIVEN VALUE
NORTHERN HEMISPHERE
OPERATIONS ONLY
DATA FROM MSN 9057 FWD
FROM PASS D06 TO END
DELETING ALL FRAMES 1-10
V/H PROGRAMMER ERROR (%)
1.0
2.0
3.0
4.0
5.0
6.0
7.0
PERCENT OF TIME
0
10
20
30
40
50
60
70
80
90
100

FIGURE

exceeds the predicted V/h error af 3.0% (90% probability) and exceeds the normally observed V/h programming error of other Mural operations. Figure 20 shows the frequency distribution of the programming error.

9. <u>Flight Program Analysis</u>

Mission 9057 flight operations were specified by orbit number, latitude on, and latitude off. The program consisted of 181 programmed operations, of which 122 were in program one and 59 were in program two. Of a total of 44 operations taken, 27 were in program one and 17 were in program two. The total number of frames taken per the card ephemeris was approximately 0.5% lower than indicated by the performance estimate.

Time pads (on and off) were of 25 seconds duration consisting of:

a. Six seconds allowance for stereo lead.

b. Three seconds allowance for possible timer error due to tape deck misalignment.

c. Balance - allowance for orbital dispersions - especially perigee latitude.

Latitude on/off data in the performance estimate and frame ephemeris compared favorably. Actual performance data indicated generally that latitude on was one degree early and latitude off was over one degree late as programmed, indicating that required stereo coverage was achieved on all operations in

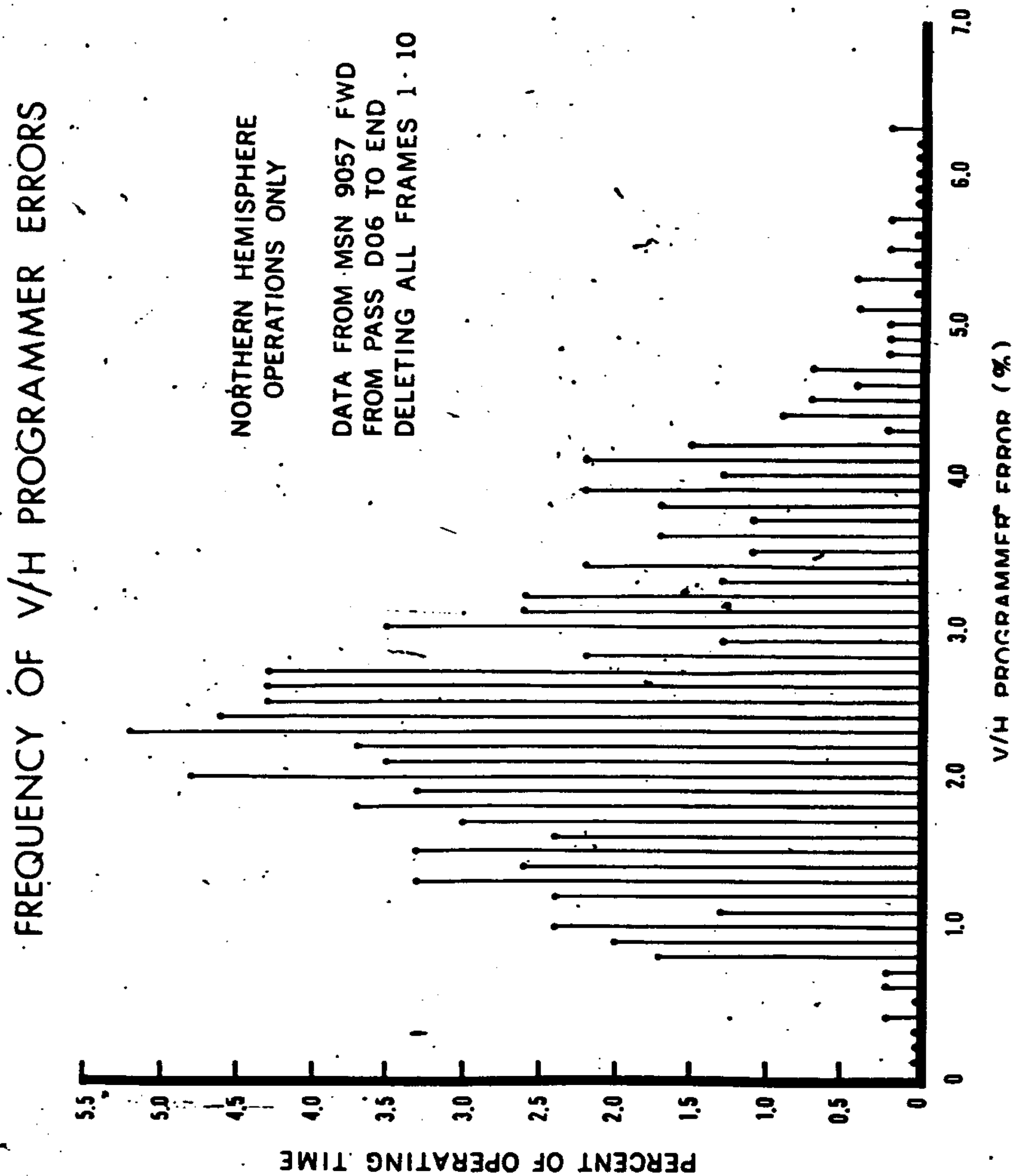

FREQUENCY OF V/H PROGRAMMER ERRORS
NORTHERN HEMISPHERE
OPERATIONS ONLY
DATA FROM MSN 9057 FWD
FROM PASS D06 TO END
DELETING ALL FRAMES 1-10
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
V/H PROGRAMMER ERROR (%)
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
PERCENT OF OPERATING TIME

FIGURE 20

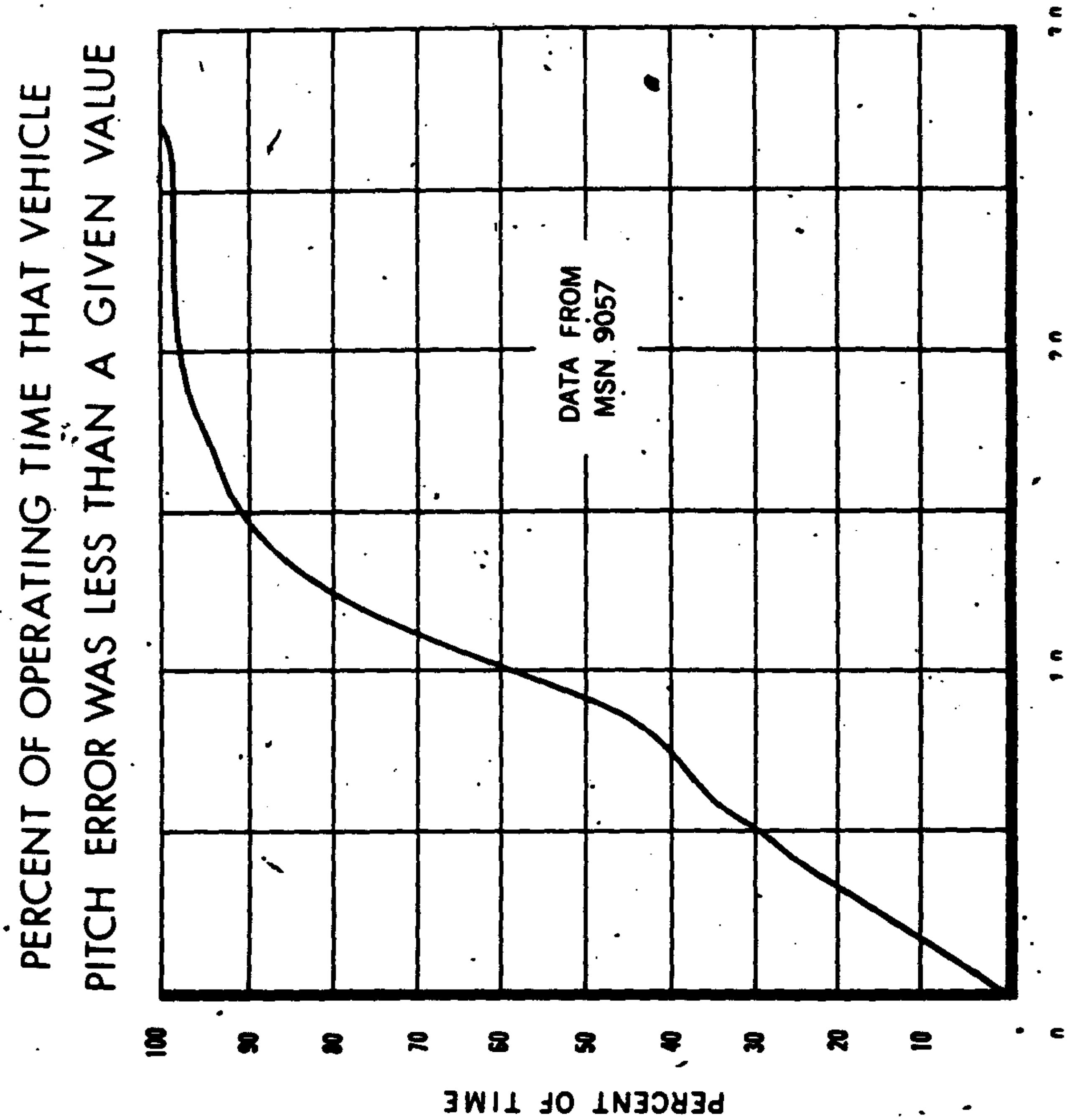

PERCENT OF OPERATING TIME THAT VEHICLE
PITCH ERROR WAS LESS THAN A GIVEN VALUE
DATA FROM
MSN 9057
100
90
80
70
60
50
40
30
20
10
PERCENT OF TIME

FIGURE 21

Handle Via [redacted] Controls Only

~~TOP SECRET~~ - CORONA [redacted]

MURAL PET REPORT/64

FREQUENCY OF VEHICLE PITCH ERRORS

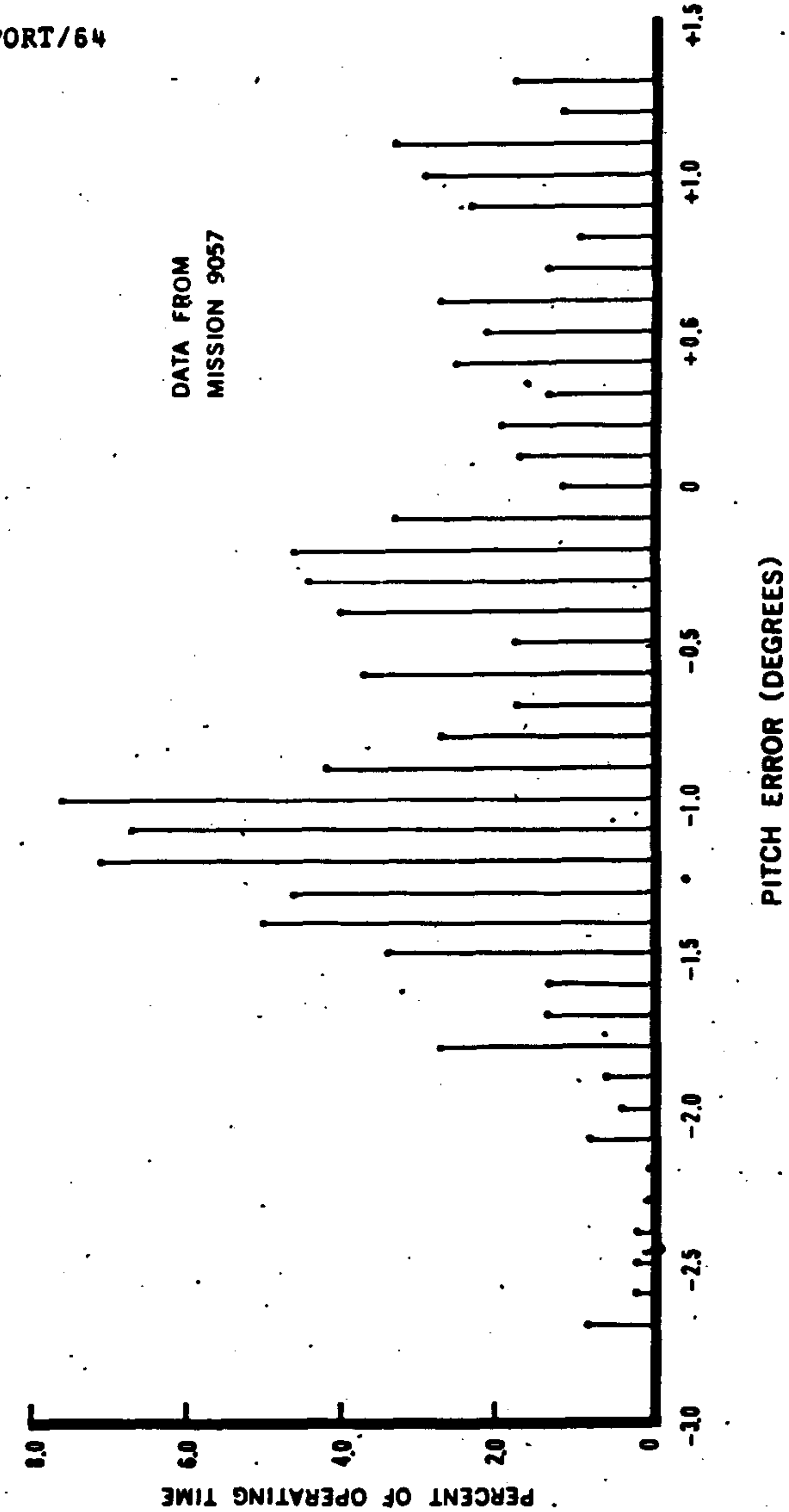


FIGURE 22

~~TOP SECRET~~ - CORONA

Handle Via [redacted] Controls O·

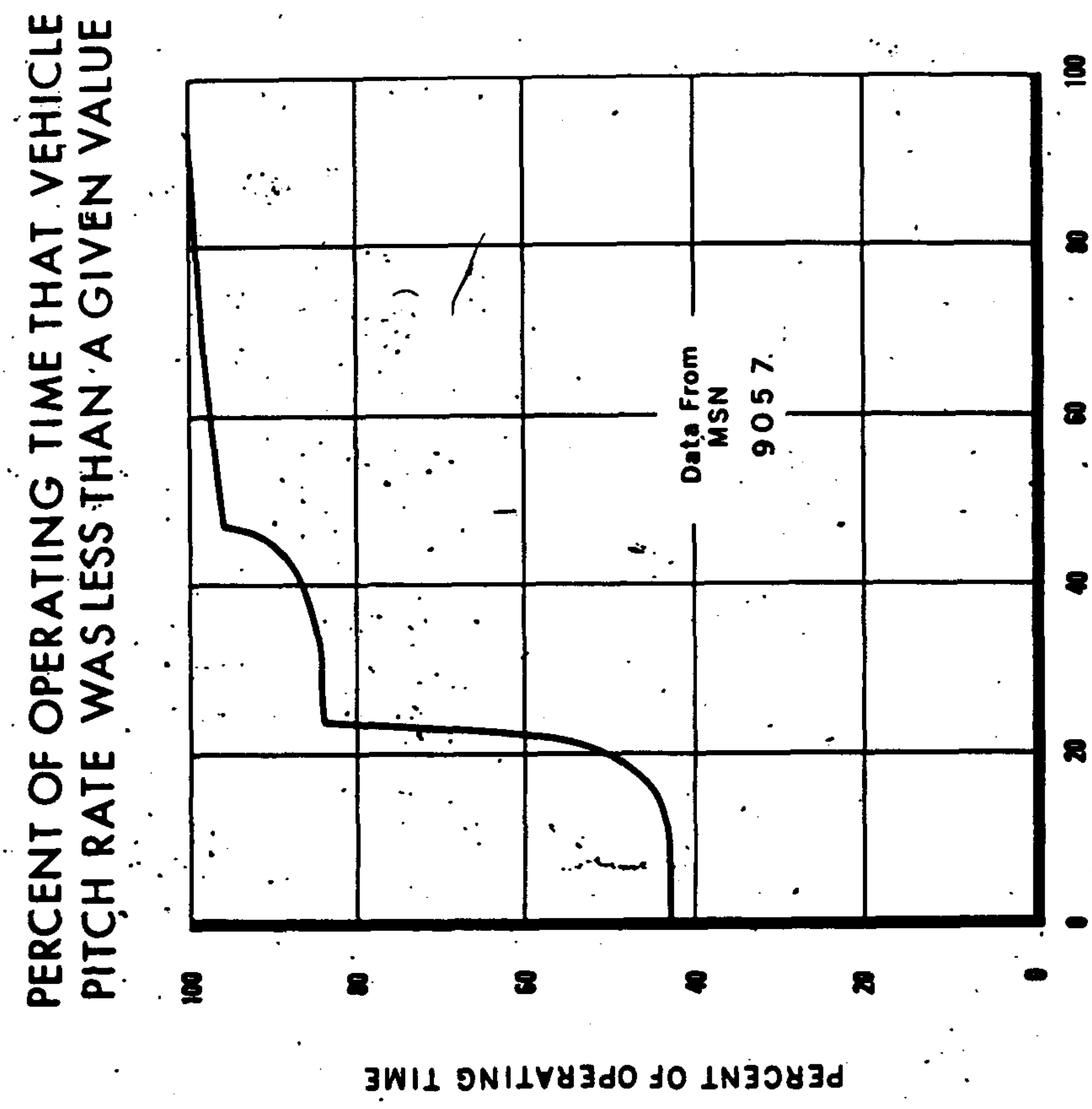

PERCENT OF OPERATING TIME THAT VEHICLE
PITCH RATE WAS LESS THAN A GIVEN VALUE
Data From
MSN
9057
100
80
60
40
20
0
PERCENT OF OPERATING TIME

FIGURE 23

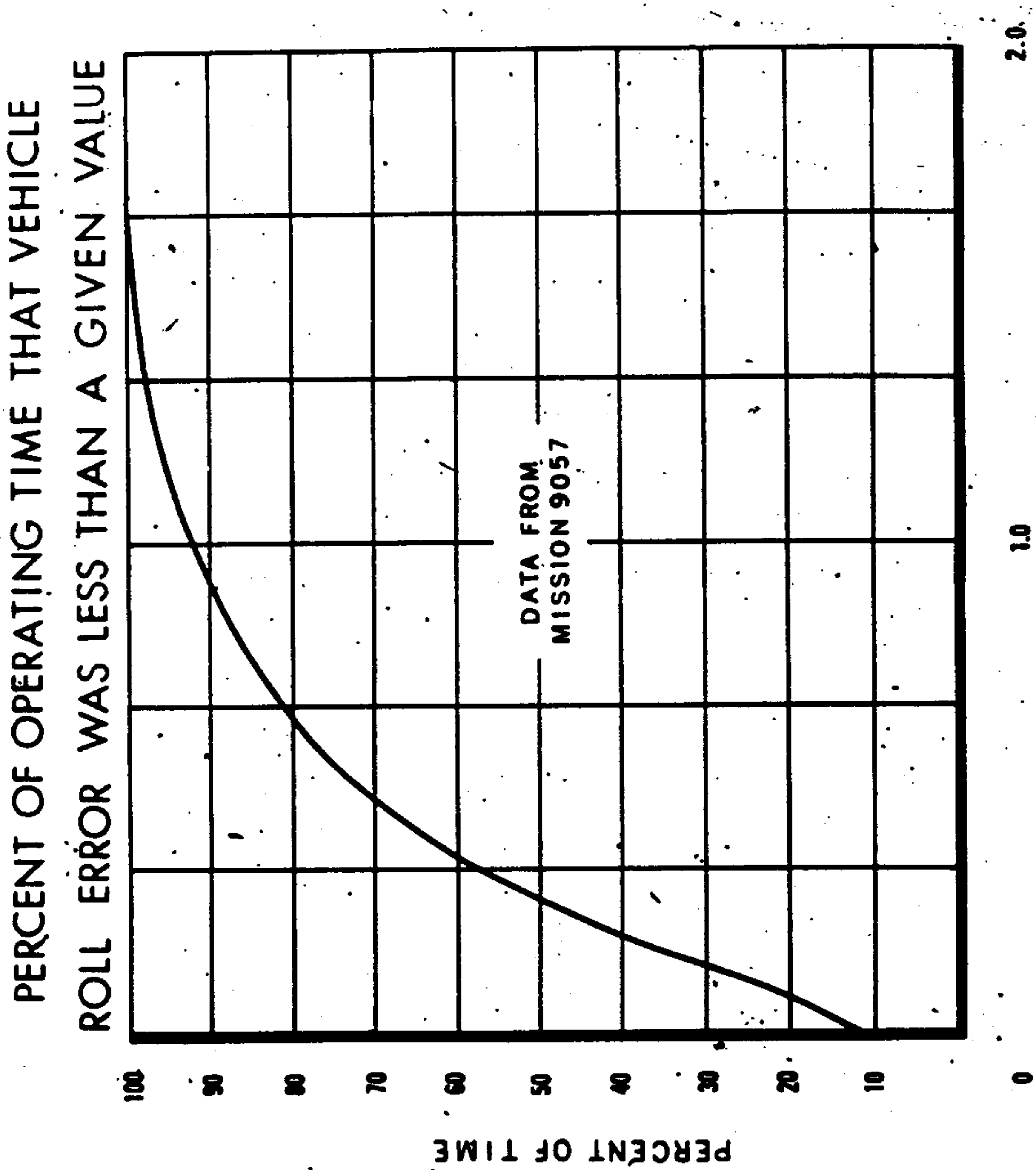

PERCENT OF OPERATING TIME THAT VEHICLE
ROLL ERROR WAS LESS THAN A GIVEN VALUE
DATA FROM
MISSION 9057
100
90
80
70
60
50
40
30
20
10
PERCENT OF TIME
0
1.0
2.0

FIGURE 24

FREQUENCY OF VEHICLE ROLL ERROR

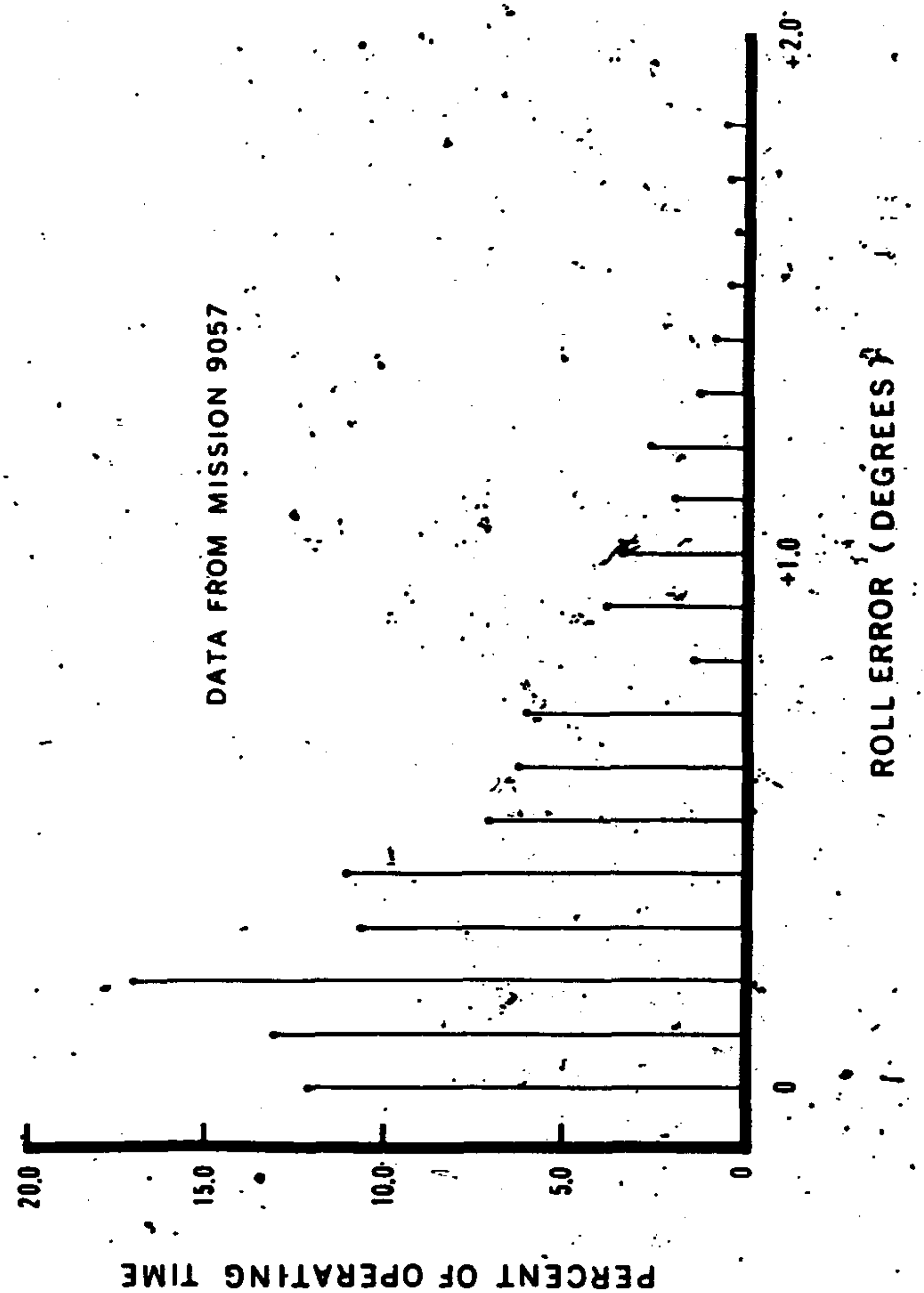


FIGURE 25

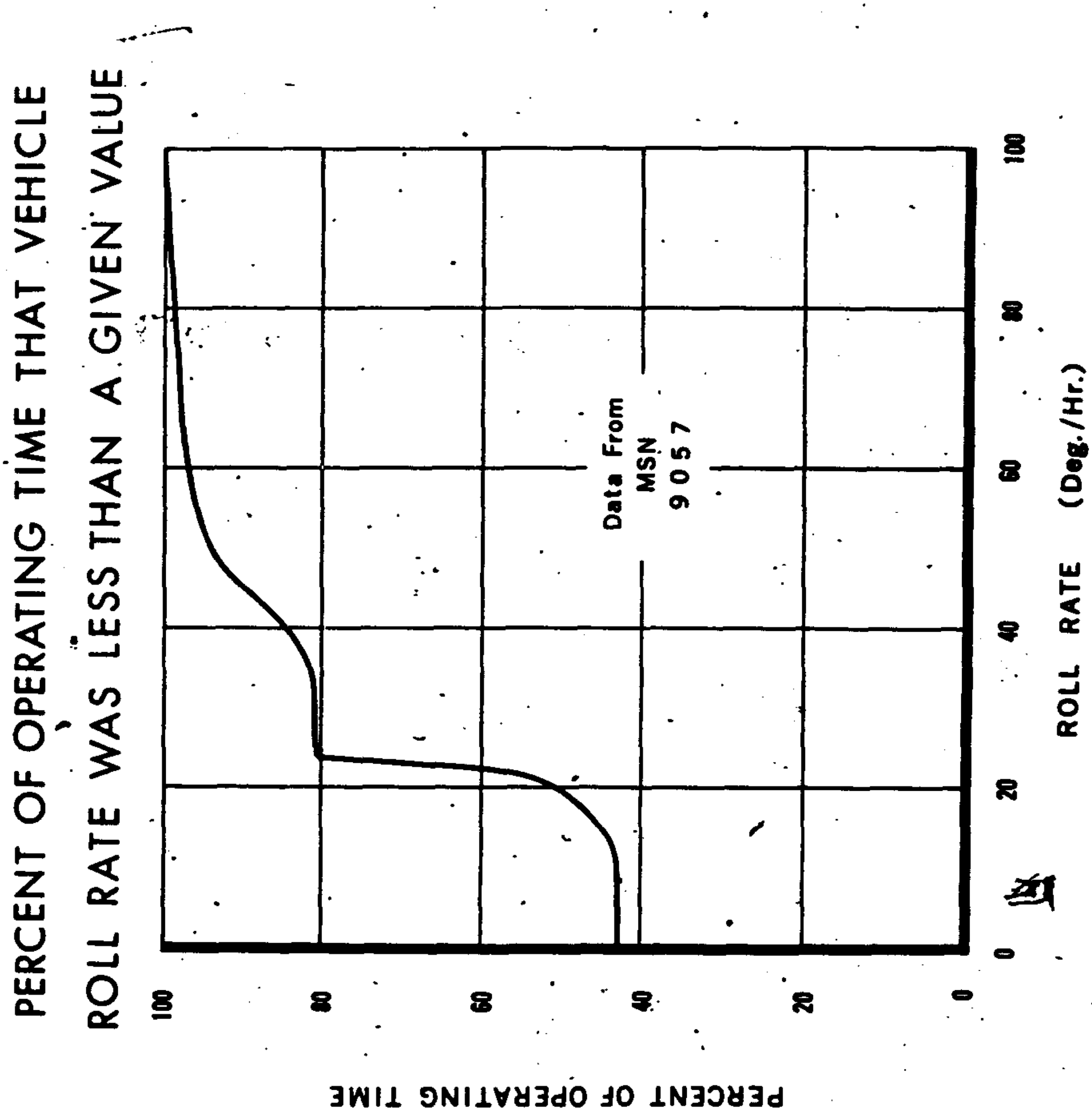

PERCENT OF OPERATING TIME THAT VEHICLE
ROLL RATE WAS LESS THAN A GIVEN VALUE
Data From
MSN
9057
ROLL RATE (Deg./Hr.)
PERCENT OF OPERATING TIME
0
20
40
60
80
100

FIGURE 26

11. <u>Vehicle Yaw Error</u>

The accuracy of the vehicle yaw attitude control system was examined in Missions 9056, 9057, and 1001-1. In addition, the crab error resulting from the earth rotation velocity vector was plotted for Mission 9057. The probability curve of this crab error is plotted in Figure 27 and shows that the crab error was 2.63° or less 90% of the operating time This error is normally a negative value for the Mural missions. This curve is considered representative for the majority of Mural missions.

The yaw error probability for Mission 9056 is plottec in Figure 28 and shows that the yaw error was -3.77° or less during 90% of the mission operations. This yaw exceeded the predicted 90% probable yaw error of ± 2.19° by a significant amount. The yaw error by frame for some of the passes of Mission 9057 is shown in Figure 29. The sum of the crab and yaw error for this mission is plotted in Figure 30. Since the yaw error was biased negative and the crab error is negative for descending operations, the total error is quite large. The plot shows a 5.75° or less yaw plus crab error during 90% of the mission operating time.

The sum of the yaw plus crab error for Misssion 9056 is shown in Figure 31. As noted in Section I, this mission hac yaw steering which places an intentional yaw bias into the

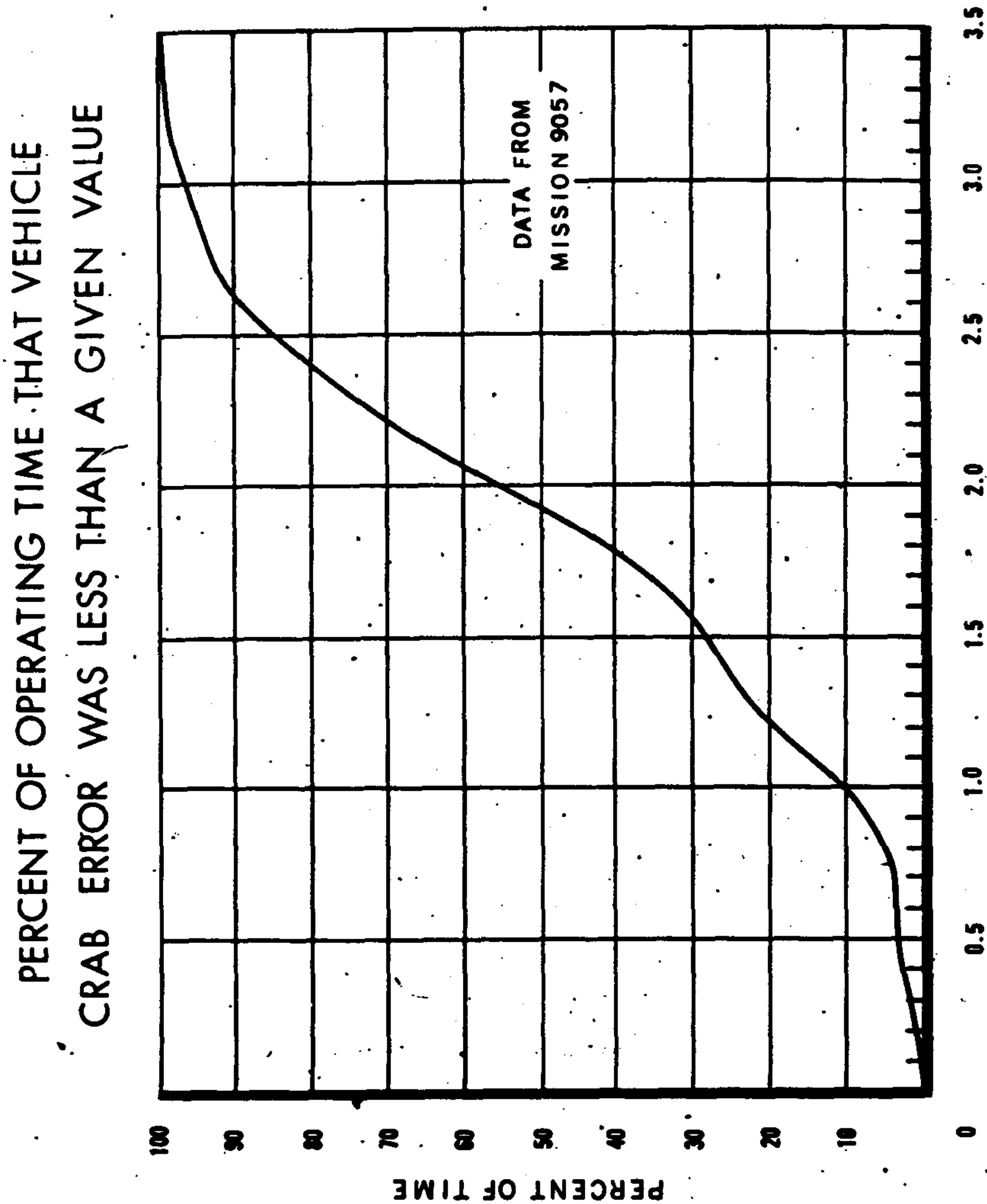

PERCENT OF OPERATING TIME THAT VEHICLE
CRAB ERROR WAS LESS THAN A GIVEN VALUE
DATA FROM
MISSION 9057
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
100
90
80
70
60
50
40
30
20
10
0
PERCENT OF TIME

FIGURE 27

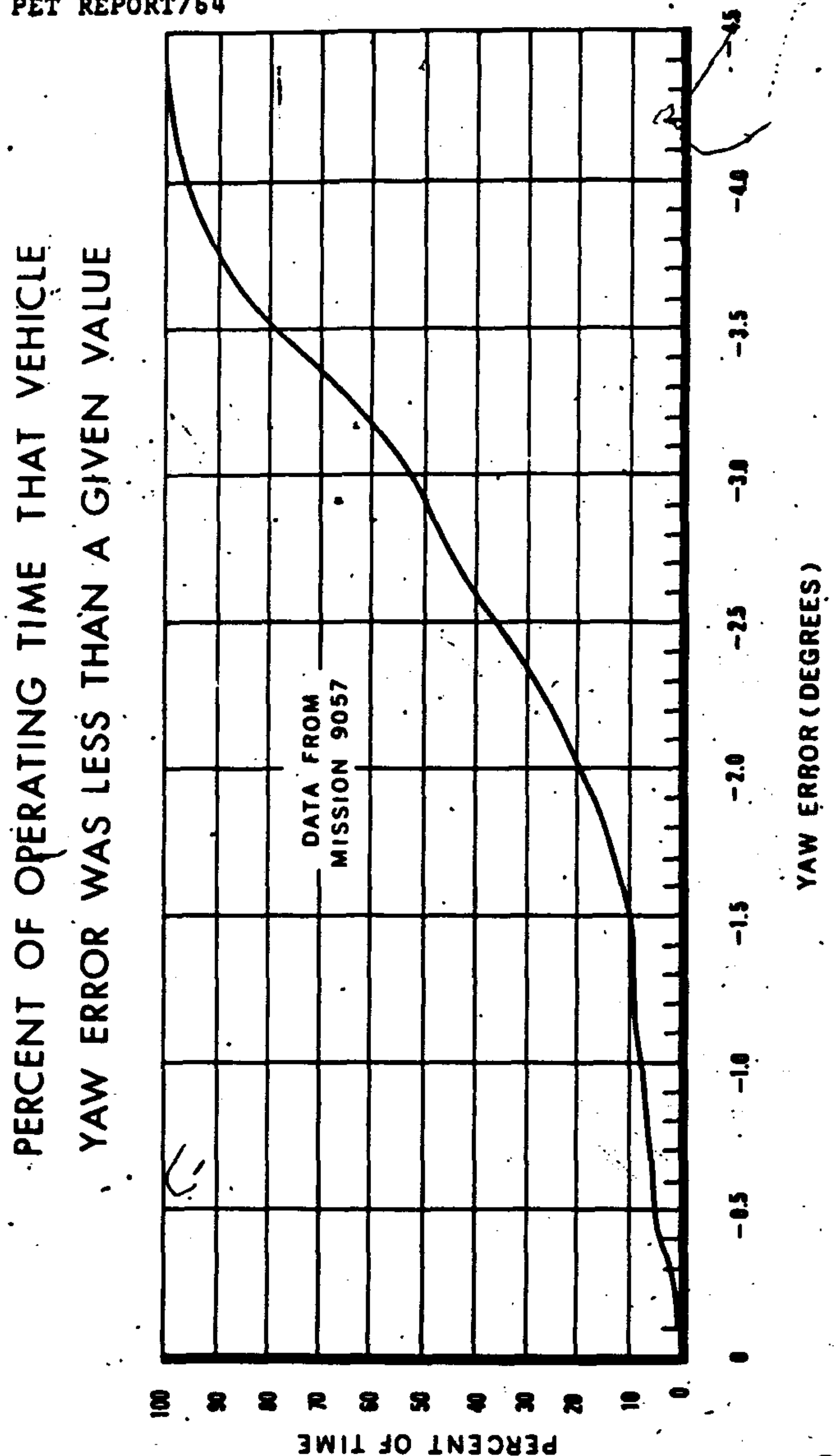

PERCENT OF OPERATING TIME THAT VEHICLE
YAW ERROR WAS LESS THAN A GIVEN VALUE
DATA FROM
MISSION 9057
YAW ERROR (DEGREES)
PERCENT OF TIME
-4.5
-4.0
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0
100
90
80
70
60
50
40
30
20
10
0

FIGURE 28

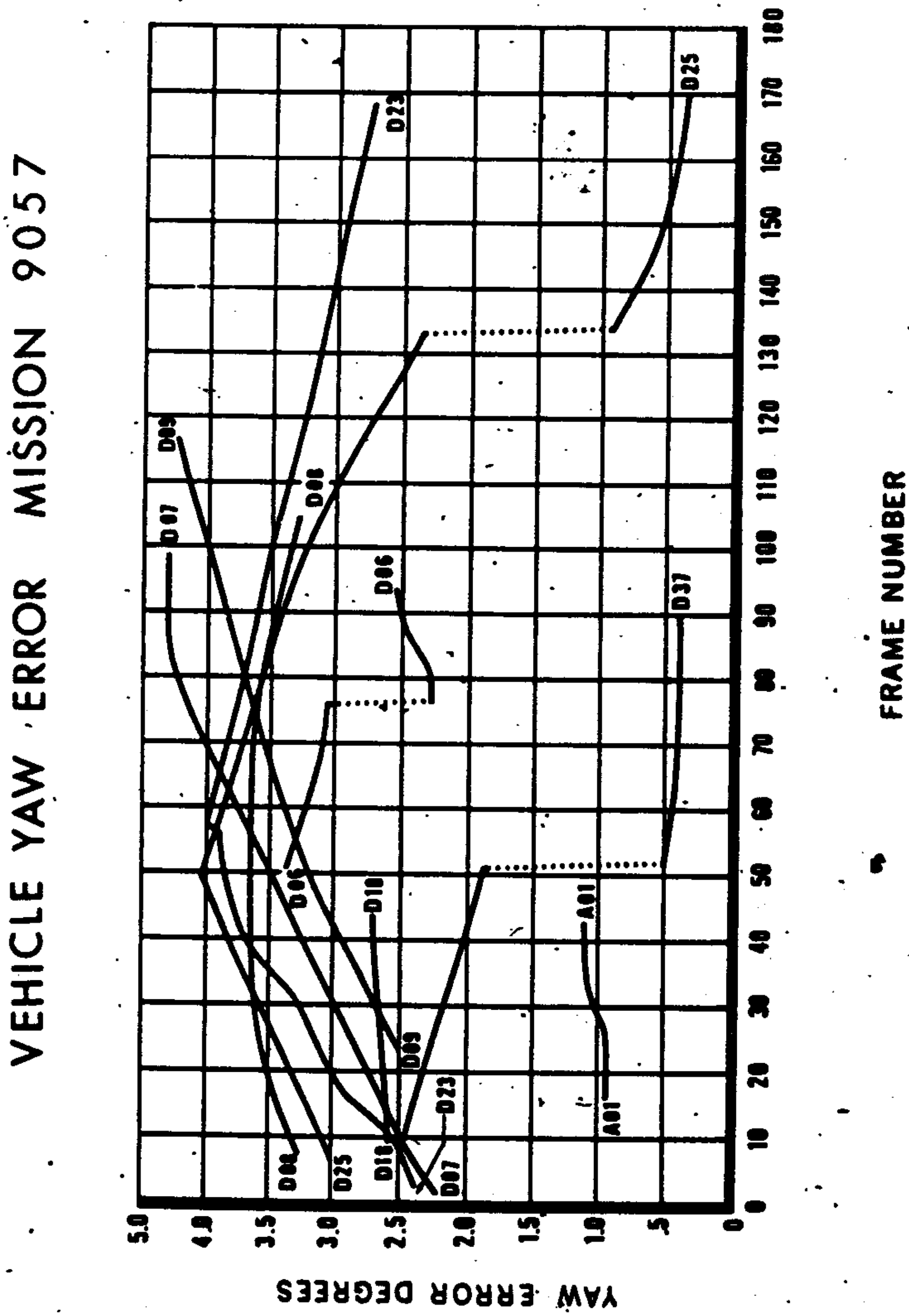

VEHICLE YAW ERROR MISSION 9057
FRAME NUMBER
YAW ERROR DEGREES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
5.0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
D25
D23
D09
D08
D07
D06
D37
D18
A01
D09
D23
D08
D25
D18
D07

FIGURE 29

PERCENT OF OPERATING TIME THAT THE SUM OF YAW & CRAB ERROR WAS LESS THAN A GIVEN VALUE

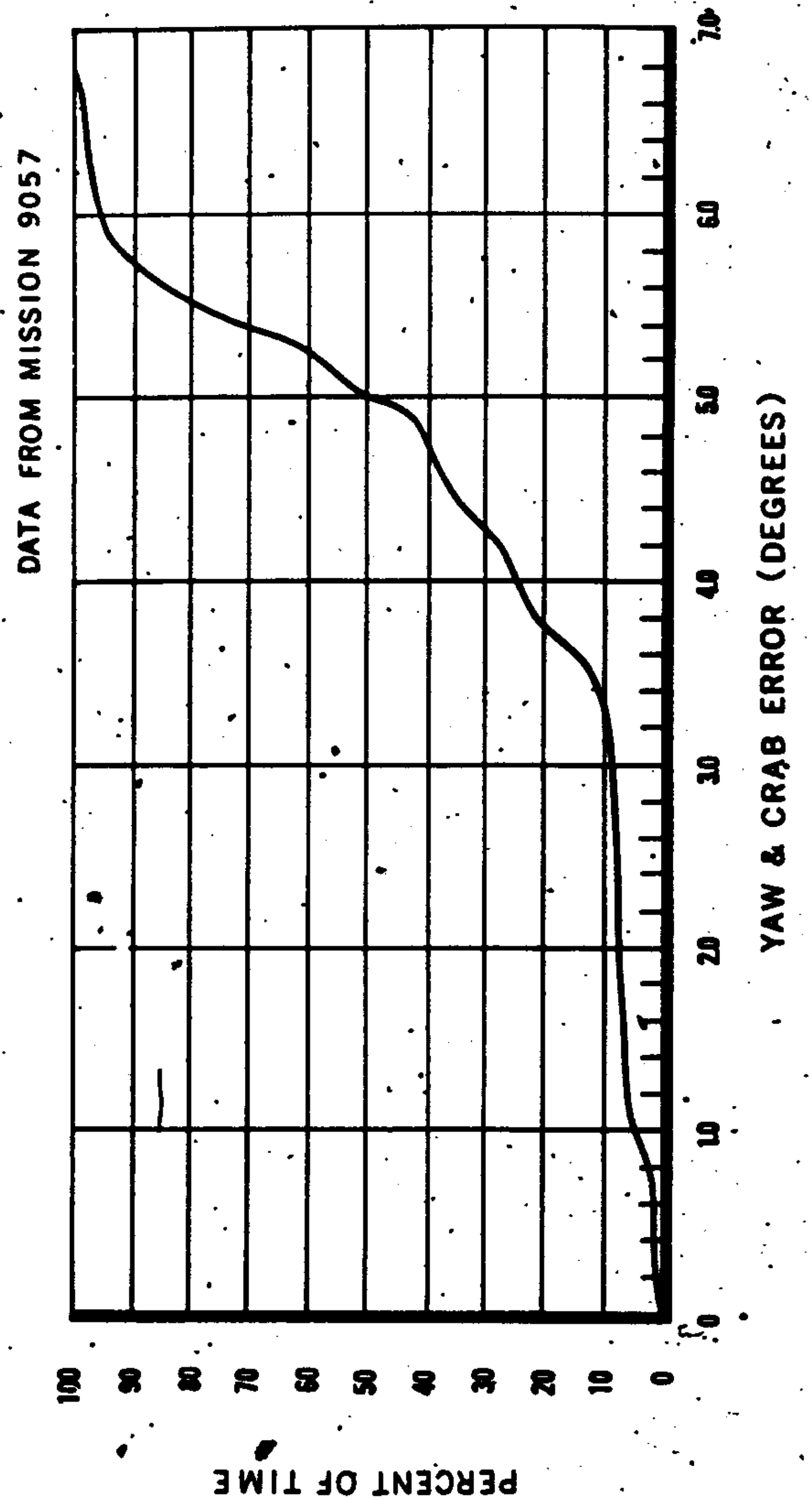


FIGURE 3

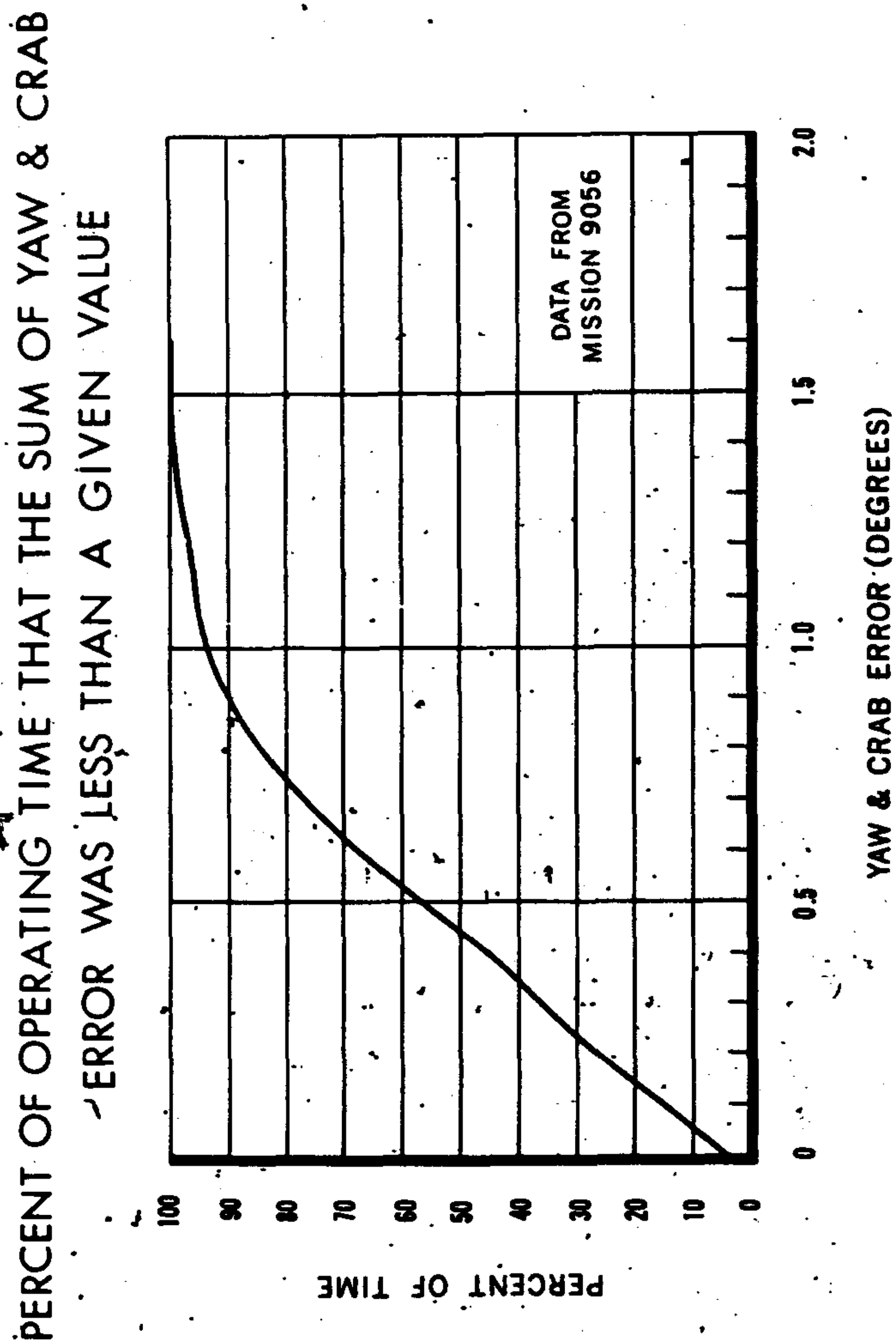

PERCENT OF OPERATING TIME THAT THE SUM OF YAW & CRAB ERROR WAS LESS THAN A GIVEN VALUE
DATA FROM MISSION 9056
0
0.5
1.0
1.5
2.0
YAW & CRAB ERROR (DEGREES)
100
90
80
70
60
50
40
30
20
10
0
PERCENT OF TIME

FIGURE 31

vehicle attitude control system to offset the crab error. The plot shows a 0.90° yaw plus crab error during 90% of the mission operations.

Figure 32 shows the vehicle yaw error for Mission 1001-1 to be 1.60° or less during 90% of the mission operation.

A summary table of the yaw and crab errors is shown below based on the 90% level:

Mission	Yaw	Crab	Yaw & Crab
Predicted	2.19°	-	-
9056	-	-	0.90°
9057	3.77°	2.63°	5.75°
1001-1	1.60°	-	-

The calculation of yaw rates for the missions examined was not possible due to the lack of data.

12. Vehicle/Instrument Damage

Mission 9056 contains an example of a light leak traced to the Master camera supply (Port) Horizon camera area. The light striking the film raises the background fog level on most of the film as reported in Appendix E. This reduces the contrast of the terrain imagery to the extent that serious degradation results.

13. Evaluation of Resolution Targets; Mission 9062

On engineering passes during Mission 9062, the Mural system imaged two ground resolution targets; the first at Fort

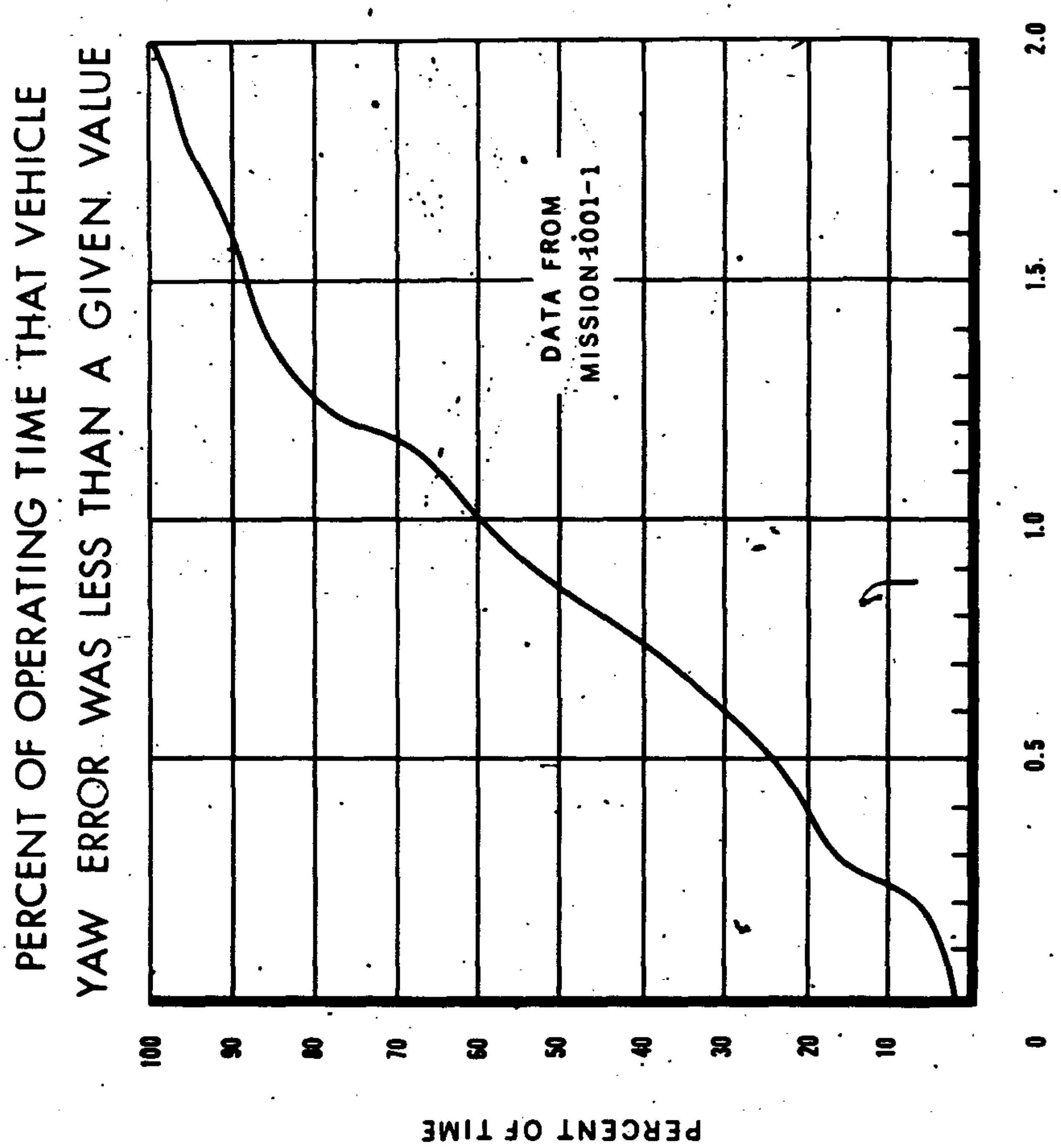

PERCENT OF OPERATING TIME THAT VEHICLE
YAW ERROR WAS LESS THAN A GIVEN VALUE
DATA FROM
MISSION 1001-1
2.0
1.5
1.0
0.5
0
100
90
80
70
60
50
40
30
20
10
PERCENT OF TIME

FIGURE 32

Huachuca, Arizona, on Pass D47, Aft Frame 037, and the second at Webster Field, Maryland, on Pass D77, Aft Frame 043. These photos have been looked at and observations are reported in the following paragraphs.

The Fort Huachuca target is located almost at the center of the panoramic photograph. The three legs of the target are clearly visible. On the low contrast leg, which is painted light grey with white bars, none of the bars can be detected in either the original negatives or the duplicate positives. On the high contrast legs, the fifth target group is resolved in the line of flight and across the line of flight The bar width of this group is 6.32 feet. One observer reports that the sixth target group is resolved in the line of flight. The above indicates an approximate ground resolution of 12.6 feet or approximately 85 lines per millimeter. No spectral information concerning the targets was available.

It was also noted that the targets appeared to be flared indicating either overexposure or overprocessing. This probably also accounts for the absence of bars in the low contrast display. The exposure for this frame is approximately 1/256 second for the solar elevation of 32 degrees; hence, Intermediate processing should have been used. Base plus fog readings indicate Full processing was used, while the processin log indicates a transition stage from Full to Intermediate processing 15 frames prior to target.

The correct exposure at this solar elevation for Intermediate processing is 1/295 seconds, and the correct exposure for Full processing is 1/448 seconds. This leads to a conclusion that information was lost due to overprocessing.

The target at Webster Field lies approximately 15 degrees off the line of flight. The smallest target group that can be observed in the line of flight and across the line of flight is Group F which has bar dimensions of 6.25 feet X 30 feet. This is equivalent to a ground resolution of 12.5 feet or approximately 90 lines per millimeter in the film. Exposure was 1/256 seconds and processing was Intermediate. Micro-Analyzer traces over the target indicate an average Dmin of 1.25 and an average Dmax of 2.00 which calculates to an average contrast ratic of 2.8 to 1. Available data indicates target contrast to be on the order of 20 to 1, although it may be less due to reported poor condition of the white paint on the bars.

It is significant to note the degrading effects of corona fogging on the Master camera. The group having clearly resolved bars is "D" in which the bar width is 8.75 feet. This is equivalent to 17.5 feet ground resolution or a 40 per cent loss when compared to the Aft camera. As would be expected, the density range is compressed by the fogging. The average Dmin rises to 1.6 and the average Dmax is 2.1. This calculates to an average contrast ratio of 2.3 to 1.

14. Effect of Ionizing Radiation

[redacted]

The system has carried for some time a film dosimeter in the recovery system. They indicate, for the missions evaluated in this report, that the total dosage received on a five day mission was approximately 1.5 Roentgen. This is well below the levels that would be considered degrading to the film used by the camera subsystems.

SECTION VI

CONCLUSIONS

The following conclusions have been reached by the PET members:

1. Performance

Performance is not identical on the three missions. Generally, the best image quality was obtained on Mission 9057, the poorest on Mission 1001-1. Numerous factors affect image quality, and are discussed below in light of their impact on quality.

A. Controllable Factors Include:

1. Vehicle Attitude Control
2. Ephemeris Error
3. Thermal Environment
4. Pressure (Corona Sensitivity)
5. Vehicle/Instrument Damage (causing light leaks or camera malfunction)
6. Ionizing Radiation
7. Exposure and Processing

B. Uncontrollable Factors Include:

1. Illumination
2. Atmospheric Haze

Although the committee was generally concerned with evaluation of Missions 9056, 9057, and 1001-1 it would be remiss if it did not comment on the results which were obtained on the last operational flight (9062). This was an M configuration and incorporated essentially all the latest improvements. The drum scan arm assembly was of the Titanium/Invar type; the Horizon camera, as previously noted, was improved as was the horizon boot venting. The Stellar-Index camera contained the long-life shutter and improved metering system.

There were no camera malfunctions whatsoever and the image quality of all cameras was rated as equal to any previously obtained. The anomalies that did occur were the appearance of corona discharge on the Master camera and the Stellar camera during the last half of the mission and excessive flare on the Stellar camera due to the faulty deployment of the light baffle.

2. Horizon Cameras

The cause of poor horizon image quality on Missions 9057 and 1001-1 has not been determined. Possible causes include damage to the filter and/or lens, from thermal shock or pressure differential during ascent. However, the changes made on a more recent mission, 9062, which include a shorter focal length lens and improved venting of the flexible boot surrounding the Horizon cameras, resulted in the best and most useful horizon photography yet obtained with the M/J System.

3. Thermal - Main Instruments

Comparison of three missions which are dissimilar in both temperature history and in scan arm materials, (magnesium versus Titanium/Invar) shows the following:

a. Defocussing occurred (Mission 1001-1, magnesium scan arm) when instrument temperatures rose well above design objective. The defocussing was sufficient to reduce overall performance significantly. It is estimated average ground resolution is approximately 40 feet (20 foot object size).

b. No measurable change in focus occurred in Mission 9056 (Titanium/Invar scan arm) under even more sever temperature rise (instruments stabilized at about 130°F). However, overall image quality on Mission 9056 was somewhat below that of Mission 9057 due to the thermal conditions and the light leak.

c. Mission 9057, operating under stable and almost perfect temperature conditions, produced the highest quality product of all three. It is estimated that average ground resolution is 24 feet (12 foot object size).

4. Performance Evaluation Criteria

In the analysis of the RES data collected for this report, the PET Team noted that the RES measurements did not noticeably reflect changes in level of performance where such changes were visually observed to have occurred. This is illustrated, for example, by the fact that RES values only grossly indicate the differences in performance between Missions 9057 and 1001-1. Gross along-track IMC errors in Frame 001 of each operate cycle are not reflected in the corresponding RES measurements.

It was also noted that RES values measured for the AFSPPL reports and the PET special requests showed a wide range of deviation. Further, the deviation did not tend to be random, indicating operator and/or equipment biases. Examples of deviations are shown in Table 3.

The RES values also showed no correlation to sun angle or latitude as can be seen by examining the photo in the TERQ report for Mission 9057. Some correlation of RES with minimum density changes was noted particularly in areas where minimum density values were influenced by cloudiness and haziness.

The general conclusion is drawn that RES as currently measured does not afford an engineering measure of system performance and that it can be used at present only as a genera figure of merit for comparison of different missions. Since it has the virtue of being a quantity measured in the photography, research effort in methods of measurement and analysis of RES through normalizing for contrast, brightness ratio, or other definable parameters appears warranted.

Deviations Between TERO and Special Request RES Data

MISSION 9056 Forward

	Pass Number					
	D07	D09	D23	D24	D25	A40
TERO Avg. RES ①	66	69	73	65	65	73
Number of Observations	28	58	96	12	38	10
TERO Special Request Observations	12	18	28	4	16	2
TERO Sample Avg. RES ②	68.2	70.5	75.3	65.0	66.8	69.5
Special Request ③ Avg. RES	56.9	65.7	63.1	57.0	54.9	49.5
Special Request Deviation Range: Highest / Lowest	+5 / -24	+44 / -22	+2 / -33	-2 / -17	-3 / -23	-18 / -22
Special Request Avg. Deviation: (excluding sign)	12.1	18.1	12.3	8.0	11.9	20

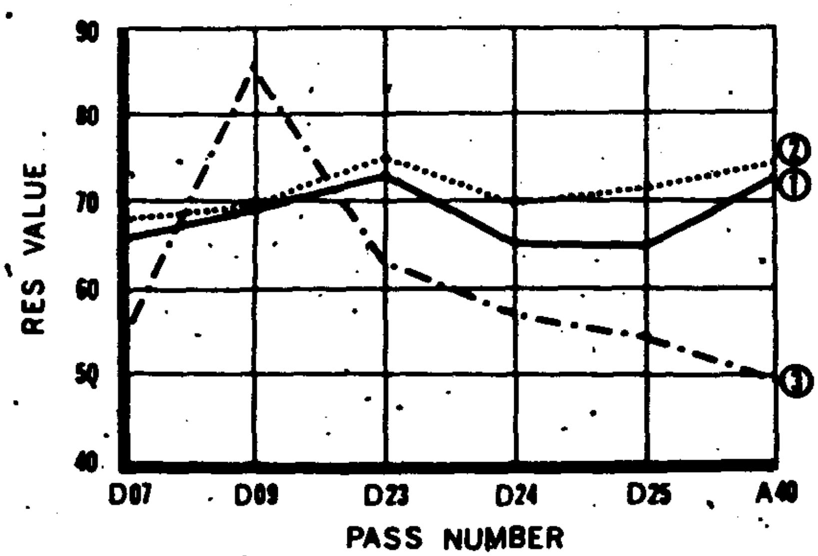


TABLE 3

It should also be noted that significant variation has also been noted in MIP values. A recheck of certain areas by NPIC, at the request of PET members, resulted in the same type of variations that have been encountered with RES values.

Correlation of RES and MIP values is shown in Figure 33. Since MIP restricts itself to the best frame in a mission and RES is a more rigorous evaluation of a mission, the lack of correlation is not surprising.

Since no other technique of measuring performance was available, subjective and pragmatic judgments by the PET Team, ACIC, and NPIC became the principal tools for determining photographic quality.

5. <u>Suitability for Intelligence</u>

From the comments of NPIC as given in Appendix D, it is concluded that the photography collected by the Mural System is suitable for photographic intelligence, and that it is accomplishing its primary mission. The class of reported objects implies ground object sizes on the order of 12 to 15 feet without specifying the object contrast ratio.

It is also highly significant to observe the photo-ma in Appendix B and note the detail visible. Such photo-maps possess great worth in industrial and military studies and the preparation of radar prediction overlays.

The building height overlay illustrates another type of intelligence product used for radar prediction. The fact

Handle Via [redacted] Controls Only

~~TOP SECRET~~ CORONA [redacted]

MURAL PET REPORT/6

SUMMARY OF RES & MIP DATA

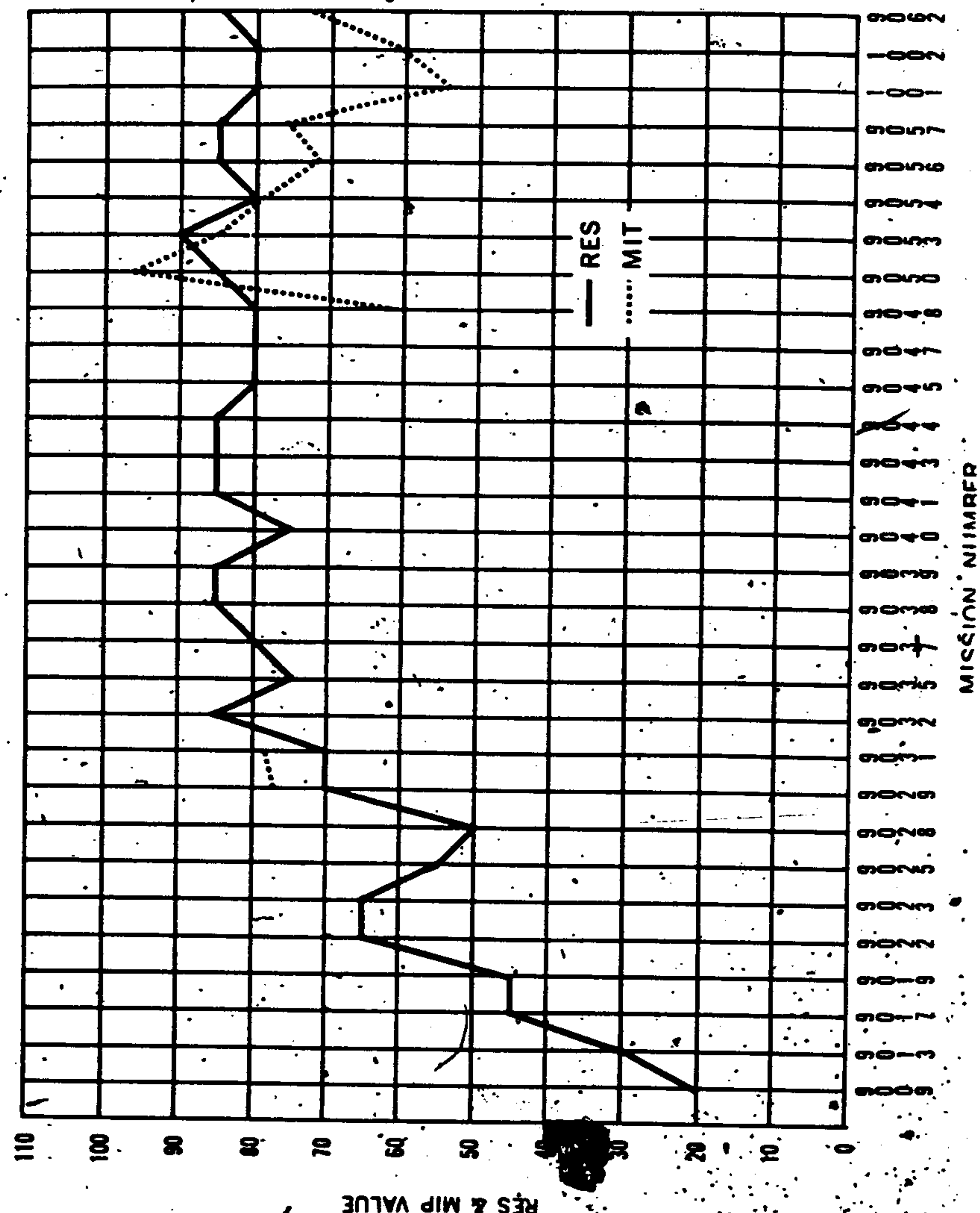


FIGURE 33

that minimum heights on the order of 10 feet can be measured directly from the photographic material with dependable accuracy also indicates that the system is performing at high resolution levels. At ten times enlargement, the height measurement capability is on the order of three feet.

6. Cartographic Suitability of Mural System; Mission 1002-1

A. Stellar Camera

a. Overall quality of the Stellar camera photos can be improved by eliminating causes of corona discharge and flare from earth light.

b. Quality of fiducial images is unsatisfactory due to lack of proper illumination control. Effort is under way to correct this problem.

c. Since internal reseau imagery in the Stellar camera is useful this feature should be retained in future missions.

d. The Stellar camera is capable of obtaining adequate images of stars down to about 7th magnitude.

e. Measurement of stellar images could be made to a standard error of .3 to 10 microns.

f. When visible, reseau fiducials could be measured within a standard error of 3 to 10 microns, in spite of poor appearance.

g. Based upon 50 millisecond error in shutter timing calibration between the frame and stellar, and errors in measurement of the reseau and stellar images, it is estimated orientation of Stellar camera is determinable to a standard error between 15 to 20 arc seconds.

h. The reseau design is satisfactory.

B. Frame Camera

a. Reseau of Frame camera is adequate, but ACIC states that it would be desirable if line width could be dropped from 10 microns to 5 microns in order to facilitate mensuration activities.

b. Calibration of lens distortion should be improved in accuracy.

c. Lens resolution is very good in the center of the frame and out to about 25 millimeters but drops to 1/6 that of the center out the remaining distance to the corners. This causes a drop in accuracy of parallax measurements from 1/2 micron at the center of the photo to 5 microns in the corners.

d. Frame camera geometry can be used to control present Panoramic camera geometry to permit compilation of medium scale maps (1:200,000) with 100 meter class A relative contours and 1:25,000 maps with at least 30 meter class A relative contours.

e. Panoramic materials can be used to prepare controlled mosaics down to scales as large as 1:10,000.

f. It is estimated that a reseau controlled Panoramic camera will permit compilation of 1:200,000 scale maps with 30 meter contours.

g. Full mapping potential of the Mural System to compile medium scale maps will not be realized until reseau pan materials are obtained at altitudes between 3 to 6 times those selected now and which would permit compilation of 1:200,000 medium scale maps with 30 meter contours.

7. <u>Image Smear</u>

Analysis of the V/h programming errors and attitude errors resulted in the conclusion that while Mission 9057 was the best of the three missions evaluated it was smear limited. The V/h program errors and yaw (plus crab) errors were beyond the predicted values.

Cursory evaluation of Mission 9056 V/h programming errors showed that they were well within tolerance. The yaw plus crab error was also significantly below tolerance, The main factor for the relatively high performance of Mission 9056 was the incorporation of the Titanium/Invar components; however, the system performance would have been significantly lower if the image smear contributors had approached the predicted values.

8. <u>Haze Attenuation</u>

The PET members concluded that the variation in system performance from mission to mission can, for the most part, be attributed to anomalies within the system equipment. A portion of this performance variation and the majority of the variation within a particular mission is attributed to the spread of object contrast presented to the lens. This large range of contrast is caused by the variation in haze attenuation.

SECTION VII

RECOMMENDATIONS

The PET members are recommending action be taken in the areas of system operation, system test and data evaluation. These recommendations are made with the knowledge of the equipment modification, testing and development activity that is now in process.

1. System Operation

A. Film Positioning

The "soft" areas in the photography observed along the edges in three missions indicate some camera misalignment, and the entire film area was not being positioned in the field of best focus during the photographic scan.

It is recommended that the Dr. Aschenbrenner Test which is performed on each camera by the contractor, be conducted again on the entire system as near to launch as feasible.

B. Original Negative Processing

The team concluded that the original negative is not being processed in accordance with the criteria used to establish the exposure time. It is recommended that the exposure and processing be made compatible on future missions.

This can be accomplished either by reducing the processing level to Intermediate, where indicated in the

Performance Estimate, or by reducing the exposure time to nominal for Full processing. Reducing the processing level has the advantage of reducing the original negative grain size whereas a faster exposure time will minimize the effects of image motion.

The margin in exposure time will permit different filters and combinations of filters (one type on the Forward and a second type on the Aft) to further reduce the effects of haze.

It is recommended that a parametric study be conducted to determine the most desirable combinations of processing level, exposure time and filtering to optimize system performance.

C. Yaw Programming

In view of the computed improvement due to the correction of crab error by yaw programming, it is recommended that further experiments to isolate the effects of yaw be performed.

A ground test during a mission operation is recommended. This test would use the portable ground resolution targets in a "V" pattern rather than the "T" pattern now used. One leg of the "V" would be parallel to the flight path and the second leg set at the proper angle, for the display latitude, to correct the residual crab error.

D. Index Camera Exposure Control

The Index camera exposure time is set prior to flight and is not altered during the mission to compensate for changes in illumination. The resultant variations in exposure could be partially compensated by varying the processing; however, this is not feasible with present machine processing due to the close spacing of the frames containing the varied exposure. It is recommended that contractors investigate and report on the modification to equipment and programming required to vary shutter speeds in flight thus providing more uniform exposures in the Index photography.

E. Solar Azimuth

The quality of photography has been observed to vary with solar azimuth. An excellent example is the Fort Huachuca target recorded by the Forward and Aft camera during Mission 9062. In order to further analyze this effect it is recommended that solar azimuth data be provided by LMSC for all future missions.

2. System Test

A. Mechanical Distortion

The space structure interface to the camera system does not provide an extremely precise mechanical surface. Tests are recommended to ascertain the mounting surface flatness and rigidity to preclude distortion of the camera in mounting and shipping.

B. Vibration Tests

Tests have been conducted on the camera to determine the degree of degradation caused by internal vibration. It is recommended that similar tests be conducted on the complete payload system.

C. Thermal Testing

Modifications to the camera structure have reduced the thermal tolerance required to maintain optimum focus. It is necessary to continue emphasis in the area of thermal control to assure that the proper tolerances are maintained for such potential problems as mechanical distortion and electronic reliability. Testing is recommended to provide realistic thermal tolerances for the thermal control activity now in progress.

3. <u>Performance Evaluation</u>

A. Evaluation Techniques

The present techniques are inadequate to evaluate system performance; however, it is recommended that they be continued until alternate techniques are developed. It is doubtful that any single value will be able to completely describe a system operation.

Research and development work is recommended to produce techniques and equipment to allow realistic performance evaluation.

B. Sampling Criteria

The AFSPPL sampling criteria for RES and Density measurements can be modified for future M/J evaluations to better express relative performance. The sampling should be amended to have the RES and Density measurements made in area 3 only on every frame of selected passes. Existing data shows negligible degradation across the frame. The selection of passes should be restricted to those operations which represent nominal mission performance. One pass during each day of the mission operation is recommended.

Evaluation of operational anomalies for each mission should also be performed in detail; however, the measurements and evaluation should be noted as resulting from the effected areas. These measurements should not be averaged and summarized with the nominal data.

C. Densitometer Measurements

There is no standard procedure for making the diffuse density measurements by the various organizations involved in Mural System fabrication and evaluation. A 0.5 millimeter spot size and a white light source are values which appear to be most desirable to the team and are recommended for reporting density values.

It is recognized that alternate methods are required by particular organizations to fulfill their assigned tasks; however, these methods should be restricted to in-house use.

SECTION VIII

APPENDIXES

A. "System Performance Evaluation of Mural Materials." Prepared by ACIC. (under separate cover)

B. "Cartographic Exploration of Mural Materials. Prepared by ACIC. (under separate cover)

C. "Cartographic Suitability of Mural Materials." Prepared by AMS. (Attached)

D. "Suitability for Photographic Interpretation." Prepared by NPIC. (Attached)

E. "Technical Evaluation Report. [redacted] - Original Negatives from Mission 9056." Prepared by AFSPPL. (under separate cover)

F. "Technical Evaluation Report [redacted] - Original Negatives from Mission 9057." Prepared by AFSPPL. (under separate cover)

G. "Technical Evaluation Report [redacted] - Original Negatives from Mission 1001-1." Prepared by AFSPPL. (under separate cover)

H. "Technical Evaluation Report [redacted] - Original Negatives from Mission 9062." Prepared by AFSPPL. (under separate cover)

CARTOGRAPHIC SUITABILITY OF MURAL MATERIALS

Prepared by

Army Map Service

2 December 1963

Appendix C to
Mural System
PET Report

CARTOGRAPHIC SUITABILITY OF MURAL MATERIALS

The following comments are furnished on Missions 9056, 9057, and 1001-1. It is assumed that these particular missions were specified since they are the more recent acquisitions. All comments are not necessarily based on an evaluation of the specified missions as they have not been completely exploited; however, evaluations are all based on materials of the same vintage.

1. <u>Stellar Photography</u>

a. Mission 9054

Stellar frames contained flare. The fiducials wer overexposed and their positions had to be frequently extrapola from the lines of the reseau. The star images generally were fair permitting stars as low as seventh magnitude to be read. The occasional failure of the camera shutter and film advance caused streaked images and double exposures.

b. Mission 9056

No Stellar measurements were made on this mission.

c. Missions 9057 and 1001-1

The reseaus on these missions appeared warped; tha is, the grid lines were curved. This precluded the recovery o the fiducial marks by the method previously described for thos marks obliterated by overexposure. The other comments made fo Mission 9054 are also applicable to these two missions.

2. Frame Photography

It has been possible to produce Long Line Extensions (LLE's) to establish photogrammetric control for mapping purposes from this photography. The quality of these products is highly correlated to the quality of the photography. This is especially true in the case of the Index photography. The scale is so small that any degradation of the image due to a loss of resolution or acutance causes a decrease in measuring precision during the mensuration processes. The Index camera calibration is another critical factor when the Index film is used for mensuration purposes in the production of 250,000 scale maps. In the establishment of control, the film measurements are corrected for lens distortion based upon the values determined by the calibration. Therefore, it is important that the calibration data is complete and reliable.

3. Panoramic Photography

a. The Panoramic photography, with its superior resolution, is particularly applicable for use in identificatior of specific ground control points and tactical and strategic targets, stereo-compilation of medium and small scale maps, and accomplishments of similar photo-mapping and intelligence operations.

b. Occasionally, difficulty is experienced due to the attitude of the vehicle. Excessive pitch or roll exceeding the geometry of rectification equipment reduces the extent of usabil

SUITABILITY FOR PHOTOGRAPHIC INTERPRETATION

Prepared by

National Photographic Interpretation Center

3 December 1965

Appendix D to
Mural System
PET Report

SECTION I

PHOTOGRAPHIC INTERPRETATION SUITABILITY

MISSION 9057

1. Image quality of Mission 9057 is slightly better than Mission 9050 (MIP 85). Target coverage was completed as programmed in stereo without vehicle or major camera malfunction and is one of the best missions to date for this camera system.

2. One hundred and seventy-five targets were reported on from the take of Mission 9057, two of which were bonus targets. The following is a list of the highlights of the mission.

a. Confirmation of a Type I irregular MRBM launch site.

b. Missile sites identified for the first time from photography include: 2 ICBM sites, 1 MRBM site, 2 SA-3 sites, 1 SA-2 site, and 1 SAM support facility.

c. Twenty submarines were identified, and five other vessels were reported as possible submarines.

d. The two bonus targets were a new configuration of SAM site and a new runway under construction at an airfield of prime interest.

3. Mission 9057 produced some of the best photography to date for this camera system; however, some degradations are present.

4. Problems encountered on the mission are as follows:

a. Focus

A small area of soft imagery is present on the Starboard side along the titled edge on all frames of the Master Panoramic take.

b. Data Block

Erratic operation occurred on both cameras.

c. Horizon Camera

The Slave Panoramic Horizon cameras malfunctioned (failed to open) consistently throughout the mission. The Master Panoramic Horizon cameras functioned throughout; however, the Starboard camera imagery is soft on all frames of the mission.

5. Atmospheric conditions obscure or degrade 57% of the mission.

SECTION II

QUALITY RATINGS

MISSION 9057

1. A subjective quality analysis was conducted on a frame-by-frame basis for Mission 9057 Master camera on Pass D08. Numerical quality ratings from one to five were given in place of MIP figures as it was not felt that the MIP figures could be determined where adverse atmospheric conditions were encountered. Criteria used to pick MIP figures expressly eliminates frames showing degradations from camera malfunctions or atmospheric conditions.

2. The analysis of Pass D08 gives a quality rating of one for the best image quality in the pass and consecutively higher figures for frames showing greater degrees of degradation. Frames rated as one contain some of the best image quality to date for this camera system.

MURAL PET REPORT/64

Mission 9057, Pass D08, Master Panoramic Camera

Frame	WX	Target	Position on East and West of Center	Rating
01	C*	Town	2" W	3
02	SC*	Town	0.5" W	2
03	HC*	Town	0.5" W	3
04	SC	City	0	1
05	SC	Town	2" W	3
06	SC	Town	4.3" W	2
07	SC	Town	2.3" W	2
08	HC	Town	3" W	3
09	SC	Town	5" W	3
10	SC	Town	3.5" E	2
11	C	Town	2.7" E	2
12	SC	Town	2.8" E	2
13	SC & CS*	Town	0	3
14	SC	Town	1.8" E	2
15	C	City	2.5" E	2
16	C	City	3.5" E	2
17	HC	City	1.5" E	4
18	SC	Town	1.5" E	2
19	SC	City	1.5" E	2
20	SC	City	0.5" W	2
21	HC	City	0.5" W	4

MURAL PET REPORT/64

Frame	WX	Target	Position on East and West of Center	Rating
22	C	Town	1.4" W	2
23	SC	City	1.2" E	2
24	C	City	1.2" E	2
25	C	U/I Installation	4.1" E	1
26	C	City	7" E	1
27	SC	City	2.2" E	3
28	C	Town	1.6" E	2
29	HC & CS	Town	0.5" E	3
30	C	City	7" E	1
31	SC & CS	City	1.5" E	2
32	HC & SC	City	0.5" W	4
33	C	City	4.5" E	1
34	C	Tank Farm	6" E	1
35	C	Town and Storage Area	7" E	1
36	C	Town	1.1" W	1
37	C	Tank Farm Along Pipeline	6.8" E	1
38	SC	Town	0.8" E	2
39	SC & CS	Town	3" E	2
40	SC & CS	Town	2" E	2
41	HC & CS	City	4" W	4
42	C	Town	2.5" E	2

MURAL PET REPORT/64

Frame	WX	Target	Position on East and West of Center	Rating
43	SC	City	2" W	1
44	C	U/I Installation	0	1
45	C	Town	2.3" E	2
46	SC	City	2" E	1
47	C	City	0	1
48	SC & CS	City	2.4" W	3
49	C	Town	2" E	1
50	C	Town	0	1
51	SC	City	12" L	3
52	C	Town	2.2" E	1
53	SC	Town	4.1" E	1
54	C	City	10.5" E	2
55	C	City	9.8" E	2
56	SC & CS	Town	5.5" W	3
57	C	Town	6" W	2
58	C	Town	10.5" W	5 (soft image
59	C	City	8.4" W	4 (soft image
60	C	Town	7" W	4 (soft image
61	SC	Town	5" W	3
62	HC & CS	Town	4" W	4
63	C	Town	1.4" W	2
64	C	Town	0.8" E	2
65	C	Town	1.7" E	1

MURAL PET REPORT/64

Frame	WX	Target	Positions on East and West of Center	Rating
66	C	Town	2.9" E	1
67	C	Town	3.7" E	1
68	HC	Town	5.8" E	5
69	C	Town	3" E	1
70	HC	Town	5.8" E	4
71	SC	Town	1.5" W	2
72	SC & CS	Town	9.5" E	2
73	SC & CS	Town	4" W	4
74	C	Town	6" E.	1
75	C	Town	10" E	1
76	C	Town	4.5" E	1
77	C	Town	4.7" E	1
78	CS	Village	3" W	5
79	C	Instrumentation Site	0.5" E	1
80	C	Village	7.5" W	1
81	C	Village	2" E	1
82	C	Town	6.3" E	1
83	C	Dam	1.3" W	2
84	C	Village	2.2" E	2
85	C	Village	2.5" E	2
86	C	U/I Activity	7.1" W	2
87	SC	Village	0.2" W	3

MURAL PET REPORT/64

Frame	WX	Target	Position on East and West of Center	Rating
88	CS	Village	1.2" E	5
89	CS	Village	4.1" W	4
90	C	Road Junction	1.8" E	2
91	CS	Instrumentation Site	1.4" E	3
92	C	U/I Activity along Road	8.4" W	3
93	C	U/I Activity along Road	7.8" W	3
94	C	Town and Landing Strip	7.1" W	3
95	C	Town and Landing Strip	6.3" W	3
96	C	Town and Landing Strip	8.6" W	5 (soft imager
97	C	Town and Landing Strip	11.8" W	5 (soft imager
98	C	Cross Roads and Buildings	8.8" W	5 (soft imager
99	C	Cross Roads and Buildings	12" W	3
100	SC & CS	Cross Roads and Buildings	6" E	3
101	C	Cross Roads and Buildings	7.6" W	3

102-107 Lack of cultural features preclude rating; would possibly be rated as 3 if cultural features were present. 83-107 appear slightly overexposed.

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* HC - Heavy Clouds
* SC - Scattered Clouds
* CS - Cloud Shadow
* C - Clear