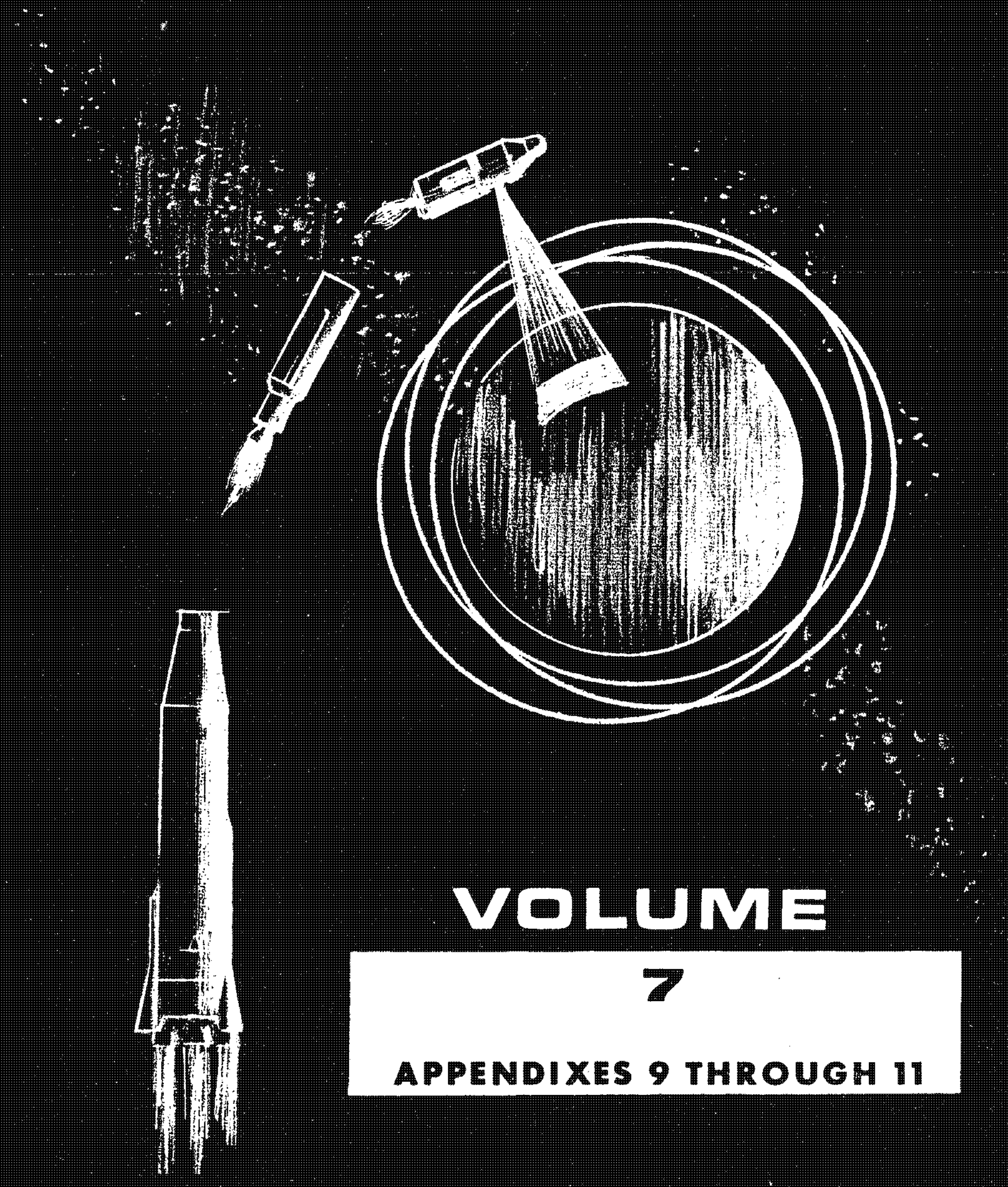
206

PROGRAM REPORT



VOLUME

7

APPENDIXES 9 THROUGH 11

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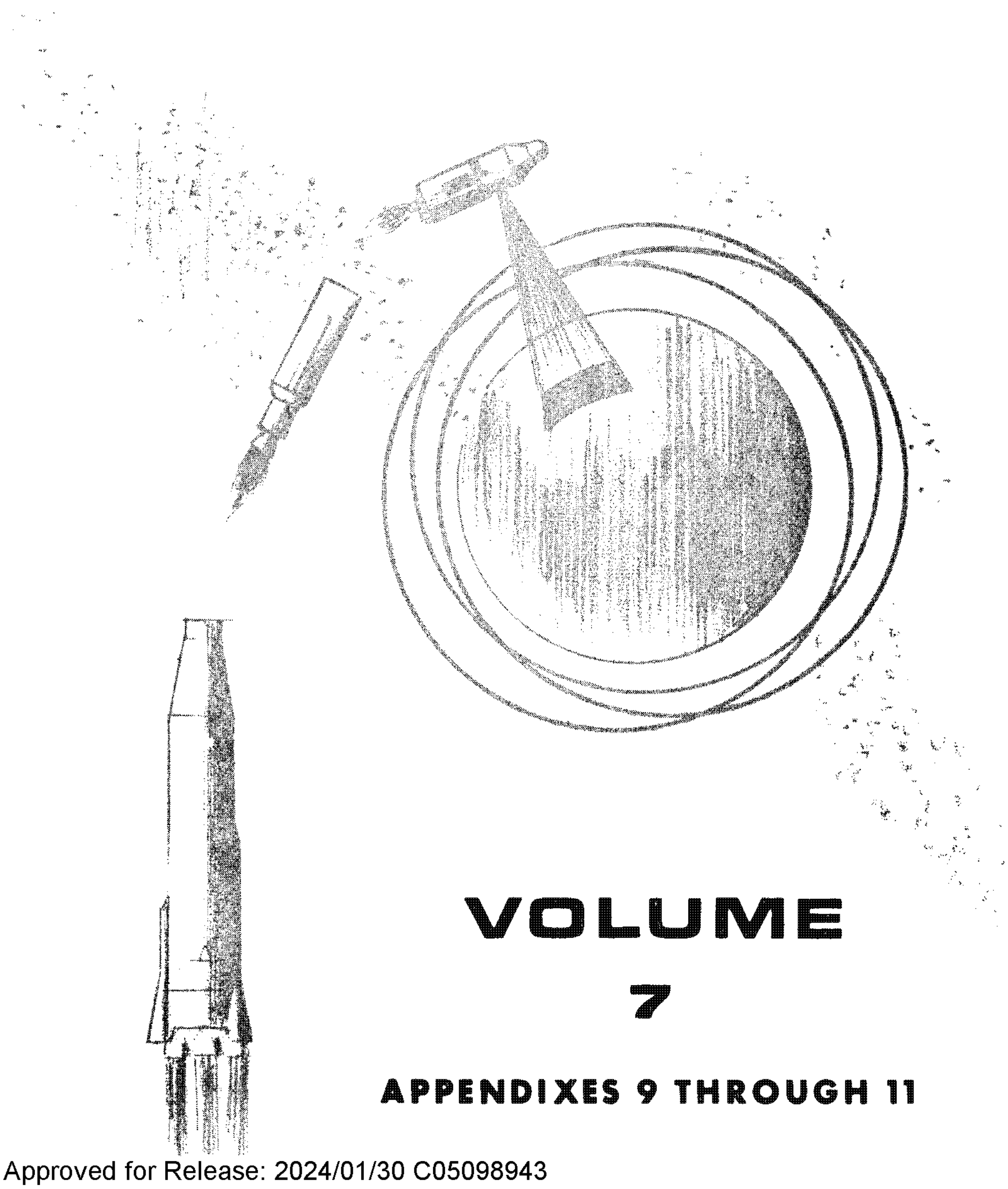
206

PROGRAM REPORT



VOLUME 7

APPENDIXES 9 THROUGH 11

CONTENTS

APPENDIX 9

PAYLOAD SUBSYSTEM ENGINEERING ANALYSIS REPORT

R-004002-RH-051

This document consists of 263 pages.

Subsystem Engineering Analysis Report

Through 1 June 1965

7th Issue

Prepared by

EASTMAN KODAK COMPANY
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Under Contract
AF-33(616)-7704

Approved by:

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for F.C.E. Oder

Date: 12 August 1965

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF ILLUSTRATIONS (continued)

LIST OF TABLES

INTRODUCTION

This is the last of a series of seven Subsystem Engineering Analysis Reports prepared under paragraph 3.11.4 of Contract AF-33(616)-7704. The report presents an analysis of the design of the Photographic Subsystem of a Recoverable Satellite Reconnaissance System as of 1 June 1965. The general technical direction and coordination of this complete system is the responsibility of Aerospace Corporation. Eastman Kodak Company (EKC) is responsible for the development and production of the Photographic Subsystem, which includes a Camera Payload and related Aerospace Ground Equipment. The Camera Payload consists of a 77-inch focal length aerial camera and its associated airborne film-handling and control equipment. Aerospace Ground Equipment is that test, handling, and auxiliary ground equipment that is delivered to Vandenberg Air Force Base and GE which is used to prepare the Camera Payload for operation in its intended environment.* General Electric Company (GE) is responsible for the development and production of the subsystem that provides an airframe, attitude control, a commanding system, and electrical power for the Camera Payload while in orbit. GE is also responsible for the development and production of the subsystem that provides the Satellite Re-entry Vehicle that returns the exposed film to earth. This exposed film constitutes the system output.

Each issue of the Subsystem Engineering Analysis Report is complete in itself as of the closing date of the report period. The format specified

* In this report the special tooling, special test equipment, and special industrial equipment used at EKC for test, fabrication, handling, or operation of the Camera Payload was included under the general title of Aerospace Ground Equipment because, in many cases, it is identical with that equipment.

in Section 3.15 of AFBM 58-1 was followed as closely as possible, although this is not a contractual requirement. This format results in a report of five sections.

Section 1 was written largely from a system concept of the subsystem. Starting from mission requirements and the capabilities of film and optical systems, a plan for the mission and the basic design parameters was established. This evaluation was presented in an Initial Study Report (S-R-004). The material of Section 1 reviews the concepts that underlie the design of the Photographic Subsystem. Section 2 describes the payload by means of graphic diagrams and photographs. In Section 3, block diagrams are used to present functional interrelationships of subsystem components. Section 4 presents a more detailed discussion and description of the major items of airborne and ground equipment. Section 5 describes and discusses the status of the program being followed to ensure subsystem reliability.

This report describes the expected characteristics of the Recoverable Satellite Reconnaissance System when in full operational status. Although modified mission and operating parameters were used on early flights for test and reliability reasons, these will not be described in detail.

SECTION 1
DESCRIPTION

1.0 GENERAL

The Recoverable Satellite Reconnaissance System (RSRS) Aerospace Vehicle consists of the following major flight components:

a. Launch Booster. Atlas, first stage booster; separates in flight before orbit injection.

b. Satellite Boost Vehicle. Agena, second stage booster; separates after orbit injection.

c. Satellite Vehicle (S/V). The orbiting photographic satellite consisting of the following:

   1. Camera Payload (C/P). The Camera Payload portion of the Photographic Subsystem consists of the flight equipment required to collect visual information on a photographic film, to transport and store this film in the SRV (except for the film chute between the supply cassette and the forward record storage assembly), and the necessary C/P electrical equipment.

   2. Payload Vehicle (P/V). The Payload Vehicle consists of the Orbit Control Vehicle, the Satellite Vehicle Adapter, and the Satellite Re-Entry Vehicle whenever they are connected as a unit.

      a. Orbit Control Vehicle (OCV). The OCV is that portion of the P/V which establishes structural continuity between the Satellite Boost Vehicle and the Satellite Vehicle Adapter. The OCV houses the Camera Payload, the satellite programmer, the battery power supplies, and other subsystems.

      b. Satellite Vehicle Adapter (SVA). The Satellite Vehicle Adapter is that portion of the P/V which joins the SRV to the OCV, contains the telemetry instrumentation and communication subsystem, and contains the record chute from the OCV to the SRV with required thermal environmental control.

c. Satellite Re-Entry Vehicle (SRV). The Satellite Re-Entry Vehicle is that portion of the P/V which houses the recoverable capsule, forward record storage assembly with exposed film, and the SRV de-orbit propulsion, telemetry, and retrieval subsystems. The SRV supporting structure protects the subsystems during descent from orbit through re-entry into the earth's atmosphere to parachute deployment. The recovery capsule protects the exposed film and retrieval aids from parachute deployment through air-snatch or water impact and recovery.

A diagram of the launch vehicle configuration is shown in Figure 1-1. The abbreviations given in the foregoing discussion are used throughout this report.

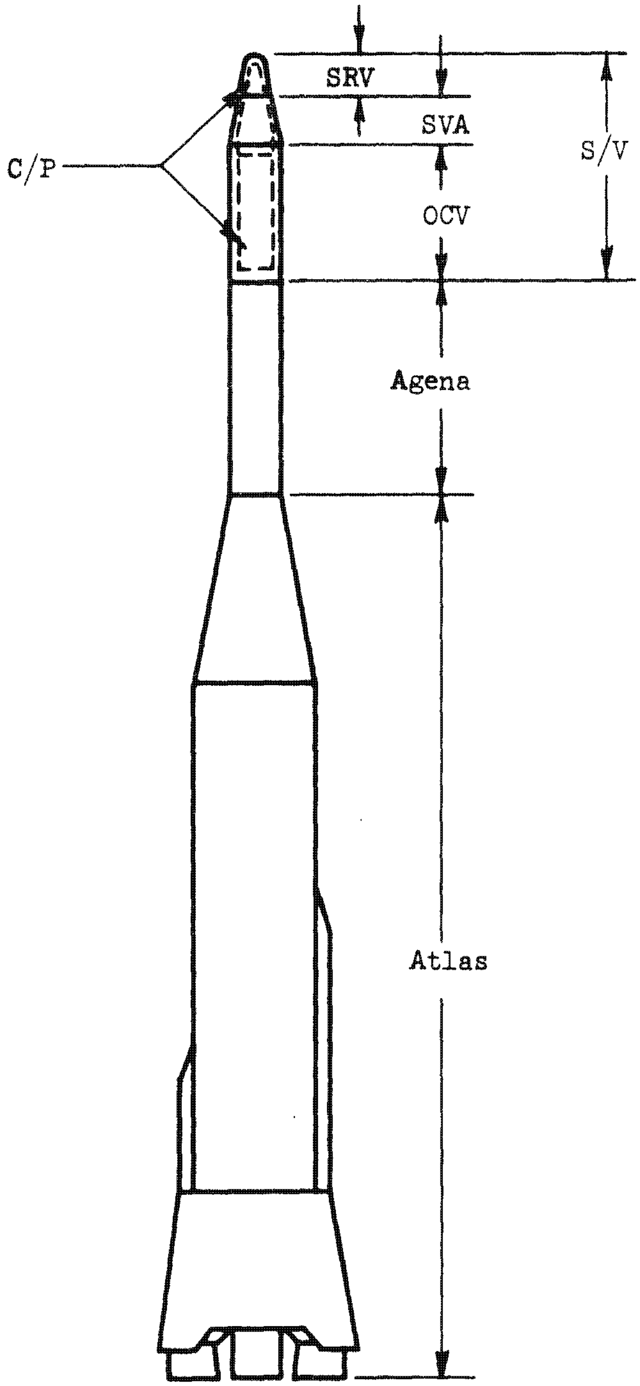

Figure 1-1. Launch Vehicle Configuration

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1.1 MISSION AND OBJECTIVES OF THE PHOTOGRAPHIC SUBSYSTEM

The objective of the Recoverable Satellite Reconnaissance System is to photograph selected areas between 30° and 80° North latitude. The orbiting vehicle was originally designed for operation at a nominal altitude of 95 nautical miles, with special provisions for operation at a nominal altitude of 116 nautical miles being made during early missions. The Camera Pyaload was modified to operate over an altitude range of 72 ± 9 nautical miles for ±44.7-degree obliquity angles for FM 7 through FM 10, and 81±11 nautical miles, with the above obliquity constants, for FM 11 and subsequent payloads. Smaller obliquity angle requirements increase the upper altitude limit. Photographs taken vertically from 95 miles will resolve ground distances of 2 to 3 feet at the center of the field. The exposed film is recovered at a preselected location within five days after launch.

This program provides a Photographic Satellite capable of photographing specific details of small, selected target areas and is not intended to obtain large area reconnaissance. The vehicle has an obliquity aiming capability of approximately ±44.7 degrees from the vertical. The camera has a field-of-view half-angle of 3.2 degrees. Photography is possible in the vertical direction and at forward and rearward stereo angles.

The camera photographs ground areas through a narrow slit near the camera focal plane. Image smear is minimized by short exposure times and by moving the film past the slit at nearly the same rate and in nearly the same direction as the image from the ground moves past the slit. (The film motion is called image motion compensation, or IMC). A crab adjustment in the optical system corrects for the lateral velocity of the earth.

Discrete camera ON and interframe times are provided for stereo photography. They are as follows:

Flight Nos.	Stereo ON Times	Stereo Interframe Times
1 through 17	2.0 to 12.5 seconds, in 0.7-second increments	3.2 to 17.9 seconds, in 2.1-second increments
18 and subsequent	3.5 to 9.5 seconds, in 0.4-second increments	3.0 to 11.4 seconds, in 1.2-second increments

Stereo pairs, lateral pairs, and strip photographs are normally programmed within the rated dynamic capacity of the film-handling looper. The looper capacity of approximately 25 inches (5.4 to 10.1 seconds of camera operation for payloads after FM 10, depending upon the IMC velocity used) allows photography of ground scenes approximately 22 to 42 nautical miles in length, which is adequate for most mission requirements. However, strip photographs can be programmed when necessary for intervals up to 102.4 seconds (in 0.1-second increments)* with intermittent reductions of photographic quality due to velocity variations each time the looper is emptied.

The ground area photographed in a single mission depends upon the number of targets, available light, time from launch to recovery, and other factors. A maximum capability of 600 stereo pairs has been specified. The C/P film supply has a capacity of 3000 feet of Estar thin-base film, which is sufficient to satisfy this requirement. Exposed film is delivered to the forward record storage assembly in the SRV during C/P operation. Prior to the recovery sequence, all unused film is normally transported to the forward record storage assembly to increase the probability of a successful recovery.

* This number is determined by the command system and is not a basic limitation of the C/P.

To increase the probability of program success, several changes were made in mission requirements and configurations for early flights. For these flights, the nominal operational altitude was increased to 116 nautical miles. The Agena remained attached to the S/V and provided stabilization during the photographic and SRV deboost portions of the mission. Obliquity aiming was not possible and the photographic mission was limited to one or two days. This mode of operation was known as Hitch-Up. The OCV was separated from the Agena and re-oriented after SRV deboost, and was used as an experimental unit for a short period of time. This mode of operation was referred to as OCV-Solo.

1.2 DESIGN CRITERIA

Some of the C/P design features are reviewed in this section. Parameter choices are based on a fundamental goal of keeping the orbiting vehicle as simple and reliable as possible.

1.2.1 Visible and Photographic Areas

The S/V orbits the earth approximately 80 times in five days. The area of interest is defined as the USSR, its satellite countries, and Communist China. Approximately 39 of the 80 passes will be over this area (roughly 10.1 million square nautical miles) during daylight hours, for a total of roughly 250 minutes during a five-day mission. However, the visible area is not only a function of the number of orbital passes over the area, but also of altitude, obliquity capability, and field of view of the camera lens. At low altitudes, the area visible is limited by the maximum attainable obliquity angle. At high altitudes, the area selectable for photography is limited by the minimum available film-drive rate for IMC. The IMC velocity limitation is more severe for stereo than for strip photography.

Nearly 100 percent of the area is visible on each mission using ± 44.7-degree obliquity aiming. Selected targets can always be made visible on a specific mission by adjustment of orbital parameters. However, a photograph taken with a large obliquity angle has lower quality (the minimum resolvable ground distance is larger) because the slant range and angle of view to the target are less advantageous.

The total photographable area depends upon S/V altitude, stereo angle, obliquity angle, and upon preparation time for each photograph or stereo pair. For example, a given mission may include 600 stereo pairs with an average of 300 square nautical miles per stereo pair. The area photographed in stereo will then be 180,000 square nautical miles, or nearly 1.8 percent of the total. When strip mode photography is used, the 3000 feet of film is capable of covering up to 470,000 square nautical miles.

Camera Payload altitude and IMC ranges are shown in the following table for 0-degree stereo angle and an obliquity range of ± 44.7 degrees.

Camera Payload Nos.	IMC Range	Altitude Range
FM 1 through 6	2.0219 to 3.7845 inch/sec	95 ± 12 n mi
FM 7 through 10	2.7888 to 5.2200 inch/sec	72 ± 9 n mi
FM 11 and subsequent	2.4841 to 4.6500 inch/sec	81 ± 11 n mi

1.2.2 Image Quality

One measure of image quality for a photographic system is resolvable ground distance; that is, the distance between centers of two similar objects on the ground which can be just resolved on the photographic record. Because resolution varies considerably with changing objects (a line is more readily resolvable than a spot), it is necessary to pick some target shape for predicting resolution. For this program, resolution predictions are based on resolving a group of three bars with a length-to-width ratio of 5:1 having the space between adjacent bars equal to the width of the bars. The contrast ratio of the bar target is 2:1, which is the predicted contrast of the fine detail in a ground scene as seen from above the atmosphere. For vertical photography from a satellite, resolvable ground distance is primarily a function of altitude, lens focal length, resolving power of the lens and film combination, image smear, atmospheric effects, field angle, and subject contrast. Figure 1-2 shows the approximate resolvable ground distance in feet at the center of the field for vertical photography as a function of altitude in nautical miles.

1.2.3 Modes of Operation

The capability for operating in many different modes can be built into the S/V. The C/P inherently allows almost all desirable modes. However, to simplify both design of the OCV and programming, only three modes of operation are commonly used. These are stereo pairs, lateral pairs, and continuous-strip photographs.

1.2.3.1 Stereo Pairs. Stereo photography is defined as two photographs of the same area taken from different viewing angles. The stereo mirror is first aimed forward and an exposure is made. The stereo mirror is then aimed aft

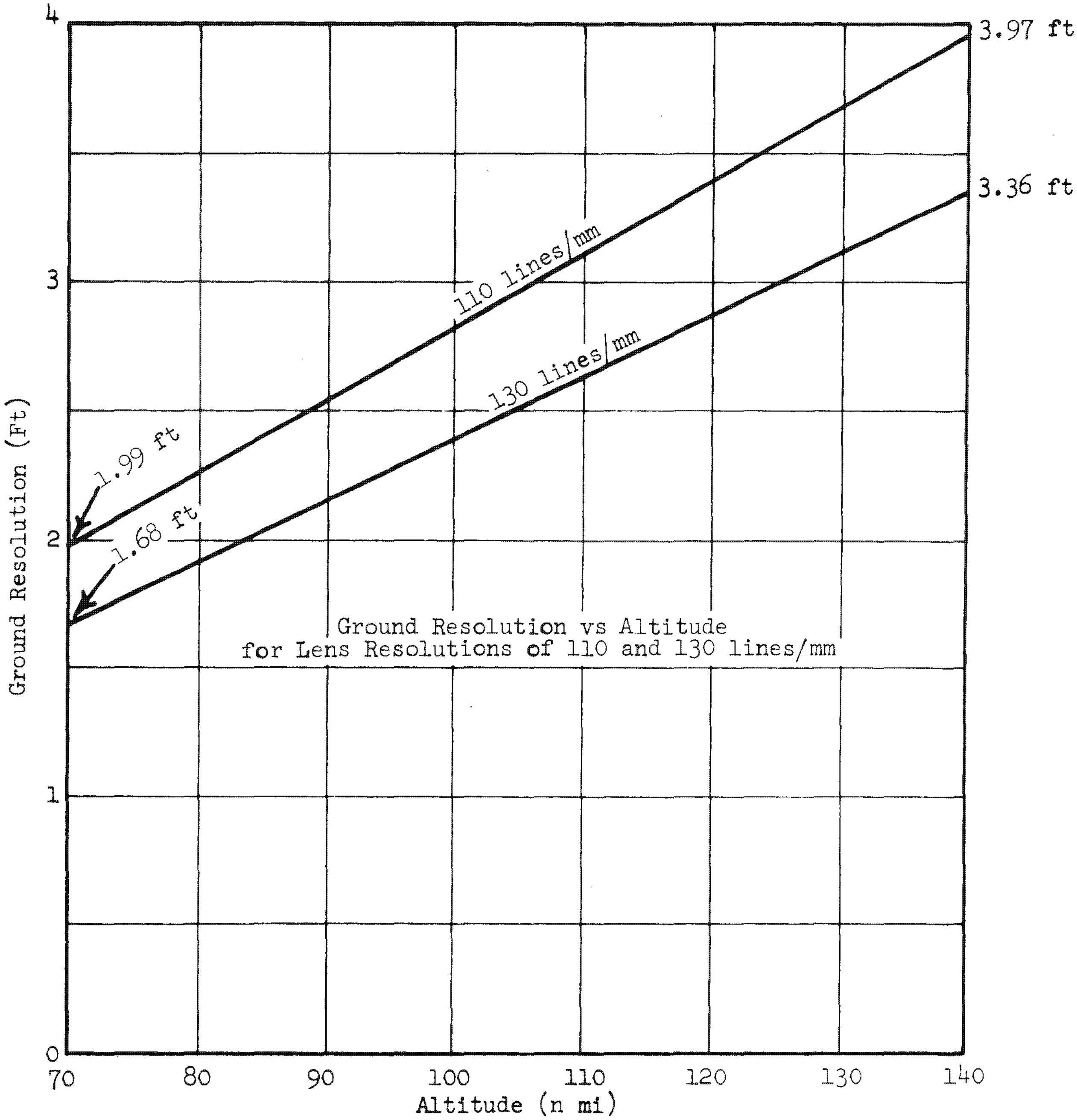

Figure 1-2. Resolvable Ground Distance vs Altitude for Vertical Photography

toward the same general target area and another exposure is made from a later position in the orbit. These photographs will produce a convergent stereo pair of the area of overlap with a stereo base-to-height ratio dependent on the angle of convergence. With slight modifications in timing, stereo pairs can be taken at any obliquity angle to provide stereo photography of areas to the left and right of the ground track. (A stereo simulation is shown in Figure 1-12.)

1.2.3.2 Lateral Pairs. A lateral pair consists of two photographs that do not intentionally overlap but are parallel to the ground track and are separated laterally. An obliquity movement of the S/V is required between forward and aft stereo mirror positions to obtain a lateral pair of photographs. A simplified diagram of a typical pair is shown in Figure 1-3. This mode makes possible double swath widths for broader coverage without stereo or the photography of two separate targets displaced laterally along the ground track.

1.2.3.3 Individual Photographs. Conventional strip photography for recording a continuous ground swath can be programmed to cover a long target within the obliquity capability. This mode of photography is also indicated in Figure 1-3.

1.2.4 Standard Orbit

The design of the C/P is strongly influenced by the orbit into which it is to be injected. For this reason, the relationships between orbital parameters, output requirements, and hardware design were studied. The output requirements place three primary restrictions on the choice of an orbit:

a. The orbit must allow the vehicle to have a five-day life with a minimum of orbit maintenance.

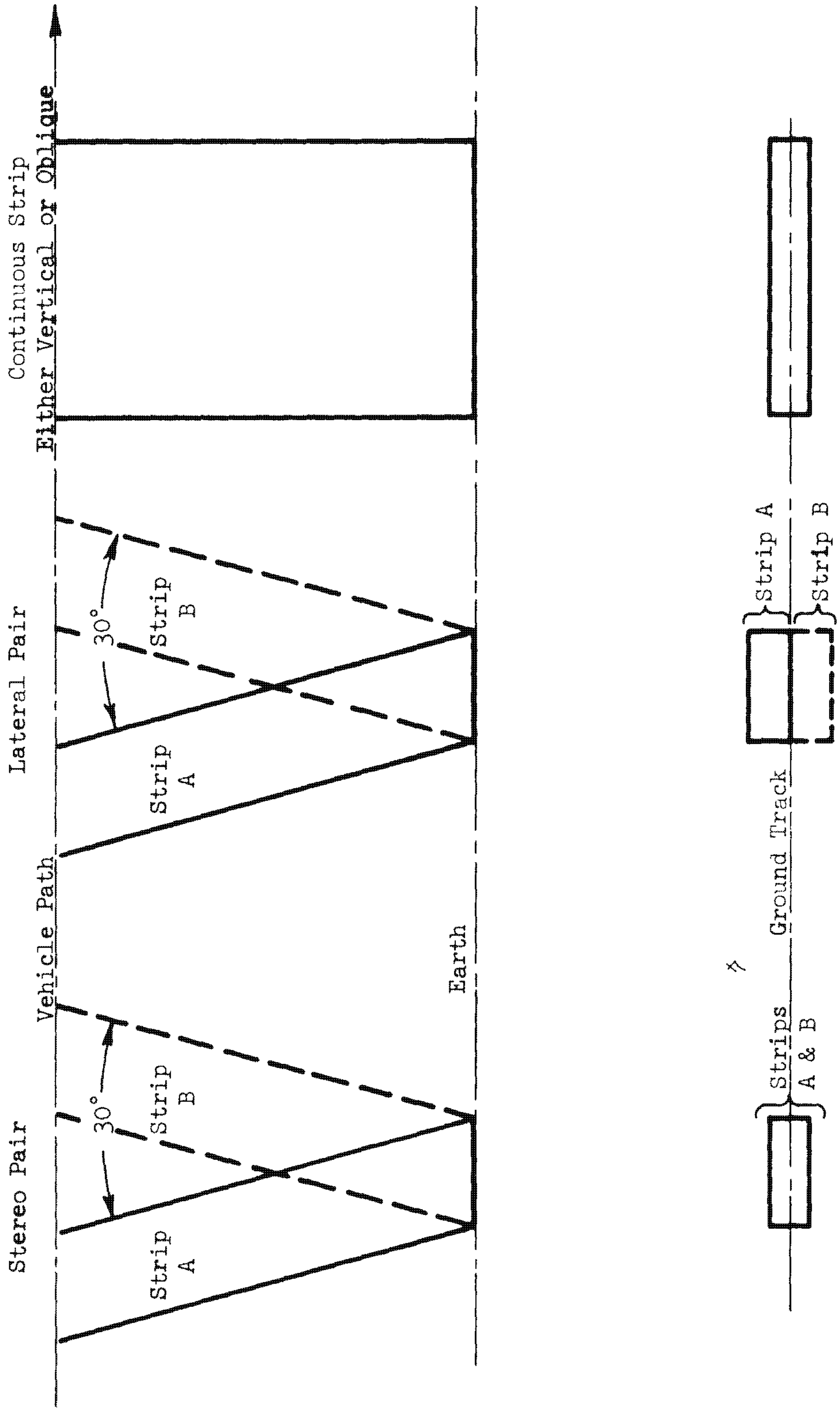

Figure 1-3. Modes of Photographic Coverage

b. The orbital altitude must be low enough to provide for 2- to 3-foot ground resolution with a 77-inch f/4.0 lens.

c. The spacing of the ground tracks must provide the desired coverage of the area of interest.

An orbit that allows the photographic system to fulfill the requirements for coverage, resolution, and lifetime was chosen and designated as the standard orbit. It is circular, or nearly circular (see paragraph 1.2.4.2), and it is defined by the following set of parameters:

Altitude:	Average	95 ± 5 nautical miles
	Instantaneous*	95 ± 12 nautical miles
Inclination:		80 to 105 degrees
Daylight equator crossing:		1000 to 1400 hours local time

Later missions were equipped with higher IMC velocities to allow operation at lower altitudes where elliptical orbits with perigees of about 70 to 85 n mi were used. For these orbits, perigee was usually located over the area of interest, with the inclination of the orbits and equator crossing times similar to the earlier circular orbits. By making a judicious selection of apogee altitude, an acceptable trade-off between coverage and lifetime is possible.

1.2.4.1 Orbit Adjusts. Specific mission requirements have dictated the use of the OCV orbit adjust capability, generally to lower perigee altitude

* The difference between the average altitude and the instantaneous altitude is attributed to the fact that the earth is not a perfect sphere, but is an oblate spheroid whose radius is approximately 12 miles less at the poles than it is at the equator.

over the area of interest. Orbit adjusts may also be used to vary the period to ensure coverage of a specific target or to add energy to the orbit to counteract the effects of atmospheric drag or orbit injection anomalies.

Orbit adjusts normally result in uncertainty in the vehicle ephemeris (particularly in-track) for several Revs afterward, until sufficient tracking data has been accumulated. The uncertainty in in-track location requires lengthened camera burst times to ensure proper target coverage. If the camera burst times are extended beyond the capacity of the film looper, the take-up motor will operate during the photograph and produce a region of banding and degraded resolution on the film.

1.2.4.2 Altitude and Eccentricity. The altitude of the vehicle above the earth depends on the orbital radius and the radius of the earth, with the orbital radius varying as a function of eccentricity and orbit decay. The variation in orbital radius should be held to ± 5 n mi for initial missions. This variation may arise from eccentricity or from variation in the semi-major axis of the orbit. In addition to the variation in orbital radius, the radius of the earth varies with latitude. This deviation is approximately ±5.8 n mi, using the radius of the earth at 45° North latitude as a mean. Nominal altitude, defined as the mean altitude of the vehicle over a spherical earth, is 95 n mi and average altitude is 95 ± 5 n mi. This is the altitude range of the vehicle over a spherical earth resulting from variations in orbital radius. Instantaneous altitude is defined as 95 ± 12 n mi. This covers the instantaneous altitude of the vehicle over an oblate earth at any time and includes variations caused by earth oblateness and orbital radius. It is understood that for initial missions, any eccentricity and semi-major axis combination which results in a departure in orbital radius of no more than 5 n mi from 95 n mi is acceptable. The low altitude missions will require the use of orbits with eccentricities on the order of 0.02. (The use of an elliptical orbit is dictated by the molecular heating of the S/V at low altitudes). In addition, a large orbit-adjust capability would be required to maintain a circular orbit at low altitudes.

1.2.4.3 Orbital Inclination. The prime requisite for the choice of orbital inclination is the coverage of the area of interest. The oblateness of the earth causes the plane of the orbit to rotate about the polar axis of the earth and the rate of this rotation is a function of the orbital inclination. Because coverage of the area of interest depends on the spacing of the ground tracks, it is necessary to choose an orbital inclination which will provide the desired coverage. (Exceptionally high or low inclination orbits will not cover targets at far northern latitudes.) A nominal orbital inclination of 95 degrees has been specified, although specific mission requirements have resulted in inclinations as high as 107 degrees.

1.2.5 Camera Aiming Considerations

S/V programming is affected by both orbital parameters and by camera aiming (stereo, crab, and obliquity maneuvers). These effects are discussed in the following subsections.

1.2.5.1 Stereo. Two views of a target area, at viewing angles of +15 and -15 degrees, from sequential positions along the orbit produce a stereo pair. The necessary time interval between forward and rearward stereo views of a target is primarily a function of altitude and obliquity angle. This time relationship is shown in Figure 1-4. The diagram in Figure 1-5 clarifies the stereo sequence.

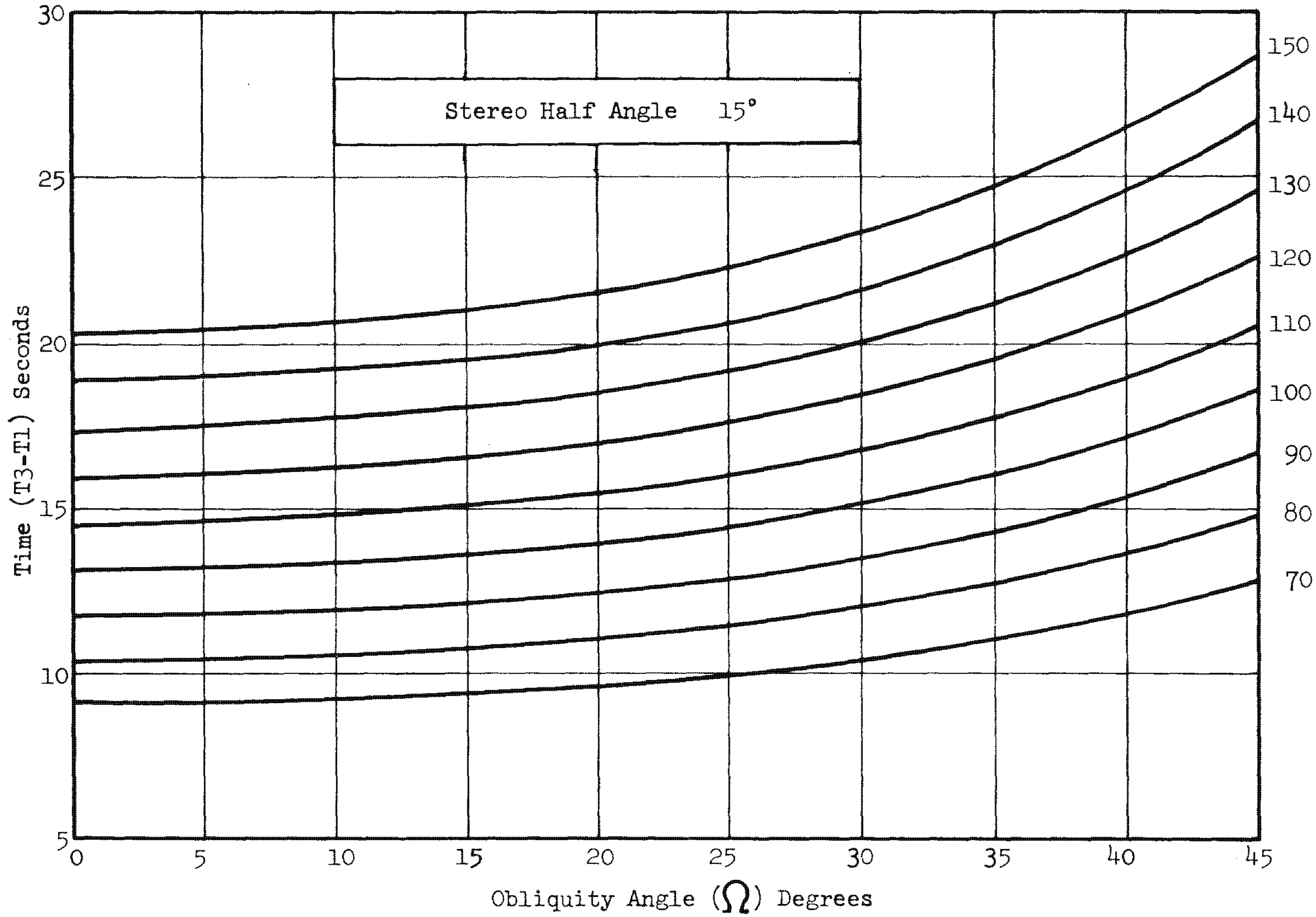

Figure 1-4. Time Interval Between Forward and Aft Stereo Looks at a Point For Altitudes Between 70 and 150 n mi

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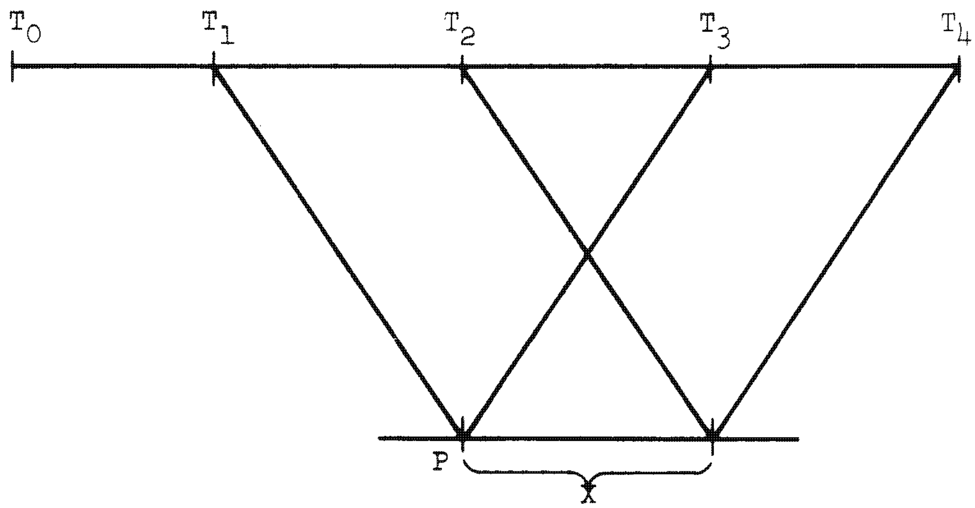

$T_1 - T_0$ = Preparation time for first shot of stereo pair

$T_3 - T_1$ = Time between the stereo looks at point P

$T_2 - T_1$, $T_4 - T_3$ = Camera on time

$T_3 - T_2$ = Preparation time for second shot of stereo pair or interframe time

P = Point at edge of area to be photographed

X = Region to be photographed in stereo

Figure 1-5. Stereo Operation Schematic

$T_1 - T_0$ is the time to make the necessary preparations for the first photograph of the pair. These preparations may include S/V obliquity positioning, stereo-mirror positioning, crab adjustment, film-speed selection, opening the port door, turning power on, and activating recorders. At time T_1, the camera is viewing point P on the edge of the area to be photographed. The camera operates for a time interval $T_2 - T_1$ to photograph the area. At time T_2, the camera ceases operation and preparations for the second half of the stereo pair begin. These preparations include changes in stereo aiming, and possible changes in S/V obliquity aiming and film drive velocity. At time T_3, the camera resumes operation and runs until time T_4. Note that at time T_3, the camera is again viewing point P at the edge of the area to be photographed. Time $T_3 - T_1$ is thus the time interval between views of a point target and is the time given in Figure 1-5 as a function of altitude and obliquity.

In C/P programming,the time intervals $T_2 - T_1$ and $T_3 - T_2$ are conveyed by stored program commands. Time interval $T_4 - T_3$ is always equal in duration to interval $T_2 - T_1$. The sum of the intervals $T_2 - T_1$ and $T_3 - T_2$ should correspond roughly to the interval $T_3 - T_1$ as given in Figure 1-4.

A set of times for each of these intervals was chosen. They were selected for the 95 n mi nominal orbits and were used for the low altitude missions through Flight 17. They are listed below:

Interval	Time (in seconds)
$T_2 - T_1$ (Camera ON time)	2.0, 2.7, 3.4, 4.1, 4.8, 5.5, 6.2, 6.9 7.6, 8.3, 9.0, 9.7, 10.4, 11.1, 11.8, 12.5
$T_3 - T_2$ (Inter-frame time)	3.2, 5.3, 7.4, 9.5, 11.6, 13.7, 15.8, 17.9,

Effective with Flight 18, the time intervals given above were changed to optimize the performance of payloads utilizing the 70 n mi camera. They are as follows:

Interval	Time (in seconds)
$T_2 - T_1$ (Camera ON time)	3.5, 3.9, 4.3, 4.7, 5.1, 5.5, 5.9, 6.3 6.7, 7.1, 7.5, 7.9, 8.3, 8.7, 9.1, 9.5
$T_3 - T_2$ (Inter frame Time)	3.0, 4.2, 5.4, 6.6, 7.8, 9.0, 10.2, 11.4

The capacity of the film looper is approximately 25 inches. If camera burst lengths exceed this capacity, the take-up motor will empty the looper during photography and produce a region of banding and degraded resolution on the film.

The lens provides a 6.4-degree field of view across the ground track. This corresponds to a 7.8 n mi swath width for vertical photography from a 70 n mi altitude. Swath width increases directly as a function of altitude and also increases in proportion to the tangent of the obliquity angle. When the stereo aim angle is 0 degree, the swath width is determined using the following expression:

$$\text{Swath width} = h \left(\tan\left[\Omega + \frac{\theta}{2}\right] - \tan\left[\Omega - \frac{\theta}{2}\right] \right)$$

where h = vehicle altitude
Ω = obliquity angle
θ = field angle of lens

Camera aiming maneuvers are normally programmed to place the target near the center of the field of view to increase the probability of covering the full target area. In addition, placing the target near the center of the field takes advantage of the high on-axis resolution of the lens.

During the time interval between halves of a stereo pair, the earth rotates and the target assumes a different lateral position with respect to the vehicle. For example, if a 9-second time interval is programmed between halves of a stereo pair taken from an altitude of 70 n mi at 30° North latitude, the target will move laterally about 2.3 n mi with respect to the S/V. Therefore, to maintain the target near the center of the field of view, a roll maneuver may be necessary for certain combinations of orbit parameters, target location, and stereo interframe times.

If an obliquity maneuver is performed between photographs, the resulting (cross-track) error in overlap between photographs can never exceed the error resulting from the coarseness of the obliquity steps. This is about ± 0.35 degree because the S/V attitude control subsystem provides 0.709-degree obliquity steps. Under these circumstances, the apparent target displacement error is ± 0.43 n mi and the resulting stereo coverage is 7.8 - 0.86 or about 6.9 n mi. Obliquity maneuvers to take into account the earth's rotation will not exceed 2 degrees. However, OCV roll settling times can make such maneuvers impractical.

1.2.5.2 Aiming Requirements (Cross Track). Table 1-1 lists the major pointing errors cross-track.

Because these errors are independent and random, their combined effect can be estimated as the root-sum-square. The 3-sigma (3σ) value of target displacement relative to the center of the field is ± 1.11 n mi for vertical photography at an altitude of 70 n mi.

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TABLE 1-1

CROSS TRACK ERRORS

Error	Approximate Magnitude at 70 n mi Altitude	Error Squared
Discreteness of obliquity steps ±0.35 degree (0.709 degree obliquity interval)	±0.43 n mi	0.1849
Attitude (roll error) ±0.7 degree	±0.86 n mi	0.7396
Satellite position uncertainty (cross track)	±0.5 n mi	0.2500
	Sum-squared error	1.2370
	Root-sum-squared error ±1.11 n mi	

For stereo photography, coupled with this error is the error resulting from movement of the target caused by the earth's rotation. If an obliquity maneuver is programmed between shots of a stereo pair, the effective stereo overlap is reduced by 0.86 n mi, and as much as 2.3 n mi (for a 9.0-sec interframe time) if no maneuver is executed. The effective stereo coverage is then 6.9 n mi and 5.5 n mi, respectively. Subtraction of the maximum possible root-sum-square error from the nominal swath width shows that in the first case there is a 3σ probability of covering a 4.7 n mi target and in the second case a 3σ probability of covering a 3.6 n mi target.

A more general analysis was conducted for stereo photography at any obliquity position to determine the tracking requirements and the probable location of the target within the field of view. The analysis for vertical photography is the limiting case, however, and established that the 0.709-degree obliquity steps provided by the attitude control subsystem were adequate.

1.2.5.3 Crab Correction. Crab correction is used to compensate for the apparent rotation of the image velocity vector as the S/V orbits the earth. The velocity vector is made up of two components. One is the velocity of the S/V, which is fixed for any given altitude. The other, which is much smaller, is the velocity of the surface of the earth at the point being photographed. Because the earth rotates on its axis with a constant angular velocity, the velocity of a point on the earth's surface varies with latitude. The second component therefore varies and produces rotation of the total image velocity vector.

The range of crab angles for vertical photography between the poles and the equator is 0 to -3.5 degrees for southbound photography and 0 to +3.5 degrees for northbound photography. A graph of this is shown in Figure 1-6. The crab angle required is also a function of the stereo and obliquity angles. The number of crab settings required for adequate compensation is determined by the permissible image smear. Eight crab settings, with three command bits required to program these settings, are currently available for either northbound or southbound photography. The choice of northbound photography (midnight launch) or southbound photography (noon launch) must be made prior to the time that the C/P completes subsystem tests at the Missile Assembly Building (MAB).

1.2.5.4 Tracking and Ephemeris Prediction Requirements. The location of the satellite at any time must be known to command the S/V to photograph specific targets. The S/V location must be predicted accurately enough to ensure that a target of given size is included in the photograph.

The attitude error, accuracy of aiming, the obliquity angle, and the precision to which the target position is known are taken into account to determine how

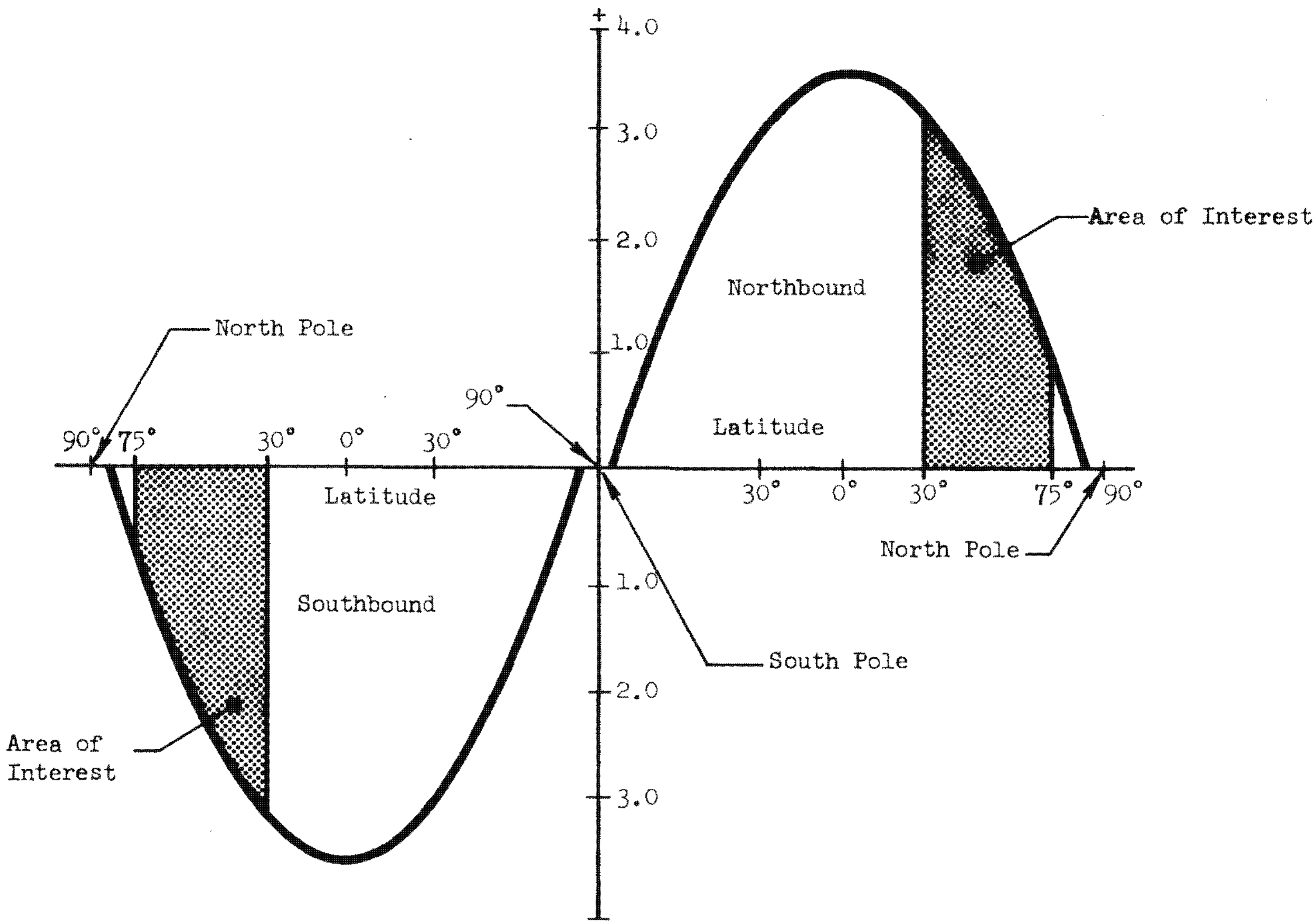


Figure 1-6. Range of Crab Angles for 85-Degree Retrograde Flight at 95 Nautical Miles in a Circular Orbit

accurately the position of the S/V must be known. The ephemeris prediction requirements differ for cross-track, in-track, and altitude.

1.2.5.4.1 Cross-Track Error. The analysis of cross-track aiming requirements given in paragraph 1.2.5.2 indicates that errors in tracking and ephemeris prediction should contribute approximately ±0.5 n mi to uncertainties in the cross-track displacement of the target relative to the vehicle.

1.2.5.4.2 In-Track Error. The in-track prediction error is less critical because the length of the photograph can be varied to allow for system errors and the size of the target. With an in-track prediction error of ±2 n mi and a timing error of ±0.2 second in the command to start photography, an 8.2-second burst will ensure coverage of a target 28-miles long from an altitude of 70 n mi. In addition, the discrete "on" and interframe times provided for stereo photography can reduce the in-track stereo overlap. For example, an error of ±0.2 sec (one-half the stereo interframe time increment) will result in a loss of stereo coverage of about 0.8 n mi at each end of the frame, at an altitude of 70 n mi.

1.2.5.4.3 Altitude Error. The smear considerations given in Appendix D limit the allowable altitude-prediction error to ±0.5 n mi to meet system performance requirements.

1.2.6 Photographic Performance Considerations

The requirements of the photographic system are stringent because of the limitations imposed by the objectives of the C/P. The requirements of the photographic image and factors influencing the resolvable ground distance of the image are discussed to show how the 2- to 3-foot ground dimension can be achieved by means of a photographic payload carried by an orbiting satellite.

1.2.6.1 Definition of Resolution. Resolution is a measure of the ability to distinguish between closely spaced objects under specific viewing conditions. For example, a photograph is said to have 2-foot ground resolution at a specified contrast ratio when light stripes one-foot wide, one-foot apart, and five-feet long, with a contrasting dark background are distinguishable in the developed negative.

Resolving power depends not only on the quality of the optics but also on the contrast of the target being photographed. Contrast of a bar-chart test object is defined mathematically as the ratio of the brightness of the light bars to the brightness of the dark background. The apparent contrast of a target photographed from an orbiting satellite is greatly reduced after transmission through the atmosphere. On the basis of extensive high altitude aerial photography above the majority of the atmosphere, a test object with a 2:1 contrast simulates the fine detail in the majority of the ground image as seen from a satellite.

Thus, this contrast ratio represents an appropriate test condition and the resolving power of the C/P is measured in the laboratory by photographing a series of test charts at 2:1 contrast, as designated in Figure 7 of MIL-STD-150A, using the collimator described in paragraph 4.9 of this report.

1.2.6.2 Measurement of Photographic Quality. The use of solid bars and contrasting backgrounds is the familiar form of specifying resolution. This method does not lend itself to any known, well-defined method for analyzing or synthesizing photographic systems component by component. Photographic-image quality can be measured and analyzed, however, by transfer functions frequently called sine-wave response. This method is analogous to the determination of the transfer function of electronic circuitry where each element in the optical system may be regarded as a low-pass filter. The sine-wave response gives the bandpass characteristics of each optical element as a function of spatial frequency. As is done in electronic circuitry, the susbystem can be divided into elements such that the output of each individual element is independent of the characteristics of the next element; for example, the image formed by the lens at the film plane is independent of the smear caused by the IMC errors. Under this condition and with the assumption that the system is linear, the output of one element can be treated as the input of the next element. Therefore, the sine-wave response of each element can now be multiplied to obtain the combined effect of two or more elements; that is, the total sine-wave response of the system. This total is then used to mathematically obtain a measure of image quality as presented to the film. Knowledge of the film response characteristics then makes it possible to predict the performance of the system.

Because the output of the S/V is intelligence information, the measure of photographic quality should be related to information capacity. It is theoretically possible to calculate the information capacity from measurements of the sine-wave response. Such measurements are tedious, however, and would not be suitable as a production test. It is felt that with proper consideration given to the scale and contrast of the detail to be recorded, the measurement of system resolution will provide an adequate indication of information capacity or photographic quality.

1.2.6.2.1 Sine-Wave Response. Sine-wave response curves used in determining system response are shown in Figure 1-7. Figure 1-7A represents the calculated response of a perfect 77-inch f/4.0 lens to a target of 2:1 contrast ratio. However, perfect optics cannot be achieved. Manufacturing tolerances and imperfections are therefore assumed to follow a Gaussian probability distribution; the perfect lens response curve is therefore

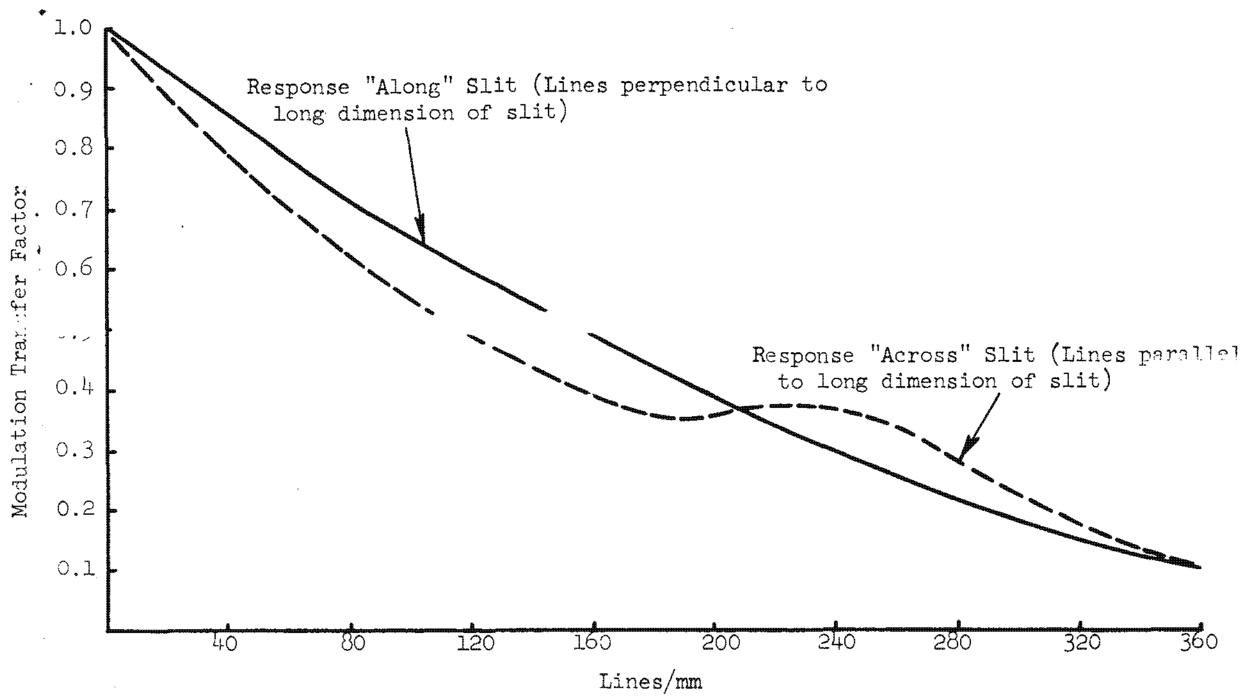


Figure 1-7A. Response of a Perfect 77-inch $f/4.0$ Lens (with a Rectangular Central Obstruction) to Monochromatic "D" Light (589 mμ)

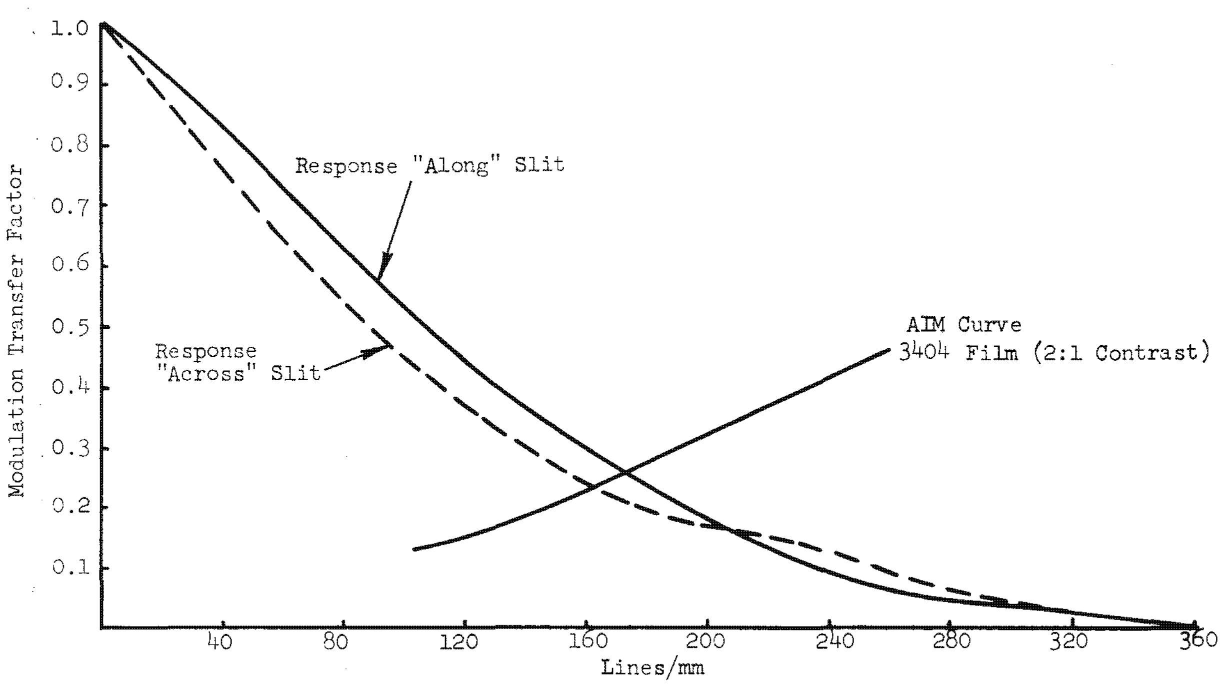


Figure 1-7B. Response of Above Lens Degraded by a Gaussian Manufacturability Function degraded slightly as shown in Figure 1-7B. Mathematically, this procedure is referred to as determining the response of the lens to a Gaussian spot having a diameter proportional to the size of the manufacturing tolerances used.

A general discussion of the concepts used in sine-wave response analysis is presented in Appendix B. The assumptions involved in establishing the magnitude of the smear allowed and the method of conversion from linear smear on the ground to the corresponding sine-wave response are given in Appendixes C, D, and E.

1.2.6.2.2 System Resolution. Using the technique outlined in Appendix E, the resolution of the system is calculated for various smear values. The approximate ground resolution can be plotted as a function of smear. Such a plot is shown in Figure 1-8 both for vertical photography and photography at 30 degrees obliquity and 15 degrees stereo, and in each case for resolution parallel to and perpendicular to film travel.

1.2.6.3 System Design Goals. To achieve the system performance objective of 2- to 3-foot ground resolution, specific design goals are required not only for vertical photography, but also for photography at oblique-stereo positions. These design goals are then used to establish the maximum allowable smear for the S/V.

In a slit camera, the resolution of perfect optics may be diminished by a difference in the motion of image points in the film plane and the motion of the corresponding points on the film. If these motions are not the same, the image of the corresponding ground point will be spread out along the direction of any such differences. The magnitude of this spread is called smear and is usually projected back to the ground plane and measured at this projection in feet.

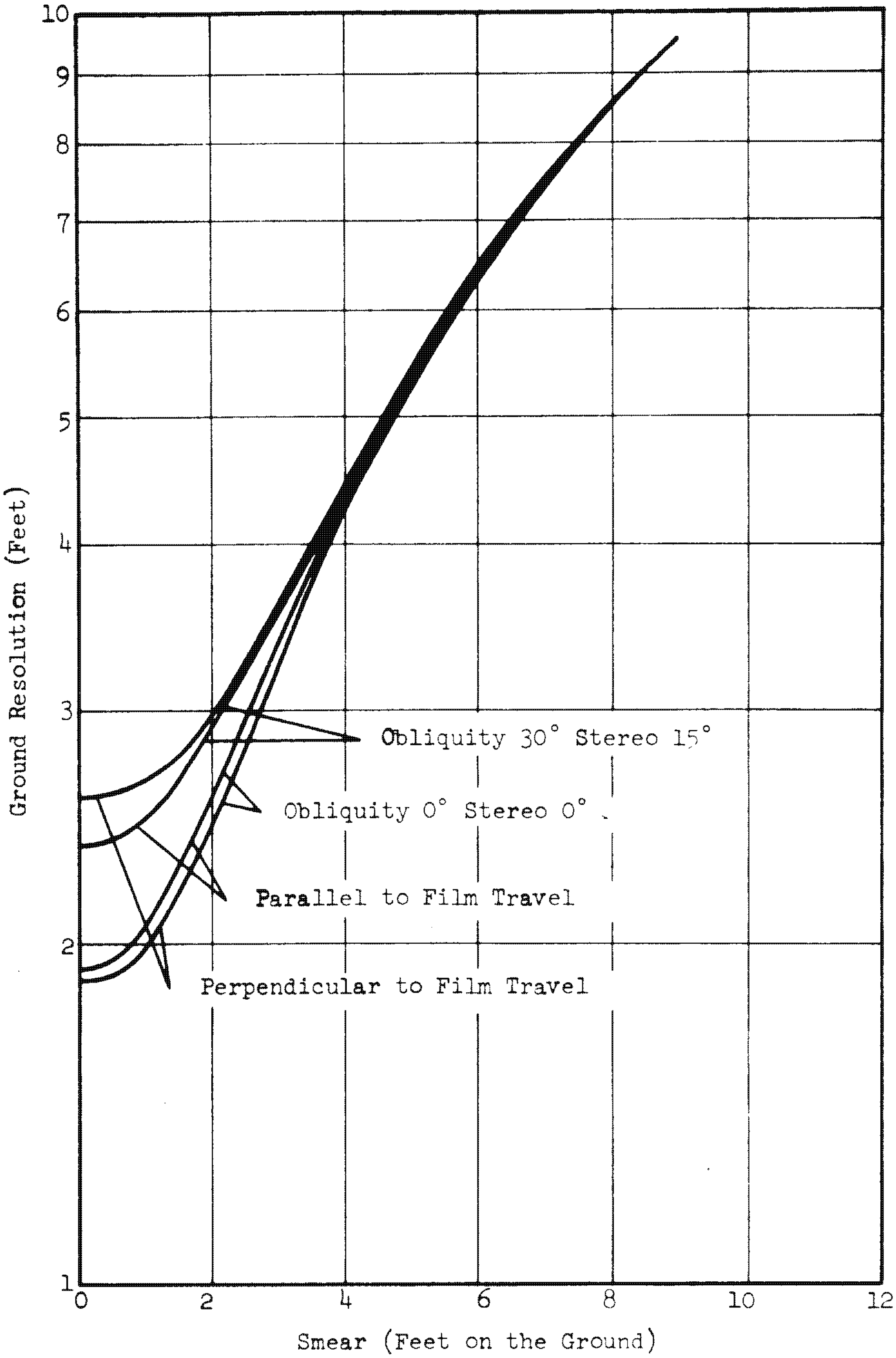


Figure 1-8. System Ground Resolution vs Smear at 70 n mi Altitude, for a Lens Resolution of 115 Lines/mm

For vertical photography, the design goal of 115 lines/mm requires that the geometric mean ground resolution be 2.6 feet from a nominal altitude of 95 n mi. For photography from 95 n mi at 30 degrees obliquity and 15 degrees stereo, the design goal requires that the geometric mean ground resolutions be less than 3.8 feet. (The design goal stated in terms of the geometric mean resolution in the film plane is 115 lines/mm. However, recent improvements in the optical system have resulted in increased specified resolution levels. Effective with FM 21, the specified minimum resolution was 130 lines/mm.)

At 70 n mi, a camera system will have a predicted resolution of about 1.9 feet for vertical photography and about 2.6 feet for photography at 30 degrees obliquity and 15 degrees stereo. Figure 1-8 indicates the allowable smear if a specified ground resolution is to be obtained.

1.2.6.4 Allocation of Smear. The total S/V smear is made up of the contributions of smear production by the C/P, the OCV, and ephemeris prediction uncertainties. A reasonable division of the total smear must be made as a basis for allocating allowable smear to these contributing components. This division of the total S/V smear can be determined from the magnitude of smear expected in the operation of the C/P. If the smear contributed by the C/P is combined in a statistically prescribed manner with that of the OCV and ephemeris-prediction uncertainties, the resultant must not exceed the total allowable S/V smear. The smear formula and the method for combining smear components are presented in Appendix D.

The allocation of smear to the OCV, the C/P, and the tracking subsystems is summarized as follows:

For 95 Nautical Miles:

Camera Payload (C/P)

	Vertical photography	30° obliquity - 15° stereo
	$S_{x(C/P)} = 0.83$ ft	$S_{x(C/P)} = 1.32$ ft
	$S_{y(C/P)} = 0.35$ ft	$S_{y(C/P)} = 0.49$ ft

Orbiting Control Vehicle (OCV)

	Vertical photography	30° obliquity - 15° stereo
On-axis	$S_{x(OCV)} = 0.31$ ft	$S_{x(OCV)} = 0.77$ ft
	$S_{y(OCV)} = 0.51$ ft	$S_{y(OCV)} = 0.87$ ft

Ephemeris Prediction

	Vertical photography	30° obliquity - 15° stereo
Knowledge of altitude	$S_{x(ALT)} = 0.21$ ft	$S_{x(ALT)} = 0.26$ ft

For 70 Nautical Miles:

Camera Payload (C/P)

	Vertical photography	30° obliquity - 15° stereo
	$S_{x(C/P)} = 0.49$ ft	$S_{x(C/P)} = 0.77$ ft
	$S_{y(C/P)} = 0.26$ ft	$S_{y(C/P)} = 0.36$ ft

Orbiting Control Vehicle (OCV)

	Vertical photography	30° obliquity - 15° stereo
On-axis	$S_{x(OCV)} = 0.17$ ft	$S_{x(OCV)} = 0.52$ ft
	$S_{y(OCV)} = 0.37$ ft	$S_{y(OCV)} = 0.62$ ft

Ephemeris Prediction

	Vertical photography	30° obliquity - 15° stereo
Knowledge of altitude	$S_{x(ALT)} = 0.21$ ft	$S_{x(ALT)} = 0.26$ ft

The symbols S_x and S_y represent the summation of smear contributors in accordance with the procedures presented in Appendix D. If the S/V is designed to these tolerances, the design goals stated in paragraph 1.2.6.3 will be met for vertical photography and for photography at 30 degrees obliquity and 15 degrees stereo.

1.2.6.5 Photographic Material. The photographic film must have high resolving power and must also be compatible with the exposure available. A film which meets these requirements is Kodak High Definition Aerial Film (Estar thin base) Type 3404. This film is a photographic negative material that has an extended red light (panchromatic) sensitivity.

It has low speed but fine grain. When developed, an image with excellent resolving power is produced on the film. The 0.0025-inch-thick polyester support is coated with a thin emulsion layer, resulting in a final thickness of approximately 0.003 inch. The width of the film in this application is 9.460 inches.

A nominal length of 3000 feet of film wound on a 4-inch diameter core results in a 13-inch diameter roll which weighs 52 ± 3 lb.

1.2.6.6 Exposure. Photographic exposure is the product of illumination and time; that is:

$$E = It$$

where E = exposure in meter-candle-seconds,

I = illumination expressed in meter-candles, and

t = time that the illumination acts on the photographic material in seconds.

The exposure time must be selected so that the illumination-time combination results in an exposure within the useful range of the photographic film under consideration.

For high-resolution satellite photography, it is desirable to use short exposure times, thereby minimizing the image motion during exposure.

1.2.6.6.1 Exposure Time. For a strip camera, the exposure time is expressed by the equation:

$$t = \frac{d}{y}$$

where t = exposure time in seconds
d = slit width in inches and
y = film velocity in inches per second

The nominal exposure time (1/400 second) was selected as the exposure time to be obtained when photographing at a slant range of 95 n mi. At many stereo and obliquity angles and at all altitudes greater than 95 nautical miles, the velocity of the film moving past the aperture will be slower and the exposures will be longer than nominal. Prior to FM 13, the slit aperture that was most appropriate for the mission was selected and positioned in the camera prior to completion of subsystem testing at the MAB. For photographing targets having lower than nominal brightness, and those at low sun altitudes, exposures longer than 1/400 second will be necessary to expose Kodak Type 3404 Film correctly. Therefore, effective on FM 13, a programmable slit aperture plate was installed in the camera for operational photography. The plate contains three operational slits providing nominal exposure times of 1/400, 1/200, and 1/100 second at a slant range of 95 n mi. A fourth slit is sometimes used for photographic testing while on-orbit. Slit changes are programmed primarily to compensate for variations in sun angle, IMC velocity, and target brightness. Figure 1-9 contains the sun angle and IMC slit-selection criteria.

1.2.6.6.2 Illumination. The luminance of a target depends on the illumination falling on the target area and the ability of elements within the target area to reflect the incident light toward the camera. Every target element becomes a secondary source of the illumination that is "seen" by the camera and recorded on the film; exposure therefore depends on the illumination of the target area and its reflectance characteristics, and on the absorption and scattering of light through the atmosphere and lens.

Exposure is selected so that the average minimum scene luminance is placed at or near the speed point* on the characteristic curve. This selection of exposures will provide sufficient contrast for shadow detail (minimum reflectance) and at the same time will use the minimum exposure time.

The available illumination for satellite photography depends largely on the altitude of the sun above the horizon (solar altitude). The solar altitude is a function of the time of day, the time of year, and the geographic latitude of the target.

A graph indicating the increase in exposure and the required slit aperture as a function of sun angle and IMC velocity is shown in Figure 1-9 for the 70 n mi camera. A noon equator crossing was assumed for the calculation. The curves are extended to give the additional exposure required down to and including twilight levels of illumination

*From extensive experience with high altitude photography, it was empirically determined that the correct exposure for an average aerial scene can be predicted from the characteristic curve at the speed point. Speed point is defined as the log exposure in meter-candle-seconds corresponding to the point of the toe of the characteristic curve where the slope is equal to 0.6 gamma. Gamma is defined as the slope of the straight line portion of the characteristic curve.

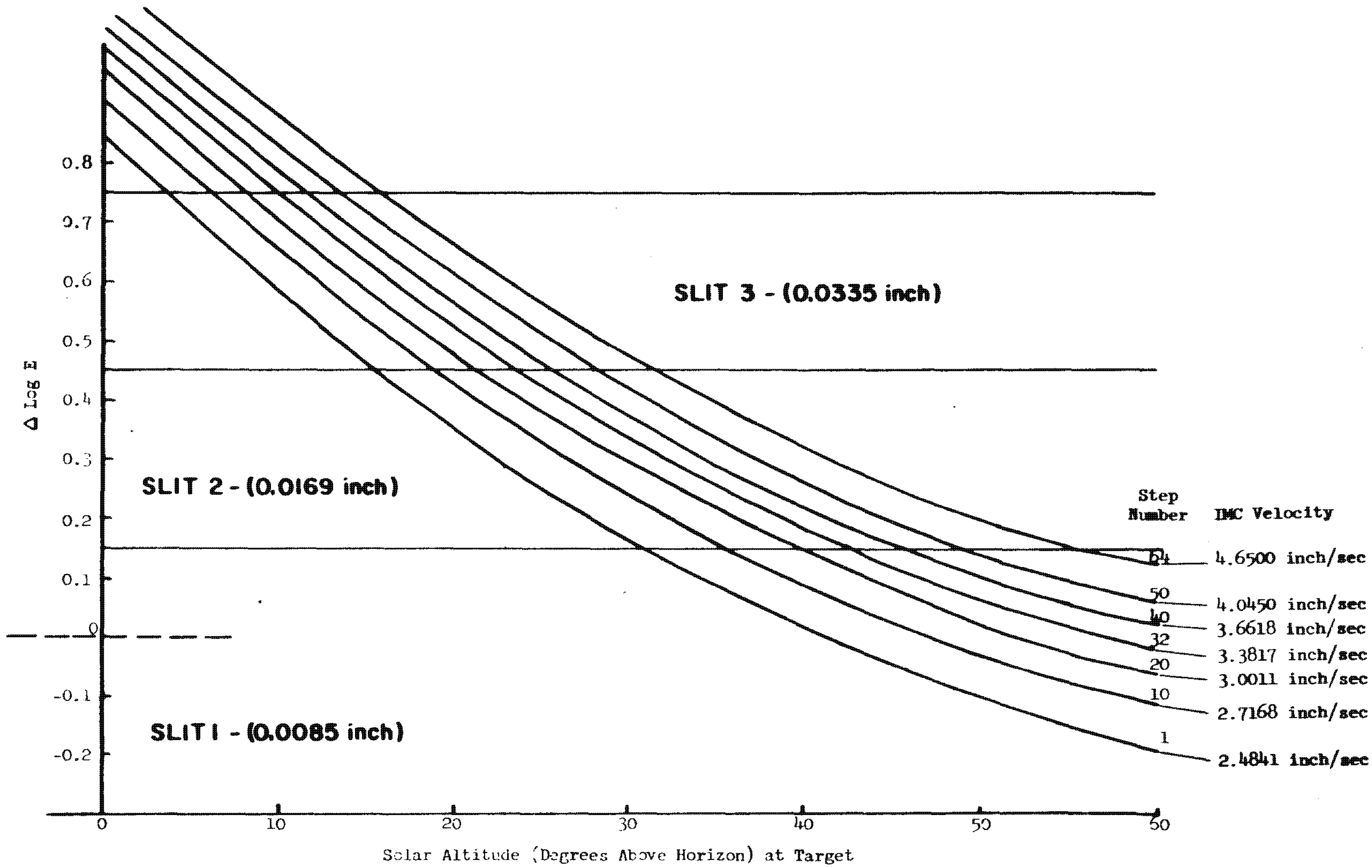


Figure 1-9. Slit Selection Parameters for the Programmable Slit Plate

1.2.6.6.3 Photographic Speed of the Lens. The properties of the lens which affect image brightness are lens speed and transmission. For objects at or near infinity, lens speed can be specified in terms of the relative aperture which for the lens in this system is approximately *f*/4.0 (actually *f*/3.95). Recent measurements have indicated that the transmittance of the system is approximately 38 percent, giving a T-number of 6.4. This includes the effect of the haze filter. The light which is transmitted by the system and produces exposure on the film is limited to the 500-700 millimicron region.

1.2.6.6.4 Exposure Index. The exposure index is a number used to describe the light sensitivity of a photographic material under fixed processing conditions. The aerial exposure index is inversely proportional to the exposure required to produce the speed-point density and is defined by the expression:

$$\text{Aerial exposure index} = \frac{1}{2E}$$

where E is the exposure in meter-candle-seconds at the speed point of the film-characteristic curve. For aerial films, the speed point is defined as the exposure for which the gradient on the toe of the characteristic curve is 0.6 gamma. The aerial exposure index corresponding to full processing for Kodak Type 3404 Film is 3.6 and the corresponding speed-point exposure is 0.138 meter-candle-seconds or a log exposure of 9.14 - 10 ($\bar{1}.14$).

1.2.6.6.5 Brightness of Target. The exposure required for Kodak Type 3404 Film can be determined from the average minimum brightness level of the target. The relationship of illumination in a photographic image to target brightness is expressed as follows:

$$I_i = \frac{kB}{4f^2}$$

where I_i = illuminance in meter-candles at the image

B = luminance of the target area in lumens/meter^2

f = *f*-number of the lens

k = transmission of the lens

Using the lens *f*-number and transmission characteristics and the luminance values of targets photographed from high altitudes, it is possible to calculate the image illuminances.

For a target photographed from high altitude where the photographic scale is small, the areas of minimum scene luminance have calculated brightness values of approximately 9593 lumens/meter^2 (890 foot-lamberts) when 5 percent haze* is included, and at sun angles greater than 60 degrees. Measurements made of observed minimum scene luminances from previous G-Program missions indicated that the average minimum scene luminance above 60-degree sun angle could be as low as 800 foot-lamberts. The illumination produced at the film plane by each of these scene luminances is as follows (for a lens transmission of 38 percent):

* Percent haze is the contribution of haze to the apparent scene luminance expressed as a percentage of an assumed nominal solar scene luminance of 10,000 foot-lamberts. Thus, 5 percent haze implies that 500 of the 890 foot-lamberts of average minimum scene luminance is contributed by haze.

	Calculated	Approximate Observed
Average minimum scene luminance	890 foot-lamberts	800 foot-lamberts
Illumination at the focal plane	57.5 meter-candles	51.8 meter-candles
Exposure time	1/400 sec	1/400 sec
Exposure	0.144 meter-candle-sec	0.130 meter-candle-sec
Log exposure	$\bar{1}.16$	$\bar{1}.11$

Both of these values of log exposure are near the speed point of 4404 film ($\bar{1}.14$).

It should be noted that the units of candles, lumens, etc. used here are not identical with their photometric definitions, which refer specifically to the spectral sensitivity of the normal human eye. For convenience in handling data and interpreting photographic measurements, the spectral sensitivity of the film in combination with the optical system is substituted in the place of the response of the eye.

1.2.6.6.6 Slit Aperture Selection. Prior to incorporation of the programmable slit aperture plate, the most appropriate slit aperture for the mission was selected on the basis of the projected launch date, launch window, orbital inclination, and the distribution and priority of targets. For the programmable slit aperture plate, Figure 1-10 shows the recommended slit as a function of sun altitude and the IMC velocity. Corrections for variations in target brightness must be made by the customer on the basis of individual target characteristics.

1.2.6.7 Environmental Effects on Film. Tests were performed on Kodak Type 3404 Film to determine the range of environmental conditions that it could withstand. Major consideration was given to the effect of extreme temperature and radiation.

1.2.6.7.1 Temperature. Keeping tests indicate that Kodak Type 3404 Film can withstand temperatures between 36 F and 90 F for periods of time greatly in excess of the mission life. However, as temperature increases, sensitometric changes occur at a faster rate, and physical deterioration eventually takes place. Kodak Type 3404 Film may remain satisfactory for photographic use provided a temperature of 125 F is not exceeded. Above 125 F, physical changes occur in this film and exposure to excessively high temperature can cause adjacent layers in a roll to laminate.

Whenever the ambient temperature exceeds 90 F, temperature control is required to ensure that the cumulation of high-temperature exposure of the film does not exceed allowable limits. Because film damage is a function of temperature and time, the following integral is used to express the limitations on cumulation of time-temperature between 90 F and 125 F:

$$\int_{t_o}^{t_f} 2^D \, dt \leq 4000 \text{ hours}$$

$$D = \text{damage index} = \frac{(T(t) - 90\text{ F})}{5\text{ F}}$$

t_o = time film is removed from conditioned storage prior to installation in the C/P

t_f = time film is returned to conditioned storage after retrieval

$T(t)$ = temperature of film environment at time t in degrees F

This limitation is based on a maximum relative humidity of 45 percent and a maximum temperature limit of 125 F.

1.2.6.7.2 Radiation. Radiation falling on a satellite with an unshielded photographic payload can fog photographic film. The extent to which the film is fogged depends on the tolerance of the photographic film to this radiation, the radiation levels encountered by the satellite, and the duration of the exposure.

Studies were conducted to determine the photographic effect of X-ray and gamma radiation on Kodak Type 3404 Film. The results of this study indicated that this film, like all other types, is more sensitive to low-energy X-rays than to high-energy X-rays or gamma radiation and that a limited tolerance to these exposures exists.

All radiation effects can be expressed in terms of the amount of high-energy gamma rays that would be required to produce a given density. This type of data is called photographic roentgens. Laboratory tests indicate that 3404 film will tolerate exposures up to approximately 30 photographic roentgens.

To investigate the radiation levels encountered by the film on-orbit, strips of radiation-sensitive test film were installed in the SRV during Flight Nos. 8 and 15. The results of analysis of the film strips after recovery indicated that the total radiation absorbed by the test film during these missions was approximately 20 to 35 milliroentgens per day in orbit. This is well below the allowable level for type 3404 film.

1.2.6.7.3 Haze and Cloud Cover. By reflecting sunlight, haze in the atmosphere increases the apparent minimum brightness of a scene photographed from high altitudes, adding non-image-forming light to the image-forming light reflected from ground objects. The ratio of light resulting from haze to light reflected from the ground is such that light from the haze is the predominant factor in determining the minimum exposure. Haze has little effect on the apparent brightness of light colored objects, but it increases the apparent brightness of dark objects and thereby lowers the luminance range of the ground areas to be photographed. The reduced luminance range limits the contrast range of the photographed image.

By limiting the width of the spectrum received by the film, the effects of haze may be reduced, along with the color aberrations of the optics. Because haze is normally most intense in the blue region, a yellow filter is incorporated in the optical system of the payload. This filter, which is a part of the slit aperture plate of the camera, is made of filter glass and has blue-light-absorption characteristics. Other atmospheric effects, such as clouds, can affect the illumination in some portions of the target area or increase the average scene brightness. No exposure corrections, however, are made to compensate for the effect of clouds.

1.2.6.8 Film Processing. Although processing of the photographic image is not a requirement of the Photographic Subsystem, knowledge of what processing will accomplish is necessary for estimating the performance of the C/P. For this reason, a brief discussion of processing is included.

Many aerial films, including Kodak Type 3404, lend themselves to a method of variable processing referred to as interrupted processing. By this method of processing, the apparent speed of the film can be varied, within limits, without significantly affecting the contrast or density range of the developed image. This flexibility can be used in conjunction with the programmable slit aperture plate to accommodate the variations in scene brightness which result in a variable exposure.

Experimental data currently indicate that when the interrupted process is used, film can be satisfactorily processed (full process) to obtain a maximum speed of 3.6 (with speed point corresponding to a log E of $\bar{1}.14$), an intermediate speed (intermediate process) of 2.3 (with the speed point at $\bar{1}.34$), and a minimum speed (primary process) of 1.4 (with the speed point at $\bar{1}.54$). All process levels will retain a gamma of 2.0 to 2.2. This technique improves the capability of recording the entire range of scene luminances in spite of variable minimum scene brightness.

1.3 PHOTOGRAPHIC OUTPUT

The output of the S/V is the exposed film recovered in the SRV. The elements of the photographic image after processing are described below.

1.3.1 Film Format

In addition to the primary photographic exposure of the ground target with fiducial lines along the sides, the film format includes two image strips of smear-error information (called smear-slit images), time-data tracks, and slit identification streaks. The fiducial lines serve to locate a point on the film accurately with respect to the camera platen, regardless of film wander. The smear-slit images serve the purpose of determining the degree and direction of smear error existing at the time of photography. The time-data tracks correlate photographic information with vehicle time. The film format is shown in Figure 1-10.

1.3.2 Image Size

The image on the film is 8.718 inches wide including the smear-slit images on each side. The length of image will depend on such factors as target-area coverage, vehicle altitude, and the time and/or mode of camera operation, as determined by vehicle programming. The scale will range from approximately 1:66,000 to 1:112,700 depending on the altitude and look-angle used.

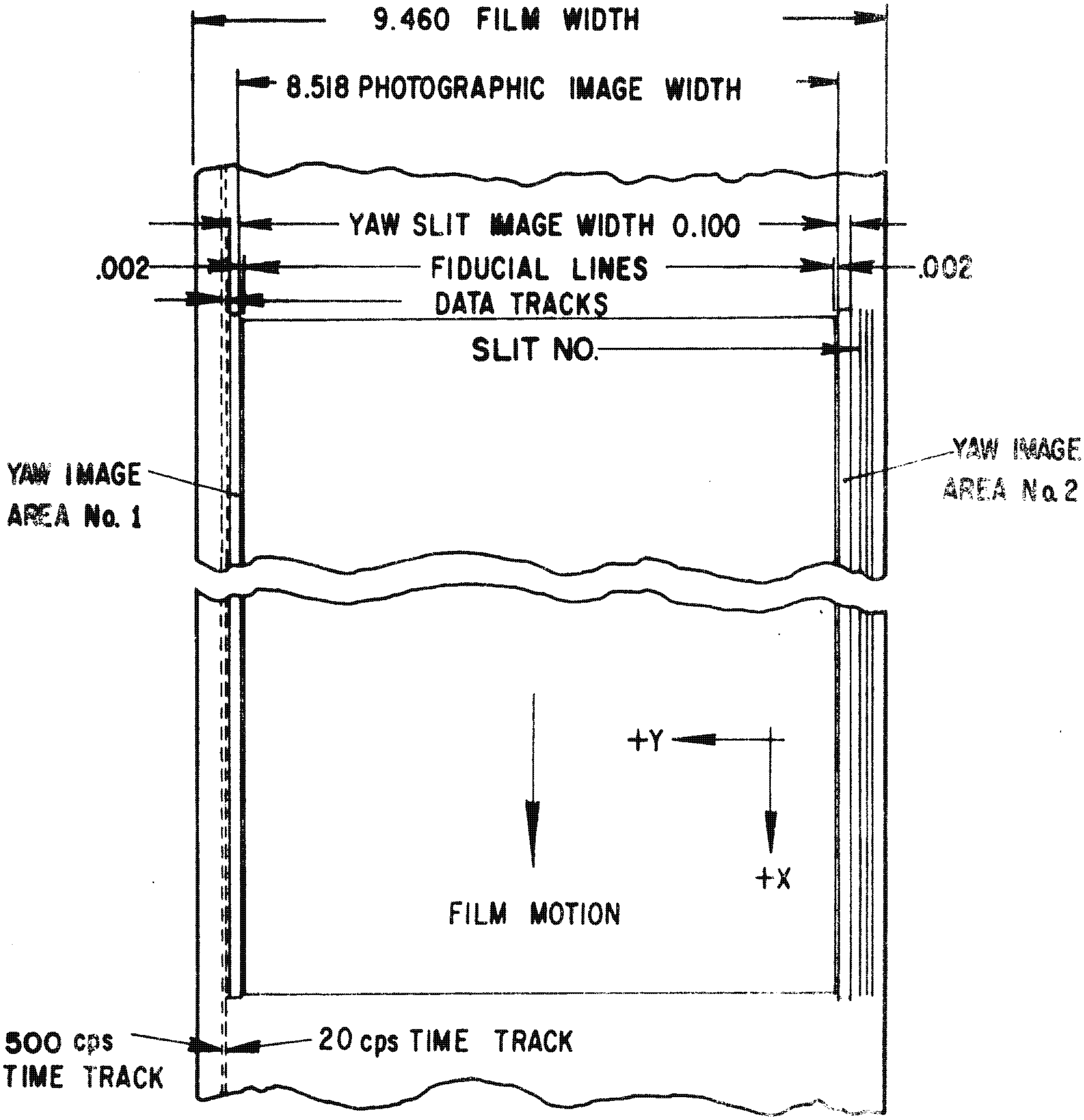


Figure 1-10. Film Format (Viewed from Emulsion Side)

1.3.3 Fiducial Marks

To minimize the errors in determining geographic locations caused by lateral film wander, fiducial lines approximately 0.002-inch wide are exposed along the edges of the primary image during camera operation. These lines are produced by overexposing (by 1 stop) a narrow strip along each edge of the film as it passes under the slit. These lines are located between the picture area and the smear-slit image, as shown in Figure 1-10.

1.3.4 Slit Identification Streaks

Effective with FM 16R (on Flight No. 22), slit identification data will be recorded along the edge of the film on the side opposite the data-mark side. The slits will be identified by overexposed streaks between the smear slit images and the edge of the film. The number of streaks will correspond to the slit number (that is, 3 streaks mean slit no. 3). The streaks are illustrated in Figure 1-10.

1.3.5 Smear Record

The camera photographs ground areas through a narrow slit near the camera focal plane. The image of the ground sweeps past the slit at a constant velocity. Ideally, a sharp photograph is obtained by moving the film past the slit at the same velocity as that of the image. The film motion is called image motion compensation, or IMC. Smear is a degradation in photographic quality caused by errors in IMC, both in magnitude and direction. It is minimized by short exposure times.

Post-flight analysis of image smear is permitted by smear-slit photographs along the two edges of the film. The aperture plate at the camera focal plane includes a wide and a narrow smear slit at each end of the main photographic slit. Each pair of smear slits is in tandem; they sequentially photograph the same ground region and produce a double exposure. If IMC is not perfect, corresponding details in the two recorded images are separated.

The two smear slits on each side of the film are sufficiently separated so that image separation in the area of double exposure offers a magnified (13:1 for the No. 1 slit) measure of image smear near the adjacent end of the camera slit. Separation between smear-slit images on the film is therefore a measure of the IMC error vector. Direction and magnitude of the IMC error vector can be measured on each edge of the recovered film.

Analysis of smear-slit data can include continuous measurement of the x-component (parallel to film motion) and y-component (perpendicular to direction of film motion) of the smear slit image separation on each edge of the film. These data permit estimates of (1) smear for any part of the photograph, (2) vehicle yaw error, (3) S/V roll position or obliquity angle, and (4) IMC error.

1.3.6 Data Tracks

Two data tracks are located between the left-smear-slit image and the edge of the film (as shown in Figure 1-10). These data tracks permit the recording of the S/V time and other pertinent data as a series of photographic codemarks on the film. The data-signal configuration consists of time-mark bits exposed for 0.001 second which are presented on separate tracks at 0.05-second (20 pps) and 0.002-second (500 pps) intervals during camera operation.

A digital time label is presented in the 20-pps data track at intervals of 0.8 second. The time label references vehicle time on the film and is used to identify each frame. The information provides a means for locating target area.

The data signal circuitry is designed so that a pulse is deleted in the 500-pps track whenever a pulse occurs in the 20-pps track. Therefore, both the 20-pps marks and the time label appear in the 500-pps track as a series of missing pulses.

1.3.7 Format Simulation

The format of the photographic output is illustrated by the simulation in Figure 1-11. This photograph was printed from a negative transparency having a brightness range of 5:1. Fiducial lines and simulated data tracks were added artificially. It represents the scale obtained when photographing vertically from an altitude of 95 n mi. The dimension of the photograph across the width of the film represents approximately 10.6 n mi.

The resolution obtainable is not shown because the mosaic that was used for this photograph does not have consistent three-foot ground resolution.

Just below the lower border of the image area in Figure 1-12 is a simulation of a typical time track. A track of very small dots can be seen which illustrates the location of the data marks with a time label periodically superimposed on the same track. The time tracks shown in this simulation are of the type that were used in early missions; no simulation of the later mission (500-pps) time tracks is included.

1.3.8 Stereo Simulation

The stereo prints shown in Figure 1-12 were made from a negative simulating the quality of the output of the Camera Payload. The prints were made using conventional enlarging equipment at a magnification of 10X and they have a low contrast resolution of about 5 feet.

The negative from which these prints were made corresponded to the typical output of the Camera Payload. The scale of the negative on Kodak Type 3404 Film was 1:90,000, and it had a ground resolution of 3 feet. The brightness range of the scene photographed was 5:1. The stereo convergence angle used was 33 degrees, 40 minutes.

1.3.9 Interpretability

The conventional method used to evaluate photographic quality is stated in terms of a resolving-power test pattern. This method is good for categorically classifying photographs according to the ability of the photograph to define objects, but it is not a complete measure of the information which is obtainable from a reconnaissance photograph. Many objects and forms with dimensions less than the resolvable dimension can be seen. The characteristic is notably true of objects that are long and narrow.

Of more importance is the information that can be obtained from the size, shape, contrast, brightness, positions, shadows, and patterns of the objects in photographs. A trained photo interpreter can therefore make numerous associations from information that cannot be described by a resolution test pattern.

Stereo photography provides additional information beyond that from a conventional aerial photograph. A stereo pair can provide information about the height and movement of objects. The ability to determine the height of objects in a pair of stereo photographs is defined as stereo acuity and is approximated by the following expressions:

$$S = \frac{R_g}{5 \tan \theta/2}$$

Photographic Simulation of Area Coverage and Format

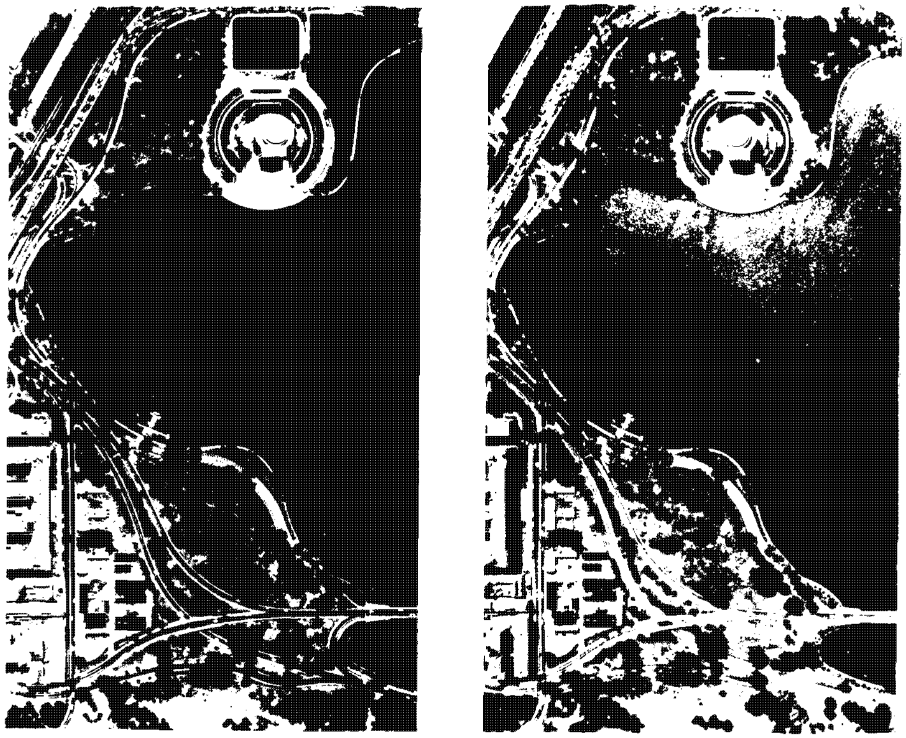


Figure 1-12. Stereo Simulation

where R_g is the ground resolution of the system and θ is the convergence angle. Using this expression, stereo acuity will be 2.1 feet with a 30-degree convergence angle when operation at 95 n mi and 0-degree obliquity (2.8 foot ground resolution) is used as the basis for calculation.

1.4 NUMERICAL SUMMARY

The numerical values associated with the various system and payload parameters are summarized below. The numbers given are correct as of 1 June 1965. Minor changes in these values may occur as a result of changes in system requirements and/or receipt of more accurate information. Unless there are major changes in direction, however, the numbers in this summary will not change appreciably in the future.

1.4.1 Photographic Output Data

A.	Ground resolution (vertical photography)	2 to 3 feet
B.	Lens-film resolution	104 to 150 lines/mm at 2:1 contrast
C.	Scale of photography	
	(95 n mi altitude)	1:90,000
	(70 n mi altitude)	1:66,000
D.	Width of photographed strip	
	(vertical photography, 95 n mi altitude)	10.6 n mi
	(vertical photography, 70 n mi altitude)	7.8 n mi
E.	Scene width on payload film	8.518 inches
F.	Scene length on payload film	Variable
G.	Scene length on the ground	Variable
H.	Number of photographs	300-600 stereo pairs or equivalent amount of continuous strip photography

1.4.2 Payload Package

A. Weight (±2%)

C/P components in OCV	1079.5 pounds (without film)
C/P components in SRV	22.6 pounds (without film)
Film	52.0 pounds (3000 feet)
Total	1154.1 pounds

B. Dimension of C/P

1. Maximum diameter	54 inches
2. Length	190 inches (front of recovery cassette to aft mounting plane)

C. Internal Pressure Environment

1. Payload in general	Ambient
2. Film handling	On orbit - 0.10 psia max. Ascent - ambient to ambient +2.5 psig

1.4.3 Payload Camera

A. Camera type	Strip
B. Exposures (nominal)	1/400 second with 0.0085-inch-wide slit 1/200 second with 0.0169-inch-wide slit 1/100 second with 0.0338-inch-wide slit
C. Number of slits	3 photographic; 1 orbital test; 1 ground test

D. Slit dimensions

1. Length	8.718 inches (including smear slits) 8.518 inches (without smear slits)
2. Slit-to-film distance	0.007 inch

E. Lens

1. Type	Maksutov
2. Focal length	77.0 ±0.1 inches
3. Aperture	19.50-inches diameter
4. Half-field angle	3.2 degrees

F. Filter

1. Type	B and L Type Y-10
2. Spectral range, film and filter	500-700 millimicrons

G. Focus Adjustment

1. Type	Single grid, single detector, dual channel with rotating focus shifter
2. Range	±0.010 inch
3. Platen Drive Rate	0.00025 inch/second (nominal)
4. Sensor	Grid, detector, AGC amplifier, signal-gating module, integrators, and differential amplifier
5. Focus drive	Direct-current motor

1.4.4 Payload Film

A. Type	Kodak High Definition Aerial Film (Estar Thin Base) Type 3404
B. Dimensions	
1. Width	$9.460 \begin{smallmatrix}+0.010 \\ -0.005\end{smallmatrix}$ inches
2. Length	3000 feet
3. Thickness	0.0030 ±0.0003 inch
4. Base type	Polyester
C. Weight	52 ± 3 lb (3000 feet)
D. Roll dimensions	
1. Core diameter	4 1/4 inches
2. Outer diameter	13 inches
E. Film Tension	3.00 ±0.25 pounds from FM 11R and subsequent 3.50 ±0.25 pounds FM 1-10

1.4.5 Image Motion Compensation

A. Film drive

1. Velocity Range (95 n mi nominal mission) (FM 1-6)	2.0219 to 3.7845 inches per second

(63 n mi minimum mission) (FM 7-10)	2.789 to 5.220 inches per second
(70 n mi minimum mission) (FM 11 and subsequent FM's)	2.484 to 4.650 inches per second

2. Image motion compensation tolerances

   a. Average velocity — ±0.2 percent
   b. Smoothness (RMS of velocity transients) — ±0.8 percent
   c. Velocity transients (maximum) — ±1.2 percent

3. Number of speed steps — 64 + on/off
4. Speed change per step — 1 percent of previous step
5. Drive speed command bits required — 7

B. IMC Design Parameters

1. Obliquity range — -45.4 to +44.7°
2. Stereo aim angle — -15°, 0°, +15°
3. Altitude ranges (for full obliquity, but 0° stereo)

   a. C/P 1-6 — 95±12 n mi
   b. C/P 7-10 — 72±9 n mi
   c. C/P 11-Subsq. — 81±11 n mi

C. IMC Operation Times

1. Camera on times:	Command Bits required	Range*	Intervals
Stereo photography Flights 1-17	4	2.0 to 12.5 sec	0.7 sec
Stereo photography Flights 18-Subsq.	4	3.5 to 9.5 sec	0.4 sec
Strip photography all flights	7	0.1 to 102.4 sec	0.1 sec

* These ranges are determined by the command subsystem furnished by GE.

	Command Bits Required	Range*	Intervals
2. Stereo pair interframe times:			
Flights 1-17	3	3.2 to 17.9 sec	2.1 sec
Flights 18-Subsq.	3	3.0 to 11.4 sec	1.2 sec

1.4.6 Optical Aiming

A. Stereo
1. Positions: -15°, 0°, +15°
2. Steps: 3
3. Command bits required: 2

B. Crab
1. Positions: 0° to +3.5° or 0° to -3.5° (selected before completion of subsystem tests)
2. Steps: 8
3. Angular intervals: 0.5°
4. Command bits required: 3

1.4.7 Data Recording

A. Smear recording
1. Length of smear slits: 0.100 inch
2. Smear slit spacing (center-to-center): 0.108 inch

B. Slit identification slits
1. Length of slit: 0.060 inch
2. Width of slit: 0.004 inch
3. Slit spacing (center-to-center): 0.010 inch

C. Data recording (2 tracks)
1. Track width: 0.005 inch each

The electrical input for the time signal will come from another subsystem. It is described in Section 1.4.9, item E, of this summary.

*These ranges are determined by the command subsystem furnished by GE.

1.4.8 General Data

A. Area of interest	Selected areas between 30° and 80° North latitude during daylight hours
B. Launch Parameters	
1. Launch booster	Atlas
2. Orbital booster	Agena
3. Launch time	1000 to 1400 hours or 2200 to 0200 hours
4. Launch site	Point Arguello, California
5. Launch direction	Southward
C. Orbit (Original Design)	
1. Altitude	
Average	95 ±5 n mi
Instantaneous	95 ±12 n mi
2. Inclination	
Range	80 to 105°
3. Period	88.0 minutes, nominal
4. Orbital lifetime	5 days
5. W/C_DA	66 lb/ft^2

Early missions had an average altitude range of 116 ± 13 n mi and an instantaneous altitude range of 116 ± 20 n mi to avoid orbit maintenance requirements. Later low orbit missions used a perigee altitude of about 70 n mi and an apogee altitude of about 200 n mi. The other parameters will remain essentially the same.

D. Components recovered	SRV with film

1.4.9 Photographic Subsystem Requirements on Other Subsystems

A. OCV Smear Allocation (70 n mi mission)

Smear resulting from attitude rates and displacements, C/P-OCV alignment errors, vibration, and thermal distortion shall not exceed the following:

	Vertical Photography	30° Obliquity 15° Stereo
On Axis	$S_{x(OCV)} = 0.17$ foot	$S_{x(OCV)} = 0.52$ foot
	$S_{y(OCV)} = 0.37$ foot	$S_{y(OCV)} = 0.62$ foot

Ephemeris Prediction Contribution

$S_x = 0.21$ foot	$S_y = 0.26$ foot

B. Position prediction over target

1. Knowledge of altitude	±0.5 n mi
2. Knowledge of vehicle location	±1.5 n mi - in track ±0.5 n mi - cross track
3. Knowledge of target position	±0.25 n mi

C. Obliquity aiming

1. Position range	from +44.667 to -45.376°
2. Angular intervals	0.709°
3. Command bits required	7
4. Angular Rate	1/4, 1-1/2, 3°/sec
5. Roll settling time	6 sec (max)

D. Electrical power from GE

1. Nominal input voltage	28 volts dc, unregulated
2. Instrumentation voltage	5 volts dc, regulated

E. Time recording signals	Data Track A	Data Track B
1. Time mark periods	0.05 second	0.002 second
2. Period between time labels	0.8 second	0.8 second
3. Number of bits in time label	23	23
4. Time label bit period (mark and space)	0.002 second	
5. Duration of time mark and time label bit	0.001 second	

SECTION 2
GRAPHIC DIAGRAMS

2.0 GENERAL

This section presents the general arrangement and dimensions of the C/P portion of the S/V in photographs and drawings.

A C/P space allocation and configuration line drawing shows the relationship of the various C/P components and their orientation within the S/V. A list of the major component assemblies is given in Section 2.1.1.

Several photographs are included that show the location and configuration of components as they appear in the C/P.

The brief descriptions and labeled illustrations in this section are intended to given an over-all view of the subsystem and to provide a reference when the detailed descriptions in Section 4 are read.

2.1 PAYLOAD DIMENSIONS

2.1.1 C/P Space Allocation and Configuration

The C/P consists of 11 major assemblies. These are: the camera, lens, film supply cassette, forward record storage assembly, structure, stereo servo, crab servo, focus control electronics, film-drive electronics, electrical distribution component, and cables. The location of these assemblies can be seen in Figure 2-1.

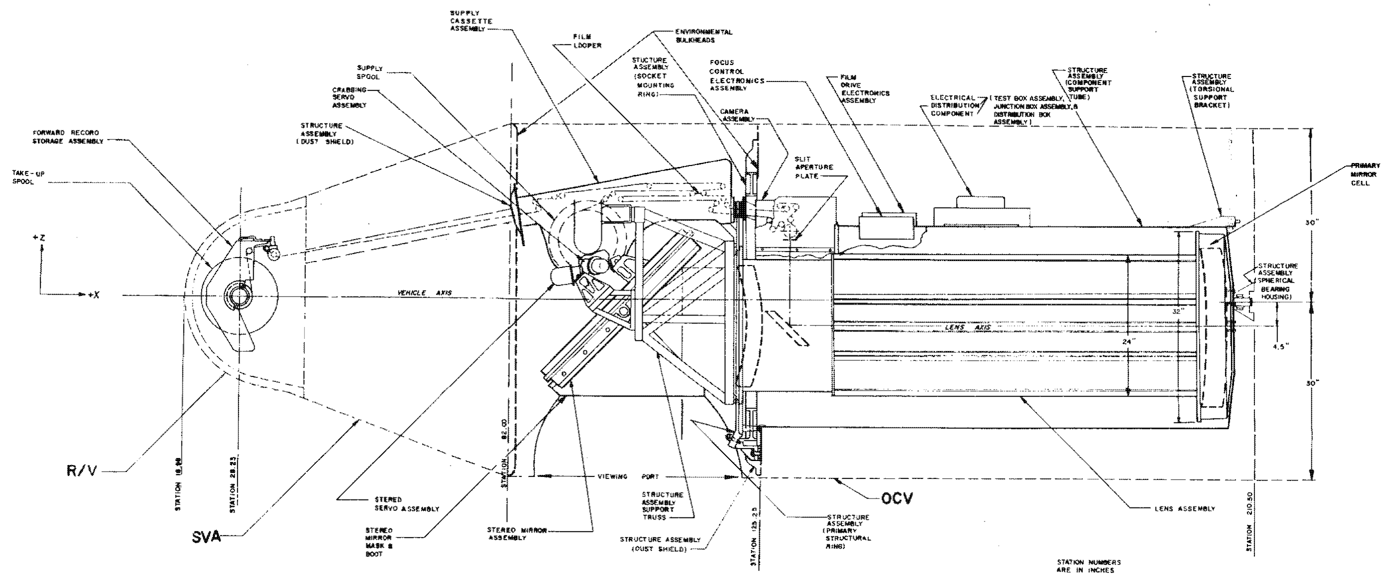


Figure 2-1. Camera Payload Schematic

The electrical distribution components, film-drive electronics, and focus control electronics packages are mounted on the component support tube, which surrounds the 77-inch lens barrel. Two servos, providing stereo and crab movement of the stereo mirror, are mounted to the stereo mirror support structure. The structure assembly supports the C/P and attaches it to the OCV. The film take-up cassette is integrally attached to the SRV.

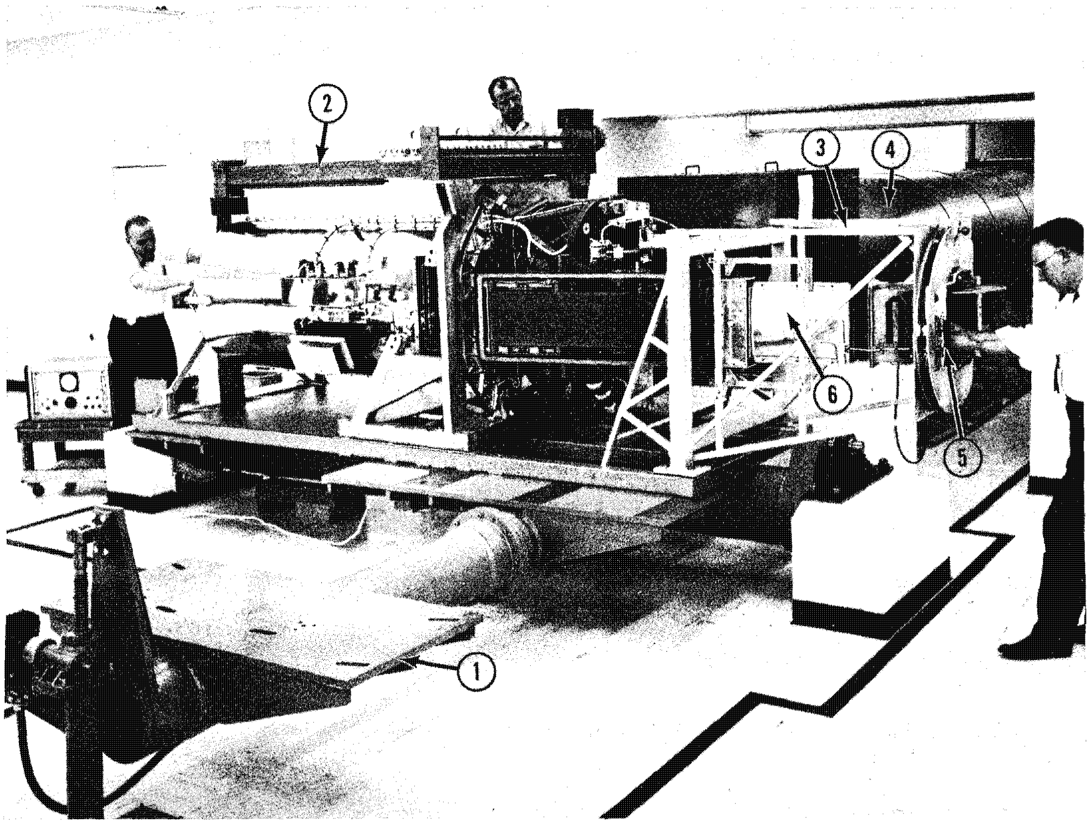
2.1.2 Engineering Model

Figures 2-2 and 2-3 show the Engineering Model of the C/P mounted in a cradle. The take-up cassette and chute, shown supported by the take-up cassette bracket, are not part of the current C/P configuration. They are now used, however, for EKC tests. Callouts on the photograph indicate the location of the various components. The use of the truck and C/P lifting yoke are shown as well as the arrangement used to mount the payload on the collimator.

2.2 COMPONENTS

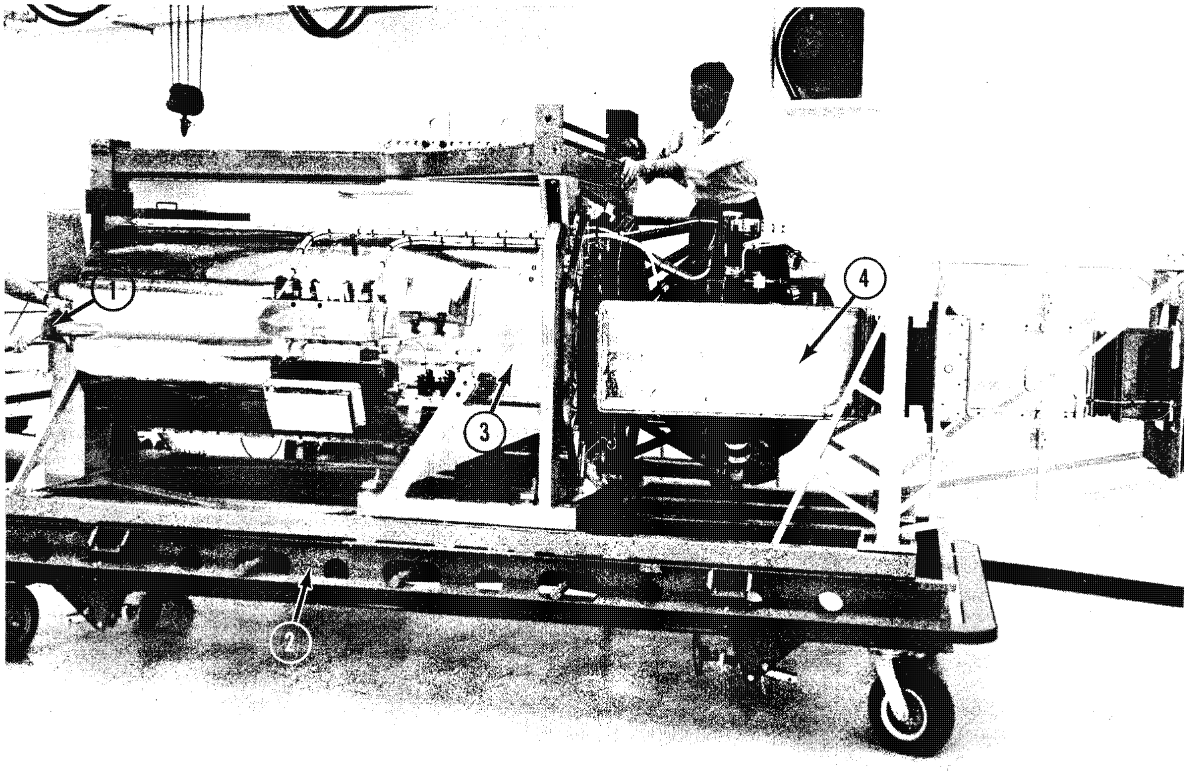
2.2.1 Electrical Components

Figure 2-4 shows the arrangement of the electrical components that are mounted on the component support tube. Callouts indicate the film-drive electronics, electrical distribution component (distribution box, junction box, test box), and the mounting location of the focus control electronics. The location of the various cabling and the cable bracket is also shown.



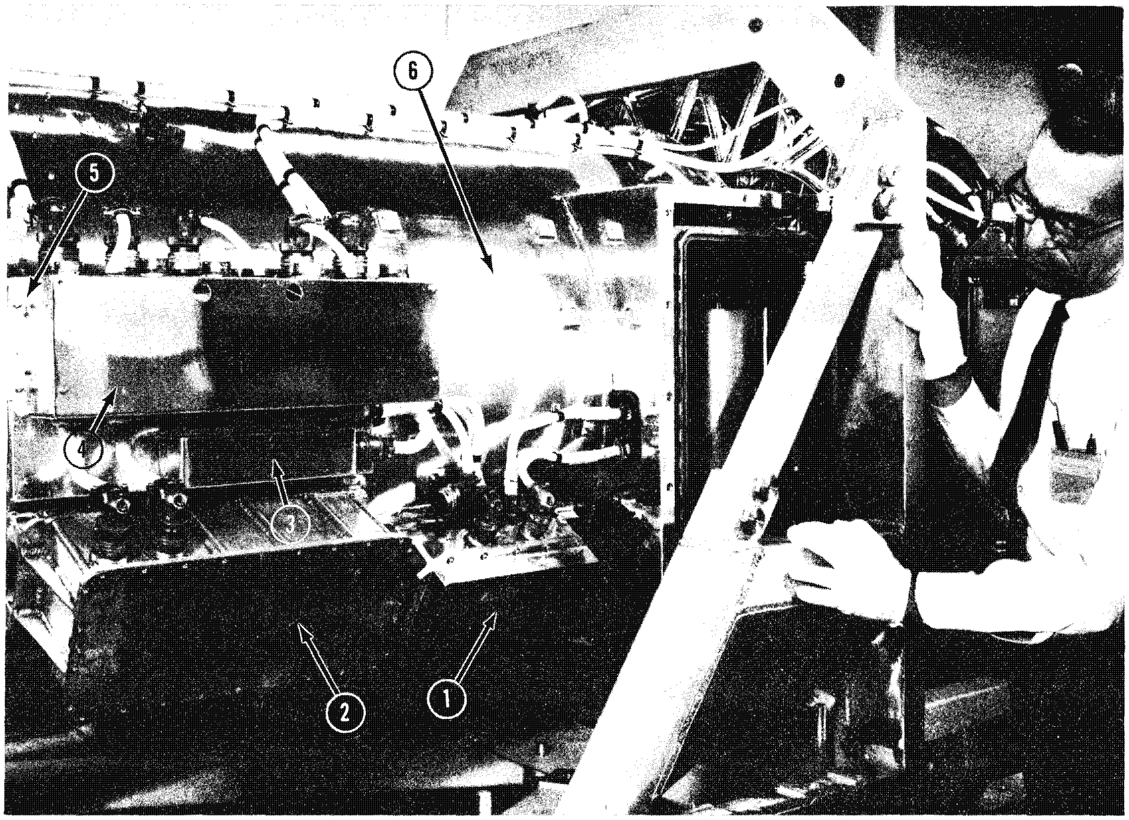
1. Payload Positioner
2. Lifting Yoke
3. Take-up Cassette Bracket
4. Collimator
5. Forward Record Storage Assembly
6. Chute (used for in-house testing)

Figure 2-2. C/P Engineering Model on Collimator



1. Torsional Stop Pin
2. Truck
3. Camera Cover
4. Supply Cassette

Figure 2-3. C/P Engineering Model on Truck



1. Film Drive Electronics
2. Distribution Box
3. Junction Box
4. Test Box
5. Cable Support Bracket
6. Focus Control Electronics Mounting Location

Figure 2-4. Electronics Packages

2.2.2 Supply Cassette

Figure 2-5 shows the interior of the film supply cassette with the looper empty. The supply reel location and various sections of the looper assembly are indicated by callouts.

Figure 2-6 shows the interior of the supply cassette as it appears when film is installed and the C/P is threaded up.

2.2.3 77-Inch Lens

The 77-inch lens is shown in Figure 2-7. The camera mounting pads, diagonal mirror, and pressure relief filters are indicated by callouts. The Invar stiffening ribs and the primary mirror cell are also clearly visible.

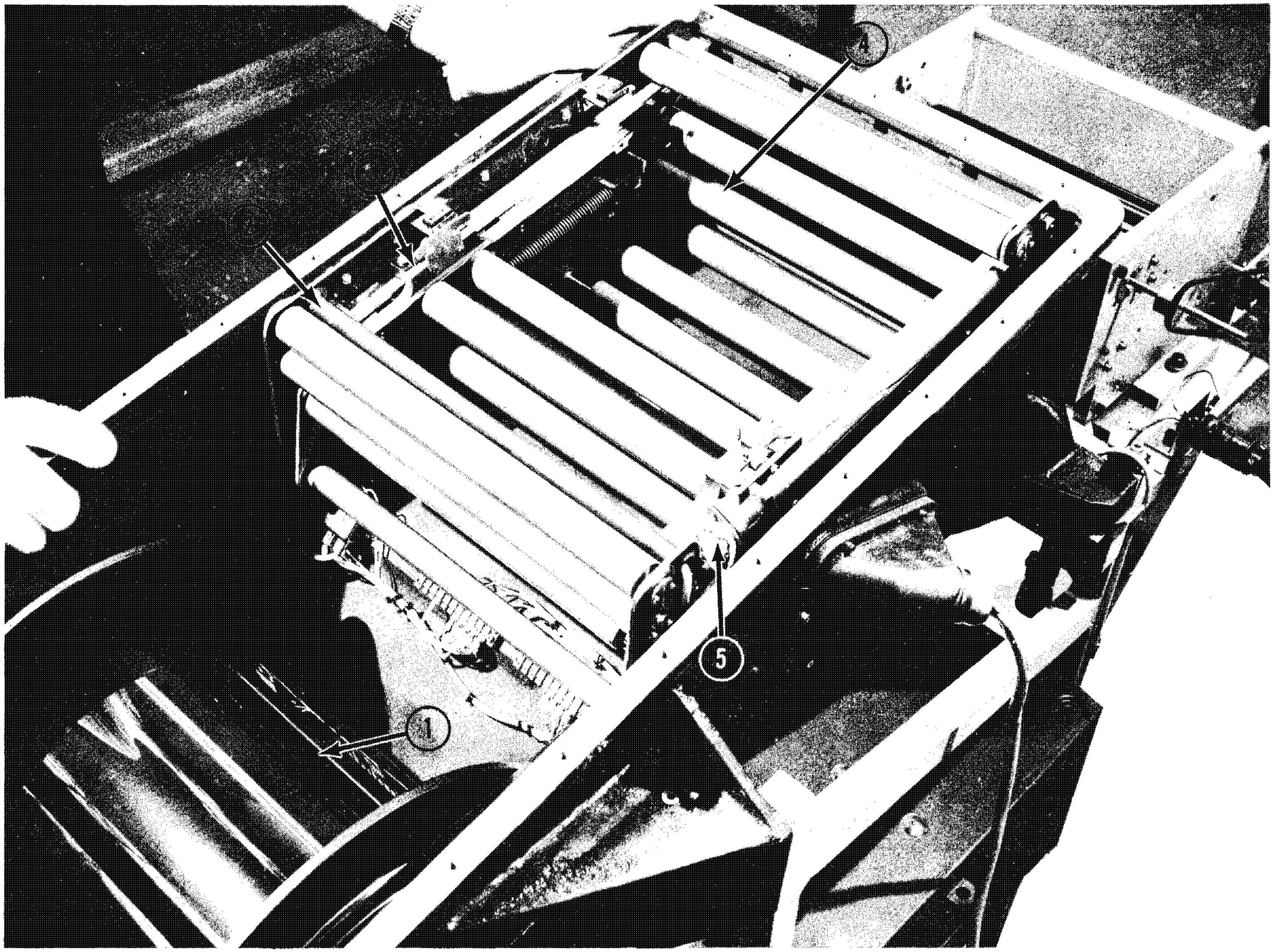
2.2.4 Component Support Tube

The lower half of the component support tube is shown in Figure 2-8. The various heaters, thermostats, and instrumentation points can be seen. Specific portions of the thermal control subsystem can be identified by referring to Figure 3-10.

2.2.5 Stereo Mirror Assembly

Figures 2-9, 2-10, 2-11, and 2-12 show the characteristics of the stereo mirror and its support assembly.

Figure 2-9 shows the front and back surfaces of the lightweight stereo mirror used for the thermal mockup. This mirror was fabricated to represent the type being used for the stereo and primary mirrors. The honeycomb pattern of the sandwich and the two flat face plates can be seen clearly.



1. Supply Reel
2. Supply Side
3. Movable Truck
4. Take-Up Side
5. Looper Position Potentiometer

Figure 2-5. Film Supply Cassette Interior

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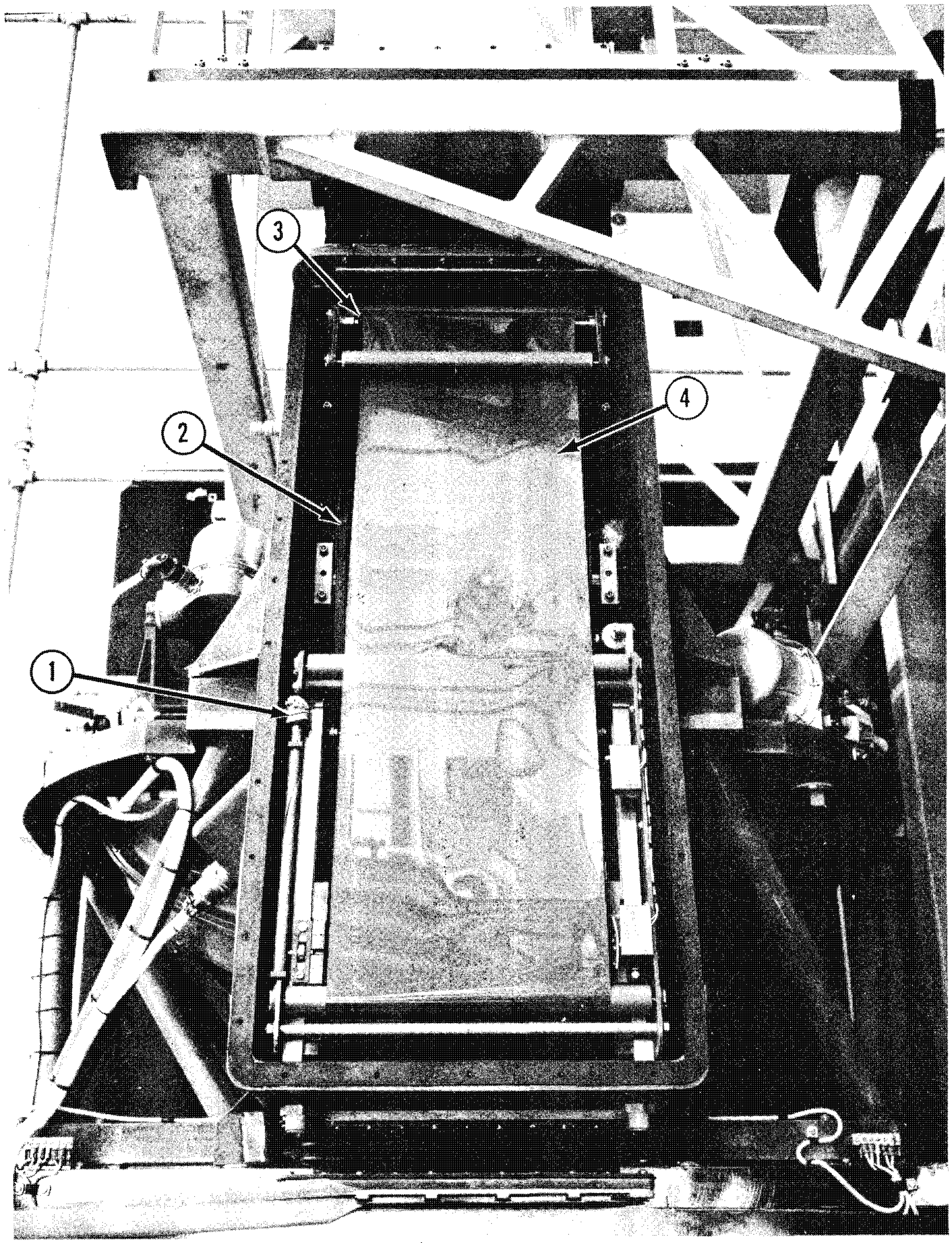
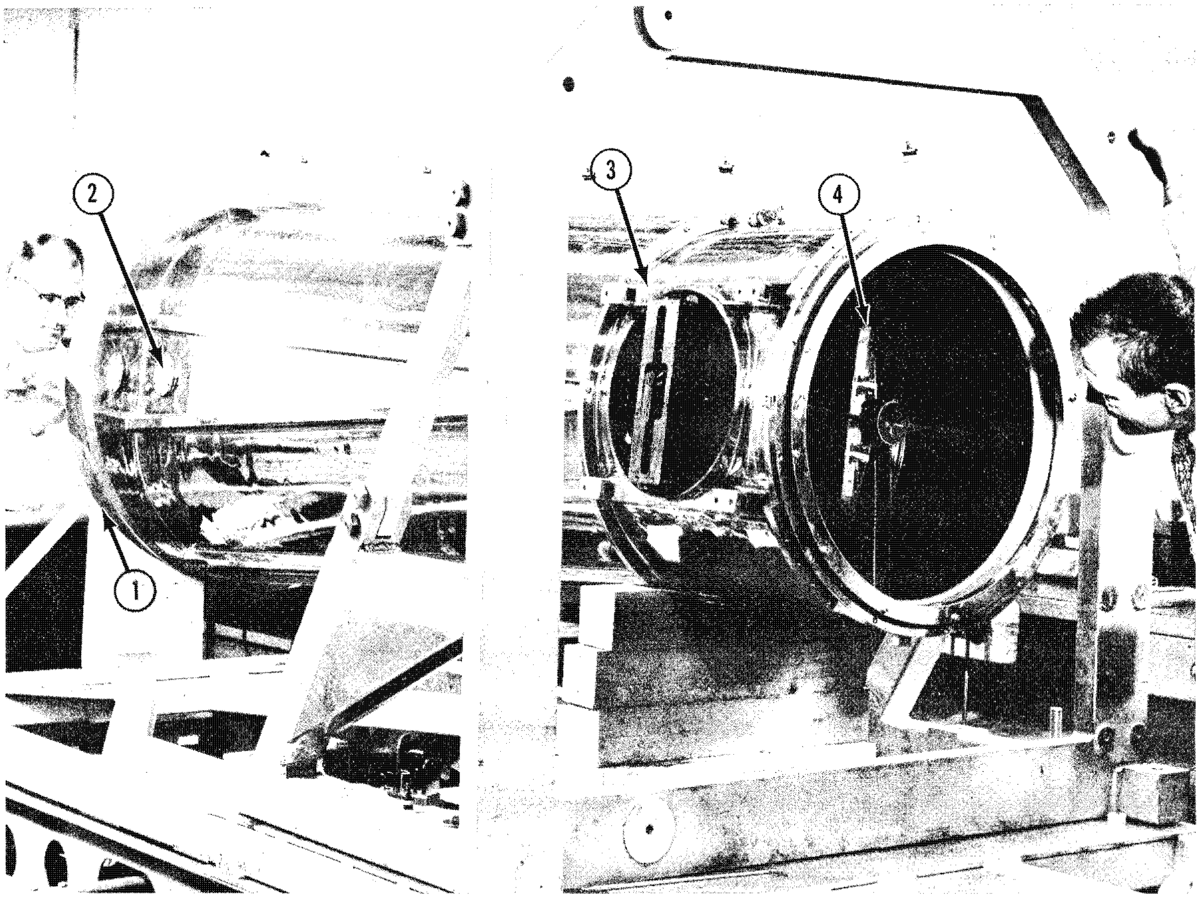


1. Looper Position Sensor
2. Supply Spool Brake Band
3. Film Alignment Roller
4. Exposed Film

Figure 2-6. Film Supply Cassette (film in looper)



1. Primary Mirror Cell
2. Pressure Relief Filter
3. Camera Mounting Location
4. Diagonal Mirror

Figure 2-7. 77-Inch Lens

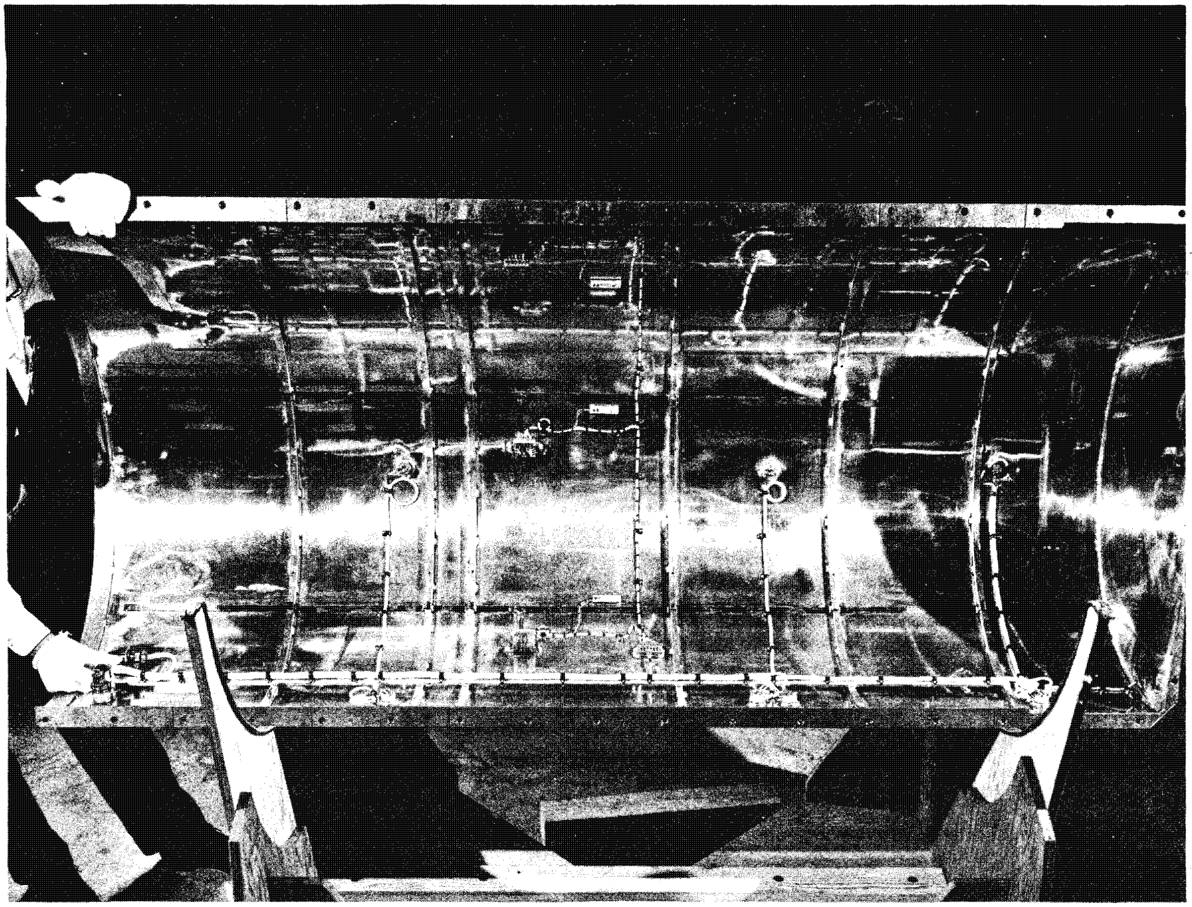


Figure 2-8. Component Support Tube (lower half)

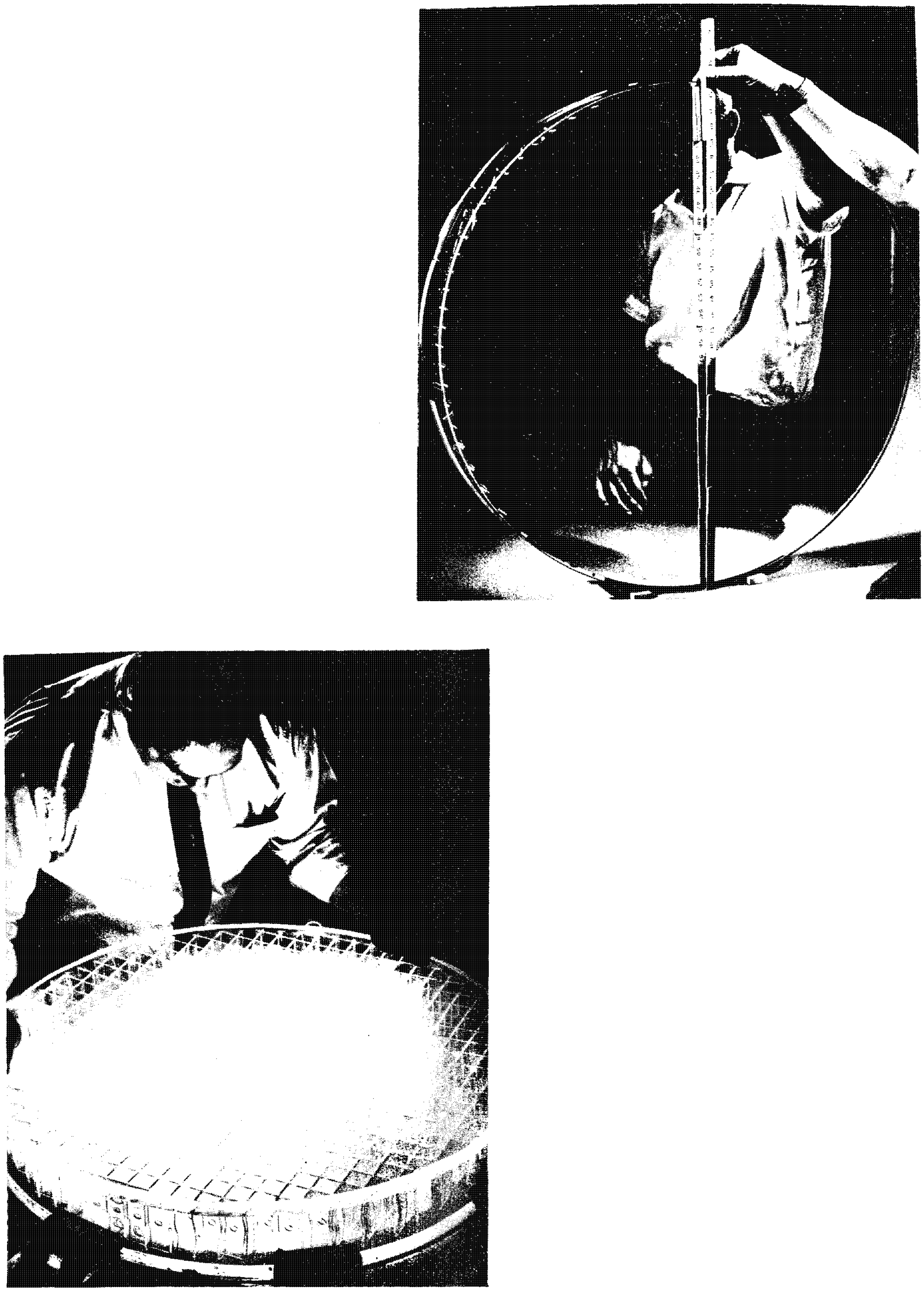
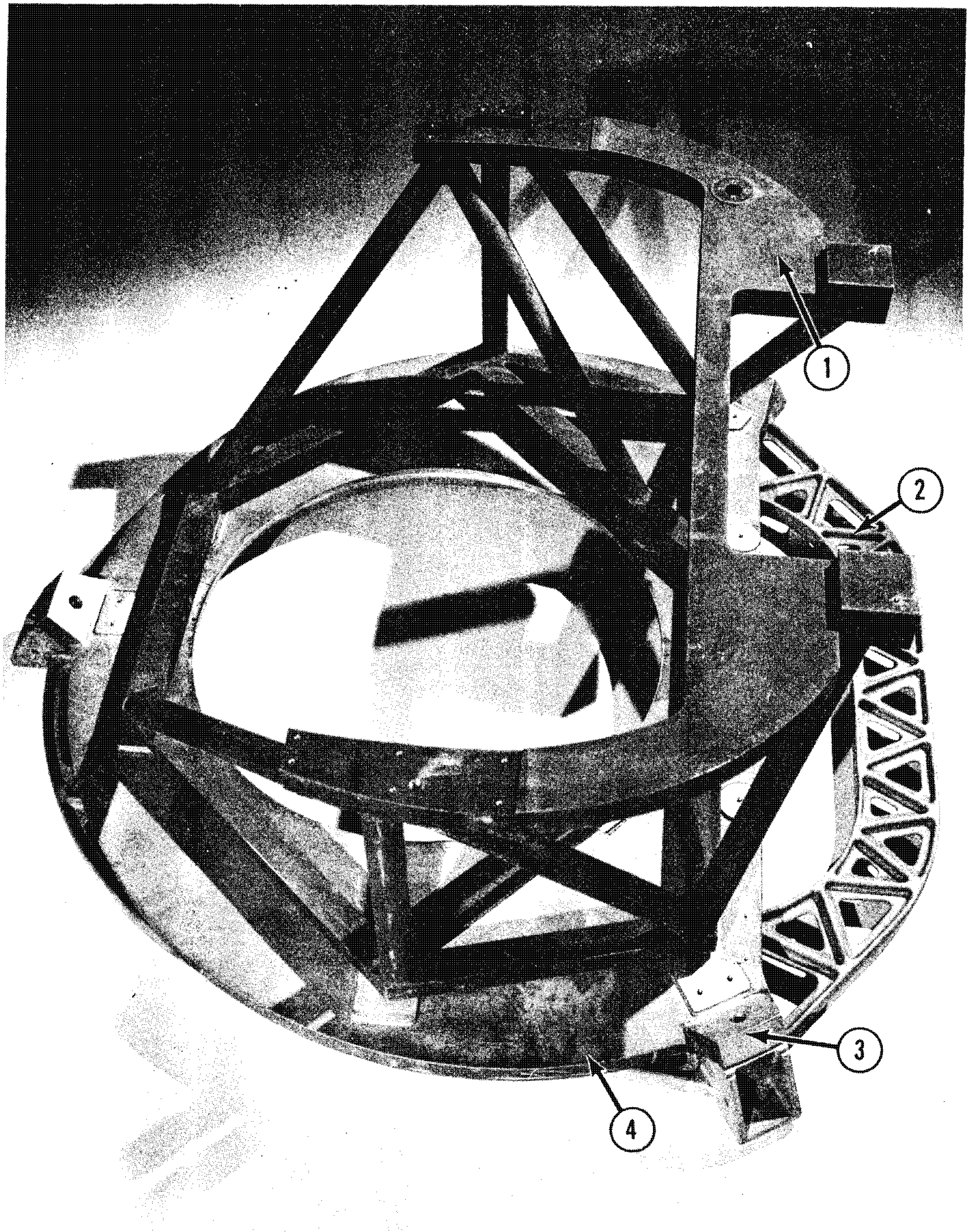
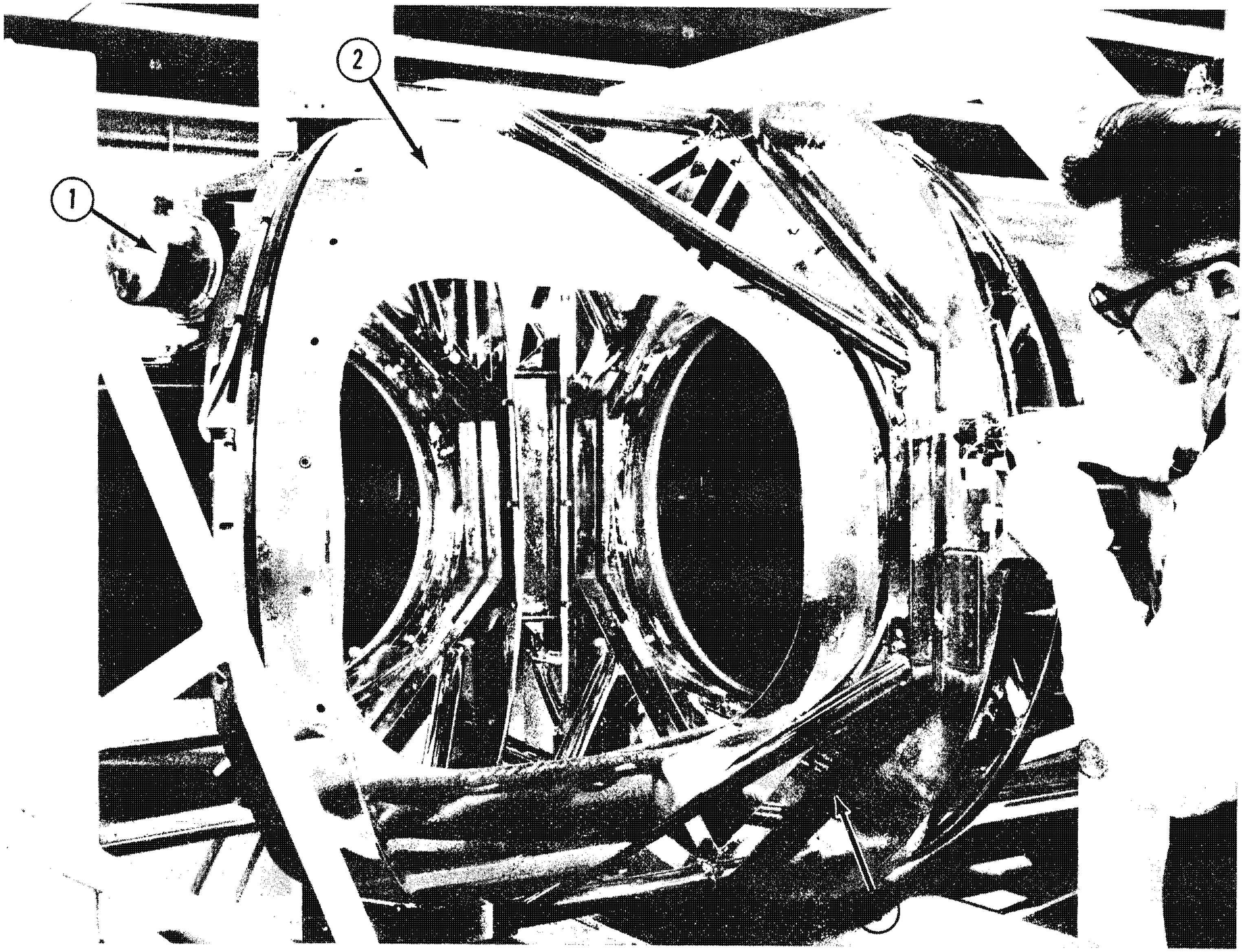


Figure 2-9. Lightweight Stereo Mirror



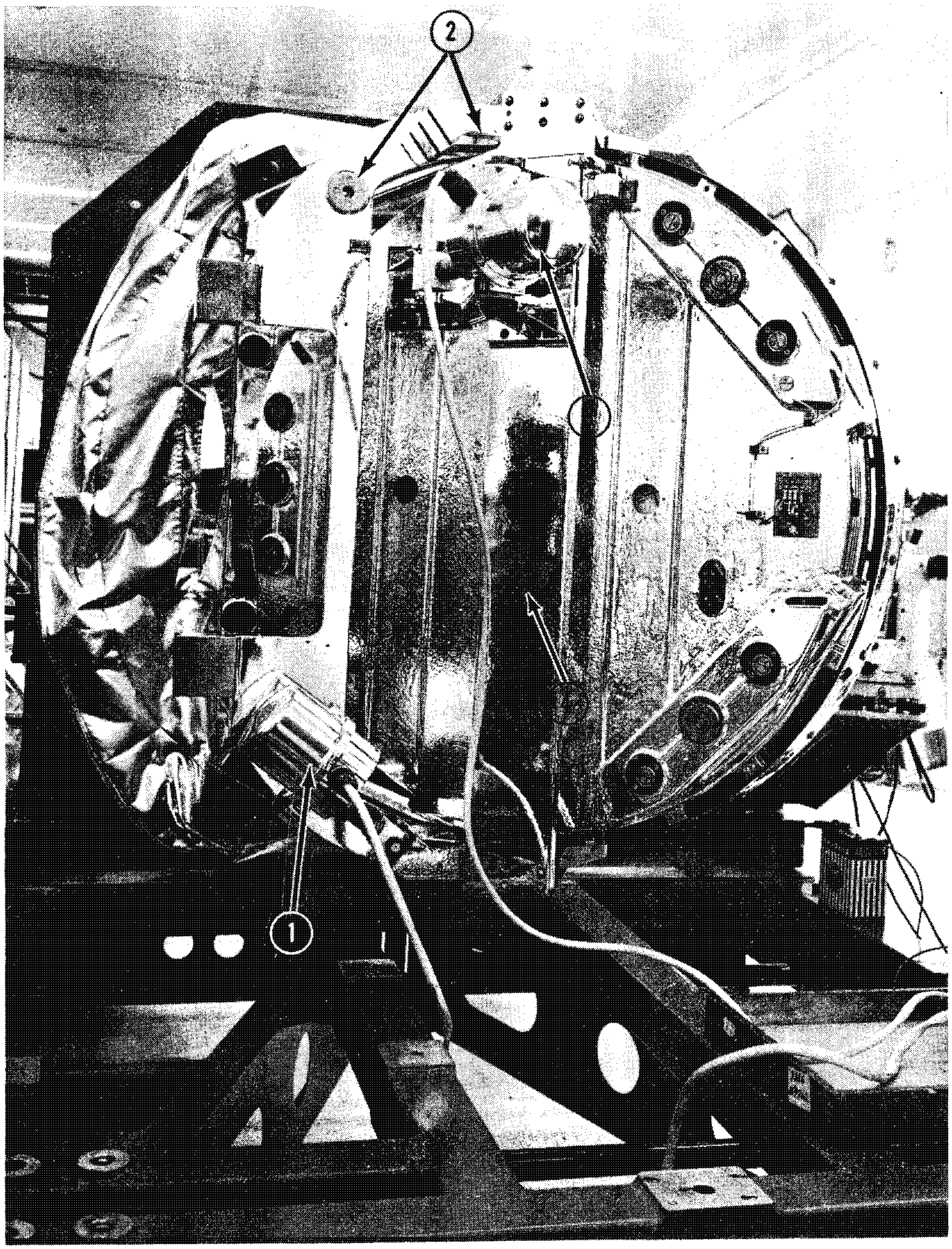
1. Stereo Mirror Support
2. Payload Socket Mounting Ring
3. Spherical Pads
4. Primary Structure Support Ring Assembly

Figure 2-10. Stereo Mirror Support Assembly



1. Stereo Servo   2. Movable Mask   3. Stereo Mirror Support Assembly

Figure 2-11. Stereo Mirror (front)



1. Crab Servo
2. Alternate Crab Servo Mounting Point
3. Stereo Servo
4. Bridge

Figure 2-12. Stereo Mirror (Back)

Figure 2-10 shows the arrangement of the components that comprise the stereo mirror support assembly and the forward spherical seat. The relationship of the primary structural ring, the socket mounting ring, and the stereo mirror support can be seen.

Figures 2-11 and 2-12 show front and rear views of the stereo mirror mounted in its cell and installed in the C/P. The mirror mounting adjustment devices, positioning servos, movable mask, and final assembly of the support structure are shown. The relationship between the stereo mirror and the 77-inch lens can also be seen.

2.2.6 Camera

Figure 2-13 shows the exterior of the camera. The supply cassette and looper assembly is attached to the cassette by means of a flexible joint at the mating face shown in the photograph. The camera is bolted directly to the lens barrel by means of the mounting feet shown.

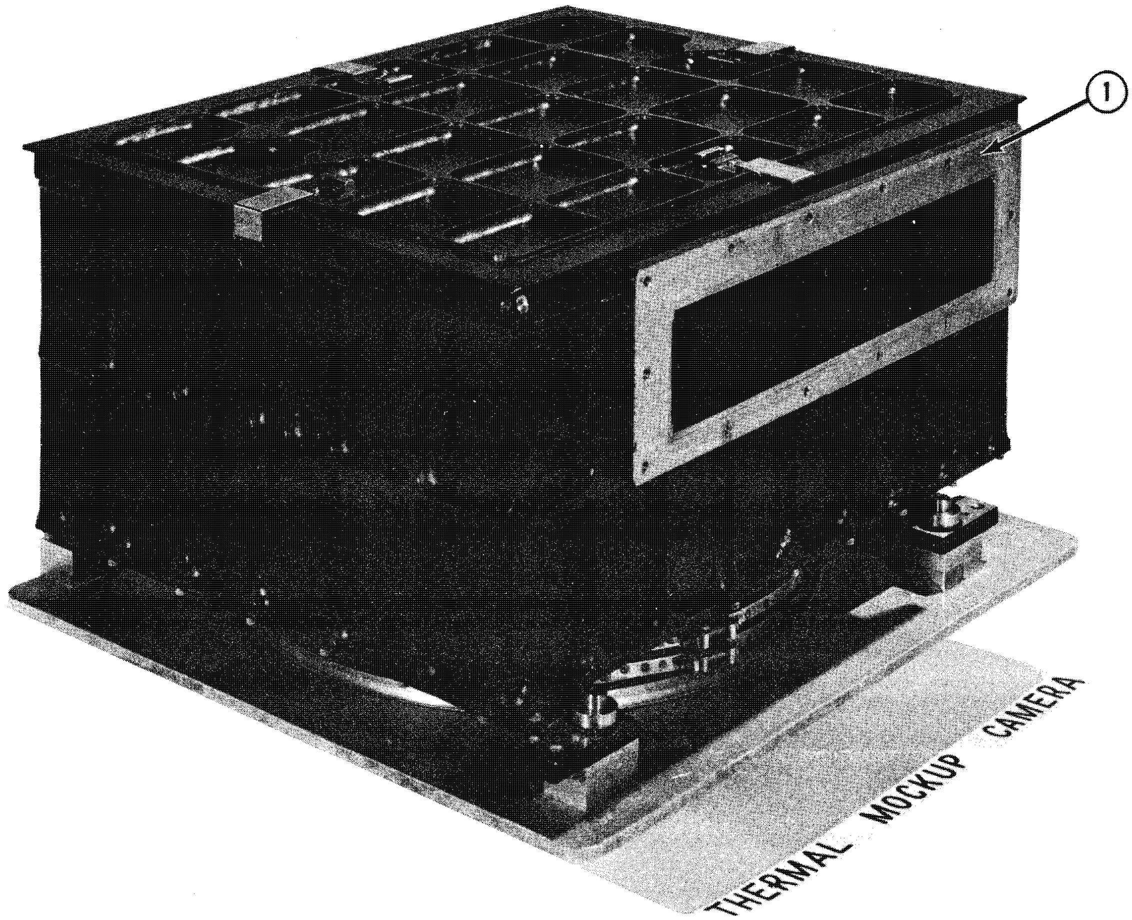
Figures 2-14 and 2-15 show two views of the interior of the camera. Callouts indicate the location of such items as the platen, drive roller, camera drive motor, and focus drive motor.

The slit plate contained within the camera is shown in Figure 2-16. The two test slits and the three flight slits are indicated. A pair of smear slits can be seen at both ends of each flight slit. The fiducial mark used for alignment and line-of-sight measurements is also noted.

2.3 AGE ITEMS

2.3.1 300-Inch Collimator

Figure 2-17 shows one of the collimator installations at EKC that is used for testing lenses and camera payloads. A section of the positioning table where the payload or lens is mounted for photographic tests is shown in the foreground of this photograph.



1. Flexible Joint Mating Face

Figure 2-13. Camera, Exterior

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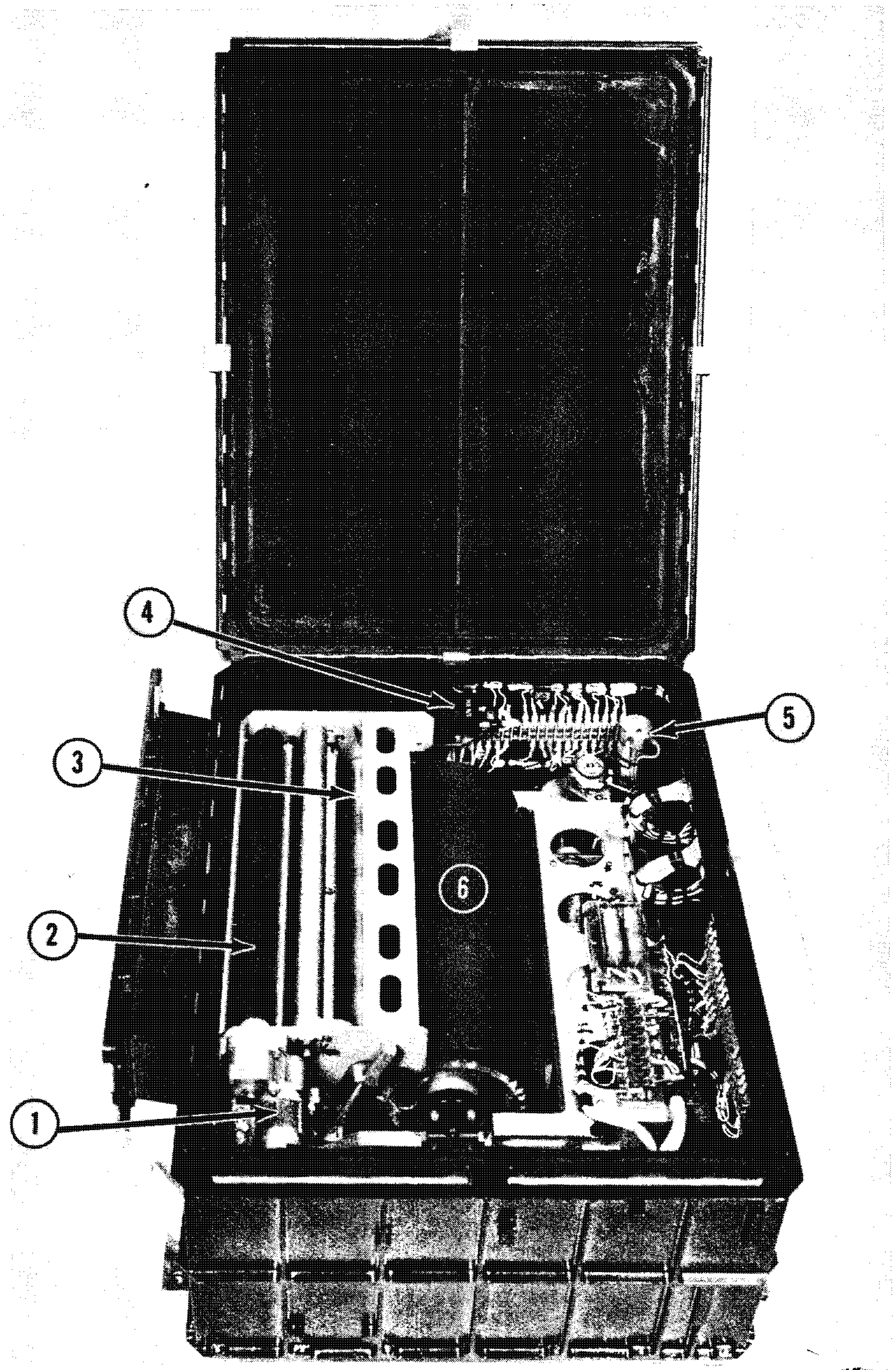


1 Camera Drive Motor

2 Camera Drive Roller

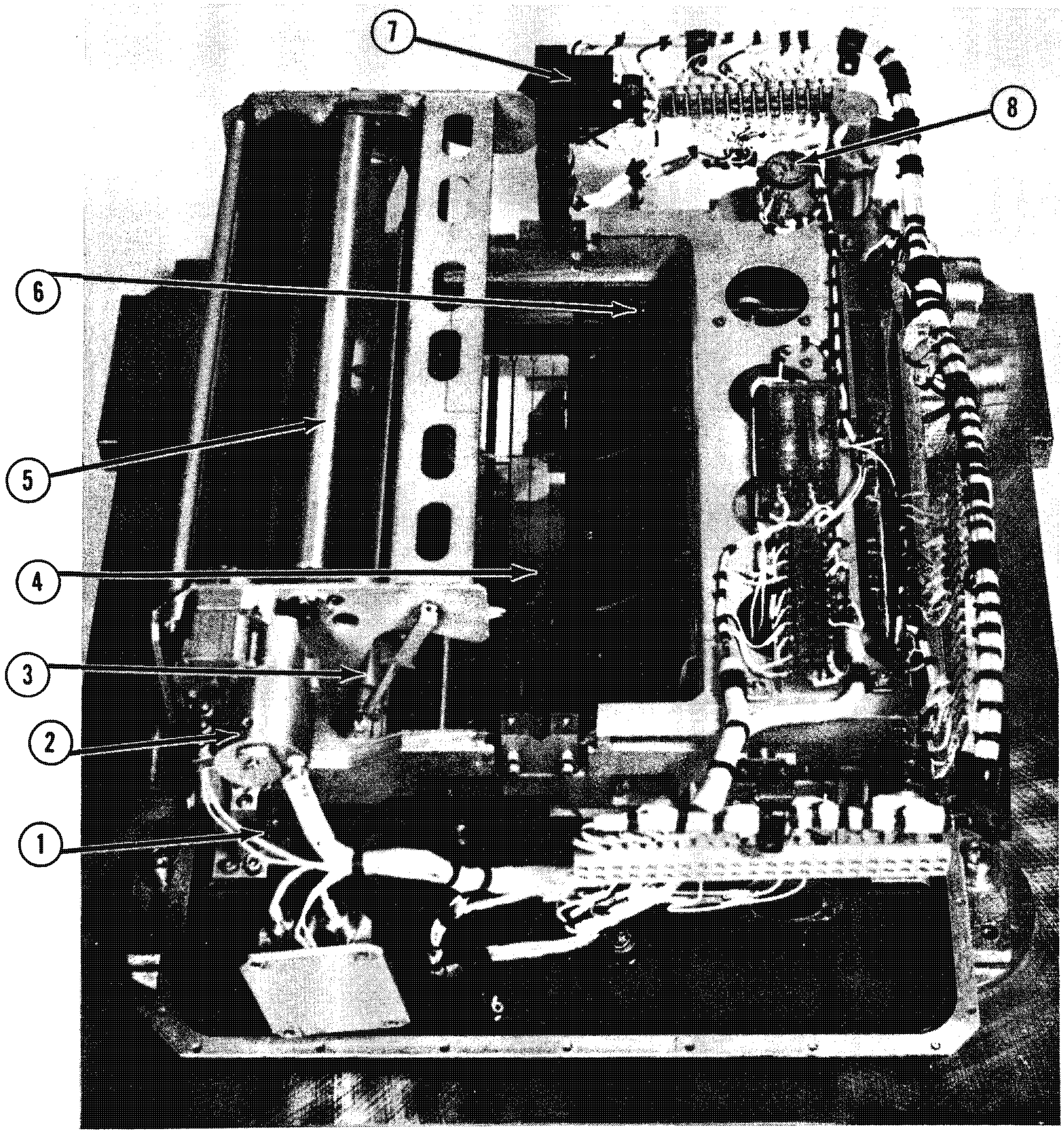
3 Upper Damper Roller with Damper Arm

4 Data Lamp Housing

5 Focus Drive Motor

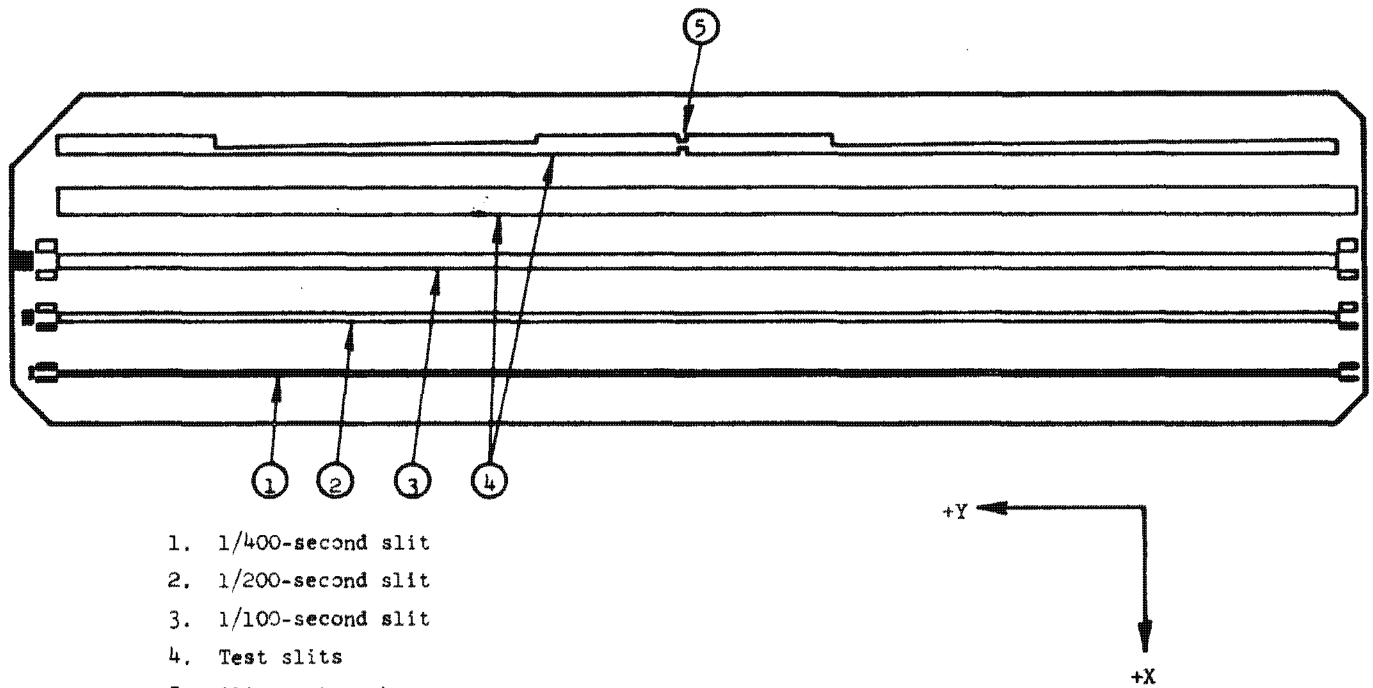
6 Platen

Figure 2-14. Camera, Cover Open



1 Pivot Flexures (Behind Wires)
2 Camera Drive Motor
3 Lower Damper Roller
4 Programmable Slit Aperture Plate
5 Idler Roller
6 Slit Positioner Detent Arm
7 Data Lamp Housing
8 Platen Position Potentiometer

Figure 2-15. Camera, Internal Components (Platen Removed)



Position	Orbital Command Code CB 20	CB 21
E	—	—
D	1	1
C	1	0
B	0	1
A	0	0

1. 1/400-second slit
2. 1/200-second slit
3. 1/100-second slit
4. Test slits
5. Alignment mark

Figure 2-16. Slit Plate (Viewed from Lens Side)

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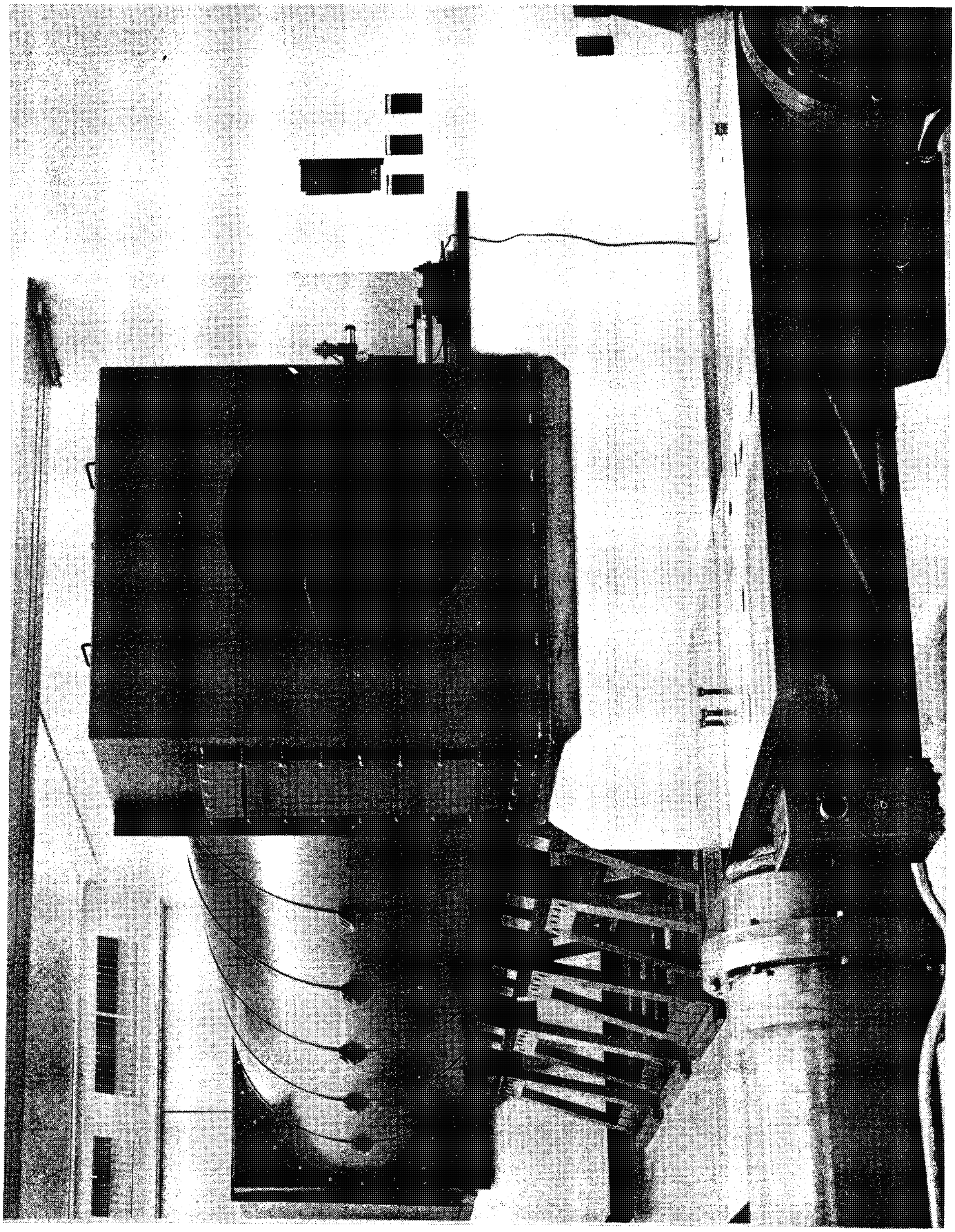


Figure 2-17. 300-Inch Collimator

2.3.2 Test Console

The C/P test console described in Section 4.8 is shown in Figure 2-18. It is used to operate both C/P equipment being tested and the collimator itself. Several of the various panels contained in the test console are indicated by callouts.

2.3.3 Portable Test Set

The portable test set, which has limited payload command and monitoring capabilities, is used to operate the C/P to a limited extent when the C/P test console is not available (see Figure 2-19).

2.3.4 Electrical Simulator

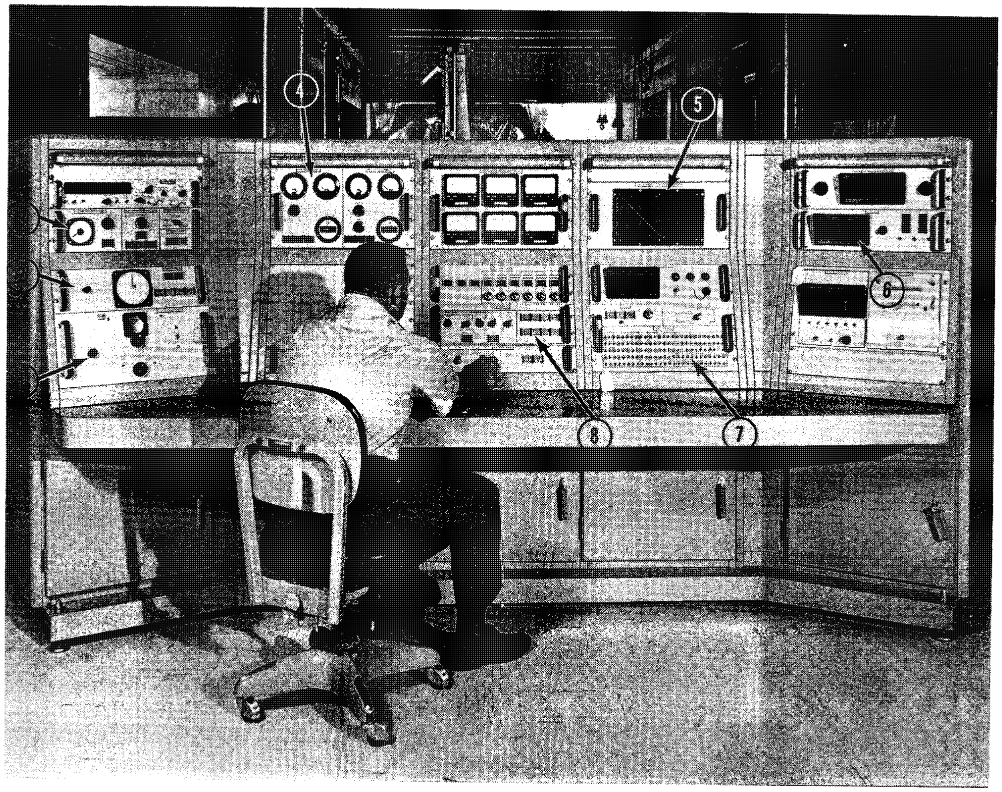
This item, shown in Figure 2-20, is used to simulate the C/P during compatibility testing. Its purpose is to ensure that the C/P can be electrically mated with the OCV, SVA, and SRV and operated without damage.

2.3.5 Cable Test Point Board

This item, shown in Figure 2-21, is used during C/P testing to provide a means for monitoring any interface cable. It consists of a jack panel and sufficient cabling to connect to the plug and jack of each interface connector on the C/P.

2.3.6 Load Box

Figure 2-22 shows the load box portion of the secondary standard. This equipment is used to test and calibrate the operation of the test console (see Section 2.3.2).



1. Test Drum Speed Control
2. Collimator Position Control
3. Target Illumination Control
4. Payload Power Monitor
5. Instrumentation Patch Board
6. Digital Instrumentation Monitor
7. Instrumentation Test Point Panel
8. Payload Command Control

Figure 2-18. Test Console

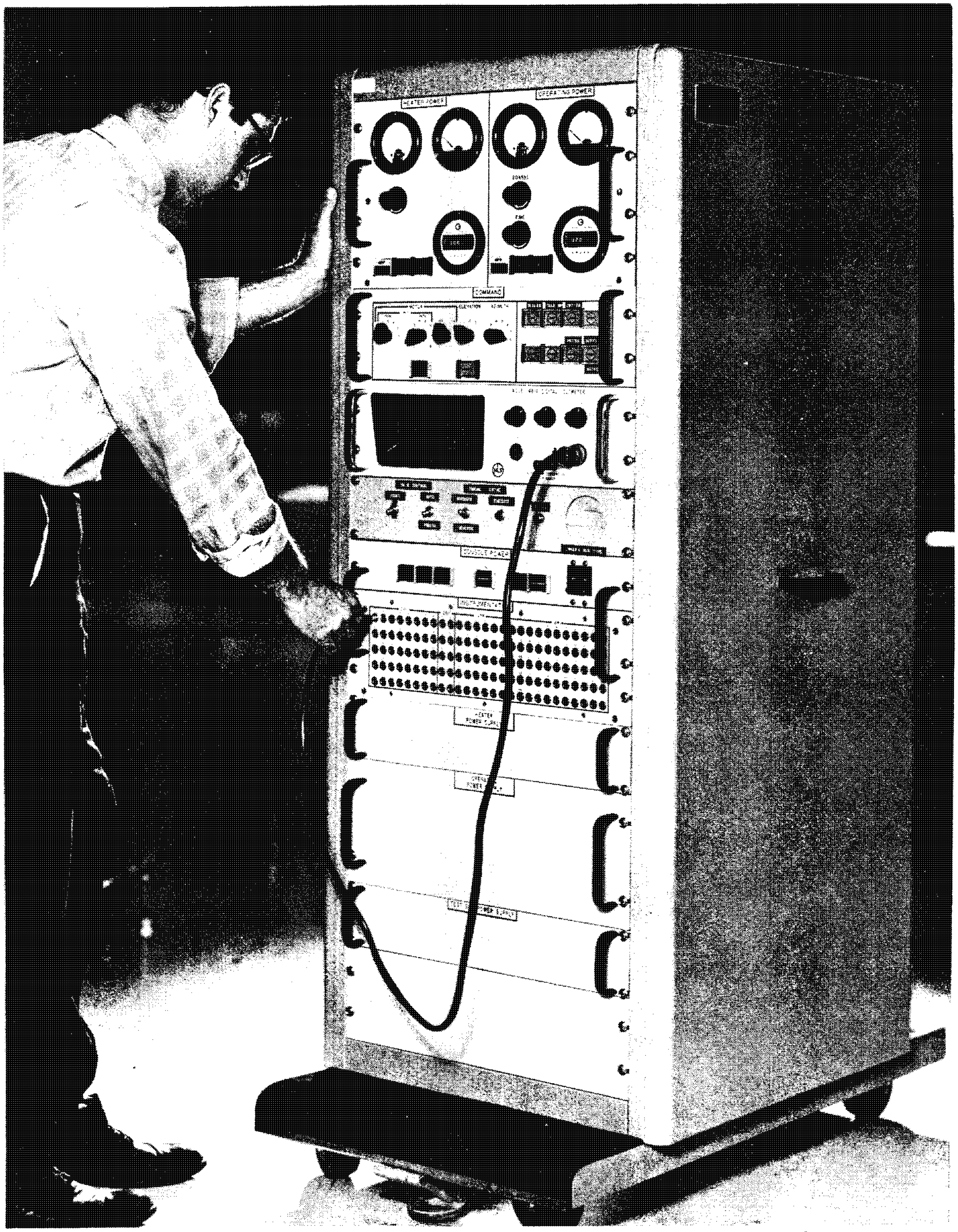


Figure 2-19. Portable Test Set

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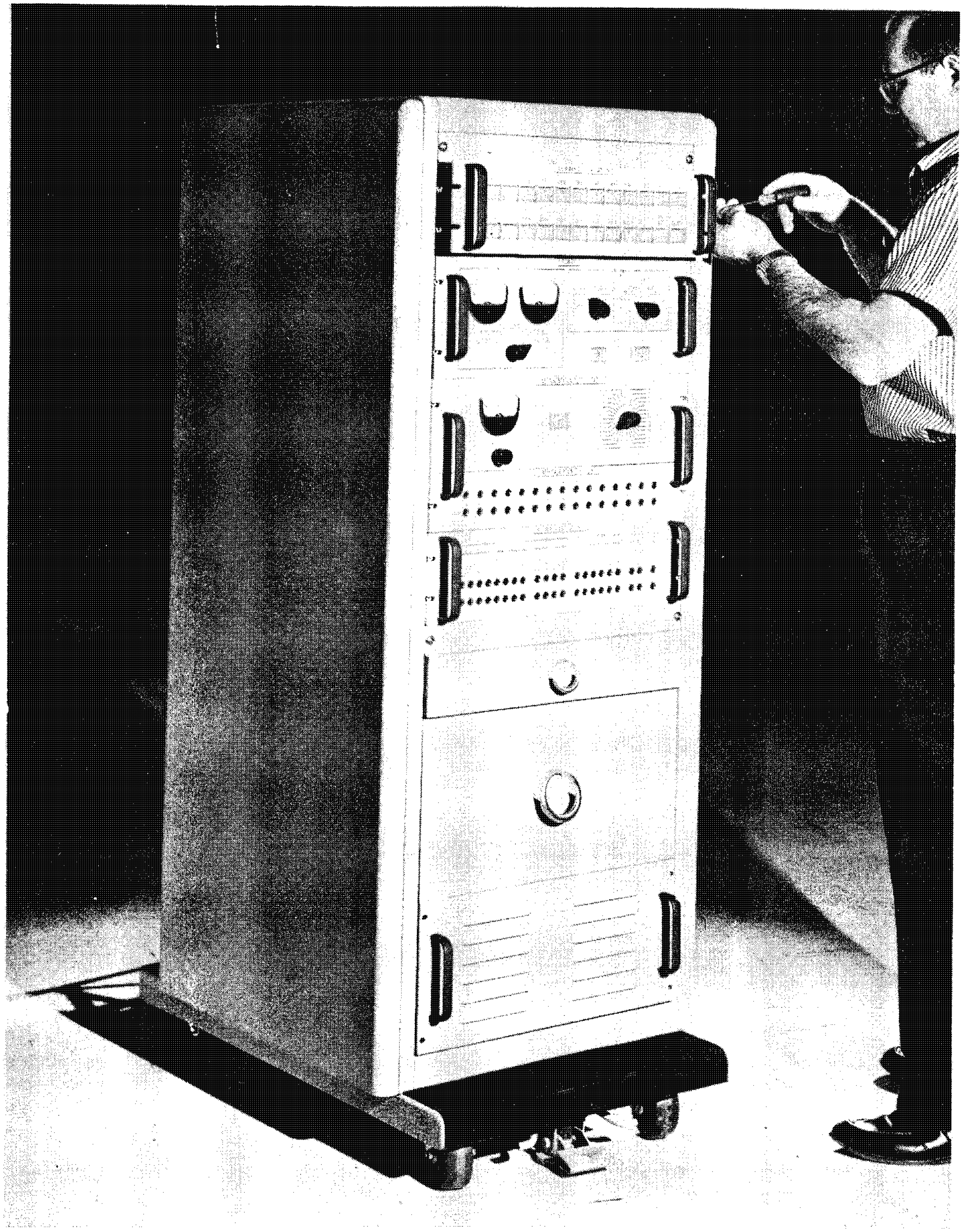


Figure 2-20. Electrical Simulator

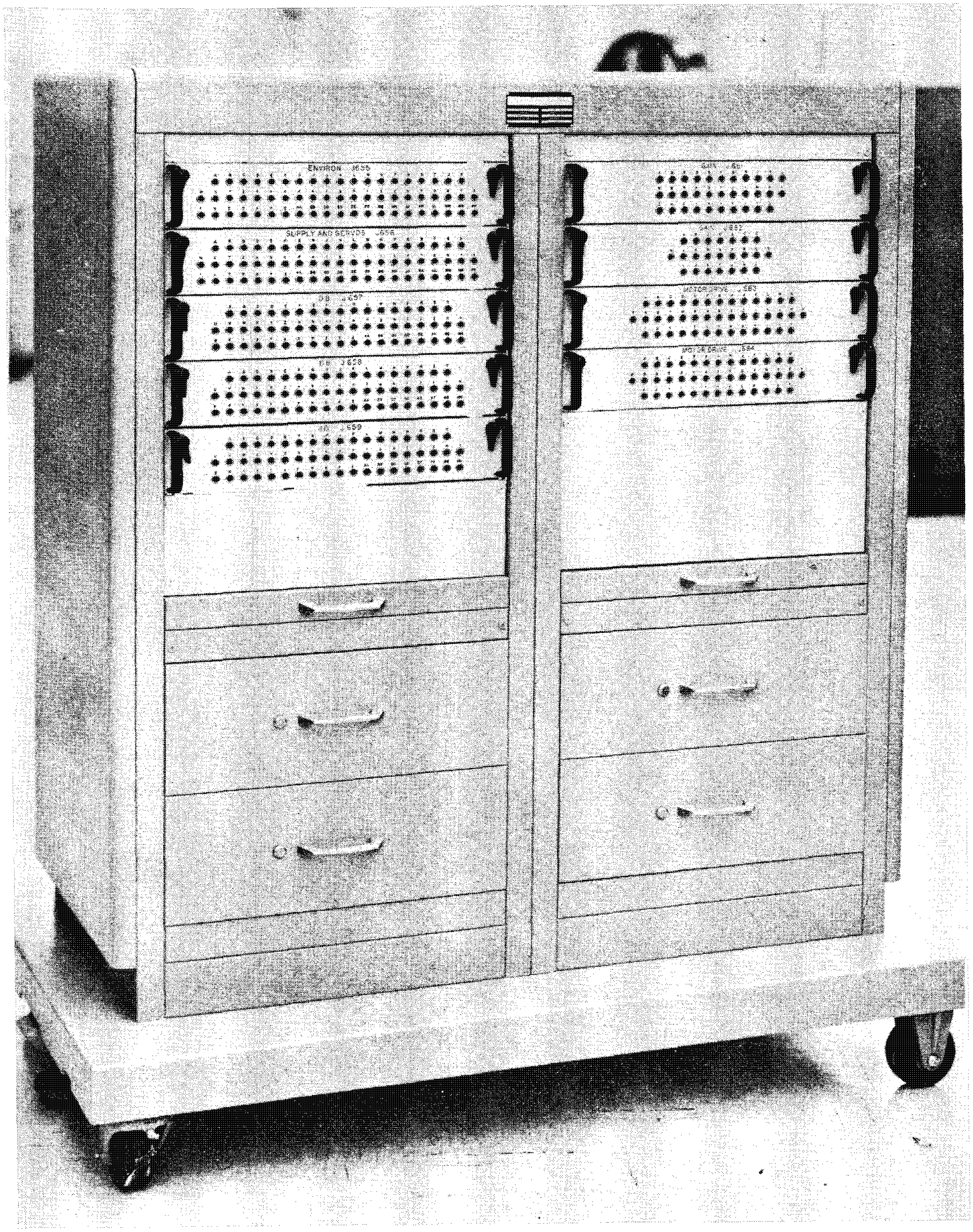


Figure 2-21. Cable Test Point Board

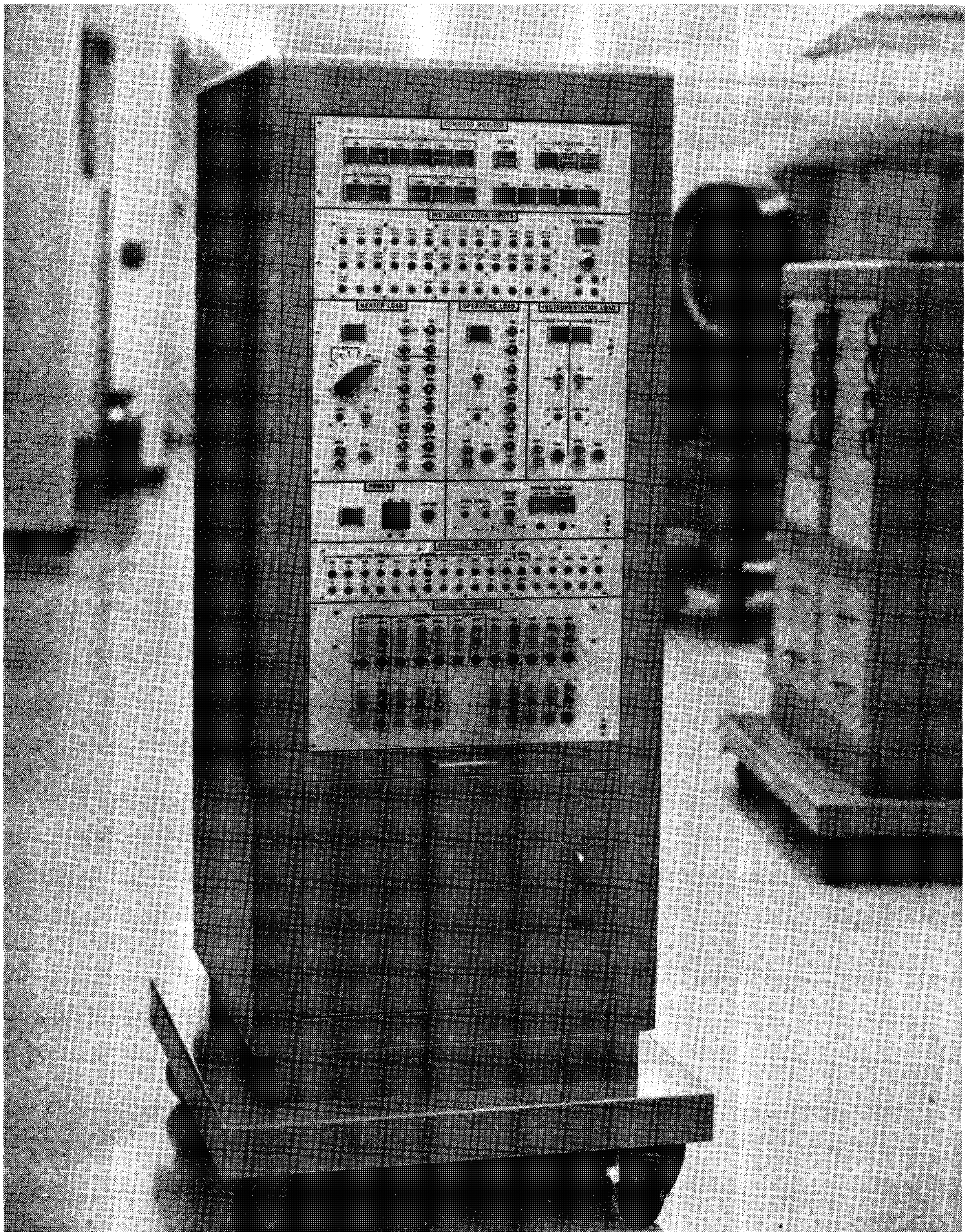


Figure 2-22. Load Box Secondary Standard

2.3.7 Command Monitor

The command monitor is shown in Figure 2-23. It connects to the C/P test box by means of the cables shown. It is used to indicate the state of all C/P commands, to monitor the C/P operating voltages (28, 22, and 5 v dc) or the output of any test point, and to check the continuity loop.

2.3.8 Payload Lifting Yokes

The C/P lifting yoke, shown in Figure 2-24, is used to move the C/P when it is mounted in the cradle (see Figure 2-2 also). It is required when the C/P is moved between the truck and the collimator, erector, or shipping container. The vertical lifting yoke shown in Figure 2-25 is used to lift the payload out of the cradle (in the vertical position on the erector) and into the OCV.

2.3.9 Erector

This item, shown in Figure 2-26, is used to rotate the C/P cradle, or other handling fixtures from the horizontal into the vertical position. This operation is required before mating with the OCV, for weight and balance measurements, and for vibration testing at EKC.

2.3.10 Integration Lifting Yoke and Erector

Figure 2-27 shows the integration lifting yoke being used to remove the C/P dynamic simulator from a vibration fixture. This fixture has been rotated into a vertical position by the erector.

2.3.11 Payload Shipping Container

The exterior of a payload shipping container is shown in Figure 2-28. The casters shown are removable and are not attached while the container is in transit

2.3.12 Record Viewer

A record viewer used for viewing test film is shown in Figure 2-29. This viewer has variable-speed motor-driven reels as well as adjustable illumination levels.

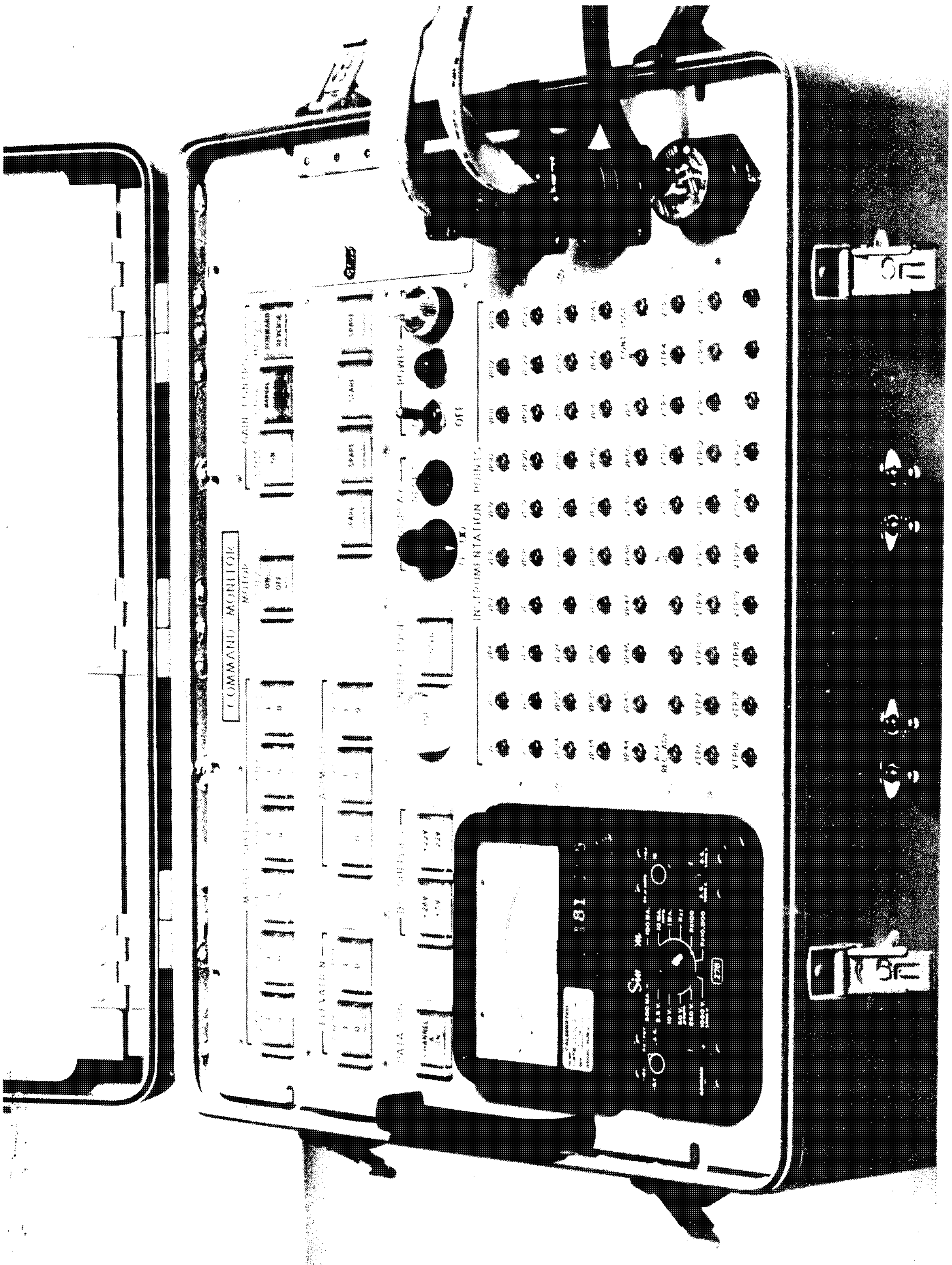


Figure 2-23. Command Monitor

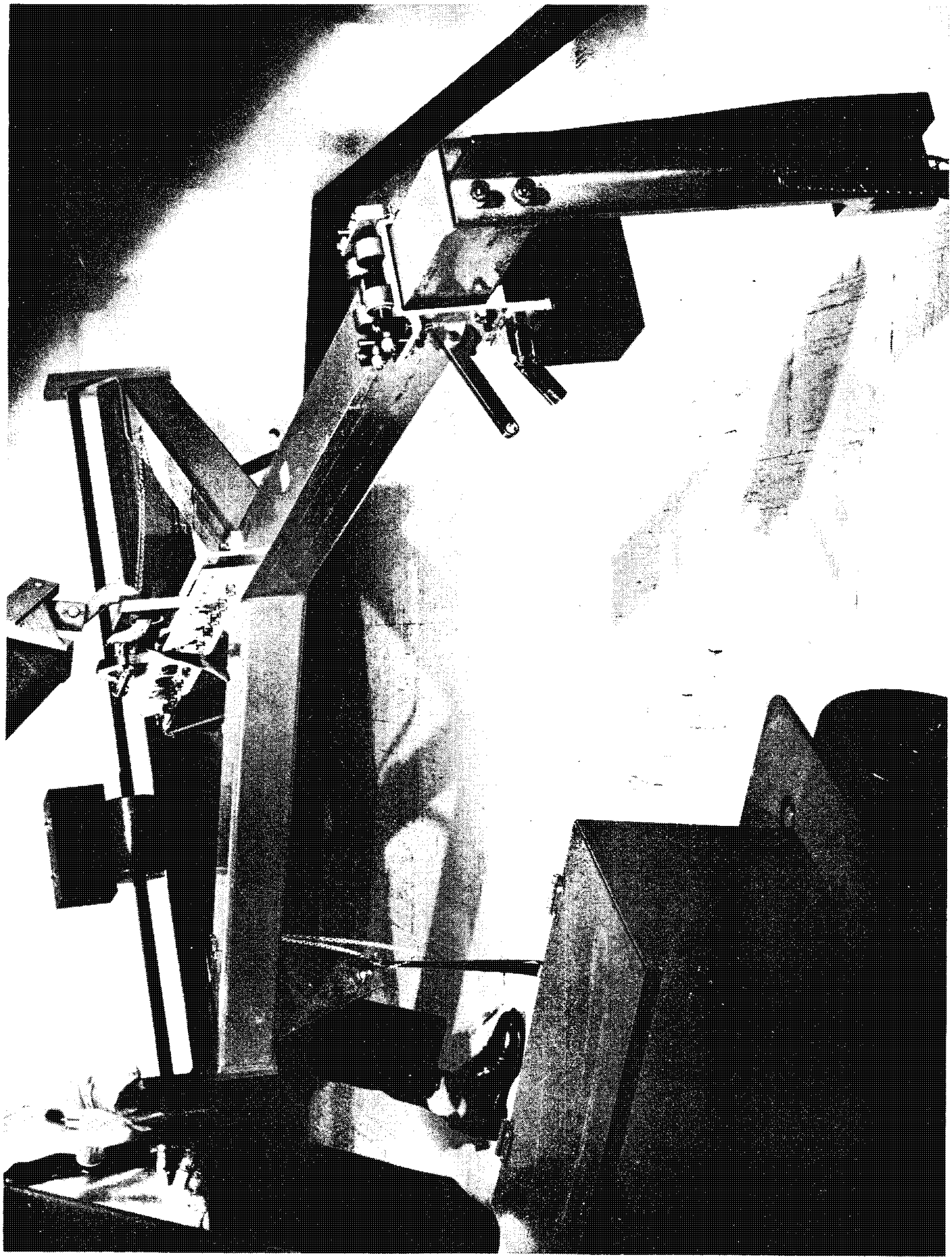


Figure 2-24. Payload Lifting Yoke

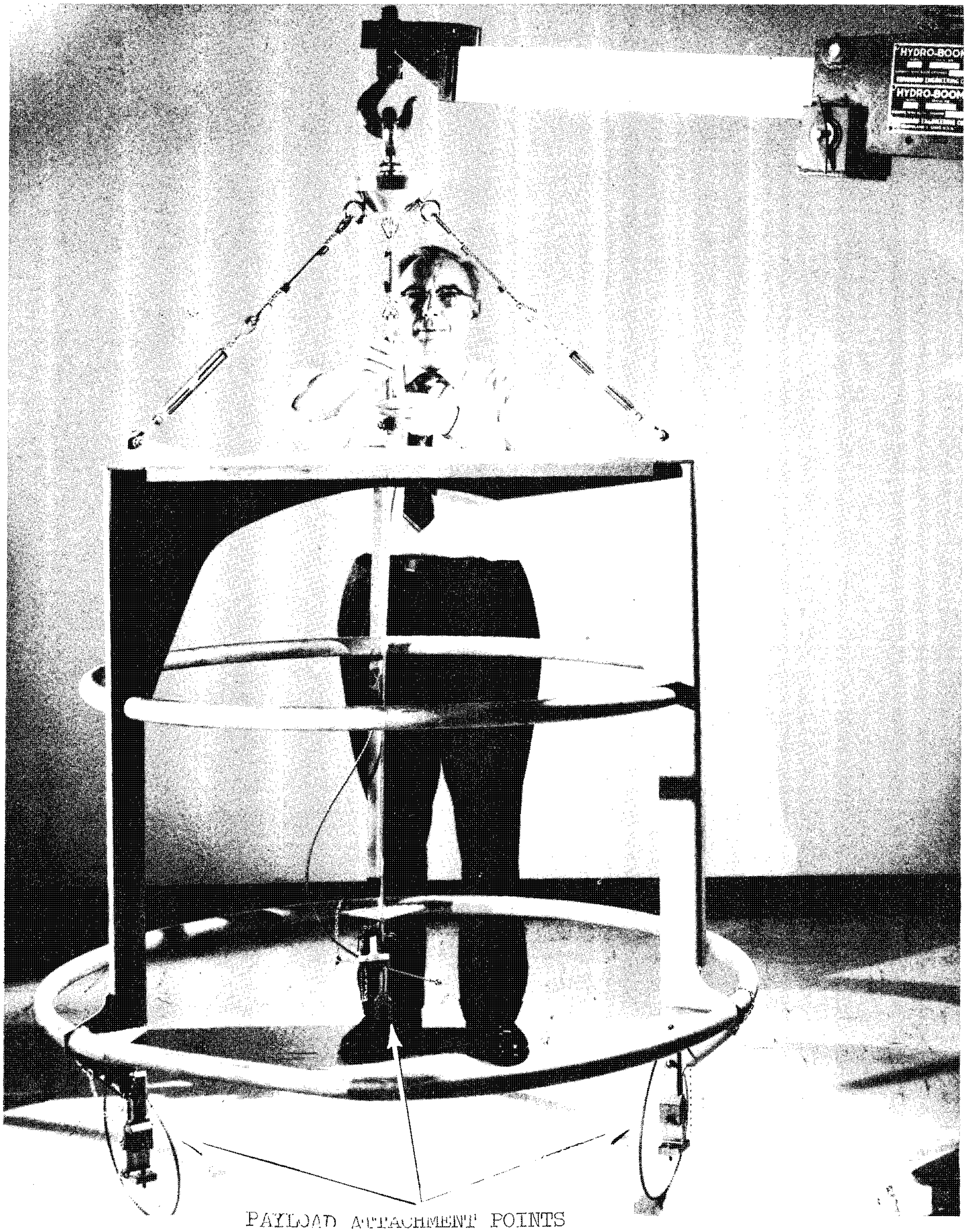
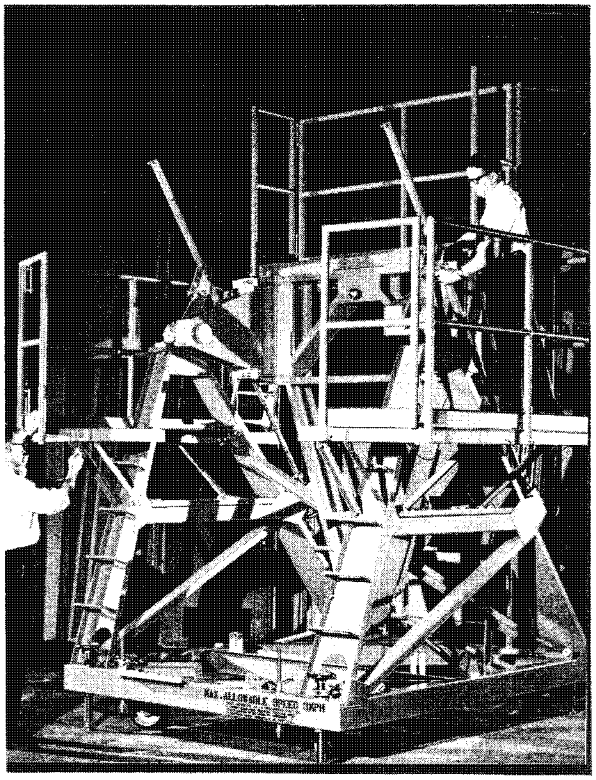


Figure 2-25. Vertical Lifting Yoke



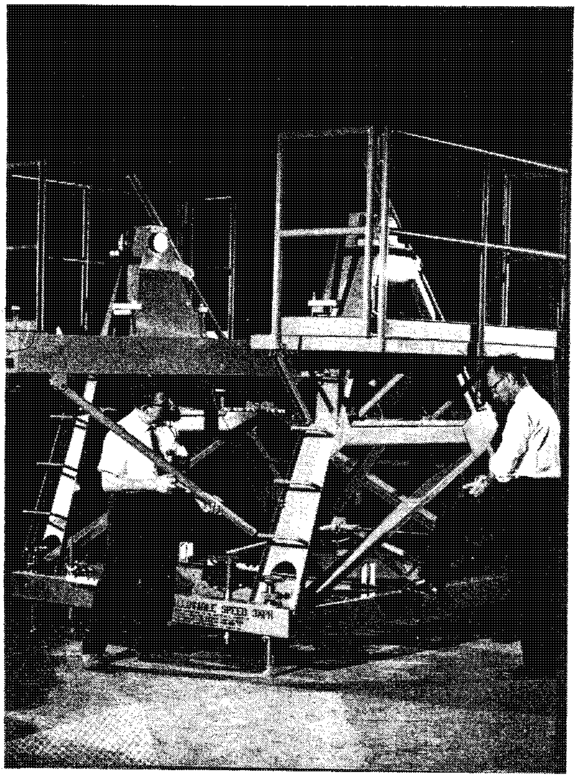
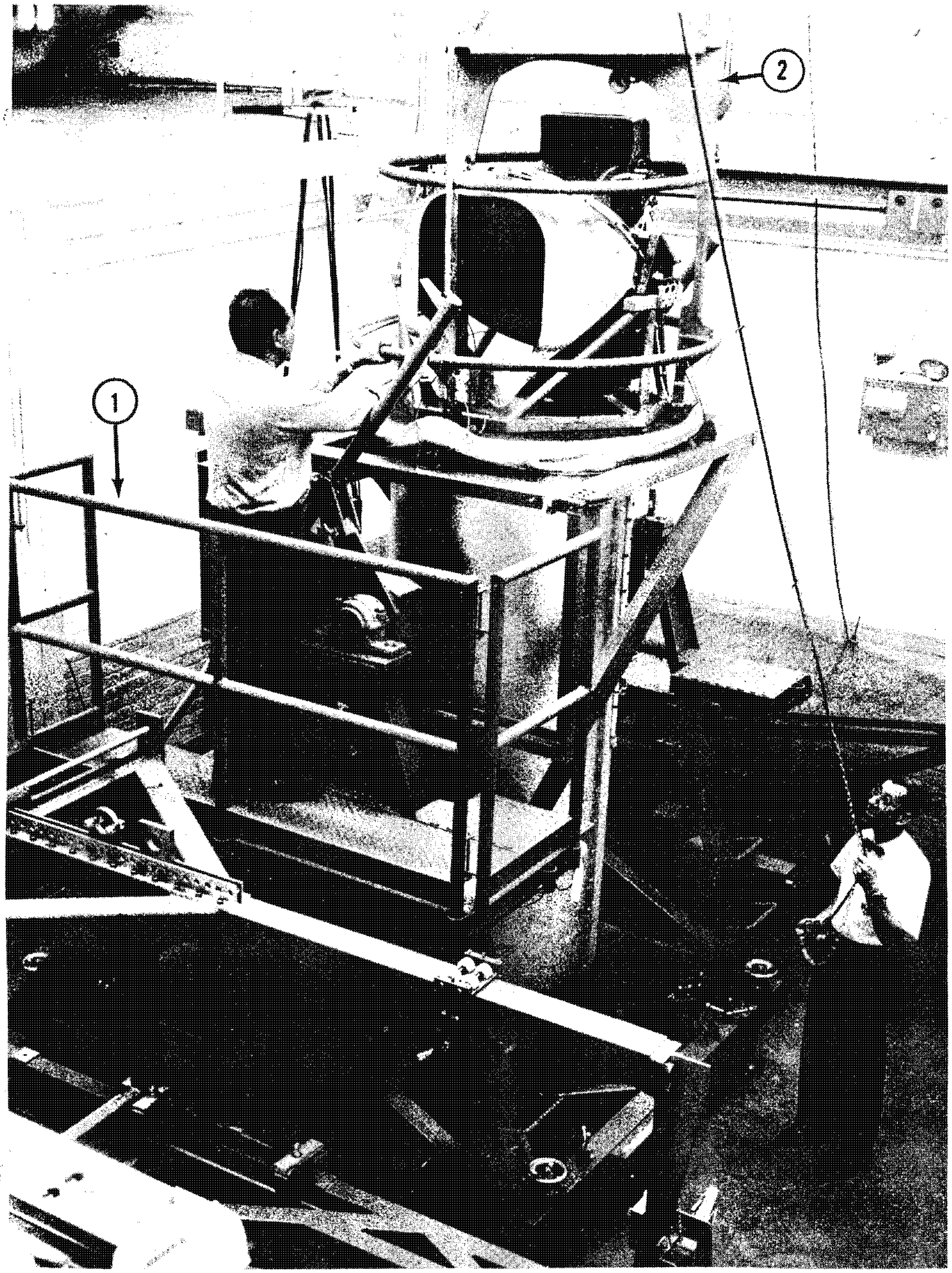


Figure 2-26. Erector



1. Erector 2. Integration Lifting Yoke

Figure 2-27. Integration Lifting Yoke and Erector

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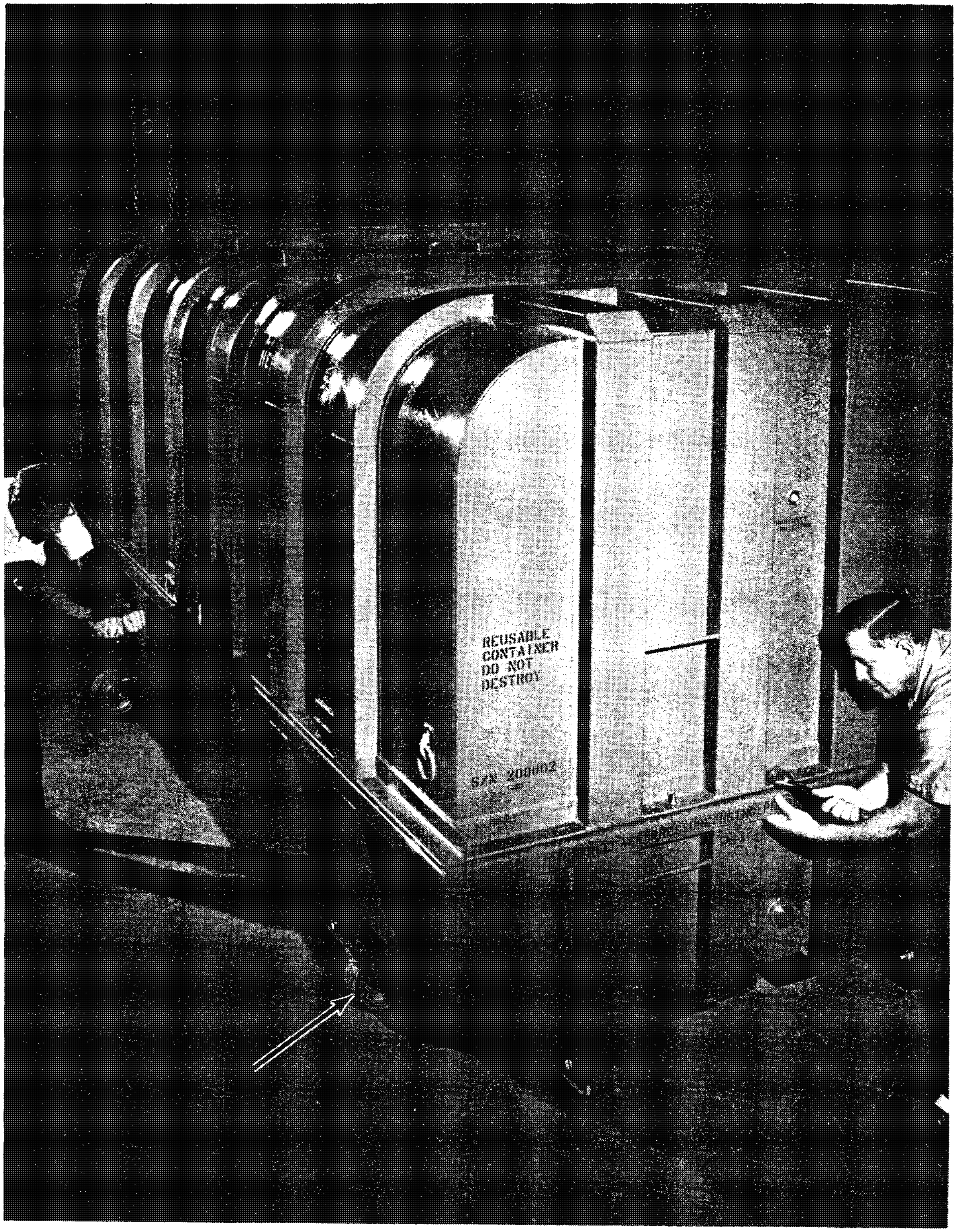

Figure 2-28. Payload Shipping Container

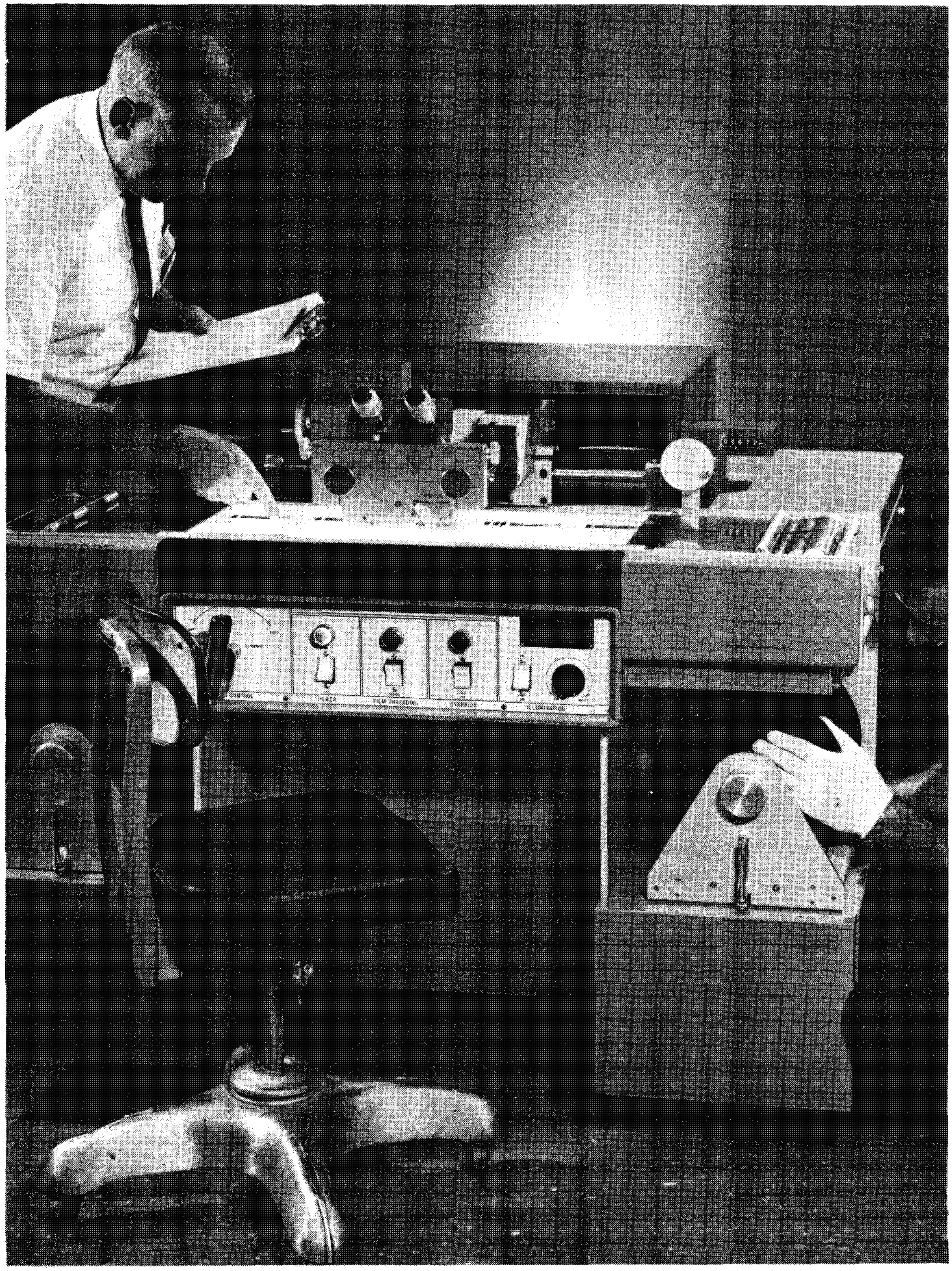

Figure 2-29. Record Viewer

SECTION 3
DESCRIPTION DIAGRAMS

3.0 GENERAL

This section provides a group of diagrams, accompanied by brief descriptions, that indicate the function and purpose of the elements of the C/P. Included are (1) a data flow diagram for the C/P, (2) electrical block diagrams, (3) schematics of the film handling, focus control, and cabling assemblies, (4) a thermal control diagram, and (5) a logic diagram of the film handling system.

3.1 PHOTOGRAPHIC RECORD AND DATA FLOW

Figure 3-1 is a block diagram of data and film flow through the C/P. It outlines the primary operations of the C/P without indicating components whose functions are secondary in nature.

The ground scene, reflected from the mirror to the 77-inch lens, is focused on the film through the slit aperture plate. The slit aperture plate also provides exposure control and permits the recording of fiducial marks. The ground scene image, fiducial marks, time data, slit identification streaks, and (through use of the smear slits) the total smear in the photograph, are recorded on the film. The time data record is optically recorded on the film by the use of electronically controlled light flashes (see Section 3.2). The spools in the film supply cassette and in the forward record storage assembly are mechanically isolated from the camera by the looper (see Sections 3.3 and 4.5). The double arrows from the camera to the looper to the forward record storage assembly represent the flow of the film with its photographically recorded data. A general description of the film format is given in Section 1.3.

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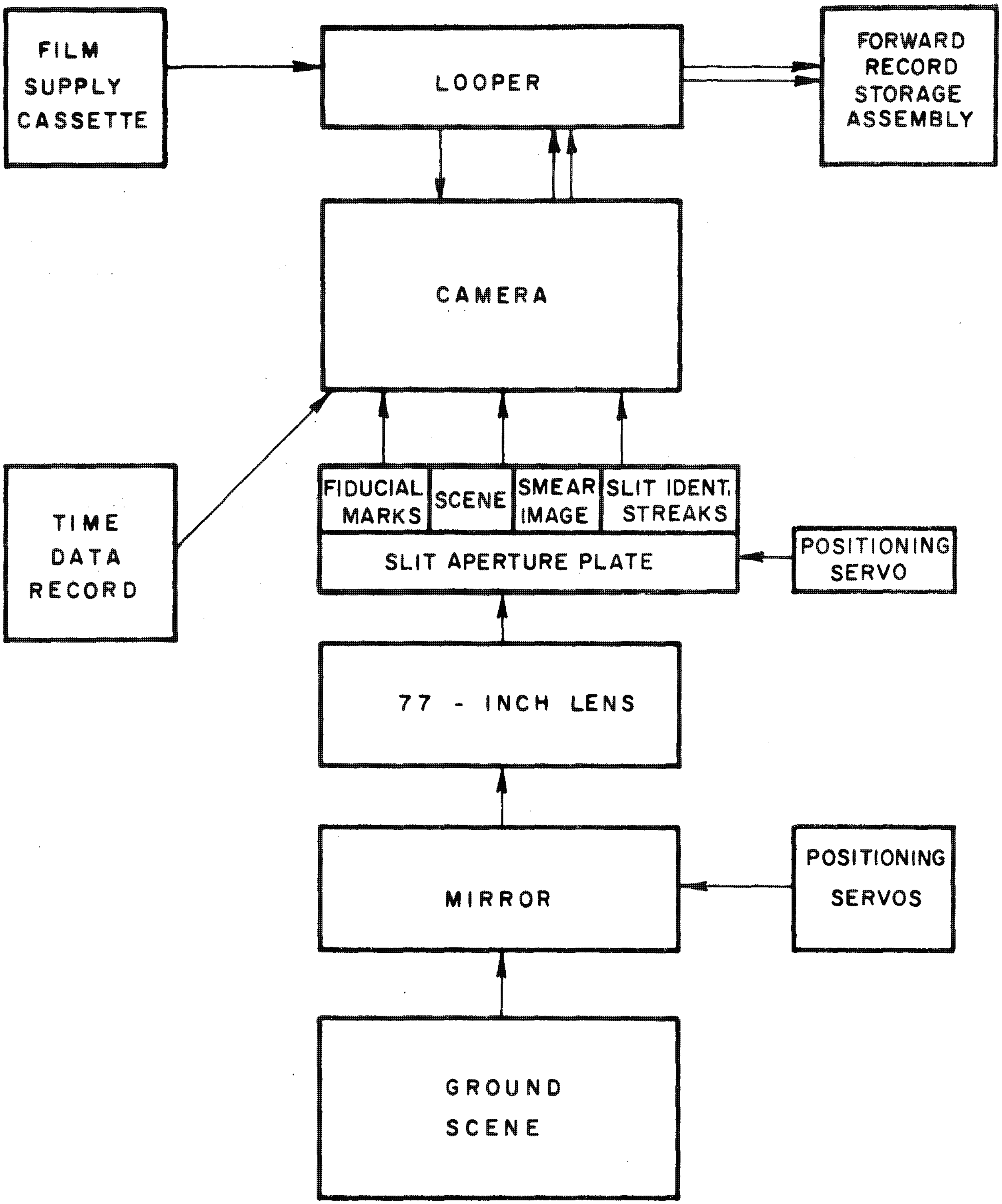

Figure 3-1. Camera Payload Record and Data Flow

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3.2 BLOCK DIAGRAMS OF THE C/P ELECTRICAL SUBSYSTEM

Detailed block diagrams of various configurations of the electrical portion of the C/P are shown in Figures 3-2, 3-3, 3-4, 3-5, and 3-6. As the diagrams show, each assembly receives two inputs: power and commands. Each assembly has a functional output. Only the electrical outputs have been indicated, with the realization that certain assemblies (such as the stereo servo assembly) have a functional output that is mechanical. Each assembly has a secondary output that indicates the operational status of the equipment and is referred to as instrumentation. The C/P electrical configuration used in FM's 1 and 2 is shown in Figure 3-2. Figure 3-3 shows the configuration for FM's 3 and 4, Figure 3-4 for FM 5, Figure 3-5 for FM's 6 through 12, and Figure 3-6 for FM 13 and subsequent payloads.

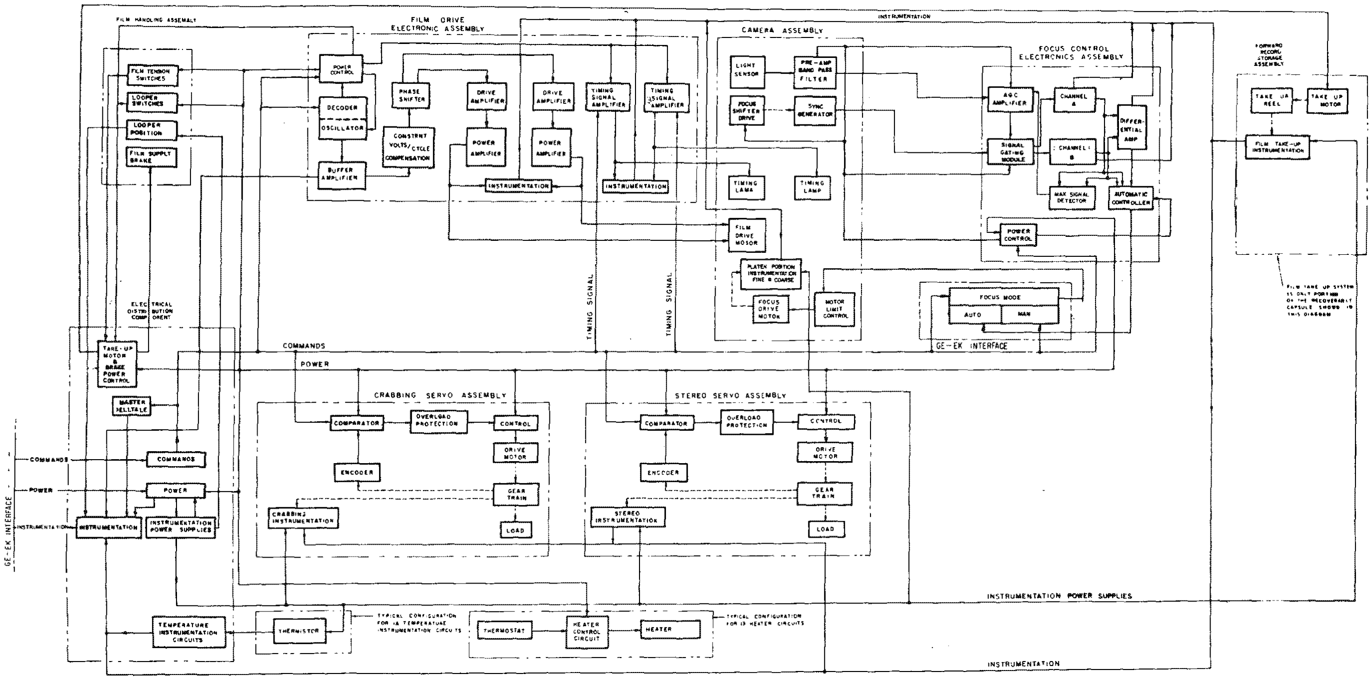

Figure 3-2. Electrical Block Diagram, Camera Payload (FM 1 and 2)

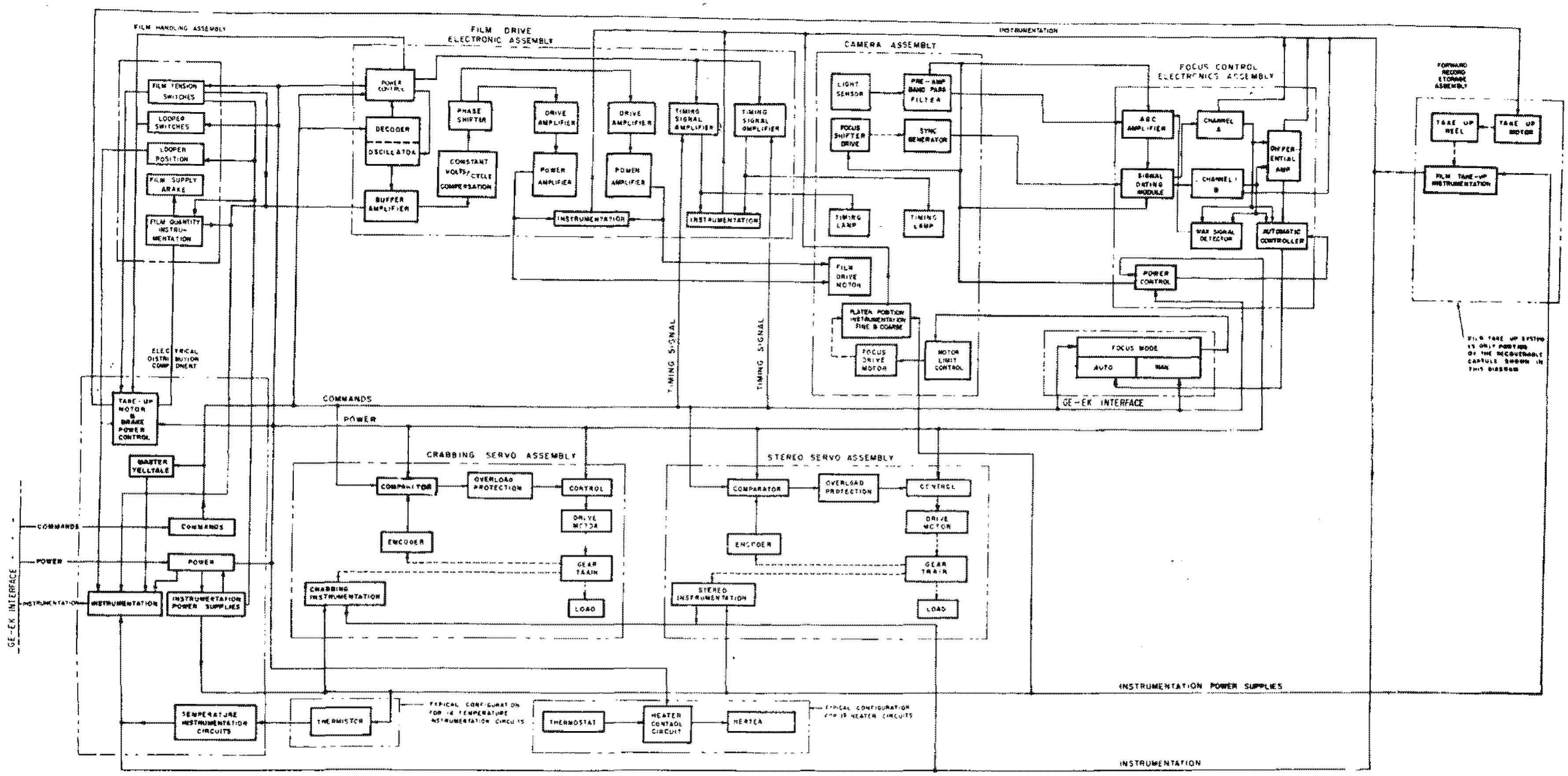

Figure 3-3. Electrical Block Diagram, Camera Payload (FM 3 and 4)

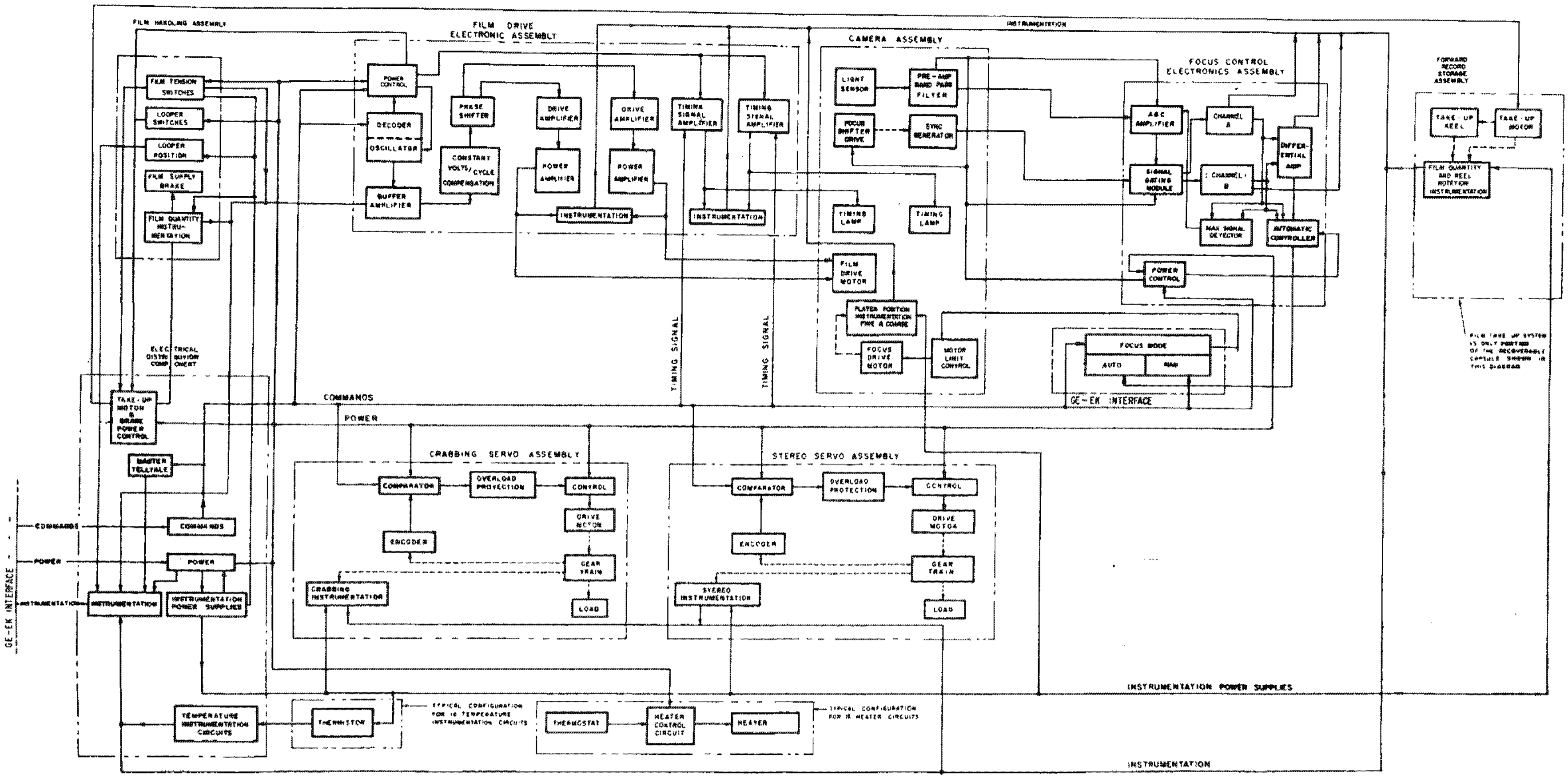

Figure 3-4. Electrical Block Diagram, Camera Payload (FM 5)

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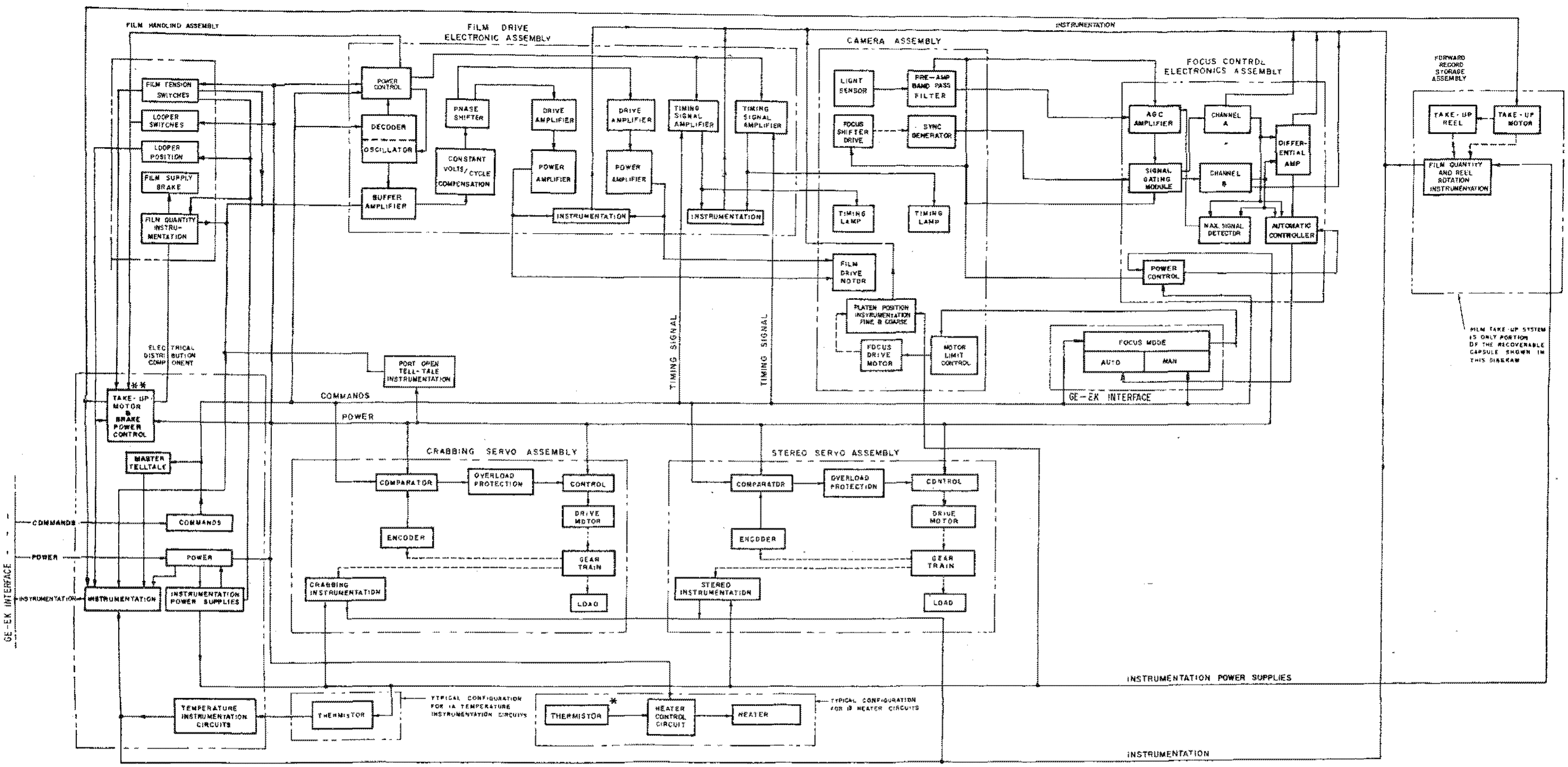
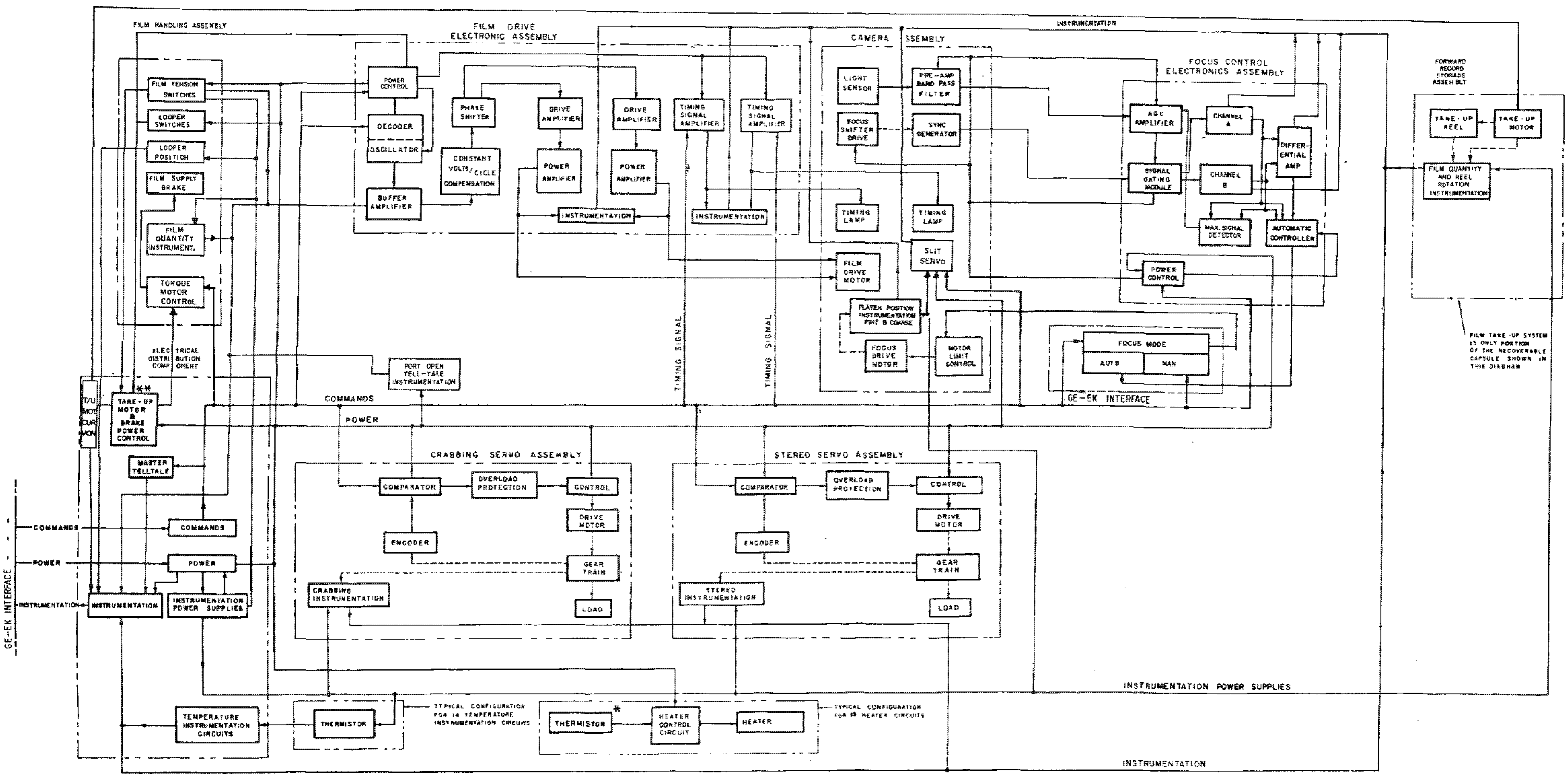


* FM-7 AND SUBSEQUENT P/L'S HAVE THERMISTOR PROBES
** FM-6 AND SUBSEQUNT P L'S HAVE T/U MOTOR CURRENT INSTRUMENTATION

Figure 3-5. Electrical Block Diagrams, Camera Payload (FM's 6 through 12)



* FM-7 AND SUBSEQUENT P/L'S HAVE THERMISTOR PROBES
** FM-6 AND SUBSEQUNT P L'S HAVE T/U MOTOR CURRENT INSTRUMENTATION

Figure 3-6. Electrical Block Diagram, Camera Payload (FM 13 and subsequent payloads)

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3.3 FILM HANDLING SUBSYSTEM SCHEMATIC

The film handling system is composed of 32 film-contacting rolling surfaces located within three separately mounted components. The components are the film supply cassette, camera, and forward record storage assembly. These components and the rollers are located as shown in Figure 3-7.

The following list identifies the components, subassemblies, and rollers associated with each subassembly in the C/P film handling system.

Each of the rollers identified with a given subassembly is aligned angularly with the other rollers in that subassembly. Each of the subassemblies is aligned angularly with the reference surfaces in its respective component. Both the film supply cassette and forward record storage assembly components are aligned with respect to reference surfaces on the camera.

Component	Subassembly	Rollers
Film Supply Cassette	Supply Spool	1
Film Supply Cassette	Looper Assembly	2,3,4,5,6 7,8,9,10,19, 20,21,22,23, 24,25
Film Supply Cassette	Guide Rollers	26,27,28
Camera	Guide Rollers	11,12,16,18
Camera	Damping and Isolation	13,15
Camera	Camera Platen	14
Camera	Camera Drive	17
Forward Record Storage	Displacement Compensation	29,30
Forward Record Storage	Guide Roller	31
Forward Record Storage	Take-Up Spool	32

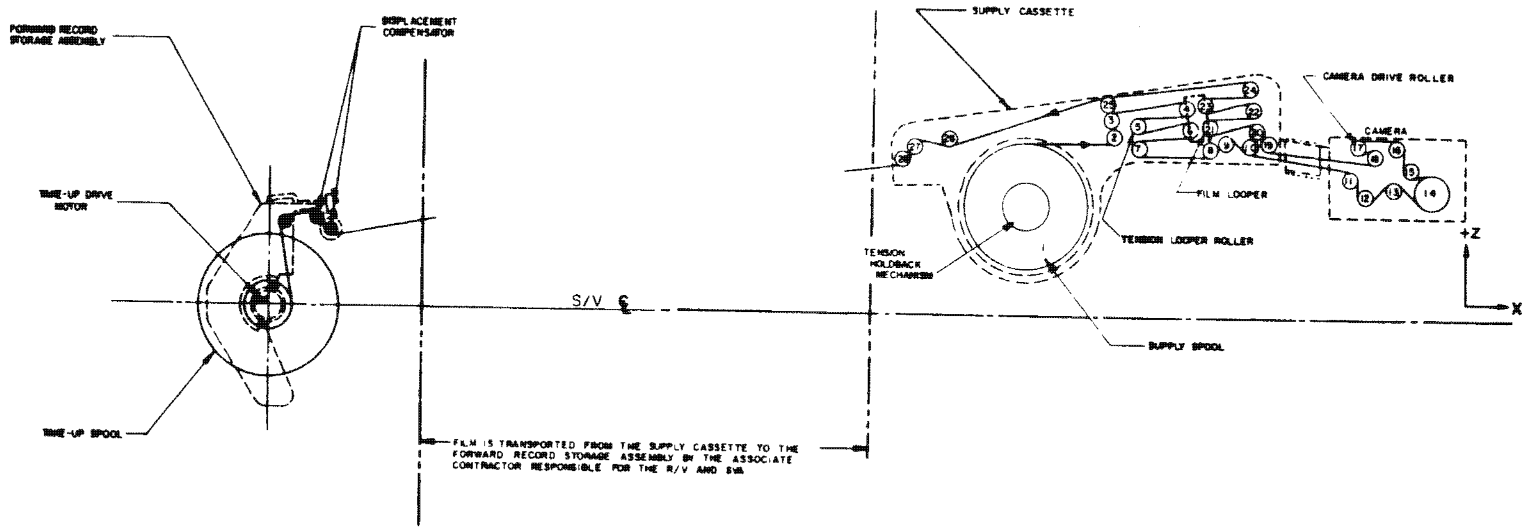

Figure 3-7. Film Handling Schematic

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The path of the film through the film handling assembly may be traced by following the sequence of the numbered rollers. The function and purpose of each of the rollers are indicated in the following list. By referring to Figure 3-7 and the following list, the detailed functions of the film handling system may be understood.

Roller	Description
1	Film supply spool. This spool stores the unexposed film for the C/P and supplies film to the film supply looper upon demand.
2	Tension sensor for supply-spool mechanical-servo brake.
3,7,8,9,10 19,20,22,24 25,27,28	Guide rollers. These rollers control film direction and position through the film handling system.
4,6,21,23	Movable rollers of film loopers. These rollers are attached to a movable truck in a track. Movement of the truck toward the camera will fill the camera supply-storage looper (film between rollers 3 and 7) and empty the camera take-up storage looper (film between rollers 19 and 24).
5	Tension roller. This roller pivots on a spring-loaded arm and maintains film tension in the film handling system. Switches mounted at the low-tension extreme of the tension-arm-travel operate the take-up motor and tension instrumentation when tension is lost.
11,12,16,18	Camera guide rollers. These rollers control film position and alignment within the camera.
14	Camera film platen. This roller controls the position of the film with respect to the slit aperture plate in the camera. The platen is positioned to ensure that the film passing the aperture slit is exactly at the focal plane.
26	Senses film quantity in supply cassette section of film handling assembly. Medium and fine ranges (0 -282 feet, 0 - 45 feet) used in FM 19 and subsequent payloads (see Section 4.5.3.5.1 for a listing of the ranges of these sensors).

Roller	Description
31	Guide roller which is also used to sense film quantity coarse in take-up cassette. Coarse range of 0 - 1017 feet used on FM 19 and subsequent payloads (see section 4.5.3.5.1 for a list of the ranges of this sensor).
13, 15	Camera isolation rollers. These rollers are mounted on pivot arms which are connected by a spring mechanism and individually damped by an oil-filled bellows arrangement. They attenuate the high-frequency film-velocity variation at the camera platen.
17	Camera drive roller. This roller is driven directly by the camera drive motor. It is Neoprene-covered and utilizes a greater than 180-degree wrap to drive the film.
29, 30	Displacement compensation rollers. These rollers provide compensation for any displacement or misalignment of the film that has occurred in the film handling system.
32	Take-up spool. This spool winds up the exposed film and stores it within the SRV until recovery and retrieval have been accomplished. In addition, magnetic pickups located in the core of the take-up reel sense reel rotation (FM 5 and subsequent payloads).

Film motion direction within each component is controlled by accurate angular alignment of the internal rollers The sidewise position of the film is not controlled except by the integrated effect of the angular alignment of the rollers. Except for the flanged roller in the displacement compensator (29), all rollers are wide enough to accommodate sidewise movement of the film base under all conditions of film wander.

Film motion direction between the film supply cassette and the camera is controlled by accurate angular alignment of the cassette reference surfaces with the camera reference surfaces. Film motion direction between the film supply cassette and the forward record storage assembly is controlled by the displacement compensator.

Accumulated angular misalignment of the film path is corrected at various points in the film handling system by the use of pivoted rollers followed by a wrap-angle controlling roller that also defines the corrected film path. The four pivoted rollers (8, 19, 27, 29) used for correcting angular misalignment of the film path are located as follows: before entering the camera, after leaving the camera, before leaving the film supply cassette, and after entering the forward record storage assembly.

3.4 C/P FILM HANDLING LOGIC

Figure 3-8 is a logic diagram of the film handling assembly. It details the condition and relationships between elements required for operation of the various portions of the film handling assembly. Some of the major relationships are:

1. Camera Start
   (a) When 28v dc is on, and
   (b) When camera drive command is given, or
   (c) Auxiliary record advance command is present (not used in flight, for MSB use only).
2. Take-up Motor Start
   (a) When 28v dc is on, and
   (b) Film tension is not present, or
   (c) Take-up side of looper is full, or
   (d) Take-up side of looper is not empty and camera is not on.
3. Torque-Motor Start
   (a) When torque motor command is given, or
   (b) 28v dc is on, and
   (c) When take-up motor is stopped.

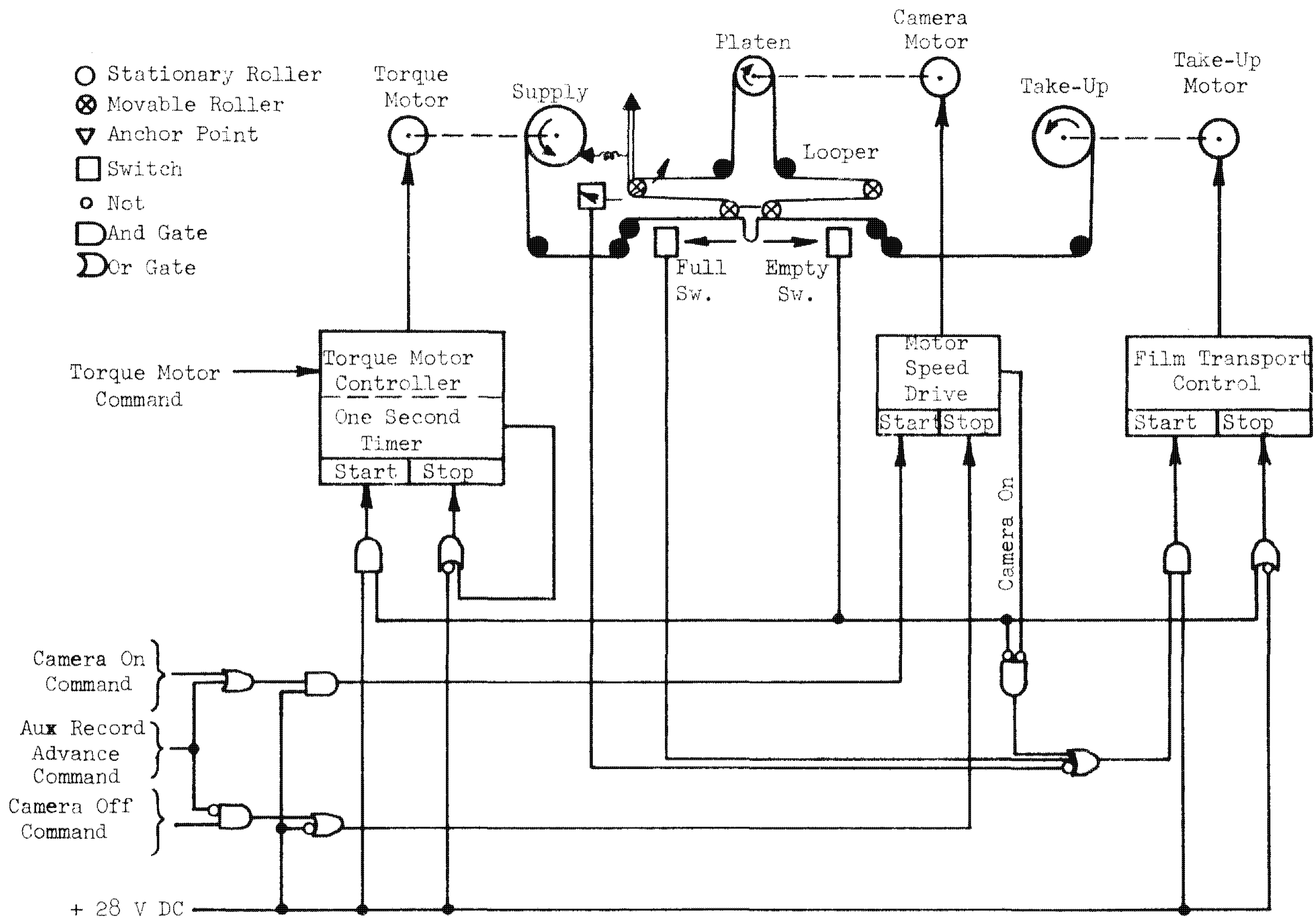

Figure 3-8. Camera Payload Film Handling Logic Diagram

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3.5 FOCUS CONTROL COMPONENT SCHEMATIC

Figure 3-9 shows a schematic of the focus control component. The mechanical and electrical elements are located either in the camera or in the focus control electronics package.

The 45-degree mirror is located near the camera optical axis and directs a small portion of the ground scene through a rotating focus shifter disk and onto the reticle and detector. Image movement across the reticle chops the ground scene, causing the detector to generate an amplitude-modulated signal. The focus shifter, by sequentially introducing two different thicknesses of glass into the optical path, causes the image to be alternately focused in two planes.

Since the image focal plane is changing as a result of the action of the focus shifter, two out-of-focus image conditions are alternately present at the reticle. The detector output therefore contains two signals on a time-shared basis. The signals are amplified, separated by the signal-gating module, integrated to produce a d-c level, and then compared in the differential amplifier. The difference signal can be monitored in real-time or via recorded data by an operator who then controls the platen position by direct commands to the focus drive motor. This signal can also be used in a closed loop mode whereby it controls the focus drive motor directly.

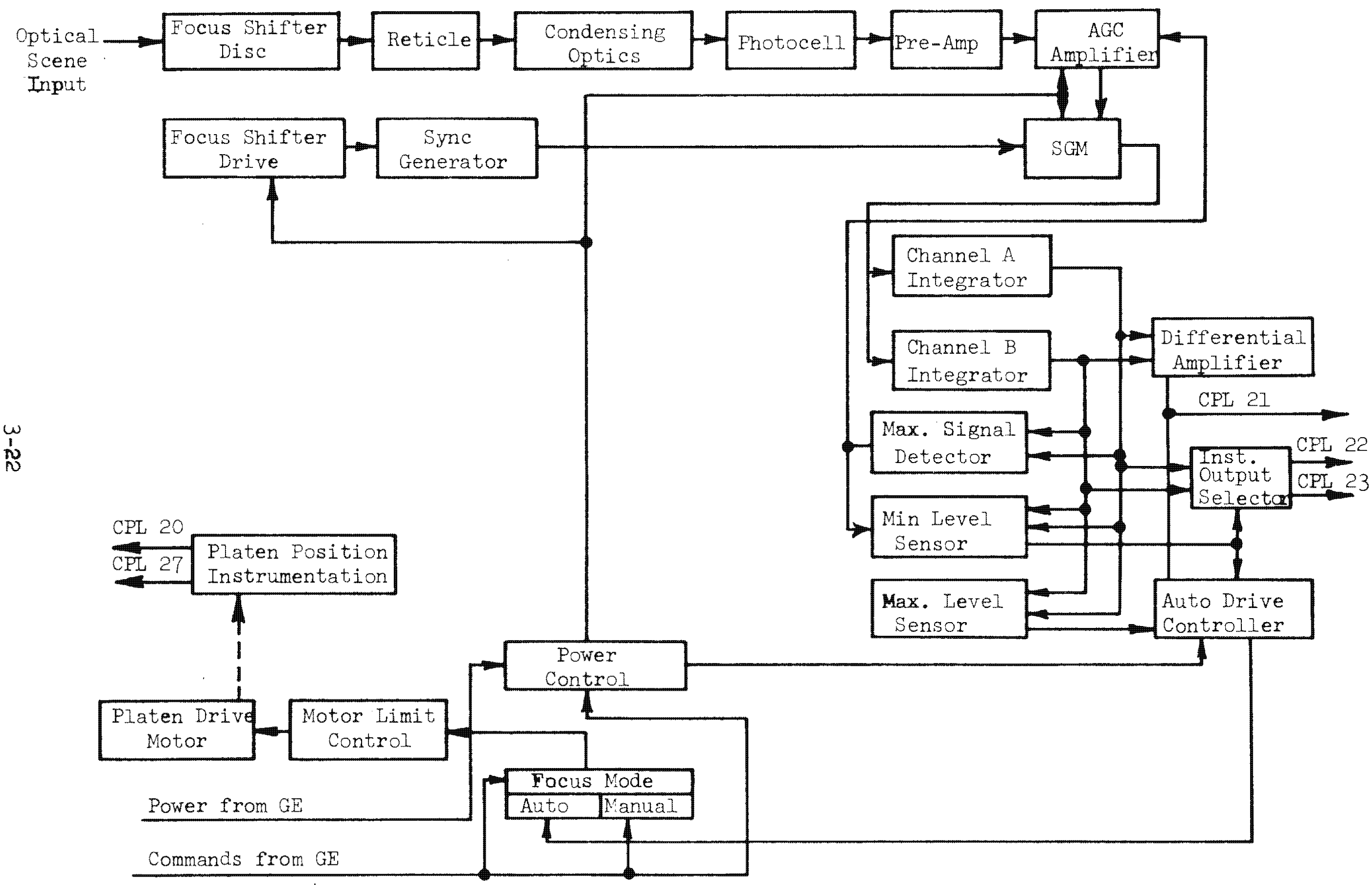

Figure 3-9. Camera Payload Focus System (Effective FM 23)

3.6 CABLING SUBSYSTEM SCHEMATIC

Figure 3-10 shows a schematic of the C/P cabling. This schematic shows the relationship of those components having electrical significance as well as the appropriate connector and cable identifications. Note that all connections which cross the SRV separation plane are provided by GE (the OCV-SRV Associate Contractor). All connectors are standard Bendix Pygmy connectors. The W-1 cable support bracket shown is considered part of the cabling assembly.

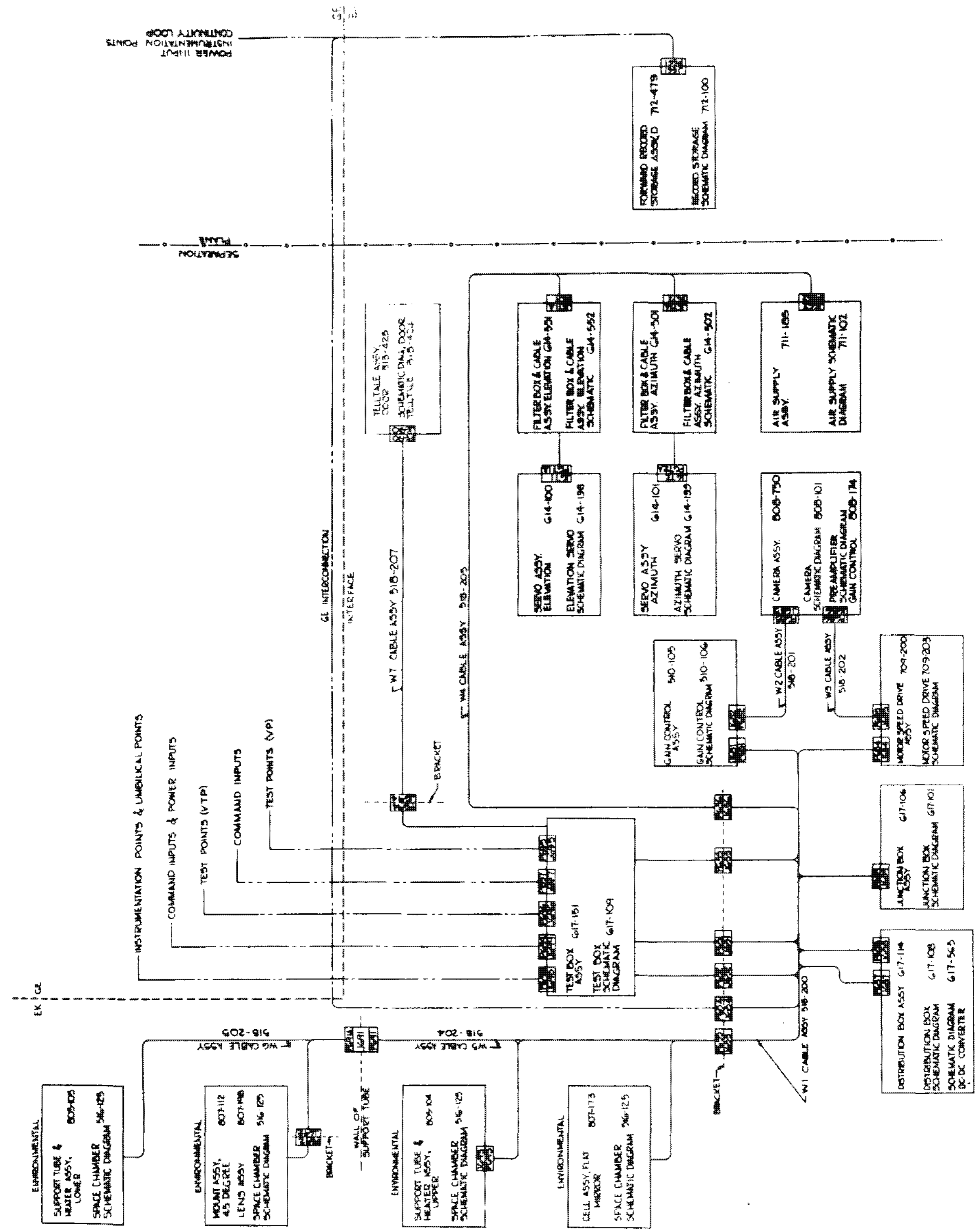

Figure 3-10. Cabling System Schematic

3.7 THERMAL CONTROL SUBSYSTEM SCHEMATIC

A schematic layout of the thermal control components is shown in Figure 3-11. This diagram shows the approximate location of the various elements. These include both thermal control and temperature instrumentation components. The numbered callouts are identified in Table 3-1. The heater powers shown in this table are specified at a nominal voltage of 29.5 volts dc. The thermistor probe temperatures specified are turn-on temperatures with turn-off temperatures as much as 0.6 F higher

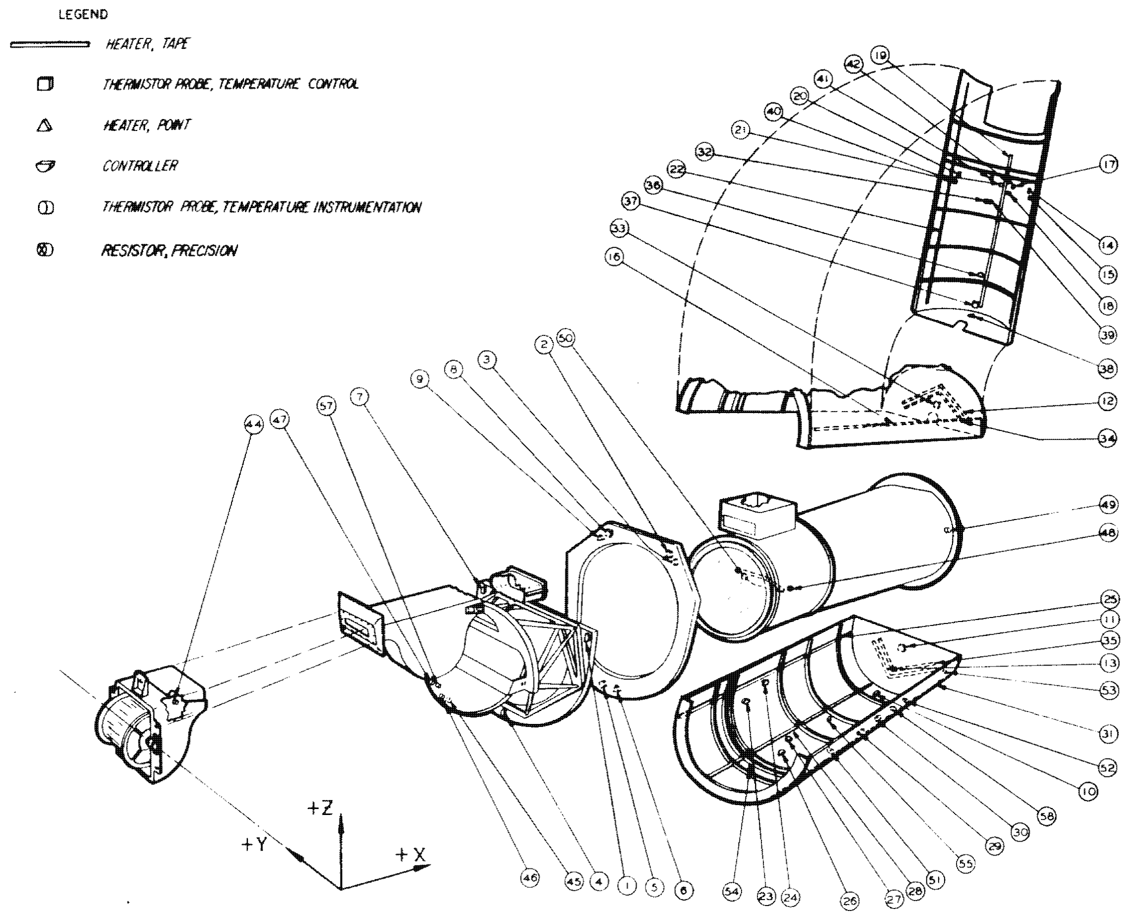

Figure 3-11. Thermal Control System Schematic

TABLE 3-1

THERMAL CONTROL SUBSYSTEM COMPONENT IDENTIFICATION

Item	Heater System Number	Component	Location
1	3	Heater Controller	Primary Structural Ring, -Y
2	3	Thermistor Probe 69.8 F*	Primary Structural Ring, -Y
3	3	Heater 5.0 W	Primary Structural Ring, -Y
4	4	Heater Controller	Primary Structural Ring, -Z
5	4	Thermistor Probe 69.8 F	Primary Structural Ring, -Z
6	4	Heater 5.0 W	Primary Structural Ring, -Z
7	5	Heater Controller	Primary Structural Ring, +Y
8	5	Thermistor Probe 69.8 F	Primary Structural Ring, +Y
9	5	Heater 5.0 W	Primary Structural Ring, +Y
10	6	Heater Controller	Component Support Tube, Rear -Z
11	6	Thermistor Probe 69.8 F	Component Support Tube, +X
12	6	Heater 2.5 W	Component Support Tube, Top, +X
13	6	Heater 2.5 W	Component Support Tube, Bottom, +X
14	10	Heater Controller	Component Support Tube, +Z
15	10	Thermistor Probe 69.8 F	Component Support Tube, +Z
16	10	Heater 5.0 W	Component Support Tube, +Z
17	11	Heater Controller	Component Support Tube, +Z
18	11	Thermistor Probe 69.8 F	Component Support Tube, +Z
19	11	Heater 5.0 W	Component Support Tube, +Z
20	12	Heater Controller	Component Support Tube, +Z

* Effective with FM 7, thermostats (controlling to 67.4 F) were replaced by thermistor probes (controlling to 69.8 F).

TABLE 3-1 (continued)

Item	Heater System Number	Component	Location
21	12	Thermistor Probe 69.8 F	Component Support Tube, +Z
22	12	Heater 5.0 W	Component Support Tube, +Z
23	13	Heater Controller	Component Support Tube, -Z
24	13	Thermistor Probe 69.8 F	Component Support Tube, -Z
25	13	Heater 5.0 W	Component Support Tube, -Z
26	14	Heater Controller	Component Support Tube, -Z
27	14	Thermistor Probe 69.8 F	Component Support Tube, -Z
28	14	Heater 5.0 W	Component Support Tube, -Z
29	15	Heater Controller	Component Support Tube, -Z
30	15	Thermistor Probe 69.8 F	Component Support Tube, -Z
31	15	Heater 5.0 W	Component Support Tube, -Z
32	16	Heater Controller	Component Support Tube, +Z
33	16	Thermistor Probe 69.8 F	Component Support Tube, Top, +X
34	16	Heater 2.5 W	Component Support Tube, Top, +X
35	16	Heater 2.5 W	Component Support Tube, Bottom, +X
36	17	Heater Controller	Component Support Tube, +Z
37	17	Thermistor Probe 69.8 F	Component Support Tube at Torsional Restraint Pin
38	17	Heater 5.0 W	Component Support Tube at Torsional Restraint Pin
39	18	Heater Controller	Component Support Tube, +Z
40	18	Thermistor Probe 69.8 F	Component Support Tube, +Z
41	18	Heater 1.0 W	Component Support Tube, +Z
42	18	Heater 1.0 W	Component Support Tube, +Z

INSTRUMENTATION COMPONENT IDENTIFICATION

Item	CPL No.	Description
43**	1	Camera Film Path Temperature
44	2	Forward Record Storage Temperature
45	3	Stereo Mirror Differential Temperature, Face Sensor
46	3	Stereo Mirror Differential Temperature, Back Sensor
47	4	Stereo Mirror Temperature
48*	5	Lens Barrel Differential Temperature, Forward Sensor
49*	5	Lens Barrel Differential Temperature, Aft Sensor
50	6	45-Degree Mirror Temperature
51	7	Component Support Tube Temperature, -Y, Sta 149
52	8	Component Support Tube Temperature, -Y, Sta 179
53	9	Component Support Tube Temperature, -Y, Sta 198
54	10	Reference Voltage
55	11	Component Support Tube Temperature, -Z, Sta 179
56**	24	Supply Cassette Film Path Temperature
57	EBT 3	Stereo Mirror Temperature (Hardline Data Only)
58	EBT 4	Component Support Tube Temperature, -Y, Sta 177 (Hardline Only)

(*) CPL-5 changed to "Lens Barrel Aft End Temperature" effective FM 13. To accomplish this, Item 48 was changed to a precision resistor. Item 49 is therefore CPL-5 for the current configuration.

(**) Eliminated, effective FM 16

SECTION 4
COMPONENT DATA

4.0 GENERAL

This section describes the C/P component design including structure, optics, camera, focus control, film handling, aiming mechanism, environmental control, and the related power and instrumentation circuitry. These components are located in the OCV except for the forward record storage assembly which is located in the SRV. This description includes the function, design, and principal parameters of these components. Any modifications scheduled for use in later flight units will also be described whenever possible. In addition, this section includes a description of various supporting equipment, generally known as Aerospace Ground Equipment (AGE).

4.1 STRUCTURE

The C/P structure establishes the position of and supports for the major components and assemblies of the payload such as the lens, stereo mirror, camera, and film handling assembly. The structure allows the C/P to be mounted so as to fulfill alignment requirements. It also provides the support for the stereo and crab positioning mechanisms. (Sections 2 and 3 contain photographs and drawings of the structural components.) The structure also minimizes the effects on the C/P of satellite vehicle bending.

4.1.1 Structural Assemblies

The structure consists of the following assemblies:

a. Payload socket mounting ring assembly
b. Primary structural support ring assembly
c. Component support tube assembly
d. Spherical bearing housing assembly
e. Stereo mirror support assembly

4.1.1.1 Payload Socket Mounting Ring Assembly. This assembly provides the main support and mounting surfaces between the C/P and the OCV. It is bolted to the OCV (at station 125.25) through three equally spaced holes at a radius of 25.25 inches. This ring assembly also contains three equally spaced spherical mounting pads which form the socket portion of a ball and socket joint. The purpose of this joint is to minimize the external forces which are applied to the payload package (see Figure 2-10).

4.1.1.2 Primary Structural Support Ring Assembly. This assembly provides the main structural support and reference surfaces for the C/P. Also provided are the three spherical pads which form the ball portion of the ball and socket joint formed by this assembly and the payload socket mounting ring. The support ring carries all longitudinal and some lateral loads imposed on the C/P by environmental conditions, and transfers these loads through the ball joint described in paragraph 4.1.1.1 It also provides mounting surfaces for the stereo mirror support assembly, the 77-inch lens, the component support tube, and the film supply cassette. The mounting surface provided for the 77-inch lens (station 121.75) is also used as the primary C/P reference surface (see Figure 2-10).

4.1.1.3 Component Support Tube Assembly This assembly surrounds the lens and camera assembly except in the area of the optical path. The functions of the tube assembly are: (1) to provide support for film-drive electronics, focus control, and electrical component boxes, (2) to provide thermal protection for the lens and camera by acting as a radiation shield and thermal shunt to minimize temperature gradients, and (3) to provide structural stiffening for the lens barrel. The ends of the tube assembly are thermally grounded to the lens and to the structural components. The highly reflective surfaces aid in maintaining an even heat distribution (see Figure 2-8). A removable cover is provided for access to the camera. One end of the component support tube is supported by the primary structural support ring assembly and the other end of the tube is attached to the aft end of the lens (see Figures 2-2 and 2-3).

4.1.1.4 Spherical Bearing Housing Assembly. This assembly is attached to the OCV just aft of the 77-inch lens. It provides an interface mounting point between the C/P and the OCV bulkhead at station 210.5. All environmentally produced lateral loads not borne by the primary structural ring are supported and transferred to the OCV bulkhead by the spherical bearing housing. This housing contains a uni-ball bearing which engages with a stud on the aft end of the lens to transfer lateral loads to the bulkhead without imposing bending moments on the lens tube.

4.1.1.5 Stereo Mirror Support Assembly. The assembly consists of a main structural support, crabbing bearing tracks, a stereo-mirror crab pivot, stereo-mirror pivot-bearing blocks, and mounting surfaces for the stereo and crab control and drive assemblies. It also provides mounting surfaces for the forward end of the film supply cassette assembly. Under gravitational loading, this assembly is capable of maintaining the Y or pivot axis of the stereo mirror parallel to the plane of the reference surface of the primary structural support within 0.010 inch over the length of the pivot axis (see Figures 2-10, 2-11, and 2-12).

4.1.2 Component Mounting

4.1.2.1 77-Inch Lens. The 77-inch lens is rigidly attached at its forward end to the primary structural ring. This mounting restricts the lateral and longitudinal movement of the lens. The aft end of the lens contains a stud that engages with the uni-ball bearing of the spherical bearing housing, an arrangement that provides lateral support for the lens, but allows freedom for differential longitudinal movement. The spherical bearing housing and lens stud is also the aft mounting support for the C/P (see Figure 2-7).

4.1.2.2 Stereo Mirror. The stereo mirror assembly is mounted to the stereo-mirror support by means of bearing blocks supported on a movable bridge. This mounting arrangement allows the mirror two degrees of freedom for controlled movement about the optical stereo and crab axes. Stereo movement is achieved by rotating the mirror in the bearing blocks about an axis parallel to the ± Y axis (at 0-degree crab angle). The movable bridge is pivoted at one end and moved in bearing tracks at the other end by the crab-servo lead-screw mechanism to achieve crabbing movement. It is designed so that the pivot point and the crab-servo attachment can be interchanged; therefore, either positive or negative rotations can be obtained. The capability of moving through the range of 0 to -3.5 degrees or 0 to +3.5 degrees must be selected prior to final subsystem tests at the MAB. This movement of the bridge physically occurs about an axis parallel to the vehicle X axis, but optically represents crab movements about the Z axis (see Figures 2-10, 2-11, and 2-12).

4.1.2.3 Camera. The camera is aligned and rigidly attached to the lens barrel. The mounting pads used for camera attachment are shown in Figure 2-7. For illustrations of the interior and exterior construction of the camera, see Figures 2-13, -14, and -15.

4.1.2.4 Electronics Packages. The component support tube is the support structure for the electrical-distribution component boxes, the film-drive electronics package, and the focus control box. These boxes are thermally and electrically grounded to the component support tube (see Figure 2-4).

4.1.2.5 Servo Mechanisms. The stereo servo is mounted to the bridge portion of the stereo-mirror support and moves in crab with the mirror and bridge assembly. The crab servo is mounted to the truss portion of the stereo mirror support assembly. Each of these servos is mounted on a pivot bearing. This mounting method allows the servo and lead-screw mechanism to follow the motion of the mirror. Bending moments in the lead screw are thereby avoided. A secondary effect of this mounting arrangement is to convert the linear movement of the lead screw to an approximately linear rotational movement of the mirror (see Figure 2-12).

4.1.3 Payload Mounting

As described previously, several of the structural elements are used to support the C/P in the OCV. The main design goal of the mounting arrangement used is to isolate the C/P from the OCV with regard to both mechanical strain and thermal conduction. The strain isolation is achieved through the use of ball and socket joints at both ends of the C/P. This allows the OCV structure to bend, within limits, without exerting any significant forces on the C/P. Such bending of the OCV may occur because of residual stresses caused by assembly in a gravitational environment, loads imposed during launch, and orbital thermal distortions. In additon, although the ball and socket joint at the forward end supports the C/P both laterally and longitudinally, the aft spherical bearing assembly incorporates a longitudinal slip joint that allows the C/P and OCV to expand and contract in length independently. Roll motion of the C/P within the OCV is restricted by a torsional stop pin which engages with the OCV bulkhead at station 209.37 (see Figures 2-1 and 2-3). The total mounting arrangement of the 77-inch lens can be thought of as a suspension between two universal (ball and socket) joints with lateral support at each end and longitudinal restriction at only one end. The forward universal joint is formed by the payload socket mounting ring assembly and the primary structural support ring assembly and has a rotational capability of 0.2 degree. The aft joint contained in the spherical bearing housing assembly can permit differential rotation greater than 5 degrees and a 0.5-inch longitudinal expansion or a 0.19-inch longitudinal contraction of the OCV.

Thermal conductive isolation is achieved through use of fiber glass epoxy insulation inserts at the forward mounting points and a Delrin housing for the aft spherical bearing assembly. In addition, the thermal isolation of the lens from the OCV is achieved through the attenuation of radiation by the component support tube and S/V insulation.

4.1.4 Weight and Balance

4.1.4.1 Reference Axes. Vehicle fixed-axis designations and nomenclature are as follows (see Figure 4-1):

Roll Axis	X -	The longitudinal axis of the vehicle; negative in the direction of the SRV.
Yaw Axis	Z -	This axis is perpendicular to the roll axis and parallel to the C/P nominal line of sight and negative in the direction of the earth.
Pitch Axis	Y -	This axis is defined by the right-hand rule and is perpendicular to both yaw and roll axes.

All positive rotations are in a right-hand sense.

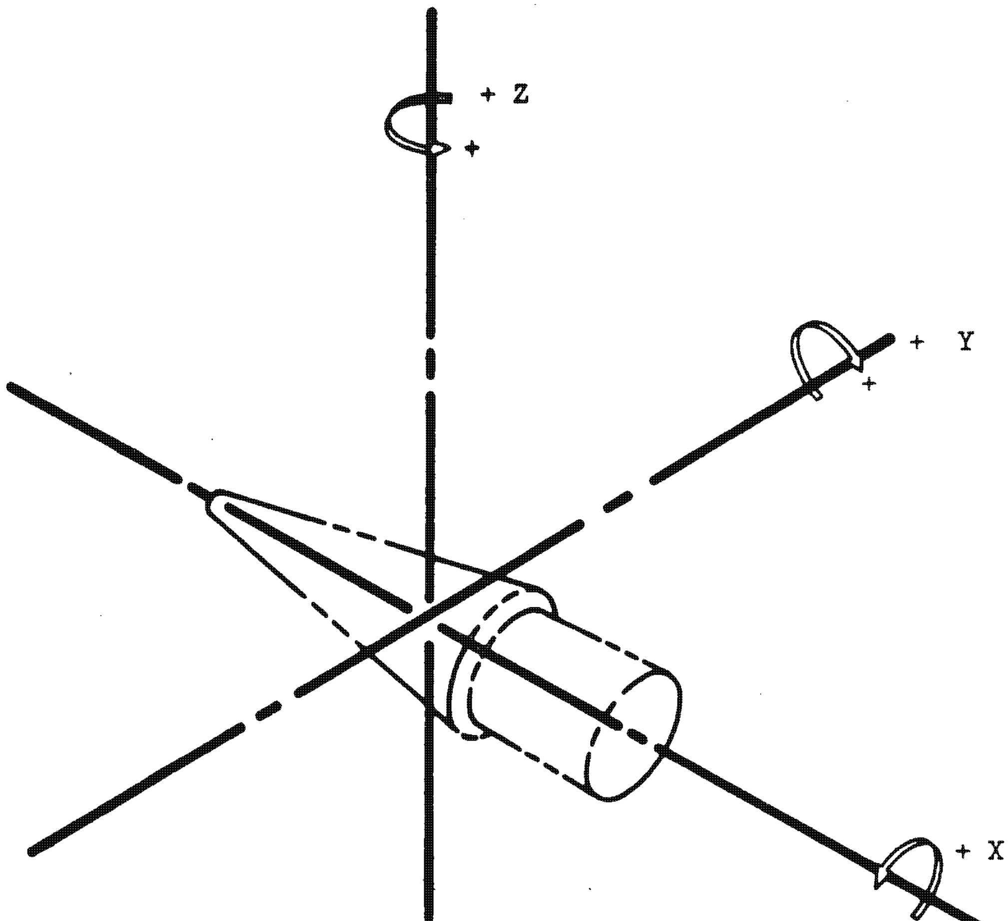

Figure 4-1. Designation of Reference Axes

4.1.4.2 Data Requirements. Weight, center-of-gravity location, and moments and products of inertia are of importance in a satellite. Prior to shipment from EKC, Rochester, the weight of each C/P is determined within one percent. Maximum weight allocation for the C/P flight hardware is 1159 pounds, ± 2 percent.

To achieve the location accuracies required for the S/V, the center-of-gravity of the C/P must be precisely located. A goal was established to position the center-of-gravity of all C/P's within 0.5 inch of the geometric X axis of the S/V. The precise location of the center-of-gravity of each C/P must be known more closely. Prior to shipment from EKC, the center-of-gravity of each C/P is measured to ±0.05 inch in the radial direction and to ±0.10 inch in the longitudinal direction. A table showing computed center-of-gravity locations and weights for the various C/P components and a summary of the totals, as of 1 June 1965, is given in Appendix A. There are no specifications for the moments and products of inertia of the C/P; however, their magnitudes are obtained by calculation, and are tabulated in Appendix A.

4.2 C/P OPTICAL DESIGN

4.2.1 General Requirements

The fundamental design objective of the C/P is to photograph, from an orbiting satellite, ground scenes with a maximum of detail. A second requirement is to minimize the size and weight of the C/P. To accomplish these objectives, the lens used must approach diffraction limitations.

4.2.2 Lens Aperture

The diameter of the lens aperture required is determined by the altitude from which the lens is to be used and the minimum ground dimensions to be resolved. The altitude and the minimum ground dimension establish an angular resolving power requirement. Angular resolving power of a perfect lens is a function of the lens aperture and the wavelength of the light to be focused and is:

$$\underset{\text{(high contrast)}}{\text{Angular resolution}} = \frac{C\lambda}{D}$$

where D is the diameter of the lens aperture, λ is the wavelength, and C is a constant depending on the criterion used to determine resolution (C = 1.22 in the case of the Rayleigh criterion). The most efficient aperture, in terms of size and weight, is an aperture just large enough to resolve the size object required where the theoretical minimum aperture for the lens alone is given by the above expression.

In actual design, the lens aperture is always larger than this theoretical minimum to allow for loss of resolution as a result of geometrical aberrations, target contrast, and effects of other elements. The minimum aperture diameter capable of meeting the resolution requirements of this system is 19.25 inches. To guarantee that this minimum aperture will be obtained after assembly, the lens is designed with an aperture diameter of 19.50 inches.

4.2.3 Focal Length

The focal length of the lens is determined by the desired relationship or scale between the ground and image size. The optimum focal length is found by applying sine wave response techniques to determine the ground resolution for a range of focal lengths, each having a 19.25-inch effective aperture. Based on such a study, a 77-inch focal length is considered optimum under ideal conditions for photography with Kodak Type 3404 Film or its equivalent.

4.2.4 Relative Aperture and f-Number

Relative aperture is defined as the ratio of the diameter of the effective aperture (entrance pupil) to the focal length of the lens. This ratio, together with the transmittance of the lens, determines the illumination of the image or the speed of the lens. The notation most commonly used to indicate the relative aperture or speed of a lens is the f-number, written as f/4, where the f-number (4) is the reciprocal of the relative aperture. Thus, as the relative aperture increases, the f-number decreases, and speed of the lens increases.

The f-number of the lens used (aperture = 19.50 inches) is 3.95 (or f/3.95).

4.2.5 T-Number of Optical System

The f-number as defined in paragraph 4.2.4 must be combined with the lens transmittance (t) when used for exposure calculations. The lens speed is stated in terms of a T-number which is defined as follows:

$$\text{T-Number} = \frac{f\text{-number}}{\sqrt{t}}$$

The transmittance is determined photometrically and therefore takes into account all light losses including those attributable to obstructions in the aperture and the spectral absorption of filters. Measurements of the transmittance of the C/P optical system indicate that approximately 38 percent of the incident light flux will be transmitted to the film plane. This transmission of the lens is limited by the yellow filter (B and L Type Y-10) to wavelengths longer than 500 mμ. Therefore, the

$$\text{T-Number} = \frac{3.95}{\sqrt{.38}} = 6.4$$

4.2.6 Lens Type

The lens used is a Maksutov-type lens and has the advantage of using only spherical surfaces. It is a 77-inch focal length f/3.95 lens with a half field angle of 3.2 degrees. The depth of focus is ±0.0005 inches at the image plane. The optical system is shown schematically in Figure 4-2.

4.2.7 Image Quality and Lens Accuracy

The quality of the image produced by the lens was demonstrated by photographic resolution tests performed on the lens by itself and as an integral part of a C/P. Sine-wave response techniques, described in paragraph 1.2.6.2, are used to relate these resolution measurements to the predicted theoretical performance of the lens.

To achieve the required image quality, the optical elements are precisely located and mounted to prevent distortion of lens and mirror surfaces. The lens must maintain the best focus position within ±0.0005 inch*, or excessive loss of resolution will result. To maintain this critical focus position throughout the mission, temperatures and temperature gradients are controlled within narrow limits. Careful consideration was also given to the lens mounts and to the choice of materials used in the lens components.

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* This value was determined from calculations based on criteria that included film response, film process control, and the manufacturability of the lens formula.

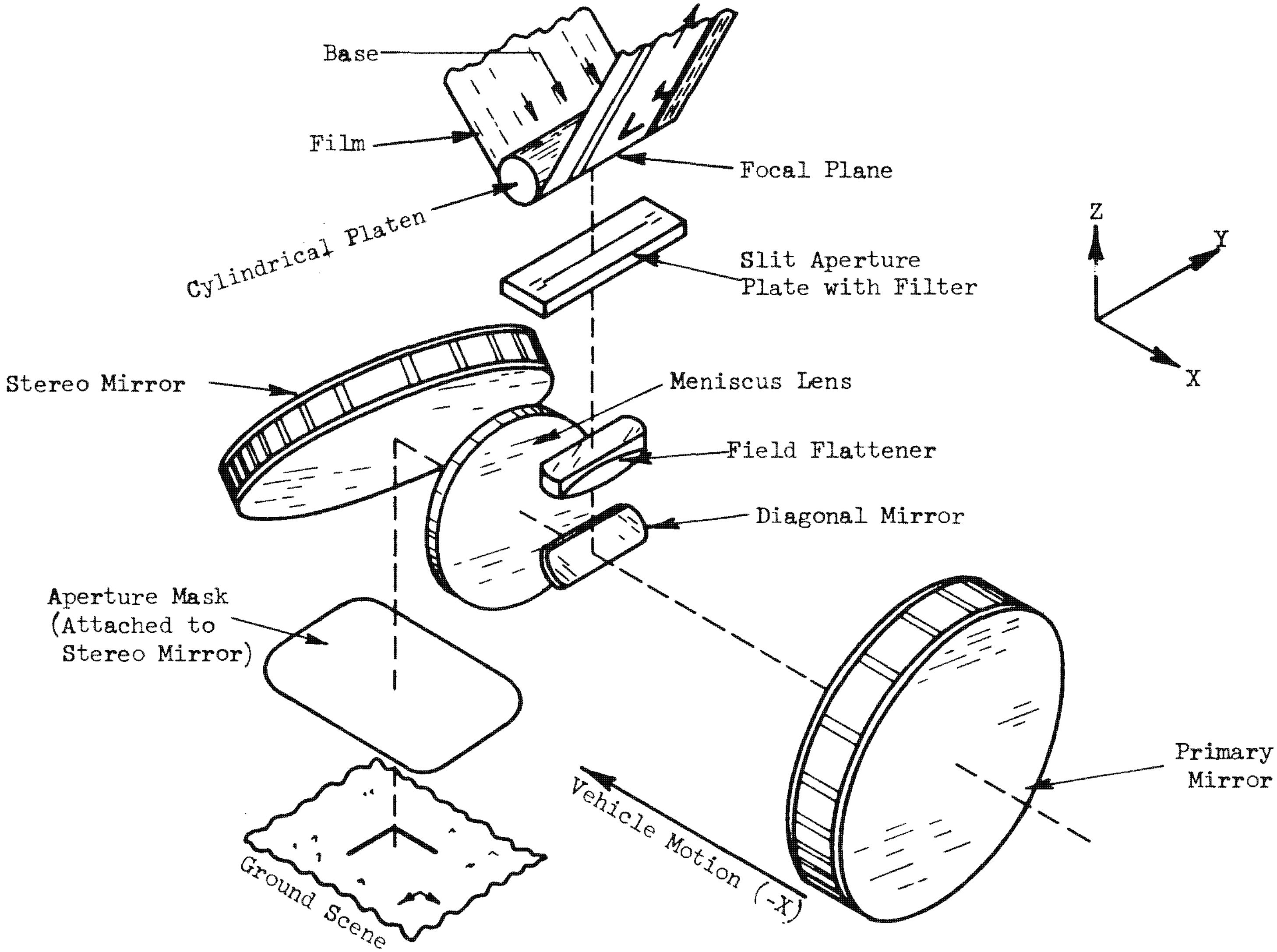

Figure 4-2. Expanded Schematic of C/P Optical Components

4.2.8 Lens and Mirror Elements

The elements of the optical assembly include both mirrors and lenses. In the order that a light ray passes through the optical assembly, these elements are: the stereo mirror, the meniscus lens, the primary mirror, the diagonal mirror, and two lens elements which make up the field-flattener.

4.2.8.1 Stereo Mirror. The stereo mirror is a 1/10 λ plano mirror which is mounted in front of the lens assembly. It reflects light from the target into the main lens assembly. The stereo mirror can be positioned for either vertical or stereo photography and is also rotated to the correct crab angle (see Figures 2-7, 2-11, and 2-12).

4.2.8.2 Meniscus Lens. The meniscus lens is a concave-convex element with very little optical power. This lens is used to correct the spherical aberration produced by the primary mirror. At the level of performance required of this lens system, the quality of the meniscus has a very significant effect.

4.2.8.3 Primary Mirror. The primary mirror is a first surface 1/10 λ spherical mirror, the rear surface of which is made parallel to the front to aid thermal and structural stability. The primary mirror alone has a focal length of approximately 84 inches. This mirror provides the principal focusing action in the 77-inch lens assembly.

4.2.8.4 Diagonal Mirror. The diagonal mirror is a rectangular flat mirror mounted in the center of the lens barrel on a hub supported by tubular Invar arms welded to the front of the lens barrel. The diagonal mirror reflects the light coming from the primary mirror through a 90-degree angle to direct the light rays into the camera.

4.2.8.5 Field Flattener. The field flattener consists of two lens elements in a cell near the film plane. As the name implies, a flat image plane is produced. Chromatic aberrations are also corrected by the field flattener elements.

4.2.9 Flare Light

Baffles are incorporated in the Invar lens barrel and the field-flattener assembly to shield the focal plane from stray light. Experience with previous lenses of similar design indicates that the amount of extraneous light should not exceed 1.5 percent of total light.

4.2.10 Image Orientation and Film Motion

The ground-scene image undergoes a complete inversion as it passes through the lens assembly. This simply means that the ground scene is inverted in the Y plane. Because several changes in orientation of the image are involved, Figure 4-2 is included to illustrate the relationship between the initial ground scene and the final image recorded on the film.

4.3 CAMERA DESIGN

4.3.1 Design Requirements

The function of a camera is to provide controlled exposure of the film on which the image is to be recorded. To do this, the camera must hold the film in the image plane and control the time of exposure. An additional requirement for cameras used in moving vehicles such as satellites is the provision to move the film in synchronism with the image of the scene during exposure.

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This provision is necessary to prevent smearing of the photographic image because of the high speed of a satellite with respect to the ground scene. An external structure is also included as part of the camera assembly to provide a lighttight enclosure for the camera mechanism. Figures 2-13, 2-14, and 2-15 are photographs of the camera.

4.3.2 Camera Type

The camera is a strip-type, which continuously exposes a narrow strip across the film as the camera passes over the area being photographed. The image is focused through a slit aperture onto a moving strip of film. The exposure time is determined by the width of the slit and the speed at which the film moves past the slit.

The film is held firmly on a cylindrical drum (platen) whose diameter (4.625 inches) is large enough to provide the necessary film flatness in the narrow area behind the slit. The velocity of the film is changed to match the image motion.

The field of the lens covers the width of the photograph only. Because lens aberrations increase rapidly with field angle, the strip camera performance over a given format will be better than the performance of the frame-type camera whose lens must cover the diagonal of the field.

4.3.3 Film Platen and Drive

The film is wrapped nearly around the platen and moved at a constant rate past the slit. Mechanical power to move the film through the camera is supplied to a film drive roller by a hysteresis-synchronous motor, whose speed is controlled by the film-drive electronics.

The roller arrangement within the camera is shown schematically in Figure 4-3. The neoprene-covered drive roller (roller 7 in Figure 4-3) is driven by the synchronous motor through a gear box. Film drive without slippage is ensured by a wrap of approximately 210 degrees around the drive roller. The damping rollers (3 and 5) are mounted on pivot arms and are connected by a spring mechanism to attenuate the high-frequency film-velocity variations at the platen. Damping is provided by a fluid-filled bellows assembly coupled to the pivot arms. The other rollers (1, 8, 2, and 6) are idler rollers that guide the film into and out of the camera and provide correct film alignment for the damping rollers.

The platen (which is driven by the film) has high inertia to help eliminate high-frequency vibrations and a special coating to eliminate surface reflections.

4.3.4 Image Motion Compensation

During photography, the film drive must provide a constant velocity to prevent (1) variation in exposure which would produce bands of non-uniform density (banding) and (2) differential movement of the aerial image and the film (smear). To compensate for image motion over the expected range of altitudes and camera aiming angles, provision is made for programmed film-velocity adjustments in sixty-four steps in 1.0 percent increments. The velocity range and size of the increments are derived from the required altitude, aiming parameters, and the resolution requirements of the system. Changes in film-drive velocity are achieved by varying the power supply frequency. (The speed of an a-c hysteresis-synchronous motor is directly proportional to the frequency of the supply voltage.) The power supply frequency and voltage are altered from the nominal by changes in the circuitry in response to a binary coded command signal.

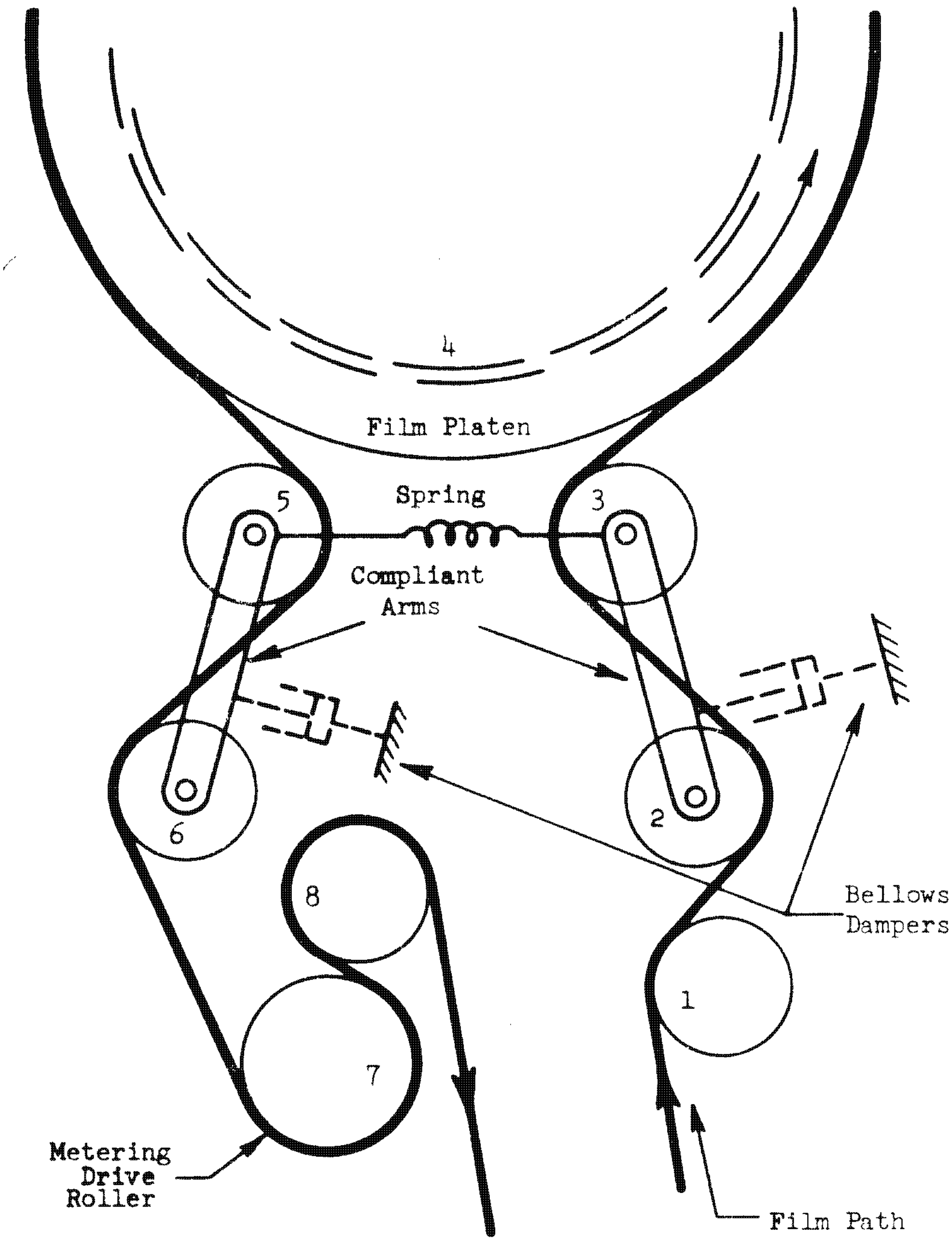

Figure 4-3. Camera Roller System

4.3.5 Film-Drive Electronics

Variable-frequency power for the film drive motor is supplied by the film-drive electronics, a block diagram of which is shown in Figure 4-4.

A binary command when received is used to actuate a relay-tree decoder to select one of eight capacitors and one of eight inductors in the tank circuits of a Clapp (series-tuned Colpitts) oscillator to provide the desired electrical frequency. The output of the oscillator is fed into a constant volts-per-cycle network which maintains an output voltage proportional to the frequency. This network is required to provide the proper input power and to match the operating characteristics of the camera drive motor. This output is fed into a phase shifter to achieve the two-phase power required for the synchronous motor. The two phase-shifter outputs are amplified in separate circuits to provide power directly to the motor. Use of a special low-voltage motor has permitted direct coupling between the transistorized power amplifier and the motor.

Table 4-1 shows the film-drive speed, electrical frequency, and command code associated with each of the 64 film-drive steps.

4.3.6 Slit Aperture Plate and Filter

The slit aperture plate contains the slits which control exposure. The three exposure slits are 0.0085, 0.0169, and 0.0338 inch wide and are equivalent respectively to exposures of 1/400, 1/200, and 1/100 seconds, when used at a film velocity of 3.3817 inch/sec (Step No. 32). When operating at higher velocities, the exposure time will be decreased proportionately. Each slit is 8.518 inches long and contains a fiducial mark at each end. Two sets of smear slits are adjacent to each slit position and two test slits are also included

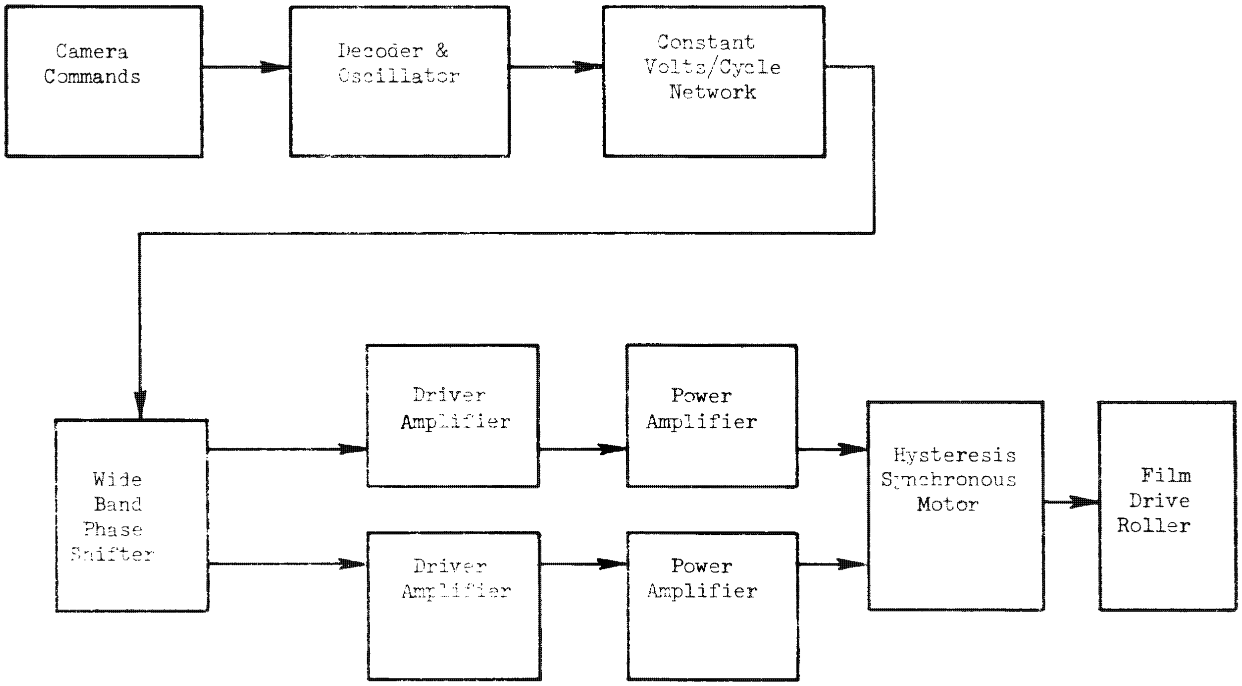

Figure 4-4. Camera Drive Schematic

TABLE 4-1

FILM-DRIVE SPEEDS, OSCILLATOR FREQUENCIES, AND COMMAND CODE

Step Number	Film-Drive Speed inches/seconds Flights 1-6	Flights 7-10	Flights 11-Subsequent	Oscillator Frequency cps	Command Code CB1	CB2	CB3	CB4	CB5	CB6
1	2.0219	2.7888	2.4841	290.92	0	1	1	0	1	0
2	2.0421	2.8167	2.5089	293.83	0	1	1	1	0	1
3	2.0625	2.8448	2.5340	296.77	0	1	1	1	1	0
4	2.0832	2.8734	2.5594	299.74	0	1	1	0	0	1
5	2.1040	2.9020	2.5850	302.73	0	1	1	1	0	0
6	2.1250	2.9310	2.6108	305.76	0	1	1	0	1	1
7	2.1463	2.9604	2.6369	308.82	0	1	1	0	0	0
8	2.1678	2.9900	2.6634	311.91	0	1	1	1	1	1
9	2.1894	3.0198	2.6899	315.03	1	0	0	0	1	0
10	2.2113	3.0500	2.7168	318.18	1	0	0	1	0	1
11	2.2334	3.0805	2.7440	321.36	1	0	0	1	1	0
12	2.2558	3.1114	2.7715	324.57	1	0	0	0	0	1
13	2.2783	3.1425	2.7991	327.82	1	0	0	1	0	0
14	2.3011	3.1739	2.8271	331.10	1	0	0	0	1	1
15	2.3241	3.2056	2.8554	334.41	1	0	0	0	0	0
16	2.3474	3.2378	2.8840	337.75	1	0	0	1	1	1
17	2.3708	3.2700	2.9128	341.13	0	1	0	0	1	0
18	2.3946	3.3029	2.9420	344.54	0	1	0	1	0	1
19	2.4185	3.3358	2.9714	347.99	0	1	0	1	1	0
20	2.4427	3.3692	3.0011	351.47	0	1	0	0	0	1
21	2.4671	3.4029	3.0311	354.98	0	1	0	1	0	0
22	2.4918	3.4369	3.0614	358.53	0	1	0	0	1	1
23	2.5167	3.4713	3.0910	362.11	0	1	0	0	0	0
24	2.5419	3.5060	3.1230	365.74	0	1	0	1	1	1
25	2.5673	3.5411	3.1542	369.39	1	0	1	0	1	0
26	2.5930	3.5765	3.1858	373.09	1	0	1	1	0	1
27	2.6189	3.6122	3.2176	376.82	1	0	1	1	1	0
28	2.6451	3.6484	3.2498	380.59	1	0	1	0	0	1
29	2.6715	3.6848	3.2822	384.39	1	0	1	1	0	0
30	2.6982	3.7216	3.3150	388.24	1	0	1	0	1	1

TABLE 4-1 (continued)

Step Number	Film-Drive Speed inches/seconds Flights 1-6	Flights 7-10	Flights 11-Subsequent	Oscillator Frequency cps	Command Code CB1	CB2	CB3	CB4	CB5	CB6
31	2.7252	3.7589	3.3482	392.12	1	0	1	0	0	0
32	2.7525	3.7965	3.3817	396.04	1	0	1	1	1	1
33	2.7800	3.8345	3.4155	400.00	0	0	0	0	1	0
34	2.8078	3.8728	3.4497	404.00	0	0	0	1	0	1
35	2.8359	3.9116	3.4842	408.04	0	0	0	1	1	0
36	2.8642	3.9506	3.5190	412.12	0	0	0	0	0	1
37	2.8929	3.9902	3.5542	416.24	0	0	0	1	0	0
38	2.9218	4.0300	3.5897	420.40	0	0	0	0	1	1
39	2.9510	4.0703	3.6256	424.61	0	0	0	0	0	0
40	2.9805	4.1110	3.6618	428.85	0	0	0	1	1	1
41	3.0103	4.1521	3.6985	433.14	1	1	1	0	1	0
42	3.0404	4.1936	3.7354	437.47	1	1	1	1	0	1
43	3.0708	4.2356	3.7728	441.85	1	1	1	1	1	0
44	3.1016	4.2780	3.8106	446.27	1	1	1	0	0	1
45	3.1326	4.3208	3.8487	450.73	1	1	1	1	0	0
46	3.1639	4.3640	3.8872	455.24	1	1	1	0	1	1
47	3.1955	4.4076	3.9260	459.79	1	1	1	0	0	0
48	3.2275	4.4517	3.9653	464.39	1	1	1	1	1	1
49	3.2598	4.4962	4.0050	469.03	0	0	1	0	1	0
50	3.2924	4.5412	4.0450	473.72	0	0	1	1	0	1
51	3.3253	4.5866	4.0855	478.46	0	0	1	1	1	0
52	3.3585	4.6324	4.1263	483.24	0	0	1	0	0	1
53	3.3921	4.67[illegible]	4.1675	488.08	0	0	1	1	0	0
54	3.4260	4.7255	4.2092	492.96	0	0	1	0	1	1
55	3.4603	4.7728	4.2513	497.89	0	0	1	0	0	0
56	3.4949	4.8205	4.2938	502.87	0	0	1	1	1	1
57	3.5299	4.8688	4.3368	507.89	1	1	0	0	1	0
58	3.5652	4.9175	4.3802	512.97	1	1	0	1	0	1
59	3.6008	4.9666	4.4239	518.10	1	1	0	1	1	0
60	3.6366	5.0162	4.4682	523.28	1	1	0	0	0	1
61	3.6732	5.0664	4.5129	528.52	1	1	0	1	0	0
62	3.7099	5.1171	[illegible]	533.80	1	1	0	0	1	1
63	3.7470	5.1682	4.6036	539.14	1	1	0	0	0	0
64	3.7845	5.2200	4.6500	544.53	1	1	0	1	1	1

in the slit aperture plate (see Figure 2-16). A fiducial mark, used for alignment and line-of-sight testing, is included on the edge of the wide test slit. It is located on the -X side of the test slit and is 0.066-inch off center in the +Y direction. The slit plate is potted into a frame which supports it in the camera at a distance of 0.010 inch from the platen.

Slit identification slits are located on the +Y side of the slit aperture plate, and are used to record the slit number on the film. These slits produce exposed streaks on the edge of the film, and specify slit number; i.e., three steaks identify slit No. 3, two identify slit No. 2, etc.

Prior to FM 13, the slit aperture which was most appropriate for a given mission was selected and positioned manually by means of an external positioning arm. This operation was accomplished during testing at the MAB. Effective on FM 13, a slit positioning mechanism was added to the camera. The slit positioner is capable of moving the slit aperture plate to any of 4 positions while on orbit. The positioner consists of a Geneva mechanism driving a rack and pinion arrangement, with a detent arm being used for accurate final positioning of the plate. A shaft encoder is used to provide digital to analog conversion such that voltage, of the correct polarity, is applied to a d-c drive motor until the commanded position is reached. During ground testing, the slit aperture plate may be commanded to a fifth position by the use of an additional command bit. The orbital command code is as follows:

Slit Position	CB20	CB21
A	0	0
B	0	1
C	1	0
D	1	1

Slit position changes can be accomplished through the use of stored commands.

The three slits used for operational photography are normally manufactured on yellow filter glass (B & L Type Y-10) which limits the transmission of the system to light having wavelengths greater than 500 mμ. The yellow filter is used to subtract the short wavelength (Blue) light reflected by atmospheric haze, because this light is non-image forming and thus decreases the apparent contrast of the scene. The use of this filter also limits the spectral bandwidth of the image to correspond more closely with the chromatic aberration corrections, improving resolution of the lens (the exact increase is difficult to measure, but was estimated at 10 lines/mm).

With the incorporation of the programmable slit plate, a number of test slits of different configurations were designed. In general, the use of specific test slits is intended to:

a. Determine optimum exposure and filter combinations for both black-and-white and color films.

b. Investigate the feasibility of photography over the dark side of the earth.

c. Investigate the characteristics of out-of-focus imagery through the use of variable-thickness glass blocks placed over the slit.

4.3.7 Time and Smear Recording

Two separate time tracks are recorded on the film through the use of light pulses of 1-millisecond duration. The pulses are repeated at 50-millisecond intervals in the A (20pps) channel and 2-millisecond intervals in the B (500pps) channel. In addition, a 23-bit time label generated by the vehicle clock is presented in the A time track at intervals of 0.8 second. The data-signal circuitry is designed such that a pulse is deleted in the 500 pps channel whenever a pulse appears in the 20 pps track. In this manner, both the time label and the 20 pps track can be obtained from this channel by examining the missing pulse positions. The time tracks are not redundant for 9.7 days, and are used to establish target locations and to make accurate measurements of distances in the photograph. Figure 4-5 is a sketch of the 20 pps format.

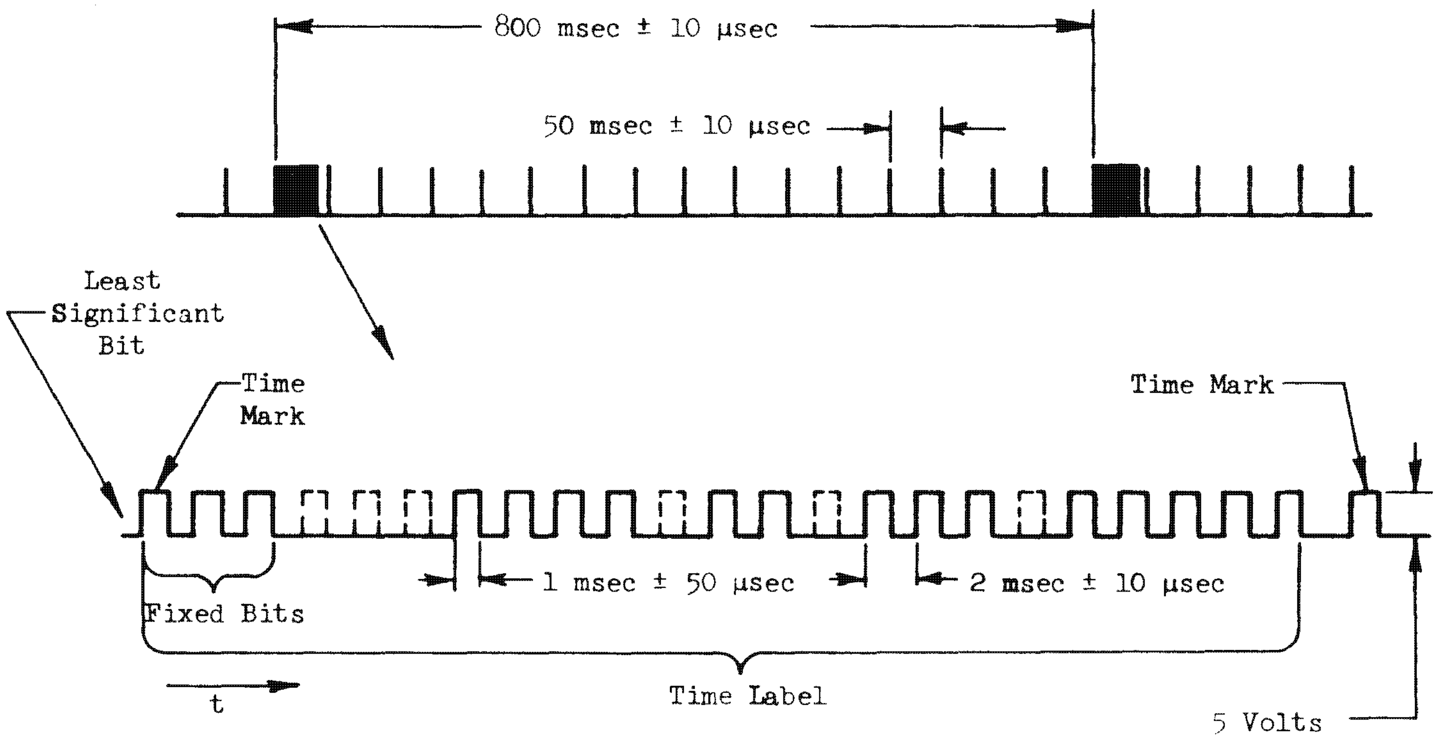

Figure 4-5. 20-cps Time-Track Format

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Smear information is also recorded on the film by using the smear slits at either end of the slit aperture plate (paragraph 1.3.4). The smear slits provide a measure of the magnitude and direction of the smear present at the edge of the frame.

4.4 FOCUS-CONTROL COMPONENT

4.4.1 General

The focus-control component operates by analyzing a small portion of the ground scene after the scene has passed through all Camera Payload optical elements, except the slit aperture plate. After the image has passed through a focus-shifter disc, a 45-degree mirror mounted in the camera and located near the optical axis of the system directs a portion of the ground scene image onto a reticle (Figure 4-6). The movement of the image across the reticle produces an amplitude-modulated light signal, which is a function of both scene contrast and the sharpness of the image at the reticle. Condensing optics then image this modulated light signal onto a photocell, producing an electrical output signal. The electrical output of the photocell varies as two different glass thicknesses and therefore two different focal planes are introduced into the optical path by the focus shifter disc. The difference between the two outputs is directly related to the state of focus of the primary optical system.

The focus control components are arranged so that the reticle is between, and equidistant from, the two focal planes when the plane of best focus is located at the film plane. It should be noted that the effects of scene content are nearly the same for both channels, due to the rapid rotation of the shifter disc (about 10 percent of the scene changes between channels).

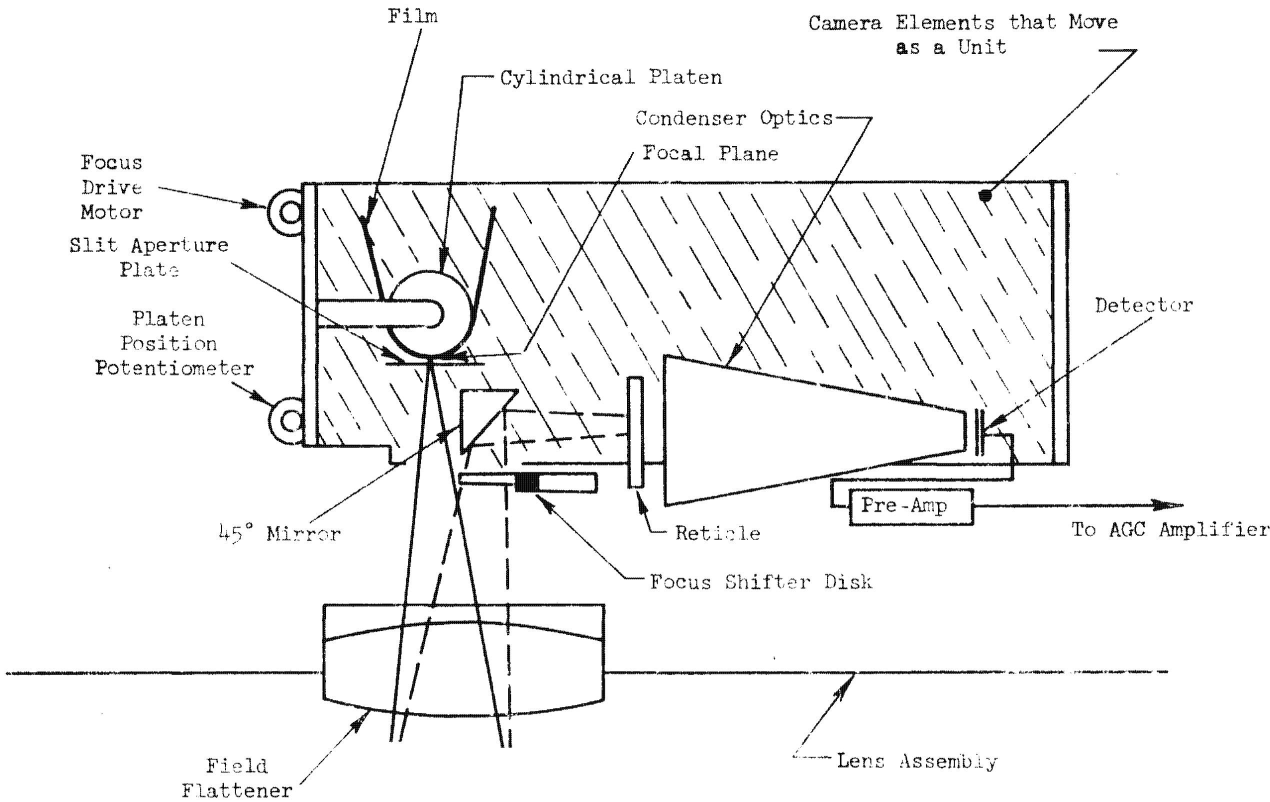

Figure 4-6. Focus Assembly and Camera Position Schematic

The focus-control component can be operated in three modes. The first is a manual mode (F-1). The operation takes place over the Vandenberg tracking station; focus output signals are telemetered to the ground and monitored by the 126 console operator who then moves the platen by real-time command, if necessary. The second mode of operation is called the remote record mode (F-2). The outputs of the focus sensors are recorded on the vehicle recorder over any suitable scene and then read out during the next tracking station contact. The data is analyzed, and any necessary platen movements are sent by real-time commands during subsequent tracking station contacts. The third mode of operation (F-3) is automatic. The focus output signals are used in a closed loop circuit to control the platen drive motor. The automatic focus system is capable of positioning the platen to within ±0.0005 inches of the point of best focus. Effective with FM 23, an inhibit loop was added to the logic circuitry to prevent platen movement by the automatic focus system when scene input (optical signal modulation) falls below a pre-determined level. An indication of inadequate scene will also appear on two telemetry points (CPL's 22 and 23). Figure 3-9 is a block diagram of the focus system. The operation of the individual components is discussed in the following paragraphs.

4.4.2 Hardware Description

4.4.2.1 Focus Shifter Disc. The focus shifter disc is 6 inches in diameter and consists of an aluminum hub encircled by a ring of glass approximately 1 inch wide. The glass ring consists of two different semi-circular thicknesses of glass, 0.030 inch thick on one half, and 0.065 inch thick on the other. Both of these plates are parallel-sided optical glass. The thickness difference between the two produces a shift in the focal plane of

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about 0.012 inch. A small iron slug is imbedded in the aluminum hub such that the slug passes over two magnetic pickups placed on either side of the disc, remaining over each pickup for about 1/4 revolution. This process generates timing signals used in the signal gating module discussed below.

The shifter disc is rotated by a d-c motor at 30 rps nominal. The motor is driven by the GE 28 v d-c supply; the 30 rps may vary slightly as the voltage level changes. The focus system is not sensitive to small changes in the angular velocity of the disc.

4.4.2.2 <u>Reticle</u>. The reticle is a glass plate (approximately 2 7/8 x 1/2 inches) aluminized on one side and ruled and etched to form a grid pattern having a spacing of 10 lines/mm. A multilayer interference filter is coated on the reticle plate; combined with the spectral response of the photocell, the focus control system responds to light in the 500 to 700 millimicron region. The reticle is installed in the camera with the rulings running in the cross-track (±Y) direction.

Movement of the image of a ground scene across the reticle produces an amplitude-modulated light signal which is a function of the scene content and the sharpness of the image at the reticle. The effect can be visualized by considering a ground scene consisting of an orchard, with the rows of trees lined up parallel to the reticle rulings, and with the width of the rows and spacing between them equal (in the image plane) to the reticle line spacing. Movement of this scene across the reticle will produce a cyclic intensity variation; in essence, the entire reticle will appear to "wink" on and off. The amplitude of the variation will depend on the contrast between the rows of trees and the spaces between them, and on the sharpness of this image as it moves past the reticle. A random scene produces essentially the same effect, the difference being that the amplitude of the variation will be much smaller because the entire scene will no longer "wink" on and off at the same time.

4.4.2.3 Condensing Optics and Detector. Condensing optics image the amplitude-modulated light signal produced by the reticle onto a photovoltaic (silicon) cell. The condensing optics produce an image (of the reticle) which is approximately 0.6-inch square; this is the size of the sensitive area of the silicon cell.

The focus shifter disc rotates and introduces two different glass thicknesses into the optical path in front of the reticle. The separation between the two thicknesses of glass appears as a dark line, as viewed by the reticle and photocell. While this line is passing in front of the reticle, the average illumination level present at the photocell decreases somewhat, causing a dip in the output of the cell.

4.4.2.4 Preamplifier and Bandpass Filter. The output of the photocell is fed into a preamplifier which amplifies the signal by a factor of 10^4. A bandpass filter is also contained in the preamplifier. Prior to FM 17, the bandpass filter limited the operating frequency range of the focus subsystem to 744 ±37 cps to improve the signal-to-noise characteristics of the system. This limitation placed stringent requirements on the slant range programmed during focus experiments. Effective with FM 17, the bandpass filter was modified to allow a wider range of operating frequencies in the focus subsystem to a range of 660 to 1300 cps (equivalent to a slant range between 63 and 120 n mi) with nominal response at 825 cps. This modification effectively eliminated the constraints on slant range which were present before the change.

4.4.2.5 Automatic Gain Control (AGC) Amplifier. The AGC amplifier is a medium-gain amplifier with a variable gain input stage. Input gain is controlled by a feedback loop from the larger of the two signals coming out of the integrators (see paragraph 4.4.2.7). The amplifier is designed to maintain the larger of these two signals at a constant level; the difference between the two signals is thus a function of the focus error.

4.4.2.6 Signal-Gating Module. The signal-gating module is a gating network which separates the signals corresponding to the two focal planes produced by the shifter disc. The network is operated by synchronizing signals generated by the shifter disc. Besides separating the two focus signals, the gating network blocks all signals during the periods when the shifter disc transition line is passing across the reticle.

4.4.2.7 Integrators and Differential Amplifier. The two signals coming from the signal-gating module are fed into separate integrators. These are rectifiers having a short time constant (3 seconds) for rising voltages, but a long time constant (10 seconds) for decreasing voltages. The result is two slowly varying d-c levels which are proportional to the a-c portion of the input signal. The differential amplifier amplifies the difference between the two d-c levels producing a signal which is proportional to the focus error.

The time constant characteristics of the rectifiers tend to minimize any errors caused by the partial scene change between the two focal planes.

4.4.2.8 Monitoring Logic. Logic circuits are incorporated in the focus-subsystem circuitry. In the automatic mode, these circuits protect against incorrect platen movements resulting from electrical failures. In addition, effective with FM 23, the automatic focus subsystem will have an inhibit mode incorporated to prevent accidental platen movement in the presence of inadequate scene input. When this condition occurs, an indication of inadequate scene will appear on the telemetry circuits, with CPL's 22 and 23 dropping to continuous 1-volt readings (whether or not the system is in the automatic mode).

4.4.3 Focus Signal Outputs

The output of the photocell is a complex signal which contains many frequencies. The distribution and amplitude of these frequencies are functions of the ground scene, the scene velocity at the reticle, the grid pattern, and the sharpness of scene focus at the reticle. The output of the photocell is shown in Figure 4-7A. The relative amplitude of the focus signal after integration is also shown in Figure 4-7B.

The integrator outputs as a function of distance of the reticle from the point of best focus for each channel are plotted and shown in Figure 4-8, with their maximum values separated by a distance corresponding to the differences between the two focus positions produced by the shifter disc. The location of the PBF can be determined from this curve if the two signals (or the difference signal between the two and its polarity) are known. Because the AGC amplifier is included in the circuit, a direct relationship between focus error and difference signal is maintained between the two channels.

4.4.4 Focus Instrumentation and Commands

4.4.4.1 <u>Focus Instrumentation</u>. The integrator outputs from each channel are monitored through the telemetry points CPL's 22 and 23. In addition, the output of the differential amplifier, a signal proportional to the difference between the integrator outputs, is read-out through telemetry point CPL 21. The difference signal indicates the direction and magnitude of the focus correction required, with the integrator outputs being used as additional

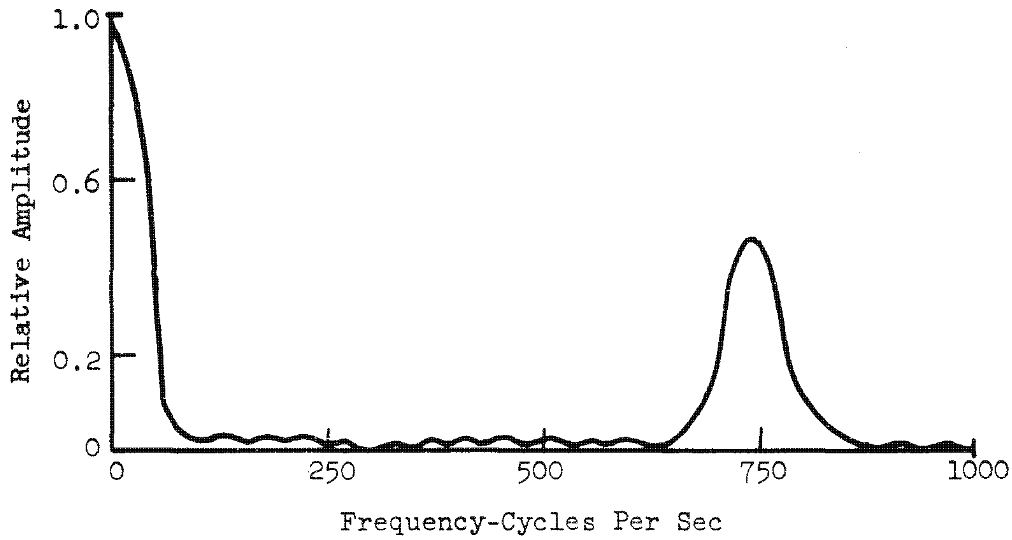

Figure 4-7A

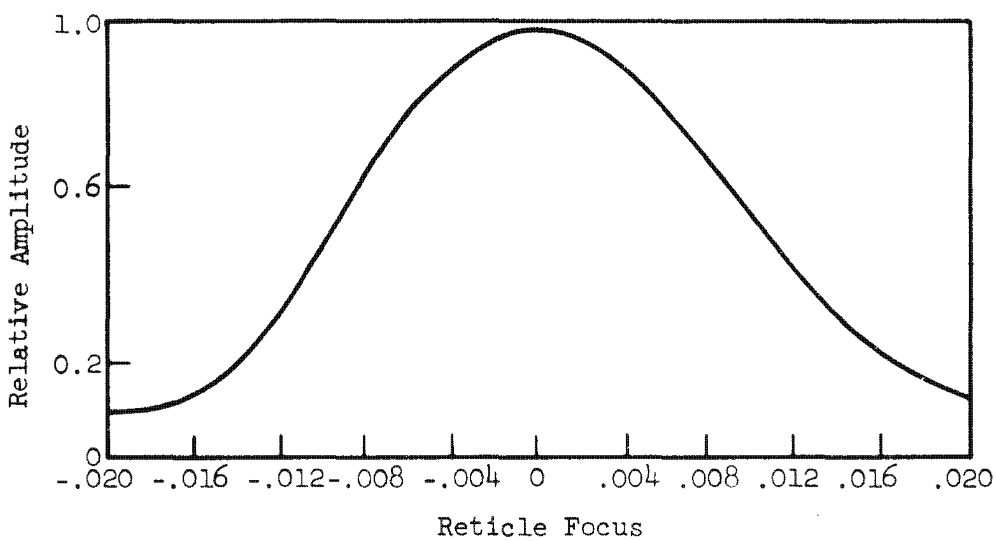

Figure 4-7B

Figure 4-7. Focus-Signal Characteristics at 107 n mi Slant Range

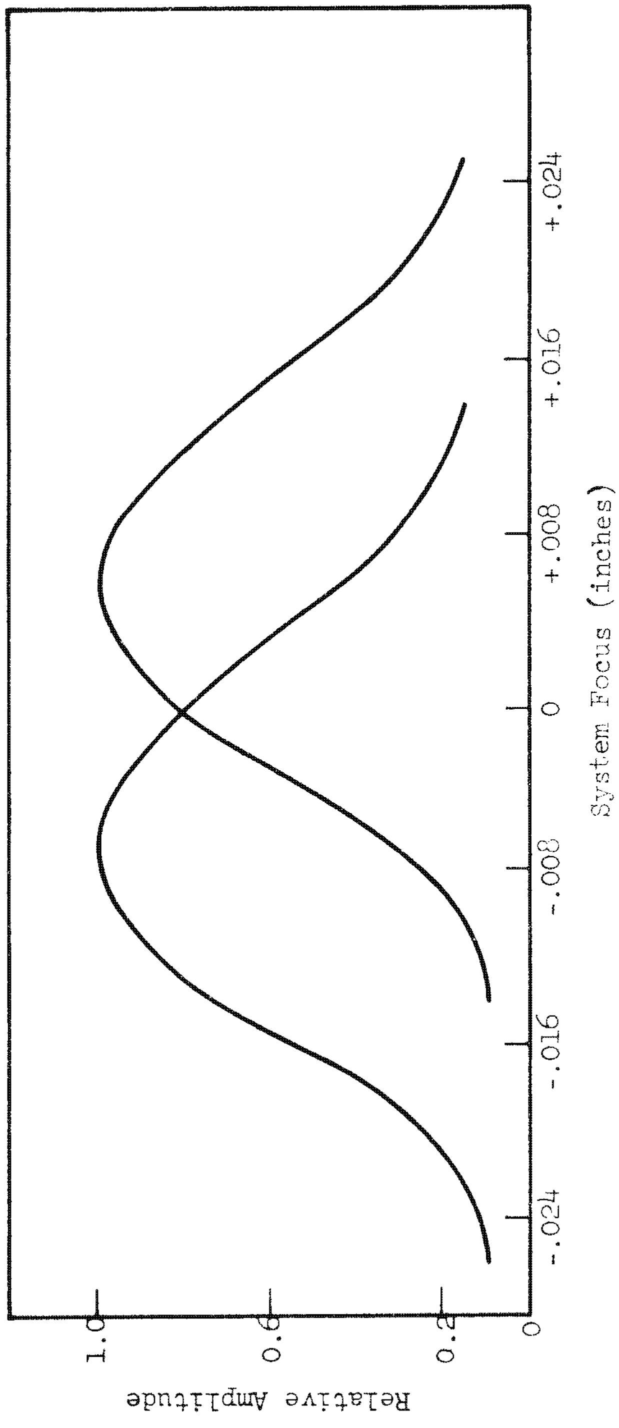

Figure 4-8. Integrator Output Signal Amplitude vs System Focus Position

verification. CPL's 22 and 23 are also used to determine the presence of inadequate optical signal modulation, as discussed in paragraph 4.4.2.8.

To determine the effect of the platen-positioning-motor commands, two instrumentation points, CPL's 20 and 27 respectively, are included. These sensors monitor coarse and fine platen position.

4.4.4.2 Focus System Commands. Four commands are used for focus detection and adjustment. They are:

	Command Name	Command Type
1.	Focus control power (on-off)	Stored
2.	Focus control mode (manual-automatic)	Stored
3.	Platen positioning motor-forward	Real time (manual mode only)
4.	Platen positioning motor-reverse	Real time (manual mode only)

It should be noted that operation in the automatic mode will result in platen movements (if necessary) without the use of real-time commands.

4.5 FILM HANDLING

4.5.1 General

The film handling assembly (shown schematically in Figure 3-7) consists of a film-supply spool, a storage looper, a take-up spool, and the necessary guide rollers. The complete film-handling assembly is housed in a light-tight enclosure, supplied partly by EKC and partly by GE. The film take-up mechanism in the SRV is called the forward record-storage assembly. Film take-up quantity sensors are included in all C/P's. The film used in the

C/P has a nominal width of 9.46 inches and a thickness of 0.003 inch. Both the film chute (connecting the film handling system and the forward record storage assembly) and the recovery capsule are provided by GE.

4.5.2 Film Environment and Tension

4.5.2.1 Temperature. To meet film environmental requirements, the temperature of the film handling area is maintained from 40 F to 90 F during flight checkout and the orbital period of the mission. The upper limit (90 F) is based on film-keeping studies, discussed in paragraph 1.2.6.7. The lower limit (40 F) is based on the low-temperature operating characteristics of the film transport components in the recovery vehicle.

4.5.2.2 Pressure and Humidity. There are no operating pressure requirements for the Camera Payload. Pressure relief valves are incorporated to limit the pressure to a maximum of 2.5 psi above ambient during launch. On orbit, the pressure will initially be reduced to 0.1 psia by supplementary relief valves and will later be determined by system leakage.

Relative-humidity control will be provided by the hygroscopic characteristics of the film emulsion because the free volume in the film enclosure is low. No active humidity control is required. As film is unwound, the system humidity will vary with leakage from the enclosure and the rate at which the film is removed from the supply spool. Vacuum-chamber tests indicate that 0.01 psia is the minimum acceptable pressure for operation of the film-transport hardware. Tests at pressures down to 0.0006 psia indicate no problem with sensitometry, handling characteristics, or static charge exposures.

4.5.2.3 Shock and Vibration. Film handling components are designed to withstand the shock and vibration specified for the launch phase. A supply-spool torque motor is energized during all periods of powered flight to prevent the film from unwinding. The forward record-storage assembly is designed to withstand the forces encountered during both launch and recovery. During ground operations involving the film handling assembly, shock and vibration forces will not exceed those which will be encountered during launch.

4.5.2.4 Film Tension. Nominal film tension is as follows:

C/P Nos.	Tension
FM 1-10	3.5 ± 0.5 lb
FM 11R-Subsequent	3.0 ± 0.5 lb

When the camera is running, input tension is from zero to 0.5 lb greater than the output tension due to the dynamics of the assembly. Uniform tension is necessary to ensure smooth film drive through the camera, and is controlled by the supply spool brake and the tension looper.

4.5.3 Film Handling Components

4.5.3.1 Film-Supply and Take-up Spools. The film-supply and take-up spools are similar in design except for the mechanisms inside the hollow core. Each spool consists of a core with approximately 1/4-inch-thick removable flanges (see Figures 2-5 and 2-6). The spool capacity is 3000 feet for 0.003-inch-thick film. The supply spool is a passive device except for the action of a torque motor which provides additional drag on the supply spool at the end of each take-up cycle to prevent excessive spool coast. A mechanical servo braking mechanism varies the supply-spool drag torque to maintain uniform film tension.

The drive motor for the take-up spool is housed within the hollow core; the spool is driven by gears meshing with the motor pinion. The drive train provides a film take-up velocity from 11 to 18 inches per second when driving against a film tension of 3.0 pounds. A ratchet installed in the core prevents loss of tension when the take-up motor is not energized. For FM 4 and subsequent payloads, a reversible clutch is installed to allow film to be unwound from the take-up spool during ground tests.

4.5.3.2 Film Looper. The dynamic capacity of the film looper is approximately 25 inches. This looper is located in the film supply cassette. The film looper consists of rollers fixed to a movable truck which slides back and forth (on ball bearings) on two longitudinal tracks. The position of the truck is determined by the quantity of film in either side of the looper because there is no force exerted on the truck except by film tension. The film looper operates such that a decrease in the quantity of film in the take-up side of the looper will be accompanied by an equal increase in quantity in the supply side. The looper engages a switch at each of its travel limits to provide control information to the take-up motor. A tension looper also is included in the film handling system. The tension looper is a redundant tension system consisting of a roller (No. 5 in Figure 3-7) capable of pivoting around a center located at roller No. 7. Roller No. 5 is restrained by two tension springs. If film tension is reduced or lost, this device pivots away from the camera and is capable of taking up two inches of film while restoring tension.

4.5.3.3 Film Housing Structure. The housing for the film supply spool and the looper serves as a light and moisture seal for the film handling assembly and its components.

A flexible connection is used between the housing and the projecting lip of the camera.

4.5.3.4 Forward Record Storage Assembly. The forward record storage assembly consists of a mounting base for the film take-up reel, the take-up reel, several guide rollers, and associated instrumentation points. During launch and recovery, acceleration and shock forces on the film spool are borne by the bearing shaft and transmitted to the SRV frame through the shaft bearings.

4.5.3.5 Film Handling Assembly Instrumentation. Several instrumentation points are provided in the film handling assembly to allow the performance and operation of the various elements to be evaluated during both ground testing and the on-orbit phase of the mission. They are as follows:

CPL No.	Function
15	Film quantity, coarse/take-up reel rotation
16	Film quantity, fine
17	Looper position/film tension
28	Film quantity, medium
29	Take-up motor current

See Table 4-5.

4.5.3.5.1 Film Quantity Sensors. Changes to the film quantity sensors are as follows:

CPL No.	Effectivity	Range
15	FM 1-8	0-300 feet
	FM 9-18	0-254 feet
	FM 19-Subsq.	0-1017 feet
16	FM 1-2	Not installed
	FM 3-18	0-30 feet
	FM 19-Subsq.	0-45 feet
28	FM 1-2	Not installed
	FM 3-18	0-300 feet
	FM 19-Subsq.	0-282 feet

Each of the above sensors is operated by rollers geared to potentiometers; one revolution of the potentiometer takes place when the correct length of film has traveled past the roller.

4.5.3.5.2 Looper Position Sensor. The looper position sensor (CPL 17) consists of a potentiometer operated by a cam which is turned by the movement of the looper carriage. This sensor provides an output voltage which varies from 2 to 5 volts as the film quantity in the looper varies from 2 to 25 inches. On FM 3 and subsequent payloads, the absence of film tension is also indicated by this instrumentation point. If film tension is lost, the sensor will cease to indicate looper position and will drop to a constant 1-volt output.

4.5.3.5.3 Take-up Reel Rotation Sensor. Effective with FM 5, CPL 15 also monitors take-up reel rotation. This sensor consists of a gear, with 15 ferromagnetic pins equally spaced around its edge, connected to the take-up motor and located in the take-up reel hub. A magnetic pickup is located 0.0035 inch away from this gear and as these pins rotate and generate a magnetic field, a voltage is induced in the pickup and monitored by the tracking station. Any output between 1 and 4.5 volts indicates that film take-up quantity is being monitored. An output of 5 volts or more indicates reel rotation. Any output under 0.5 volt means that the take-up is energized but the reel is not rotating; that is, a malfunction indication.

4.5.3.6 Film Handling Elements Provided by the Associate Contractor. GE supplies the portion of the film handling assembly that connects the supply cassette and the forward record storage assembly. It consists of a film chute, film cutters, chute separators, and a sealing device for the film path into the SRV. No film contacting surfaces (rollers, etc.) are required in the equipment furnished by GE. The commands to operate the cutter, sealer, and chute separator are also the responsibility of GE.

4.5.4 Film Handling Logic

4.5.4.1 Command Logic. The take-up motor will operate and empty the film looper whenever the camera is turned off, or when the looper becomes full while the camera is operating. As the looper is emptied, film is pulled from the supply spool and stored in the supply side of the looper.

The intent of the command logic in emptying the looper when the camera is turned off is to eliminate unnecessary vibration caused by reel rotation during a camera run. Twenty-five inches of film are stored in the supply side of the looper to provide for most operations. If the camera operation calls for more than 25 inches of film, the capacity of the supply side will be exceeded causing the film reels to operate intermittently during the camera run. Vibrations and variations in tension will result in a region of banding and degraded resolution on the photograph.

The de-orbit command and associated programming are part of a re-entry sequence. Before this sequence occurs, the camera is normally run until the film supply spool is empty. (The SRV, however, is capable of recovery independent of the film load). At that time, loss of tension will cause the take-up drive to run continuously until payload power is turned off. The film cutters, capsule sealer, and chute separator provided by GE will then be operated.

4.5.4.2 Film Handling and Photographic Modes. Stereo and continuous strip photography require variable camera operating times. Each photographic mode was studied to determine the capacity of the looper and the velocity of the take-up drive that would limit take-up motor operations to camera nonoperating periods. A film looper capacity of 25 inches, combined with the current minimum take-up speed of 11 inches per second, meets all of the expected requirements for stereo photography with approximately 3.5 seconds interframe time. (Minimum take-up speed is only experienced early in the mission when the supply spool has maximum inertia, and late in the mission when the supply spool brake has maximum leverage. See Figure 4-9.) Strip photographs can be programmed for durations up to 102.4 seconds. However, as previously noted, frames longer than 25 inches will cause the take-up motor to operate during photography while emptying the looper, resulting in an intermittent loss in quality.

4.6 CAMERA AIMING

4.6.1 Aiming Requirements

Three angular degrees of freedom in aiming the camera are necessary to fulfill the requirements of stereo and lateral photography. The OCV is rotated about its roll axis to provide obliquity aiming. The other two degrees of freedom are provided by movement of the stereo mirror in the C/P.

4.6.1.1 Stereo. In-track (stereo) aiming of the camera is accomplished by rotating the stereo mirror to any of three positions about an axis parallel to the C/P pitch axis. These mirror positions are +7.5 degrees, 0 degrees, and -7.5 degrees. The stereo mirror reflects light from the ground into the lens and enables the C/P to photograph objects 15 degrees ahead of, directly below, or 15 degrees behind the vehicle. Convergent stereo photography makes use of the two extreme positions; the 0-degree position is used for vertical photography.

4.6.1.2 Crab. For oblique viewing, the lens and stereo mirror rotate with the OCV about the roll axis. The stereo mirror by itself is then rotated about the same axis to make a crab correction. In addition to the crab correction, the motion of the mirror introduces a further change in the obliquity angle. In practice, therefore, a computation is necessary to program the proper

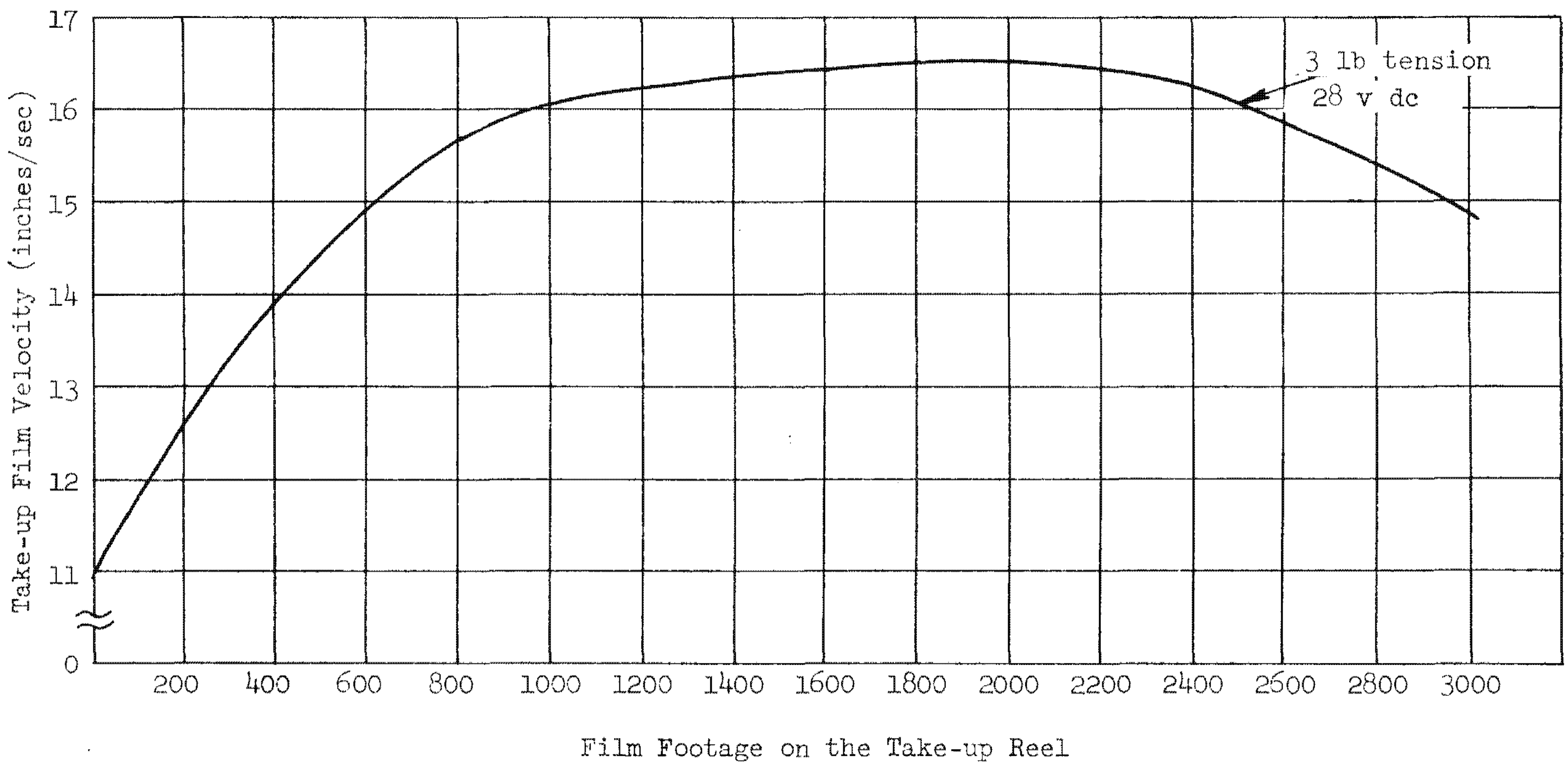

Figure 4-9. Nominal Take-up Velocity vs Film Footage on Take-up Reel

combination of roll and crab angles needed to achieve the desired viewing angle. Crab correction from 0 to 3.5 degrees can be made in 0.5-degree steps (see paragraph 1.2.5.3).

4.6.2 Aiming Drives

The stereo and crab aiming drives are digital servomechanisms. Each of these servos drives the stereo mirror by means of a lead-screw and nut combination having a 0.2 inch-per-inch pitch (see Figure 2-12). As a result of this lead-screw pitch, the servomechanisms need not be locked in position during powered-flight sequences. (A lead screw whose pitch is below a critical angle determined by the coefficient of friction will not convert thrust loading into rotational motion.) Each aiming servo is capable of positioning the mirror in a number of discrete positions within a specified time after receipt of a command. Commands are supplied to the servos from the OCV. Each command consists of several bits presented to the servo in parallel form. The commands are satisfied by rotating the servo output shaft until the internal position code (within the encoder) matches the input command.

Each servo receives two electrical power inputs. These are +28 volts, unregulated, for operational power and +5 volts for the instrumentation circuits. Each servo assembly contains a potentiometer which is geared so that the output voltage corresponds to servo position in stereo or crab.

4.6.2.1 Stereo Servo. The stereo servo is capable of positioning the stereo mirror at any one of 3 discrete positions. The commands and associated mirror positions are shown in Table 4-2. Under conditions of low voltage and maximum anticipated load, the stereo servo can move the mirror from one extreme position to the other within 4 seconds. The average electrical power required by the servo when driving the stereo mirror is 32 watts. No operational power is required after a given command has been satisfied.

TABLE 4-2

SERVO POSITION CODES

Stereo Mirror Position	CB8	CB9
-7.5°	0	0
0°	0	1
+7.5°	1	1*

Command Codes

Crab Position	CB10	CB11	CB12
0°	0	0	0
0.5°	0	0	1
1.0°	0	1	0
1.5°	0	1	1
2.0°	1	0	0
2.5°	1	0	1
3.0°	1	1	0
3.5°	1	1	1

* Prior to Flight No. 17, a 1,0 command was used to move the stereo mirror to the +7.5° position. Effective Flight No. 17, a 1,1 command was used to produce this movement.

Means are included to automatically disable the servo drive if it is impossible to satisfy a command within approximately 7.0 seconds. Should this occur, the servo drive is re-enabled whenever the most significant command bit (CB8) is changed, or whenever power to the servo is turned off and re-applied. The servo has an electrical limiting action which prevents the mirror from being driven more than 0.277 degree beyond the two extreme positions.

Mechanical stops are also provided should a malfunction occur which would attempt to drive the mirror outside the electrical limit stops.

4.6.2.2 Crab Servo. The crab servo is capable of positioning the stereo mirror at any of eight crab positions. The servo can be mounted to produce either positive or negative crab correction (see Section 4.6.3). The positions and associated command codes are given in Table 4-2. The same command and position relationship applies to both positive and negative correction. Under conditions of maximum load and low supply voltage, the servo can drive the stereo mirror from one crab extreme to the other (3.5° to 0°) within eight seconds. The average electrical power required while the servo is driving is 27 watts; no operational power is required once the command is satisfied.

The crab servo also has a disable circuit which will operate if a command is not satisfied within approximately 13 seconds. This circuit is reset in the same way as the stereo servo (see paragraph 4.6.2.1). The servo assembly is electrically constrained to limit motion of the mirror to within 0.178 degree of the two extreme positions. Mechanical stops are also included.

4.6.3 Northbound and Southbound Photography

By mounting a servo at one of two specific locations (see Figure 2-12) two crab correction directions are available, one for northbound and one for southbound photography.

4.6.3.1 Southbound Correction. With the crab servo mounted on the positive (+) Y side of the mirror bridge, commands to the servo cause negative (-) mirror rotation in the Y-Z plane. In this manner crab correction for southbound (noon launch) photographic passes is provided. It is currently planned that all payloads will have the servo mounted in this southbound position when delivered by EKC.

4.6.3.2 Northbound Correction. With the crab servo mounted on the negative (-) Y side of the mirror bridge, commands to the servo cause positive (+) rotation of the stereo mirror in the Y-Z plane. In this manner the required crab correction for northbound (midnight launch) photographic passes is provided.

4.7 ENVIRONMENTAL CONTROL

4.7.1 General

The high resolution required of the photographic subsystem necessitates close control of temperature and humidity from flight checkout to retrieval. The purposes of the environmental control system are:

a. To keep the lens in focus,

b. To prevent condensation on or contamination of any optical surface,

c. To prevent condensation on any surface that comes in contact with the film, and

d. To prevent environmentally caused change in the film (see Section 1.2.6.7)

The optical surfaces of the plano stereo mirror and spherical primary mirror are ground and polished within 1/10 wavelength of light (or 2.5 micro-inches). Distortion of these surfaces by more than 1/4 wavelength (6 micro-inches) as a result of mechanically or thermally induced stress will defocus the lens enough to degrade resolution to more than 3 feet on the ground. Asymmetric stresses may produce astigmatism in addition to defocussing, so that a focus adjustment cannot re-focus the lens. Thus, the environmental control problem, with respect to large optical elements, is to prevent the creation of large enough temperature differentials across or through the mirrors to cause them to flex more than 1/4 wavelength. In addition, thermal expansion of the lens tube must be limited to a value such that the focal plane will not move out of the ±0.0005-inch depth of focus.

Whenever moisture condenses on a surface, it carries airborne solids with it. Inland, dust particles comprise the principal solids, but near the ocean, the air also contains considerable salt. When the condensate re-evaporates, the dust and salt are left as a residue on the surface. As a film on an optical surface, such a residue reduces the transmittance and/or reflectance of the surfaces. A complex relationship exists between resolution and exposure from which it is known that a loss in exposure from the nominal will degrade resolution from the optimum value. In the case of salt residue, chemical attack on the optical surface may occur. For this reason, it is essential that no condensation take place on an optical surface at any time after the optical element has been fabricated. Care must also be taken that oily films are not deposited during environmental tests.

Condensate on the film-contacting surfaces may cause emulsion to be transferred from the film to such surfaces. This transferred emulsion may later mar, or be wiped off on, other areas of film, damaging these areas as well as the area from which it came. In addition, marring of the film-contacting surfaces may cause errors in film handling alignment and film drive velocity. Therefore, the humidity within the film handling enclosure must be controlled so that condensation is prevented at all times. The film itself normally effects this control, so that special conditioning other than temperature control is not required.

By its nature, C/P environmental control is inseparable from that of the OCV and the SRV. Therefore, its design and evaluation are a joint effort of GE and EKC.

4.7.2 Flight Test Through Ascent

4.7.2.1 Temperature. Uniform and stable payload temperatures can be achieved soon after launch only by adjusting the temperatures to the desired orbit temperature of 70 F while on the launch pad. Analysis indicates that the large mirrors as installed in the OCV have thermal time constants in vacuum of approximately 12 hours. This time constant represents the time required for 63.2 percent of a temperature adjustment to be completed; 86.5 percent adjustment requires twice as long, and 95 percent adjustment requires three times as long. Thus, GE's ground conditioning equipment and techniques must be capable of bringing the C/P to flight temperature by lift-off.

The high skin temperatures produced during ascent by friction with the atmosphere are attenuated by insulation in the OCV and the SRV and they therefore have no significant effect on the C/P.

4.7.2.2 Pressure. Both the simulated ascent tests on the thermal mockup and the flight results have proved the adequacy of the vent designs for both the lens and the film handling enclosure.

4.7.2.3 Relative Humidity. Control of the ambient relative humidity is necessary at all times from fabrication through lift-off to prevent moisture condensing on any C/P optical surface, as discussed in paragraph 4.7.1. While indoors, such control is produced by air conditioning in assembly and test areas. During shipment from EKC-Rochester to EKC-VAFB, the payload is contained in a pressure vessel purged with dry nitrogen to a dew point below -35 F. Under nominal controlled conditions at the MAB of 70 ± 5 F and 50 ± 5 percent relative humidity, the highest dew point expected is 58 F. Therefore, the minimum C/P temperature allowed between integration and lift-off has been set at 60 F. The ground handling equipment and procedures must be adequate to prevent the C/P from cooling below that temperature or from being exposed to an atmosphere having a dew point above the payload temperature.

The film handling enclosure is closed and is not affected by ambient humidity except when it is open during loading. The nature of the film is such that, if the film is loaded at a temperature of 70 ± 5 F and a relative humidity of 40 ± 5 percent, no temperature cycle between 60 F and 90 F can produce condensation inside the enclosure.

4.7.3 On-Orbit

4.7.3.1 General. Once on-orbit, heat transfer takes place by radiation and conduction only; all heat eventually flows to or from the skin. The on-orbit effective thermal time-constant of the vehicle is large because of the large heat capacity and thermal insulation of the skin.

4.7.3.1.1 Heat Loads. External irradiation on the vehicle comes from three sources: earth emission (long wavelengths); insolation (direct solar irradiation of short wavelength); and albedo (solar energy reflected from the earth, in short wavelength). Earth emission is assumed constant for the entire orbit. The amount of this radiation received by a surface of the vehicle is a function of altitude, orientation, and absorptivity for the long-wavelength energy. The effects of insolation and albedo on a vehicle surface, however, vary with the orbit inclination to the earth-sun line in addition to the altitude, orientation, and absorptivity for short-wavelength radiation.

The heating effect on the cylinder arising from frictional resistance as the vehicle moves through the low-density atmosphere (2 to 9 x 10^{-11} lb/ft^3) is estimated to be on the order of 0.5 to 1.0 $watt/ft^2$ at 95 n mi altitude, which is usually considered negligible compared to the radiant-heat loads. Internal heat loads are discontinuous. For example, the internal component power dissipation of the C/P is about 32 watts in the OCV during photographic periods over the target; however, it drops to about 0.3 watt during the remainder of the orbit cycle. Average C/P internal power dissipation during the mission is less than 2 watts.

4.7.3.1.2 Control System. The temperature of the payload is controlled in a passive manner supplemented by active heaters (see Figure 3-11). This type of design is dictated by the large payload mass, the relatively small internal power dissipation, and the short operating life of the payload. Control is accomplished by choosing surface finishes and materials having the proper emissive and absorptive properties. The control of the skin temperature is the responsibility of GE. Heat transfer between the C/P and the skin is reduced by minimizing the number of conducting paths and by use of insulating materials for all mounting supports. Stabilization of the payload will occur within the allowable average temperature range of 70 F ±5 F. Conversely, the payload components are mounted so as to insure high conductances among themselves, tending to minimize temperature gradients within the payload. The allowable temperature differentials within the C/P are as follows: lens, end-to-end, 10 F; stereo mirror bay to lens bay, 10 F; stereo mirror and primary mirror, linear front to back, approximately 0.2 F.

4.7.3.2 Optics Environment. To thermally isolate the optics, the lens assembly (excluding the stereo mirror) is surrounded by an outer aluminum cylinder (component support tube) that acts as a radiation baffle and an end-to-end thermal shunt. This construction helps produce an isothermal operating zone for the lens. Further protection is afforded by thermostatically controlled resistance heaters mounted on the component support tube and the primary structure ring. Thermal analysis of the stereo mirror showed the necessity for a door over the viewport during portions of the orbit when photographic or focus operations are not under way.

Heat flux in or out of the S/V as a whole through the open viewport is reduced to a minimum by use of the aperture mask and the flexible thermal boot which blocks all holes but those through which photographic light rays must pass.

4.7.3.3 Film Environment. See paragraph 4.5.2.

4.7.4 Recovery

Environmental control in the SRV is GE's responsibility. An environment must be provided during re-entry and retrieval that will protect the film from foreign matter and from temperatures beyond the limits described in Section 1.2.6.7.1.

4.8 CAMERA PAYLOAD ELECTRICAL DESIGN

The C/P electrical assembly is comprised of the necessary electrical components, cabling, and packaging necessary to transmit power and commands to, and derive instrumentation data from, the C/P. Block diagrams of the C/P electrical assembly are shown in Figures 3-2 through 3-6. Figure 2-4 shows the location of the primary electrical packages. A cabling block diagram is shown in Figure 3-10.

4.8.1 Payload Power

Electrical power for the C/P is supplied by the OCV. Three separate power supplies are required; operational, environmental, and instrumentation. These sources are provided at the following d-c voltage levels:

Operational power	+28 volts nominal (unregulated)
Environmental power	+28 volts nominal (unregulated)
Instrumentation power	+5 volts nominal (regulated)

4.8.1.1 Operational Supply. The unregulated +28 volt d-c operational supply is the primary power source for the C/P. During normal operation, the energy consumption of the C/P components drawing power from this supply is 254 watt-hours for a 5-day orbital lifetime and a 600 stereo-pair mission. An analysis of the energy consumption of the C/P, by components, is presented in Table 4-3. The operational supply voltage measured at the interface between the C/P and the OCV is from 27 to 32.5 volts if the C/P is not operated during the first hour of flight. The steady state load current is less than 7 amperes during any operating period. Surge current will not exceed 15 amperes, and surge transients decay to normal load currents in less than 0.5 second. The application of operational power to the C/P is controlled by the S/V programmer. The operational circuits are isolated by at least 30K ohms from the environmental circuits except for a common d-c return.

TABLE 4-3

C/P OPERATIONAL POWER CONSUMPTION

Item	Duty	Operational Time (Hours)	Estimated Power (Watts)	Maximum Power (Watts)	Estimated Energy Dissipation (Watt-Hours)	Maximum Energy Dissipation (Watt-Hours)
Stereo servo	6 sec/stereo pair	0.57	18	38	10.0	21.5
	3 sec/strip shot	0.26	13.3	32	3.5	8.5
Crab Servo	16 sec/active orbit	0.29	13.3	33	4.0	9.5
Camera	2400 sec-focus operations	0.67	2	3	1.3	2.0
Film Drive electronics	6 sec/stereo pair	0.5	36	49	18	25
	14 sec/strip mode operation	2.2	36	49	80	110
Distribution component	7 min/active orbit	4.9	7	18	35	87
	400 sec/R.O. contact	1.1	7	18	8	20
	2400 sec-focus operations	0.67	16	18	11	12
Film transport C/P	2 sec/stereo pair	0.2	10	14	2	3
	1 sec/strip mode operation	0.16	10	14	1.5	2
Film transport SRV	2.7 sec/stereo pair	0.26	15	18	4	4.5
	3.5 sec/strip operation	0.57	15	18	8.5	10
Focus control	2400 sec-focus operation	0.67	16	19	11	13
Cables (approximation)					2	3
				Total	199.8	331.0

For the calculations, it was assumed that there were 350 stereo pairs each using 1.7 ft of film, 570 strip mode operations each using 4.1 ft of film, and 81 Revs prior to SRV de-boost.

4.8.1.2 Environmental Supply. The environmental supply provides power for all environmental heaters within the C/P. Total energy consumption is not specified because energy demands are dependent on the thermal control of the OCV. The maximum current drain is 4.8 amperes, and the voltage measured at the interface is from 26.0 to 33.4 volts. Environmental power is supplied on demand from launch until the photographic portion of the mission has been completed under nominal operating conditions. Environmental power may also be removed or applied by stored command from the OCV during unusual situations. All environmental power inputs to the C/P have some form of overload protection within the C/P.

4.8.1.3 Instrumentation Supply. The instrumentation supply provides regulated power to a number of instrumentation transducers within the C/P. The voltage at the interface between the instrumentation supply and the return wires is between 4.9 and 5.1 volts dc. The maximum current drain of the instrumentation circuitry is 10 milliamperes. Power application is controlled by the S/V programmer. The energy consumption of the instrumentation supply is slight and has been included with the various C/P components listed in Table 4-3.

4.8.1.4 Electromagnetic Interference, Grounding and Shielding. Care has been taken in the design and construction of all C/P components to reduce the susceptibility to, and generation of, electromagnetic interference (EMI) to a tolerable level. The EMI limits defined by MIL-I-26600 have been used as the design goal and testing guide.

To minimize ground loops, no low impedance, direct-current paths exist between C/P circuitry and the structure. In addition, cables that may cause or be susceptible to EMI radiation, were shielded. Each assembly enclosure and all shielding is grounded to the C/P structure, which is in turn grounded to the S/V through ground straps. The forward record storage assembly is electrically isolated from the remainder of the C/P and is grounded to the SRV. The remainder of the C/P is grounded to the OCV by a strip "tied" to hardware mounted on the component support tube.

4.8.1.5 C/P Power Control. The 28-volt, d-c operational power supply is modified in the C/P to supply the various input voltages necessary for the operation of the electrical components. This voltage is inverted, transformed, rectified, and regulated to provide ±22 volts dc for some instrumentation circuitry and the focus control electronics. The film drive electronics is a variable frequency supply which furnishes power for the camera film-drive motor. Aside from these power control functions, the C/P generally uses unregulated operational power.

4.8.2 C/P Commands

Operation of the C/P is controlled by the S/V programmer in the OCV. Commands will be transmitted to the S/V during tracking station contacts. Some of these commands may be executed immediately; others are stored for use during photography, recovery, and other phases of the mission. The nature of the commands required by the C/P is discussed in the following subsections.

4.8.2.1 Command Requirements. The C/P commands are listed in Table 4-4. Commands CB1 through CB12 and CB20 and 21 are required for every photographic sequence; that is, for each stereo or lateral pair and each continuous strip photograph. The supply-spool torque motor (command CB24) is operated during powered flight. Focus commands CB15 through CB18 are required whenever a focusing sequence is desired. Furthermore, focus commands CB15 and CB16 are required whenever operation of the focus control component in the remote-record mode is desired.

TABLE 4-4

C/P COMMANDS

Code	Function	Type of Command
CB1	Film speed bit No. 1	Stored
CB2	Film speed bit No. 2	Stored
CB3	Film speed bit No. 3	Stored
CB4	Film speed bit No. 4	Stored
CB5	Film speed bit No. 5	Stored
CB6	Film speed bit No. 6	Stored
CB7	Camera drive	Stored
CB8	Stereo, most significant bit	Stored
CB9	Stereo, least significant bit	Stored
CB10	Crabbing, most significant bit	Stored
CB11	Crabbing, 2nd most significant bit	Stored
CB12	Crabbing, least significant bit	Stored
CB15	Focus control power	Stored
CB16	Focus control mode	Stored
CB17	Focus forward drive	Real time
CB18	Focus reverse drive	Real time
CB20	Slit, most significant bit	Stored
CB21	Slit, least significant bit	Stored
CB24	Supply-spool torque motor	Stored

4.8.2.2 Film-Drive-Speed Commands (CB1 through CB6). A separate film-drive-speed command is required for each photograph of a stereo or lateral pair and each continuous strip photograph.

Six command bits are used to command the selection of one of 64 drive speeds; each differing by one percent of the previous step.

The film-drive electronics receives the film-drive-speed commands as pulses on six pairs of wires and decodes the command through a relay tree to produce the proper frequency for the film drive (see Table 4-1 and paragraph 4.3).

4.8.2.3 Camera Drive Command (CB7). A camera drive command is used to turn a camera power "ON" and "OFF" before and after each photograph of a stereo pair, lateral pair, or continuous strip photograph.

4.8.2.4 Stereo Mirror Position Command (CB8 and CB9). A stereo mirror position command must be received for each photograph of a stereo or lateral pair, for each continuous strip photograph and for each focus operation. The stereo mirror is commanded to assume one of three positions. These are +7.5, -7.5, and 0 degrees. A two-bit binary code command specifies the stereo mirror position (see Table 4-2).

4.8.2.5 Crab Position Command (CB10 through CB12). A crab setting is required for each stereo or lateral pair, for each strip photograph, and for each focus operation. It is not necessary to change the crab setting between shots of a stereo or lateral pair. Eight crab settings are possible from 0 to 3.5 degrees in 0.5-degree steps. These settings can be either positive or negative depending on the location of the crab servo in the C/P. A three-bit binary code command specifies crab position (see Table 4-2).

4.8.2.6 Slit Aperture Plate Position Command (CB20 and 21). A slit setting is required for each photograph. On orbit, the slit aperture plate may be commanded to any of four positions. During ground tests only, the slit aperture plate can be commanded to a fifth position by means of an additional command bit.

4.8.2.7 Supply Spool Torque Motor Command (CB24). Because the camera drives film by frictional contact, tension must be maintained in the film handling system at all times. Two possible causes of film tension loss are coasting of the film supply reel at the conclusion of the normal film transport cycle, or movement of the film supply reel caused by vibration during powered flight. To prevent these from occurring, a torque motor was included which opposes the normal rotation of the film supply reel. This motor is energized by command CB24 during all powered flight sequences and by the looper logic circuits at the conclusion of each film transport cycle.

4.8.2.8 Focus Commands (CB15 through CB18). The optical system of the C/P will be focused prior to launch. Provisions are made to refocus while in orbit to allow correction of any out-of-focus condition resulting from vibration, shock, or abnormal temperature variation that might occur during launch or on orbit. Refocusing on-orbit will be accomplished only if an out-of-focus condition is detected by means of telemetry. The focus-control power command (CB15) is used to turn the focus control component power "ON" and "OFF" before and after each focus sequence. The focus-control-mode command (CB16) selects either the manual or automatic mode of operation. When the manual mode is being used, the focus forward and reverse drive commands (CB17 and CB18) are required to command the platen-drive motor (see paragraph 4.4).

4.8.2.9 De-Orbit Commands. Several commands are required to prepare adequately for re-entry. These commands are the responsibility of GE.

To maximize re-entry reliability, the entire film load is normally wound onto the take-up reel in the SRV prior to re-entry. If it is not feasible to complete film windup, the GE hardware contains equipment which will cut the film on command and only the film already in the SRV will be recovered. When the film load has been completely wound onto the take-up roll (or is cut by the GE cutter/sealer), the loss of tension will cause the take-up motor to operate continuously whenever payload power is applied. Whether film windup has been completed or not, the GE cutter/sealer is actuated, sealing the capsule for the deboost sequence.

4.8.3 Camera Payload Instrumentation

C/P instrumentation provides the information necessary to determine the health of the C/P and provides information on abnormal operation which may be circumvented by appropriate programming. It also provides information for post-mission analysis and for updating the design of subsequent payloads. Included in the instrumentation system are focus subsystem sensors and sensors which monitor temperatures, stereo and crab position, the status of the film handling assembly, and the port-door (FM 6 and on). Indications of the status of each of these items will normally be recorded during any photographic or focus sequence and telemetered to a ground station at first opportunity. These items will also be monitored directly whenever the S/V is in contact with a ground station.

4.8.3.1 Electrical Characteristics. C/P instrumentation transducers will be supplied by GE with either +22 (converted from +28 v within the C/P) or +5 v d-c regulated power. The nominal voltage output of each instrumentation point will vary from 0 to +5.0 volts. The nominal output impedance of these circuits 5.6 K ohms or less; 10 K ohms output impedance is a maximum.

4.8.3.2 Instrumentation Points. Table 4-5 lists the C/P instrumentation points with the range of measurements and sampling rate. The table describes the instrumentation existing in the current configuration (as of FM 21).

4.8.4 Port-Open Telltale

The telltale sensor is designed to monitor the status of the OCV port door, and has been installed in FM 6 and subsequent payloads. The sensor is capable of indicating whether the view-port door is open or indicating the number of times it was closed in the past up to four times. An output of one volt corresponds to one closing, two volts for two closings, three volts for three closings, four volts for four closings, and five volts for currently open.

4.8.5 Test Plug and Umbilical

C/P flight instrumentation is not continuously available during ground test and countdown. Therefore, two additional sources of information concerning payload condition are provided. The sources are the payload test plug and umbilical circuits. In addition, these instrumentation points provide valuable supplementary information during ground testing.

4.8.5.1 Test Plugs. The C/P test plugs consist of 78 test points including 1 spare (see Table 4-6). These circuits are carried from the test box mounted on the component support tube through a special hatch cover and down the gantry through the transfer room to the VSB via hardline circuits. These circuits will be recorded in the VSB and will be available until gantry removal (about two hours before launch).

TABLE 4-5

CAMERA PAYLOAD INSTRUMENTATION POINTS
As of FM 21

Designation Code	Function	Range	Sampling Rate (samples/sec)
CPL 1	Camera film-path temperature*	35 F to 120 F	1/18
CPL 1	CB-12 Monitor**	4-state	2.5
CPL 2	Forward record storage temperature	35 F to 120 F	2.5
CPL 3	Stereo mirror differential temperature	-1 F to +3 F	1/18
CPL 4	Stereo mirror temperature	35 F to 120 F	1/18
CPL 5	Lens barrel aft end temperature	63 F to 80 F	1/18
CPL 6	45-degree mirror temperature	35 F to 120 F	1/18
CPL 7	Component support tube -Y temp. sta. 149	35 F to 120 F	1/18
CPL 8	Component support tube -Y temp. sta. 179	35 F to 120 F	1/18
CPL 9	Component support tube -Y temp. sta. 198	35 F to 120 F	1/18
CPL 10	Reference voltage	Fixed at 2.1 volts	1/18
CPL 11	Component support tube -Z temp. sta. 179	35 F to 120 F	2.5
CPL 12	Slit Position	4-state	5
CPL 13	Stereo position	-15° to +15°	5
CPL 14	Crab position	0° to 3.5°	5
CPL 15	Film take-up quantity, coarse/reel rotation***	0 to 1017 ft.	2.5
CPL 16	Film take-up quantity, fine ***	0 to 45 ft.	5
CPL 17	Looper position/film tension	2 in. to 25.5 in.	5

* Deleted, effective Flight No. 15
** Effective Flight No. 17 (FM 19)
*** See Section 4.5.3.5.1

4-61

Approved for Release: 2024/01/30 C05098943

TABLE 4-5 (Continued)

Designation Code	Function	Range	Sampling Rate (samples/sec)
CPL 18	Film-drive electronics output	2-state	2.5
CPL 19	Amplified data signals	4-state	5
CPL 20	Platen position (coarse)	0 to 0.020 in.	5
CPL 21	Focus output	±0.002 in.	2.5
CPL 22	Focus forward channel output	±0.020 in.	2.5
CPL 23	Focus reverse channel output	±0.020 in.	2.5
CPL 24	Supply cassette film path temperature*	35 F to 120 F	1/18
CPL 24	CB-10 Monitor**	4-state	2.5
CPL 25	Port-open telltale	5-state	5
CPL 26	Environmental power supply - OCV	14 - 34 volts	5
CPL 27	Platen position (fine)	0 to 0.0043 in.	5
CPL 28	Film take-up quantity medium****	0 to 282 ft.	2.5
CPL 29	Take-up motor current	0 to 1.5 amp.	2.5
CPL 30	CB-8 monitor**	4-state	2.5
CPL 31	CB-9 monitor**	4-state	2.5
CPL 32	CB-11 monitor**	4-state	2.5
CPL 33	Stereo servo logic monitor***	5-state	2.5
CPL 34	Crab servo logic monitor***	5-state	2.5
CPL 35	28-volt supply***	23 - 34 volts	2.5

* Deleted, effective Flight No. 15
** Effective Flight No. 17 (FM 19)
*** Effective Flight No. 19 (FM 21)
**** See Section 4.5.3.5.1

Approved for Release: 2024/01/30 C05098943

TABLE 4-6

CAMERA PAYLOAD TEST POINTS

VTP 1	1	CPL 1
VTP 2	-	CPL 2
VTP 3	-	CPL 3
VTP 4	-	CPL 4
VTP 5	-	CPL 5
VTP 6	-	CPL 6
VTP 7	-	CPL 7
VTP 8	-	CPL 8
VTP 9	-	CPL 9
VTP 10	-	CPL 10
VTP 11	-	CPL 11
VTP 12	-	CPL 12
VTP 13	-	CPL 13
VTP 14	-	CPL 14
VTP 15	-	CPL 15
VTP 16	-	CPL 16
VTP 17	-	CPL 17
VTP 18	-	CPL 18
VTP 19	-	CPL 19
VTP 20	-	CPL 20
VTP 24	-	CPL 24
VTP 25	-	CPL 25
VTP 28	-	CPL 28
VTP 29	-	CPL 29
VTP 30	-	CPL 30
VTP 31	-	CPL 31
VTP 32	-	CPL 32
VTP 33	-	CPL 33
VTP 34	-	CPL 34
VTP 35	-	CPL 35
--	-	VTP Instrumentation return

Table 4-5 shows CPL assignments

TABLE 4-6 (Continued)

VP1		CPL 22
VP2		Slit Position, most significant bit, N.O.
VP3		Slit Position, most significant bit, N.C.
VP4		Slit Position, least significant bit, N.O.
VP5		CPL 21
VP6	CB 8	Stereo, most significant bit, N.O.
VP7	CB 8	Stereo, most significant bit, N.C.
VP8	CB 8	Stereo, most significant bit common
VP9	CB 9	Stereo, least significant bit, N.O.
VP10	CB 9	Stereo, least significant bit. N.C.
VP11	CB 9	Stereo, least significant bit common
CP12		CPL 23
VP13		+5 volts d-c supply
VP14		Automatic focus lead A
VP15		Automatic focus lead B
VP16		Focus motor lead A
VP17		Focus motor lead B
VP18	CB 10	Crabbing, most significant bit, N.O.
VP19	CB 10	Crabbing, most significant bit, N.C.
VP20	CB 10	Crabbing, most significant bit common
VP21	CB 11	Crabbing, 2nd most significant bit, N.O.
VP22	CB 11	Crabbing, 2nd most significant bit, N.C.
VP23	CB 11	Crabbing, 2nd most significant bit common
VP24	CB 12	Crabbing, least significant bit, N.O.
VP25	CB 12	Crabbing, least significant bit, N.C.
VP26	CB 12	Crabbing, least significant bit common
VP27		Film-speed bit No. 1 on

TABLE 4-6 (Continued)

VP28	Film-speed bit No. 1 off
VP29	Film-speed bit No. 2 on
VP30	Film-speed bit No. 2 off
VP31	Film-speed bit No. 3 on
VP32	Film-speed bit No. 3 off
VP33	Film-speed bit No. 4 on
VP34	Film-speed bit No. 4 off
VP35	Film-speed bit No. 5 on
VP36	Film-speed bit No. 5 off
VP37	Film-speed bit No. 6 on
VP38	Film-speed bit No. 6 off
VP39	Camera drive on
VP40	Camera drive off
VP41	Common for command bit 1-7
VP42	Data Signal A
VP43	Data Signal A return
VP44	-22 volts d-c supply
VP45	+22 volts d-c supply
VP46	+28 volts d-c supply
VP47	DC return
VP48	Slit Position, least significant bit, N.C.
VP49	Focus control power command
VP50	Environmental supply
VP51	CPL 27

4.8.5.2 Umbilical. In addition to the C/P test points, seven umbilical points plus one spare are available for verifying the C/P condition until lift-off. These functions are listed in Table 4-7 and are self-explanatory with the exception of BBT6. This function, designated Master umbilical telltale, will provide an indication whenever power is applied to either of the following command circuits:

a. Focus forward drive (CB17)
b. Focus reverse drive (CB18)

4.9 AEROSPACE GROUND EQUIPMENT

4.9.1 Purpose and Scope

EKC Aerospace Ground Equipment (AGE) is defined as the equipment required on the ground to make the photographic subsystem operational in its intended environment. The necessary equipment was chosen through detailed studies of the procedures in assembly, handling, and testing used to bring the payload into satisfactory operation.

4.9.2 AGE Requirements

AGE is subdivided into four functional groups: payload test equipment, payload support equipment, payload handling equipment, and photographic support equipment. The equipment groups and the various items included are discussed in the following paragraphs. Photographs of several items are shown in Section 2.

4.9.2.1 Payload Test Equipment. Payload test equipment is that equipment required to test the electrical, optical, mechanical, and environmental performance of the payload. The three major items of equipment which are used at the payload test level are:

a. Test console

TABLE 4-7

C/P UMBILICAL POINTS

Code	
BBT1	Looper position umbilical instrumentation
BBT2	Drive frequency umbilical instrumentation
BBT3	Stereo mirror umbilical temperature
BBT4	Tube station 177 umbilical temperature
BBT5	Torque motor command umbilical instrumentation
BBT6	Master umbilical telltale
BBT7	Spare umbilical instrumentation
BBT8	Umbilical return

b. Portable test set
c. Collimator

Also included are several items of component test equipment and test support equipment. They are:

a. Record storage test set
b. Line-of-sight test set
c. Leak rate test set
d. Cable test point board
e. Record storage mount and enclosure
f. Test take-up cassette
g. Breakout box
h. Secondary standard
i. Command monitor
j. Film advance control

4.9.2.2 Payload Support Equipment. Payload support equipment is equipment used in direct support of the payload. In general, it is the equipment needed for final flight preparation and mating, or at the recovery site. The equipment in this group includes:

a. Record loading and unloading kit
b. Record dolly
c. Supply cassette and record storage alignment measuring equipment
d. Integration accessory kit
e. Purging equipment
f. Film cooler
g. Cleaning equipment
h. Forward storage table and lifting yoke
i. Record travel viewer

4.9.2.3 Payload Handling Equipment. Payload handling equipment is the equipment used to handle, ship, and maneuver the C/P and its accessory equipment throughout all activities up to insertion in the OCV. Included are:

a. General purpose mobile hoist
b. Truck
c. C/P assembly lifting yoke
d. Handling accessory kit
e. Erector
f. Payload shipping container
g. Accessory shipping container
h. C/P assembly integration lifting yoke
i. Cradle
j. Aperture mask cover assembly

4.9.2.4 Photographic Support Equipment. Tests using the collimator and other payload tests depend largely on the evaluation of photographic data. Five items of photographic equipment are therefore included as deliverable AGE. They are:

a. Record viewer
b. Record splicer
c. Test record support equipment
d. Microdensitometer
e. Test record transfer

4.9.3 Equipment Description

A description of each item of AGE is outlined in the Photographic Subsystem Specification. Only that equipment which is directly used for functional tests of a completed payload is discussed in this report. These items are:

a. Collimator
b. Test console
c. Portable test set

4.9.3.1 Collimator. The purpose of the collimator is to provide a high resolution target at a simulated distance of 80 n mi and to optically test the complete payload and the payload lens assembly. The collimator focus adjustment also compensates for any C/P optical effects caused by operation in a vacuum environment.

Targets are provided for use in analyzing the optical and photographic components of the C/P. One of the targets moves to simulate a ground image. Mounts are provided to support the payload lens assembly or complete payload during test.

4.9.3.1.1 Optical Parameters. The collimator is a reflecting telescope with a Newtonian focus. It is provided with an illuminated target at the focus position which can be adjusted to simulate a target distance of approximately 80 n mi. Some of the significant data for the collimator are shown in Table 4-8, and a schematic of the optical component is shown in Figure 4-10.

The collimator entrance aperture is 21 inches and the collimator primary mirror has a diameter of 24 inches. Because the 19.50-inch aperture of the payload lens is less than the aperture of the collimator, the aperture of the C/P is not limited by the collimator.

The collimator has a 17-minute of arc half-field angle which is limited by the aberrations of coma and astigmatism. It appears that this is about the maximum field usable at the high resolution required.

TABLE 4-8

OPTICAL DATA FOR COLLIMATOR

Collimator	
Focal length	300 ±3 inches
f-number	12.5
Field of view (half-angle)	17 minutes
Optical axis direction	Horizontal
Primary Mirror	
Diameter	24.000 ±0.062 inch
Thickness (edge)	4.00 ±0.062 inch
Mirror curve	Parabolic ±1/10 wavelength of green light
Secondary (Diagonal) Mirror	
Aperture	3.5-inches wide; 6-inches long
Thickness	0.895 ±0.010 inch
Mirror curve	Flat
Target Field	34-minutes vertical height; 5.4-minutes horizontal width
Resolution	
Diffraction limit size at the image plane	0.000314 inch or a resolution of 108 lines/mm at 600 mμ and *f*/15.4

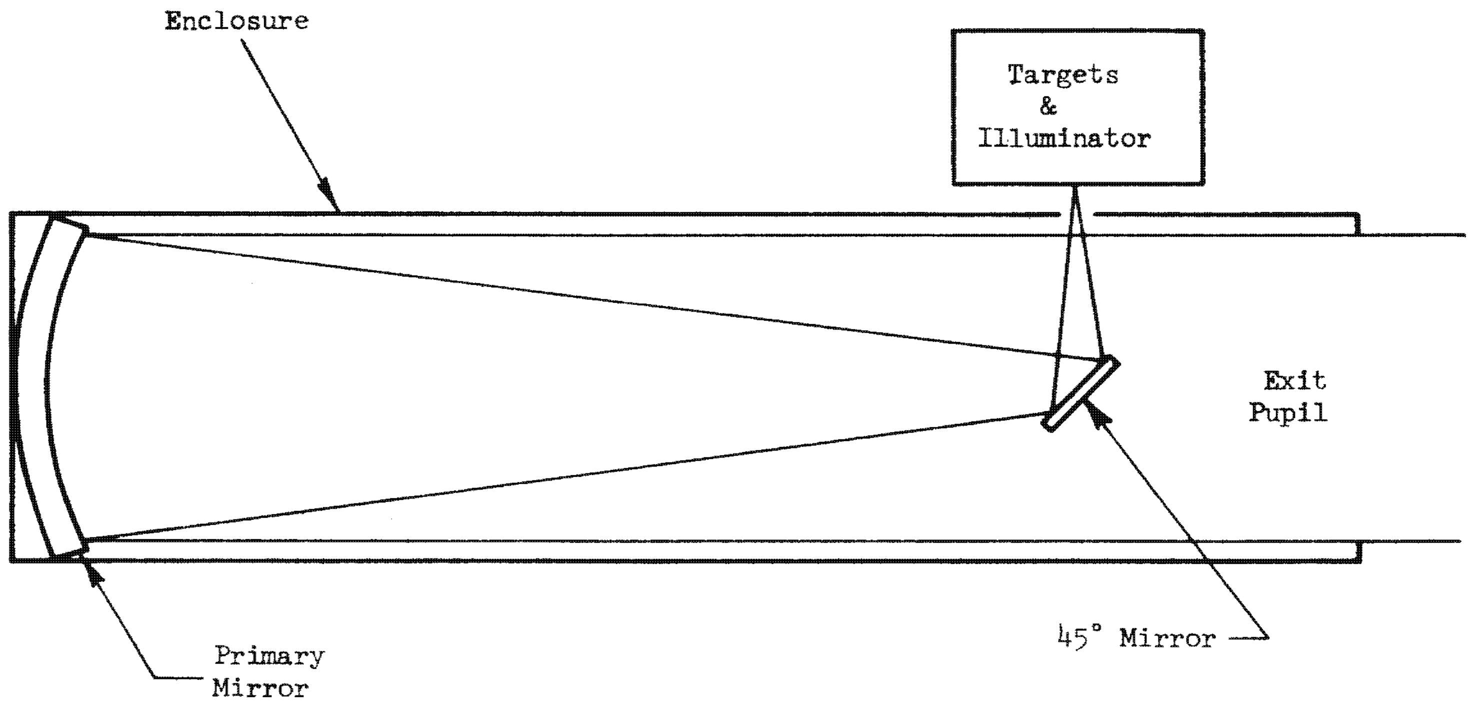

Figure 4-10. Collimator Schematic

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The optical reduction produced by the collimator when viewed with a 77-inch focal length lens is 3.90 (±1 percent). This reduction permits the targets used in the collimator focal plane to be made to a large enough scale that their quality does not impair the quality of the image in the C/P focal plane. The optical quality of the collimator is such that its performance on axis is diffraction limited.

4.9.3.1.2 Mechanical Design. The collimator consists of the following major sections:

- Primary mirror assembly
- Diagonal mirror assembly
- Optical frame assembly
- Enclosure and bed
- Test unit mounting assembly
- Target and illuminator assemblies

The primary mirror assembly supports and positions the 24-inch primary mirror. This mount is capable of adjusting the mirror about azimuth and elevation axes for alignment of the collimator axis.

The diagonal mirror mount provides a bearing surface so that the 45-degree collimator mirror can be rotated about the optical axis. Vertical and horizontal movement in a plane perpendicular to the optical axis is also provided. It is possible to alter, if needed, the 45-degree mirror angle. The size of the 45-degree collimator mirror mount does not exceed the size of the payload lens diagonal mirror so as not to obstruct the wave front presented to the lens being tested by the collimator.

An enclosure is provided to protect the collimator air path from convection currents, thermal disturbances, dirt and dust, and stray light (through baffles and painted interior surfaces).

The test unit mounting assembly contains the mounts necessary to support the payload lens assembly in front of the collimator aperture. This mounting assembly is capable of ±3.2 degrees movement to position the collimator image in the lens-film plane aperture. This assembly is capable of supporting the complete C/P with its X axis at an angle of 90 degrees to the collimator horizontal optical axis. The payload can be moved to position the collimator image at all positions in the 6.4-degree field of the payload lens.

A flat test mirror, which has a diameter equal to that of the primary mirror, is supplied as a collimator assembly accessory. It is used as an alignment reference for the collimator image. The mirror is mounted in a sling-type mount similar to the primary-mirror support structure and is used only during the alignment of the collimator and during other selected times for collimator image evaluation.

4.9.3.1.3 Targets and Illuminators. Three different targets (a fixed target, a moving target, and a focus control assembly target) are required for correct evaluation and testing of the C/P on the collimator.

The fixed target assembly provides a means for locating the following charts or reticles at the collimator image plane:

a. Resolving power charts: Tri-bar
b. Resolving power charts: Sine-wave response
c. Distortion pattern chart

The moving target simulates the type of scene to be viewed by the complete payload lens assembly during operation of the actual payload. Also included are resolution charts and other test charts. The velocity of this target is continuously adjustable over the range corresponding to the camera-drive velocity range.

The focus control target is similar to the moving target assembly. The target covers a wide enough field to provide an adequate signal to the focus control component thereby permitting correlation between optimum photographic focal position and the focal position output of the focus control assembly.

Each of these target assemblies includes the light source and optics necessary to evenly illuminate the complete target area. A fan and ducts for cooling are used to conduct the heat from the lamp area away from the collimator optical path.

4.9.3.1.4 Environmental Requirements. The temperature in the collimator room is controlled to 69.5 ±1 F. The allowable relative humidity is 50 ±20 percent. The area is free from vibration above a 10-microinch amplitude.

Studies of thermal effects on the collimator indicate that temperature changes limited within a linear gradient of 0.1 F over the 20-inch beam will result in a negligible wave-front change inside the collimator 300-inch air path. Another possible source of optical error causing wave-front deformation could be variation in air density in an air column 20 inches high. However, on the basis of theoretical considerations and practical experiments, evacuation of the collimator path is not necessary. The collimator, therefore, is built without a vacuum enclosure.

Instead, it is provided with a relatively simple enclosure with insulated walls to exclude transient turbulence and minimize thermal effects in the air path. In addition, suitable baffles and shrouds are provided at the entrance window of the lens or payload to prevent optical inhomogeneities in these regions.

4.9.3.2 Test Console. The purpose of the test console is to control the collimator, to provide the C/P with the inputs required for proper operation, and to monitor the outputs of all transducers in the C/P. It will coordinate the operation of the C/P and collimator under test program operation and, in conjunction with the collimator, provides complete test equipment for the simulated operation of the subsystem.

The test console is set up near the collimator. The console is divided into four functional groups: command, instrumentation, collimator functions, and test power supply, as shown in Figure 4-11. The test console is shown pictorially in Figure 2-18.

4.9.3.2.1 Command Group. The command group supplies the commands necessary to simulate C/P operation. The commands are manually set but are sent to the C/P properly coded. A patchboard of interconnectable jacks enables all the C/P functions to be checked with a limited number of instruments.

4.9.3.2.2 Instrumentation Group. The instrumentation group measures and records instrumentation voltages in analog and digital form, and indicates out-of-limit instrumentation conditions. The test console has provisions to receive 134 instrumentation channels from the payload. These payload instrumentation channels present either an analog function voltage, a step function, or a discrete voltage pulse. The console has the facility to connect any one of 40 selected instrumentation channels with an instrumentation input by means of the patchboard. Six vacuum-tube voltmeters are available in the console to measure a signal range of 0 to 5 volts. Eight go no-go indicator lights are used on the console to provide out-of-limit information.

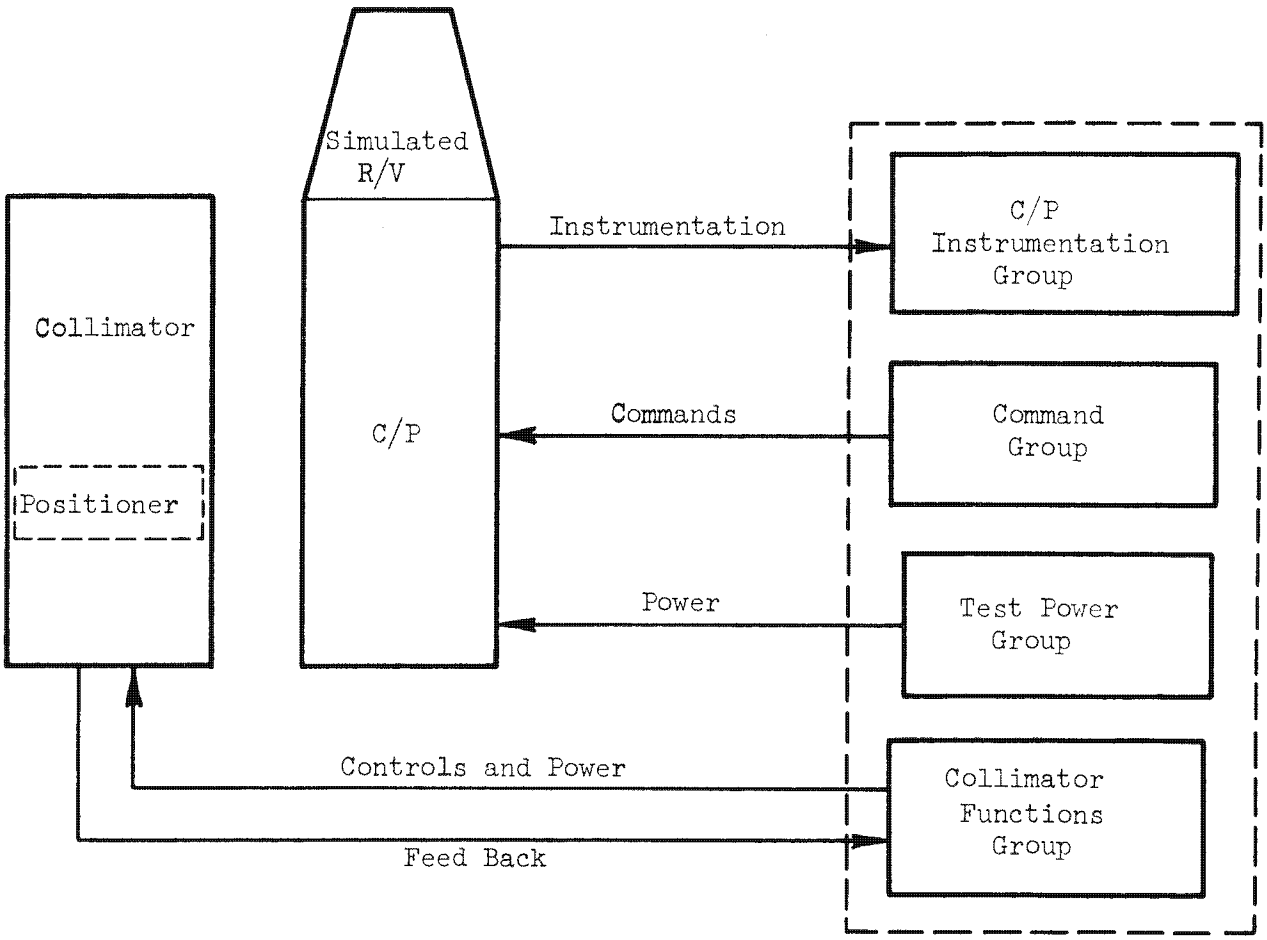


Figure 4-11. Test Arrangements for Collimator, Test Console, and C/P

The test console also contains the necessary equipment and circuitry to sample all instrumentation voltages, payload power-supply voltages and currents, and time; to convert these to digital form; and to record them numerically on a permanent paper-tape record. Additional recorders are also included as built-in equipment.

The instrumentation group includes a self-calibration or test facility, which provides the circuitry necessary to calibrate the instrumentation meters, recorders, and go, no-go devices during test and checkout of the payload.

4.9.3.2.3 Collimator Functions Group. The collimator functions group provides control and instrumentation of the moving target and the light intensity of all targets as well as for alignment of the positioner.

4.9.3.2.4 Test Power Supply Group. The test console supplies and monitors power required by the C/P during test and checkout. Four different power supply units are used for the environmental, operating, and instrumentation functions of the C/P. The power requirements for these supplies are:

	Adjustable Voltage Range	Max. Current
Operating	22-34 volts	15 amps
Environmental	22-34 volts	5 amps
Instrumentation	4.9-5.1 volts	10 ma
Instrumentation Bias	0-12 volts	10 ma

The console has provision to protect the C/P from overvoltage or excessive current. If the voltage at the payload exceeds the set voltage by 5 percent, the power will be disconnected from the C/P within one millisecond.

Protection against current is provided over a range of 3 to 15 amps for the operating power supply and 1 to 5 amps for the environmental power supply. If payload current exceeds the set value, the power is disconnected from the C/P within one millisecond.

A C/P power monitor records the application of voltage, the voltage level, current level, and the total time during which power is applied.

4.9.3.3 Portable Test Set. The portable test set shown in Figure 2-19 is similar in its purpose to the test console. It is housed in a portable cabinet and contains no readout instrumentation except a digital voltmeter. All instrumentation points are supplied at labeled jacks for use with external instruments. The portable test set supplies the payload with commands and power for limited operation and provides test points for the output of all transducers in the payload. The portable test set does not provide the coordinating functions to the collimator that are provided in the test console. The payload can be put through a test program using the portable test set without returning the C/P to the collimator area. The portable test set can be divided into three functional groups: command, instrumentation, and test power supply.

4.9.3.3.1 Command Group. The command group provides the controls to initiate digital commands required by the C/P during test and checkout. The commands and the required equipment are essentially the same as those used in the test console. The portable test set does not, however, supply the clock generator or function that is available in the test console.

4.9.3.3.2 Instrumentation Group. The instrumentation group of the portable test set has provision for measuring instrumentation voltages using external meters and recorders (not part of this equipment). A test jack, located on the front of the test set cabinet, is also provided for each of the 134 instrumentation channels.

4.9.3.3.3 Test Power Supply Group. This group is equivalent to the test power supply group for the test console.

SECTION 5
RELIABILITY

5.0 RELIABILITY PROGRAM

The reliability program has followed basic procedures established to meet the program objectives. MIL-R-27542 was used as a guide in organizing the reliability program, which was divided into six areas: design review, training, testing, parts reliability, monitoring, and analysis.

A significant portion of the reliability program was a thorough and systematic review of the design as it developed. Early phases consisted primarily of an independent review of the engineering effort with emphasis on systems and requirements, design approach, and specifications. More recent efforts toward reliability improvement included a review of minor design changes and failure analyses. In addition, some contract changes requiring major redesign necessitated review effort consistent with that expended in the earlier phases of the program.

Training was provided for all employees who contributed to payload reliability.

For the test program, developmental testing was extended into regions of environmental extremes and operational life. These tests were performed using components of the Reliability Model (RM) Payload and Reliability Enchancement Components (RC) to demonstrate subsystem reliability.

The parts reliability program was an effort to select and upgrade the quality of the parts used in the Photographic Subsystem. Through information from data-exchange programs, vendor surveys, prior usage, test programs and flight proven hardware, a reliability approved parts list was prepared and was the basis for the selection of parts by design engineering. Analysis of part failures with appropriate recommendations for corrective action is a continuing and important function of the parts reliability program.

Reliability Monitoring included the establishment of a continuing program of surveillance over (1) procurement, handling, storage, and packaging of both purchased and fabricated parts, (2) manufacturing methods and procedures, and (3) the adequacy of test equipment, tools, fixtures and facilities.

Reliability analysis included the analytical, statistical, and mathematical phases of the reliability program and the determination of reliability objectives for the payload.

5.1 GENERAL

The reliability objective for the photographic subsystem is to provide a 95 percent probability of success, where success is defined as acquiring at least 60 percent of the available information. The probability that a mature and adequately tested design would attain this goal was estimated. The first step in the estimate was the definition of the various tasks of the Camera Payload where the over-all mission of the C/P was logically divided into three parts:

a. Launch phase (drop of umbilical cord through injection into orbit).

b. Orbit operations phase (photography, data recording, environmental control, and telemetry functions).

c. Re-entry phase (execution of de-orbit maneuvers through impact).

The second step was to mathematically define the task of acquiring photographic information. Block diagrams were developed for the active reliability elements of the C/P, and the probability of success of each of these elements was estimated.

5.2 LAUNCH PHASE RELIABILITY

The C/P performs a passive role during launch; with the exception of the pressure relief valves and the torque motor in the film supply, the function of the C/P is to (1) provide adequate support for the payload components, (2) maintain alignment of the optical elements, and (3) provide a means of attachment to the vehicle. Film alignment and tension must also be maintained in the film path.

5.2.1 Launch Survival Demonstration

All payload components were qualified, although some minor differences existed between the RM components and flight hardware. Current flight payloads are of a design which meets the qualification requirement of the Flight Model Payload Specification as demonstrated by the tests outlined in the Qualification Test Plan.

It was concluded from qualification tests that the design of the payload demonstrated its launch survival capability. The operation of all Camera Payloads on orbit has substantiated this conclusion.

5.2.2 Launch Phase Reliability Estimate

The probability of launch survival was estimated to be 0.99.

5.3 ORBIT OPERATIONS PHASE RELIABILITY

The C/P performs its active functions during the orbit operations phase. A mathematical model was developed which associates information with the amount and quality of the photography. Accordingly, the C/P components necessary to provide both the amount and quality elements were defined and an estimate was made of probability of success of each of these elements for this phase of the photographic mission.

5.3.1 Mathematical Model of Orbit Operations Phase Reliability

The approach to reliability on this program was to define a utility function which was called "Information Return". To construct a mathematical model, an analytical definition of information return in terms of quality and amount was developed.

5.3.1.1 Quality. Resolution is recognized as a measure of photographic quality. This model assumes that photographic quality is directly related to the resolution at the film plane. Based on this assumption, the quality index, Q, may be expressed as:

$$Q = r/R$$

where:

r = Resolution achieved at the film plane (lines/mm) and
R = Resolution specified at the film plane (lines/mm)

Q is expected to be normally distributed about a mean value, say $\bar{Q}$, with a standard deviation of 0.09. Knowledge of the normal distribution parameters readily permits the calculation of the probabilities associated with minimum acceptable qualities.

A number of factors will affect the value of $\overline{Q}$; the two most important are focus and image motion compensation. Degradation resulting from the combination of these factors is obtained by sine-wave response techniques (Appendix B). An estimate of $\overline{Q}$ is made in Table 5-2.

5.3.1.2 Amount Index. Assuming that payload operation time is related to the amount of photography acquired, the amount index may be expressed as:

$$A = 1 \text{ or } \frac{t}{T} \quad \text{(whichever is smaller)}$$

where:

A = An index representing the amount of photography
t = Time the payload operates properly, and
T = Specified operating time

The amount index (A) cannot exceed 1.0; i.e., there is no credit given for life beyond the specified mission life. However, credit is given for partial completion of the photographic mission.

It is expected that failures will occur at a constant rate. Therefore, using mean time between failures as the parameter, the time of failure, t, has an exponential probability density function f (x) as follows:

$$f(x) = \frac{1}{m} \exp\left(-\frac{x}{m}\right)$$

where

m = mean time between failures, and
x = dummy variable with dimensions of time

Note that, from the nature of f (x),

$$\int_0^T f(x)\, dx = P \text{ (probability that a failure will occur within a specified operating time, T)}$$

$$= 1 - \exp\left(-\frac{T}{m}\right) = 1 - \rho$$

where ρ is an estimate of the parameter, A, and

$$\rho = \exp\left(-\frac{T}{m}\right) = \text{probability of operating for the entire mission.}$$

5.3.1.3 Information. The amount of information return is defined as:

$$I = QA$$

where

I = Information return

Q = Quality index, and

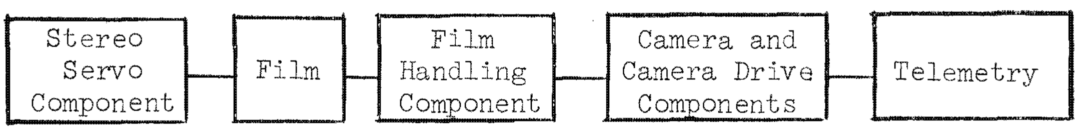
A = Amount index

Both Q and A are random variables; therefore, information return is a random variable. The aim of the reliability program is to ensure that the components affecting Q and A will operate successfully after having survived the anticipated environments so that for 95 percent of the missions, information return will be at least 0.6.

For a given $\bar{Q}$ and ρ, the probability distribution of information return can be determined. Since the integrals involved are too difficult to obtain in closed form, numerical methods were used. From calculations, pairs of $\bar{Q}$ and ρ have been determined so that the probability is at least 95 percent that information return is greater than 0.6. The results are graphically presented in Figure 5-1. The ordinate, $\bar{Q}$, is the average value of the quality index. A standard deviation of .09 has been assumed for the distribution of Q. The abscissa, ρ , is the probability of no failures during the photographic mission. Any combination of values of $\bar{Q}$ and ρ that locate a point within the cross-hatched portion of Figure 5-1 meets the engineering performance requirements. It is evident from the figure that requirements on both operating life and photographic quality are stringent. As an example, if the average quality index, $\bar{Q}$, is 0.98 and the probability of operating for mission life, ρ , is 0.9, the intersection is point B of Figure 5-1 and performance requirements are not met.

5.3.2 Reliability of Amount Elements

Based on the mathematical model, the amount factor (A) can be diagrammed as follows:



A reliability estimate can be determined by the number of catastrophic failures expected to result as a function of time. Only those parts are considered whose independent failures would cause loss of an essential amount-element function.

Estimates were made for the amount elements using techniques outlined in Rome Air Development Center Reliability Notebook; the values are shown in Table 5-1.

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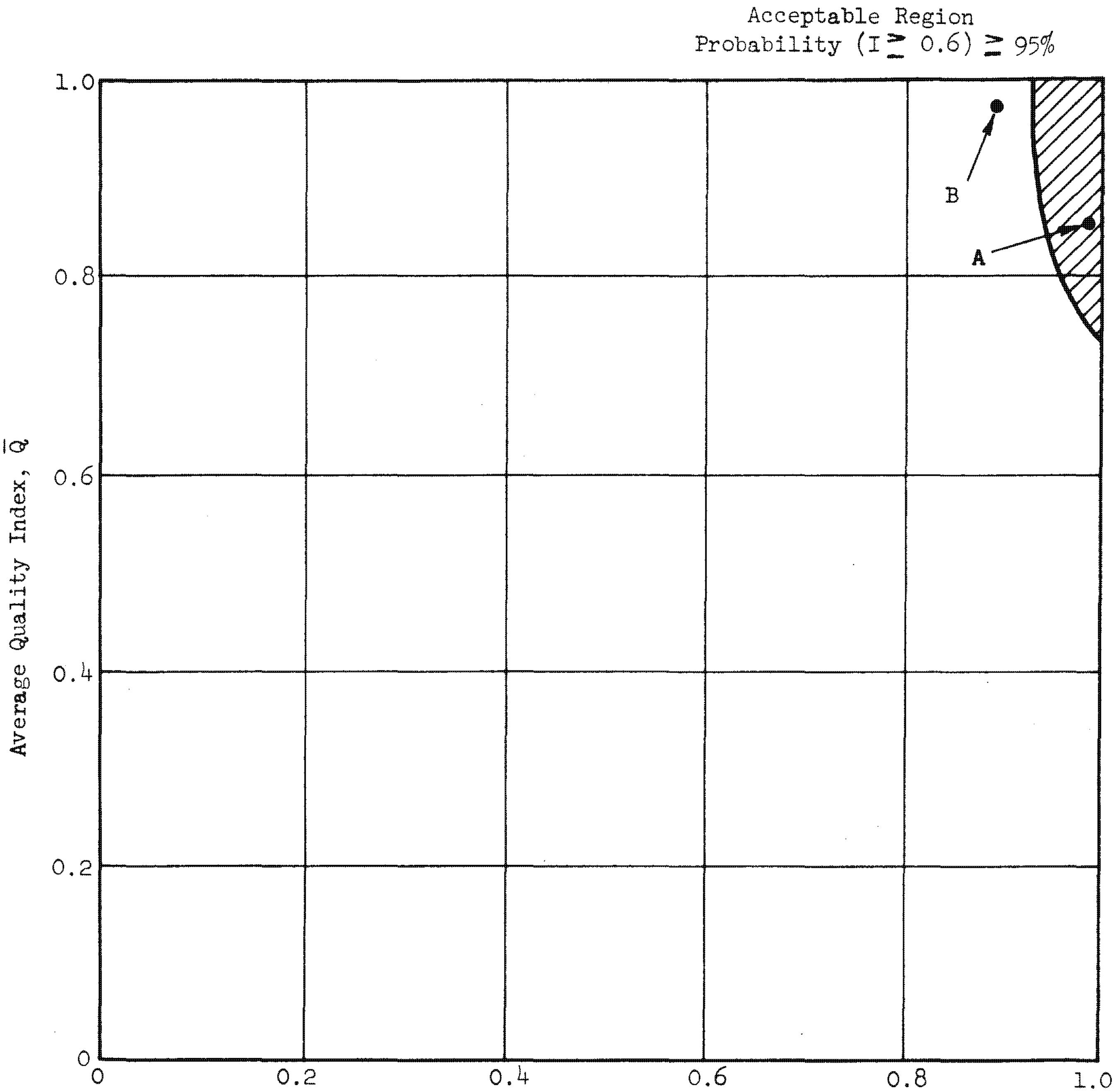


Figure 5-1. Probability of Operating for Mission, ρ

TABLE 5-1

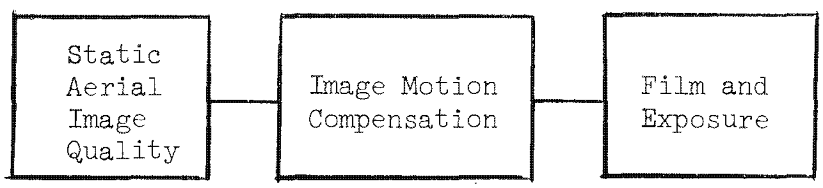
RELIABILITY ESTIMATE OF AMOUNT ELEMENTS

Element	Prediction
Stereo Servo	0.999
Camera and Camera Drive Components	0.993
Film Handling Components	0.999
Film	0.999
Telemetry	0.999
Over-all reliability estimate of amount elements	0.989

One of the basic assumptions underlying the above estimates is that the design is mature and qualified by adequate testing.

5.3.3 Reliability of Quality Elements

The performance elements that contribute to photographic quality (Q), measured in terms of resolution, are depicted in the following block diagram.



QUALITY ELEMENTS

The reliability prediction for the Quality Elements was based on laboratory performance evaluation and engineering judgement; the values are shown in Table 5-2.

TABLE 5-2

SUMMARY OF PHOTOGRAPHIC QUALITY INDICES

	Average Quality Index	
Reliability Element	Based on System Analyses	Estimated From Test Results
Static Image Quality	.997	.96
Image Motion Compensation	.997	.99
Film and Exposure	.999	.999
Quality Index ($\overline{Q}$)	.993	.95

5.3.4 Combined Reliability - Quality and Amount Elements

The results of the reliability prediction for the photographic phase of the mission may be combined graphically in accordance with the reliability mathematical model as shown in Figure 5-2.

The average value of the quality index ($\overline{Q}$) is equal to 0.95 as shown in Table 5-2. The probability of no failures during the photographic mission is equal to .989 as shown in Table 5-1. These coordinates locate a point in Figure 5-2 which meets the specified reliability requirements. The calculated probability of achieving at least 60 percent information return is .994.

5.4 RE-ENTRY PHASE RELIABILITY

The majority of the functions that contribute to the reliability of film re-entry are provided by the OCV and the SRV and are not analyzed as a part of this report since they are the responsibility of an associate contractor.

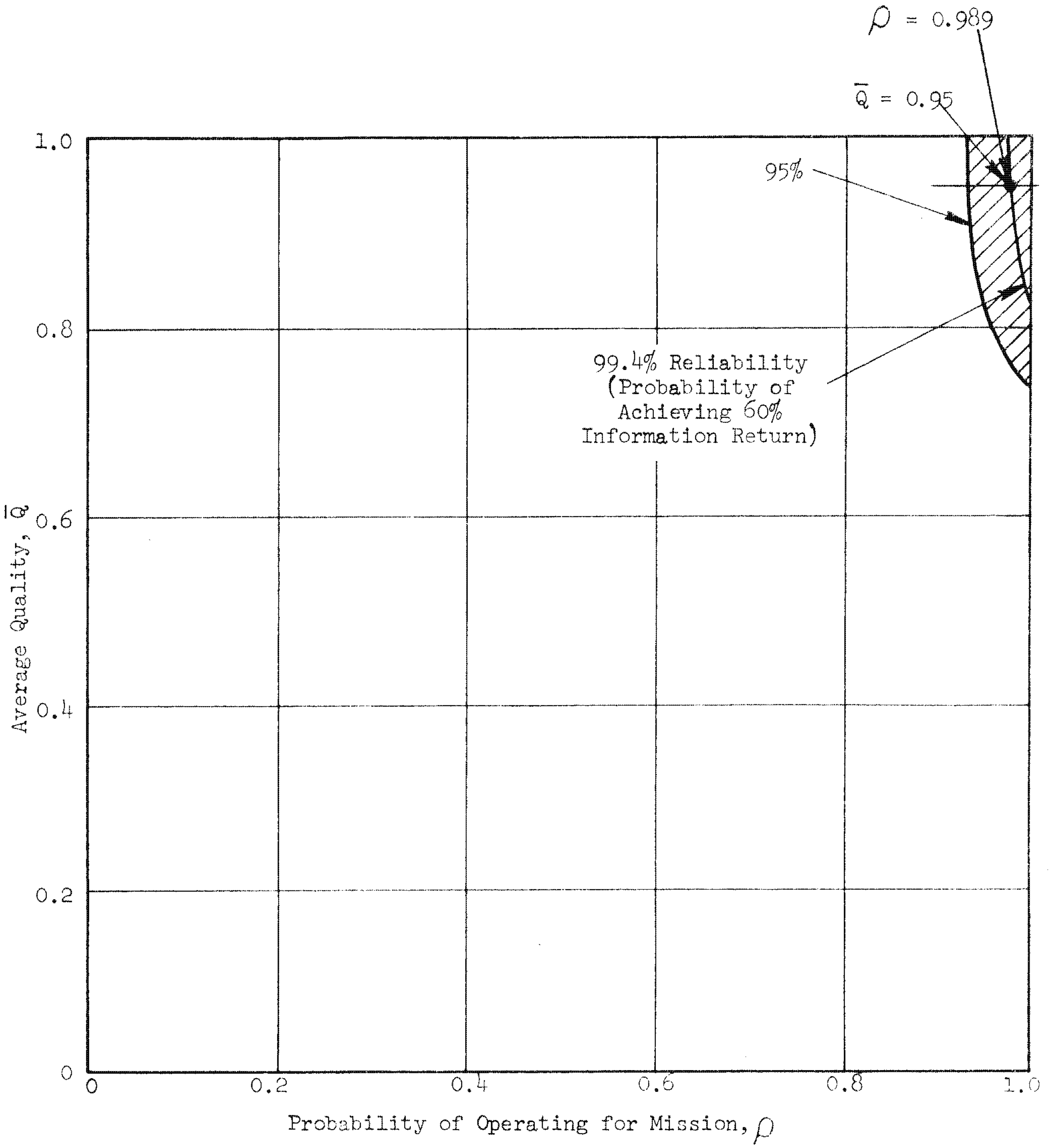


Figure 5-2. Reliability Prediction for Photographic Phase

The reliability estimate of the C/P portion of re-entry phase operations was estimated to be at least 0.999.

5.5 C/P RELIABILITY PREDICTION

The reliability predictions may be combined as shown in Table 5-3. The over-all reliability estimate for the combined launch, photographic, and recovery phases is .983.

TABLE 5-3

RELIABILITY PREDICTION SUMMARY

Phase	Reliability Prediction
Launch Phase	0.990
Photographic Phase	0.994
Recovery Phase	0.999
Over-all C/P Reliability	0.983

It is difficult to confirm the prediction outlined above. However, the binominal distribution can be used to make a statistical inference which does not account for the margin by which the required 60 percent information return is exceeded. Only failures which can be directly attributed to EKC should be considered in the computation of the amount parameter. Thus, if a failure occurs which is not the responsibility of EKC, the amount parameter should be taken as one.

On the above basis, if information return is greater than 60 percent, the mission is considered to be a success. The minimum system reliability can be estimated from the knowledge of the number of successes out of the total number of trials. Figure 5-3 describes demonstrated minimum system reliability

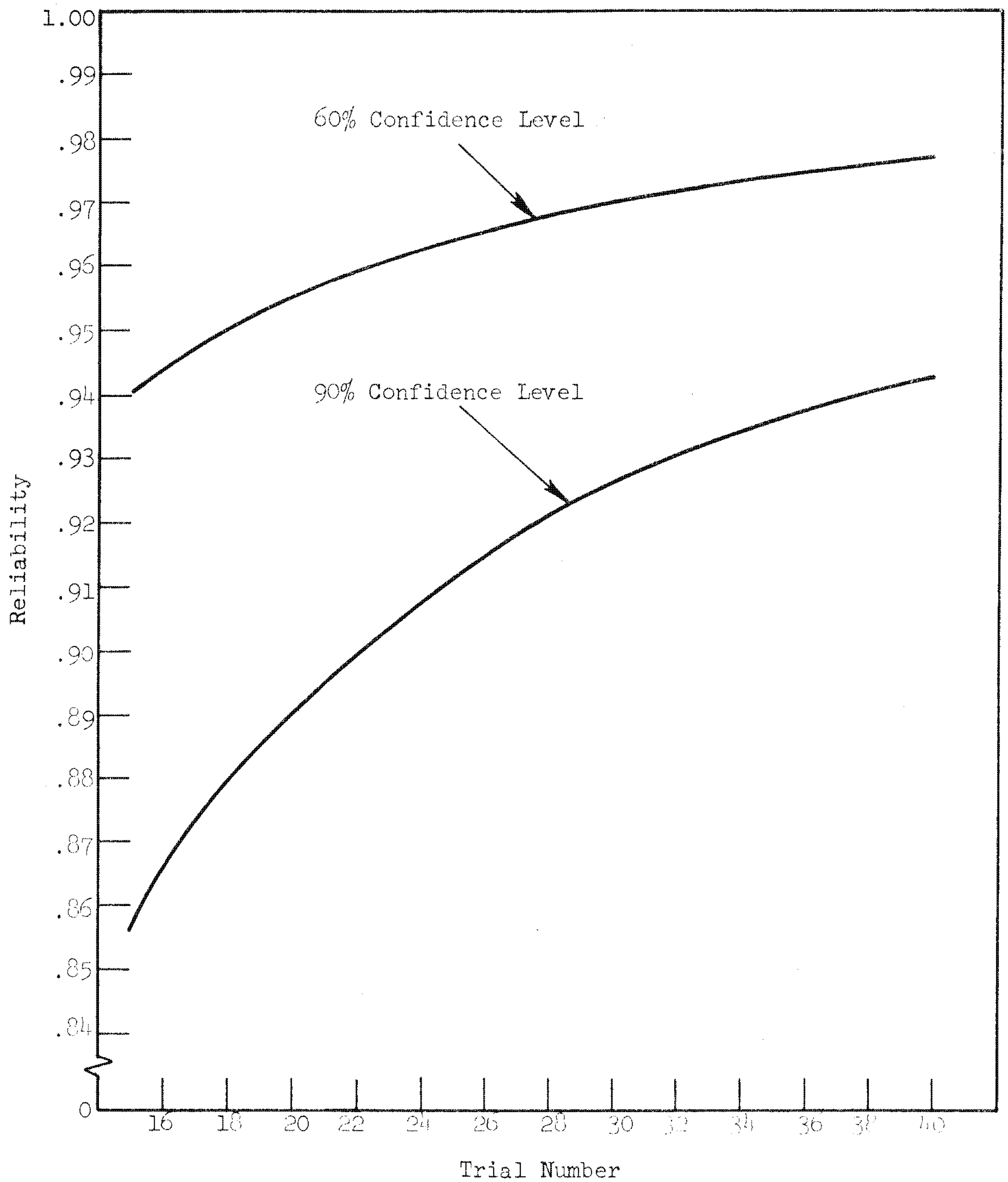


Figure 5-3. Demonstrated Minimum System Reliability Assuming Success at Each Trial

at both 90 and 60 percent confidence levels assuming success at each trial. For example, at the confidence level of 90 percent, 22 consecutive successes would demonstrate a minimum reliability of .90:

APPENDIX A
WEIGHT AND BALANCE DATA

A.1 REFERENCE AXIS SYSTEM

The weight and balance data given in Table A-1 are referred to axes oriented as shown in Figure 4-1. The origin is at station 0,0,0 in the GE coordinate system. Moments and products of inertia at the component level are referred to their own centers of gravity. At the C/P level, they are referred to station 0,0,0.

The data given in Table A-1 are applicable when the crab servo is located on the +Y side of the mirror bridge for southbound photographic orbits. This information reflects the C/P status as of 1 June 1965, and will be effective up to and including Flight Model 25.

A.2 INFORMATION SOURCES

The weights reported in this table are all based on measured values. However, since manufacturing tolerances cause variations in component weights, the values shown do not necessarily reflect exact values for any given C/P.

A.3 PRODUCTS OF INERTIA

The products of inertia are point-mass approximations using only the components shown as contributors.

TABLE A-1

WEIGHT AND BALANCE DATA

(Crab Servo on +Y Side of Mirror Bridge)

	Weight (pounds)	$\bar{X}$ (inches)	$\bar{Y}$ (inches)	$\bar{Z}$ (inches)	I_{xx} (slug ft^2)	I_{yy} (slug ft^2)	I_{zz} (slug ft^2)	I_{yz} (slug ft^2)	I_{xz} (slug ft^2)	I_{xy} (slug ft^2)
Component										
Primary Structure and Elevation Plate Assembly	360.00	105.67	-.02	-.98	15.60	13.28	15.17	.041	2.000	.062
Component Support Tube	88.00	170.23	0.00	-4.74	4.96	17.45	17.49	.000	.005	-.002
Lens Assembly	452.30	169.07	-.03	-4.09	15.17	183.33	183.12	.006	-1.575	.034
Supply Cassette with Reel	66.02	102.32	-.19	13.88	.64	1.72	2.05	-.011	.190	-.016
Camera	39.20	131.21	-.43	12.09	.22	.16	.29	.008	-.009	-.008
Electrical	50.92	154.61	3.68	13.73	.74	1.03	1.65	-.067	.111	.046
Film-Supply Position	52.03	96.00	0.000	9.81	.21	.25	.21	0.000	0.000	0.000
Film-Recovery Position	52.03	28.23	0.00	0.00	.21	.25	.21	0.000	0.000	0.000
Forward Record Storage	25.50	28.86	-.17	1.97	.29	.27	.12	-.002	.038	0.000
Cables and Miscellaneous	25.13	136.82	-4.25	9.36	.68	3.28	3.24	.138	.105	.134
Camera Payload - Full Supply Reel										
Camera Payload less Recovery Elements	1133.60	139.11	.03	.19	48.21	5201.48	5194.72	.387	-15.440	1.812
Recovery Elements	25.50	28.86	-.17	1.97	.31	4.87	4.71	-.004	.351	-.027
Camera Payload	1159.10	136.69	.02	.23	48.52	5206.35	5199.43	.382	-15.089	1.785
Camera Payload - Full Take-up Reel										
Camera Payload less Recovery Elements	1081.57	141.18	.03	-.27	46.92	5096.66	5091.01	.387	-26.016	1.812
Recovery Elements	77.53	28.44	-.06	.65	.52	14.07	13.87	-.004	.351	-.027
Camera Payload	1159.10	133.64	.02	-.21	47.44	5110.73	5104.88	.382	-25.665	1.785

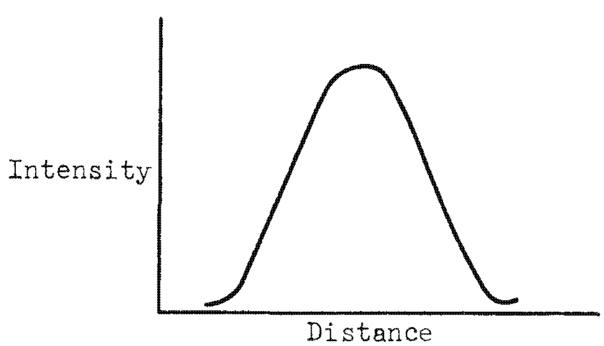
APPENDIX B

SINE-WAVE RESPONSE

GENERAL

Sine-wave analysis is a mathematical technique which is useful in analyzing each element of a system and the system as a whole with regard to their effects on the quality of the photographic image produced. This appendix gives a cursory description of sine-wave response. A comprehensive discussion of the subject can be found in the references listed at the conclusion of this appendix.

If it were possible to start with an infinitely small spot of light and to image it with a lens, the image would not be infinitely small. Diffraction and aberrations in the lens would spread the image out over a finite area. The intensity distribution of the light in this area is called the point-spread function. A cross section might look something like this:



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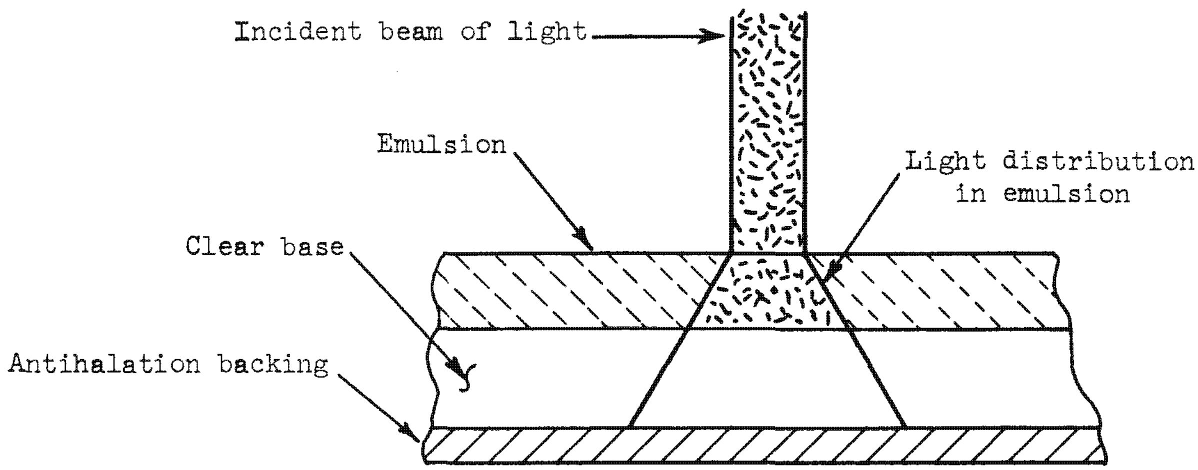
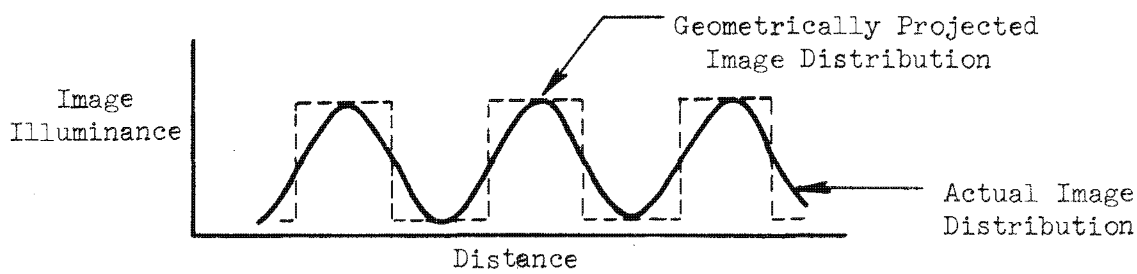
Similarly, if it were possible to image an infinitely small spot of light on a piece of film, the light distribution in the film would not be a narrow shaft through the thickness of the emulsion, but would spread out because of diffraction, reflection, absorption, and so on. The light distribution in the emulsion might look like this:



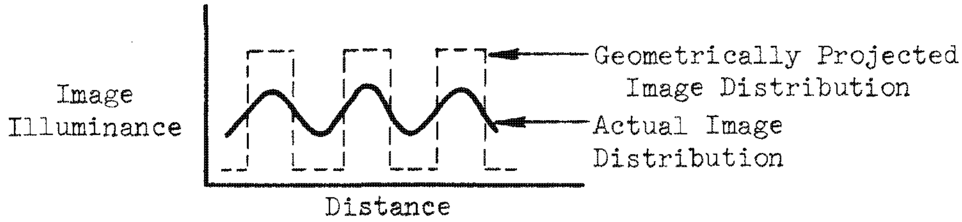
Now consider a light source consisting of a small but finite spot, imaged on a piece of film by a lens. Each infinitesimal element of the source forms its own spread function and all of these combine to make the spot image. Similarly, each element of the image forms its own spread function in the emulsion. These combine to produce the light distribution in the emulsion which in turn determines the distribution of density in the developed film. This distribution of density is a fundamental index of the quality of the photographic image. However, it is difficult to measure directly the distribution in the image of a point source because the measuring sensor must be much smaller than the image. The sensor must have high sensitivity, and its position with respect to the image is critical. If a line source is used instead of a point source, the scanning aperture of the measuring device can be a slit and the light available for measurement is greatly increased. A line source can be thought of as a series of point sources, and the image as a series of overlapping point-spread functions. The energy cross section of this image is called the line-spread function. The point-spread function and the line-spread function are not equal, but they are mathematically related. The line-spread function is therefore a valid measure of the quality of the image.

TEST OBJECTS

The most common type of test object is one made up of a series of broad, sharply defined lines rather than of one narrow line. The spacing of the lines determines the magnitude of the light variation in the image. When the spacing of lines in the image of the test object is slightly larger than the light spread function of the image, the energy cross section of the actual image and the geometrically projected image may be shown as follows:

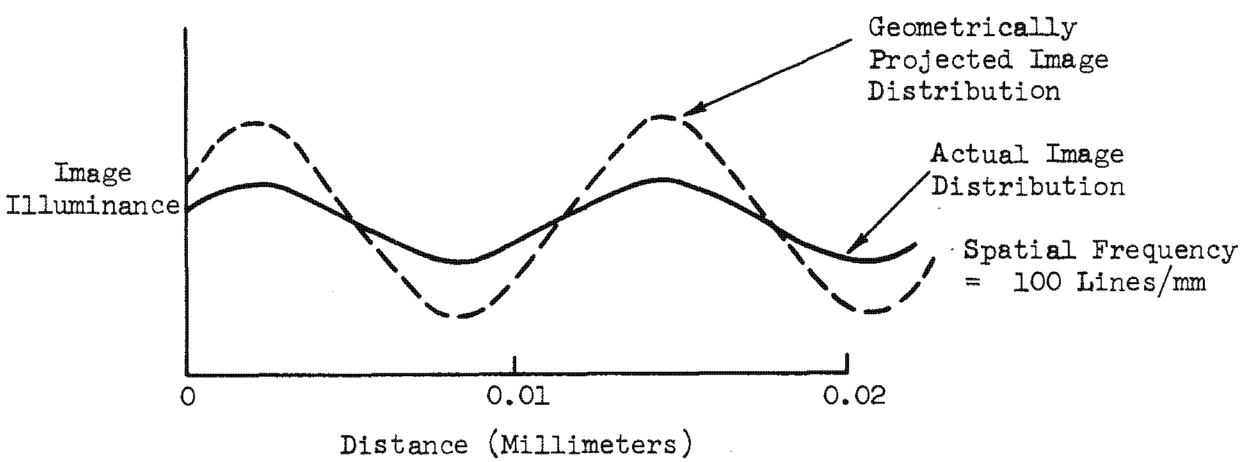


As the spacing and width of lines in the test object decrease, the light variation in the image is decreased as follows:



The magnitude of the light variations in the image is clearly related to the line-spread function, but to establish this relationship mathematically is tedious. Square-wave test objects are therefore used only to determine the spatial frequency at which light variations in the image are no longer discernible to the eye. This is the well-known resolving-power test. Since resolving power depends on the variation of light in the image, which in turn is related to the spread function, there is in general good correlation between the resolving power of a system and the size of the spread function. The shape of the spread function, however, is not derivable from measurements of resolving power.

If the light configuration of the object varies as a sine wave instead of as a square wave, the image produced by a linear system is sinusoidal in character and is completely defined by measuring the maximum and minimum light values in the image. For a typical case, the actual image and the geometrically projected image of a sine-wave test object can be shown as follows:



An important advantage in the use of the sine-wave test object lies in the fact that it is relatively easy to show mathematically the relationship between the line-spread function of a system and the light variations in the image measured over the spatial frequency spectrum. A plot of these measured light variations against spatial frequency, called the sine-wave response, is equivalent to the line-spread function and contains the same information with respect to the quality of the system. A more detailed discussion of sine-wave response as applied to the photographic system follows:

Sine-wave test objects have been made and the transmittance variations measured as a function of the spatial frequency of the sine wave. When such a test object is placed in front of an extended source of known luminance, the luminance variation at any frequency can be expressed as follows:

$$M = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \qquad (1)$$

where I_{max} and I_{min} are the maximum and minimum luminance values and M is defined as the modulation of the test object. The fact that the luminance modulation of the test object is, in general, a function of spatial frequency can be stated mathematically as follows:

$$f(w, x) = D + A(w) \sin wx \qquad (2)$$

where $D = \frac{I_{max} + I_{min}}{2}$, the average luminance level;

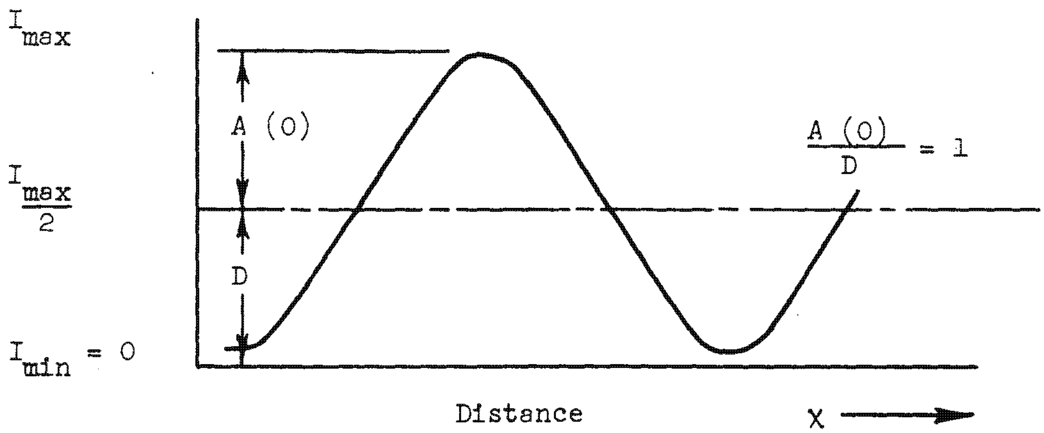
$A(w) = \frac{I_{max} - I_{min}}{2}$, the amplitude of the luminance modulation; and

w = spatial frequency of the chart.

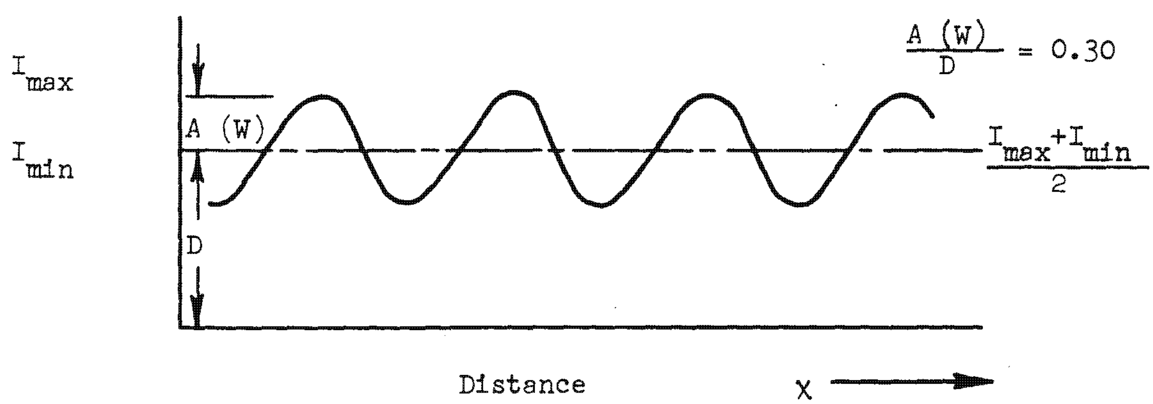
Rewriting equation (1) in terms of the amplitude A(w) and the average level D, the modulation is given by:

$$M = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} = \frac{A(w)}{D}$$

At low frequencies ($w \approx 0$), the minimum luminance in the test object can be made to approach zero, so that the modulation might appear as follows:



In this case the modulation, $\frac{A(0)}{D}$, is said to be 100 percent. Similarly at some higher frequency the modulation of the test object might appear as follows:



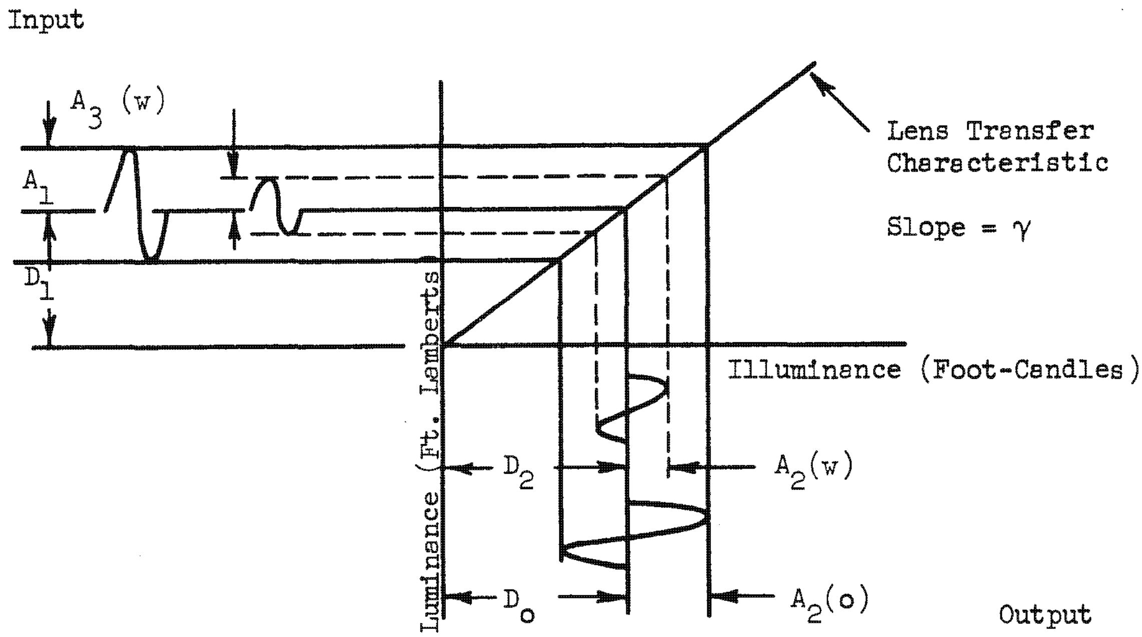
The modulation, $\frac{A(w)}{D}$, is about 30% in this case. This change in the modulation of the test object with frequency is taken into account in obtaining the sine-wave response of a lens-film system.

EXPLANATION OF SINE-WAVE RESPONSE

The best way to define the sine-wave response of a system is to consider a typical sine-wave test of a lens, together with the mathematical expressions for the input and output functions.

One method of determining the sine-wave response of a lens is to use the lens to image a sine-wave test object onto a fine slit with a phototube behind it. The output of the phototube is measured as the slit scans the image. The effect of the spread function of the lens is to reduce the amplitude of modulation in the image without altering its sinusoidal character. This property of the lens to transfer a sine-wave test object (inputs in units of luminance) into a sine-wave image (outputs in units of illuminance) is fundamental to the sine-wave analysis of a system, and systems exhibiting this property are said to be linear systems. For a mathematical definition of a linear system, see reference 12.

The steady-state transfer characteristic of a lens or of any linear system can be shown as a straight line having a slope, γ , as follows:



MODULATION OF TEST OBJECT

If an ideal sine-wave test object is assumed, having a constant amplitude for all frequencies, equation 2 describing the sine-wave input may be rewritten:

$$f(w, x) = D_1 + A_1 \sin w x \qquad (4)$$

where the modulation,

$$M_1 = \frac{A_1}{D_1} \qquad (5)$$

is independent of frequency.

MODULATION OF IMAGE IN A LINEAR SYSTEM

The illuminance variations in the image may be described by the equation

$$g(w, x) = D_2 + A_2(w) \sin \left[w x + \phi(w)\right], \qquad (6)$$

where ϕ (w) is called the phase shift. A phase shift is associated with a non-symmetrical spread function. In the analysis of performance of a lens system on axis, spread functions are in general symmetrical so that the phase shift is zero. The expected modulation at all frequencies for a perfect system would be equal to the modulation at very low frequency,

$$M_o = \frac{A_2(0)}{D_o} \qquad (7)$$

and the actual modulation at any frequency is

$$M_2 = \frac{A_2(w)}{D_2} \qquad (8)$$

The difference between equation (7) which gives the modulation expected from a perfect system and equation (8) which gives the modulation of an actual system is the reduction in peak-to-peak amplitude of the signal and a possible shift in average illuminance level from D_o to D_2 (which could occur if the lens transfer characteristic varies with frequency).

SINE-WAVE RESPONSE OF A LINEAR SYSTEM

By definition, the ratio of the modulation at some frequency to the modulation at zero frequency, $\frac{M_2}{M_o}$, is called the sine-wave response of the system at that frequency. Dividing equation (8) by equation (7) the sine-wave response is given by

$$R(w) = \frac{A_2(w)\,D_o}{A_2(0)\,D_2} = \frac{A_2(w)}{A_2(0)} \qquad (9)$$

since the average levels D_o and D_2 are equal for a linear system and cancel. Sine-wave response can also be defined in terms of the input and output modulation as follows:

$$R\ (w) = \frac{M_2}{M_1} \tag{10}$$

since the gain of a linear system acts on the average level as well as on the amplitude, and the output modulation at zero frequecy, M_0, is therefore equal to the input modulation, M_1.

EFFECTIVE INPUT MODULATION

The effective input modulation is given by

$$M_3 = \frac{A_3\ (w)}{D_1} \tag{11}$$

where the effective input modulation, M_3, is obtained by projection of the maximum and minimum values in the output back through the transfer characteristics of the system.

SINE-WAVE RESPONSE OF A NON-LINEAR SYSTEM

By definition, the sine-wave response of the system is the ratio of the effective input modulation, M_3, to the actual input modulation, M_1, given by

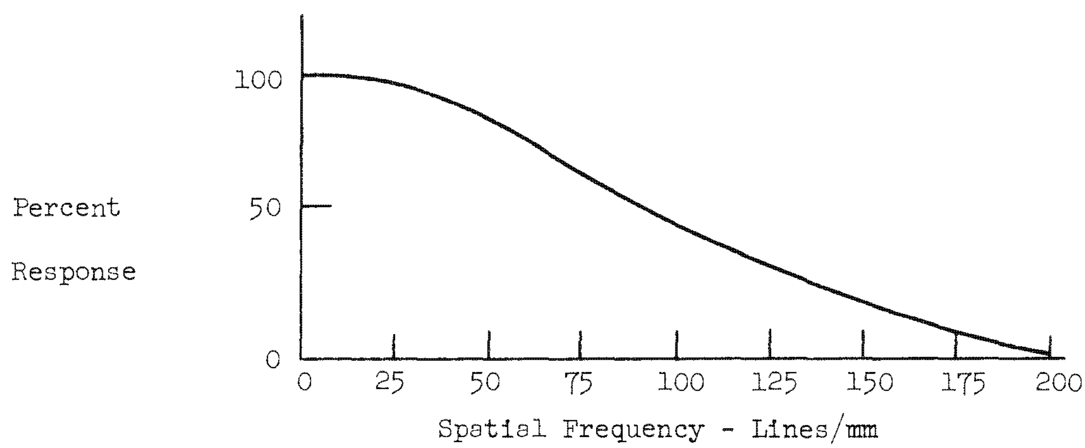
$$R\ (w) = \frac{A_3\ (w)}{D_1} \cdot \frac{D_1}{A_1} = \frac{A_3\ (w)}{A_1} \tag{12}$$

Note: This definition is equivalent to the definition given by equation (9) where the system is linear since $A_3(w) = \gamma A_2(w)$ and $A_1 = \gamma A_2(0)$.

Further, if the test-object modulation is 100%, $A_1 = D_1$ and the sine-wave response is sometimes given as

$$R(w) = \frac{A_3(w)}{D_1}$$

The sine-wave test of a lens consists in measuring the sine-wave response at selected frequencies from very low frequencies to frequencies at which the lens response approaches zero. A typical plot of response vs spatial frequency might look like this.



The response of a film is found by using the film to photograph sine-wave test objects through a lens. The photographic images on the test film are developed along with special calibration images that make it possible to plot the transfer characteristics for the film. Because the photographic process is nonlinear, the photographic image of a sine-wave test object is not sinusoidal, either in transmission or in density, and it becomes necessary to state the sine-wave response of a film in terms of the effective exposure rather than of transmittance. The effective exposure modulation of the film $A_4(w)/D_2$ can be found by projection of the maximum and minimum density values back through the transfer characteristic of the film. The effective exposure modulation is then referred to the object space of the lens by projection through the transfer characteristic of the lens. This procedure is illustrated on the opposite page.

The effective input modulation, $\frac{A_3(w)}{D_1}$, is then compared with the test object modulation, $\frac{A_1}{D_1}$, where the ratio $\frac{A_3(w)}{A_1}$ is the combined sine-wave response of the lens and film. It follows then that the response of the film alone, $R_F(w)$, is obtained by dividing the response of the lens-film combination, $R_{LF}(w)$, by the response of the lens, $R_L(w)$, since

$$R_{LF}(w) = \frac{A_3(w)}{A_1},$$

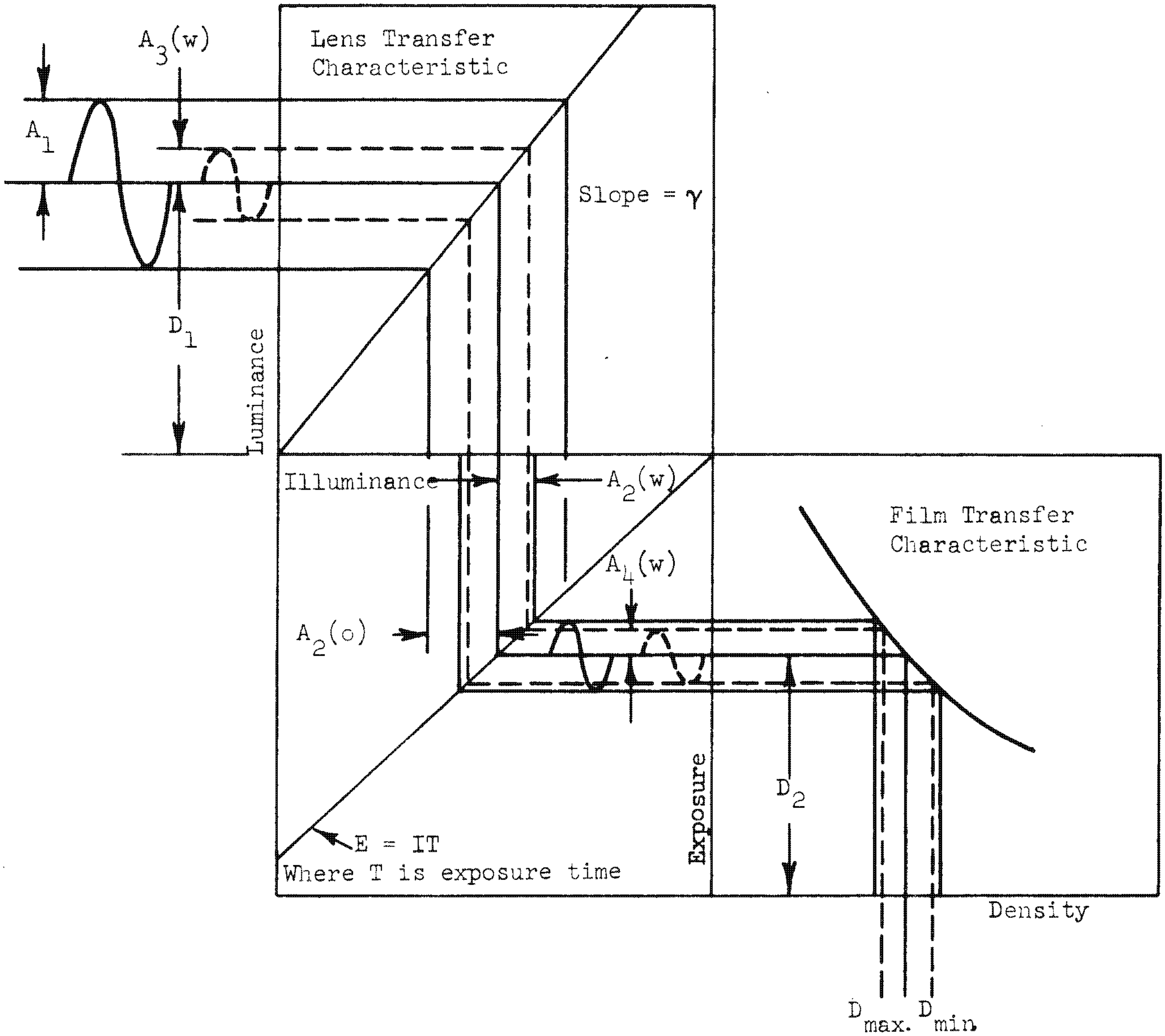
$$R_L(w) = \frac{A_2(w)}{A_2(0)} = \frac{A_2(w)}{A_1}$$

and $$R_F(w) = \frac{R_{LF}(w)}{R_L(w)} = \frac{A_3(w)}{A_1} \times \frac{A_1}{A_2(w)} = \frac{A_3(w)}{A_2(w)}$$

Since $$A_3(w) = A_4(w),$$

$$R_F(w) = \frac{A_4(w)}{A_2(w)}$$

where $\frac{A_4(w)}{A_2(w)}$ is by definition the response of the film. By a similar, argument, the effective response of the test object can also be divided out if necessary.


Lens Transfer Characteristic
A3(w)
A1
Slope = γ
D1
Luminance
Illuminance
A2(w)
Film Transfer Characteristic
A4(w)
A2(o)
Exposure
D2
E = IT
Where T is exposure time
Density
D max.
D min.

As is done in electronic circuitry, the subsystem can be divided into elements such that the output of each individual element is independent of the characteristics of the next element; for example, the image formed by the lens at the film plane is independent of the smear caused by IMC error. Under this condition and with the assumption that the system is linear, the output of one element can be treated as the input of the next. Therefore, the sine-wave response of each element can be multiplied to obtain the combined effect of two or more elements. Once the sine-wave response of the film has been determined, any system of elements ahead of the film that complies with the above restrictions can be combined with the film by multiplying the response of the individual elements, frequency by frequency.

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APPENDIX C

IMAGE SMEAR

The magnitude of the image-motion compensation (IMC) error, or smear, in the film plane can generally be determined from camera tolerances. For performance studies, it is necessary to convert the image spread caused by smear to a modulation transfer function. The following discussion indicates the method of converting the calculated values of smear to a modulation transfer function (MTF).

Figure C-1 is the Line Spread Function that appears on the film of a point object if the slit (shutter) is 100 percent efficient. The point is smeared to a distance τ_o, and no other degradations are present.

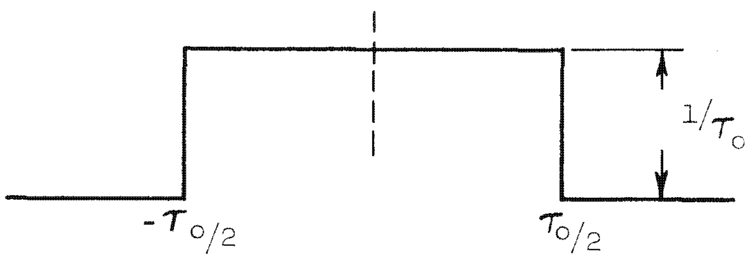

FIGURE C-1

If the slit is not 100 percent efficient, then two things happen:

a. The total smear is slightly longer.

b. The edges are no longer as sharp.

This is depicted in Figure C-2.

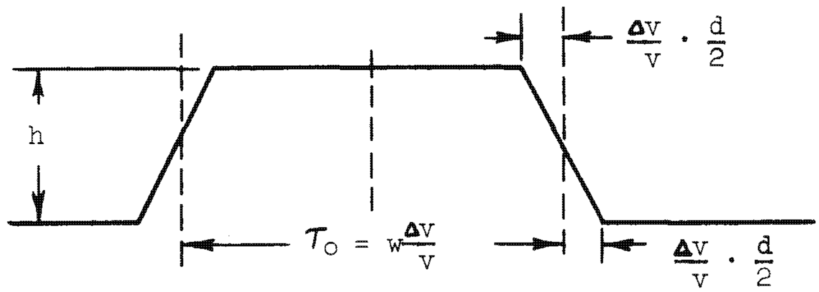

FIGURE C-2

where: d = Diameter of the cone of light at the slit aperture plate

w = Slit width

$\frac{\Delta v}{v}$ = Uncompensated image motion

Note in particular that the definition of τ_o is the smear that would occur if the slit were 100 percent efficient.

With reference to Figure C-2 the total light that would have produced the image if all points had received the same amount of light is proportional to:

$$h(w + d) \frac{\Delta v}{v}$$

The total light that produces the image is proportional to:

$$\frac{h\left[(w + d) + (w - d)\right]}{2} \frac{\Delta v}{v} = hw \frac{\Delta v}{v}$$

The ratio of these two quantities is used as a measure of slit efficiency and is denoted by E. Therefore:

$$E = \frac{w}{w + d} \quad \text{and} \quad d = \frac{w - wE}{E}$$

In terms of the E notation, the length of the base of Figure C-2 is:

$$(w + d)\frac{\Delta v}{v} = \frac{\Delta v}{v}\left(\frac{w}{E}\right) = \frac{\tau_o}{E}$$

The length of the top is:

$$(w - d)\frac{\Delta v}{v} = \frac{\Delta v}{v}\left(w - \frac{w - w\,E}{E}\right) = \frac{\tau_o(2E - 1)}{E}$$

By theory of linear systems then, if the area of Figure C-2 is normalized to 1, the MTF is the Fourier Transform of the resulting function. This function is shown in Figure C-3.

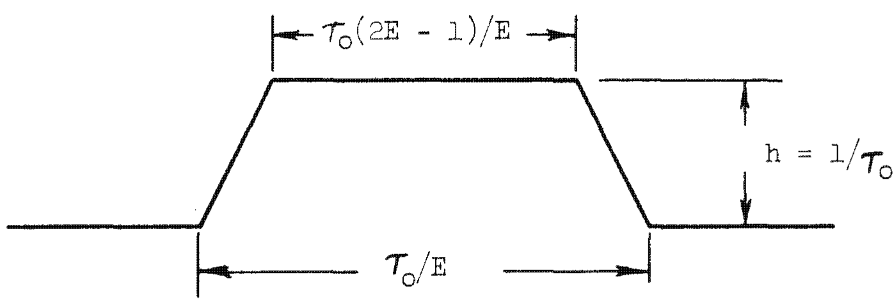

FIGURE C-3

There are several ways to obtain the transform of Figure C-3. The method used was to appeal to the linearity property of the Fourier Transform and recognize that Figure C-3 is the difference between the two triangles given in Figure C-4.

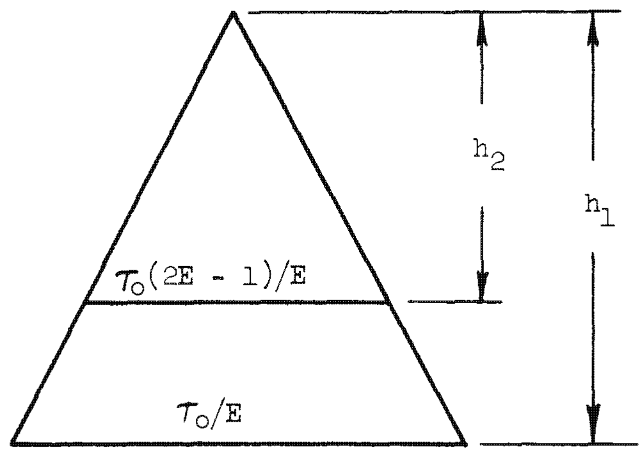

FIGURE C-4

The values of h_1 and h_2 satisfy the relations:

$$h_1 - h_2 = \frac{1}{\tau_o}$$

and

$$\frac{h_1}{h_2} = \frac{\tau_o/E}{\tau_o(2E - 1)/E} = \frac{1}{2E - 1}$$

If these equations are solved, the result is:

$$h_1 = \frac{1}{2\tau_o(1 - E)}$$

$$h_2 = \frac{(2E - 1)}{2\tau_o(1 - E)}$$

Now the transform of the triangle in Figure C-5 is:

$$G(\nu) = B\left(\frac{\sin\alpha}{\alpha}\right)^2$$

where $B = A\tau_1$; $\alpha = \pi\tau_1\nu$; and ν = Spatial Frequency.

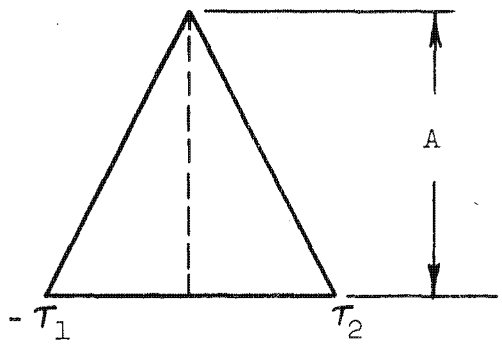

FIGURE C-5

Therefore the Fourier Transform of Figure C-3 is:

$$G(\nu) = \frac{1}{2\tau_o(1 - E)} \left(\frac{\tau_o}{2E}\right) \left[\frac{\sin(\pi\nu\tau_o/2E)}{\pi\nu\tau_o/2E}\right]^2$$

$$- \left(\frac{2E - 1}{2\tau_o(1 - E)}\right)\left(\frac{\tau_o(2E - 1)}{2E}\right) \left[\frac{\sin(\pi\nu\tau_o(2E - 1)/2E)}{\pi\nu\tau_o(2E - 1)/2E}\right]^2$$

$$G(\nu) = \left(\frac{E}{\pi^2\nu^2\tau_o^{\,2}(1 - E)}\right) \left[\sin^2(\pi\nu\tau_o/2E) - \sin^2(\pi\nu\tau_o(2E-1)/2E)\right]$$

$$\text{or} \quad G(\nu) = \left(\frac{\sin(\pi\nu\tau_o)}{\pi\nu\tau_o}\right) \left(\frac{\sin\left[\pi\nu\tau_o(\frac{1}{E} - 1)\right]}{\pi\nu\tau_o(\frac{1}{E} - 1)}\right)$$

The MTF's for two shutter efficiencies can be obtained from the nomograph in Figure C-6, which has been derived from the preceding equation. For example, if one follows the dotted line from the lower right to the upper left, a smear of 2.9 microns at a spatial frequency of 100 lines per millimeter corresponds to a transfer factor for smear of 85 percent at a 74 percent shutter efficiency.

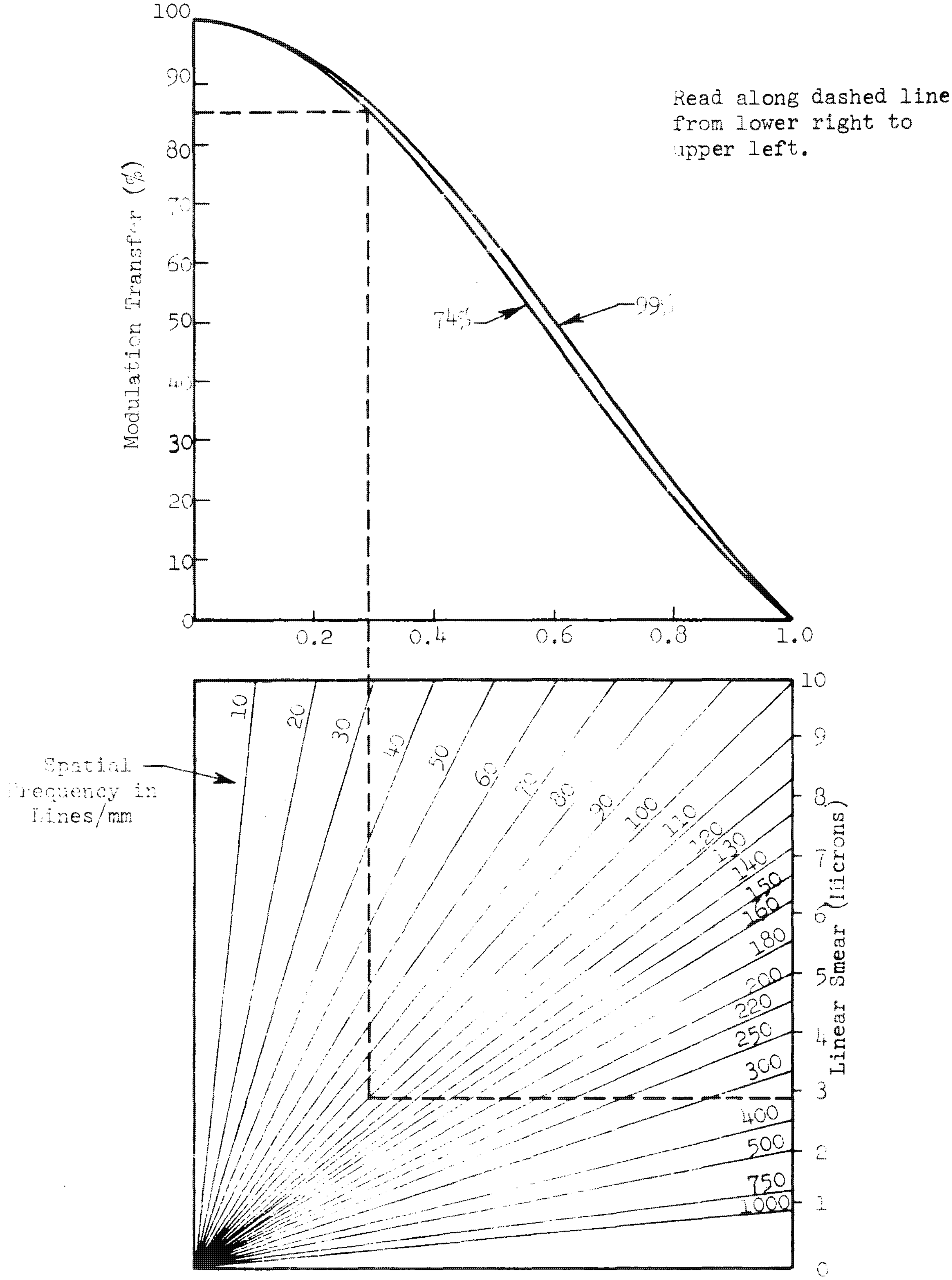

Figure C-6. MTF of Linear Image Smear for Shutter Efficiencies of 99 and 74 Percent

Because the camera is designed to provide a nominal 0.007-inch clearance between the slit and the emulsion surface, and the relative aperture is *f*/3.95, the diameter of the light cone at the slit (d) is 0.0018 inch. Let the slit width (w) be 0.0085 inch. Substituting these values in the shutter-efficiency equation:

$$\text{Shutter Efficiency} = \frac{w}{w + d} = \frac{0.0085}{0.0085 + 0.0018} = 82.5 \text{ percent}$$

Once the normalized smear plus shutter efficiency curve has been calculated, the modulation transfer factor at a given spatial frequency in lines per millimeter may be read from the appropriate scale for the calculated value of image smear. By multiplying the MTF for smear by the MTF's for other elements of the system, a combined MTF describing the system can be determined.

APPENDIX D
SMEAR BUDGET

D.1 SMEAR ALLOCATION AND SUBSYSTEM PERFORMANCE TOLERANCES

If the location, attitude, and orbital parameters of the satellite are known, it is theoretically possible to determine a film velocity that would exactly compensate for image motion along the center line of the photograph. Errors in knowledge of satellite location and attitude, the small changes in attitude during exposure, vibrations in the film drive mechanism, and the discreteness of the film velocity steps can cause slight errors in image motion compensation that will produce smear.

For this issue of the EAR, an improved method of calculating total smear has been used. This method is explained in Section D.1.1. Total smear is defined as that on-axis smear which will be exceeded in less than 5 percent of the frames from a single mission, with a confidence level of 95 percent. Table D-1 gives the formulas for the X and Y components of smear at the center of the field.

D.1.1 Smear Budget Theory

Each on-axis contributor is assigned to one of two categories:

a. Category A consists of those contributors whose smears vary independently within a single mission. The smears produced by individual members of this category can be root-sum-squared.

b. Category B is characterized by the property that the smear which its members cause is different from mission to mission. Because these smears are not variable within a mission, they cannot be root-sum-squared with the members of Category A. Because these category B contributors are independent, however, they can be root-sum-squared within themselves.

The smear contributed by Categories A and B must be combined to produce an over-all allowable smear that will not be exceeded in 95 percent of the frames taken during any one mission at a 95 percent confidence level. The total smear is computed by the following formula:

$$\text{Total smear, } S_x \text{ or } S_y = Q\, S_A + S_B$$

$$= Q\sqrt{\sum_{i=1}^{12} S_i^2} + \sqrt{\sum_{i=13}^{20} S_i^2} \qquad (1)$$

Where: S_i is the smear due to the ith contributor listed in Table D-2

S_A = Smear due to the combined Category A (within mission) contributors,

S_B = Smear due to the combined Category B (between mission) contributors.

Note that the smear for each contributor corresponds to its two-sigma variability as given in Table D-2, so that $S_i = 2\sigma_i$. The 95 percent confidence level is established by assuming that during any single mission the B category smears combine to give a smear approximately equal to the two-sigma variability of their sum. This value (S_B) is then treated as a constant for the mission and for the analysis which follows. Note that a confidence level of 95 percent is quite conservative. The A contributor distribution is then considered to be shifted, with its mean at S_B during a mission (See Figure D-1). The 95 percent probability of having a total actual smear less than or equal to the total allowable smear is established by choosing the factor Q correctly. If the Q chosen is too small, the smear computed by equation (1) bounds less than 95 percent of the cases. If the Q chosen is too large, the smear bounds more than 95 percent of the cases. There is one Q such that the total smear either side of zero, as computed by equation (1) bounds 95 percent of the area under the (shifted) A-distribution. This is the one that is used. Two extreme cases of this situation are illustrated by Figure D-1. In Figure D-1A, S_B is essentially zero, so that the A-distribution is not shifted. The number of standard deviations (sigma units) which include 95 percent of the A-distribution is by definition, $1.96\sigma_A$, or 0.98 S_A, since S_A is a two-sigma smear. In Figure D-1B, S_B is large. In this case Q = 0.83.

For the G-System, on axis, Q is approximately 0.92, since the "B" contributors are small, but not zero. In actual computation, the factor Q is determined iteratively by computer to establish the 95 percent probability for any given smear budget.

D.1.2 Assignment of Contributors to Sources

A different breakdown of smear contributors is required to separate the contributors according to their source. Each contributor attributable to the payload section is placed in one group, and those resulting from the OCV are placed in another. Tracking contributions belong to a third group.

The total smear (in the ground plane) attributable to the Camera Payload is computed as follows: The value of the individual smear contributors

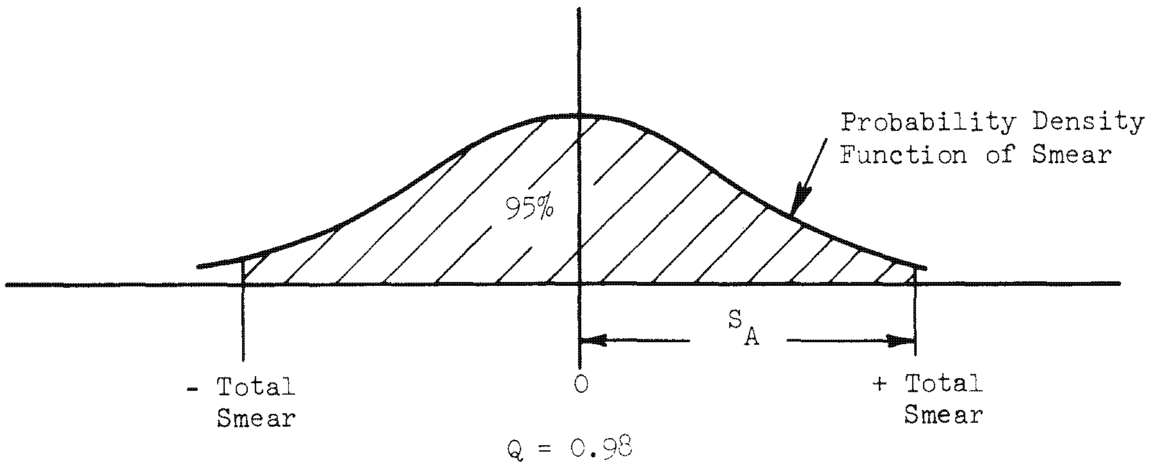

Figure D-1A. "A" Contributors Only

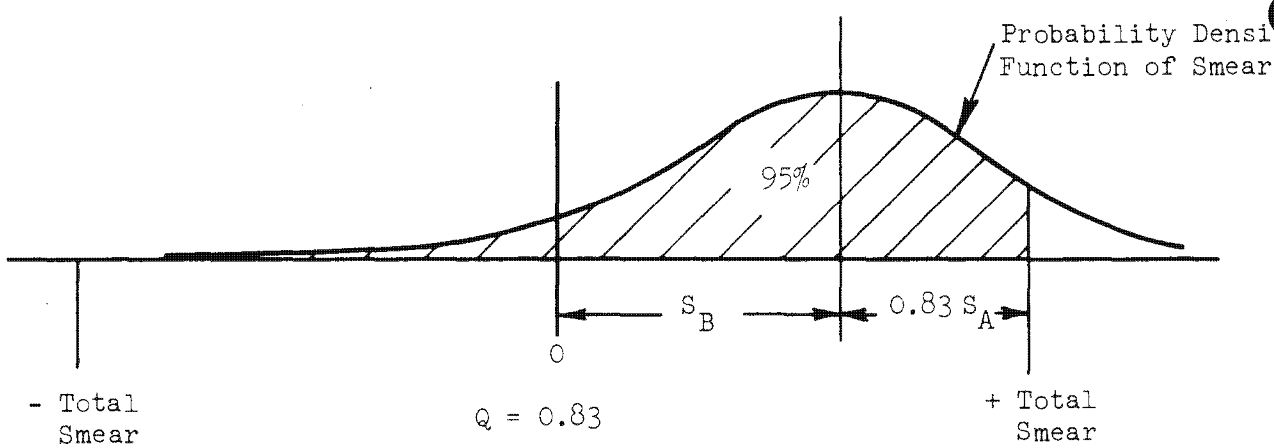

Figure D-1B. Large "B" Contributors
("A" Contributors Shifted an Amount S_B)

Figure D-1. Smear Probability Density

(X_i, Y_i) are taken from Table D-2. These calculations are based on an 0.0085-inch slit width, at a 70 n mi altitude, and vertical photography.

$$S_{X(C/P)} = Q\sqrt{\sum_{i=8}^{12} X_i^2} + \sqrt{\sum_{i=18}^{20} X_i^2} = 5.9 \text{ in.} = 0.49 \text{ ft} \qquad (Q = 0.92)$$

$$S_{Y(C/P)} = Q\sqrt{\sum_{i=8}^{12} Y_i^2} + \sqrt{\sum_{i=18}^{20} Y_i^2} = 3.1 \text{ in.} = 0.26 \text{ ft} \qquad (Q = 0.92)$$

Similarly, the OCV contributors total as follows:

$$S_{X(OCV)} = Q\sqrt{\sum_{i=2}^{7} X_i^2} + \sqrt{\sum_{i=15}^{17} X_i^2} = 2.0 \text{ in.} = 0.17 \text{ ft} \qquad (Q = 0.92)$$

$$S_{Y(OCV)} = Q\sqrt{\sum_{i=2}^{7} Y_i^2} + \sqrt{\sum_{i=15}^{17} Y_i^2} = 4.4 \text{ in.} = 0.37 \text{ ft} \qquad (Q = 0.92)$$

The only tracking contributor (X_1, Y_1), (knowledge of altitude) yields smear of:

$$S_{X(T)} = 2.5 \text{ in} = 0.21 \text{ ft} \qquad (Q = 0.92)$$

$$S_{Y(T)} = 0 \text{ in} = 0 \text{ ft}$$

For the 15 degree stereo, 30 degree obliquity, -2.0 degree crab case at 70 n mi, the results of solving the above equations are:

$$S_{X(C/P)} = 9.2 \text{ in.} = 0.77 \text{ ft}$$

$$S_{Y(C/P)} = 4.3 \text{ in.} = 0.36 \text{ ft}$$

$$S_{X(OCV)} = 6.2 \text{ in.} = 0.52 \text{ ft}$$

$$S_{Y(OCV)} = 7.4 \text{ in.} = 0.62 \text{ ft}$$

$$S_{X(T)} = 3.1 \text{ in.} = 0.26 \text{ ft}$$

$$S_{Y(T)} = 0 \text{ in.} = 0 \text{ ft}$$

TABLE D-1
SMEAR EQUATIONS

	On Ground	In Image Plane
Knowledge of Altitude	$X_1 = \frac{Wh}{F}\left(\frac{\Delta h}{h}\right) \sec^2 \Sigma \sec \Omega$	$x_1 = W\frac{\Delta h}{h}$
	$Y_1 = 0$	$y_1 = 0$
Roll	$X_2 = \frac{Wh}{F} A_x \sec^2 \Sigma \tan \Omega \sec \Omega$	$x_2 = W A_x \tan \Omega$
	$Y_2 = 0$	$y_2 = 0$
Pitch	$X_3 = \frac{Wh}{F} A_y (1 + \sec^2 \Omega) \tan \Sigma \sec^2 \Sigma$	$x_3 = W A_y (\cos \Omega + \sec \Omega) \tan \Sigma$
	$Y_3 = \frac{Wh}{F} A_y \sec^2 \Sigma \tan \Omega \sec \Omega$	$y_3 = W A_y \sec \Sigma \sin \Omega$
Yaw	$X_4 = \frac{Wh}{F} A_z \tan \Omega \tan \Sigma \sec^2 \Sigma$	$x_4 = W A_z \sin \Omega \tan \Sigma$
	$Y_4 = \frac{Wh}{F} A_z \sec^2 \Sigma \sec \Omega$	$y_4 = W A_z \cos \Omega \sec \Sigma$
Roll Rate	$X_5 = 0$	$x_5 = 0$
	$Y_5 = \frac{Wh^2}{FV_x} \dot{A}_x \sec^2 \Sigma \sec^3 \Omega$	$y_5 = \frac{Wh}{V_x} \dot{A}_x \sec \Sigma \sec \Omega$
Pitch Rate	$X_6 = \frac{Wh^2}{FV_x} \dot{A}_y \sec^4 \Sigma \sec \Omega$	$x_6 = \frac{Wh}{V_x} \dot{A}_y \sec^2 \Sigma$
	$Y_6 = \frac{Wh^2}{FV_x} \dot{A}_y \tan \Sigma \sec^2 \Sigma \tan \Omega \sec^2 \Omega$	$y_6 = \frac{Wh}{V_x} \dot{A}_y \tan \Sigma \sec \Sigma \tan \Omega$

TABLE D-1 (Continued)

	On Ground	In Image Plane
Yaw Rate	$X_7 = \frac{Wh^2}{FV_x} \dot{A}_z \sec^4\Sigma \tan\Omega \sec\Omega$	$x_7 = \frac{Wh}{V_x} \dot{A}_z \tan\Omega \sec^2\Sigma$
	$Y_7 = \frac{Wh^2}{FV_x} \dot{A}_z \tan\Sigma \sec^2\Sigma \sec^2\Omega$	$y_7 = \frac{Wh}{V_x} \dot{A}_z \tan\Sigma \sec\Sigma$
Crab Servo Steps and Error	$X_8 = \frac{Wh}{F} \Delta\chi \sec^2\Sigma \tan\Omega \sec\Omega$	$x_8 = W \Delta\chi \tan\Omega$
	$Y_8 = \frac{Wh}{F} \Delta\chi \sec\Sigma \sec^2\Omega$	$y_8 = W \Delta\chi$
Film Drive Oscillation Amplitude	$X_9 = \frac{Wh^2}{FV_x} (Vib) \sec^4\Sigma \sec^2\Omega$	$x_9 = \frac{Wh}{V_x F} (Vib) \sec^2\Sigma \sec\Omega$
	$Y_9 = 0$	$y_9 = 0$
Stereo Servo	$X_{10} = 4\frac{Wh}{F}\Delta\Sigma_m \tan\Sigma \sec^2\Sigma \sec\Omega \cos\chi$	$x_{10} = 4 W \Delta\Sigma_m \tan\Sigma \cos\chi$
	$Y_{10} = 4\frac{Wh}{F}\Delta\Sigma_m \tan\Sigma \sec\Sigma \sec^2\Omega \sin\chi$	$y_{10} = 4 W \Delta\Sigma_m \tan\Sigma \sin\chi$
Film Velocity Steps	$X_{11} = \frac{Wh}{F} \left(\frac{\Delta V_F}{V_F}\right) \sec^2\Sigma \sec\Omega$	$x_{11} = W \left(\frac{\Delta V_F}{V_F}\right)$
	$Y_{11} = 0$	$y_{11} = 0$

TABLE D-1 (Continued)

	On Ground	In Image Plane
Film Velocity Drift	$X_{12} = \frac{Wh}{F}\left(\frac{\Delta V_F}{V_F}\right) \sec^2\Sigma \sec\Omega$	$x_{12} = W\left(\frac{\Delta V_F}{V_F}\right)$
	$Y_{12} = 0$	$y_{12} = 0$
Roll Alignment	$X_{15} = \frac{Wh}{F} B_x \sec^2\Sigma \tan\Omega \sec\Omega$	$x_{15} = W B_x \tan\Omega$
	$Y_{15} = 0$	$y_{15} = 0$
Pitch Alignment	$X_{16} = \frac{Wh}{F} B_y (1 + \sec^2\Omega)\tan\Sigma \sec^2\Sigma$	$x_{16} = W B_y (\cos\Omega + \sec\Omega)\tan\Sigma$
	$Y_{16} = \frac{Wh}{F} B_y \sec^2\Sigma \tan\Omega \sec\Omega$	$y_{16} = W B_y \sec\Sigma \sin\Omega$
Yaw Alignment	$X_{17} = \frac{Wh}{F} B_z \tan\Omega \tan\Sigma \sec^2\Sigma$	$x_{17} = W B_z \sin\Omega \tan\Sigma$
	$Y_{17} = \frac{Wh}{F} B_z \sec^2\Sigma \sec\Omega$	$y_{17} = W B_z \cos\Omega \sec\Sigma$
Crab Mirror Mounting Error	$X_{18} = \frac{Wh}{F} M_c \sec^2\Sigma \tan\Omega \sec\Omega$	$x_{18} = W M_c \tan\Omega$
	$Y_{18} = \frac{Wh}{F} M_c \sec\Sigma \sec^2\Omega$	$y_{18} = W M_c$

TABLE D-1 (Continued)

	On Ground	In Image Plane
Stereo Mirror Mounting Error	$X_{19} = 4 \frac{Wh}{F} M_s \tan\Sigma \sec^2\Sigma \sec\Omega \cos\chi$	$x_{19} = 4\, W\, M_s \tan\Sigma \cos\chi$
	$Y_{19} = 4 \frac{Wh}{F} M_s \tan\Sigma \sec\Sigma \sec^2\Omega \sin\chi$	$y_{19} = 4\, W\, M_s \tan\Sigma \sin\chi$
Knowledge of Focal Length	$X_{20} = \frac{Wh}{F} \left(\frac{\Delta F}{F}\right) \sec^2\Sigma \sec\Omega$	$x_{20} = W \left(\frac{\Delta F}{F}\right)$
	$Y_{20} = 0$	$y_{20} = 0$

TABLE D-1 (Continued)

NOMENCLATURE

X_i = Component of smear on ground parallel to the ground track for the ith contributor

x_i = Component of smear in the image plane perpendicular to the slit for the ith contributor

Y_i = Component of smear on ground perpendicular to the ground track for the ith contributor

y_i = Component of smear in the image plane parallel to the slit for the ith contributor

W = Slit width

h = True altitude of the camera above ground

F = Focal length

Δh = Uncertainty in knowledge of altitude

Σ = Stereo angle of line of sight

Σ_m = Stereo mirror angle = $\Sigma/2$

$\Delta\Sigma_m$ = Uncertainty in stereo mirror angle due to errors in the positioning mechanism

Ω = Obliquity angle of the line of sight

χ = Crab Angle of the mirror

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TABLE D-1 (Continued)

NOMENCLATURE

A_x = Roll angle error (includes error in obliquity maneuver)

A_y = Pitch angle error

A_z = Yaw angle error

$\dot{A}_x$ = Roll rate error

$\dot{A}_y$ = Pitch rate error

$\dot{A}_z$ = Yaw rate error

B_x = Vehicle alignment error about roll axis

B_y = Vehicle alignment error about pitch axis

B_z = Vehicle alignment error about yaw axis

$\Delta \chi$ = Error in crab compensation (steps and servo error)

Vib = Amplitude of the linear velocity error of the platen due to vibration (oscillation)

ΔV_F = Amplitude of the linear velocity error of the platen due to discreteness and drift of the drive mechanism and/or electronics

M_c = Angular error in stereo mirror crab alignment (radians)

M_s = Angular error in stereo mirror stereo alignment (radians)

TABLE D-2

SMEAR CONTRIBUTORS

Smear (95% level)
(At 70.0 n mi altitude, with 0.0085 inch slit width, and 2.0° crab angle)

Smear Contributor	Suggested Tolerance	Distribution	Estimated STD Deviation	Vertical Photography x(in.)	Vertical Photography y(in.)	30° Obliquity 15° Stereo x(in.)	30° Obliquity 15° Stereo y(in.)	Allocation	Smear Component
Knowledge of Altitude (n mi)	±0.5	Normal	0.167	2.68	0	3.34	0	Ephemeris	X_1
Roll Attitude (deg)	±0.7	Normal	0.233	0	0	3.30	0	OCV	X_2
Pitch Attitude (deg)	±1.0	Normal	0.333	0	0	4.42	4.74	OCV	X_3, Y_3
Yaw Attitude (deg)	±0.6	Normal	0.200	0	3.93	0.66	4.92	OCV	X_4, Y_4
Roll Rate (deg/sec)	±0.01	Normal	0.003	0	1.11	0	1.86	OCV	Y_5
Pitch Rate (deg/sec)	±0.02	Normal	0.007	2.21	0	2.97	0.50	OCV	X_6, Y_6
Yaw Rate (deg/dec)	±0.015	Normal	0.005	0	0	1.29	0.65	OCV	X_7, Y_7
Crab Steps (deg) Crab Error (deg) (RSS)	±0.25 ±0.15	Uniform Normal	0.145 } RSS 0.050 }	0	3.00	2.16	4.19	C/P	X_8, Y_8
Film Dr. Oscillation Amplitude (microns/sec)	1554.0	Normal	518.0	5.04	0	7.81	0	C/P	X_9
Stereo Servo (not LOS)(deg)	±0.22	Normal	0.073	0	0	1.92	0.08	C/P	X_{10}, Y_{10}
Film Velocity Steps (%)	±0.50	Uniform	0.289	3.25	0	4.05	0	C/P	X_{11}
Film Velocity Error (%)	±0.20	Normal	0.067	0.75	0	0.94	0	C/P	X_{12}
Roll Alignment (deg)	±0.04	Normal	0.013	0	0	0.19	0	OCV	X_{15}
Pitch Alignment (deg)	±0.04	Normal	0.013	0	0	0.18	0.19	OCV	X_{16}, Y_{16}
Yaw Alignment (deg)	±0.1	Normal	0.033	0	0.66	0.11	0.82	OCV	X_{17}, Y_{17}
Crab Mirror Mounting (deg)	±0.05	Normal	0.017	0	0.33	0.24	0.46	C/P	X_{18}, Y_{18}
Stereo Mirror Mounting (deg)	±0.05	Normal	0.017	0	0	0.44	0.02	C/P	X_{19}, Y_{19}
Knowledge of Focal Length (in.)	±0.062	Normal	0.021	0.30	0	0.38	0	C/P	X_{20}
			Total Smear(in.)	6.88	5.18	11.67	8.35	S/V	

(Will be exceeded in less than 5% of the frames from a single mission with a 95% confidence level.)

APPENDIX E
EXPOSURE MODULATION AND RESOLUTION

E.1 INTRODUCTION

The performance of this reconnaissance system is specified in terms of the ground dimension that can be resolved through the system, using standard Air Force resolving-power targets at 2:1 contrast. These square-wave targets, therefore, must be used in finally evaluating the performance of the system. During the development of a system, however, it is more convenient to analyze system and component performance by sine-wave response techniques. In order to take advantage of the mathematical simplicity of the sine-wave response technique to describe a photographic system, it is necessary to establish the relationship between the limiting resolution of the system to a square-wave test object and the sine-wave response of the system at the limiting resolution frequency.

This appendix describes the mathematical and experimental procedures used for the prediction of limiting resolution when the lens system is described by a theoretical sine-wave response curve and the film is characterized by measured data, either in the form of a sine-wave response curve or a calibration curve of the limiting resolution frequency of the film vs aerial image modulation. The term, aerial image modulation, refers to the actual modulation of light incident on the film as distinguished from the effective input modulation defined in Appendix B.

E.2 THE EQUIVALENCE OF SQUARE-WAVE AND SINE-WAVE ANALYSIS FOR THE PREDICTION OF LIMITING RESOLUTION

The relationship between sine-wave and square-wave response can be shown by considering the simple case of a lens. Because the sine-wave and square-wave responses of a linear system are mathematically related, it is possible to predict the square-wave resolution of a lens from sine-wave response data if the characteristics of the resolution measuring device can be defined. Two factors need to be specified: (1) the contrast or modulation of the test object and (2) the threshold aerial image modulation to which the measuring device will respond. (Note that a lens contributes no noise, and the average light level in the image is assumed to be well above the absolute sensitivity of the receiver.) Equation 10 of Appendix B can be restated as follows:

$$\overline{M}_1 \ \overline{R}\,(w) = \overline{M}_2(w) \qquad (1)$$

where $\overline{M}_1$ is the square-wave modulation of the test object, $\overline{R}\,(w)$ the square-wave response of the lens at frequency (w), and $\overline{M}_2$ is the square-wave aerial image modulation. The square-wave response, $\overline{R}(w)$, is given by the expression

$$\overline{R}(w) = \frac{4}{\pi}\left[R(w) - \frac{R(3w)}{3} + \frac{R(5w)}{5} - \frac{R(7w)}{7} + \dots\dots\dots\right] \qquad (2)$$

where R(w) is the sine-wave response at w lines/mm in the absence of astigmatism.[1]

[1] J. W. Coltman, "The Specification of Imaging Properties by Response to A Sine-Wave Input," Journal of the Optical Society of America, June 1954.

Astigmatism is a field aberration and is not present on the axis of the photographic system. When $\overline{M}_2$ is the threshold square-wave aerial image modulation of the receiver and $\overline{M}_1$ is known, then the threshold square-wave response of the lens, $\overline{R}$, can be determined by equation (1). Using the sine-wave response curve of the lens and equation (2), the frequency, w, corresponding to the threshold square-wave response can be determined. This frequency is the limiting resolution of the lens. It is important to note that in solving equations (1) and (2) for the limiting resolution frequency, the square-wave response, $\overline{R}(w)$, is required only at or near the limiting resolution frequency where the higher order terms of equation (2) become negligible. Transformation from sine-wave to square-wave response, therefore, may be simplified by the following approximation, since $\frac{R(3w)}{3}$ and succeeding terms of equation (2) are small compared to R(w):

$$\overline{R}(w) \approx \frac{4}{\pi} \; R(w) \qquad (3)$$

Since the threshold aerial image modulation of a system generally occurs at high frequencies, the square-wave threshold response and the sine-wave threshold response are related by the constant, $4/\pi$, and both occur at the same frequency. Therefore, in determining the limiting resolution frequency by this method either the square-wave or the sine-wave response of the lens can be used, provided the constant, $4/\pi$, is taken into account. For example, when measurements of the square-wave resolution of a known lens are used to establish a practical value for the threshold aerial image modulation, $\overline{M}_2$, and when the sine-wave response approach is to be used, the constant, $4/\pi$, is included in the experimentally determined value of the constant $\overline{M}_2$.

In practice, equation (1) is written in terms of the sine-wave response of the lens:

$$M_1 R(w) = M_3(w) \qquad (4)$$

where $M_3(w)$ is a function of frequency which is referred to as the aerial image modulation required at the resolution limit. In general, equation (4) is more convenient for predictions of resolution and is valid for this purpose as long as $M_3(w)$ can be determined by experiment.

E.3 AERIAL IMAGE MODULATION REQUIRED TO RESOLVE AIR FORCE TARGETS

In a photographic system, measurements of resolution depend in some measure on the film granularity or noise in the system and the ability of the receiving device to respond to small signals in the presence of this noise. Every effort is made to eliminate both of these factors in sine-wave response measurements; that is, apertures are selected to integrate out the effect of noise and in general the signal level is well above the threshold sensitivity of the measuring device. Because of the method of measurement used, sine-wave response data alone do not provide sufficient information for the prediction of resolution, since the noise affecting the resolution measurement has been filtered out. Threshold response characteristics of the receiver and the effect of noise in the system must be introduced before the limiting resolution of the system can be determined.

Prediction of the lens-film resolution from sine-wave response data is complicated by the fact that film cannot be treated as a linear element of the system and the threshold contrast discrimination of the eye is influenced by grain "noise" or the apparent graininess of the film.

Graininess, in turn, depends on the exposure used in producing the photographic image and the method of processing the film. To avoid the problem of finding a general mathematical expression relating these variables to lens-film resolution, the following empirical methods are employed.

All of the effects associated with the film process, including granularity, can be taken into account by means of a calibration of the particular film and film process to be used in the system. Calibration of the film consists in measuring the resolution of the film in combination with a lens for which the sine-wave response is known. By varying the test object modulation, M_1, and computing the modulation of light incident on the film, $M_3(w)$, from equation (4), a calibration curve of limiting resolution frequency of the film vs aerial image modulation of the light incident on the film can be plotted. Lens-film resolution can then be determined from this curve for any system of elements preceding the film, as long as the modulation in the aerial image can be calculated and average exposure levels are preserved. The independence of element characteristics described in Appendix A must also be preserved.

The calculated response of the G lens is plotted in Figure E-1 for the limiting case of zero smear (within tolerance smear levels will not significantly degrade resolution). The experimentally determined Aerial Image Modulation (AIM) required in the image plane to resolve a standard 2:1 contrast tri-bar target on 3404 film is also plotted in Figure E-1. The points of intersection between the AIM curve and the lens response curves specify the predicted resolution of the system. As shown on Figure E-1, the curves yield a system resolution of 161 lines/mm along the slit and 149 lines/mm across the slit. The geometric mean resolution is therefore 155 lines/mm.

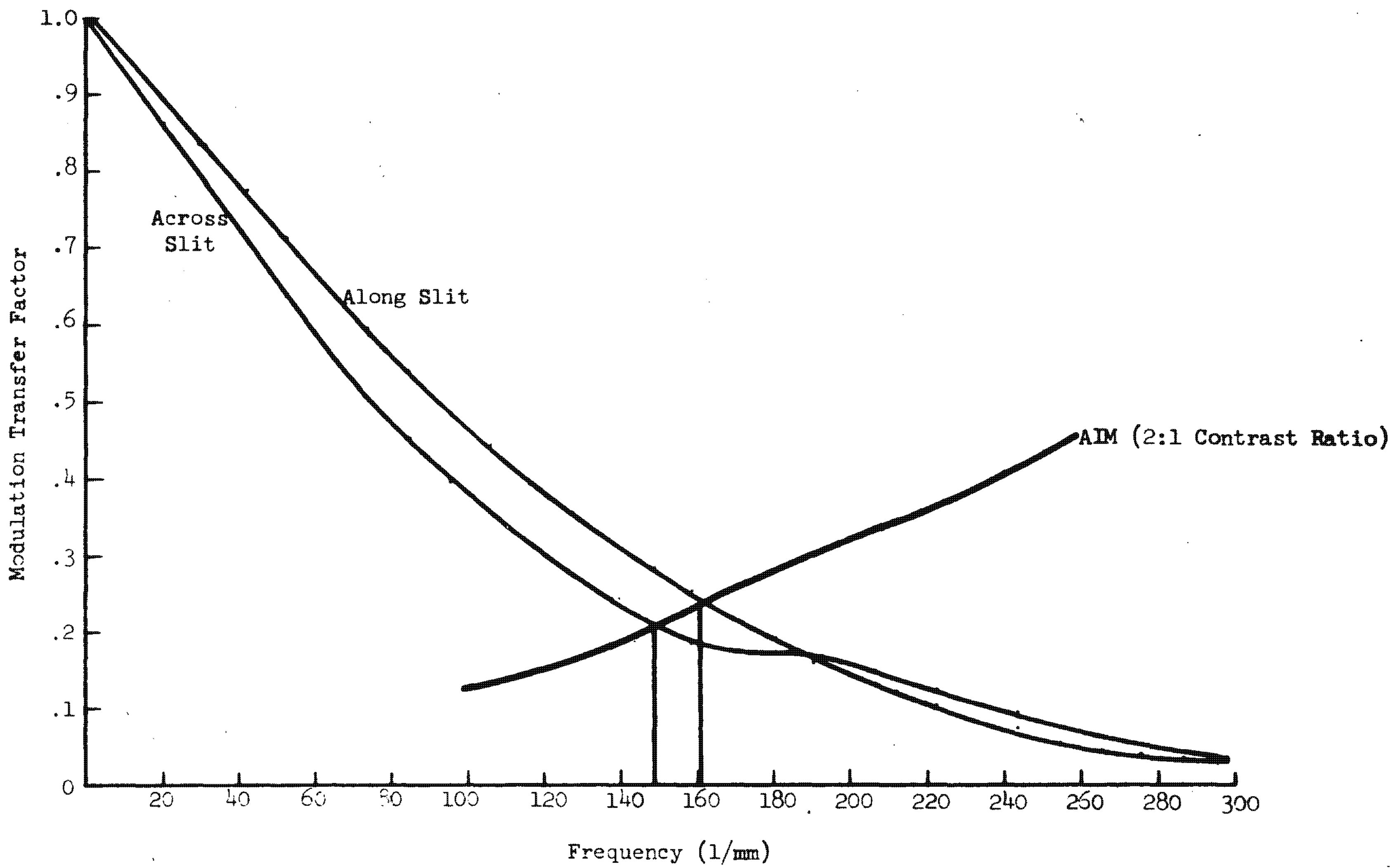

Figure E-1. Response of the G Lens in the Wavelength Region 0.480 to 0.720 Microns, for the Limiting Case of Zero Smear

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APPENDIX 10

POST FLIGHT REPORT

R-008690-RH - 037

This document consists of 9 pages.

Post Flight Report

for

Flight No. 38

4 to 12 June 1967

Prepared by

EASTMAN KODAK COMPANY
Apparatus and Optical Division
Rochester, New York 14650

Under Contract

AF 33(616)-7704

Approved by

[signature]

[signature]

Date: 2 August 1967

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

SECTION 1
INTRODUCTION

This is the Eastman Kodak Company (EKC) Post-Flight Report for Flight No. 38 (FM 39). It supplements the information presented in the Preliminary Flight Evaluation Report (PFER), and describes the anomalies encountered during the mission and the results of the System Test Objectives (STO) which were performed.

This report supersedes all previously published documents concerning EKC post-flight information from Flight No. 38.

SECTION 2
ANOMALIES

2.1 LOOPER-FULL LOGIC NOT INITIATED WHEN THE TAKE-UP SIDE OF LOOPER WAS FILLED WITH FILM

Analysis of telemetry data from operations on Revs 27, 28, 29, 31, and 32 indicated that the take-up looper was not emptied when it was filled with film. No additional film was moved after the looper-full condition was achieved. The looper was emptied by the camera OFF command. Only six camera operations were commanded which would have moved more than a looper-full (2.19 feet) of film. Five of these were the processing blanks (6.06 feet) moved prior to photography each rev. The sixth frame (Rev 27, Frame 8) was commanded with only 1.2 inches more than the looper capacity. Commanding was changed in the message loaded on Rev 36 that restricted the film quantity commanded to less than the looper capacity. The computer program which assembles the commands restricted the maximum quantity of film commanded each frame to 2.07 feet. The technical advisor was informed that a camera OFF command followed by a camera ON command, a minimum of 0.1 second later, would empty the take-up side of the looper with little photographic loss. This was evaluated by analysis and testing in Rochester as soon as the problem was reported and determined to be a satisfactory means for reducing any loss of targeting.

The logic of the film handling subsystem will normally cause the take-up side of the looper to be emptied whenever any of the following occurs.

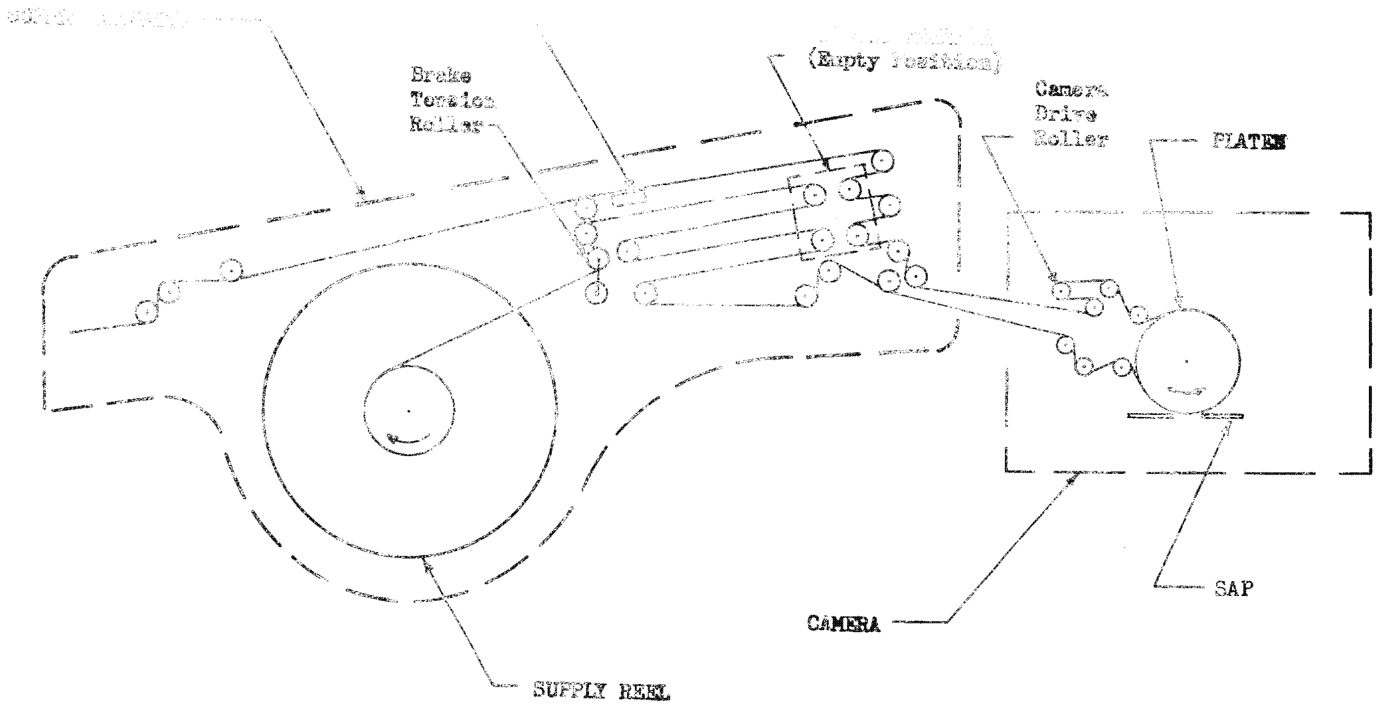
a. The looper-full microswitch is actuated (by a cam on the looper carriage when the take-up side of the looper is filled with film).

b. A camera OFF command (CB 7B) is received.

c. The film tension switch is actuated by a decrease of film tension to 1.5 pounds or less.

The film is removed from the take-up side of the looper by the take-up motor pulling the film from the take-up side and spooling it on the take-up reel. See Figure 2-1. The supply side of the looper is filled with film pulled from the supply reel by the looper carriage motion as the take-up side is emptied. When the take-up side of the looper is empty, a cam on the looper carriage actuates a microswitch stopping the take-up motor. The only other means for stopping the emptying of the take-up side of the looper once it is started is by removing the voltage (28-volt camera power) from the camera payload (CP- command). Film is moved from the supply side of the looper to the take-up side by the camera drive motor. This particular motor will develop a torque sufficient to produce approximately 2.2 pounds tension in the film; which is substantially more tension than is required to pull film from the supply side of the looper to the take-up side. In this particular case, the tension developed in the film is less than that required for overcoming the resistance of the band-brake on the supply reel (2.75 to 3.25 pounds). When the take-up side of the looper fills, the camera drive motor will probably stall because it cannot develop enough torque to overcome the band-brake and pull film from the supply reel. Neither the drive motor nor the electronic package supplying the motor power is damaged when in the stalled condition.

No loss of tension was observed in the telemetry for any of the six occasions when a quantity of film larger than the looper capacity was



FILM HANDLING SUBSYSTEM SCHEMATIC

FIGURE 2-1

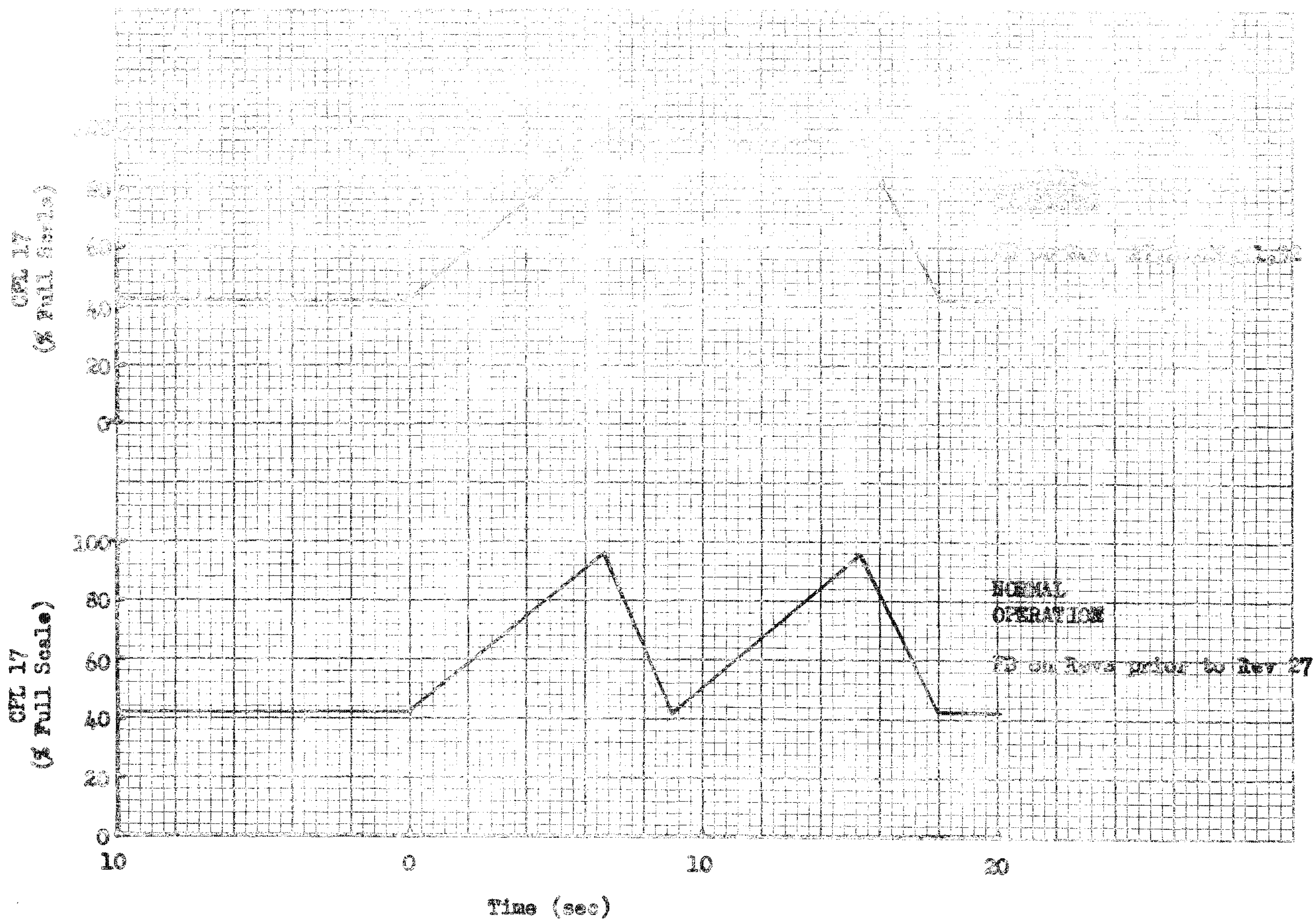
R-008690-RH

commanded. A loss of tension would have caused the take-up motor switching logic to start the take-up motor. The loss of tension indication did occur when the film was run out. The telemetry also indicated that the looper carriage traveled to the end of its travel (94-98 percent on CPL 17) each time the looper filled. The same level was observed when the film handling subsystem was operating normally prior to Rev 27. See Figure 2-2.

On 6 June, the anomalous conditions noted on the telemetry were simulated by EKC on the engineering model payload. The looper carriage was kept from actuating the looper-full switch by stopping the carriage motion early. In this simulation the camera drive motor pulled film from the supply reel. The tension of the film dropped low enough (1.5 pounds) to trip the film tension switch which also starts the take-up motor. The camera drive motor on the engineering model was capable of producing a higher torque than the one on this flight. In order to more closely simulate the flight conditions, the band-brake friction was raised to increase the film tension required about 0.5 pound. This produced results similar to those observed during the mission (processing blanks on Revs 27, 28, 29, 31, and 32). It is therefore concluded that the anomalous condition was encountered because a signal did not reach the take-up motor switching relay when the take-up side of the looper was filled.

The lack of a signal for the take-up motor switching circuit may have been caused by any of the items listed below in order of probability.

a. Microswitch failure.
b. Microswitch position changed.
c. Position of cam which actuates the microswitch changed.
d. Open EMI filter.



Analog of CPL 17 (looper position/film tension) before and during anomalous operation on Flight 38.

Figure 2-2

e. Open connector.

f. Loose terminal board connection.

g. Broken wire.

The insufficient torque of the camera drive motor to pull film from the supply reel was not an anomalous condition. The torque measured on this motor was within specification (8 percent above minimum) and it is not intended that the camera film-drive motor be the prime mover for film from the film supply reel.

APPENDIX 11

ADDENDUM TO POST FLIGHT REPORT

R-008730-RI-004

This document
consists of
15 pages.

ADDENDUM I

TO THE

POST FLIGHT REPORT FOR

FLIGHT NO. 38 ON 4 THROUGH 12 JUNE 1967

(R-008690-RH)

PREPARED BY

EASTMAN KODAK COMPANY

Rochester, New York 14650

Under Contract
AF-33-(616)-7704

Prepared by:

D.P. Monteith E.L.P. for S.A.T.
D.P. Monteith

Approved by:

Date: 16 August 1967

V.F. Vinkey
V.F. Vinkey

P.E. Murfin
P.E. Murfin

Table of Contents

List of Tables

Section 1

Introduction

This report describes and evaluates the performance of Camera Payload FM 39 during Flight No. 38 (4-12 June 1967).

The data normally generated by the Performance Evaluation Team (PET) was not available at the time of this writing. As a result, material contained in this report is based strictly on studies and data gathered during post-flight analysis at Eastman Kodak Company (EKC).

This report supplements the "Post Flight Report" (R-008690-RH). Because of its sensitivity this report is classified Top Secret in accordance with paragraph 3 of SAFSP document number V-2428, dated 21 August 1963.

Section 2

Summary

EKC Photo Science reported the photographic quality of the mission was uniformly good. Ground resolution calculations yielded consistent results, with a geometric mean of 3.0 feet. Because of the June launch date high sun elevation angles were encountered thereby permitting extensive use of slit 1. The short exposure times minimized smear, which contributed to the uniformly good photographic quality achieved on FM 39.

Three platen adjust operations were made during the mission. The first two movements were made to compensate for positional errors. The third platen movement, made on rev 106, compensated for the thinner base UTB film, SO-380. EKC Photo Science resolution estimates indicated no observable change in resolution as a result of any of the three platen movements.

Exposure estimates made by Photo Science indicated that FM 39 exposure levels were generally good. Where improper exposure did occur, the error was generally due to overexposure. This can be attributed in part to the high sun angle experienced during June.

Some photography was taken during the ascending portion of flight on rev 15 using slit 3. Results in this mode were generally poor because of underexposure, resulting from low sun angles, and high smear levels.

Due to the absence of a PET report at the time of this writing, film velocity variation numbers were available for quoting only from Photo Science. EKC reported variations in film velocity, detected in yaw slit images and by measurements of the 20 cps data track, as high as 2.5 percent. Excessive film velocity variations were reported in frames 20-1, 31-2, 32-1 and 79-2.

Ground test coast data was not in good agreement with flight coast data. The large error is believed to have been caused by an incorrectly positioned looper-empty switch which resulted in erratic looper behavior and film pull through.

3.0 Primary Flight Objective

The primary objective for flight 38 was to conduct an eight day reconnaissance mission to obtain high resolution photography of specific targets selected by the NRO. Based on data received from EKC Photo Science, it is concluded that the primary objective of Mission 4038 was satisfied.

3.1 Resolution

The average resolutions reported by EKC Photo Science are:

Source	CORN Targets Ft.	CORN Targets Lines/mm	Miscellaneous Frames Ft.	Miscellaneous Frames Lines/mm
EKC Photo Science (subjective)	3.24	86	3.0	111

3.1.1 CORN Target Analysis (EKC Photo Science)

EKC Photo Science reported ground resolutions varied from 2.0 feet to 3.6 feet for the 11 CORN targets (6 X-direction, 5 Y-direction) photographed under good conditions and 2.8 feet to 5.0 feet for the 7 CORN targets (3 X-direction, 3 Y-direction) photographed in hazy areas and deep shadows. CORN target resolution data is shown in Table 3-1.1.

3.1.2 Subjective Resolution Analysis (EKC Photo Science)

Subjective resolution estimates which were made by EKC Photo Science on 20 frames are summarized in Table 3-1.2. As indicated by this table Flight 38 photography was of uniformly good quality.

CORN TARGET ESTIMATES

EKC PHOTO SCIENCE TEAM MEASURED RESOLUTION

REV/FRAME	X (FEET)	Y (FEET)	GM (FEET)	X (L/MM)	Y (L/MM)	GM (L/MM)	SLIT NO.	PHOTOGRAPHIC CONDITION	FIELD ANGLE (DEGREES)
15/10	4.5	5.0	4.7	76	69	72	1	HAZE	-2.4
31/01[1]	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
31/02	2.8	5.0	3.7	91	51	68	1	X-EDGE OF SHADOW Y-DEEP SHADOW	-1.2
63/01	2.3	2.5	2.4	111	102	106	1	- - - - - - - - -	-1.15
79/02	4.0	2.8	3.3	65	93	78	1	SLIGHT HAZE	-0.3
80/02	3.6	2.0	2.7	70	126	94	1	SLIGHTLY OVER-EXPOSED	ON-AXIS
95/05	2.8	2.0	2.4	90	127	107	1	- - - - - - - - -	-1.3
96/02	3.5	2.3	2.8	72	109	89	1	- - - - - - - - -	ON-AXIS
111/06	3.6	5.0	4.2	71	51	60	1	HAZY	0.8
111/07	2.8	2.0	2.4	91	127	108	1	X-PARTLY CLOUD SHADOW	0.7
AVERAGE	3.3	3.2	3.2	82	95	86			0.87

1-CORN NOT LOCATED

Table 3.1.1

EKC SUBJECTIVE RESOLUTION ESTIMATES

REV/FRAME	OBLIQUITY (DEGREES)	STEREO ANGLE (DEGREES)	SLANT RANGE (N.M.)	SUN ELEVATION (DEGREES)	EXPOSURE TIME (SEC.)	SUBJECTIVE RESOLUTION (FEET)	SUBJECTIVE RESOLUTION (L/MM)
4/07	-31.05	15.0	102.1	45.6	1/360	3.5	100
4/08	-31.29	-15.0	102.8	45.6	1/352	3.0	118
5/01	-20.75	15.0	112.6	42.9	1/307	3.0	123
5/17	- 0.80	-15.0	91.1	41.5	1/201	3.7	77
8/01	-18.34	15.0	101.4	54.9	1/356	3.0	110
13/07	19.87	-15.0	122.1	25.5	1/295	3.0	133
15/10	35.11	0.0	99.7	65.1	1/378	3.7	92
20/01	-30.68	15.0	113.5	47.5	1/316	3.0	129
21/02	5.06	-15.0	94.5	52.4	1/385	2.5	120
25/13	-24.9	-15.0	94.8	62.3	1/389	3.5	90
25/14	-33.4	0.0	99.1	62.6	1/383	3.0	113
25/16	-42.7	-15.0	116.1	62.6	1/304	2.5	172
25/22	8.7	-15.0	95.7	33.5	1/191	3.0	102
29/03	8.7	15.0	122.3	27.5	1/151	3.7	104

Table 3.1.2 (Continued on following page)

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REV/FRAME	OBLIQUITY (DEGREES)	STEREO ANGLE (DEGREES)	SLANT RANGE (N.M.)	SUN ELEVATION (DEGREES)	EXPOSURE TIME (SEC.)	SUBJECTIVE RESOLUTION (FEET)	SUBJECTIVE RESOLUTION (L/MM)
31/01	-13.1	0.0	83.5	64.8	1/457	2.5	106
32/01	25.7	15.0	93.0	65.9	1/397	2.5	124
56/03	8.2	15.0	88.3	62.5	1/413	2.75	102
63/01	0.4	0.0	82.0	65.0	1/466	2.25	114
63/01	0.4	0.0	82.0	65.0	1/466	3.0[1]	85
63/01	0.4	0.0	82.0	65.0	1/466	4.25[2]	60
79/02	11.7	0.0	82.2	68.2	1/461	3.0	86
79/02	11.7	0.0	82.2	68.2	1/461	4.0[1]	65
79/02	11.7	0.0	82.2	68.2	1/461	5.0[2]	52
105/06	9.8	15.0	89.3	57.6	1/409	2.5	114
AVERAGE	|19.0|		99.3	50.7	1/319	3.0[3]	111

1. 3.2° OFF-AXIS
2. -3.2° OFF-AXIS
3. ON-AXIS AVERAGE

Table 3.1.2 (Continued)

3.2 Focus Control Component Operation

Telemetry indicated that operation of the Focus Control Component was nominal through rev 117. On Cook station contact 119, rev 118 data, it was found the on-board recorder had malfunctioned. Consequently only real time data was received for the remainder of the mission. As a result, no focus data was available for the final 14 revs. Since resolution remained good during the balance of the mission it can be assumed that the platen was positioned near the plane of best focus for the entire flight.

While the recorder was operational, 34 focus exercises were performed. In 29 of these exercises, data validity estimates ranged from fair to good.

Between revs 6 and 85, the Focus Control Component indicated that the average PBF was approximately .0002 inches from the point where the platen was positioned. To compensate for this error and an anticipated further shift of PBF away from the lens the platen was moved .0004 inches away from the lens on rev 86. Focus data continued to indicate that the PBF was further from the lens than the platen was positioned. Consequently, on rev 101 the platen was moved an additional .0004 inch.

The third and final platen adjust occurred on rev 106. This was a movement of .001 inch toward the lens to compensate for the thinner base UTB film, SO-380. Reports from EKC Photo Science Team indicated that no observable change in resolution could be detected after the first two platen movements and that the UTB photographic quality was comparable to the Type 3404.

It is concluded that the Focus Control Component functioned properly during flight 38.

3.3 Smear

Table 3.3.1 lists EKC smear data for lens field angles of ±3.2 degrees along with the expected smear (0.8 σ smear contributors) at the edge of the lens field. Average smear levels provided by EKC Photo Science were well within expected limits with the exception of Y-direction smear levels at the far side of the data field. Frames 5-1, 8-1, and 32-1 had excessive smear values which significantly contributed to the high average smear value for this Y-field position. 77.3 percent of the in-track smear levels and 68.6 percent of the cross-track smear levels reported were less than the expected smear values.

EKC SMEAR ESTIMATES

Rev/Frame	Measured Smear (Microns) X-Smear		Measured Smear (Microns) Y-Smear		Expected Smear (Microns) X-Smear	Expected Smear (Microns) Y-Smear
	3.2°	- 3.2°	3.2°	- 3.2°		
4/08	10	8	2	4	10.0	4.1
5/01	6	6	0	10	6.0	4.0
5/17	0	4	0	-12	4.4	8.0
8/01	4	6	0	10	5.7	4.0
13/07	- 4	6	- 2	2	5.7	4.0
15/10	-10	10	0	0	8.8	1.0
20/01	8	12	0	6	8.8	4.1
21/02	0	0	4	2	2.0	4.0
25/13	6	10	2	2	7.6	4.1
25/14	8	4	2	4	9.8	1.0
25/16	0	0	0	8	13.8	4.1
29/03	0	0	0	10	4.8	8.0
31/01	- 4	- 4	- 4	- 4	4.3	0.8
32/01	10	10	0	10	6.4	4.1
56/03	0	4	0	0	2.4	4.0
63/01	0	0	0	0	1.4	0.8
79/02	2	4	0	0	2.9	0.9
80/02	0	0	0	0	2.0	0.8
95/05	2	2	2	4	2.4	0.8
96/02	0	0	0	0	1.0	0.8
111/06	0	2	0	0	3.0	0.9
111/07	0	0	2	0	1.9	0.8
AVERAGE	|3.36|	|4.18|	|0.91|	|4.0|	5.23	2.96

Table 3.3.1

A factor contributing to the relatively low average smear levels obtained during flight 38 was the June launch period. Relatively high sun elevation angles are encountered at this time of the year, allowing for use of the narrowest slit width, .0085 inch, for a high percentage of targets. Of the 22 targets where smear data was provided, 20 were photographed using the .0085 inch slit. Since smear is linearly proportional with exposure time, the high percentage use of the narrow slit significantly contributed to the low average smear values obtained.

3.4 Exposure

The absence of a PET report has prevented the quoting of specific exposure data. However, based on EKC Photo Science subjective data, exposure during FM 39 was generally good.

Where data was reported, exposure was generally good with the exception of exposure data reported on rev 15. The first six frames on rev 15 occurred on the ascending portion of flight using slit 3. Under-exposure resulted for these frames. These results were not too surprising in that sun angles for these frames ranged from 0.1 to 5.1 degrees. Except for rev 15 the narrow slit was used extensively. Shown below are the flight 39 slit usage figures:

Slit No.	No. of Frames	Percentage of Total
1	942	88.7
2	66	6.2
3	54	5.1

3.5 Film Velocity

As shown in Figure 1, ground tests made on stop transients were not in good agreement with flight results, the average error at any film step being approximately one inch. Flight coast data was obtained from 463 frames, 206 of which were at film speed step 64, the film velocity used for runouts and processing blanks.

Density measurements were made on several of the frames that indicated additional film coast. These measurements were made in an effort to determine the nature of the film coast, by calculating the variations in film velocity after the camera was commanded off. The approach taken was to make exposure measurements along the flight record from camera turn OFF to slit burn-in, a distance D. Film velocity and exposure are related by:

$$V_f(D) = \frac{2.69\ B\ (\theta)\ W}{E\ (D)\ T^2}$$

where

$V_f(D)$ = film velocity during camera OFF (in/sec)

E (D) = exposure during camera OFF period (mcs)

B (θ) = scene luminance at a sun angle, θ (foot-lamberts)

W = slit width (inches)

T = lens T-stop

The film velocity, V_f, relative to the time the camera was turned OFF was then plotted versus the distance D. These curves are shown for two frames in Figure 2. These curves show that the film velocity began to decrease as expected when the camera was turned OFF. However, the film velocity on these frames suddenly increased. It was calculated that this increase in film velocity occurred approximately at the time the looper carriage reached the looper-emtpy microswitch. Therefore, it was concluded that the looper-empty microswitch may not have been correctly positioned during the flight thus allowing the looper carriage to strike the mechanical stop. The impact of the looper carriage striking the mechanical stop resulted in additional film to be advanced past the slit accounting for the increase in film coast.

There was no indication during Camera Payload testing at EKC that the looper-empty microswitch was incorrectly set. Due to the location of this switch however, it is susceptible to being bumped and possible misaligned. Also, while making an adjustment to the looper film capacity at VAFB, the looper-empty microswitch was repositioned. It is possible that a misalignment may have occurred at that time or while work was taking place in the vicinity of the looper-empty switch.

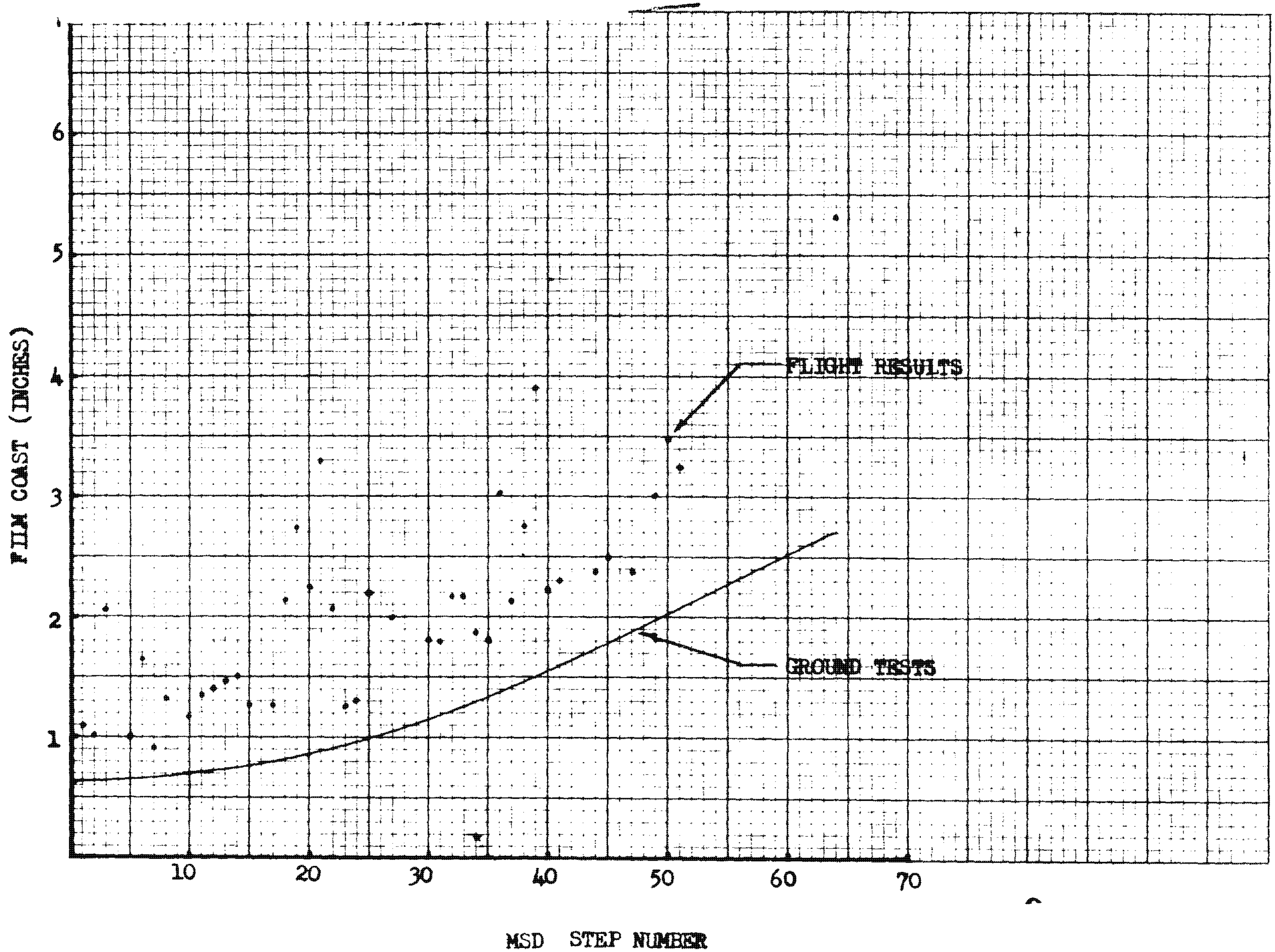
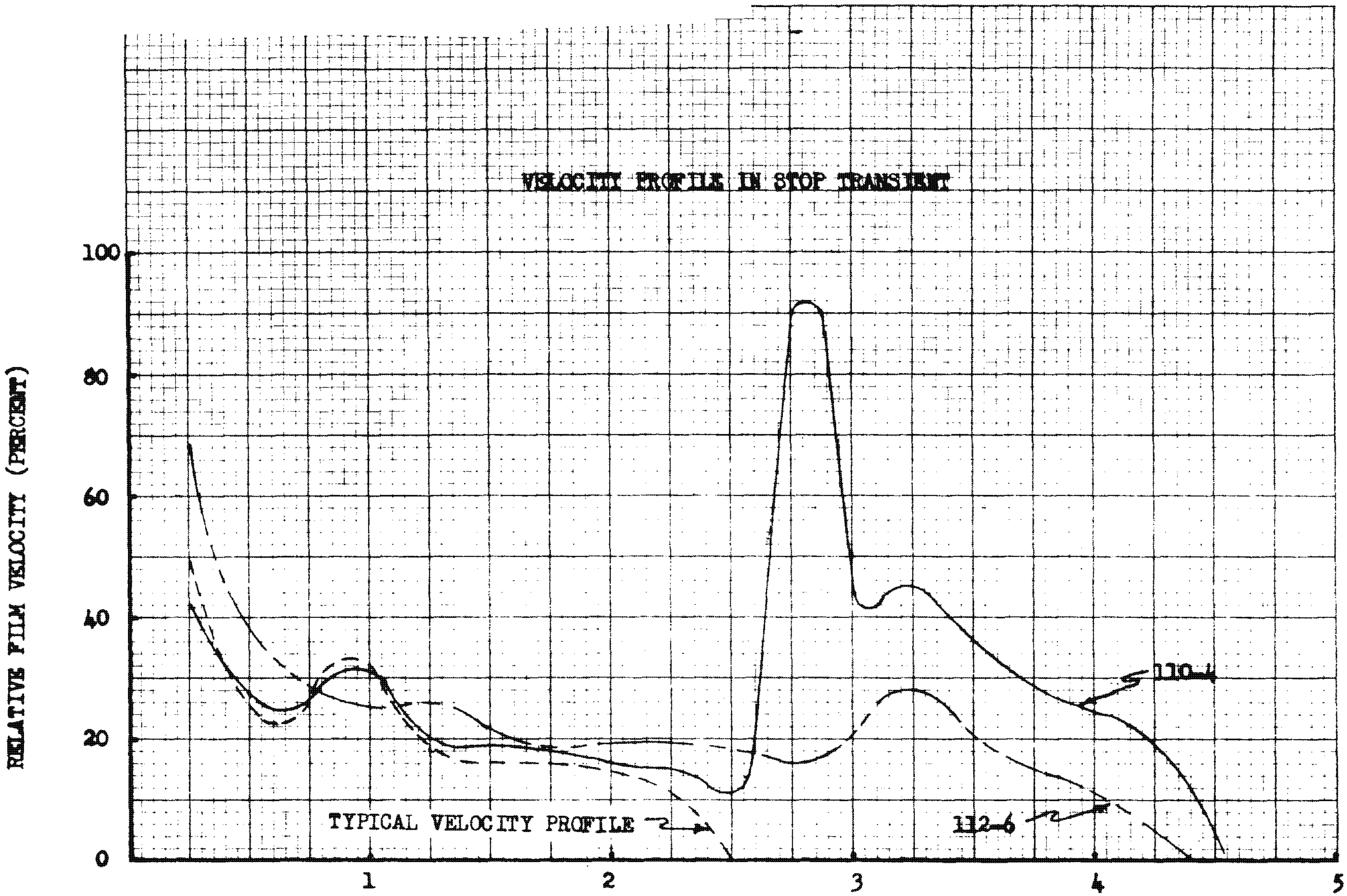

FILM COAST (INCHES)
1
2
3
4
5
6
10
20
30
40
50
60
70
FLIGHT RESULTS
GROUND TESTS
MSD STEP NUMBER

FIGURE 1



INCHES AFTER STOP COMMAND

FIGURE 2