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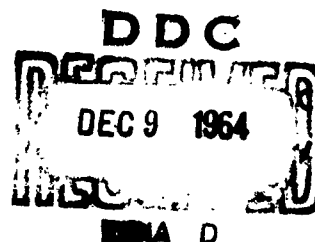IBM CD No.: 3-260-8414

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Image Velocity Sensor Subsystem (IVSS) Study Final Report

Volume I : SUMMARY

NOVEMBER 1964

Prepared for

**HEADQUARTERS, SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE**
Los Angeles, California

DDC

DEC 9 1964

Contract No.: AF04(695)-656

IBM Space Guidance Center, Owego, New York

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Image Velocity Sensor Subsystem (IVSS) Study Final Report

Volume 1 : SUMMARY

Prepared by the

Advanced Systems Research Staff

IBM Space Guidance Center, Owego, New York

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NOVEMBER 1964

Prepared for

HEADQUARTERS, SPACE SYSTEMS DIVISIONS
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Los Angeles, California

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Abstract

The five volumes making up this Technical Documentary Report describe the results of a 3-month study of the Image Velocity Sensor Subsystem conducted for the Space Systems Division of the Air Force Systems Command under Contract AF04(695)-656. This study involved the analyses, parametric studies, simulations, preliminary design efforts, and planning necessary to develop meaningful definitions of the experiments and experimental hardware required to fulfill the objectives of the MOL program.

Volume I summarizes the entire study. Volume II presents the results of an elemental simulation program conducted to assess man's ability to perform the planned experiments. Simulation plans are also discussed in this volume. The results of trade-off and equipment design analyses are given in Volume IV, while Volume V presents detailed plans for conducting subsequent phases of the IVSS program.

In general, this study has demonstrated the basic feasibility of the proposed MOL experiments, indicated the high degree of precision that human participation can provide to the system, and developed designs and plans compatible with MOL program guidelines.

Accepted and approved by: _____

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Image Velocity Sensor Subsystem (IVSS) Study
Final Report
SSB-TR-54-237

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- 3.0 Simulation and Analysis
- 4.0 Subsystem Integration
- 5.0 Experiment Definition
- 6.0 Critical Problem Areas
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Volume III — Subsystem Definition:
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Illustrations

This volume presents a summary of the results of the 3-month IVSS (Image Velocity Sensor Subsystem) study program. The relationship between the statement of work for the program, the summary volume and the technical volumes is shown in the cross-reference index included with each volume.

The ITEK Corporation, acting as a subcontractor to IBM, provided technical data on the optical subsystems.

1.0 Introduction and Summary

1.1 Objectives of Study

The objective of the IVSS Study was to perform parametric studies, analyses, and simulations to determine what man could do in acquiring and tracking visual targets and in compensating for image motion from satellites. The results form the basis for a preliminary design of an orbital, high-accuracy, image velocity sensor subsystem which could be used for orbital experiments to obtain additional experimental data as justified by the nonorbital experiments and simulation. Consistent with the above design for the IVSS, studies were performed relative to experimental procedures, planning, techniques for evaluation of the experimental results, and the definition of a comprehensive simulation program.

The Image Velocity Sensor Subsystem consists primarily of a direct viewing, pointing and tracking telescope, with coupled camera, and a tracking servo system used in conjunction with a general-purpose computer. It would be capable of providing accurate data regarding the angles and angular velocity of a target line-of-sight with respect to the spacecraft. Such angular rate data would be used to apply necessary corrective motion to either slow down the image for visual inspection by the astronaut, or provide synchronized motion of a recording medium to enhance the resolution of a recorded image. The experimental subsystem was to be designed to permit the assessment of man's capability to track compatible with line-of-sight angular rate determination to an accuracy better than 0.2 percent.

A brief description of the experiments which would make use of this subsystem follows:

1.1.1 Acquisition and Tracking of Ground Targets

The objectives of this experiment are to evaluate man's performance in acquiring preassigned ground targets and tracking them with an accuracy compatible with the requirements for precise image velocity determination. As originally conceived, the equipment required for this experiment

---

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included a direct viewing, pointing and tracking scope (PTS), a general-purpose computer, and a coupled camera. The PTS consisted of a stationary refractive optical system having a variable magnification capability and utilizing a gimbaled mirror arrangement for scanning, pointing, and tracking. The configuration had to be compatible with the provision of capabilities for utilization (1) in the scanning mode, that which would employ low magnification and wide field of view, and (2) in a tracking mode, where high magnification would be required. During the study, the choice of magnifications and corresponding fields of view were to be substantiated.

1.1.2 Acquisition and Tracking of Space Targets

The objectives of this experiment are to evaluate man's ability to acquire and track satellite targets in fly-by maneuvers and determine precise image velocity and to evaluate man's ability to acquire and track targets in a co-planar orbit in order to provide rendezvous guidance. The same equipment would be used as in the previous experiment.

1.1.3 Direct Viewing for Ground and Sea Targets

The objective of this experiment is to evaluate man's ability to acquire and scan land targets of opportunity and to detect ships and surfaced submarines. Verification might be obtained by taking pictures with a coupled camera. The same equipment is to be used as for the previous two experiments.

1.2 Study Summary

The performance of parametric studies, analyses, simulations, preliminary designs and planning to define a high-accuracy image velocity sensor subsystem and experiments necessarily involved many interactions and required numerous iterations. The results of the elemental simulations and analyses, plus the experiment planning, governed the configuration and design of the IVSS. Therefore, the study was subdivided into time phases and iteratives cycles, as shown in Figure 1-1. The bulk of the effort during the first phase was directed toward the establishment of preliminary design criteria for the IVSS, based on the initial results of the elemental simulations, analyses, and experiment procedural planning, plus the derivation of significant parametric trade-off data and equations for the subsequent design phases.

Subsystem design and integration studies were then initiated using the design criteria and the parametric trade-off data and equations previously defined. By the end of the study, a second iteration of elemental design simulations and the planning of the experiment procedures was completed.

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Final revisions to the design criteria were fed into the subsystem design and integration. The remainder of the study was devoted to the completion of the subsystem preliminary design and the enhancement of elemental simulation data.
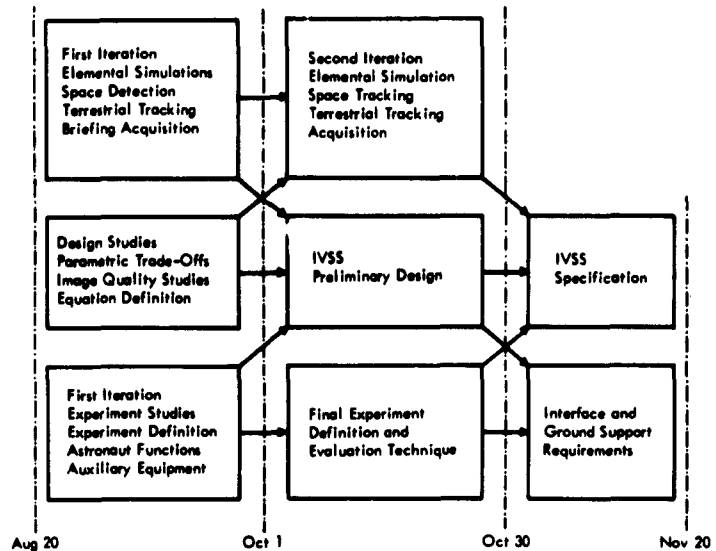
Figure 1-1. IVSS Study Plan

1.2.1 Task I — Elemental Simulation

The elemental simulation was subdivided into two sequential groups. The first group consisted of tracking of prominent targets, acquisition of pie-assigned targets, unaided scanning of moving imagery, demonstration of briefing techniques, and satellite acquisition. The second grouping consisted of refined target tracking, briefed target acquisition, scan pattern evaluation, and acquisition and tracking of space targets. The results of this study task are detailed in Volume II

1.2.1.1 Ground Tracking

The ground tracking studies were also broken up into two categories: (1) continuous nonregenerative tracking and (2) discrete tracking. Both categories used basic human capabilities with minimum aiding.

1.2.1.2 Acquisition of Typical Ground Targets

Parametric studies were performed to assess the influence of time pressures and angles of obliquity on acquisition time for typical targets, such as airfields and industrial sites.

1.2.1.3 Briefing Demonstrations

Simulations were performed to determine an effective means of presenting briefing material to the eyepiece. Four means of presentation were tested using both monocular and binocular techniques.

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1.2.1.4 Target of Opportunity Studies

The target of opportunity studies consisted of analytic and simulation studies to determine major parameters of the aided and unaided scanning to acquire targets whose geographical position is not precisely known.

1.2.1.5 Acquisition and Tracking of Space Targets

One study determined rate detection thresholds for space targets, and a second measured man's tracking performance under high-error and worst-case space-to-space closing conditions.

1.2.2 Task II — Parametric and Trade-off Studies

The studies performed under this task were related to the definition of

- The optical configuration of the pointing and tracking scope
- The optically coupled camera
- The associated ancillary equipment, such as the briefing presentation unit
- The IVSS displays and controls and performance evaluation equipment
- The tracking servo system
- The computation requirements.

The results of this study task are contained in Volume III. Preliminary performance and design requirements specifications are appended to this volume.

1.2.3 Task III — Functions of Man

Human and system functions were analyzed. Allocation of functions to the system and the human were carried out according to established human factors and systems engineering principles. A detailed task analysis of the human role was completed with identification of means of assessing the human role or contribution to each function. Training criteria, selection criteria, and other relevant training standards data were provided. The results of this study task are contained in Volume IV.

1.2.4 Task IV — Vehicle Interface

Interfaces of the IVSS with the various subsystems of the MOL were investigated in order to ensure compatibility of design. The following interface requirements were defined:

- Guidance and navigation
- Stabilization and control
- Data management
- Communications
- Power requirements
- Environmental control
- Vehicle structure
- Equipment duty time

The results of this study task are detailed in Volume III.

1.2.5 Task V — Image Quality Analysis

A technique for image quality analysis of the IVSS was developed. This technique involved graphical methods and digital computation. It was applied in various parts of the program to produce criteria and performance specifications for subsequent design and development activities. The results of this study task are discussed in Volume III.

1.2.6 Task VI — Experimental Testing and Mock-Up

With Air Force concurrence, IBM fabricated a mock-up of the IVSS crew station. The results of this study task are described in Volume IV.

1.2.7 Task VII — Preliminary Design Configuration and Recommendations

This task comprised the following efforts:

- Preparation of preliminary performance specifications and drawings
- Reliability predictions
- Procurement schedules and costs
- Definition of AGE problems
- Ground support analysis
- Test site analysis
- System integration
- Description of reliability and maintainability.

A full-scale mock-up of the system is shown in Figure 1-2. The results of the study task are contained in Volume III.

1.2.8 Task VIII — Experiment Procedures Planning

The experiments and subexperiments that will be performed in space were designed. The goal of this task was to provide experimental designs and sequences of experiment performance which reflected a detailed analysis of astronaut functions in space, error sources, and other contributing factors to measurement of man's capabilities to function with this system in the space environment. Volume IV contains the results of this study task.

1.2.9 Task IX — Experiment Simulation Planning

The object of this task was to define a simulation program for subsequent phases of IVSS and MOL development. This plan encompasses the evolution of simulations, definition and conceptual design of new simulation equipment required, projection of a total simulation plan, and isolation of critical areas. The results of this task are explained in Volume II.

1.2.10 Task X — Program Planning

During this study, plans for the remainder of the IVSS program were constructed. Detailed plans for Phase I and general plans for Phase II were prepared as detailed in Volume V.

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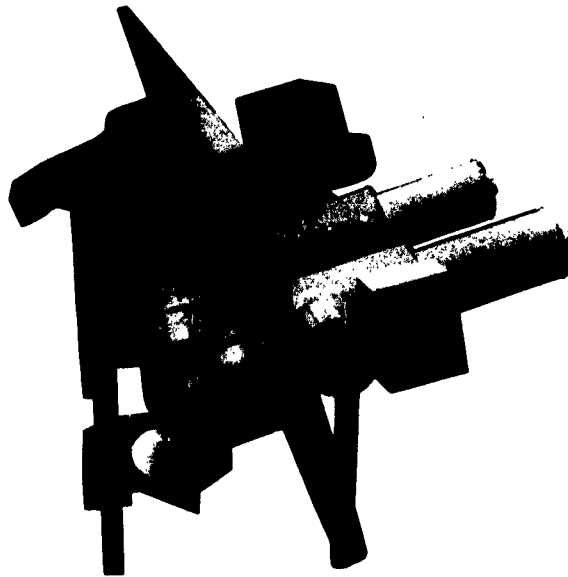
Figure 1-2. Mock-up/Form Factor Configuration

1.3 Summary of Results

The most significant conclusion resulting from this study is that man's
terrestrial target tracking ability is well below 0.2 percent and apparently
will be limited by equipment performance. Tracking accuracy better than
0.05 percent was achieved with a magnification of 108X and in the presence
of error functions equivalent to a 1 percent computation of LOS rate.

Simulation results indicate that performance will improve with each addi-
tional improvement in simulation capability, until the validity and exact-
ness of the simulation becomes unquestionable. A high degree of confidence
exists in measured performance as good as 0.05 percent. Results below
this level cannot be trusted until vehicle control disturbances, atmospheric
attenuation (haze), instrumentation disturbances and error functions, and
illumination and target image characteristics at the telescope are known
precisely and can be precisely simulated. Most of these parameters are
known well enough so that the simulation results alone provide an extremely
high confidence in man's ability to track terrestrial targets with an accur-
acy better than 0.2 percent.

Final verification of man's ability to track with an accuracy of 0.05 per-
cent or better will probably have to be performed in space, because the
exact nature of the disturbances and error functions which man will have
to cope with will not be known precisely beforehand. Furthermore, the
space environment will definitely affect the operation of the tracking scanner,
which has been identified as the performance-limiting equipment.

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The scanner will have to be designed to avoid adverse effects of operating in a hard vacuum and conversely to take advantage of the beneficial effects of operating at zero gravity. The effects of operating the scanner in a vacuum can be adequately evaluated in high vacuum chambers on the ground. However, evaluation of design features which take advantage of the fact that no mass has to be supported at zero gravity, such as a minimum friction suspension designed to carry practically no load, must be performed in space, since zero gravity cannot be simulated on the ground.

In order to achieve the required performance, a visual resolution of 4 arc seconds and a scanner velocity error of 2 arc seconds/second are required. To measure the performance, a photo-optical resolution of 2.3 arc seconds and a focal length of 32 to 40 inches are required.

Because of the confidence in the simulation results, which indicate that man's tracking ability will be significantly better than 0.2 percent, it was concluded that the useful space experiment should be designed to measure performance on the order of 0.05 percent or better. Although there does not seem to be any "on the shelf" equipment which can satisfy this requirement, an experimental configuration can be designed around a conservative lens transfer function taken from an existing system.

To minimize risk a 36-inch focal length, f/4.5 photo-optical system has been chosen. This is slightly larger than would be necessary if based on the best lens design achievable and maximum optical tuning. Furthermore, the tracking scanner can be configured around existing torquing and sensing elements, and existing 70-mm cameras are adequate for the experiment requirement.

Preliminary investigations show that a simple analog (LOS rate) instrumentation will satisfy the rate prediction requirement for 0.05 percent performance. A digital primary mode of operation is recommended, however, because of its inherent flexibility, which will be useful in measuring the effects of various degrees of rate prediction and state variable filtering during the orbital experiments.

The configuration selected satisfies the field-of-view and magnification requirements for space tracking and is capable of torquing rates up to 33.5 degrees/second required for a 90-degree 10-n mi fly-by encounter.

Furthermore, the configuration also satisfies the 10-foot photo-optical resolution requirement for recognition of aircraft near nadir at 160 n mi but does not satisfy the specified requirement for ship classification from 160 n mi.

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The configuration selected has the following advantages:

- Minimum weight for size due to a minimum of optical path folding
- Minimum internal volume
- Coincidence of the optical axis with the thrust axis during boost, which is the favorable orientation for preservation of optical alignment.

The recommended configuration has the following physical characteristics:

Weight: 680 pounds

Volume: 40 cu. ft. total (15 cu. ft. outside of vehicle)

Power: 740 watts

The Phase I and Phase II program planning studies indicate that the required number of IVSS experiment packages can be produced and qualified within the time periods designated in the statement of work, provided detailed design activity is accelerated during the 2-month interim period between Phase I and Phase II.

Finally, the reasons for performing the space tracking experiment are threefold:

- To verify man's tracking performance at 0.05 percent or better
- To verify the validity of ground tracking simulation prior to commitment to design, or as a design verification
- To make precise measurements of all of the quantities which affect the validity of the ground simulation, such as
  - (a) actual vehicle control disturbances
  - (b) atmospheric attenuation and haze
  - (c) orbital effects on instrumentation
  - (d) significant tracking error functions under orbital conditions
  - (e) illumination and target characteristics at the telescope.

If man's performance in orbit is better than anticipated, it will be possible to (1) create an exact simulation on the ground, based on data acquired from the space experiments, to measure man's ultimate performance, and (2) simulate, synthesize, and evaluate the system capable of utilizing this performance to the utmost prior to its injection into orbit.

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2.0 Definition of Requirements

The requirements for the synthesis of the IVSS evolve from four sources:

- Experiment functional requirements
- Analysis of experiment performance requirements
- Simulation and analyses of human performance
- Compatibility with mission and MOL constraints.

The functions to be performed during the experiment were derived from the requirements delineated in the statement of work. Using functional flow block diagrams, one can identify the detailed experiment functions and translate their impact on the experiment equipment into functional requirements.

The design objectives of the statement of work are the origin of the performance requirements. The design objectives, when analyzed and evaluated with the functional requirements, yielded the performance requirements upon which the IVSS design criteria were based. The constraints associated with the mission dynamics and the MOL vehicle combine to form the framework of the equipment design trade-off studies.

Simulation and analysis of human performance was required to perform functional allocation between man and equipment based on his performance capability.

2.1 Experiment Functional Requirements

The statement of work instructions were interpreted as a requirement for accurate data regarding angles and angular velocity of a line-of-sight with respect to a spacecraft. This data will be used to apply corrective motion to slow down or immobilize a target's motion in the field of view to permit visual inspection or photographic recording. The experimental IVSS should permit assessment of man's capability to perform image motion compensation better than 0.2 percent of the line-of-sight rate for ground and space targets.

2.1.1 Requirements

The requirements for the IVSS imposed by the statement of work and by the requirements of the three primary experiments are discussed in Volume III. The work statement requirements for each of the three MOL experiments making use of the IVSS are detailed in Section 1.1 of Volume V.

2.1.1.1 Experiment P-1, Acquisition and Tracking of Ground Targets

The objectives of this experiment are to evaluate man's performance in acquiring preassigned ground targets and tracking them to an accuracy compatible with the requirements for precise image velocity determination.

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Preselected test targets both in and out of the orbital plane will be acquired and tracked from a nominal altitude of 100 to 160 n mi. These may include military airfields, operational missile sites, AMR, ships, surfaced submarines, specially prepared target areas, and various targets of opportunity. The illumination conditions may vary from those of twilight (predawn) to a sun angle of approximately 40 degrees. Contrast ratios down to 1.2:1 at the objective should be assumed. Photographs obtained with a coupled camera during acquisition and tracking, and/or upon completion of the tracking run, will be used to evaluate the man's proficiency in performing the experiment.

2.1.1.2 Experiment P-2, Acquisition and Tracking of Space Targets
The objectives of this experiment are (1) to evaluate man's ability to acquire and track satellite targets for providing precise image velocity determination in fly-by maneuvers (oblique crossing), and (2) to evaluate man's ability to acquire and track targets in a co-planar orbit in order to provide rendezvous guidance. The image velocity of the space target will be determined during the tracking run.

Photographs will be obtained with a coupled camera during the tracking run and will be used to evaluate the astronaut's performance in determining image velocity. The shape of the space targets may be assumed to be a sphere, cone, cylinder, or a combination of these elements with or without appendages such as antenna, photocell arrays, or sensor elements. The average reflectance of the target vehicles may be assumed to be 0.5. The variance of the reflectance along the surface of any given target may be assumed to vary from 0.03 to 0.8. Relative velocity between the MOL and the target vehicles will be as high as 35,000 feet/second. (90-degree inclined orbits) for the case of the fly-by experiment. In addition, the targets may be rotating with peripheral speeds as high as 30 fps.

2.1.1.3 Experiment P-3, Direct Viewing for Ground and Sea Targets
The objective of this experiment is to evaluate man's ability to scan and acquire land targets of opportunity, to scan and detect ships and surface submarines, and to examine ships and surface submarines for classification purposes. To classify certain land and sea targets, the astronaut will arrest all image motion, change to a magnification for detail viewing, and then note his observations with a direct voice recorder. In some cases, he may obtain verification pictures with a coupled camera. In the case of sea targets, prelocated vessels will be employed, and the astronaut will record his impressions of ship class, heading, and any uniquely identifying features.

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2.1.2 Subsystem Characteristics

The IVSS consists primarily of a direct-viewing pointing and tracking telescope (PTS), with coupled camera, and a tracking servo.system used in conjunction with the general-purpose computer. The MOL vehicle, which will contain the IVSS, will be subjected to launch environments and sustained orbital environments, and is expected to perform reliably for a period of up to 1 month. The laboratory vehicle will include one or more pressurized sections, plus an unpressurized section. The 10-foot diameter by 7-foot long pressurized sections will provide a "shirt sleeve" environment. The dimensions of the unpressurized section will be approximately 10 by 10 feet. The date of the first flight test of this subsystem may be assumed to be late 1967.

The applicable spacecraft performance parameters are as follows:

- Altitude: 100 to 160 n mi
- Inclination: less than 40 degrees
- Altitude error: ±3 n mi (3 σ SPADATS value)
- Attitude error: 0.25 to 0.30 degree mean error in each axis.

All or a major portion of the stationary refractive optical elements of the IVSS, as well as a coupled camera and general-purpose computer, will be housed in a pressurized module of the MOL vehicle. The scanning elements will, however, either project beyond the walls of the pressurized vehicle compartment, or be located in a vacuum module of the MOL vehicle just behind a suitable aperture. An unobstructed view over the major portion of the half space below the vehicle is required.

2.1.3 IVSS Functional Flow Block Diagrams

The functions required to carry out experiments P-1, P-2, and P-3 are detailed in Figure 2-1. The top-level functions are categorized into: preparing, conducting, and evaluating the experiments. See Volume III, Section 2, where the third-level indenture for conducting the experiments is presented. These detailed functions impact the equipment and define their operations.

2.2 Experiment Performance Requirements

The equipment/facility categories listed below are required to implement the functional requirements:

- Visual/photo/optical configuration
- Tracking scanner servo subsystem
- Recording cameras and film processors
- Computers
- Displays and controls

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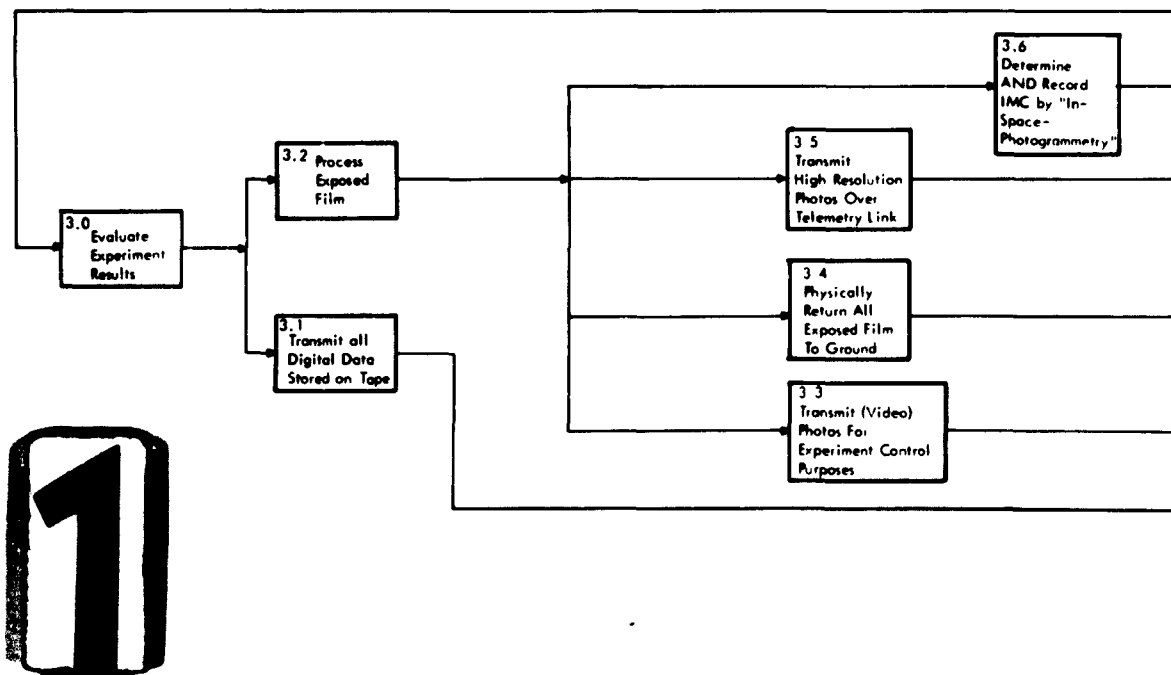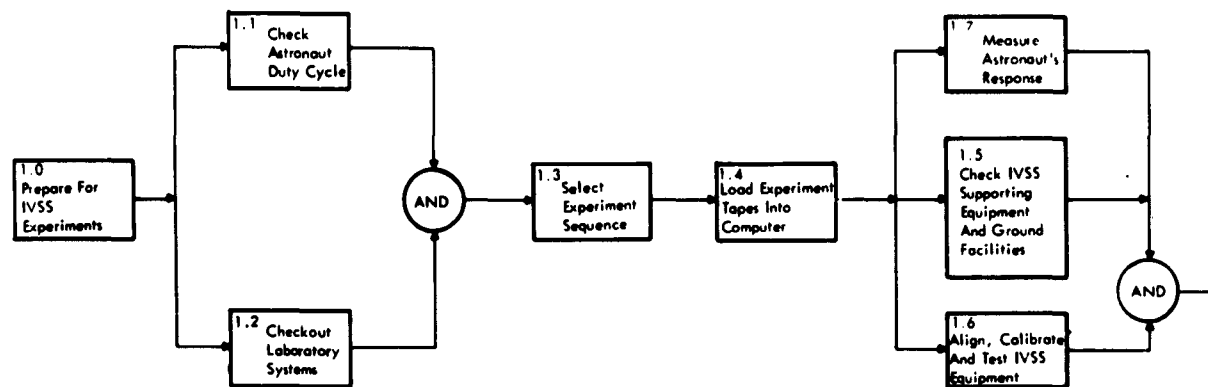
Figure 2-1. Functional Flow Block Diagram
Second-Level Indenture

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- ...asure ...ronaut's ...ponse
- IVSS ...ting ...ent ...round ...ies
- Calibrate IVSS ...nt

AND

1.10 Check Experiment Procedures

1.8 Specify Sensor Modes And Control Setting

1.9 Select Target And Briefing Material

AND

2.0 Conduct IVSS Experiments

2.1 Conduct P-1 Experiment

2.2 Conduct P-2 Experiment

2.3 Conduct P-3 Experiment

OR

3.6 Determine AND Record IMC by "In-Space-Photogrammetry"

3.7 Transmit Space Evaluation Results

OR

AND

AND

3.8 Comprehensive Evaluation Of Experiment

3.9 Recommend Further Action (If Required)

- Data acquisition and recording subsystem
- Vehicle system interface
- Experiment evaluation subsystem
- Ground support facilities.

The studies performed in Volume III indicate that, of the listed equipment, only two are of critical importance to performance requirements of the IVSS. These are the tracking scanner servo and the visual/photo/optical configuration.

The tracking servo requirements are obtained by considering the motion of the line-of-sight to the target and insuring that a smooth drive of the gimbals is obtained.

The optical requirements are obtained by considering the following:

- Target recognition
- Assurance against loss of target that has been acquired
- Target classification
- Experiment evaluation.

2.2.1 Tracking Servo Performance Requirements

The information flow for the acquisition and tracking of terrestrial or space targets is shown in Figure 2-2. The necessary MOL and target parameters are supplied from ground sources and the line-of-sight (LOS) parameters are precomputed. This in turn allows computations for orientation of pointing angles and scanning plane. After acquisition of the target, the astronaut generates error signals to the PTS pitch and roll servos. These error signals are used to both stabilize the image presentation and, if required, to update the MOL's orbital parameters.

The geometry, rotated into the MOL pitch plane, of the relative motion of the MOL to target LOS is shown in Figure 2-3. These equations are essentially true only in the region of closest approach, since it assumes a straight line for relative MOL-target motion. The dynamics of the LOS during tracking are shown in Figure 2-4 in a normalized form. As shown in this figure, the critical time in tracking occurs at about ±30 degrees from the point of closest approach, at which time the angular accelerations are highest. Typical values for these quantities are shown in Table 2-1.
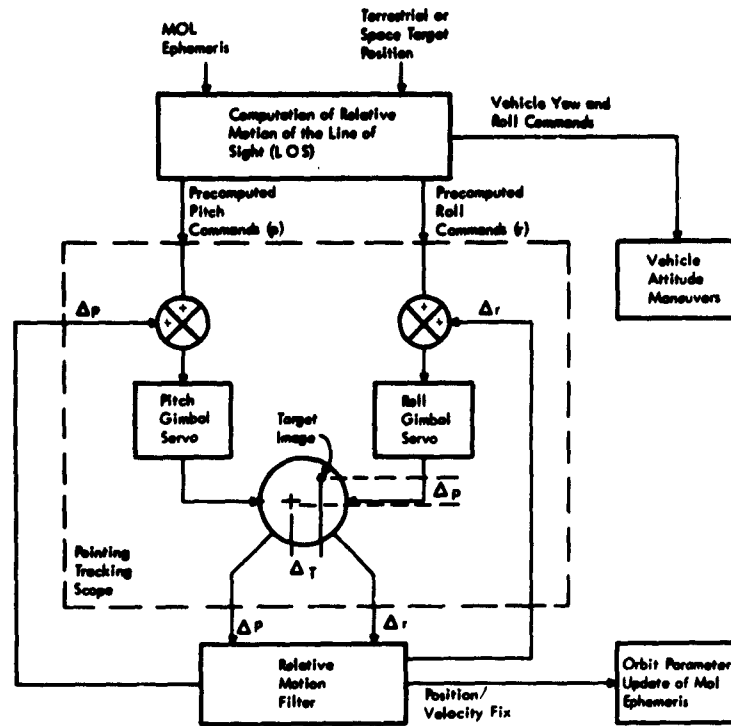
Figure 2-2. Information Flow for Acquisition and
Tracking Terrestrial or Space Targets

$$\theta = \tan^{-1}\left(\frac{V_R t}{R_{min}}\right) = \tan^{-1}\left(\frac{t}{\theta_{max}}\right)$$

$$\dot{\theta}_{max} = \frac{V_R}{R_{min}}$$

$$\dot{\theta} = (\dot{\theta}_{max}) \cos^2\theta$$

$$\ddot{\theta} = -2 (\dot{\theta}_{max})^2 \sin\theta \cos^3\theta$$

$$R = R_{min} \sec\theta$$
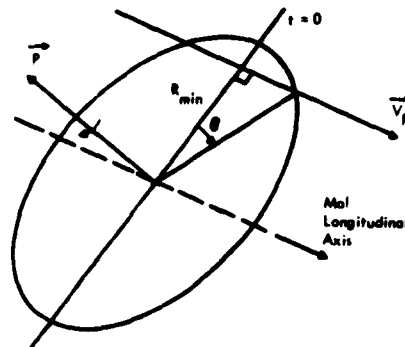
$$\dot{R} = V_R \sin\theta$$

Figure 2-3. Pitch Plane Tracking Geometry

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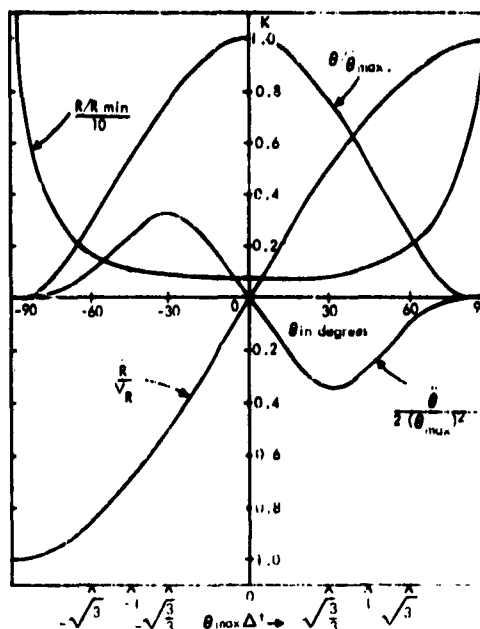
Figure 2-4. Pitch Plane Tracking Dynamics

Table 2-1

TYPICAL VALUES OF TRACKING PARAMETERS

Parameter	Ground Targets	Space Targets*
R_{min}	160 n mi	10 n mi
V_{rel}	25×10^3 feet/second	35×10^3 feet/second
θ_{max}	1.5 degrees/second	33.5 degrees/second
$\ddot{\theta}_{max}$	0.03 degree/second^2	14.6 degrees/second^2
* Perpendicular crossing of orbits is assumed.		

These quantities constitute only a portion of the performance requirements of the servo. The IMC requirement of better than 0.2 percent should be satisfied for obliquity angles of ±45 degrees in order to maintain reasonable values of coverage and tracking times for out-of-plane ground targets. The criticality of the tracking time constraint is depicted in Figure 2-5.

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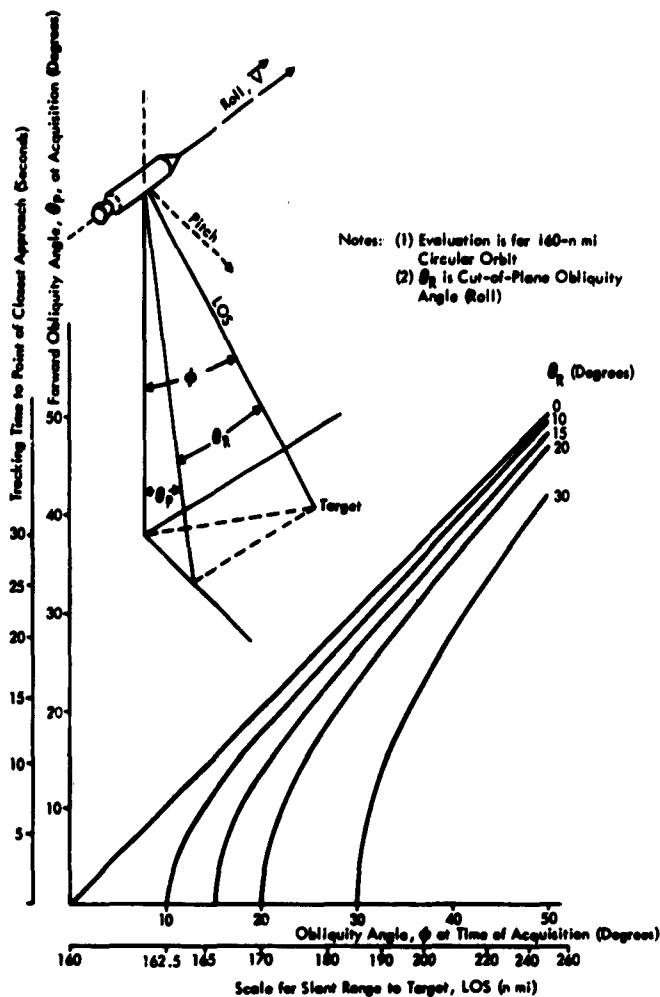
Figure 2-5. Target Tracking Time vs Acquisition Obliquity Angle

A desired target tracking time of approximately 30 seconds imposes lower limits on the obliquity angle of the LOS to target (at acquisition). This limit is a function of the out-of-plane (roll) angle to the target. From the graphs, to obtain a tracking time of 30 seconds for an out-of-plane target angle of 30 degrees (θ_R), an obliquity angle at the time of acquisition of 47 degrees is required. The criteria of 45 degrees slant range compromises the requirements for tracking time and probable roll angles.

Analytic digital simulations and other studies* have indicated a design goal of 10 arc seconds of PTS pointing error, which would allow IMC's

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*TOR-269(4107-40)-7, "Application of the Wiener Kalman Filter to MOL Manned Tracking," J. E. Lesinski, Aerospace Corporation, August 1964 (Confidential).

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down to below 0.05 percent to be attained. The requirement for gimbal
drive smoothness is derived from the need to obtain high-quality verifica-
tion photographs (on the order of 15 feet of resolution). For vibration
frequencies on the order of one divided by exposure time and higher, the
smoothness requirement relates to an amplitude requirement (1.0 arc
second) above which excessive photographic blur will result. At lower
frequencies, the vibration produces essentially a linear image motion in
which allowable rate is a requirement. The optical design was predicated
on the assumption of 45 arc seconds/second image motion. The servo, in
order to contribute a negligible amount of this total error, is then re-
quired to insure that the error response does not exceed a maximum rate
of 15 arc seconds/second.

The summary of the tracking servo requirements is listed in Table 2-2.

Table 2-2

SUMMARY OF TRACKING SERVO REQUIREMENTS (3 SIGMA)

● Maximum Dynamic Pointing Accuracy	
(1) Terrestrial Targets	±10 arc seconds
(2) Fly-By Space Targets	±30 arc seconds
● Maximum Angular Rate	
(1) Terrestrial Targets (100-n mi altitude)	2.5 degrees/second
(2) Fly-By Space Targets (10 n mi)	33.5 degrees/second
● Maximum Angular Accelerations	
(1) Terrestrial Targets (100-n mi altitude)	0.07 degrees/second^2
(2) Fly-By Space Targets (10 n mi)	12.6 degrees/second^2

● Maximum Angular Rate Error
 	
  0.05 Percent of $\dot{\theta}$ at nadir (160
  n mi altitude)
	2.5 seconds/second

● Maximum Slope of Error Response	15 seconds/second
● Maximum High Frequency (f > 50 cps) Vibration Amplitude	1.0 arc seconds

2.2.2 Optical Configuration Performance Requirements

Table 2-3 lists the requirements to be imposed on the optical system.
A detailed derivation will be found in Volume III, Section 3.2.1.

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Table 2-3

OPTICAL PERFORMANCE REQUIREMENTS

Experiment	Photo/Visual	Requirement	Contrast Ratio
P-1	Visual/Optical	Resolution $\leq$ 4.4 arc seconds at or below 45 degrees obliquity	1.6:1
P-1	Photo/Optics	• Post Tracking Evaluation Resolution = 2 arc seconds FTp ≈ 2.2 at or below 45 degrees obliquity • Concurrent Tracking Evaluation Resolution 1.2 to 3 arc seconds	1.6:1
P-3 Part 1	Photo/Optics and Visual/Optics	Resolution = 10 feet or 2 arc seconds from 160 n mi (nadir viewing)	1.6:1
P-3 Part 2	Photo/Optics and Visual/Optics	Resolution = 5 feet or 1 arc second from 160 n mi (nadir viewing)	4:1

The visual-optical P-1 requirements were obtained by demanding instrumentation of such quality that the observer shall have negligible probability of losing targets he may typically desire to track (postulated to have horizontal dimensions on the order of 40 feet and with a contrast ratio of 1.6:1 at the periscope's objective). This criterion is not necessarily equivalent to demanding instrumentation which will maximize man's performance in arresting image motion.

The photo-optical P-1 requirements were obtained by demanding capability for post-tracking evaluation (drift rate measurement) and for concurrent tracking evaluation (fix-taking error measurement) to an accuracy of 20 percent of the anticipated magnitudes of the quantities to be measured.

The P-1 requirement FTp = 2.2 is derived from the experiment evaluation requirements. Here, F is focal length (in inches), T is time between photographs used for drift rate measurement, while p represents the error allowed in the drift rate measurement (percent of the total image motion occurring when viewing an earth-bound target with an inertially fixed optical system). Taking p equal to 20 percent of the anticipated performance of the astronaut leads to p = 0.04 - 0.004 percent. For details, see Volume III, Section 3.2.1. The above requirement principally

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sets a lower limit on T. For example, a 36-inch focal length is required for a "T" equal to 6 seconds and a "p" equal to 0.01 percent, which would allow performance evaluation to 0.05 percent IMC.

P-2 performance requirements for the optical system are less stringent than those for P-1 and P-3, so that its impact on the optical system is rather minor. This is not so in the case of the P-2 requirements for the scanner servo.

The visual and photo-optical P-3 requirements were split into two parts. The first part demands a ground resolution of 10 feet at a contrast ratio of 1.6:1, and assuming nadir viewing. According to available recognition effectiveness data (see Figure 2-6) this choice of ground resolution is reasonable in that it permits recognition of such ground targets as fighter aircraft, whereas a much smaller resolution appears necessary for recognition of details such as trucks of various types.

The second part of the P-3 requirements, involving warship classification, was supplied by SSD to be used for trade-off analyses purposes only. It requires a 5-foot resolution at a contrast ratio of 4:1 at the periscope's objective, again for nadir viewing only.

For converting to angular resolutions, at an altitude of 160 n mi, a ground distance of 5 feet at nadir subtends an angle of 1 second of arc.
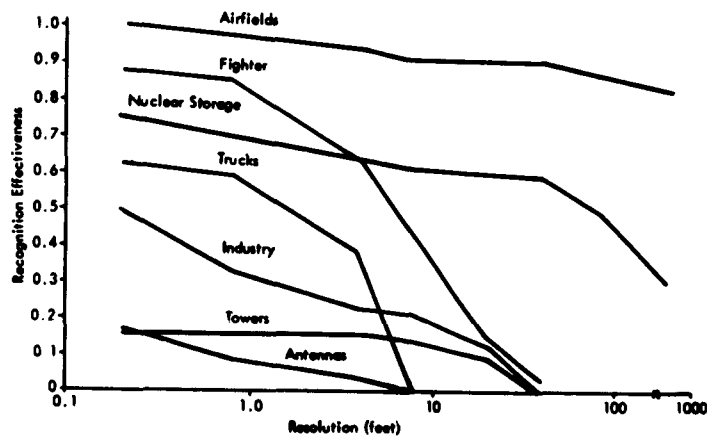
Figure 2-6. Effectiveness as a Function of Resolution
for Briefed Targets

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3.0 Simulations

The elemental simulation program initiated a series of studies intended to ultimately result in the precise definition of in-space experiments and equipments for the designated experiments. The program was oriented to the obtaining of data concerning the basic feasibility of human participation in the experiments and the initial development of design data, following a sequential pattern of research over the entire range of tasks required of the human in the experiments. Sequential "worst case" studies were performed to determine the limits of human capability for the designated tasks, as well as the experimental equipment requirements for each of the major in-space experiments.

3.1 Acquisition and Tracking of Ground Targets

A series of studies were performed to supply information on various aspects of the human's capability in the acquisition and tracking of pre-briefed ground targets. These studies used the Earth-Sighting Simulator (ESS) shown in Figure 3-1. The ESS provided a space analog, or scale model, of the real viewing situation from a spacecraft, except that the observer remained stationary while the earth model moved on a track. A telescopic view of the ground target or area was provided continuously as the spacecraft approached, passed by, and receded from the area of interest. The simulator is designed about a line-of-sight coordinate system which results in appreciable simplification of the mechanism with inherent increase in reliability and accuracy. The earth model is a photo-mosaic of appropriate scale for the orbit simulated.

For these studies, most runs were conducted at the "worst-case" altitude of 200 n mi, although some simulations were performed at 100 n mi for acquisition. The observer viewed the model through a theodolite telescope that was automatically focused for distance. Haze effects were simulated by reducing the contrast in the mosaic view by directing diffuse light into the telescope objective.

The telescope was equipped with a turret eyepiece to achieve variable magnification. The angular field of view varied from 0.19 degrees to 1.72 degrees, depending upon the magnification and aperture used. The range of magnifications possible was 5X through 53X in the strict space analog. However, by rescaling mosaics and positions on the viewing track, the range of magnification was extended with only a slight distortion of the space analog. Magnifications up to 106X were studied in the later portions of this program. Scan patterns were generated by using the computer to control the mirror drives and the mosaic position. The computer also controlled all other appropriate drive signals and error forcing signals.

Figure 3-1. The Earth-Sighting Simulator

Because aerial mosaics were used, built-in limitations existed regarding the inherent resolution and consequent maximum magnification which could be simulated. For the studies, two different mosaic resolutions were used as indicated in Figure 3-2. Comparison of these curves with similar curves for the real space view shows only a 0.3-to 0.8-foot difference for all cases.

Analog and digital computation systems were programmed to provide realistic tracks and errors for the tracking program. The error functions used were characteristic of tracking error sources in space and are shown in Figure 3-3. An error measurement was provided by the monitoring of rate error and angle error signals as shown in Figure 3-4. In order to achieve highly precise measurement capability required for the criterion of 0.2 percent or better, an error compensation program was developed to account for the repeatable errors of the simulator. Such compensation made it possible to measure to approximately 1.6 seconds/second in rate and 10 seconds in position. Subsequent rescaling of the simulator further reduced these errors.

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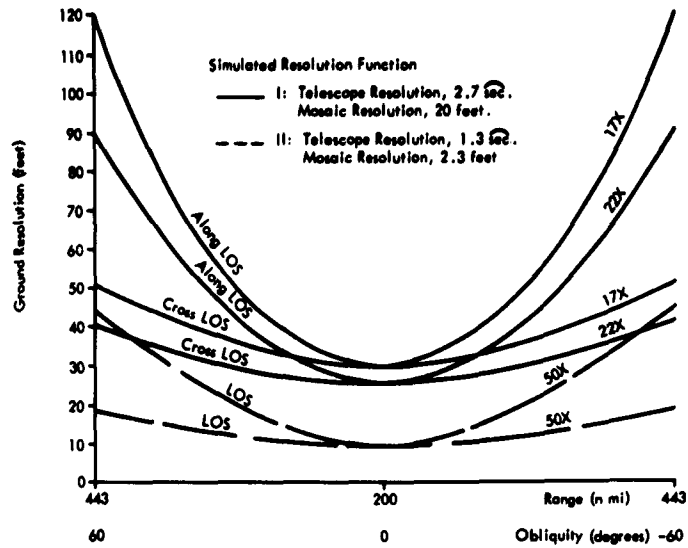
Figure 3-2. Simulated Resolution Function
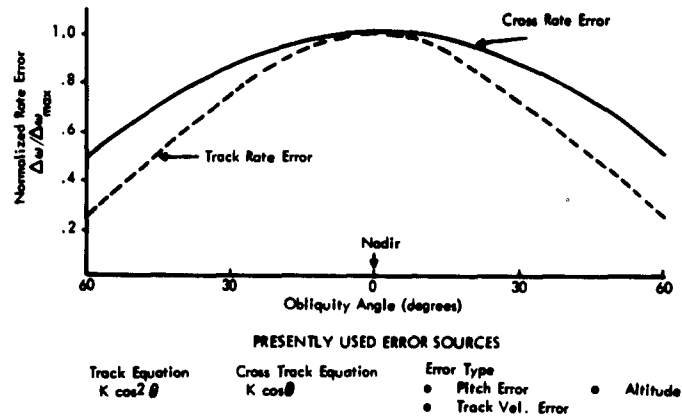
Figure 3-3. Reference Error Functions

Data recording was accomplished in the continuous case by direct recording of analog traces of error measurement signals, and digital data sampling of these signals at selected intervals during the tracking runs. During the discrete tracking runs, pointing angle errors were recorded digitally at the command of the operator. Acquisition runs were recorded visually by the experimenter. The details of the simulation device are important to the program since it was found throughout the study that minor improvements in the simulation allowed more capability to be shown by the operator.

In the sections that follow, applications of this simulation device to the basic problems of human image motion correction for ground sighting and for the acquisition of typical ground targets are presented.
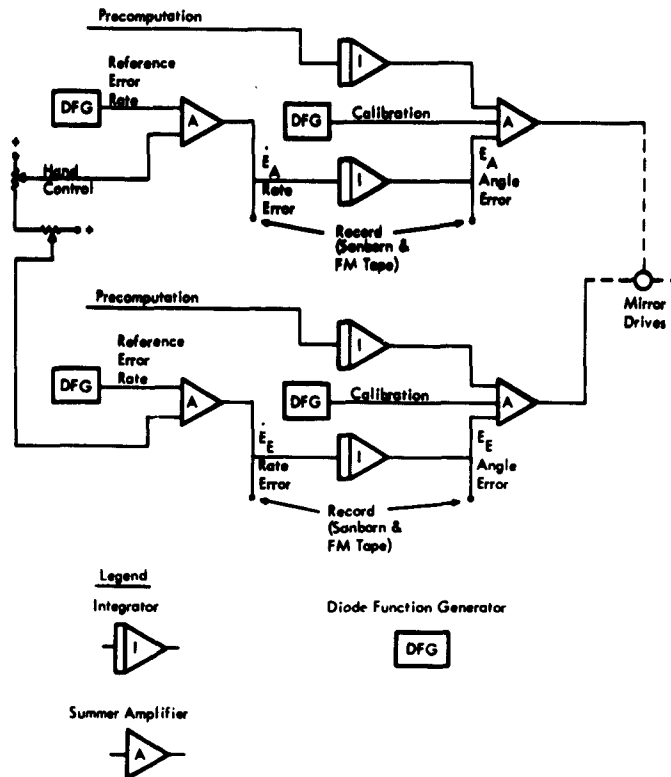
Figure 3-4. Tracking Signal Flow Diagram

3.1.1 Ground Tracking (Human Image Motion Compensation)

A sequential series of studies were conducted to assess human tracking capability with very simple aiding under worst case conditions to determine the amount of error compensation that a man could provide. Continuous tracking v as the basically non-regenerative tracking by the operator in which he was required continuously to arrest image motion. The man was required to continuously compensate for velocity error $\sim$ (250 feet-per-second resultant in most cases) along both directions in the simulation. The strategy of research was to find out what his basic capability was, without an attempt to immediately optimize sophisticated aiding schemes to attain more precision. Discrete tracking consists of pointing to the target and indicating superposition of the crosshair with the target on a periodic basis, with appropriate signals to the computational system. This digital approach to tracking requires a special filter computation to generate the image motion compensation.

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3.1.1.1 Continuous Tracking

The continuous tracking study proceeded in four major sequential steps, or study phases. Both IBM and Air Force personnel contributed to the results obtained in the first three phases.

Continuous tracking in the first phase was performed with ranges of magnification from 18X to 53X, and error functions typical of a 1-percent velocity error in along track and cross track directions. This study included blocks to test for the effects of training. Results indicated that both Air Force and IBM personnel trained to their ultimate tracking performance with a small number of trials. The first simulation produced results which subsequently proved to be limited by the particular hand control device that was being used, although the 0.2-percent performance criterion was achieved some of the time. Refinements in gain, torque characteristcs, and incorporation of a fingertip control were used for a subsequent series of studies.

The second study phase was concerned with the size of the reference error function, and magnification ranging from 18X to 53X, for the continuous tracking tasks. The data obtained indicate that the personnel could achieve the 0.2-percent performance criterion a significant portion of the time and, in fact, for a fraction of the time could achieve considerably better performance. It was also concluded that the size of the error function or amount of aiding has a significant bearing on resolution.

A third study phase assessed human tracking capability on unaided orbital rate error continuous tracking. In this study, no aiding was given to the man in tracking the target, It was found that the subjects could recover from orbital rate levei errors and could reduce the rate error of a continucus tracking mode to approximately 1.6 percent rms.

A fourth major portion of the continuous tracking simulation program was the detailed determination of image motion compensation (IMC) capability under conditions of refined inherent resolution and higher magnifications. These studies were undertaken when it became apparent that man's performance might be limited by the basic nature of this simulation in these ranges, rather than by any inherent human limit. Studies were performed with the 36X, 54X, and 106X magnifications against basic photographic materials that had an inherent resolution of 2.3 feet when measured by standard techniques. This improvement in the inherent capability of the simulator produced dramatic changes in the results.

3.1.1.1.1 <u>Results</u> - Figures 3-5 and 3-6 show the comparative results of
the two major simulation programs on continuous tracking with the various
levels of improvement of the simulation equipment. These data represent
2,880 data points for four highly trained Air Force/IBM personnel. The
results show that human continuous tracking performance limits (with aid-
ing) have not yet been established. Human performance during the sim-
ulated conditions of 2.75 arc sec/sec can be achieved almost half of the
time within ± 15 degrees from nadir local vertical. Thus, man can meet
the performance criterion, with simple rate aiding, in a continuous
tracking mode virtually all the time when the standard is set at the 0.2-
percent IMC contractual criterion. With minor improvements in aiding,
the crew member should be able to increase precision in IMC to at least
the 0.05-percent (2.75 seconds) level on an rms basis. Simulation data
are still required, however, to determine the absolute limit for a trained
subject for this very basic human tracking function.

Studies are currently in progress to develop simple closed loop regenera-
tive analog systems. Several loop closing techniques are being evaluated,
and gain scaling is being performed.

3.1.1.2 Discrete Tracking

The discrete tracking studies also went through several iterations reflect-
ing increased precision in the hand control channels and simulation cali-
bration. Figure 3-7 shows the results of the discrete mode tracking
studies for highly trained IBM observers. These data show that human
performance approaches the position measurement accuracy of the simu-
lation device and that discrete pointing accuracy numbers are well within
those required by typical digital filter systems to achieve 0.2-percent
IMC or better. For example, Figure 3-8 shows the plot of such data
(assuming perfect instrumentation) when run through a typical Kalman
filter, indicating that 15 seconds pointing accuracy can be used to produce
0.02 percent IMC for approximately 20 seconds after the last fix.

The discrete pointing data, summarized briefly here, validates the use of
human precision pointing and an appropriate filter to provide the IMC.
Such a digital computation scheme has merit for multiple target applica-
tions where sighting on one target might be preliminary to tracking a
second target.

3.1.2 <u>Acquisition of Typical Ground Targets</u>

Studies were performed to assess the influence of time pressures and
angles of obliquity on acquisition time for typical targets such as air
fields, and industrial sites. The study was oriented to the determination
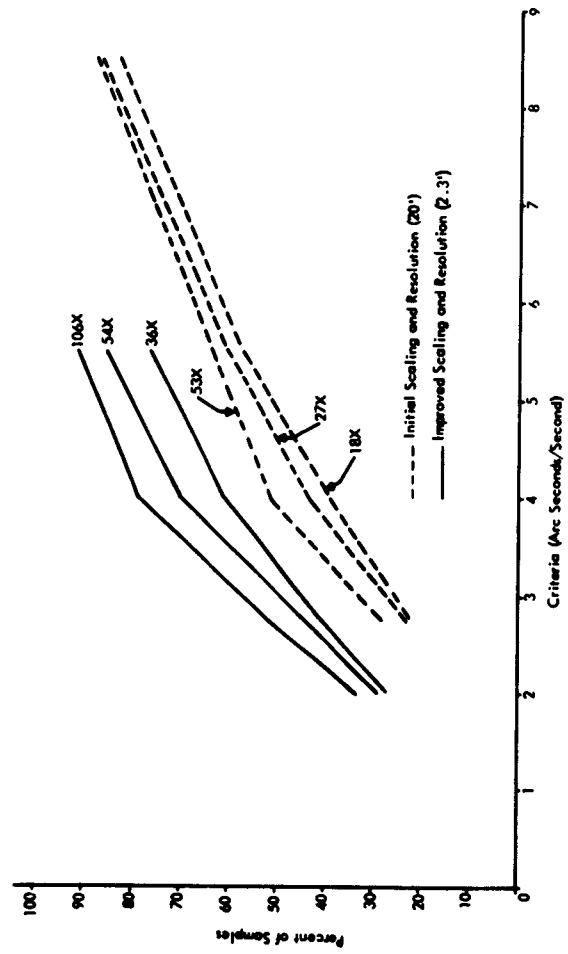
Figure 3-3. Summary of Continuous Tracking Error Distribution

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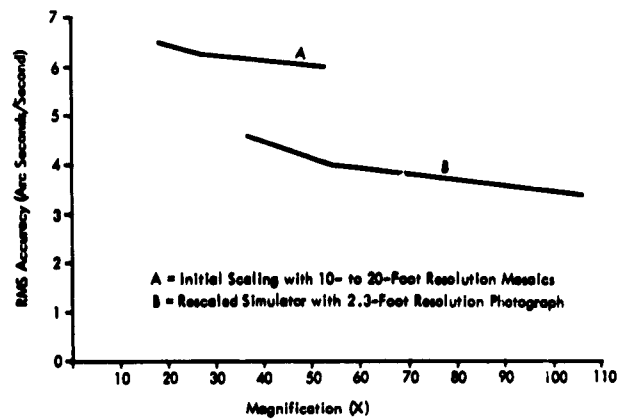
Figure 3-6. Summary of Continuous Tracking RMS Accuracy
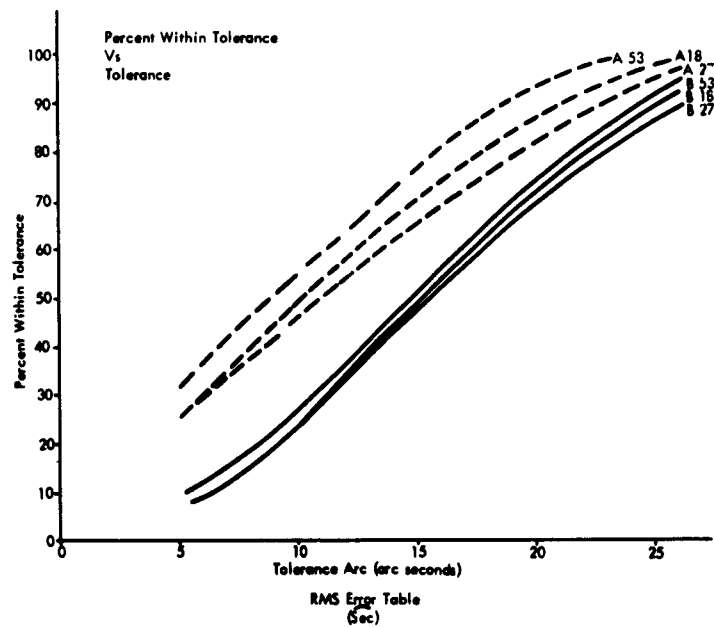
Figure 3-7. Discrete Tracking Performance

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Notes: (1) First Fix 180° after Update
(2) 16° Fix Error = 15 Arc Seconds
(3) Fix Errors Assumed Uncorrelated
(4) Initial Update Errors — 300 Feet,
2 Feet/Second

8 Observations , 3 Seconds Apart

5 Observations, 5 Seconds Apart

Last Fix

Time From First Fix (Seconds)

Percent IMC
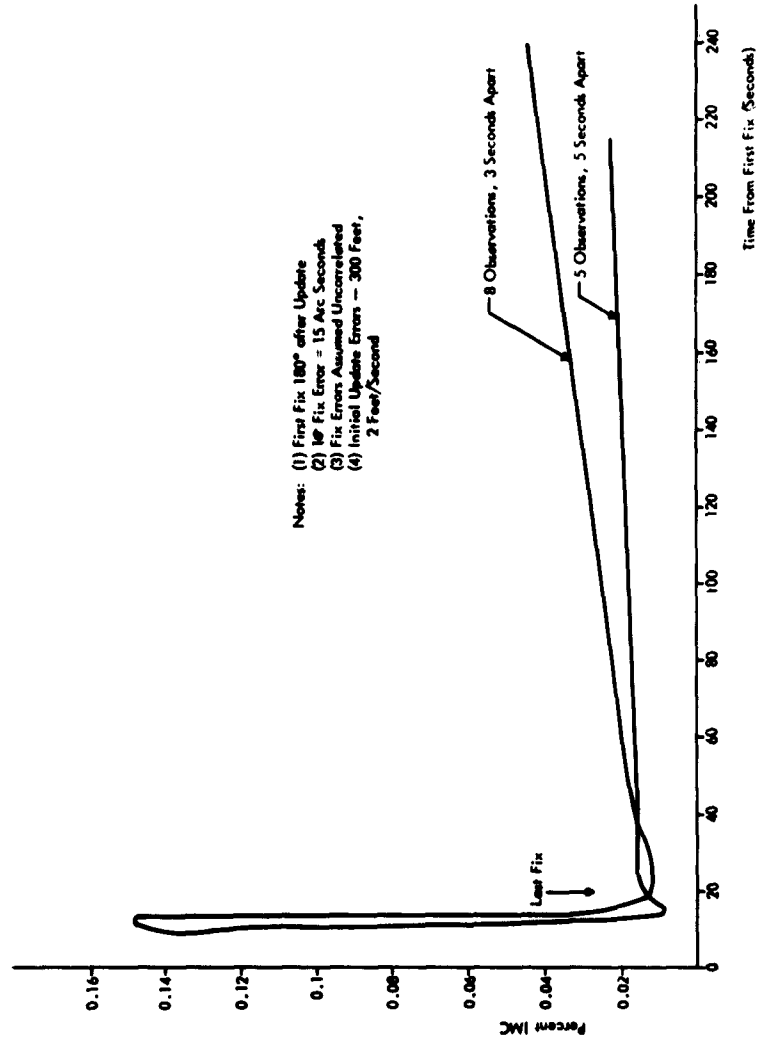
Figure 3-8. Variation of IMC for Discrete Fixing

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if the astronaut could acquire a target in sufficient time to allow precision tracking. Parametric studies involving four different magnifications, different levels of haze, and different target types, were conducted. The results of these studies are summarized in Figures 3-9 and 3-10. The figures show that, for virtually all conditions, the acquisition presented no significant problem to the observers from 45 degrees into nadir, allowing the desired 15 degrees for line of-sight motion correction. The studies for more obscure targets such as missile sites are continuing in this area.

Bench simulations were performed to determine an effective means of presenting briefing data to the eyepiece. Four means of data presentation were tested, using both monocular and binocular techniques. The results summarized in Table 3-1 show that a binocular side-by-side approach, if adjusted to the particular astronaut, will suffice.

Table 3-1
BRIEFING MODES STUDY

Mode Of Presentation	Limitations Of Briefing Material	Advantages	Disadvantages
Binocular Side-By-Side Psychological Mixing	No Limitations	No Interference With Sensor Display	None
Monocular Side-By-Side Optical Mixing	No Limitations	Stable Field	Must Use Very Wide Angle Eyepiece
Binocular Superposed Psychological Mixing	Lines On Opaque Background With Obvious Border	Minimal Physical Interference With Sensor Display	Drift Of Image May Occur Suppression Of One Image Is Possible, Particularly During Periods Of Fatigue
Monocular Superposed Optical Mixing	Lines On Opaque Background	Briefing Material Could Be Used For Some Reticle Functions	None

Trade-Off Table   ● All Modes Feasible   ● Binocular Approach Most Flexible

3.1.3 <u>Significance of Acquisition and Tracking Results for Ground Targets</u>
The following conclusions resulted from the extensive series of studies on continuous ground tracking, discrete tracking, and ground target acquisition:

● No limit has yet been conclusively determined for the human ability to perform image motion compensation in a relatively unaided continuous tracking mode. Successive improvements in simulation have resulted in demonstrations of increased human effectiveness for this task. Currently, the human is providing rms performance which is competitive with the state-of-the-art in servo system design for large scanning elements.

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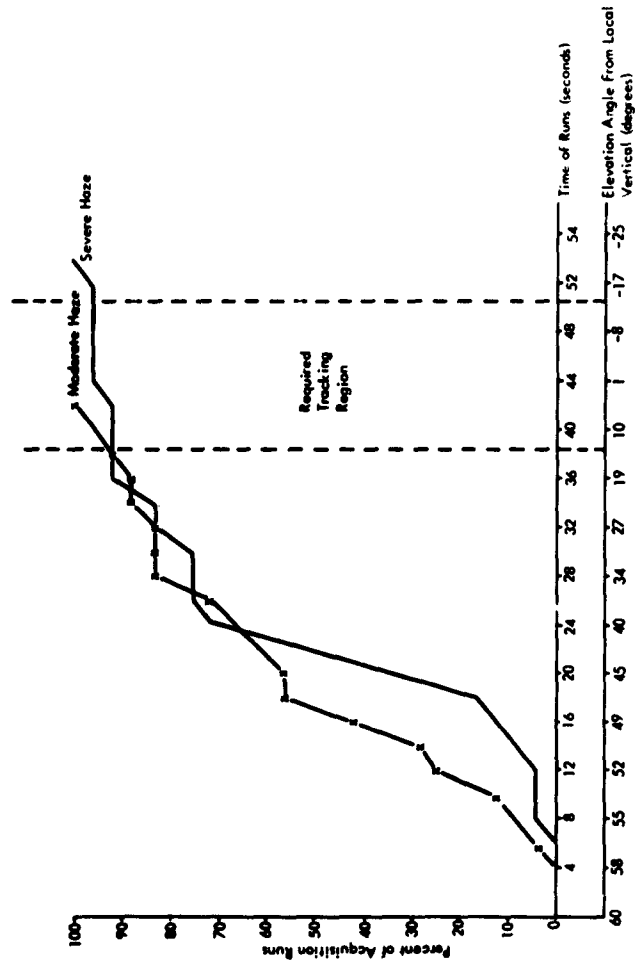
Figure 3-9. Cumulative Frequency for 100 n mi Altitude Target Acquisition
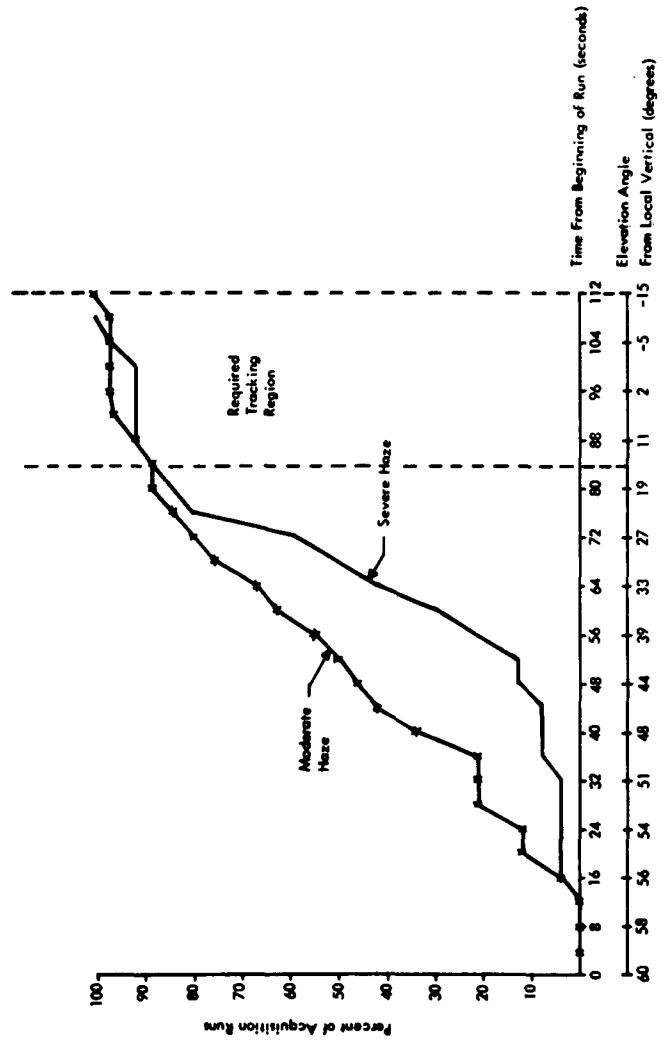
Figure 3-10. Cumulative Frequency Distribution for 200 n mi Altitude

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- The human can adequately perform all tasks necessary for target acquisition during Experiment P-1.
- Man requires aiding to the extent of a simple rate aiding to 99 percent, which he can have through standard analog pre-scaled instrumentation. The very simple aiding given him during the continuous tracking studies indicates that some computational assistance is necessary; but, perhaps, not to the degree of sophistication previously anticipated.
- The man has adequate time to acquire briefed targets and to reduce the uncompensated image motion before passing through nadir.

The design criteria for the in-space experimental subsystem, based on the simulation results to date, are as follows:

- A magnification of 18X through 100 + X for tracking
- A field-of-view from 0.45 to 2 degrees
- A telescope "zoom" to encompass extreme ranges: Magnification appears warranted, on the basis of continual IMC improvement, at the 100X, or better, level. (If the 0.2-percent criterion is used, zoom may not be warranted because the magnification at which effective acquisition takes place (13X to 18X) is quite close to the magnification required for tracking to meet the criterion (28X); thus, simple switching of magnifications might be more appropriate.)
- Acquisition capability in the region of 45 degrees from local vertical is desirable; 30 degrees is necessary.

Future studies are required to determine the exact parameters of the data indicated by these elemental simulations. For example, continual studies are needed to determine the nature and the reasons for this high precision capability of the human. Also, the nature of all the errors possible and their frequency components need more exact simulation to determine if this tracking performance exists in the presence of all possible disturbances.

3.2 Target of Opportunity Studies (P-3)

The target of opportunity studies were fourfold, consisting of analytic and simulation studies to determine major elements of the aided and unaided scanning to acquire targets whose geographical position is not precisely known.

IBM conducted an analytic program in which the details and parameters of various scan modes (boustrophedon, spiral, etc.) were evaluated, and

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the major parameters and programs required to implement them in the space vehicle were derived. The details are contained in Volume III.

Originally, rate-of-motion was thought to be a key determinant of the amount of coverage to be achieved by scan pattern. This was indicated by several sources in the literature. An initial elemental simulation used film strips to determine the effect of rate-of-motion on human acquisition performance for a graduated series of targets (airfields). This study showed that familiarity with airfields, and target variables, were of considerably more influence on unaided scanning acquisition than were the rates. No difference was shown for image motion rates of 4 through 16 degrees per second. Table 3-2 shows the data summarized for various Air Force and IBM personnel.

Table 3-2

UNAIDED SCANNING RESULTS BY AIRPORT SIZE

Rank	Film Position	Size × Width	Probability of Seeing (percent)		
			6X 14 degrees/sec	4X 10 degrees/sec	2.5 6 degrees/sec
1	16	50	100	100	96
2	11	49	100	96	92
3	6	11 to 55	96	100	93
4	5	33	4		
5	2	30	100	100	100
6	10	18	4		4
7	17	16	74	92	78
8	7	12	26	52	22
9	8	10.5	44	48	15
10	4	8	7	7	
11	12	6.6	11	11	15
12	1	3.9			
13	9	3.8	7	4	
14	15	2.9	11		
15	15	2.1	41	41	19
Data From All Subjects					

An analytic computer program was developed during this study to allow fast time assessment of various target-of-opportunity procedures, based on information available in the literature. and on some of the results of the simulation program. This computer program was not developed in sufficient time to allow detailed testing of alternatives, but does provide a model of the process available for subsequent studies.

The various scan patterns described analytically, with rates typical of a previously assumed limit (8 degrees/second) were implemented on the earth-sighting simulator. These scan patterns were demonstrated for acquisition of various targets, principally airfields. Although a parametric study was not run, subjective comments indicated that the 8 degree-per-second rate was indeed too low. This substantiated the results of the unaided study.

The conclusions to be obtained from the four elements of the target of opportunity study are as follows:

- Scan pattern programs are capable of being implemented in the spacecraft, which can accommodate a variable rate as one of the conditions of scanning.

- A particular rate seems appropriate for a particular target type in scanning. Further study is needed to define exactly which rates are appropriate for the ocean classes of targets since mosaic materials are not available to support such a study. (On the basis of the scan study of limited scope, rates from 0 to 16 degrees-per-second are appropriate.)

- There appeared to be no problems in human acquisition of the target of opportunity studied in these simulations. Obviously, if magnification, resolution, and scan rate, are interrelated for the aided acquisition task, the final determination of all of these factors may have to be performed in space where adequate representation of target type viewing conditions are appropriate.

3.3 Acquisition and Tracking of Space Targets

Elemental simulations for acquisition and tracking of space targets were designed to provide information concerning human capability for the space-to-space problem. Two basic simulations were performed: (1) a space acquisition study to determine rate detection threshold; and (2) an acquisition and tracking study to validate lock-on capability, and to measure man's tracking performance under high rate errors (1.6 degrees/second, maximum) and worst-case closing conditions.

3.3.1 Space Target Acquisition

For the first study, an optical simulation of a starfield was combined with a cathode-ray-tube simulation of target rates to assess rate detection thresholds for typical magnifications (6X, 12X, and 24X). Various apparent rates were produced at the eyepiece by the manipulation of closing geometry with low acceleration. The experimental results for this acquisition study are given by Figure 3-11, which shows an example of the 90-degree, 5-n-mi-closest-approach problem.

TASK 1 — SPACE TARGET ACQUISITION
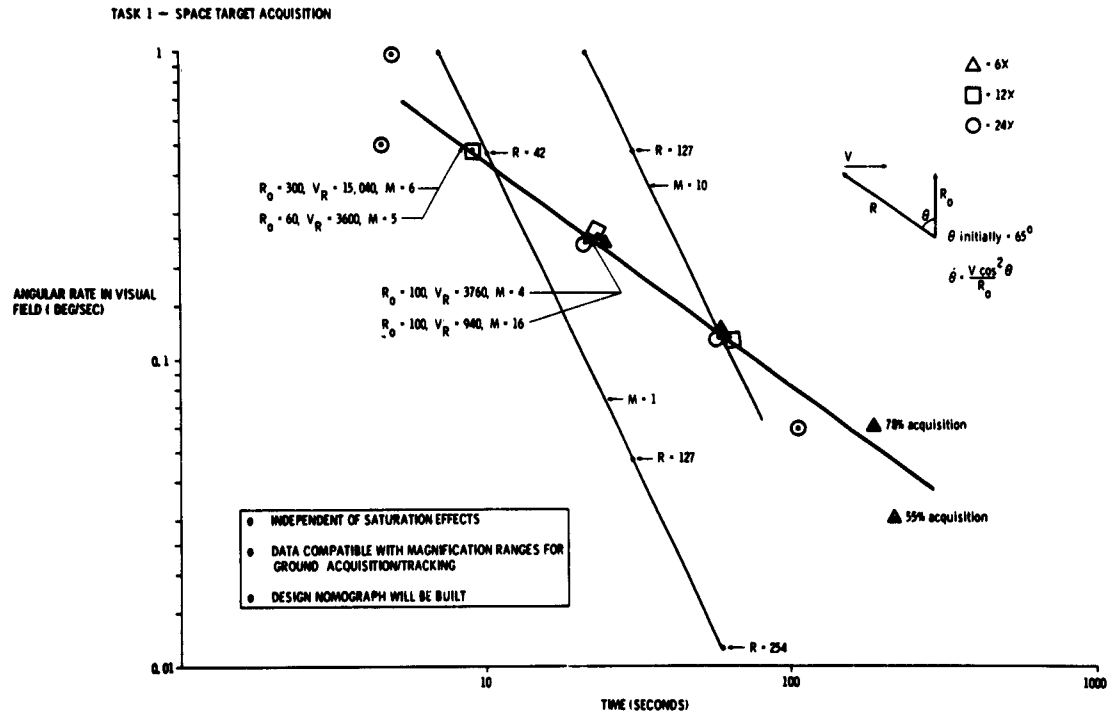
Figure 3-11. Space Target Acquisition

Esentially, this acquisition study demonstrated that the time to determine which of the objects was moving against a stationary background was a direct function of the angular rate, and was relatively uninfluenced by the level of magnification. Also, a direct relationship between the standard deviations of time and the rate was shown. These data are shown in Figure 3-12. On the basis of regular function shown in the figure, a design technique can be established by applying these linear data to typical closing geometries.

The magnification required for this acquisition task (in the range of 6X to 24X) should basically be determined by the error volume anticipated at the initial moments of the problem. The design process should include this error volume as an initial condition; and then pick an appropriate magnification such that the time-to-acquire allows a reasonable

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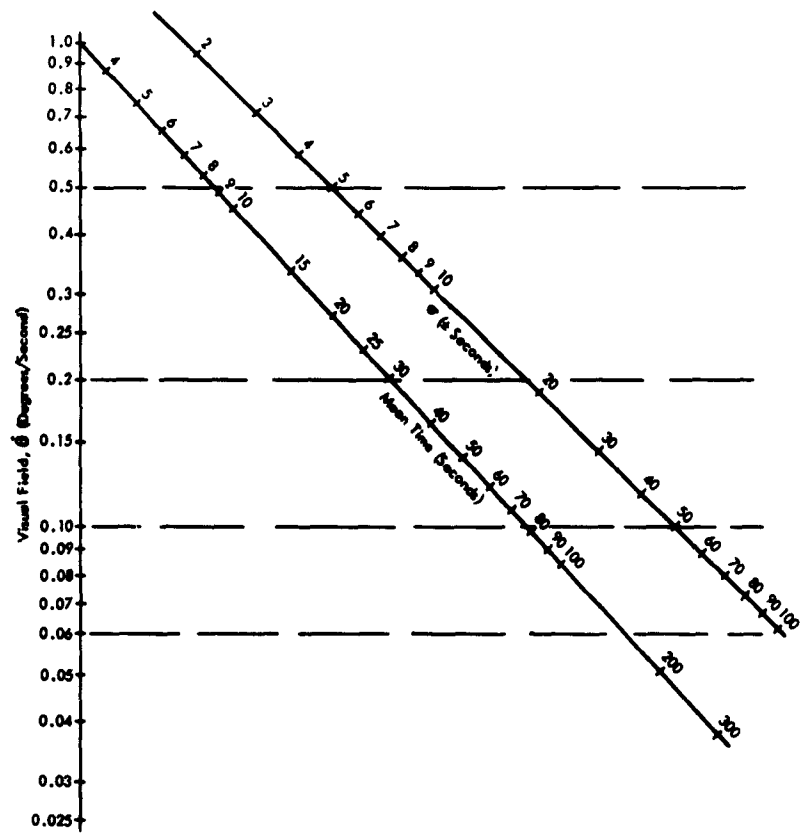
Figure 3-12. Graphical Solution for Mean Time and σ

time-to-track after the acquisition has taken place. The data on time-to-track were produced from the second study in this series. The data for rate threshold detection in typical star-field backgrounds and encounter geometries indicate that the human should have little difficulty in acquiring space targets having greater than threshold visibility. This conclusion applies to typical encounter situations.

3.3.2 Tracking of Space Targets

IBM performed a study to determine the effects of various magnifications, tracking-loop aiding techniques, and tracking modes (discrete or continuous) on the IMC for satellite targets. For this study the "worst case" condition was typical of an encounter with relative velocities of 15,000 feet per second, with a closest approach of 20 n mi and initial acquisition of approximately 115 n mi. Maximum reference errors of 1.6 degrees per second were present. These errors represent a 4-n-mi error in range.

Magnifications of 12X, 30X and 100X were used with damped and undamped control loops, and continuous and discrete modes. The discrete mode differed from the continuous mode in that, for the discrete mode, data were sampled only when the operator felt performance was good. For this study, a closed-circuit television representation of the total encounter process was fabricated and used. The simulation used is shown in Figure 3-13. For typical cosine-cubed error functions, it was found that the subject's performance improved as a function of magnification, and as a function of the amount of aiding. Figure 3-14 shows the results of these simulations. As chown in the figure, the performance for both discrete and continuous tracking improves as a function of increased magnification and aiding. This study concludes that:

- Performance in reducing rate and positional errors improves as magnification increases between the range of 12X and 100X.
- Discrete tracking mode was clearly superior to continuous tracking for both conditions of aiding.
- Increased aiding by closed-loop damping allowed the subject to achieve near-criterion performance (0.2-percent IMC).
- Refined studies of aiding concepts, and more complete and higher fidelity simulations of star backgrounds are projected to allow the stipulated tracking performance. As with the ground tracking data, magnifications up to 100X were found desirable; and, again, the limit has not yet been determined for the human tracking capability with maximum aiding.
- Specification of error sources and encounter constraints greatly influence design and performance.

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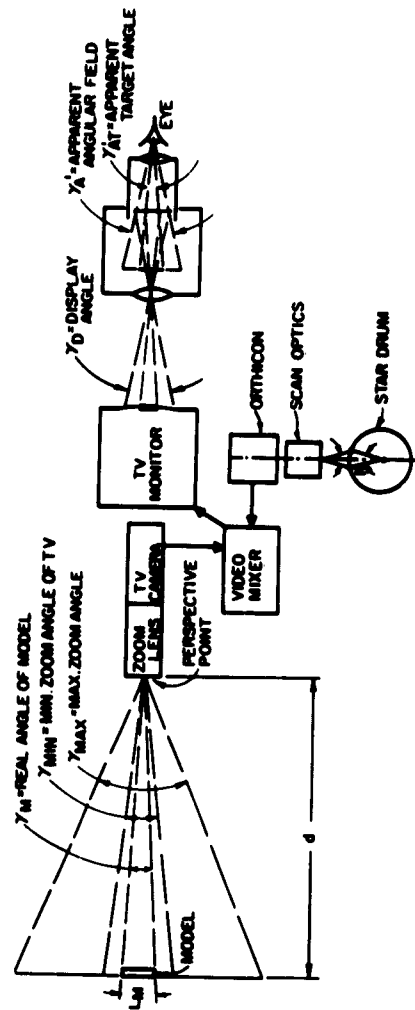
Figure 3-13. Space Acquisition and Tracking Simulator
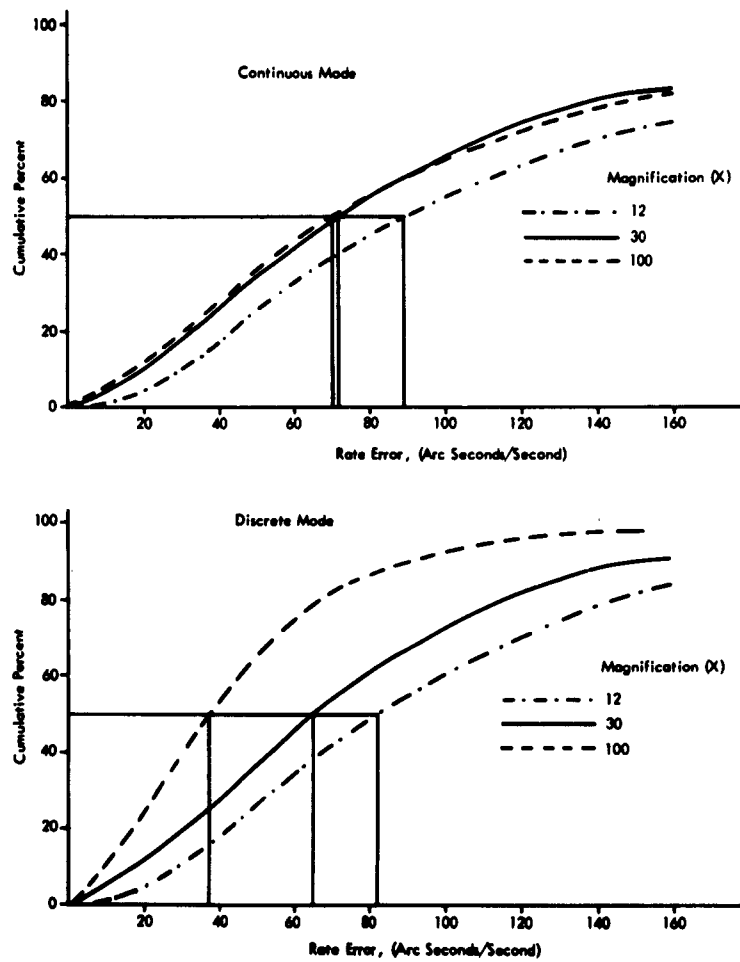
Figure 3-14. Space Tracking Performance Summary

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3.3.3 Significance of Simulations for P-2 Experiments

The two simulation studies of elements of the space target acquisition and tracking study have demonstrated that the man can perform all of the tasks required in the experiment, with certain qualifications.

The acquisition study demonstrated unaided target motion detection; indicated a highly predictable function, and a very low threshold for human motion detection when no other clues are present. This means that for those conditions studied, the subject can acquire space targets if the magnification is chosen to bring the rate above threshold values.

The tracking studies indicated that the man's performance improved with system aiding, when large errors were present; and could achieve the desired performance with a simple closed-loop damping system. Further study is required, however, to define the exact nature and optimization for this aiding to achieve total desirable performance. System design criteria resulting from the space target acquisition and tracking studies are:

- Magnifications from 6X to 100X
- Real field of view at low magnifications to be chosen commensurate with error volumes (25 to 30 degrees)
- Analog or digital aiding will aid in arresting image motion for the space tracking task, and further study is warranted to develop the aiding concept.

4.0 Subsystem Design and Integration

This section presents the salient features of the parametric and tradeoff analyses that are used as the basis for selecting a technical approach. The recommended configuration is then discussed in functional and physical terms, and the interface requirements are summarized.

4.1 Design Criteria

The design criteria presented immediately below combine the performance requirements (Volume III, Section 3) with the results of the elemental simulations (Volume II) and experiment definition (Volume IV).
The portions of the IVSS specifically addressed here are:

    (1) Optical System Synthesis

    (2) Servo-Computer Modes of Operation

    (3) Candidate Servo Systems

    (4) Displays and Controls

The salient criteria that affect the IVSS design are listed in Table 4-1.

Table 4-1

IVSS DESIGN CRITERIA

Design Parameter	Design Criteria	Source
Man's Discrete Pointing Performance	Will center crosshairs over target to within 15 sec. σ 1	ESS Volume II
Man's Tracking Performance	Will track to within 2.75 sec./ sec. more than 50 percent of the time	ESS Volume II
Range of Magnification	Man's performance will improve with magnification up to at least 100X	ESS Volume II
Maximum Field of View	(FOV) $\geq$ 7.5 degrees for acquisition of preassigned ground targets	Section 3.1.1.1
	(FOV) $\geq$ 12 degrees for acquisition of space targets	Section 3.1.2.1
	(FOV) for automatic scan acquisition, compatible with magnification selected for various targets of opportunity (range of magnification 2X to 18X)	Volume III
Optical Requirements	See Table 2-3	Section 2.2 Volume I
Servo Requirements	See Table 2-2	Section 2.2 Volume I
Minimum Photograph Sampling Time	T $\cong$ 2.2/Fp	Section 3.2.1 Volume III
PTS Interior Measurements	6 ft. along longitudinal axis 3 ft. radially 1 ft. thick	USAF SSD

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4.2 Major Trade-Offs and System Selection

The major effort associated with the IVSS equipment design was addressed to the following areas:

- PTS Optical Configuration
- PTS Tracking Servo
- IVSS Modes of Operation and Computational Requirements

The effort associated with the PTS optics was directed towards seeking compromise values of objective aperture and focal length. Section 4.3 of Volume III discusses the evolution of the optical system.

The critical servo parameters depend heavily on the nature of the optical scanning elements. Once these have been selected, it only remains to select the torquing, sensing, and comparator elements and the compensation networks for both the digital and analog instrumentation. Considerable effort was expended on defining the servo interface requirements with the computer. Both digital and analog modes of operation are discussed, along with methods of aiding the operator to achieve the required IMC with certain prediction techniques.

4.2.1 Optical Configuration Studies and Selection

4.2.1.1 Field of View

One of the basic requirements of the optical system is that the field of view must be wide enough to insure that it contains the preselected target. Since the requirement for a wide field of view is diametrically opposed to the other optical requirements, a viewfinder telescope of low power and wide field was incorporated into the optical design. The viewfinder, by having its scanning system synchronized with that of the high-power, narrow-field-of-view telescope, can be used to acquire and center the target on the crosshairs so it will be within the narrow field of view. The viewfinder has a magnification of 1.5X to 9X, 40 degree field of view, and approximately a 2-inch focal length. An auxiliary eyepiece allows one astronaut to use the viewfinder while the other uses the tracking telescope; a retractable mirror permits switching between the viewfinder and the tracking scanner.

4.2.1.2 Objective Aperture and Focal Length

Optical equipment requirements were derived in accordance with Table 2-3, which delineates optical performance requirements in terms of angular resolution and contrast ratio at the periscope.

It is clearly desirable to rephrase these performance requirements in terms of the more convenient optical design parameters "D" (aperture diameter) and "f" (focal length). To this end, curves were calculated

displaying those combinations of D and f values necessary to achieve a specified angular resolution for a specified contrast ratio and a specified amount of image motion (measured in terms of arc seconds per second).

The mathematical method used, as well as a large number of D versus f curves and a discussion of their general appearance, can be found in Volume III, Section 3.2.1. Figures 4-1 through 4-3 show D versus f functions. Figure 4-1 is a graph of the transfer functions of the two lenses considered (lens I should be thought of as an upper limit in lens manufacture, while lens II appears to be well within present state-of-the-art). A high-resolution film (SO 243) was used for the calculations.

According to Table 2-3, the P-1 experiment performance requirements demand an angular resolution between 1.2 and 3 arc sec at a contrast ratio of 1.6 : 1 at the periscope's objective. Hence, it is reasonable to demand values for D and f that would lead to a resolution of 3 arc sec when lens II is assumed, and 2.2 arc sec (i. e., about midway between 1.2 and 3 arc sec) for a lens design better than lens II but not as perfect as lens I. Furthermore, the 2.2 arc sec resolution almost satisfies the first part of the P-3 and the post-tracking evaluation requirements. From Figure 4-2, it then follows that D = 7 to 8 inches, and f = 32 to 40 inches are sensible choices for fulfilling P-1 and the first part of P-3.
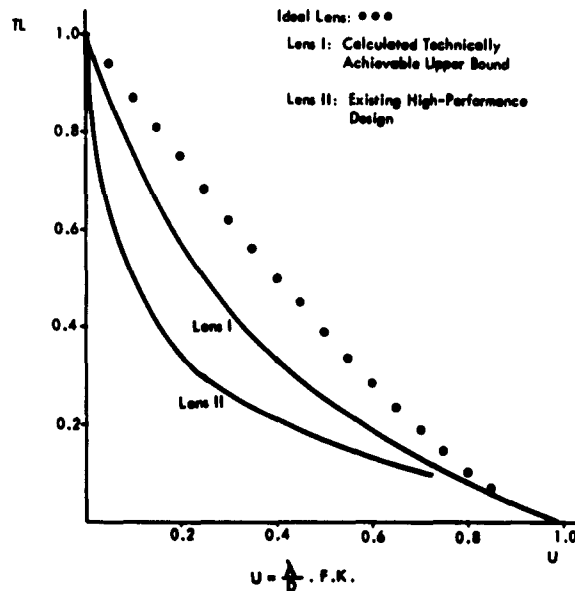
Figure 4-1. Lens Transfer Functions
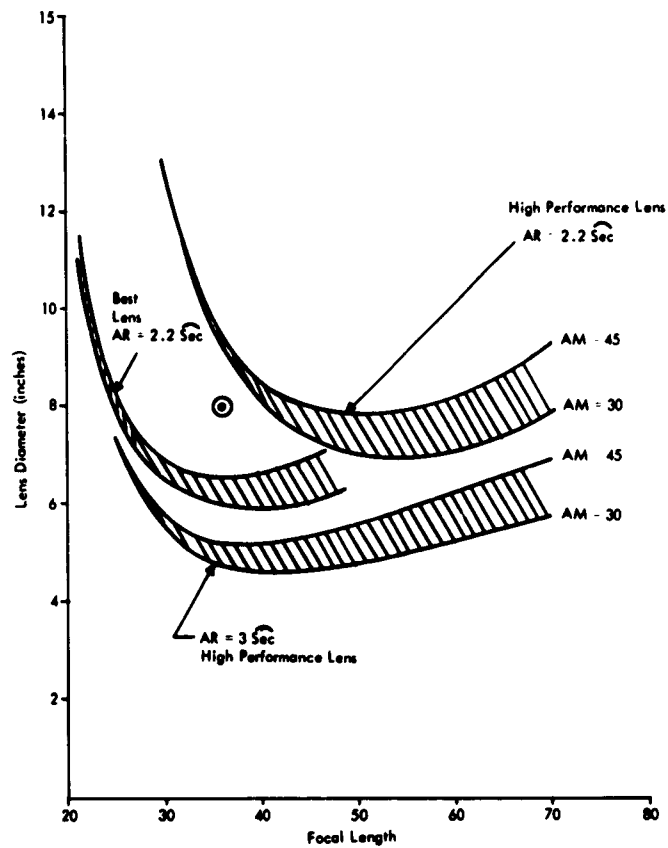
Figure 4-2. P-1 Photo Optical Trade-Off

The reason for not attempting to satisfy the lower limit of 1.2 arc sec resolution at a contrast ratio of 1.6 : 1 lies in the excessive values of D and f that would be required and the consequent penalties imposed on the system (see Figure 4-2).

The same can be said for fulfilling the second part of the P-3 (i.e., the warship classification), which requires 1 arc sec resolution at a 4:1 contrast ratio from 160 n mi altitude. Referring to Figure 4-3, this would lead to values of D = 12 to 14 inches, and f = 45 to 60 inches.

Table 4-2 and Figure 4-4 contain the physical trade-off data associated with various PTS aperture diameters. It is readily seen that the selection of the 7 to 8-inch aperture is a reasonable choice. The optical system needed for warship classification is significantly heavier (by 200 pounds) than the 7 to 8-inch aperture system. Also, the number of designing, manufacturing, and testing problems associated with the

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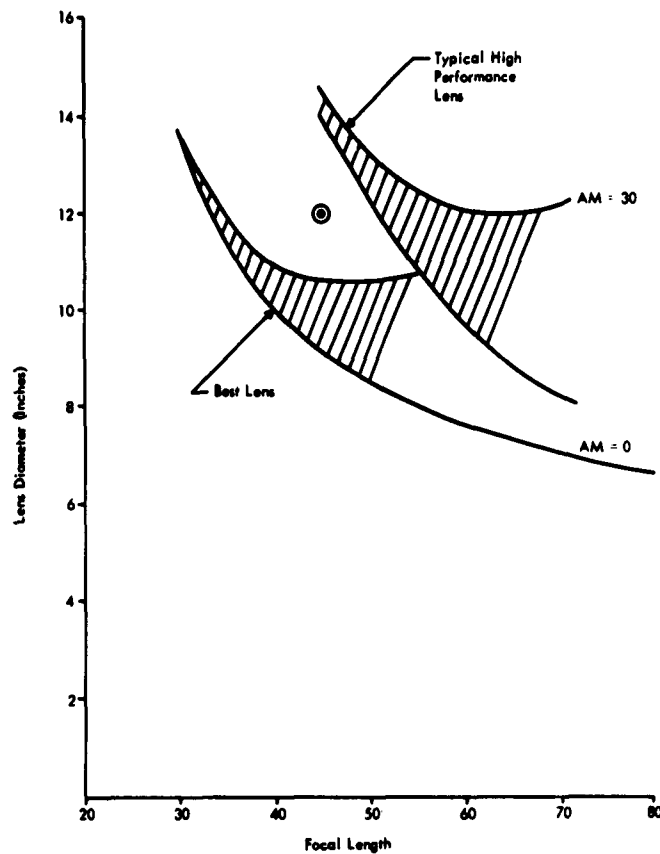
Figure 4-3. High Resolution P-3 Photo Optical Trade-Off

heavier design is increased. For these reasons, it is not recommended
that this design be used for the IVSS experiments.

4.2.1.3 Recording Camera Considerations

Recording cameras, needed to provide "hard copy" data for measuring
drift rates and man's contribution to image motion compensation, are to
be placed in the focal plane of the primary optics of both the viewfinder
and the tracking scope. This scheme provides a continuous record of
both acquisition and tracking to aid in analyzing the results, and it entails
minimum degradation of the high-resolution image. Figure 4-5 graph-
ically illustrates the P-1 design equation $FT_p = 2.2$.

The time (T) between the photographs used to measure drift rates be-
comes T = 1.5 to 10 seconds for a 36-inch focal length and p = 0.04 to
0.006 percent. A choice of T of about 5 seconds thus appears reasonable.
This T also sets minimum requirements on the servo loop accuracy.

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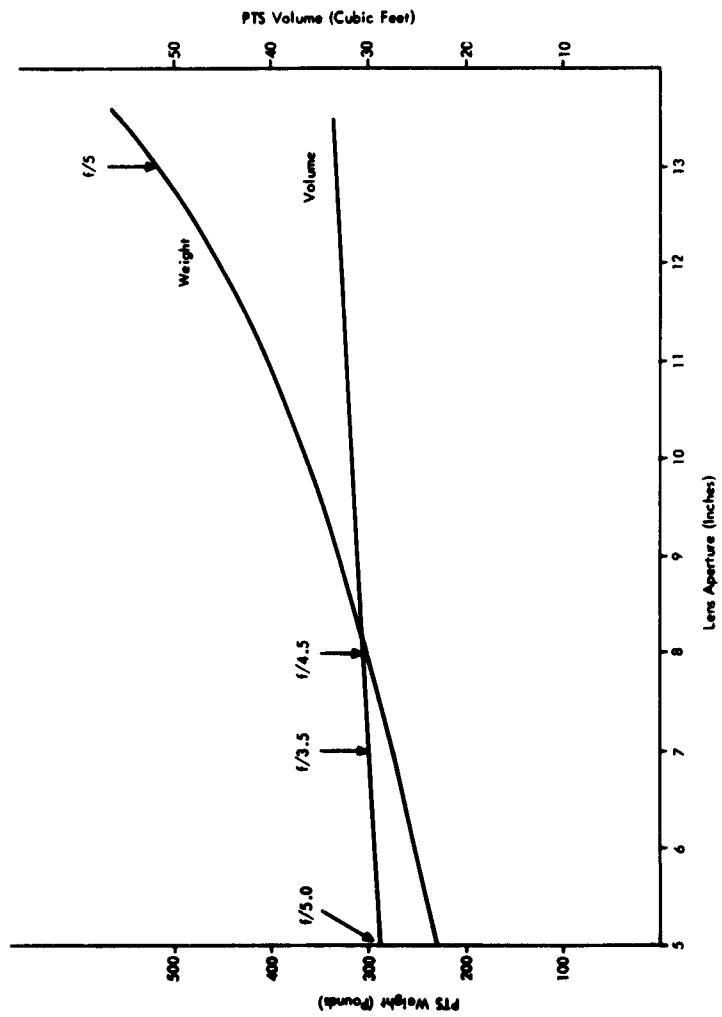
Figure 4-4. PTS Weight Volume vs Lens Aperture
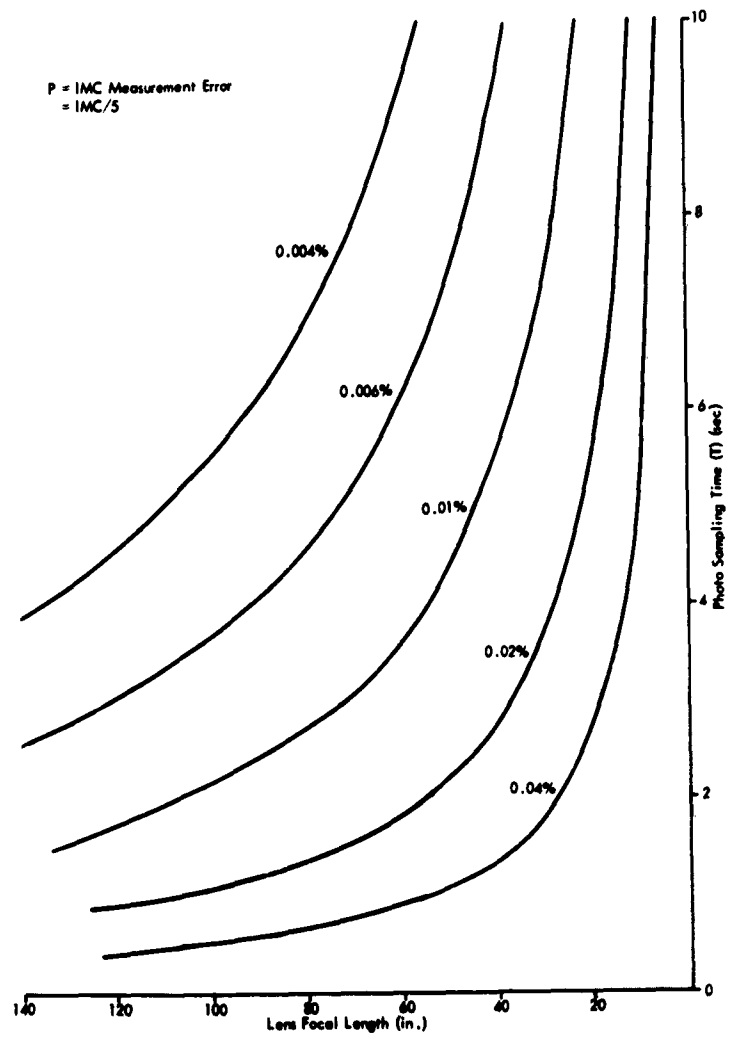
Figure 4-5. Focal Length vs Photograph Sampling Time
for Various IMC Measurement Errors

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Table 4-2

PTS PHYSICAL PROPERTIES

Part		Weight (lbs.) Aperture (in.)				Volume (cu. ft.) Aperture (in.)			
		5	7	8	13	5	7	8	13
Telescope	Internal	51	51	51	51	10	10	10	10
	External	14	14	14	14	10-3/4	10-3/4	10-3/4	10-3/4
Objective		10	25	50	175	3/4	1-3/4	2-1/4	3-1/4
Scanners	Wide Field	20	20	20	20	3/4	3/4	3/4	3/4
	Large Aperture	50	70	85	150	3/4	1	1-1/4	2-1/4
Auxiliary Eyepiece		5	5	5	5	1/4	1/4	1/4	1/4
Base Plate		87	87	87	100	6	6	6	6
	Totals	237	272	312	515	29-1/4	30	31-1/4	33-1/4

4.2.2 PTS Tracking Servo

4.2.2.1 Scanning Elements

The choice of the scanning elements for the pointing and tracking scope becomes primarily a weight trade-off. This is shown in Figure 4-6, which gives the weight of four different scanner elements as a function of field angle for a 7-inch aperture. A two-mirror system employing a "pitch within roll" gimballing was selected primarily on the basis of weight, since the optical qualities of the mirrors and prisms are essentially the same.

4.2.2.2 Servo Studies

Several servo configurations were investigated during the study; a digital computer with position and rate servos, and an analog computer with different rate servo loops were among those defined. Table 4-3 gives the pertinent physical characteri_tics of some of the more promising configurations. The pitch servo is listed because it requires higher velocities and accelerations than the roll servo. The roll servo is functionally identical.

The high torque, high resolution, and frequency response called out in Table 4-3 for the IVSS experiments dictated the selection of a direct drive d-c servo for the scanner elements. The insensitivity of tachometers to the low servo shaft speeds expected makes their use impractical. Furthermore, to satisfy the sensitivity requirements, the tachometer would be heavy and costly. Therefore, a compensation network is recommended for stabilizing the candidate servo loop.

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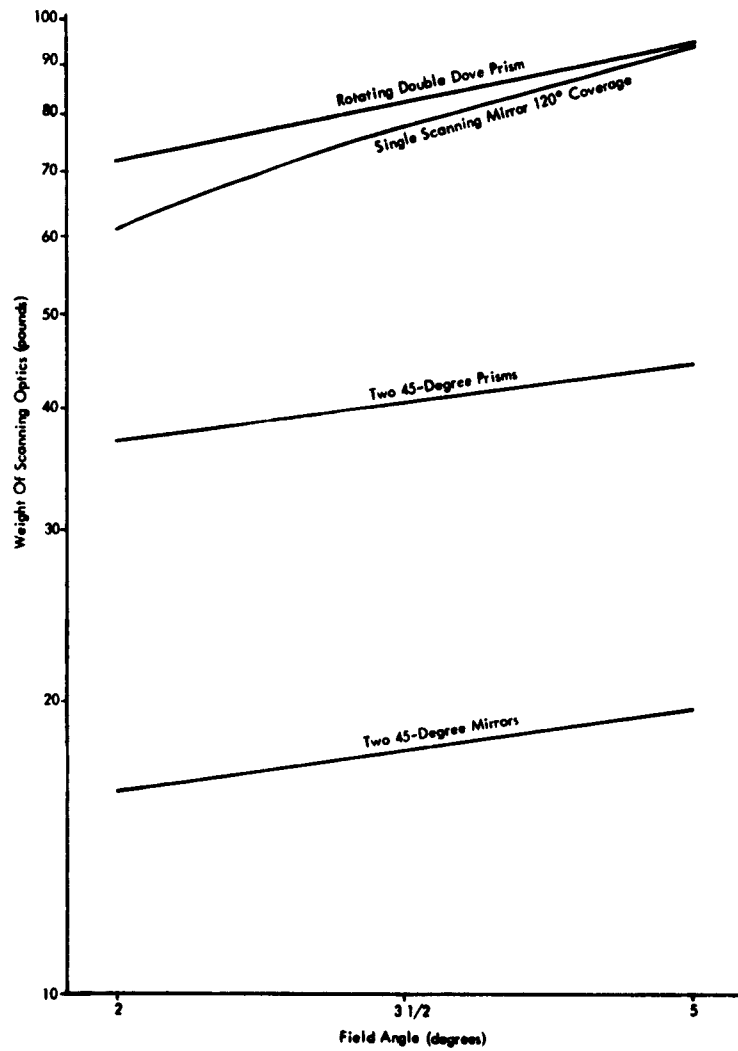
Figure 4-6. Weight of Scanning Optics

Table 4-3

SERVO TRADE-OFF DATA SUMMARY

Type	Computer	Sensor	Comparator	Weight (lbs)*	Volume (in. ^{3})*
1	Digital	Digital Encoder	Frequency	18	561
2	Digital	Digital Encoder	Digital	18	526
3	Analog	Digital Encoder	Frequency	19	591
4	Analog	Tachometer	Analog	31	659
4'	Analog	Tachometer	Analog	89	1,174

* Does not include scanning mirror weight and volume.

Type 4 is a degraded mode of operation (associated IMC > 0.2 percent). If a tachometer is employed and the requirements are to be met, 4' are the estimated trade-off parameters.

Power was not a significant parameter in the trade-off analysis since average power for all servo modes was between 60 and 65 watts.

All of the servo components, including the digital encoders, are well within the state-of-the-art and present no serious design problems. Two servo candidates, types 2 and 3, were selected for both digital and analog instrumentations. These servos are described in Section 4.3.1. The electromechanical components in both candidate servos are identical. Minor electronic additions are required to allow the electromechanical portion to be operated either as a digital or analog servo. This feature will make the pointing and tracking scanning servo system extremely flexible and reliable.

4.2.3 IVSS Modes of Operation

During the course of the study, three candidate modes of operation were investigated:

    (1) <u>Primary Digital Tracking Modes</u>
- Minimum Rate Prediction Techniques
- Extended Rate Prediction Techniques

    (2) <u>Analog Tracking Modes</u>
- No Rate Prediction Techniques
- Minimum Rate Prediction Techniques
- Extended Rate Prediction Techniques

    (3) <u>Extended Capabilities Digital Tracking Mode</u>

4.2.3.1 Primary Digital Tracking Mode

4.2.3.1.1 Minimum Rate Prediction Technique (Figure 4-7) – The goal of the minimum rate prediction scheme was to partially reduce the operator burden from complete generation of the target LOS rate functions to that of a vernier function, and more importantly, to provide at least a short time interval for post-track evaluation to ensure system performance of IMC within desired limits.

Pointing angles for target acquisition are computed using stored vehicle and target state data. Upon acquisition, a rate prediction computation aids the operator in tracking. Generation of this prediction function is also based on the briefing material. The orbital ephemeris is not updated, so, in effect, the operator will have to compensate only for the rate errors that accrue because of inaccuracies in the knowledge of the various sources of pointing and tracking error. The computed LOS rate will be correct only for the target being tracked and only for a short time after the operator relinquishes control.

A detailed discussion of the scheme and a description of a servo-computer configuration to supplement the recommended minimum rate prediction technique are presented in Volume III, Section 4.2, wherein the primary limitation of the mode is shown. This limitation is the requirement for precise alignment between the vehicle's relative velocity vector and the roll gimbal axis. For example, a 0.5 degree misalignment causes the LOS rate error to exceed 0.05 percent of the LOS rate in 2 seconds or less after the operator relinquishes control.

4.2.3.1.2 Extended Rate Prediction Techniques – To date, the extended rate prediction schemes have been assessed to the point of functional equation development. The relative importance of IMC sensitivity to errors in vehicle state parameters has been established and recommendations are made for an IMC prediction filter. The detailed analysis is presented in Volume III, Section 4.2, "Extended Capabilities of the Digital Tracking Mode"; however, the functional requirements for the servo-computer configuration are not complete.

4.2.3.2 Analog Tracking Mode

4.2.3.2.1 No Rate Prediction — The simplest analog tracking mode considered was a rate servo with no prediction capability. This mode of operation requires the operator to constantly insert acceleration pulses to keep up with the changing angular rate of the LOS, so only extremely short open-loop tracking times are available for experiment evaluation purposes. Furthermore, tracking simulations indicated that 0.2 percent

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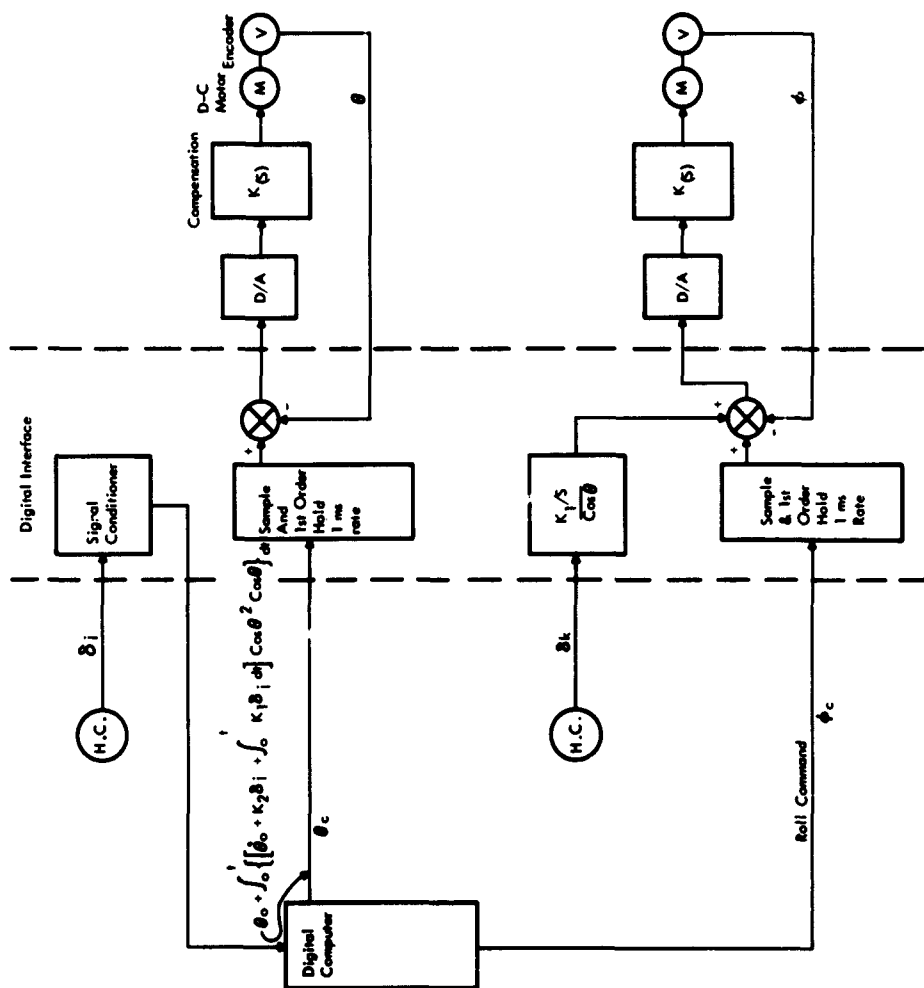
Figure 4-7. Extended Capability Digital
Tracking Servo Computer Mode

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IMC accuracy could not be achieved with this mode. Therefore, this scheme was no longer considered for incorporation into the IVSS.

4.2.3.2.2 Minimum Rate Prediction Techniques (Analog) (Figure 4-8) – The minimum rate prediction scheme is designed to make the most of the short observation time available for post-track evaluation. The rationale of the minimum analog instrumentation is presented in the error analysis of Volume III, Section 3.7. The limitations of this instrumentation parallels the constraint for the minimum digital configuration, i.e., there is a requirement for precise alignment between the vehicle's relative velocity vector and the roll gimbal axis. Both schemes illustrate the desirability of a more sophisticated rate prediction technique to maintain IMC performance in post-track, open-loop operation.

4.2.3.2.3 Extended Rate Prediction Technique (Figure 4-9) – Candidate analog IMC filtering schemes have been based on the relative importance of the IMC sensitivities to vehicle state variables as summarized in Table 4-4. The errors in the angular rates of the LOS relative to the vehicle are functions of the position and velocity errors of the satellite, the attitude and attitude rate errors of the vehicle, and the errors in commanded LOS pitch and roll.

A list of state variables that are tentatively recommended for inclusion in an IMC filtering concept are contained in Table 4-5.

Table 4-5

RECOMMENDED STATE VARIABLES FOR THE IMC FILTER

Roll Rate		Pitch Rate	
Horizontal Cross Velocity	$\dot{Z}$	Altitude	Y
Vehicle Roll Rate	ω_X	Horizontal In-Plane Velocity	$\dot{X}$
Vehicle Yaw Rate	ω_Y	Vehicle Yaw Rate	ω_Y
Vehicle Yaw Attitude	θ_Y	Vehicle Pitch Rate	ω_Z
		Vehicle Pitch Attitude	θ_Z

The states contained in Table 4-5 are not necessarily optimum from an implementation viewpoint. A comprehensive trade-off is necessary prior to final selection of the state variables. These trade-offs consider the difficulty of computational implementation versus the IMC performance limitations imposed by the exclusion of the filter term.

Table 4-4

RELATIVE IMPORTANCE OF IMC SENSITIVITY PARAMETERS

Parameter	1σ Error	Roll Rate Error		Pitch Rate Error	
		Functional Representation	Typical Value** (arc/sec)	Functional Representation	Typical Value** (arc/sec)
X	1350 ft	$-\dfrac{v_r}{\rho^2}\sin\phi\tan\theta\,\delta X_v$	0 (Approx.)	$-\left(\dfrac{v_\phi\cos\theta + v_r\cos\phi\sin\theta}{\rho^2}\right)\sin\theta\,\delta X_v$	1.4*
Y	1800 ft	$-\dfrac{v_r}{\rho^2}\sin\phi\cos\theta\,\delta Y_v$	0 (Approx.)	$-\left(\dfrac{v_\theta\cos\theta + v_r\cos\phi\sin\theta}{\rho^2}\right)\cos\phi\cos\theta\,Y_v$	5.8
Z	1200 ft	$-v_r\dfrac{\sin^2\phi}{\rho^2}$	0 (Approx.)	$-\left(\dfrac{v\theta\cos\theta + v_r\cos\phi\sin\theta}{\rho^2}\right)\sin\phi\cos\theta\,\delta Z_v$	1.0
$\dot{X}$	85 fps	0	0	$\dfrac{-\cos\theta}{\rho}\,\delta\dot{X}_v$	12.8
$\dot{Y}$	85 fps	$\dfrac{\sin\phi}{\rho\cos\theta}\,\delta\dot{Y}_v$	4.2	$+\dfrac{\cos\phi\sin\theta}{\rho}\,\delta\dot{Y}_v$	6.0*
$\dot{Z}$	85 fps	$-\dfrac{\cos\phi}{\rho\cos\theta}\,\delta\dot{Z}_v$	12.8	$\dfrac{\sin\phi\sin\theta}{\rho}\,\delta\dot{Z}_v$	1.7*
θ	± 10 sec	$\left(\dot{\phi}\sin\phi + \dfrac{v\theta}{r}\cos\theta\sin\phi\right)\dfrac{\delta\theta}{\cos\theta}$	0.004	$\left(\dfrac{v\theta}{\rho}\sin\theta - \dfrac{v_r}{\rho}\cos\theta\cos\phi\right)\delta\theta$	0.09*
ϕ	± 10 sec	$\left(\dfrac{v\theta}{r}\sin\theta - \dfrac{v_r}{\rho}\right)\dfrac{\cos\phi}{\cos\theta}\,\delta\phi$	0.006	$\dfrac{v_r}{\rho}\left(\sin\phi\sin\theta - \dfrac{v\theta}{r}\sin\phi\right)\delta\phi$	0.01
ω_x	±36 sec/sec	$-\delta\omega_{x_v}$	36	0	0
ω_y	±36 sec/sec	$\cos\phi\tan\theta\,\delta\omega_{y_v}$	21.6*	$-\sin\theta\,\delta\omega_{y_v}$	10.8
ω_z	±36 sec/sec	$\sin\phi\tan\theta\,\delta\omega_{z_v}$	5.76*	$\cos\theta\,\delta\omega_{z_v}$	35
θ_x	720 sec	$-\dfrac{v_r\cos\phi}{\rho\cos\theta}\,\delta\theta_{x_v}$	0	$\dfrac{v_r}{\rho}\sin\phi\sin\theta\,\delta\theta_{x_v}$	0
θ_y	720 sec	$-\dfrac{v\theta\cos\phi}{\rho\cos\theta}\,\delta\theta_{y_v}$	13.6	$\dfrac{v\theta}{\rho}\sin\phi\sin\theta\,\delta\theta_{y_v}$	1.7*
θ_z	720 sec	$-\dfrac{v\theta\sin\phi}{\rho\cos\theta}\,\delta\theta_{z_v}$	3.6	$\dfrac{1}{\rho}(v_r\cos\theta - v\theta\cos\phi\sin\theta)\,\delta\theta_{z_v}$	5.6*

* Denotes sensitivity. Vanishes monotonically as sighting angle approaches nadir.
** Landmark 60 n mi out of orbital plane. The orbit is taken as circular at a 200 n mi altitude.
   Value is taken to be the maximum for sighting angles below –30° degrees.
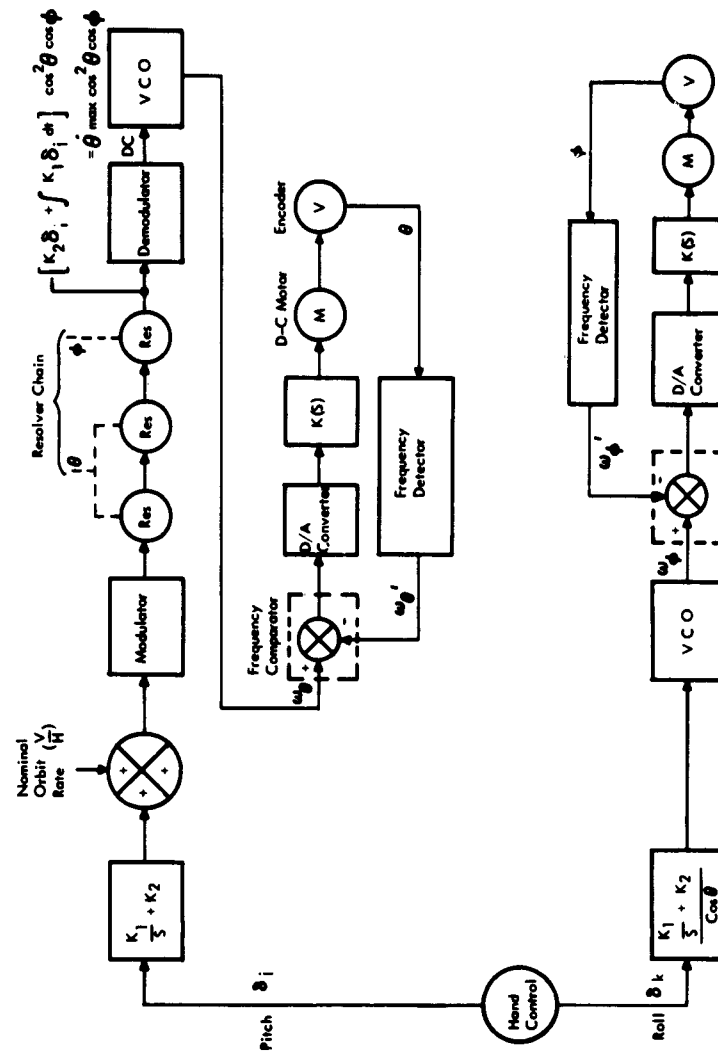
Figure 4-8. Analog Tracking Servo Computer Mode
with Minimum Rate Prediction

An example of the form of regenerative error function computation that might be implemented to extend the time of post-track evaluation is developed in Volume III, Section 4. 2. 2. This mode of operation would provide the flexibility needed to vary the gains of the error functions used in orbit. The significance of this capability in assessing the nature of the error in the system is discussed in Volume III, Section 4. 2. 2.

4. 2. 3. 3 Extended Capability for Digital Tracking Mode

The detailed capabilities of the extended digital mode are presented in Volume III, Section 4. 2. 3. The major innovation is that the vehicle orbit ephemeris is updated (for tracking multiple ground targets) by processing tracking data using a Kalman filtering procedure and a precise attitude reference.

4. 2. 3. 4 Selection of Modes of Operation

Two modes of operation are recommended for inclusion in the IVSS:

- Primary Digital Mode
- Analog Mode
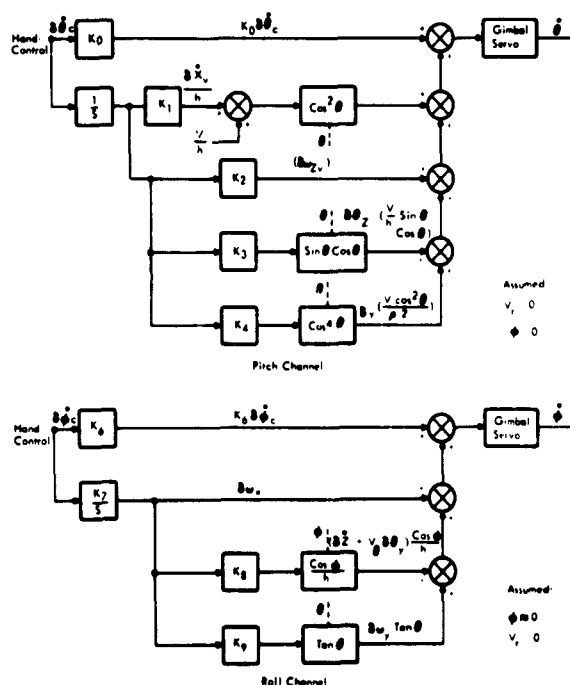
Figure 4-9. Analog Extended-Rate Prediction Filter

The extended capability mode has desirable features for multiple-target tracking missions where precise vehicle attitude and position information is required. Of the two recommended modes, the primary digital mode is preferred over the analog mode because all equation errors can be reduced to zero. In addition, the digital computer can perform several functions that are helpful to the astronaut in controlling, conducting, and evaluating the experiment. These additional functions include:

- Pointing Angle Commands
- LOS Rate
- Vehicle Present Position
- Time-To-Go To Target Acquisition
- Sun Angles for Operator and Telescope Safety
- Track Time
- Geographical Determination of Ground Target
- Automatic Scanning
- Space Target Tracking with Operator Aid
- Alignment and Calibration of PTS

4.2.4 IVSS State-of-the-Art/Engineering Status

The results of this study indicate that no advance in the component state-of-the-art is required to meet a performance requirement of 0.05 percent IMC. All the necessary equipment exists, or can be readily manufactured. This applies to the digital encoders, bearings and torquers for the servos, and lenses for the optics.

A slight weight penalty (50 pounds) must be absorbed if conservative lens designs are used (Table 4-2 and Figures 4-1 and 4-2). However, this is considered justified in view of the MOL objectives of minimizing development costs and lead times.

The PTS tracking servo has been identified as the most critical unit of the IVSS due to the stringent rate accuracy requirements it must meet.

4.3 Description of the Recommended IVSS Design

Figure 4-10 is the over-all block diagram of the IVSS. The subsystem
can be logically subdivided into seven categories, which, at this stage
of the development program (preconceptual phase), are identified as
Contract End Items (CEI's):

    (1) Pointing and Tracking Scope

    (2) Recording Cameras

    (3) Displays and Controls

    (4) Star Trackers (optional)

    (5) Experiment Evaluation System

    (6) Power Supply

    (7) AVE Software.

The remainder of this section functionally describes the IVSS, presents
its performance and physical characteristics, and specifies the vehicle
interface and Aerospace Ground Equipment (AGE) requirements.

4.3.1 Functional Description

The PTS CEI (Figures 4-11 and 4-12) contains the tracking scanners, the
acquisition scanners, the telescopic system, and the PTS electronic inter-
face unit. Also included is the visual evaluation tracker (VET), which is
replaceable, depending upon the inclusion of the P-11 and P-12 experi-
ments. The performance of the PTS and crew members is recorded
using two pulsed cameras having frame rates from 1 to 4 frames per
second, and by an optional cine camera capable of frame rates from 4
to 60 per second. The cine camera would only be mounted on the high-
magnification relay optics, but the frame cameras could be mounted on
either the high or the low-magnification relay optics. Also included in
the recording cameras CEI is the data block that essentially identifies
the frame and data-tags the exposed film. Table 4-6 lists the properties
of the recommended optical configuration.

The PTS servo systems best able to meet the pitch servo requirements
for the primary (digital) mode and the analog mode are shown in Figure
4-13. Direct-drive d-c torque motors are recommended, using 19-bit
optical shaft encoders to supply the accurate (2.47 arc second resolution)
shaft position required for tracking terrestrial targets. An 8 kc sampling
rate used in the primary mode insures that each bit from the encoder will
be sampled twice during maximum scanner slewing for ground targets.

The analog servo system uses the encoder as a precise pulse tachometer.
Frequency and phase circuits operate simultaneously in the comparator
in the coarse error signal (frequency) and a fine error signal (phase) such
that the frequency output of the encoder exactly equals the voltage-

Overall Dimensions:
Length — 160 Inches
Width — 29 Inches
Height — 42 Inches
Radial — 12 Inches Beyond Ship
Direction 30 Inches Within Ship

Alignment Accuracy:
Tracking Scanner LOS To Objective   1.5 arc min
Tracking Scanner LOS To Acquisition Scanner LOS   5 arc min

Figure 4-11. PTS Mechanical Configuration

IVSS EXPERIMENT EQUIPMENT

Visual Evaluation Tracker

Pointing & Tracking Scope

Frame Cameras

Film Drive

Star Trackers (2)

Inertial Reference Package

Zoom Drive

Acquisition Scanner

Cine Camera

Star Tracker Interface Unit

Servo Drive

Tracking Scanning

Film Processor

Attenuation, Magnification, Filters, Reticle, Polarizer

Spacecraft +28 VDC

Servo Drive

Servo Drive

Speed

On-Off Film Drive

Shaft Angles

Servo Drive

Gimbal Angles

Shutter Opening

Angle Interrogate Angle Commands

Power Supply System

PTS Electronic Interface Unit

Pointing Angle & Commands, Camera Controls

PTS, VET Data

Regulated & Unregulated Power to all IVSS Equipments

Hand Control Signals, Time

Display & Control Electronic Interface Unit

Briefing Commands Console Data

Brie Dat

Clock

Time Updates

Analog Decimal Wheels, Discretes

Ground & Sp Data, Time

Time Reference Unit

Time

Displays & Controls Console

MISSION CONTROL CENTER

IVSS Simulator

Displays & Control

Digita Comm System

Briefing Material & Film File

Shaft Angles

Film Viewer

Hand Control

Computer

Comma Transm

Film Comparator

Briefing Presentation Unit

Communication Link

Figure 4-10. IVSS - MOL Interface

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Overall Dimensions:
Length — 160 Inches
Width — 29 Inches
Height — 42 Inches
Radial 12 Inches Beyond Ship
Direction 30 Inches Within Ship

Alignment Accuracy:
Tracking Scanner LOS To Objective 1.5 arc min
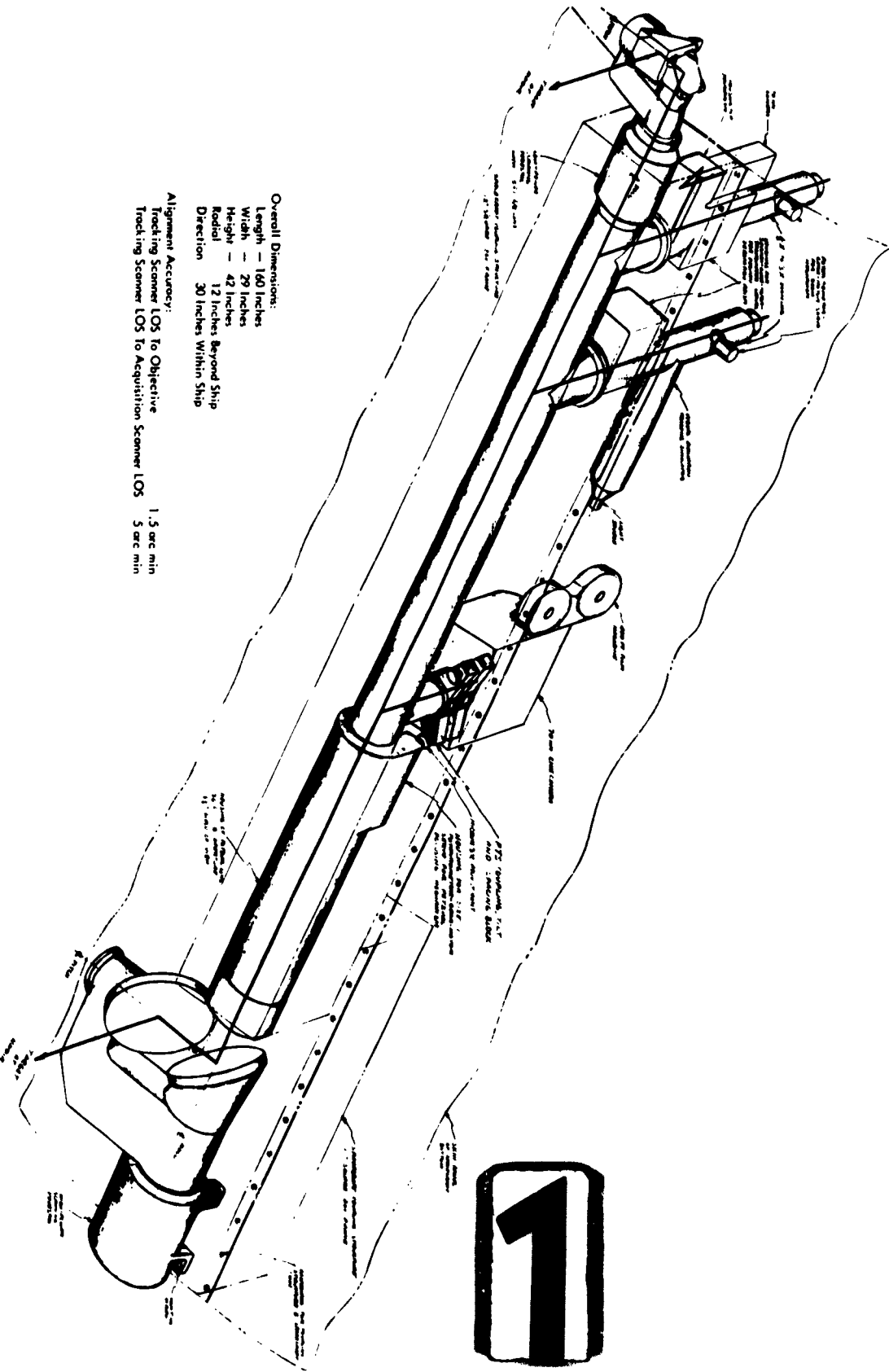Tracking Scanner LOS To Acquisition Scanner LOS 5 arc min

Figure 4-11. PTS Mechanical Configuration

31° FULL FIELD
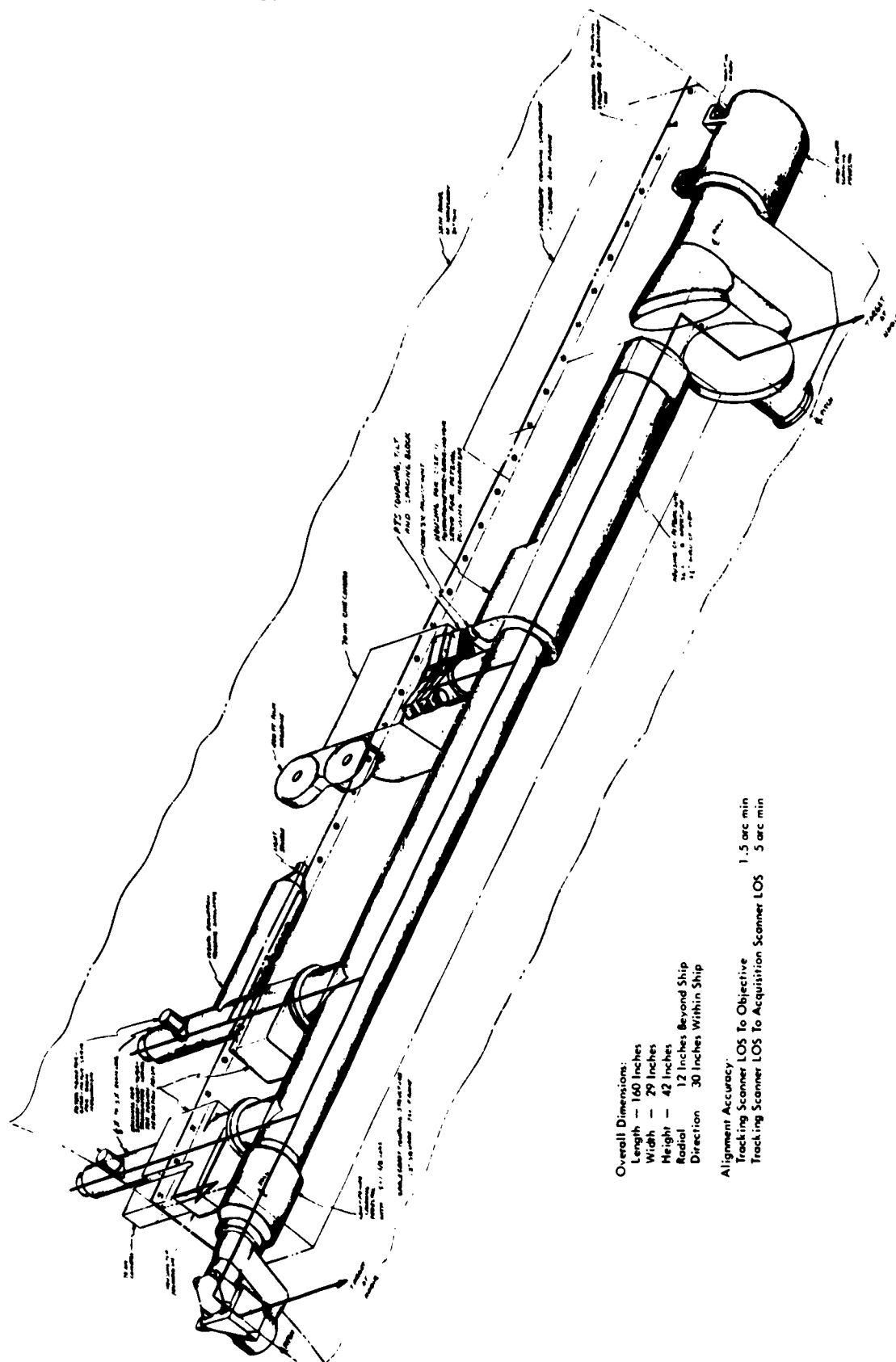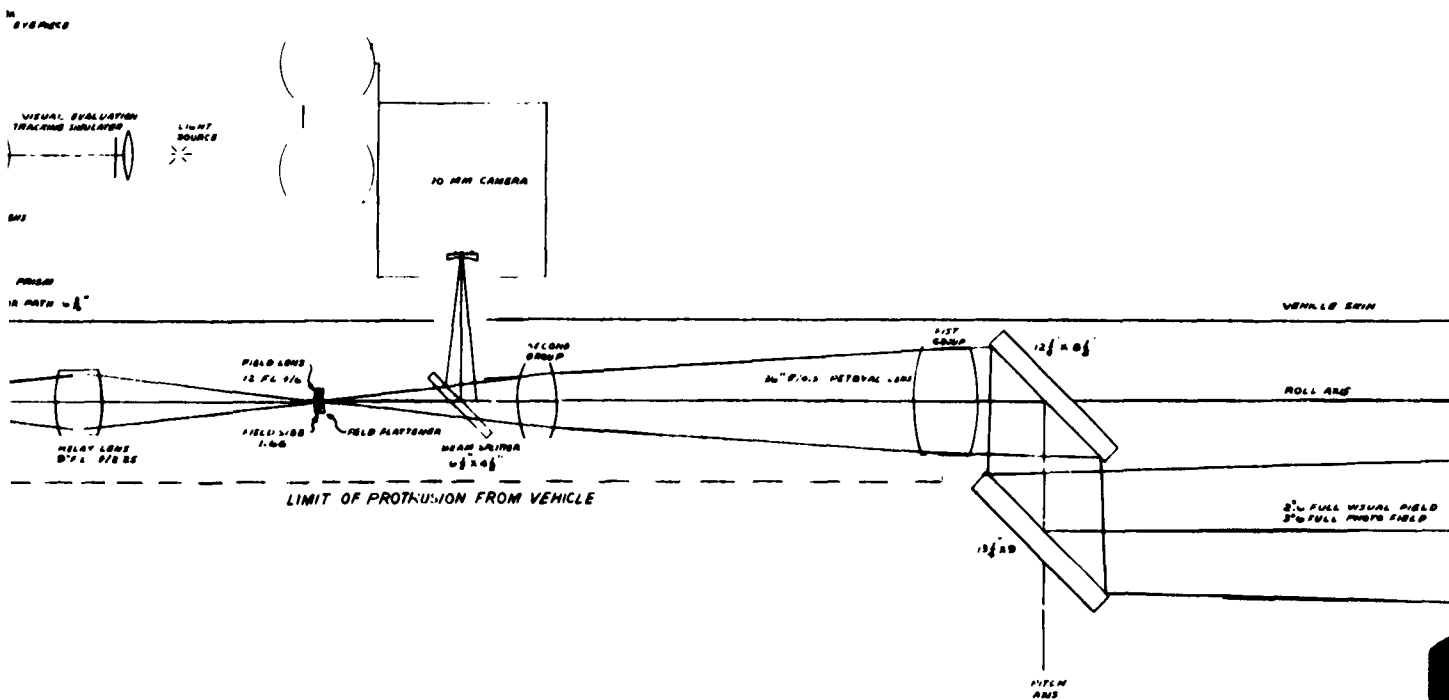
Figure 4-12. PTS Optical Schematic
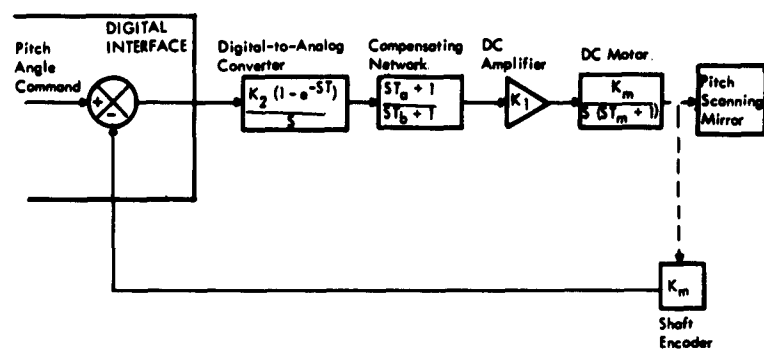
a. Candidate Pitch Tracking Servo - Primary Digital Mode
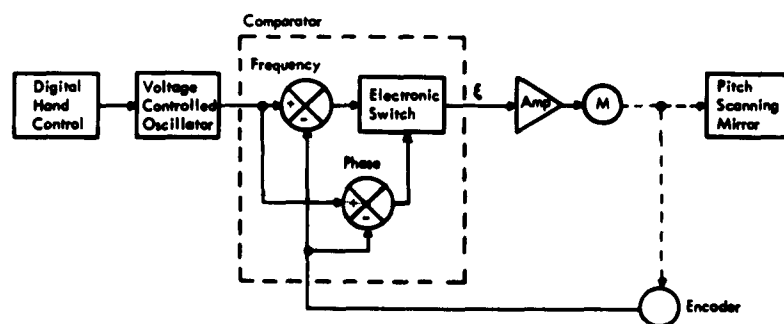
b. Candidate Pitch Tracking Analog Servo

Figure 4-13. Candidate Servo Systems

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Table 4-6

POINTING-TRACKING SCOPE CANDIDATE OPTICAL CONFIGURATION
GENERAL PROPERTIES

Wide-Field System (Acquisition)	Magnification range: 1.5 to 9.0 × 300 m Objective focal length: 1.5 in. Exit pupil dia.: 13 to 2 mm. Real field angle: 30 to 5 degrees Objective diameter: 0.75 in. Apparent field angle: 45 degrees
High Magnification System (Pointing-Tracking)	Magnification range: 18 to 108 × 300 m Objective focal length: 36 in. Exit pupil dia.: 11 to 2 mm. Photographic field angle: 30 degrees At 160 n mi altitude, photo ground coverage: 85 n mi diameter Scale factor: 17,680,000 Real field angle: 2.5 to 0.4 degrees Objective diameter: 8.0 in. Photographic field angle: 3.6 degrees At 160 n mi altitude, photo ground coverage: 10 n mi diameter Scale number: 320,000 Apparent field angle: 45 degrees
Scanners	Roll-pitch gimbals: For acquisition, two 45 to 90-degree prisms; for pointing, tracking, two 45-degree elliptical mirrors
Camera (Frame)	Film size: 70 mm Format size: 2.25 in. diameter Frame rate: 1-4 fps Focal plane shutter: 1 to 1/1000 sec
Camera (Cine)	Film size: 70 mm Format size: 2.25 in. diameter Frame rate: 4-60 fps Disc shutter: 1/25 to 1/1000 sec.
Film	Kodak Special High-Definition Aerial Film, Type SO-243
In-flight Processing	Kodak Bimat Process

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controlled oscillator frequency. Absolute speed synchronization is an inherent property of this system; short term perturbations of one part in one million can be maintained.

Other servos required to perform the IVSS experiments, such as the acquisition pitch and roll servos, briefing film, VET, reticle, zoom, and derotation servos are shown in the functional schematic, Figure 4-14.

The displays and controls CEI (Figure 4-15) is composed of a console, a briefing presentation unit, briefing material and a film file, a film viewer, a time reference unit, and an electronic interface unit. The major portions of the console are the hand control voice recorder, VET control panel, malfunction control panel, and PTS controls. The PTS controls are required for zoom magnification, changing filters, reticles, and orientation of the driftmeter grid reticle.

The star tracker CEI is an optional piece of equipment since it is required only for multi-target tracking (extended capability mode). The experiment evaluation system CEI is made up of two units: the film comparator by which the astronaut's performance could be evaluated in space, and the film processor, whereby the astronaut would process the exposed film.

The power supply must interface with the raw 28 vdc of the vehicle bus and regulate it to meet the requirements of the IVSS equipment.

The aerospace vehicle equipment (AVE) software system CEI will consist of: (1) maintenance manuals; (2) operational procedures manuals, such as for setting up, running, and evaluating the experiments; (3) the tapes for conducting the experiment, i. e., loading the computer storage for such things as diagnostic check-out and the operation of the experiment. The AVE software includes the briefing material for pre-assigned ground targets. The IVSS has the basic capability of generating additional briefing material, especially of relatively inaccessible targets, which may be used on future IVSS experiments.

4.3.2 Physical Description of Proposed Equipment
Table 4-7 summarizes the physical parameters of the IVSS equipment. The tabular items most subject to change are the parameters for the briefing material and film file, since they are sensitive to film parameter changes. Other units in the table are state-of-the-art and for the most part insensitive to film changes. Therefore, the physical parameters of these units can be stated with confidence.

4.3.3 Performance Predictions
Estimates of IVSS performance in terms of accuracy, reliability, and maintainability are summarized.
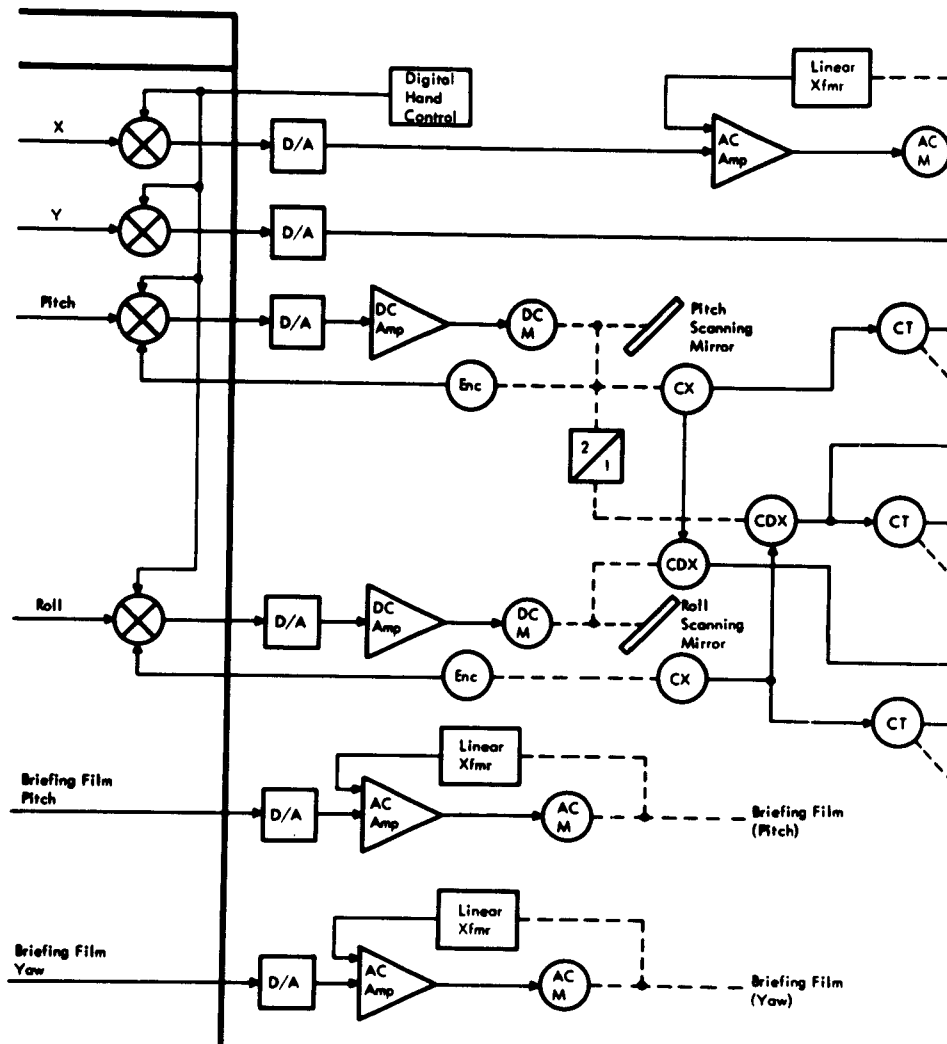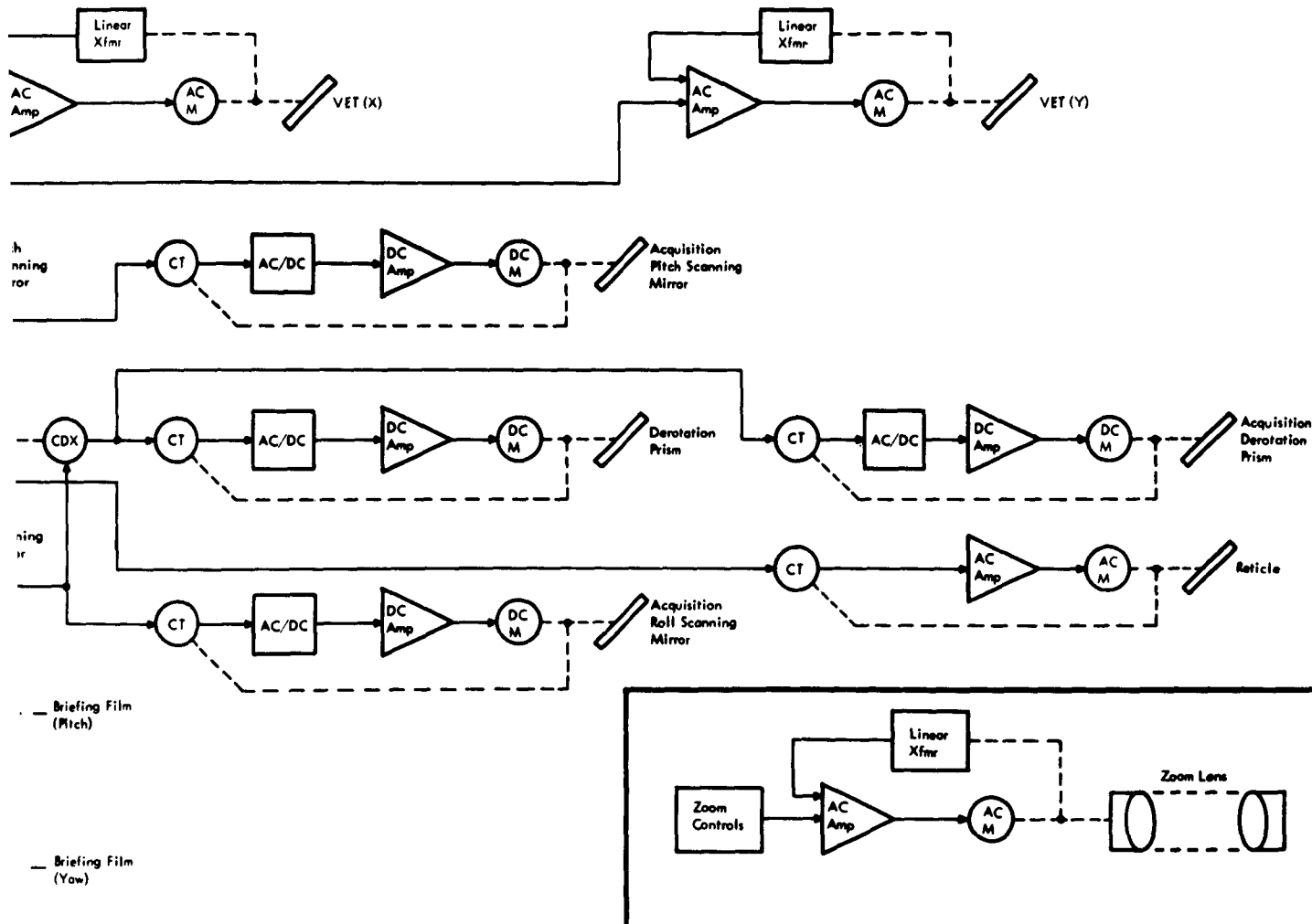
Figure 4-14. IVSS Servo Functional
Schematic

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TEST PROBLEM

ELECTRICAL POWER
MONITOR PANEL

RESET

Y-AXIS
CROSSHAIR
CONTROL

FILM PROJECTION SCREEN

PHOTO DATA

FRAME NO

FRAME SELECT

DISPLAY MODE

SLIDE ORIENT

BRIEF INTENS

RECORD

RESET

X-AXIS
CROSSHAIR
CONTROL

MAGNIFICATION

RADIO COM
INTERCOM

DATA
MANAGE

ADDRESS

CANCEL

1
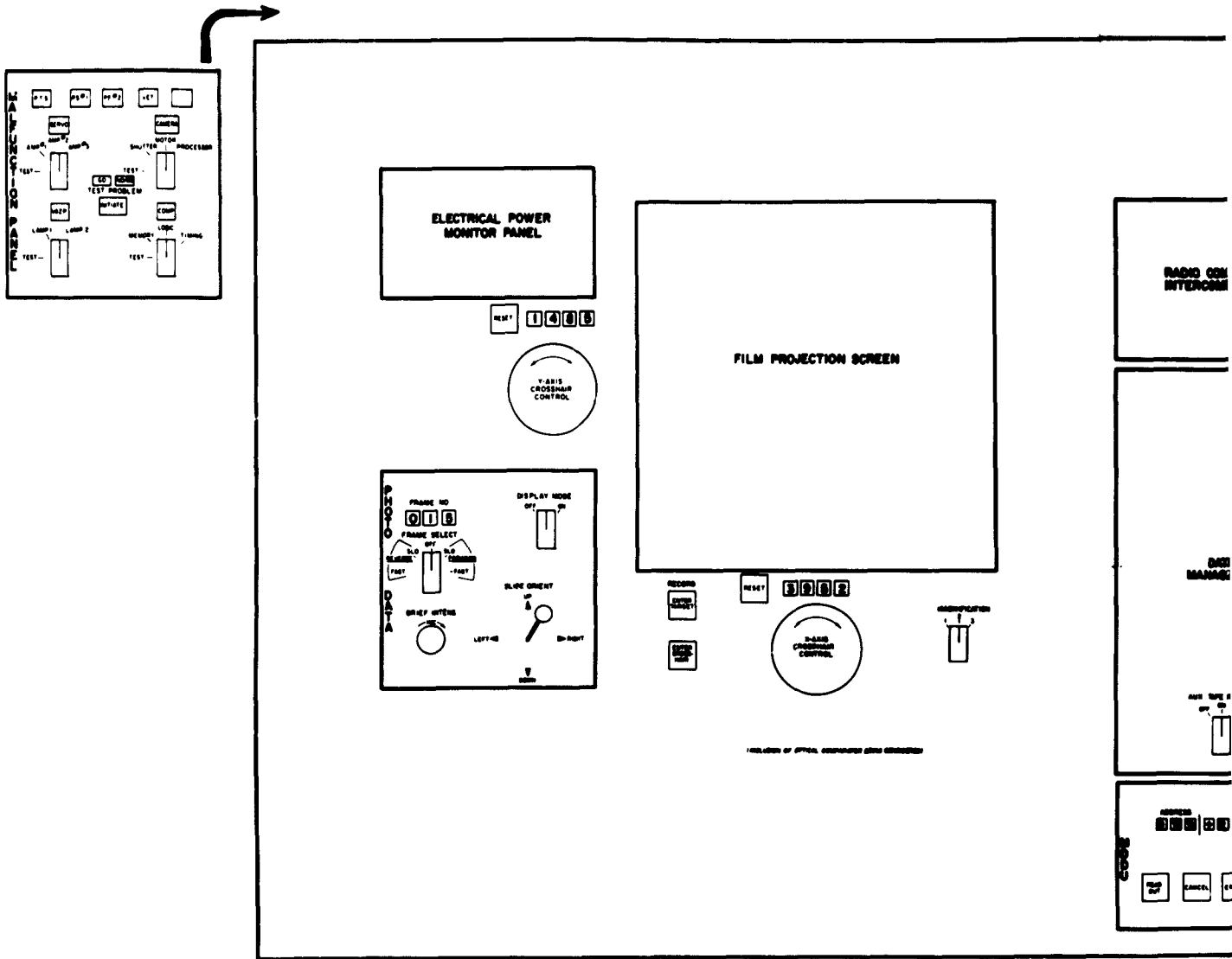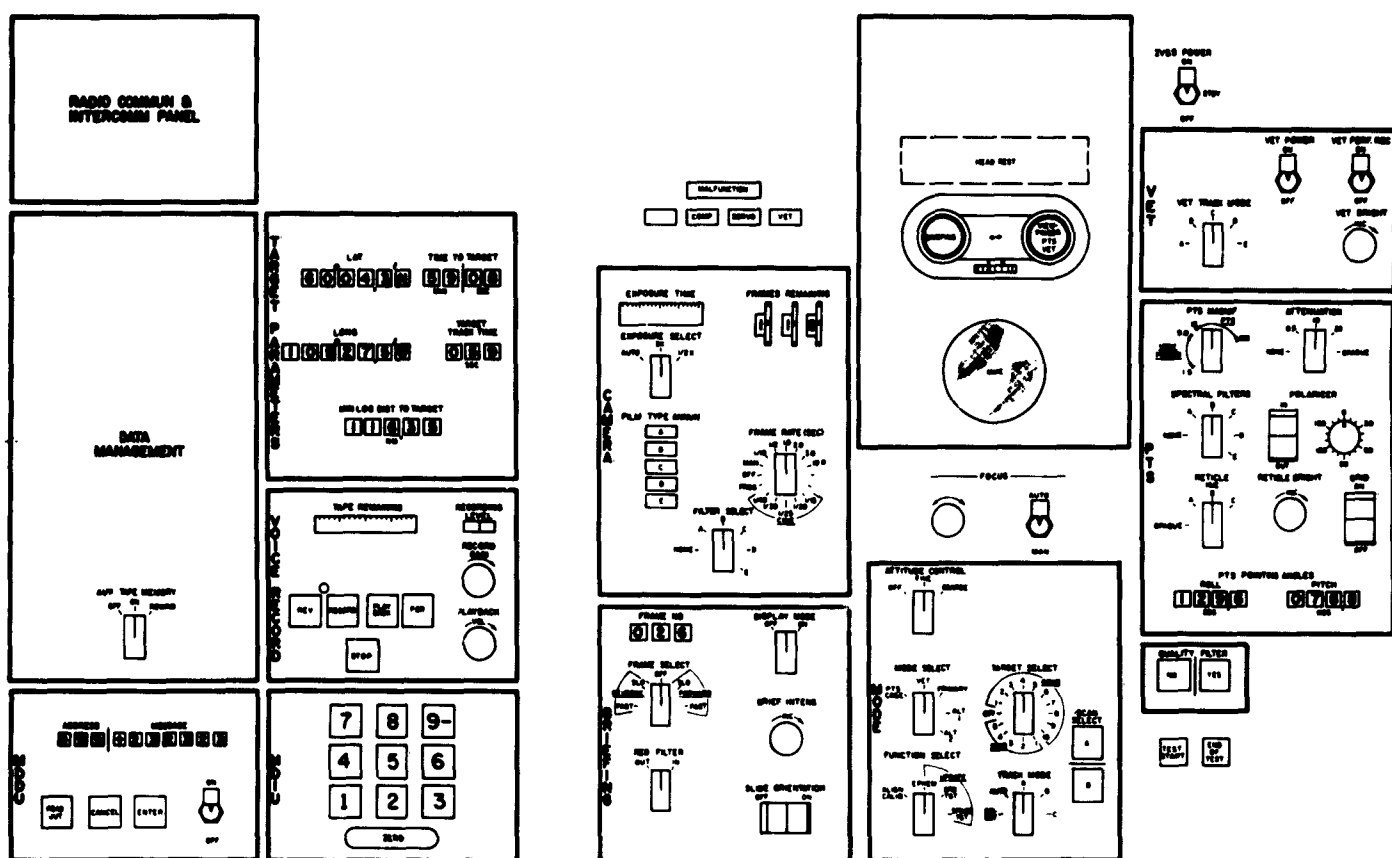
Figure 4-15. Man-IVSS Interface

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Table 4-7

POWER, WEIGHT, AND VOLUME
SUMMARY FOR IVSS EQUIPMENT

Subsystem	Average Power (watts)	Weight (lbs.)	Volume (cu. ft.)
Pointing and Tracking Scope (Including Scanner)	---	312	15 outside vehicle 16.3 inside vehicle
Visual Evaluation Tracker	45	8	0.4
Frame Camera (2)	10	12	0.5
Film Processor	---	10	0.5
PTS Electronic Interface Unit	271	25	0.5
Briefing Material and Film File	---	90	1.5
Briefing Presentation Unit	45	16	0.8
Film Viewer	125	25	0.5
Film Comparator	8	25	1.0
Time Reference Unit	3	5	0.1
Displays and Controls Unit	20	100	2.1
Displays and Controls Interface	5	10	0.2
Power Supply	205 (losses)	40	0.3
TOTAL	737	678	39.7
Optional Equipment			
Cine Camera	50	80	1.0
Star Trackers (2)	30	60	2.0
	80	140	3.0
Total with Optional Equipment	817	818	42.7

Table 4-8 shows estimated IVSS error magnitudes for different operations, including variations resulting from different component procurement approaches. "Off-the-shelf" means ordering standard components that are within standard manufacturing tolerances. "State-of-the-art" components have a longer lead time, have the best available tolerances, and require extensive testing for selection.

Theoretical analyses have indicated that the results of the experiment can be evaluated reasonably well down to 0.05 percent of the LOS angular rate. This assumes photogrammetric measurement errors corresponding to 0.01 percent, which, from Figure 4-5, requires sampling times between verification photos of about 5 seconds. The evaluation of man's discrete pointing accuracy while tracking can be conducted to better than 2.5 arc seconds.

Further studies are required to better identify a practical limit for evaluation accuracy, and to determine whether additional penalties in weight and volume should be incorporated to meet the evaluation limit.

Table 4- 9 lists mean-time-between-failure (MTBF) values for the IVSS and its equipment groups. Simple maintenance procedures of the type anticipated and the possibility of non-catastrophic failures give the IVSS a greater reliability than the MTBF's shown would indicate. For example, assume 60 hours effective equipment operating time (including both boost and orbit phases) during the 1-month mission. In this case, the primary mode has a 0.938 probability of success. Including all the degraded modes, the system has a reliability of 0.968, wherein the following operating conditions are assumed:

- Manual operation, or without the derotation spectral filter, attenuation, and polarizer PTS functions.
- Operation without visual evaluation tracker.
- Operation with only selected, essential digital display read-outs.
- Operation without the IVSS voice tape recorder.
- Pursuance of primary experiment objectives that do not require the star tracker.
- Inclusion of scanner encoder redundancy (not a requirement in the present pre-Phase I configuration).

Listed below are the estimated times for scheduled maintenance and the mean time to repair a failure. Scheduled maintenance consists of calibration/alignment and check-out of the equipment.

- Daily scheduled maintenance time: 15 minutes
- Mean time to repair failure: 80 minutes

Table 4-8

ESTIMATED IVSS ERROR MAGNITUDES (1 SIGMA VALUES)

	Static Pointing	Relative Pointing	Open Loop Tracking – Extended Capability
Pointing-Precision: (arc-seconds)			
Operator	15	15	15
Off-the-shelf instrumentation	27	3	34
State-of-the-art instrumentation	7	3	16
Total system (operator and state-of-the-art instrumentation)	17	16	21
Rate Precision: (arc sec/sec)			
Operator and Instrumentation	N/A	1.2	1.2

Table 4-9

RELIABILITY PREDICTIONS

Subsystem	MTBF (Hours)
PTS	2,500
Recording Cameras	11,500
Display and Control	2,000
Experiment Evaluations	28,500
Power Supply	25,000
IVSS Primary Mode: 940 hours MTBF	

4.3.4 Aerospace Ground Equipment

The following have been identified as the critical portions of the IVSS AGE:

- Optical Bench
- Precision Rate Table
- Dynamic System Test

The optical bench would permit precision alignment, collimation, and image quality measurement of the telescopic system. The PTS, including the optical baseplate, would be mounted on the optical bench.

The precision rate table, accurate to 0.1 degree per hour for an angular rate of 2 degrees per second and capable of supporting the 85-pound tracking scanner, would be used to determine the velocity stability of the tracking and acquisition scanners. This equipment is commercially available.

The dynamic system test equipment will evaluate over-all tracking performance of the PTS. It will consist of the optical bench operating in concert with an accurately controlled, simulated moving target.

None of the listed equipment presents serious implementation problems.

4.3.5 Vehicle Interface Requirements

The IVSS will interface with the MOL vehicle in several important areas. One of the more important interfaces upon which IVSS performance depends is the MOL attitude reference. The attitude reference performance figures used in this study are given in Table 4-10.

The central data processor would have a digital interface with the IVSS equipment through two electronic interface units, mainly those associated with the PTS and the displays and controls. The auxiliary tape storage system contains the tapes for loading the computer with the four IVSS programs. The requirements for each of the experiments are listed in Table 4-11.

The telemetry/communications/ground support interfacing required by the IVSS results from the data continuously recorded during the experiments, photo tag data, photo interpretation data, and alignment and calibration data. Based on experiment time and photographs taken and interpreted, the following data represents the number of bits per day generated by the IVSS:

- Normal data: 5.58×10^6 bits per day
- Photo tag data: 0.26×10^6 bits per day
- Photo interpretation data: 0.0024×10^6 bits per day
- Alignment and calibration data: 1.44×10^6 bits per day.

Table 4-10

MOL ATTITUDE PERFORMANCE REQUIREMENTS

Required Performance	Attitude Control	Rate Gyros	Horizontal Sensors
Threshold	0.05 deg/sec^2 0.01 deg/sec 0.5 deg	0.01 deg/sec	10.1 to 0.5 deg of local vertical
Maximum	Slew 15 deg/sec 0.2 deg/sec^2 (for space targets)		
Linearity		0.5% to 7.5 deg/sec 1.5% to 15 deg/sec	

Table 4-11

DIGITAL COMPUTER REQUIREMENTS

Requirements	Primary	Extended Capabilities	Remarks
Total Instruction Storage*			
P-1 Only	6,000 words	12,600 words	Preassigned ground targets - IMC evaluation
P-2 Only	6,300 words	8,350 words	Space target tracking
P-3 Only	7,700 words	7,700 words	Target of opportunity
P-1, P-2, and P-3	12,400 words	18,970 words	
Word Size	26 bits	26 bits	
Solution Times	1/computer cycle to 3/sec	1/computer cycle to 3/sec	
Largest Computation Cycle	1 sec	2 sec	
* Including provision for constants and variables, scaling, and subroutines.			

The total, 7.3×10^6 bits per day, was raised by 25 percent to allow a safety factor in arriving at data storage and transmission requirements of 9 million bits per day.

The environmental interfacing used in this study is based upon what seemed most applicable from either Titan III or Gemini. They are not presented here because the relatively undefined structure and vehicle environmental control systems will most likely cause changes. While the IVSS will require a heat sink for its power supply, conduction without extensive heat-sinking should suffice for the other units. Depending on the environment supplied to the MOL laboratory in space, some humidity and/or temperature control may be required for the more sensitive optics and film.

The PTS had to be externally mounted because of its size and the limited volume available in the MOL for IVSS equipment. Figure 4-11 shows this mounting configuration.

Tentatively, the PTS will be mounted on the belly of the craft. If, however, star trackers are used (as they would be in the extended capability digital mode and in the auto navigation experiment) it may be desirable to mount the PTS 45 degrees up from this position. In this latter position, the PTS would allow the astronaut to manually assist the star tracker to lock on, if the two were slaved, and would also serve to check alignments between the star tracker and the PTS. If the 45-degree mounting were made, there would be a sacrifice of 45 degrees in viewing on the opposite side of the orbital plane. This is not felt to be a serious restriction since it encompasses the 30-degree out-of-plane coverage requirement.

The star trackers, when required, should be mounted on or near the PTS pedestal. The alignment tolerances between the PTS pedestal and the star trackers should be 10 to 15 arc sec (3 sigma). At this time it does not appear that the optical system will be one casting, but rather that the optics within the vehicle will be joined to the optics outside the vehicle via an optical bar. This would insure rigidity of the PTS during boost when the maximum acceleration is along the longitudinal axis and would also serve as a mounting reference when aligning internal and external optics.

To protect the optical lenses and the astronaut's eyes, sun sensors are required on the pitch gimbals for both the acquisition and the tracking scanners. The mounting tolerances between the lines of sight between the sun sensors and the pitch gimbal are approximately 10 arc sec (3 sigma).

4.3.6 The Impact of Related Experiments on the IVSS

During this study, the Aerospace Corporation supplied data indicating the nature of the other experiments and their requirements on the IVSS. Study results for these requirements are indicated below:

Experiment	Requirements	Comments
P-8 Autonomous Navigation	Field of View:	
	1X - 60 deg/FOV	Not Included
	30X - 2-1/2 deg/FOV	Included in IVSS
	Zoom to 30X	Included in IVSS
	Forward: -70 deg from local vertical	
	Rear: 45 deg	Included in IVSS
	+45 deg roll toward Northern Sky	Requires simple reprogramming
	Slew of 22 deg/sec	Included in IVSS
	Azimuth Elevation Pickoff to 5 arc sec	Included in IVSS
	Alignment to 10 arc sec	IVSS will not limit
P-10 Multi-Spectral	Slaved tracking	No problem.

5.0 Human Functions, Human Engineering Considerations, and Experimental Procedures Planning

5.1 Objectives and Approach

Assessment of man's contribution to the acquisition, tracking, and analysis of terrestrial and space targets, with emphasis upon the precise determination of image velocity, establishes the rationale and justification for development of the IVSS. Simulation studies and analyses of functions have demonstrated man's capabilities to perform the required tasks; they remain to be demonstrated and measured in space.

The major objective of each experiment is to establish how well man can contribute to precise image velocity determination; defining boundaries of human performance over a variety of targets, dynamics, and environmental constraints. To permit controlled assessment of mans' role, three primary experiments have been designed along a continuum of target characteristics and dynamic constraints, as follows:

- Primary Experiment P-1 "Acquisition and Tracking of Pre-Assigned Ground Targets"
- Primary Experiment P-2 "Acquisition and Tracking of Space Targets"
- Primary Experiment P-3 "Acquisition and Tracking of Targets of Opportunity on Land and on the Oceans".

Definition of human functions and level of contribution, establishment of the experiment functional requirements, and type of data analysis provided the fundamental criteria for system functional requirements and the man-subsystem interface (refer to Volume IV). Simplicity in design and function was stressed, while including the necessary flexibility of mode, function, and operability deemed essential in subsystem designed expressly to support experimental assessment of human capability.

Design of three primary in-space experiments has been completed. Experimentation in orbit will involve conducting all three in a parallel fashion, using a sequential testing paradigm, the number and type of tests having been established by a series of simulation studies during the development of the IVSS and the training of the crew.

Modification of the experiment being conducted will be permitted as a function of knowledge of results gained through on-board measurement and analysis of results by the crew members and by analyzing results at the Ground Experiment Control station. Random degradation of results caused by system malfunctions, undesirable environmental factors, or physiological condition of the crew will be handled by the sequential design which permits

changes in tests, by quick-response scheduling of sub-experiments as substitutes, and by parallel tests, such as P-11. If factors are such that meaningful sighting must be abandoned, a contingent optical subsystem maintenance experiment may be substituted.

It is recommended that both crew members participate as subjects and experimenters in the three primary experiments. Initial design indicates that the three experiments can be conducted in parallel during the initial 30-day deployment of the laboratory. They will require a total of 84 hours and 40 minutes of crew time. This total reflects a thorough consideration of the availability of crew time, the requirements of the sequential approach to experimentation, the availability of targets, and the probable degradation of results by environment and system operational constraints.

In summary, an approach to the three primary photo-optical experiments involving the assessment of human contribution to precise image velocity determination involves: (1) the use of sequential experimental designs, the parameters or "critical points" of which are established by simulation; (2) parallel conduct of the three experiments; (3) on-board analysis of results by the crew; and (4) an approach to scheduling by Ground Experiment Control to handle environmental conditions and other effects which, if not adequately handled, could result in an unacceptable level of degradation of the primary experiments.

The crew time requirements necessary for conduct of primary experiments P-1, P-2, and P-3 are included in Table 5-1. The table reflects an analysis of the availability of crew time, the constraints of environment, the availability of targets, and the probable number of tests necessary to complete the proposed experimental design during the initial deployment of the laboratory. Detailed definitions of the primary experiments and human functions are included in Volume IV.

5.2 Functions of Man and Human Engineering Considerations in Design and Application of the IVSS

The evaluation of the experiments, the definition of functional requirements imposed by the experiments, and the allocation of functions to man and to the system, all proceeded with close coordination during the course of the study. Upon allocation of functions to man, each requirement was analyzed in detail with respect to operability, severity of time constraint, criticality, and method of measurement, if warranted by the experimental design. Decision points and complex perceptual motor requirements were given particular attention, both from the human function and the assessment standpoint. Task analysis and time-line analytic techniques were applied to the human functions to gain an adequate understanding of the impact of P-1, P-2, and P-3 upon the flight crew segment.

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Table 5-1

PARAMETERS UNDER CONSIDERATION, PRIMARY EXPERIMENTS
P-1, P-2, AND P-3

Accepted human engineering criteria and design principles were applied
to the man-IVSS interface (Figure 5-1) as it evolved during the study.
Applicable military standards and design guides were imposed to insure
that the console reflected the best human engineering principles of safe,
reliable, and efficient operation, while satisfying the requirements gen-
erated by P-1, P-2, and P-3. Procedures development and application of
human engineering principles to the interface design shall continue during
Phase I. Procedures simulation will permit the final design of the inter-
face and assessment of the human functions. These will be organized
according to accepted human engineering principles and will permit ac-
curate and reliable in-space assessment of human performance by ap-
plication of the experiment design.

5.3 Primary Experiment P-1

5.3.1 Experiment Objectives and Designs

Simulation research to date has established that man can contribute in a
significant and unique manner to the acquisition and tracking of pre-assigned
targets and achieve an accuracy compatible with precise image velocity
determination. Experiment P-1 will evolve from continued simulation
research, ultimately consisting of a sequential method of testing in space
to establish man's capabilities regarding acquisition and tracking of classes
of pre-assigned ground targets. Emphasis will be placed early in the
space testing upon the precise determination of image velocity, with at-
tention focused upon human contribution in analysis of data and higher-
order intellectual functioning once the primary goals have been met.

Other objectives of experiment P-1 include the assessment of man's
ability to conduct "change detection", to comment upon system perform-
ance and experimental progress, and to meet the primary experiment ob-
jectives in alternate modes of system operation. Assessment of human
capabilities will consider probable degradation of the experiment design
and impact upon results of environmental constraints, subsystem operating
characteristics, physiological and mental states of the crew, and other
factors. The application of a sequential design with "critical tests"
established and verified by ground simulation, measurement of results
at least to the threshold level (less than 0.2 percent) on board, and
modification of in-space testing by a ground experiment control group
will overcome expected, but not directly controllable, degradation of
the experiment.

5.3.2 Analysis and Conduct of Experiment

A major element of P-1 consists of on-board measurement and analysis
of photographic data by the crew, who by definition must be qualified as
experimenters as well as subjects. Primary experiment P-1 will require
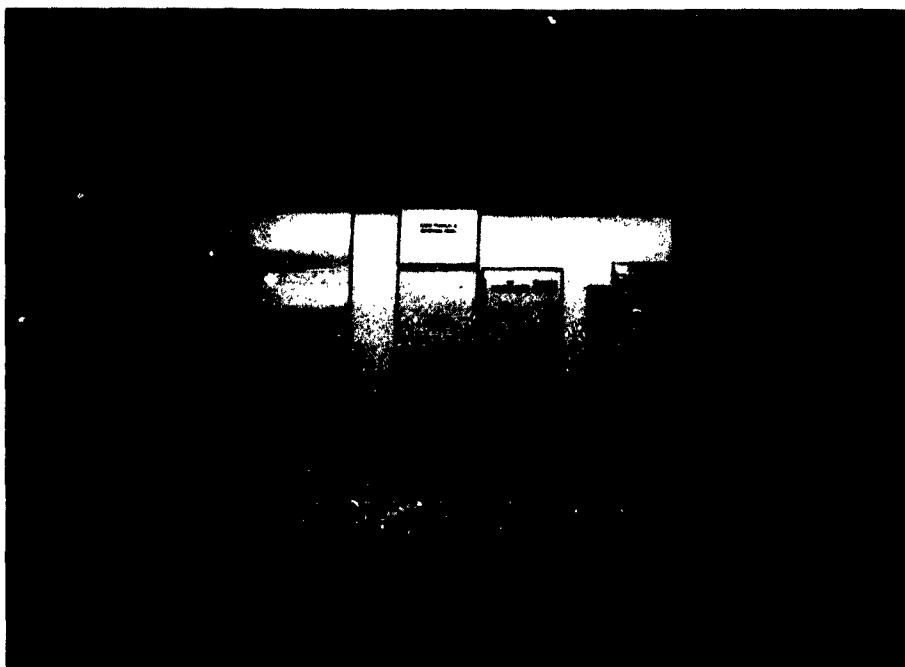
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Figure 5-1. Man-IVSS Interface Mock-Up

a total of 45 hours and 10 minutes of crew time, including on-board meas-
urement of results, study of protocol and briefing material, and subsystem
alignment checking. Table 5-2 lists the subexperiments comprising P-1.

With systematic assessment of human capability by ground simulation, the
in-space testing will be refined, with "critical tests" reflecting only those
functions of man that cannot be assessed by means other than the orbiting
laboratory. Factors such as random degradation of the experiment due to
unexpected human performance results, unanticipated system behavior,
or environmental contingencies will be handled by a sequential test design
that can be modified in type and sequence by ground experiment control.

By measuring significant contributing factors such as atmospheric haze,
aerosol content, and weather conditions, and subsequent correlation of
these conditions with human performance by means of a conventional
factorial experiment design on the ground, human contribution may be
predicted for future orbital deployments with acceptable degrees of con-
fidence.

5.4 Primary Experiment P-2

5.4.1 Experiment Design and Objectives

The potential human contribution to the acquisition and tracking of space
targets has been evaluated during the course of the study by elemental

Table 5-2

P-1 SUBEXPERIMENTS

Subexperiment Number	Priority Within Experiment	Total Time	Subexperiment Title
Man-Calibration	(Note 1)	(To be determined)	Basic visual testing, perceptual motor skills evaluation
P.1.1	(Note 2)	3 hrs 0 Min	Alignment and calibration of the pointing tracking telescope, recording cameras, and reference axes.
P.1.2	Priority 1	14 hrs 0 Min	Assessment of accuracy of man's pointing and contribution to LOS angular rate determination.
P.1.3	Priority 3	(part of P.1.2)	Assessment of man's capability to detect "changes in level" of pre-assigned ground targets.
P.1.4	Priority 2	8 hrs 10 Min	Assessment of man's ability to acquire and track pre-assigned targets in alternate IVSS modes.
P.1.5	Priority 4	20 hrs 0 Min	Assessment of man's capability to classify and interpret photo data in space.
P.1.6	(Note 3)	(15 hrs 0 Min)	Assessment of man's capability to maintain the IVSS in space.
	Totals	45 hrs 10 Min	

Note 1 - Visual testing and tracking evaluation required for base-line data. To be performed on a fixed schedule.
Note 2 - Must be performed prior to experiment P-1 and at specified intervals thereafter.
Note 3 - A contingent formal experiment. To be undertaken if mission or subsystem contingencies warrant cancellation of all or part of P-1, P-2, or P-3.

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simulations. Boundaries of human contribution to the acquisition of space targets have been established, as have performance characteristics for typical tracking requirements. Experiment P-2, evolving from continual research in this area, will ultimately assess human contribution under operational space constraints and environment, with major interest upon acquisition and subsequent tracking to an accuracy compatible with precise image velocity determination. Other objectives deal with assessing human ability to describe and characterize the time-varying visual image, and to identify salient characteristics of the target by visual and photographic techniques.

Experiment P-2 will consist of a series of measurements of a psychophysical nature, rather than a full-blown experiment design, primarily due to the nature of the visual environment, orbital dynamics, and availability of targets. Essential measurements recommended for P-2 include: (1) time to acquisition or detection of satellite target, if acquisition occurs; (2) tracking and pointing errors characterized as a function of time; and (3) crew ability to characterize and classify targets based upon visual and photographic data. Crew performance will be compared against their own simulation performance and with the flight crew data pool.

5.4.2 Analysis and Conduct of Experiment

On-board measurement of performance is recommended for P-2, which will result in satisfactory knowledge of results within a reasonable time period. Classification and measurement of target characteristics by visual and photographic techniques will permit assessment of human ability to perform this operationally significant role. Primary experiment P-2 will require approximately 17 hours of crew time during initial laboratory deployment, including on-board measurement and analysis of photographic data. Table 5-3 illustrates the two subexperiments comprising P-2.

Laboratory study of the human role in acquisition and tracking of space targets under a wide range of dynamic relationships will establish boundaries of human performance. These will remain to be validated in space. Simulation results will establish "critical tests" or important dynamic relationships which will in turn define the orbital relationships between co-planar and fly-by targets necessary to assess human capabilities.

5.5 Primary Experiment P-3

5.5.1 Experiment Design and Objectives

A major potential contribution by man to space operations is the acquisition and tracking of terrestial "targets of opportunity". By higher-order intellect, perception, perceptual-motor tracking, and analysis of images, man can deal effectively with targets of known characteristics whose

Table 5-3

P-2 SUBEXPERIMENTS

Subexperiment Number	Priority Within Experiment	Time Requirements	Subexperiment Title
Man-Calibration	(Note 1)	--------	Basic visual testing, perceptual motor skills evaluation.
P.1.1	(Note 2)	--------	Alignment and calibration of the PTS and recording camera.
P.2.1	Priority 1	12 hrs 0 Min	Acquisition and tracking of targets in co-planar orbits
P.2.1.1			Characterization of targets in co-planar orbits by use of visual image and photographic data.
P.2.2	Priority 2	5 hrs 0 Min	Acquisition and tracking of targets in fly-by maneuvers for precise image velocity determination.
P.2.1.1			Characterization of targets in fly-by by utilizing time-varying visual image and photographic data.
	Total	17 hrs 0 Min	

Note 1 – Visual testing and tracking performance required for man-calibration.
Note 2 – To be performed prior to experimentation and at fixed intervals during mission.

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locations are not precisely known. While interest in tracking with ac-
curacies compatible with precise image velocity requirements remains
high, the probability of acquisition, and subsequent analysis and charac-
terization, of targets of opportunity emerge as a major criteria for ex-
periment design. A sequential design approach will be followed, with
tests established during P-1. Major emphasis will be placed upon
characterization of the atmosphere and measurement of contrast and
other key characteristics of targets and test pattern complexes. Meas-
urement and analysis of results will be done on-board, with final analysis
and prediction of human performance on subsequent MOL deployments
accomplished on the ground.

5.5.2 Analysis and Conduct of Experiment

On-board analysis of photographic data and results will be accomplished
by the crew. Primary experiment P-3, consisting of two subexperiments,
will require a total of 22 hours and 30 minutes of crew time. Analysis
is included in the totals. The subexperiments comprising P-3 are
described in Table 5-4.

Measurement of ships in port and at sea under controlled conditions, and
their subsequent classification by the observer, will be based upon:
(1) briefing data; (2) characterization of the time-varying image; and
(3) analysis and measurement of the photographic data. The design of
primary experiment P-3, including the approach to on-board measure-
ment and analysis of data, is included in Volume IV.

5.6 Conclusions and Areas of Continued Emphasis and Crew Research

Assessment of man's contribution to the acquisition, tracking, and
analysis of terrestrial and space targets will be accomplished by using
an IVSS developed specifically for this application. Elemental simula-
tion studies, conducted during pre-Phase 1 activity, have established the
desirability and potential usefulness of man as an element in the system,
particularly with respect to precise determination of image velocity re-
quirements. An experiment design based upon sequential testing is
recommended, which, in light of constraints on crew time and availability
of targets, will require approximately 84 hours and 40 minutes of crew
time over the initial deployment of the laboratory.

The design, the tests of which are established by simulation, will permit
assessment of man's contribution to a variety of functions other than pre-
cise image velocity determination, resulting in prediction of human per-
formance on subsequent flights as well as detailed definition of the second
and third in-space experimental designs.

Table 5-4

P-3 SUBEXPERIMENTS

Subexperiment Number	Priority Within Experiment	Time Requirements	Subexperiment Title
Man Calibration	(Note 1)	————	Basic visual testing—evaluate perceptual motor tracking.
P.1.1	(Note 2)	————	Alignment and calibration of the PTS recording cameras and reference axis.
P.3.1	Priority 2	12 hrs 0 Min	Detection, acquisition, and tracking of ground targets of opportunity.
			Interpretation, classification and characterization of ground targets of opportunity.
P.3.2	Priority 1	10 hrs 30 Min	Detection, acquisition and tracking of ocean targets of opportunity.
			Classification and characterization of ships and surfaced submarines by photo data.
	Totals	22 hrs 30 Min	

Note 1 – Visual testing and tracking performance used as base-line data.
Note 2 – To be performed prior to any formal experimentation and at specified intervals thereafter.

Simulation studies have proven their worth in assessing man's contribution in establishing designs and tests for the in-space experiments, and in defining the system functions and man-subsystem interface. Continued close coordination among simulation researchers, designers of the in-space experiments, and human engineering personnel is mandatory to insure that final system and human functional capabilities reflect the requirements of the in-space experiments. Study to date has indicated that man will contribute in a most significant role in precise determination of image velocity, while providing his intellect for target recognition and analysis of results. Continued refinement of system, human, and experimental functions must continue v..th the keystone resting in simulation studies. With simulation as a fundamental research and development tool, human function, potential contribution, and system function will be assessed in increasing degrees of refinement and fidelity, insuring that ultimate in-space experiment testing reflects the utmost in efficiency, singularity of purpose, and simplicity of design so urgently required of experiments designed for conduct on a space laboratory.

6.0 Critical Areas

In addition to the major conclusions, the study has identified several areas which warrant immediate attention to provide a better base upon which to build the IVSS development program. These areas represent either extensions of work along avenues uncovered during this program, or recommended supplementary efforts to resolve still remaining questions. These critical areas are discussed below by major grouping.

6.1 Simulation Requirements

Immediate attention to the following simulation studies is recommended.

6.1.1 The Limit of Human Contribution to Image Motion Compensation
Basically, the elemental simulations related to IMC indicated that equipment or simulations limit the maximum contribution the human can make to the IMC process. Every improvement in simulation characteristics, or hand control implementation, or magnification resulted in an improvement in human performance. No limit has yet been established, although it is obvious that the human capabilities will be limited by the equipment to support his operations rather than the other way around. Therefore, with very simple aiding, studies should be performed to determine this base upon which alternative experiments can be built.

6.1.2 A Comparative Evaluation of Analog Aiding Programs
This involves the determination of that point at which increased aiding, involving increased equipment complexity, no longer really facilitates human performance improvement. So far, studies have indicated that this cross-over point will result in fairly simple instrumentation, but exact design requirements cannot yet be established without further simulations.

6.1.3 Higher Fidelity Simulations
These simulations will be required of both the ground and space acquisition and tracking problems before a firm experimental baseline data pool can be established. Generally, an increase in fidelity of the simulation allowed increased or higher precision determination of human performance. The technology for the earth-sighting simulator, which has undergone extensive calibration and refinement, now supports 0.02 percent baseline determination. The space target tracking and simulation has not yet met full fidelity expectations, and requires further augmentation to determine all the parameters of that program. In general, the highest fidelity possible appears justified on the basis of our early simulation results.

Simulation will be required to measure the effectiveness of the in-space photometric performance evaluation technique and instrumentation.

6.1.4 Parametric Simulation Programs

Immediate emphasis should be given to parametric simulation programs which attempt to systematically isolate remaining minor design points. For example, it has not yet been successfully demonstrated as to which of the two elements of the increase of magnification are more important related to human performance: (1) increased resolution obtained with higher magnification, or (2) increased rate sensitivity. A parametric study to assess these variables differentially is required before final design limits can be firmly established.

6.2 Design Areas

The following sensitive areas have been indicated for the system designs:

- **Servo System Mechanization:** The tracking precision required in the servo systems (better than 3 arc seconds/second) will require a concentrated design effort to effectively demonstrate all of the contributions that a man can make in space. Particularly, the effects of the space environment on servo components will remain a critical design area.

- **Structural and Environmental Integrity of the PTS:** The conceptual design of the PTS has resulted in a system for which detailed study is required on the alignments, thermal sensitivity, vibration sensitivity, and general mounting problems. A continuity effort at determining sensitivities of this equipment to these factors is required to be initiated as soon as possible.

- **Simulation Designs:** The requirements for an experimental support simulation in conjunction with mission support simulations at Cape Kennedy on a time frame to facilitate early launches means that the earliest possible simulator designs should be initiated.

6.3 Sensitive Analytic Areas

The following have been identified as immediate start work areas for analytic effort:

- **Selection of Appropriate Digital Filters for Real-Time IMC Determination and Post-Flight Support:** The study has indicated that a parametric study of various alternative Kalman or least-square filters is required, using analytic simulations, to generate system design requirements. Several alternative means of implementing the filter are possible, and a comparative program is required.

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- <u>Identification of Extended Application Possibilities and Appropriate Trade-Off Analyses</u>: Identification is required in the areas of:
  - (1) Use of the PTS and IVSS drift meter mode to correct for yaw
  - (2) Use of the IVSS as a sextant
  - (3) The integration of the IVSS with other related experiments (P-8, P-4, P-10, P-13).

6.4 Test Areas

The following concepts related to the simulation and test of experimentation should be analyzed and defined as soon as possible.

- <u>Aircraft Programs</u>: The concept of use of A-11 aircraft, which offers a compatible V/H environment and possible payload capabilities, as a validation test bed for IVSS experimental operations has enough initial feasibility to merit a more detailed study. Use of this device, correlated with late Phase I or early Phase II programs might well prove to be a meaningful element of the total program.
- <u>The Obtaining of Appropriate Aerial Mosaic Materials</u>: The requirements for stimulus materials for training, simulations, and subject and target selection warrant the earliest possible attention to the generation of appropriate mosaic materials. It is suggested that the survey be made by the Air Force as to the availability of all mosaic materials.

6.5 Long Lead Items

The following represent currently identified long lead items:

- <u>Hardware Areas</u>: The servo breadboards will ultimately require high precision digital encoders. These should be obtained as early as possible in the program to facilitate design. Likewise, glass for lens systems should be ordered as early as practical to insure availability of same-melt glassware.
- <u>Software</u>: It can be expected that software requirements, particularly programs for in-space operations, will require extensive development. Earliest implementation of these is recommended.

6.6 Logical Extensions to the IVSS Program

The study has indicated several broader applications of the IVSS system which should be evaluated as soon as practicable to allow system design requirements decisions. The three main areas of extensions of the IVSS program are as follows.

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- The Implementation of a Low-Light-Level TV System: A low-light-level TV system, as discussed in Volume III, offers the possibilities of providing augmented contrast in difficult target viewing situations, such as dusk viewing, or atmospheric obscuration. Design study and a decision should be made supporting this extension.

- Two-Man Operation: A two-man operation would be possible with the PTS, by the addition of a second eyepiece or by use of the low-light-level TV system mentioned above and appropriate controls. In either case, one man could deal with the acquisition task, and another with the detailed tracking and photographic elements, thus increasing the rate of target acquisition. Detailed ramifications of this two-man operation have not been traced throughout the whole IVSS system, and study to define these from an analytic design point of view is required. It is proposed that this approach might well optimize in-space data gathering on both acquisition and tracking tasks. Fortunately, the requirements for double scanning heads facilitates the operation.

- Combined Experiments: There are several possible combined experiments using multiple sensors. Particularly, ESDE/IVSS experiments consisting of cueing one sensor by the other would seem to be fruitful. These combined experiments, which combine P-3 and P-4, require detailed study in order to determine their suitability. First analyses indicate that some interconnection will be required between the systems, especially in the display and control area, but that they can support such combined usage at a procedural level.

7.0 Future Plans

A major output of the study program was the development of plans (suitable for Air Force program planning) which reflect the management requirements of the 375 series manuals, and reflect the special technical and production requirements of the IVSS subsystem.

7.1 Phase I Plans

A statement of work and necessary equipment specifications for the issuance of a Request for Proposal for Phase I are presented in Volume V. Key features of this RFP and the program plan associated with its implementation are included in this section.

7.1.1 Phase I Tasks

The main elements of Phase I are concentrated in two general areas: system engineering activities necessary to complete the design and provide basic data regarding the IVSS subsystem; and the initiation of appropriate management groups in anticipation of Phase II and to generate necessary documentation. Figure 7-1 shows the main elements and key milestones of the Phase I activities. The obvious emphasis on the systems engineering tasks is shown by the interrelationship of these activities with reporting requirements.

The systems engineering program consists of basically a two-segment operation. The first segment, 2 months duration, consists of preliminary configuration of the equipment design in parallel with systems studies, analyses, simulations and experiment definition tasks needed to finalize the design criteria, culminated by a detailed preliminary design review. A final revision of the design criteria systems requirements and functional requirements will be made during the second segment, also 2 months duration. Important design problems and results of systems studies will be correlated.

The simulation program will concentrate on those design simulations required for final validation of alternative equipment concepts. These simulations, undertaken in parallel, will refine knowledge of the ability of man to perform the tasks required for P-1, P-2, and P-3, and will concentrate on aiding systems to enhance the precision of human tracking capability and validation of the data-reduction techniques.

The four management groups to be formed for Phase I, in compliance with AFSCM 375 series in addition to engineering are:

    (1) Program Control Management

    (2) Configuration Management

    (3) Procurement and Production Management
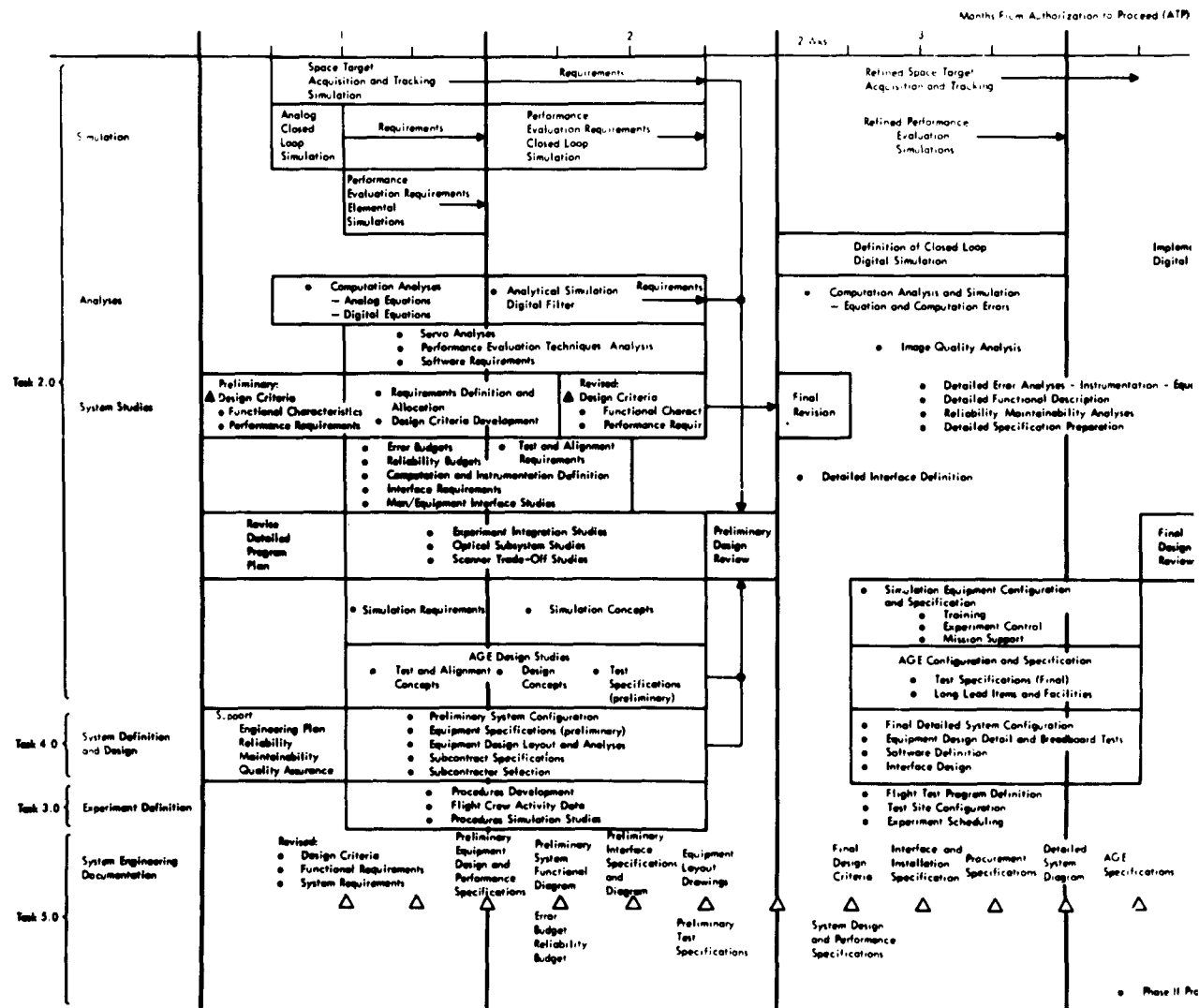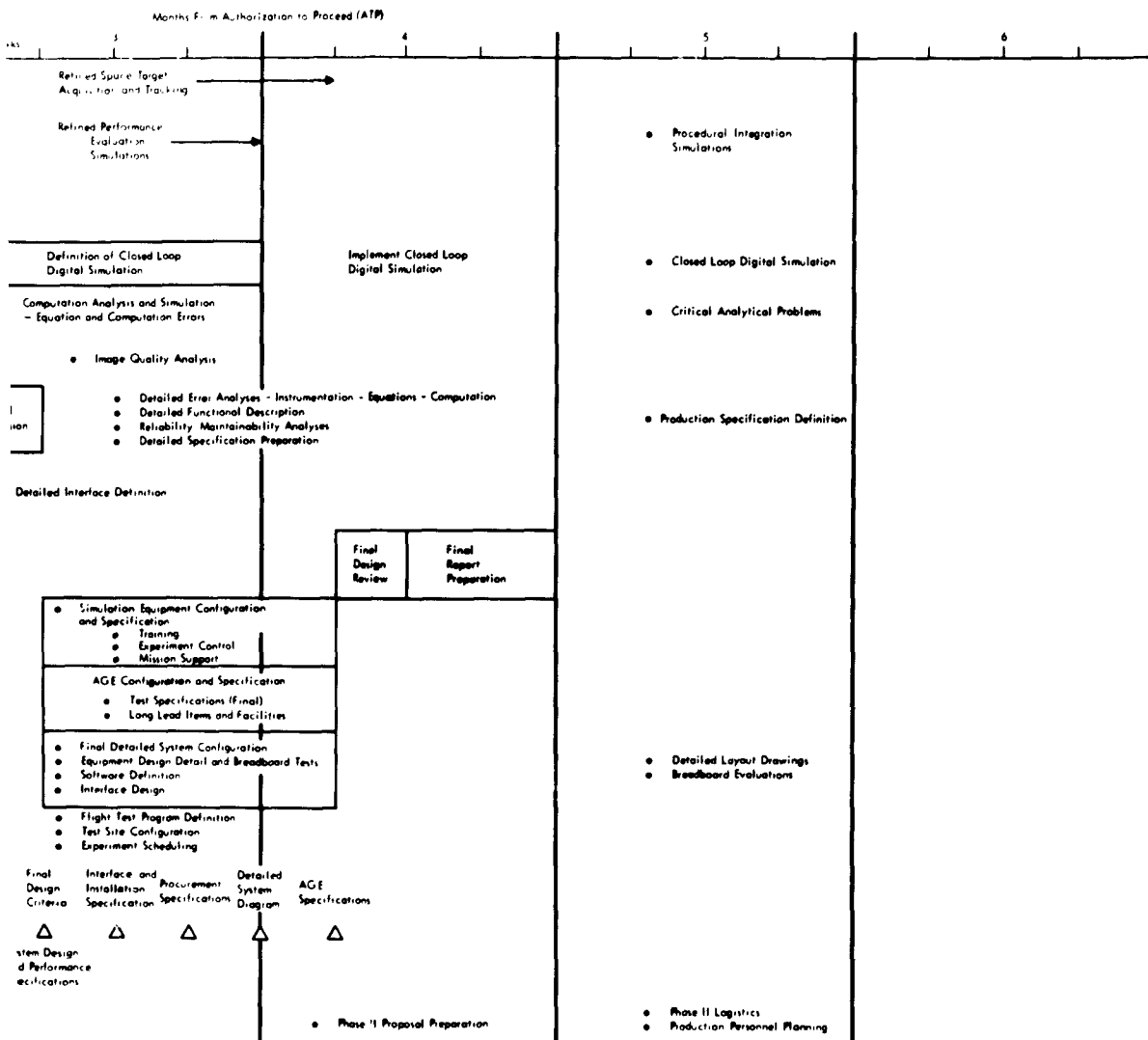
    (4) Test and Employment Management.

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Secret

Figure 7-1. IVSS Engineering Schedule

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Secret

3   4   5   6

iks

Retined Spare Target
Acquisition and Tracking

Refined Performance
    Evaluation
    Simulations

● Procedural Integration
   Simulations

Definition of Closed Loop
Digital Simulation

Implement Closed Loop
Digital Simulation

● Closed Loop Digital Simulation

Computation Analysis and Simulation
— Equation and Computation Errors

● Critical Analytical Problems

● Image Quality Analysis

● Detailed Error Analyses - Instrumentation - Equations - Computation
● Detailed Functional Description
● Reliability Maintainability Analyses
● Detailed Specification Preparation

● Production Specification Definition

Detailed Interface Definition

Final Design Review	Final Report Preparation

● Simulation Equipment Configuration
   and Specification
      ● Training
      ● Experiment Control
      ● Mission Support

AGE Configuration and Specification

   ● Test Specifications (Final)
   ● Long Lead Items and Facilities

● Final Detailed System Configuration
● Equipment Design Detail and Breadboard Tests
● Software Definition
● Interface Design

● Detailed Layout Drawings
● Breadboard Evaluations

● Flight Test Program Definition
● Test Site Configuration
● Experiment Scheduling

Final Design Criteria	Interface and Installation Specification	Procurement Specification	Detailed System Diagram	AGE Specifications
△	△	△	△	△

stem Design
d Performance
ecifications

● Phase II Proposal Preparation

● Phase II Logistics
● Production Personnel Planning

7.1.2 General Information Regarding Phase I

The IVSS Phase I Program Plan shows the need for continual systems engineering, the requirement for early implementation of 375 series management programs, and the requirements for an extensive simulation program to define the in-space experiments. Equipment integration activities begin during Phase I on the basis of common use of many of the experimental subsystems. The IVSS provides a possible focal point for this integration. The Air Force should consider a very early implementation of some of the segments of this plan, such as simulation and systems design, to minimize tight schedule risks.

7.2 Intermediate Phase Activities

The 2-month intermediate period of activities has been defined to keep a hard core of contractor personnel working and progressing in the program to eliminate discontinuities between Phase I and Phase II. Also, the intermediate phase allows the performance of those activities suitable for minimizing risks or more extensive design activities. This intermediate period is an area in which the skill mix can be broadened and the program management will concentrate on the delineation and refinement of all plans.

Systems engineering will concentrate on generating detailed layouts of the equipment, generating appropriate production level specifications, and resolving outstanding problem areas. Simulation will continue, with a shift in emphasis toward preparation for detailed experiment integration and personnel training. Interface studies will be pre-eminent in the experiment integration activities.

This intermediate period should be considered more than just a "keep alive" program. The definition of high risk areas during Phase I and the implementation of corrective engineering and management activities can lessen the risk inherent in the short development program.

7.3 Phase II Plans

Phase II, the acquisition phase of the equipment, is oriented toward the development, qualification, and delivery of the contractual minimum of two qualified flight items and three support items. All appropriate tasks, program planning; AVE development and delivery, AGE development and delivery, supporting programs of reliability, quality assurance, maintainability, safety, personnel subsystems, and value engineering will be performed.

7.3.1 Tasks

Generally, the emphasis will be on an initial engineering design program encompassing 2 to 3 months providing a design engineering inspection late

in 1965. Initial test models of the system will be built to an engineering level, emphasizing functional identity but with the relaxation on exact form factor to facilitate early qualification. Fabrication of the flight units will begin almost simultaneously with testing of the item. The master schedule of system development (Figure 7-2) and system utilization (Figure 7-3) shows:

(1) The supply of two qualified flight units and three ground support units. The progressive use of AGE to provide internal qualification and subsequent delivery to AMR is also shown.

(2) An 18-month Phase II program resulting in the delivery of all units by the end of the program.

(3) Simultaneous delivery of AGE and deliverable flight units.

(4) The requirement for one non-flight qualified set of AVE with appropriate AGE to be delivered to the vehicle integration facility in addition to the delivery of the five units above. (This is an assumption, reflecting the desirability of a vehicle integration model.)

(5) A 6-month integration and ground test period for each flight model AVE.

(6) The use of one set of nonqualified flight items for experiment integration and control at IBM.

(7) A requirement for sensor environment simulators to support whole mission training.

7.3.2 Critical Areas

The program laid out in the planning charts represents one which has the following inherent risks:

(1) The limitation of qualified flight AVE to two pieces of equipment does not provide for a backup for the second manned flight.

(2) Qualification cannot be completed without overlapping the development of the first flight vehicle, thereby creating difficulty in making mandatory changes.

(3) Long leads necessary to set up and calibrate the necessary alignment tools and fixtures may make it necessary to deliver the first flight articles with somewhat less accuracy than predicted.

The basic planning assumptions should be studied to minimize these various risks.
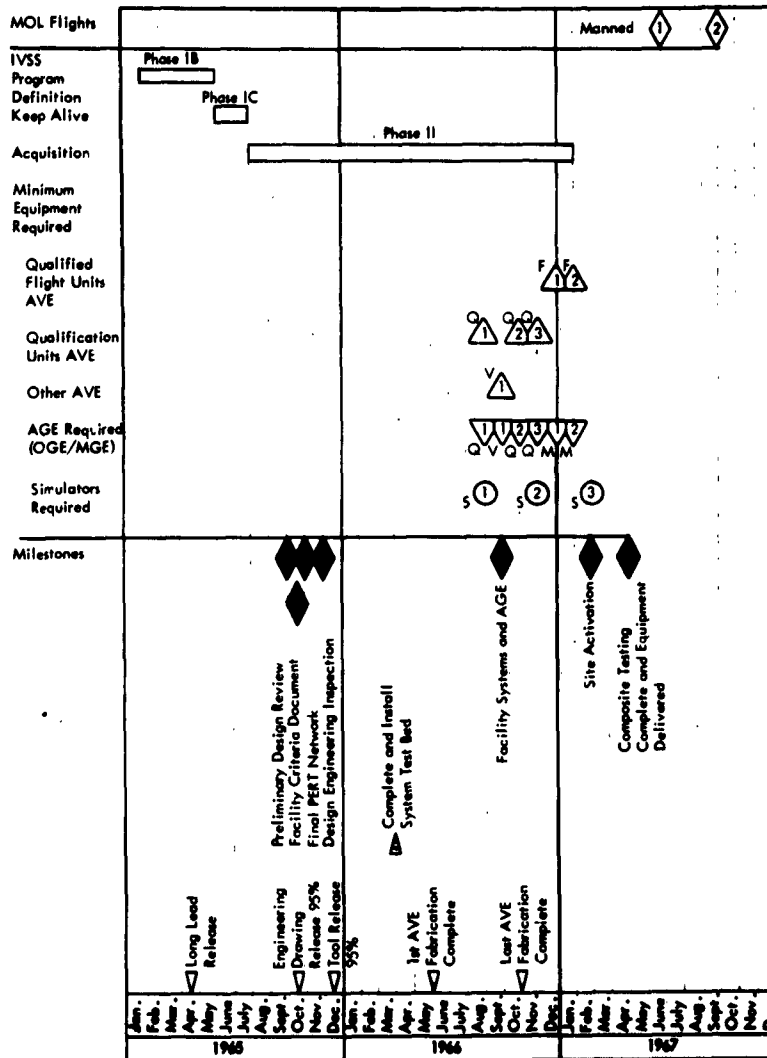
Figure 7-2. Phase II Schedule

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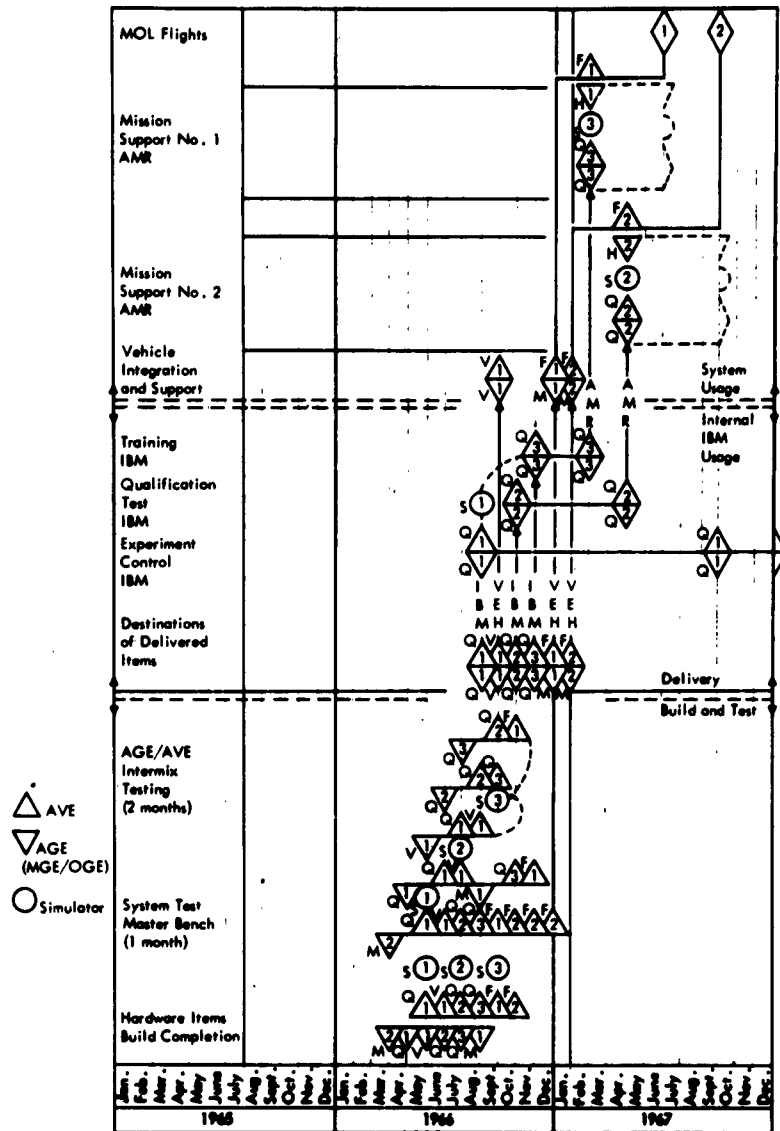
Figure 7-3. System Utilization

7.3.3 Phase II General Information

The Phase II program plan shows that the development program for IVSS contains some risk because of the tight time schedule.

There seems to be very little risk, however, associated with the requirements for technological advances. A detailed review by the Air Force of the assumptions related to each of the subsections will provide possible schedule relief.

7.4 Immediate Action Recommendations

- The use of nonqualified items for training equipment and simulations. This would result in a savings in equipment and time.
- Consider use of the interim 2-month period to start critical activities and long-lead procurements. This would relieve much of the risk imposed by tight schedules.
- Implement subsequent phases of the IVSS program to minimize risk of missing scheduled launch dates.

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Appendix

Preliminary Performance and Design

Requirements Specifications

Exhibit 1

```
1   ┌─────┐
    │ MOL │
    └──┬──┘
       │
   ┌───────────┬──────────────┬──────────┬───────────┬───────────┐
┌──┴────────┐┌─┴──────────┐┌──┴──────┐┌──┴──────┐┌───┴──────┐
│Launch Vehicle-││Re-entry    ││Vehicle  ││Ground   ││Integrated│
2 │Titan IIIC  ││Vehicle-Gemini││         ││Support  ││Experiment│
│           ││Blue        ││         ││         ││          │
│     Martin ││        MAC ││    DAC  ││   USAF  ││      IC  │
└───────────┘└────────────┘└─────────┘└─────────┘└──────────┘
```

2a (P1, 2, 3 : P4, 6 ──

```
3   ┌──────┐
    │ IVSS │
    │ AVE  │
    │  IBM │
    └──┬───┘
```
                                                    Technical

                                                    Inputs

```
4  ┌──────────┐┌──────────┐┌──────────┐┌──────────┐┌──────────┐┌──────────┐
   │Pointing and││Recording ││Displays  ││Star-     ││Experiment││Power     │
   │Tracking  ││Camera    ││and       ││Tracking  ││Evaluation││Supply    │
   │System    ││System    ││Controls  ││System    ││System    ││Subsystem │
   │      IBM ││     TEK  ││     IBM  ││     GFE  ││     IBM  ││     IBM  │
   └────┬─────┘└────┬─────┘└────┬─────┘└────┬─────┘└────┬─────┘└──────────┘
```

4a (Telescope Sys.)   (Frame Camera)   (Console)   (Trackers (2))   (Film Comparator)

    (Tracking Scan.)   (Cine Camera)   (Briefing Unit) (Interface)   (Film Processor)

    (Acq. Scan.)   (Data Block)   (Film File)

    (PTS Interface)   (Film Viewer)

    (VET)   (Interface)

                                          (Time Ref. Unit)

IVSS Basic Program Breakdown Structure

Integrated
Experiment
IC

Technical
Inputs

IVSS
Simulators
IBM

COGE
MGE
IBM

Experiment
Evaluation
System

Power
Supply
Subsystem
IBM

AVE
Software
(Programs, etc.)

Electrical
Simulators

Task/Design
Simulators

Optical
Equipment
Attachments

Film Comparator

Film Processor

Space Sim.

Ground Sim.

Servo Mock-up

Scan. Heads

LEGEND

Prime CEI's (AFSCM 375-1, Exhibits I/II,
System Specifications)

Subsystem CEI's (Exhibit II)

Inv. Equipment Req.
(Exhibit V)

Exhibit II

Specification No. <u>IBM IVSS--1.</u>0

PERFORMANCE AND DESIGN REQUIREMENTS

FOR THE

IMAGE VELOCITY SENSOR SYSTEM (IVSS)

GENERAL SPECIFICATION FOR

Basic Approved By_____   Basic Approved By_____
              Preparing Agency   System Program Agency

Date _____   Date _____

1.0   SCOPE

This specification establishes the performance, design, development, and test requirements for the Image Velocity Sensor Subsystem (IVSS). All elements and contract end items of the IVSS shall conform to the requirements delineated herein.

1.1   DESCRIPTIVE TITLES

Orbital, high-accuracy, image velocity sensor system, primary equipment consisting of a direct viewing, pointing and tracking scope with coupled cameras.

2.0   APPLICABLE DOCUMENTS

The following documents, of the exact issues shown, form a part of the specification to the extent specified herein. In the event of conflict between documents referenced here and other detail content of sections 3, 4, 5, and 10, the detail requirements of sections 3, 4, 5 and 10 shall take precedence.

System Program Documents

Specifications

MIL-E-5400	Electronic Equipment, Aircraft, General Specification for
MIL-E-6051	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft
MIL-S-38130	Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements For

Standards

MIL-STD-143	Specification and Standards Order of Procedure for the Selection of
MIL-STD-454	Standard General Requirements for Electronic Equipment

Bulletins

ANA Bulletin No. 400   Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents

3.0   REQUIREMENTS

3.1   PERFORMANCE

The IVS system shall permit assessment of man's capability to track with line of sight angular determination to an accuracy better than 0.2 percent. The system shall be designed to provide accurate data regarding the angles and angular velocity of a target line-of-sight with respect to the spacecraft. The angular rate data shall be used to apply the necessary corrective motion to slow down or immobilize the target image for visual inspection and recording.

3.1.1   PERFORMANCE CHARACTERISTICS

The IVSS shall operate reliably and satisfactorily for a period of up to 1 month in the MOL spacecraft. The system will be subjected to launch environments and sustained orbital environments during this period.

The system shall provide an acquisition and tracking telescope, with coupled cameras, which, when used with ancillary equipment, shall:

(1)   Evaluate man's performance in acquiring and tracking preassigned ground targets to an accuracy compatible with requirements for precise image velocity determination.

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(2)   Evaluate man's ability to acquire and track satellite targets both for providing precise image velocity determination in fly-by maneuvers and for providing rendezvous guidance.

(3)   Evaluate man's ability to scan, acquire, track, and examine land and sea targets of opportunity.

The design of the IVSS shall allow for operation in degraded modes in the event of a non-catastrophic failure in any part of the system. There shall be provisions for limited maintenance on the system, such as replacement of servo amplifiers, display decimal wheels, lights, etc. There shall be annunciators to indicate if and when any major part of the system fails. Provisions shall also be made for alignment, calibration, and checkout of all subsystems prior to and during IVSS use for acquiring and tracking targets.

3.1.1.1   Operational

3.1.1.1.1   Employment

The system shall interface with the following **MOL** systems:
- Digital computer and auxiliary tape system.
- Digital command system.
- Telemetry system.
- Attitude reference system.
- Attitude control system.
- Environmental control system.
- Voice communication system.

During the scanning, acquisition, and tracking process, the digital computer shall be used to solve all IVSS equations; in addition, the computer shall command initial pointing angles to the telescope, control t..e cameras, and control vehicle attitude.

The digital command system shall supply **MOL** orbit ephemeris, time updates, initial space target ephemerides to the IVSS, and, if requested, pointing angles for the telescope.

The telemetry system shall record all sampled data accrued during the IVSS experiments, including alignment and calibration data.

The attitude reference and the attitude control systems will be used to indicate and control **MOL** spacecraft attitude and attitude rates prior to and during the pointing and tracking experiments.

The environmental control system shall be used to maintain all IVSS subsystems at proper temperatures, etc.

The voice communication system shall be used by the astronaut to tape-record his verbal comments during use of the IVSS for later transmission to a ground site.

The **MOL** spacecraft, which will carry the IVSS, will operate at an orbital altitude of 100 to 160 n mi. with an inclination less than 40 degrees. The error in knowledge of **MOL** altitude will be $\pm$ 3 n mi (3σ), and the mean attitude error will be 0.25 to 0.30 degree.

3.1.1.1.2 Deployment

The IVSS shall be completely assembled and checked out at the Integrating Contractor's facility. It shall then be disassembled, shipped to Cape Kennedy and integrated with the MOL system, where it will undergo final check-out.

3.1.1.2 Logistics

The system shall be logistically supported in its entirety by the Integrating Contractor. The types and number of spares of each subsystem to be produced will be defined when reliability data become available for these subsystems.

3.1.2 System Definition

3.1.2.1 System Engineering Documentation

System-level functional schematics are shown in Figures 3-1 and 2. A system block diagram is shown in Figure 3-3.

Figure 3-1 Top-Level Functions

3.1.2.2 System Segment/Contract End Item List

There shall be seven system segments/contract end items:

(1) Pointing and tracking scope.

(2) Recording cameras.

(3) Displays and controls.

(4) Startracker.

(5) Experiment evaluation system.

(6) Power supply.

(7) Aerospace Vehicle Equipment (AVE) software

A CEI specification tree is shown in Figure 3-4.

3.1.3 Operability

3.1.3.1 Reliability

The reliability requirements for the IVSS shall be 0.932 probability of success for a 60-hour mission. This mission time is based on approximately 45 hours allocated for performance of the experiments in orbit; the additional 15 hours result from boost stress. The probability of mission success without the startracker shall be 0.943; probability of mission success without the visual evaluation tracker (VET) shall be 0.949.

The reliability of the system in a degraded mode of operation shall be greater than the reliability in a primary mode, i.e., reliability may go up to 0.97 in a degraded mode.
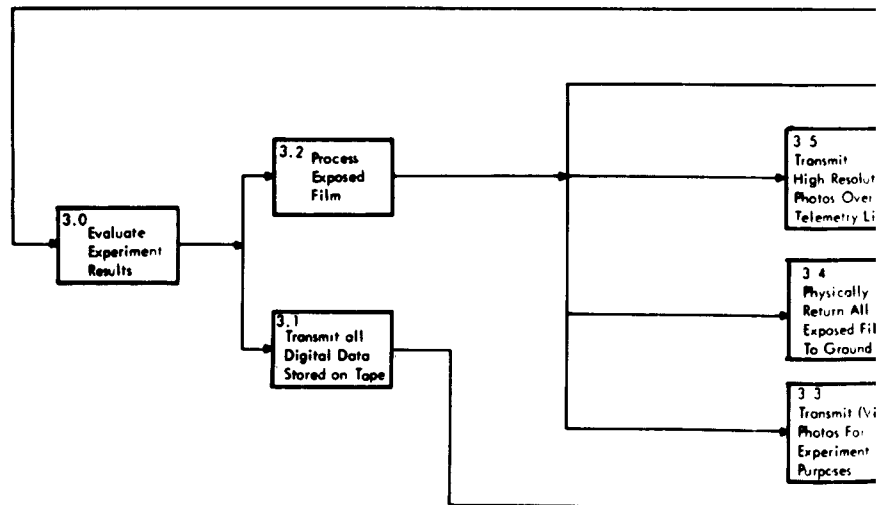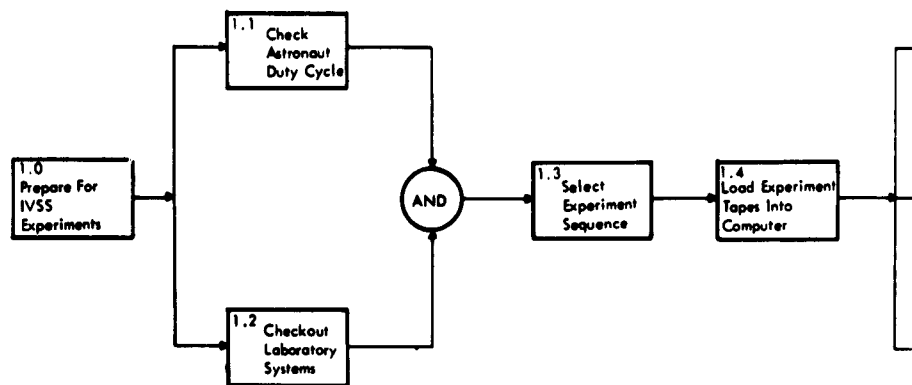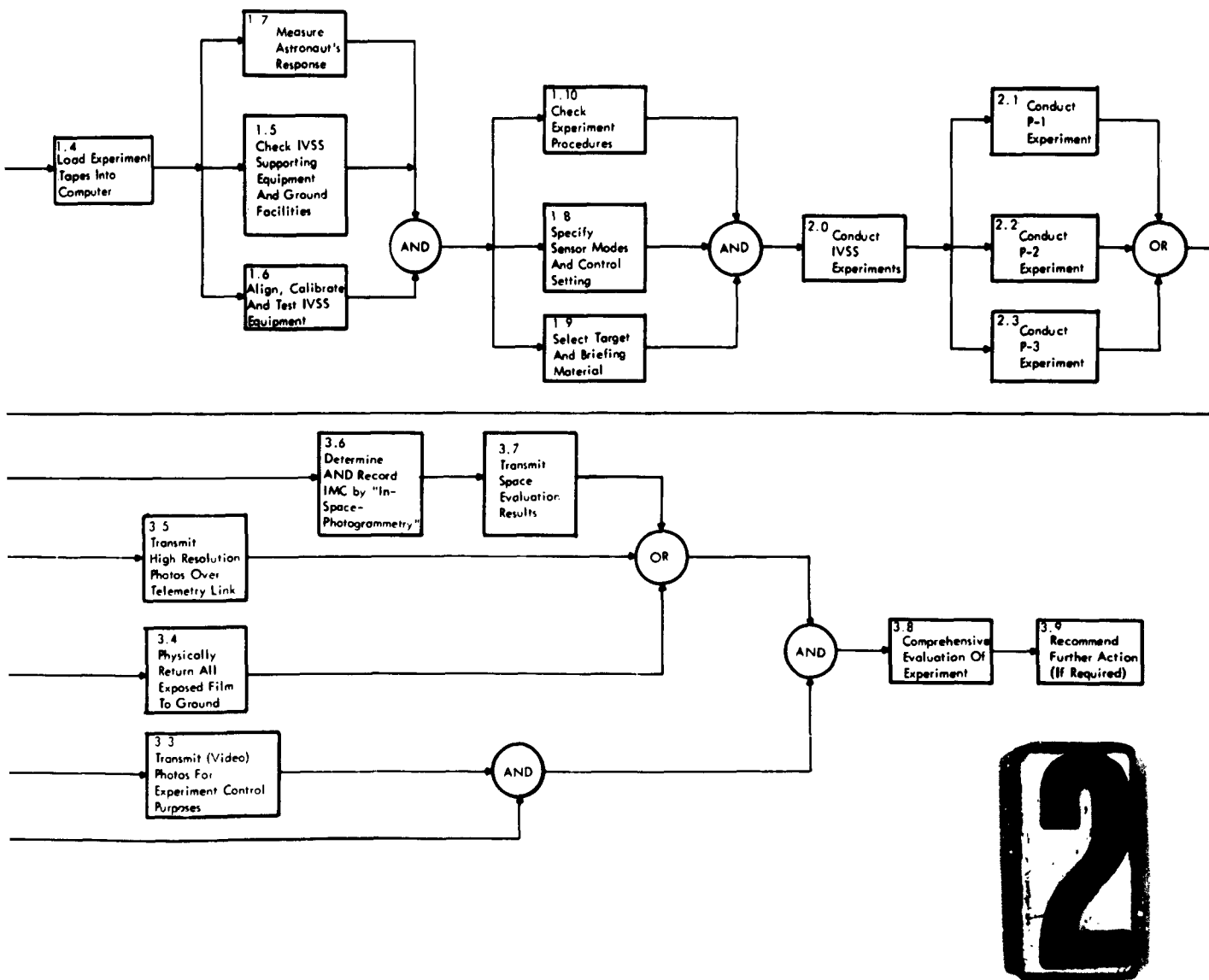
Figure 3-2. Second-Level Indenture Functions

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IVSS EXPERIMENT EQUIPMENT

Spacecraft
28 VDC

Power
Supply
System

Regulated &
Unregulated
Power to all
IVSS Equipments

Visual
Evaluation
Tracker

Film
Processor

On-Off
Film Drive | Shaft
Angles

Servo
Drive

Zoom
Drive

Attenuation, Magnification,
Filters, Reticle, Polarizer

Pointing
&
Tracking
Scope

Acquisition
Scanner

Tracking
Scanning

Servo
Drive

Gimbal
Angles

Film
Drive

Frame
Cameras

Cine
Camera

Servo
Drive

Speed

Shutter
Opening

Star Tracker
(2)

Star Tracker
Interface
Unit

Angle
Interrogate
Angle
Commands

PTS Electronic Interface Unit

Pointing Angle &
Commands, Camera
Controls

Hand
Control
Signals,
Time

Briefing Commands
Console Data

Display & Control
Electronic Interface Unit

Clock | Time
Updates

Analog
Decimal Wheels,
Discretes

MISSION CONTROL CENTER

Time
Reference
Unit

Time

Displays & Controls
Console

IVSS
Simulator

Displays
&
Control

Briefing
Material &
Film File

Shaft
Angles

Film
Viewer

Hand
Control

Computer

Film
Comparator

Briefing
Presentation
Unit

Communication Link

Figure 3-3. Interfaced IVSS-MOL Block Diagram
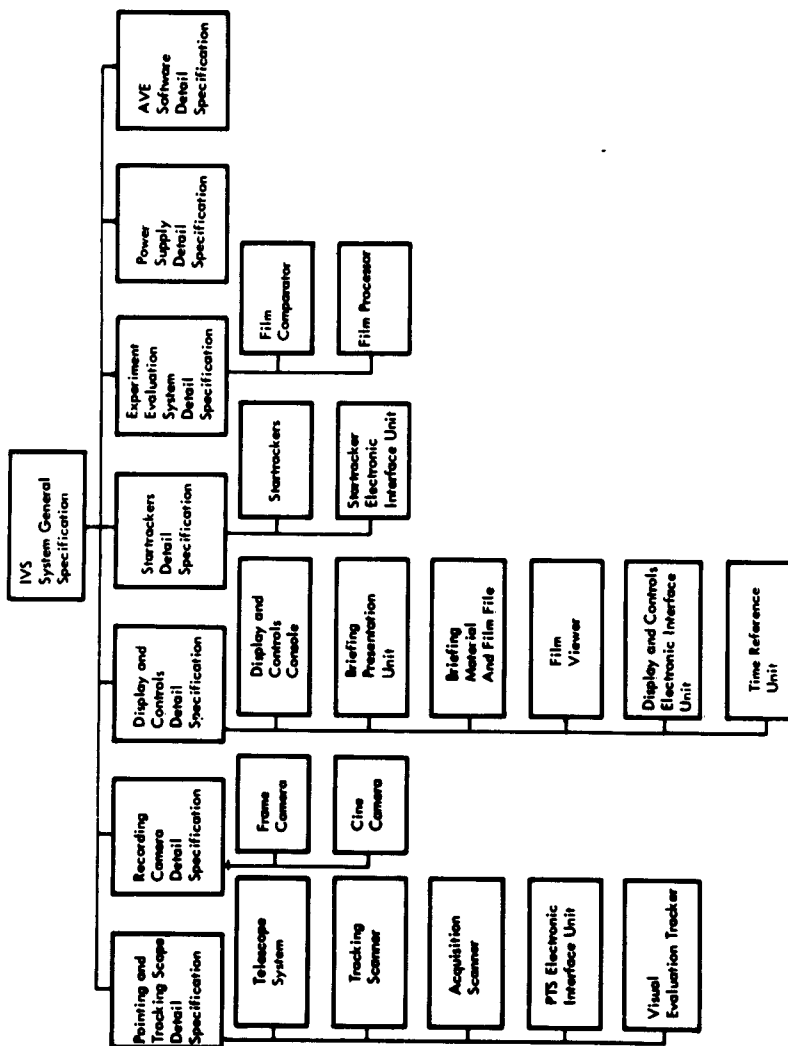
Figure 3-4. CEI Specification Tree

The following table gives the breakdown MTBF of the IVSS segments:

		MTBF (hours)
(1)	Pointing and tracking scope	2,500
(2)	Recording cameras	11,800
(3)	Displays and controls	2,000
(4)	Startrackers	5,000
(5)	Experiment evaluation	28,500
(6)	Power supply	25,000

3.1.3.2 __Maintainability__

The IVSS shall provide for scheduled calibration, alignment and check-out at least once per 24-hour period after the system is initially turned on in orbit. This scheduled maintenance period shall last 15 minutes.

The system mean-time-to-repair shall be no greater than 1.3 hours.

3.1.3.2.1 __Maintenance Requirements__

Maintenance in orbit shall be restricted to removal and replacement of failed units; there will be no provisions made for detection of malfunctions to the component level except for critical components, e.g., pointing and tracking telescope scanner servo motors.

3.1.3.2.2 __Maintenance and Repair Cycles__

Scheduled maintenance periods shall be as specified in paragraph 3.1.3.2.

3.1.3.3 __Useful Life__

The intended operation service life of this system as a system is 30 days in earth orbit. Anticipated time between integration of the IVSS for system check-out and the time this system is launched in the MOL spacecraft vehicle will be approximately 6 months.

3.1.3.4 __Natural Environment__

The system must be designed to operate satisfactorily in the projected MOL environment. Temperature, humidity, and atmospheric pressure environments found during normal transportation, handling and storage shall no adversely affect system operation after it has been reacclimated to the MOL projected environment.

3.1.3.5 __Transportability__

All system elements shall be air-transportable. Maintenance ground equipment shall also be designed to be air transportable.

3.1.3.6 __Human Performance__

The IVSS evaluation segment shall be designed such that man can evaluate, in space, if the IMC requirement of 0.2 per cent is achieved.

3.1.3.7 __Safety__

Safety requirements shall conform to MIL-S-38130.

3.2 SYSTEM DESIGN AND CONSTRUCTION STANDARDS

3.2.1 General Design and Construction Requirements

3.2.1.1 Selection of Specifications and Standards

Selection of specifications and standards shall be as indicated in paragraph 2.0 above.

3.2.1.2 Materials, Parts, and Processes

Materials, parts, and processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the best commercial quality of the lightest practicable weight, entirely suitable for the intended purpose and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

3.2.1.3 Standard and Commercial Parts

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3.2.1.4 Moisture and Fungus Resistance

3.2.1.4.1 Humidity

The equipment shall withstand the effects of 100 percent humidity environments, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operations, short-time operations, and in a nonoperating condition.

3.2.1.4.2 Fungus

The requirements for fungus-inert materials shall be in accordance with **MIL-STD-454**.

3.2.1.5 Corrosion of Metal Parts

Corrosion resistance including electrolytic corrosion protection shall conform to **MIL-E-5400**.

3.2.1.6 Interchangeability and Replaceability

Interchangeability shall be in accordance with **MIL-STD-454**.

3.2.1.7 Workmanship

Workmanship shall be in accordance with **MIL-STD-454**.

3.2.1.8 Electromagnetic Interference

The electronic environment of the system shall be determined to be interference free, i.e., the equipment shall function properly in the electromagnetic environment created by other systems and equipment that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with **MIL-E-6051**.

3.2.1.9 Identification and Marking

Identification and marking of this equipment shall conform to **MIL-E-5400**.

3. 3   PERFORMANCE ALLOCATIONS

3. 3. 1   POINTING AND TRACKING SCOPE SYSTEM SEGMENT/CONTRACT END ITEM

3. 3. 1. 1   ALLOCATED PERFORMANCE AND DESIGN REQUIREMENTS

The requirements for the telescope portion of the PTS are:

● Design that permits ease of equipment alignment and calibration and which allows equipment testing prior to experimental use.

● Sufficient visual resolution to allow position fixing by the astronaut.

● Resolution and field of view which allows either acquisition of a preselected target with the projected errors in initial pointing, or acquisition of targets of opportunity.

● Sufficient visual resolution to allow tracking of targets.

● Aperture size and resolution consistent with camera requirements.

● Photo-optical resolution compatible with evaluation of image motion compensation, based on restrictions placed on minimum sample times for this evaluation.

● Visual resolution which allows for classification of targets.

● Safety features, such as sun sensors and sun shades, which prevent damage to the telescope.

The Servo Scanner (acquisition and tracking) requirements are:

● Alignment and calibration to a known vehicle and/or celestial reference.

● Provision for testing commanded rate response.

● Implementation of pointing commands.

● Automatic scan capability which allows for acquisition of a variety of targets.

● Tracking smoothness.

● Dynamics permitting acquisition and tracking for both ground and space targets.

● Provisions for determining line-of-sight rates.

● Extreme reliability in hard vacuum conditions.

● Capability of being commanded manually and/or automatically.

The requirements of the Visual Evaluation Tracker are:

● Attach to the telescope.

● Present to operator a number of images that simulate tracking problems.

● Evaluate operator vision and tracking ability under conditions present at time the VET experiment is performed.

The requirements of the PTS electronic interface unit are:

● Provide for interconnection of the system segment.

● Contain all electronics for the system segment.

3. 3. 1. 2   FUNCTIONAL INTERFACE

The pointing and tracking telescope must accept pointing angles from the computer and hand-control. Discrete commands (such as filter, polarization, attenuation, and focus) will be accepted from the display and control console. The telescope must supply shaft encoder outputs to the computer to show its relative position with respect to the MOL spacecraft.

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3.3.2   RECORDING CAMERAS SYSTEM SEGMENT/CONTRACT END ITEM

3.3.2.1   ALLOCATED PERFORMANCE AND DESIGN REQUIREMENTS

The recording cameras,which produce "hard copy" experimental data, have the following requirements:

- Have provisions for alignment, calibration and testing.
- Record the astronaut's performance during the target acquisition phase.
- Record the tracking of targets, providing sufficient photo-optical resolution to permit evaluation of image motion compensation photogrammetrically.
- Have sufficient resolution to allow verification of the observer's classification of targets.
- Have sufficient film available to comprehensively evaluate the man's performance.

3.3.2.2   FUNCTIONAL INTERFACES

The camera must accept shutter speed, shutter opening, filter, and film drive commands from the computer and display and control console. In addition, a data block must be provided in a corner of each photograph for displaying pertinent data, such as frame number, time, etc.

3.3.3   DISPLAY AND CONTROL SYSTEM SEGMENT/CONTRACT END ITEM

3.3.3.1   ALLOCATED PERFORMANCE AND DESIGN REQUIREMENTS

The display and control console must provide:

- PTS control and display of pointing angles.
- Camera filter, frame rate, and exposure control: display of frame number, film type, and exposure time.
- PTS mode and function control (ground or space target, update).
- Track mode, target select, and scan mode select switches.
- Mode select (PTS primary, PTS alternate, VET).
- Display of target parameter, time to target, and target track time.
- Film evaluation projector control.
- Voice tape control: display of tape remaining and recording level.
- Computer data insert and display panels.
- Hand control for the PTS.
- Malfunction test panel for IVSS equipment.
- Mode switches for aligning, calibrating, and testing IVSS subsystems.
- Experiment sequence mode switch.
- VET control.
- Briefing presentation unit control.
- Auxiliary tape control.
- Attitude control system.
- PTS magnification, attenution, filter, polarization, reticle, and focus.
- Space target minimum line-of-sight distance.
- DCS update parameter (sample only).
- Photograph tag data (frame, f number, pertinent sensor, and console data).

- Calibration data (PTS commanded rate response, etc.).
- Unit malfunction indicators.
- Crew member's voice depicting his impressions of target characteristics or other data.

The briefing presentation unit should:

- Present a briefed target in the same perspective as the line target.
- Have magnification capability for inspection of the target area in the briefing film.

The briefing material and film file should provide for storage of exposed and unexposed film and film processing material.

The film viewer requirements are presentation of briefed and photographed targets on a screen on the console for astronaut interpretation.

The display and control electronic interface unit will hold most of the electronics for the display and control system segment. Included in this will be a programmable formatter for the display wheels on the console, etc. The interface unit will also provide for all interconnections, such as to the computer and the PTS interface unit.

The time reference unit requirements are:

- Accurate elapsed time between photographs (good short-term stability) for computing image motion compensation.
- Accurate Greenwich Meridian Time (good long-term stability) for determining **MOL** ephemeris.

3. 3. 3. 2   Functional Interface

The time reference unit shall accept time updates via the digital command system from the ground. The console provides the man-IVSS interface. The briefing presentation unit shall accept computer commands to its film drive for briefing film orientation.

3. 3. 4   Startracker System Segment/Contract End Item

3. 3. 4. 1   Allocated Performance and Design Requirements

The startracker requirements are:

- Capability to acquire and track two stars, 2. 0 magnitude or brighter.
- Read out telescope gimbal angles.
- Position to any desired angle in its range within 1 arc minute.

3. 3. 4. 2   Functional Interface

The startracker must accept positioning commands from the computer. It must indicate star presence by sending a discrete signal to the computer when it acquires a star.

3. 3. 5   Experiment Evaluation System Segment/Contract End Item

3. 3. 5. 1   Allocated Performance and Design Requirements

The experiment evaluation system must have the capability to permit evaluation of:

- Accuracy in alignment and calibration.
- Man's performance during acquisition.

- Man's performance during tracking.
- Man's contribution to image motion compensation.
- Man's ability to detect maneuvering space targets.

The above requirements indicate that the evaluation system must at least be capable of determining, from processed photographs, whether man is accomplishing image motion compensation to 0.2 percent.

3.3.5.2   Function Requirements

The film processor portion of this system must accept exposed film which it then processes without loss of photographic detail.

3.3.6   Power Supply System Segment/Contract End Item

3.3.6.1   Allocated Performance and Design Requirements

The power supply requirements are:

- Operation from input voltages between 18 and 30.5 volts.
- Non-damage during 30 ms high-or low-voltage transients.
- Outputs with regulation of 2 to 5 percent to most IVS equipments, some voltage-sensitive loads requiring 1 percent or better regulation.

3.3.6.2   Functional Interface

The power supply unit accepts d-c power from the prime MOL power supply, and will also interface with the environmental control system for cooling.

3.3.7   AVE Software System Segment/Contract End Item

3.3.7.1   Allocated Performance and Design Requirements

The AVE software system segment requirements are:

- Computer operational and check-out programs for the MOL (and ground) computers for use during IVS system experiments.
- Briefing film and other operator displays.

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION

REQUIREMENTS

CEI NO. 1

POINTING AND TRACKING SCOPE

Basic Approved By _____   Basic Approved By _____
          (Preparing Activity)   (System Program Office or
                                                     Equivalent)

Date _____   Date _____

1.0   SCOPE

This part of this specification establishes the requirements for performance, design, test and quali-
fication of one type-model-series of equipment identified as Pointing and Tracking Scope System Segment CEI
No. 1. This CEI is used to provide the astronaut with the capability of pointing and tracking in two axes within a
near hemisphere, with a wide-and a narrow-field optical system. This CEI is mounted to the space vehicle such
that part of the CEI extends outside the normal vehicle contour and part of it extends into the vehicle to the op-
erator and observer stations.

2.0   APPLICABLE DOCUMENTS

The following documents, of the exact issues shown, form a part of the specification to the extent
specified herein. In the event of conflict between documents referenced here and the detail content of Sections 3,
4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

System Program Documents

Specifications

MIL-E-5400   Electronic Equipment, Aircraft, General Specification for

MIL-E-6051   Electrical-Electronic System Compatibility and Interference Control Requirements for Aero-
nautical Weapon Systems, Associated Subsystems, and Aircraft

MIL-S-38130   Safety Engineering of Systems and Associated Subsystems and Equipment, General Require-
ments for

Standards

MIL-STD-143   Specifications and Standards, Order of Procedure for the Selection of

MIL-STD-454   Standard General Requirements for Electronic Equipment

Bulletins

ANA Bulletin   Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents
No. 400

3.0   REQUIREMENT

The PTS System Segment provides the capability of viewing a near hemisphere. The system shall
be capable of pointing for the acquisition and tracking of terrestrial/space targets.

3.1   PERFORMANCE

3.1.1   Functional Characteristics

The PTS shall provide the following characteristics:

(1) Two-axes pointing capability for acquisition and tracking.

(2) Image projection to two camera stations, operator station, and observer station.

(3) Low magnification for acquisition.

(4) High magnification for tracking.

(5) Line-of-sight orientation.

(6) Visual tests for operator effectiveness.

(7) Continuous alignment calibration.

(8) Sun sensor and shutter for eye protection.

3.2 CEI DEFINITION

The PTS system segment shall be a self-contained structure that attaches to the space vehicle. It shall provide wide- and narrow-field images from within a near hemisphere, and present them in eyepieces for viewing and in cameras for recording.

3.2.1 Interface Requirements

The PTS shall be capable of being digitally controlled and/or operator controlled where all interfaces are of a digital nature.

The PTS system segment as well as its interface with the vehicle shall provide a positive seal of the space vehicle pressure envelope.

Means of alignment of the PTS system segment to the vehicle shall be provided.

3.2.2 Component Identification (N/A)

3.2.3 CEI Subsystem List

The PTS system segment shall consist of the following subsystems:

(1) Dual-field scope

(2) Acquisition scanner

(3) Tracking scanner

(4) PTS electronic interface unit

(5) Visual evaluation tracker

3.3 DESIGN AND CONSTRUCTION

3.3.1 Physical Characteristics

The PTS system segment shall be designed and constructed to adhere to the following physical and electrical characteristics:

Weight - Not to exceed 310 pounds

Volume - Not to exceed 15 cubic feet external to the vehicle; 16 cubic feet internal to the vehicle

Power - The average power required to operate shall be less than 270 watts.

Maximum Dimensions:*

Internal - 6 feet in direction of the vehicle axis (length)

3 feet radially (height)

1 foot perpendicular to the axis (width)

External - 1 foot protrusion

3.3.2 Selection of Specifications and Standards

Selection of specifications, standards, and publications shall be made for ANA Bulletin No. 400 wherever practicable. However, engineering judgement must be exercised to utilize the documents which will allow selection of parts and processes that are commensurate with the function, environment, quality, and re-liability requirements of this equipment.

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* Not including VET, VAZP, wide-field camera, auxiliary eyepiece, and cine camera.

MIL-STD-143 shall be used as a guide for selection and precedence of the specifications utilized.

All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3.3.3   Materials, Parts, and Processes

Materials, parts, and processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein, Materials and parts not c.vered by applicable specifications shall be of the best commercial quality, of the lightest practicable weight, entirely suitable for the intended purpose, and readily available. However, only nonflammable materials shall be us3d in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

3.3.4   Standard and Commercial Parts

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3.3.5   Moisture and Fungus Resistance

3.3.5.1   Humidity

The equipment shall withstand the effects of humidity up to 100 percent, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operations, short-time operations, and in a nonoperating condition.

3.3.5.2   Fungus

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3.3.6   Corrosion of Metal Parts

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3.3.7   Interchangeability and Replaceability

Interchangeability shall be in accordance with MIL-STD-454.

3.3.8   Workmanship

Workmanship shall be in accordance with MIL-STD-454.

3.3.9   Electromagnetic Interference

The electronic environment of the system shall be determined to be interference free, i. e., the equipment shall function properly in the electromagnetic environment created by other systems and equipment that must operate in the same location, and the radiated electromagnetic radiation of this system be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with MIL-E-6051.

3.3.10   Identification and Marking

Identification and marking of this equipment shall conform to MIL-E-5400.

3. 4   CEI SUBSYSTEMS

3. 4. 1   Dual Field Scope

This subsystem shall include the wide- and the narrow-field image focusing optics, optical relays, optical switching, oreintation systems, and operator/observer eyepieces.

3. 4. 1. 1   Wide Field Optics

This optical system shall be capable of simultaneously focusing images at the following three locations:

(1) Operator's eyepiece

(2) Observer's eyepiece

(3) Wide- Field camera

3. 4. 1. 1. 1 Field Size

The wide-field optics shall form images representing a 30-degree field of view. Both eyepieces shall have a 45-degree apparent field angle, and at a system magnification of 1. 5X, the real field angle will be 30 degrees. The full 30-degree field shall be a 2. 25-inch diameter image in the film plane.

3. 4. 1. 1. 2 Resolution

The visual and photographic systems shall have an angular resolution of 8 arc sec when viewing a target having a 1. 6:1 contrast ratio (at telescope), with an image motion of 45 arc sec/second and with a background brightness of 1000 foot-lamberts.

3. 4. 1. 2   Narrow-Field Optics

This optical system shall be capable of simultaneously forming images at the following two locations:

(1) Operator's eyepiece

(2) Narrow-field camera

3. 4. 1. 2. 1 Field Size

The narrow-field optics shall form images representing a 3. 6-degree field of view. The real field of view for the visual system will be 2. 6-degrees for 18X magnification and with a 45-degree apparent field eyepiece. The full 3. 6-degree field shall be a 2. 25-inch diameter image in the film plane.

3. 4. 1. 2. 2 Resolution

The visual and photographic systems shall have an angular resolution of 2. 2 arc sec when viewing a target having a 1. 6:1 contrast ratio (at telescope), with an image motion of 45 arc sec/second, and with a background brightness of 1000 foot-lamberts.

3. 4. 1. 3   Operator Eyepiece

This eyepiece shall have an automatic 6:1 zoom system with a 45-degree maximum apparent field and 25-mm to 150-mm effective focal length. The apparent system resolution at the eyepiece shall be a minimum of 1 arc min for all magnifications. The eyepiece shall automatically zoom to the low power when the operator switches from wide field to narrow field.

3. 4. 1. 4   Observer Eyepiece

This eyepiece shall have a manual 6:1 zoom system with a 45-degree maximum apparent field and 25-mm to 150-mm effective focal length. The apparent system resolution at the eyepiece shall be a minimum of 1 arc min for all magnifications.

3.4.1.5   Image Switching

The operator shall, by means of a manual control, be able to select either the wide- or the narrow-field image, without interferring with the images in the observer's eyepieces or the cameras.

3.4.1.6   Image Orientation

Automatic derotation of all eyepiece images shall be provided as a function of angular motion in pitch and roll. All eyepiece images shall have identical orientation. Both camera images shall have identical orientation, but not necessarily derotated.

3.4.1.7   System Reticle

System reticles shall be superimposed on all visual and camera images. The reticle defines the line-of-sight in each of the images. The reticle hue and brightness shall be variable and shall be controllable from the operator's console.

3.4.1.8   Focus

A manually controlled motorized focusing system shall be provided to permit adjustment of the focal distance on the narrow-field system from infinity to 500 feet.

3.4.1.9   Sybsystem Interface

The dual-field scope shall provide mounting surfaces, connectors, etc., that will enable it to accept the remaining CEI subsystems. It shall also provide the structural rigidity required to obtain and maintain the required alignment of the CEI to the vehicle as well as the alignment within the CEI suosystems.

3.4.1.10   Alignment

The static alignment of the line-of-sight of the wide-field to the narrow-field line-of-sight shall be 5 arc min. The alignment of the narrow-field line-of-sight to the mounting pedestal shall be a maximum of 1.5 arc min.

3.4.1.11   Configuration

The placement of the operator's and observer's eyepieces shall take into account a nominal separation between the two persons. The man/machine interface shall be optimized to the greatest extent possible. The position and orientation of the camera mounting surfaces shall be selected such that easy access can be obtained and the following tasks can be performed:

        (1) Change camera

        (2) Focus camera

        (3) Change magazine

        (4) Cnange filter

3.4.1.12   Filters

Three different spectral filters shall be provided for automatic insertion in the optical paths to the eyepieces and two for the cameras. The desired filter shall be selected by remote control from the operator's console.

3.4.1.13   Polarizer

A variable polarizer shall be provided in the paths of the eyepieces. It shall have an in and an out position plus be rotateable through 180 degrees.

3.4.2   Acquisition Scanner

The acquisition scanner shall contain two servo-positioned reflecting elements that direct the line-of-sight of the wide-field optical system in pitch and roll. The roll axis shall be paralled with the space vehicle roll axis, and the pitch axis shall be orthogonal to that axis, with the line-of-sight parallel with the roll axis.

3.4.2.1   Scanning Field

The acquisition scanner shall be capable of pointing the line-of-sight within a near hemisphere defined as the field from nadir to 80 degrees above nadir in all directions.

3.4.2.2   Angular Accuracy

3.4.2.2.1   Pointing Accuracy

The pitch and roll drives of the acquisition scanner shall be slaved to the respective drives of tracking scanner subsystem to dynamic accuracy of less than ±10 arc min.

3.4.2.2.2   Motion Stability

The pitch and roll drives shall be capable of a velocity resolution of 0.5 arc min/second.

3.4.2.3   Angular Velocity

The pointing accuracy shall be maintained for angular rates not to exceed 33.5 degrees per second for fly-by space targets, and 2.5 degrees per second for terrestrial targets.

3.4.2.4   Angular Acceleration

The maximum angular accelerations are:
(1)   Terrestrial Tracking   - 0.07 degree/second^2
(2)   Fly-By Space Tracking   - 12.6 degrees/second^2

3.4.2.5   Optical Quality

The reflecting elements and instability in their support and position shall not degrade the optical quality of the wide-field image beyond tolerance.

3.4.3   Tracking Scanner

The tracking scanner shall contain two servo-positioned reflecting elements that direct the line-of-sight of the narrow-field optical system in pitch and roll. The roll axis shall be parallel with the space vehicle roll axis, and the pitch axis shall be orthogonal to that axis, with the line-of-sight parallel with the roll axis.

3.4.3.1   Scanning Field

The tracking scanner shall be capable of pointing the line-of-sight within a near hemisphere defined as the field from nadir to 80 degrees above nadir in all directions.

3.4.3.2   Angular Accuracy

3.4.3.2.1   Pointing Accuracy

For pitch and roll angles not to exceed ±30 degrees, the following dynamic pointing accuracy shall be maintained:

(1) Terrestrial targets   -   ±10 arc sec

(2) Fly-by space targets   -   ±30 arc sec

3.4.3.2.2   Motion Stability

The pitch and roll drives shall be capable of a velocity resolution of 2 arc sec/second.

3.4.3.3   Angular Velocity

The angular accuracy shall be maintained for the following angular velocities:

(1) Terrestrial tracking rate   -   2.5 degrees/second, maximum

(2) Fly-by tracking rate   -   33.5 degrees/second, maximum

3.4.3.4   Angular Acceleration

The maximum angular accelerations are:

(1) Terrestial Tracking   - $0.07 \text{ degree/second}^2$

(2) Fly-By Tracking   - $12.6 \text{ degrees/second}^2$

3.4.3.5   Optical Quality

The reflecting elements and instability in their support and position shall not degrade the optical quality of the narrow-field image beyond tolerance.

3.4.4   PTS Electronic Interface Unit

The PTS Electronic Interface Unit provides for the interconnection of the PTS system segment to the main computer and control and displays. It shall also contain all the necessary electronics as required by the subsystems of the PTS system segment.

3.4.4.1   Visual Evaluation Tracker (VET Interface)

The PTS Electronic Interface Unit shall provide the following functions for the VET subsystem:

(1) Provide variable speed image drives.

(2) Provide hand control tie-in for IMC.

(3) Record and/or evaluate tracking error function.

(4) Provide for packaging of electronics required for the VET.

3.4.4.2   Tracking Scanner Interface

This subsystem shall provide the following functions for the tracking scanner subsystem:

(1) Provide error signal drives for position and/or velocity control of the tracking scanner.

(2) Provide for packaging of electronics such as the stabilization network, servo amplifier, error detector, encoder electronics, digital-to-analog converter, etc., as required by the tracking scanner.

3.4.4.3   Acquisition Scanner Interface

This interface unit shall provide the following functions for the acquisition scanner:

Provide the same function as provided for the tracking scanner with degraded performance during failure of the tracking scanner.

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3.4.4.4   Dual Field Scope Interface

The PTS interface unit shall provide the following functions for the dual field scope:

Provide for packaging of electronics such as servo amplifiers, and stabilization required for the servos in the telescopic subsystem.

3.4.5   Visual Evaluation Tracker

This subsystem shall present in the operator's eyepiece a number of dynamic images that simulate tracking problems. The purpose of this device is to evaluate the operator's vision and tracking ability under the conditions prevailing at the time the experiment is performed.

3.4.5.1   Interface

The visual evaluation tracker shall attach to the dual-field scope. It shall be capable of interpreting the optical path to the operator's eyepiece, and present the simulated image in place of the scope images.

3.4.5.2   Image Characteristics

The image motion shall be capable of being stabilized in position to $\pm 2/3$ minute of arc at rates varying from 0.5 degree/second to 10 degrees/second.

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Exhibit IV   Specification No. <u>IBM IVSS--1.2</u>

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION

REQUIREMENTS

CEI NO. 2

RECORDING CAMERAS

Basic Approved By_____ Basic Approved By _____
           (Preparing Activity)   (System Program Office or
                                                              Equivalent)

Date _____   Date _____

1.0   <u>SCOPE</u>

This part of this specification establishes the requirements for performance, design, test, and qualification of one type-model-series of equipment identified as Recording Cameras Subsystem, CEI No. 2.

This CEI is used to provide photographs for evaluating results of the IVSS experiments. The equipment required to perform these functions includes a low frame-rate camera, a high frame-rate camera, and instrumentation for recording photographic identification data.

2.0   <u>APPLICABLE DOCUMENTS</u>

The following documents, of the exact issues shown, form a part of the specification to the extent specified herein. In the event of conflict between documents referenced here and the content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

<u>System Program Documents</u>

<u>Specifications</u>

MIL-E-5400   Electronic Equipment, Aircraft, General Specification for

MIL-E-6051   Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystem, and Aircraft

MIL-S-38130   Safety Engineering of Systems and Associated Subsystems, and Equipment, General Requirements for

<u>Standards</u>

MIL-STD-143   Specifications and Standards, Order of Procedure for the Selection of

MIL-STD-454   Standard General Requirements for Electronic Equipment

<u>Bulletins</u>

ANA Bulletin   Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents.
No. 400

3.0   <u>REQUIREMENTS</u>

3.1   <u>PERFORMANCE</u>

This CEI must satisfy the over-all requirements for photographic recording of images used in the evaluation of the IVSS experiments. The camera(s) coupled to the pointing tracking scope (PTS) must be capable of photographic recording at widely varying rates due to the requirements of the various experiments and experiment modes. As a design trade-off compromise of desired frame rates and photographic definition, two cameras, a slow-rate frame camera and a high-rate cine camera are required. Each camera will have a data recording block for recording pertinent evaluation facts of system and vehicle state parameters in the unused corners of the camera formats.

3.1.1   <u>Functional Characteristics</u>

3.1.1.1 <u>Primary Performance Characteristics</u>

The limiting performance characteristics for the PTS-coupled recording camera(s) are the photo-optical resolution limit, film capacity, camera frame rate, and film drives.

3.1.1.1.1 Mechanical Tolerances

For low frequency vibrations (< 50 cps) the equivalent uniform motion in the image plane shall be less than 45 micron/sec. For high frequency vibrations (>50 cps) the amplitude of vibration in the image plane shall be less than 1 micron. The emulsion surface of the film shall be located within 0.0005 inch of the image plane.

3.1.1.1.2 Film Capacity

A performance characteristic of the camera(s) is the capability of accommodating large film loads of 50, 100, or 200 feet.

3.1.1.1.3 Frame Rates

At this point in the CEI definition it is difficult to place specific limits on frame-rate performance requirements. The performance will vary from one frame taken at several second intervals to rates of 60 frames per second.

3.1.1.1.4 Film Drives

The large film loads specified require the modification of film drives of conventional cameras to compensate for the increased inertia of the film on the supply and take-up spools. The camera film transport must be provided with spool drives as well as a film drive so that start and stop characteristics do not degrade camera performance.

3.1.1.2 Secondary Performance Characteristics

Parameters for the PTS-coupled recording cameras which are not necessarily mission critical are the film magazine changing time, the alignment and focusing procedure and time, and the possible environmental characteristics such as maintenance of camera temperature, humidity, and pressure. These parameters are enumerated but are not described quantitatively since these characteristics are a product of the design process. These parameters are yet to be determined. They will be included herein along with the applicable tolerances when they have been determined.

3.1.2 Operability

3.1.2.1 Reliability

Based on the system reliability measure, the MTBF for the combined PTS-coupled recording camera subsystem is 11,800 hours. The frame camera is assessed as more mission critical than the cine camera, and a redundant frame camera will be provided. Component reliability of the two frame cameras and the cine camera will be apportioned to provide the specified subsystem MTBF.

3.1.2.2 Maintainability

Maintenance of the power supply subsystem will be severely limited. Spare parts will be available on a critical component basis only. Therefore, replacement of components shall be as simple as practical, and periodic maintenance requirements shall be kept to a minimum.

3.1.2.2.1 Malfunction Isolation

All malfunction detection and isolation will be accomplished by means of built-in test points and on-board test equipment.

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3.1.2.3   Safety

Safety requirements shall conform to MIL-S-38130.

3.2.1   Interface Requirements

3.2.1.1   Schematic Arrangement

The relationship of the CEI to other equipment is shown in Figure 3-1.
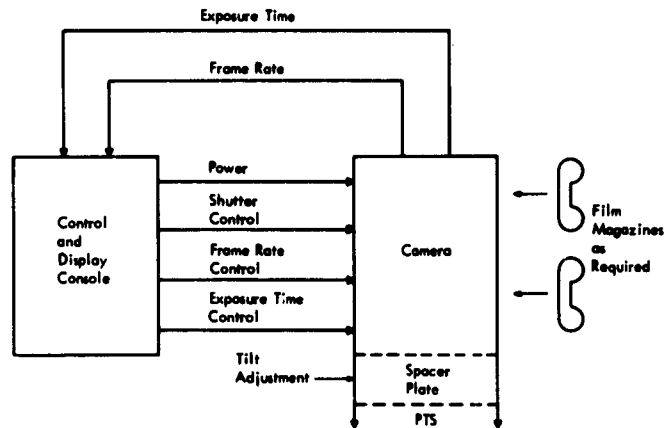
Figure 3-1 Schematic Arrangement - PTS Cameras

3.2.1.1.1 Raw Power

Input power for drive mechanisms shall be the prime d-c power source of the spacecraft and shall have the following characteristics:

(1) Nominal Voltage - Specified operation shall be obtainable with input voltages ranging from 18.0 to 30.5 volts.

(2) High Voltage - The spacecraft power source may produce steady-state (up to 30 minutes) voltages up to 32.6 volts and may produce spikes up to 80 volts of not more than 30 ms duration. The equipment is not required to operate within specification at these voltages but must continue to operate and not be damaged when exposed to these high voltages.

(3) Low Voltage - The spacecraft power source may produce voltages as low as 5 volts for periods up to 100 ms and may also produce negative spikes not exceeding -75 volts and 30 ms duration. The equipment is not required to operate within specification limits below 18.0 volts but must not be damaged by lower voltages and/or negative going spikes.

(4) Ripple Voltages - The spacecraft power system may have a 1 volt peak-to-peak maximum ripple at frequencies between 400 and 2400 cps. The wave shape is primarily composed of two drifting 800 cps (spike type) signals which have an unsynchronized beat frequency. Equipment performance shall not be degraded by the presence of this voltage being superimposed on the d-c input voltage.

(5) Power Interruptions - The equipment shall not be damaged or malfunction during power interruptions up to 30 ms.

3.2.1.1.2 Shutter Control

A method of closing the electrical path to ground will be provided that will cause the shutter to cycle.

3.2.1.1.3 Frame Rate Control

An electrical signal will be provided that will cause the frame to change to a desired rate.

3.2.1.1.4 Exposure Time Control

An electrical signal that will cause the exposure time to move plus or minus one stop from the manually set position.

3.2.1.1.5 Mechanical Interface

All cameras will interface with the PTS by individual but identical spacing blocks. The spacing blocks will be removable from the camera. Three micrometer adjusting screws will be provided for operator adjustment of the camera focal plane position and tilt.

3.2.1.1.6 Mounting Arrangements

All cameras will have identical mounting arrangements to the spacing blocks, and focal planes will be in identical positions relative to the spacing blocks.

3.3 DESIGN AND CONSTRUCTION

Appearances, form factors, packaging, circuit parameters. interface methods. and connectors will all evolve and be coordinated with the IVSS system design. As these various parameters are determined, they will be included herein.

3.3.1 General Design Features

3.3.1.1 Size

The low frame-rate camera and magazine shall not occupy a volume larger than 0.25 cubic feet. The high frame-rate camera and magazine shall not occupy a volume larger than 1.20 cubic feet.

3.3.1.2 Weight

The low frame-rate camera loaded with 50 feet of 70 mm film shall not weigh more than 8 pounds. The high frame-rate camera loaded with 100 feet of 70 mm film shall not weigh more than 100 pounds.

3.3.1.3 Power

Exclusive of the need for any environmental control power (the need for which will be determined in the future and included herein), shutter-trip power, and film rate adjust power, neither camera shall require more than 120 watts of raw d-c power. That power shall be required only during film drive.

3.3.1.4 Frame Rates

Slow frame-rate cameras shall operate from a one frame on demand rate to a maximum rate of 4 frames per second. Fast frame-rate cameras shall operate from a minimum rate of 4 frames per second to a maximum rate of 60 frames per second. The high rate camera shall provide pin register at all frame rates. Frame rates shall be remotely adjustable, by electrical means. from the control and display console.

3.3.1.5   Film Capacities

The slow frame-rate cameras shall accommodate a removable film magazine containing 50 and 100 feet of 70 mm perforated film. The high frame-rate camera shall accommodate 100, 200, and 400 feet of per- forated 70 mm film in a removable two compartment magazine (for removal of film before complete use of the supply spool).

3.3.1.6   Shutter Speeds

The low frame-rate camera shall have a focal plane shutter with exposure time stops at 1, 1/10, 1/15, 1/100, 1/250, 1/500, and 1/1000 second. The high frame-rate camera shall have a disk type, focal plane shutter adjustable to cover the range of exposure times from 1/25 to 1/1000 second. The disk shutter shall be capable of easy replacement so that multiple exposures can be made.

3.3.1.7   Filters

All cameras will have provisions for easy manual filter change. Filters shall be replaced by a clear glass slide when it is not desired to maintain focal distance.

3.3.2   Selection of Specification and Standards

Selection of specifications, standards, and publications will be made from ANA Bulletin No. 400 wherever practicable. However, engineering judgment must be exercised to use the documents that will allow selection of parts and processes that are commensurate with the function, environment, quality, and reliability requirements of this equipment.

MIL-STD-143 shall be used as a guide for selection and precedence of the specifications utilized.

All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3.3.3   Materials, Parts, and Processes

Materials, parts, and processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the best commercial quality and of the lightest practicable weight. Also, the materials and parts must be entirely suitable for the intended purpose and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical ma- terials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

3.3.4   Standard and Commercial Parts

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3.3.5   <u>Moisture and Fungus Resistance</u>

3.3.5.1   <u>Humidity</u>

The equipment shall withstand the effects of humidity up to 100 percent, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operation, short-time operation, and in a nonoperating condition.

3.3.5.2   <u>Fungus</u>

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3.3.6   <u>Corrosion of Metal Parts</u>

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3.3.7   <u>Interchangeability and Replaceability</u>

Interchangeability shall be in accordance with MIL-STD-454.

3.3.8   <u>Workmanship</u>

Workmanship shall be in accordance with MIL-STD-454.

3.3.9   <u>Electromagnetic Interference</u>

The electronic environment of the system shall be determined to be interference free, i. e., the equipment shall function properly in the electromagnetic environment created by other systems and equipment that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with MIL-E-6051.

3.3.10   <u>Identification and Marking</u>

Identification and marking of this equipment shall conform to MIL-E-5400.

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION

REQUIREMENTS

CEI NO. 3

DISPLAY AND CONTROL CEI

Basic Approved By _____ Basic Approved By _____
    (Preparing Activity)   (System Program Office
                                        or Equivalent)

Date _____ Date _____

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1.0   <u>SCOPE</u>

This part of this specification establishes the requirements for performance, design, test and quali-
fication of one type-model-series of equipment identified as Display and Control, CEI No. 3. This CEI is used
to provide the interface between the experiments and other IVSS subsystems. It will be used for data collection,
insertion and analysis as well as providing information to the operator regarding experiment parameters.

2.0   <u>APPLICABLE DOCUMENTS</u>

The following documents, of the exact issues shown, form a part of the specification to the extent
specified herein. In the event of conflict between documents referenced here and the detail content of Sections 3,
4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

<u>System Program Documents</u>

<u>Specifications</u>

MIL-E-5400	Electronic Equipment, Aircraft, General Specification for
MIL-E-6051	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft.
MIL-S-38130	Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements for
MIL-H-27894A	Human Engineering Requirements for Aerospace Systems and Equipment.

<u>Standards</u>

MIL-STD-143	Specifications and Standards, Order of Procedure for the Selection of
MIL-STD-454	Standard, General Requirements for Electronic Equipment.

<u>Bulletins</u>

ANA Bulletin No. 400	Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents.
USAF Spec. Bulletin No. 523	Space Environment Criteria for Aerospace Vehicles.

<u>Publications</u>

AFSCM80-1	Handbook of Instructions for Aircraft Designers (HIAD)
AFSCM80-3	Handbook of Instructions for Aerospace Personnel Subsystem Designers (HIAPSD).

3.0   <u>REQUIREMENTS</u>

3.1   <u>Performance</u>

The Man-IVSS interface shall provide the functional capabilities and degrees of human control nec-
essary to fulfill the requirements of the major primary experiments P-1, P-2, and P-3. Functional capability
for system activation, check-out, conduct of any or all portions of the major experiments, and analysis of ex-
perimental results shall be incorporated in a manner that reflects consideration of human engineering and life
support factors which affect human performance. Major functional requirements include: (1) provisions for
human performance during weightlessness; (2) provisions for minimizing disorientation; (3) adequate space for

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man, his movement and his equipment; (4) optimum visual, physical and auditory links between man, his environment, and his equipment; (5) protection from toxological and electromagnetic hazards; and (6) provisions for minimizing psycho-physiological stresses and physical-emotional fatigue.

3.1.1   Functional Characteristics

The Control and Dislay CEI gives the human operator the capability to monitor status, change modes, and generally manage the function of the following equipment:

     (1)   PTS system

     (2)   Camera

     (3)   Briefing

     (4)   Tracking

     (5)   Visual evaluation tracker

     (6)   Target parameters

     (7)   Voice recording

     (8)   Communication

     (9)   Data management

     (10)   Manual data insertion and display

     (11)   Film projection

     (12)   Photo data analysis

     (13)   System malfunction

3.1.1.1   Primary Performance Characteristics

Performance characteristics shall reflect functional requirements of primary experiments P-1, P-2, and P-3, incorporating all applicable military specifications and design standards with respect to human engineering and life support criteria.

3.1.2   Operability

3.1.2.1   Reliability

The reliability of the controls and displays shall be the highest practical value the state-of-the-art will allow. Exclusive of incandescent lamps, the mean time between failures of the controls and displays will be at least 2000 hours. Allotments of this reliability between the various sub-units of the controls and displays will be made in the future and included herein.

3.1.2.2   Maintainability

Maintenance of the controls and displays will be severely limited, and spare parts will be available on a critical component basis only. Therefore, replacement of components shall be as simple as practical and periodic maintenance requirements kept to a minimum.

3.1.2.2.1   Malfunction Detection

All malfunction detection and isolation will be accomplished by means of built-in test points and on-board test equipment.

3.1.2.3   Safety

Safety requirements shall conform to MIL-S-39130.

3.2   CEI DEFINITION

3.2.1   Interface Requirements

3.2.1.1   Schematic Arrangement

Figure 3-1 shows a schematic diagram of the display and controls CEI.

3.2.1.2   Detailed Interface Definition

3.2.1.2.1 Input Power

The controls and displays console, film viewer, and briefing presentation unit, shall receive unregulated voltage which has the following characteristics:

(1) Nominal Voltage - Specification importance shall be obtainable with input voltages ranging from 18.0 to 30.5 volts.

(2) High Voltage - The power source may produce steady-state (up to 30 minutes) voltages up to 32.6 volts and may produce up to 80-volt spikes for not more than 30 ms duration. The equipment is not required to operate within specification at these voltages, but must continue to operate and not be damaged when exposed to these high voltages.

(3) Low Voltage - The power source may produce voltages as low as 5 volts for periods up 100 ms and may also produce negative spikes, of not more than 30 ms duration, which can reach -75 volts. The equipment is not required to operate within specification limits below 18.0 volts but must not be damaged by lower voltages and/or negative-going spikes.

(4) Ripple Voltages - The power system may have a 1-volt peak-to-peak maximum ripple at frequencies between 400 and 2400 cycles per second. The wave shape is primarily composed of two drifting 800 cps (spike type) signals which have an unsynchronized beat frequency. Equipment performance shall not be degraded by the presence of this voltage superimposed on the d-c input voltage.

(5) Power Interruptions - The equipment shall not be damaged or malfunction during power interruptions up to 30 ms.

The time reference unit, because of its susceptibility to errors resulting from unregulated voltage, shall receive voltages regulated to better than 1 percent.

3.2.1.2.2 Control

There shall be provisions made for on-off control of the briefing presentation unit from the console, and control of briefing film orientation by use of the hand control. The briefing film orientation shall also be controlled by the computer.

The time reference unit shall be controlled by updates through the MOL digital command system.

The console shall have provisions for on-off control of certain sections, in addition shall provide for control of the film viewer.

Other controls found necessary will be defined at a later date.

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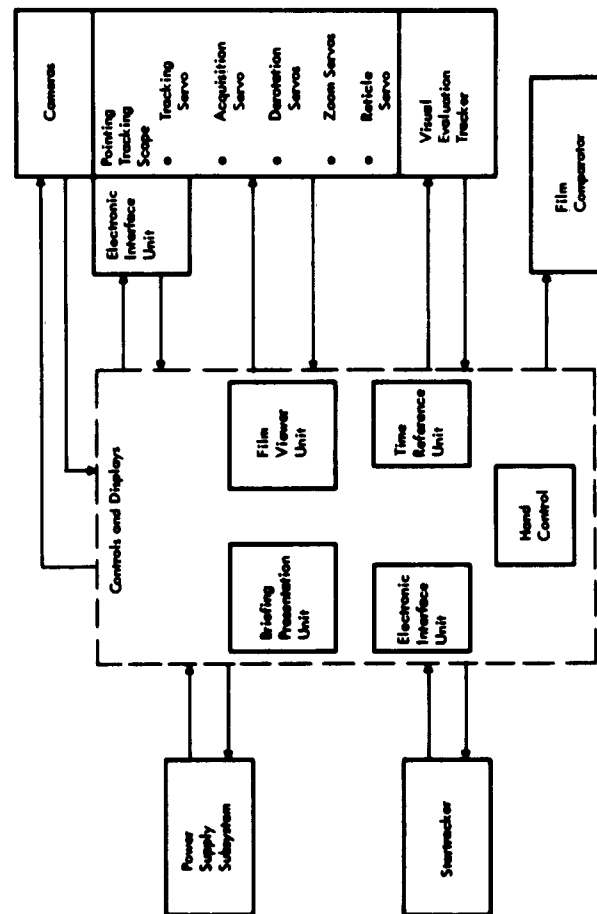
Figure 3-1. Schematic Arrangement Controls and Displays Subsystem

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3.2.3   CEI Subsystem List

(1) Display and control console

(2) Briefing presentation unit

(3) Briefing material and film file

(4) Film viewer

(5) Display and control electronic interface unit

(6) Time reference unit

3.3   DESIGN AND CONSTRUCTION

3.3.1   General Design Features

The power, weight, and volume for the controls and displays subsystems are given below:

Subsystem	Avg. Power (watts)	Weight (lbs.)	Volume (cu. ft.)
Console	20	100	2.1
Briefing Presentation Unit	45	16	0.8
Briefing Material and Film File	--	90	1.5
Film Viewer	125	25	0.5
Interface Unit	5	10	0.2
Time Reference Unit	3	5	0.1

A possible layout of the display and control console is given in Figure 3-2.

3.3.2   Selection of Specifications and Standards

Selection of specifications, standards and publications shall be made for ANA Bulletin No. 400 wherever practicable. However, engineering judgment must be exercised to use the documents which will allow selection of parts and processes that are commensurate with the function, environment, quality, and reliability requirements of this equipment.

MIL-STD-143 shall be used as a guide for selection and precedence of the specifications used.

All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3.3.3   Materials, Parts, and Processes

Materials, parts, processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the best commercial quality of the lightest practicable weight, entirely suitable for the intended purpose and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

Figure 3-2. IVSS Console Layout

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3. 3. 4   <u>Standard and Commercial Parts</u>

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3. 3. 5   <u>Moisture and Fungus Resistance</u>

3. 3. 5. 1   <u>Humidity</u>

The equipment shall withstand the effects of humidity up to 100 percent, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operations, short-time operations, and in a nonoperating condition.

3. 3. 5. 2   <u>Fungus</u>

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3. 3. 6   <u>Corrosion of Metal Parts</u>

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3. 3. 7   <u>Interchangeability and Replaceability</u>

Interchangeability shall be in accordance with MIL-STD-454.

3. 3. 8   <u>Workmanship</u>

Workmanship shall be in accordance with MIL-STD-454.

3. 3. 9   <u>Electromagnetic Interference</u>

The electronic environment of the system shall be determined to be interference free, i. e., the equipment shall function properly in the electromagnetic environment created by other systems and equipment that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with MIL-E-6051.

3. 3. 10   <u>Identification and Marking</u>

Identification and marking of this equipment shall conform to MIL-E-5400.

3. 4   <u>CONTROLS AND DISPLAYS</u>

3. 4. 1   <u>Console Sub-Unit</u>

The console sub-unit will serve to physically hold and interconnect the other sub-units, provide interfacing to other subsystems of the IVSS and contain actual controls and displays. The proposed console will generate approximately 150 discrete signals, 10 analog signals and will have approximately 56 display wheels and 3 thumb wheels. Because of the multiple display wheels it will be advisable to use a programmable formatter for the wheels. By use of the formatter, which drives one wheel at a time, a simple interface may be used for all display wheels. The analog interface will be an analog-to-digital converter.

3. 4. 2   <u>Briefing Presentation Unit</u>

The briefing presentation unit should have the capability for presenting a briefed target in the same perspective as the live target will be viewed. For close inspection of particular areas of the film, it is also

desirable to have a magnification capability in the briefing unit. The unit will have servo drives, controlled by either the computer or manually through the hand control, for both rotating the film and presenting it in oblique perspective.

A 25-watt light source will provide the necessary light for film viewing. There will be magnifications of 1X, 2X and 3X to choose from.

3.4.3   Briefing Material and Film File Unit

A unit will be provided to store briefing material, exposed and unexposed film and the necessary processing material in an organized manner.

3.4.4   Film Viewer Unit

The film viewer unit will contain a film holder, lenses and projection lamp arranged to project the film on a self-contained 9- x 9-inch translucent screen. Three levels of magnification will be provided as well as separate X and Y axis crosshair controls with calibrated read-outs for measuring relative distances between points on the film.

3.4.5   Displays and Controls Interface Unit

The displays and controls interface unit will contain the necessary equipment for interconnection between CEI subsystems, briefing unit servo electronics, and will serve as the main connection point for MOL systems and other Image Velocity Sensor CEI's to the Controls and Displays CEI. Included in this interface unit will be a programmable formatter for the console decimal display wheels, because of the projected large number (over 50) of these wheels. There will be one analog-to-digital encoder for the console also included in this unit.

Exhibit VI   Specification No.   IBM IVSS--1.4

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION

REQUIREMENTS

CEI NO. 4

STAR TRACKER

Basic Approved by _____   Basic Approved by _____

(Preparing Activity)   (System Program Office or

Equivalent)

Date _____   Date _____

1.0   SCOPE

This part of this specification establishes the requirements for performance, design, test and qualification of one type-model-series of equipment identified as Star Tracker, System Segment, CEI No. 4. This CEI provides an accurate inertial reference frame for inertial to vehicle axis transformation.

2.0   APPLICABLE DOCUMENTS

The following documents, of the exact issues shown, form a part of the specification to the extent specified herein. In the event of conflict between documents referenced here and the detail content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

System Program Documents

Specifications

MIL-E-5400   Electronic Equipment, Aircraft, General Specification for
MIL-E-6051   Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft
MIL-S-38130   Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements for

Standards

MIL-STD-143   Specifications and Standards, Order of Procedure for the Selection of
MIL-STD-454   Standard, General Requirements for Electronic Equipment

Bulletins

ANA Bulletin Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents
No. 400

3.0   REQUIREMENTS

The star tracker(s) shall be capable of acquiring and simultaneously tracking two stars of magnitude 2.0 and brighter and have a gimbal angle read-out capability with respect to the mounting base plate.

3.1   Performance

The performance shall be specified in accordance with paragraphs 3.1.1, 3.1.1.1, and 3.1.1.2. It shall define functional characteristics and in-space performance criteria capable of being verified on the ground.

3.1.1   Functional Characteristics

The following functional characteristics shall apply:
(1) Capability to acquire and track stars of 2.0 magnitude or brighter.
(2) Capability to read out telescope gimbal angles.
(3) The star tracker shall be capable of being positioned to any desired angle within its range to 1 arc min
(4) The star tracker system shall include, protection against excessive radiation input, star presence signals, and a digital star tracking signal whenever the error is below a specified value.

3.1.1.1   Primary Performance Characteristics

Star Recognition - The star tracker subsystem will acquire stars of 2.0 magnitude and brighter within a 1-degree field of view of the telescope.

Star Tracking Null - The star tracker subsystem will indicate tracking null conditions when the sum of the two gimbal angle errors is equal to or less than 4 minutes of arc.

Acquisition - Acquisition will occur if the apparent path of the star approaches within 0.4 degree of the field of view of the telescope with a rotational rate of 0.35 degree/sec. or less.

Accuracy - The composite track g error will not exceed 30 sec. of arc. (rss).

The pointing error when following vehicle rate up to 0.5 degree/sec. shall not exceed 5 arc min. The noise content of the signal shall be 5 arc sec.

Tracking Angle - The star tracking subsystem tracking angle shall be at least -60 degrees about each gimbal.

Tracking Restriction - The star tracker will track stars to 30 degrees to the sun line and 15 degrees to the earth line.

Tracking - The maximum angular rate while tracking is 0.5 degree/sec. The maximum acceleration shall be 0.045 degrees/sec.^{2}

3.1.2   Operability

The star tracker shall be capable of operating in the ground environment for check-out purposes and specifically to operate in accordance with performance specifications in the hostile space environment.

3.1.2.1   Reliability

The MTBF design goal for the star tracker is 10,000 hours for continuous use in orbit at a maximum altitude of 200 n mi.

3.1.2.2   Service and Access

Capability shall exist for servicing tracker on the ground. The input/output test points shall include but not be limited to the following:

Inputs
(1) Stellar radiation
(2) Inner gimbal error signals for command mode and for resolution
(3) Outer gimbal error signals for command mode
(4) Power command signal
(5) Mode signal (command or tracker).

Outputs
(1) Inner gimbal stop pulses of gimbal pickoff
(2) Outer gimbal stop pulses of gimbal pickoff
(3) Inner gimbal error signal resolved about outer gimbal angle (sine resolver output-analog)
(4) Inner gimbal error signal resolved about outer gimbal angle (cosine resolver output-analog)

(5) Star presence signal

(6) Star tracking signal.

3.1.2.3 Safety

Safety requirements shall conform to MIL-S-38130.

3.2 CEI Definition

The star tracker shall be compatible with the mounting requirements of the PTS and shall be mounted external to the spacecraft on the PTS pedestal. Therefore, detailed specifications must be applied to the reference mounting surface of the CEI.

Also it is necessary that proper interface signal compatibilities be maintained as regards input/output, to and from the digital computer or digital interface and the controls and displays section.

3.2.1 Interface Requirements

The interface requirements are:

(1) Mounting compatibility with PTS vehicle

(2) Signal compatibility with the digital or analog interface

(3) Vehicle attitude, position, rate and acceleration. Compatibility to maintain lockon and meet accuracy requirements.

3.2.1.2 Detailed Interface Definition

The mounting flange shall be aligned to the gimbal axis within ± 4 arc sec and the orthogonality of the gimbal axis shall be ± 3 arc sec.

3.3 Design and Construction

3.3.1 The star tracker(s) required to meet this specification shall be contained within 2.0 cubic feet, weigh less than 60 pounds, and consume less than 30 watts average.

3.3.2 Selection of Specifications and Standards

Selection of specifications, standard and publications shall be made for ANA Bulletin No. 400 wherever practicable. However, engineering judgment must be exercised to use the documents which will allow selection of parts and processes that are commensurate with the function, environment, quality, and reliability requirements of this equipment.

MIL-STD-143 shall be used as a guide for selection and precedence of the specifications used.

All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3.3.3 Materials, Parts, and Processes

Materials, parts, processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the best commercial quality of the lightest practicable weight, entirely suitable for the intended purpose, and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

3.3.4 Standard and Commercial Parts

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3.3.5 Moisture and Fungus Resistance

3.3.5.1 Humidity

The equipment shall withstand the effects of humidity up to 100 percent, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operations, short-time operations, and in a non-operating condition.

3.3.5.2 Fungus

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3.3.6 Corrosion of Metal Parts

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3.3.7 Interchangeability and Replaceability

Interchangeability shall be in accordance with MIL-STD-454.

3.3.8 Workmanship

Workmanship shall be in accordance with MIL-STD-454.

3.3.9 Electromagnetic Interference

The electronic environment of the system shall be determined to be interference free, i. e., the equipment shall function properly in the electromagnetic environment created by other systems and equipment that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be inaccordance with MIL-E-6051.

3.3.10 Identification and Marking

Identification and marking of this equipment shall conform to MIL-E-5400.

3.4 CEI Subsystems

The star tracker CEI is broken up into two packaged subsystems.

(1) Optical mechanical package

(2) Electronic interface unit.

The Optical Mechanical Package consists of a telescope on a precision pitch roll two-gimbal system. The optics consists of an off-axis parabolic vibrating-reed scanner and photomultiplier tube. The gimbal drives shall be directly coupled d-c torque motors.

The Electronic Interface Unit works in conjunction with the optical package and consists of the following subassemblies:

(1) Inner/outer gimbal servo amplitude and associated compensating circuitry

(2) Command and track selector circuits

(3) Star presence detector

(4) Star tracking detector

(5) Power control circuits

(6) Resolver modulator and demodulator circuits

(7) Telescope electronic circuits.

Exhibit VII   Specification No. IBM IVSS--1.5

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION

REQUIREMENTS

CEI NO. 5

EXPERIMENT EVALUATION SUBSYSTEM

Basic Approved By _____   Basic Approved By _____
                  (Preparing Activity)   (System Program Office or
                                                             Equivalent)

Date _____   Date _____

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1.0   SCOPE

This part of this specification establishes the requirements for performance, design, test and qualification of one type-model-series of equipment identified as the Experiment Evaluation Subsystem, CEI No. 5. This CEI is used to provide photographic hard copy and perform photographic data interpretation to evaluate the results of the IVSS experiments. The CEI equipment required to perform these functions are a film processor and photo comparator.

2.0   APPLICABLE DOCUMENTS

The following documents, of the exact issues shown, form a part of the specification to the extent specified herein. In the event of conflict between documents referenced here and the detail content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

System Program Documents

Specifications

MIL-E-5400   Electronic Equipment, Aircraft, General Specification for

MIL-E-6051   Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft

MIL-S-38130   Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements for

Standards

MIL-STD-143   Specification and Standards, Order of Procedure for the Selection of

MIL-STD-454   Standard, General Requirements for Electronic Equipment

Bulletins

ANA Bulletin   Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents
  No. 400

3.0   REQUIREMENTS

3.1   Performance

A film processor which develops the exposed film without degrading the photographed target is a requirement. The photointerpretative process has as a general requirement a device to enable precision measurement of distances on the photograph for evaluation of image motion compensation.

3.1.1   Functional Characteristics

3.1.1.1   Primary Performance Characteristics

The limiting performance characteristics of the processing method in combination with those of the films should provide the specified photographic characteristics in Table 3-1.

Table 3-1
REQUIRED FILM AND PROCESSING REQUIREMENTS

Function	Negative Transparency	Positive Transparency
Gamma	1.45	2.50 For 1 min contact at 70^OF
Density Scale	2.48 max	2.18 max
	0.28 min	0.04 min
	0.20 base density	0.0 base
Fog (Net Diffuse)	0.08	0.0
Resolution Lines/mm (Log contrast: 0.2 ± 0.05)	100 c/mm 96%	40 c/mm 10%
	245 c/mm 50%	15 c/mm 50%
	330 c/mm 30%	
Keeping Properties	archival with post fix treatment	Storage at 35-55°F
Exposure Index (0.5 gamma method)	1.66	
Processing Time	1 minute contact at 70^OF	

In addition the developing process, in the case of emulsions of normal thickness, causes l
tortions in the emulsions. Studies indicate that these distortions may be as large as 1 micron. A req
of the processor must be that distortion between any two points on the film be less than 1 micron.

A primary requirement for the photocomparator is that the device should be capable of me
the distance between any two points on the plate or film to within 0.001 percent of the true separation.

3.1.1.2   Secondary Performance Characteristics

Parameters for the film processor which are not necessarily mission critical are the env
constraints, the abrasion resistance of the processed prints, the number of frames per reel and poss
degree of keeping property of the processed film. The parameters are enumerated but are not quanta
described since these characteristics are a product of the design process.

Secondary performance characteristics for the film comparator are the operational tempe
and vibration limits, a calibration procedure at 68° F, and launch environmental conditions yet to be
mined and will be included herein.

3 1.2   Operability

3.1.2.1   Reliability

Based on the system reliability measure the MTBF for the combined film processor and
comparator shall be 28,500 hours.

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3.1.2.2   Safety

Safety requirements shall conform to MIL-S-38130.

3.2   CEI DEFINITION

3.2.1   Interface Requirements

The film processor interface requirements with other equipment consists of interfacing to the power supply, the control and display unit, and an environmental control unit to maintain the temperature and humidity of the transport chamber (assuming a "dry film processing" technique).

There are no primary requirements for the photocomparator since the developed photographs are manually inserted in the comparator and the device is essentially self-contained. There will be an interface to the power supply unit for the lighting requirements.

3.2.1.1   Schematic Arrangement

The relationship of the CEI to other equipments is shown in the block schematic of Figure 3-1.
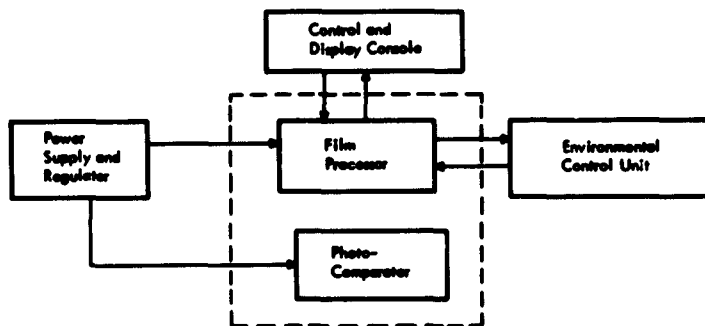
Figure 3-1 Experiment Evaluation Subsystem Interfacing

3.2.2   Engineering Critical Components List

No critical components are listed for the film processor individually. The film processor physically is not expected to contain any extensions of state-of-the-art in the film drives. The critical areas of the processing are in the lamination and separability of the film itself.

The critical components of the photocomparator are the precision lead screws for the film stage (optical viewer assumed stationary). The screws should have dials and indicies by which the stage position may be read directly to within 0.001 mm.

3.2.3   CEI Subsystem List

The subsystem list for the experiment evaluation CEI consists of:

(1) Film processor

(2) Photo-comparator

Specification No. IBM IVSS--1.5

3.3   DESIGN AND CONSTRUCTION

3.3.1   General Design Features

3.3.1.1   Weight
          Film processor   10 lbs.
          Film comparator   25 lbs.

3.3.1.2   Power
          Film processor   8 watts
          Film comparator   8 watts

3.3.1.3   Volume
          Film processor   0.5 cu. ft.
          Film comparator   1 cu. ft.

3.3.2   Selection of Specifications and Standards
          Selection of specifications, standards and publications shall be made for ANA Bulletin No. 400 wherever practicable. However, engineering judgment must be exercised to use the documents which will allow selection of parts and processes that are commensurate with the function, environment, quality, and reliability requirements of this equipment.

          MIL-STD-143 shall be used as a guide for selection and precedence of the specifications used.

          All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3.3.3   Materials, Parts, and Processes
          Materials, parts, processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the best commercial quality of the lightest practicable weight, entirely suitable for the intended purpose and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

          Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

3.3.4   Standard and Commercial Parts
          Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3.3.5   Moisture and Fungus Resistance

3.3.5.1   Humidity
          The equipment shall withstand the effects of humidity up to 100 percent, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operations, short-time operations, and in a nonoperating condition.

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3.3.5.2 **Fungus**

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3.3.6 **Corrosion of Metal Parts**

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3.3.7 **Interchangeability and Replaceability**

Interchangeability shall be in accordance with MIL-STD-454.

3.3.8 **Workmanship**

Workmanship shall be in accordance with MIL-STD-454.

3.3.9 **Electromagnetic Interference**

The electronic environment of the system shall be determined to be interference free, i.e., the equipment shall function properly in the electromagnetic environment created by other systems and equipments that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with MIL-E-6051.

3.3.10 **Identification and Marking**

Identification and marking of this equipment shall conform to MIL-E-5400.

Exhibit VIII

Specification No. IBM IVSS--1.6
Part I of Two Parts

CONTRACT END ITEM DETAIL SPECIFICATION

PART 1

PERFORMANCE/DESIGN AND QUALIFICATIONS

REQUIREMENTS

CEI NO. 6

POWER SUPPLY SUBSYSTEM

Basic Approved By_____   Basic Approved By_____
          (Preparing Activity)   (System Program
                                                         Office or Equivalent)

Date _____   Date _____

1.0 SCOPE

This part of this specification establishes the requirements for performance, design, test, and qualification of one type of equipment identified as the Power Supply Subsystem for the Image Velocity Sensor Subsystem (IVSS). This CEI is used as an interface buffer between the vehicle's raw power lines and the specific power requirements of the IVSS.

2.0 APPLICABLE DOCUMENTS

The following documents, of the exact issues shown, form a part of the specification to the extent specified herein. In the event of conflict between documents referenced here and other detail content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

System Program Documents

Specifications

MIL-E-5400	Electronic Equipment, Aircraft, General Specification For
MIL-E-6051	Electrical Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems, and Aircraft.
MIL-S-38130	Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements For

Standards

MIL-STD-143	Specifications and Standards, Order of Procedure for the Selection of
MIL-STD-454	Standard General Requirements for Electronic Equipment

Bulletins

ANA Bulletin No. 400   Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents

3.0 REQUIREMENTS

3.1 Performance

The Power Supply Subsystem shall operate from the prime d-c power line and from it provide the various d-c voltages required by other subsystems of the IVSS. The other subsystems will require several different voltage levels and regulation requirements.

3.1.1 Performance Characteristics

3.1.1.1 Efficiency

The efficiency of the power supply shall be the highest practical value consistent with the state-of-the-art. In no case shall the efficiency be less than 65 percent including all losses from input connectors to output connectors.

3.1.2 Operability

3.1.2.1 Reliability

The reliability of the power supply shall be the highest practical value consistent with the state-of-the-art. The power supply shall exhibit a minimum mean time between failures of 25,000 hours.

3.1.2.2 Maintainability

Maintenance of the Power Supply Subsystem will be severely limited. Spare parts will be available on a critical-component basis only. Therefore, replacement of components shall be as simple as practical, and periodic maintenance requirements will be kept to a minimum.

3.1.2.2.1 Malfunction Isolation

All malfunction detection and isolation will be accomplished by means of built-in test points and on-board test equipment.

3.1.2.3 Safety

Safety requirements shall conform to MIL-S-38130.

3.2 CEI Definition

3.2.1 Interface Requirements

3.2.1.1 Schematic Arrangement

A schematic of the power supply's interconnections with other equipments is shown in Figure 3-1.

3.2.1.2 Detailed Interface Definition

3.2.1.2.1 Inputs, Electrical

3.2.1.2.1.1 Input Power

The input power to the power supply shall be the spacecraft's prime d-c power source having the following characteristics:

(a) Nominal Voltage - Specification importance shall be obtainable with input voltages ranging from 18.0 to 30.5 volts.

(b) High Voltage - The spacecraft power source may produce steady-state (up to 30 minutes) voltages up to 32.6 volts and may produce spikes up to 80 volts (total) of not more than 30 ms duration. The equipment is not required to operate within specification at these voltages, but must continue to operate and not be damaged when exposed to these high voltages.

(c) Low Voltage - The spacecraft power source may produce voltages as low as 5 volts for periods up to 100 ms and may also produce negative spikes, of not more than 30 ms duration, which can reach -75 volts. The equipment is not required to operate within specification limits below 18.0 volts, but must not be damaged by lower voltages and/or negative-going spikes.

(d) Ripple Voltages - The spacecraft power system may have a 1 volt peak-to-peak maximum ripple at frequencies between 400 and 2400 cps. The wave shape is primarily composed of two drifting 800 cps (spike type) signals which have an unsynchronized beat frequency. Equipment performance shall not be degraded by the presence of this voltage superimposed on the d-c input voltage.

(e) Power Interruptions - The equipment shall not be damaged or malfunction during power interruptions up to 30 ms.

3.2.1.2.1.2 Control Signals

The Controls and Displays Unit shall provide control signals to turn sections of the power supply on and off as required in the different modes of operation. The power supply shall be closely coordinated with the Controls and Displays Units to produce the optimum sectioning of the power supply from both the weight and efficiency standpoints.

3.2.1.2.2 Outputs, Electrical

The Power Supply Subsystem shall provide d-c power with 2 to 5 percent regulation to the units of the IVSS. Certain fairly constant excitation and low power, voltage-sensitive loads will receive voltages regulated to 1 percent or better. The probability of all units of the IVSS operating at the same time is remote, so a design for the peak 1378-watt load is impractical. A practical power profile can be described as follows:

      (a)   Steady State Maximums - 800 watts during search.

      (b)   Peaks - 1,000 watts during servo slewing for a 10-second period every 15 minutes.

Details of voltage levels, percentage regulation, and loading levels and profiles will be determined in the future and included herein. Units whose power is supplied by the Power Supply Subsystem and their anticipated peak and average power values are given below.

3.2.1.2.2.1   PTS Tracking Servo System

The Pointing/Tracking Scope (PTS) Tracking Servo System will require 362 watts peak and 122 watts average.

3.2.1.2.2.2   PTS Acquisition Servo System

The Acquisition Servo System will require 120 watts peak and 60 watts average.

3.2.1.2.2.3   Derotation and Auxiliary Derotation Servos

The Derotation Servos will require 120 watts peak and 60 watts average.

3.2.1.2.2.4   Zoom and Reticle Servos

The Zoom and Reticle Servos will require 35 watts peak and 24 watts average.

3.2.1.2.2.5   Startracker

The Startracker will require 60 watts peak and 30 watts average.

3.2.1.2.2.6   Cine Camera

The Cine Camera requires 200 watts peak and 50 watts average.

3.2.1.2.2.7   Frame Cameras

The Frame Cameras require 200 watts peak and 50 watts average.

3.2.1.2.2.8   Controls and Displays

The Controls and Displays require 200 watts peak and average.

3.2.1.2.2.9   Film Viewer

The Film Viewer required 125 watts peak and average.

3.2.1.2.2.10   Film Comparator

The Film Comparator requires 8 watts peak and average.

3.2.1.2.2.11   Briefing Presentation Units

The Briefing Presentation Units require 49 watts peak and 45 watts average.

3.2.1.2.2.12   Time Reference Unit

The Time Reference Unit requires 20 watts peak and 3 watts average.

3. 2. 1. 2. 2 13   Electronic Interface Units

The Electronic Interface Units will require 10 watts peak and average.

3. 2. 1. 2. 2. 14   Visual Evaluation Tracker

The Visual Evaluation Tracker will require 49 watts peak and 45 watts average.

3. 2. 1. 2. 3 Outputs, Thermal

The Power Supply Subsystem will be mounted on a cold plate that effectively approaches an infinite plate held at 120° F.

3. 3   Design and Construction

Appearances, form factors, packaging, circuit parameters, interface methods, and connectors will all evolve from and be coordinated with the IVSS system design. As these various parameters are determined they will be included herein.

3. 3. 1   General Design Features

3. 3. 1. 1   Size

The size of the Power Supply Subsystem shall not exceed 500 cubic inches.

3. 3. 1. 2   Weight

The weight of the Power Supply Subsystem shall not exceed 40 pounds.

3. 3. 2   Selection of Specifications and Standards

Selection of specifications, standards, and publications shall be made from ANA Bulletin No. 400 wherever practicable. However, engineering judgment must be exercised to utilize those documents that will allow parts and processes to be selected commensurate with the function, environment, quality, and reliability requirements of this equipment.

MIL-STD-143 shall be used as a guide for selection and precedence of the specifications utilized.

All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3. 3. 3   Materials, Parts, and Processes

Materials, parts, and processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the best commercial quality of the lightest practicable weight, entirely suitable for the intended purpose, and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency).

3. 3. 4   Standard and Commercial Parts

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

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3.3.5   Moisture and Fungus Resistance

3.3.5.1   Humidity

The equipment shall withstand the effects of up to 100 percent humidity environments, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during continuous operation, intermittent operations, short-time operations, and in a nonoperating condition.

3.3.5.2   Fungus

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3.3.6   Corrosion of Metal Parts

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3.3.7   Interchangeability and Replaceability

Interchangeability shall be in accordance with MIL-STD-454.

3.3.8   Workmanship

Workmanship shall be in accordance with MIL-STD-454.

3.3.9   Electromagnetic Interference

The electronic environment of the system shall be determined to be interference free, i.e., the equipment shall function properly in the electromagnetic environment created by other systems and equipment that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with MIL-E-6051.

3.3.10   Identification and Marking

Identification and marking of this equipment shall conform to MIL-E-5400.

Figure 3-1. Interface Schematic for Power Supply Subsystem

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Exhibit IX

Specification No. <u>IBM IVSS--1.7</u>

CONTRACT END ITEM DETAIL SPECIFICATION

PART I

PERFORMANCE/DESIGN AND QUALIFICATION

REQUIREMENTS

CEI NO. 7

AEROSPACE VEHICLE EQUIPMENT SOFTWARE

Basic Approved by _____   Basic Approved by _____

(Preparing Activity)   (System Program Office or

Equivalent)

Date _____   Date _____

Specification No. IBM IVSS--1-7

1.0 SCOPE

This part of the specification establishes the requirement for performance, design, test and qualification of one type of equipment identified as AVE software. This CEI is used to provide as much detail as possible on the briefing films, maintenance and operational film strips and the computer programming tapes.

2.0 APPLICABLE DOCUMENTS

The following documents, of the exact issues shown, form a aprt of the specification to the extent specified herein. In the event of conflict between documents referenced here and the detail content of Sections 3, 4, 5, and 10, the detail requirements of Sections 3, 4, 5, and 10 shall take precedence.

System Program Documents

Specifications

MIL-E-5400	Electronic Equipment, Aircraft, General Specification for
MIL-E-6051	Electrical-Electronic System Compatibility and Interference Control Requirements for Aeronautical Weapon Systems, Associated Subsystems and Aircraft
MIL-S-38130	Safety Engineering of Systems and Associated Subsystems, and Equipment: General Requirements for

Standards

MIL-STD-143	Specifications and Standards, Order of Procedure for the Selection of
MIL-STD-454	Standard, General Requirements for Electronic Equipment

Bulletins

ANA Bulletin No. 400	Electronic Equipment: Aircraft and Guided Missiles, Applicable Documents

3.0 REQUIREMENTS

The software requirements for IVSS experiments shall encompass the following areas in general:

(1) Briefing films and other operator displays

(2) Computer operations and check-out programs.

3.1 Performance

The requirement shall be satisfied by adhering to the following subparagraphs.

3.1.1 Functional Characteristics

The computer operational and check-out programs shall be supplied for capability of both ground and space loading. These program tapes shall be punched mylar and magnetic for ground and space loading respectively.

The briefing materials shall be entirely on film for insertion into the briefing presentation display optics.

3.1.1.1 Primary Performance Characteristics

The extended capabilities digital program will perform the following functions:

(1) Initialization

(2) Executor

(3) Diagnostics

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(4) Align and calibrate by pointing to preselected stars

(5) Update and integrate equations of motions

(6) Compute circular error coefficients

(7) Compute filtering matrices for ephemeris updating

(8) Pointing angle commands

(9) V_N - vector computation

(10) LOS - rate computation

(11) Latitude and longitude of ground track

(12) Time to go

(13) Sun angles

(14) Ground target geographical determination

(15) Auto scanning computation

(16) Space target tracking

3.1.1.2   Secondary Performance Characteristics

All briefing, maintenance and experiment operating data will be on film because of easier handling and less weight.

Log Books (two per craft) shall be supplied to enter pertinent experiment activity.

3.1.2   Operability

The reliability and maintainability shall be compatible with the computer CEI for the program tapes and with the controls and display CEI for the briefing material.

The safety requirement shall conform to MIL-S-38130.

3.2   CEI Definition

The briefing material shall be compatible with the viewing apparatus and have a weight not exceeding 10 pounds (about 1000 feet of 35 mm. film) for each mission.

The program tapes shall operate with the computer loading system and may be removed, transported and stored in accordance with generally accepted methods.

3.3.2   Selection of Specifications and Standards

Selection of specifications, standards and publications shall be made for ANA Bulletin No. 400 wherever practicable. However, engineering judgment must be exercised to use the documents which will allow selection of parts and processes that are commensurate with the function, environment, quality, and reliability requirements of this equipment.

MIL-STD-143 shall be used as a guide for selection and precedence of the specifications used.

All standards or specifications other than those established and approved for use by the Air Force must be approved by the procuring agency prior to use.

3.3.3   Materials, Parts, and Processes

Materials, parts, processes shall conform to applicable specifications as specified in ANA Bulletin No. 400, except as specified herein. Materials and parts not covered by applicable specifications shall be of the

best commercial quality of the lightest practicable weight, entirely suitable for the intended purpose and readily available. However, only nonflammable materials shall be used in the construction of the equipment.

Special attention shall be exercised to prevent unnecessary use of strategic and/or critical materials. (A Strategic and Critical Materials List can be obtained from the procuring agency.)

3.3.4   Standard and Commercial Parts

Military standard parts shall be used whenever their use allows the equipment to satisfy the design parameters. Nonstandard parts shall be selected for use only when standard parts do not fulfill the desired requirements. Nonstandard parts must be equivalent to, or better than, similar standard parts.

3.3.5   Moisture and Fungus Resistance

3.3.5.1   Humidity

The equipment shall withstand the effects of humidity up to 100 percent, including conditions wherein condensation takes place in and on the equipment. The equipment shall withstand the above conditions during operation, intermittent operations, short-time operations, and in a nonoperating condition.

3.3.5.2   Fungus

The requirements for fungus-inert materials shall be in accordance with MIL-STD-454.

3.3.6   Corrosion of Metal Parts

Corrosion resistance including electrolytic corrosion protection shall conform to MIL-E-5400.

3.3.7   Interchangeability and Replaceability

Interchangeability shall be in accordance with MIL-STD-454.

3.3.8   Workmanship

Workmanship shall be in accordance with MIL-STD-454.

3.3.9   Electromagnetic Interference

The electronic environment of the system shall be determined to be interference free, i.e., the equipment shall function properly in the electromagnetic environment created by other systems and equipments that must operate in the same location, and the radiated electromagnetic radiation of this system shall be suppressed to levels that do not produce abnormal functioning of these other systems.

The design requirements and test procedures shall be in accordance with MIL-E-6051.

3.3.10   Identification and Marking

Identification and marking of this equipment shall conform to MIL-E-5400.

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No Text On This Page

SECRET

1. Sensors — Image Velocity
2. Experiments — MOL
3. Simulations — Human Factors Evaluations
I. Advanced Systems Research Staff
II. Contract AF04(695)-656
III. Volume I — Summary
IV. Volume II — Simulations
V. Volume III — Subsystem Definition
VI. Volume IV — Experiment and Human Function Definition
VII. Volume V — Program Plans

SECRET

International Business Machines Corporation, Space Guidance Center, Owego, N.Y. IMAGE VELOCITY SENSOR SUBSYSTEM (IVSS) STUDY FINAL REPORT (UNCLASSIFIED TITLE). Advanced Systems Research Staff. November 1964. 985 p. including illus. tables (IBM CD Nos 3-260-8414 through 8418; SBD-TR-64-237 (II) through V) (Contract AF04(695)-656)

Secret report

The five volumes making up this Technical Documentary Report describe the results of a 3-month study of the Image Velocity Sensor Subsystem conducted for the Space Systems Division of the Air Force Systems Command under Contract AF04(695)-656. This study involved the analyses, parametric studies, simulations, preliminary design efforts, and planning necessary to develop meaningful definitions of the experiments and experimental hardware required to fulfill the objectives of the MOL program.

Volume I summarizes the entire study. Volume II presents the results of an extensive simulation program conducted to assess man's ability to perform the planned experiments. Simulation plans are also discussed in this volume. The results of trade-off and equipment design analyses are given in Volume IV, while Volume V presents detailed plans for conducting subsequent phases of the IVSS program.

In general, this study has demonstrated the basic feasibility of the proposed MOL experiments, indicated the high degree of precision that human participation can provide to the system, and developed designs and plans compatible with MOL program guidelines.

No Text On This Page

1. Sensors – Image Velocity
3. Experiments – MOL
3. Simulations – Human Factors Evaluations
I. Advanced Systems Research Staff
II. Contract AF04(695)-656
III. Volume I – Summary
IV. Volume II – Simulations
V. Volume III – Subsystem Definition
VI. Volume IV – Experiment and Human Function Definition
VII. Volume V – Program Plans

International Business Machines Corporation, Space Guidance Center, Owego, N.Y. IMAGE VELOCITY SENSOR SUBSYSTEM (IVSS) STUDY FINAL REPORT (UNCLASSIFIED TITLE). Advanced Systems Research Staff. November 1964. 985 p. including illus. tables (IBM CD Nos 3-260-9414 through 9418: SSD-TR-64-227 (I) through V) (Contract AF04(695)-656)

Secret report

The five volumes making up this Technical Documentary Report describe the results of a 3-month study of the Image Velocity Sensor Subsystem conducted for the Space Systems Division of the Air Force Systems Command under Contract AF04(695)-656. This study involved the analyses, parametric studies, simulations, preliminary design efforts, and planning necessary to develop meaningful definitions of the experiments and experimental hardware required to fulfill the objectives of the MOL program.

Volume I summarizes the entire study. Volume II presents the results of an elemental simulation program conducted to assess man's ability to perform the planned experiments. Simulation plans are also discussed in this volume. The results of trade-off and equipment design analyses are given in Volume IV, while Volume V presents detailed plans for conducting subsequent phases of the IVSS program.

In general, this study has demonstrated the basic feasibility of the proposed MOL experiments, indicated the high degree of precision that human participation can provide to the system, and developed designs and plans compatible with MOL program guidelines.

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