NASA Technical Memorandum 89429

Astrometric Telescope Facility: Preliminary Systems Definition Study
Volume I: Executive Summary

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PREFACE

This report documents the results of the Astrometric Telescope Facility (ATF) Preliminary System Definition Study conducted in the period between March and September 1986. The main body of the report consists primarily of the charts presented at the study final review which was held at NASA Ames Research Center on July 30 and 31, 1986. The charts have been revised to reflect the results of that review. Explanations for the charts are provided on the adjoining pages where required. Note that charts which have been changed or added since the review are dated 10/1/86, unchanged charts carry the review date 7/30/86. In addition, the report contains a narrative summary of the study results and two appendices. The first appendix is a copy of the ATF Characteristics and Requirements Document generated as part of the study. The second appendix shows the inputs to the Space Station Mission Requirements Data Base (MRDB) submitted in May 1986.

The report is being issued in three volumes. The first volume contains an executive summary of the ATF mission, strawman design, and study results. Volume Two contains the detailed study information. Volume Three contains the detailed ATF cost estimate, and will have limited distribution.

The study and report presented here are the result of a team effort including personnel from the University of Arizona, the Allegheny Observatory, the University of California at San Diego, and the Ames Research Center. Members of the team were:

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ATF PRELIMINARY SYSTEM DEFINITION STUDY

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ATF ABBREVIATIONS AND ACRONYMS

AEDC	Arnold Engineering Development Center
AGS	Advanced Gimbal System
ARC	Ames Research Center
ARCMIN	Arcminute
ARCSEC	Arcsecond
ASE	Airborne Support Equipment
ASPS	Annular Suspension and Pointing System
ASSY	Assembly
ATF	Astrometric Telescope Facility
AU	Astronomical Unit
AVG	Average
ber	Bit Error Rate
BR	Network Bridge
C	Celsius
CCD	Charge Coupled Device
CDS	Command and Data Subsystem
CG	Center of Gravity
C/L	Center Line
cm	Centimeter, Center of Mass
COMPLEX	Comittee on Planetary and Lunar Exploration
CONTD	Continued
CPS	Coarse Pointing System
CRT	Cathode Ray Tube
CSSA	Committee on Space Sciences and Astronomy
CTE	Coefficient of Thermal Expansion
D	Diameter
dB	Decibel
DC	Direct Current
DEC	Declination
DEF	Definition
DIA	Diameter
DMS	Data Management System
DOD	Department of Defense
EDP	Embedded Data Processor
EFL	Effective Focal Length
EMC	Electromagnetic Compatibility
EVA	Extravehicular Activity
FOV	Field of View
FPI	Focal Plane Instrument
ft	Feet
FWD	Forward
g	Gram, Gravity
Gbit	Gigabit
gm	Gram
GR/EP	Graphite-Epoxy
GSFC	Goddard Space Flight Center

HST	Hubble Space Telescope
H/W	Hardware
Hz	Hertz
IN.	Inch
INST	Instrument
IOC	Initial Operating Capability
IPS	Inertial Pointing System
IR	Infrared
I/F	Interface
J	Joules
JSC	Johnson Space Center
K	Kelvin
kbps	Kilobits per Second
kg	Kilogram
km	Kilometer
KSC	Kennedy Space Center
kW	Kilowatt
lbf	Pound-Force
lbs	Pounds
LEO	Low Earth Orbit
LOS	Line of Sight
LPL	Lunar and Planetary Laboratory
m	Meter
MAP	Multichannel Astrometric Photometer
mm	Millimeter
MB	Megabyte
Mbps	Megabits per Second
MDM	Multiplexer/Demultiplexer
MGMT	Management
MHz	Megahertz
MIN	Minute
MIPS	Mega-Instructions per Second
MPAC	Multipurpose Applications Console
MRDB	Mission Requirements Data Base
MSC	Mobile Servicing Center
MSFC	Marshall Space Flight Center
MSU	Mass Storage Unit
MUX/DEMUX	Multiplexer/Demultiplexer
N	Newtons
NAR	Nonadvocate Review
NIU	Network Interface Unit
ORU	On-orbit Replaceable Unit
PIU	Power Interface Unit
PMT	Photomultiplier Tube
PSD	Power Spectral Density
QSO	Quasi-Stellar Object
RA	Right Ascension
RAD	Radius
RFP	Request For Proposal

RMS	Root Mean Square
SAA	South Atlantic Anomaly
SAVI	Space Active Vibration Isolation
SCU	Signal Conditioning Unit
SDP	Standard Data Processor
SEC	Second
SETI	Search for Extraterrestrial Intelligence
SIRTF	Space Infrared Telescope Facility
SME	Solar Mesospheric Explorer
SOT	Solar Optical Telescope
SS	Space Station
SSEC	Solar System Exploration Committee
STS	Space Transportation System
S/W	Software
TBD	To Be Determined
TDRS	Tracking and Data Relay Satellite
TGS	Time and Frequency Generation System
UOA	University of Arizona
V	Volts
VDC	Volts-direct current
W	Watts
X-STRAP	Cross-strap
Å	Angstrom
(°)	Degree
⊕	Earth
μsec	Microsecond
μ	Micron

SUMMARY

ASTROMETRIC TELESCOPE FACILITY

PRELIMINARY SYSTEMS-DEFINITION STUDY

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INTRODUCTION

The Astrometric Telescope Facility (ATF) is a spaceborne observatory proposed for use on the Space Station (SS) as an Initial Operating Capability (IOC) payload. The primary objective of the ATF will be the search for extrasolar planetary systems and a detailed investigation of any discovered systems. In addition, it will have the capability of conducting other astrophysics investigations; e.g., measuring precise distances and motions of stars within our galaxy.

There have been a number of workshops and studies from 1974 to the present to examine various methods for, and the feasibility of, approaches to search for other planetary systems. These studies and reviews by science peer groups have concluded that the ATF approach appears to be the most promising for the initial investigations. Mutual interests in this facility at the University of Arizona and NASA Ames Research Center have led to an agreement between these institutions to work jointly on the development of the ATF project. Toward that end and with a joint team, the ATF Preliminary System Definition Study was initiated in March 1986. The purposes of the study were to:

1. Define Mission and System Requirements
2. Define a Strawman System concept for the facility at the Prephase A level
3. Define the need for additional trade studies or technology development
4. Estimate program cost for the Strawman concept

It has been assumed for the study that the ATF will be a SS payload, will use a SS-provided Coarse Pointing System (CPS), will meet SS constraints, and will make maximum use of existing flight qualified designs or designs to be qualified by the SS program for general SS use.

SCIENCE

The primary goal of the ATF Mission is the search for, and the study of extrasolar planetary systems. This goal is motivated by a desire to verify current ideas about the origin of our solar system and further develop these ideas into a firm theory of star and planetary system formation and evolution.

The orderly nature of our solar system suggests it originated from a single precursor object and not a series of accidents. Present evidence suggests it was formed from a rotating cloud which, when acted on by viscous effects and self-gravitation, resulted in the overall configuration of the solar system. This theory is consistent with the observation that planetary composition varies with the distance from the Sun and that planetary masses are correlated with the cosmic abundance of material from which they are made. If this theory is correct, then planetary systems are formed as a natural consequence of star formation, at least for single stars, and it is believed that our solar system is not unique. If, on the other hand, a statistically significant survey of stars shows our system to be unique, existing theories would have to be reexamined. Therefore the basic ATF goals are to examine nearby stars for evidence of planetary systems and if planets are discovered, study the systems in detail. An important objective is to ensure that a negative result would be scientifically significant. To reach these goals, the investigation should have the capability to detect planets as small as 10-20 Earth masses at distances on the order of 2-10 AU from the central star and should investigate on the order of 100 candidate stars.

The ATF approach is to make astrometric measurements with respect to a frame of distant stars, to an accuracy which would show the reflex motion of a star as it and the associated planets orbit around the system's center of mass. To accomplish this, the system must have the capability of detecting relative motion of 10^{-5} arcsec allowing useful studies of stars to a distance of 10 parsecs from the sun. In addition, the duration of the observations must continue for 10-20 yr, commensurate with expected orbital periods of planets. Although the ATF is being designed specifically for planetary detection, these capabilities will provide the opportunity for other important astrophysical investigations.

MEASUREMENT APPROACH

The basic scientific requirement is to be able to measure the motion of the target stars relative to the reference star background with accuracy of 10 μarcsec. The ATF measurement approach is to extract the metric information from the star images by passing a Ronchi ruling (a series of transparent and opaque lines) across the telescope focal plane, thus modulating the signals to sensors located beyond the ruling. The distance between the target and reference star images is determined grossly by the number of lines between images and, with a very high level of accuracy, by comparing the relative phases of the modulated signals. Relative stellar motions can therefore be determined from the phase shifts between images as measured over periods commensurate with planetary orbital periods, 10-20 yr.

It is important to remember that in the context of Planetary Detection, the measurement being made is the star's change in position through a series of observations, rather than in the star's absolute position. Thus the ATF's 10 μarcsec accuracy refers to the accuracy in the knowledge of the star's change in position, not position itself. Many general astrometric investigations, apart from Planetary Detection, also require measurement of an object's change in position over time and are well suited to the ATF. The ATF has not been designed for general astrometric investigations requiring absolute positional measurements, and its ability to perform such investigations will be limited, consistent with the requirements to do Planetary Detection.

Figure 1 shows the basic concept schematically. For the ATF, the modulated telescope focal-plane image is magnified and redirected to the Focal Plane Instrument (FPI) pickup plane located at the side of the telescope tube by a set of relay optics and a diagonal mirror located behind the ruling. The FPI contains a total of 32 individual pickups each of which can be positioned to receive the light from a single star.

This study and the work done prior to its initiation show that the ATF system can achieve the required accuracy. Analyses include consideration of both systematic and random errors. The effect of random errors on the final result can be reduced by increasing the observation time. This is not true of the more critical systematic errors. Therefore, it is essential that potential systematic errors be identified and removed either by design or system calibration.

Figure 2 shows a list of systematic errors considered to date and the solutions identified for their resolution. As can be seen from the list, control of some of these can be achieved by the basic design, others will require tracking through the detailed design and calibration of the system.

Detailed analyses of random errors have been conducted and are continuing. Based on the results to date, it appears that the ATF mission requirements can be met. The following is a discussion of the analyses showing the impact of these errors on integration time.

MEASUREMENT APPROACH

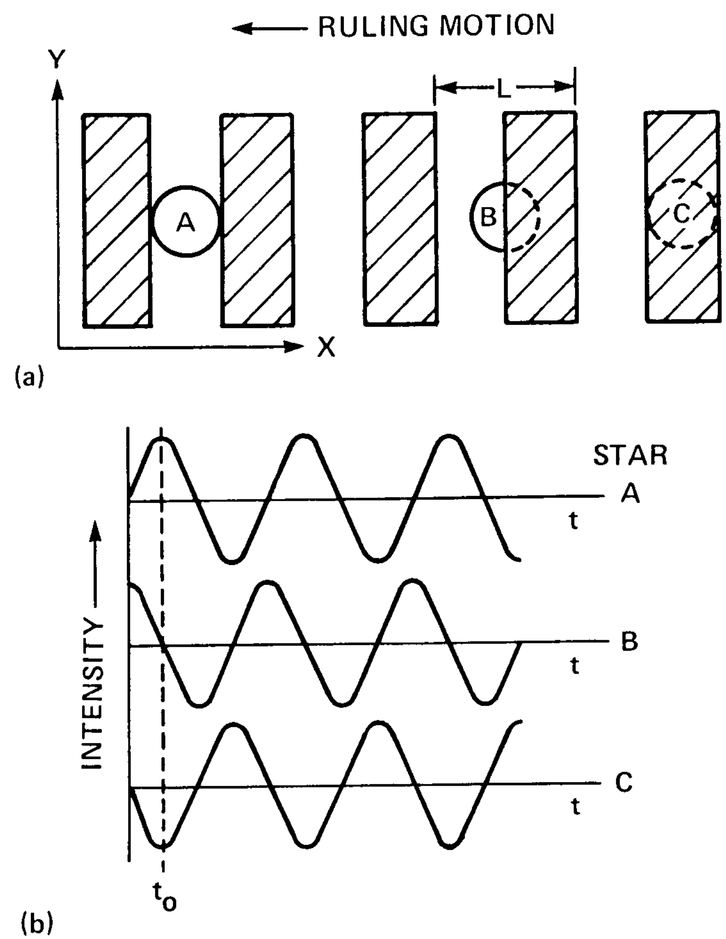

FIGURE 1

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ATF SYSTEMS STUDY

POTENTIAL SYSTEMATIC EFFECTS

EFFECT	SOLUTION
OPTICAL SURFACE VARIATIONS	USE ONE OPTICAL SURFACE IN ENTRANCE PUPIL
COMA	OPTIMIZED RULING -- 2 COLOR BANDS
CHANGES OF MIRROR COATING	OVERCOAT TO HOLD WITHIN SPECS AND PROTECT FROM CONTAMINATION
NONUNIFORM RULING DEFORMATION	MATERIAL SELECTION AND STATISTICAL TESTING
TRANSMISSION CHANGES OF SECONDARY OPTICS (RULING, OPTICAL FIBERS, ETC.)	MATERIAL SELECTION
FIELD CROWDING	EXAMINATION OF FIELDS FOR OPTICAL DOUBLES
UNKNOWN NONLINEAR REFERENCE STAR MOTIONS	SELECTION OF DISTANT REFERENCE STARS AND CONTINUOUS MODELING

FIGURE 2

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The prime requirement is to find the centroid of the photons from the star with a relative accuracy of 10 μarcsec. For a normal distribution of photons from the star, the maximum achievable measurement accuracy is

$$\sigma = \sigma_o / \sqrt{N}$$

where σ_o is the size of the diffraction image and N is the total number of photons detected. Since the diffraction limited image for the telescope is the order of 0.1 arcsec, the equation shows that 10^8 photons are required for the measurement exclusive of any error sources. The effects of random errors add in the following way

$$\sigma^2 = \sigma_o^2 + \sigma_o^2 \sum_{i=1}^{n} (\sigma_i / \sigma_o)^2$$

where the σ_i are the standard deviations for the various random error sources. The recognized error sources (figure 3) combined with the efficiency factor associated with various losses in the system (figure 4) increase the integration time required for one determination of a target star position by a factor of 1160. Note that the total number of photons required can be accumulated over multiple integration periods. Figure 5 shows the total time required for one observation (integration time for required astrometric accuracy); it is shown as a function of galactic latitude because of the systematic dependence of reference star brightness with galactic latitude. As indicated by the figure, the mission analysis shows that target stars with average latitudes of up to about 30° can be studied.

RANDOM ERRORS

- INTEGRATION TIME NEEDED TO REACH A GIVEN ACCURACY IS INCREASED BY RANDOM ERRORS

	ERROR SOURCE	F*
1.	PHOTON STATISTICS (σ_o)	1.000
2.	BACKGROUND LIGHT	.002
3.	IMAGE SHAPE/SIZE	.30
4.	IMAGE MOTION (JITTER)	(a)
5.	GRATING IMPERFECTIONS	(a)
6.	GRATING MOTIONS	(b)
7.	GRATING ALIGNMENT	TBD
8.	FIELD MODELING	0.060
9.	REDUCTION ALGORITHM	<< 1
10.	POSTFOCAL RESPONSE VARIATION	TBD
11.	REFERENCE STAR ERRORS	(c)
12.	CONTAMINATION	TBD
	TOTAL TIME FACTOR:	1.362 + TBD

*F = CONTRIBUTION TO THE INTEGRATION TIME ENHANCEMENT FACTOR;
TOTAL TIME ENHANCEMENT IS THE SUM OF THE INDIVIDUAL F'S.

NOTES:
(a) THE DESIGN REQUIREMENT CORRESPONDING TO F << 1 IS FEASIBLE.
(b) INCLUDED IN JITTER.
(c) WITH PROPER SELECTION OF FIELDS AND REFERENCE STARS THIS ERROR WILL BE NEGLIGIBLE (F << 1).

FIGURE 3

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ATF SYSTEMS STUDY

LIGHT LOSS EFFECTS

- INTEGRATION TIME NEEDED TO REACH A GIVEN ACCURACY IS INCREASED BY LIGHTAND OTHER INFORMATION LOSSES

SOURCE OF INFORMATION LOSS	TYPE OF LOSS	THROUGHPUT
A. GRATING REJECTION	LIGHT	0.25
B. MASK FOR GRATING SHADOW	LIGHT	0.75
C. GRATING INTRINSIC	INFORMATION	0.50
D. LOSS IN OPTICS	LIGHT	0.50
E. DETECTOR QUANTUM INEFFICIENCY	LIGHT	0.10
F. ONE-DIMENSIONAL ENGINE	INFORMATION	0.50
G. OPERATIONAL INTERRUPTIONS	INFORMATION	0.50
	TOTAL THROUGHPUT	0.00117

INTEGRATION TIME INCREASED BY 1/THROUGHPUT = 853

FIGURE 4

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OBSERVATION TIME CALCULATIONS

- TOTAL OBSERVATION = INTEGRATION TIME FOR IDEAL SYSTEM
  X
  TIME FACTOR FOR LIGHT AND INFORMATION LOSSES (853)
  X
  TIME FACTOR FOR RANDOM ERRORS (1.36)

- FOR ATF: OVERALL TIME FACTOR = 853 X 1.36 = 1160

  OBSERVATION TIME = 1160 X IDEAL INTEGRATION TIME

GALACTIC LATITUDE	IDEAL INTEGRATION TIME (MIN)	AVERAGE OBSERVATION TIME (HR)	
0	0.030	0.58	
10	0.57	10.98	
20	1.37	26.6	MOST OBSERVATIONS
30	2.19	42.4	AT LOW LATITUDES
40	3.12	60.4	
50	4.12	80.6	
60	5.00	96.6	
70	5.95	115	
80	6.25	120.8	
90	6.58	127.2	

FIGURE 5

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MISSION

The plan is for the ATF to be a SS Initial-Operating-Capability (IOC) payload, launched by the Space Transportation System (STS). The strawman design has been sized to best accomplish the mission science goals constrained by the requirement to be launched by the STS in a single launch. The resulting design takes essentially all of the available space in the bay and will therefore require a dedicated launch.

The ATF has been designed to be accommodated by the SS on an extension attached to the aft side of the upper science boom. Figure 6 shows the baseline location and mounting configuration used for the study, although the study indicated that the ATF mission could be accomplished by a variety of different mounting locations and CPS configurations. It has been assumed that one of the SS CPS mounts will be dedicated to ATF use.

Analyses also show that the ATF mission could be accomplished in the presence of the presently specified levels of contamination. However, the team is aware of studies which indicate contamination levels could be considerably higher. If so, contamination could present a problem for the ATF and will clearly require continued attention.

Mechanical jitter in the general range of the ruling frequency is also of concern to the ATF. Therefore, SS vibration at the ATF mounting location must be controlled. Analyses show that the strawman ATF design will meet the mission requirements for the maximum station vibration currently anticipated.

For the strawman ATF design, the facility would be launched in three pieces and assembled on orbit. The baseline plan is to assemble the ATF in the SS service bay, then move it to the mounting location where it would be attached to the CPS. Subsequent to the initial assembly, the facility will be operated from the ground, requiring no further on-orbit activity except for maintenance required by hardware failure, and possibly preemptive shutdown by the SS crew. In the event the Service Bay is not part of the IOC configuration, the ATF could be assembled directly onto the mounting location.

The ATF design mission lifetime is 20 yr with a minimum time between maintenance of 5 yr. The ATF uses no expendables. The minimum maintenance period is established to be consistent with the use of flight hardware for which the qualified life is typically five years. Experience has shown that most hardware normally exceeds its qualification life. Therefore it is anticipated that maintenance will be required less frequently than specified. One of the major attributes of using the SS is the practicability of supporting maintenance for a 20-yr mission.

Hardware design and location on the station has been selected to provide full sky coverage over the life of the mission. The all-sky viewing is achieved while still meeting the avoidance constraints; >30° from the Sun and Earth, >10° from

ATF
SYSTEMS STUDY

ATF MOUNTED ON SPACE STATION (BASELINE DESIGN)

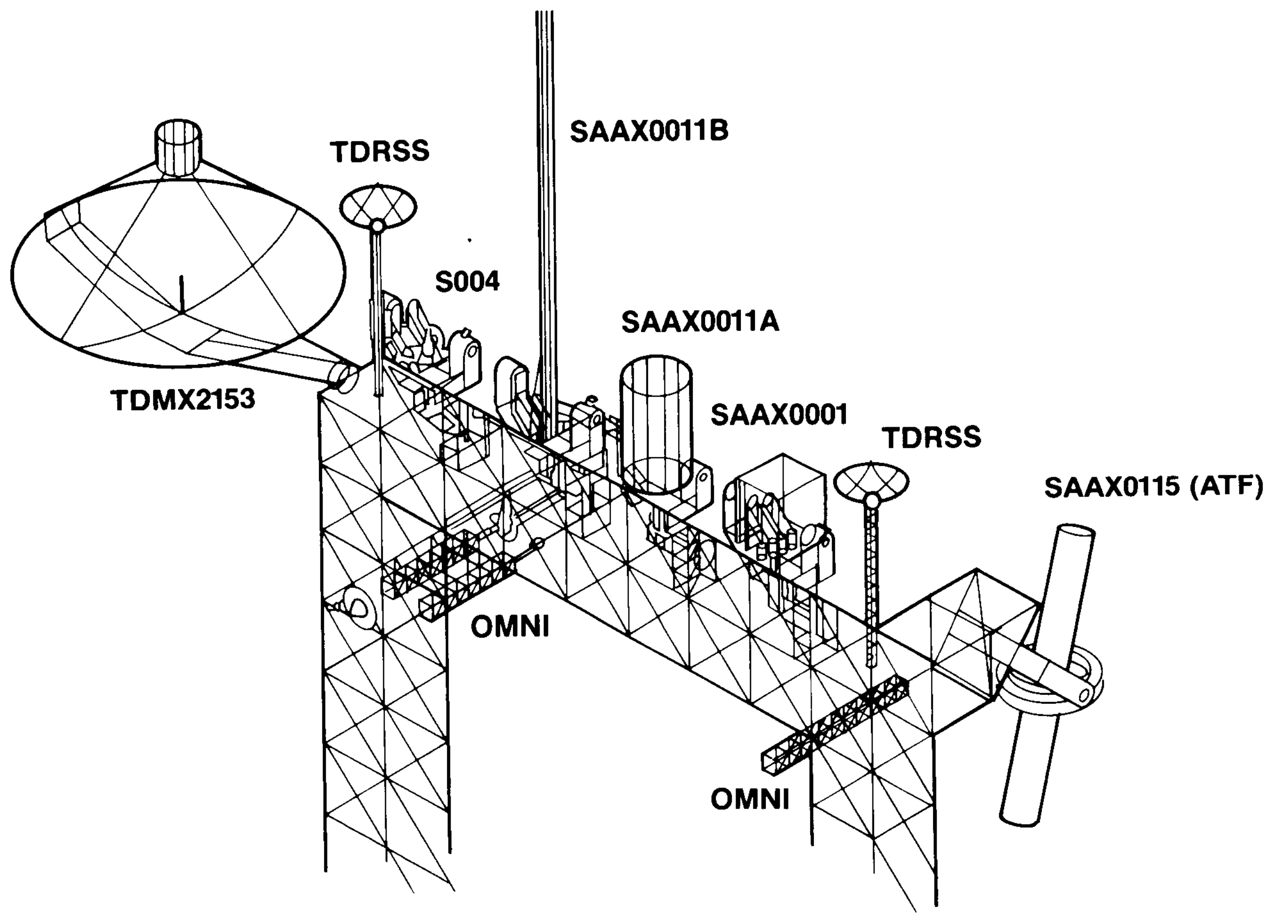

FIGURE 6

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the Moon and >90° from the velocity vector. With this configuration and the capabilities of the hardware design, it will be possible to investigate 100 target stars in the visual magnitude range of -1.5 to +13.5 against reference fields with stars down to +15 visual magnitude in about two-thirds of the total available viewing time.

SYSTEM DESCRIPTION

The ATF system is composed of six subsystems (Optics, Structure and Mechanisms, Thermal Control, Command and Data, Pointing and Control, and Power and Harness) plus the Focal Plane Instrument. These elements are integrated into a system designed to meet the mission requirements and the basic science requirement to measure relative star motion with an accuracy of 10 μarcsec. In addition, one rack of ATF electronic equipment will be located inside a SS pressurized module. This equipment, designated as the ATF control console, will contain all required control functions for on-board safing plus a computer for contingency ATF operation and data-reduction. The on-board data-reduction capability would be used only if there were significant periods (days) when the station could not support the full ATF downlink data rate. It is preferable to transmit all of the raw data to the ground for reduction.

Figure 7 shows the overall layout of the ATF. The telescope is designed as a F/D13 system with a 1.25-m-diameter primary mirror. The Ronchi ruling is located at the prime focus. A bar across the front of the telescope tube supports the ruling and the relay optics which direct the beam to the side of the tube and refocus and magnify the image at the Focal Plane Instrument. Also shown on the figure is the sunshade and protective cover. The overall length of the telescope is about 22 m, including the sunshade. The telescope is wrapped with a thermal blanket to minimize thermal changes associated with varying solar and Earth-illumination conditions. Overall diameter of the assembly including the blanket is approximately 1.85 m. The telescope is held at its center of gravity in the ATF Vibration Isolation/Vernier Pointing System which is, in turn, attached to the SS CPS. The Vibration Isolation/ Vernier Pointing System isolates the telescope from the SS vibrations and provides a second level of pointing to reach the mission pointing accuracy requirement of 1 arcsec (CPS capability is limited to approximately 30 arcsec). Also included in this assembly is a mechanism to rotate the telescope ±180° about the optical axis. Electronics units are located on a thermally isolated plate at the back of the tube and at the front of the tube in the region of the Focal Plane Instrument. Simple passive radiators are used to reject heat from the electronics and keep the detectors cool. The mass of the ATF mounted to the CPS is 5100 kg.

Figure 8 is a schematic of the ATF system showing the system approach to redundancy and the electrical/electronic interface with the station. Redundancy has been implemented by providing two independent strings of electronics, cross-strapped only at the three non-redundant units, the FPI, visible imager, and gyroscope. It appears impractical to make the FPI redundant and, as will be seen later, the instrument does contain important elements of redundancy. The gyros are internally redundant. The interface with the station has been kept to a standard data and power interface. The maximum data rate is 1.75 Mbps. Power levels are 1400 W average, 2500 W maximum.

The system is designed to be fail-safe and single-fault tolerant. It is assumed that the CPS will include safety features to prevent telescope pointing which

ASTROMETRIC TELESCOPE FACILITY

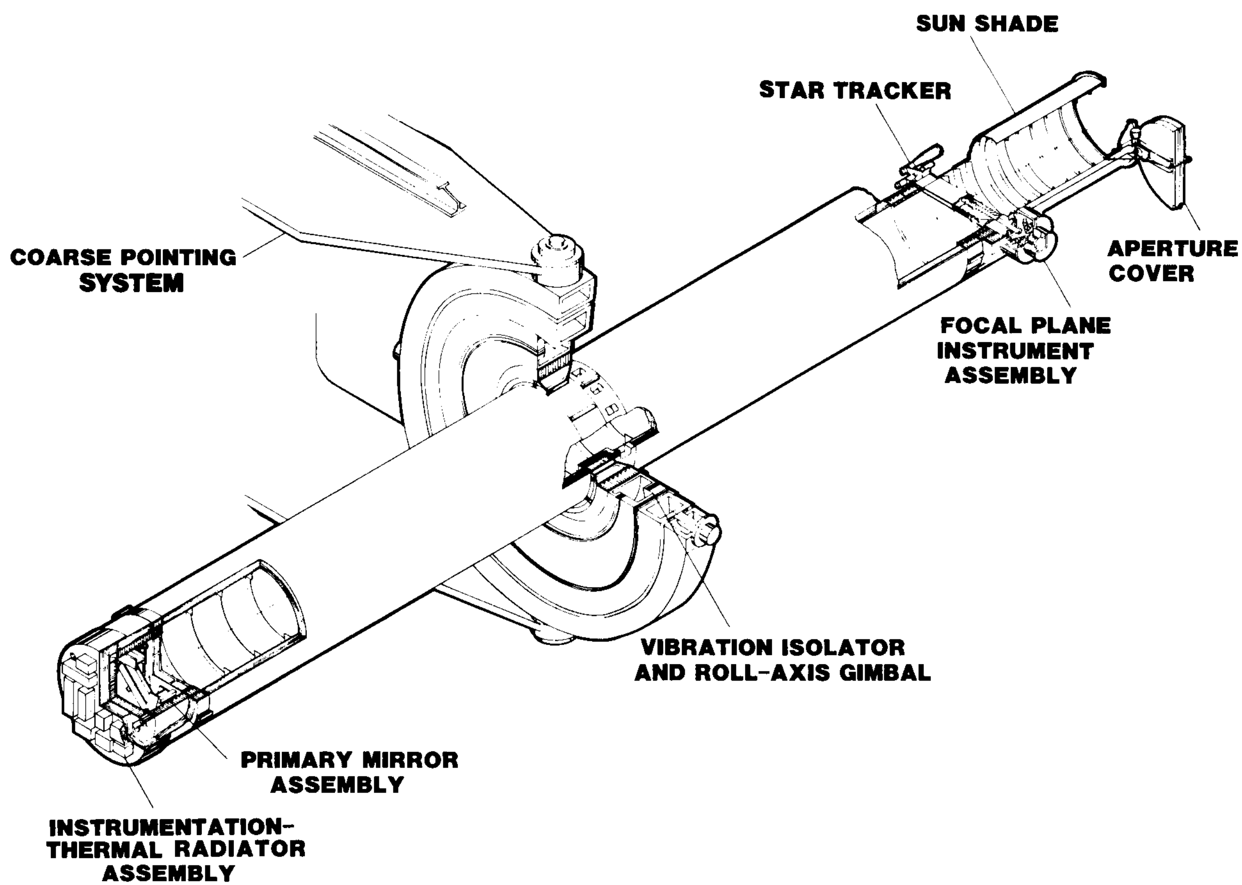

FIGURE 7

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ATF BLOCK DIAGRAM

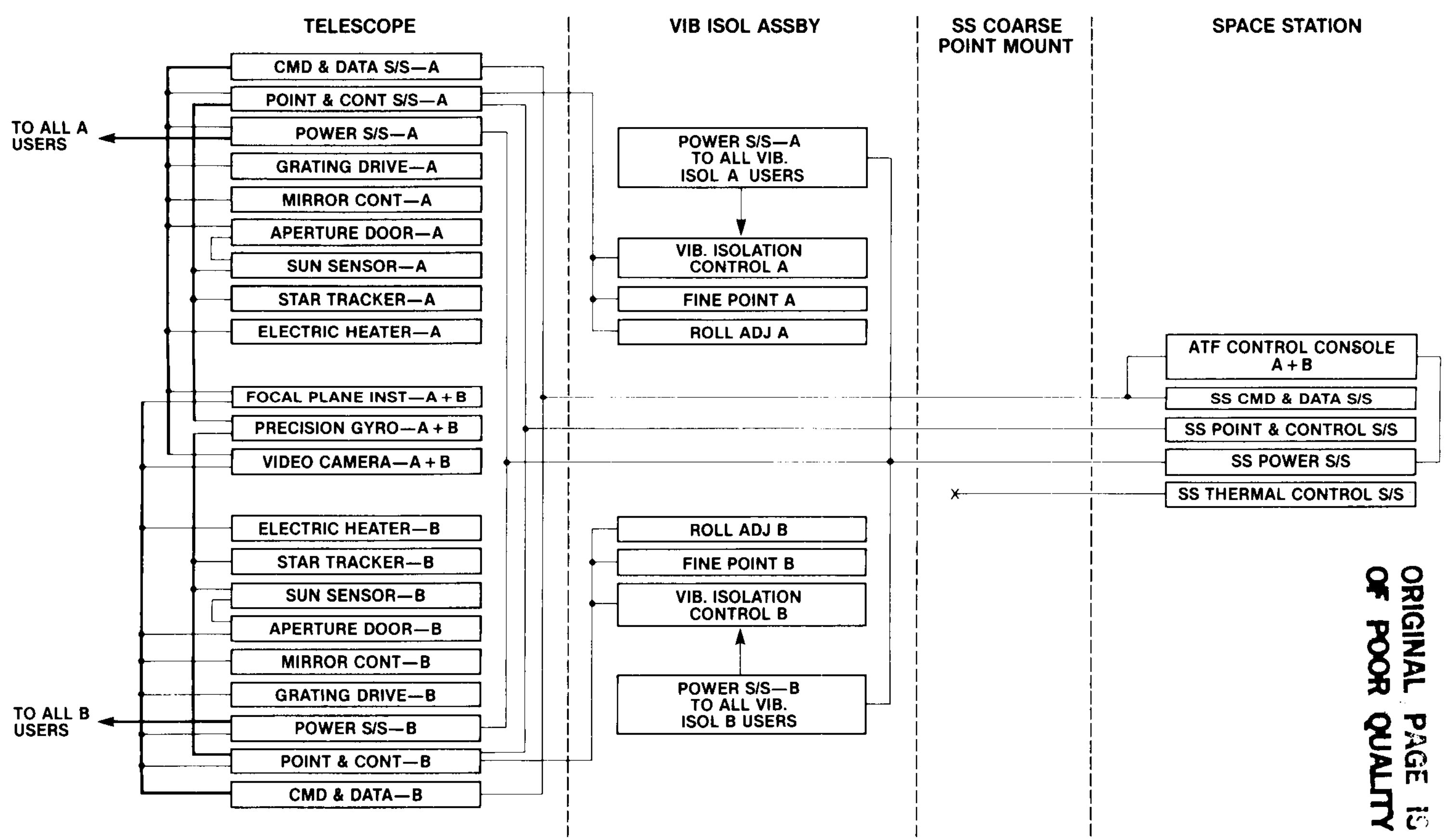

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FIGURE 8

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could physically damage the telescope, SS, or other science payload hardware. Based on this assumption, the potential critical conditions for ATF are pointing of the telescope into the Sun, exposure to high levels of contamination, or significant over or under-voltage conditions. An aperture cover will protect against improper pointing or contamination and is designed to close automatically, without need of external power, if power to ATF is lost or critical mispointing is detected by onboard sun sensors. The SS is expected to provide a contamination warning signal should it be necessary. The ATF system is protected from anomalous voltage conditions by the power sub-system electronics. Noncritical failures have been accommodated by the redundancy approach described previously. Should a failure occur in one string, the system would be switched to the other and continue to operate. Replacement of the failed unit would be scheduled at the next convenient opportunity from an overall SS standpoint, since the ATF can continue to operate in its normal manner in the meantime.

OPTICS AND FOCAL PLANE INSTRUMENT (FPI)

Figure 9 shows the optical train for the ATF. The image of the star field is focused at the Ronchi ruling by the primary mirror. After the light is modulated by the ruling, it is directed to the side of the tube by a diagonal mirror and is magnified at the focal plane of the FPI by a relay lens assembly. The figure shows the light path through, and the optical elements contained in, one of the 32 movable pickup assemblies in the FPI.

A single paraboloid mirror with a focal length of 16.25 m and diameter of 1.25 m is used to focus the field at the ruling. For best performance, the strawman design strives to maximize these dimensions while meeting the constraints of the STS launch envelope. The field of view of the system is 10 arcmin. This design has the advantage that the mirror is pupilar. It is therefore resistant to metric errors caused by spatial variations in the mirror performance because every portion of the mirror reflects light from the entire field. However, this system does have significant comatic and chromatic effects. The chromatic effects have been reduced by dividing the spectral region into two ranges (0.4 to 0.6 and 0.6 to 0.8 μ) each with its own dedicated detectors, while coma is addressed by optimizing the ruling constant and increasing integration times.

A two-mirror ("folded optics") configuration is still to be studied as a possible alternative. It would be essentially free of comatic effects, which might compensate for the additionally introduced error sources. If it can be shown to be practical for the planetary detection mission, this configuration would be substantially shorter than the strawman design described in this report (although somewhat larger in diameter), and may offer some improvement in ability to perform other astrometric measurements.

A diagonal mirror and relay lens redirects and magnifies the image, at a secondary focus, by a factor of two and one half (from 5 to 12.5 cm), to provide a larger area for the pickup arms to function within.

The "Medusa" concept for the FPI has been demonstrated by a similar multihead instrument currently in use for spectroscopic investigations at Steward Observatory, University of Arizona. Figures 10 and 11 show two views of the instrument for the ATF based on this experience. Note that for the ATF instrument the pickups are at two different levels to permit packaging of the 32 pickups. Also shown is the visible imager located at the back of the FPI. The imager will be a standard 512 x 512 charge-coupled device (CCD) with three lens groups. The various lenses will provide the capability of imaging the telescope objective for diagnostic purposes, providing a telescope field-of-view picture, or a magnified image of a single star.

ATF OPTICAL TRAIN SCHEMATIC

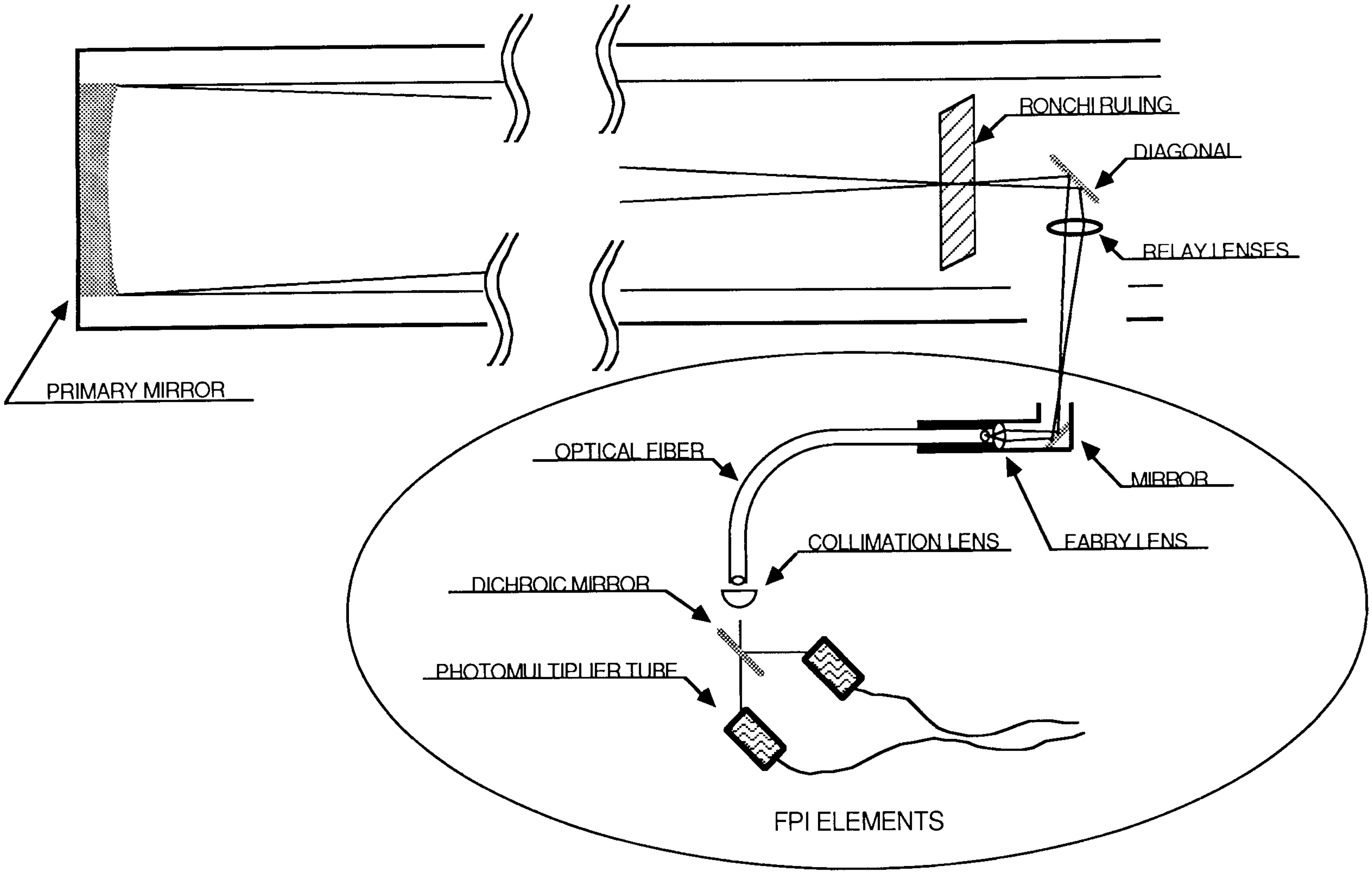

FIGURE 9

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ATF SYSTEMS STUDY

ATF FPI "MEDUSA" TOP VIEW

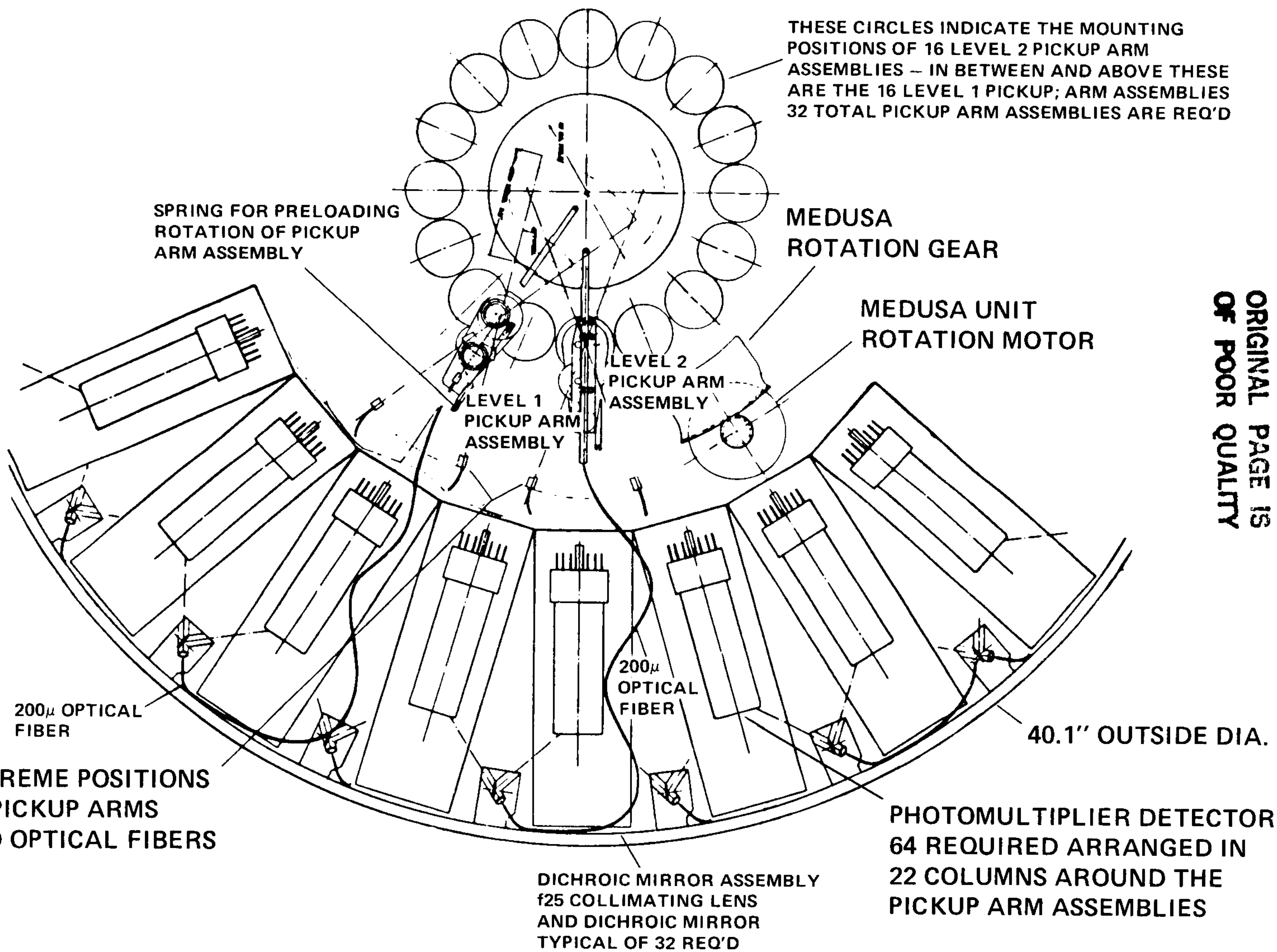

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FIGURE 10

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ATF SYSTEMS STUDY

ATF FPI "MEDUSA" SIDE VIEW

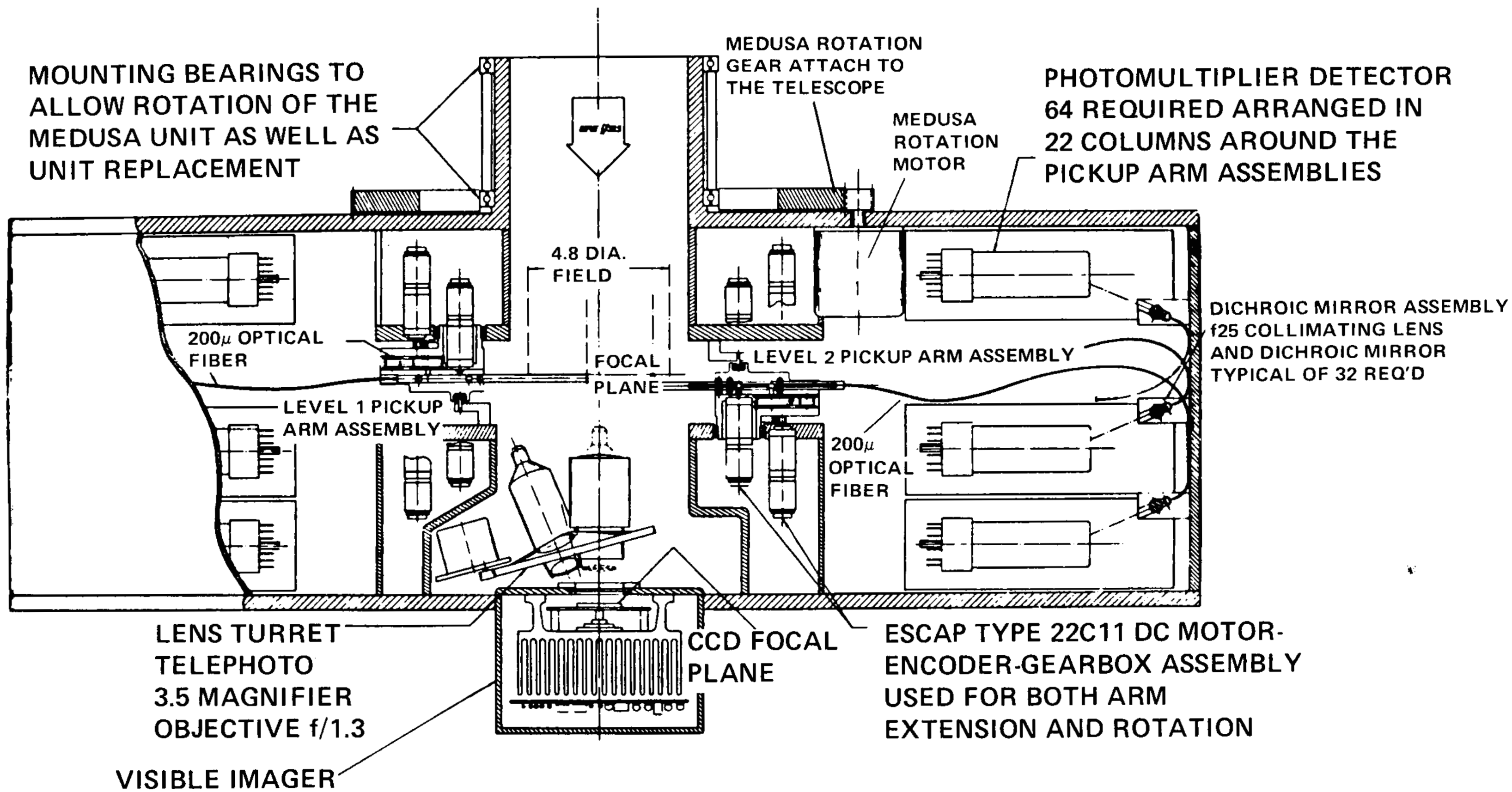

FIGURE 11

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SUBSYSTEM DESCRIPTION

Structure and Mechanisms. The basic structure of the telescope is a tube of graphite-epoxy material formulated to minimize the axial coefficient of thermal expansion. Where required, the tube is reinforced locally with honeycomb material. The monocoque design has the feature that it is relatively straightforward to fabricate and will have few resonant modes. This is particularly important for ATF because the accuracy of the measurement is sensitive to image jitter at the ruling frequency. Limiting the number of resonances thus reduces the frequency bands of concern. A NASTRAN model of the structure was developed during the study and the results of this model were used to determine the vibration isolation requirements.

The Ronchi ruling assembly is shown in figure 12. This assembly has been designed as a cartridge for ease of installation or replacement. The ruling rides in a set of bearings and is driven by a variable speed motor using a metal belt. Redundant motors have been incorporated in the design. The variable speed drive provides the capability to drive the ruling over the required modulation frequency range of 10 to 100 Hz.

Figure 13 shows the mirror mount mechanism. The mount holds the mirror kinematically and includes a mechanism which will allow the system to be collimated and focused on orbit with motions in the axial, tilt and radial directions. It also provides a mechanism for locking the mirror in place during the launch phase. The locking system is designed to be released manually during the initial on-orbit assembly process.

The strawman aperture cover concept is shown in figure 14. It is designed to close automatically to protect the optical system and FPI in case of anomalous conditions including power failure. The folded cover design protects the inside surface of the cover from contamination in the open position.

Thermal Control. The ATF thermal control design depends on standard thermal blankets to minimize temperature variations, fixed passive radiators to reject electronics heat, and replacement heaters. First-order, steady-state analyses, using a conservative value for the coefficient of thermal expansion for the graphite epoxy, show the system has adequate dimensional stability to meet the optical alignment requirements for the calculated temperature extremes.

Command and Data. A block diagram of the Command and Data Subsystem (CDS) and its interface with the SS data system is shown in figure 15. The electronic units used in this subsystem, with the exception of the Signal Conditioning Unit and the data reduction processor, are SS units with little or no modification. This approach will minimize ATF project costs and ensure interface compatibility with the SS data system. The ATF requirements are well within the capabiliy of the SS unit designs.

RONCHI RULING ASSEMBLY

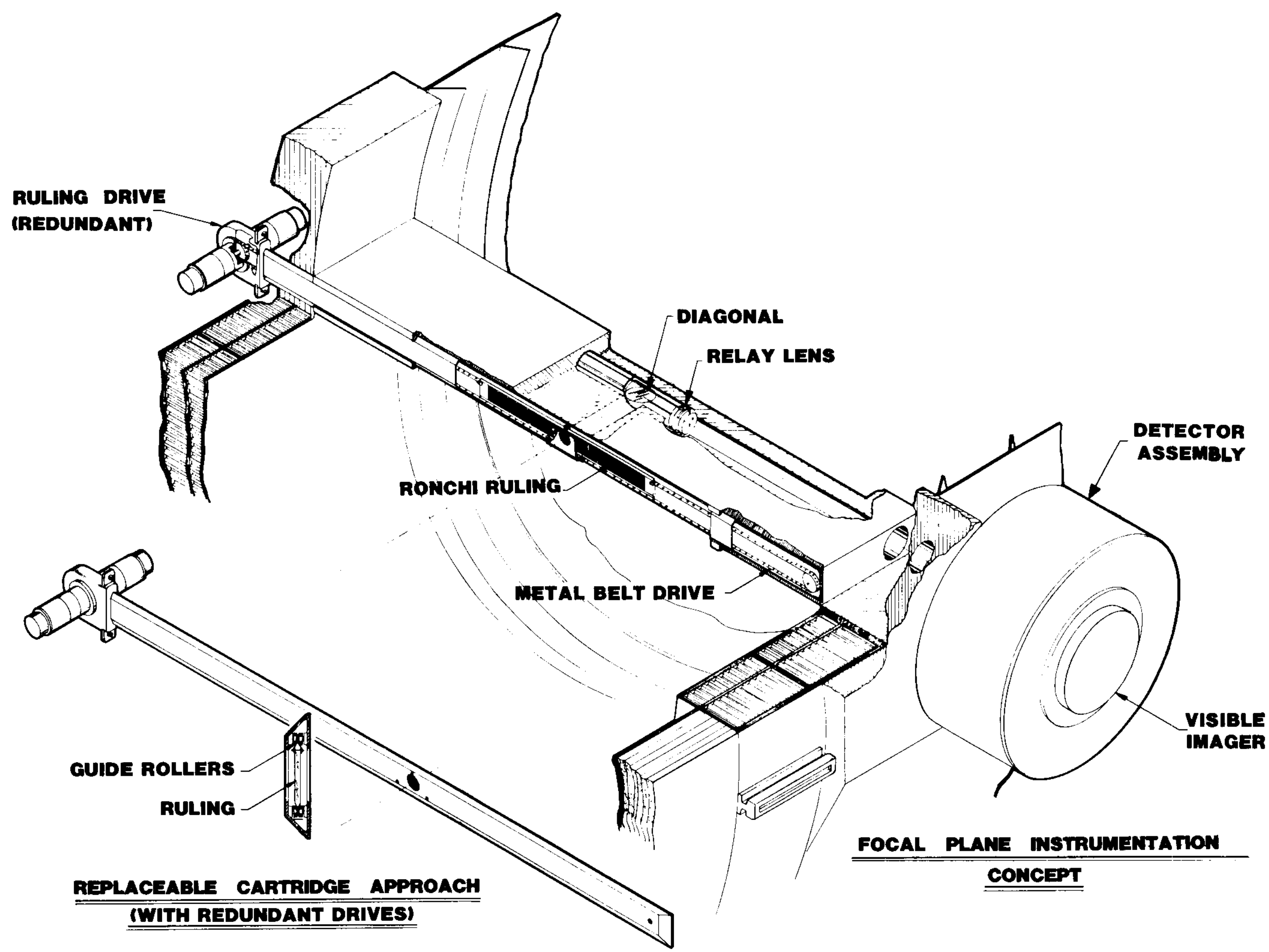


FIGURE 12

10/1/86

MIRROR MOUNT

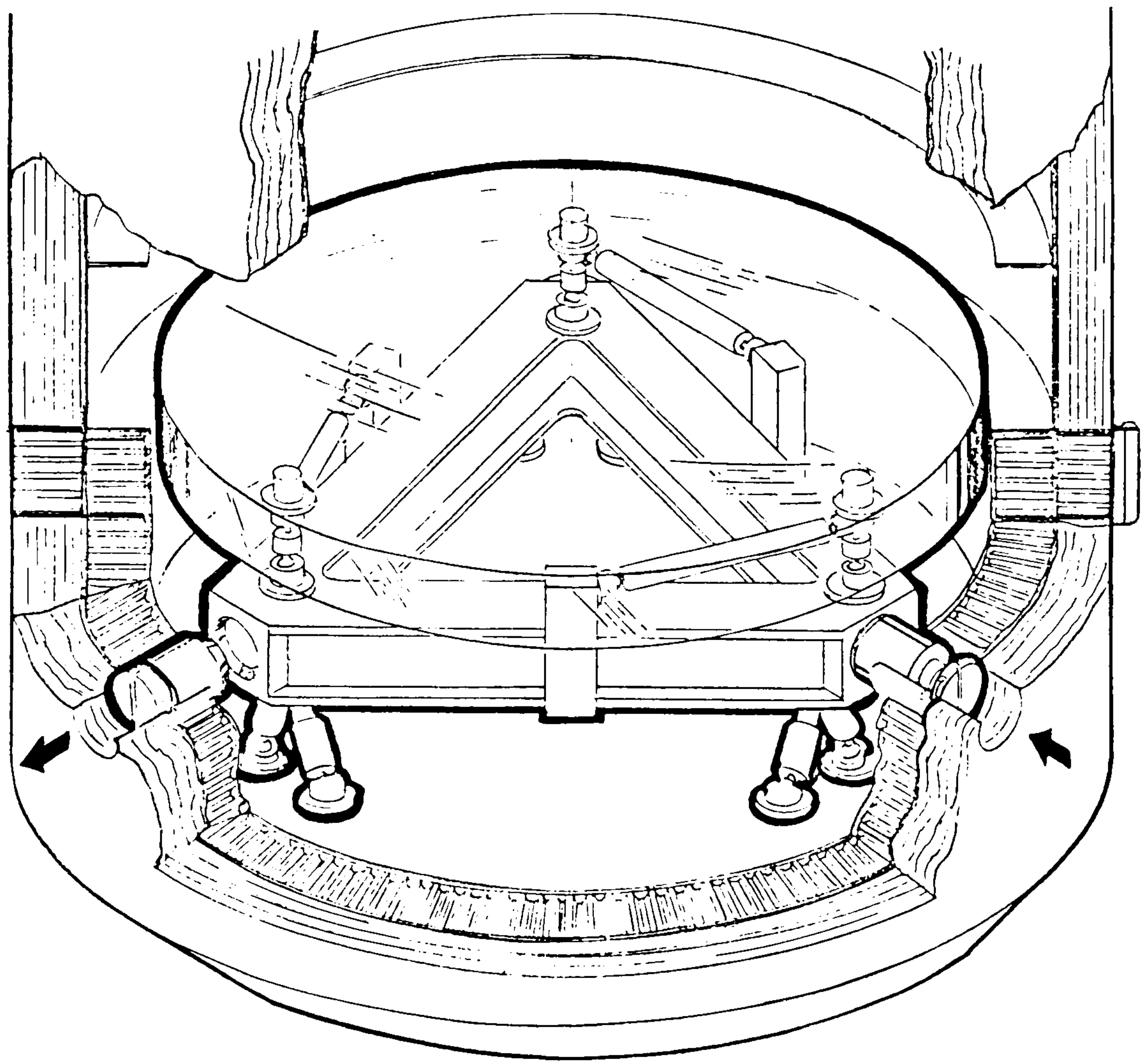
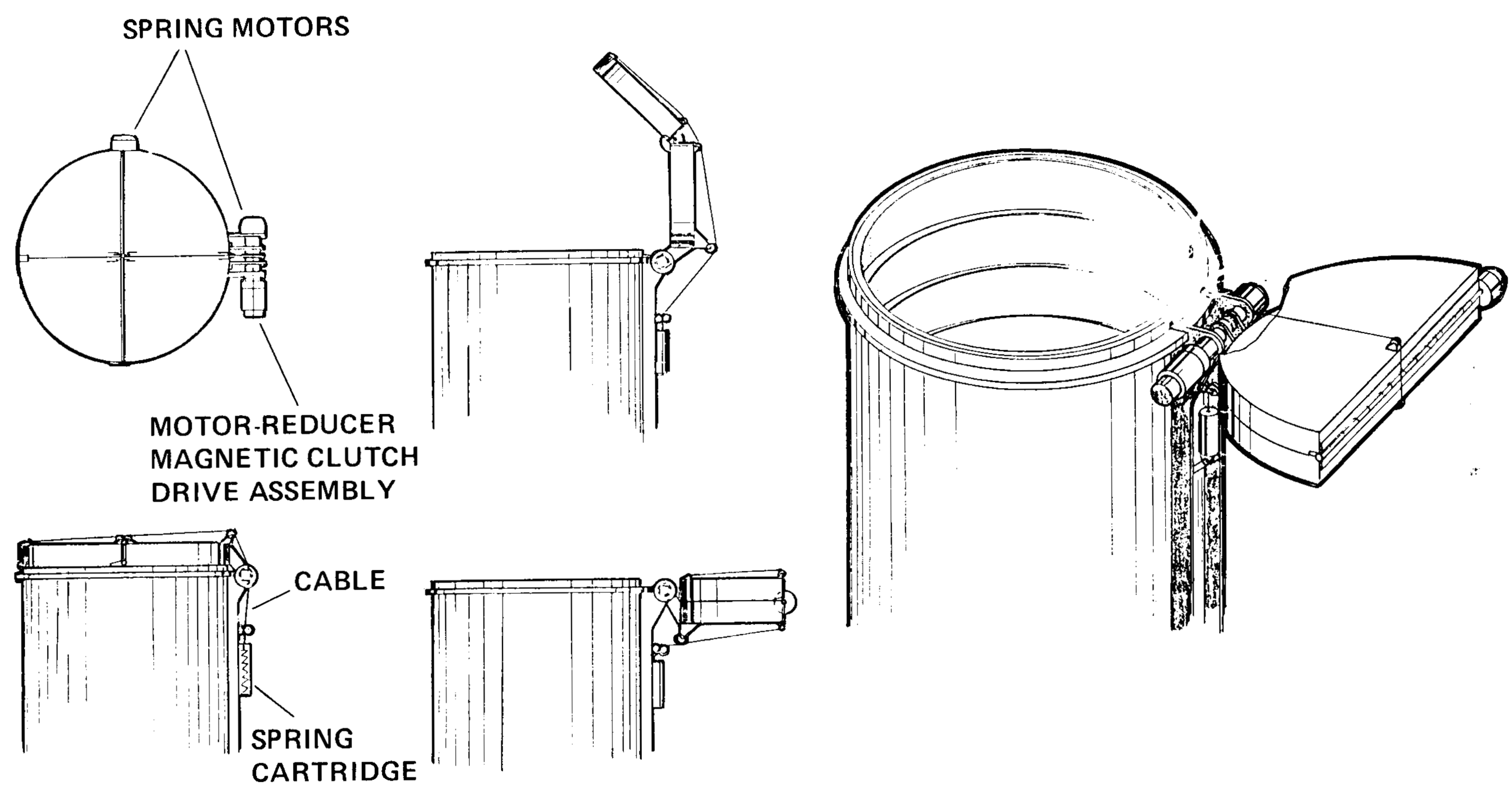


FIGURE 13

10/1/86

APERTURE COVER



COVER CONCEPT

FIGURE 14

10/1/86

ATF
SYSTEMS STUDY

COMMAND AND DATA SUBSYSTEM

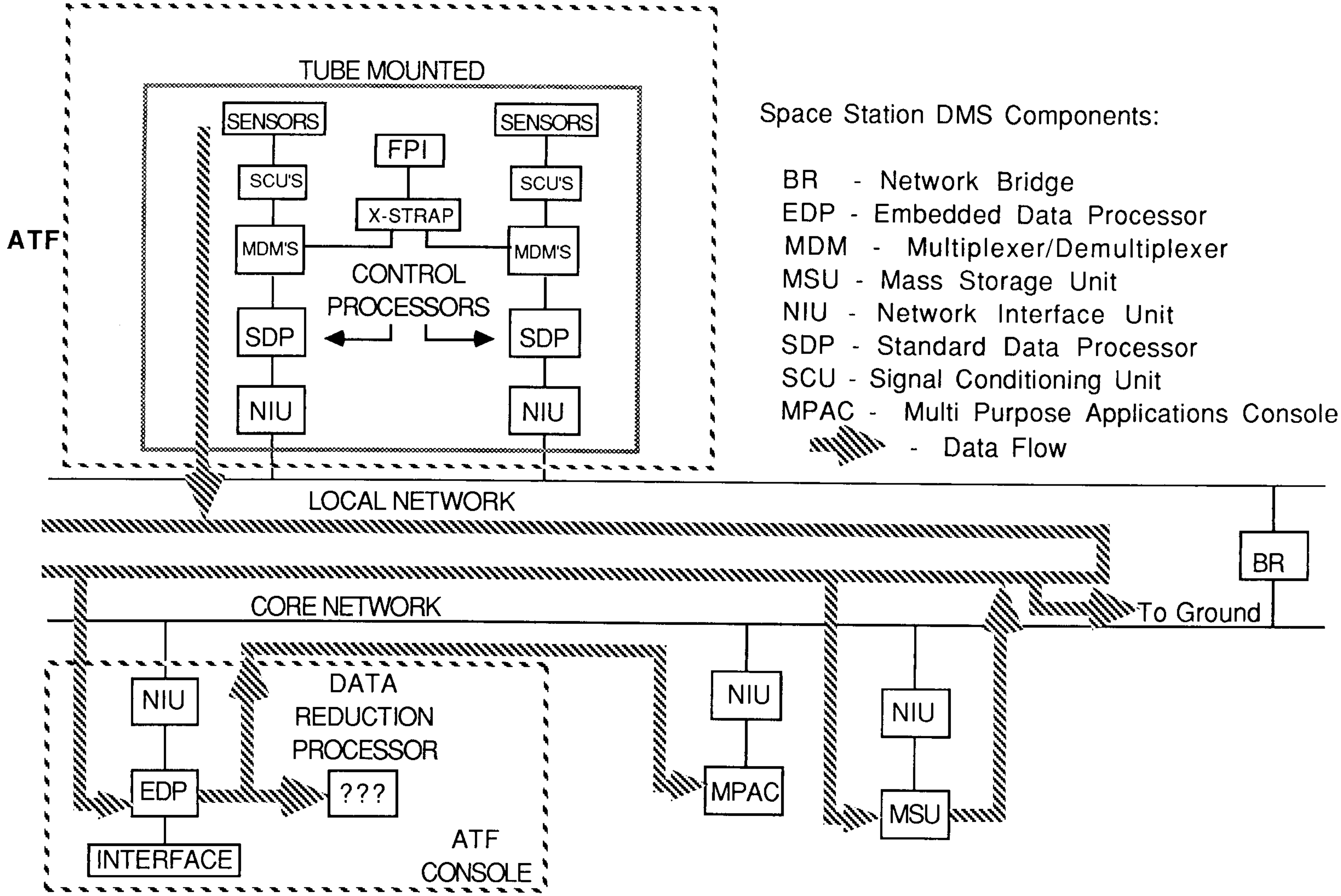


FIGURE 15

10/1/86

Pointing and Control. A schematic of the Pointing and Control Subsystem is shown in figure 16. The precision gyro reference selected for ATF is a flight proven unit, the star tracker has been built and tested for flight but it has not been flown at this time. (It was scheduled to be used on a STS payload during the summer of 1986.) The Vibration Isolation/Vernier Pointing System will have to be designed and built for ATF. However, systems with more severe requirements have now been built and tested at the breadboard level. The most severe subsystem requirement is to control the jitter of the image at the Ronchi ruling to 0.01 arcsecond in a bandwidth between one half, and two times the ruling frequency. Analyses of the system assuming vibration levels of 10^{-2} g's from the SS and using the most important modes from the NASTRAN model of the ATF structure show that vibration isolation performance of the order of 50 dB is required. This appears to be well within the capabilities of systems tested on the ground.

Power and Harness. Primary power is supplied by the SS. The ATF power electronics unit (Power Interface Unit or PIU) provides voltage regulation, power switching, and under/over-voltage control for the system. The system will have the capability to switch on or off individual ATF units. This unit will be designed specifically for ATF but incorporates standard voltage regulation boards designed and qualified for the SS program. A schematic of this subsystem and its interface with the SS is shown in figure 17. The harness will be standard flight design with connectors designed and qualified for on-orbit mating and demating as required.

POINTING AND CONTROL SUBSYSTEM

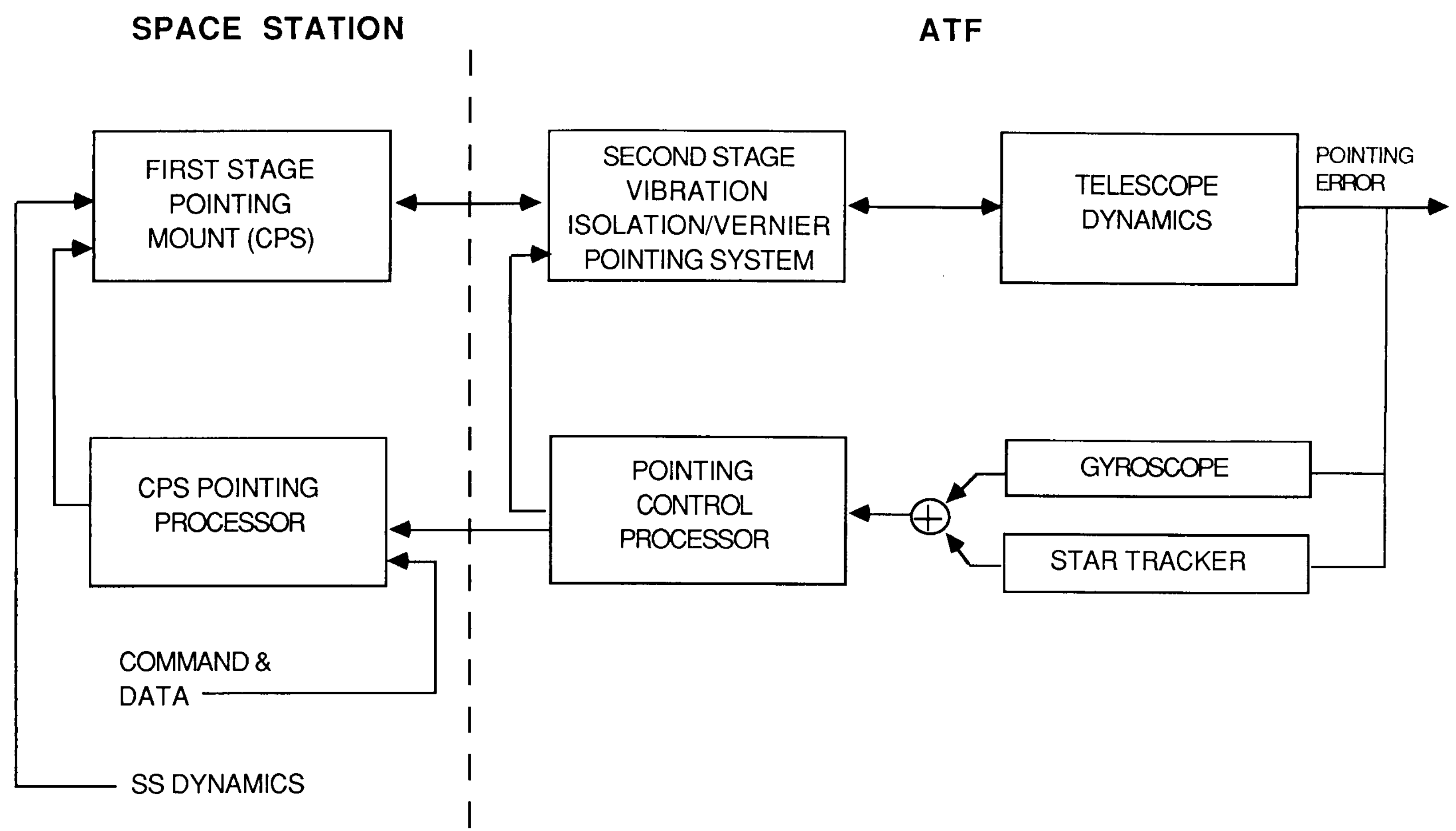


FIGURE 16

10/1/86

ATF SYSTEMS STUDY

POWER AND HARNESS SUBSYSTEM

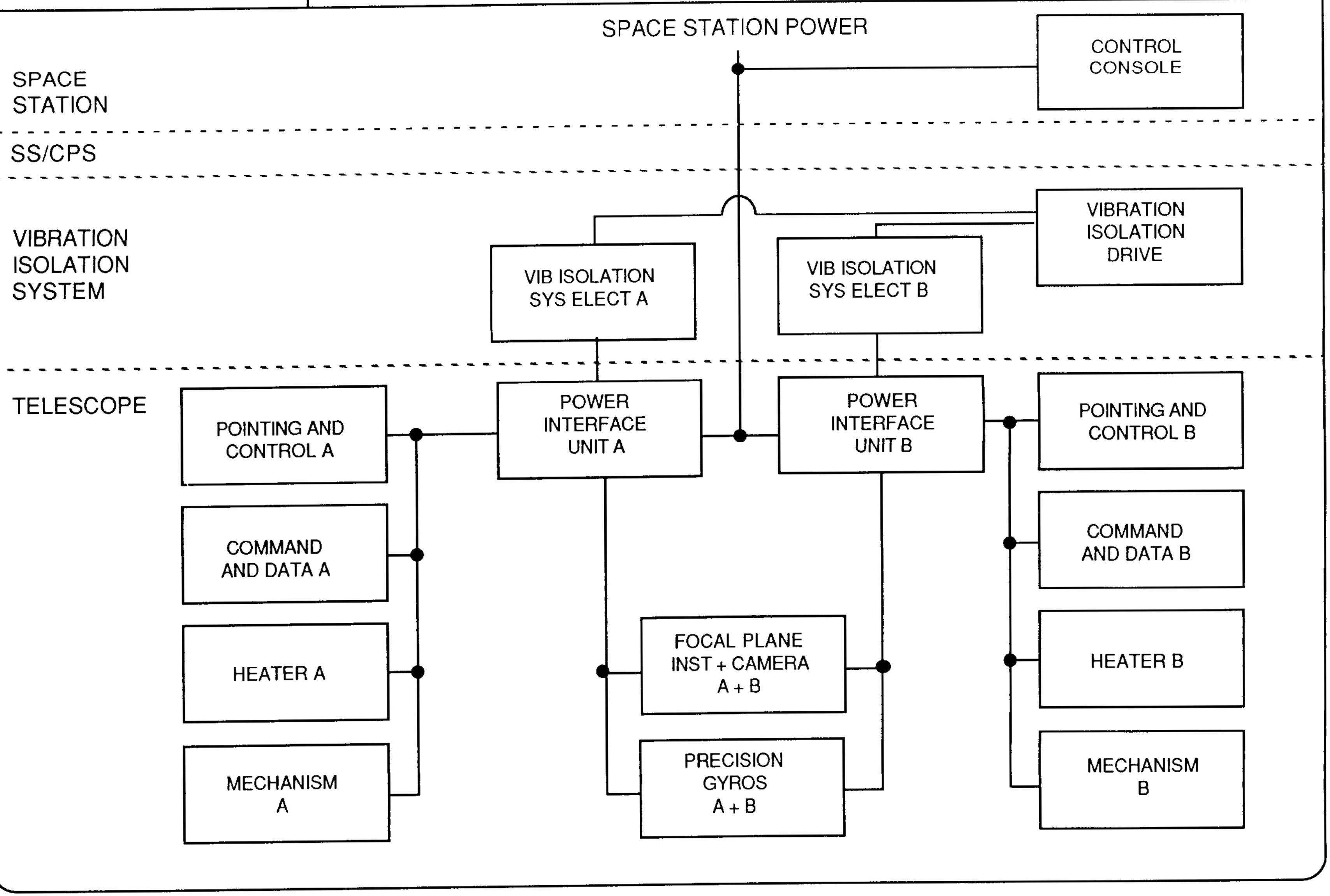


FIGURE 17

10/1/86

OPERATIONS

The study examined the operations requirements for ATF and defined a strawman approach. Basic assumptions for the study were:

(1) The ATF will receive high priority for use of SS resources during assembly and initial checkout.

(2) During normal operations, ATF will need a minimum of planning coordination with the SS and with other payloads.

(3) The ATF operation interruptions caused by SS and other sources will be infrequent or short.

(4) SS will provide warning and all-clear signals for disturbance events.

Based on these assumptions, the basic functional approach to operations and an outline of the initial mission events (assembly, checkout and initial operation), normal operations, and approach to anomalous events or conditions has been defined. Operations as defined by this study appear to be straightforward. It is anticipated that ATF data will be transmitted to the ground and the ATF operations center on a near realtime basis, therefore the receipt and logging of the data will be a continuous full-time task. The baseline operations plan requires generation and updating of the ATF onboard command sequence once per week. It appears that observation and facility management sequence generation can be accomplished on a regular 5-day per week, single shift basis.

A straightforward approach is also planned for anomalous or failure conditions. This is possible because the science data collection is not timecritical and there are no mission events which are timecritical except pointing into the sun or loss of power (which could lead to critical mispointing). These critical conditions are handled automatically by closing the facility cover and waiting for ground intervention for recovery. In the event of short term (hours) noncritical interruptions, the plan is to continue the existing sequence. The portion of the data lost during the down-time would be rescheduled in a subsequent sequence.

MISSION ANALYSIS

The study analyzed the capability of the proposed mission and hardware to provide the viewing and tracking time for the required planetary detection observations. A baseline set of 127 possible target stars, including a number of different star types, was used for the analysis (figure 18). Viewing constraints used in the analysis are shown in figure 19. Figure 20 shows a typical viewing window when all of the constraints are considered. The results of the analysis for a one year period of operation is shown in figure 21. In general the results show that nearly 80% of the time is spent actually looking at a target, and that the observation time is relatively evenly distributed over the stars. A parametric examination showed the total amount of viewing time to be relatively insensitive to changes in the constraints, although significant variations in overall efficiency can result from changes to the set of target stars.

DESCRIPTION OF STAR FIELD

- TOTAL NUMBER OF STARS: 127
- APPROXIMATELY EQUALLY SPACED OVER CELESTIAL SPHERE IN 114 REGIONS
- 12 REGIONS HAVE BINARY STARS
- DISTRIBUTION OF STAR TYPES INCLUDES:

  2 GIANTS
  3 SUBDWARFS
  7 WHITE DWARFS
  1 B
  11 A
  16 F
  32 G
  23 K
  32 M

- TOTAL OF NEAR-SOLAR TYPE = 56%

FIGURE 18

10/1/86

VIEWING CONSTRAINTS

- MINIMUM AVOIDANCE ANGLES (DURING VIEWING AND SLEWING):

  SUN = 30°

  EARTH = 30°

  MOON = 10°

  VELOCITY = 90°

  SPACE STATION CONSTRAINT = TBD

- EARTH LIMB = 12 km

- ORBITAL ALTITUDE = 470 km

- DOWN TIMES CAUSED BY:

  - SHUTTLE DOCKING EVERY 90 DAYS WITH DURATION OF SHUTTLE OFF/ON LOADING = 12 HR

  - SPACE STATION REBOOST AND THRUST CONTAMINATION SETTLING TIME OF 36 HR EVERY 45 DAYS

  - OTHER INTERRUPTIONS TBD

FIGURE 19

10/1/86

ATF VIEWING WINDOW

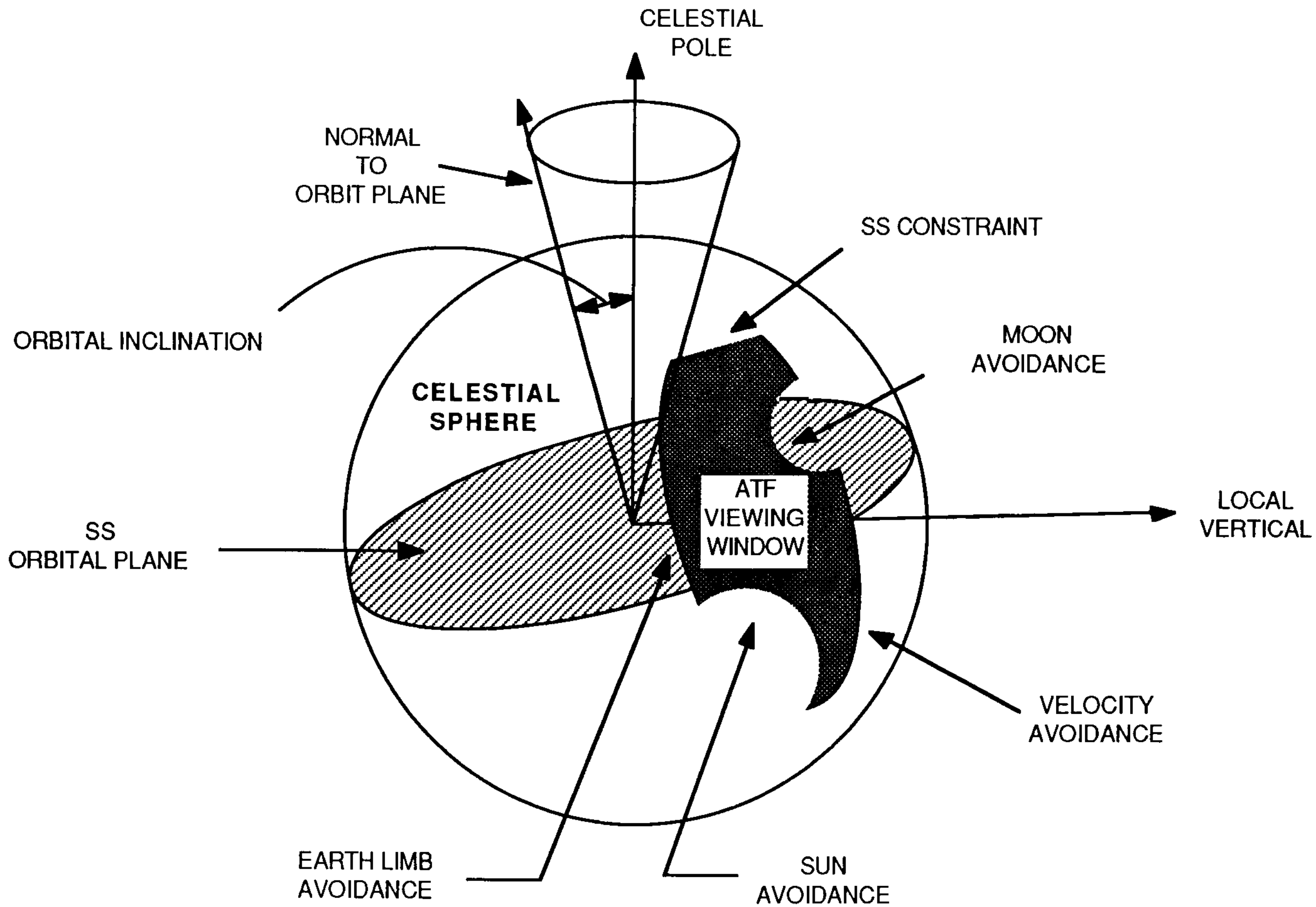


FIGURE 20

10/1/86

MISSION ANALYSIS
RESULTS OF ONE YEAR OF OPERATION **

TOTAL VIEWING TIME	6936 HR (79.2%)
TOTAL SLEWING TIME	1538 HR
TOTAL DOWN TIME	286 HR
NUMBER OF DIFFERENT STARS	127
NUMBER OF SIGHTINGS	33,337 (91/DAY)
AVERAGE VIEW TIME PER STAR (NORMALIZED TO GALACTIC EQUATOR PHOTON RATE)	23.84 HR
AVERAGE VIEW TIME PER SIGHTING	12.5 MIN
AVERAGE SIGHTINGS PER STAR	262
AVERAGE SLEW ANGLE	61.2°
AVERAGE TIME OF A SLEW	2.9 MIN

** THE ATF MOMENT OF INERTIA = 160,000 kg•m ^{2}; TORQUE FORCE = 30 N•m; MINIMUM VIEWTIME = 7 MIN; AVOIDANCE ANGLES: SUN = 30°, EARTH = 30°, MOON = 10°, VELOCITY = 90°, SOUTHWARD = 0°, REARWARD = 0°

FIGURE 21

10/1/86

COST ESTIMATE

The study included the development of a cost estimate for the ATF mission. The following assumptions were used for the estimate:

(1) The design, development and test of the facility will be the responsibility of a system contractor to NASA, selected through a competitive process.

(2) The length of the development program is 4 years from start of the Phase C/D contract to launch.

(3) A Protoflight approach will be taken. Only one full flight vehicle will be assembled and tested. One spare of each electronics unit, one spare Ronchi ruling Assembly, and one spare FPI will be built and tested. The structure will be qualified using an engineering model.

(4) Development will be limited to 1986 proven technology.

(5) Standard services (Communications, and Power) plus a CPS will be supplied by the SS.

(6) Qualified SS unit hardware will be used with only minor modifications.

Project Management, Science Support, and Operations cost estimates were developed based on past experience with ARC projects (Pioneer, Galileo, and IRAS). The hardware costs were estimated using the RCA Price Model. This model estimates costs at the unit level based on weight, volume and complexity (both design and manufacturing). All costs are in fixed fiscal year 1986 dollars.

Figure 22 shows the resulting costs broken down by major elements. The development cost is approximately $230 million including a 20% contingency and the estimated operations cost is $7.2 million/yr.

ATF SYSTEMS STUDY

COST ESTIMATE

TASKS	MILLION DOLLARS*	
ATF DEVELOPMENT PROGRAM		
H/W DEVELOPMENT COSTS	159.4	
S/W DEVELOPMENT	12.6	
OPERATIONS DEVELOPMENT	16.6	
SCIENCE SUPPORT	3.2	
PROJECT MANAGEMENT	2.0	
SUBTOTAL		193.8
CONTINGENCY (20%)		38.8
TOTAL DEVELOPMENT COSTS		232.6
ATF OPERATIONS	7.2/YR	

* CONSTANT FISCAL YEAR 1986 DOLLARS

FIGURE 22

10/1/86

OPEN AND TRADE ISSUES

The study identified a number of open and trade issues requiring further work. The primary issues were:

(1) Measurement Error Budget: Effort on this is continuing at NASA Ames Research Center.

(2) SS CPS Configuration and Performance: This is a SS activity which will be tracked by the ATF Study Office.

(3) SS Contamination Specification and Validation: This is the same category as Item 2.

(4) SS Mechanical Activity: Again this is a SS activity to be tracked by the ATF Study Office. Once the dynamics environment is defined, the vibration isolation requirements will be reexamined.

Trade Issues

(1) Optical Configuration: The University of Arizona is presently examining a two mirror system. It is anticipated that the study will be complete by Summer 1987.

(2) Detector Selection: A more detailed examination of detectors will have to be made in the future. This task is not presently scheduled.

(3) Ronchi Ruling Drive: Ames Research Center is planning an in-house effort to examine the drive mechanism concept in more detail.

(4) Vibration Isolation/Vernier Pointing System Design: Ames Research Center has a study contract in place to investigate vibration isolation. In addition, Ames Research Center will continue to examine the drive mechanism concept in more detail.

CONCLUSIONS

The ATF Preliminary System Definition Study has defined a relatively straightforward strawman system which can meet the requirements for a search for planetary systems. The facility will be useful in a number of other astrophysics investigations, including measurements of stellar distances and motions. The basic measurement approach proposed for ATF has been proven by ground based investigations conducted at the Allegheny Observatory.

The facility is designed as a SS payload, using the standard SS services plus one of the SS CPS. A major portion of the engineering system hardware in the strawman design is either already flight qualified or will be designed and qualified for the SS program. The strawman multiple-pickup FPI design is based on an instrument presently in use at Steward Observatory. The study did not identify any feasibility issues or any areas where basic technology development is required.

A basic operations approach was identified. This included the approach to initial on-orbit assembly and checkout, normal operations, and the response to anomalous conditions or failures. The results of the study show that ATF operations should be comparable in scope to Pioneer operations at Ames Research Center or Solar Mesospheric Explorer at the University of Colorado.

Mission analysis shows the basic viewing required for planetary detection can be accomplished in approximately two-thirds of the total viewing time. This leaves about 2000 hr/yr for other astrophysics investigations.

A cost analysis for the strawman system projects the development costs to be $200 million including a 20% reserve. Operations costs were estimated to be the order of $7 million/yr including $3 million for science investigations.

The study concludes that the concept is ready to go forward to a full Phase A study. As the SS configuration is finalized in fiscal year 1987, accommodations and compatibility for early science operation of the ATF can be secured with early definition of the facility.

APPENDIX A
ASTROMETRIC TELESCOPE FACILITY
MISSION AND SYSTEM CHARACTERISTICS

Appendix A appears here exactly as it does in the ATF Study Office documentation administered by NASA Ames Research Center.

Revisions

No.	Date	No.	Date	No.	Date
1	4/28/86				
2	9/1/86				

CHARACTERISTICS	VALUE
I. MISSION/SYSTEM	
Launch Date	Mid to late 1990's
Launch Vehicle	STS from KSC
Operational Orbit	463 to 555 km altitude 28.5 degree inclination
Mission Lifetime	20 years 5 year minimum component life
On-orbit Operations	Design for on-orbit assembly, replacement of active units, and recovery. Designs compatible with SS requirements. EVA not required for normal operations.
Viewing	Provide full sky coverage subject to the following viewing constraints: Sun Avoidance Angle $\geq 30^\circ$ Earth Limb Avoidance Angle $\geq 30^\circ$ (for Earth Limb Altitude = 12 km) Moon Avoidance Angle $\geq 10^\circ$ Ram (Velocity) Vector Avoidance Angle $\geq 90^\circ$
Star Survey	Perform astrometric measurements on $\geq$ 100 nearby single stars of visual magnitudes -1.5 to +13.5. Reference stars to visual magnitude +15. Provide capability to accommodate TBD secondary targets.

CHARACTERISTICS	VALUE
Planetary Detection	Detect single or multiple planets of masses greater than 10 Earth masses about target stars to approximately 10 parsecs.
Measurement Orientation	Rotate telescope to permit astrometric measurements to be made about two orthogonal axes (X and Y) in both plus and minus directions for each axis. Provide tube rotation range of $\pm 180^{\circ}$ with position setting accuracy of ± 2 arcmin.
Measurement Sensitivity	< 10) arcsec
Tracking Periods	Provide continuous tracking periods within the range 7 to 25 min. The total time for each observation should be sufficient to acquire $\geq 10^{8}$ photons from the reference stars for each axis.
Failure Tolerance	Block redundancy to the extent possible. No single point failures to result in permanent loss of system functions or preclude deployment, recovery, or on-orbit operations. No propagation of failures to interfacing equipment.
Fault Protection	Automatic fault detection and safing for mission catastrophic anomalies or failures. Reconfigure by ground command.
Contamination	Function within Space Station environment, provide aperture door to protect against contamination.
Dynamics	Provide vibration isolation system to minimize dynamic interactions with Space Station.
Alignment	Provide for periodic alignment and focus of optical elements between observations.

CHARACTERISTICS	VALUE
Stray Light	Provide sunshade and baffling to minimize stray light and prevent direct sunlight from impinging on internal Ronchi Ruling subassembly.
Balance	CG mount telescope to within ±1 cm.

II. OPTICAL SYSTEM/FOCAL PLANE INSTRUMENT

A. Primary Optical System

Configuration	Single mirror with grating at prime focus followed by post focal plane optics to direct beam to side of tube and increase the plate scale.
Effective Aperture	1.25 m
System f Ratio	f/13
Focal Length	16.25 m
Field of View	10 arcmin
Focal Plane Scale	12.7 arcsec/mm
Spectral Range	0.4) to 0.8)

B. Primary Mirror

Type	On-axis Paraboloid
Surface Quality	1/20 g on a scale of 5 cm
Substrate	Ultra low expansion glass
Expansion Coefficient	$<10^{-8}$ °C
Coating	Aluminum with overcoating
Mirror Masks	Shadow mask 10 cm wider than width of focal plane assembly. Apodization ring with 100% obscuration at outer edge and full reflectivity in center.
Temporal Stability of Reflectivity	<0.3% per quadrant of surface with possible quartering boundaries
Mirror Mounting	Kinematic with 3 degrees of translation freedom and 2 tilt axes with caging for launch

CHARACTERISTICS	VALUE
C. Ronchi Ruling	
Type	Transmission with alternating opaque and transparent lines of unequal width. Clear area at one end.
Ruling Constant	10 lines/mm
Active Area	48 mm x 600 mm
Line Direction	Perpendicular to length
Dimensional Accuracy	<0.05u
Substrate	Ultra low expansion glass
Scan Rate	10 to 100 line pair/sec
Linear Motion Rate	1 to 10 mm/sec
Motion Rate Adjustment	Continuously variable to ±0.01%
Motion Rate Stability	±0.01% outside of 5 to 200 Hz ±TBD within 5 to 200 Hz
Movements	Bi-directional, limits, zero points, optional overlap to clear area at one end.
Expansion Coefficient	$<10^{-8}/^{\circ}C$; uniform to within 1 part in 6 x 10^{8} on a spatial scale of 100 mm and on a time scale of 2 min.
Alignment to Optical Axis	Perpendicular to within TBD.
Straightness of Ruling Motion	Roll: ±1.8 arcmin Pitch: ±12 arcsec on a scale of 100 mm Yaw: ±12 arcsec on a scale of 100 mm
Measurement Axis	Angle between X and Y known to TBD; stability in angle during observations controlled to within TBD.
D. Relay Lens	
Type	Multiple element achromat with movement for lens elements for focusing.
Magnification Rates	2.5x
Transmissivity	>80% within 0.4 to 0.8u

CHARACTERISTICS	VALUE
E. Diagonal	
Type	45 degree elliptical.
Surface Quality	TBD
Substrate	Ultra-low low expansion glass.
Coating	Aluminum plus overcoating
F. Light Pickups	
Configuration	Two levels of fishermen around a pond.
Number	32
Positioning Granularity	±10 microns
G. Fiber Optics	
Spectral Range	0.4 to 0.8u
Reflection losses at ends	<2%
Transmissivity	>90% in red light >6000/ >80% in blue light <6000/
H. Dichroic Mirror	
Type	45 degree inclination with bandpass tuned to 6000/
I. Detector	
Type	Photo multiplier tubes (for strawman design).
Number of detectors	Two detectors/pickup, one detector for <6000/, one detector for >6000/
J. Visible Imager	
Type	Slow scan video camera with lens turrent and CCD detectors.
Photometric Dynamic Range	>10,000
Readout Noise	<100 electron hole pairs/pixel/readout
Quantum Efficiency	30%

CHARACTERISTICS	VALUE
III. STRUCTURE/THERMAL	
A. Structure	
Structural Rigidity	ATF structure designed for maximum rigidity consistent with weight constraints of the pointing mount.
Structural Stability	Positioning of optical elements to remain stable over each observational period to within the following tolerances: Axial ≤15u Lateral ≤25u Rotational ≤0.1 arcmin about optical axis
Focus	Tilt/focus/decenter adjustments shall be provided for the primary mirror. Focus adjustment between primary and instrument image plane.
Structural Design	Satisfy STS and Space Station safety requirements; design for on-orbit replacement of ATF active elements.
B. Thermal	
Electronics	All ATF elements exclusive of the detectors/preamps shall be designed to function in the following temperature ranges: Operating -20 to +50°C Non-operating -40 to +50°C
Detector/Preamps	Design to function in the following temperature ranges: Operating -10°C nominal Non-operating -40 to +50°C
Heaters	Heaters to prevent condensation on optical elements and to maintain elements within their specified temperature limits. Primary mirror maintained 20°C above ambient temperature.

CHARACTERISTICS	VALUE
VI. COMMAND AND DATA	
Data Rate	1750 Kbps
Data Quality	Bit Error Rate: $<10^{-6}$
Command Rate	5-150 Kbps/sec
Onboard Data Storage	1000 M bits (contingency)
Clock Rate	1 MHz
V. POINTING AND CONTROL	
Vibration Isolation	Provide >40-50 dB of attenuation of disturbances in the frequency range 5 to 200 Hz.
Slew Capability	$\geq$90 deg in 5 min.
LOS Pointing	Initial acquisition error $\leq$1 arcmin. Pointing accuracy during observation period $\leq$1 arcsec. Pointing stability during observation period $\leq$0.01 arcsec within the frequency range 5 to 200 Hz.
VI. POWER	
A. Telescope Assembly	
Voltage, Type	28 Vdc
Average Power	1.3 kW
Peak Power	2.4 kW
B. Control Console	
Voltage, Type	28 Vdc
Average Power	100 W
Peak Power	100 W

APPENDIX B

ASTROMETRIC TELESCOPE FACILITY

Input for Space Station
Mission Requirements Data Base

Appendix B appears here exactly as it does in the Space Station Mission Requirements Data Base, administered by NASA Johnson Space Center.

SAAX115

NAME

PAYLOAD ELEMENT NAME	ASTROMETRIC TELESCOPE FACILITY
LAST UPDATE	090986
COUNTRY OF ORIGIN	USA NASA OSSA (SAAX)
CONTACT	K NISHIOKA MS 244-14 ASTROMETRIC TELESCOPE STUDY OFFI NASA AMES RES CTR E LEVY -SCIENTIST UNIV OF ARIZ - TUCSON
PHONE NUMBER	415/ 694-6540 OR 602/621-6962
STATUS	CANDIDATE

FLIGHTS

FLIGHT SCHEDULE

FLIGHT YEAR	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
EQUIPMENT UP	1	0	0	0	0	0	0	0	0	0
EQUIPMENT DOWN	0	0	0	0	0	0	0	0	0	0
OPERATIONAL DAYS	365	365	365	365	365	365	365	365	365	365
OTV FLIGHTS	0	0	0	0	0	0	0	0	0	0
EARLY FLIGHTS										
LATE RETURN										

OBJECTIVE

TO DETERMINE THE EXISTENCE AND SOME CHARACTERISTICS OF PLANETS IN ORBIT ABOUT NEARBY STARS, TO VERIFY OR REFUTE A BASIC EXPECTATION OF THEORISTS THAT A SUBSTANTIAL FRACTION OF STARS HAVE LARGE PLANETS. LONG TERM PERTURBATIONS OF AT LEAST 100 STARS WILL BE EXAMINED RELATIVE TO SETS OF BACKGROUND STARS WITH A PRECISION SUFFICIENT TO DETECT THE PRESENCE OR ABSENCE OF PLANETS EQUIVALENT TO ANY OF THE LARGER SOLAR SYSTEM PLANETS.

DESCRIPTION

THE MAJOR ATF SYSTEM ELEMENTS TO BE ACCOMODATED ON THE MANNED SS CONSISTS OF THE TELESCOPE ASSEMBLY, AN ELECTRONICS PALLET, & A CONTROL CONSOLE. THE TELESCOPE ASSEMBLY WILL BE ASSEMBLED IN THE SS POINTING MOUNT IN 3 SUBASSEMBLIES: (1)A COMBINED VIBRATION ISOLATION, FIVE POINT-ING, & ROLL CONTROL SYSTEM, (2)THE AFT SECTION OF THE TELESCOPE, (3)THE FORWARD SECTION OF THE TELESCOPE. THE ELECTRONICS PALLET WILL BE MOUNTED NEAR THE SS POINTING MOUNT & THE CONTROL CONSOLE WILL BE IN A RACK IN A MANNED MODULE. BASIC OPERATIONS WILL BE PROGRAMMED FROM THE GROUND WITH

INTERVENTION FOR SAFE OPERATION NEAR THE INSTUMENT AVAILABLE TO THE CREW. THE TECHNIQUE USED BY ATF, PROVEN IN GROUND OPERATION, FEATURES SIMULTANEOUS RECORDING OF LIGHT INTENSITY VARIATIONS AS A FINE RONCHI-RULING IS DRAWN THROUGH THE SET OF STAR IMAGES. THE RESULTANT PHASE VARIATIONS ARE DIRECTLY RELATED TO STAR MOTIONS RELATIVE TO THE BACKGROUND.

TYPE/SCALE

TYPE NUMBER	2
IMPORTANCE OF SPACE STATION	9
NON-SERVICING OMV FLIGHTS (PER YEAR)	0
ADD RESOURCES	YES
RESOURCE REFERENCE	

ORBIT

ANY ORBIT

SPECIAL CONSIDERATIONS (ORBIT): 4

POINTING/ORIENTATION

VIEW DIRECTION:
INERTIAL

HOURS 24

TRUTH SITES
TARGET STARS DISTRIBUTED ABOUT THE CELESTIAL SPHERE

POINTING ACCURACY (ARC SEC)	1.00
POINTING KNOWLEDGE (ARC SEC)	1.00
FIELD OF VIEW (DEG)	-0.0
POINTING STABILITY RATE (ARC SEC/SEC)	1.000
POINTING STABILITY (ARC SEC)	0.100
PLACEMENT (ARC SEC)	1.000

SPECIAL CONSIDERATION (POINTING/ORIENTATION):
THE ATF WILL POINT WITHIN A HALF CONE DEFINED BY THE LOCAL VERTICAL TO 90 DEG AFT, NORTH, & SOUTH, POINTING WILL AVOID SUN, EARTH, MOON, VELOCITY VECTOR, SS APPENDAGES, & CONTAMINATION SOURCES. SS UPPER BOOM-END CORNER-BACK-FACE, (ANTI-VELOCITY VECTOR-SIDE) LOCATION REQUIRED.

POWER

*DC

OPERATING (KW)	NOMINAL	1.50
HOURS PER DAY (OPERATING)		24.00
VOLTAGE	NOMINAL	28.0
PEAK (KW)	NOMINAL	3.00
HOURS PER DAY (PEAK)		4.00
STANDBY POWER (KW) (NON OPERATIONAL PERIODS)		1.00

SPECIAL CONSIDERATIONS (POWER):
NONE

THERMAL

*ACTIVE TEMPERATURE, DEG C	OPERATIONAL	MIN	-20.0	MAX	50.0
	NON-OPERATIONAL	MIN	-40.0	MAX	60.0
HEAT REJECTION, KW	OPERATIONAL	MIN	1.00	MAX	3.00
	NON-OPERATIONAL	MIN	0.00	MAX	1.00

SPECIAL CONSIDERATIONS (THERMAL):
OPTICS MAINTAINED ABOVE AMBIENT TEMP TO PREVENT CONDENSATION. DETECTORS MUST BE KEPT BELOW 0 DEGREE C.

DATA/COMMUNICATIONS

ONBOARD DATA PROCESSING REQUIRED	NO
ONBOARD STORAGE (MBIT)	1000.00

STATION DATA REQUIRED:
SS WARNING SIGNALS BEFORE FOV VIOLATION, MAJOR MECH DISTURBANCES, EMI AND CONTAMINATION EVENTS.

COMMUNICATION LINKS:

FROM:	STATION	DIGITAL DATA	VIDEO DATA	VOICE
TO:	GROUND			

A.	GENERATION RATE (KBPS)	1750.00	-0.00	NA
B.	DURATION (HOURS)	0.25	-0.00	0.00
C.	FREQUENCY (PER DAY)	60.00	-0.00	0.00
D.	DELIVERY TIME (HOURS)	24.00	-0.00	0.0
E.	SECURITY (YES/NO)	NO		NO
F.	RELIABILITY (%)	100.00	-0.00	0.00
G.	INTERACTIVE (YES/NO)	NO		YES

	FROM: GROUND TO: STATION	DIGITAL DATA	VIDEO DATA	VOICE
A.	GENERATION RATE (KBPS)	20.00	-0.00	NA
B.	DURATION (HOURS)	0.50	-0.00	-0.00
C.	FREQUENCY (PER DAY)	0.20	-0.00	-0.00
D.	DELIVERY TIME (HOURS)	24.00	-0.00	0.0
E.	SECURITY (YES/NO)	NO		NO
F.	RELIABILITY (%)	100.00	-0.00	-0.00
G.	INTERACTIVE (YES/NO)	NO		YES

COMMENT (DATA/COMMUNICATIONS):

STO TIME-SLICED, BUFFERED, NEAR REAL TIME UPLINK & DOWNLINK CHANNELS FOR A NEAR CONTINUOUSLY OPERATING EXPERIMENT SHOULD BE APPROPRIATE. DATA LINKS ACROSS THE SS PROVIDED CPS BETWEEN THE ATF TELESCOPE ASSBY & ELECTRONICS PALLET WILL BE REQUIRED

EQUIPMENT

PRESSURIZED MODULE CODE: 1

SHARED FACILITIES: NONE

EQUIPMENT LOCATION LEGEND

1. INTERNAL/PRESSURIZE
2. EXTERNAL/ATTACHED/PRESSURIZED
3. EXTERNAL/ATTACHED/UNPRESSURIZED
4. FREE FLYER (REMOTE)

EQUIPMENT LOCATION	1	2	3	4
DIMENSIONS (M)				
LENGTH	.60		20.80	
WIDTH OR DIAMETER	.60		4.00	
HEIGHT (OR BLANK)	1.90			
VOLUME (CU. M.)	.700		80.000	
PKG. DIMENSION (M)				
LENGTH	.60		13.50	
WIDTH OR DIAMETER	.60		4.00	
HEIGHT (OR BLANK)	1.90			
PKG. VOL. (CU. M.)	.700		100.000	
LAUNCH MASS (KG)	200.00		6800.00	
ACCEL. MAX (G)	1.0000000		1.0000000	

EQUIPMENT LOCATION LEGEND

5. FREE FLYER (CONTACT-NAME-ORBITING)
6. 28.5 DEGREE PLATFORM
7. SUN SYNC/POLAR PLATFORM

EQUIPMENT LOCATION	5	6	7
DIMENSIONS (M)			
LENGTH			
WIDTH OR DIAMETER			
HEIGHT (OR BLANK)			
VOLUME (CU. M.)			
PKG. DIMENSION (M)			
LENGTH			
WIDTH OR DIAMETER			
HEIGHT (OR BLANK)			
PKG. VOL. (CU. M.)			
LAUNCH MASS (KG)			
ACCEL. MAX (G)			

ATTACH POINTS 1
SET UP CODE:
DEPLOYMENT
ASSEMBLY

HARDWARE DESCRIPTION:
THE ATF TELESCOPE ASSBY CONSISTS OF A 1.8M DIA X 20.8M LONG TELESCOPE WITH AN ANNULAR 4M DIA. VIBRATION ISOLAT. SYS (WHICH INTERFACES WITH THE CPS) ATTACHED TO ITS MIDSECTION. AN ATF ELECTRONICS PALLET IS MOUNTED NEAR THE CPS. ATF CONTROL MODULES ARE MOUNTED IN A PRESSURIZED MODULE.

CREW
*INITIAL CONSTRUCTION/SET UP
TASK:
SET UP/INTEGRATE ATF WITH SS. PERFORM CHECKOUT
PERIOD (DAYS) 5.00
IVA TOTAL CREWTIME (MHR) 160.00
EVA PRODUCTIVE CREW TIME (MHR) 8.00

CI SKILL LEVEL	CI-SKILL-TYPE	1	2	3	4	5	6	7
	TASK TRAINABLE	0	0	0	0	0	0	0
	TECHNICIAN	0	0	0	0	1	0	1
	PROFESSIONAL	0	0	0	0	1	0	1

*DAILY OPERATIONS NONE
*PERIODIC OPERATIONS NONE
*TEARDOWN AND STOW NONE
COMMENTS (CREW):
REMOTE MANIPULATOR TRANSFERS ATF ELEMENTS FROM STS TO SS IN THE FOLLOWING ORDER FOR INSTALLATION ON THE SS: CONTROL CONSOLE, ELECTRONICS PALLET, VIBRATION ISOLATION SYS, TELESCOPE (2 SECTIONS). AFTER SETUP, PERFOR CHECKOUT TESTS. CONTAMINATION AVOIDANCE DURING ASSBY CRITICAL.

SERVICING NONE
SPECIAL CONSIDERATIONS (SERVICING):
NONE

CONFIGURATION CHANGES
INTERVAL (DAYS) 1825
CHANGE-OUT EQUIPMENT:
TYPE -
ELECTRO/MECH ELEMENTS & SCIENCE INSTS SUSCEPTIBLE TO WEAROUT/FAILURE
WEIGHT (KG) 500.000
RETURN (KG) 500.00
VOLUME UP (CUBIC METERS) 1.000
VOLUME DOWN (CUBIC METERS) 1.000
POWER (KW) 0.000
HOURS FOR POWER 0.00
EVA HOURS PER CHANGE 4.00
TYPICAL TASKS (EVA) -
REPLACE MODULAR UNITS
IVA HOURS PER CHANGE 4.00
LOCATION OF CHANGE LOCAL
TYPICAL TASKS (IVA) -
REMOTE MANIPULATOR, COMMUNICATE WITH GROUND, OPERATE CONTROL PANEL
SPECIAL CONSIDERATIONS (CONFIG. CHANGES):
CONTAMINATION AVOIDANCE DURING REPLACEMENT OF TELESCOPE MODULES CRITICAL.

SPECIAL NOTES
CONTAMINATION-
CONTROLLED CLEAN ENV REQD. CONTAMINATION EVENTS SHOULD BE SMALL

& OCCUR AT PREDICTABLE TIMES.

STRUCTURES-

ATF SUSCEPTIBLE TO DYNAMIC DISTURBANCES. MAXIMUM DYNAMIC ISOLATION FROM DISTURBANCES IN THE FREQUENCY RANGE 10 TO 100 HZ SHOULD BE PROVIDED.

MATERIALS-

MATERIALS IN THE VICINITY OF ATF SHOULD NOT PRESENT SIGNIFICANT OPTICAL CONTAMINATION SOURCES.

RADIATION-

ATF DETECTORS SUSCEPTIBLE TO RADIATION LEVELS SIGNIFICANTLY ABOVE THE BACKGROUND LEVELS.

SAFETY-

WILL SATISFY STS/SS SAFETY RQMTS. NO SPECIAL HAZARDS IMPOSED BY THIS MISSION.

STORAGE-

HAVE REDUNDANT SYSTEM. WILL STORE MOST SPARES ON GROUND. ONLY CRITICAL SPARES NEED BE STORED ON SS.

OPTICAL WINDOW-

SCIENTIFIC AIRLOCK-

TETHER-

VACUUM VENTING-

OTHER-

SS OBSTRUCTIONS IN THE FOV OF THE ATF SHOULD BE AVOIDED. 6800 KG TOTAL INCLUDES TELESCOPE, ASE, CRITICAL SPARES, VIBRATION ISOLATION PACKAGE, DOES NOT INCLUDE COARSE POINTING SYSTEM. INTERNAL MODULE CONSOLE IS FOR CONTINGENCY SERVICING TASKS ONLY,(EMERGENCY CONTROL BY CREW).

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16. Abstract

The Astrometric Telescope Facility Systems Definition Study Report documents the results of a six month effort to define the basic goals and requirements of, and identify a strawman design for a spaceborne telescope facility capable of the detection and study of extra-solar planetary systems.

The study iterates the basic science rationale for Planetary Detection and describes an astrometric measurement technique using a Ronchi ruling to extract metric information. A strawman design, based on ground and space proven systems, is presented using the Space Station as the telescope platform.

The study concludes that the detection of extra-solar planets realizable through astrometry, using current technology in a long life Earth orbiting telescope.

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