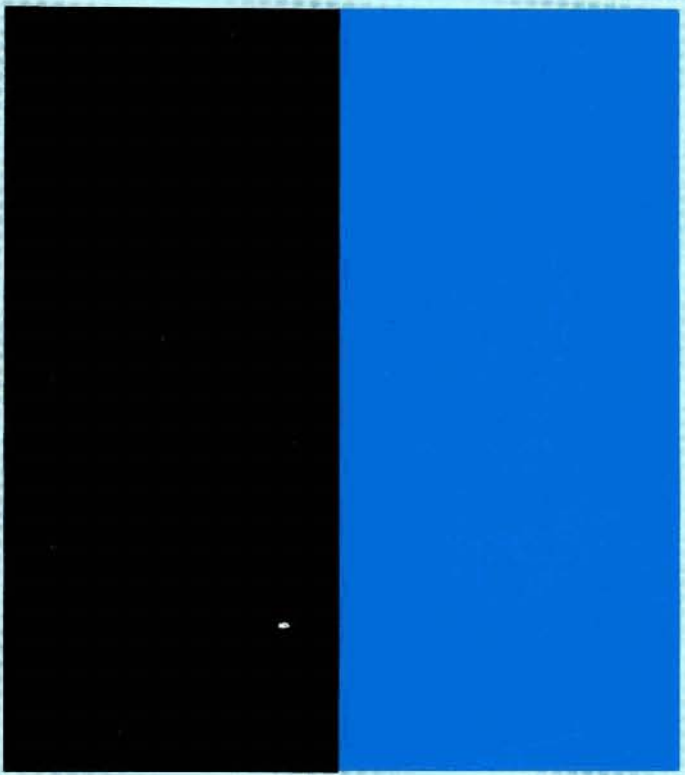




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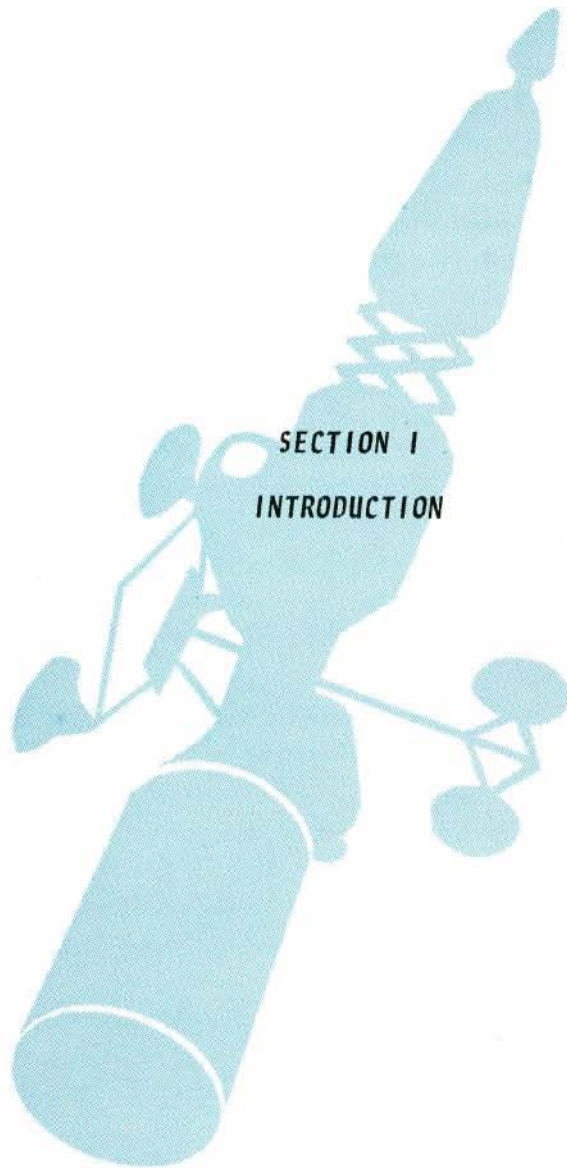


SPACE SUPPORT
DIVISION



**EARTH ORBITAL WORKSHOP
CAPABILITIES BROCHURE**

SPACE SUPPORT DIVISION



SECTION I
INTRODUCTION

SPACE SUPPORT DIVISION

INTRODUCTION

The Sperry Rand Space Support Division presents this brochure to depict a competence and capability in the area of large earth-orbital workshops. Workshops that are:

- In fabrication (ATM)
- Proposed for Saturn V Vehicles (B₀ & M_x)
- Conceptually designed for specific advanced applications (Nuclear Power)

Sperry's ability to offer a depth of experience in the orbital workshop area is directly attributable to the technical support the Space Support Division is providing to the MSFC Astrionics Laboratory. In this role a technical foundation and competence in design and development of orbital workshops has been established. The Apollo Telescope Mount provided the hardware, subsystem and system experience. Then follow-on studies developed the necessary mission analysis experience. Hence, an overall workshop capability has evolved.

The areas of demonstrated proficiency are:

I. EXPERIMENTATION

- X-Ray Telescope Design
- X-Ray Camera Design
- Television System Design
- Laser Research

II. POWER

- Solar Array Design
- Nucleonics Analysis
- Fuel Cell Design

III. COMMUNICATIONS

- Data Compression Studies
- Information Coding Techniques Studies
- Modulation Techniques Studies
- Phaselock Loop Analysis
- Phase Compensation Analysis
- Hardware Design
 - Antenna Systems
 - Pulse Code Modulated Data Acquisition Systems
 - Telemetry Ground Station

270-Channel Multiplexer
Single Side Band/Double Side Band Filters
Airborne Telemetry Power Supplies

IV. CONTROL

Control Moment Gyro System Analysis
Experiment Pointing Control Analysis
Control System Analysis and Design
ATM
Orbital Workshop
Reaction Control Jets
Sizing
Fuel Consumption
Momentum Dumping
Optimal
Backup
Star Tracker Analysis

A summary of the engineering effort related to orbital workshop experience is presented in the Capabilities Section (Section II). In that section there are four subsections which are uniquely categorized by NASA's Phased Project Planning. The four steps of Phased Project Planning are Advanced Studies, Project Definition, Design, and Development and Operations Categorized as Phase A, B, C and D respectively.

The remainder of the brochure provides an insight into the Division's background, organization makeup and manpower level.

The capabilities reported herein were developed by the Space Support Division under Contract NAS8-20055 to the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Astrionics Laboratory, Huntsville, Alabama.

SECTION II
WORKSHOP CAPABILITIES SUMMARY

II. WORKSHOP CAPABILITIES SUMMARY

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WORKSHOP CAPABILITIES SUMMARY

PHASE A - ADVANCED STUDIES

In the Advanced Study Phase concept feasibility studies of various mission approaches are made. Requirements for each are analyzed, engineering assessed and experiment programs grossly defined. From this a report is written detailing all analytical work, alternate solutions, tradeoff criteria and recommendations.

The Phase A definition adequately defines the work performed by the Space Support Division's Advanced Studies Group in support of the Astrionics Laboratory's Advanced Studies Office. The recent studies as documented by Sperry are:

A Study of the Backup Saturn I Workshops (AS210 Wet Launch) Astrionic Equipments' Potential for use in an Austere Dry Launch Saturn V Workshop (B)

An investigation into the system and sub-system modifications required to adapt the Saturn I "Wet Launch" workshop's backup equipment to an austere Saturn V "Dry Launch" workshop was performed. Conversion time, cost and mission scheduling were traded off against versatility and lift capability.

SP 590-0132

Completion date: 9/68

Selected Studies of Some Conceptual Earth-Orbital Workshops

Systems analysis and trade-off studies were made on a number of conceptual earth-orbital workshops in an effort to size systems and obtain the best configuration. Areas studied included experiment payload, power systems, instrumentation and communications, thermal controls, control and display, and video imaging.

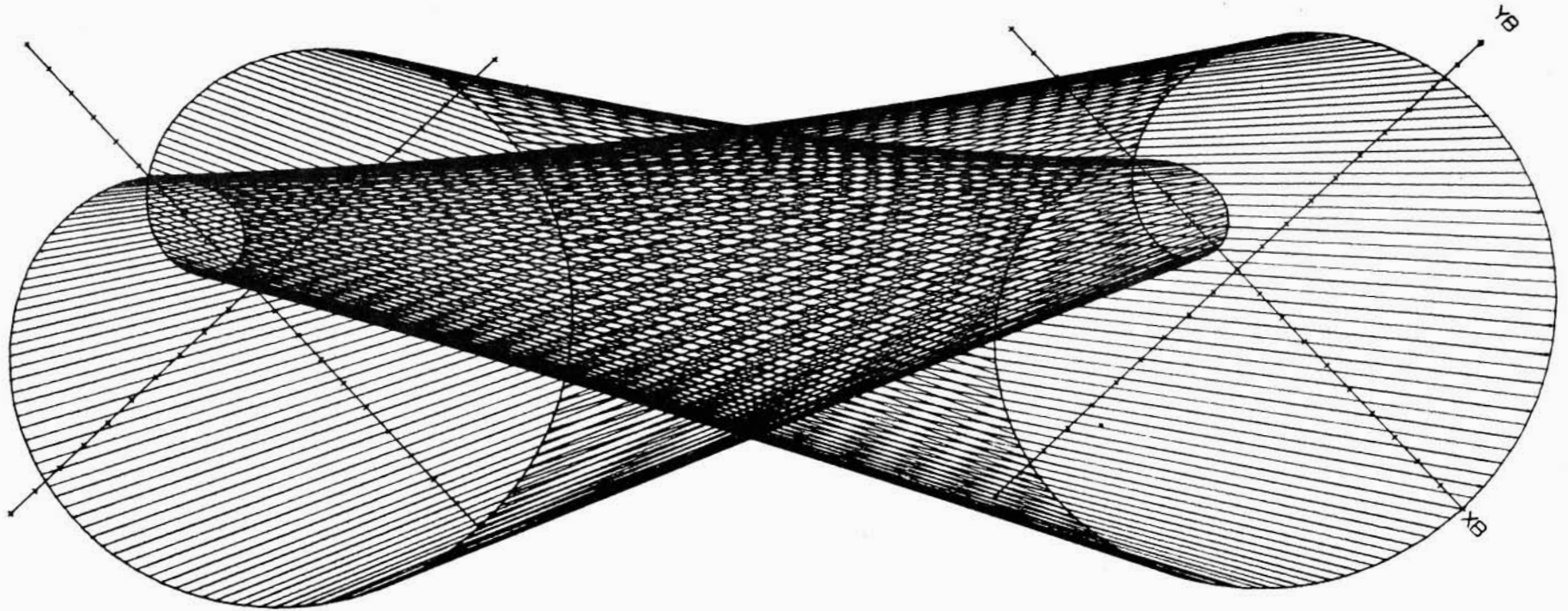
SP 590-0098

Completion date: 7/68

Attitude Control System Synthesis for Conceptual Saturn V Launched Earth-Orbital Workshop/Space Stations

Identified Eight Conceptual Workshop/Space Station configurations and studied in detail four to determine overall attitude control requirements to be expected. Then, using these requirements two potential attitude control systems are synthesized.

50-56 X-Ray Telescope



2-2

Distortion in ray bundle introduced by alignment imperfections in the reflective elements of the telescope - hyperboloid tilted 30 arc seconds with respect to the optical axis.

General concepts were derived from NASA's current Saturn V Earth-Orbital Workshop/Space Station planning activities.

Disturbance torques considered are gravity gradient, aerodynamic, solar, magnetic and man motion. The control systems included reaction control jets, control moment gyros and various combinations of both.

SP 590-0097

Completion date: 7/68

Microwave Power Transmission Study for Space Applications

Considered the feasibility of transmission of power by microwave beaming from a master satellite to one or more smaller satellites. Theoretical and quantitative results are presented detailing the efficiency of each subsystem plus total system efficiency using either the elliptic or the parabolic reflector antenna.

SP 590-0072

Completion date: 4/68

Signal-to-Noise Considerations for Orbiting Astronomical X-Ray Telescope

Presented data that helps provide fundamental information on establishment of criteria to postulate on the temperature, density and composition of matter in the galactic and intergalactic space, presence and strength of magnetic and electric fields in space, the origin and distribution of cosmic rays and the creation of matter.

SP 590-0110

Completion date: 8/68

Large Aperture Telescope: Phase 1, 2, 3, 4 and Summary

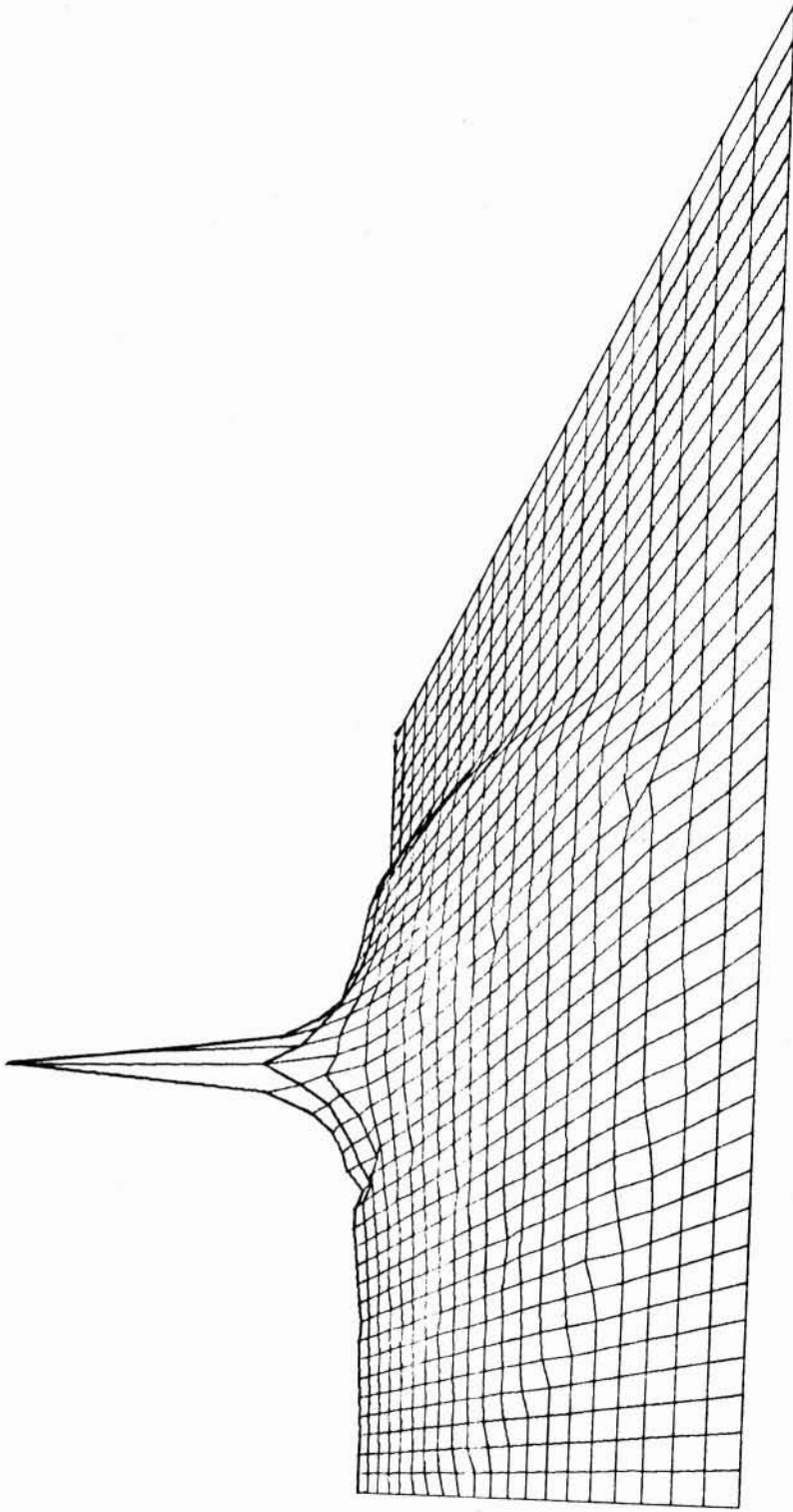
Performed control system analysis on suggested high accuracy large aperture telescopes. The studies were confined to the fine pointing control of a one meter diameter large aperture telescope mounted on an SIVB type orbital workshop. The pointing accuracy of the systems analyzed is 0.01 arc second maintained for extended periods of time.

A two body analog simulation was developed to test the various hardware configurations and evaluate the effects of disturbances, including man motion, on pointing accuracy.

SP 590-0034-0.1.2.3.4

Completion date: 5/68

SO-56 X-Ray Telescope



High resolution energy diagram of image formed by x-rays in film plane of telescope (125,000 input rays were used to form energy diagram)

Phased Array Antenna Study - Phase I and II

A comprehensive study of the characteristics of phased arrays was performed. State-of-the-art information is presented from the literature on weight, size, gain, number of elements, scan and efficiency. Also detailed is the pattern effect due to radiator mislocation caused by manufacturing errors and thermal gradients.

SP 590-0108

Completion date: 8/68

SP 390-0134

Completion date: 9/68

Boom Extended Nuclear (Orbiting) Reactor Control Study

In suggesting nuclear reactors for large space stations the question of vehicle control came to the forefront. This study endeavors to answer that question by considering the reactor mounted on a boom extended from the side or end of the vehicle.

An investigation into the interrelations between the boom mounted reactor and the vehicle control system was performed. Analog and Digital simulation programs were developed to compute external disturbance torques, composite mass and inertia data. In addition, a complete two-body vehicle dynamic simulation containing a vehicle control system was developed to verify analytical results.

SP 209-01

Completion date: 12/68

An investigation of Redundancy Concepts Applied to Strapdown Inertial Sensors

Strapdown inertial navigators appear to have a place in large space stations of the future. A study input, to system development, was a method to detect and isolate defective sensors by comparing individual sensor output with the mean output of all the sensors.

A digital program was developed to study various approaches and evaluate trade-offs in the detection and isolation of sensor malfunctions.

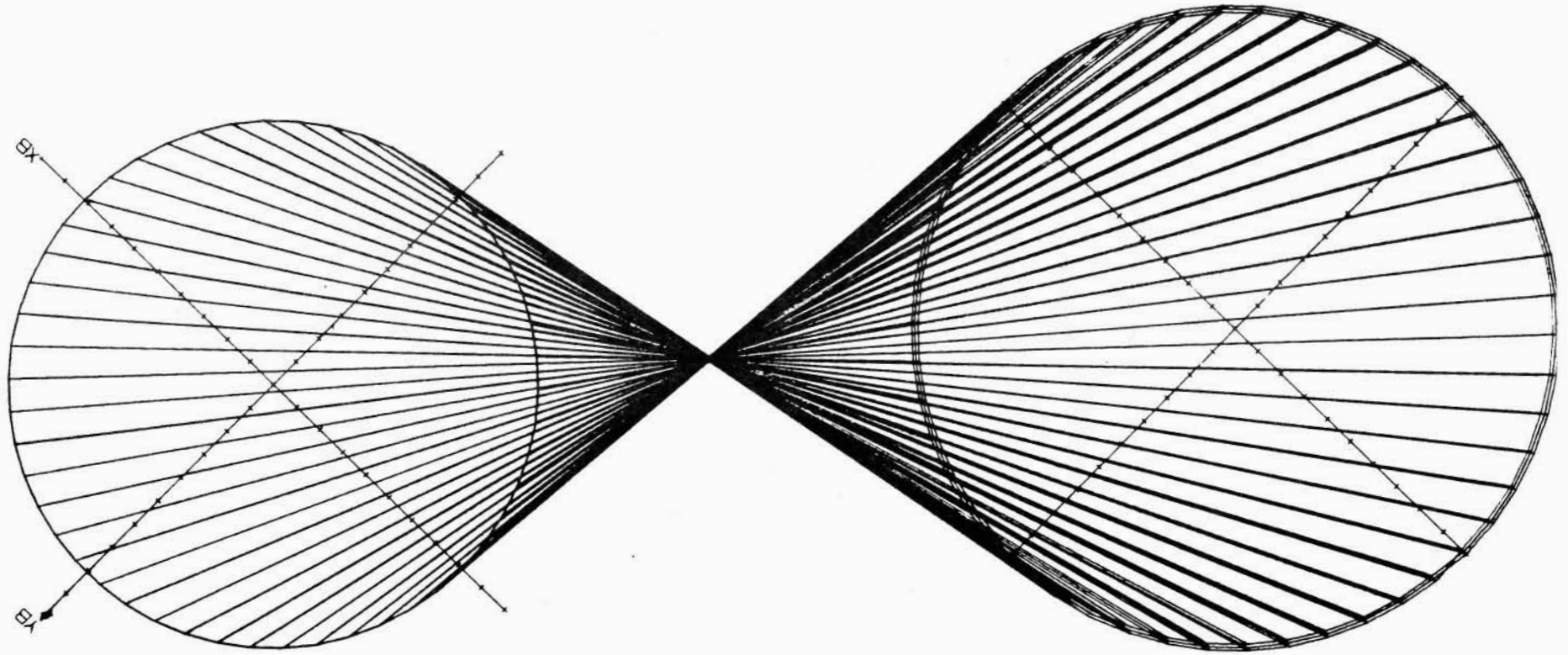
SP 590-0084

Completion date: 7/68

Saturn I/V Six Degree Dynamical Simulations with Iterative Guidance Modified for Advanced Vehicles and Missions

Strap-on solid fuel engines. Saturn V vehicles without the S11 stage and variable thrust liquid fuel engines are analyzed to determine impact on

50-56 X-Ray Telescope



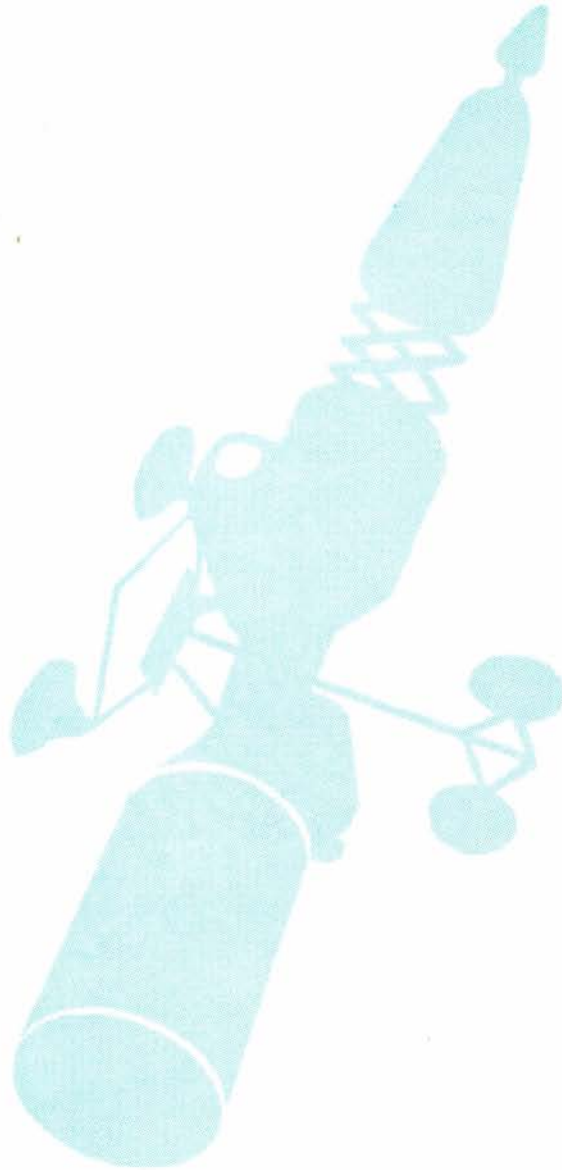
2-6

Ray diagram of perfect x-ray telescope viewing a point source of x-rays on optical axis 100 meters distant.

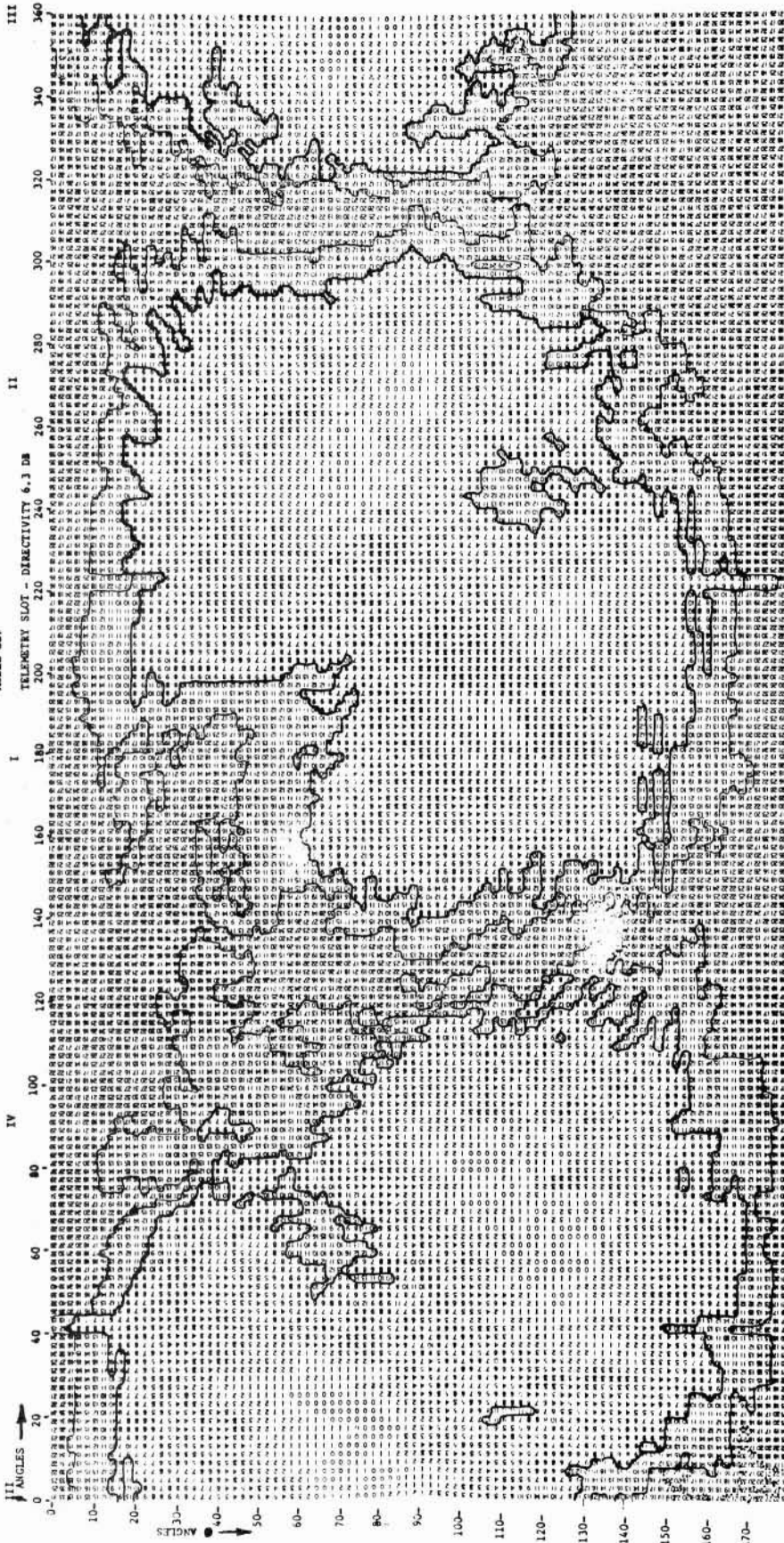
the present guidance modes. Full scale digital simulations have been developed utilizing the latest MARVESS trajectory techniques making lift-off to injection studies possible.

SP 209-TD-04

Completion date: 1/69



PATTERN CONTOUR
ATH TELEMETRY ANTENNA PANEL
MODEL 217



Pattern Contour for an Apollo Telescope Mount Telemetry Antenna panel

WORKSHOP CAPABILITIES SUMMARY

PHASE B - PROJECT DEFINITION

In the project definition phase selected concepts are refined, assessments of total mission requirements are made and a system analysis prepared. From the study results presented a project plan emerges which specifies a single concept, recommends a plan for phase C and presents a preliminary Project Development Plan.

The Sperry Rand Space Support Division by supporting the Astrionics Laboratory on the Apollo Telescope Mount Vehicle (ATM) was an integral part of the ATM Phase B endeavor. This produced experience by association which, in our opinion, gives a depth of knowledge in the area of large orbital space station technology obtainable only by day-to-day contact with the cognizant NASA organizations. A sampling of reports applicable to the phase B planning process is presented below.

Antenna Pattern Measurements

Analyzed three methods of measuring antenna patterns in relation to the antenna attitude in a 200 nautical mile orbit. The study was made to evaluate a contractor's proposal to NASA for measuring the characteristics of a large space erectable parabolic antenna. Comparison studies were conducted and recommendations submitted for the most accurate method of measuring antenna patterns.

RL # 16-022

Completion date: 5/66

Discussion of the Torque Rectification Dump Scheme

Scrutinized contractor's proposal for a gravity gradient dump scheme designed for momentum relief of the Control Moment Gyros. The scheme utilized the rectification of the cyclic gravity gradient torques by changing signs of the commanded maneuver angles at specified times in the orbit.

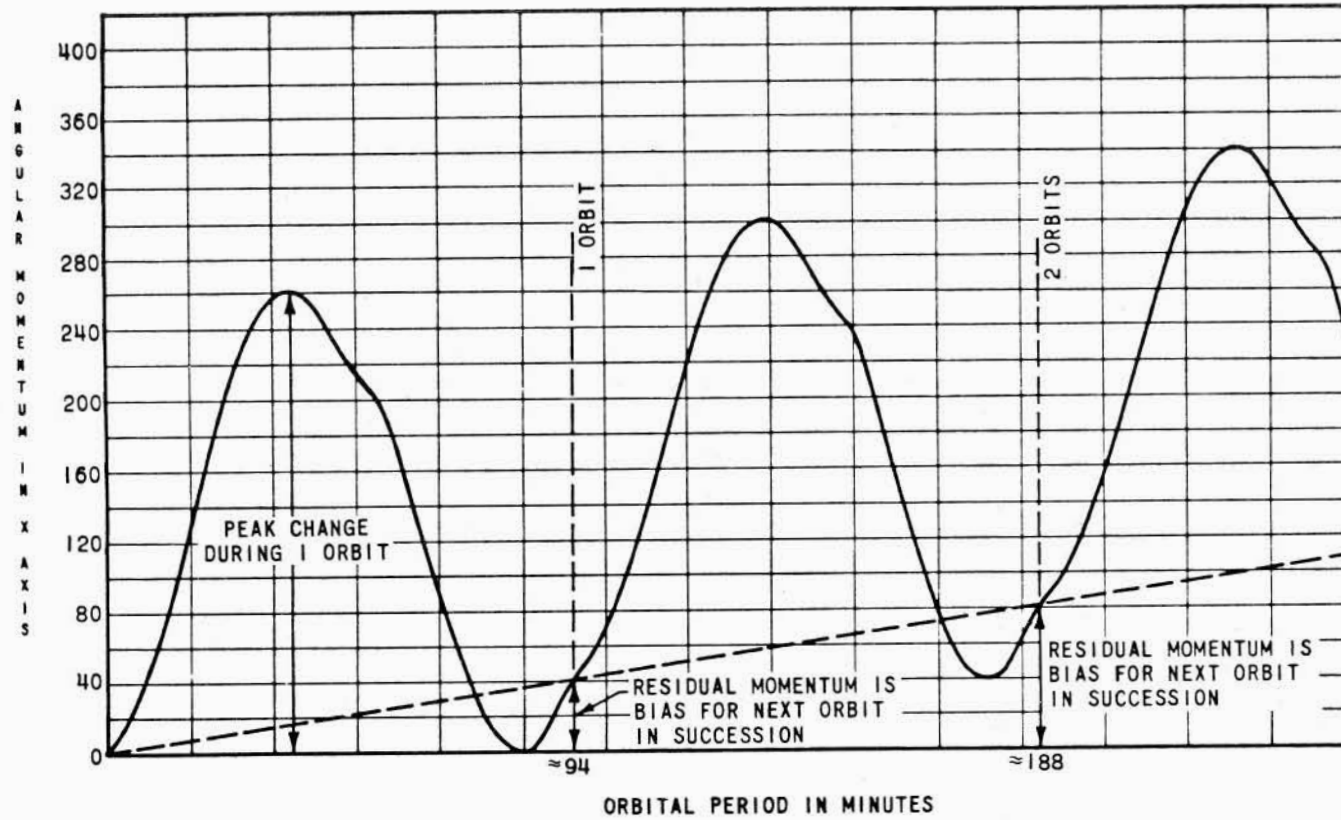
The attractive and unattractive features of the scheme was presented after a detailed analytical and computer simulation study was performed.

OWS-2-1

Completion date: 4/67

Double Gimbal Control Moment Gyros in Vehicle Attitude Control

The System for Inertial Experiment Pointing and Attitude Control (SIX-PAC) as proposed by NASA (Langley Field, Virginia) is investigated.



Angular momentum change due to aerodynamic drag torques about the elongated axis of an Apollo Telescope Mount (ATM) type vehicle.

The fundamentals of the CMG system are presented and the derivation of the equations for a space vehicle using the SIXPAC configuration is developed. Along with this a block diagram of the CMG and vehicle dynamics are developed for system study.

The characteristics of the CMG as an attitude control device are also discussed and a comparison with other attitude control schemes is made. Then advantages of the various systems are presented in conclusion.

SP 517-67-1

Completion date: 1/67

Charger-battery Regulator Module - Prototype Test Model

An engineering analysis was performed to establish design requirements for the thermal, mechanical and vibration prototype of the ATM charger-battery-regulator-module. The packaging design required compliance with MSFC Document 50M02408, Environmental Design and Qualification Test Criteria for ATM Components. The thermal and vibrational analysis of the prototype charger-battery regulator was conducted to verify the packaging design per requirements of 50M02408.

RF # 10-004

Completion date: 7/68

Generation of Orbital Coordinate Systems and Aerodynamic and Gravity Gradient Torques

To evaluate and confirm the ATM control system configuration and interface a detailed soft mockup of the vehicle pointing and control system was developed.

The developed program presents a complete Mathematical Model of an earth orbital space station. The Earth-sun-satellite motion model is simulated along with all external torques acting on the vehicle. The control system containing control moment gyros and reaction jets is also simulated making it possible to do detailed fuel studies of any earth orbital vehicle control system. Presently this simulation is programmed on both the 7094 digital and 8900 hybrid computers.

SP 522-0058

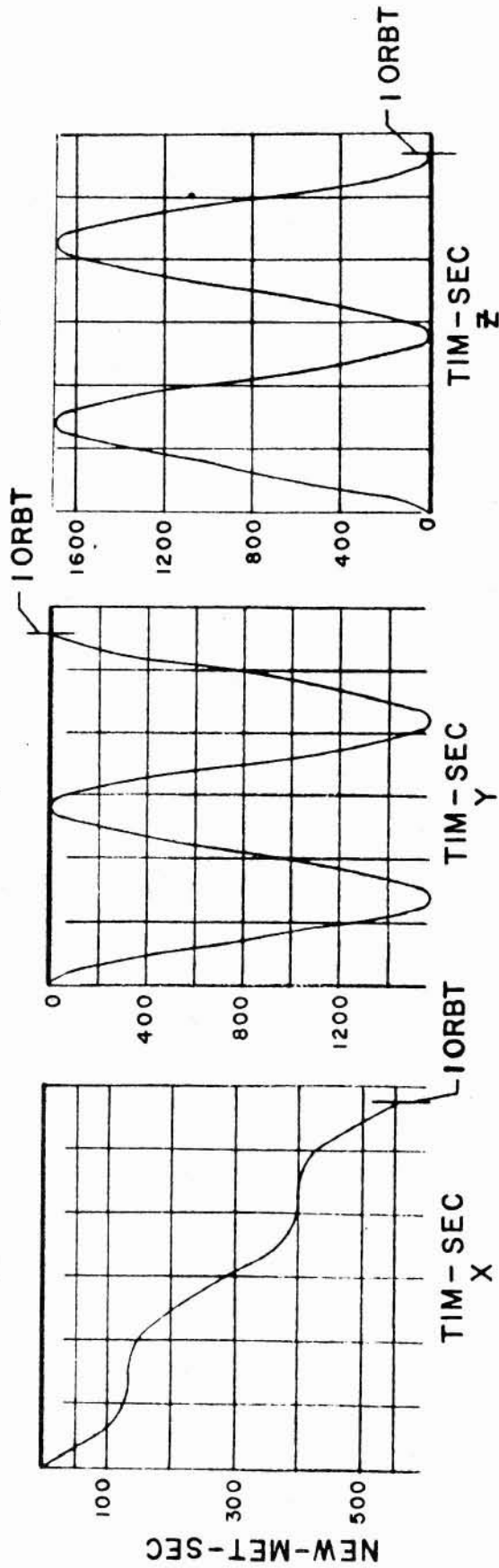
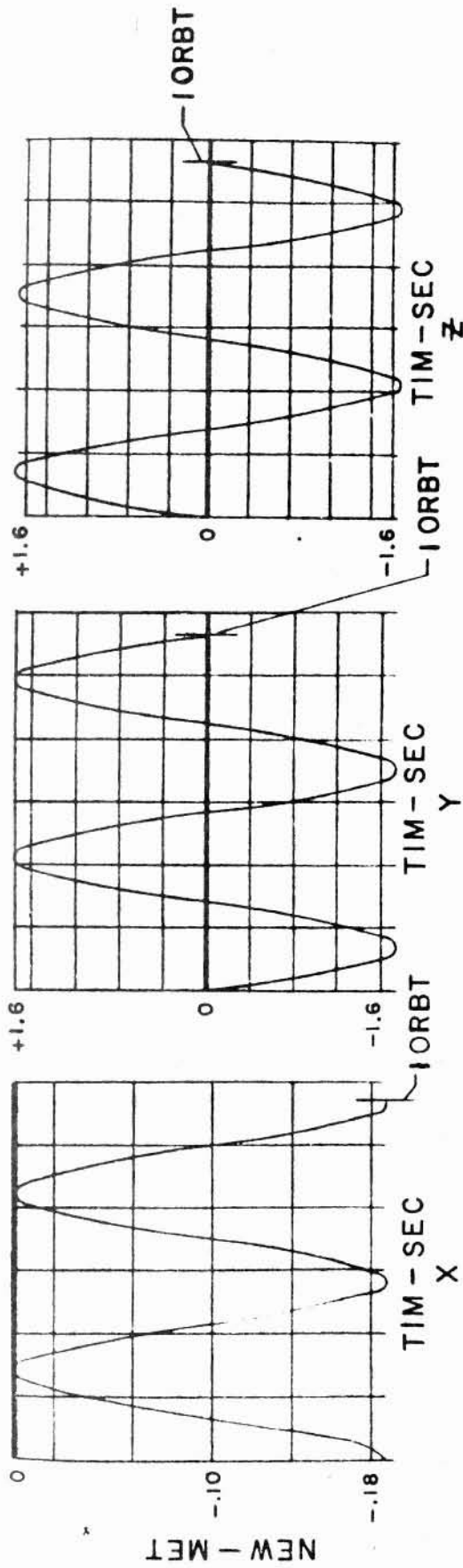
Completed: 4/67

Updated: 4/68

ATM Command and Telemetry Antennas

Originated the design concept and fabricated scale models and prototypes of ATM antennas. The antennas are mounted on the solar wings. An edge-mounted scimitar antenna was used for the 450 MHz command system and

GRAVITY GRADIENT TORQUE



MOMENTUM DUE TO GRAVITY GRADIENT

Plots of the external gravity gradient torque and resultant momentum for an Apollo Telescope Mount (ATM) type vehicle.

an edge-mounted dipole antenna for the VHF telemetry. The design concept was formulated by building 1:20 scale models of the proposed antennas and checking the radiation characteristics on a 1:20 scale model of the Apollo Telescope Mount cluster.

RL # 16-006

Completion date: 11/68

A Technique for Stabilizing the ATM Vehicle for Extended Time Periods
By use of Momentum Exchange Devices

If an ATM revisit is envisioned thermal control will be necessary. To supply thermal control a source of power will be required. If this power is provided by solar cells facing the sun a control system will be required either active or inactive. If an active system is used the system described in this report is applicable.

The study presents a momentum management scheme to permit control of the ATM with control moment gyros during the unmanned phase of the mission. The momentum management scheme reverses the direction of disturbance torque through simple CMG-controlled maneuvers, thus eliminating the requirement for reaction jets to relieve the unidirectional stored momentum of the control moment gyros.

Presented to

May 1967

American Astronautical Society
National Symposium

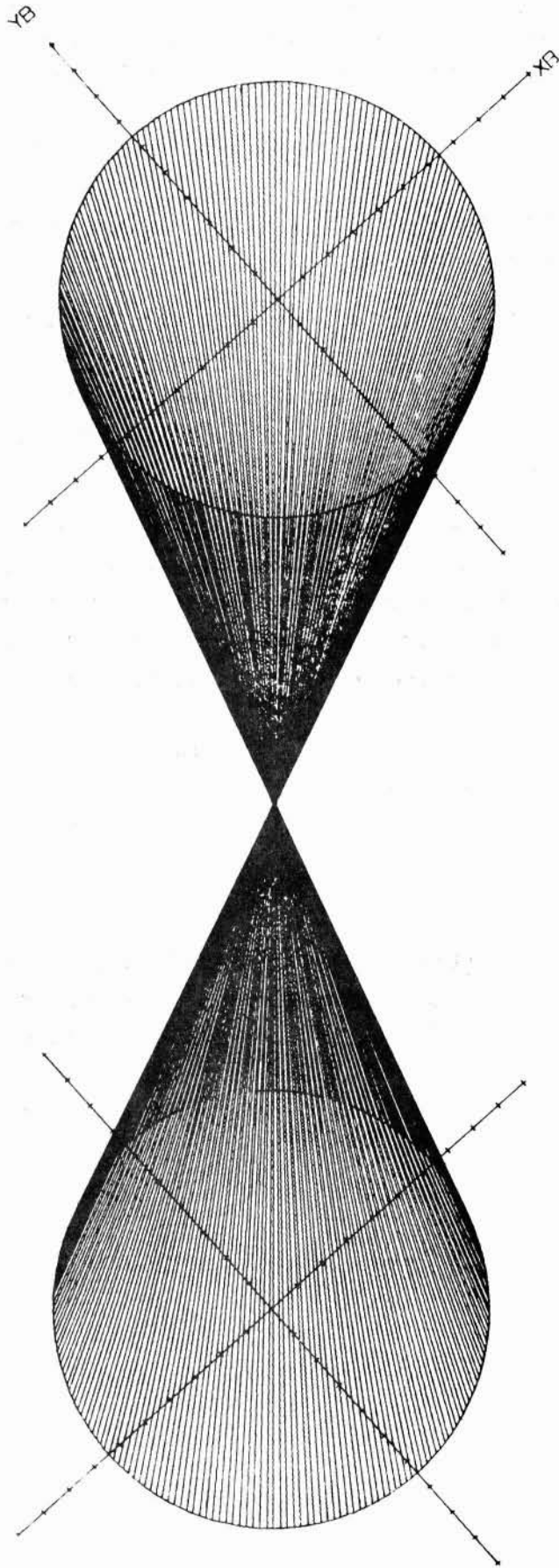
SIVB Stage Digital Filter

An all-digital flight controller for the SIVB stage is considered in detail. Several mechanizations of the digital compensator are designed and comparisons made by means of frequency response measurements and hybrid simulation.

SP 551-0045

Completion date: 4/24/68

50-56 X-Ray Telescope



Hyperboloidal and paraboloidal elements in perfect alignment - no distortion in ray bundle.

WORKSHOP CAPABILITIES SUMMARY

PHASE C - DESIGN

In this phase the final concepts are developed; designs are made to required specifications; and a total system analysis made. From this an analytical report is assembled and the finalized Project Development Plan (PDP) released.

The Apollo Telescope Mount (ATM), as the first large orbital workshop, has been through this phase. The Space Support Division's contribution in this phase, as documented, is presented in the following paragraphs.

ATM SO-56 X-Ray Telescope: Final Report

Final analysis of the optical properties of the SO-56 X-Ray Telescope is presented. Analysis includes ray tracing with special emphasis on ray diagrams, spot diagrams and point spread functions. All aspects of the X-ray reflection dynamics were considered.

OBS-3-1

Completion date: 3/69

ATM Configuration Management

Established a system for configuration control and documentation flow for the ATM program. The concept of a workable configuration management plan and documentation control plan was presented to and approved by the MSFC ATM Project Office; then documented and implemented. Technical documentation is generated from research and data gathering, as required, to determine a basis for the ATM program. The configuration management plan keeps engineering management informed on the program status.

RL # 18-002

Completion date: This is a continuing program.

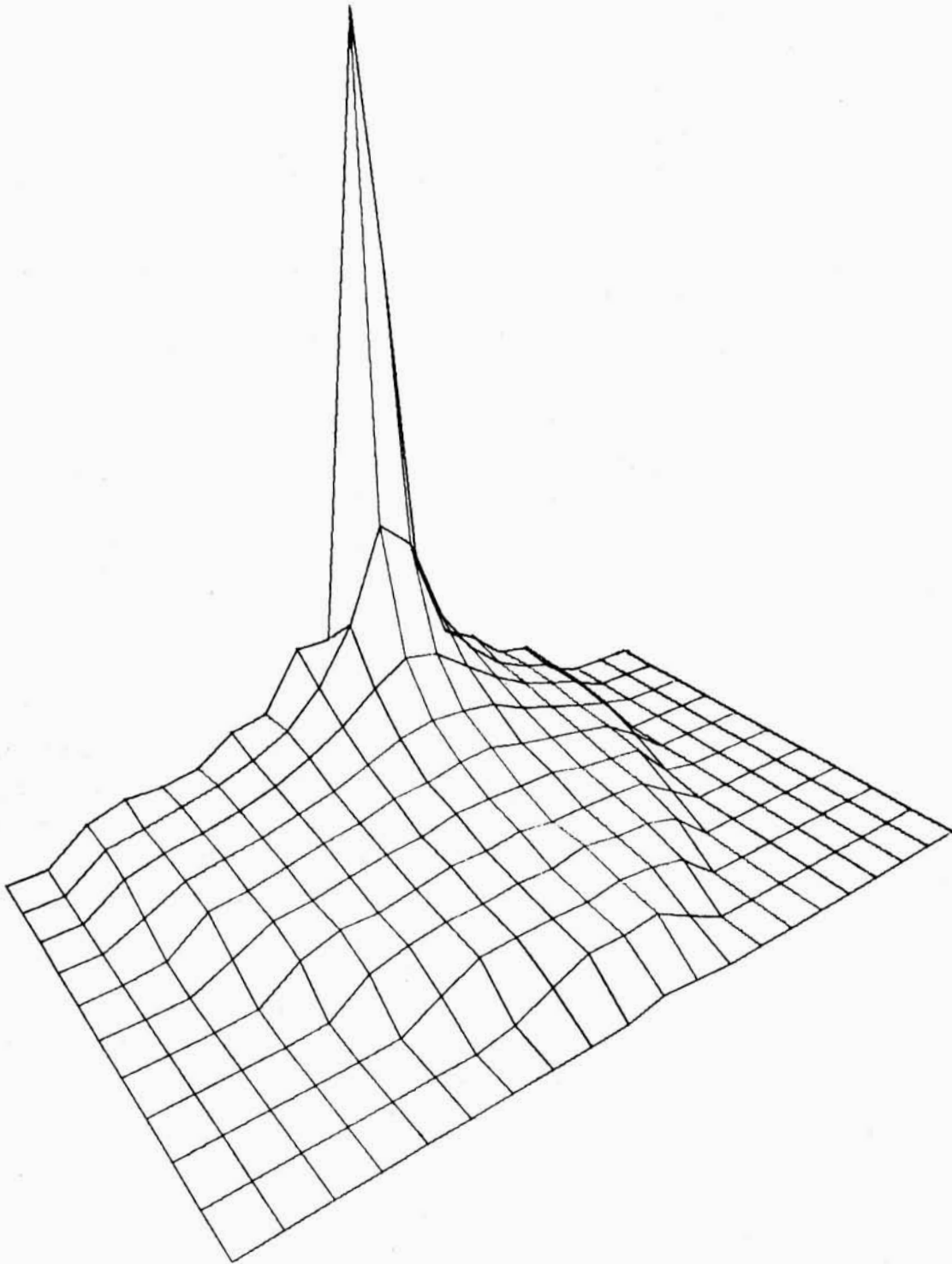
ATM Experiment Interface Control Documents

Reviewed and analyzed experimenter and ATM electrical circuits, and maintained electrical systems compatibility between experimenters, MSFC, and Manned Spacecraft Center by generating electrical interface control documents and electrical interface defining documents. Reviewed experimenter's proposed changes and recommended acceptance or refusal by the Configuration Control Board.

RL # 09-012

Completion date: 4th Quarter/70

50-56 X-Ray Telescope



Energy diagram of image formed by x-rays in film plane of telescope

Cable and Distribution System

A 700-cable distribution system is currently being designed to provide control, power distribution, and data transmission interconnections between a 52-rack, 260-panel electrical support equipment checkout system and the ATM. An analysis has been made of the entire cable and distribution check-out system to establish design goals and criteria. A study of the Saturn V, 500FS system was made to determine usability of cables for the design. A continuing systems interface study is being performed and cable interface control is being maintained.

RL # 09-006

Completion date: 11/68

ATM Distributors

Preliminary studies of ATM power, measuring, and command signal distribution requirements established the need for especially designed distributors. The distributors route commands, measurements, and electrical power between the command capsule control panel, the ATM experiment packages, and the electrical support equipment, both prior and subsequent to launch of the ATM. Designed the complete distributors to include housing, cabling, and components. Thermal vacuum tests are performed to verify the design. A reduction in the number of distributors required is achieved through the utilization of TO-5 type relays.

RL # 9-004

Completion date: 8/68

Optimal Desaturation of Control Moment Gyro Systems in Orbit

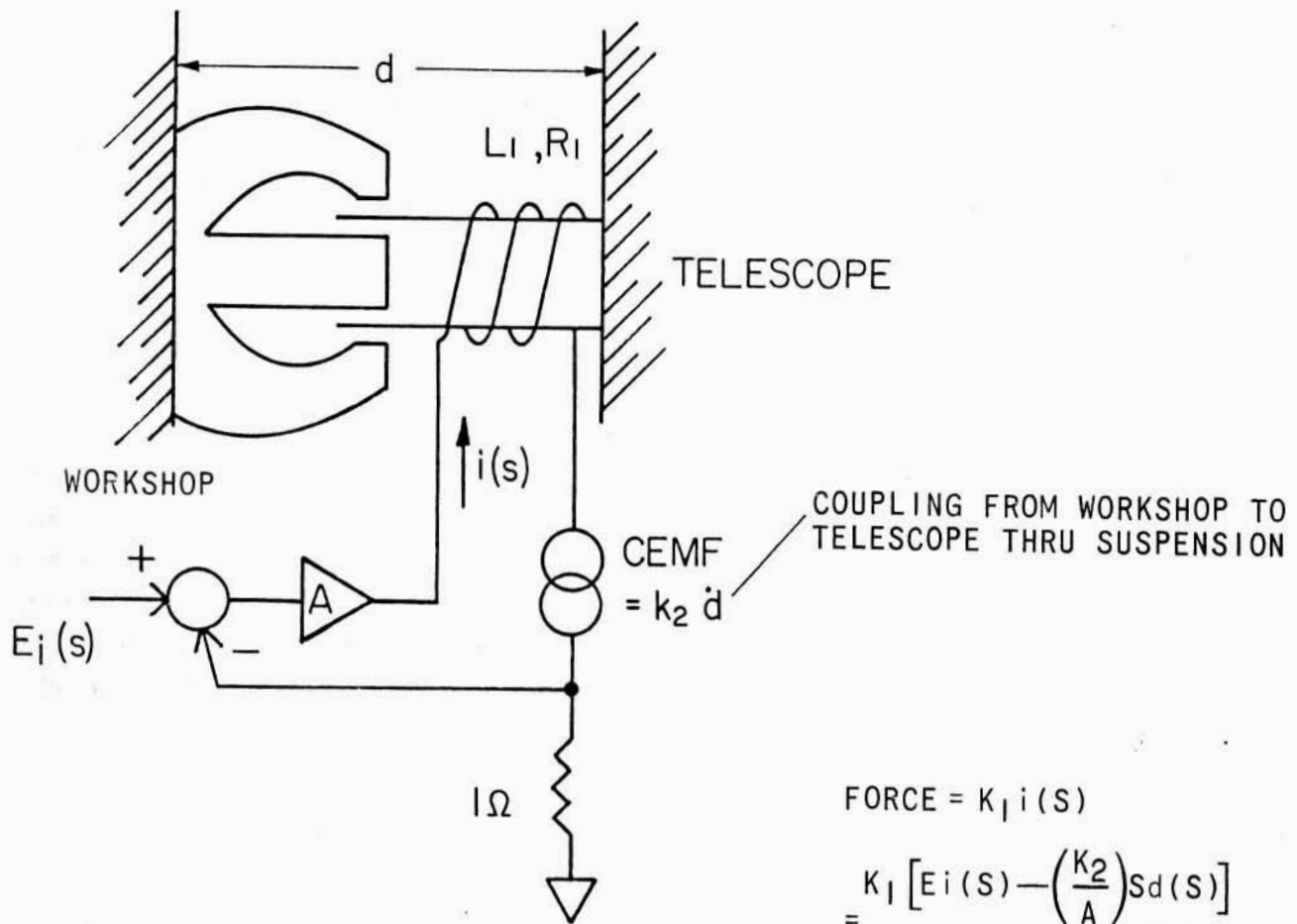
Space vehicles on missions that require fine pointing will perhaps utilize Control Moment Gyros (CMGs) for a long time to come because of the precise pointing capability offered by a continuous controller. Like other systems, CMGs do run out of "fuel" (which, in this application is measured by CMG gimbal angles). The "saturated" condition (analogous to an empty fuel tank) is reached when the CMG gimbal angles approach their limits. External torques must be applied to the vehicle/CMG system to reset the gimbal angles. A systematic approach to this "refueling" process is described using the free "fuel" source available in the gravity gradients.

The problem of momentum desaturation of pointing control systems with CMG controllers is cast into the format of a minimal energy optimization problem. The system model has the form of a linear time-varying equation with a state and control independent, time-varying forcing function.

OWS-3-4

Completion date: 1/69

TELESCOPE TO WORKSHOP MAGNETIC SUSPENSION DYNAMICS



$$\text{FORCE} = K_1 i(s)$$

$$= \frac{K_1 \left[E_i(s) - \left(\frac{K_2}{A} \right) S d(s) \right]}{(TS+1)}$$

A magnetic suspension of this type can be an almost perfect isolator, especially when feedback principles are applied. Coupled force due to workshop motion is reduced by open loop gain A . In addition, the isolation characteristics are essentially frequency invariant.

$$T = \frac{L_1}{A+R_1}$$

$$K_1 = 1.47$$

$$K_2 = 1.65$$

$$A > 1000$$

ATM Clock

Designed the logic and packaging of the ATM clock to provide ultra-stable time references for various ATM experiments. The clock is capable of providing time references in milliseconds, seconds, minutes, hours, and days, with a stability of 1×10^8 throughout the temperature range of -20 degrees to 85 degrees Celsius. The clock can be reset to any time period by ground command signals, and has a reliability of 0.99965. One prototype unit was fabricated and tested.

RL # 17-008

Completion date: 9/67

ATM Switch Selector Panel

Prepared Class I documentation of the ATM switch selector panel. The panel is required for ATM selector switch test and check out. The packaging design of the panel (component layout) was prepared to meet MSFC requirements. Documentation was completed in accordance with MSFC Drawing 40M-00224A.

RL # 10-013

Completion date: 12/67

ATM Electrical System Networks

The electrical circuitry to interconnect all ATM subsystems and to perform switching, control, power distribution, and signal conditioning functions is currently being designed. The system consists of three power distributors, five control distributors, three measuring distributors, a transfer assembly, a controls and display logic distributor, and approximately 500 interconnecting cables. The subsystems are designed to ATM specifications.

RL # 09-011

Completion date: 1/69

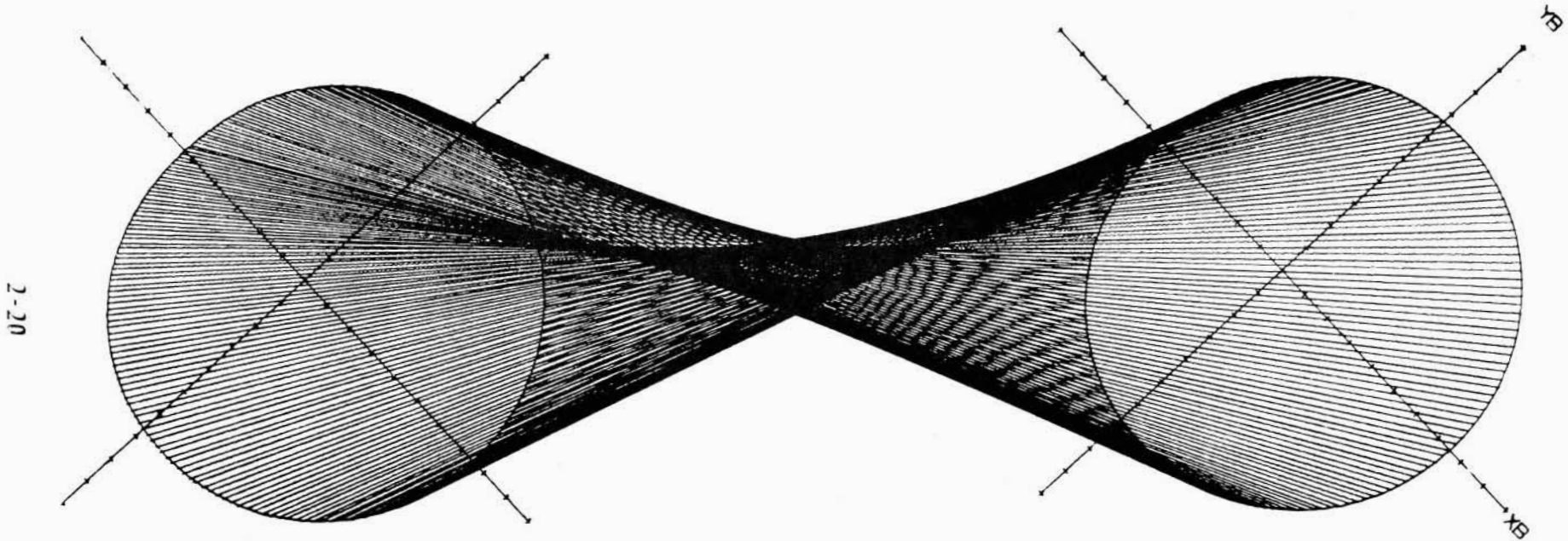
Time - Division Multiplexer

A time-division multiplexer was designed to accept up to 270 data inputs of 0 to 5 volts in amplitude, and to provide two parallel output wave trains. The multiplexer has 30 primary channels with a sampling rate of 120 samples per second. Principal subassemblies of the multiplexer are: the dc/dc converter and regulators that provide isolation of signal and missile power grounds; an isolation amplifier for each output; main channel multiplexer cards; calibrator; and clock and timing subassembly. One multiplexer was breadboarded and successfully tested. Documentation and prototype fabrication are in process. Several of these multiplexers shall be used on the second ATM flight.

RF # 16-025

Completion date: 9/68

50-56 X-Ray Telescope



Distortion in ray bundle introduced by alignment imperfections in the reflective elements of the telescope - hyperboloidal element de-centered by 0.002 inches.

Control Circuitry for Data Acquisition System

Designed the amplifier and switch assembly to be used on the ATM to amplify and select the proper output of redundant PCM digital data acquisition subsystems. Switching between the two PCM subsystems is accomplished by commands to internal control circuitry. These control circuits employ electro-optical devices to provide maximum isolation between the external command signal circuitry and the control circuits.

RL # 17-005

Completion date: 11/67

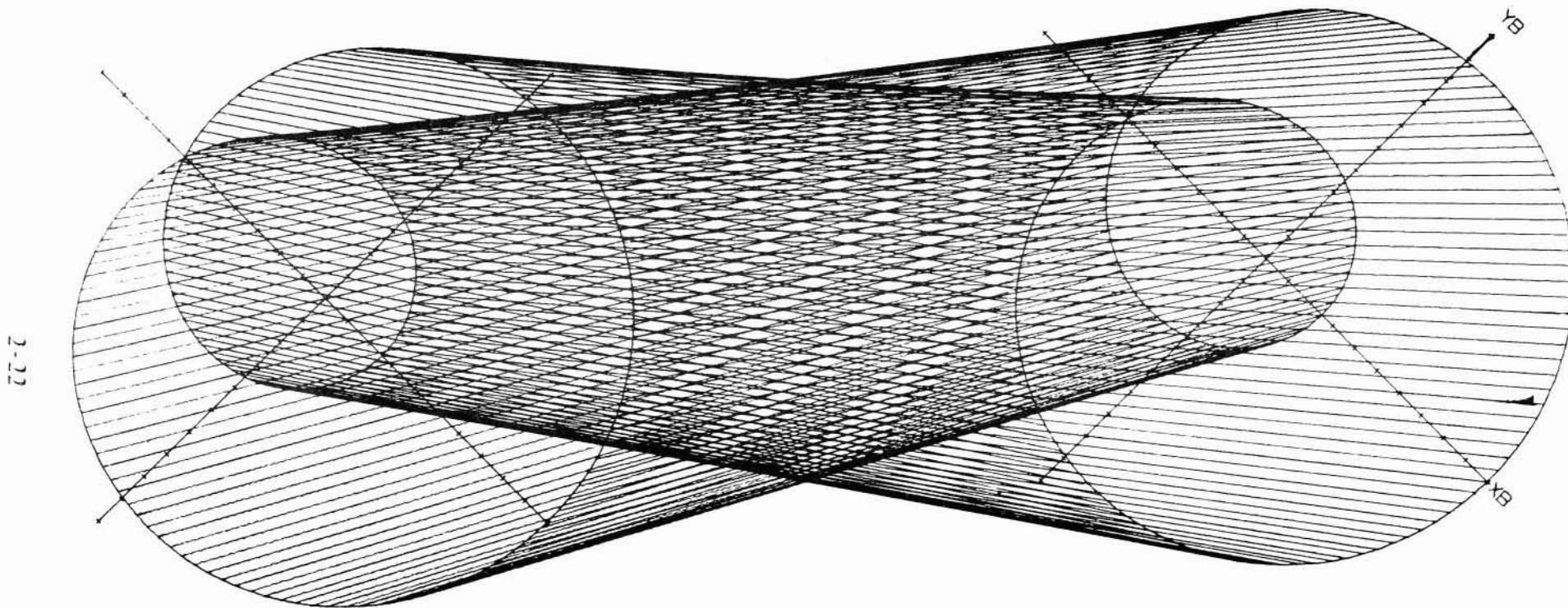
Charger-Battery Regulator-Module Documentation

This effort involves preparation of the specification, and the acceptance preliminary and qualification test procedures for the Apollo Telescope Mount (ATM) charger-battery-regulator module. A review of the ATM power requirements and prototype circuitry provided detail requirements for the three documents. The specification establishes purchasing/manufacturing requirements; the acceptance test procedure sets forth module acceptance standards; and the qualifications test procedure details environmental operating requirements for the modules.

RL # 10-001

Completion date: 4/68

50-56 X-Ray Telescope



2-22

Distortion in ray bundle introduced by alignment imperfections in the reflective elements of the telescope - hyperboloid tilted 15 arc seconds with respect to the optical axis.