14 00023159D

SECRET/[redacted]

[redacted]

COPY #[redacted]

FEASIBILITY STUDY FINAL REPORT

GEODETIC ORBITAL PHOTOGRAPHIC SATELLITE SYSTEM

VOLUME 5 PROGRAM PLAN, PHASES 2 THROUGH 5

JUNE 1966

SECRET/[redacted]

SECRET/[redacted]

[redacted]
Copy No.[redacted]

FEASIBILITY STUDY FINAL REPORT

GEODETIC ORBITAL PHOTOGRAPHIC SATELLITE SYSTEM

VOLUME 5 PROGRAM PLAN, PHASES 2 THROUGH 5

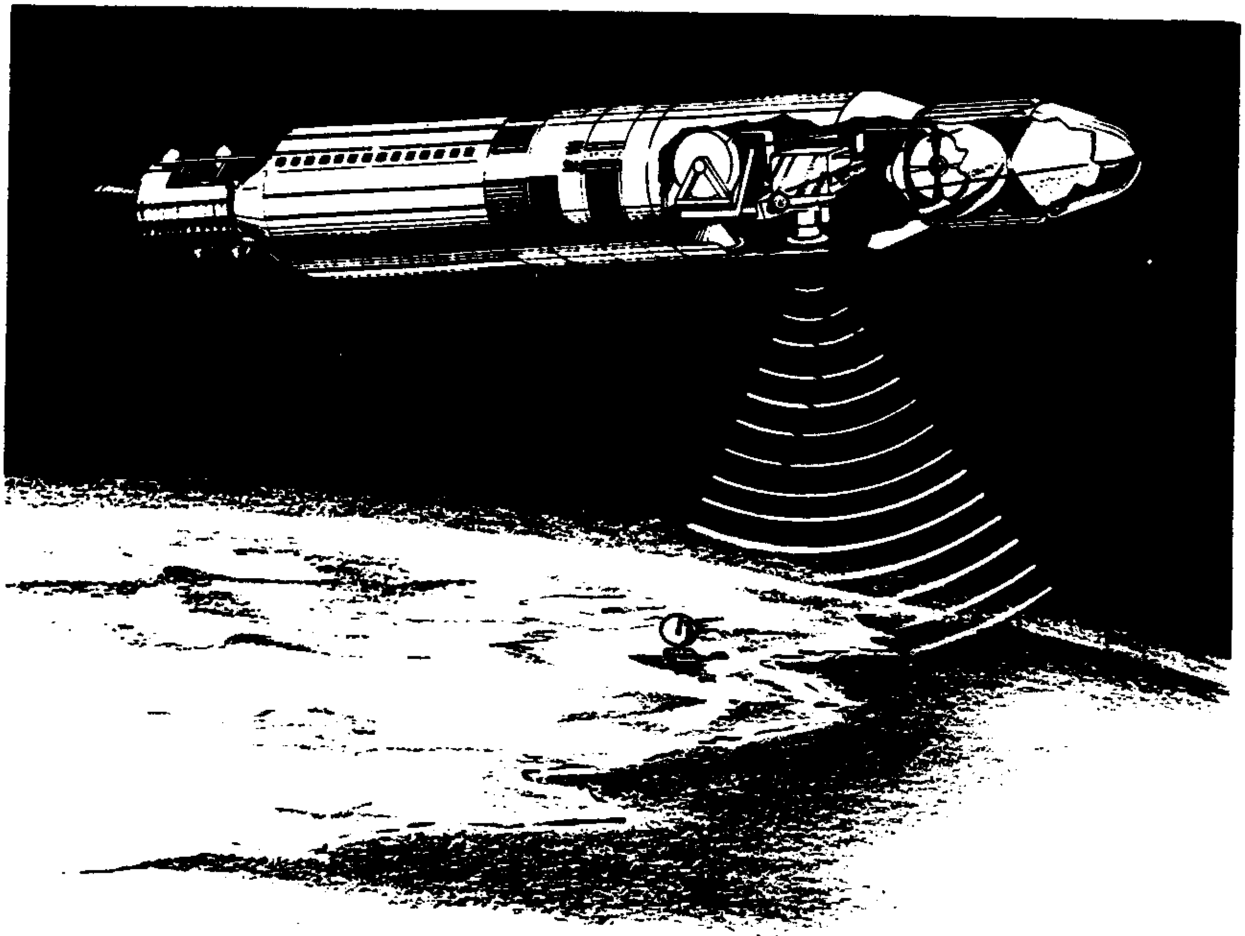
JUNE 1966

Itek

ITEK CORPORATION LEXINGTON 73, [redacted]

ATCH 1
Vol 5
Cy #[redacted]

SECRET/[redacted]



Geodetic Orbital Photographic Satellite System

PREFACE

The objective of the Geodetic Orbital Photographic Satellite System (GOPSS) is to accurately determine the location of landmarks widely distributed over the earth's surface and provide better information concerning the geophysical parameters which affect this system and other systems operating at similar altitudes. The means chosen to accomplish this objective is to orbit a series of data acquisition systems supported by ground-based instrumentation. The data gathered by this system is incorporated into a sophisticated data reduction scheme which determines the geodynamic parameters and landmark locations.

Detailed studies were conducted to determine the feasibility of the GOPSS. The study period was designated as Phase I, and the results of these studies have been compiled into five volumes for reader convenience.

This volume describes the planning activity as it has been programmed through Phases II to V for the engineering, fabrication, and operational support for the delivery of five systems. Continuing studies which are required are also defined in this volume.

The division of the remaining volumes and their content are now briefly described for information and reference purposes.

Volume 1, Program Compendium and Conclusions, was prepared to provide briefly the details essential to a comprehensive understanding of the effort conducted during Phase I of the GOPSS feasibility study. System concept and objectives are described plus conclusions which concern the attainment or modification of the initial objectives, along with recommendations for a system configuration and a solution of the attendant data handling problems.

Volume 2, Data Collection Systems, describes the effort for implementation of the data acquisition requirements for the GOPSS program. This volume presents the preliminary design which defines and describes the various sensors, considers their functional interdependencies, and shows their evolvement into an integrated GOPSS.

Volume 3, Data Processing, Part 1, considers the photogrammetric data subject to constraints imposed by orbital and auxiliary data, the mapping capabilities of the system, and ground handling of mission photography.

Volume 4, Data Processing, Part 2, discusses orbital considerations affecting the feasibility of the GOPSS. Physical models and computational procedures are reviewed and error studies involving typical sensor and model inaccuracies are described. Based on these studies, recommendations are made for tracking networks, auxiliary on-board sensors, and detailed orbit plans. In addition, the data reduction procedure, whereby the acquired data are simultaneously located to yield geodynamic parameters and landmark locations, is considered.

SUMMARY

Phases II through V describe the implementation of the results of the Phase I feasibility study into an operational Geodetic Orbital Photographic Satellite System (GOPSS) payload configuration. The following phases are defined separately to permit efficient program management and control funding allocations. Although separately defined, many program requirements are interwoven among the phases to ensure total program accomplishment.

Phase II of the program plan develops the final design of the photosensor and auxiliary sensors, the data collection module, and the general design requirements of the recovery section. Tasks performed during this phase are system engineering and design, design of tooling and test equipment, breadboarding and test of critical assemblies, generation of design specifications for AGE, auxiliary equipments, and the recovery section.

Phase III consists of four primary tasks: production, testing, and qualification of the first photosensor; final design of the recovery section; fabrication of tooling associated with Phase III; and design of AGE and MAB specifications.

During Phase IV, the second photosensor and the first recovery section are produced; in addition, auxiliary sensor equipments are procured. The photosensor and auxiliary sensors are integrated as a system, and the system is subjected to a qualification test program. After completion of the qualification tests, the system is refurbished for delivery as one of the operational systems.

Three new flight systems will be produced during Phase V. Acceptance tests will then be performed on these three plus the two from previous phases which will be refurbished. The five systems will be delivered at two-month intervals. Also auxiliary ground equipment will be produced, missile assembly building construction will be monitored, and field service operations will be initiated.

Extensive functional or baseline, environmental, and calibration testing which is required to ascertain the suitability of the system for launch will be conducted. Also described are equipments required to perform these tests.

Strict and efficient management is required to implement a program of this nature. A detail management phase which discusses scheduling, project organization and control manpower requirements, and the facilities required to implement the GOPSS program is therefore provided.

5.1 INTRODUCTION

The study to establish the feasibility of locating landmarks over the earth's surface to high accuracies from data collected by an orbiting vehicle has been successfully completed. The analyses concluded that the TRANSIT tracking network, supplemented by selective photogrammetric and other inputs, would adequately describe the orbit from the accumulation of data from five missions, and that once the subsequent vehicle positions were determined, photogrammetric techniques would then permit landmark locations to the specified accuracies of 200 feet in the horizontal and 40 feet in the vertical direction.

In addition, to ensure compatibility with the prescribed operational environment, a preliminary design study was conducted, illustrating the employment of the various data collection systems that the systems analysis determined to be necessary. This task, in addition to generating the specifics of individual sensors, fully considered the functional interdependencies of these sensors and evolved an integrated payload concept, the implementation of which is described in the body of the program plan for the continuing phases of the GOPSS.

Within this integrated concept, a payload system responsibility in which all equipment forward of the Agena has been considered a single assembly has been developed. This assembly, composed of the section containing the data collection sensors and a dual recovery section, is shown in Figure 5-1. This volume described a four-phase plan which fully designs, manufactures, integrates, tests, and assumes field responsibility for this integrated payload. It implies the availability of recovery vehicles and TRANSIT transmitters as GFE. As part of the initial design phase, substantial breadboarding of critical elements is contemplated. This breadboarding is followed first by a qualification model of the critical photo-optical sensor and then by a qualification model of the entire payload as herein described. Finally, a manufacturing and qualification model refurbishment program is developed to produce a total of five operational payload systems, and a field engineering activity is programmed.

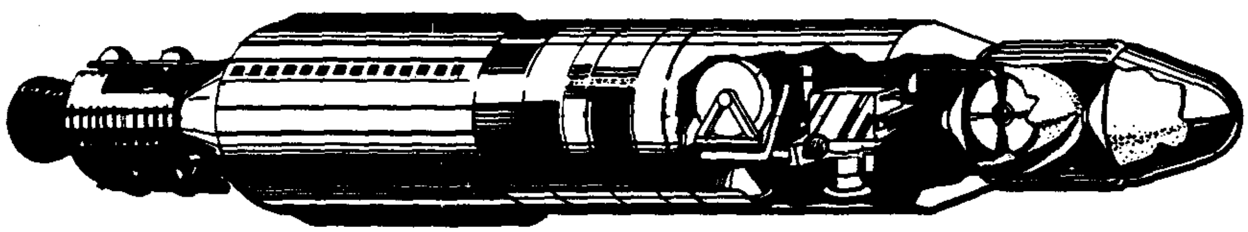


Fig. 5-1 — Geodetic orbiting photographic satellite system

5.2 PROGRAM DESCRIPTION

The Phase II through V Program Plan describes the implementation of the results of the Phase I software feasibility study into an operational payload configuration to accomplish the objectives of the GOPSS program. Figure 5-2 is a family tree of the payload configurations. The various segments encompassed in this task are design, breadboarding, fabrication, integration, testing, and field service, all of which are woven into an efficient flow by strict management control. Best engineering practices are reflected in this plan to (1) design and take all necessary steps through to actual operation, and (2) to construct the advanced equipment necessary to gather the required data. Design tasks are strengthened by breadboarding during the design phase. Test procedures have been developed for comprehensive debugging during fabrication and assembly. Integration test programs facilitate orderly system integration with formal qualification and acceptance tests programmed to make the most economical use of test facilities during the short schedule. In general, all program events follow a sequential order which permits design modifications that result from testing to be implemented without schedule slippages. This order is reflected in the division of the program into four phases following the presently concluded feasibility phase. Although these phases are separately defined, many requirements are interwoven among the phases to ensure total program accomplishment. However, these four phases have the necessary separation of effort to permit efficient program management and control of funding allocations. A Phase II through V schedule is shown in Figure 5-3.

Phase II is devoted primarily to the design of the GOPSS payload and the breadboarding of critical designs. Figure 5-4 is a schedule of Phase II effort. Included are designs for the cameras, DCM structure, and film transport system, generation of auxiliary sensor specifications, and a general design of the recovery section. Support to this design function includes a configuration control effort, necessary interface liaison, construction of a mockup, design of Phase III special tooling, formal test program specifications, and the initiation of the reliability program. Breadboarding is started immediately using Phase I design information. Sufficient notification of the choice of recovery vehicle will permit design of the recovery section during the 10 months of Phase II. All design tasks during this phase terminate in complete drawings and specifications for all of the GOPSS except the recovery section.

Procurement of glass blanks for lens manufacture is an initial requirement of Phase III, which is primarily devoted to the fabrication, assembly, and qualification testing of a complete photosensor system. Phase III effort is actually initiated during Phase II to allow immediate fabrication of photosensor parts. During Phase III, tooling and test equipment are fabricated, the final recovery section design is completed, and AGE design and MAB layout are accomplished.

Phase IV, which runs concurrently with Phase III, requires the fabrication, assembly, integration, and qualification testing of one complete GOPSS payload. The phase is scheduled so that system qualification testing follows Phase III qualification testing to permit design modifications, if needed, and judicious use of test facilities.

CONTENTS

FIGURES

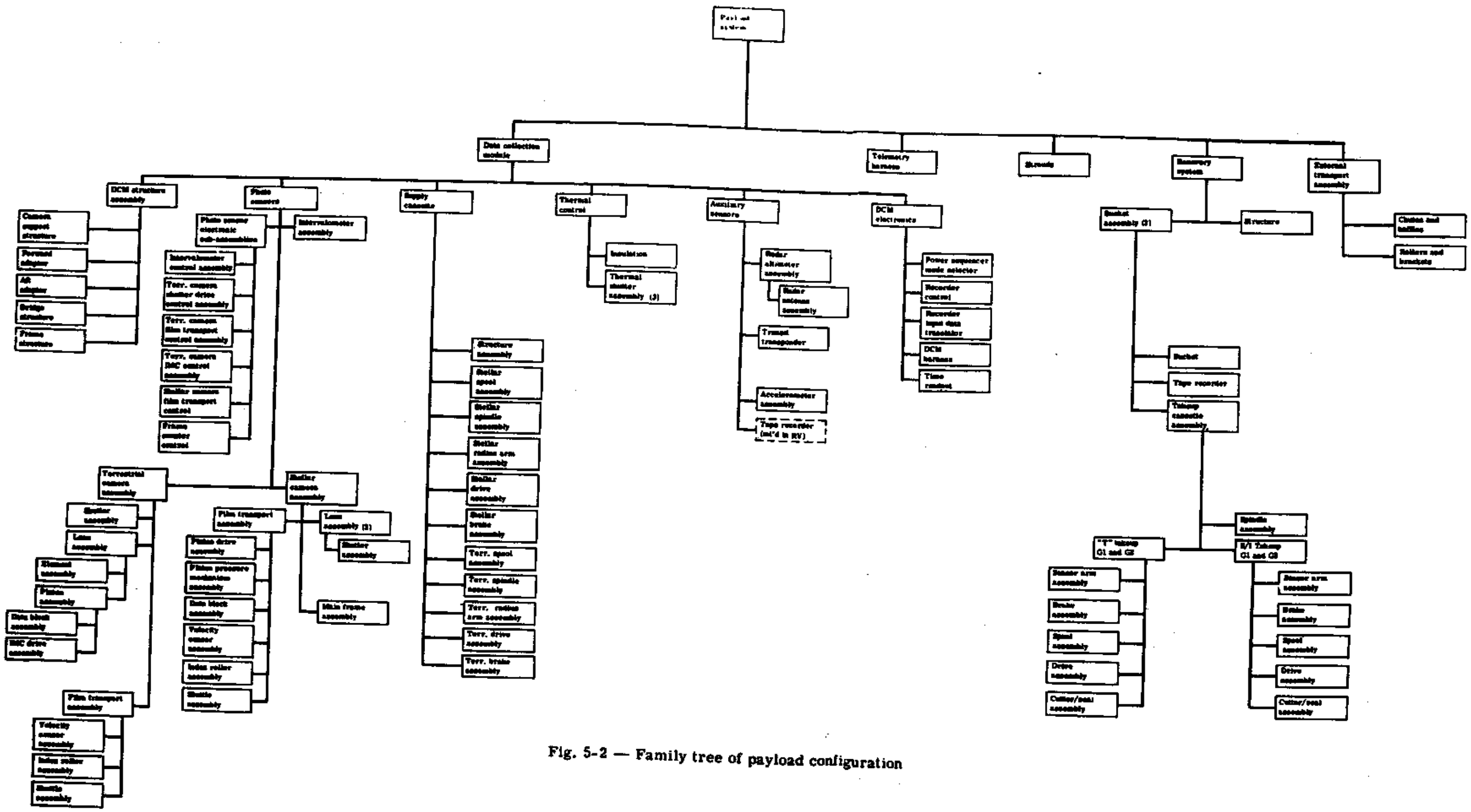


Fig. 5-2 — Family tree of payload configuration

[redacted]

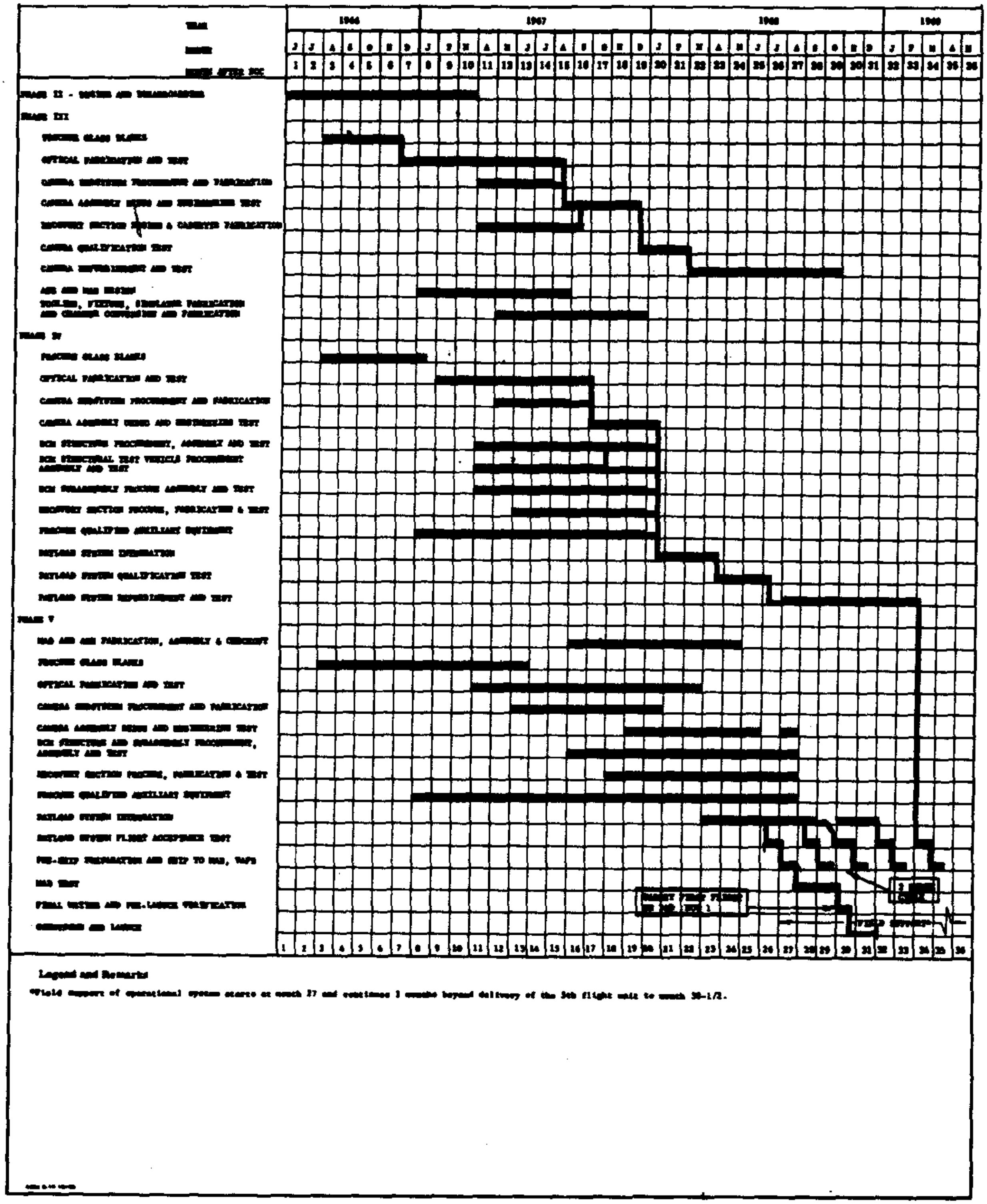


Fig. 5-3 — Phase II through V schedule bar chart

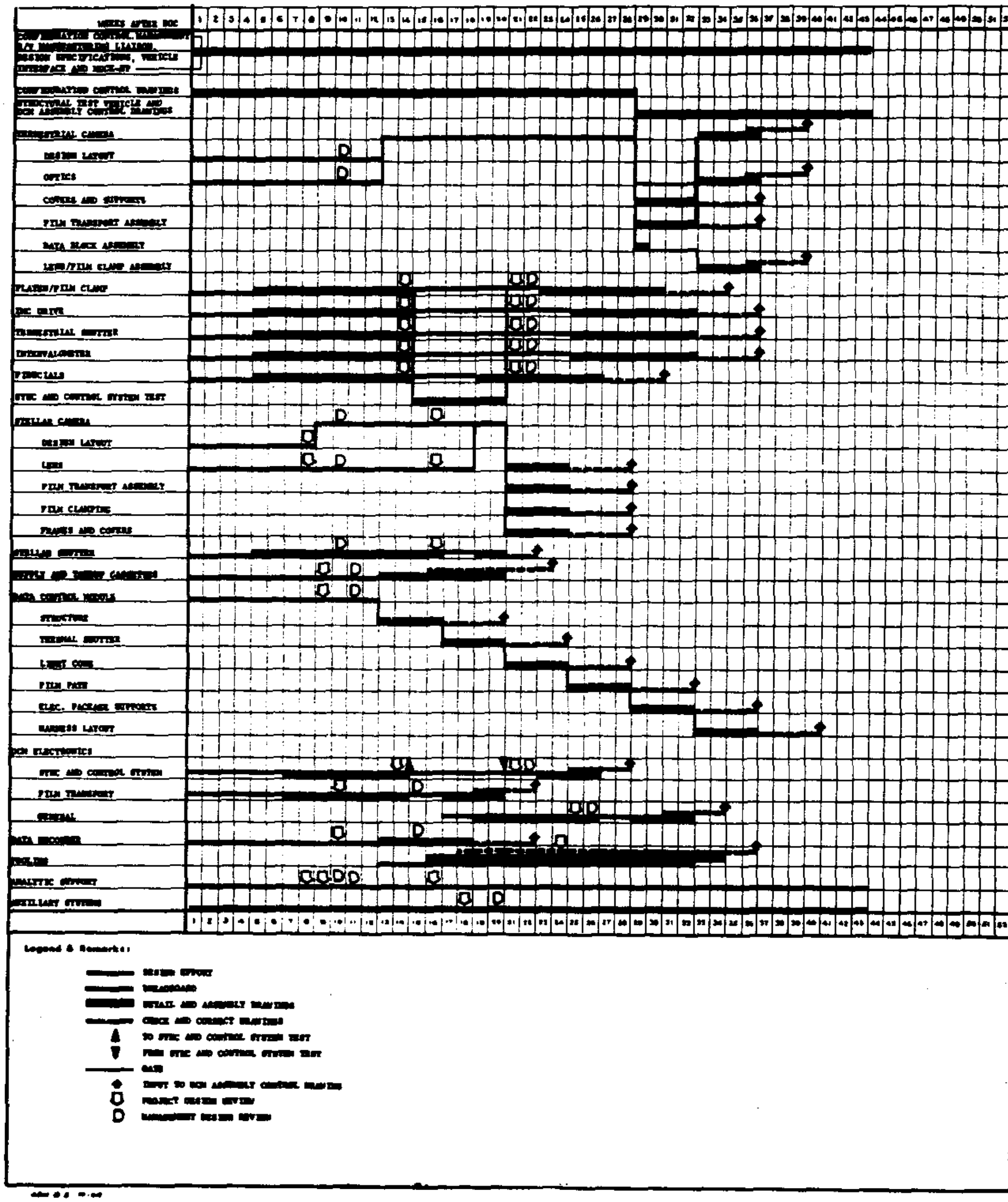


Fig. 5-4 — Phase II schedule bar chart

Phase V effort consists of the fabrication of three complete GOPSS payloads, the fabrication of a fourth to mate with the refurbished "qual" photosensor system, and acceptance testing of these four systems plus the refurbished "qual" system as the fifth deliverable flight system. Fabrication and test of AGE, MAB, construction liaison, and field support of launch site efforts are additional tasks under Phase V.

5.3 PHASE II DESCRIPTION

This section describes in detail the work which will be performed during Phase II. Major tasks performed during this phase are system engineering and design, design of Phase III tooling and test equipment, breadboarding and test of critical assemblies, generation of design specifications for AGE, auxiliary equipments, and the recovery section, and the construction of a DCM mock-up. A separate section has been accorded to this particular phase since it is the next step in implementing the GOPSS.

5.3.1 Scope

Phase II of this program will develop the final design for the Data Collection Module of the Geodetic Orbital Photographic Satellite System (GOPSS) and the general design requirements for the recovery section which were established in preliminary form in Phase I. To ensure proper work flow, maximum utilization of allotted time, and total program coordination, Phase II has been charted as shown in a summary PERT network, Figure 5-5. All critical assemblies will be breadboarded and integrated to determine design compatibility and eventual performance with respect to system requirements. After completion of the design effort and approval, both by Itek project and management personnel, detail and assembly drawings will be completed under a strict drawing configuration control. The final drawings will be an input to the DCM assembly control drawing for the procurement and fabrication of the GOPSS. Structural and thermal analytic support will be furnished throughout this phase.

Strict management configuration control will be administered to ensure the following activities: proper liaison between customer, vehicle manufacturer, and RV manufacturer; review and evaluation of system control and design specifications; completion of preliminary vehicle interface requirements; and generation of vehicle interface specifications. During the course of the program, a full scale DCM mockup will be built as an aid to the design effort and to provide proper interface between the various subsystems.

Major design areas which comprise the Phase II effort are as follows:

1. Terrestrial camera
2. Stellar camera
3. Supply cassette
4. Data collection module
5. DCM electronics design
6. Data recorder
7. Auxiliary systems

In addition, Phase III tooling and test equipment design as described in Section 5.3.1.2 will be required.

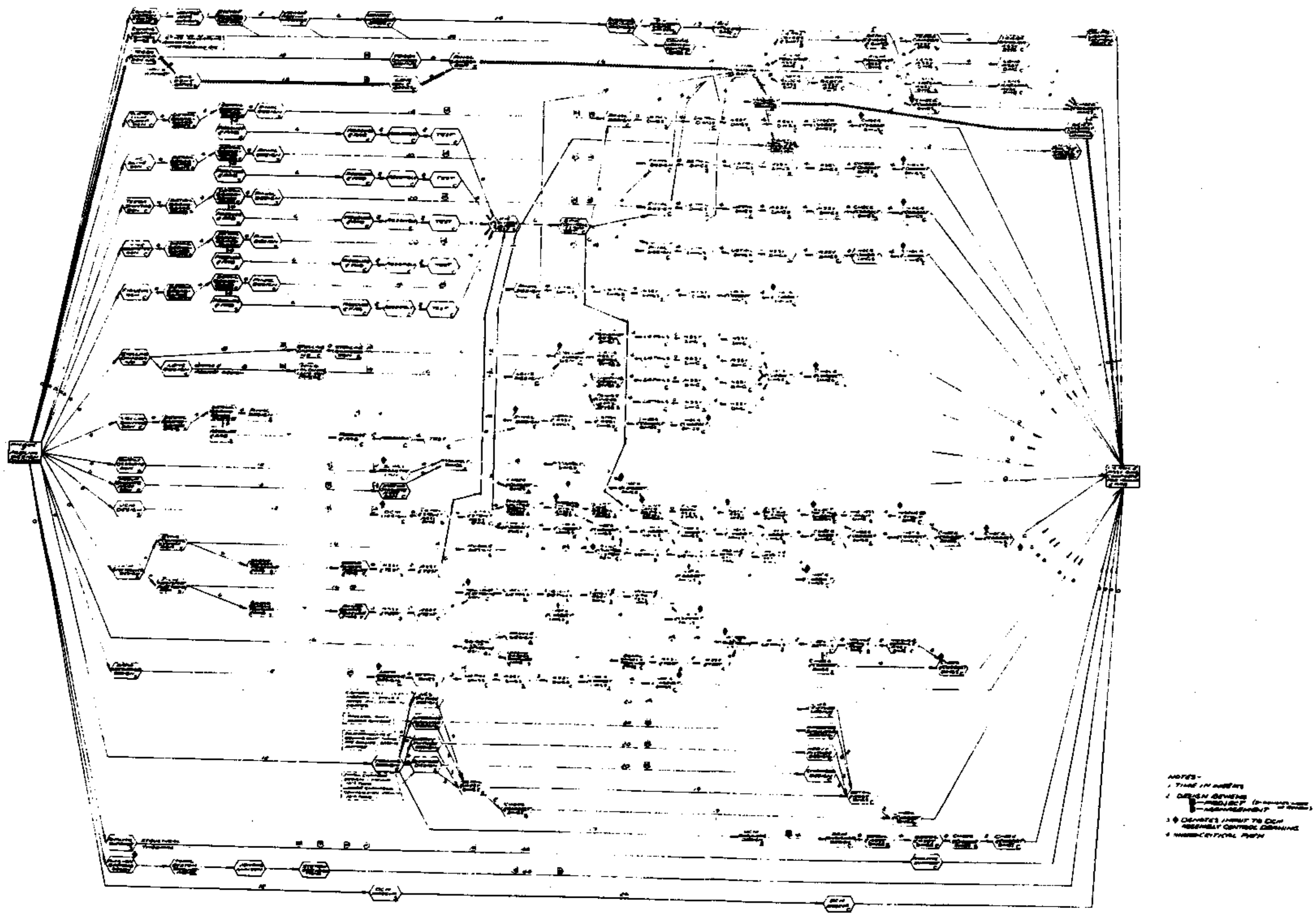


Fig. 5-5 — Phase II summary network

5.3.1.1 System Engineering and Design

5.3.1.1.1 Terrestrial Camera Design

Terrestrial camera layout, including lens design and optics, will form the basis for the final camera design.

Individual design subtasks within the terrestrial camera structure include the platen film clamp, IMC drive, shutter, intervalometer and fiducials. These subtasks will all be breadboarded and integrated into a synchronization and control system test generated during the DCM electronics design effort. After completion of this test, any changes deemed necessary within the various subtasks will be incorporated into the final design; all subtasks will then be fitted into the final camera design. Once the final design is approved, detail and assembly drawings will be completed.

5.3.1.1.2 Stellar Camera Design

Stellar camera design will follow a design phase similar to that for the terrestrial camera. A layout will be initiated, and the Wild Falconar lens design modified to meet the requirements of the stellar camera. A subtask for the design of the stellar shutter will be performed, and the design will be breadboarded.

5.3.1.1.3 Supply Cassette Design

The supply cassette will be designed, and assembly drawings detailing the structure, spool, spindle radius arm, drive, and brake will be completed.

5.3.1.1.4 DCM Design

Initial effort during DCM design will result in detail and structural assembly drawings. During the course of this design task, detail and assembly drawings will be made for the thermal shutter, light cone, film path assemblies, electronic packaging supports, and harness layouts.

5.3.1.1.5 DCM Electronics Design

The DCM electronics design effort is basically divided into two areas: (1) the synchronization and control system, and (2) the film transport electronics. Both are concerned with the electronics required for the photosensor operation.

Electronics included under the synchronization and control systems are the shutter, IMC drive, and intervalometer servos, plus a matrix which uses the V/h and t_e signals to govern the speed ratios of these servos.

Electronics included under the film electronic transport design are the spool servos, shuttle servo and relay controls for speed regulation, and the calibration film sensor.

The synchronization and control system will be breadboarded and integrated with the other breadboards to perform the synchronization and control tests. During these tests, modular design will be implemented for the electronic circuits. After the test, circuit details will be completed, and module and detail assembly drawings provided.

General DCM electronic design will be initiated in the sixteenth week of Phase II. This effort will be concerned with the electronics which join the photosensors, radar altimeter, accelerometer, and TRANSIT transponder. Also included are the mode control circuits which tie into the system power and control lines to provide proper operational sequencing. A data readout electronic system will also be designed to transfer individual component readouts to the film data block or to the recorder.

5.3.1.1.6 Data Recorder Design

A mission recorder design will be initiated since available hardware does not meet system power requirements at the present time. This will be a design of a film recorder utilizing a light diode array.

5.3.1.1.7 Auxiliary Systems

Auxiliary systems design is concerned with those systems required for operational suuport: the radar altimeter, clock, TRANSIT, accelerometers, data recorder, and signal conditioner. Evaluation of total system requirements, vendor liaison, and generation of specifications will be accomplished during this design effort period.

The effort is largely one of liaison with the end product a set of procurement, technical, and test specifications for each system. It is expected that vendors for these auxiliary systems will not be required to engage in an actual design effort during this phase, but instead will perform the engineering work necessary to support the specification and control drawing generation.

5.3.1.2 Design of Phase III Tooling and Test Equipment

Tooling design will be initiated during the twelfth week of the program. Design items will include manufacturing jigs, assembly and environmental test fixtures, a payload/photosensor interface simulator, heavy fixtures, and environmental chamber design and conversion.

Jigs and fixtures are required for the assembly of both the terrestrial and stellar cameras; also required are vibration fixtures for the shock and acceleration tests, and shipping crates for the spools and system.

The payload/photosensor interface simulator will be a console which will provide an electrical interface with other payload systems.

Heavier fixtures to be designed are a film handling and rewind unit, handling dollies for the cameras and takeup spools, and a photosystem spatial fixture. A commercial film processor will be converted to handle the system spool sizes.

The following are descriptions of some of the key Phase III tools and test equipment used from assembly through qualification testing. They are referred to extensively in the sections which describe Phases III, IV, and V when their use is required.

5.3.1.2.1 Assembly Fixtures

The film supply cassette assembly fixture and dolly permits assembly of the cassette at a convenient working height. The dolly is equipped with casters for transporation of the supply cassette to other assembly areas (see Figure 5-6). It is a pipe and flange construction with a plywood top. The cassette frame may be fastened to brackets on the top and the assembly built up from this point.

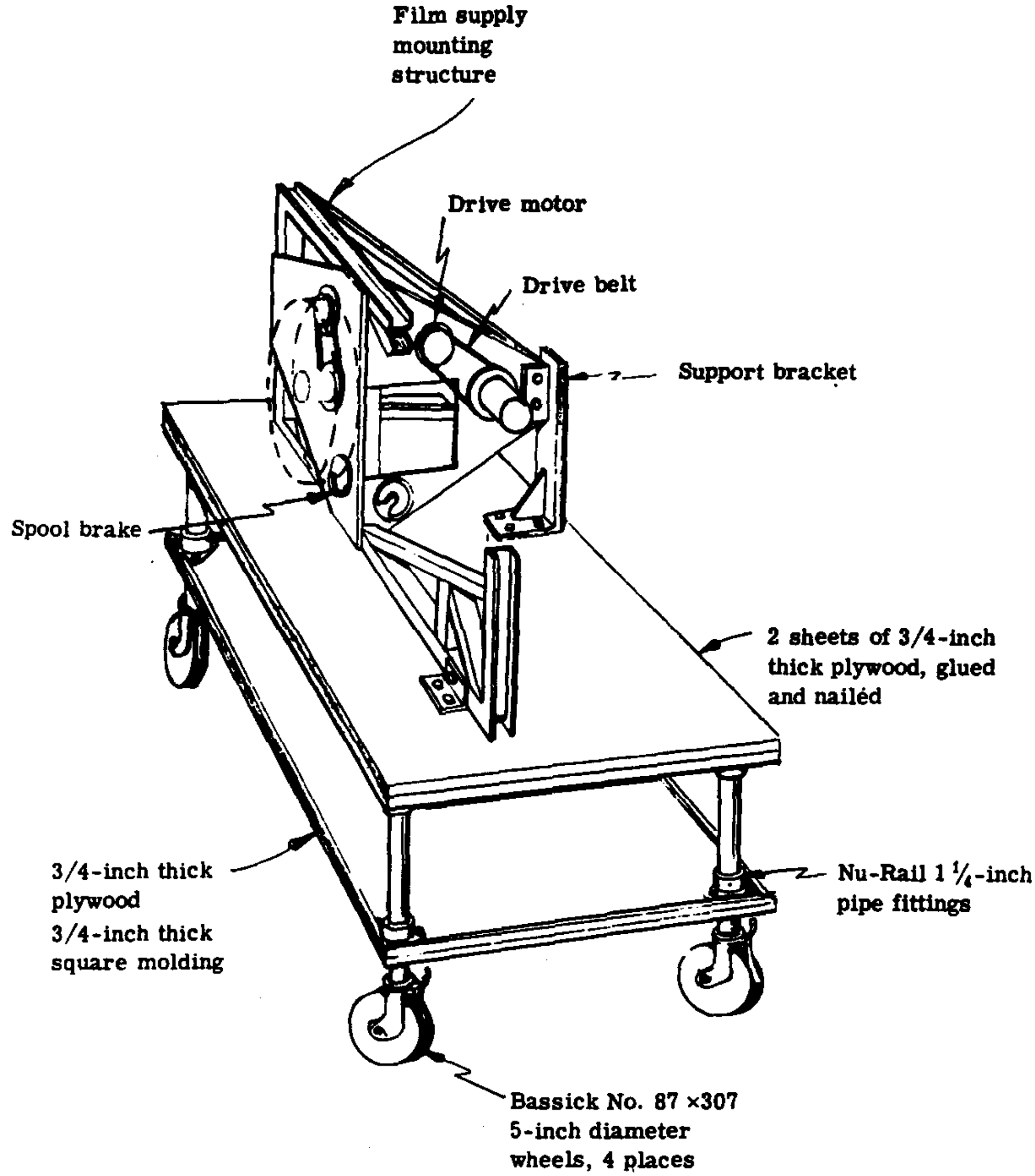


Fig. 5-6 — Film supply cassette assembly fixture and dolly

The terrestrial camera assembly fixture and dolly (Figure 5-7) permits mounting of the terrestrial camera during assembly at a convenient working height. It has a single gimbal mounting frame for rotation of the camera to permit easy access. It is also equipped with casters for mobility.

5.3.1.2.2 Spatial Frame

This device is a framework on which the cameras, cassettes, shutters, and electronic modules may be mounted to simulate the spatial arrangement of these components in the payload structure (Figure 5-8). This simulation will permit the establishment of a film path. The unit will have a harness similar to that of the payload and will be made a collimator with a target drive. The collimator will be used to provide an image for the IMC verification. The design of the spatial fixture will be such that the photosensor system can be checked in the assembly areas while in a horizontal position, and will also fit within the environmental chamber in a vertical position.

5.3.1.2.3 Collimator and Target Drive Assembly

This device consists of a 24-inch focal length, f/8, (3-inch aperture), collimator with a target drive (Figure 5-9). It is a single unit construction, i.e., the drive and collimator are housed in a single assembly. The target drive subassembly consists of a servo-driven wheel approximately 7.60 inches in diameter and a velocity pick-off to provide V/h signals through the photosensor/payload simulator or the AGE to the photosensor system. A series of standard Air Force resolution targets are placed on the surface of the wheel, which is located tangent to the focal plane of the collimator. When illuminated and moving, the targets provide a moving image to the terrestrial camera to verify IMC.

5.3.1.2.4 Erecting Dolly

The erecting dolly is used in the environmental test area for rotating the complete satellite system from a horizontal to a vertical position prior to mounting in the large chamber (see Figure 5-10).

5.3.1.2.5 Payload/Photosensor Interface Simulator

This device provides an electrical and control interface for the photosensor system similar to that of the operational installation. The following inputs are provided to the photosensor system from this console.

a. 28 vdc power
b. V/h signal
c. Exposure signal
d. Time signal
e. Altitude signal
f. Mode selection

The interface simulator is presently envisioned as a two-rack console. Although the V/h is generated within the console, the signal will control the rate of the target wheel in the target-collimator assembly, and a signal from its tachometer will provide the V/h rate for the photosensor system.

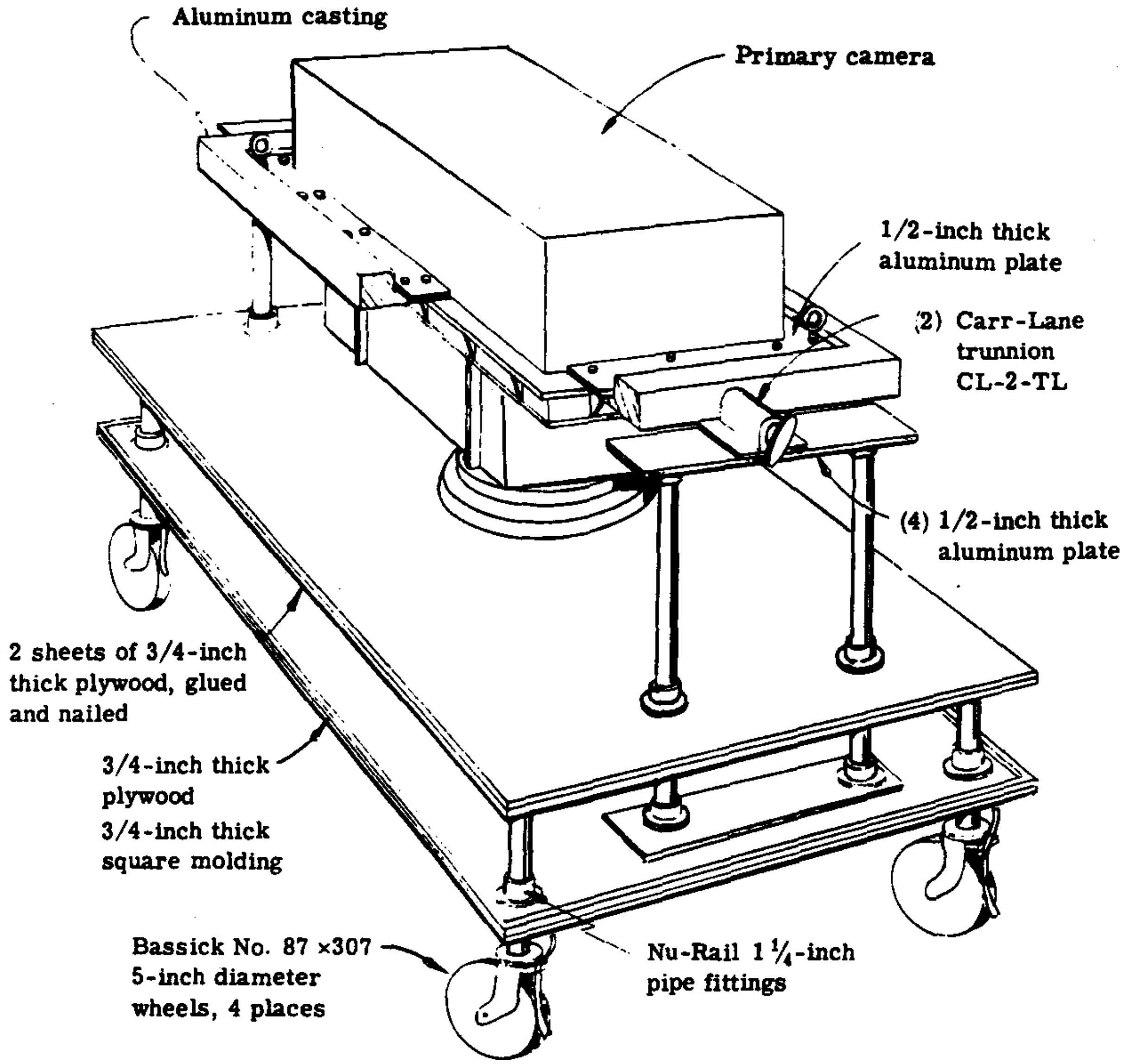


Fig. 5-7 — Terrestrial camera assembly fixture and dolly

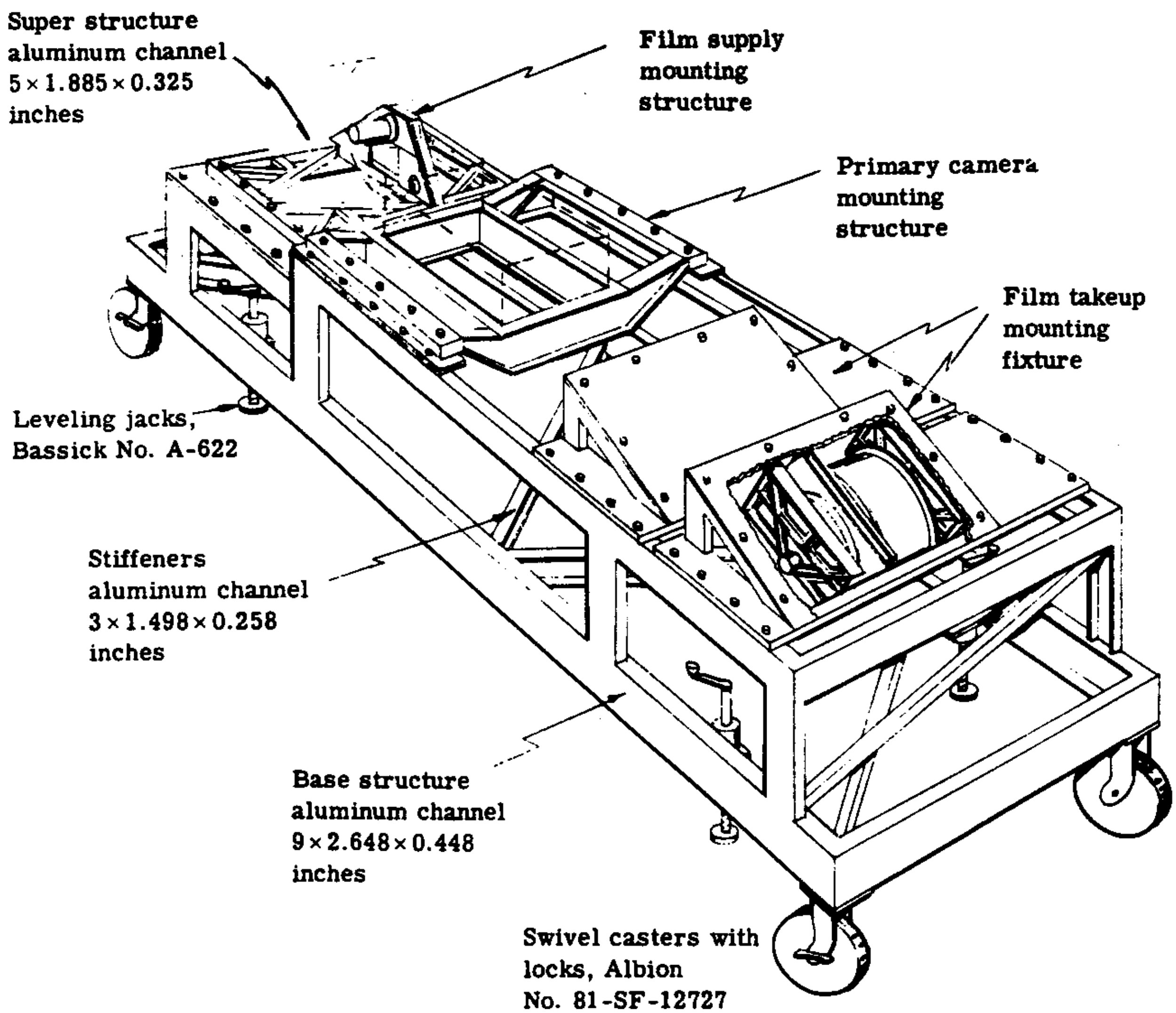


Fig. 5-8 — Spatial fixture

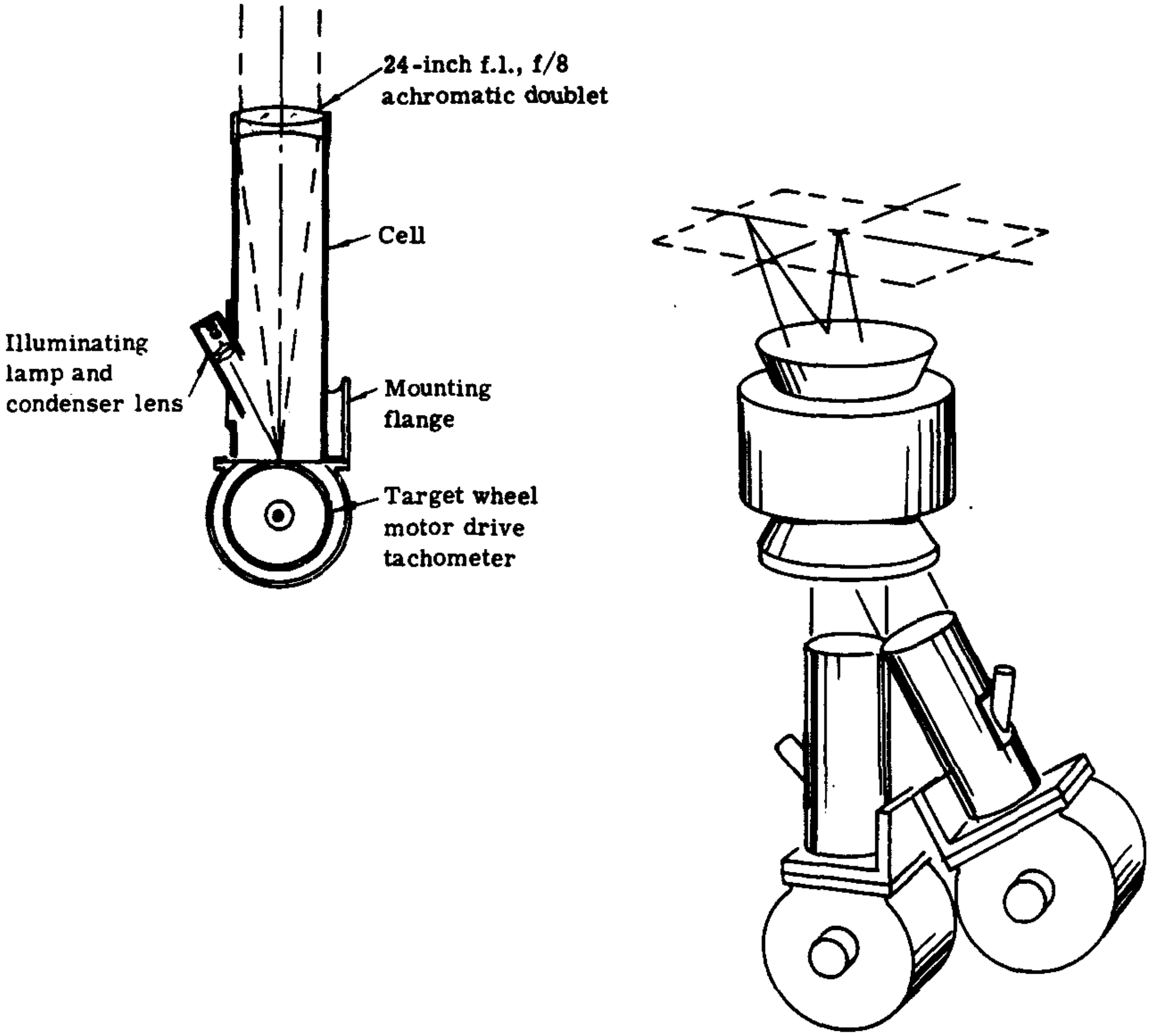


Fig. 5-9 — Collimator/target drive assembly

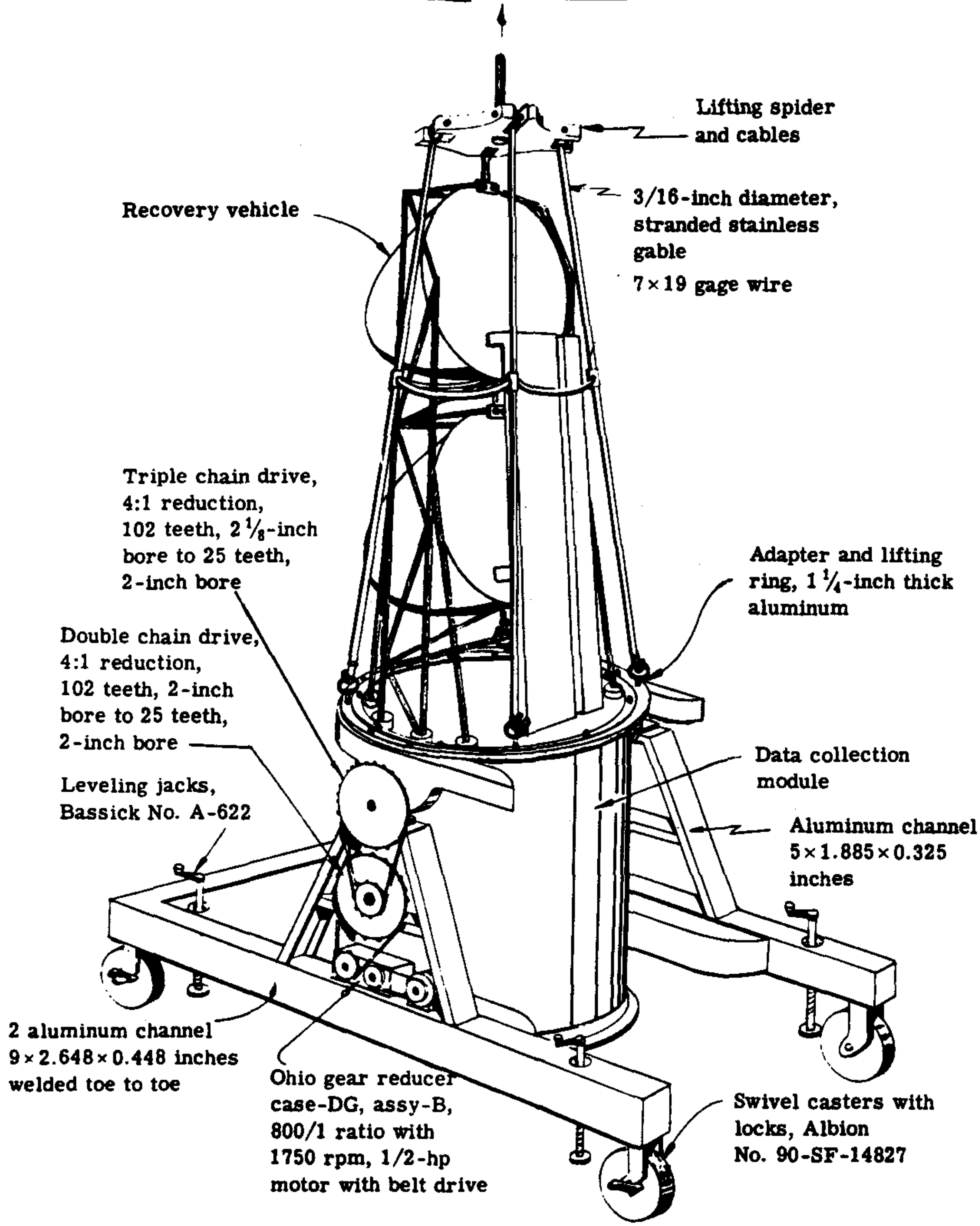


Fig. 5-10 — Erecting dolly

5.3.1.2.6 Shipping Containers

Shipping containers for the supply spools loaded with film (Figure 5-11), for the DCM, and for the RS (Figures 5-12 and 5-13), will be designed during Phase II. The supply spool containers will be constructed of plywood and light-tight; the DCM and RS containers will be aluminum, pressure sealed, humidity-controlled, and equipped with isolators.

5.3.1.2.7 Chamber Design and Conversion

Two chambers which will be designed during Phase II are required for the later phases of the program. One small chamber, basically a bell jar system, will be used for calibration of film distortion and the terrestrial-stellar camera knee angle. Vacuum requirements are 10^{-3} Torr. This unit will be approximately 6 feet in diameter and 6 feet high.

A large chamber is required for environmental testing and is presently available, but must be modified to meet the vacuum requirement of 10^{-6} Torr. It is a 50-foot vertical chamber, 9 feet in diameter. Its pump apparatus and fittings will be modified, and provision will be made to accommodate two small collimators external to the chamber.

5.3.1.3 Breadboarding and Test

Phase II breadboarding and breadboard testing will be undertaken primarily to evaluate the designs of critical hardware generated during Phase I. The assemblies which will be breadboarded are:

1. Terrestrial camera shutter
2. Terrestrial camera IMC drive
3. Intervalometer
4. Synchronization and control system electronics
5. Fiducial assembly
6. Platen and pressure mechanism
7. Stellar camera shutter

In addition, the electronics for the photosensor system will be breadboarded, not because these assemblies are critical but because this approach is common practice in electrical design. The breadboard approach consists of: (1) rough circuit layout, (2) breadboard, (3) test, (4) evaluation, and (5) final circuit design. The assemblies that will be breadboarded are as follows:

1. Film transport electronics and servos
2. General control electronics
3. Data recording system electronics

Where assemblies are to be breadboarded, the breadboarding and test efforts will run parallel with the design efforts. As knowledge is gained from testing, it will be reflected immediately in the formal design efforts.

5.3.1.4 Software Efforts

Special consideration will be given during Phase II to the generation of controlling specifications for auxiliary equipments, AGE design and manufacture, and to recovery section design scheduled during Phase III interface and configuration.

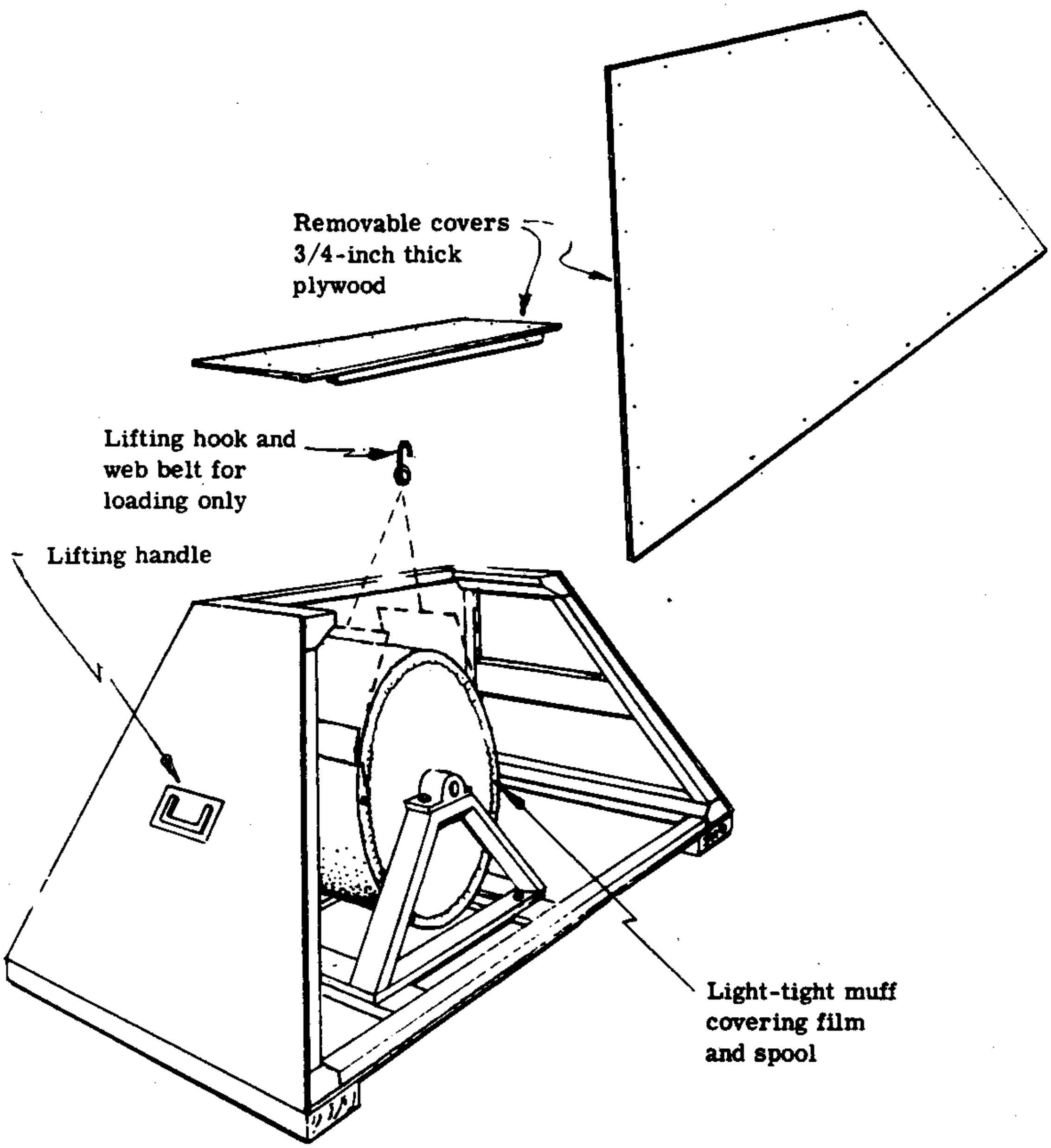


Fig. 5-11 — Film shipping container

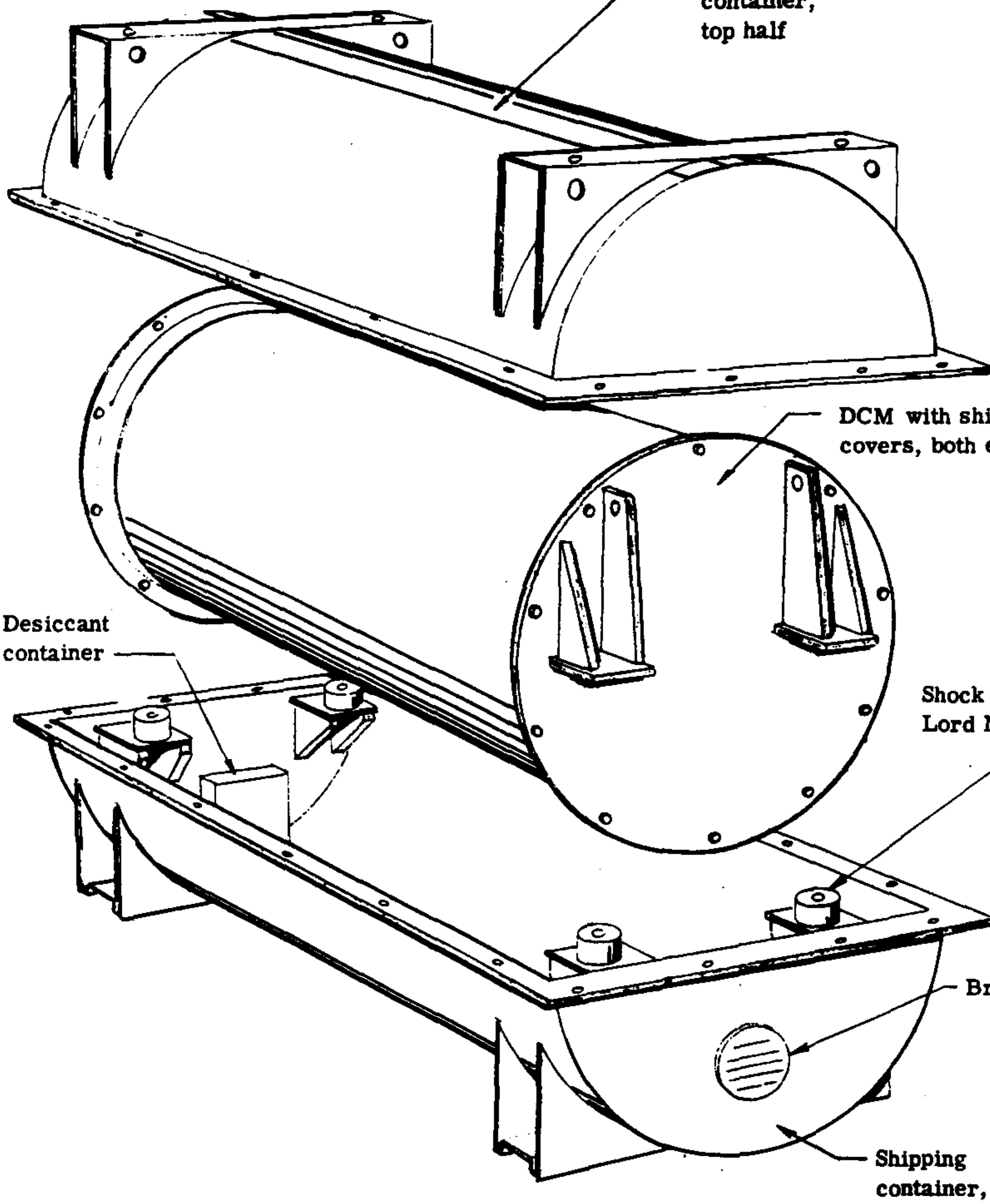


Fig. 5-12 — Data Collection Module shipping container

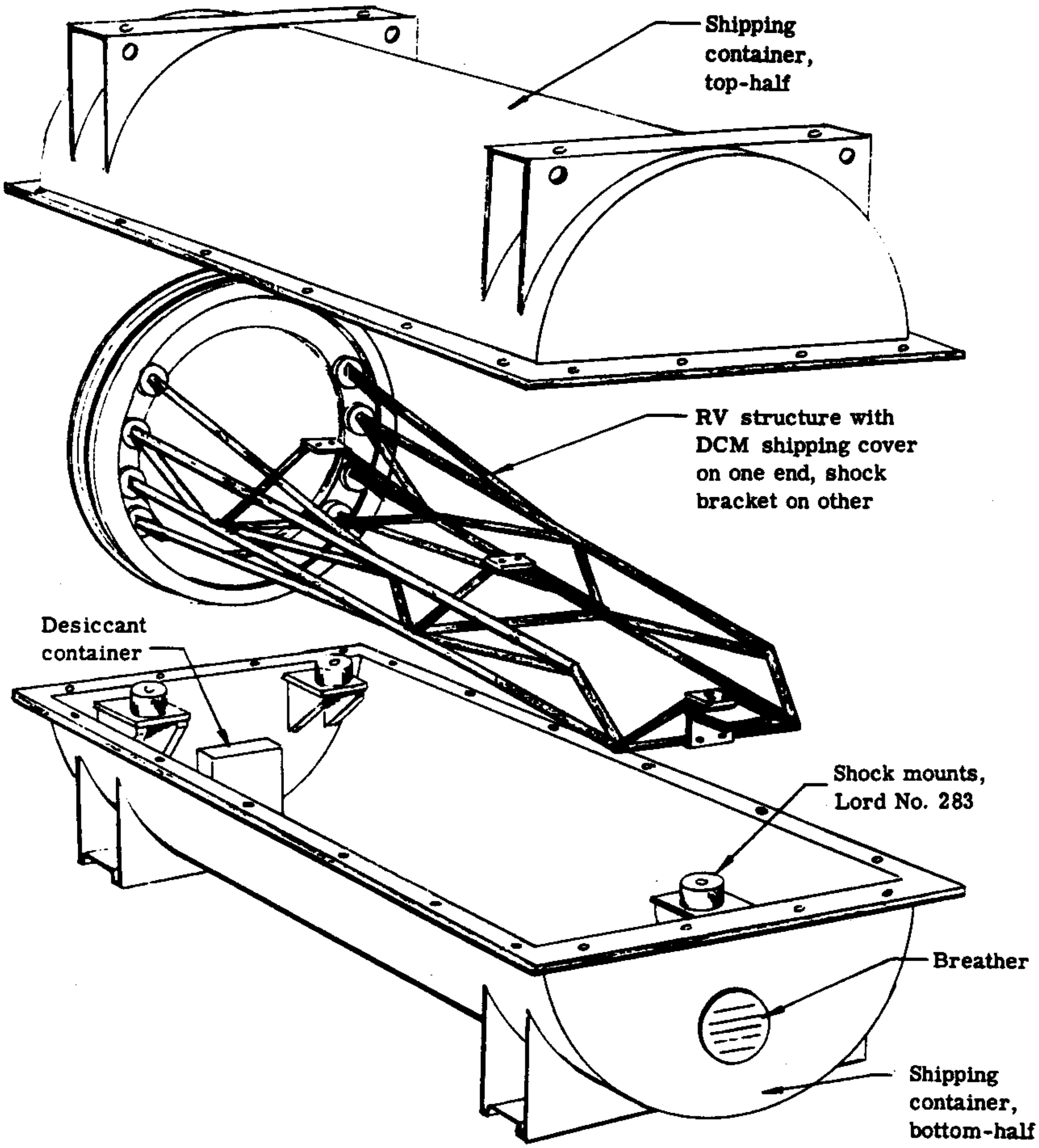


Fig. 5-13 — Recovery Section structure shipping container

The AGE specification effort during Phase II will develop design specifications to delineate functions to be controlled and monitored, by the vehicle-payload interface simulator console. Requirements for payload handling follies, photographic processing, viewing equipment, etc., will also be formally specified.

The recovery section design requirements will be documented as part of the system configuration control. It will be the prime responsibility of configuration control to document and maintain liaison on vehicle and other GFE interfaces, and to main an overall configuration drawing of the DCM. These interface problems include mechanical and electrical mating, control, assembly, and flight line integration, and all must be well defined by the end of Phase II. This configuration control group will also be responsible for developing and maintaining the weight and balance and power profiles for the entire payload system.

5.3.1.5 DCM Mockup

During the latter portions of Phase II and prior to completion of the major drawings, a DCM mockup will be constructed. This will be a full size nonfunctioning model fabricated of wood and metal. It will serve as a reference for the designers, for checking interferences, and as an aid in wiring and harness layouts.

5.4 DESCRIPTION OF PHASES III, IV, AND V

5.4.1 Scope

During Phases III, IV, and V, five payload systems are fabricated, assembled, integrated, qualification tested, acceptance tested, and delivered ready for mating with the Agena and booster. Each of these three phases serve different purposes leading to the eventual delivery of the five flight systems.

In Phase III, one photosensor system consisting of the terrestrial and stellar cameras' supply cassette, two takeup cassettes, and an electrical control system is fabricated, assembled, qualification tested, and refurbished for use in the fourth flight system. From the eleventh through seventeenth month, final design of the recovery section is completed, test tooling fabricated, and formal AGE design and MAB specification completed.

The first complete satellite system will be fabricated, assembled, integrated, and qualification tested in Phase IV. Each of the four major subsystems—photosensor, DCM structure, recovery section, and auxiliary equipment—will be run through acceptance testing prior to integration as a complete system. After qualification testing, this system will be refurbished as the fifth flight system. This phase starts in the 11th month and ends with refurbishment in the 33rd month. In addition, the AGE sets are fabricated during this phase, and the first set is discussed in the 20th month.

Phase V involves the fabrication, assembly, integration, and acceptance testing of five flight systems, starting in the 12th month and ending in the 36th month. MAB construction is completed during this phase in the 25th month just prior to delivery of the first flight system at Vandenburg AFB.

These three phases are functionally separate and are kept so for accounting purposes but in reality, they are run concurrently in an attempt to meet a November 1968 launch date. The schedule has been designed to meet the following milestones in serial order to maintain continuity despite the overlap.

1. Photosensor system qualification complete
2. Payload qualification complete
3. Delivery of five flight systems

A brief description of the functional baseline tests used during Phases III through V are described at this point, since an understanding of them is required before the following sections become meaningful to the reader. The details of these baseline tests are provided in Section 5.5.

The functional baseline tests are used as follows: (1) during assembly to perform debugging; (2) prior to qualification or acceptance testing to verify in-tolerance operation before testing; (3) after qualification and acceptance testing to determine if the hardware has deviated from specifications as a result of such testing; and (4) as a preflight check. There are two types of baseline tests for the GOPSS program; the first is called the Photosensor System Baseline Tests (PSSBT), and the second is called the Integrated System Baseline Tests (ISBT). During Phase III, only the PSSBT are used, since the photosensor is being fabricated and qualified during this phase. Both types of tests are used during Phases IV and V.

5.4.2 Phase III

Phase III consists of the following four primary tasks: (1) production, testing, and qualification of the first photosensor; (2) the final design of the recovery section; (3) the fabrication of tooling associated with Phase III; and (4) the design of AGE and MAB specifications.

5.4.2.1 Production, Testing, and Qualification of the First Photosensor

This task comprises the fabrication, procurement, assembly, and debugging of the terrestrial camera and the stellar cameras. The unit is then given a comprehensive engineering test; following this, a qualification test program is performed, and the qualified photosensor is subsequently refurbished. Since the manufacture of the optical components is in the initial critical path portion of the PERT analysis, a detail description of the optical manufacture is included after the discussion of terrestrial camera production.

5.4.2.1.1 Production

1. Terrestrial Camera

The terrestrial camera assembly comprises four major subassemblies and a number of supplementary components.

Initial effort concerns the production of the lens assembly. This is combined with additional elements to form the lens/film assembly. The lens assembly task is a combined project/optics section effort.

The several lens elements, the reseau grid platen, the lens cell, and various miscellaneous items such as the desiccator assemblies, and aperture plate, are procured and/or fabricated during optical manufacture. The bezel, the flexures, support guide posts, the light cone, etc., which are camera parts, are procured separately.

The lens elements are assembled into two sub-groups (forward and rear) and prior to final assembly, optical tests are required to assure optimum alignment. The two element groups are assembled into the central cell along with the desiccator assemblies and the aperture plate. The reseau grid is etched on the glass platen and measured, and the coordinate locations of the grid intersections are recorded. Glass contact photo-duplicates of the reseau pattern are also made as a permanent record.

After the glass platen has been completed, measured, and photo-copied, the glass and bezel are combined and the guide posts and flexures are added to form the platen/bezel subassembly. This completed lens assembly is given a series of optical tests to assure proper location of all elements and lens performance within specifications. The terrestrial camera shutter assembly is completed independently of the lens assembly.

The IMC drive and servo are assembled and debugged, and then assembled to the lens assembly with the platen pressure mechanism to form the lens/film clamping assembly. This assembly is placed on the distortion bench for final optical testing.

During this test program, the location of the focal plane is established at the correct distance and attitude relative to the lens nodal points for best photo-optical lens performance. Bench tests (both visual and photographic) establish the platen center dimension, and determine the EFL, BFL, resolution capabilities, and inherent distortions. During the test program, adjustments and alignments are made as required for optimum performance. All test data are recorded for future reference.

The film transport assembly consists of about fourteen hardware items including springs, dancers, switches, guide rollers, index roller, index drive, side plates, the shuttle subassembly, etc. In addition, the calibration film sensor, and the film velocity sensor assembly are components of the overall transport assembly. A special holding fixture (produced under the tooling sub-phase) is used in conjunction with the completed supply and takeup cassettes to test and debug the film transport.

After completion of the lens/clamping assembly test program, and test and debugging of the shutter and transport assemblies, the three units are combined with the main support, the covers, and the terrestrial camera cable harness to form the terrestrial camera assembly.

2. Optical Fabrication Procedure

As a part of the Phase I feasibility program, a feasibility lens system (described in Vol. II) is scheduled for completion in February 1967. At the time of this report, fabrication of this system was proceeding well; all elements were fine ground; spherical surfaces were polished; aspheric polishing had started, and special aspheric measuring machinery was available. In addition, lens system test facilities and apparatus are proceeding in pace with the optical element fabrication. It is anticipated that this experience and equipment will be directly applicable to the fabrication program herein described.

a. Glass Procurement and Element Generation

Glass blanks are received from the vendor and subjected to a rigid pre-acceptance inspection program wherein they are checked for bi-refingence strain, bubbles and homogeneity. If the glass meets or exceeds the specifications, it is accepted; if not, it is rejected and arrangements are made with the vendor to replace it with satisfactory material on a high priority basis. In addition to the physical inspection program, the melt data sheets, which contain pertinent lens design data such as index of refraction and dispersion, are analyzed for completeness and satisfactory characteristics.

When both glass and melt data have been found acceptable, the data are forwarded to the Lens Design Department for initiation of a procedure entitled "melt design." This consists of a redesign of the lens based on the actual glass data instead of the catalog (or theoretical) data. Often there is considerable variation between these two types of data, requiring design modifications to the optical system.

Completion of the "melt design" culminates in the production of final lens element drawings which serve to define the actual element configurations from which the elements are generated.

Element generation is a physical process whereby large amounts of glass are removed from the blank in a relatively short time. The generating machines, while rapid in action, do not produce the exact curvatures necessary for precision elements; therefore, the generating procedure is applied to "rough out" the elements to a general approximation of the final configuration, leaving the dimensions somewhat oversize so that the individual elements can be shaped to size by subsequent equipment and operations.

After completion of the generation task, the elements are ground, using grinding equipment and various size grit particles, to a very close approximation of the final configuration. Again this is oversize and is generally within 0.0005-inch sag accuracy as measured with a mechanical spherometer.

When the elements have been ground to an optimum configuration, they are lapped by hand and machine-lapping techniques, and are constantly checked against their test plates until they match the plates within the number of fringes specified by the lens designer's tolerance analysis.

After satisfactory completion of generation, grinding, and lapping, and when all physical inspection criteria have been satisfied, the elements are centered and edged down to their final outside diameters. After this, they are surface coated as indicated by lens design specifications.

b. Large Element Fabrication

Fabrication of the large elements (I, II, IX, X) for the GOPSS lens design will vary slightly from the normal Itek procedure.

Acceptance inspection and "melt design" will be performed on a regular basis and generation will be initiated. The generated configuration will be 0.030 inch greater than final center thickness (C_t), and 0.100 inch greater than the final outside diameter.

When generation is completed to the above specifications, the blanks will be transferred to Itek's optical shop where they will be ground, lapped, and polished to the specified regularity and power, and then edged to final OD. Final sag-to-flat dimensions will be accomplished when these dimensions have been established so that final calculation of the glass sag-to-flats will assure glass-to-metal cell contact; then the elements (with the exception of element II) will be coated with an anti-reflective film. In the case of element II, a spectral transmission filter is applied instead of the anti-reflective material.

c. Small Element Fabrication

Fabrication of the six small elements (III, IV, V, VI, VII, VIII) will vary more from the normal Itek procedure than the fabrication of the large elements. This is because the small elements are combined into two cemented triplets each having an aspheric surface ground into one face.

Acceptance inspection, melt design, and generation procedures will proceed normally with the generated configurations meeting the previously mentioned plus 0.030 inch C_t and plus 0.100 inch OD specifications.

Upon completion of the generating cycle, elements III, IV, VII, and VIII will be ground and polished in the small optics shop to specification power and regularity. This will be followed by edging to the specified OD, but sag-to-flats will be deferred until sufficient cell information is available for precise definition.

The generated elements V and VI will be initially polished to the aspheric "best fit" sphere, and then edged to the final OD. The lens will be aspherized in the small shop and the aspheric configuration will be verified by the aspheric measurement machine.

Upon completion of the aspherizing procedure, the spherical sides will be configured to the final C_t.

When all the configuration fabrication procedures have been completed, the six elements will be transferred to the cementing area. Here elements IV and V will be cemented together to form the front doublet and elements VI and VII cemented into the rear doublet. After this, element III will be cemented to the front doublet and element VIII will be cemented to the rear doublet, resulting in completed front and rear triplets.

d. Reseau Plate Fabrication

The complete fabrication of the reseau plate can be divided into eight different operations as follows:

1. Grinding of the aspheric contour by a vendor in Massachusetts
2. Polishing and figuring of the aspheric by Itek
3. Testing of the final figure by Itek
4. Final polishing and figuring of the flat side by Itek
5. Cutting and shaping of the disc into a rectangle by a vendor in Massachusetts
6. Grid application by a vendor in Philadelphia
7. Grid measurement and calibration at Itek's Washington Data Center.
8. Application of the anti-vignetting filter by Itek

The first three operations approach state-of-the-art tasks. There may be a number of cycles required between operation 2 and 3 before a satisfactory aspheric is obtained. All possible precautions will be taken to ensure that regrinding will not be necessary. Operations 4 to 8 are relatively straightforward, but handling must be kept to a minimum so that the finished aspheric surface is not defaced.

e. Final Assembly of Optical Elements

The production of the two internal aspherics will be the most difficult optical problem in the optical fabrication cycle.

A unique electro-mechanical measuring device (described in Volume 2) will accurately measure aspheric contours. The opticians then will make local corrections on an element which has been ground and polished to the nearest sphere. They will check the contour they have obtained on the measuring machine, reworking and remeasuring until the desired aspheric shape is attained.

The elements which have been edged, contoured, and cemented will then be assembled into the cell (fabricated to very tight concentricity tolerances) using standard Itek shimming techniques.

The final aspheric figuring (tuning) will be done after the lens has been tested and debugged on the resolution test bench. A number of cycles between the test bench and the aspherizing table may be necessary until the required lens performance is attained.

The resolution test bench is an instrument designed specifically for this contract (described in detail in Volume 2). In general, this instrument consists of a bank of 17 collimators located at 5-degree increments. A moving light source illuminates each of the collimators sequentially. The lens is mounted horizontally in a cylindrical drum such that the collimated light is presented at the lens entrance pupil.

A 360-degree rotational capability of the lens drum is provided so that the lens may be rotated about the optical centerline during test. A traveling microscope and a film pack assembly are provided