SAN-1604-2

SOLAR CENTRAL RECEIVER PROTOTYPE HELIOSTAT

Volume II: Phase II Planning (Preliminary)

June 1, 1978

Work Performed Under Contract No. EG-77-C-03-1604

Boeing Engineering and Construction
Seattle, Washington

U.S. Department of Energy

Solar Energy

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VOLUME II

SOLAR CENTRAL RECEIVER PROTOTYPE HELIOSTAT

PHASE II PLANNING

(Preliminary)

1 June, 1978

MASTER

Prepared For
United States
Department of Energy

Under
Contract EG-77-C-03-1604

By

Boeing Engineering and Construction
a Division of The Boeing Company
Seattle, Washington

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This document (Vol II) presents Phase II Planning developed under DOE Contract EG-77-C-03-1604, "Solar Central Receiver Prototype Heliostats". Companion documents include the Final Technical Report (Vol I) and Commercial Plant Cost Estimates (Vol III). The primary objective of this study was to develop a preliminary design of heliostats which is consistent with production quantities and rates projected for future commercial utilization of solar energy. Work under this Phase I contract was initiated on October 1, 1977, and is scheduled for completion on June 30, 1978. Program management was performed by the DOE office in Oakland, California, and technical performance was monitored by Sandia Laboratories in Livermore, California. This report complies with the Contract Reporting Requirements Checklist.

1.0 MANAGEMENT PLAN

1.1 INTRODUCTION

This Management Plan defines the program objectives, the technical approach for accomplishing the objectives, and the management plan for assuring that all objectives of the Solar Central Receiver Prototype Heliostat Phase II Program are achieved within contract costs and schedules.

This plan provides the logical detail breakdown of tasks against which manpower resources, costs, and schedules are identified to provide management control and both contractor and Sandia continuing visibility of program status.

The Program Management and Control will be based on the Integrated Management System (IMS) as adopted for use by Boeing for Sandia/DOE programs. This system, as described in Section 1.4, is fully responsive to Sandia's reporting requirements and will be the source of Boeing and Sandia management visibility.

1.2 PROGRAM OBJECTIVES

1.2.1 Program Description

The Department of Energy has sponsored programs which have evaluated the technical feasibility of Solar Central Receiver concepts for electric power generation. A currently planned DOE program will develop and construct a 10 MW_e Pilot Plant to demonstrate the feasibility and operational characteristics of Solar Central Receiver Power Generation.

The field of heliostats is a major element of the Solar Central Receiver Power Generation system. The reflectors in heliostats redirect sunlight to continuously focus the suns energy on a central receiver (heat exchanger) located within or adjacent to the field of heliostats.

The program described herein is Phase II of a two-phase program. The primary objective of the effort is to establish and verify the manufacturability, performance, durability, and maintenance requirements of the commercial plant heliostat design defined in Phase I. End products of the 16 month Phase II effort include: (1) design, fabrication, and test of heliostats; (2) preliminary designs of manufacturing, assembly, installation, and maintenance processes for quantity production; (3) detailed design of critical tooling or other special equipment for such processes; (4) refined cost estimates for heliostats and maintenance; and (5) an updated commercial plant heliostat preliminary design.

1.2.2 Technical Goals

A summary of technical goals to be accomplished follows:

- Verification of predicted image size for optimally gravity-focused reflectors;
- Verification of 2mr (1σ) beam pointing accuracy;
- Selection of preferred technique for attachment of dome to base;

- Verification of enclosure leak rate predictions;
- Demonstration of satisfactory operation of air supply system;
- Verification of structural design performance including dome deflection, base structure deflection, reflector/pedestal dynamics, piling load capability, and gimbal/actuator load performance;
- Verification of thermal design analyses;
- Verification of predicted overall heliostat reflection efficiency;
- Establishing preliminary maintenance requirements (4 month basis);
- Verification of manufacturability and assembly/installation procedures.

1.2.3 Schedule Objectives

Figure 1.2.3-1 provides the preliminary master program schedule for Phase II.

The major features indicated by this schedule are:

1) Immediate order of required long-lead materials and purchased components for prototype heliostat fabrication.
2) Immediate start on design of tooling for manufacture of prototype heliostats.
3) Detail design review 3 months after receipt of order (ARO).
4) Installation of test heliostat at the Boeing, Kent facility 9 1/2 months ARO to verify compatibility of interfaces and to prove-out installation/maintenance processes and test equipment.

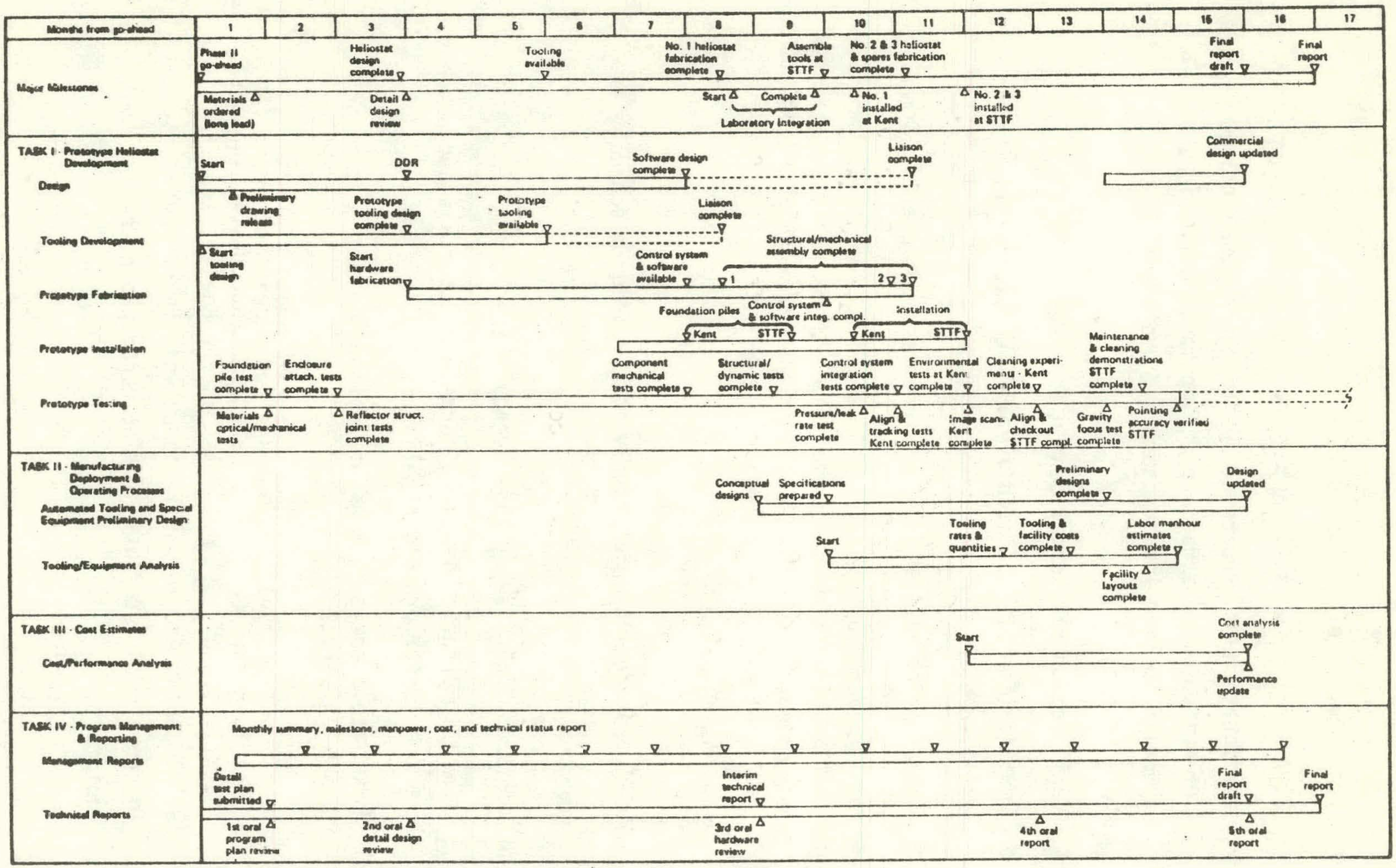

Figure 1.2.3-1. Phase II Master Schedule

5) Installation of demonstration/test heliostats at the STTF 11 months ARO.

6) Sufficient total program time to accomplish the significant critical testing which will then influence the design update of the commercial heliostat and allow update, where necessary, of the tooling and equipment preliminary design.

7) Completion of testing at the STTF 14 months ARO.

8) Oral reviews with Sandia at key points in the program.
   - Program Plan Review one-month after go-ahead.
   - Detail Design Review 3-months after go-ahead.
   - Hardware Review 8-months after go-ahead.
   - Test Results Review 12-months after go-ahead.
   - Final Report Review 15-months after go-ahead.

9) Monthly management reports, an Interim Technical Report 8 months after go-ahead, and a Final Technical Report 15 months after go-ahead.

1.2.4 Cost Objectives

Time-phased allocation of costs into cost accounts will be provided in response to a Sandia Request for Quotation. The key cost objectives will be:

- Maintain continuous visibility over cost status of each cost account.
- Provide flexibility to reallocate funds, if appropriate, to complete critical tasks.
- Maintain reserve fund in management account to support critical tasks if required.
- Provide monthly cost status visibility to Sandia within 20 days following status report period.
- Complete total program within contracted cost estimates.
- Accomplish Phase II objectives with a minimum cost effort.

1.3 TECHNICAL APPROACH

The technical approach to be utilized in accomplishing Phase II objectives will be to fabricate and test a prototype heliostat design which best represents the commercial plant design developed in Phase I. In the first three months, detailed design drawings will be prepared using preliminary design drawings from Phase I as a basis. Design modifications will be required to permit manufacturability in prototype quantities, to incorporate test instrumentation, and to allow installation and test without development of special equipment. Additionally it is recommended that several alternative design options be included in the prototype heliostats to permit full scale evaluation and comparison.

Commercial plant preliminary design options which are under consideration for the above reasons include:

- Fabrication of domes from gores rather than thermoforming.
- Fabrication of domes from two alternative materials; ultraviolet stabilized oriented polyester film, and Kynar (polyvinylidene flouride).
- Fabrication of base shell from fabric reinforced laminate rather than sheet steel.
- Fabrication of one reflector incorporating a variable tension device for adjusting focal length. Membrane tension (focal length) of other reflectors will be pre-set for the STTF target range.
- Fabrication of two alternative dome attachment devices to permit full scale evaluation of competitive designs.
- Fabrication of one reflector with a protective coating on the aluminized surface. Other reflectors will utilize an unprotected aluminized reflective surface.

The first-heliostat fabricated will be installed at the Boeing/Kent Environmental Test Laboratory. This installation, as described in the Phase II test plan, will include assembly/integration tests, optical performance testing, structural testing, and checkout of the control system. Following thorough checkout of the heliostat at Kent, two additional heliostats with differing design features will be installed at the STTF. These heliostats will be evaluated over a 4 month time period for optical/mechanical performance, environmental effects, maintenance requirements, and control system performance.

The expertise of selected subcontractors and consultants will be utilized to support the plastic film development, and the high rate production techniques to achieve low cost. Additionally, preliminary design of the gimbal/actuator assembly may be subcontracted.

Utilizing experience gained in heliostat fabrication and test, design of manufacturing processes and maintenance equipment will be carried to the PD-level, detail designs will be prepared for critical tooling, commercial plant preliminary design will be updated, and commercial plant cost estimates will be refined.

A program logic flow network will be provided in response to a Sandia Request for Quotation.

1.4 PROGRAM MANAGEMENT AND CONTROL

The management control system will ensure that techniques and procedures are available to monitor technical, schedule, and cost performance. Program Management and Control will be based on the Integrated Management System (IMS) as adopted for use by Boeing for various DOE and Sandia programs. This system has received government (tri services) validation and will be the source of Boeing and Sandia visibility.

The IMS provides a fully integrated cost and schedule system and is fully responsive to Sandia's reporting requirements. Detailed data is automatically generated for the following monthly status reports:

- Technical Status Report
- Cost Management Report
- Manpower Management Report
- Monthly Milestone Plan and Management Report
- Contract Management Summary Report

The key to effective management control is to define the program into finite work packages which are scheduled, budgeted and for which definitive personnel responsibilities are assigned. These management tools are defined in the following paragraphs.

1.4.1 Work Breakdown Structure

The Work Breakdown Structure (WBS) is the framework for planning, performance monitoring and reporting. The WBS for this Phase II study is provided in Table 1.4.1-1.

Levels 1 and 2 of the WBS represent the major tasks as defined by the contract Statement of Work. Levels 3 and 4 represent the subsets of these tasks.

TABLE 1.4.1-1

CENTRAL RECEIVER PROTOTYPE HELIOSTAT

PHASE II WORK BREAKDOWN STRUCTURE

WBS LEVEL 1 2 3 4	
0 0 0 0	CENTRAL RECEIVER PROTOTYPE HELIOSTAT
1 0 0 0	TASK I -- PROTOTYPE HELIOSTAT DEVELOPMENT
1 1 0 0	Design
1 2 0 0	Tooling Development
1 3 0 0	Prototype Fabrication
1 4 0 0	Prototype Installation
1 5 0 0	Prototype Testing
2 0 0 0	TASK II - MANUFACTURING, DEPLOYMENT AND OPERATING PROCESSES
2 1 0 0	Preliminary Design
2 2 0 0	Detail Design Critical Tooling/Equipment
3 0 0 0	TASK III - COST ESTIMATES
3 1 0 0	Capital Costs
3 2 0 0	Maintenance Costs
4 0 0 0	TASK IV - PROGRAM MANAGEMENT AND REPORTING
4 1 0 0	Management
4 2 0 0	Technical and Status Reports

1.4.2 Program Schedules

Detailed program schedules will be developed for each major task and related to the master program schedule (Figure 1.2.3-1) upon receipt of an RFQ from Sandia.

1.4.3 Program Cost Accounts

Major elements of the WBS are utilized as Cost Accounts. These accounts are established at WBS levels 2 or 3 for which management personnel accountability is assigned. The cost accounts and responsibilities for this effort are provided in Table 1.4.3-1.

Time phased budgets for each cost account will be established by manloading and material estimates in response to a Sandia Request for Quotation.

1.4.4 Management Structure

The following paragraphs describe the organizational structure and the personnel responsibilities and qualifications which will be applied to this program.

1.4.4.1 Contractor Organizational Elements

Boeing Engineering and Construction will achieve the objectives of the Solar Central Receiver Prototype Heliostat Phase II project through an organization of capable and experienced personnel that are backed by firm corporate commitment. These people have been supporting previous DOE/Sandia heliostat contracts, and therefore are experienced in solar technology and in interfacing with Sandia.

All work in terrestrial solar power is assigned to Boeing Engineering and Construction (BEC), a Division of The Boeing Company. In this role, they have an in-house staff and also have access to a wide range of technological capabilities from all the other divisions of The Boeing Company. Boeing Aerospace Company, co-located with BEC, supplies

TABLE 1.4.3-1 PROGRAM COST ACCOUNTS

WBS	TITLE	RESPONSIBLE MANAGER
1100	Design	
1200	Tooling Development	
1300	Prototype Fabrication	
1400	Prototype Installation	
1500	Prototype Testing	
2000	Manufacturing, Deployment and Operating Processes	
3000	Cost Estimates	
4000	Program Management and Reporting	

manufacturing support. This is particularly advantageous for access to a full spectrum of manufacturing technology skills only as needed, and for minimizing long term project commitments for personnel that are required for only short times.

Figure 1.4.4-1 shows the relationship of BEC to The Boeing Company organization. Figure 1.4.4-2 shows the relationship of the Solar Central Receiver Prototype Heliostat project to other elements of the BEC organization.

With the firm support of H. K. Hebeler, Vice President and General Manager of BEC, Mr. R. B. Gillette has been assigned to head the Solar Central Receiver Prototype Heliostat Phase II project team and has complete authority to draw upon the necessary company resources to ensure all problems and deficiencies are resolved in a timely and cost effective manner.

With this authority as project manager, Mr. Gillette will be able to obtain personnel with specialized skills as the need arises, secure additional facilities and equipment, and in general, assure the success of the heliostat project. Mr. Gillette has coordinated with Boeing Aerospace and has received commitments for assignment of discrete skills and/or particular personnel for specified periods of time for identified contracted activities.

With these arrangements, Mr. Gillette can obtain the manpower and facilities to correct technical and/or schedule deficiencies as they are identified and, conversely, can readily transfer personnel back to their functional organizations as work is completed.

The detailed project organization chart will be provided in response to RFQ from Sandia.

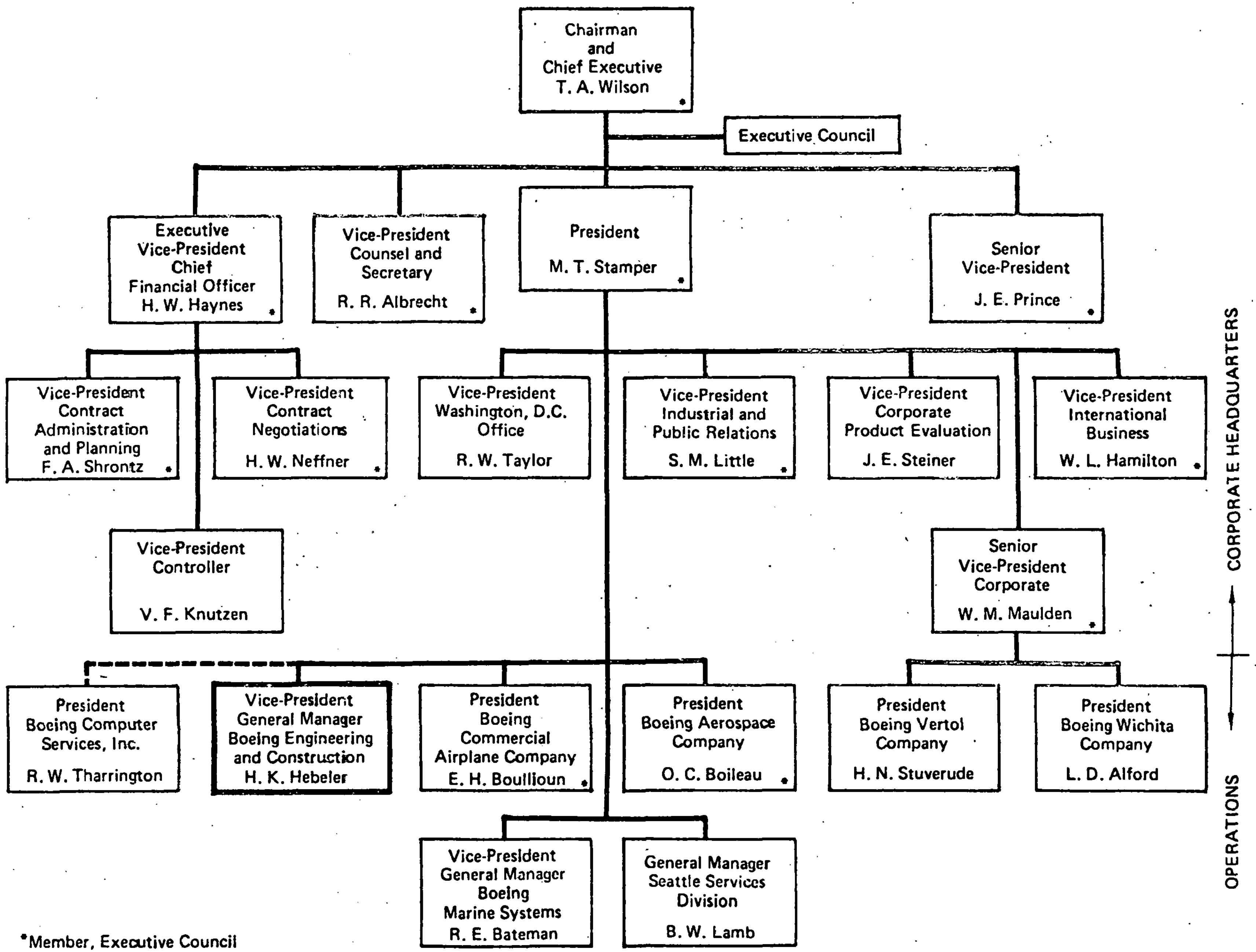

Figure 1.4.4-1. The Boeing Company Organization

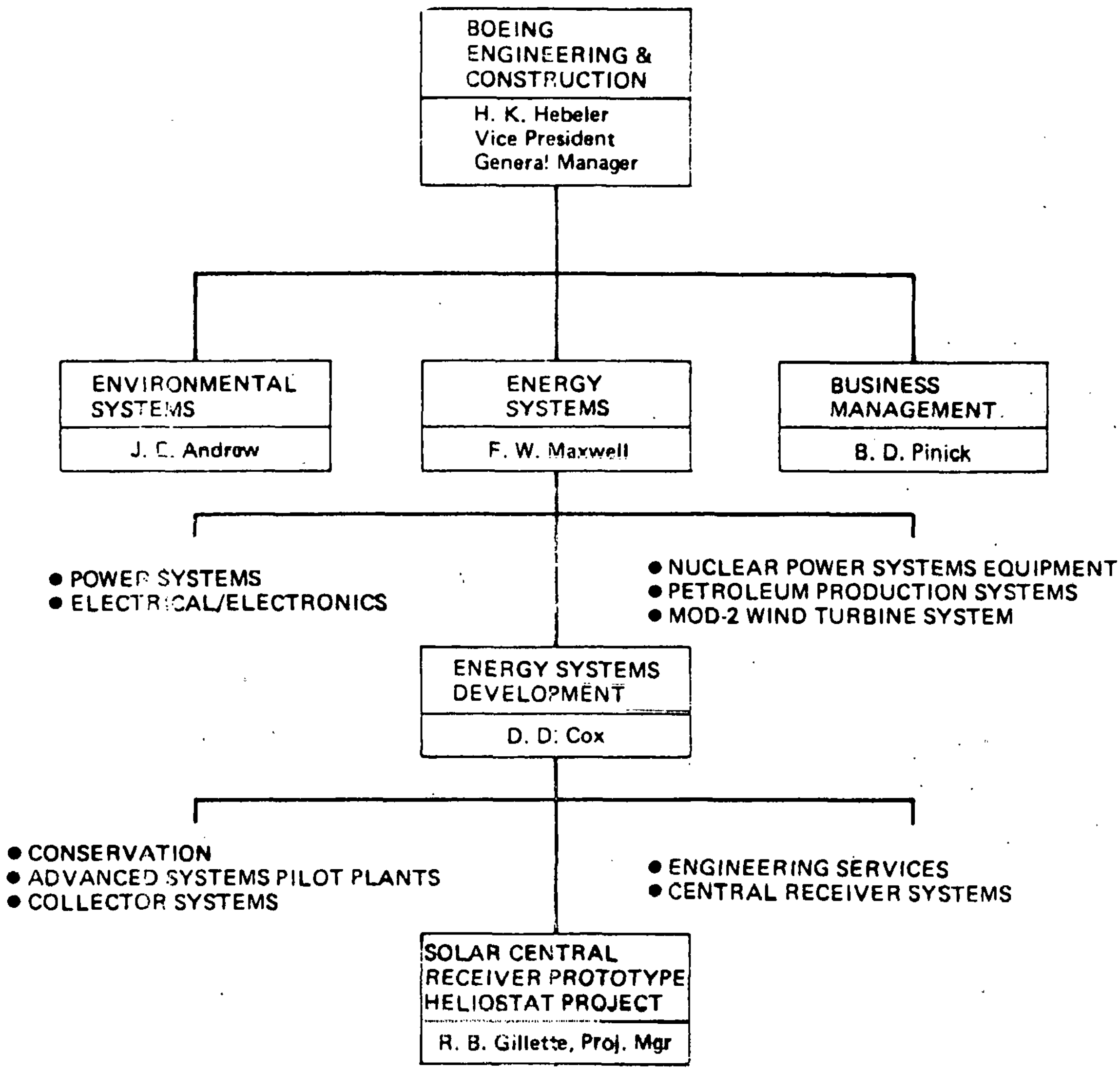

Figure 1.4.4-2. Boeing Engineering & Construction Organization

In carrying out these basic responsibilities the project manager will:

1) Coordinate project activities with the Sandia contracting officer and technical manager as appropriate.

2) Provide management visibility to Sandia and to BEC management.

3) Provide technical and administrative direction for the conduct of all project tasks and activities.

4) Allocate and control all budgets, including those for support elements.

5) Approve and monitor all project schedules.

6) Approve all formal reports and documentation.

7) Organize and chair informal reviews, support the Sandia Program Manager in the organization and conduct of formal reviews, and initiate corrective action as required.

8) Ensure that there is timely communication between The Boeing Company and Sandia.

The project organization has been specifically designed to meet the project requirements and to satisfy the following objectives:

- A core of project-dedicated personnel who are co-located and directly responsible to the project manager for cost, schedule and technical performance of specifically assigned work breakdown structure packages.
- Appropriate part-time utilization of functional specialists.
- Compatibility of the Prototype Heliostat Phase II project with other DOE/Sandia Central Receiver Solar Thermal Power System programs.

1.4.4.2 Personnel Responsibilities and Qualifications

The names, positions and a description of the related experience of key personnel who will be responsible for performance of Phase II task activities will be provided in response to an RFQ from Sandia.

1.4.4.3 Subcontractor Elements

Consistent with Phase I activity, it is currently planned to involve pertinent commercial industry to the maximum extent possible in Phase II. This will be done by cooperative development effort and subcontracts. At the present time subcontracts are planned for the following heliostat components:

- Domes;
- Reflector membrane coating and assembly.
  (Not including attachment to tubular support structure);
- Steel pipe support structure;
- Base shell;
- Concrete piling foundations;
- Gimbal/actuator assembly

Upon receipt of a Request for Quotation from Sandia, definite subcontracting plans and costs will be developed.

1.4.5 Integrated Management System

The Integrated Management System (IMS) is a methodology established for Boeing programs which assures continuing management visibility and capability to effectively control resources to accomplish program objectives within schedule and cost. The IMS has been tailored to encompass all activities of Phase II.

The IMS provides the discipline to accomplish the following:

- Implement a system of project reviews
- Define tasks and responsibilities involved in the performance of the project
- Estimate, schedule and budget work packages
- Authorize work
- Monitor project status for schedule and cost performance and their interrelationship
- Provide visibility regarding cost, schedule and technical performance
- Problem analysis
- Reporting

A schematic of the IMS and its interface with the program is shown in Figure 1.4.5-1. This schematic shows the closed loop interface between the Boeing Project Manager and the Sandia Project office which assures continuing status visibility and direction. The upper management of BEC also has the visibility through status reports and periodic reviews to provide guidance and commit resources where required.

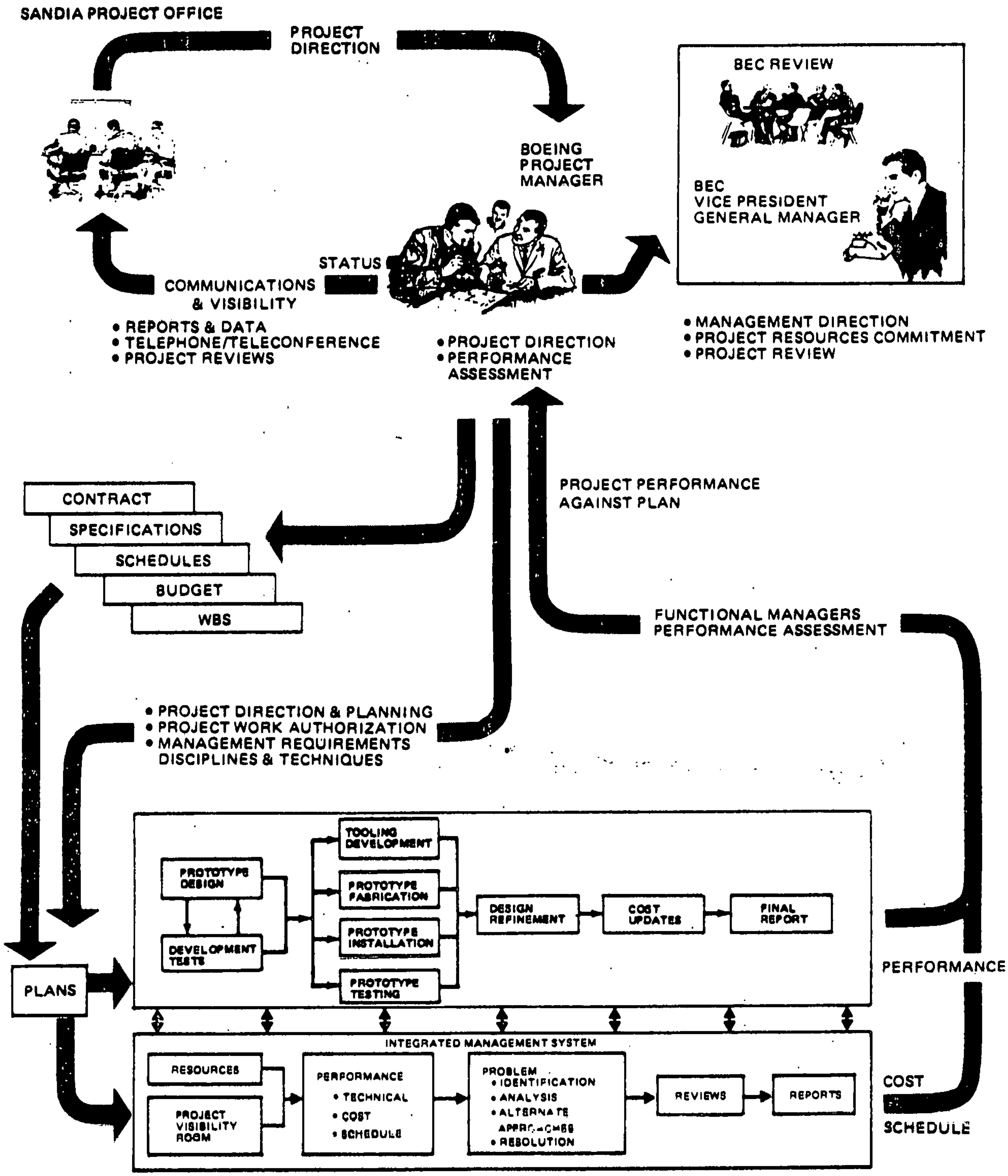

Figure 1.4.5-1. Integrated Management System

The contract instrument defines the overall statement of work, the system specifications, and the total program schedule and budget constraints. The statement of work is then defined to detail elements of work - the WBS. The WBS for Phase II is provided in Section 1.4.1. Each item of the WBS is then scheduled and budgeted as provided in Sections 1.4.2 and 1.4.3.

The complete hierachy of schedules and budgets ensures logical schedule baseline continuity from the top level program requirements to WBS elements and the detail schedule and cost account/work package level. Each successive lower level of tier schedules reflects and is restrained by pertinent higher level tier schedule milestones and forms the basis of summation for contract schedule control and status visibility. Schedules may be revised, as required, to reflect any new commitments without losing the visibility of the original contract schedule milestones.

1.4.5.1 IMS Work Authorization and Accountability

Work to be performed will be authorized through the formal BEC work authorization system. Authorization begins with the receipt of contract or a formal change notice by the BEC contracting organization. This authorization is formally documented in the Work Authorization Document which includes: (1) The contract receipt at go-ahead; (2) The contract SOW; (3) The contract WBS; (4) Contractural schedules, and (5) The list of deliverable items.

SOW task packages are assigned work order numbers at appropriate WBS levels and become the basis for cost accounting. Work Authorizations (EWA) "A" sheets are budgeted and assigned by the Project Manager to each investigator responsible for a given task. If the work needs to be further divided or some sub-tasks performed by other organizations, the investigator writes EWA "B" sheets for these elements of his cost account, providing budget accountability for these subtasks. EWA "B" sheets include time-phased budgets, schedules and definition of measurable events. These schedules provide input information for the event logic network that ensures compatability of all scheduled tasks. Figure 1.4.5.1-1 illustrates the IMS Work Authorization System.

Boeing has established a policy which permits obtaining products or services by one division from another, through inter-divisional transfers where required skills and services are available. For Phase II this includes any testing, computing and manufacturing support.

These inter-divisional work transactions are formally agreed upon between the prime and support division through an Interdivisional Work Authorization (IDWA), which identifies the requirements, responsibilities, commitments, cost schedules and technical performance targets. The prime division exercises surveillance of the support organization identical to that which is performed over outside suppliers.

A valuable cost control tool is the Management Estimate at Completion (MEAC). Periodically the project manager will formally estimate the costs required to accomplish the tasks remaining to complete the contract. These estimates and their variations from the residual budget are examined at various levels, and summed to the total contract value. Such reviews can be the basis for budget redistribution within the program to reflect improved understanding of more credible planning. Such redistribution, if effected, is done with customer knowledge and concurrence and visibility of initial baseline is maintained. This accounting system therefore provides data for all monthly management status reports.

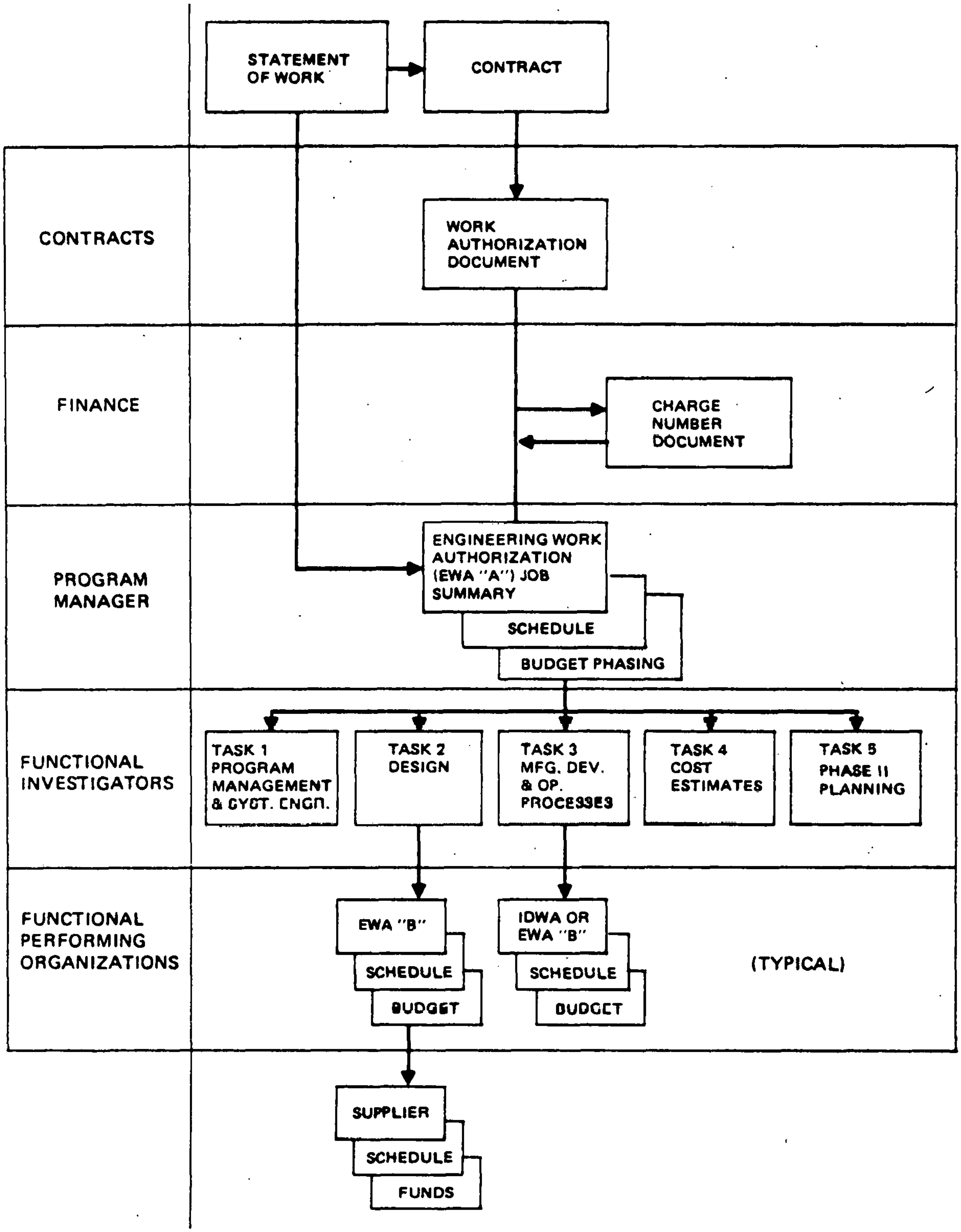

Figure 1.4.5.1-1. IMS Work Authorization

1.4.6 Reporting

Reporting consists of monthly Management Status reports, periodic oral reviews with Sandia and documented Technical Reports per the contractural requirements.

1.4.6.1 Monthly Management Status Reports

Fifteen monthly reports will be submitted to Sandia. These reports include:

- Technical Status Reports - This report highlights the activities during the reporting period.
- Cost Management Report - DOE Form 533M
- Manpower Management Report - DOE Form 534M
- Monthly Milestone Plan and Management Report - DOE Form 535
- Contract Management Summary Report - DOE Form 536

The initial issue of these forms, together with the Cost Plan (DOE Form 533P) and the Manpower Plan (DOE Form 534P) will be provided in response to a Sandia RFQ, and will be updated on the 20th day of each month following the monthly reporting period.

1.4.6.2 Oral Reviews

Five oral reviews with Sandia are scheduled to coincide with key schedule milestones of the program. Agenda's for these reviews will be provided to Sandia for approval three weeks prior to the scheduled review. These reviews will allow Sandia visibility of technical progress, accomplishments or problems and provide the interchange for further project direction by Sandia.

1.4.6.3 Technical Reports

The following reports are contractually required:

- Interim Technical Progress Report (Draft)

  This report is submitted 8 months after contract award. The report communicates the results of the R & D study activity to date. It is required to support the Technology Transfer and dissemination program of Sandia/DOE.

- Final Technical Report (Preliminary)

  This report is submitted 15 months after contract award for Sandia review and concurrence or comments. Comments are required within 10 days to allow revisions if necessary.

- Final Technical Report (Release)

  BEC will incorporate Sandia comments as required and release this final report 16 months after contract award.

2.0 PRELIMINARY TEST PLAN

This section describes the individual tests planned in support of the Phase II program. The purposes of the test program are to provide data for detail design early in the program, verify component performance later on, and demonstrate heliostat performance near the end of Phase II.

2.1 Materials Tests

Acceptance tests will be performed on the enclosure and reflector materials as they are received from suppliers. Included will be optical (specular transmittance and specular reflectance) and mechanical (yield, ultimate, elongation and thickness) measurements of the materials at various positions along the delivered roll stock.

2.2 Foundation Pile Test

Tensile and compression tests on a single foundation pile will be performed early in the program. Test data will be used to support design analysis. Tensile loading will be performed using a crane with a load cell in series. Dead weights will be used for compression loading. As load is applied deflection will be monitored.

2.3 Enclosure/Basewall Attachment Test

Prior to final design completion a section of the enclosure to basewall attachment will be fabricated with representative materials and several configurations. This attachment will be subjected to tensile loading, leakage measurement and general handling evaluation.

2.4 Reflector Structural Joint Test

Prior to final design completion, full scale tests on reflector structural joints will be performed. Included will be tensile and torsional testing of the electromagnetic swaged joints used at rim-to-spoke and spoke-to-hub connections.

2.5 Gimbal Mechanical Test

Tests will be conducted to evaluate gear lash, the orthogonality of the elevation and azimuth axes, and the thermal performance and survivability of the gimbal assembly. The gear lash and axis orthogonality tests will be used in assessing mechanical contribution to system pointing error.

2.6 Reflector Structural Dynamic Test

The natural frequency, simple mode shapes, and dynamic response from drive motor inputs will be measured on the reflector assembly which includes the reflector, pedestal and gimbal drive assembly. The reflector and pedestal will be instrumented with accelerometers. This test will be performed with the reflector installed inside the protective enclosure.

2.7 Heliostat Integration

All assemblies of the prototype heliostat will be assembled indoors in a large high bay. The build-up will be accomplished in a stepwise fashion for fit and clearance verifications. Handling, assembly and disassembly operations will be formulated and demonstrated. Functional operation of the drive and control and air supply system will be performed After satisfactory functional performance demonstration the heliostat will be relocated outside in a field at the Kent site for further testing

2.8 Pressure and Leak Rate Test

The enclosure will be pressurized to design pressure and inspected for conformity to design configuration. A flow meter will be installed on the blower/filter inlet to measure flow and determine heliostat leakage.

Next, the enclosure pressure will gradually be increased until stresses in the dome film have reached the maximum design condition (TBD). The intent of this test is to verify survival under combined pressurization and maximum wind loading.

2.9 Control System Testing

Control system software will be developed during the first seven months of the contract. Hardware will also be fabricated by the 7th month. Bench testing of the control system will follow. This involves end-to-end verification using the developed software, computer, heliostat controller and a gimbal assembly. All modes of operation (not requiring sun) will be exercised and verified prior to installation in the Kent Test Site heliostat.

2.10 Alignment and Tracking Tests

The Kent site heliostat will be aligned by laser geodolite. All drive and control system manual and automatic control modes will be demonstrated.

The STTF heliostats alignment will be coordinated with STTF personnel and equipment. All control modes will be demonstrated. One of the two heliostats will be dedicated to an extended period of continuous tracking. Image scans would be taken throughout the full day, for several days periodically spaced over a two month period.

2.11 Optical Performance Tests at Kent Site

An optical scanner, consisting of a radiometer capable of translation in two axes in the vertical plane will be used to map the reflected image. This scanner will be located on the top or side of a high building near the heliostat. The iso-solar map provided by the scanner will be used to evaluate non-uniformities and gravity focusing effects. The variable tension reflector will be installed in the Kent heliostat and the effect of membrane tension on focal length will be evaluated.

2.12 Environmental Tests

Environmental effects will be monitored and recorded periodically. Included will be:

1) Enclosure and base ring deflection due to wind loading.
2) Critical component temperatures.
3) Inside and outside relative humidity and temperature.
4) Internal and external dust accumulation material samples will be periodically removed for laboratory evaluation of reflectance and transmissivity.

5.13 Maintenance Requirements and Cleaning Tests

Methods for washing the dome will be tested. A small array of spray nozzles will be fabricated and used to further define washing techniques, procedures and cleaning water requirements for a full scale washing facility. Maintenance experience will be documented for future use in development of procedures.

3.0 RECOMMENDED RESEARCH AND DEVELOPMENT

Research and development activities which should be pursued to complement the Phase II mainstream effort are summarized as follows:

- Thermoforming of Protective Enclosures (Domes)

  Small scale thermoforming of domes from polyester film has been demonstrated. Studies have shown that thermoforming is compatible with high rate production processes and will be very cost effective for large commercial quantity production. The technique and process controls need to be developed for full-scale domes thermoformed from polyester or other low-cost, high transmittance materials. The preferred initial material form needs to be selected, and the resulting mechanical and optical properties need to be proven. This development is expected to be carried out under a related Sandia contract.

- Plastic Film Selection

  Development and testing of candidate enclosure and reflector plastic films must continue to evaluate and select the optimum materials, verify design parameters and predict lifetime. The plastic industry is cooperating in this development effort as a result of intensive liaison initiated during Phase I. For the enclosure, a low-cost, high-strength, high-transmissivity, long-life film must be selected which is compatible with thermoforming processess. For the reflector, a low-cost, ultraviolet-stabilized, long-life coated metalized reflector membrane must be selected. Proof of material capabilities requires accelerated and long term environmental exposure tests.

- Spherical Segment Base Shell

  The current concept of stretch forming the base shell from steel sheet is feasible and appears to be cost-effective for commercial quantity production. An alternate concept of forming the base shell from an impregnated fabric sandwich material has certain advantages that should be evaluated. First, the flexible fabric concept provides no transportation restrictions and can be manufactured off-site. The material would be similar to that used in air-inflated structures. Use of a fabric base shell could eliminate some initial investment in tooling and facility costs. Second, the fabric dish could be of lighter weight than the steel dish, thus, reducing shipping costs. Additionally, it is believed that the fabric shell will be cost effective for low quantity production such as a demonstration plant quantity.

- Contamination Evaluation

  Quantitative dirt/dust accumulation data is needed for heliostats located in a representative desert environment. These studies should quantify contaminants in the environment, assess their interaction with heliostat components, and determine required cleaning frequency over an annual cycle. This study is required to establish air-supply filter requirements, and to provide supportive data for selection of suitable cleaning processes.

- Dome Cleaning Process Development

  Requirements for dome cleaning to maintain high specular transmittance could become a significant increment of life cycle cost. Dome cleaning could also have an environmental impact if significant amounts of water are required. Accordingly, the objective of this effort would be to develop a design of cleaning apparatus which maintains the highest annual-average specular transmittance for minimum life-cycle cost and water consumption. Recovery and reuse of water would be considered in design studies. Design supportive tests should be run to verify cleaning performance and assess environmental effects.

  This effort would be complimentary to the Contamination Evaluation task.

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