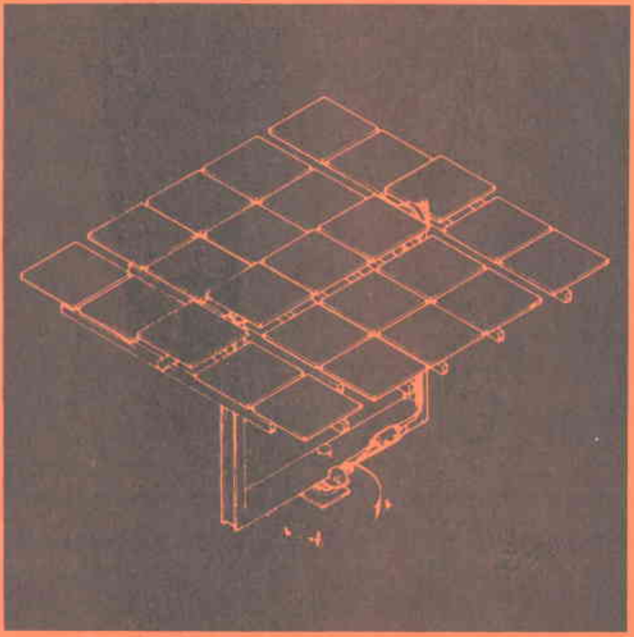
P75-48341-2

Volume II

Program Plans

December 1975

Heliostat Array and Control System for 5-MW Solar Thermal Test Facility



MARTIN MARIETTA

Volume II

Program Plans

Heliostat Array and Control System for 5-MW Solar Thermal Test Facility

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P75-48341-2

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HELIOSTAT ARRAY AND CONTROL SYSTEM FOR 5-MW SOLAR THERMAL TEST FACILITY

MARTIN MARIETTA CORPORATION
DENVER DIVISION
Denver, Colorado 80201

FOREWORD

Submitted in response to Sandia Laboratories, Albuquerque, New Mexico request for quotation (RFQ) 03-3731, this document outlines Martin Marietta's plan for design, test, manufacture, installation, focusing, alignment, and calibration of a Heliostat Array and Control System for ERDA's 5-Megawatt Solar Thermal Test Facility.

Our proposal is submitted in four volumes:

Volume I - Technical Proposal;

Volume II - Program Plans;

Volume III - Cost Proposal;

Volume IV - Addenda for P75-48341.

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I. Introduction

I. INTRODUCTION

This volume discusses in detail the plans that will be followed in conduct of the proposed program. These methods have been successfully used in many industry, NASA, DOD, NSF, and ERDA programs over the years in which they have been evolved, refined, and validated by Martin Marietta. Since founded in 1956, the Denver Division has performed within 3% of target costs on over 2300 contracts totaling in excess of 4.5 billion dollars. This record of cost management was established while maintaining schedule performance. Over the past eight years we have achieved a 99.9% record of on-time software and hardware deliveries. This background lends credence to the effectiveness and validity of our program management plans.

Successfully completed related programs include Solar Power System and Component Research Program, NSF AER 75-07570, and Preliminary Insolation Investigation and Solar Feasibility Study for St. Croix U.S. Virgin Islands, VIWAPA P07700. The same techniques are used in such current related programs as the Central Receiver Solar Thermal Power System (CRSTPS) Phase 1, ERDA Contract E(04-3)-110, 1-MWt Bench Model Cavity Receiver Steam Generator, ERDA E(04-3)-1068, and recently awarded contracts to NASA-Lewis Research Center for definition of photovoltaic residential prototype systems, and a collector system for the Parker Junior High School in the Douglas County School District, Colorado. The plans used in these contracts will be modified to the extent necessary to meet the specific requirements of the HAACS program.

Chapter II discusses the personnel who will conduct the program, how the program will be organized, the facilities that will be used, and the related Martin Marietta experience that will substantially contribute to performance of the program to the satisfaction of the Sandia Laboratories.

Chapter III discusses the program control plan we will follow, giving the program schedule and describing the management tools we will use for procurement/subcontract and configuration and data management.

Chapters IV, V, and VI detail the quality assurance, installation and checkout, and safety plans for the proposed program.

II. Organization, Facilities, and Experience

II. ORGANIZATION, FACILITIES, AND RELATED EXPERIENCE

This chapter presents Martin Marietta's management qualifications and methods proposed to effectively perform the heliostat array and control system (HAACS) program. Our management plan is completely responsive to the RFQ and no exceptions are taken.

Lines of communication with Sandia will be short and direct. The Martin Marietta program manager will be the principal point of contact with Sandia for all matters pertaining to this program. The program manager will be the technical focal point of design, fabrication, and test, and will maintain technical liaison with Sandia. Direct technical communication channels will be established between our cognizant engineers and Sandia cognizant engineers. Contractual direction from Sandia will be issued to the HAACS team by our contracts representative.

The controls that will be imposed on the HAACS work by our corporation and our program organization will assure that cost, schedule, and performance requirements will be met.

Our background relative to the HAACS program is extensive. Our current manpower resources provide the highest quality engineering and manufacturing and administrative skills. Our monetary resources are excellent and our facilities can be used in the program without modification. In summary, we can provide all the resources necessary to accomplish the HAACS program.

A. ORGANIZATION

The relationship of our solar energy activities to our Denver Division organizational structure is illustrated in Figure II-1. We have placed the heliostat array and control system program high in the division's structure to give top-level management visibility and to emphasize the importance with which solar energy technology is viewed by Martin Marietta. Mr. Laurence J. Adams, Vice President and General Manager of the Denver Division, has pledged to supply all corporate resources necessary to support the program. Dr. George W. Morgenthaler, Vice President of Technical Operations, and his director of product development, Lester J. Lippy, have committed management and technical personnel directly to the program and have delegated authority to manage and control the program to Mr. M. Marx Hintze. All technical work on HAACS will be reviewed and approved by Mr. Floyd A. Blake, Program Director of our Solar Energy Research Projects. To best employ our proven resources, we have selected the Bechtel Corporation to provide the heliostat foundation design and to provide the design for the power and control wiring. The HAACS personnel will be located with existing solar energy research projects personnel.

The organization of our program team and the key team members are shown in Figure II-2. Team members have been selected for their particular expertise and experience in the required technical disciplines as evidenced by the resumes presented in

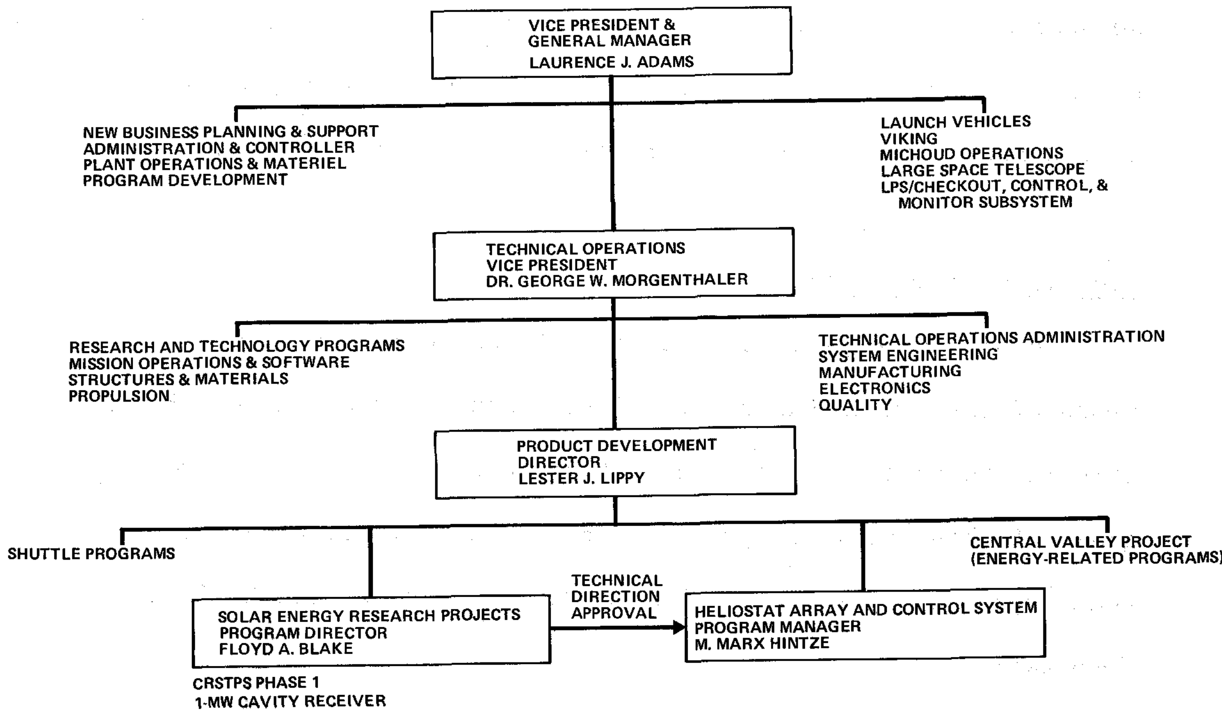


Figure II-1 Denver Division Organization

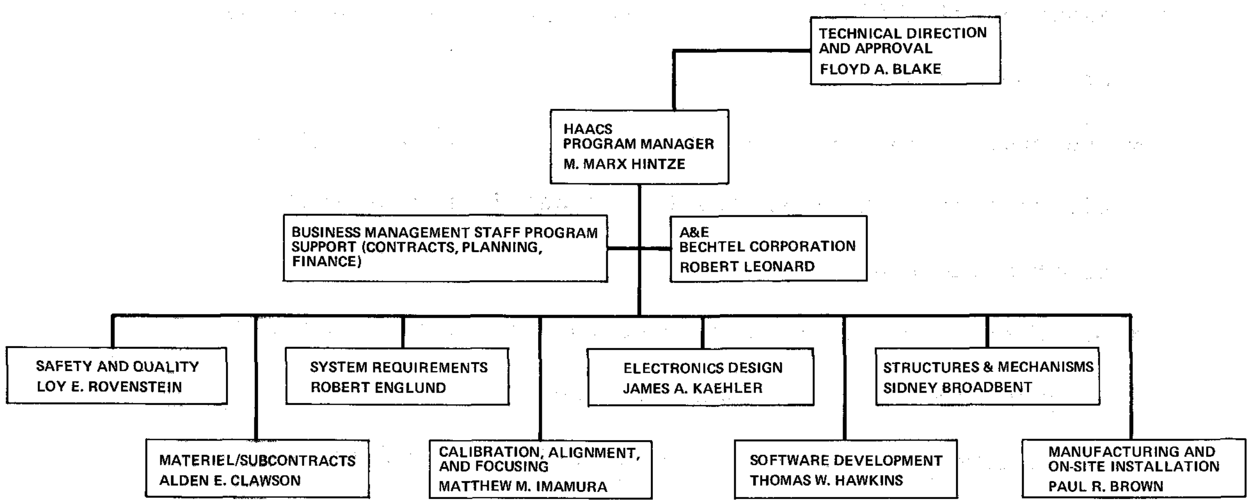


Figure II-2 Heliostat Array and Control System Program Organization subsection 2. The personnel responsible for performance of the business management and administrative functions have been selected for their background and experience in programs similar to this program.

1. Organization Rationale

The program organization is structured to meet the requirements of the Sandia Laboratories' statement of work in the RFQ. This is the same kind of organization we normally use for programs of this type. It provides an autonomous, quick-reacting team supported by the complete resources of the Martin Marietta Corporation.

The key features of our program organization are:

- M. Marx Hintze reports directly to executive management, assuring visibility of any program problems and priority for program needs.
- The program manager has the commitment authority to direct all program activities and is personally accountable for program success.
- Mr. Hintze has personally selected the program team and their program commitment has been secured.
- We believe that we have significantly enhanced the design maturity for accomplishment of the HAACS program by selecting Bechtel to provide the heliostat foundation design and to provide the heliostat foundation design and to provide the design for the power and control wiring. In addition to being recognized as a leader in architectural engineering, they have

performed studies for Sandia of a point focus solar thermal power concept and are currently engaged with Martin Marietta in the design of a 10-MWe solar thermal power system. Bechtel's project manager will maintain a close technical interface with our program manager as shown in Figure II-2.

The program organization will be responsible for management and control of all phases of the program from inception to completion, including contract negotiations, establishment of program requirements and criteria, identification and authorization of work to be performed, establishment of direct budget and schedule requirements, monitoring and reporting to Sandia and division management on program status and performance, and maintenance of liaison with Sandia on all program matters.

In our proven program team concept, functionally oriented central organization groups maintain personnel to man our programs, provide overall management across all programs, ensure technical and management continuity, and audit performance in support of our program managers. Any specialized support necessary to achieve particular program objectives is provided.

2. Personnel Qualifications

This subsection presents key and supporting personnel for Martin Marietta. They possess a solid accumulation of practical hardware and software experience with an extensive system design and analysis background directly applicable to the heliostat array and control system.

LESTER J. LIPPY. Director, Product Development

EDUCATION: Baltimore Polytechnical Institute, University of Maryland, McCoy College at John Hopkins University, Maryland Institute and Graduate Business School at Stanford University

EXPERIENCE: Technical 35 years, Martin Marietta 35 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Site Director at the Titan I and II ICBM activation remote bases. Responsible for the total installation and integration. Prior to this, Chief Project Engineer on the Titan ICBM in Denver. Honored by the Air Force System Command for outstanding management on these assignments and awarded the Commander's Award twice by the Ballistics System Division.
- Director of Quality, System Test and Support, Logistic Support, Fabrication Departments as well as manager of Factory and Ground Based Systems.
- Deputy Director of the Mission Operations and Assurance Department for Viking Lander Project.

FLOYD A. BLAKE. Principal Investigator and Project Director

EDUCATION: BSME, University of Denver, 1949

EXPERIENCE: Technical 26 years, Martin Marietta 5 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Program manager, manage and direct all aspects of CRSTPS, Phase 1 contract. Provide primary interface with ERDA Technical Manager and previously managed the solar power system and component research contractual program.
- Responsible for power system and component performance computer models, including flight performance modeling of the Orbital Workshop solar array and Viking battery.
- Coinvestigator of in-house R&D programs covering high-intensity solar array performance testing and modeling and solar cell performance.
- Consultant to JPL Photovoltaic Groups on computer modeling of solar cell data, correlation analyses of Mariner VI and VII flight data with computer model, evaluation of Mariner '71 susceptibility to "hot spot" failure mode. (G.E.)
- Development engineer of in-house research that discovered "hot spot" failure mode of solar arrays. (G.E.)
- Program manager of two programs that developed array fabrication practices for CdS solar cells sponsored by Lewis Research Center. (G.E.)
- Supervisory engineer of JPL Table Mountain solar test facility during 1963 to 1965 solar thermionic development testing. (G.E.)

- Supervisory engineer of General Electric solar test facility in Phoenix during 1961 to 1963 solar thermionic development testing.
- Applied mechanics group leader responsible for technology supporting design practices in gearing, bearings, and hydraulics for constant-speed drives (CSDs) and gearboxes. (Sundstrand)

PATENTS: Spark Ignition Combusion of Lean Mixtures Required for Diesel Compression Ratios, U.S. Patent No. 2,723,653.

PROFESSIONAL AFFILIATIONS: Member, International Solar Energy Society.

M. MARX HINTZE. Program Manager

EDUCATION: BS, Electrical Engineering, University of Idaho, 1960; Postgraduate engineering and management courses UCLA and University of Colorado, 1961 to present

EXPERIENCE: Technical 15 years, Martin Marietta 10 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Project Engineer responsible for the design of the Guidance and Control Computer I/O for MJS'77 Hybic and the NASA Viking Lander valve drive amplifier (digital input and power amplifier output for motor control).
- Senior Group Engineer charged with supervision of Control Sensors and Electronic Circuit Design Unit with 40 engineers.

- Group Engineer with lead responsibility for NASA Skylab earth resources experiment package electronics. This involved the design of the electronics required to servo-control a slewing mirror, perform analog-to-digital conversion of mirror angular displacement and blackbody reference circuitry.

PATENTS: No. 3,706,044, December 12, 1974, Analog Majority Circuit

PROFESSIONAL AFFILIATIONS: Registered Professional Engineer, State of Colorado PE 12799; Member of IEEE

LOY E. ROVENSTINE. Quality and Safety

EDUCATION: Mathematics, Physics, University of Denver, 1957

EXPERIENCE: Technical 18 years, Martin Marietta 18 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Supervisory responsibilities for planning, controlling, organizing, directing and staffing quality and safety activities on Titan programs in the fabrication and test areas.
- Defined quality and safety requirements, developed quality and safety plans and directed quality assurance and safety activities on numerous Denver Division research and development programs, including Skylab, Viking and Mariner Jupiter-Saturn '77 components.

- Part time instructor in quality assurance at Metropolitan State College, Denver, Colorado.

PROFESSIONAL AFFILIATIONS: Member of American Society for Quality Control

ROBERT A. ENGLUND. System Requirements

EDUCATION: BS, Engineering Physics, Montana State University, 1950; Graduate Business Courses at Arizona State University and University of Colorado.

EXPERIENCE: Technical 25 years, Martin Marietta 10 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Project Engineer responsible for the selection and integration study of experiment support subsystems (power, data, communications, thermal, structure) for pre-Shuttle Space Station. Charged with the Titan III ground checkout equipment installation and checkout as well as vehicle tests. Responsible for design of Titan II system ground checkout equipment at the activation sites.
- Consultant engineer to Messerschmitt, Belkow and Blohm, Munich, Germany for the European Space Program Cos 'B' System Design.
- Electrical system designer responsible for the Viking Lander electrical system test, checkout and launch and the integration and test of overall system design, including power, data, control, communications, optical, thermal and structural subsystems.

JAMES A. KAEHLER. Electronics Design

EDUCATION: BS, Electrical Engineering, Ohio University, 1963 and MS, Electrical Engineering, University of Colorado, 1969.

EXPERIENCE: Technical 12 years, Martin Marietta 10 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Lead Circuit Designer for the guidance and control computer I/O for MJS'77 Hybic, the control electronics for a dual-spin-stabilized spacecraft involving a hybrid system of digital computation and analog output circuits, and the evaluation of circuit designs for the MOS-LSI proposals for the Viking guidance and control computer.
- Cognizant engineer responsible for the Viking Surface Sampler Control assembly and the camera duster control assembly. These packages receive data from the guidance computer and perform various control functions such as linear actuator and solenoid/torque motor control. Also responsible for budget, schedules, and supervision of fabrication and test of these packages.
- Designed the core memory sequencer for the Voyager/Viking program and developed specialized analog control and switching circuits for Titan computers.

PATENTS: Disclosure for a method for significantly reducing the number and size of components in an analog computer.

SIDNEY BROADBENT. Structures and Mechanisms

EDUCATION: Chartered Engineer, Institute of Mechanical Engineers, United Kingdom, 1949, Registered Professional Engineer in Colorado and Canada.

EXPERIENCE: Technical 33 years, Martin Marietta 6 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Lead engineer on the mechanical drive and bearing design of the collector subsystem of the Central Receiver Solar Thermal Power System (ERDA Project). Also has acted as a consultant to various in-house design activities related to mechanisms, motorized systems, bearings and lubrication technology.
- Supervisor of the Failure Analysis Laboratory. Conducted research concerning performance and failure modes of electromechanical devices and motors. IR&D tasks involving electromechanical mechanism evaluation, bearings, and lubrication design for use in space.Responsible for design of radar bearing and drive systems, aircraft and industrial hydraulic design, detail structure design for aircraft and associated equipment and industrial tooling design.

PROFESSIONAL AFFILIATIONS: Member AIAA, ASLE

ALDEN E. CLAWSON. Materiel

EDUCATION: BS, Electrical Engineering, University of Utah, 1958, MBA, University of Utah, 1963, Graduate Studies toward PhD, University of Colorado.

EXPERIENCE: Technical 16 years, Martin Marietta 12 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Subcontract Manager for Viking Lander Biology instrument two radar sets, Lander cameras, tape recorder and meteorology instruments. As subcontract manager responsible for monitoring management activities of subcontractors to ensure their compliance with specific requirements.
- Contracts administrator on Skylab prime contract with NASA/JSC responsible for all customer interfaces on contract matters and for contract direction to the program. Involved in the hardware aspects from the beginning of the Skylab definition phase through operation and mission analysis.

MATTHEW S. IMAMURA. Calibration, Alignment & Focusing

EDUCATION: BSEE, Marquette University, 1958, completed requirements for MS, Electrical Engineering, University of Colorado, Direct Energy Conversion System, Arizona State University.

EXPERIENCE: Technical 16 years, Martin Marietta 9 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Program Manager on NASA Lewis Research Center contract for Individual Battery Cell Protection Circuits.
- Principle Investigator on NASA research study on solar cell dark forward characteristics and their applications to large array checkout. Also responsible for an IR&D task involving automated power system development using microprocessors.
- Unit Manager for the Skylab Power Sources Unit; the unit is responsible for solar cells, fuel cells, and primary and secondary batteries.
- Group Engineer for the Skylab 8kW electrical power system integration, including design, analysis and sunlight testing of multikilowatt solar arrays, evaluation testing of nickel-cadmium batteries and technical coordination between NASA and various Skylab contractors.
- Program Plan volume manager for the Central Receiver Solar Thermal Power System (ERDA Project) (prepared the technical work plan, schedule and management plan).
- Published 10 papers on solar array, battery and fuel cell power systems, submitted 3 NASA new technology disclosures on solar array systems and has one patent application on battery control and protection system.

THOMAS W. HAWKINS. Software Development

EDUCATION: BS, Mathematics, West Texas State University, 1967

EXPERIENCE: Technical 8 years, Martin Marietta 3 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Lead Computer Programmer responsible for design of computer interfaces to allow intercity computer utilization. Responsible for design and development of communications software and hardware test programs for ground support and flight software projects, and the design and development of methods to define, integrate and generate real-time computer software operating systems capable of batch processing, telecommunications, time sharing and basic factory control processing.
- Responsible for developing a digital computer simulator for Apollo mission guidance, navigation, environments and dynamics.

PAUL R. BROWN. Manufacturing and On-Site Installation

EDUCATION: Mathematics Major, California State Polytechnic College

EXPERIENCE: Technical 20 years, Martin Marietta 16 years

EXPERIENCE BENEFICIAL TO PROJECT:

- Program Manager responsible for Space Shuttle External Tank transporter design and build.

- Viking Lander final assembly, test and logistics manager responsible for manufacturing engineering and final assembly, test engineering and operations logistic support, and launch site facilities activation.
- Manager of Denver Division test engineering and operations.
- Manager of Titan I update program with responsibility for prototype complex activation and installation as well as testing of new hardware.
- Chief of Titan II activation program and test operations.
- Chief of Titan I activation program and test operations.

B. FACILITIES

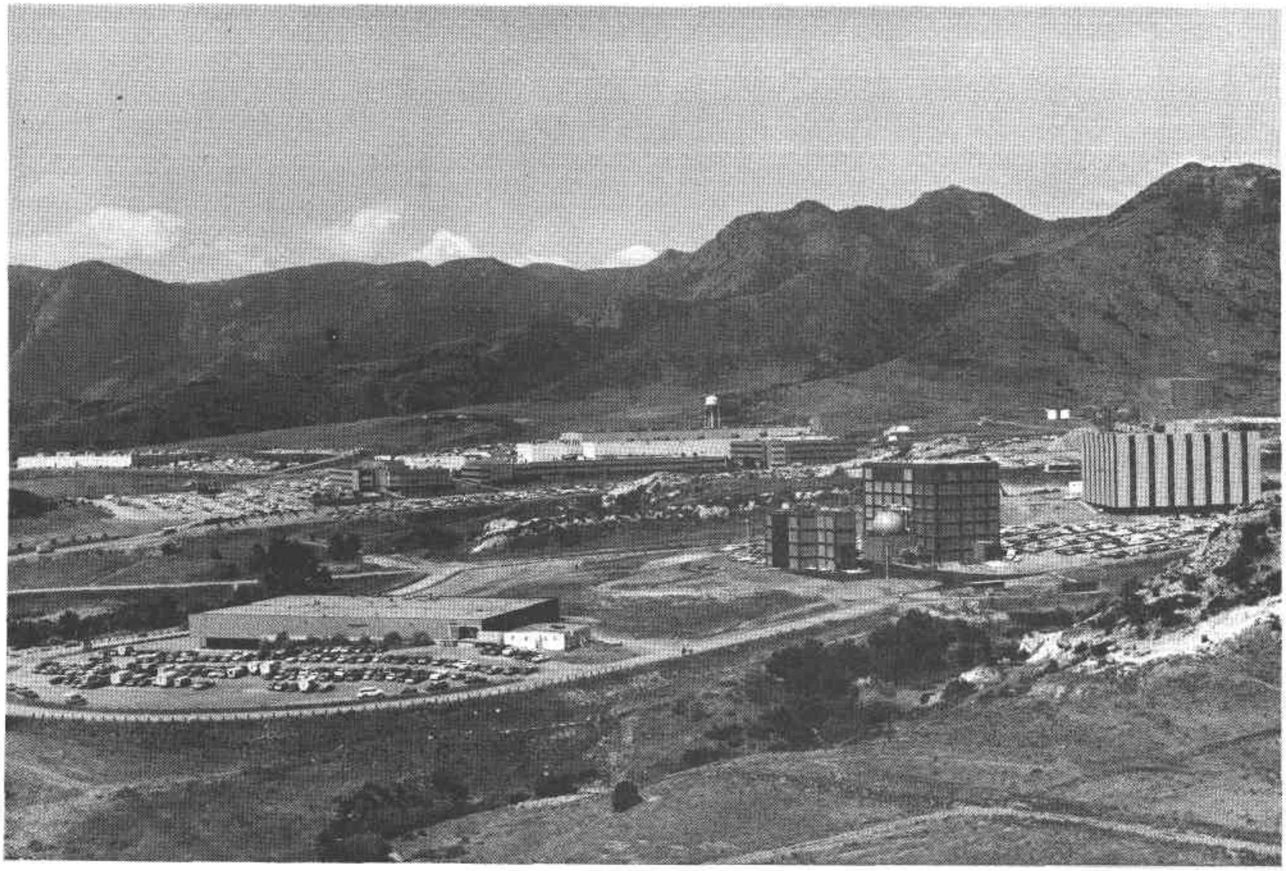
Martin Marietta's Denver Division is a fully integrated system and support facility that provides a broad base of essential engineering, scientific, and manufacturing technologies required for energy programs. The facility is located on a 5057-acre site approximately 25 miles southwest of Denver. Existing buildings contain a total of 1,881,604 square feet on-site plus off-site leased office areas.

The map (Fig. II-3) shows the close proximity of engineering and administrative offices, manufacturing facilities, general-purpose laboratories, engineering research laboratories, and our on-site sunlight solar array test facility.

Although most of the facilities will not be required for the proposed program, we have included facilities relevant to solar thermal conversion (STC). In this manner we hope to further convey our commitment in capital expenditure to related STC tasks.

The facilities and equipment available for this program at Martin Marietta rank with the best in the industry and some are being used in related solar programs.

Minimum cost and maximum technical effectiveness will be achieved by locating the HAACS program personnel and facilities immediately adjacent to the ERDA central receiver solar thermal power system (CRSTPS) and 1-MWt receiver program teams.



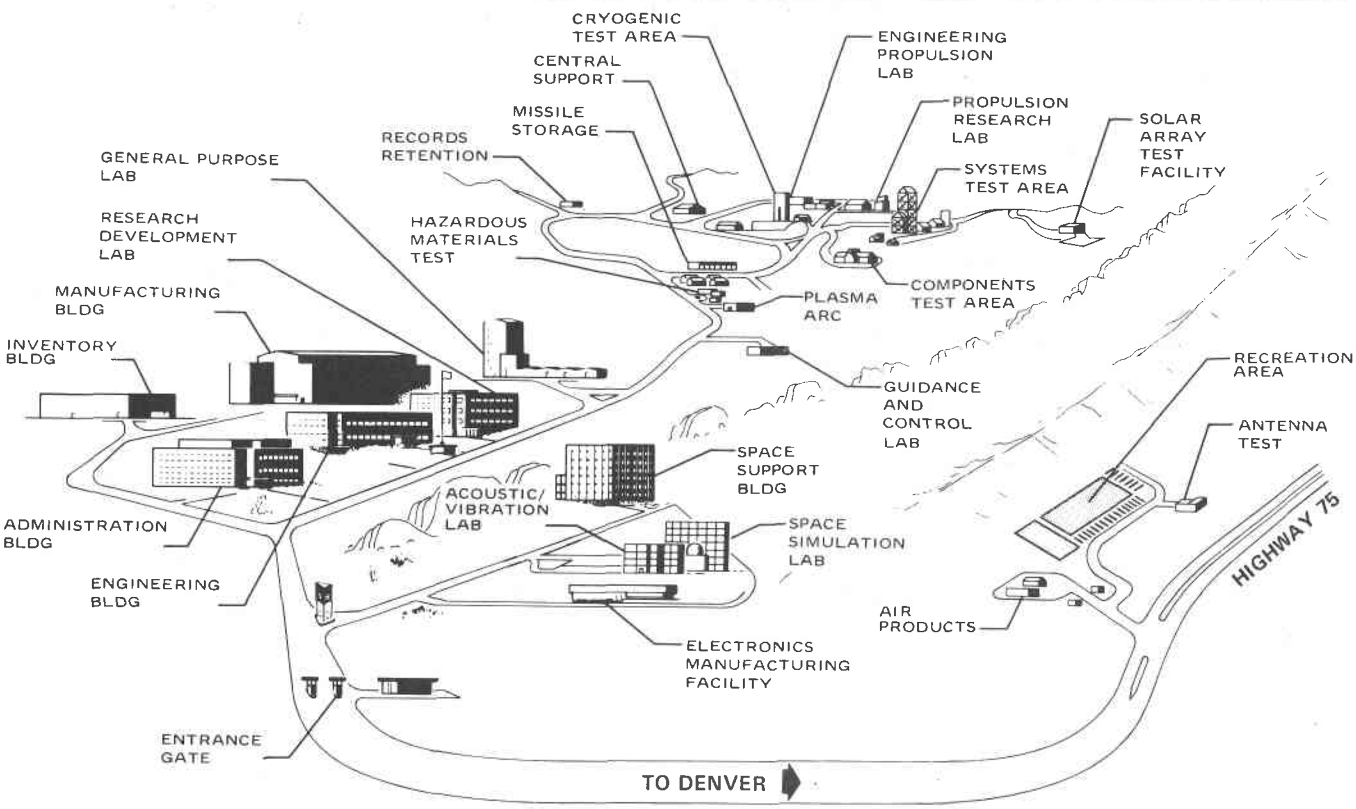


Figure II-3 Denver Facility Overview

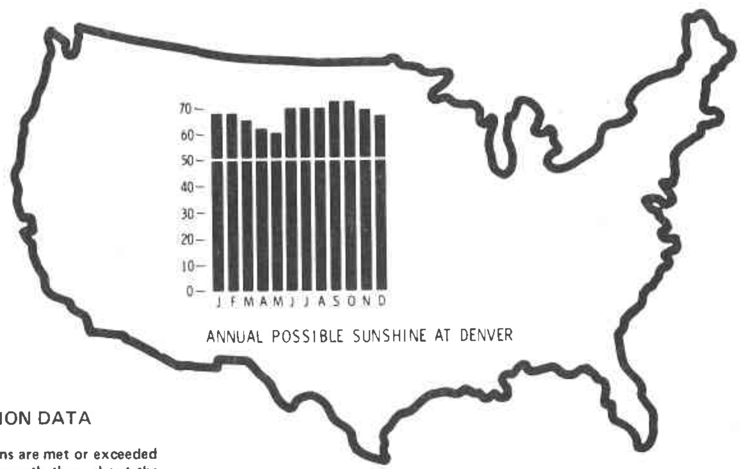
We have planned to assemble the main heliostat structure on-site at Sandia and procure structural framework from a local Albuquerque supplier. All complex mechanical hardware and all electronic control and heliostat array control hardware will be manufactured at Martin Marietta.

The following paragraphs describe the facilities at Martin Marietta that will be used in this program. They also include brief descriptions of supporting laboratories whose disciplines apply directly to the HAACS program.

1. Solar Facilities

The solar cell laboratory located in the research and development laboratory building includes a storage room with dust, temperature, and humidity control, and a darkroom for testing. The darkroom is equipped with a Spectrosun solar simulator with lenses and filters providing up to six "suns" with spectral simulation of the "Johnson spectrum." A tungsten illuminator providing ±3% uniformity over a square meter is also available. Thermal chambers with test environments from -195 to 120°C can be combined with vacuum to 10^{-5} torr if necessary. Standard cells calibrated against a balloon standard are maintained.

The sunlight solar array test facility is identified on the map of Figure II-4. This test area occupies the top of a hill at an elevation of 6200 feet overlooking the main plant to the south. There is unobstructed sunlight and no reflecting obstacles during the whole of a testing day either summer or winter. Figure II-4 shows typical intensities, scatter radiation, and times of occurrence. The test area is a 50 by 75-foot concrete pad equipped with tiedowns and manholes carrying power and instrumentation conduits.



TEST CONDITION DATA

(The following test conditions are met or exceeded from six to ten times per month throughout the year.)

Solar Energy Time/Intensity	Minimum of two hours per day with intensity in excess of 100 milliwatts per square centimeter.
Cloud Conditions	No clouds within 25 degrees of the sun line.
Light Scatter	Less than 10 percent
Winds	No wind in excess of 25 miles per hour.
Major Equipment	Automatic Data Acquisition System Equatorial Tracking Mounts Thermal Control Systems Vacuum Chambers Spectrosun X-25L Solar Simulator with capability of from one to six suns. (A sun equals 139.6 milliwatts per square centimeter.)

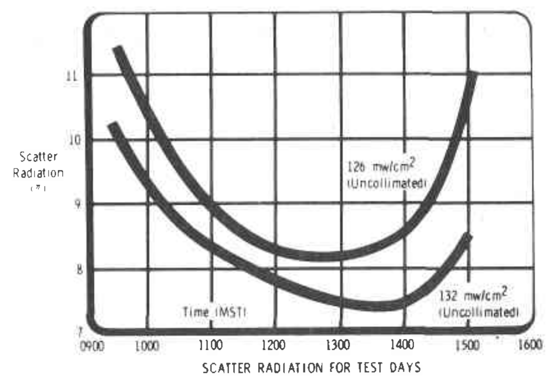


Figure II-4 Sunlight Solar Array Test Facility

Adjacent to the test pad where it will not cause reflections is a combination instrumentation, assembly, and storage building. This building is temperature- and humidity-controlled and will accept support structures and heliostats.

Our solar facilities are being expanded as a result of the CRSTPS program with ERDA. These additional facilities can be shared directly with the HAACS program and are designed to prove principle, establish baseline configurations, and provide a basis for minimizing the cost of both installation and operation of heliostats. The collector subsystem will comprise four heliostats, their tracking controls, and the associated electric power, communication, wiring, and calibration equipment. The heliostats are depicted in position (Fig. II-5) in the valley north of the solar facility. A heliostat automatic control center will be provided on top of the mesa adjacent to the receiver subsystem.

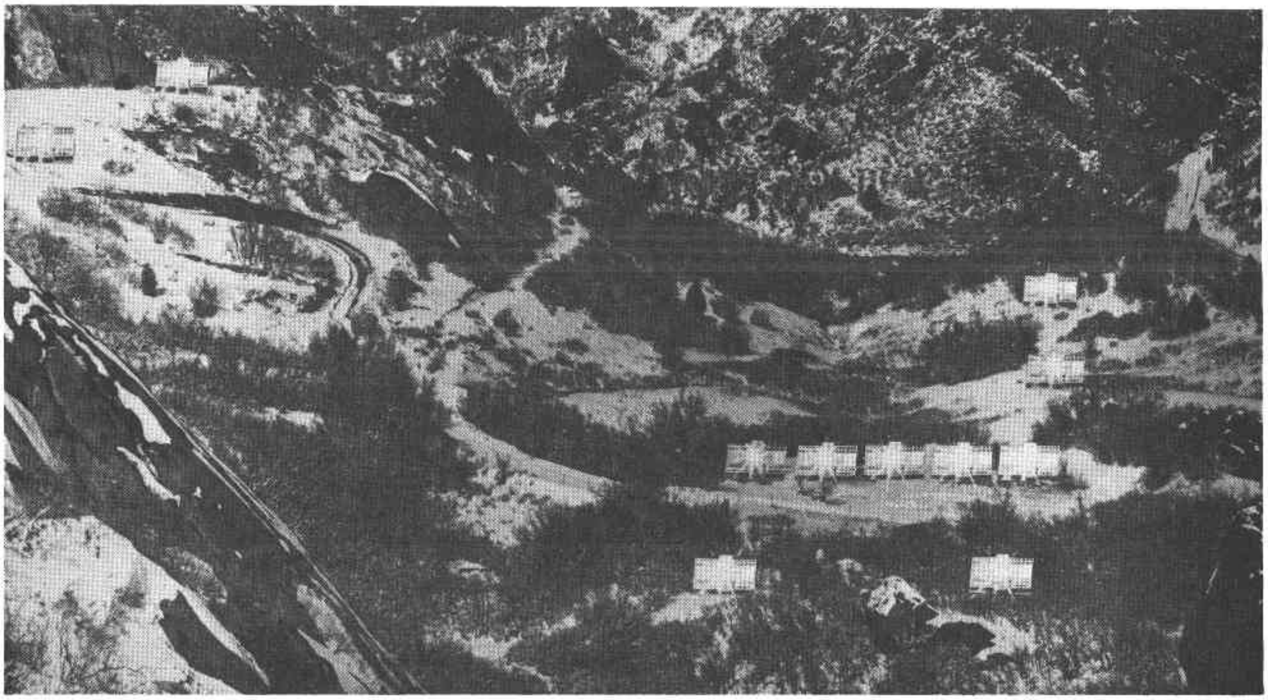


Figure II-5 Photo of Proposed Research Experiment Heliostat Field

The receiver subsystem will consist of support structure for the alignment target and calorimeter, the means for moving this structure and support equipment back and forth between two receiver site locations, and the necessary power, communication, and safety equipment. The two sites are on the top of the hill immediately adjacent to the solar test facility, which eliminates the need for a tower since the heliostat sitings to receiver target are compatible with the power tower STC plant.

2. Atmospheric Sciences Laboratory

The atmospheric sciences laboratory consists of a 1000-square-foot conventional lab. The laboratory is equipped with four spectral pyrheliometers (Eppley model NIP) and two spectral pyranometers (Eppley model 2). An equatorial mount is available and a complete data recording system is maintained. Calibration of the pyrheliometers and pyranometers is maintained with a primary standard angstrom unit. This complete complement of solar radiometers and measurements can be used at almost any location. Support measurements/instrumentation consisting of automatic meteorological stations are also available. This technology will have application to the heliostat array and control system program.

3. Electronics Manufacturing Facility (EMF)

The EMF contains more than 79,000 square feet specifically designed for production of high-reliability electronic equipment. Features of the facility include:

1) A 7500-ft^2 clean room operated in compliance with FED-STD 209a, Class 100,000;
2) A 1200-ft^2 potting/encapsulation room equipped with Class 100 benches, flow soldering and ultrasonic cleaning equipment, a vacuum encapsulator, curing ovens, refrigeration units, and an X-ray system;

3) A 400-ft^2 coil winding room with toroidal- and bobbin-type winding machines and a reflow solder system;

4) Functional and environmental test equipment, including a computerized automatic test system (Sigma V), a vibration exciter system, and temperature chambers;

5) A wire, plug, harness, and chassis assembly area;

6) A mechanical support shop.

4. Power Conditioning Laboratory

Design, development, and test of heliostat electronics hardware is supported in the SSB by over $750,000 in test equipment including 13 oscilloscopes, 32 power supplies, voltmeters, ammeters, curve tracers, signal generators, wave analyzers, frequency counters, and other items of miscellaneous equipment.

5. Guidance and Control Laboratory

Our guidance and control laboratory has been developed specifically for airborne applications; however, the technology necessary for heliostat control is also provided by this facility (Fig. II-6).

6. Failure Analysis Laboratory

This facility is a focal point for failure analysis, including physics of failure for parts, components, and subsystems. It is supported in its function, however, by all other laboratories in the Denver Division as needed. This laboratory will be available to consider potential technical difficulties that typically arise during the development of electronic assemblies and mechanical mechanisms.

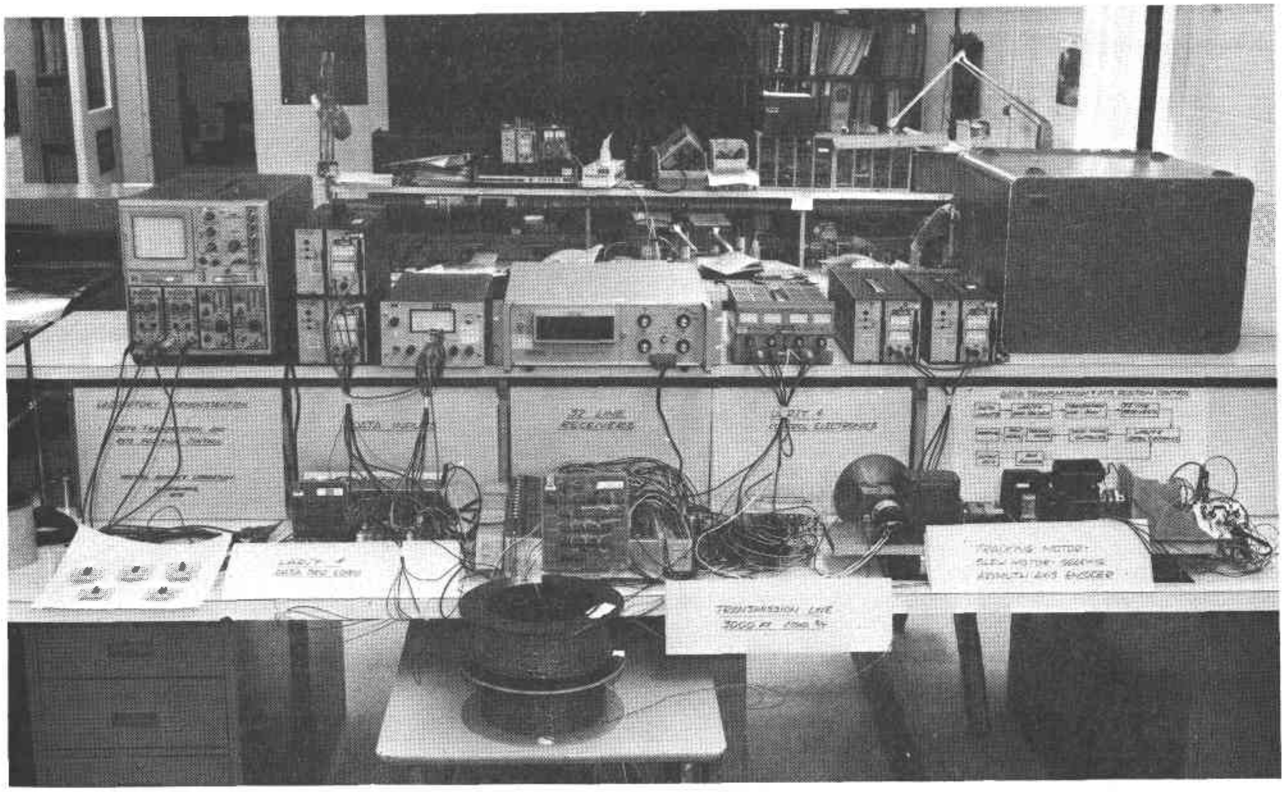


Figure II-6 Guidance and Control Laboratory Heliostat Control Hardware Demonstration

The laboratory is comprehensively equipped to perform in-depth analyses of solid-state electronics, including fine and gross leak testing, encapsulated gas analysis using a mass spectrometer, decapping, microscopic examination of internal construction and dice using stereoscopic and high-power microscopes, electrical parameter testing using curve tracers, thermal impedance measurements, and catswhisker bond-strength testing of individual device characteristics. Thermal shock and temperature cycling are accommodated by various temperature chambers and temperature baths. Microsectioning and depotting of parts is routine. X-ray, mechanical shock, vibration, and scanning electron microprobe facilities are available in adjacent laboratories. Analyses of mechanical, electrical, electromechanical, and fluid system parts and components are also conducted.

7. Scientific and Business Computer Facilities

Martin Marietta's computers provide a complete hardware/software data processing service in support of our energy programs. The computer systems available are listed in Table II-1.

Table II-1 Computers

ENGINEERING	BUSINESS
CDC 6500 DIGITAL CDC 6400 DIGITAL EAI 89000 HYBRID CONSISTING OF THREE EAI 8800 ANALOGS AND ONE EAI DIGITAL THREE IBM 1130 SYSTEMS AND CDC 3150 DATA PROCESSING SYSTEM FIVE UNIVAC 9200/9300 COMPUTERS AND COMMUNICATION TERMINALS	IBM 360-65 COMPUTER SYSTEM

C. EXPERIENCE AND PAST PERFORMANCE

Martin Marietta Corporation is a diversified industrial organization engaged in the development and production of energy and energy control systems, aerospace systems, dyestuffs, organic chemicals, construction materials, refractories, and aluminum. As a major contractor to U.S. government agencies, we are engaged in a wide variety of engineering, research, development, manufacturing, and field support activities relating to programs in environmental quality, energy programs, space exploration, defense systems, data systems, communications, and others.

Analytical, experimental, and developmental studies have been performed by Martin Marietta for the National Science Foundation, Energy Research and Development Administration, U.S. Environmental Protection Agency, U.S. Department of the Interior, all military branches of the U.S. Department of Defense, New York State Environment Facilities Corporation, Orange County (Florida) Solid Waste Management System, Great Lakes Basin Commission, U.S. National Aeronautics and Space Administration, and the Maryland Department of Natural Resources.

Martin Marietta's Denver Division is a major system and hardware contractor dedicated to fulfilling national and industry goals in the broad field of aerospace. In recent years with changes in national priorities we have shifted our emphasis to the equally important field of energy-related programs, including power systems, energy management, solar energy conversion, and resource management.

1. General Experience

Our major competence is the management of complex programs with many interfaces (government, associate contractors, and subcontractors) such as the Titan III launch vehicles, Viking project, and the experiment integration and a number of hardware portions of Skylab. This system engineering experience has necessarily included developing and applying a wide range of technologies prerequisite to successful participation in the nation's unmanned and manned space programs and new terrestrial energy technology developments.

We have extensive experience in performing work at off-site locations. Since 1956 we have provided personnel and material to 16 projects at 11 separate locations. For example we have located our people for (1) Titan II intercontinenatal continental ballistic missile site activation in Arizona, Kansas, and Arkansas, (2) Skylab program integration support in Texas, Alabama, Florida, and Washington, DC, (3) Titan III launch site activation and operations in Florida and California.

Off-site Titan operational basing activities accounted for more than one-third of the Denver Division employees during construction of the Titan I and II bases. The Titan II bases near Tucson, Arizona, Wichita, Kansas, and Little Rock, Arkansas involve 54 launch silos and control centers. All 54 Titan II sites were operational on schedule.

During the Titan II activation program, Martin Marietta interfaced with three different government organizations--the Air Force Ballistic Systems Division, the Army Corps of Engineers, and the Strategic Air Command, as well as a host of contractors. We were responsible for defining the physical and functional interfaces between the facilities and the ground equipment--we surveyed the facility construction, we designed and fabricated the ground equipment, we installed and checked out the ground equipment, and we provided spares, maintenance, and operational manuals for the complete system. Table II-2 identifies the major disciplines we have dealt with during site activation.

2. Related Energy System Experience

a. Central Receiver Solar Thermal Power System (CRSTPS) Phase 1 [*ERDA E(04-3)-110*] - Martin Marietta Aerospace as prime contractor, in cooperation with Bechtel Corporation, Foster Wheeler Energy Corporation, and Georgia Institute of Technology as major subcontractors, has been awarded a contract to perform the CRSTPS Phase 1 project. Major elements of the project include (1) formulation of a conceptual baseline design of a 10-MWe proof-of-concept experiment pilot solar power plant, (2) three substantial subsystem experiments to accomplish technology demonstration of vital features of the pilot plant, and (3) a preliminary design of the pilot plant to serve as the basis for the envisioned Phase 2 project to design, build, and test a 10-MWe pilot plant. An artist's conception of the CRSTPS Solar power plant is shown in Figure II-7.

Table II-2 Site Activation Experience

Table II-2

EFFORTS	TITAN I				TITAN II				TITAN III		
	OPERATIONAL SITES	DENVER TEST STANDS	ETR	WTR	OPERATIONAL SITES	DENVER TEST STANDS	ETR	WTR	ETR	WTR	DENVER TEST STANDS
1. FACILITY CRITERIA	X	X	X	X	X	X	X	X	X	X	
2. FACILITY PLANS AND SPECIFICATIONS		X	X			X	X				
3. REVIEW OF FACILITY PLANS AND SPECIFICATIONS	X	N/A	X	X	X	N/A	X	X	X	X	N/A
4. FACILITY SURVEILLANCE	X	N/A	X	X	X	N/A	X	X	X	X	N/A
5. FACILITY ACCEPTANCE	X	N/A		X	X	N/A		X		X	N/A
6. CUSTODIAL RESPONSIBILITY	X	X		X	X	X		X		X	X
7. CONFIGURATION MANAGEMENT	X	X	X	X	X	X	X	X	X	X	X
8. INSTALLATION ENGINEERING	X	X	X	X	X	X	X	X	X	X	X
9. INSTALLATION AND CHECKOUT	X	X	X	X	X	X	X	X	X	X	X
10. SUBSYSTEM DEMONSTRATIONS	X	X	X	X	X	X	X	X	X	X	X
11. SYSTEM DEMONSTRATIONS	X	X	X	X	X	X	X	X	X	X	X
12. SUBCONTRACT MANAGEMENT	X	X	X	X	X	X	X	X	X	X	X

Figure II-7

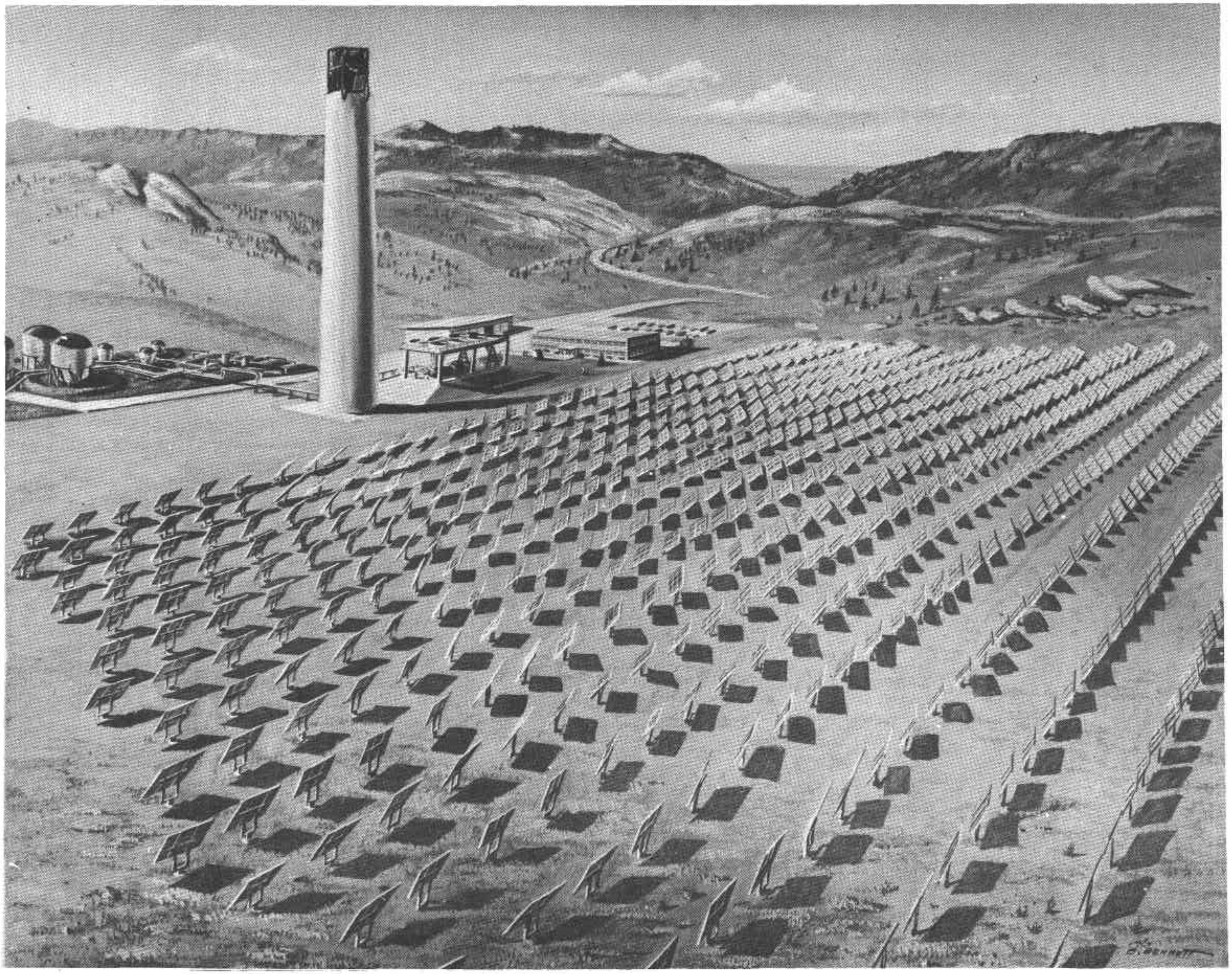


Figure II-7 Artist's Concept, CRSTPS Solar Power Plant

Three subsystem experiments will be designed, fabricated, and tested to verify performance, reliability, and the economics of potential facilities. These experiments form the core technology vital to the attainment of 21.5 overall thermal efficiency around which the CRSTPS design will be optimized. These experiments in summary are (1) design, fabricate, and test a 5-MW cavity receiver, (2) design, fabricate, and test 4 20x20-foot full focusing concentrating heliostats, and (3) design, fabricate, and test a 1.6-MW-hour storage system utilizing sensible-heat storage in high-temperature liquids.

b. *Solar Power System and Component Research Program (NSF AER75-07570)* - This program, completed in January 1975, included both system analysis and component design for a 100-MWe solar energy conversion power system with the component design phase concentrated on the boiler/superheater steam generation equipment. Martin Marietta (as prime contractor) and Georgia Institute of Technology (as major subcontractor) led the team of cooperating organizations performing the program. Two broad objectives were established:

1) Evaluate the potential utilization of solar thermal conversion central receiver/hydroelectric hybrid power systems;
2) Define requirements for a bench model central receiver test program consistent with the CNRS Solar Energy Laboratory's 1-MW thermal furnace at Odeillo, France.

The solar/hydroelectric hybrid power system was selected for analysis because of its promise as near-term energy displacement and load-following utilization of a solar thermal power system. The cooperating organizations for the user application analyses included the Salt River Project of Phoenix, Arizona, and the Bonneville Power Administration of Portland, Oregon. A 100-MWe solar energy conversion system was evaluated relative to its contribution when integrated into the existing power systems of those two organizations.

The second objective focused on the component design effort, the boiler, and the superheater energy conversion subsystem. A potential result of this effort is early demonstration of solar-powered steam generation in the 1000-kW range, using equipment technology representative of that required in the full-sized power system. The Centre National de la Recherche Scientifique solar energy laboratory of Odeillo, France collaborated in this segment of the program.

c. Preliminary Insolation Investigation and Solar Power Feasibility Study for St. Croix, U.S. Virgin Islands (Contract VIWAPA PO 7700) - The islands represent a unique opportunity to utilize solar energy and replace oil, which is primarily the energy source for all the Virgin Islands. The program initiated by the Virgin Islands' Water and Power Company was to determine the feasibility of using solar energy for power generation on St. Croix. The program included insolation studies, a 25-MWe solar power station preliminary design, site selection, and energy storage concepts utilizing the islands' greatest natural resource, the sea, for hydrogen generation and storage.

A corporation-sponsored program has also been conducted by Martin Marietta Laboratories to prevent thermal and chemical pollution from a major processing plant at St. Croix, V.I. This Martin Marietta plant is a bauxite-to-alumina conversion facility that processed approximately one-half million tons of beauxite per day and includes a power plant (electricity, steam, and water) for both in-plant and community needs. The laboratories have performed engineering and economic studies of the facility and its power plant and made recommendations for cooling systems, discharge systems, etc.

d. Definition Study for Photovoltaic Residential Prototype System - This study will evaluate the adaptation and integration of photovoltaic energy conversion to residential applications. The program includes site selection, parametric sensitivity studies, conceptual design of the residence, identification of institutional and environmental problems, and development of test plans, test requirements, and detailed test procedures.

3. Related Hardware Experience

a. 1-MW Bench Model Cavity Receiver Steam Generator [*ERDA E(04-3)-1068*] - The program discussed in the preceding subsection 2.b established a high-performance baseline design of a 100-MWe solar power system of the central receiver/multiple-heliostat type, the configuration of a bench model cavity receiver steam generator, and a test installation configuration compatible with the CNRS solar laboratory furnace at Odeillo, France.

This is a follow-on program to build the bench model steam generator and its test support equipment. The program team of Martin Marietta Aerospace and Georgia Institute of Technology will perform the program in collaboration with the CNRS solar laboratory and Sandia in the radiant heat facility and the 5 MW thermal solar test facility.

Fabrication of the bench model 1-MW cavity receiver steam generator designed in the previous program, its test installation and test plan, and its compatibility with the CNRS and Sandia test facilities form the major work elements of this program.

b. Subsystem Components, Collectors, and Tracking Heliostats - We have been performing experiments with concentrating heliostats and low-cost tracking mechanisms on corporate research funds since 1973. These efforts have now been effectively transposed into functional designs in the ERDA CRSTPS program, Figure II-8. These tests have evaluated the characteristics of a multiplicity of reflecting surfaces, particularly as related to specular reflectivity, cost, availability, life expectancy, and maintenance. Collector efficiency has been determined using a calorimeter.

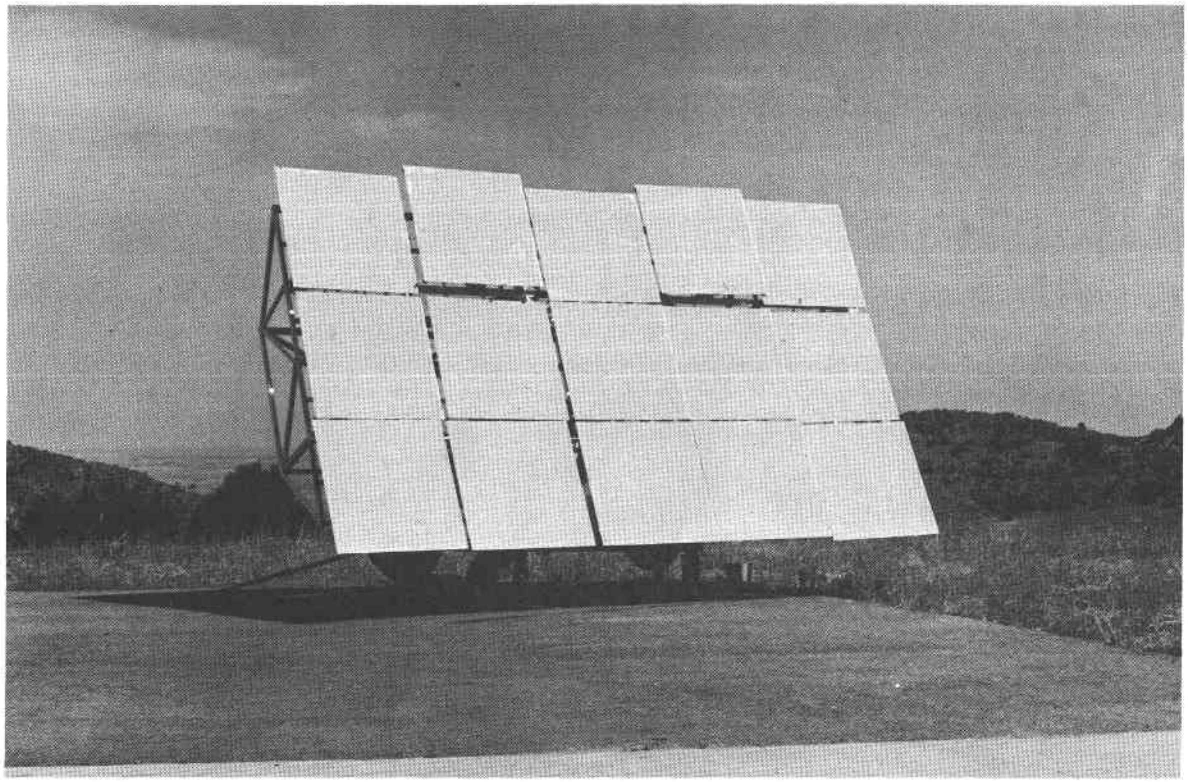


Figure II-8 15-Mirror Prototype Heliostat

Various mirror support and warping structures have been evaluated and wind tunnel tests have been performed to establish the separation angle for a collector configuration, evaluate the Reynolds number effect of mirror spacing, and determine peak torques. As a result of these evaluations a quarter scale model has been built (Fig. II-9) and is undergoing tests.

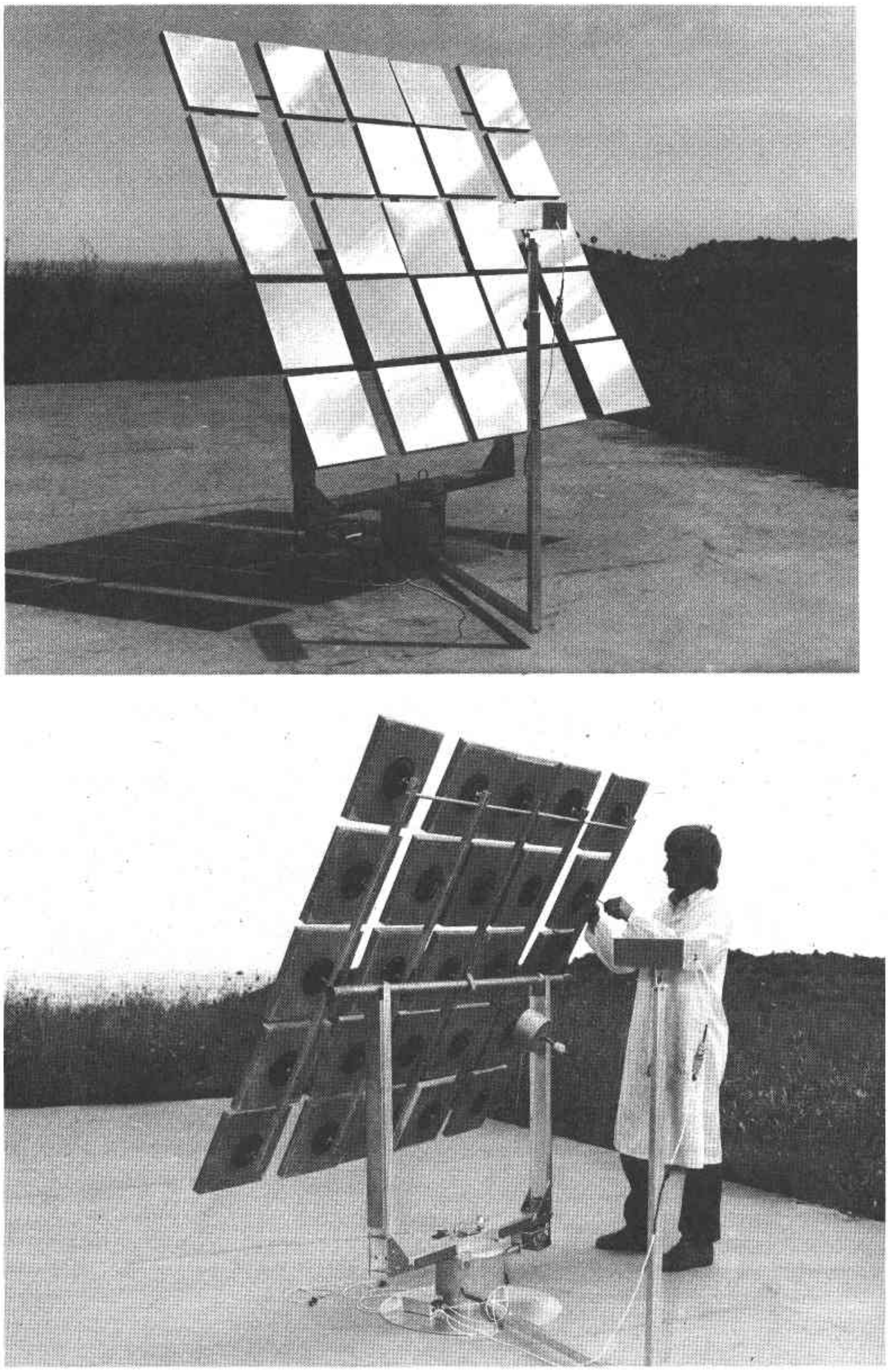


Figure II-9 1/4 Scale Model Heliostat

a. Collectors - Martin Marietta has developed an optical black surface (OBS) that absorbs 23% more solar radiation than highly absorbent black paint. The MMOBS has been incorporated in solar energy collectors as shown in Figure II-10. The success of these collectors resulted in Martin Marietta being awarded a contract from Douglas County School District, Colorado, to install 2880 square feet of collectors on the Parker Junior High School. The total system will utilize a heat pump.

Figure II-10
Improved Collector Test Setup

b. Mariner-Series Solar Cell Testing - Tests of a Mariner '69 sample panel (built by JPL) in a four-mirror solar intensifier provided correlation of predicted performance with test data from 0.9 to 2.2 suns intensity. Tests indicated mismatch at higher intensities would produce errors on the order of 4% or greater if the cell matching were based on cell selection tests performed at one sun. Figure II-11 shows this panel in the solar intensifier.

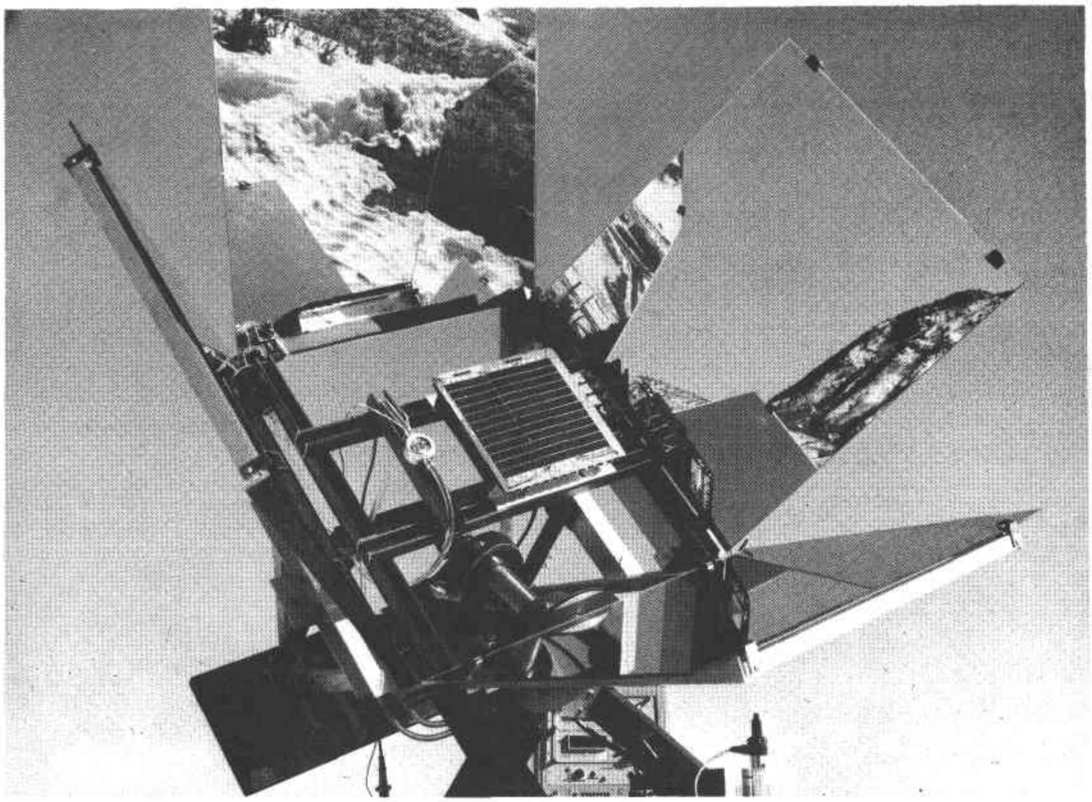


Figure II-11
Four-Mirror Solar Concentrator Test of Mariner '69 Sample Panel

c. Meteorological Experience - Martin Marietta's atmospheric sicences laboratory provides detailed support analysis and measurements of ambient temperature, pressure, wind, humidity, and incident solar radiation (direct, total, and diffuse).

The measurements of incident solar radiation are analyzed by computer for transmission properties of the atmosphere. These analyses have been performed for NASA Goddard Space Flight Center, the Lyndon B. Johnson Space Center, National Oceanic and Atmospheric Administration (NAA), the National Science Foundation, and the Virgin Islands' Water and Power Company.

A computer program developed by Martin Marietta is used extensively in our terrestrial solar power programs. The program accepts inputs of site location, date, time and output levels to, and calibration constants for, pyrheliometers and pyranometers. Outputs provide absolute amounts of direct, diffuse, and total solar radiation, atmospheric optical depth (attenuation) as a function of time of day, year, and air mass, integrated amounts of direct and total radiation, and the ratio of diffuse to total radiation and atmospheric clarity as a function of time of day, year, and air mass. This computer program is being used in preparation of the HAACS proposal and will be extensively used as we enter the design-development phase.

d. Calorimeters - Under the CRSTPS program Martin Marietta has developed a prototype calorimeter with a focal plane of 1.7 m^2 (18.1 ft^2), Figure II-12. The focal plane consists of three strips of Olin brass roll-bond (type FS-7610-SW) solar panels. The strips are treated with the Martin Marietta optical black surface that provides an absorptance of greater than 99.9%.

Heliostat-reflected energy is focused on the focal plane receiver of the calorimeter. The characteristics of the water flowing through the roll bond panels determines the heat flux in Btu/hr.

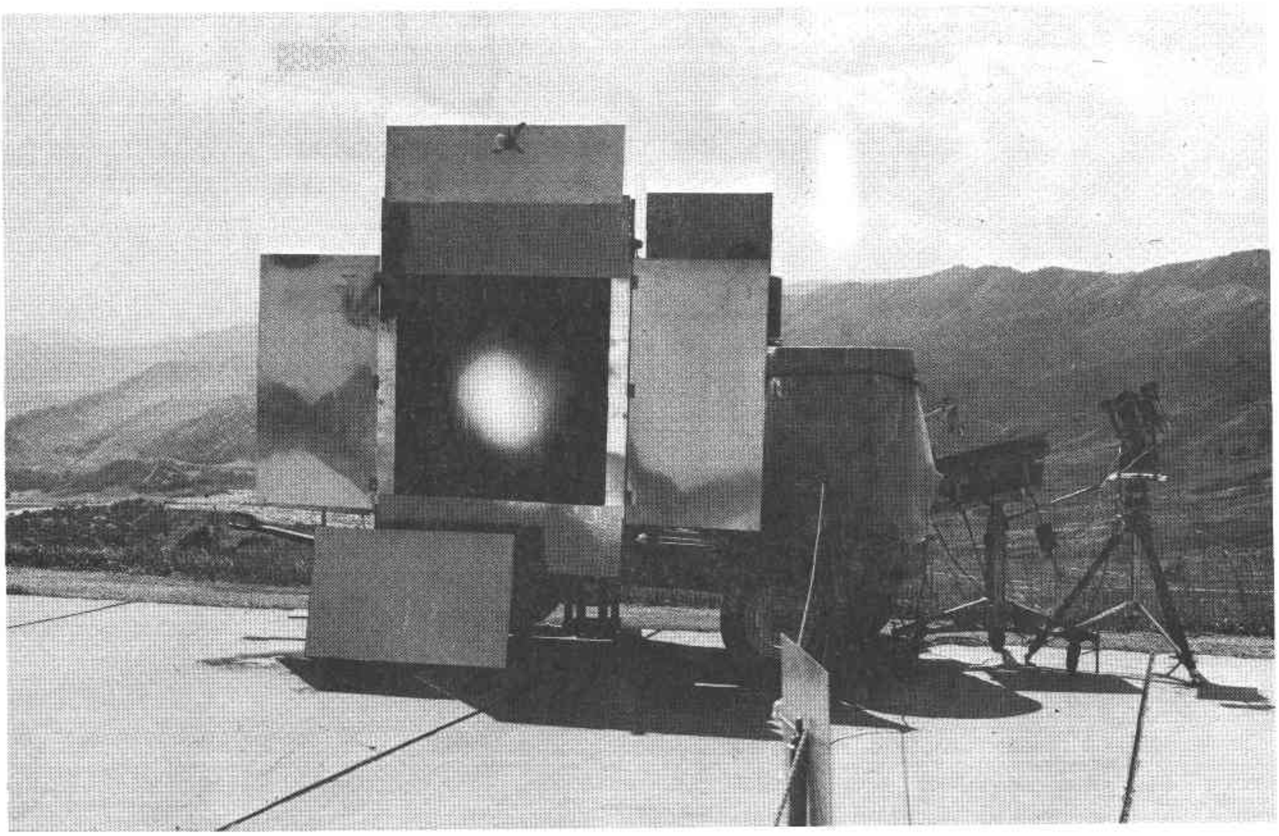


Figure II-12
Collector Efficiency Test Calorimeter

e. Controls - Martin Marietta has pioneered the development of several computer-controlled test systems for use with ground systems, aircraft, launch vehicles, and spacecraft, both manned and unmanned. These systems, which are tabulated, use state-of-the-art hardware and advanced, English-like test languages to simplify their programming.

SYSTEM	CONTROLLER
• VIKING LANDER CAPSULE SYSTEM TEST EQUIPMENT	HONEYWELL H632
• SKYLAB MEDICAL DATA ACQUISITION SYSTEM	VARIAN 620F/I
• SKYLAB MOBILE MEDICAL DATA ACQUISITION SYSTEM	VARIAN 620I
• DIGITAL DATA ACQUISITION & TEST SYSTEM (DIGIDAT)	XDS SIGMA 5
• TITAN III DATA RECORDING & QUICK-LOOK DATA SYSTEM	VARIAN 620L
• ONBOARD CHECKOUT SYSTEM (OCS)	IBM 4PI EP
• MARTRON 1200, AVIONICS LRU TEST SET	HONEYWELL H316
• MARTRON 12000 AVIONICS LRU TEST SET	HONEYWELL H316
• MARTRON 12 JET ENGINE FUEL CONTROLLER TEST SET	DEC PDP11
• TITAN III MOL COMPUTERIZED AGE (CAGE)	2 SDS SIGMA 7s
• TITAN III SPACE LAUNCH VEHICLE AGE	TAPE PROGRAMMER
• TITAN II ICBM LAUNCH CONTROL & CHECKOUT SET	TAPE PROGRAMMER
• TITAN I ICBM LAUNCH CONTROL & CHECKOUT SET	SPECIAL PURPOSE SEQUENCER

C. HELIOSTAT ARRAY CONTROL SUBSYSTEM (HACSS)

The HACSS will link the master control system (MCS) to the heliostats as shown in Figure II-C-1. Each HACSS may contain up to six heliostat array controllers (HACs) and up to six heliostat interface modules (HIMs). Six HACSS will control five zones of heliostats (one HAC for each of zones A, C, D, and E, and two HACs to allow control of 216 heliostats in zone B). The HACSS will interface with the master control system through one 9600-baud asynchronous line using universal asynchronous receiver/transmitter (UAR/T) couplings. Table II-C-1 presents a compilation of the major requirements the HACSS must satisfy and our approach to meeting these requirements. (See Volume IV, Addendum III for the preliminary HACSS requirements specification.) We will buy the HAC as an off-the-shelf minicomputer and build the HIM unit - as indicated in Figure II-C-2.

The HAC will communicate with individual heliostats through the heliostat array interface module (HIM). HIM will receive heliostat command data from HAC and multiplex and route the data to the appropriate heliostat line and the heliostat control electronics (HCE), which is part of the heliostat array subsystem. HIM will also relay data from HCE to HAC. HIM units that are capable of reliably driving 32 devices over 600- to 1000-m (1968.5- to 3280-ft) lines at the data rates will use are not commercially available at reasonable costs.

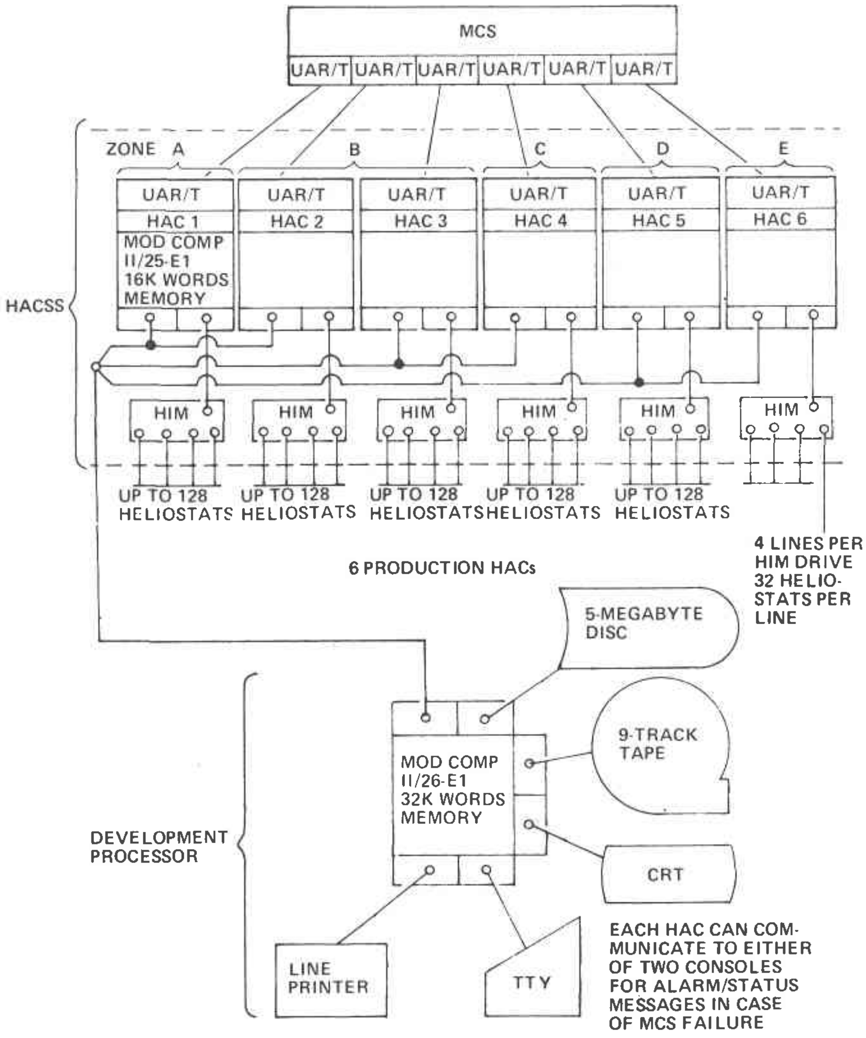


Figure II-C-1 MCS-HACSS Functional Schematic

1. Control Loop

A block diagram of the HACSS is shown in Figure II-C-3. Control mode commands (standby, on-target, etc), sun position, and target position will be transmitted from the facility master control system to the heliostat array controllers. Each HAC will calculate the required azimuth and elevation gimbal angles and transmit the angle and mode commands to the heliostats over serial data buses. The gimbal angles will be calculated as a function of sun position, target position, and heliostat location.

Table II-C-1 Heliostat Array Control Subsystem Major Requirements and Proposed Approach

ITEM	KEY RFQ REQUIREMENTS	K93681 PARA.	PROPOSED APPROACH
1.	HELIOSTAT CONTROLLER TO MAINTAIN REFLECTED RAYS ON SOLAR EXPERIMENTS ON TOWER; INDIVIDUAL CONTROL OF EACH HELIOSTAT	3.1.3.1	COMPUTER/SOFTWARE WILL CONTROL AND MONITOR EACH HELIOSTAT. POINTING PARAMETERS WILL BE PLACED IN COMPUTER MEMORY AT TIME OF HELIOSTAT CALIBRATION.
2.	HAC CAPABILITIES		
	CONTROL POSITION AND MONITOR UP TO 128 HELIOSTATS	3.1.3.2	COMPUTER/SOFTWARE WILL CONTROL UP TO 128 HELIOSTATS.
	INTERFACE WITH MCS; RESPOND TO DIGITAL SIGNAL FROM MCS; FULL-DUPLEX COMMUNICATION; 9600-baud DATA RATE	3.1.3.2 3.1.3.2b	WILL PROVIDE COMPATIBLE INTERFACE ELECTRONICS AND SIGNAL LEVELS.
	STORE STANDBY COORDINATES	3.1.3.2	DATA WILL BE STORED IN HELIOSTAT ATTRIBUTE TABLE IN COMPUTER MEMORY.
	ELECTRICAL CHARACTERISTICS CONFORM TO EIA RS-232-C	3.1.3.2a	UAR/T WITH 9600 baud WILL INTERFACE WITH MCS.
3.	TRANSMIT HELIOSTAT POSITION INFORMATION WITHIN 50 mrad	3.1.4.3c	WILL PROVIDE ENCODER WITH 24.6 mrad ANGULAR RESOLUTION FOR EACH HELIOSTAT AXIS.
4.	MODES OF OPERATION		
	ACQUISITION IN LESS THAN 15 MINUTES; STANDBY POSITION OFF THE EXPERIMENT	3.1.4.4 3.1.4.4.a	COMPUTER WILL CONTROL OPERATIONAL MODES.
	POWER, INTO EXPERIMENT, OR REDUCTION TO ZERO WITH HELIOSTAT SLEW RATE OF 2 mrad/s OR FASTER	3.1.4.4b	HELIOSTAT DRIVE SYSTEMS: AZIMUTH 3.66 mrad/s (755 deg/hr), 135 deg IN 10.73 minutes HELIOSTAT DRIVE SYSTEM: ELEVATION 4.95 mrad/s (1133 deg/hr), 270 deg IN 14.29 minutes
	STANDBY, WHEN SUN IS OBSCURED AND WHILE IN POWER MODE; PROVIDE SUN SENSOR FOR AT LEAST 10% OF HELIOSTAT ZONE	3.1.4.4.c	WILL PROVIDE ONE SENSOR FOR AT LEAST EACH 10 HELIOSTATS.
	MANUAL FOR MAINTENANCE AND SET-UP; ALL OTHER MODES LOCKED OUT	3.1.4.4d	WILL PROVIDE MANUAL (LOCAL) CONTROL PANEL FOR HELIOSTAT CONTROL. CONTROL PANEL LOCKS OUT COMPUTER CONTROL.
	STOW IN LESS THAN 15 MINUTES FROM STANDBY POSITION	3.1.4.4e	WILL PROVIDE HELIOSTAT DRIVE SYSTEMS WITH SLEW RATE CAPABILITY OF 4.95 mrad/s (1133 deg/hr), 270 deg IN 14.29 minutes
	EMERGENCY SHUTDOWN, RESPOND WITHIN 5 sec, THEN TO STOWAGE IN LESS THAN 15 min	3.1.4.4f	STOWED POSITION ANGLES WILL BE STORED IN COMPUTER MEMORY FOR CONTROL OF HELIOSTAT POSITION. WILL STORE DATA IN COMPUTER MEMORY FOR HELIOSTAT POSITION CONTROL AND PROVIDE HELIOSTAT DRIVE SYSTEMS CAPABLE OF SLEWING 270 deg IN 14.29 minutes
	FAIL-SAFE FROM FACILITY FAILURE AND LOSS OF COMMERCIAL POWER; RETURN TO STOWAGE IN LESS THAN 15 min	3.1.4.4g	WILL UTILIZE FACILITY BACKUP POWER SOURCE. COMPUTER WILL EMPLOY BATTERY BACKUP SOURCE TO MAINTAIN MEMORY.

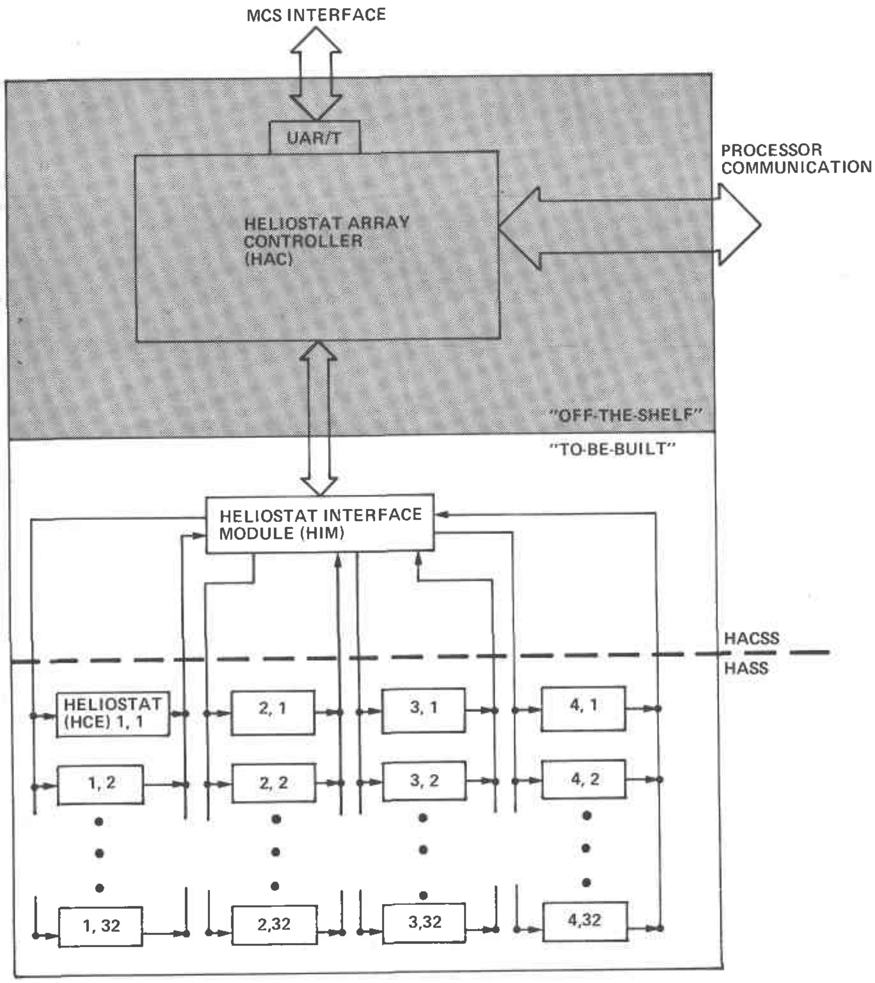


Figure II-C-2 Heliostat Array Control Subsystem (HACSS)

The heliostats will be driven by either fast slew motors or slower tracking motors through gear drives. The slew mode is for acquisition (bringing the heliostat to a standby position) and for moving the heliostat to the stow position either for normal stowage or for emergency shutdown. The tracking motor is for continuous tracking either in the coarse tracking/standby mode of operation or in the fine-tracking/on-target mode.

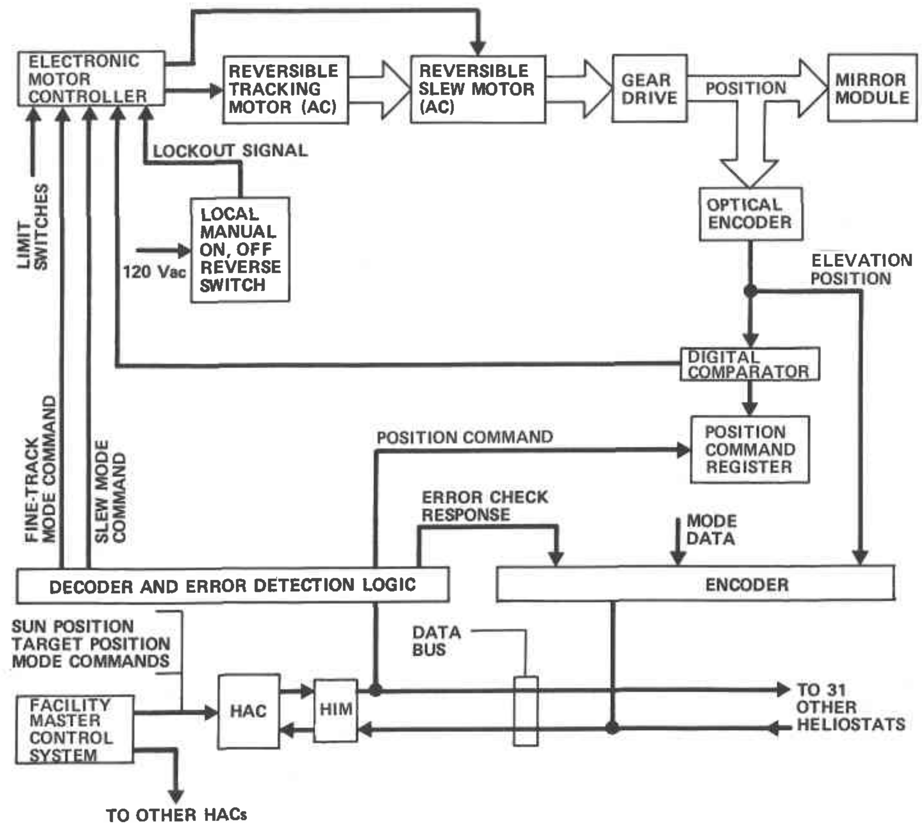


Figure II-C-3 Heliostat Control System Block Diagram (One Axis)

The control loop will use absolute optical encoders to determine actual gimbal positions. The actual gimbal position will be digitally compared to the commanded position; the resulting position error signal will turn on either the tracking motor or the fast slew motor, depending on the mode command, in a direction determined by the sign of the position error. The actual gimbal positions will be transmitted by the data bus to the HAC where they will be available when a status command is received from the MCS.

A manual control panel will connect with any heliostat to allow manual control of azimuth and elevation. Connection of the manual control panel will lock out data bus control yet retain heliostat status feedback. A sun-present sensor (SPS), located on at least every tenth heliostat, will determine sun presence and transmit that information to the HAC and thence to MCS. If sun presence is lost with heliostats in the power mode, the HAC will automatically compute standby positions (offset from the target) and command those positions. When the sun becomes present again, the HAC will continue to transmit standby commands to the heliostat until until commanded on target by the MCS.

We built a laboratory breadboard demonstration system to evaluate the control loop. A photograph of the test setup is shown in Figure II-C-4, and Figure II-C-5 is a block diagram of the setup. Our objectives were to evaluate:

1) Long transmission line and transmitter/receiver compatibility;
2) Effects of 32 receivers on one line that is long between individual receivers;
3) Data rate margin;
4) Compatibility of the UAR/T with wiring and data simulating the actual system;
5) Data errors possible with various sync and space character arrangements;
6) Servo response with actual gear ratios, encoders, ac motor, and drive electronics;

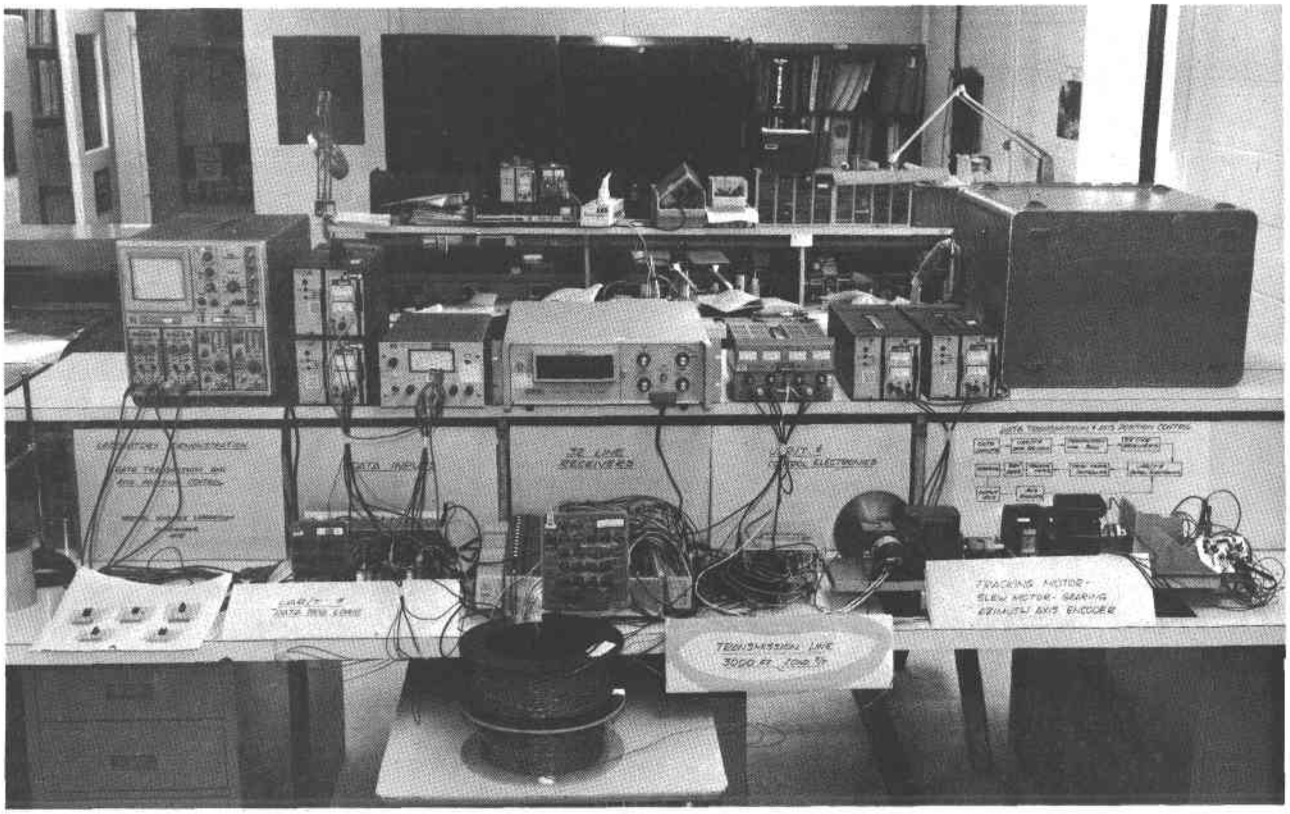


Figure II-C-4 Block Diagram of Breadboard Data Transmission and Control System

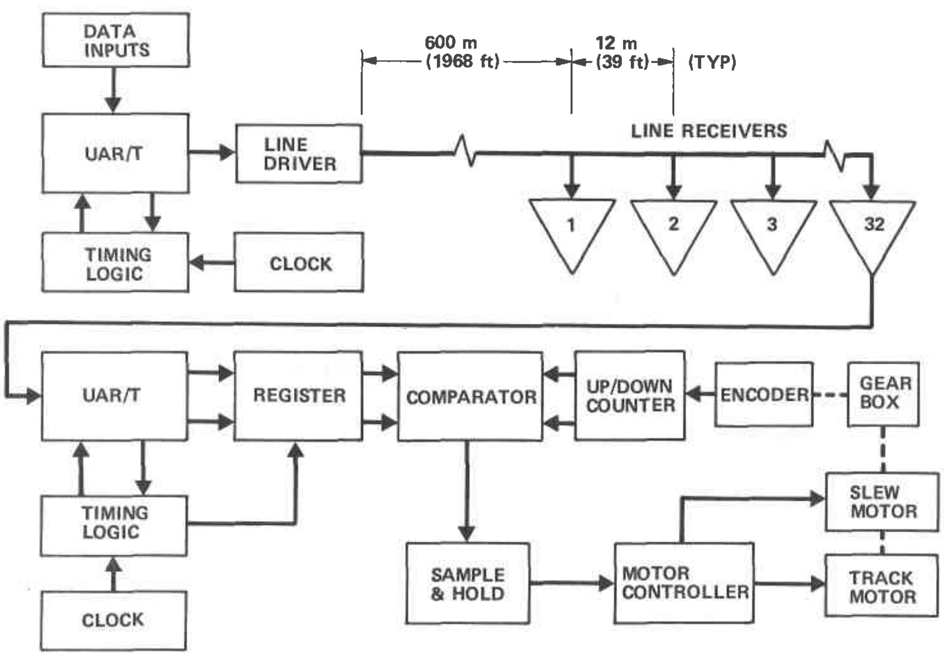


Figure II-C-5 Block Diagram of Breadboard Data Transmission and Control System

7) Servoloop and gearing mechanisms' influence on positioning errors;

8) AC motor drive techniques;

9) Electromagnetic interference effects.

The capability of the breadboard test setup is illustrated in Figure II-C-4 and includes:

1) A 12-bit manual data input control unit;

2) A UAR/T unit with associated clock and timing logic connected to one line receiver;

3) A line driver, 600-m (1985-ft) transmission line using two-conductor shielded/twisted cable, and 32 line receivers spaced apart with 12 m (39.7 ft) of cable;

4) A register to hold position command word;

5) A digital comparison of the actual and commanded positions;

6) Solid-state controllers for both the tracking and slew motors;

7) A tracking motor, Superior Electric Slo-syn, with 50-oz.-in. output torque at 200 rpm;

8) A Bodine 1/12-hp, 1700-rpm, 180 to 1 gearhead reducer unit;

9) An Ohio Gear Co. #8-133 40-to-1 reducer driving a 6-to-1 reduction spur gear stage;

10) An output encoder, Sequential Information Systems model #25D10241DZ-MADZ1A driving an up/down counter that provides actual position data to the control system comparator. Since an incremental encoder was the only available sensor, it was used in lieu of an absolute encoder.

Simulation tests using the breadboard have shown that 350 kilobaud can be successfully transmitted over 600 meters to 32 receiving stations, each separated by 12 meters. There have been no data errors as a result of the long lines and receiver loads.

The electronic ac motor drive developed for the breadboard is compatible with both the Slo-Syn tracking motor and the Bodine slew motor.

The gear reduction drive to the output axis and position encoder simulates the azimuth drive ratio and provided closed-loop positioning with the required accuracy (1 mrad).

The encoder output pulse integrated by the up/down counter provides an actual axis position signal of the required accuracy. The physical mounting of the encoder relative to the output axis is critical and must be solid and deflection free.

2. Heliostat Array Controller

The HAC is the nucleus of the subsystem. It is under control of the master control system but must be capable of limited decision-making by itself in case of system failure. The HAC will insure responsive, economical, and fail-safe operation of a heliostat array. It will perform all necessary computations with liberal system growth capability and in addition will provide versatile, unrestricted software development and usage capabilities during the life of the project. The HAC will operate alone or in a combination of six HACs that, under MCS control, can operate up to five zones of heliostats. The HAC production computer must:

1) Service nine 11-bit messages (8-bit data word) from MCS over 9600-baud asynchronous RS-232-C line through UAR/T-type interface;

2) Execute 34,000 heliostat position control calculation instructions each second;

3) Perform 1792 word transactions per second (seven 8-bit commands and seven 8-bit status responses from each heliostat);

4) Provide hardware floating-point arithmetic.

These requirements will be satisfied by the production computers.

To prevent development, maintenance, or modification work from interfering with or impeding normal heliostat array testing, our system includes a development processor that will serve multiple purposes;

1) Control interprocessor communication including HAC loading;

2) Support source input, compiling, assembling, testing, and editing;

3) Allow easy input of vendor-supplied system software (by magnetic tape);

4) Provide fast hardcopy output;

5) Support software development;

6) Provide off-line processing/storage (primary storage on disc and backup storage on magnetic tape);

7) Be capable of supporting HAC operations.

Advantages to be gained through this configuration are:

1) Reduced costs through elimination of low-usage peripheral devices such as secondary storage units and separate interface consoles;

2) Reduced operator requirements (one operator can easily handle operation of all five zones through one console);

3) Reduced maintenance costs (less devices).

a. Growth Capability - The HAC will have sufficient capability for normal software growth. Our experience in projects like those listed in Table II-C-2 indicates that software requirements for core storage and functions to be executed generally increase or "grow" during development. Therefore, we have allowed processor storage and timing margins for growth. At the start of software development:

1) Projected software storage space requirements should be approximately 50% of the available processor memory;

2) Projected timing requirement for execution of software functions should be approximately 60% of available processor timing cycle capacity.

Table II-C-2 Successful Software Systems

SYSTEM	CONTROLLER	TEST LANGUAGE AND/OR SOFTWARE SYSTEM
VIKING LANDER CAPSULE SYSTEM TEST EQUIPMENT	HONEYWELL 632	VIKING TEST LANGUAGE (VTL) INCLUDED AS PART OF THE SYSTEMS TEST EQUIPMENT SOFTWARE.
SKYLAB MEDICAL DATA ACQUISITION SYSTEM	VARIAN 620 F/I	SKYLAB MEDICAL DATA ACQUISITION SOFTWARE SYSTEM.*
SKYLAB MOBILE MEDICAL DATA ACQUISITION SYSTEM	VARIAN 620R (RUGGEDIZED 620I)	SKYLAB MOBILE MEDICAL DATA ACQUISITION SOFTWARE SYSTEM.*
DIGITAL DATA ACQUISITION AND TEST SYSTEM	XDS SIGMA 5	TEST INPUT LANGUAGE TRANSLATOR (TILT) INCLUDED AS PART OF THE DIGITAL DATA ACQUISITION AND TEST SYSTEM SOFTWARE.
TITAN III DATA RECORDING AND QUICK-LOOK DATA SYSTEM	VARIAN 620L	TITAN III DATA RECORDING AND QUICK-LOOK DATA SYSTEM SOFTWARE.*
ONBOARD CHECKOUT SYSTEM	IBM 4 PI-EP	TEST-ORIENTED ONBOARD LANGUAGE (TOOL) INCLUDED AS PART OF THE ONBOARD CHECKOUT SYSTEM SOFTWARE.
MARTRON® 1200/12000 AVIONICS LRU TEST SETS	HONEYWELL H316	ATLAS LANGUAGE COMPILERS USED TO GENERATE TESTS TO RUN ON THE MARTRON® 1200/12000 SOFTWARE SYSTEMS.
MARTRON® 12 JET ENGINE FUEL CONTROLLER TEST SET	DEC-PDP11	MARTRON® TEST TRANSLATION SYSTEM (MTTS) INCLUDED AS PART OF THE MARTRON® 12 SOFTWARE SYSTEM.
TITAN III MOL COMPUTERIZED AGE	TWO SDS SIGMA 7s	CAGE TEST LANGUAGE (CTL) INCLUDED AS PART OF THE COMPUTERIZED AGE SYSTEM SOFTWARE.
TITAN III SPACE LAUNCH VEHICLE AGE	TAPE PROGRAMMER	VEHICLE CHECKOUT SET SOFTWARE SYSTEM (VECOS).

*TEST PROGRAMS–IN ASSEMBLY LANGUAGE ONLY.

b. *Instruction Cycle Requirements* - We estimate 34,000 instruction cycles per second to position 128 heliostats in both axes. This is a worst case, but our analysis indicates that for 20% of the time during midday hours this is realistic, especially for south zone heliostats. Using the projected requirements, several alternative computer configurations were evaluated for their ability to meet timing requirements. The results shown in Table II-C-3 are discussed in the following paragraphs.

c. *Computer Interrupt Levels* - For immediate MCS response such as an emergency shutdown command, multiple-level interrupts will be provided with the following priority levels:

1) MCS commands;

2) Heliostat return status messages;

3) Control algorithm calculations;

4) Interprocessor communication.

To minimize possible interference from interrupts, we will use direct memory access (DMA) for heliostat communication.

d. Floating-Point Arithmetic - There is a slight cost penalty for hardware floating-point arithmetic. An alternative is software floating point. As seen in Table II-C-3 for computer configurations F, software floating-point requires a 77% duty ratio. Considering normal software growth, this initial margin is insufficient. The floating-point hardware in this case allows an average 35% duty ratio, which is acceptable. This is the average of computers B and H for the floating-point estimates of Table II-C-3.

Table II-C-3 Computer Timing Comparison

COMPUTER MANUFACTURER	MODULAR COMPUTER SYSTEMS INCORPORATED		DATA GENERAL CORPORATION		DIGITAL EQUIPMENT CORPORATION			
COMPUTER CONFIGURATION	A	B	C	D	E	F	G	H
COMPUTER MODEL	II/25-E1	II/25-E1 HARDWARE FLOATING POINT	NOVA 3-12	NOVA 2-10	PDP 11-04	PDP 11-04 SOFTWARE FLOATING POINT	PDP 11-35	PDP11-35 HARDWARE FLOATING POINT
CONTROL ALGORITHM INSTRUCTION MIX								
47% LOAD/STORE	6.2	6.2	2.4	2.5	15.3	15.3	7.9	7.9
23% ARITHMETIC	12.4	18.6	2.6	2.8	7.5	52.5	3.9	22.0
13% SHIFT	1.9		1.4	1.4	2.9		2.9	
17% REGISTER-TO-REGISTER	2.5	2.5	0.4	0.46	1.7	1.7	0.5	0.5
% DUTY RATIO FOR CONTROL ALGORITHM INSTRUCTION/sec	23.0	27.3	6.8	7.2	27.3	69.5	15.2	30.4
% DUTY RATIO FOR /sec FOR OPERATING SYSTEM	5.6	5.6	6.3	6.3	7.2	7.2	7.2	7.2
% DUTY RATIO FOR /sec TOTAL CYCLES REQUIRED	28.6	32.9	13.1	13.5	34.5	76.7	22.4	37.6
% DUTY RATIO FOR MARGIN (100 MINUS TOTAL ABOVE)	71.4	67.1	86.9	86.5	65.5	23.3	77.6	62.4

e. Memory Estimate - The memory estimate is 5K of algorithm program, 1.5K words of operating system, and 2K words of buffer table area for a HAC software total of 8.5K words of memory; therefore we recommend at least 16K-word memory.

f. Selection of HAC Processor - The HAC processor we will use is the Modcomp II/25-E1. This selection is based on the results of an extensive study of available and applicable minicomputers. This study involved evaluation of system requirements and software requirements, development of generalized computer specifications, solicitation of responses from interested vendors, elimination of nonapplicable systems, and several conferences with the top three vendors to develop the best configurations. The top three responses were from Modular Computer Systems, Inc. (Modcomp), Data General Corporation (Nova), and Digital Equipment Corporation (PDP). All three responses were essentially the same configuration. The final ratings resulted from delivery availability, machine characteristics, and computer availability over the projected lifetime of the project. Since the machine characteristics are essentially the same, Table II-C-4 tabulates delivery dates, and computer availability. Configurations B, C, and H have floating-point hardware.

Computer availability, as shown in Table II-C-4, during the lifetime of the project will reduce maintenance costs and allow easy configuration expansion and/or modification. Only configurations B and C can really offer any continuity at this time. In order to insure schedule performance, we must be able to start using the computer within 50 days from award-of-contract. Only configuration B offers 45-day delivery. Configuration B represents the Modcomp computer as shown in Table II-C-3.

Table II-C-4 Computer Availability Comparison

COMPUTER CONFIGURATION	A	B	C	D	E	F	G	H
COMPUTER DELIVERY DATE IN DAYS FROM RECEIPT OF ORDER	45	45	60	80	90	90	90	90
COMPUTER MODEL AVAILABILITY DURING PROJECT LIFE	CURRENT MODEL	CURRENT MODEL	NEW MODEL	MODEL BEING REPLACED IN 1976	MODEL BEING REPLACED IN 1976	MODEL BEING REPLACED IN 1976	MODEL BEING REPLACED IN 1976	MODEL BEING REPLACED IN 1976

The Modcomp model II/25-E1 computer to be used in the production units offers the following capabilities:

1) Arithmetic unit;
2) Read-only control memory;
3) Modular bus control interface;
4) 16,384-word core memory (800 ns);
5) General register file (15 hardware registers);
6) Register I/O and three interrupts;
7) Operator console;
8) Rack-mountable enclosure and power supplies;
9) Hardware fill;
10) Multiply/divide;
11) Floating-point hardware;
12) Power fail-safe/automatic start;
13) Memory parity;
14) Director memory processor (DMP).

In addition to the above features, the development processor model II/26-E1 offers:

1) 32,768 words of core memory,

2) 5.2-megabyte dual-cartridge moving head disc;

3) 9-track 45-ips magnetic tape;

4) 50 to 150 lpm printer;

5) CRT operator console;

6) ASR-33 teletype console.

g. HAC Capabilities - Our HAC will provide:

1) Immediate response to MCS commands;

2) Fail-safe control of up to 128 heliostats per HAC;

3) 1-Hz service to each heliostat;

4) Control of up to six array controllers in five zones;

5) Easy access to heliostat position data for input and modification purposes;

6) Retention of standby position for each heliostat;

7) Immediate availability of station information on any heliostat;

8) MCS interface to each HAC via 9600-baud asynchronous RS-232-C line and UAR/T computer coupling.

3. Software Design Concepts

Our software system will meet or exceed the requirements for response to the MCS, provide fail-safe control of up to 128 heliostats per HAC, perform all required computations, and be easily modified. Through its interdevice communication concept it will minimize both operational and physical requirements. It will maximize use of off-the-shelf vendor software thereby minimizing development effort and risk.

Our software will be modular and use high-order language in the development phase. Modular software greatly reduces maintenance and modification costs and allows parallel and simultaneous group programming through careful module interface definition.

a. Software Planning - The phases and documentation of Figure II-C-6 will provide systematic development of the software subsystem. The documentation will provide easily understood system definition and user instruction *before* system delivery. Our software system plan will assure the orderly hardware/software event relationship of Figure II-C-7 that shows how we will coordinate HAACS development.

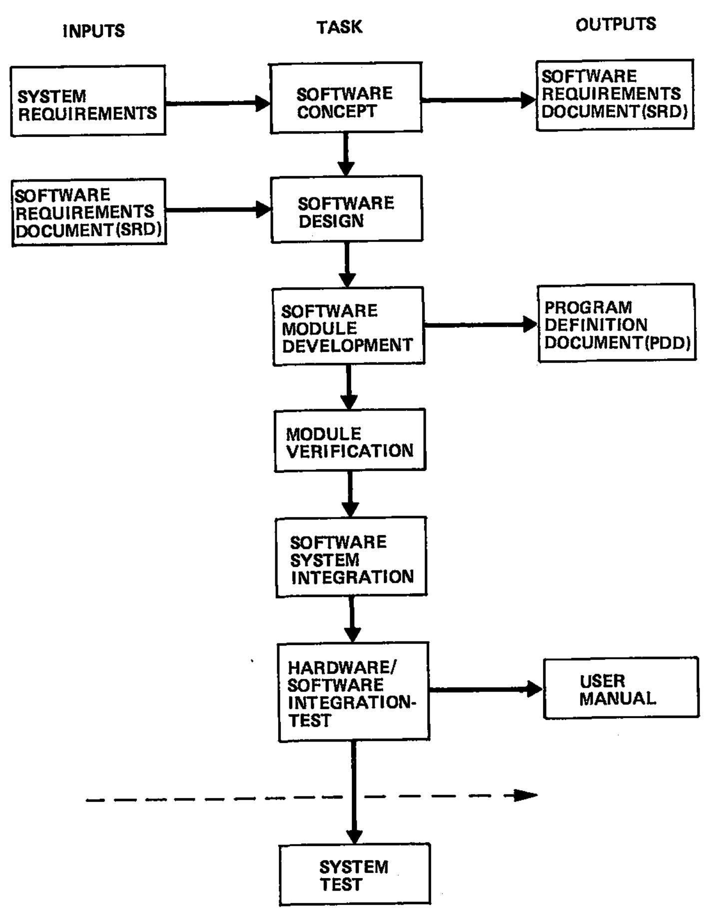


Figure II-C-6 Software Planning Guide

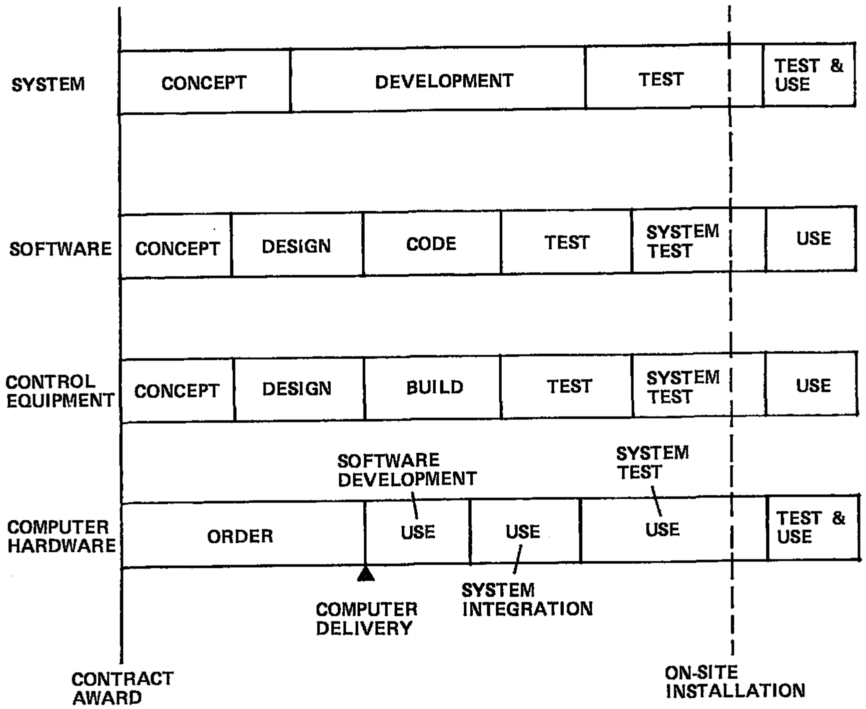


Figure II-C-7 Hardware/Software Event Relationship

b. Software Requirements Document - Software requirements will be developed and published in the Software Requirements Document (SRD). Volume IV, Addendum IV is a preliminary version of the SRD. The SRD will be a comprehensive definition of total software requirements and will be presented to the customer for review.

Technical information exchange will be provided through the SRD. As shown in Figure II-C-6, the SRD is one of three documents we will provide. We will also provide the Program Definition Document (PDD) and the User's Manual. All three will be used regularly to discuss our design.

c. Software Categories - We have identified the following five software categories:

1) On-line heliostat control;

2) Off-line heliostat control;

3) Heliostat communication control;

4) System communication control;

5) Heliostat encoder offset correction.

In the design phase, we will group these five categories into three units:

1) Heliostat control algorithms;

2) Communication control;

3) Calibrate update.

The first unit, heliostat control algorithms, will contain the logic to position the heliostats (categories 1 and 2). The second unit, communication control, will contain the logic to control data and message interchange between MCS and HAC and between HAC and heliostats (categories 3 and 4). The third unit, calibration update, will incorporate encoder offset data from MCS or through a development processor console (category 5).

The design of the three software units will be based on the SRD. This design will include the development of detailed flow charts as a part of the PDD. Derived from the SRD, the flow charts consist of the exact (not functional) programming requirements in the form of detailed flow diagrams and equations. The PDD will guide actual coding activity.

The PDD will also provide the basis for our verification program (see Section I) which describes the necessary tests to assure that the coded program is in exact "one-for-one" correspondence with the program requirements. After the program is coded and verified, the validation or system test phase will be entered. At completion of validation, the software will be certified for operational use.

d. Software Discipline - Our software discipline will assure that the program specifications have a logical modular structure and that standards are developed and rigorously enforced. Specifications will be precisely satisfied—no deviations will be allowed without a specification change. Consistent nomenclature will be used throughout and programmer comments will be mandatory to make the code readable. Program module test plans will be documented before coding starts.

A vital part of our software discipline is configuration control to prevent deviations between code and specifications. Configuration control problems that may be discovered during software testing are of two types:

1) Program errors that require coding changes for compliance with the specification;
2) Specification errors that require a specification change before recoding.

Modular programming techniques facilitate configuration control. As modules are completed, testing will demonstrate specification compliance. Testing will consist of verification and validation phases. The verification phase will show that:

1) The code complies with the SRD;

2) The code is error free;

3) The code is complete.

Manual verification will be performed before software system integration by extensive desk checking, visual code review, and correlation with the SRD.

Each module will be validated using open-loop checks of function code paths. Once the functional operation of each module has been shown, the modules will be integrated and system validation will be performed to show:

1) Functional operation of all of the modules working together as an integrated software system;

2) That functional performance of the integrated software system complies with the SRD.

Following system integration, but before delivery, extensive system simulations using HCEs and HACs will prove the integrity of the integrated system.

e. *Minimum Software Development Costs* - All of the software development, verification, and validation will be done in Denver and will use the computational facilities and experience of Martin Marietta. Preliminary hardware/software integration and test activities will also be done in Denver. All hardware/software interfaces will be fully developed and tested before delivery to insure the operational integrity of the total HACSS. By using currently available Modcomp computers, we can initiate software development immediately on award of contract. Furthermore, we will benefit from Modcomp computer interprocessor communication and digital control software developed by Martin Marietta for the Bureau of Reclamation Central Valley hydroelectric control project.

f. *System Usability* - Before system delivery, all user documentation will be developed and used. The user manuals will be submitted for customer review. All system operation procedures will be fully defined. Modular system generation procedures will be fully documented. After system delivery, software can be easily modified because of the use of modular programming and a higher order language such as Fortran.

g. *Software Development Schedule Integrity* - To ensure schedule maintenance, we will conduct weekly status meetings that will show total contract performance to management. Our past success in maintaining schedules in similar software tasks demonstrates our effective management.

Martin Marietta leads in the design and operation of computer-controlled control, automatic checkout, and status monitoring systems. Some of these systems are itemized in Table II-C-2.

We are currently using modular programming and our described disciplines in three other similar projects: the Central Valley hydroelectric control system, programmable automatic checkout equipment (PACE), and a launch checkout and control monitor subsystem (LPS).

4. Software Details

Our software will use the data flow scheme of Figure II-C-8 to provide maximum flexibility in heliostat operation. The MCS/HACSS interface via UAR/T will use the highest priority of the HAC computer interrupt circuits for the fastest response possible to MCS commands, yet maintain 1-second service of each heliostat. A user at an MCS keyboard will be able to elicit HAC response. HAC software will respond to all errors that software can recognize or intercept. It will either correct such errors or alert personnel for action.

a. HAC Console Capability - Every production HAC will be able to communicate bidirectionally with either console attached to the development processor. Two consoles will be provided--one a CRT and the other a standard teletype. The CRT will allow source program data to be input and edited, while the teletype will be used primarily for operator control of the production HACs. Each production HAC will load rapidly from the development processor disc, thereby avoiding individual loading devices.

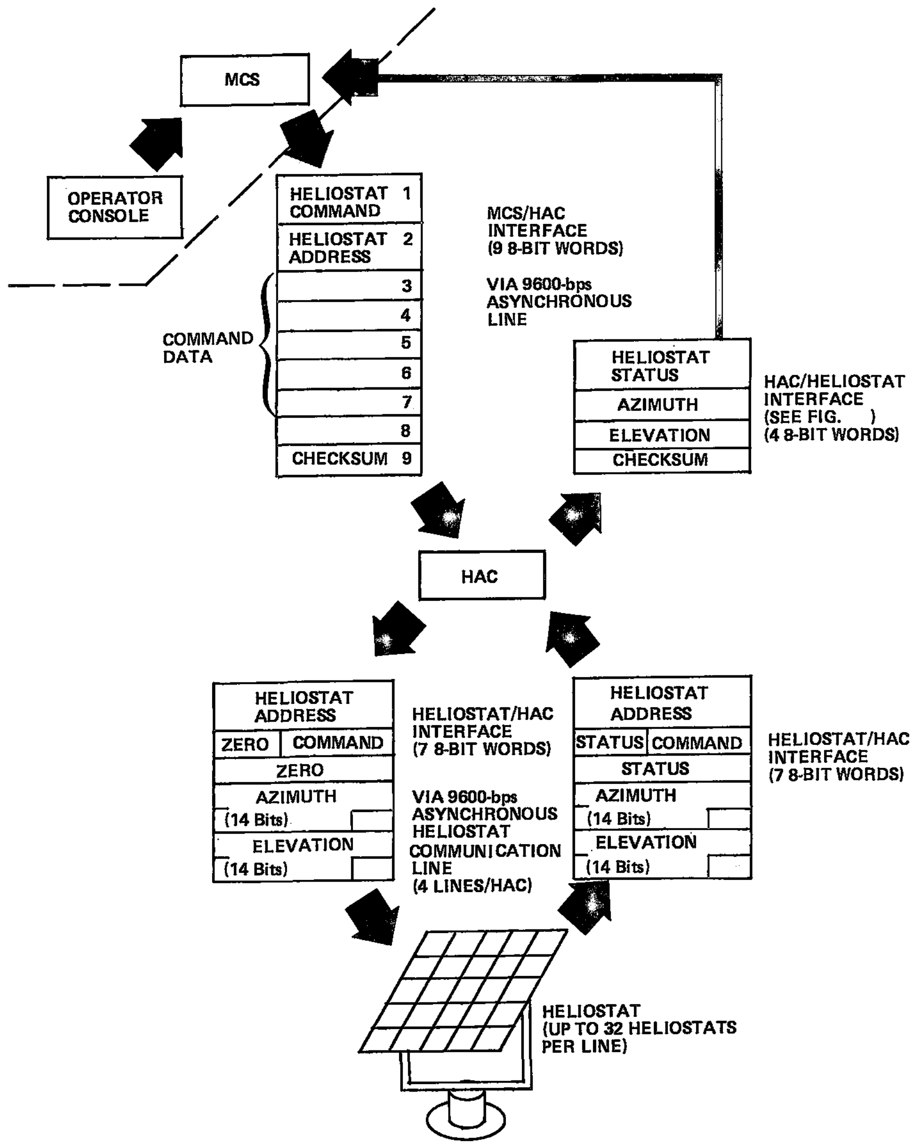


Figure II-C-8 System Data Flow

Our system will allow keyboard insertion of heliostat encoder zero offset data from the HAC and easy user operational control of the software system. If MCS is off-line, heliostats can be controlled through a development processor console. Our software will provide console responses to user keyboard requests for commanded or actual azimuth, elevation, or status.

b. MCS-HAC-HCE Communication - Except for the MCS EMERGENCY STOW command that will apply to all the HAC-assigned heliostats, MCS heliostat commands address a particular heliostat. For an MCS heliostat command to be acceptable to a HAC, it must be immediately preceded by a CLEAR command addressed to the same heliostat.

Every HAC, as it starts up, will come on line transmitting CLEAR commands to every assigned heliostat at 1-second intervals, using the heliostat interface command (HIC) format of Figure II-C-9. Every HAC will continue thus until instructed otherwise by acceptable MCS commands. At the addressed heliostat, CLEAR will stop the motors and clear the HCE status registers.

When energized, every HCE will come on line with cleared mode registers and motors off by means of a CLEAR command from an internal power turn-on initialization (PTOI) circuit. Therefore the HAC-HCE turn-on sequence is designed to be safety oriented.

Every HCE will reply (using the HIC format) with status, azimuth, and elevation data in response to any HAC command. Thus HAC will be fully informed on all assigned heliostats 1 second after it comes on line and at 1-second intervals thereafter. A heliostat with power turned off or experiencing a power failure will identify itself with a missing reply.

Heliostat commands are defined in Figure II-C-9. HAC will relay every acceptable MCS command to the addressed heliostat within 1 second after receipt and continue to transmit these commands at 1-second intervals until new commands are issued by the MCS. Thus a data error from transmission problems will be corrected 1 second later.

7	6	5	4	3	2	1	0
A			B				
C	D	E	F	G			
H				J			
K							
L						M	
N							
P						R	

HELIOSTAT INTERFACE COMMAND

A = LINE DESIGNATOR PORTION OF HELIOSTAT ADDRESS
B = 5-BIT HELIOSTAT ADDRESS (32 DEVICES PER LINE)
C = 0 SUN AVAILABLE
1 SUN NOT AVAILABLE
D = 0 HELIOSTAT UNDER MCS CONTROL
1 HELIOSTAT IN MANUAL CONTROL (WILL NOT RESPOND TO ANY COMMAND)
E = HELIOSTAT ELECTRONICS RECEIVER ERROR CONDITION
0 IS NO ERROR
1 INDICATES ANY OR ALL OF THE FOLLOWING:
1) LOSS OF LINE SYNCHRONIZATION
2) PARITY ERROR
3) FRAMING ERROR (LOSS OF PROPER STOP BIT)
4) OVERRUN (TOO MANY DATA BITS BEFORE STOP BIT)
F = SPARE (1 BIT ZERO)
G = HELIOSTAT COMMAND (SEE TABULATION)
*H = AZIMUTH GIMBAL STATUS (SEE BELOW)
*J = ELEVATION GIMBAL STATUS (SEE BELOW)
†K = AZIMUTH POSITION (UPPER 8 BITS)
†L = AZIMUTH POSITION (LOWER 6 BITS)
M = SPARE (2 BITS-ZERO)
†N = ELEVATION POSITION (UPPER 8 BITS)
†P = ELEVATION POSITION (LOWER 6 BITS)
R = SPARE (2 BITS-ZERO

GIMBAL STATUS (FIELDS H AND J)

Bit 1 (rightmost):
0 POSITION COMPARE (NO GIMBAL MOVEMENT)
1 GIMBAL MOVEMENT

Bit 2:
0 NO LIMIT REACHED CLOCKWISE (CW)
1 LIMIT REACHED CLOCKWISE

Bit 3:
0 NO LIMIT REACHED COUNTERCLOCKWISE (CCW)
1 LIMIT REACHED COUNTERCLOCKWISE

Bit 4 (leftmost):
0 CLOCKWISE MOVEMENT (NORMAL GIMBAL ACTION)
1 COUNTERCLOCKWISE MOVEMENT (NORMAL GIMBAL ACTION)

*HAC WILL ISSUE ALL ZEROES IN THIS FIELD AND HCE WILL INSERT REQUIRED STATUS VALUES
†HAC WILL ISSUE POSITION COMMAND AND HCE WILL INSERT ACTUAL POSITION

HELIOSTAT COMMAND TABLE

FIELD G OF HIC BINARY VALUE	COMMAND	HELIOSTAT RESPONSE
0000	STATUS	NO PHYSICAL ACTION BY HELIOSTAT. THE ENTIRE CONTENTS OF THE HELIOSTAT CONTROL ELECTRONICS (HCE) REGISTERS ARE RETURNED TO HAC.
0001	CLEAR	ALL HCE MODE REGISTERS ARE CLEARED AND ALL MOTORS ARE STOPPED.
0010 0011	SPARE SPARE	RESERVED FOR FUTURE USE.
0100	COARSE-TRACK AZIMUTH	AZIMUTH SLEW MOTOR IS ACTIVATED IN CLOSED-LOOP OPERATION. DEADBAND OF AZIMUTH COMPARATOR IS CHANGED TO 0.012 RADIAN.
0101	COARSE-TRACK ELEVATION	ELEVATION SLEW MOTOR IS ACTIVATED IN CLOSED-LOOP OPERATION. DEADBAND OF ELEVATION COMPARATOR IS CHANGED TO 0.012 RADIAN.
0110	FINE-TRACK AZIMUTH	AZIMUTH TRACK MOTOR IS ACTIVATED IN CLOSED-LOOP OPERATION WITH FULL 14-BIT COMPARATOR.
0111	FINE-TRACK ELEVATION	ELEVATION TRACK MOTOR IS ACTIVATED IN CLOSED-LOOP OPERATION WITH FULL 14 BIT COMPARATOR.
1000	DIRECT SLOW AZIMUTH CW	THESE COMMANDS TURN ON RELATED AXIS TRACK MOTOR. ONLY LIMIT SWITCHES OR CLEAR COMMAND WILL TURN MOTOR OFF.
1001	DIRECT SLOW AZIMUTH CCW	
1010	DIRECT SLOW ELEVATION CW	
1011	DIRECT SLOW ELEVATION CCW	
1100	DIRECT SLEW AZIMUTH CW	THESE COMMANDS TURN ON RELATED AXIS SLEW MOTOR. ONLY LIMIT SWITCHES OR CLEAR COMMAND WILL TURN MOTOR OFF.
1101	DIRECT SLEW AZIMUTH CCW	
1110	DIRECT SLEW ELEVATION CW	
1111	DIRECT SLEW ELEVATION CCW	

Figure II-C-9 Heliostat Interface Command (HIC) Definition

Heliostat motion will not occur if the actual and commanded angles are equal. The absolute encoders on both heliostat axes assure nonvolatile position feedback sources. Heliostat movement in 1 second will not exceed 0.4315 mrad in the fine-track mode. Up to three erroneous data transmissions to any given heliostat can be tolerated without exceeding minimum pointing requirements (1.5 mrad). The heliostat movement status bit will be monitored to detect runaway.

c. *Encoder Offset Correction and Standby Position Storage* - Our software will have two zero offsets and standby position associated with its attribute table as shown in Figure II-C-10. The offsets may be manually input via the HAC console or transferred from the MCS. They will be used to correct the commands before issuance. The desired heliostat positions will be calculated using the heliostat control algorithm and the sun position issued by the MCS every second.

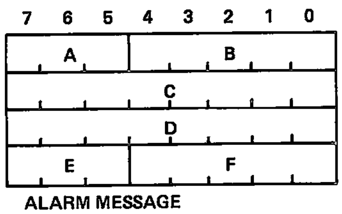
d. *Heliostat Movement Control* - On-target pointing will be to within 1.5 mrad (see K93681, para 3.1.4.3.b) and the position will be updated on

HELIOSTAT ATTRIBUTE TABLE REQUIRES 2048 WORDS CONSISTING OF 128 ENTRIES OF 16 16-BIT WORDS EACH WITH EACH ENTRY CONTAINING THE FOLLOWING:

WD		
0	C1, 1	CURRENT POSITION DATA
1	C1, 2	CURRENT POSITION DATA
2	C2, 1	CURRENT POSITION DATA
3	C2, 2	CURRENT POSITION DATA
4	C3, 1	CURRENT POSITION DATA
5	C3, 2	CURRENT POSITION DATA
6	X STDBY	STANDBY COORDINATES
7	Y STDBY	STANDBY COORDINATES
8	Z STDBY	STANDBY COORDINATES
9	X LIB	HELIOSTAT INITIAL COORDINATES
10	Y LIB	HELIOSTAT INITIAL COORDINATES
11	Z LIB	HELIOSTAT INITIAL COORDINATES
12	AZIMUTH	SAFE STOW COMMAND
13	ELEVATION	SAFE STOW COMMAND
14	AZIMUTH	ENCODER OFFSET CORRECTION
15	ELEVATION	ENCODER OFFSET CORRECTION

Figure II-C-10 Heliostat Attribute Table (HAT) a 1-second basis. Large standby and on-target movements will result in a coarse commands (K93681, para 3.1.4.3.a) until fine tracking limits have been achieved. HAC software will insure stowed to standby and standby to on-target positioning well within the required 15-minute limit (K93681, para 3.1.4.4.a and 3.1.4.4.c). HAC software will be able to stow any assigned heliostat autonomously or by MCS command. Stowing will require less than 15 minutes in accordance to K93681, paragraph 3.1.4.4.f. In all cases, unsafe target zones will be avoided to prohibit possible harm to facilities and personnel. For emergency stowing, our software will command for each heliostat the quickest safe path based on its current position. Safe zones will be determined at heliostat installation and their position data will be input to each controlling HAC and maintained in the heliostat attribute table.

e. Sun Obscuration - Our system will provide a sun-present sensor (SPS) for at least every 10 heliostats in each zone. This sensor will provide control of the sun-availability bit in field C of the HIC as shown in Figure II-C- 9. If this bit is set, the assigned heliostats will be told to stand by. This includes the heliostat with the sensor (K93681, para 3.1.4.4.c). An alarm message "2" (Fig. II-C-11) will be transmitted from the HAC to MCS for each obscured heliostat and each will remain in standby until commanded otherwise by the MCS.



A = HAC ADDRESS
(3 BITS, BINARY 0–5)

B = SPARE (5 BITS)

C = HELIOSTAT ADDRESS (8 BITS)
(ZERO IF MULTIPLE-HELIOSTAT FAILURE)

D = HELIOSTAT STATUS
(10000000 = FAULT DETECTED
SEE K93681 FIGURE 4)

E = INDICATES LINE NUMBER OF
HELIOSTAT FAILURE–3 BITS
(= 111 IF ALL LINES DETECTED
IN FAILURE)

F = 00000 - ALL HELIOSTATS FAIL TO RESPOND
(FIELD C = ZERO)
00001 - HELIOSTAT OBSCURED (STANDBY
COMMAND ISSUED)
00010 - HELIOSTAT FAILURE (WILL NOT
RESPOND)

Figure II-C-11 HAC/MCS Alarm Message

f. Total Versatility - Our proposed system will support simultaneous operation of up to five heliostat zones using six HACSS. This system will provide adequate computation, communication and control for up to 128 heliostats per HACSS and service each heliostat once a second. Although this configuration will meet or exceed operational requirements, it will provide an easy expansion capability without affecting current system design and operation. Our system will provide maximum versatility and reliability.

g. Minimum Overall Costs - This HAC will minimize cost for the life of the project. By using as many off-the-shelf units as possible, development expense will be minimized. Hardware floating point will significantly reduce software development costs. Sufficient storage and timing margins will prevent outgrowing hardware. A multiple-interrupt capability provides top priority to the MCS, assuring fail-safe system response.

5. Manufacturing

Manufacture of the HACSS will consist of building HIM chassis and assembling these into the HIM rack, building cables that connect the computers with the HIM rack, connect to facility power, and distribute data. The computers and their peripherals, including the interconnecting wiring, will be bought from the supplier as an integrated assembly.

The HIM will contain integrated circuits and discrete components mounted on printed circuit (PC) boards. These PC boards will be assembled, and then tested in our Denver facility. This existing facility has the capability, in both equipment and personnel, to build and deliver HACSS hardware on schedule and at minimum cost. Close coordination will be maintained with the designers to promote use of proven available techniques and processes developed in other ground equipment contracts.

Cable assemblies will be fabricated by experienced personnel using standard soldering/crimping and connector assembly procedures.

Final acceptance testing will use an existing automated test system that has proved to be the fastest and most economical for this type of equipment.

All fabrication operations will be controlled by manufacturing process plans that indicate to fabrication and inspection personnel the fabrication operations, mandatory inspection points, applicable engineering documents, special handling requirements, and provisions for indicating completion and acceptance of fabrication operations. The plans will be used to support engineering requirements in the most economical manner. Figure II-C-12 depicts assembly flow for fabrication of the HIM rack.

6. <u>Interfaces</u> - Interfaces between the HACSS and other subsystems are discussed in the following. The electrical interfaces are described in Section G.4.

a. HACSS/MCS Interfaces - Communications between MCS and HACSS will be on a full duplex basis. MCS will transmit commands and sun position data to HACSS. HACSS will return the same

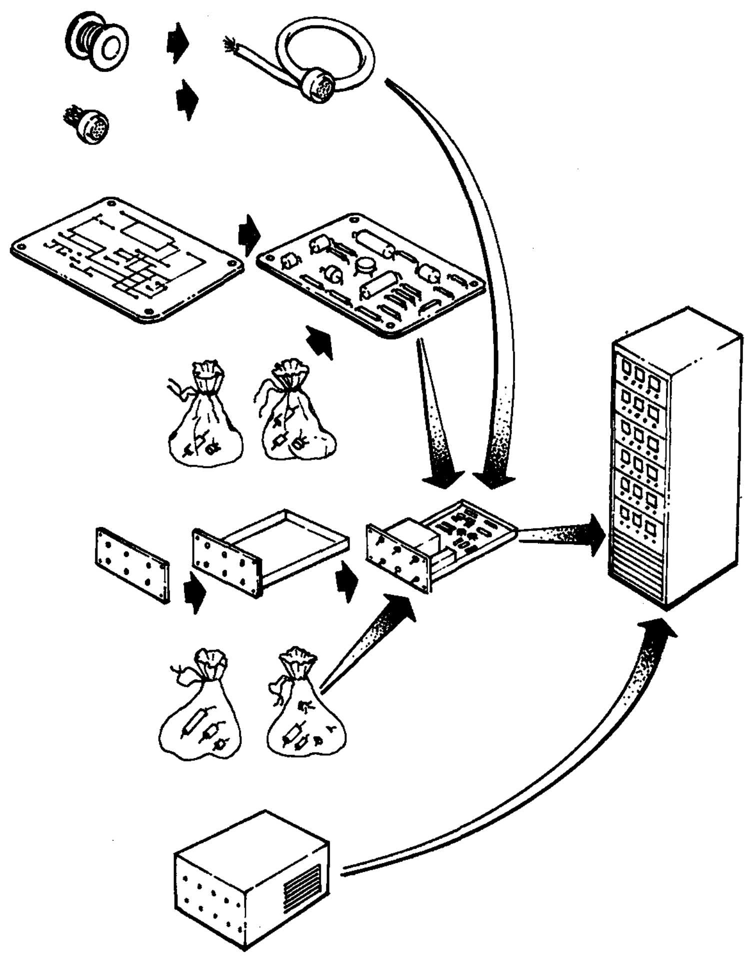


Figure II-C-12 Fabrication of the Heliostat Interface Module

commands and sun position data to HACSS. HACSS will return the same commands and sun position data to MCS. HACSS will transmit heliostat position and status data to MCS on request.

The MCS will transmit to HACSS as follows:

1) In format compatible with UAR/T components;

2) At a 9600-baud maximum data rate;

3) With even parity.

Signal levels and designations will confirm to EIA RS-232-C. Table II-C-5 lists each command, associated parameters, and a description of HACSS action. Each command string is composed of a block of nine 8-bit data words. Parity is determined and transmitted (received) via the UAR/T component. Each communication word will consist of a start bit followed by the eight data bits—least significant data bits first, followed by the parity bit, followed by one stop bit for a total of 11 bits. All binary quantities that can be negative will be represented in two's complement form. The first word of the command string is the command word, as shown in the left-hand column of Table II-C-5. Depending on the command, additional parameters will be transmitted as shown in Table II-C-5. For all binary data words, bit 7 will be the most significant. The last word of the command string will be the checksum word, which is the two's complement of the sum of the previous words (i.e., binary addition of all words in the string produces zero). All data words will be passed as binary counts, each count representing units such as 0.01 m, 0.0001 rad, etc. HACSS will be compatible with the format of Table II-C-5.

Table II-C-5 MCS/HACSS Interface Formats

COMMAND WORD (BINARY CODE, COMPUTER REGISTER)	PARAMETERS TRANSMITTED TO HACSS (BY MCS)	ACTION BY HACSS IN RESPONSE TO COMMAND WORD
CLEAR (00000001)	HELIOSTAT ADDRESS	CANCELS CURRENT COMMAND TO ADDRESSED HELIOSTAT, IF ANY; ENABLES NEW COMMANDS TO BE ACCEPTED. HELIOSTAT STOPS AT CURRENT POSITION.
STANDBY (00000011)	HELIOSTAT ADDRESS AND AIMING POINT	ADDRESSED HELIOSTAT WILL BE MOVED TO SPECIFIED POSITION.
ON-TARGET (00000101)	HELIOSTAT ADDRESS AND AIMING POINT	ADDRESSED HELIOSTAT WILL BE MOVED TO SPECIFIED POSITION.
STOW (00001001)	HELIOSTAT ADDRESS	ADDRESSED HELIOSTAT WILL MOVE TO ITS FIXED STOWAGE POSITION.
EMERGENCY SHUTDOWN (10000001)	NONE	RETURNS ALL HELIOSTATS TO STOWAGE.
STATUS (00010001)	HELIOSTAT ADDRESS, STATUS, AZIMUTH POSITION, ELEVATION POSITION, AND SUN AVAILABILITY	CURRENT STATUS OF ADDRESSED HELIOSTAT WILL BE TRANSMITTED TO MCS
SUN POSITION (00100001)	SUN AZIMUTH AND ELEVATION IN RADIANS	INFORMATION ONLY; NO ACTION REQUIRED. TRANSMITTED FROM MCS AT ONE-SEC INTERVALS. THE SUN POSITION DATA ARE CORRECTED FOR REFRACTION PRIOR TO TRANSMITTAL.
NOTE: ALL INTERFACE SIGNALS DO NOT HAVE TO BE USED AS LONG AS OPERATIONAL MODES CAN BE ACCOMPLISHED.		

Missed Standby position without command / Sun sensor

The HACSS will transmit to MCS as follows:

1) In format compatible with UAR/T components;

2) At a 9600-baud maximum data rate;

3) With even parity.

Signal levels and designations will confirm to EIA RS-232-C.

HACSS will format heliostat status and position data as shown in Table II-C-6 for transmittal to MCS.

Table II-C-6 Heliostat Status and Position Data Format

STATUS TRANSMISSION - HACSS TO MCS

BIT	7 6 5 4 3 2 1 0
WORD 1	STATUS
WORD 2	AZIMUTH
WORD 3	ELEVATION
WORD 4	CHECKSUM

WORD 1	STATUS:	BIT 0 = IN TRANSIT TO CONDITIONS INDICATED BY BITS 1-3 BIT 1 = STOW POSITION BIT 2 = STANDBY POSITION BIT 3 = ON-TARGET BIT 4 = (UNASSIGNED) BIT 5 = MANUAL CONTROL BIT 6 = SUN AVAILABLE BIT 7 = FAULT DETECTED BY HACSS
WORD 2	AZIMUTH:	POSITION DATA (8 BITS) BIT 0 = LSB
WORD 3	ELEVATION:	POSITION DATA (8 BITS) BIT 0 = LSB
WORD 4	CHECKSUM:	SAME FORMAT AS DESCRIBED IN 3.1.1.1(a).

NOTE: 1. CORRESPONDING STATUS BIT IS SET IF CONDITION IS TRUE.
2. IF STATUS BIT 5 IS SET, OTHER BITS IN STATUS WORD ARE NOT NECESSARILY VALID.

b. HACSS/HASS (HIM-HCE) Interfaces - The data interfaces between HACSS and HASS are shown in Figure II-C-13. HAC will output data through an optically coupled isolator to a differential current-mode line driver. The line driver will interface with a twisted shielded pair that runs approximately 600-m (1969 ft) maximum to the first of 32 heliostats. Differential line receivers will receive the serial data at each heliostat. Each receiver will be isolated from the electronics in each heliostat by optical couplers and isolated power supplies.

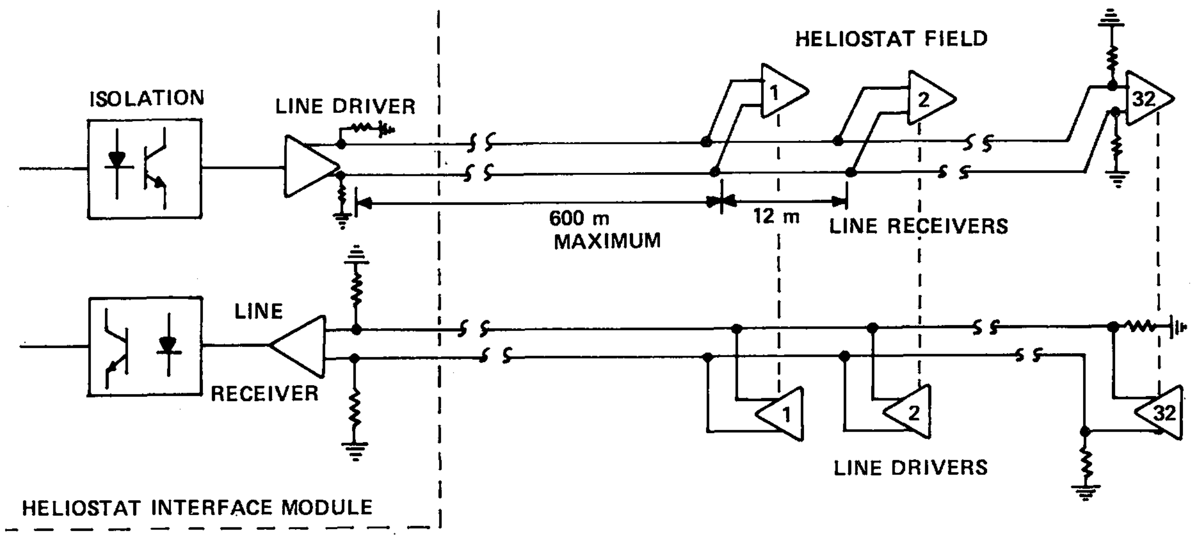


Figure II-C-13 Typical Interface between Heliostat Interface Module and Heliostat Control Electronics

HAC/HIM output will be messages consisting of 7 characters (a character is the basic word made up of 8 bits). A character format will be used that consists of 8 bits of data, 1 parity bit, 1 start bit, and 2 stop bits (refer to Fig. II-B-23). This scheme is being used on other long-line computer/peripheral interfaces at Martin Marietta with excellent results. The first character of the message will consist of 5 address bits, a sync bit, and 2 spare bits. Every heliostat will receive this character. One of the 32 decoders looking at this character will recognize it and open a gate accepting the next 6 characters. Each of these characters will contain 8 bits of data. The data will be marking one for 10 bit times prior to the start of a block of

32 messages (a message is the group of 7 characters), and for 5 bit times between messages. This will synchronize all 32 receiving heliostats to start looking for an address. If the first character of the message does not contain the proper sync bit, the character will be rejected until a character with the proper sync is received.

A block of 32 messages will be sent once a second to all four groups of 32 heliostats.

The return data format will be the same as the received data. A separate line for 32 line drivers will be provided. Only one three-state driver will be active or enabled at one time. Thirty-one drivers will be in a high-impedance output state while one is active. A particular heliostat line driver will go active at acceptance of that heliostat address. It will go inactive at the completion of data tranmission from that heliostat. The required data rate between the HAC and the heliostats is computed as follows, assuming an 8-bit data word, 1 start bit, 2 stop bits, and a parity bit:

(12 bit/word)x(7 words/message)x(32 messages) ÷ (1 s - 170 bit times) = 2858 baud.

The maximum transmission rate capability of the 6-mA current driver in conjunction with our line lengths is calculated by the following:

1) 600 m from HAC to field;

12 m x 32, spacing between heliostats;

3 m x 32, stub lengths;

180 m, total line length.

Capacitance per meter of twisted shielded pair (Belden 8227) is approximately 50 pF. Total line capacitance = 50 x 1080 = 54000 pF. Driver output current capability - load = 6.5 mA - 32 (0.150) = 4.8 mA.

The time to translate through a 0.025 V receiver sensitivity band is

$$t = \frac{54000 \times 10^{-12} (.026)}{.0048} = 0.28\ \mu S.$$

Considering that data should be allowed to stabilize for at least 4 times the translation time, this would give an effective data rate of

$$\frac{1}{4(0.28)10^{-6}}$$

or 890 kilobaud. This number agrees with both manufacturers' data regarding the capability of this part and our test results.

In conclusion, the above calculations show the long-line system is capable of data rates far in excess of the 2.858 kilobaud requirements.

c. HACSS/CSS Interface - A functional interface will exist between the HACSS and the calibration subsystem (CSS) during the calibration sequence. HACSS will position the heliostat to focus incident solar rays on the target. The MCS will send the necessary pointing commands to HACSS during all phases of calibration, including beam quality checks and determination of beam energy distribution across the face of the target.

The azimuth and elevation encoders will have residual offsets that must be measured and compensated for to point and track accurately. This measurement will be performed during initial calibration operations. Encoder azimuth and elevation offset data will be recorded when the heliostat is pointed on target. The offset data will be stored in HAC memory for subsequent heliostat pointing.

III. Program Control Plan

III. PROGRAM CONTROL PLAN

A. PROGRAM MANAGEMENT AND CONTROL

Application of proven management control techniques will assure meeting the HAACS program requirements. The two key-elements of meeting the program requirements are a strong and aggressive program manager supported by an experienced program team and by the employment of dynamic scheduling and techniques that control where the program is going as opposed to reporting and monitoring work that has already transpired.

As previously identified in the Key Personnel section of this proposal Marx Hintze has been identified as the program manager. His program team is made up of senior specialists in the functional areas of engineering, contracts, procurement, planning and control, configuration management, finance, manufacturing and test, and quality control. These senior specialists will be assigned to Mr. Hintze during the time needed for their particular specialties. Additional support, as required by the individual lead specialist, will be provided from our central organizations to assure proper and efficient staffing and destaffing throughout the life cycle of the program.

Staffing and destaffing plans will be coordinated with the Sandia Laboratories project manager before being implemented. Charters and procedures of the program staff are well defined and can be provided on request. To assure daily communication with each member of his staff outside of normally required meetings, the program manager will conduct a daily early morning standup meeting. It is our plan to initiate a weekly telecon status meeting with the Sandia Laboratories HAACS project manager.

The HAACS program presents challenging schedule requirements. Our plan for accomplishing the total program described in the RFQ is shown in Figure III-1. The schedules for all options are in Volume III (Cost Proposal). The primary areas of concern are:

1) The short time available in which to have our system ready for installation in Zone A - 6 1/2 months;
2) The build and assembly rate required to support the required installation schedules, specifically the heliostat assemblies, the heliostat control electronics assembly, and the drive mechanism. We will have to reach a rate of 20 completed units per week;
3) Our ability to align and focus heliostats at the required rates for the various zones - up to four per day.

In recognition of these schedule concerns we will take the following actions to prevent them from becoming schedule problems:

1) Establish priorities for release of engineering to enable the procurement and manufacturing actions to get a jump on the critical-path items. For the heliostat assembly we have much of the engineering available now, and will use some of the same engineering generated in the CRSTPS program;
2) Select suppliers who have proven capabilities to meet our delivery rate requirements and, if required, will have a second source as insurance;

our cost control approach. The key issues in making any cost control system work is the issuance of realistic budgets that can be accurately measured against performance. Budget adjustments shall not be made without the concurrence of Mr. Hintze.

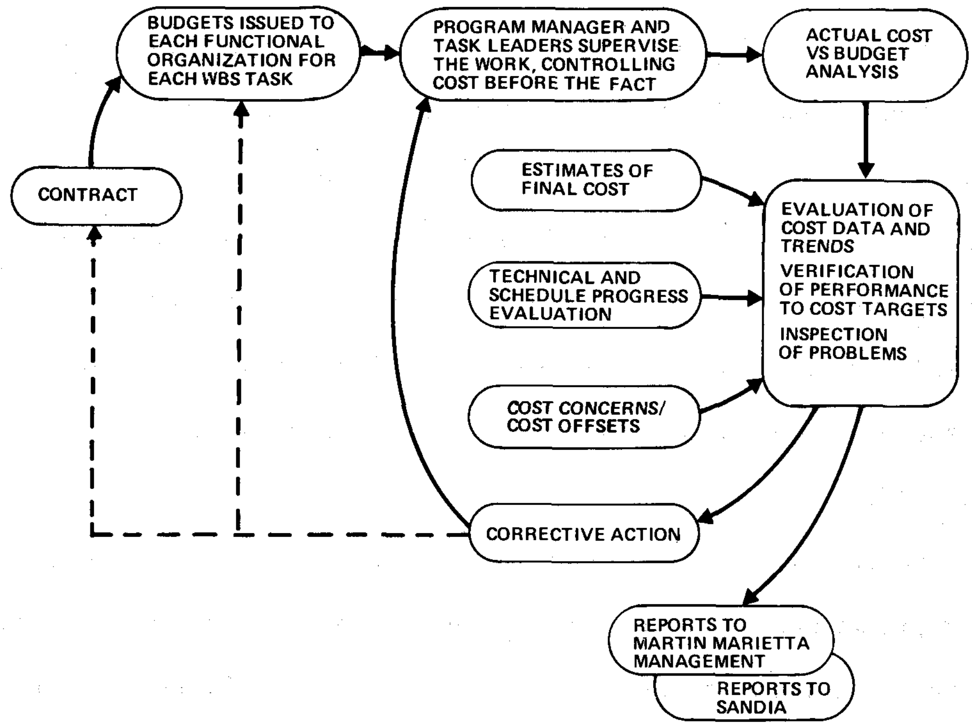


Figure III-2 Program Cost Control

B. PROCUREMENT/SUBCONTRACT

Application of existing proven hardware at the component level and commercial standards for structural and electrical raw materials will assure meeting the HAACS program requirements. Our procurement plan is formulated to provide such hardware and raw materials in a fixed price environment to the maximum extent.

Vendor and subcontracted items account for a significant portion of the total program costs. For economic reasons, we plan selected fabrication of details and major subassemblies near the point of use in Albuquerque. A technical and managerial discussion of our choice of off-site fabrication of the major structures portion of the HAACS is discussed in Volume II, Chapter III.A.

We have a government-approved and audited procurement system. Our procurement system provides the tools, systems, and associations required to meet without exception the clauses identified in the RFQ terms and conditions. Therefore, such items as "make and buy," small business subcontracting, labor surplus area subcontracting, minority business enterprise subcontracting, and equal opportunity are well established as a part of our procurement operations. What this means to the HAACS program is that we will use an existing proven organization structure and procurement system to provide the source selection, contracting, and most important, cost control, for items purchased or subcontracted for. These items are identified in Tables III-1 thru III-4.

Table III-1 Heliostat Array and Control System Equipment List for Assembly and Installation

ITEM	MAKE OR BUY	ON-SITE ASSEMBLY AREA QUANTITY	STORAGE AREA QUANTITY	DESIGN
1. MIRROR RACK ASSEMBLY FIXTURE	MAKE	2		MARTIN MARIETTA
2. MIRROR DOLLY	MAKE	2		MARTIN MARIETTA
3. MIRROR MODULE TRANSPORTER	BUY	2		MARTIN MARIETTA
4. 1-Ton PICKUP	LEASE			
5. SPREADER BAR/SLING	MAKE	2		MARTIN MARIETTA
6. WELDER	MARTIN MARIETTA-AVAILABLE	3		
7. SIDEWINDER GRINDER	MARTIN MARIETTA-AVAILABLE	2		
8. FORKLIFT	BUY	1		STANDARD CATALOG ITEM
9. ACETYLENE TORCH UNIT	MARTIN MARIETTA-AVAILABLE	1		
10. GLASS SUCTION GRIPS	BUY	12		STANDARD CATALOG ITEM
11. RTV MIXER AND DISPENSER	BUY	3		STANDARD CATALOG ITEM
12. ADJUSTABLE FLOOR STAND	MARTIN MARIETTA-AVAILABLE	30		
13. STORAGE RACKS	MARTIN MARIETTA-AVAILABLE	200 ft^2		
14. FLOOR-MOUNTED DRILL PRESS	MARTIN MARIETTA-AVAILABLE	1		
15. PEDESTAL OR BENCH GRINDER	MARTIN MARIETTA-AVAILABLE	1		
16. FORKLIFT	BUY		1	STANDARD CATALOG ITEM
17. SPREADER BAR/SLING (YOKE)	MAKE		1	MARTIN MARIETTA
18. VANS, STORAGE	LEASE		2	
19. FLATBED TRUCKS	LEASE		2	
20. TRANSIT SET	MARTIN MARIETTA-AVAILABLE		1	
21. 1-Ton PICKUP	LEASE		1	
22. OFFICE TRAILERS-EQUIPPED	LEASE		2	
23. YOKE TRANSPORTER	BUY		1	MARTIN MARIETTA
24. MIRROR MODULE TRANSPORTER	BUY		1	MARTIN MARIETTA
25. PORTABLE LIGHTING SYSTEM	LEASE		1	
26. STORAGE RACKS	MARTIN MARIETTA-AVAILABLE		200 ft^2	
27. CRANE, 40-ft BOOM	LEASE/BUY		1	
28. CRANE, 20-ft BOOM	LEASE/BUY		1	
29. METERS, SCOPES, ETC	MARTIN MARIETTA AVAILABLE			
30. SPREADER BAR/SLING (YOKE ASSEMBLY)	MAKE		2	
31. 3x8-ft WORK BENCHES-WOOD TOP	MARTIN MARIETTA-AVAILABLE	6		
32. LIGHT STANDARD	MARTIN MARIETTA-AVAILABLE	10		
33. DRILL, PORTABLE 1/2 in.	MARTIN MARIETTA-AVAILABLE	3		
34. AIRLESS SPRAY, PRIMER	MARTIN MARIETTA-AVAILABLE	3		
35. DRILL, PORTABLE 1/4 in.	MARTIN MARIETTA AVAILABLE	3		
36. AIR COMPRESSOR	MARTIN MARIETTA-AVAILABLE	1		
37. 8-ft LADDER, PORTABLE	MARTIN MARIETTA-AVAILABLE	1		
38. HOIST, PORTABLE, MONORAIL	LEASE	2		
39. DESKS, TABLES, CHAIRS	MARTIN MARIETTA-AVAILABLE	6 SETS		

Table III-2 Heliostat Array Control Subsystem Make or Buy

ITEM	MAKE OR BUY	A	C	D	E	B	A&B	ACDE	ABCDE	DEVELOPMENT TESTS	SPARES	DESIGN
HELIOSTAT ARRAY CONTROLLER												
1. HELIOSTAT ARRAY COMPUTER	BUY	1	1	1	1	2	3	4	6	1		STANDARD CATALOG ITEM
2. UAR/T	BUY	5	5	5	5	10	15	20	30	5*	3	STANDARD CATALOG ITEM
3. I/O CIRCUITS	MAKE	1	1	1	1	2	3	4	6	1*	1.5	MARTIN MARIETTA
4. BATTERIES FOR I/O	BUY	5	5	5	5	10	15	20	30	5*	8	OFF-THE-SHELF ASSEMBLED INTO RACK
5. TELETYPE	BUY	1 (FOR ALL ZONES)										STANDARD CATALOG ITEM
6. CABINET	BUY	2	2	2	2	3	4	5	7	2*		STANDARD CATALOG ITEM
7. TAPE DECK	BUY	1	1	1	1	1	1	1	1		1	STANDARD CATALOG ITEM
8. HAC-TO-MCS CABLE	MAKE	1	1	1	1	2	3	4	6		1	MARTIN MARIETTA
HELIOSTAT ASSEMBLY												
9. MANUAL CONTROL PANEL	MAKE	2 TOTAL (1 ZONE OR ALL ZONES)								1*	2†	MARTIN MARIETTA
10. CONTROL ELECTRONICS TEST SET (2) AND HAC STIMULUS TEST SET (2)	MAKE	4 TOTAL (1 ZONE OR ALL ZONES)								1*		MARTIN MARIETTA
11. MIRRORS	BUY	1950	2075	2500	2075	5400	7350	8600	14000	25		MARTIN MARIETTA
12. MIRROR FRAMES	BUY	1950	2075	2500	2075	5400	7350	8600	14000	25		MARTIN MARIETTA
13. LIMIT SWITCHES	BUY	624	664	800	664	1728	2352	2752	4480	8		STANDARD CATALOG ITEM
14. HELIOSTAT CONTROLS	MAKE	78	83	100	83	216	294	344	560	2*	1	MARTIN MARIETTA
15. MIRROR MODULES	MAKE ASSEMBLY ON SITE	1950	2075	2500	2075	5400	7350	8600	14000	25		MARTIN MARIETTA
16. HELIOSTAT SUPPORT FRAME	BUY	78	83	100	83	216	294	344	560	1		MARTIN MARIETTA
17. MANUAL CHECKOUT CABLES	MAKE	2 TOTAL (1 ZONE OR ALL ZONES)								1*	2†	MARTIN MARIETTA
18. YOKE MODULES	BUY	78	83	100	83	216	294	344	560	1		MARTIN MARIETTA
19. SUN-PRESENT SENSORS	BUY	8	9	10	9	22	30	35	56	1	1	STANDARD CATALOG ITEM
20. HELIOSTAT WIRE BUNDLES	MAKE	78	83	100	83	216	294	344	560	1	3	MARTIN MARIETTA
21. POWER SUPPLIES	BUY	312	332	400	332	864	1176	1376	2240	4	15§	STANDARD CATALOG ITEM
22. HELIOSTAT ASSEMBLIES	MAKE	78	83	100	83	216	294	344	560	1		MARTIN MARIETTA
DRIVE MECHANISM												
23. AZIMUTH DRIVE UNIT	BUY	78	83	100	83	216	294	344	560	1	2§	STANDARD CATALOG ITEM
24. ELEVATION DRIVE UNIT	BUY	78	83	100	83	216	294	344	560	1	2§	STANDARD CATALOG ITEM
25. AZIMUTH ENCODER	BUY	78	83	100	83	216	294	344	560	1	4§	STANDARD CATALOG ITEM
26. ELEVATION ENCODER	BUY	78	83	100	83	216	294	344	560	1	4§	STANDARD CATALOG ITEM
27. SLEW MOTOR (AZIMUTH & ELEVATION)	BUY	156	166	200	166	432	588	688	1120	2	4§	STANDARD CATALOG ITEM
28. TRACKING MOTOR AZIMUTH	BUY	78	83	100	83	216	294	344	560	1	2§	STANDARD CATALOG ITEM
29. TRACKING MOTOR ELEVATION	BUY	78	83	100	83	216	294	344	560	1	2§	STANDARD CATALOG ITEM
30. COUPLING	BUY	156	166	200	166	432	588	688	1120	2	4§	STANDARD CATALOG ITEM

*USE IN DENVER FOR ENGINEERING TESTS AND THEN SHIP TO SANDIA
†FOR QUANTITY OF 12 BUY ONLY
§ ZONE A - OTHER OPTIONS WILL VARY PROPORTIONATELY

Table III-3 Focusing and Alignment Subsystem Make or Buy

ITEM	MAKE OR BUY	QUANTITY	DESIGN
1. HELIOSTAT CONTROL BOX	MAKE	1	MARTIN MARIETTA
2. MAGIC CARPET WORK STAND	BUY	1	STANDARD CATALOG ITEM
3. PROTECTIVE CLOTHING	BUY	4 SETS	STANDARD CATALOG ITEM
4. EYE PROTECTION	BUY	4 SETS	STANDARD CATALOG ITEM
5. FIELD GLASSES	BUY	2 PAIR	STANDARD CATALOG ITEM
6. LAMP REPLACEMENT PROTECTIVE SUIT	BUY	2 SETS	STANDARD CATALOG ITEM
7. EQUIPMENT BOX	BUY	1	STANDARD CATALOG ITEM
8. ALIGNMENT TOOL SET	BUY	1	STANDARD CATALOG ITEM
9. MOBILE LIGHT POSITIONING SYSTEM	BUY	1	MARTIN MARIETTA
10. ALIGNMENT LIGHT SOURCE	BUY	1	MARTIN MARIETTA
11. ALIGNMENT SCREEN 18x 24 ft	BUY	1	MARTIN MARIETTA
12. REFLECTOR MATERIAL	BUY	800 ft^2	STANDARD CATALOG ITEM
13. TRANSIT	BUY	1	STANDARD CATALOG ITEM
14. EMERGENCY LANTERN	BUY	2	STANDARD CATALOG ITEM
15. 2-WAY RADIO	BUY	3	STANDARD CATALOG ITEM

Table III-4 Calibration Subsystem Make or Buy

ITEM	MAKE OR BUY	QUANTITY	DESIGN
1. CALIBRATION TARGET	MAKE	1 CSS MODULE	MARTIN MARIETTA
2. STRUCTURAL AND MECHANICAL ASSEMBLY	MAKE	1 CSS MODULE	MARTIN MARIETTA
3. MODULE DRIVE MECHANISM	MAKE	1 CSS MODULE	MARTIN MARIETTA
4. MODULE DRIVE MOTOR	BUY	1 CSS MODULE	STANDARD CATALOG ITEM
5. TARGET DRIVE MECHANISM	MAKE	1 CSS MODULE	MARTIN MARIETTA
6. TARGET DRIVE MOTOR	BUY	1 CSS MODULE	STANDARD CATALOG ITEM
7. LIMIT SWITCHES	BUY	6 CSS MODULES	STANDARD CATALOG ITEM
8. SOLAR CELL UNIT	MAKE	64 SOLAR CELL SENSOR ASSEMBLIES	MARTIN MARIETTA
9. SENSOR STRUCTURAL ASSEMBLY	MAKE	1 SENSOR ASSEMBLY	MARTIN MARIETTA
10. SENSOR ASSEMBLY DRIVE MECHANISM	MAKE	1 SENSOR ASSEMBLY	MARTIN MARIETTA
11. SENSOR ASSEMBLY DRIVE MOTOR	BUY	1 SENSOR ASSEMBLY	STANDARD CATALOG ITEM
12. NEUTRAL DENSITY FILTERS (COVERS FOR SOLAR CELLS)	BUY	2 SETS OF SENSOR ASSEMBLIES	MARTIN MARIETTA
13. CALORIMETER ASSEMBLY	MAKE	1 CALORIMETER ASSEMBLY	MARTIN MARIETTA
14. SOLAR COLLECTOR PANEL	BUY	1 CALORIMETER ASSEMBLY	MARTIN MARIETTA
15. WATER TANK	BUY	1 CALORIMETER ASSEMBLY	MARTIN MARIETTA
16. WATER SYSTEM CONTROLS (ASSEMBLY BY MARTIN MARIETTA)	MAKE ASSEMBLY (BUY ALL COMPONENTS)	1 CALORIMETER ASSEMBLY	STANDARD CATALOG ITEM
17. INTERFACE ELECTRONICS & CABLING	MAKE	1	MARTIN MARIETTA
18. DIGITAL INTERFACE UNIT	MAKE	1	MARTIN MARIETTA
19. POSITION CONTROL UNIT	MAKE	1	MARTIN MARIETTA
20. HARNESS & CABLING 1 2000-ft CABLE TO MCS 6 20-ft CABLES, 5 POWER CABLES	MAKE	1 SET	MARTIN MARIETTA
21. C&D CONSOLE	MAKE	1 I/F ELECTRONICS & CABLING	MARTIN MARIETTA
22. CALIBRATION INTERFACE MODULE (BUY ELECTRONICS, ASSEMBLY BY MARTIN MARIETTA	MAKE	1 I/F ELECTRONIC CABLING	MARTIN MARIETTA

As can be seen from the tables, the majority of this equipment is commercially available and is not of the esoteric type required for space hardware. Since we have been the prime contractor for several test sites and facilities, basically structural and control in nature and using commercial equipment, our procurement system is equipped for and has been proved in this field.

Presuming selection of the most cost effective and competent component and raw material suppliers, we plan our greatest emphasis to be on delivery performance and on monitoring of suppliers to assure that the priorities established result in delivery of high-quality raw materials and reliable components to the next level of assembly for the heliostats, HACs, focusing and alignment subsystem, and the calibration subsystem on a scheduled and controlled basis.

With respect to fabrication of details and subassemblies at off-site locations, we plan our greatest emphasis on selection of the most cost effective and competent subcontractors based on schedule performance, and on their ability to fulfill appropriate acceptance criteria. The criticality of the flow of the heliostat details at this stage of a given build rate calls for a resident team at the Albuquerque location. This team will be composed of a contract administrator and a quality control specialist as a minimum, and other functions as necessary, to oversee the critical fabrication(s).

To provide procurement emphasis as well as essential visibility of supplier activities to the program, we have selected Alden E. Clawson to carry out the materiel function. His qualifications are identified in Section A of Chapter II. He will report directly to Mr. Hintze for this contract and will be the pivotal source of control for all procurement actions. These, of course, include source selection, buying/subcontracting, negotiations, cost analysis/cost control, and delivery performance. Our procurement system, as directed by Mr. Hintze through Mr. Clawson is fully committed to the HAACS program.

C. CONFIGURATION AND DATA MANAGEMENT

Application of our proven and demonstrated configuration management system will assure a minimum of interface difficulties and that the requirements for field-to-field heliostat interchangeability can be met.

The key issue in configuration and data management is what degree of application of configuration control procedures is commensurate with the degree of complexity of the hardware/ software and system. The HAACS is basically a mechanical/ electrical control system addressed by computer software. Within this context, it is equivalent to ground test facilities and equipment with which we have ample configuration management experience. For this system we will apply the techniques currently applied to our current ERDA programs. These programs will be modified to accept and accommodate a potential delivery of up to 560 heliostats. Our detail procedures, which are available for review, cover all of the appropriate disciplines applicable to this task, including engineering release, design reviews, baseline control, change control configuration accounting, subcontractor configuration control, and acceptance and delivery. With the potential number of heliostats identified, configuration will be the particular discipline we will focus on to assure meeting our configuration control commitments.

Figure III-3 portrays our documentation approach, which will be implemented to the extent necessary to assure submitting the required documentation to the contractual delivery dates. Table III-5 lists the deliverable documentation required by the contract. To provide continuity and total configuration and data management status, the configuration and data management representative will be assigned to the program manager, Marx Hintze, with additional support being brought on board at appropriate program milestones.

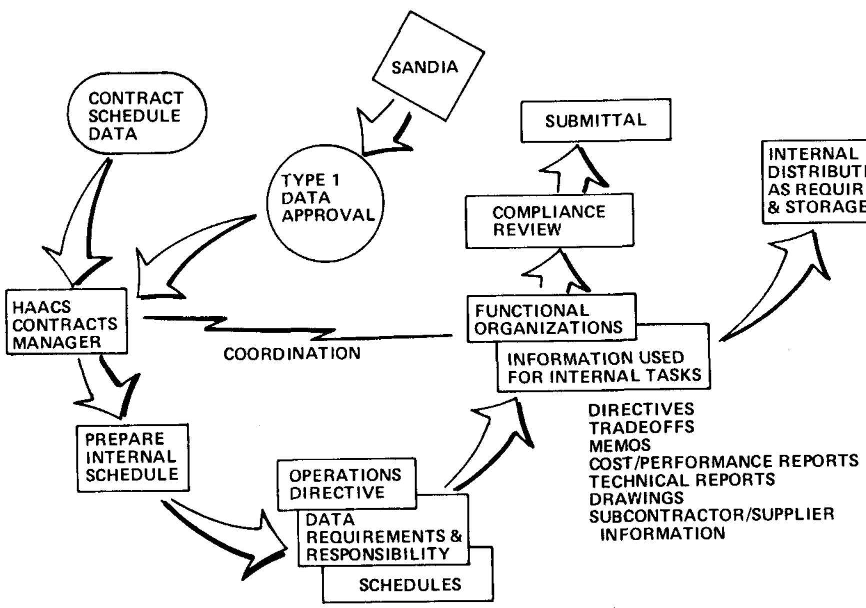


Figure III-3 Closed-Loop Documentation Management System

Table III-5 Documentation Requirements

RFQ REFERENCE	DOCUMENTS	DELIVERY DATA
ARTICLE III, ITEM 1A AND SPEC K93681 PARA 3.1.2.a–HELIOSTAT FOUNDATION DESIGN	TWELVE COPIES OF DESIGN DRAWINGS FOR THE HELIOSTAT FOUNDATION AND PLOT PLAN.	MARCH 1, 1976
ARTICLE III, ITEM 1B AND SPEC K92681 PARA 3.1.2.b–POWER AND CONTROL WIRING REQUIREMENTS	THREE COPIES OF THE DESIGN REQUIREMENTS FOR POWER AND CONTROL WIRING	FEBRUARY 1, 1976
ARTICLE III, ITEM 1C AND SPEC K93681 PARA 3.1.2.d–POWER REQUIREMENTS	THREE COPIES OF THE COLLECTOR SYSTEM POWER REQUIREMENTS.	FEBRUARY 1, 1976
ARTICLE III, ITEM 1D–INSTRUCTIONS	THREE COPIES OF INSTRUCTIONS FOR INSTALLATION, OPERATION, AND MAINTENANCE	JULY 1, 1976
ARTICLE III, ITEM 2A AND SPEC K93681 PARA 3.1.2.c–CALIBRATION SYSTEM	THREE COPIES OF CALIBRATION SYSTEM INTERFACES, MECHANICAL AND ELECTRICAL.	MARCH 31, 1976
ARTICLE III, ITEM 2B AND SPEC K93681 PARA 3.1.2.h–CALIBRATION SYSTEM	THREE SETS OF CALIBRATION SYSTEM OPERATING INSTRUCTIONS.	JULY, 1976

IV. Quality Assurance Plan

IV. QUALITY ASSURANCE PLAN

The primary thrust of the Martin Marietta quality assurance activity for the heliostat array and control system program will be to control the workmanship and configuration, and to certify the function of the heliostat arrays when exercised by the control system. The following paragraphs address the specific tasks to be conducted during the program.

A. DRAWING AND CHANGE CONTROL

The drawing and drawing change system for the program will be maintained by program engineering personnel and will be monitored by the quality assurance and safety representative.

B. CONTROL OF PROCURED MATERIAL

Since the system is "commercial" in nature, the items procured for this contract will not undergo source inspections by Martin Marietta quality personnel but will be treated as "commercial" hardware and inspected by the program quality assurance and safety representative on arrival in the program area. The quality assurance and safety representative will review and approve all vendors/suppliers. All purchase requisitions will be reviewed and coded for "end user" inspection. Defective shipments from suppliers will be identified on a nonconforming material record form called a MARS and routed back to the supplier for repair or replacement of the hardware.

C. INSPECTION

The inspection of hardware will be directed at the control of workmanship and configuration. The Martin Marietta installation and assembly plans define the necessary guidelines for the workmanship standards and the engineering personnel will furnish "shop-type" drawings against which the configuration will be maintained. The systems will be inspected after assembly of the hardware prior to the first system-level test. Inspection activities relative to the testing will consist of audits by the quality assurance and safety representative during the validation activities to verify the compatibility of the hardware/software inputs/outputs. On completion of the software validations, the quality assurance and safety representative will certify the configuration of the software and all subsequent changes.

D. TEST

The quality assurance and safety representative will audit all system-level tests and verify that the system(s) is exercised correctly when interfaced with the validated software. He will support the program personnel in defect identification and documentation.

E. NONCONFORMING MATERIAL CONTROL

Control and dispositioning of nonconforming material will primarily be the responsibility of the program manager, subject to approval of the quality assurance and safety representative.

F. CONTROL OF INSPECTION, MEASURING, AND TEST EQUIPMENT

All inspection standards, gages, and measuring and test equipment necessary to determine conformance to specification, drawing, and contract requirements will be properly selected, maintained, and controlled. Calibration will be maintained by the quality metrology laboratory, which maintains standards traceable to the National Bureau of Standards.

G. RECORD OF INSPECTION

A certification sheet will be created for the deliverable end-item hardware and/or software produced under this contract. A description of the end-item hardware and certification of workmanship and configuration will be contained in this document and delivered with the end-item shipment. Inspection stamps will be applied to the hardware and certification sheet by the quality assurance and safety representative to evidence satisfactory workmanship and configuration compliance.

H. PRESERVATION, PACKAGING, PACKING, AND SHIPPING

Packaging and shipping operations will be as specified on drawings. Martin Marietta will prepare material handling requirements especially for this project.

V. Installation and Checkout Plan

V. INSTALLATION AND CHECKOUT PLAN

A. SITE ACTIVATION REQUIREMENTS

Logistics and site operations activation personnel will arrive on site approximately 30 days prior to the scheduled heliostat installation start to assure readiness of all facilities to support the installation and checkout effort. The site activation activities are outlined in Table V-1.

B. INSTALLATION AND CHECKOUT SEQUENCE

The installation and checkout activities are outlined in Table V-2. All installation and checkout activities will be accomplished per the deliverable instruction packages. Each package will be validated and fully updated prior to final turnover to Sandia.

1. Installation

As currently scheduled the heliostat array control subsystem, focusing and alignment subsystem, calibration subsystem, and heliostat array subsystem installation activities will start concurrently.

2. Checkout

As soon as the HACSS is checked out and on line, available heliostats will be exercised individually and in groups. Alignment and focusing of the heliostats will begin as soon as the

Table V-1 Site Activation

SITE ACTIVATION ACTIVITY	EQUIPMENT

1. ASSEMBLY BUILDING (KIRTLAND HANGAR)
A. TRANSPORT, RECEIVE, AND INSTALL NECESSARY EQUIPMENT TO ASSEMBLE THE MIRROR MODULES
	• FIXTURES FOR ASSEMBLY STATIONS
	• WELDERS
	• FORKLIFT
	• A FRAMES
	• MIRROR MODULE TRANSPORTER (SEE FIG. IV-3)
	• RTV MIXER AND DISPENSER
	• STORAGE FACILITIES/AREAS
	  • MIRRORS
	  • ATTACHMENT HARDWARE AND MATERIAL
	  • MIRROR HOLDER ASSEMBLIES
	  • RTV
	  • ELEVATION DRIVE UNITS
	  • STRUCTURAL TUBING
	  • MAX/MIN HARDWARE
	  • COMPLETE MIRROR MODULES

B. SET UP OFFICE AREA	• OFFICE EQUIPMENT • PHONES • SUPPLIES
2. TEST SITE	• NOTE: DEPENDENT ON BUILDING AVAILABILITY; TRAILERS MAY BE REQUIRED
A. SET UP OFFICE AREA	• OFFICE EQUIPMENT • PHONES • SUPPLIES

B. TRANSPORT, RECEIVE, AND INSTALL NECESSARY EQUIPMENT FOR STORAGE FACILITIES/AREAS, MAINTENANCE FACILITIES, AND A STAGING AREA	• STORAGE FACILITIES/AREAS
	  • MIRROR MODULES
	  • YOKE MODULES
	  • AZIMUTH DRIVE MODULES
	  • HELIOSTAT CONTROL BOXES AND HARNESSES
	  • ATTACHMENT HARDWARE
	  • TOOLS
	  • MAINTENANCE EQUIPMENT
	  • POL
	• BENCHES, ELECTRICAL AND SMALL HARDWARE STAGING
	• WELDER
	• FORKLIFT

3. RECEIVE AND PREPARE/STORE INSTALLATION AND MAINTENANCE EQUIPMENT	• CRANES • WORK PLATFORMS • MOBILE FOCUSING AND ALIGNMENT TOWER AND LIGHT • SLINGS • CALIBRATION SYSTEM • MOBILE MIRROR CLEANER • FLATBED TRUCK
4. ESTABLISH NORMAL FIELD SUPPORT FUNCTIONS, I.E., SECURITY, FIRST AID, TRANSPORTATION, ETC	
5. VERIFY READINESS OF THE TEST FACILITY A. HELIOSTAT PADS • INSTALLED, LEVELED AND TRUE POSITION IDENTIFIED B. ALIGNMENT PADS • BENCH MARK IN PLACE AND TRUE POSITION IDENTIFIED C. POWER AND CONTROL WIRING • INSTALLED D. COMPUTER AND CONTROL ROOM • AVAILABLE FOR HARDWARE INSTALLATION E. EXPERIMENT TOWER • AVAILABLE FOR HARDWARE INSTALLATION	
6. START STAGING HARDWARE FOR INSTALLATION ACTIVITY	

Table V-2 Installation and Checkout Activities

ACTIVITY	EQUIPMENT	LOGISTICS
1. INSTALL AND CHECK OUT THE HELIOSTAT ARRAY CONTROLLER SUBSYSTEM A. INSTALL THE COMPUTER AND CONDUCT SELF-CHECK B. INSTALL THE SUPPORT EQUIPMENT • COMPLETE TERMINATIONS C. PERFORM SUBSYSTEM TEST D. EXERCISE INDIVIDUAL HELIOSTATS E. SUPPORT FOCUSING AND ALIGNMENT ACTIVITY F. SUPPORT CHECKOUT OF THE CALIBRATION SUBSYSTEM	• METERS, SCOPES, ETC	• RECEIPT AND MOVEMENT TO COMPUTER ROOM
2. ASSEMBLE AND INSTALL THE FOCUSING AND ALIGNMENT SUBSYSTEM A. ASSEMBLE AND CHECK OUT THE MOBILE FOCUSING AND ALIGNMENT TOWER AND LIGHT B. INSTALL THE TARGET ON THE RECEIVER TOWER	• FORKLIFTS • CRANE (75-ft BOOM) • OPTICAL ALIGNMENT EQUIPMENT • FLATBED TRUCK • SLING	• FUELS FOR MOBILE TOWER AND GENERATOR • STAGE ATTACHMENT HARDWARE
3. INSTALL AND CHECK OUT THE CALIBRATION SUBSYSTEM A. INSTALL THE CALIBRATION TARGET, ASSOCIATED ELECTRONICS, AND COOLING SYSTEM AT THE RECEIVER TOWER B. PERFORM SUBSYSTEM CHECKOUT C. INTEGRATE WITH MASTER CONTROL SYSTEM (MCS) D. PERFORM CALIBRATION SYSTEM CHECKOUT WITH SEVERAL HELIOSTATS	• FLATBED TRUCK • SLING • METERS, SCOPES, ETC	• STAGE ATTACHMENT HARDWARE
4. INSTALL AND CHECK OUT THE HELIOSTAT ARRAY A. ASSEMBLE MIRROR MODULES (SEE PARA 3F) TRANSPORT MIRROR MODULES TO TEST SITE B. INSTALL THE AZIMUTH DRIVE MODULE AND YOKE MODULES • INSTALL THE AZIMUTH DRIVE MODULE • DELIVER TO PAD • INSTALL ON BASEPLATE (BASEPLATE INSTALLED AND LEVELED BY FACILITY CONTRACTOR) • INSTALL THE YOKE MODULE • (OPTION) MOUNT HELIOSTAT CONTROL BOX. PARTIALLY ROUTE AND CLAMP HARNESS. • DELIVER YOKE TO PAD • INSTALL ON AZIMUTH DRIVE MODULE C. INSTALL THE MIRROR MODULE • DELIVER TO PAD • INSTALL ON YOKE • ATTACH ELEVATION DRIVE UNIT TO YOKE • ATTACH RETAINER ON OPPOSITE END	• SEE TABLE V-1, SITE ACTIVATION • MIRROR MODULE TRANSPORTER • FLATBED TRUCK • CRANE • SLING • TORQUE WRENCH • YOKE MODULE TRANSPORTER • CRANE • SPREADER BAR/SLING • TORQUE WRENCH • DRIFT PIN • MIRROR MODULE TRANSPORTER • CRANE (5-ton, 40-ft BOOM) • SPREADER BAR/SLING • WORK PLATFORMS	• DELIVER TO TEST SITE AT A RATE COMPATIBLE WITH THE INSTALLATION SCHEDULE • STAGE ATTACHMENT HARDWARE • STAGE ATTACHMENT HARDWARE • STAGE ATTACHMENT HARDWARE
5. ELECTRICAL INSTALLATION AND CHECKOUT A. INSTALL HELIOSTAT CONTROL BOX, ROUTE AND CLAMP HARNESS (COMPLETE ROUTING IF OPTION EXERCISED ON YOKE INSTALLATION) • SPLICE TO AZIMUTH AND ELEVATION DRIVE • CONNECT TO • AZIMUTH AND ELEVATION ENCODERS • SOLAR SENSORS (EVERY TENTH HELIOSTAT) • DATA/CONTROL FACILITY INTERFACE • VERIFY COARSE POSITIONING OF EMERGENCY SHUTDOWN SWITCHES AND CONNECT HARNESS • CONNECT MANUAL CONTROL BOX • CONNECT POWER CABLE • MANUALLY OPERATE HELIOSTAT • ADJUST EMERGENCY SHUTDOWN SWITCHES • STOW HELIOSTAT • REMOVE POWER • REMOVE MANUAL CONTROL BOX • COMPLETE ENVIRONMENTAL PROTECTION INSTALLATION	• WORK PLATFORM	• STAGE ATTACHMENT AND SPLICING HARDWARE
6. ALIGN AND FOCUS HELIOSTAT A. POSITION THE MOBILE FOCUSING AND ALIGNMENT TOWER AND LIGHT • ADJUST THE LIGHT FOR CENTER MIRROR ALIGNMENT AND FOCUS B. POSITION HELIOSTAT IN CALCULATED AZIMUTH AND ELEVATION • ALIGN AND FOCUS CENTER MIRROR • REPOSITION THE LIGHT (24 TIMES) • ALIGN AND FOCUS EACH OF THE 24 REMAINING MIRRORS	• MOBILE FOCUSING AND ALIGNMENT TOWER • FOCUS/ALIGN TARGET • WORK PLATFORM • HELIOSTAT ARRAY CONTROLLER	NOTE: THIS IS A 24-HOUR/DAY OPERATION AND EXCESSIVE DOWNTIME WILL CAUSE SCHEDULE PROBLEMS FOR ZONES C, D, E & B. • MAINTENANCE AND OPERATING SUPPLIES • SPARES FOR FOCUSING AND ALIGNMENT SYSTEM • LIGHTING FOR NIGHTTIME OPERATIONS • SPARE MIRROR/HOLDER ASSEMBLIES • ATTACHMENT HARDWARE
7. SYSTEM TEST AND CALIBRATION A. VERIFY OPERATIONAL CAPABILITY WITH INDIVIDUAL HELIOSTATS AND GROUPS OF HELIOSTATS AS THEY BECOME AVAILABLE B. DEMONSTRATE CONTROL OF ALL HELIOSTATS OPERATED BY THE HAC (ALL MODES OF OPERATION INCLUDING CALIBRATION) C. RANDOMLY SELECT HELIOSTATS AND DEMONSTRATE COMPLIANCE WITH THE PERFORMANCE REQUIREMENTS D. DEMONSTRATE RESPONSE TO MCS COMMANDS AND CALIBRATION SYSTEM/MCS INTERFACE	• HELIOSTAT ARRAY CONTROLLER • CALIBRATION SYSTEM • HELIOSTAT ARRAY • MASTER CONTROL SYSTEM	

focusing and alignment subsystem equipment is assembled, installed, and checked out. The HACSS will also be required to support the alignment.

Calibration, for checkout purposes, will begin when the calibration subsystem is operational. The official heliostat calibration will be included in the system test. The system test will operate the heliostat array through all operational modes and demonstrate compliance with the performance requirements (Table V-2, Item 7).

3. Support Requirements

Facility and equipment requirements are identified in Tables V-1 and V-2.

A cadre of personnel experienced in skills pertinent to activation programs of this type (management, planning and scheduling, training, resident engineering, and logistics) will be responsible for locally hiring and supervising the work force that will accomplish this task.

VI. Safety Plan

VI. SAFETY PLAN

This chapter describes the safety program for the solar test facility heliostat array and control system. The application of safety engineering principles in design is an integral part of the detailed design and development phase. For the production/ test activities, the safety function includes responsibilities for system and personnel protection. The installation/operations phase is approached with the concept that man/machine relationships can either assure or void all safeguards incorporated in the designs. Therefore, our approach is to plan and implement the safety tasks to be commensurate with each phase of the program.

A. SCOPE AND PURPOSE

The purpose of this plan is to define a safety program related to design features and the requirements for personnel safety and fail-safe operation of the heliostat array and control system. The plan also provides the management and technical controls required to eliminate or control accident risks to an acceptable level.

The scope of this plan is to provide for implementation of the safety requirements necessary to achieve the program safety goal of minimizing hazards to operating and maintenance personnel, the public, the environment, and the hardware systems involved with the facility.

B. APPLICABLE DOCUMENTS

The latest issue of the documents listed at the date of the contract will be used as reference documents during conduct of the safety program:

1) Code of Federal Regulations 29 Chapter XVII Part 1926 - *Safety and Health Regulations for Construction*;
2) Code of Federal Regulations 29 Chapter XVII Part 1910 - *Occupational Safety and Health Standards* (this includes the National Electrical Code);
3) Code of Federal Regulations 49, *Transportation* (this is Graziano's Tariff No. 25);
4) National Fire Protection Association Codes, Vol 1 thru 15;
5) MIL-STD-882, *Systems Safety Program for Systems and Subsystems and Equipment, Requirements for;*
6) M-70-29, Martin Marietta Corporation, Denver Division, *Accident/Incident Investigation Manual*;
7) ANSI Z16.1, *Recording and Measuring Work Injury Experience.*

C. SAFETY ORGANIZATION AND RESPONSIBILITIES

1. Prime Contractor Organization and Responsibilities

Policies with a direct effect on the Denver Division safety program are generated by the Division Vice President and General Manager. The delegation of authority for implementation of the policies and the safety program requirements promulgated as a result of these policies is vested in the Vice President, Technical Operations. The manpower and technical resources available for the conduct of our safety program are under the jurisdiction of the technical operations organization.

An overview of the division's safety program, safety policy requirements, customer contractual safety obligations, and problem area identification and resolution is accomplished by monthly meetings of the management safety committee. The committee membership includes all executive management personnel, program directors, and program managers, and is chaired by the Vice President and General Manager.

2. Division Safety Organization

The organizational placement of our safety organization in the Denver Division is shown in Figure VI-1.

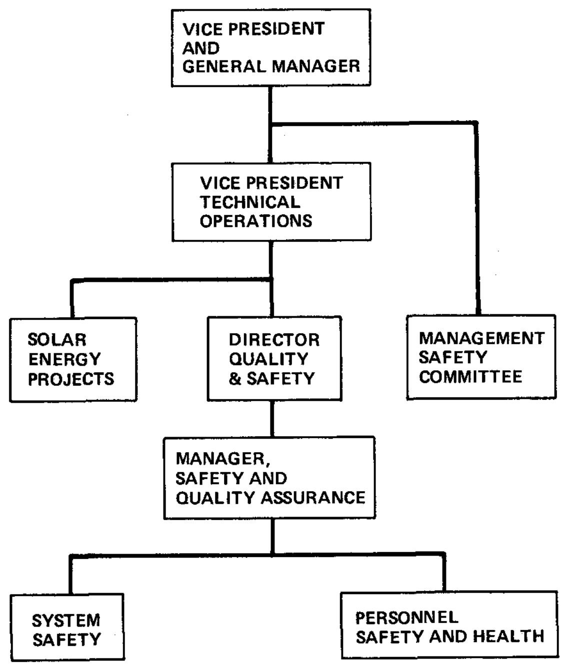


Figure VI-1 Denver Division Safety Organization

3. Project Safety

The program quality assurance and safety representative will report directly to the program manager and will be responsible for implementation of the program safety plan. Specific responsibilities include:

1) Provide a single-point contact with Sandia and applicable contractors for safety-related matters;

2) Maintain approval authority over safety-critical program documentation;

3) Provide internal approval and coordination on waivers and deviations to requirements;

4) Provide support to program and design reviews;

5) Coordinate system safety and personnel safety and health efforts in the program to ensure total coverage while eliminating redundancy;

6) Provide for the investigation and reporting of accidents/incidents.

4. Subcontractor Safety

Safety requirements and responsibilities of subcontractors and vendors will be controlled by the separate contracts and procurement specifications. The program quality assurance and safety representative will assure that safety design criteria and requirements are clearly defined in all procurement specifications.

5. Safety Working Group

The safety working group will be established during the design phase of the program to assure that safety requirements are developed and complied with to meet the goals of the solar thermal test facility. The working group will consist of the prime contractor, the subcontractors, Sandia Labs, and other contractors as deemed necessary by Sandia Labs. The working group will meet at the direction of the chairman or at least once every quarter during the design phase. The purpose of the working group is to resolve safety problems, recommend changes in approaches, and assure the development of a safe facility.

D. SYSTEM SAFETY MILESTONES

The system safety program milestones will be scheduled to coincide and complement the specific program milestones. This will provide visibility of safety status at critical checkpoints such as design reviews.

E. SYSTEM SAFETY CRITERIA

1. Definitions

The following definitions apply to this safety plan:

1) Accident - An unforeseen occurrence that results in major injury or equipment damage;
2) Accident potential - A condition that can result in an accident;
3) Damage - Breakage, mangling, ruin of items, or obstruction of functions generated across system or component interfaces by internal or external action, including human error, and requiring repair or replacement;
4) Hazard - Any real or potential condition that can cause injury or death to personnel, or damage to or loss of equipment or property;

5) Incident - An unforeseen occurrence that results in minor injury or damage;

6) Disabling injury - An injury that results in death, permanent total disability, permanent partial disability, or temporary total disability (see American National Standards Institute Z16.1);

7) Safety-critical - Any condition, event, operation, process, equipment, or system that can, by its inherent nature, lead to a situation with a potential for major personnel injury or equipment damage.

2. Hazard-Level Categories (ref MIL-STD-882)

For purposes of this plan, conditions caused by personnel error, environment, design characteristics, or procedural deficiencies that result in subsystem or component failure or malfunction or personnel injury are defined and established by the following hazard levels:

1) Category I, negligible - Will not result in personnel injury or system damage;

2) Category II, marginal - Can be counteracted or controlled without injury to personnel or major system damage;

3) Category III, critical - Will cause personnel injury or major system damage, or will require immediate corrective action for personnel or system survival;

4) Category IV, catastrophic - Will cause death or severe injury to personnel, or system loss.

3. Safety Precedence

The order of precedence for actions to eliminate or control accident potentials is to design for minimum hazard, use appropriate safety devices, use warning devices, or develop special procedures.

4. Waivers and Deviations

Compliance with all applicable criteria contained in the documents listed in Section B is mandatory unless exceptions are approved by Sandia. Noncompliance of any system equipment design, documentation, software, or procedure requires formal approval.

F. SAFETY HAZARD ANALYSIS

The purpose of the hazard analysis is to identify accident potentials, establish design criteria and operational constraints to eliminate or control these accident potentials, and provide the basis for accident risk assessments. The analysis will consider the complete system in all planned operations including transportation, testing, facility operations, and maintenance.

1. Hazard Identification

Potential hazard identification activities include the techniques of independent safety engineering evaluation, other related analyses, and safety checklists. Conditions identified by all techniques as suspect of having accident potential are considered to be potential hazards and are documented in Figure VI-2, with a reference to a specific hazard analysis item.

PROGRAM/PHASE:					POTENTIAL HAZARD MATRIX					DATE:	
SYSTEM:										PAGE:	
OPERATIONAL PHASE / SUBSYSTEM/ COMPONENT	DEVELOPMENT	FABRICATION	TEST	TRANSPORTATION AND HANDLING	INSTALLATION	ACCEPTANCE TEST	OPERATION	MAINTENANCE	OTHER ANALYSES: FMEA/SFP	OTHER ANALYSES: OPERATIONS & MAINTENANCE	OTHER ANALYSES: SYSTEM SAFETY CHECKLIST

Figure VI-2 Hazard Form

a. *Safety Engineering Evaluation* - The independent safety engineering evaluation will consist of an examination of each system/subsystem in each operational mode. An accident potential checklist will be used as a guide in identifying potential hazards. the evaluation is an iterative process that will continue throughout the program from design to operation.

b. *Related Analyses* - The hazard identification process will not duplicate other analyses but will use the data produced by them. A failure mode and effects analysis will identify single failure points having accident potential. Operations and maintenance analysis will identify potentially hazardous tasks.

c. Safety Checklists - Safety requirements and criteria will be prepared in checklist format, Figure VI-3, by safety engineering personnel. The responsible engineering activities will provide appropriate response for each criterion, including an explanation of the provisions for compliance, or the rationale for noncompliance, prior to design reviews. Each instance of noncompliance will be considered an accident potential and entered in the potential hazard matrix (Fig. VI-2).

HELIOSTAT ARRAY AND CONTROL SYSTEM
SYSTEM SAFETY CHECKLIST

ITEM NUMBER	SYSTEM/SUBSYSTEM	COMPLIANCE	NON-COMPLIANCE	NOT APPLICABLE	REVISION: DATE: COMPLETED BY:	SECTION NO.: PAGE NO.:
	CRITERION				RESOLUTION	

Figure VI-3 Safety Checklist

2. <u>Qualitative Hazard Analysis</u>

Each identified potential hazard will be analyzed to assess the system accident potential. The analysis will include definition of how the hazard can propagate into an accident, the potential effects, the assumptions and rationale, the hazard level in accordance with the definitions of Section E.2, and the design and/or operational changes required to eliminate or control the hazard, with references to specifications. The analysis format is illustrated in Figure VI-4.

3. <u>Analysis Reporting</u>

The hazard analysis will be summarized as a system hazard catalog in the format presented in Figures VI-5 and VI-6. Part I (Fig. VI-5) will consist of a list of all accident potentials analyzed and their current status. Part II will contain a summary of the analysis of each open item or "residual hazards." The hazard catalog will be available for review as part of each design review.

HAZARD ANALYSIS

HAZARD LEVEL		NO.	
STATUS		PAGE	
PROGRAM PHASE		DATE	

SYSTEM: SUBSYSTEM:

OPERATION/PHASE:

HAZARD GROUP:

REFERENCES:

HAZARD DESCRIPTION:

POTENTIAL EFFECTS:

ASSUMPTIONS/RATIONALE:

HAZARD CONTROL REQUIREMENTS:

DISPOSITION:

ORIGINATOR/LOCATION:

Figure VI-4 Hazard

HAZARD CATALOG
PART I—HAZARDS LIST

SECTION:	PAGE:					
HAZARD NO.	HAZARD	ELIMINATED	RESIDUAL	HAZARD LEVEL	ACCEPTED	OPEN

Figure VI-5 Hazards List Form

HAZARD CATALOG
PART II—RESIDUAL HAZARDS

SYSTEM: ______ ITEM NO. ______
SUBSYSTEM: ______ HAZARD LEVEL ______
COMPONENT: ______ DATE ______

HAZARD DESCRIPTION:

RECOMMENDATION:

DISPOSITION:

Figure VI-6 Hazard Catalog Form

G. SAFETY ACTIVITIES

1. Design Specification Review

The system requirement specifications will be reviewed by the quality assurance and safety representative to ensure that the safety requirements identified from design standards and hazard analyses are incorporated. A log of documentation reviewed will be maintained showing concurrence or nonconcurrence, reasons, and actions resulting from nonconcurrence. The log will be available for review by Sandia.

2. Design Reviews

The quality assurance and safety representative will participate in all scheduled program and design reviews. Presentations of safety status and problems will be included in each review.

3. Procedure Review

Each test/operating/maintenance procedure will be reviewed for apporval by the quality assurance and safety representative. The review will be based on the results of the hazard analyses. Approval of the procedures will be provided when each procedure meets the safety requirements and contains appropriate caution and warning notations.

4. Accident/Incident Investigations

Martin Marietta has established an accident prevention program with the prime purpose to eliminate potential hazards and risks associated with the operation of our facilities and the products we produce. An integral part of this program is the need for comprehensive investigations when incidents occur. The investigation identifies the root causes of incidents and provides the corrective action to prevent similar occurrences.

This accident prevention program requires that a report be completed on each accident/incident to ensure orderly follow-up and corrective action, and to document the incident for future reference. Therefore, any incidents/accidents that may occur during the performance of this program will be investigated and reported in accordance with the Denver Division *Accident/ Incident Investigation Manual*, M-70-29.

H. TRANSPORATION AND HANDLING

The safety requirements for the handling, transportation, and installation of the heliostat arrays will be identified by the hazard analysis. Requirements for the installation and maintenance equipment and procedural constraints will be considered. The safety review and approval of the transportation and handling, installation and maintenance, and operations procedures will ensure incorporation of all safety procedural constraints and will identify all safety-critical procedures.