HELIOSTAT SYSTEMS

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DEPARTMENT OF ENERGY - UNITED STATES OF AMERICA

DIVISION OF THERMAL POWER SYSTEMS

FIELD PROGRAM MANAGEMENT FOR LARGE SCALE SYSTEMS APPLICATIONS -
San Francisco Operations Office

FIELD PROGRAM MANAGEMENT FOR CENTRAL RECEIVER TECHNOLOGY DEVELOPMENT -
Sandia National Laboratories/Livermore, CA 94550

MARCH 1980

HELIOSTAT TECHNOLOGY

The development of heliostat technology has been underway since 1975 to support the Solar Central Receiver research, development, and demonstration effort. The objectives of the heliostat development program are to:

- Establish heliostat designs, with associated manufacturing assembly, installation, and maintenance approaches, that in quantity production will yield low capital and operating costs over an assumed 30-year plant lifetime.
- Stimulate broad industry participation in the DOE solar energy program.
- Obtain design data, manufacturing plans, and projected production cost for release to the solar community.
- Identify areas for research and development which offer significant payoffs in the reduction of the cost of energy from solar central receiver power plants.

HELIOSTAT DEVELOPMENT STATUS: The chronology of the heliostat development effort is summarized below and a brief description of each design follows:

Central Receiver Test Facility (CRTF), Albuquerque, NM -
Two hundred and twenty two heliostats installed (March 1978)

1st Generation -

Boeing, Honeywell, Martin Marietta, and McDonnell Douglas each built and tested four to six heliostats. McDonnell Douglas's concept was recommended for the Barstow, California Solar 10-MW Pilot Plant (July 1977).

Barstow Pilot Plant -

Martin Marietta and McDonnell Douglas delivered heliostats to the CRTF for test and evaluation (July 1979). The Martin Marietta design was selected for the Pilot Plant (December 1979).

Brookhaven -

Brookhaven National Laboratory built a prototype heliostat for a small central receiver plant and made preliminary cost estimates to produce steam for heating and cooling in the Northeastern United States (June 1979).

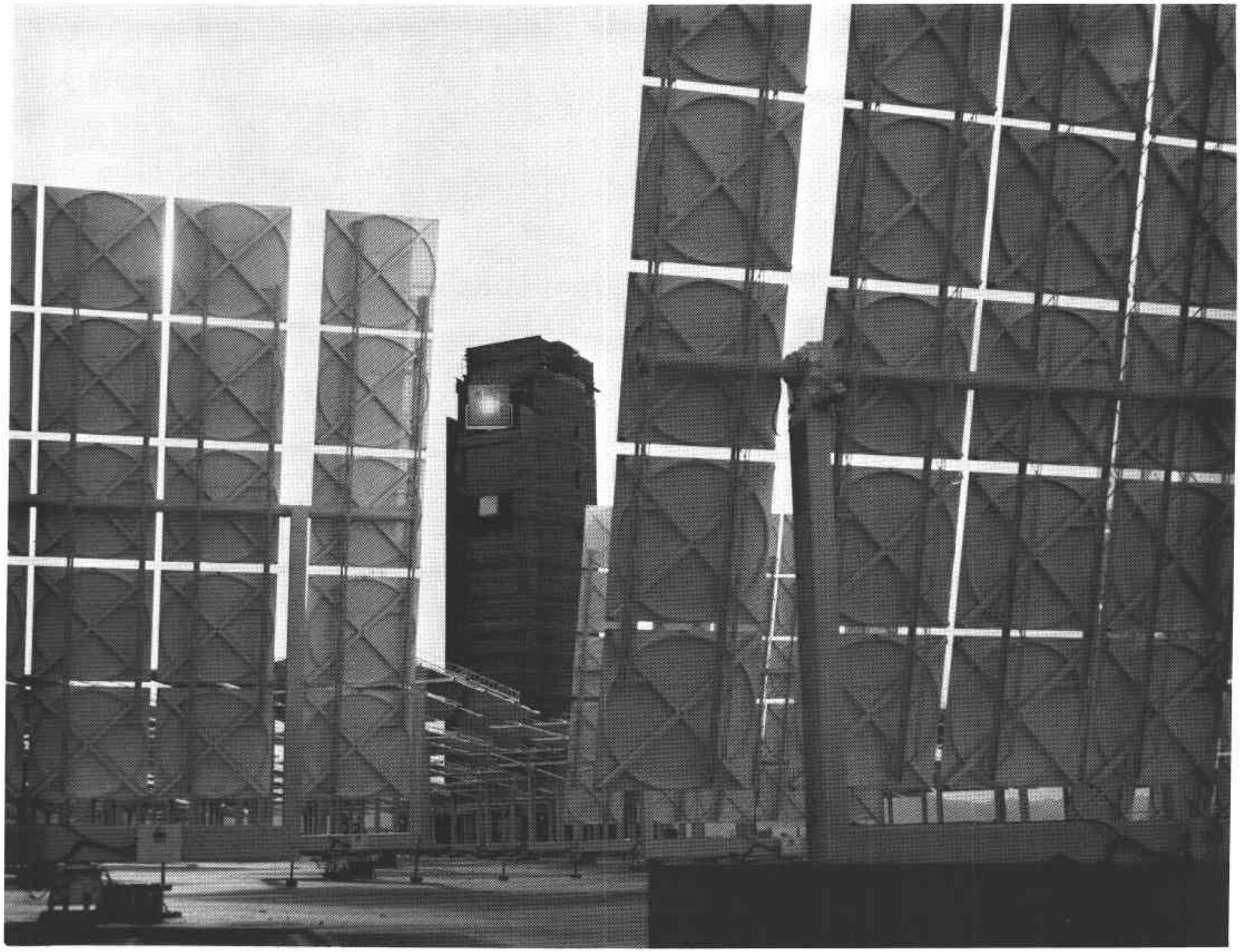
2nd Generation -

Boeing, General Electric, McDonnell Douglas, and Solaramics developed conceptual designs with production plans and cost estimates which resulted in component or materials development contracts which started in late 1978 and early 1979.

Westinghouse funded the fabrication of a heliostat prototype which was tested at the CRTF in mid-1979.

Boeing, Martin Marietta, McDonnell Douglas, Northrup Inc., and Westinghouse were awarded 18-month contracts in August 1979 for heliostat design, prototype fabrication, production planning, installation procedures, maintenance approaches, and life-cycle cost estimates.

CRTF HELIOSTAT (see facing page)	Manufacturer:	Martin Marietta Corporation, Denver, Colorado
	Number Built:	222
	Area:	37.2 m^2 (400 ft^2)
	Weight:	93.9 kg/m^2 (19.2 lb/ft^2)
	Mirrors:	Laminated 3-mm (1/8 inch) float glass, second surface silver reflector, 83% reflectivity, adjustable focus
	Drives:	Conventional gear box for azimuth and elevation drives
	Cost:	First build (78) - \$650/m^2 Second build (144) - \$520/m^2

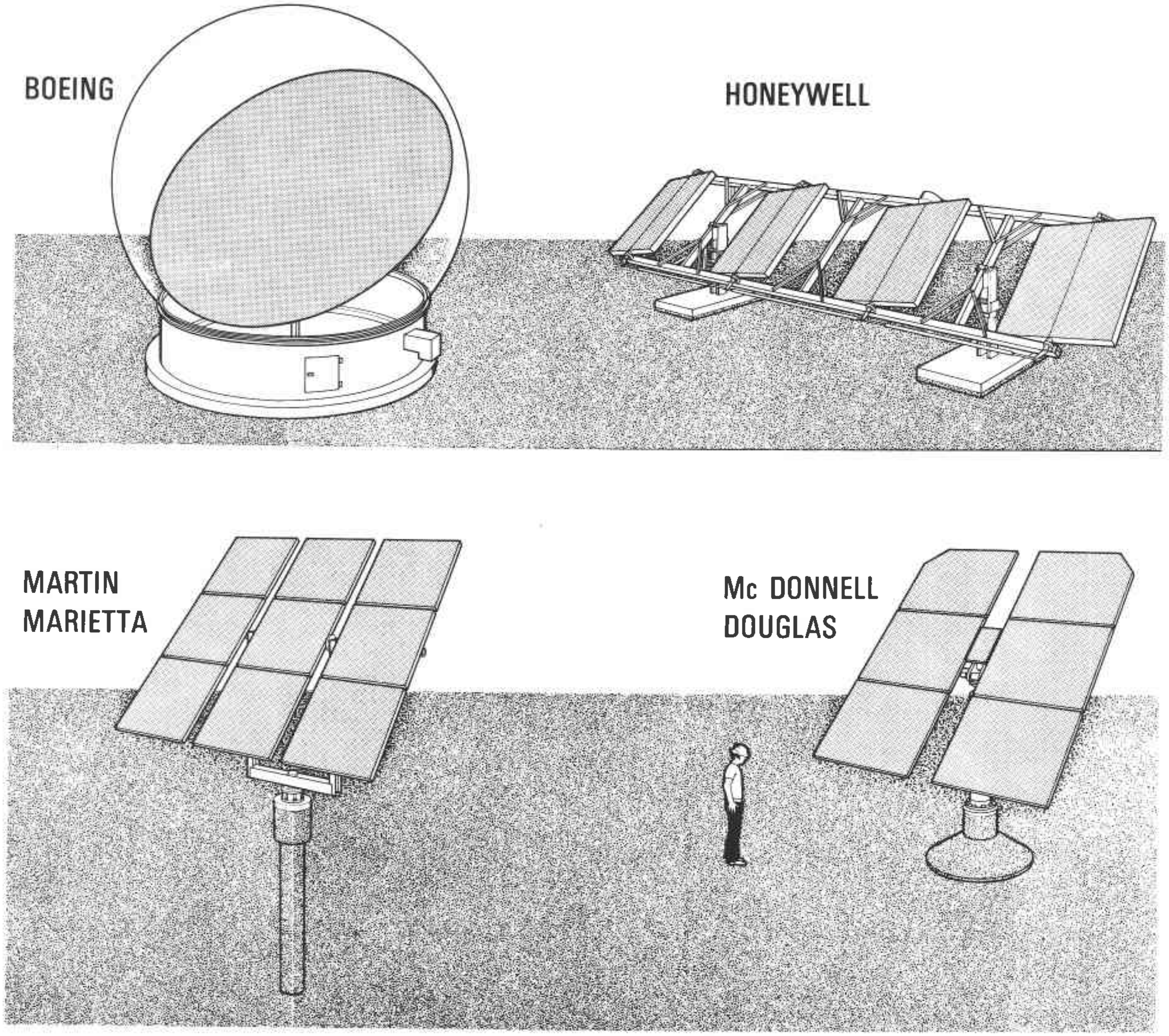


1ST GENERATION HELIOSTATS (see facing page)

The McDonnell Douglas concept was recommended for the 10-MW_e Pilot Plant at Barstow, California. Each of the designs is briefly described below.

DESIGN SUMMARY

	Boeing	Honeywell	Martin Marietta	McDonnell Douglas
Mirror Area (m^2)	48.5	40	41	38
Mirror Type	Aluminized Mylar	2nd surface silver, float glass, Al honeycomb-steel sandwich	2nd surface silver, float glass, Al honeycomb-steel sandwich	2nd surface silver, float glass, polystyrene-steel sandwich
Drive Type:				
Azimuth	Harmonic	Gear box	Gear box	Harmonic
Elevation	Harmonic	Machine screw linear actuator	Gear box	Machine screw linear actuator
Structural Material	Aluminum	Steel	Steel	Steel
Weight in kg/m^2 (lb/ft^2) - excluding foundation	5.3 (1.1)	60 (12.3)	57.6 (11.8)	42.6 (8.7)

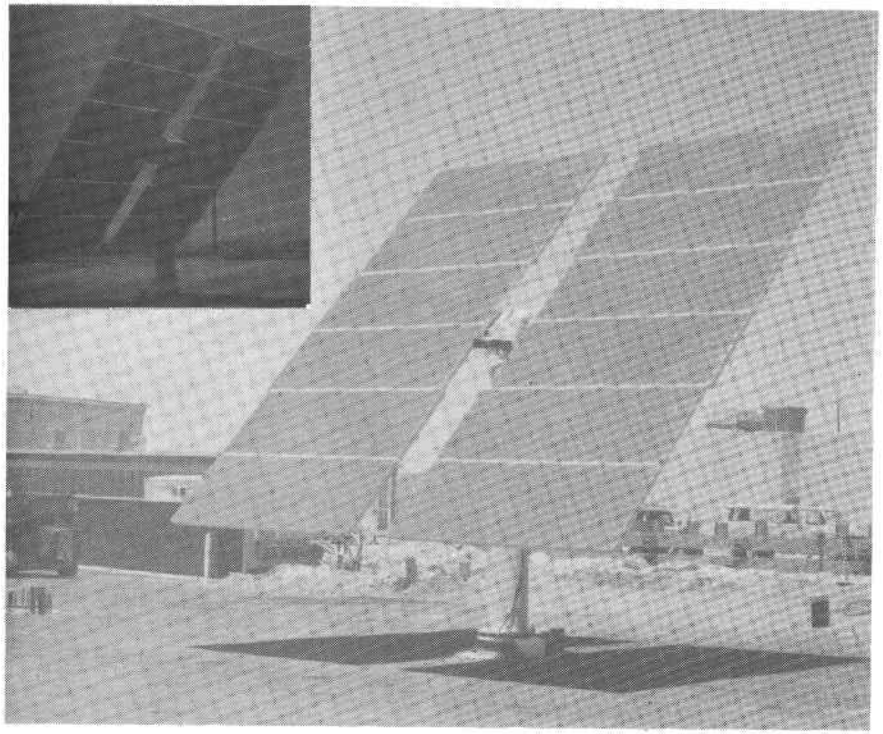


BOEING
HONEYWELL
MARTIN
MARIETTA
Mc DONNELL
DOUGLAS

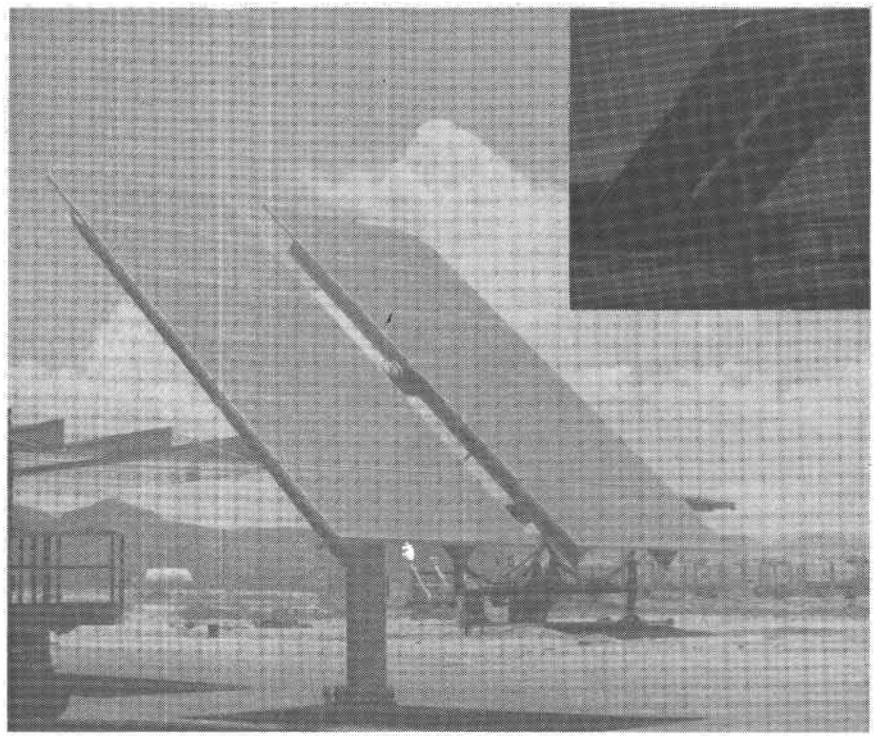
BARSTOW PILOT PLANT PROTOTYPE HELIOSTATS

The two pilot plant prototype heliostat designs are shown on the facing page. The Martin Marietta heliostat was selected for installation in the 10-MW_e Pilot Plant at Barstow, California. Three of each of these heliostats were built and two underwent testing at the Central Receiver Test Facility in Albuquerque, New Mexico. Each of the design is briefly described below.

	Martin Marietta	McDonnell Douglas
Mirror Area (m^2)	39.9	45.2
Mirror Type	2nd surface silver, 3-mm low iron float glass - Al honeycomb - steel sandwich	2nd surface silver, 3-mm low iron float glass - polystyrene foam-steel sandwich
Drive Type	Single gear box	Azimuth - harmonic Elevation - 2 machine screw linear actuators
Structural Material	Steel	Steel
Weight in kg/m^2 (lb/ft^2)	47 (9.6)	41.6 (8.5)



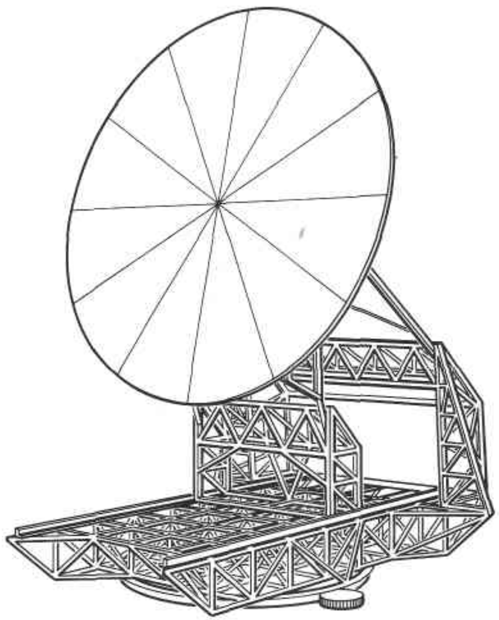
MARTIN MARIETTA
PILOT PLANT PROTOTYPE



MCDONNELL DOUGLAS
PILOT PLANT PROTOTYPE

BROOKHAVEN NATIONAL LAB PROTOTYPE HELIOSTAT

Brookhaven has built and tested a small, lightweight heliostat for small central receiver solar plants that would supply steam for heating and cooling, process heat, or small community or industrial electric generating plants. The heliostat has a 4.6-m-diameter mirror supported by an aluminum structure. The mirror is aluminized plastic supported by a polystyrene foam core mirror sandwich and protected with an overcoat. The total weight is 500 kg (1100 lb), for a density of 30 kg/m^2 (6 lb/ft^2).



BROOKHAVEN NATIONAL LABORATORY HELIOSTAT

SECOND GENERATION HELIOSTATS

The second generation heliostat development started in late 1977 when Boeing, General Electric, McDonnell Douglas, and Solaramics were funded for the conceptual design of lower cost heliostats. At the conclusion of these contracts critical components and materials contracts were let to the same companies, and a request for proposals was released for development of a heliostat which could be mass produced at low cost in the early 1980s. The request for proposals resulted in contracts with Boeing, Martin Marietta, McDonnell Douglas, Northrup Inc., and Westinghouse. These 18-month contracts started in August 1979 and will provide two prototype heliostats from each contractor with production and installation planning and cost estimates.

Westinghouse funded the fabrication of a prototype heliostat which was tested at the Central Receiver Test Facility in Albuquerque, New Mexico. This design became their baseline for their second generation heliostat contract.

The second generation heliostat designs are illustrated and described on the following pages.

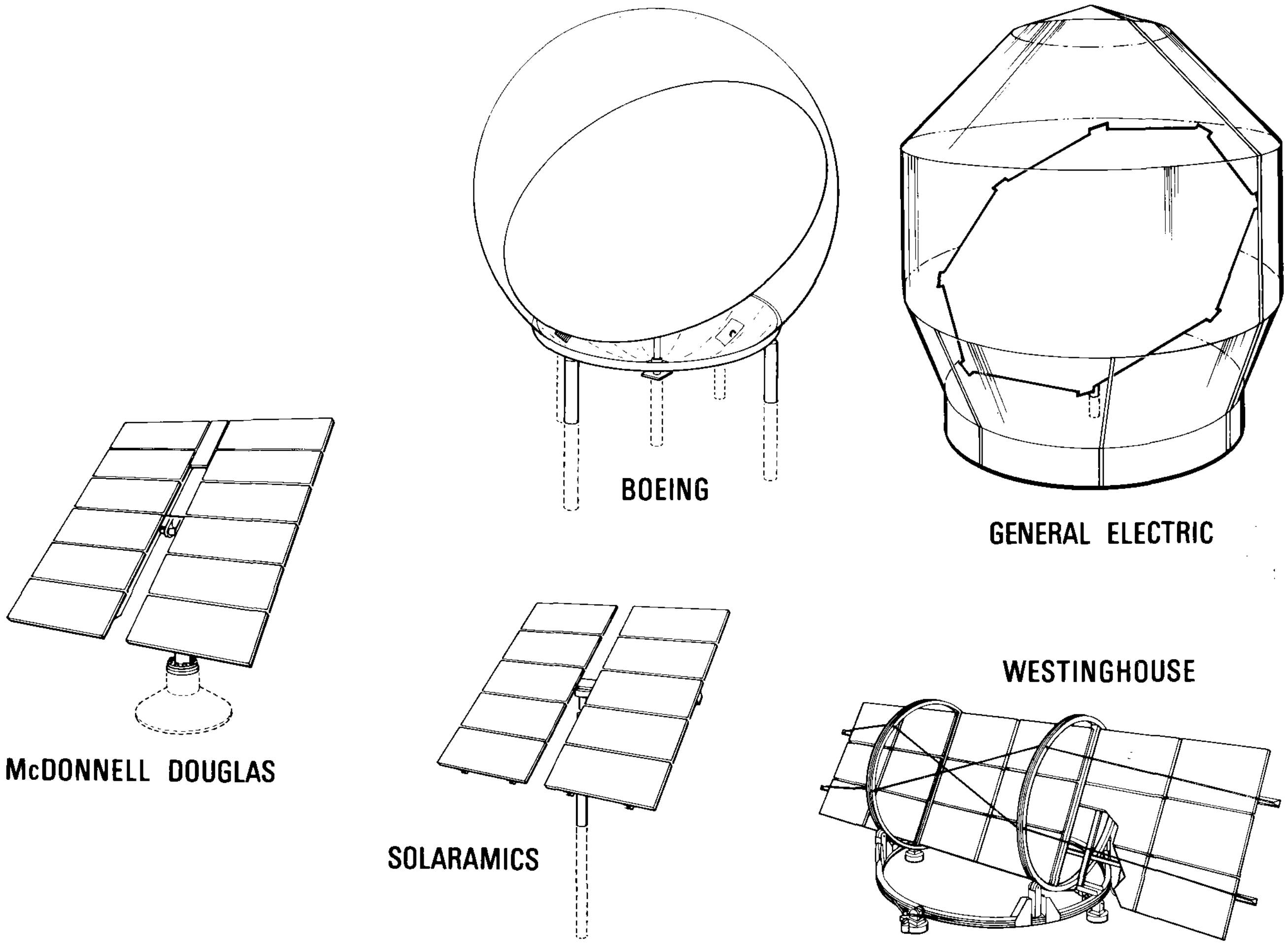
CONCEPTUAL SECOND GENERATION HELIOSTATS

The conceptual heliostat designs shown on the facing page were developed along with production cost estimates. Westinghouse's heliostat was not funded by DOE and was the only one that was built and tested. These heliostats are the basis for the current cost estimates on mass-produced heliostats.

These conceptual designs led to development contracts for generic heliostat components and plastic materials development. The designs and the ongoing development activities are summarized below.

DESIGN SUMMARY

	Boeing	General Electric	McDonnell Douglas	Solaramics	Westinghouse
Mirror Area (m^2)	66	55	49	38.6	40
Mirror Type	Aluminized Mylar	Aluminized Mylar	2nd surface silver, 1.5-mm fusion glass bonded to 3-mm float glass-steel hat sections	2nd surface silver, 1.5-mm fusion glass bonded to foamed glass	2nd surface silver, 3-mm float glass-polystyrene steel sandwich
Drive Type	Harmonic	Linear Motor	Azimuth-harmonic elevation; 2 machine-screw linear actuators	Titled axis, 2 machine-screw linear actuators, bell crank arrangement	Gear box, belt-drive
Structural Material	Aluminum, plastic protective enclosure	Aluminum, plastic protective enclosure	Steel	Steel	Steel
Weight in kg/m^2 (lb/ft^2) - excluding foundation	16.5 (3.4)	3.9 (0.8)	37.2 (7.6)	70.6 (14.4)	72 (14.6)
Ongoing Development	Develop one-piece plastic enclosure	Plastics R&D	Refine drive design, develop mirror bond	Build and test tilted-axis drive	None

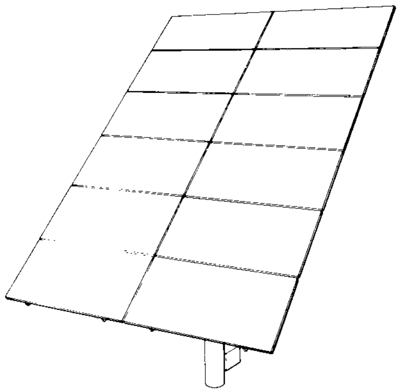

BOEING
GENERAL ELECTRIC
McDONNELL DOUGLAS
SOLARAMICS
WESTINGHOUSE

SECOND GENERATION HELIOSTATS

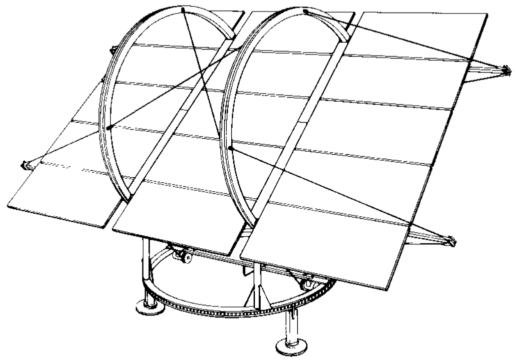
The five heliostats shown on the facing page are to be developed under 18-month contracts started in August 1979. Prototypes of the different heliostat designs will be built and tested, and cost estimates will be made for a production rate of 50,000 per year. Production planning, plant layouts, installation planning, and maintenance approaches will be completed to provide life cycle cost estimates. The baseline designs are summarized below.

DESIGN SUMMARY

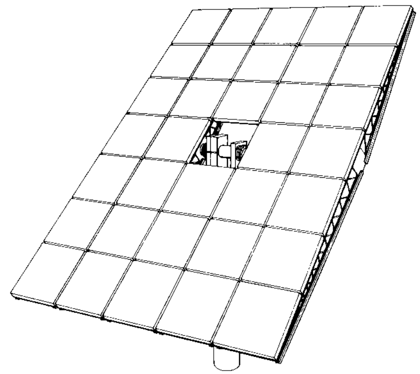
	Boeing	Martin Marietta	McDonnell Douglas	Northrup	Westinghouse
Mirror Area (m^2)	50.2	53.5	49	49	58.6
Mirror Type (2nd Surface Silver Reflector)	Glass-foam-glass-glass sandwich	Laminated fusion-float glass, steel edge support	Laminated fusion-float glass, steel hat sections	Glass-polystyrene foam-steel sandwich	Laminated fusion-float glass, steel hat sections
Drive Type: Azimuth	Planetary gear	Integrated Az/El differential gear box, single-motor drive	Harmonic	2-stage worm	Gear box-belt drive
Elevation	Machine screw linear actuators		2-stage machine screw linear actuators	2-stage worm	Gear box-belt drive
Structural Material	Steel	Steel	Steel	Steel	Steel
Stow Position	Mirror up	Mirror down	Mirror down	Mirror up	Mirror down
Weight in kg/m^2 (lb/ft^3) - exclude pedestal and foundation	30 (6)	39 (8)	35 (7)	32 (6.5)	34 (7)
Width/Height (Aspect Ratio)	0.74:1	1:1	1:1	0.71:1	1.5:1



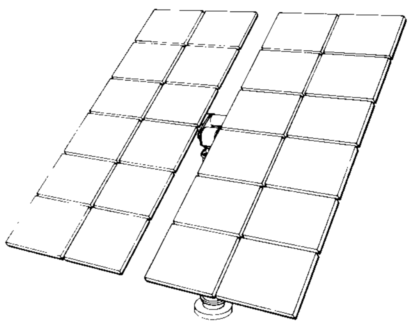
BOEING



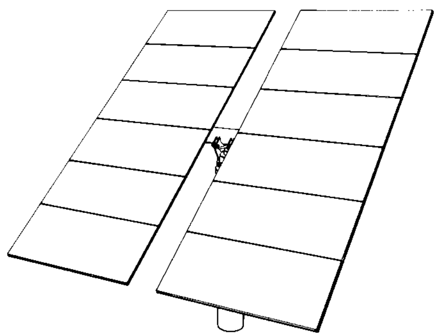
WESTINGHOUSE



NORTHRUP



MARTIN MARIETTA



MCDONNELL DOUGLAS

HELIOSTAT COMPONENT DEVELOPMENT AND SPECIAL STUDIES

The major concerns for long-life, low-cost heliostats are materials and high-cost components such as drive mechanisms and mirror modules. Materials concerns center around glass, plastic, adhesives, and degradation of reflective surfaces. Heliostat cleaning methods, dust buildup rates, and measurement and evaluation techniques are also areas requiring attention. Sandia Laboratories, Battelle Pacific Northwest Laboratories, and several commercial companies are performing component development and special studies required to develop heliostats with high efficiency and low life cycle cost. A list of the major activities is shown on the following pages.

HELIOSTAT COMPONENT DEVELOPMENT AND SPECIAL STUDIES

Contractor/Laboratory	Activity
Battelle Pacific Northwest Laboratories	Glass Specification Mirror Silvering Specification Mirror Degradation Study
Beckman Instruments	Portable Reflectometer
Boeing Engineering & Construction	One-piece Plastic Dome Protective Coatings for Mirrors and Plastic Domes Desert Exposure Testing for the Above
Foster Miller	Heliostat Washing System
General Electric - Philadelphia	Epoxy-Fiberglas Molded Mirror Module
General Electric - Schenectady	Plastic Film Development for Mirrors and Heliostat Enclosure
Martin Marietta	Mirror Degradation Study Wind Tunnel Testing
McDonnell Douglas	Mirror Degradation Study Dust Buildup Study Wind Tunnel Testing Heliostat Production Alignment Technique

HELIOSTAT COMPONENT DEVELOPMENT AND SPECIAL STUDIES (Con't)

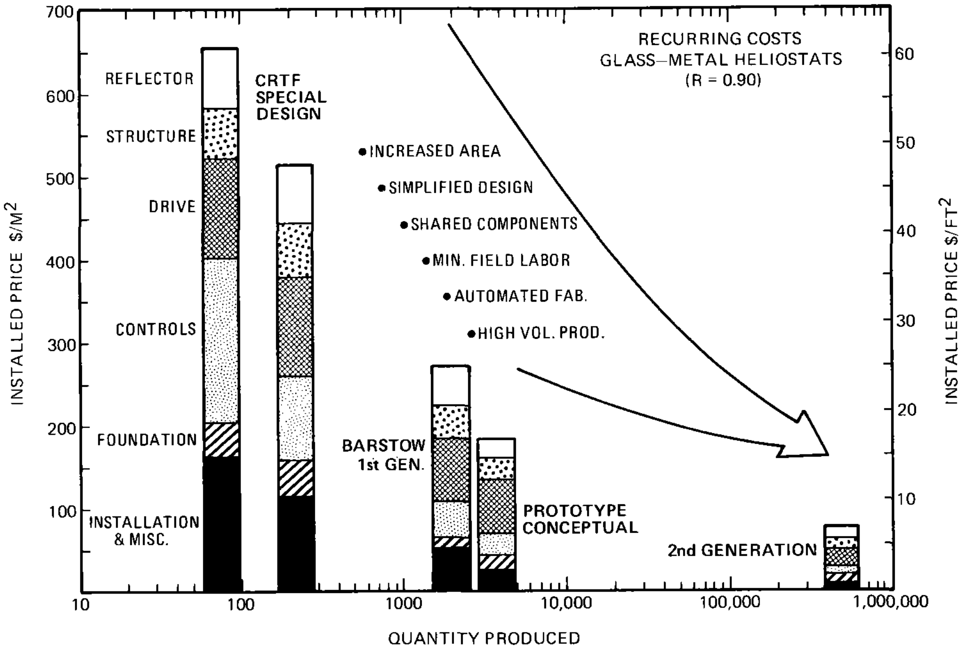
Contractor/Laboratory	Activity
Progress Industries	Heliostat Cable Drive Heliostat Protective Cover
Sandia Laboratories	Heliostat Performance Code Development Testing Methods and Techniques Glass Solarization Glass Weatherability Portable Reflectometer Mirror Degradation Study Safety Studies Cost/Performance Studies Dust Buildup Studies Wind Tunnel Testing Materials Studies
Schumacher & Associates	Ultrasonic Heliostat Cleaning Method Portable Reflectometer
Springborn Laboratories	Glass and Plastic Anti-Soiling and Antistatic Agents
Sun Power Corporation	Drive Concepts for Feathering Clamshell Heliostat

HELIOSTAT COST PROJECTIONS

The installed price and operations and maintenance costs for heliostats has been estimated by Sandia Laboratories and each of the heliostat design contractors. For a steel heliostat with glass mirrors the annual operations and maintenance costs (includes washing) are approximately 10 percent of the heliostat costs. The projected price for steel heliostats with glass mirrors is shown on the following page. The CRTF and the Barstow Pilot Plant heliostats are also shown. The two Barstow estimates are for the first generation design and the second generation conceptual designs from McDonnell Douglas.

Cost reductions per unit area result from increasing the area, simplifying the design, shared components (more mirror area per controller), minimizing field labor, automated fabrication, volume production and reduced labor due to learning.

HELIOSTAT COMPONENT BREAKDOWN
(1978 Dollars)



BACK COVER

McDonnell Douglas's Conceptual Design of a Heliostat Field