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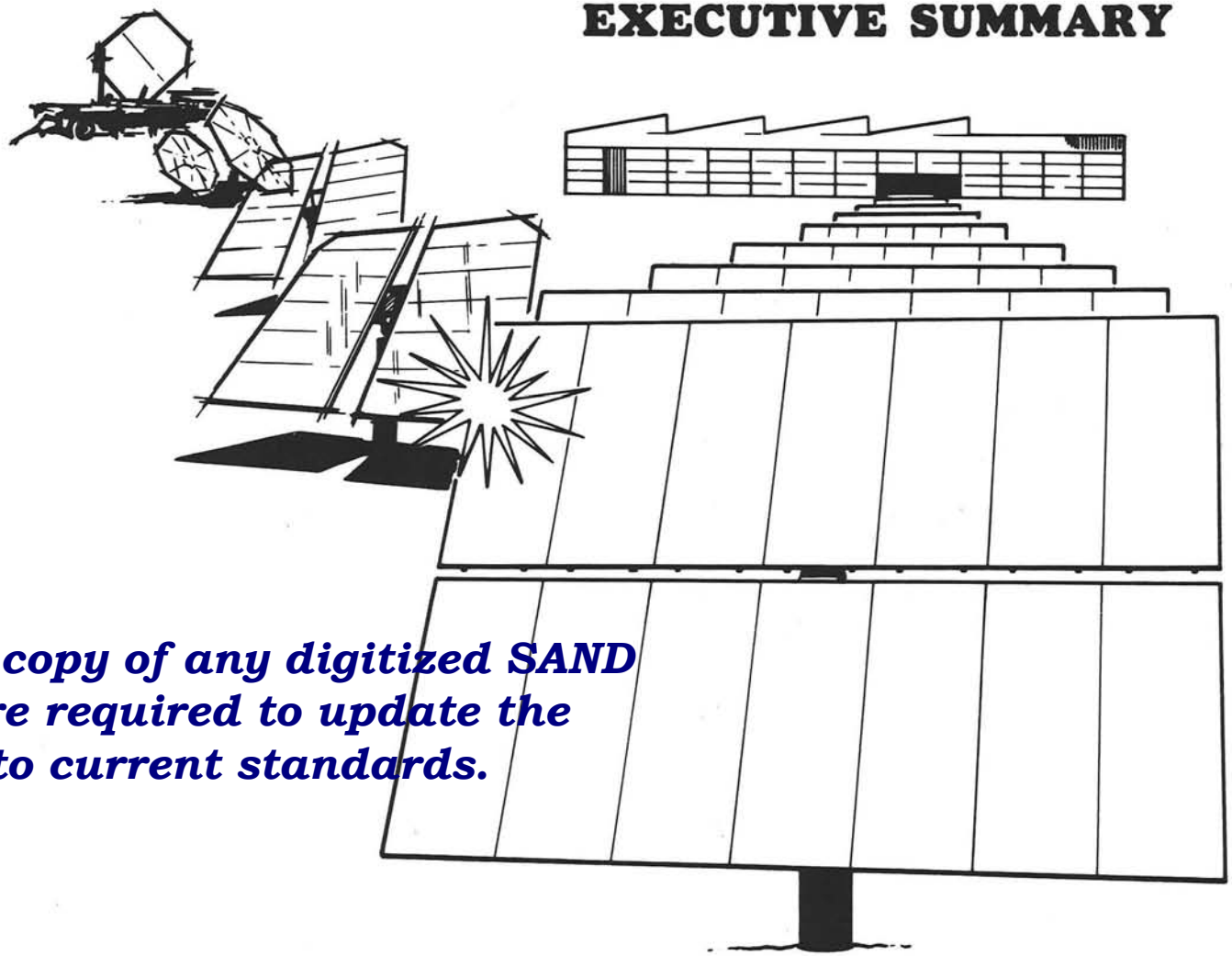
APRIL 1981

MCDONNELL DOUGLAS

SECOND GENERATION HELIOSTAT PROGRAM

EXECUTIVE SUMMARY



MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH

SECOND GENERATION HELIOSTAT PROGRAM

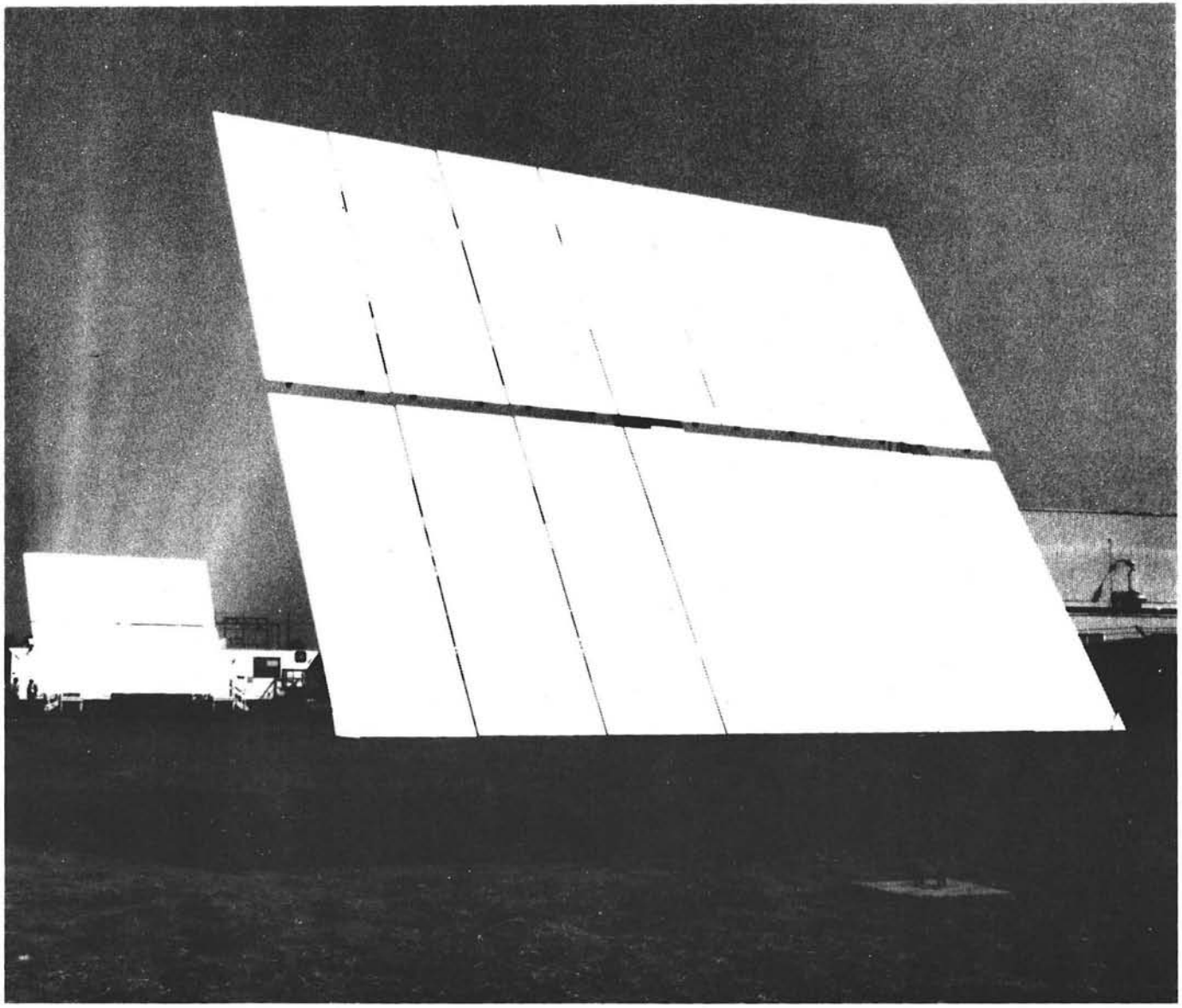
Performed by
McDonnell Douglas
Astronautics Company

Contract No. 830024A

For Sandia National Laboratories

Livermore, California

Sept 1979 Through March 1981



MDAC has developed and demonstrated a production design and production plans

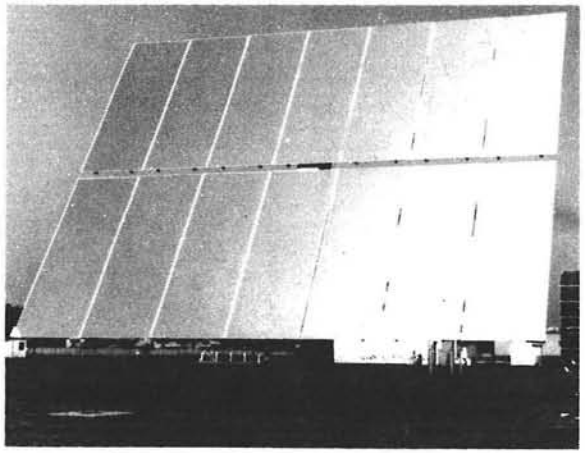
PROGRAM SUMMARY

MDAC has completed the design and preproduction unit demonstration of a production heliostat for application in solar central receiver plants. The design included definition of volume manufacturing, installation, and maintenance facilities, and resource requirements. Solar plant investment and life cycle costs have been identified. The design, production development requirements and costs meet the DOE goals for technical and economic readiness in the early 1980's. Hardware quality and simplicity supports the 30 year life goal.

The key features of the MDAC program include:

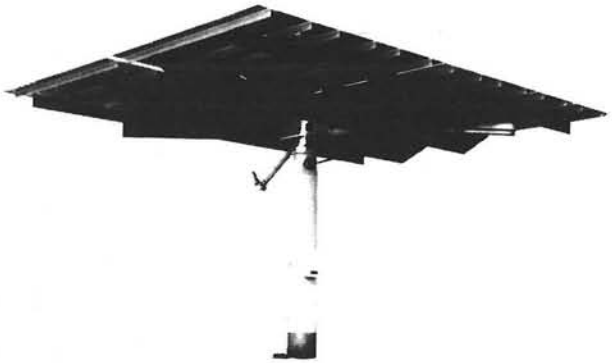
- **DESIGN EVOLVED FROM 4 PREVIOUS HARDWARE PROTOTYPES**
- **FACTORY DESIGN AND COST BY GENERAL MOTORS/F. JOS. LAMB**
- **SIMPLE FUNCTIONAL DESIGN-LOW PARTS COUNT**
- **LOW SITE ASSEMBLY LABOR**

MDAC Production heliostat is ready now for economical production, delivery/installation at all volume levels.



OPERATING

STOWED



SURVIVAL

SELECTED CONFIGURATION

Cost reductions are achieved from collector system features as well as direct heliostat costs

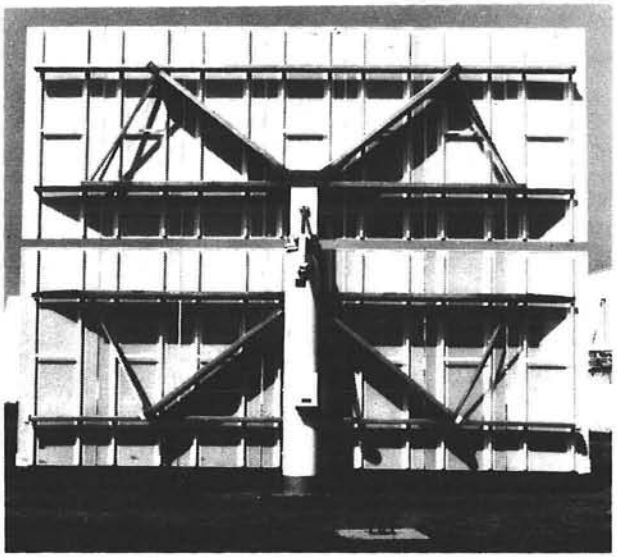
- **LOW PROFILE — 1.27/1 ASPECT RATIO**
- **LARGE AREA — 57 m²**
- **TOTAL FRONTAL AREA REFLECTIVE**
- **VERTICAL MIRROR ORIENTATION**
- **CURVED AND CANTED SURFACE**

THE CONFIGURATION IS RESPONSIVE TO COLLECTOR SYSTEM AND SITE OPERATIONS ECONOMIES

SYSTEM LEVEL COST REDUCTION IS BASED ON EMPHASIZING FULL UTILIZATION OF THE HELIOSTAT ENVELOPE TO PROVIDE REFLECTED ENERGY TO THE TOWER. THE LOW PROFILE REDUCE BLOCKING AND SHADOWING OR LAND REQUIREMENTS, AS WELL AS REDUCING WIND LOADS AND TOTAL STRUCTURE REQUIREMENTS. THE AREA AND ASPECT RATIO ARE ACHIEVED WITH MINIMUM STRUCTURE THROUGH VERTICAL MIRROR ORIENTATION. THE LARGE AREA MINIMIZES FIELD INTERCONNECTS AS WELL AS REDUCING THE AMOUNT OF POINTING AND CONTROL HARDWARE IN THE FIELD. THE OVERALL EFFECT OF REFLECTION FROM THE FULL FRONTAL AREA MAY BE; DECREASED FIELD AREA, LOWER TOWER HEIGHT AND RECEIVER SIZE, LESS ATTENUATION LOSS AND BEAM SPREADING FROM OUTER HELIOSTATS, AND A RESULTING REDUCTION IN TOTAL HELIOSTATS REQUIRED.

SELECTED DESIGN

THE MDAC DESIGN USES PROVEN PROCESSES AND MATERIALS WITH FLEXIBILITY TO APPLY FUTURE COST REDUCING PROCESSES AND MATERIALS



SUBSYSTEM	DESIGN FEATURE
REFLECTOR	• CONVENTIONAL AUTO SAFETY GLASS LAMINATE • BONDED STIFFENERS-DOUBLE CURVATURE
SUPPORT STRUCTURE	• HIGH VOLUME ROLL FORMED PARTS • AUTOMATED SPOT WELDED ASSEMBLY
DRIVE	• PROVEN AZIMUTH HARMONIC DRIVE • CONVENTIONAL BALL SCREW ELEVATION • ONLY TWO REDUCTION STAGES, BOTH DRIVES
CONTROLS	• HIGH RELIABILITY EXTENDED TEMPERATURE • HIGH POINTING ACCURACY SOFTWARE
FOUNDATION	• POURED IN PLACE REINFORCED CONCRETE • TAPER FIT PEDESTAL JOINT • COMPATIBLE WITH ANY SOIL
SITE ASSEMBLY	• THREE SELF-JIGGING FIELD COMPONENTS • FACTORY ALIGNMENT OF MIRRORS • SOFTWARE FIELD ALIGNMENT

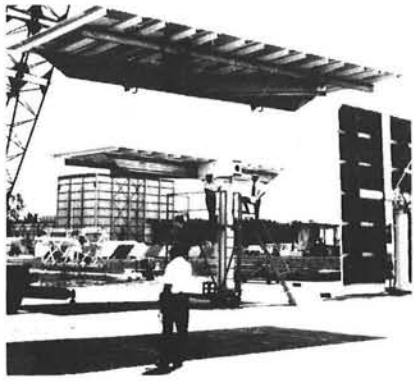
HELIOSTAT ASSEMBLY

Low site labor is inherent in the MDAC design

BY USING SPECIAL SITE ASSEMBLY EQUIPMENT AND SELF JIGGING INTERFACES, RAPID ASSEMBLY OF THE HELIOSTAT IS POSSIBLE WITH MINIMUM SKILL LABOR

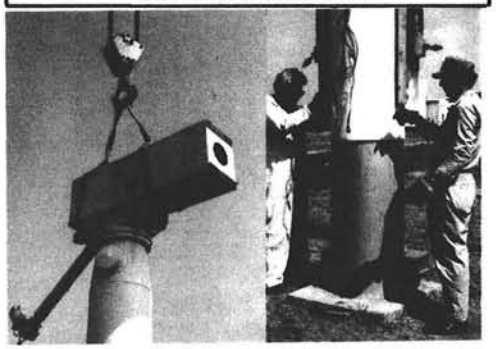
DELIVERED TO THE SITE

PEDESTAL DRIVE MAIN BEAM ASSEMBLY



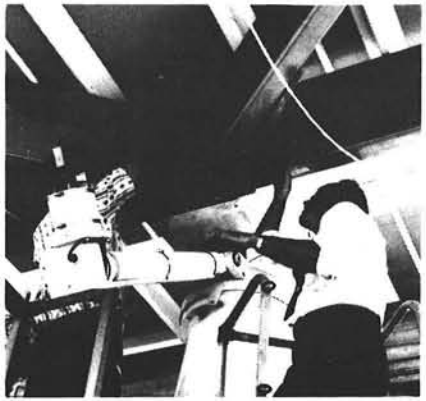
REFLECTOR ASSEMBLY

INTERFACES



FIELD INTERFACES

1° vertical alignment is controlled by foundation cone. It has been easily achieved with a carpenter's level



REFLECTOR INSTALLATION

PROCEDURE

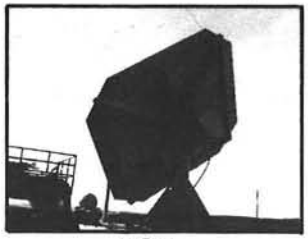
- **EMPLACE PEDESTAL, 3° ROTATION TOLERANCE**
- **CONNECT ELECTRICAL — TWO CABLES; POWER, CONTROL**
- **ADDRESS HELIOSTAT SERIAL LOCATION. SWITCH IN CONTROL BOX**

Installation times of 10 minutes per component have been achieved in the test program

- **INSTALL REFLECTOR OVER GUIDE PINS ON MAIN BEAM**
- **SECURE WITH 8 BOLTS**

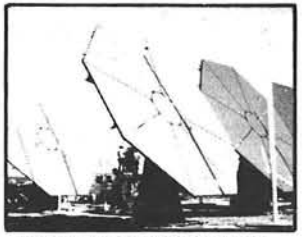
The MDAC heliostat subsystem has been thoroughly tested at the component and subsystem level.

TEST PROVEN DESIGN



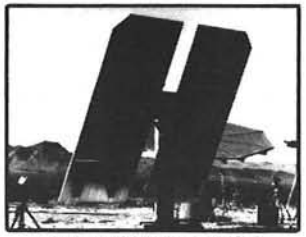
NSF

Elevation over azimuth drive
harmonic drive
jack actuator
Bonded structure
Noninverting



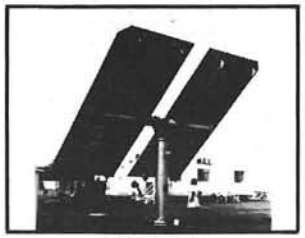
SRE OCTOGONAL

Area increase
Laminated mirror
Distributed structure
Urethane adhesive
AC motors



SRE INVERTING

Tube pedestal
Standard mirror sizes
Wind tunnel loads
Intel micro processor



10 MWe

Roll formed structure
Mirror edge seal
Mirror curvature
Open loop control
Mirror cant

SECOND GENERATION

Tapered fit pedestal
Wire race bearing
Ball screw jack
Helical gears
Factory assembly
Vertical mirrors
Double curvature

Extensive Test History Data Base Includes
- **5 Generations of Hardware**
- **Component Tests**
- **Life Tests**
- **Performance**

Subsystem tested at MDAC and CRTF verify performance within the A10772-D Specification

SECOND GENERATION SUBSYSTEM LEVEL

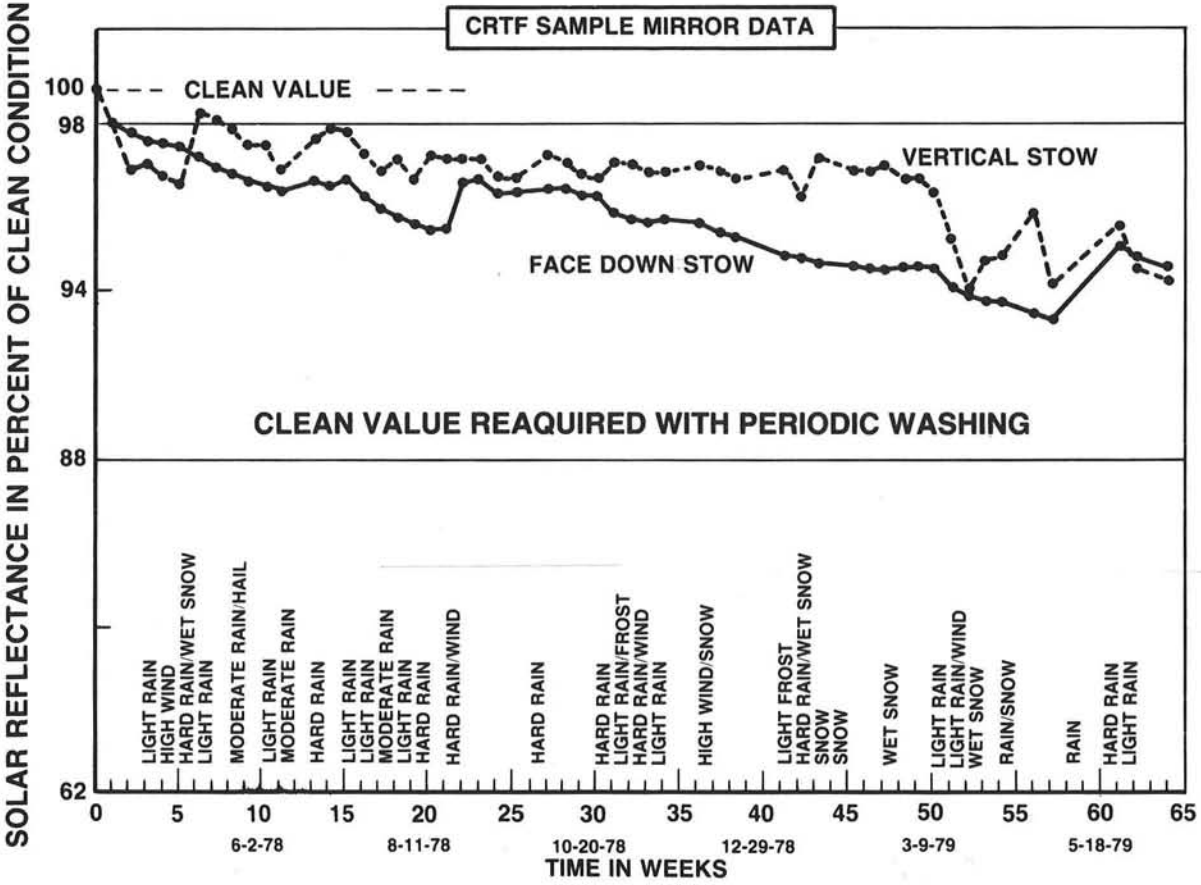
TEST	MDAC	SANDIA	TEST	MDAC	SANDIA
SITE INSTALLATION	•	•	POWER LOSS RECOVERY	•	•
TRACK ACCURACY	•	•	POWER CONSUMPTION	•	•
LIFE CYCLE	•	•	BEAM QUALITY	•	•
OPERATIONAL WINDS		•	SLEW RATES	•	•
SURVIVAL WINDS		•			
LONG TERM TRACK	•	•			

MAINTENANCE

A thorough maintenance analysis has defined spares, maintenance equipment, and labor requirements.

SCHEDULED MAINTENANCE
- **MIRROR WASHING —**
- **PERIODIC FIELD INSPECTION**

Mirror washing is scheduled each month. Natural environments in some locations may reduce the frequency.



Component maintenance predictions have been developed based on standard industry data sources to provide spares inventory requirements and maintenance labor. Off heliostat repairs are stressed with major component replacement.

TYPICAL 50 MWe FIELD
POPULATION 5412 HELIOSTATS

REPLACEMENT UNIT	FAILURE RATE $\times 10^{-6}$	SPARES
CONTROLLER	1.65	37
DRIVE ASSEMBLY EL	2.73	6
AZ	2.94	7
MOTOR ENCODER	4.73	88
MIRROR MODULE	0.1	70

Detail production processes, equipment selection, and the production facility design were provided by General Motors Energy Systems and the F. Jos. Lamb Company. Factory costs were also provided.

PRODUCTION FACILITY

FACTORY DESCRIPTION MODEL LOCATION — TUSCON, ARIZONA	
PRODUCTION CAPABILITY	50,000 YEAR, TWO SHIFTS
PLANT AREA	260,280 FT^2
PLANT SITE	40 ACRES
PLANT COST	$36,000,000
EQUIPMENT AND TOOLS	$50,500,000

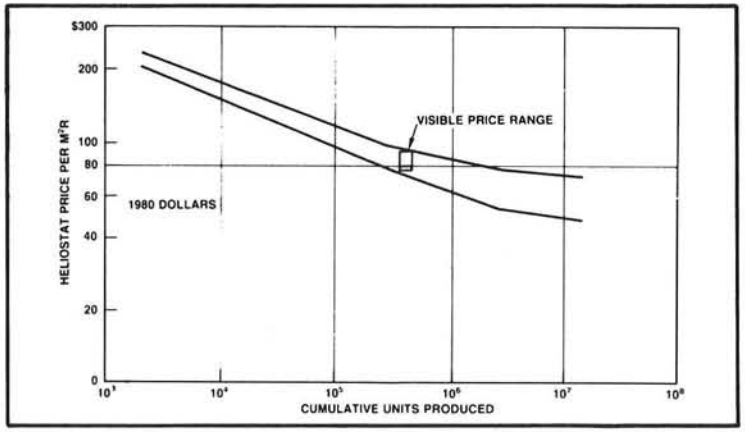
The plant is fully air conditioned, and highly automated so that less than 11 man hours are required to manufacture a heliostat. Staging area for trucks supporting 2 1/2 days production are provided.

HELIOSTAT COST FROM FACTORY			
RATE (YEAR)	37,500	50,000	62,500
MATERIAL	2921.36	2921.36	2921.36
LABOR	90.80	90.80	90.80
BURDEN	713.63	602.36	535.59
SPECIAL TOOLS	54.47	40.80	32.68
FACTORY	3780.26	3655.37	3580.43
OUTSIDE COSTS	38.83	29.12	23.30
TOTAL COSTS	3819.09	3684.49	3603.73
COST/M^2	67.00	64.64	63.22

Factory costs are based on a 1980 composite labor rate for the southwest USA.

PURCHASE	COMPONENT	FACTORY FABRICATION
BACKLIGHT MIRROR	MIRROR MODULE	LAMINATING BOND STIFFENER
ROLL FORMED PARTS	SUPPORT STRUCTURE MAIN BEAM	SPOT WELDING WELD COMPONENTS
BEARINGS, GEARS	AZIMUTH DRIVE	• WELD HOUSING • BROACH HARMONIC GEARS • MACHINE COMPONENTS • ASSEMBLE
JACK, SUPPORT CASTING	ELEVATION DRIVE	MACHINE SUPPORT
	PEDESTAL	FORM AND MACHINE
	REFLECTOR ASSEMBLY	ASSEMBLE AND CANT
MOTOR, CONTROLLER	PEDESTAL, DRIVE, MAIN BEAM	ASSEMBLE AND ALIGN

VOLUME PRICE



INSTALLED HELIOSTAT PRICE

The MDAC heliostat price meets the projection and targets of previous studies adjusted to current dollars, and supports commercially competitive solar power plants.

COMPARISON WITH PREVIOUS RESULTS

(1980 DOLLARS/M²)

ELEMENT	PDR MDAC	PROTOTYPE (25K/YEAR) MDAC	BATTELLE	GM	2ND GEN. MDAC/GM
REFLECTOR UNIT	$ 24.80	$21.70		$ 36.90	$30.30
DRIVE UNIT	45.50	32.00	$80.02	63.30	33.60
CONTROL AND INSTRUMENTATION	6.05	2.80		4.40	3.50
HELIOSTAT SUPPORT	4.50	3.30		8.50	2.90
FOUNDATION AND SITE	11.65	15.00			10.20
FIELD ASSEMBLY AND CHECKOUT	22.35	3.68	16.90	16.90	3.00
TRANSPORTATION		0.82			4.20
SITE PLANT ACTIVATION	2.65				
TOTAL INSTALLED PRICE	$117.50	$79.30	$96.92	$130.00	$87.70
ANNUAL OPERATIONS					
FIRST YEAR		$ 1.36			$ 1.32
AVERAGE	$ 2.31	.76			1.02
DATE OF STUDY	MAY 77	AUG. 78	OCT. 79	DEC. 79	JAN. 81

COST BREAKDOWN

SECOND GENERATION COST BREAKDOWN (1980 DOLLARS — 50,000/YEAR RATE — 10TH YEAR — 5412 HELIOSTATS/FIELD)

COST ELEMENT	COST PER HELIOSTAT	$/m²
HELIOSTAT INVESTMENT		
REFLECTIVE UNIT	$1,648.00	$28.98
DRIVE UNIT	1,837.00	32.32
CONTROL/INSTRUMENTATION	191.00	3.36
FOUNDATION/SITE PREPARATION	569.00	10.00
HELIOSTAT SUPPORT STRUCTURE	158.00	2.78
FIELD ASSEMBLY AND CHECKOUT	168.00	2.95
TRANSPORTATION	237.00	4.17
TOTAL INSTALLED COST	$4,808.00	$84.56
PLANT CONTROL (HAC)	$ 22.00	$ .38
INITIAL SPARES	$ 8.00	$ .14
MAINTENANCE EQUIPMENT		
HANDLING EQUIPMENT	$ 26.00	$ .46
TOOLS AND CALIBRATION	7.00	.12
WASHING EQUIPMENT	32.00	.56
TOTAL	$ 65.00	$ 1.14
OPERATIONS AND MAINTENANCE FIRST YEAR		
SPARES	$ 6.79	$ .12
REPAIR PARTS	1.62	.03
OTHER	19.36	.34
CORRECTIVE MAINTENANCE	31.92	.56
SCHEDULED MAINTENANCE	15.32	.27
TOTAL	$ 75.21	$ 1.32
FOLLOW-ON	$ 57.78	$ 1.02
MEMO: FACTORY COST		
PLANT AND LAND	$ 36.8M	
EQUIPMENT	42.3	
TOOLS	8.2	
	$ 87.3M	

This cost data is highly significant in that it is based on fabricated, tested hardware; subjected to indepth manufacturing analysis; based on direct vendor quotes and detailed tool and labor routing analysis.

Future developments will continue the efforts toward cost reduction and cost realization, with emphasis on near term intermediate production levels.

FUTURE DEVELOPMENT

POTENTIAL COST REDUCTIONS

- **MANUFACTURING PROCESSES**
- **PARTS COUNT**
- **MATERIAL REDUCTIONS**
- **FOUNDATION MATERIAL**
- **INSTALLATION TECHNIQUES**

Consistent with past development, the completed second generation program has illuminated additional areas for cost avoidance or reduction. The implementation of these changes is paced by the market development.

THE CURRENT DESIGN IS READY FOR PRODUCTION AND MDAC IS READY FOR THE COMMERCIAL MARKET

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