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The Cost of Heliostats in Low Volume Production

Prepared by
Pacific Northwest Laboratory
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THE COST OF HELIOSTATS IN LOW
VOLUME PRODUCTION

January 1980

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PROJECT MANAGER
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PREFACE

In addition to serving as project monitor for SERI, Dennis Horgan, SERI, functioned as an invaluable member of the team.

LeRoy Weinstein, Don Steinmeyer, and the staff of McDonnell Douglas were extremely helpful in interpreting design and providing procurement information. Several Pacific Northwest Laboratory staff members, including R. G. Nelson, D. R. Brown, S. A. Weakley, M. S. Nordmeyer, and Naomi Brimhall contributed to this program:

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FOREWORD

This final report was prepared under subcontract AH-9-8043-1 as a part of SERI Task 5121.11, the Supply Task of the Repowering Strategy Analysis. The objective of the Repowering Strategy Analysis is to define a government role in repowering that constitutes an efficient investment in pursuit of viable private markets for heliostat-based energy systems. The purpose of the Supply Task is to determine the installed cost of solar systems and components in a repowering program and outline the manufacturing investment required to achieve those costs.

The objective of this study is to estimate the cost of producing heliostats using low volume production techniques. The purpose of investigating low volume production is to determine the cost of heliostats which may be expected during a demonstration program such as that proposed by the repowering strategy analysis. To accomplish this objective, this study used the same methodology as that used for earlier studies of high volume manufacture [1]. Vendor quotations were obtained for purchased parts and supplies and the costs of labor, capital, and installation were added to produce an installed price estimate.

The conclusion of this study is that, at production volumes of 2500 units per year, the installed cost is expected to be less than 216 \$/M². While this cost is significantly higher than the cost of sustained high volume production, it is much less than the cost of a one-time purchase. This result implies that there are some economies of production scale, even at the low production volumes needed for a demonstration program.

Dennis N. Horgan, Jr.
Project Manager

[1] Drumheller, K., et al. "Heliostat Manufacturing Cost Analysis." Pacific Northwest Laboratory, SERI/TR-8043-1, October 1979.

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SUMMARY

The purpose of the study is to estimate the cost of heliostats in low volume production.

This study indicates that in small volumes, heliostats can be produced at an installed cost of approximately 200 \$/M² for a 49.053 m² heliostat. Initial one-time costs of \$10 to \$15 million would be required, although part of the one-time costs are recoverable.

This study provides estimated costs of heliostats that are produced in a plant operating on a continuous basis for a period of four years at a production rate of 2,500 heliostats per year. This scenario was selected somewhat arbitrarily as a scenario that could lead to a heliostat market of 5,000 to 10,000 units per year.

The approach to this study was essentially the same as that used in previous heliostat manufacturing cost studies. This approach is the basic approach used by any industry in costing a product. It simply breaks down the cost elements in a product into their individual components and adds them up. The cost elements in a heliostat include direct materials, direct labor, manufacturing overheads, and plant overheads.

The design information needed for cost estimating was developed from the McDonnell Douglas prototype design and supplemented where necessary to provide a consistent basis for cost estimating.

For this analysis, direct materials costs were estimated by requesting engineering estimates or price quotations from suppliers. Direct labor costs were estimated based on moderately detailed industrial engineering analysis. Manufacturing overheads and company overheads were applied based on moderate analysis of comparable industry and the experience of the principal author in comparable work with several companies.

Two distinct analyses were made. One was a scenario that utilized purchased components to a large extent. In this scenario, mirror modules are purchased silvered and glued together. The drive components are purchased complete (but not assembled). The pedestal is purchased complete and the electronics and power supply are purchased almost complete. The only in-house operations are the assembly of the support structure, the assembly of the drive and components, and the checkout prior to shipment.

A second scenario contemplates making most of the parts inhouse. This scenario is essentially the same as was used in the production of 25,000 and 250,000 heliostats. It requires a greater capital investment than a purchased components approach. However, it will produce heliostats at significantly less cost.

These two scenarios are considered outside ranges. The first scenario approaches the cost of buying assembled heliostats. The second approach assumes a complete manufacturing plant that could be expanded as production increases.

The estimated installed cost of a heliostat with mostly procured components is \$10,557. The estimated cost of a heliostat with mostly in-house components is \$9,153.

There are several basic differences in this startup operation approach and the estimate for a continuing plant operation, even though the production rates of 2,500 heliostats per year are the same. The principal differences are:

- For the startup case, glass and control cost estimates are based on supplier quotations or estimates without adjustment for technology and negotiating differences which might result from a continuing leveled-out operation.
- It is assumed almost completely standard equipment is used, so it can be converted to other use if necessary.
- Fixed charges of 35% are used on plant and equipment to compensate for the short-time guarantee on the market.
- In the "procured components" case, much more of the heliostat is procured from independent suppliers.

In practice, it is considered likely that product design improvements, negotiation with vendors, and production improvement can result in some reduction of the costs arrived at herein. Our conclusion is that actual costs near the \$9,153 of the "in-house components" case can be achieved.

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SECTION 1.0

INTRODUCTION

1.1 PURPOSE

The first report of this contract [1] examined the production of heliostats using automated manufacturing techniques to estimate the amount by which heliostat costs could be reduced in mass production volumes. The cost was found to be about a third of what it would be in custom production. However, the achievement of those costs is dependent on substantial capital investment. While the market is growing, as during a demonstration program, the demand is not high enough to justify the capital investment. The purpose of this study is to estimate the cost of manufacturing heliostats using the types of production processes which are likely to be used in supplying a limited demonstration market.

1.2 SCOPE OF THIS STUDY

This study provides estimated costs of heliostats that are produced in a plant operating on a continuous basis for a period of four years at a production rate of 2,500 heliostats per year. This scenario was selected somewhat arbitrarily as a scenario that could lead to a heliostat market of 5,000 to 10,000 units per year.

1.3 APPROACH

The approach to this study was essentially the same as that used in previous heliostat manufacturing cost studies [1,2]. This approach is the basic approach used by any industry in costing a product. It simply breaks down the cost elements in a product into their individual components and adds them up. The cost elements in a heliostat, or any other product, include direct materials, direct labor, manufacturing overheads, and plant overheads.

The design information needed for cost estimating was developed from the McDonnell Douglas prototype design [3] and supplemented where necessary to provide a consistent basis for cost estimating. The heliostat configuration is shown in Fig. 1-1. The design is more fully described in Reference 3.

For this analysis direct materials costs were estimated by requesting engineering estimates or price quotations from suppliers. Direct labor costs were estimated based on moderately detailed industrial engineering analysis. Manufacturing overheads and company overheads were applied based on a moderate analysis of comparable industry and the experience of the principle author in comparable work with several companies.

Within this approach two distinct analyses were made. One was a scenario that utilized purchased components to a large extent. In this scenario, mirror modules are purchased silvered and glued together. The drive components are

Fig. 1-1. MCDONNELL DOUGLAS PROTOTYPE HELIOSTAT [3]

purchased complete (but not assembled). The pedestal is purchased complete and the electronics and power supply are purchased almost complete. The only in-house operations are the assembly of the support structure, the assembly of the drive and components, and the checkout prior to shipment.

A second scenario contemplates making most of the parts inhouse. This scenario is essentially the same as was used in the production of 25,000 and 250,000 heliostats. It requires a greater capital investment than a purchased components approach. However, it will produce heliostats at significantly less cost.

These two scenarios are considered outside ranges. The first scenario approaches simply buying heliostats assembled. The second approach assumes a complete manufacturing plant that could be expanded as production increases.

SECTION 2.0

ESTIMATING RESULTS

The estimates for each of the two cases are summarized in Tables 2-1 and 2-2. The estimated installed cost of a heliostat with mostly procured components is \$10,557. The estimated cost of a heliostat with mostly in-house components is \$9,153. One time costs of \$8,723,076 and \$12,719,800 are required for procured components and in-house components cases, respectively.

2.1 MANUFACTURING COMPANY COSTS

2.1.1 General

Estimates of material costs were obtained by asking vendors for engineering estimates. In many cases the estimates were provided as firm quotations. Whether the suppliers will actually supply within a reasonable range of the numbers provided is open to some question. In our opinion the values obtained are in a reasonable range. Almost invariably suppliers are reluctant to quote on an item unless they feel they can deliver. This is particularly true with raw material such as float glass and steel. In fact, many raw material estimates are provided as specific firm quotations with a specific delivery date and lifetime for the quotation. In the case of materials which may not be routinely produced in quantity today, such as low iron float glass or fusion glass, there is a range of numbers from different suppliers. For this analysis we have used the upper part of the range. For previous estimates of steady-state costs we have tended more to the middle or lower part of the range.

Direct labor costs of some operations, such as turning a part on a machine, can be established with reasonable accuracy by people who produce similar parts on their machines. In fact, it is possible to visit a producing specialty shop, observe the production of similar parts and time with a stop

Table 2-1. HELIOSTAT COST SUMMARY

	Cost, \$/Heliostat	
	Procured Components	In-House Components
Company Manufacturing Cost	9,201	7,797
Installation Cost	1,356	1,356
TOTAL	<u>\$10,557</u>	<u>\$9,153</u>
COST \$/M ²	\$215.22	\$186.59

Table 2-2. ONE-TIME COSTS, HELIOSTAT MANUFACTURING

Cost Item	Investment Cost, \$	
	Procured Components	In-House Components
Outside Tooling	1,042,000	1,042,000
Plant Capital	5,072,076	9,068,800
Subtotal	6,114,076	10,110,800
Installation Capital	1,109,000	1,109,000
Subtotal	7,223,076	11,219,800
Product Development	1,500,000	1,500,000
TOTAL	<u>\$8,723,076</u>	<u>\$12,719,800</u>

watch the operations to produce the parts. On parts like this one can be reasonably certain that his labor costs are in a reasonable range. In the case of assembling a mirror module, for example, it is not really known whether the mirror figure required can be obtained with the present commercially available equipment. Thus, there is an element of uncertainty. In this analysis a contingency has been added to provide for such uncertainties. In the case of operations such as assembly of the support structure and boring support holes in the mirror structure for attaching the hat section stringers, it is known how long it takes to make a spot weld and how long it takes to drill a hole through a piece of metal. The times required to move from one point to another could be established through time motion studies. However, they are established herein by simply observing people performing similar operations.

Manufacturing overheads will vary to a certain extent with company policy; for example, will you have a 20-man crew with a single supervisor or will you have a 50-man crew with a single supervisor? Also, will you maintain a supply of three spare sets of tooling or will you only keep one spare set of tooling? These costs will vary to some extent from company to company. But a large variation does not have an overwhelming effect on heliostat prices.

One of the biggest unknowns in heliostat costing is the general overheads. These include general administration, contracts people, sales people, personnel and public relations people, the cost of working capital, taxes, and profit. A review of several companies' cost statements in Moody's Industrial Manual shows variation from 15 to 35% of total cost. We have used a range of companies that produce fairly simple products and sell to the utilities market. Whether the heliostat business will operate in this way is not really known. However, a difference by a factor of two in overhead costs does not have an overpowering effect on heliostat costs.

For this analysis and assuming a short-term recovery, we have used fixed charges of 35% on equipment. Fixed charges include depreciation, interest, taxes,

capital repairs, and return on investment. They are basically an annualized cost of owning a capital facility. For a public utility it is common to use about 10% fixed charges. A private utility will use something like 20% fixed charges. Manufacturing operations utilizing standard equipment and a well established product will use 20 to 30%. Because of the 4-year operation ground rule, we have chosen to use the relatively higher number of 35%, it is highly probable that if the operation were terminated after four years, much of the capital equipment could be sold, so this provides a conservative result.

2.1.2 Direct Materials

2.1.2.1 Procured Components Scenario

Direct materials are summarized in Table 2-3 and detailed in Table 2-4.

The glass cost is based on a formal estimate from a major glass supplier. It contemplates the use of 0.063 low iron float glass for the mirror, and commercial clear float glass for the mirror backing.

Table 2-3. SUMMARY OF DIRECT MATERIAL COSTS FOR MANUFACTURING

Item	\$ / Heliostat at 2,500 Annual Production Rate	
	Procured Components	In-House Components
Mirror Module	1,318.92	1,094.92
Support Structure	382.14	382.14
Azimuth Drive	211.55 ^a	327.84
Elevation Drive	1,018.54 ^a	1,157.88
Fabricated Components, AZ DR, EL DR, and PED	2,700.00 ^b	---
Motors	239.14	239.14
Pedestal ^a	150.60	205.56
Controls	450.69	450.69
Allowance for Materials Not Detailed and Yield	100.00	200.00
Total Direct Materials, Mfg.	<u>\$6,571.58</u>	<u>\$4,058.17</u>

^aThis includes only those items not included in "Fabricated Components, AZ DR, EL DR, and PED."

^bThis cost element includes components of the azimuth drive, elevation drive, and pedestal.

Table 2-4. DIRECT MATERIALS COST ESTIMATE - DETAIL

Descriptive Part Name	Quantity Per H	Procured Components		In-House Components	
		Unit Price, \$	Cost/ Heliostat, \$	Unit Price, \$	Cost/ Heliostat, \$
<u>Mirror Module</u>					
Mirror Panel, 48 x 132, silvered	12	55.88	670.56	55.88	670.56
Glass Panel, Float, 48 x 132	12	32.03	384.36	32.03	384.36
Bonding, Mirror Module	12	22.00	264.00	20.00 ^b	40.00
Subtotal, Mirror Module	-		1,318.92		1,094.92
<u>Support Structure</u>					
Outboard Cross Beam	2	14.11	28.22	14.11	28.22
Inboard Cross Beam	2	52.08	104.16	52.08	104.16
Diagonal Beam	4	20.17	80.68	20.17	80.68
Hat Section Stiffener	24	4.39	105.36	4.39	105.36
Outboard Angle	4	0.25	1.00	0.25	1.00
Inboard Angle	4	0.30	1.20	0.30	1.20
Gusset Angle	4	5.56	22.24	5.56	22.24
Clinch Nut - 1/4 in.	48	0.05	2.40	0.05	2.40
Bolt, 1/4 x 3/4, UNC-20	48	0.05	2.40	0.05	2.40
Washer, SAE Flat, 1/4	48	0.01	0.48	0.01	0.48
Adhesive, Mirror to Hat Section	1.7	20.00	34.00	20.00	34.00
Subtotal, Support Structure			382.14		382.14
<u>Azimuth Drive</u>					
Main Cylinder, AZ DR HSG, 16 OD x 0.5 Wall x 5.5, Raw Stock	1		--- ^a	8.69	8.69
Retainer, AZ DR HSG, 14 ID x 20 ID x 1.25	1		---	13.00	13.00
Top, AZ DR HSG, 16 D x 1/2 t	1		---	8.95	8.95
Motor Mount, AZ DR HSG, 1/2 x 4 x 8 Raw Stock	2		---	0.99	1.98
Motor Mount, AZ DR HSG, 1/2 x 4 x 7 Raw Stock	2		---	0.88	1.76
Shaft Mount, AZ DR HSG, 3.25 OD x 1.75 ID x 3, Raw Stock	1		---	5.54	5.54
Ears, AZ DR HSG, 1 1/4 x 5 x 9	2		---	3.96	7.92
Ears, AZ DR HSG, 1 1/4 x 8 x 14	2		---	9.08	18.16
Membrane, AZ DR, 10 OD x 0.156 Raw Stock	1		---	1.33	1.33
Tube, AZ DR, 10 OD x 0.156 x 8 Raw Stock	1		---	5.70	5.70
Spline, AZ DR, 10 OD x 0.312 x 3 Raw Stock	1		---	7.44	7.44
Doubler, AZ DR, 6.5 OD x 0.375 Raw Stock	2		---	1.27	2.54
Plug, AZ DR, 7.0 OD x 1.5 Raw Stock	1		---	6.23	6.23
Drive Shaft, AZ DR, 1.75 OD x 0.75 ID x 10.75 Raw Stock	1		---	5.11	5.11

^aParts included in \$2,700 quotation on "Fabricated Components for Azimuth Drive (AZ DR), Elevation Drive (EL DR), and Pedestal (PCD).

^bTwo gallons of adhesive per heliostat at \$20 per gallon.

Table 2-4. (contd)

Descriptive Part Name	Quantity Per H	Procured Components		In-House Components	
		Unit Price, \$	Cost/ Helio-stat, \$	Unit Price, \$	Cost/ Helio-stat, \$
<u>Azimuth Drive (contd)</u>					
Retainer-Outer, AZ DR, 19.625 OD x 15.1875 ID x 1.25 Raw Stock	1	11.44	11.44	11.44	11.44
Pan Oil, AZ DR, 15 OD x 0.125 Raw Stock	1	2.25	2.25	2.25	2.25
Circular Spline, AZ DR, 15 OD x 10 ID x 2.75 Raw Stock	1		---a	21.94	21.94
Tube, Electric Wire, AZ DR, 0.688 OD x 0.63 Wall x 13 Raw Stock	1	0.26	0.26	0.26	0.26
Cover, AZ DR, 9 OD x 0.125 Raw Stock	1	0.88	0.88	0.88	0.88
Cover, AZ DR, 8 OD x 0.125 Raw Stock	1	0.73	0.73	0.73	0.73
Helicon, AZ DR	1	3.60	3.60	3.60	3.60
Pinion, Helicon, AZ DR	1	8.40	8.40	8.40	8.40
Ring, Pinion, Ret., AZ DR, 3/4 External	1	0.11	0.11	0.11	0.11
Shim-Gear, AZ DR, 1.50 OD x 1.125 ID	1	0.11	0.11	0.11	0.11
Key-Gear, AZ DR, Use 1/4 x 1/4 x 1 sq.	1	0.07	0.07	0.07	0.07
Nut-Gear, AZ DR, Use 1 in., AFBMA Standard W-05	1	1.20	1.20	1.20	1.20
Washer-Gear, AZ DR, Use 1 in., AFBMA Standard W-05	1	0.07	0.07	0.07	0.07
Bearing-Drive Shaft, AZ DR, Use 1 ID x 2 1/4 OD x 3/4 L	1	3.11	3.11	3.11	3.11
Ring, Bearing Ret., AZ DR, 2 1/4 OD Internal	1	0.11	0.11	0.11	0.11
Bushing, Pivot, AZ DR, KJS-1616060	2	0.31	0.62	0.31	0.62
Bearing, AZ DR, BB-2151	1	93.89	93.89	93.89	93.89
Bearing, AZ DR, BB-2149, Turret	1	43.25	43.25	43.25	43.25
Nut, AZ DR, 1/2	8	0.05	0.40	0.05	0.40
Bolt, AZ DR, 1/2 x 2, Class 5	8	0.11	0.88	0.11	0.88
Bolt, AZ DR, 1/2 x 3, Class 5	8	0.14	1.12	0.14	1.12
Washer, AZ DR, 1/2	16	0.01	0.16	0.01	0.16
Screw, AZ DR, 1/2 L, FH	8	0.01	0.08	0.01	0.08
Bolt, AZ DR, High Strength	12	1.30	15.60	1.30	15.60
Nut, AZ DR, High Strength	12	1.92	23.04	1.92	23.04
Clamp, AZ DR, Wire Tube	1	0.11	0.11	0.11	0.11
Screw, AZ DR, Cover to Drive	4	0.01	0.04	0.01	0.04
Grommet, AZ DR	1	0.02	0.02	0.02	0.02
Subtotal, Azimuth Drive			211.55		327.84
<u>Elevation Drive</u>					
Sides, Drag Link, EL DR, 8 x 24 x 3/4 Blank	2	---	---a	12.29	24.58
Ears, Drag Link, EL DR, 4 x 14 x 3/4 Blank	2	---	---	4.03	8.06
Top, Drag Link, EL DR, 15 x 20 x 1/2 Blank	1	---	---	9.31	9.31

aParts included in \$2,700 quotation on "Fabricated Components for Azimuth Drive (AZ DR), Elevation Drive (EL DR), and Pedestal (PED).

Table 2-4. (contd)

Descriptive Part Name	Quantity Per H	Procured Components		In-House Components	
		Unit Price, \$	Cost/ Heliostat, \$	Unit Price, \$	Cost/ Heliostat, \$
<u>Elevation Drive (contd)</u>					
Tube, EL DR, 16 OD x 0.105 x 81 1/2, Pipe	1	---	--- ^a	47.83	47.83
Tab, Actuator, EL DR, 0.5 x 10 x 10 Blank	2	---	---	3.95	7.90
Tab, Hinge, EL DR, 0.5 x 9 x 9 Blank	4	---	---	3.39	13.56
Flange, EL DR, 0.625 x 18 x 18 Raw Stock	2	---	---	14.05	28.10
Tube, Clevis, EL DR, 1 OD x 3/4 ID	2	0.40	0.80	0.40	0.80
Dushing, EL DR, KJS 1620060	2	0.41	0.82	0.41	0.82
Bushing, EL DR, KJS 1624060	2	0.46	0.90	0.45	0.90
Bushing, EL DR, 1612060	4	0.29	1.16	0.29	1.16
Seal, EL DR, 1 x 1 1/2	4	0.24	0.96	0.24	0.96
Seal, EL DR, 1 1/2 x 2 x 1/8	8	0.24	1.92	0.24	1.92
Seal, EL DR, 1 1/2 x 2 x 1/4	2	0.24	0.48	0.24	0.48
Shim, EL DR, 3/4 ID x 1 1/2 OD x 1/8	4	0.15	0.60	0.15	0.60
Shim, EL DR, 1 ID x 1 1/2 OD x 1/16	4	0.10	0.40	0.10	0.40
Shim, EL DR, 1 ID x 1 1/2 OD x 1/8	6	0.12	0.72	0.12	0.72
Bolt, EL DR, 3/4 x 5, Class 5	2	0.53	1.06	0.53	1.06
Thrust Bearing, EL DR, KTM 1628063	4	0.27	1.08	0.27	1.08
Nut, EL DR, 0.75	2	0.30	0.60	0.30	0.60
Bushing, Clamp Up, EL DR, 0.75 dia x 5 long, Class 8	2	0.12	0.24	0.12	0.24
Bolt, Rod End, EL DR, 3/4 x 3 1/4, Class 8	2	0.34	0.68	0.34	0.68
Nut, Rod End, EL DR, 3/4	2	0.30	0.60	0.30	0.60
Bushing, Clamp Up, EL DR	2	0.12	0.24	0.12	0.24
Jack, Screw, EL DR	2	500.00	1,000.00	500.00	1,000.00
Shaft, Pivot, EL DR, 1 1/8 T, 1 in. Shaft, 2 LG	4	1.20	4.80	1.20	4.80
Washer, EL DR, AN-960-416L, Lawrence Eng.	4	0.12	0.48	0.12	0.48
Subtotal, Elevation Drive			1,018.54		1,157.08
<u>Motors</u>					
Motors, Tracking, 1/4 HP	1	75.75	75.75	75.75	75.75
Motors, Storage, 1/4 HP	1	75.75	75.75	75.75	75.75
Motors, Azimuth	1	87.32	87.32	87.32	87.32
Bolts, Motor, 1/4 x 1, Class 2	8	0.02	0.16	0.02	0.16
Nuts, Motor, 1/4	8	0.01	0.08	0.01	0.08
Washer, Motor, 1/4	8	0.01	0.08	0.01	0.08
Subtotal, Motors			239.14		239.14
<u>Pedestal</u>					
Tube, Pedestal, 24 in. OD x 0.105 Wall x 123.5 (Tapered)	1	150.00	150.00	143.21	143.21
Cap, Pedestal, 0.375 x 30 x 30 Blank Formed	1	---	--- ^a	61.75	61.75

^aParts included in \$2,700 quotation on "Fabricated Components for Azimuth Drive (AZ DR), Elevation Drive (EL DR), and Pedestal (PED).

Table 2-4. (contd)

Descriptive Part Name	Quantity Per H	Procured Components		In-House Components	
		Unit Price, \$	Cost/ HelioStat, \$	Unit Price, \$	Cost/ HelioStat, \$
<u>Pedestal (contd)</u>					
Cover, Pedestal, 0.0396 x 10 x 10	1	0.60	<u>0.60</u>	0.60	<u>0.60</u>
Blank					
Subtotal, Pedestal			150.60		205.56
<u>Controls</u>					
Microprocessor, INTEL 8748, 3030204	1	65.00	65.00	65.00	65.00
Quad Diff Line Driver, DS 1488	2	0.75	1.50	0.75	1.50
National, 3030205					
Quad Diff Line Receiver, National DS 1489, 3030206	2	0.75	1.50	0.75	1.50
Hex D Flip Flop, T.I. 74174, 3030207	3	0.55	1.65	0.55	1.65
Capacitor, 0.1 UF @ 50V Sprague (Cramer) 3030208	3	0.12	0.36	0.12	0.36
Power Supply, Semiconductor CKT, MP 1.5, 750/2.15.100, 3030209	1	40.90	40.90	40.90	40.90
Plastic Box, Mac Dac, 3030210	1	1.28	1.28	1.28	1.28
24 Pin Connector, Cramer-Amphenol 24-28P 3030211	1	5.21	5.21	5.21	5.21
Optical Transceiver, Spectronics, WPX-4141 Trans, SPX-4140 Receiver, 3020204	1	99.90	99.90	99.90	99.90
Eaom, 128 x 8, Nitron NC7035PC	8	9.00	72.00	9.00	72.00
Uart, T.I., TMS 6011	1	5.00	5.00	5.00	5.00
Hall Effect Sensor Microswitch 1AV3A, 2040201	6	3.50	21.00	3.50	21.00
Line Driver, Fairchild 9614, 2040202	3	0.60	1.80	0.60	1.80
Ferrous Metal Disc, Mac Dac 2040203	3	1.42	4.26	1.42	4.26
Line Receiver, Fairchild 9615, 2040301	1	0.75	0.75	0.75	0.75
Opto Triac, Motorola MDC 3011, 2040302	4	1.00	4.00	1.00	4.00
Resistor, Cramer Catalog, 2040303	4	0.25	1.00	0.25	1.00
Capacitor, 0.1 UF @ 1,400 V, Cramer Catalog PKM101P1, 2040304	4	0.29	1.16	0.29	1.16
PC Board, 6 in. x 6 in. Plated thru Electronic Layout Fabricators 2040305	1	6.00	6.00	6.00	6.00
Plastic Cover, Mac Dac, 2040306	1	1.28	1.28	1.28	1.28
Connectors for Fiber Optic Couple, Estimate, 2050303	2	2.50	5.00	2.50	5.00
PC Board, 4 in. x 5 in. Plated thru Electronic Layout Fabricators, 3030201	1	6.50	6.50	6.50	6.50
24-Pin Connector, Cramer-Amphenol 24-28 S, 3030203	1	3.64	3.64	3.64	3.64
Central Computer, allow			50.00		50.00
Connections allow			<u>50.00</u>		<u>50.00</u>
Subtotals, Controls			450.69		450.69

The silvering and bonding of the mirror module is based on engineering quotations from two different suppliers. One of the suppliers made a fairly detailed study and spent approximately one week in his analysis. The other used back-of-the-envelope-type calculations. The latter produced the lower estimate. We have averaged these two estimates to produce our cost.

The roll formed sections costs are based on firm quotations from a supplier of roll formed shapes.

The cost of most of the fabricated steel components is based on a single quotation from a specialty fabricator. This supplier quoted these units as a lot and did not wish to break his quotation down simply because he did not want to be pressured to sell one component out of the bunch. However, his quotation was provided as a firm quotation. His quotation was based on sketches we made of the McDonnell Douglas parts. These sketches were simplified and did not provide firm specifications such as ASTM specifications on weld quality. Rather, we allowed the supplier to quote on his best method of producing the results.

Estimates of materials such as bolts were generally based on obtaining new quotations from suppliers; however, if our previous conversations with suppliers indicated that there would not be much difference at lower production volumes we increased the previous quotation for production of 25,000 to obtain the costs for the current estimate. The total value of parts on which this approach was used is less than \$200 per heliostat.

2.1.2.2 In-House Components Scenario

In this scenario, virtually all of the components are the same as those identified in the previous high volume study [1]. The one significant difference that we have in this scenario is that pipe and tooling for the pedestal and the main beam will not be fabricated in-house. There is not enough volume at these levels to warrant any kind of in-house pipe mill.

We are also assuming that the rings, such as retainer rings and the circular spline, will be procured as plain cut circles, but that the supplier will have a reasonable use for the "donut holes."

Glue costs are based on a firm telephone quotation from the supplier. Because there may be some variation in final glue specifications, the glue cost might vary somewhat. However, there is no reason to think that it would vary more than 10% even if we changed the specification significantly.

Costs for steel are based on quotations for steel in the quantities of interest.

Other materials' costs are discussed in Section 2.1.2.1 above. Direct materials for this case are detailed in Table 2-4.

2.1.3 Direct Labor

Direct labor costs were estimated utilizing the manufacturing cost work sheet approach used in previous studies. A sample of this is shown as Fig. 2-1. Operating conditions used are summarized below.

MANUFACTURING OPERATING CONDITIONS

Production rate	2500 heliostats/yr (approximately 10 MWe/yr)
-----------------	---

Operating efficiency	90%
----------------------	-----

Man-hr/work day	7
-----------------	---

Work days/yr	240
--------------	-----

$$\text{hr/yr} = 240 \text{ days/yr} \times 7 \text{ man-hr/day} \times 0.90 \text{ operating efficiency}$$
$$= 1512 \text{ man-hr/yr} - \text{shift}$$

Operation-shifts/day	2
----------------------	---

hr/yr, two shifts	3024
-------------------	------

$$\frac{2500 \text{ heliostats/year}}{3024 \text{ hours/year}} = 0.827 \text{ heliostats/hour}$$

$$\text{Paid man hours} = 40 \text{ mh/week} \times 52 \text{ weeks/year} = 2080 \text{ mh/man year}$$

$$\text{Man hours/heliostat man} = \frac{2080 \text{ mh/man year}}{2500 \text{ heliostats/year}} = 0.832 \text{ mh/heliostat man}$$

Estimated direct labor requirements and costs are summarized in Tables 2-5 and 2-6. Several of the operations require only a one shift operation.

2.1.4 Manufacturing Equipment

2.1.4.1 Procured Components Scenario

An estimate for a total package of equipment for spot welding the support structure was obtained from a supplier of spot welding equipment. This equipment includes two manually held and operated spot welding heads and a jig for clamping the pieces. This is fairly standard equipment and standard operations. People experienced in the business can estimate costs on this type of equipment with considerable accuracy.

Part No. ID 40045
 No. Per Assembly ---
 No. Per Heliostat 2
 Heliostats Per Year 2,500
 Output From Step, Hel. 2,512

Part Name PANEL SUPPORT STRUCTURE
 Output From Step, Pcs/Hr 1.7
 Net Yield 99%
 Starting No. Per Yr. 5,076
 Starting No. Per Hr. 1.7

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Line No.	Operation	Required Thruput Pcs/Hr	Pcs/Hr Per Mach.	Machine Time Hrs/Pc	Machine Requirements				Life, Yrs	Depr Cost Per Pc	No. Per Shift	Operators				Floor Space		
					M	S	T	Cost				MH/	C	Rate,	Direct	Per	Total	Type
	Receive	1.7	100		1			30	30	15	1							
	Inspect, Stat.	1.7	20		1	-	1	50	50	10	1							
	Transfer from Storage	1.7							_a		_a							
	Set Main Beam	1.7																
	Set Diagonal Beam	1.7																
	Set Outboard Angle	1.7																
	Set Inboard Angle	1.7																
	Set Gusset Angle	1.7	2		1	-	1	100	100	10	2							
	Clamp	1.7																
	Spot Weld	1.7																
	Drill Mounting Holes	1.7																
	Transfer	1.7																
	Inspect	1.7																
	Assemble Stringers																	
	to Mirror Mod	10.2	12		1	-	1	100	100	10	2							
	Inspect Mirror Mod	10.2	12		1	-	1	250	250	5	_b							
	Assemble Mirror Mod																	
	to Sup Structure	10.2	12		1	-	1	25	25	10	_c							
	Subtotal								555		6							
	^a Same as Receive	^c Same as	Mirror Mod	Assy.														
	^b Same as Inspect, Stat.																	

Fig. 2-1. MANUFACTURING COST WORK SHEET

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Prepared By KD

Net Yield _____

Date 11/12/79

Starting No. Per Yr. _____

Starting No. Per Hr. _____

[illegible]

Fig. 2-1. (contd)

Table 2-5. DIRECT LABOR REQUIREMENTS FOR MANUFACTURING

Item	Persons Required			
	Procured Components		In-House Components	
	1 Shift	2 Shifts	1 Shift	2 Shifts
MIRROR MODULE, Receive and Inspect	<u>1</u>	<u>2</u>	<u>3</u>	<u>6</u>
PANEL-SUPPORT STRUCTURE	<u>6</u>	<u>12</u>	<u>6</u>	<u>12</u>
AZIMUTH DRIVE	<u>5</u>	<u>10</u>	--b	<u>27</u>
Housing Assy				
Main Cylinder				1 ^c
Retainer				1
Shaft Mount				1
Motor Mount				3
Ears (Procured)				3
Welding				3
Machining				
Flex Spline				e
Membrane				d
Tube				d
Spline				6
Flex Spline Assy				
Drive Plug	1 ^a	2		d
Plug				d
Drive Shaft				1
Drive Plug Assy				c
Retainer-Outer				3
Circular Spline				e
Doubler				e
Pan-Oil				d
Tube-Electric Wire				e
Cover, 9-in. OD				e
Cover, 8-in. OD				
Azimuth Drive Assy	4	8		8
ELEVATION DRIVE-PEDESTAL	<u>5</u>	<u>10</u>	--b	<u>17</u>
Drag Link				--
Sides (Procured)				--
Ears (Procured)				--
Top (Procured)				2
Drag Link Assy				
Main Beam				1
Tube	1 ^a	2		--
Tab, Actuator (Procured)				--
Tab, Hinge (Procured)				--
Flange (Procured)				--
Tube, Clevis (Procured)				4
Main Beam Assy				
Pedestal				--
Cap (Procured)				--
Cover (Procured)				--c
Tube				2
Pedestal Assy				
Elevation Drive Assembly	4	8		8
CONTROLS, allow	<u>5</u>	<u>10</u>	<u>5</u>	<u>10</u>
CENTRAL QUALITY CONTROL, allow	<u>1</u>	<u>2</u>	--b	<u>4</u>
LOAD	<u>1</u>	<u>2</u>	<u>1</u>	<u>2</u>
TOTAL, MANUFACTURING	<u>24</u>	<u>48</u>	--b	<u>78</u>

^aPrincipally inspection.^bSeveral operations on one shift only.^cLabor all shown under main cylinder.^dLabor all shown under shaft mount.^eLabor all shown under motor mount.

Table 2-6. SUMMARY OF MANUFACTURING DIRECT LABOR COSTS

Item	Total No. of Persons at Given Annual Production Rate		Total Man-hr per Heliostat		Total Direct Labor Cost, \$ per Heliostat at Given Annual Production Rate ^a	
	Procured Components	In-House Components	Procured Components	In-House Components	Procured Components	In-House Components
Mirror Module Assy	2	6	1.664	4.992	19.97	59.90
Pannel Support	12	12	9.984	9.984	119.81	119.81
Structure Assy						
Azimuth Drive	10	27	8.320	22.464	99.84	269.57
Elevation Drive	10	17	8.320	14.144	99.84	169.73
Pedestal						
Controls	10	10	8.320	8.320	99.84	99.84
Central QC	2	4	1.664	3.328	19.97	39.94
Loal	2	2	1.664	1.664	19.97	19.97
TOTAL, MANUFACTURING	<u>48</u>	<u>78</u>	<u>39.94</u>	<u>64.896</u>	<u>479.24</u>	<u>778.76</u>

^aFigured at \$12/hr including benefits.

The cost of of azimuth and elevation drive assembling and checking equipment was estimated by us. This is fairly specialized jigs and fixtures. At the low volume rates it is a modest cost.

Equipment costs are summarized in Table 2-7.

2.1.4.2 In-house Components Scenario

The additional equipment for the in-house production case includes a mirror washing and gluing line. This line will handle substantially more than the required production on a single shift.

Glass preparation equipment quotations were based on a telephone quotation from a supplier of glass cleaning, laminating and handling equipment. The supplier has had prior discussions with others in the heliostat business and a fair background in the business.

One large NC lathe is provided. This equipment will handle all of the large turned parts such as the main cylinder for the azimuth drive housing. This setup will handle substantially more than the required production on a single shift.

A second cutoff station and NC lathe is provided for the small parts such as the shaft mount on the azimuth drive housing and the drive shaft. This single lathe also will handle substantially more than the required production on a single shift.

One machine is provided for machining of the azimuth drive housing. This could be a machining center or an NC lathe with special multi-hole drilling stations. This station requires a two-shift operation.

Table 2-7. COST SUMMARY FOR MANUFACTURING CAPITAL EQUIPMENT

Item	Thousands of Dollars	
	Procured Components	In-House Components
MIRROR MODULE	<u>300</u>	<u>800</u>
PANEL-SUPPORT STRUCTURE	<u>965</u>	<u>965</u>
AZIMUTH DRIVE	<u>325</u>	<u>1,500</u>
Housing Assy		
Main Cylinder		200
Retainer		--a
Shaft Mount		150
Motor Mount		150
Ears (Procured)		--
Welding		50
Machining		350
Flex Spline	100	--b
Membrane		--c
Tube		--c
Spline		--c
Flex Spline Assy		275
Drive Plug		--b
Plug		--b
Drive Shaft		--b,d
Drive Plug Assy		--a
Retainer-Outer		100c,e
Circular Spline		--c
Doubler		--c
Pan-Oil		--b
Tube-Electric Wire		--c
Cover, 9-in. OD		--c
Cover, 8-in. OD		--c
Azimuth Drive Assy	225	225
ELEVATION DRIVE-PEDESTAL	<u>300</u>	<u>775</u>
Drag Link		
Sides (Procured)		
Ears (Procured)		
Top (Procured)		
Drag Link Assy		100
Main Beam	100	--a
Tube		
Tab, Actuator (Procured)		
Tab, Hinge (Procured)		
Flange (Procured)		
Tube, Clevis (Procured)		
Main Beam Assy		375
Pedestal		
Cap (Procured)		
Cover (Procured)		
Tube		--a
Pedestal Assy		100
Elevation Drive Assembly	200	200
CONTROLS, allow	<u>200</u>	<u>200</u>
CENTRAL QUALITY CONTROL, allow	<u>200</u>	<u>200</u>
LOAD	<u>100</u>	<u>100</u>
TOTAL, MANUFACTURING	<u>2,390</u>	<u>4,540</u>

aOne cutoff and NC lathe handles all large diameter parts on one shift.

bOne NC lathe handles all small diameter parts on one shift.

cOne press handles all press fabricated parts on one shift.

dWelded with flex spline assembly welder.

eHeat treated with flex spline heat treating equipment.

fWelded with main beam assembly equipment.

One punch press at 150 ton capacity is provided for all of the punched components such as the flex spline membrane and the oil pans. This press also will handle substantially more than the required production with a single shift operation.

Each of these stations has an operator even though an operator is not required the full time at the stations. This provides a moderately conservative estimate.

An estimate for equipment for the welding of the azimuth drive housing, the drag link, main beam, and the pedestal cap was provided by a supplier of welding equipment who works with organizations producing similar parts.

Separate welding stations are estimated for the azimuth drive welding, the small parts such as the flex spline assembly and the drive plug assembly, and the large parts such as the main beam assembly and the pedestal assembly. An integrated weld station could, according to welding equipment suppliers, handle all of the parts. However, in our analysis we have assumed that the provision of separate stations as above will provide for better quality control. These operations also can be on a one-shift basis with the provision of additional equipment.

A separate machining station is provided for the drag link assembly. Again, it might be possible to integrate this as a part of the main beam assembly and drilling station. However, for quality control purposes we feel additional equipment is desirable.

The main beam assembly station includes a specially built machine for trueing the ends and a specially built machine for drilling, pressing, and reaming the clevis tubes.

The pedestal assembly operation includes specialized equipment for drilling and tapping pedestal holes.

Quite possibly the plant could be provided for less money. One of the major areas for potential saving is in mirror inspection equipment. We have assumed fairly conservative numbers for specially developed mirror bond and mirror figure checking. If other development work results in commercially available equipment, the costs for this item could be significantly reduced.

2.1.5 Manufacturing Plant

Plant layouts were made utilizing the above equipment requirements and in-process storage requirements from Table 2-8. Plant layouts for the procured components assembly operation are shown in Figure 2-2. Plant layouts for the additional operations of the in-house production case are shown in Fig. 2.3. Plant floor space requirements are summarized in Table 2-9 and 2-10. Land requirements of three times the building and pad requirements are shown in Table 2-11.

Table 2-8. MANUFACTURING IN-PROCESS STORAGE

Item	Hours of In-Process Storage	Square Feet of Plant Space Needed
Reflector Surface	8	17
Backlite	8	17
Mirror Module	8	17
Inboard Cross Beam	8	26
Outboard Cross Beam	8	8
Diagonal Beam	8	17
Hat Section Stringers	8	8
Support Structure Angle, allow	8	4
Mirror Module w/Stringers	8	59
Assembled Reflector Panel	8	540

2.1.6 Support Facilities, Engineering, and Contingency

The estimates consider support facilities as an allowance. Fifteen percent each was added for engineering and contingency costs. The 15% for engineering costs is higher than a conventional architect's fee, but is, in this writer's experience, within a normal range for this type of plant design. The contingency is provided for items such as process steps that are not foreseen, machinery that is more complicated than expected, and estimate inadequacies that may result from the moderate degree of detail in this study. Normally, a greater contingency would probably be used at this stage of design. However, because of the conservative philosophy used in estimating, this percentage was considered reasonable. From a practical standpoint, the facilities could definitely be built within the estimates by adjusting make-or-buy decisions to fit the facility dollars available.

2.1.7 Capital Cost Summary

Estimated capital costs are summarized in Table 2-12. These costs were used with a 35% fixed charge rate to obtain the cost per heliostat.

The fixed charge rate converts the capitalized cost into a series of uniform annual costs over the life of the asset. The annual cost is divided by the annual production rate to determine the appropriate cost for each heliostat.

2.1.8 Manufacturing Cost Summary

Manufacturing costs are summarized in Table 2-13. These costs are used with manufacturing company costs and installed costs to arrive at the total estimated cost for an installed heliostat.

Fig. 2-2. PLANT LAYOUTS, PROCURED COMPONENTS CASE

^aIPS stands for in-process storage.

Fig. 2-3. PLANT LAYOUTS, IN-HOUSE COMPONENTS CASE

^aIPS stands for in-process storage.

Fig. 2-3. (contd)

Table 2-9. MANUFACTURING FLOOR SPACE REQUIREMENTS, PROCURED COMPONENTS

Item	Space Requirements, ft ²				
	Hi Bay	Lo Bay	Office	Warehouse	Pad
MIRROR MODULE INSPECT, allow	<u>1,000</u>			<u>1,000</u>	
PANEL-SUPPORT STRUCTURE ASSY	<u>14,250</u>			<u>1,000</u>	<u>4,000</u>
AZIMUTH DRIVE	<u>3,700</u>			<u>500</u>	<u>2,000</u>
Housing	1,000				
Main Cylinder Retainer					
Motor Mount					
Shaft Mount					
Welding					
Machining					
Components					
Lathe					
Press					
Flex Spline Assy					
Plug Assy					
Circular Spline					
Outer Retainer					
Azimuth Drive Assy	2,700				
ELEVATION DRIVE-PEDESTAL	<u>3,700</u>			<u>500</u>	<u>2,000</u>
Drag Link Assy	1,000				
Pipe Fabrication					
Main Beam Assy					
Pedestal Assy					
Elev. Drive-Ped. Assy	2,700			500	2,000
CENTRAL QUALITY CONTROL	<u>500</u>	<u>500</u>		<u>500</u>	
CONTROL ASSY AND POWER SUPPLY, allow		<u>500</u>		<u>500</u>	
LOAD					<u>2,000</u>
SUBTOTAL, MANUFACTURING	<u>23,150</u>	<u>1,000</u>		<u>4,000</u>	<u>10,000</u>
ENGINEERING, allow	<u>500</u>	<u>500</u>	<u>500</u>	<u>500</u>	<u>1,000</u>
SERVICE, allow	<u>500</u>	<u>500</u>	<u>500</u>	<u>500</u>	<u>500</u>
ADMINISTRATION, allow			<u>1,000</u>		
SUBTOTAL, SUPPORT	<u>1,000</u>	<u>1,000</u>	<u>2,000</u>	<u>1,000</u>	<u>1,500</u>
TOTAL ft ²	24,150	2,000	2,000	5,000	11,500
Unit Cost per ft ²	35	30	30	15	5
Total Cost	<u>\$ 845,250</u>	<u>\$60,000</u>	<u>\$60,000</u>	<u>\$75,000</u>	<u>\$57,500</u>
TOTAL COST	<u>\$1,097,750</u>				
TOTAL SPACE (ft ²)	44,650				

Table 2-10. MANUFACTURING FLOOR SPACE REQUIREMENTS, IN-HOUSE COMPONENTS

Item	Space Requirements, ft ²				
	Hi Bay	Low Bay	Office	Warehouse	Pad
MIRROR MODULE	<u>3,900</u>			<u>2,000</u>	
PANEL-SUPPORT STRUCTURE ASSY	<u>14,250</u>			<u>1,000</u>	<u>4,000</u>
AZIMUTH DRIVE	<u>13,850</u>			<u>1,000</u>	<u>3,000</u>
Housing					
Main Cylinder	1,200				
Retainer	---				
Motor Mount	1,200				
Shaft Mount	900				
Welding	1,200				
Machining	1,200				
Components					
Lathe	---				
Press	---				
Flex Spline Assy	4,250				
Plug Assy	---				
Circular Spline	1,200				
Outer Retainer	---				
Azimuth Drive Assy	2,700				
ELEVATION DRIVE-PEDESTAL	<u>8,100</u>			<u>1,000</u>	<u>3,000</u>
Drag Link Assy	1,000			500	---
Pipe Fabrication	---				---
Main Beam Assy	4,400				1,000
Pedestal Assy	---				---
Elev. Drive-Ped. Assy	2,700			500	2,000
CENTRAL QUALITY CONTROL	<u>500</u>	<u>500</u>		<u>1,000</u>	
CONTROL ASSY AND POWER SUPPLY, allow		<u>500</u>		<u>1,000</u>	
LOAD					<u>2,000</u>
SUBTOTAL, MANUFACTURING	<u>40,600</u>	<u>1,000</u>		<u>7,000</u>	<u>12,000</u>
ENGINEERING, allow	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>	<u>500</u>
SERVICE, allow	<u>2,000</u>	<u>1,000</u>	<u>1,000</u>	<u>1,000</u>	<u>500</u>
ADMINISTRATION, allow			<u>2,000</u>		
SUBTOTAL, SUPPORT	<u>3,000</u>	<u>2,000</u>	<u>4,000</u>	<u>2,000</u>	<u>1,000</u>
TOTAL, ft ²	43,600	3,000	4,000	9,000	13,000
Unit Cost per ft ²	35	30	30	15	5
Total Cost	\$1,526,000	\$90,000	\$120,000	\$135,000	\$65,000
TOTAL COST	<u>\$1,936,000</u>				
TOTAL SPACE	72,600 ft ²				

Table 2-11. LAND REQUIREMENTS FOR MANUFACTURING

Type of Operation	Total Bldg. Space, ft ² (Including Pad)	Total Land Area Required		Cost per acre Improved, \$	Land Cost, Improved, \$
		ft ²	Acres		
Procured Components	44,650	134,000	3	20,000	60,000
In-House Components	72,600	218,000	5	20,000	100,000

Table 2-12. SUMMARY OF CAPITAL COSTS FOR MANUFACTURING

Item	Capital Cost, \$	
	Procured Components	In-House Components
Land and Roads	60,000	100,000
Buildings	1,097,750	1,936,000
Manufacturing Equipment	2,390,000	4,540,000
Support Equipment, allow	200,000	300,000
Support Facilities, allow	100,000	100,000
Subtotal	3,847,750	6,976,000
Engineering, 15%	577,163	1,046,400
Contingency, 15%	577,163	1,046,400
TOTAL	<u>\$5,002,076</u>	<u>\$9,068,800</u>
Annualized Capital Cost per Hellostet, 35%		
Fixed Charges	\$700.29	\$1,269.63 /

2.1.9 Manufacturing Company Cost Summary

Company costs for manufacturing are summarized in Table 2-14 for the procured components case and in Table 2-15 for the in-house components case. The tables include all manufacturing costs in a business, summarized in the format of an IRS corporate income tax form.

In Tables 2-14 and 2-15, the cost of goods sold and fixed-charge are based on moderately detailed analyses. The other numbers are based on limited analysis and can vary significantly from industry to industry or company to company.

Table 2-13. ESTIMATED MANUFACTURING COSTS, 1979 DOLLARS

Item	\$/Heliostat	
	Procured Components	In-House Components
Direct Costs		
Direct Materials	6,571.58	4,058.17
Direct Labor	479.24	778.76
Indirect Manufacturing Expense and Contingency	<u>150.00</u>	<u>200.00</u>
Subtotal - Direct and Indirect Manufacturing Costs	7,200.82	5,036.93
Annualized Capital Cost per Heliostat, 35% Fixed Charges	<u>700.29</u>	<u>1,269.63</u>
TOTAL PER HELIOSTAT	7,901.11	6,306.56
TOTAL PER m ²	<u>\$ 161.07</u>	<u>\$ 128.57</u>

449,053 m² per heliostat.

2.1.10 One-Time Costs

One-time costs on the part of suppliers are summarized in Table 2-16. The glass company costs are not included in manufacturing company costs because it is believed other uses for low iron glass may eliminate this. However, it should be noted as a possible requirement.

The roll forming tooling costs, as with capital costs, are considered in the manufacturing company costs.

2.2 HELIOSTAT INSTALLATION COST ESTIMATE

2.2.1 Approach

Estimating procedures established for the previous estimates [1] were adhered to, except where indicated. Costs were revised from the prior estimates where:

- New cost information was obtained which was considered to be more reliable.

Table 2-14. MANUFACTURING COMPANY COST ELEMENT SUMMARY (ILLUSTRATIVE PROFIT AND LOSS STATEMENT) PROCURED COMPONENTS

Items	\$ Per Heliostata	Annual Cost, \$
INCOME		
Gross Receipts, Less Returns and Allowances	9,201	23,002,500
Less Costs of Goods Sold (includes indirect manufacturing expenses)	<u>7,201</u>	<u>18,002,500</u>
Gross Profit	2,000	5,000,000
Other Income	---	---
TOTAL INCOME	<u>2,000</u>	<u>5,000,000</u>
DEDUCTIONS		
Compensation of Officers	50	125,000
Salaries and Wages (not deducted elsewhere)	50	125,000
Repairs	30	75,000
Bad Debts	10	25,000
Rents, Light, and Heat	50	125,000
Taxes	700	1,750,000
Interest ^b		
Amortization		
Depreciation		
Working Capital Interest	20	50,000
Contributions	10	25,000
Advertising	10	25,000
Pension, Profit-Sharing, etc.	20	50,000
Employee Benefit Programs ^c	20	50,000
Other Deductions	20	50,000
Legal and Accounting Fees	10	25,000
Consultants	10	25,000
Travel	20	50,000
Product Development	<u>50</u>	<u>125,000</u>
TOTAL DEDUCTIONS	1,080	2,700,000
TAXABLE INCOME	920	<u>2,300,000</u>
INCOME TAX	460	<u>1,150,000</u>
NET AFTER TAXES	460	<u>1,150,000</u>

a49.053 m² per heliostat.

^bEquipment only, construction interest on heliostats not included.

^cDirect labor benefits included in \$12/hr.

Table 2-15. MANUFACTURING COMPANY COST ELEMENT SUMMARY (ILLUSTRATIVE PROFIT AND LOSS STATEMENT) IN-HOUSE COMPONENTS

Items	\$ Per Heliostat ^a	Annual Cost
INCOME		
Gross Receipts, Less Returns and Allowances	7,797	19,492,500
Less Costs of Goods Sold (includes indirect manufacturing expenses)	<u>5,037</u>	<u>12,592,500</u>
Gross Profit	2,760	6,900,000
Other Income	<u>---</u>	<u>---</u>
TOTAL INCOME	<u>2,760</u>	<u>6,900,000</u>
DEDUCTIONS		
Compensation of Officers	100	250,000
Salaries and Wages (not deducted elsewhere)	100	250,000
Repairs	60	150,000
Bad Debts	10	25,000
Rents, Light, and Heat	120	300,000
Taxes	1,270	3,175,000
Interest ^b		
Amortization		
Depreciation		
Working Capital Interest	40	100,000
Contributions	10	25,000
Advertising	10	25,000
Pension, Profit-Sharing, etc.	40	100,000
Employee Benefit Programs ^c	40	100,000
Other Deductions	30	75,000
Legal and Accounting Fees	10	25,000
Consultants	10	25,000
Travel	20	50,000
Product Development	<u>120</u>	<u>300,000</u>
TOTAL DEDUCTIONS	<u>1,990</u>	<u>4,975,000</u>
TAXABLE INCOME	770	<u>1,925,000</u>
INCOME TAX	385	<u>962,500</u>
NET AFTER TAXES	385	<u><u>962,500</u></u>

^a49.053 m² per heliostat.

^bEquipment only, construction interest on heliostats not included.

^cDirect labor benefits included in \$12/hr.

Table 2-16. MANUFACTURING ONE TIME INITIAL COSTS, SUPPLIERS

Mirror Module	
Glass Plant Modifications	\$1,000,000
Panel Support Structure Assembly	
Roll Forming Tooling	43,200
Azimuth Drive	---
Elevation Drive - Pedestal	---
Controls	---
	<u>\$1,043,200</u>

- Cost information from prior estimates was judged to be inappropriate because of the lower production rates involved.

Costs are categorized as materials costs, labor costs, fixed costs for capital equipment, and subcontractor costs. The subcontractor cost category includes tasks completely subcontracted, such as soil stabilization, and was not presented in the previous estimates. It was judged that subcontracting certain installation tasks would be economically attractive at the production rate assumed for this estimate.

2.2.2 Assumptions

Cost estimates are based upon the installation of 2500 heliostats per year. It was assumed that 2500 heliostats would be installed per site, with an average distribution of 20 heliostats per acre.

Costs for installation tasks were estimated independently of each other, without direct allowance for possible lag times, on site inventory costs, or construction bottlenecks.

All cost estimates for tasks not subcontracted are based upon purchasing major installation equipment. Although information on equipment lease rates was obtained for several items, an in depth analysis of leasing versus purchasing equipment was not made.

Specific assumptions, such as the amount of paving and site preparation required, are described in Reference 1.

2.2.3 Installation Cost Estimate

Estimated installation costs are summarized in Table 2-17. Cost summaries for materials, labor, equipment, and subcontracted services appear in Tables 2-17 through 2-21. Overall estimated costs are \$1355.72.

Table 2-17. ESTIMATED INSTALLATION COSTS (1979 Dollars)

	Installation Cost \$/Heliostat
Direct Materials	354.61
Direct Labor (Includes Overhead)	258.07
Total Direct	<u>612.68</u>
Equipment (at 35% Fixed Charges)	155.20
Equipment Operation	43.05
Total Equipment	<u>198.25</u>
Subcontracted Services	421.54
Subtotal	<u>1232.47</u>
General Contractor Contingency and Fee	123.25
TOTAL INSTALLATION	<u>1355.72</u>

Table 2-18. INSTALLATION DIRECT MATERIALS COST SUMMARY (1979 Dollars)

Item	Quantity/Heliostat	Cost, \$/Heliostat
Land	1/20 Acre	35.00
Primary Feeder Cable	3 ft	10.35
Secondary Feeder Cable	54 ft	48.06
Miscellaneous Electrical Equipment	--	108.60
SBR Soil Stabilizer	4.5 gal	18.00
Tapered Steel Form	1	22.54
Concrete	3.004 yd ³	111.13
Chain Fence	0.08 ft	0.90
Water	110 gal	0.03
TOTAL		<u>\$354.61</u>

Table 2-19. INSTALLATION DIRECT LABOR COST SUMMARY

Activity	Labor Rate ^a	Cost, \$/Heliostat
Miscellaneous Electrical Installations	\$20.80/hr	5.12
Augering Foundation Hole	\$33.95/hr	16.98
Transportation	\$15.00/hr	78.00
Unloading Rebar Cages	\$64.00/hr	10.67
Manufacturing Tapered Steel Forms	--	0.65
Installing Rebar Cages	\$95.30/hr	31.77
Vibrating and Finishing Concrete	\$ 8.50/yd ³	25.53
Installing Drive Units	\$72.70/hr	21.81
Miscellaneous Unloading	\$33.80/hr	0.07
Laying Electrical Cable	\$33.80/hr	2.25
Connecting Cabling to Drive Units	\$35.40/hr	8.85
Installing Panel Units	\$86.00/hr	30.10
Installing Power Transformer	\$51.03/hr	2.98
Electrical Checkout and Calibration	\$51.15/hr	12.79
Heliostat Alignment	\$42.01/hr	10.50
TOTAL		\$258.07

^aLabor Rates include overheads

Table 2-20. INSTALLATION CAPITAL EQUIPMENT COST SUMMARY

Equipment	Cost	Cost, \$/Heliostat (at 35% Fixed Charges)
Truck Mounted Auger	60,000	8.40
Seven Semi Trucks and Trailers	462,000	64.68
Small Crane	45,000	6.30
Five Ton Flatbed Truck	8,600	1.20
One Ton Forklift	13,000	1.82
Modified Truck Mounted Crane	85,000	11.90
Ditch Witch Trencher Plover	13,700	1.92
Straddle Crane	150,000	21.00
Oscilloscope and Volt-Ohm Meter	3,300	0.46
Van and Test Equipment	12,000	1.68
Contingency, 15%	128,000	17.92
Engineering, 15%	128,000	17.92
TOTAL	\$1,108,600	\$155.20

Table 2-21. CONTRACTED SERVICES SUMMARY

Service	Rate, \$	Cost, \$/Heliostat
Surveying	575/acre	28.75
Brush Clearing	200/acre	10.00
Site Leveling	1.00/yd ³ moved	40.35
Graveling and Paving Roads	26,136/acre	130.68
Application of Soil Stabilizer	297/acre	14.85
Rebar Cage Fabrication	196/cage	196.00
Transporting Cables and Transformers	275/day for truck and trailer	
	120/day for driver	<u>0.91</u>
	30/day for fuel and lubrication	
TOTAL		\$421.54

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SECTION 3.0

COMPARISON OF STARTUP AND CONTINUING PRODUCTION CASES

There are several basic differences in this startup operation approach and the estimate for a continuing plant operation, even though the production rates of 2,500 heliostats per year are the same. The principal contributors to the cost difference (\$6,519 company cost in continuing plant [1] versus \$7,797 company cost here for in-house components) are:

- For the startup case, glass and control cost estimates are based on supplier quotations or estimates without adjustment for technology and negotiating differences which might result from a continuing leveled-out operation
- It is assumed almost completely standard equipment is used, so it can be converted to other use if necessary.
- Fixed charges of 35% are used on plant and equipment to compensate for the short-time guarantee on the market.
- In the "procured components" case, much more of the heliostat is procured from independent suppliers.

In practice, it is considered likely that product design improvements, negotiation with vendors, and production improvement can result in some reduction of the costs arrived at herein. Our conclusion is that actual costs near the \$9,153 of the "in-house components" case can be achieved.

The capital investment requirement includes extensive equipment for quality control. For example, the mirror figure test equipment is estimated at \$250,000. This function may possibly be performed for less money. However, it is our opinion that quality is one of the prime requisites for the success of the heliostat business and ample allowance should be made for quality control equipment.

The 35% fixed charge assumption may be overconservative because much of the building and equipment can probably be sold if necessary.

From the capital investment standpoint, it is probable that some reduction in requirements could be achieved by leasing building space and equipment, utilizing even less mechanization, and operations on a three or four shift-basis (four shifts being three shifts, seven days a week). Some additional steps, such as control component assembly, could also be farmed out.

Thus, both the production and capital requirements are believed to represent the high side of the cost range.

The company costs are less predictable. The actual selling price will reflect market conditions at the time of sale.

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SECTION 4.0

CONCLUSIONS

The principal conclusion of this study is that a new operation could be expected to produce installed heliostats at a cost of \$9,000 to \$11,500 per unit, using the McDonnell Douglas prototype heliostat design.

There is room for improvement which could be reasonably expected to result in installed heliostat costs of less than \$200/m² even at this low volume and even under startup conditions.

Initial one-time costs of \$10 to \$15 million would be required to achieve this. A part of the one-time costs are recoverable.

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SECTION 5.0

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