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Heliostat Manufacturing Cost Analysis: Volume I

Prepared by
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Richland, Washington

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HELIOSTAT MANUFACTURING COST ANALYSIS: VOLUME I

OCTOBER 1979

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PROJECT MANAGER
DENNIS HORGAN

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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 manufactured cost of the current generation of heliostat designs at various production volumes. To accomplish this objective, this study used two independent cost estimating approaches. The first was a cost estimate derived by obtaining vendor quotations on purchased parts and supplies and manually computing the cost of the labor and capital required to produce a finished heliostat. The second approach was the use of the JPL SAMICS methodology to perform rapid parametric analyses and sensitivity studies. Except for the common data bases, these two approaches were used to produce independent answers that were compared to ensure the validity of the estimates.

The principal conclusion of this study is that second generation heliostats should be producible at an installed cost of less than $100/m^2 at production volumes of 25,000 units/year. A second and more controversial conclusion is that mass production benefits begin to appear at relatively low production volumes (5,000 to 15,000 units/year) and that there are rather modest cost reductions over the upper range of production rates used for this study (up to 250,000 units/year). One underlying rationale for this conclusion is that even 250,000 units/year is relatively low production by the standards of mass production industry. Another reason for this conclusion is that much of the dollar cost of a heliostat is in materials or parts produced by high-volume methods. Hence, some high volume benefits are achieved even at low volumes. This second conclusion implies that the required level of producer investment may be lower than previously thought and that intermediate heliostat markets may be accessible without extensive government market intervention.

Dennis N. Horgan, Jr.
Project Manager

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PREFACE

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

Marcia Metcalfe, Judy Bevan, and Don Heimburger of CACI provided exceptional support in computer programming and operation. Bob Chamberlain of JPL provided great assistance in the understanding of the SAMICS model and the modifications required to use the SAMICS model and the SAMIS III program for heliostats. LeRoy Weinstein, Don Steinmeyer, and the staff of McDonnell Douglas were extremely helpful in interpreting design and providing procurement information. Leo Davey and the staff of F. Joseph Lamb and John Britt and the staff of General Motors were very helpful in discussion of current production technology. Naomi Brimhall, Pacific Northwest Laboratory, provided her usual incredible service in converting my dictation or undecipherable handwriting into words.

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SUMMARY

This study has two primary objectives. The first is to provide a detailed cost evaluation of the second generation of DOE heliostats, from which repowering heliostat designs are likely to be derived. A second objective is to provide an analytical foundation for the evaluation of future heliostat designs.

The primary conclusion of this study is that the second generation of heliostat designs should cost approximatey $100/m^2$ at volumes of 25,000 units/year. This price falls to approximately $80/m^2$ at volumes of 250,000 units/year. A second conclusion is that cost reduction begins at relatively low production volumes and that many production benefits can be obtained at production rates of 5,000 to 15,000 units/year. This conclusion, if supported by further study, could have significant implications for the penetration of intermediate markets and for government commercialization programs. A third conclusion is that the SAMICS model and the SAMIS III program can be useful tools in heliostat manufacturing, costing, and economics studies.

This study produced a cost estimate for the production of the McDonnell Douglas (MDAC) prototype design by generating estimates of the materials, labor, overhead and facilities costs for two different production scenarios. The scenarios are:

- A low-volume facility (25,000 heliostats per year) with some expansion capability. This facility represents the type of facility needed to service a limited intermediate heliostat market.

- A high-volume facility (250,000 heliostats per year) using high levels of plant integration to attain the lowest production cost. Such a facility represents the type of plant which will be used to service a mature heliostat market.

The study used two independent cost estimating approaches. The first was a cost estimate derived by obtaining vendor quotations on purchased parts and supplies and manually computing the cost of the labor and capital required to produce a finished heliostat. The second approach was the use of the JPL SAMICS methodology to perform rapid parametric analyses and sensitivity studies. The SAMICS methodology computes a normative price for a manufactured product through the use of a standard procedure for calculating direct and indirect costs. This procedure is implemented by a computer program (SAMIS III) to speed the calculations and allow a wide variety of sensitivity and parametric studies to be performed. Except for a common data base, these two approaches were used to produce independent answers that were compared to ensure the validity of the estimates. There is close agreement between the estimate obtained by SAMICS and the manual calculations.

The conclusion from the sensitivity tests is that the SAMICS price estimates are remarkably robust. That is, large variations in the cost of individual components are required to produce an appreciable change in the selling price. For example, a reduction of 67% in the price of the jack screw produces a 7% change in the manufactured price or a 6% reduction in the installed price. Since components and materials can be priced reasonably accurately (probably ± 10% in total) for this application, it appears that the SAMICS price estimates are relatively insensitive to random errors in the pricing of labor, capital, or materials.

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SECTION 1.0

INTRODUCTION

This study is an analysis of the cost of mass producing a recently designed prototype heliostat. This report is in two volumes. The first volume contains the analysis and conclusions of the study. The second volume consists of technical appendices which contain the input data and summaries of the computer output. The first part of this introduction is an overview of the Repowering Strategy Analysis of which this study is a part. The remainder examines the scope and methodology of the study and outlines this report.

1.1 PERSPECTIVE ON THE REPOWERING STRATEGY ANALYSIS

The retrofit of solar central receiver heat supply systems to existing steam-generating stations, an application known as "repowering," is being considered as a major programmatic effort by the Department of Energy's Large Solar Central Power Systems Program. Several promising features of repowering lead to this interest:

- Technical: Repowering offers a relatively low-risk technical path to large-scale test and demonstration of central receiver technology. Partial reliance on existing hardware places both cost and technical emphasis on the heat supply system, where the major uncertainties lie. However, the hybrid nature of repowered plants permits them to operate even when the solar heat supply system is not providing heat.

- Demand: The confinement of risk to the solar portion of the plant makes utility involvement more attractive and facilitates cost-sharing arrangements between the public and private sectors. Early involvement of the eventual user group promises to increase the market development value of the test and demonstration program in several important areas, including relevance, credibility, information dissemination, and response.

- Supply: The requirements for cost effectiveness of the solar heat supply system are possibly less stringent in repowering than in new capacity applications. If this is so, then the opportunity for early hardware sales for repowering may be an important advantage for the development of the supply industry.

- Energy Displacement: While the likely population of repowerable plants in the Southwest is not large (roughly 4-6 GWe), it is heavily reliant on oil and gas. Thus the direct effects of repowering on energy displacement are in the desired categories.

The determination of an appropriate government response to the opportunities of repowering is an important policy question and is the major reason for the Repowering Strategy Analysis. The Repowering Study objective is to define a government role in repowering that constitutes an efficient program investment in pursuit of viable private markets for heliostat-based energy systems. In support of that objective, this study is designed to identify the scope and nature of the repowering opportunity within the larger context of its contributions to central receiver technology development and commercialization.

1.2 SCOPE AND LIMITATIONS OF THIS STUDY

This study has two primary objectives. The first is to provide a detailed cost evaluation of the second generation of DOE heliostats, from which repowering heliostat designs are likely to be derived. A second objective is to provide an analytical foundation for the evaluation of future heliostat designs. Each of these objectives and the limitations on meeting them will be discussed in turn below.

To provide a detailed cost estimate for the second generation prototype heliostats, this study used a specific design. The design that was chosen was the McDonnell Douglas (MDAC) prototype heliostat of August 1978.[1] This design was the product of the DOE low-cost heliostat program in which four contractors developed conceptual designs for heliostats intended to be more producible and lower in cost than earlier designs. The MDAC design was chosen for this study because Sandia had previously selected the MDAC design as a basis for follow-on work.[2] At the present time, this generic design appears to be one of the best candidates for a repowering heliostat. In part, this is due to its glass/steel construction that does not have the technical risks attendant with plastics. It also is a mature design which provides relatively complete information for a cost study.

The limitations of this study are those of any detailed manufacturing cost estimate and are best explained in terms of what the study does not accomplish.

- This study is a detailed estimate of the cost to manufacture the MDAC prototype design. While we believe it to be generally applicable to similar heliostat designs, this study is not applicable to heliostats which differ radically in design or production processes. For example, plastic heliostat prices cannot be inferred from the data presented here.

- This study is not a forecast of market prices nor is it a technology projection. As will be discussed, the price projections given here are based on dedicated mature factories. Variations in design or production scenario will produce prices different than those quoted here. Similarly, the MDAC heliostat is not an "ultimate" heliostat nor are the prices presented here ultimate heliostat prices.

1.3 OVERVIEW OF THE STUDY METHODOLOGY

The approach taken for this study was to produce a cost estimate for the production of the MDAC design by generating estimates of the materials, labor, overhead, and facilities costs for two different production scenarios. The scenarios are:

- A low-volume facility (25,000 heliostats per year) with some expansion capability representing the type of facility needed to service a limited intermediate heliostat market.

- A high-volume facility (250,000 heliostats per year) using high levels of plant integration to attain the lowest production cost representing the type of plant which will be used to service a mature heliostat market.

The study relied on the use of Solar Array Manufacturing Industry Costing Standards (SAMICS) [3] methodology. This methodology computes a normative price for a manufactured product through the use of a standard procedure for calculating direct and indirect cost. This procedure is implemented by a computer program (SAMIS III) [4] to speed the calculations and allow a wide variety of sensitivity and parametric studies to be performed. For simplicity, the term SAMICS is used throughout this report. Although the methodology is applicable to a wide variety of manufactured products, the data base was designed around photovoltaic processes. As a result, a major effort of this study was the development of a data base suitable for solar thermal systems.

While a detailed discussion of the analytical methods used for the study will be given in the appropriate sections, an outline of the methods used for this study is given below.

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

- Process descriptions were prepared beginning at the lowest level of purchased material and proceeding through assembly and installation. Steps such as transportation of material, field assembly, and checkout were included.

- The process descriptions were input into the SAMICS computer model, which produced price estimates for various production quantities.

- Parallel manual cost estimates were performed at production rates of 25,000 and 250,000 heliostats per year to validate the SAMICS results.

1.4 OUTLINE OF THE REPORT

This report is organized in a chronological form that follows the study methodology. Section 2 describes the MDAC prototype heliostat. Section 3 outlines the processes and equipment used to produce the heliostat, including possible manufacturing trades. Manual cost estimates are discussed in Section 4. Estimates produced by the SAMICS computer model are presented in Section 5. The final section discusses conclusions.

SECTION 2.0

HELIOSTAT DESIGN DESCRIPTION

The heliostat configuration is shown in Fig. 2-1. This design and the description are extracted nearly verbatim from the MDAC prototype heliostat design report.[1]

The laminated mirror modules, each of which measures 1.22 by 3.35 m (48 by 132 in.), are assembled in groups of six on their respective support structure assemblies to produce a reflector assembly which measures 3.35 by 7.38 m (132 by 290.5 in.). Two of these reflector assemblies are bolted to the main beam on each side of the drive unit to produce overall dimensions of 7.38 by 7.42 m (290.5 by 292 in.), with a slot 0.71 m (28 in.) wide down the middle. the reflecting area is 49.053 m^2 (528 sq ft).

Each of the 12 laminated mirror modules is made by bonding a mirrored pane of 1.52-mm-(0.060-in.-) thick fusion glass to a pane of 4.76-mm-(3/16-in.-) thick float glass. These modules are stiffened with a pair of hat-section 16-gage steel stringers, which are part of the support structure assembly and are bonded to the glass when the reflector assembly is fabricated. Each of the 12 stiffeners is attached to the two cross beams which run the long distance of the reflector assembly. Two diagonal, tapered beams attach the shallow outboard cross beam to the deep inboard cross beam where they attach to the tubular main beam. The diagonal beams tie into the outboard cross beam at two points that are 4.26 m (167.9 in.) apart. Each reflector

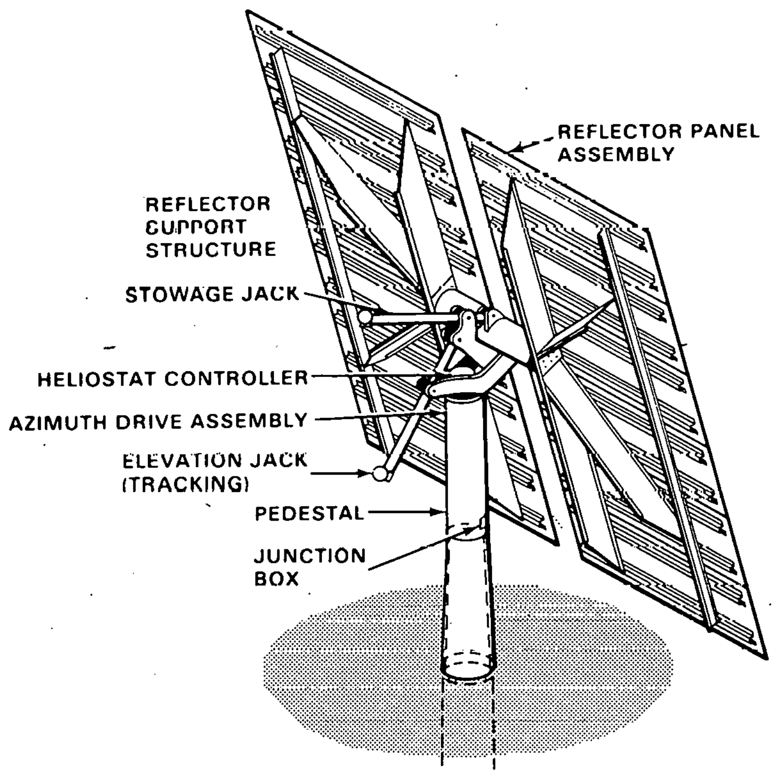


Fig. 2-1. MCDONNELL DOUGLAS PROTOTYPE HELIOSTAT[1]

assembly is bolted to a flange at each end of the main beam, which is a part of the drive unit.

The drive unit consists of an azimuth drive assembly, two linear actuator assemblies, a drag link, a short main beam, and the pedestal. Maximum rotation in elevation is 190°, obtained with a motor-driven double-jack system. Maximum azimuth rotation is 540°, obtained with a motor-driven helicon gear and harmonic drive mechanism.

The pedestal is a vertical tube 3.18 m (125 in.) high. At the top, the drive unit is welded to the pedestal; at the bottom, the lower 1.12 m (44 in.) is expanded to give a slight taper for slip-joint attachment to the rigid foundation.

Connnectors and a circuit breaker in a junction box located on the side of the pedestal join the electrical system of the heliostat with the secondary power and data feeders. The cabling is routed through the hollow harmonic drive shaft to the heliostat controller located on the top of the azimuth drive unit. The heliostat controller makes all calculations necessary to operate the heliostat and execute tracking and stowage algorithms. The power cable is routed directly to the motor controllers located on each motor. The heliostat controller switches the motors on and off to execute the required number of motor revolutions. Motor revolution feedback is provided by Hall-effect sensors on the motors.

The field electronics interface with the system master control and the electric power generation subsystem.

With this design, a collector controller may be used as a separate controller, or its functions may be incorporated into the master control. The collector controller commands operating modes, transmits and coordinates the reference time, and requests and receives data from the field on the heliostat's status. The collector controller communicates with the heliostats through a series of data distribution interfaces. Data from the collector controller are received and routed to one of 15 to 20 parallel data feeders, along which are located 24 heliostats.

Data links in the system are made by means of fiber-optics. The fiber-optics data link provides a nearly noise-free environment and eliminates the need for line drivers/receivers.

The secondary data feeder connects each heliostat on the line in series. Data received by a heliostat controller are decoded, and, if addressed to the heliostat the data are retained and a message relayed onto the next heliostat, and then to a data distribution interface at the end of the line. If the data are not addressed to the heliostat, the message is relayed to the next heliostat.

Power distribution resembles data distribution. Power from the electric power generation subsystem is transmitted in a radial net to field transformers. Two to three transformers are located on each primary power feeder. The transformers are collocated with the data distribution interfaces. The transformers reduce the 4160-volt primary power to the 480-volt secondary feeder voltage.

The secondary feeders connect the heliostats in a daisy chain (through wiring with power tapped off for each heliostat). The chain is connected on each end to a transformer so a failure of a transformer does not result in complete loss of power to any heliostat. The fiber-optics secondary feeders and the secondary power feeders are in the same cable.

The heliostats are capable of operating independently of the data network, except for commanding operating modes and updating time calculations. Hence, a failure of the data network would not result in the immediate shutdown of the affected portion of the heliostat field.

SECTION 3.0

PROCESS AND EQUIPMENT DESCRIPTIONS

3.1 MANUFACTURING

This section outlines the fabrication process for this analysis. The general approach to this study was to describe one workable manufacturing process for the prototype design selected. Alternatives considered are discussed at the end of this section. The scope of the study did not provide for in-depth analysis of alternatives. A detailed process step table is illustrated in Fig. 3-1. Similar descriptions for each process are included in Appendix A. A general process description is provided below.

PROCESS STEPS
MIRROR MODULE ASSEMBLY

1. Receive the mirrored front surface and backlites in crates, by truck from the supplier. Transfer directly to storage with a modified forklift.
2. Pull small mirror specimens for analytical testing.
3. Transfer glass from storage to the processing line, using special forklift.
4. Inspect all mirrored glass and mirrored surface for:
    - mirror figure
    - reflectivity
    - reflector bond
    - reflector coverage (voids)
    - reflector quality, e.g., thickness
    - mechanical integrity

   with specially developed nondestructive test equipment operating with conveyor line.
5. Clean the mirrored surface with a cleaning method compatible with surface protection. Vacuum only, on the conveyor line.
6. Inspect the backlite glass for dimensional characteristics and mechanical integrity with specially developed nondestructive test equipment operating with the conveyor line.
7. Clean backlite with a detergent wash, rinse, and hot-air dry, on the conveyor line.
8. Spray glue with a gluer operating on the conveyor line.
9. Assemble the mirrored surface and the backlite with conventional conveyer line glass handling equipment.
10. Press and cure glass panels. This analysis is based on a mechanized plywood type press with loader and unloader to achieve the full capacity of the conveyor line. This is a conservative approach. Flat platens with plywood type presses can optimize mirror figure. If simple roller bonding systems are demonstrated to be effective, the equipment cost for bonding can be greatly reduced.

Fig. 3-1. EXAMPLE PROCESS STEP TABLE

The mirror module is assembled from purchased mirror panels and purchased backlites. Parts are cleaned, the adhesive sprayed, and panels assembled on a mechanized conveyor line. Panels are pressed in a plywood-type press for maximum surface regularity. The process for assembling the mirror module is illustrated in Fig. 3-2.

This analysis is based on the use of purchased components for the support structure. At high production levels, it may be desirable to set up a roll-forming line. The breakpoint for this decision will probably depend to a large extent on site locations and transportation requirements. The support structure is assembled with mechanized equipment as Fig. 3-3 illustrates. The clamping jigs are similar for low and high-volume production. The spot-welding heads are largely manually operated at the lower production levels; at the higher production levels, spot welding, with multiple heads, is almost completely mechanized. Mirror modules are attached to the support structure with manual jigs; the process is mechanized at higher production levels.

The azimuth drive housing components are fabricated onsite, except the heavy plate ears, which are procured as finished parts. The azimuth drive housing assembly process is illustrated in Fig. 3-4. The drives are assembled with manual jigs and tooling at all production levels. Extensive test equipment is provided.

The elevation drive is assembled from fabricated and purchased components. The drag link is assembled from purchased components, and the linear actuators are purchased complete. The 16-in.-OD tube of the main beam is fabricated with an in-house pipe mill; tabs and end flanges are procured as finished parts and assembled and machined as illustrated in Fig. 3-5. The components are assembled with manual jigs and tools at both the lower and higher production rates. Extensive test equipment is contemplated.

Drive motors are purchased complete and assembled in the drive with manual jigs and tools.

The 24-in. tube that forms the pedestal is fabricated with an in-house pipe mill; the cap and cover are procured as finished components. Mechanized arc welding is used to attach the cap to the tube, and the tube is expanded with a hydrosizer.

3.2 INSTALLATION

The installation scenario used for this study was developed from the philosophy that the highly repetitive nature of heliostat installation operations would justify the development of special purpose machines to improve productivity and reduce cost. All of the operations described in this section could be performed with general purpose construction machinery, but the machines proposed here offer higher labor and capital productivity. However, these machines are relatively simple adaptations of conventional machinery and could be developed without extensive research.

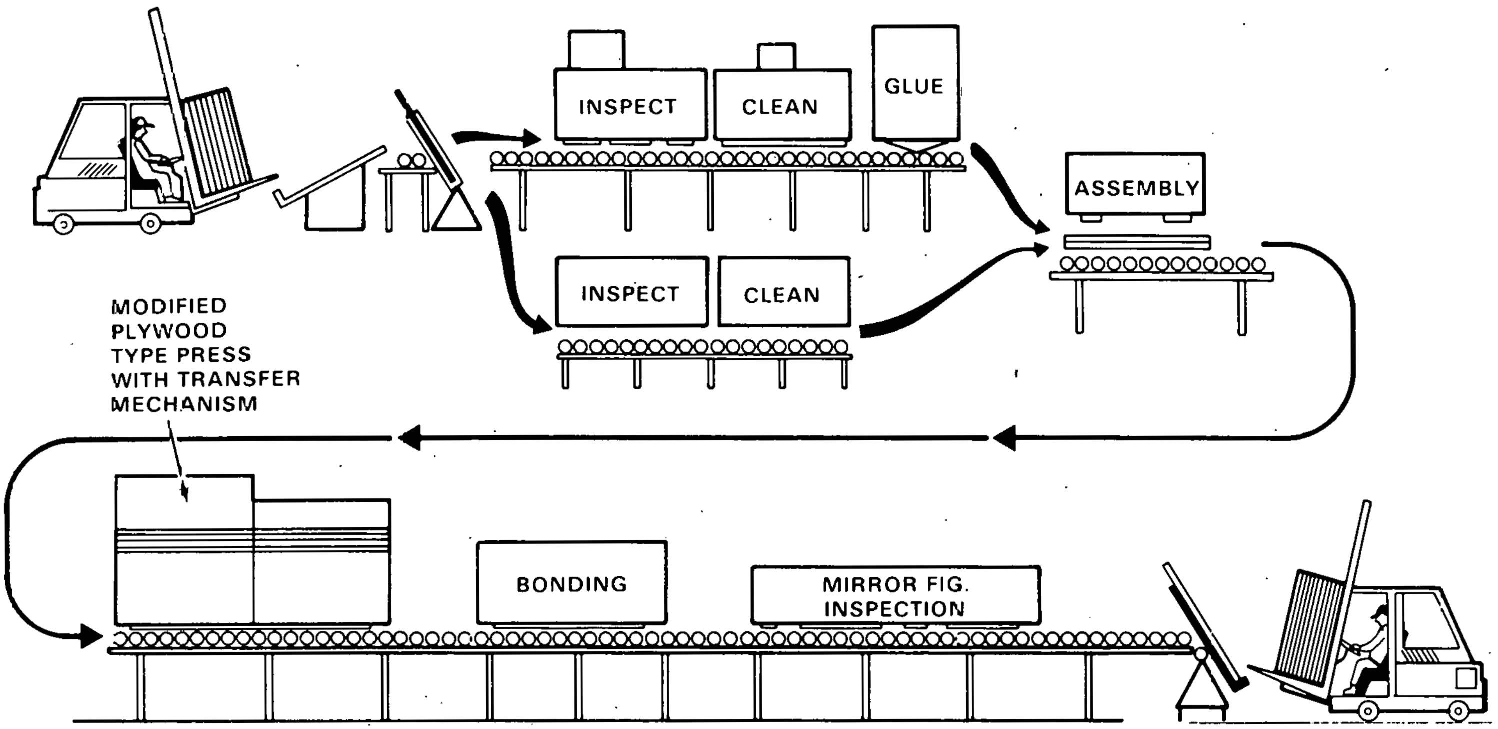
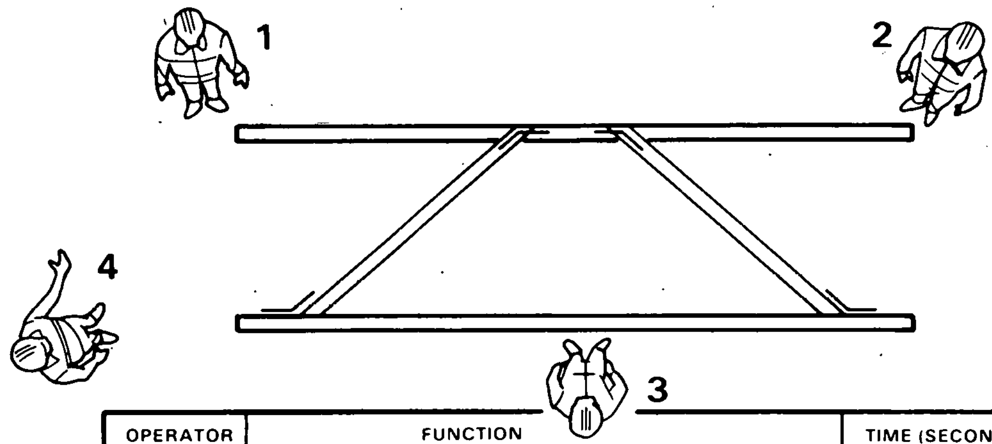
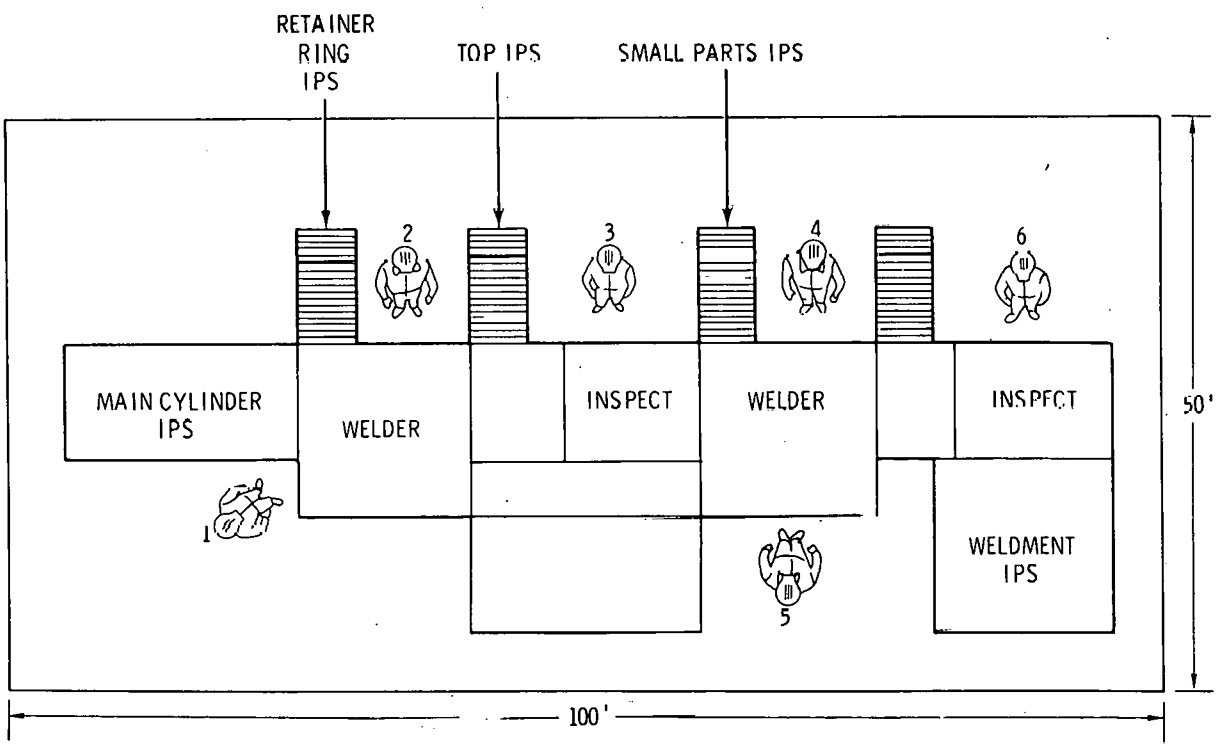


Fig. 3-2. REFLECTOR SURFACE ASSEMBLY



OPERATOR	FUNCTION	TIME (SECONDS)
1-2	SET MAIN BEAM	20
1	SET GUSSET ANGLE	10
2	SET INBOARD ANGLE	10
3	SET OUTBOARD BEAM	10
3	SET DIAGONAL BEAM	15
3	SET OUTBOARD ANGLES WELD/DRILL	10
4	ATTACH HOIST, MOVE, AND VISUAL INSPECT	30
	TOTAL, USE	2 MINUTES

Fig. 3-3. JIG FOR AUTOMATIC CLAMPING AND SPOTWELDING - SUPPORT STRUCTURE



1 IPS = IN PROCESS STORAGE

Fig. 3-4. AZIMUTH DRIVE HOUSING WELDMENT ASSEMBLY

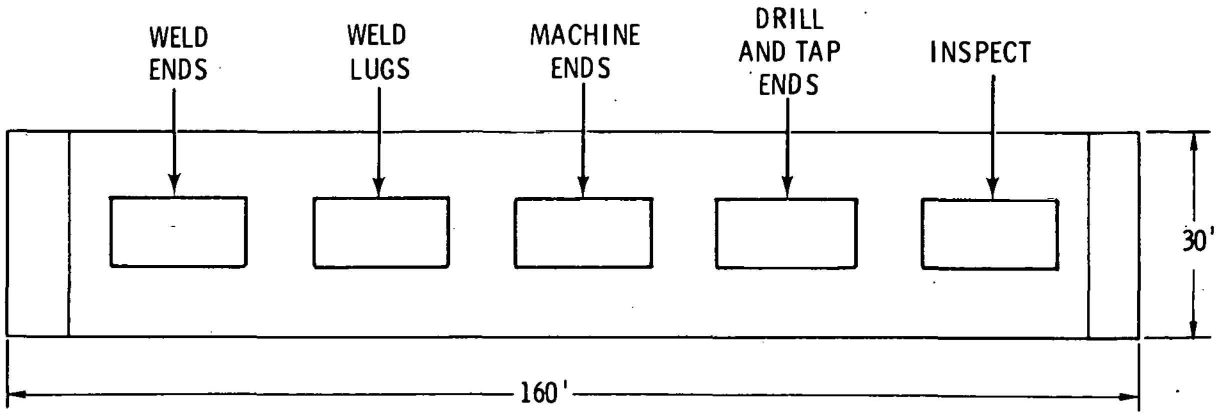


Fig. 3-5. MAIN BEAM ASSEMBLY

For this analysis, we chose a hypothetical site in the California desert, not more than 100 miles from the heliostat manufacturing plant. The first steps in installing a heliostat system are to survey the site, define boundaries, implant grade stakes for leveling, and lay out access roads and heliostat positions. There are 20 heliostat locations per acre, and a control monument is placed on an average of every 2 acres.

The site is prepared by removing some surface vegetation and leveling or terracing the area. Brush is removed with a bulldozer and chain combination. Because the California desert is relatively level, the leveling process is expected to shift an average of 3 in. of top soil.

Once the site area is surveyed, cleared, and leveled, road right-of-ways are graded and paved. During the process, a soil stabilizer (as yet undefined) is laid down to control wind-generated particulates. Road construction includes two passes with a motor grader and rolling. Site roads are surfaced with 3 in. of asphalt. Using the base figure of 20 to 21 heliostats per acre, it is assumed that 10% of the total site area will be paved roads between rows of heliostats.

Four steps are necesary to prepare the foundation for the heliostat: 1) drilling the foundation hole, 2) fabricating and transporting the steel cage, 3) installing the steel cage and steel tapered form, and 4) pouring the concrete.

Before concrete is poured for the foundation, a hole is drilled 2 ft in diameter and 22 ft deep for each heliostat (Fig. 3-6). Cages made of 430 lb of reinforcing steel are prefabricated near the installation site (Fig. 3-7) and trucked to heliostat locations. The fabricated cages are lowered into the pre-drilled holes and fitted with a steel tapered form. The tapered form, with a special holding device, is positioned with a forklift, as Fig. 3-8 illustrates. At the lower production rate, concrete is contracted from local dealers; at the higher rate, it is produced in portable batch plants and transported to the foundation sites by a conveyor or other mechanized system (see Fig. 3-9).

Drive units are trucked from the central distribution point, a maximum of 100 miles from the site. Twelve drive units, each weighing 803 lb, are located on each flat-bed semitrailer and transported to the installation

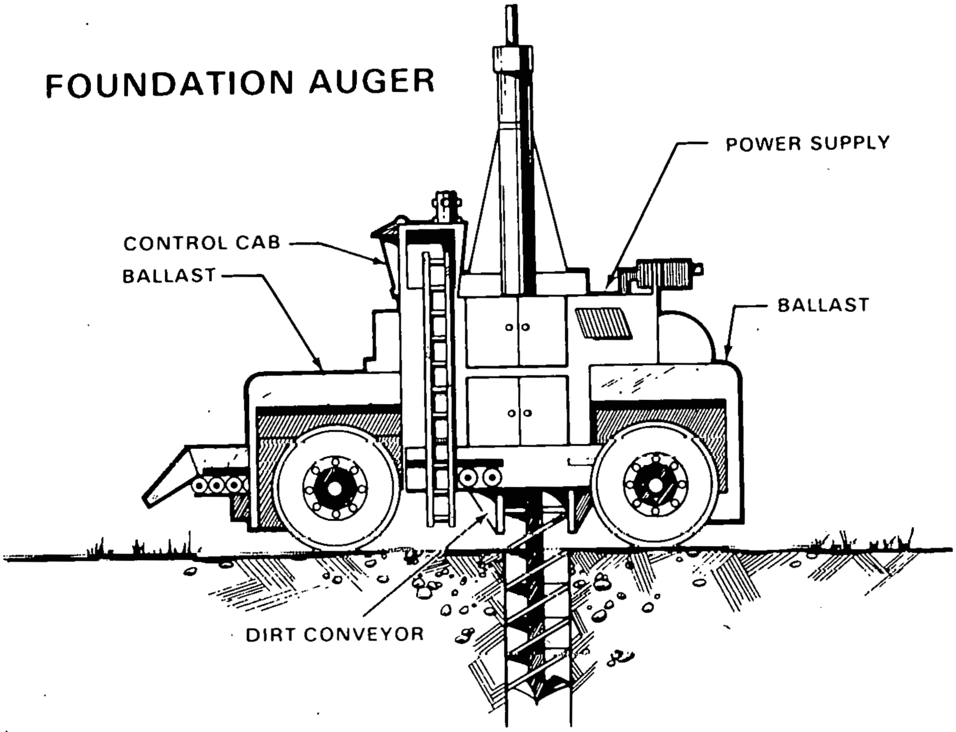


Fig. 3-6. FOUNDATION AUGER

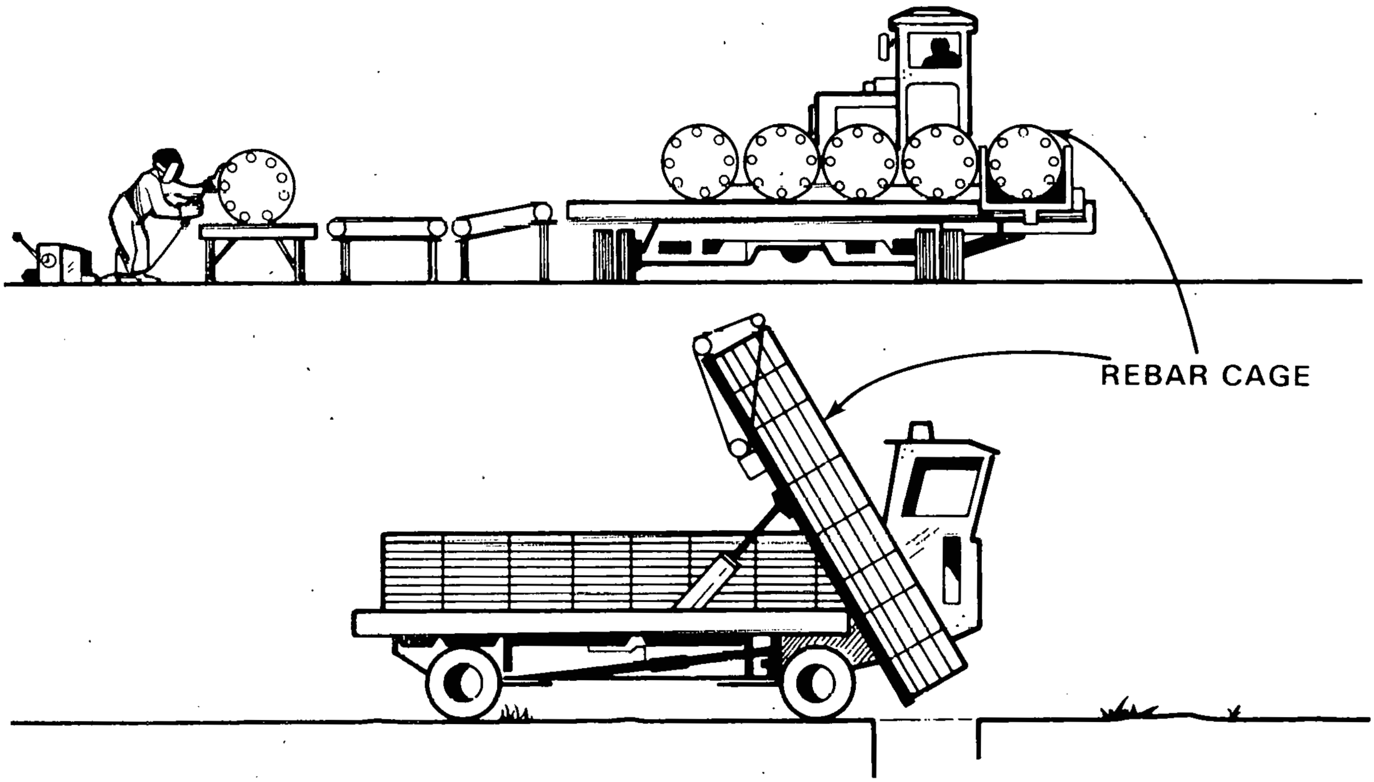


Fig. 3-7. REBAR CAGE TRANSPORT AND INSTALL

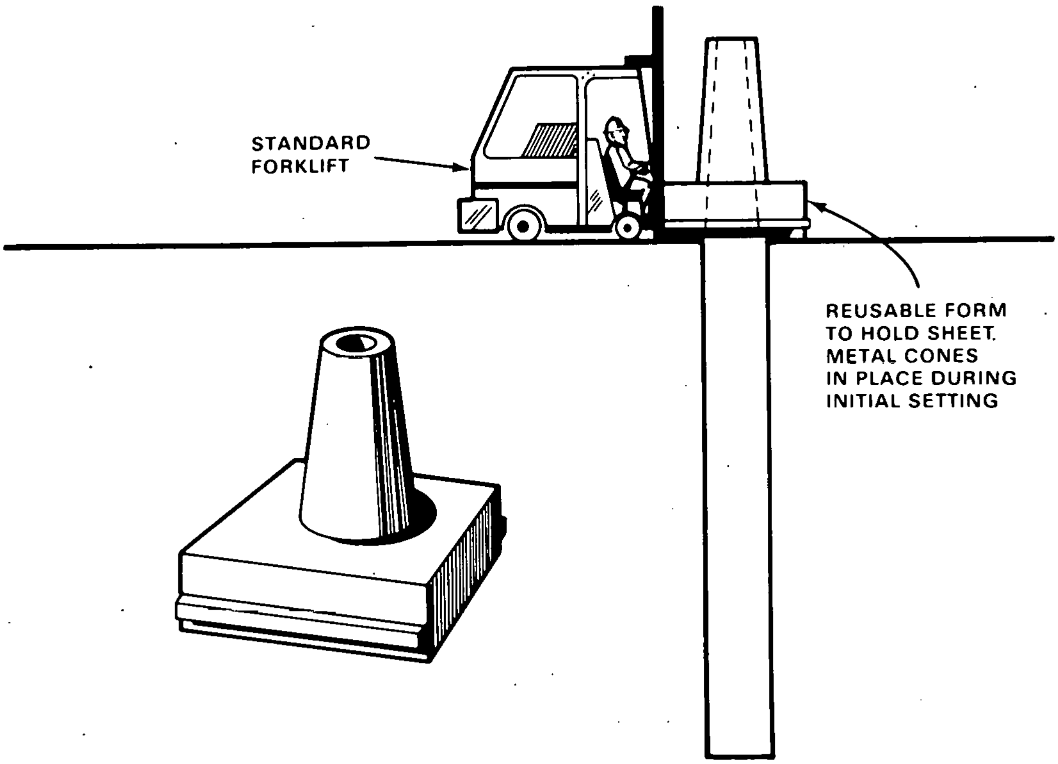


Fig. 3-8. FORM SETTING

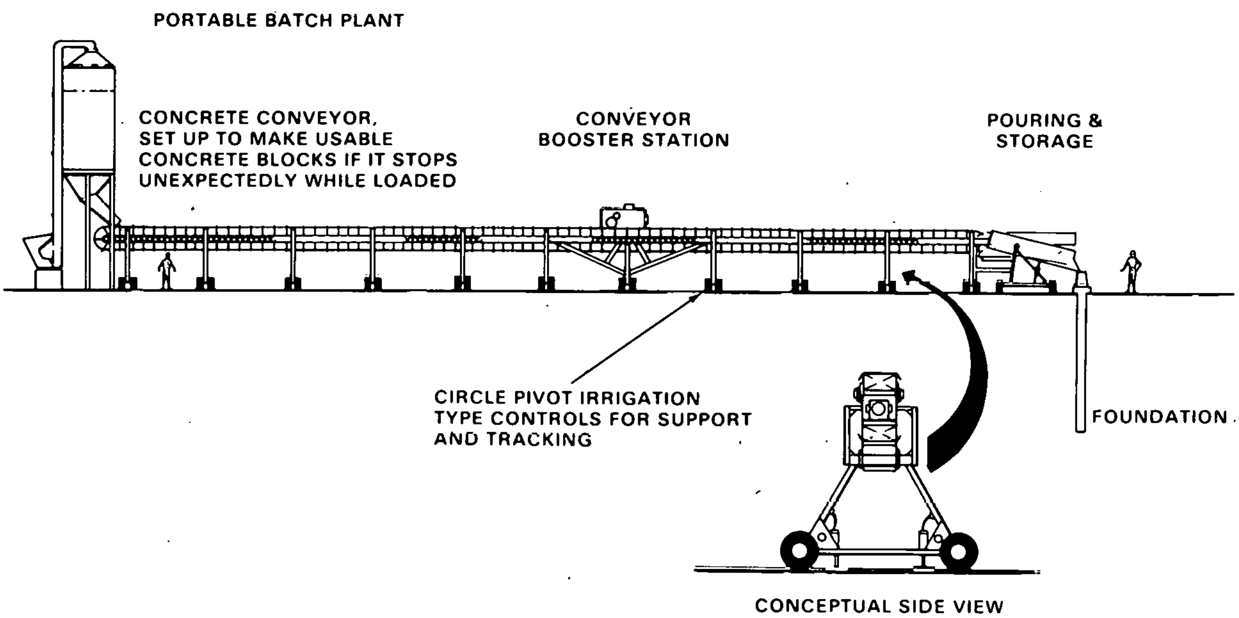


Fig. 3-9. CONCRETE CONVEYOR HELIOSTAT FOUNDATIONS

area. Special fixtures are provided on the trailers so crating is not required. The drive/control units are unloaded directly from the truck and mounted on foundation pedestals by a special mobile hydraulic crane.

Installing the power supply system involves laying and connecting the cable, installing the power transformer, and checking the electrical system.

Power transformer installation costs include pouring a concrete slab, installing a chain link fence, and making the electrical connections.

Conventional forklifts and semitrailers transport the cables for the control and power supply system. The inter-heliostat field cabling is buried 27 in. underground in a single operation by a cable plow. When the cables have been buried, the ends are attached to the control boxes on the drive units.

Reflector panels are trucked on a semitrailer approximately 100 miles to the installation site. Costs are included in the estimate for fuel and maintenance and for equipping the semitrailer so that crates are not needed. A unique straddle crane is used to unload and install the reflector panel units.

The heliostat system is checked to ensure that system elements are functioning properly. Checks are performed on the following system elements:

(1) individual heliostats

(2) small groupings of heliostats operating off the same secondary feeder cable

(3) larger groupings of heliostats operating off the same primary feeder cable

(4) the entire heliostat field.

Heliostats are individually aligned to ensure that each heliostat tracks the sun in its unique, yet proper fashion. Alignments are made in both an interactive man-machine alignment mode and an automatic search alignment mode.

3.3 POSSIBLE MAKE-OR-BUY TRADES

The following discussion considers potential make-or-buy trades in heliostat manufacturing. Potential trades are not analyzed in detail, but are discussed as items that should be considered for in-depth analysis, usually near the time that actual decisions are necessary.

The mass production approach taken in this study implies that vertical integration will tend to produce lower manufactured costs by allowing economies of scale and higher contributed value for the firm. As a result, a simplistic analysis would conclude that the most economic choice would be to make all components in house. However, there are a variety of technical, economic, and strategic decisions which influence the decision whether to make or buy a product or service.

In most cases, the optimum make-or-buy decision will depend on factors varying to some extent with time. For example, if U.S. business is booming at the time decisions are made, specialty houses may be loaded to the point that more in-house work by the heliostat manufacturer will be necessary. Subjective factors, such as company type and policy and industry maturity, also affect the decision. Most of the heliostat's parts can be made by custom fabricators who own equipment sized to produce the volumes needed. A company new to the heliostat business would use specialty fabricators to a large extent initially, making parts in-house as the industry matures and its future becomes more predictable. A typical operating company would require that the cost of new equipment to make a part in-house would be paid back in savings in two years or less. That time requirement could be shortened if the market were uncertain. However, a company with cash may choose to invest in its own plant on the basis of more normal return-on-investment criteria.

Make-or-buy decisions in themselves are not expected to have a major effect on heliostat costs. However, they can have a significant effect on the capital investment required to produce heliostats.

3.3.1 Mirror Module Components--Mirrored Glass

The MDAC analysis[1] considers mirroring the surface of the glass in the mirror module assembly process. Because mirroring is a specialized process to a large extent, we feel that a company new to the business of manufacturing heliostats may not handle the mirroring in-house for small volumes, although in high-volume production, the development of in-house mirroring capability could be warranted.

If mirroring is done offsite, special care must be taken in protecting the back surface of the mirror. Protection methods compatible with both shipping and mirror module bonding may require development.

Offsite fabrication of the mirror module, which involves glueing the mirrored surface to the backlite, could be particularly desirable to minimize handling if thinner glasses are developed. Generally, glass can be shipped with very little breakage if it is properly packed. If the mirroring and assembly are done close to the glass plant, shipping costs should not be greater than shipping costs for the glass itself. Although our estimates are based on assembly of the mirror module glass sandwich at the heliostat manufacturing plant, we feel there is a real possibility that the assembled panels will be procured offsite.

3.3.2 Support Structure

In the support structure there are four types of components:

- light-weight roll-formed sections
- heavy-weight roll-formed sections

- small angles
- fasteners.

Because roll forming is inherently a very high-volume process, large quantities can be produced by specialty fabricators in a short time. Roll forming might thus best be done offsite, except for two considerations. One is shipping and the other is the relatively low cost of roll forming equipment.

Roll-formed shapes generally require much greater shipping volume than coil stock. It is possible that the light-weight hat-section pieces could be roll formed with a slight taper so that they would stack. If so, additional shipping costs could be almost eliminated.

Roll-forming equipment is relatively low cost. For example, the hat sections will be produced with a roll former operating at about 60 ft/min. There are 24 hat sections per heliostat, or 600,000 units/yr at the 25,000 heliostats/yr production rate. Each hat section measures about 11 ft long. Five hat sections can be produced per minute, or with a two-shift operation of 3,024 hr/yr, 907,000 units can be produced each year (5 X 3024 X 60 = 907,000 units/yr). The roll-forming equipment costs about $100,000. The annual cost of procured parts is about $2,700,000 ($4.50 X 600,000). The cost of the roll-forming equipment for the hat sections spread over the production year is thus relatively very small. Each hat section stringer weighs about 14.4 lb; the raw stock costs about $3.24 per stringer (14.4 lb X $0.225/lb = $3.24). The difference between the quoted price of $4.50 and the raw material cost is about $1.25/unit, or $750,000/yr. Equipment write-off and four operators could easily be handled within this amount.

In the heavy-weight roll-formed sections, shipping costs can become more significant. Again, it may be possible to roll form most of the shapes so that pieces can be stacked and put in the final form with relatively inexpensive tooling and equipment at the heliostat manufacturing plant.

However, because of the relatively low equipment cost (on the order of $350,000 for these sections), it may prove desirable to set up roll-forming operations even if the equipment is operating only 10 to 30% of the time.

The light-weight angles and small pieces can be readily formed and punched by high-volume specialty shops. Until a new business matures, these components may well be procured offsite.

In the support structure, as in the balance of the heliostat, it is expected that all standard fastening devices will be procured offsite.

3.3.3 Azimuth Drive Housing

While this analysis uses a weldment for the azimuth drive housing, we feel this component process needs further consideration. Castings and forging should also be considered, primarily because the weight of materials required can be less. This recommendation could be modified on the basis of further study of inertial welding. Preliminary vendor information indicates the housing and flex spline may be simplified to significantly reduce the cost of the assembly with inertial welding; however, any decisions about the applicability of inertial welding to these components will depend on demonstration of design and fabrication feasibility.

If we assume that the housing is produced as a weldment, there are four types of components:

(1) heavy tubing

(2) light tubing

(3) flame-cut shapes

(4) large-diameter circles.

The heavy tubing can be obtained as a standard tube or pipe cut to length, although rolling the pipe to form and welding it as a ring should be considered, particularly at high production volumes. The tubes can probably be procured almost as inexpensively offsite as they can be fabricated in-house. If the components are procured in tubing form, the shipping costs for both cut and uncut are almost the same.

The small tubular pieces, like the small parts for the support structure, can be readily procured from specialty houses at relatively low cost. The principal considerations are the production scheduling and the potential for minor changes.

The heavy, outer retainer ring may be cut from plate, and if a supplier has a use for the "donut hole," this may be the best approach. However, to reduce basic material required, the ring can be rolled from bar stock and butt welded or obtained as a casting or forging. This piece will probably be procured offsite until the company produces large volumes of heliostats.

The large disc for the top of the housing can probably be procured at minimum cost from a flame-cutting house in small quantities and from a large press operator in the larger quantities. Because the volumes required are relatively small for a press operation, pieces are likely to be procured offsite for some time.

The ears can most likely be procured offsite from a flame-cutting house. Ultimately, in-house cutting, possibly plasma-jet, may be worthwhile. The ears might also be forged when high volumes are obtained. During the early days when the pieces are flame cut, rounded corners, tapers, and the like can be eliminated so that the pieces can be cut from bar stock.

The housing will probably be machined in-house, primarily because of quality and scheduling considerations.

3.3.4 Azimuth Drive Components

The components of the azimuth drive, other than the housing, are:

(1) small tubing

(2) small punched components

(3) gear components

(4) heavy rings.

The small tubes and punched components can be obtained from specialty houses at competitive cost until the industry matures. The heavy retainer ring and circular spline, as with the outer retainer ring in the azimuth drive housing, can be flame cut, forged, rolled and welded, or cast. Machining of these components is likely to be done in-house. However, a detailed analysis of these systems will be required at the time of procurement.

The joining of small components, for example the welding of the drive shaft to the wave-generator plug, can easily be done in-house, and it may be desirable to procure welding equipment to perform this kind of operation.

The broaching and heat treating of gear teeth will probably be done in-house for quality control purposes. In very small quantities, these operations may be done by simple machining in specialty houses.

3.3.5 Elevation Drive

The main beam, being standard pipe, can be procured very inexpensively as raw stock. Because of shipping considerations, it may be desirable to procure the main beam from a pipe mill that makes both the beam and the pedestal pipes closer to the heliostat site. For high volume, the pipe mill could be in-house. The most economical way to cut and end finish the main beam will be decided on the basis of detailed analyses at the time. Specialty cutting houses can provide this service at very competitive cost, and whether a pipe is shipped as a whole or in parts has little effect on the shipping costs. Because the end plates for the main beam can be cut with relatively low-cost machinery and because hole patterns may be modified, it may be best to produce these components onsite.

Whether the drag link is best produced as a weldment or by forging or casting will be determined by a detailed analysis. Drilling, pressing, and reaming will most likely be done in-house.

3.3.6 Pedestal

Because of shipping costs, in-house fabrication of the tube for the pedestal may be cheapest. Pedestal caps probably will be procured offsite because they are not needed in sufficient volume to warrant purchasing a forming press even at the higher production rates.

3.3.7 Foundation

There has been considerable discussion of the best method of assembling the reinforcing steel for the foundation. Our opinion, based on only crude analysis, is that a semiportable field-type shop that assembles the cages, using mechanized equipment and a minimum of operators is best.

One possible method for fabricating the present foundation design is to precast a reinforced structure in a semiportable plant operated in the field. This method could save concrete. A spun-cast foundation, or a cardboard core, can reduce concrete needs by up to 50%. Mechanizing the installation of a precast post can be simpler and installation labor can be minimized.

Concrete for foundations can be obtained by procurement from a local ready-mix supplier. However, a portable batch plant operation by the contractor may prove best. At the rate of 25,000 units per year, 75,000 yards of concrete would be needed per year. The present price for ready-mix concrete is about $35/yd, or $105 per heliostat. With a five-sack mix, the cement will cost only about $9/yd in bulk. If sand, gravel, and water are reasonably available at the site, a portable batch plant might be economical. If the ingredients in the concrete cost $15, about $20/yd is available for equipment and labor; $20 X 75,000 yd/yr is $1,500,000. That amount would pay for a batch plant and a fair amount of labor.

The thin, tapered cap will probably be fabricated onsite by an inexpensive Pittsburgh seam-type forming process similar to that used with stove pipe.

3.3.8 Controls

Controls for the heliostat may be produced in-house or procured offsite. Components such as the computer chips will almost surely be bought offsite. The production process would then involve assembling procured components. The make-or-buy decision for this operation is more likely to be based on the background of the manufacturer than on economic considerations. Controls can be produced by specialty houses, but the heliostat manufacturer may opt to produce them if developing that production capability fits his long-range goals.

SECTION 4.0

MANUAL COST ESTIMATE

4.1 PROCEDURE

The approach to costing was basically as follows:

- Develop detailed designs.
- Estimate material costs.
- Develop process flow sheet.
- Develop manufacturing plans.
- Develop manufacturing costs.

This manual analysis, in addition to providing for a complete cost estimate at two production rates, provides the input data for the SAMICS computer model estimate described in Section 5.0 of this report.

The study used the design information in the MDAC 1978 prototype heliostat report [1] (see Section 2.0). The detail necessary for cost estimating was added by Pacific Northwest Laboratory with substantial assistance from McDonnell Douglas. McDonnell Douglas has not reviewed or concurred with the detail added.

As previously noted, the study assumes a continuously operating plant. This type of operation would normally be achieved in the second or third year after startup. It requires a continual market. All dollar figures are early to mid-1979.

4.2 MANUFACTURING COST ESTIMATE

4.2.1 General

The ground rules for the operation of a manufacturing facility to produce the heliostat assume the following:

- A low-volume facility (25,000 heliostats per year) with some expansion capability. This facility represents the type of facility needed to service a limited intermediate heliostat market.
- A high-volume facility (250,000 heliostats per year) using high levels of plant integration to attain the lowest production cost. Such a facility represents the type of plant which will be used to service a mature heliostat market.

Some form of quotation, catalog price, or vendor estimate has been obtained on all the significant components of the heliostat. While some quotations or estimates are not firm and may change when firm quotations are received, direct materials cost estimates are believed to be reasonably accurate. Materials are estimated for production rates of 2,500 and 100,000 heliostats per year, as well as rates of 25,000 and 250,000 units per year. The primary reason for including the 2,500 and 100,000 cases for materials estimates was to provide additional points for extrapolation in the SAMICS program. This estimate assumes that capital facilities required by suppliers, such as a new glass making facility, would be included in suppliers costs.

Process descriptions were prepared beginning at the lowest level of purchased material (which could be a component such as a motor, or raw stock) and proceeding through assembly and installation. Steps such as transportation of material and field assembly and check-outs were included. Process descriptions were prepared in a form suitable for use in the SAMICS computer program.

Equipment descriptions, plant layouts, and manpower requirements were developed based on the above process descriptions. Detailed manufacturing cost work sheets (illustrated in Fig. 4-1) were used to estimate manpower and equipment requirements. The balance of the work sheets will be found in Appendix B. Production scenarios are preliminary, and cost estimates for special mechanized equipment are based primarily on judgment. However, there is sufficient conservatism in the total of annualized equipment costs and direct labor costs that the direct manufacturing costs are believed to be in a reasonable range.

The indirect costs used are based on a limited analysis of industries similar to the heliostat industry. If the industry structure for heliostats differs greatly from the structure we have assumed, then indirect costs would vary. It is unlikely that they would vary sufficiently to cause a difference of more than 25% in the total cost estimates.

In making the manual cost estimate, we have assumed that a single company or operation performs the complete job, from materials procurement through installation and startup of the heliostat field. Slightly different estimating procedures were used for manufacturing and installation to provide for different overhead systems.

4.2.2 Direct Materials

Direct materials are summarized in Table 4-1 and detailed in Table 4-2. Table 4-2 is included to show the extent of the detail on direct materials. Except for controls and installation, the cost of every item has been identified, even washers costing less than one-tenth of a cent each. (If the quoted cost of an item was less than $0.01, it was estimated at $0.01 in this document.)

Costs for direct materials were estimated by obtaining formal or informal quotations or estimates from vendors on both finished parts and raw materials. In general, the approach to obtaining estimates was to ask vendors for a defensible engineering estimate rather than a formal quotation. The raw materials

Part No. ______ | Part Name MIRROR MODULE ASSEMBLY | Page No. 1
No. Per Assembly 1 | Output From Step, Pcs/Hr 99.7 | Prepared By KD
No. Per Heliostat 12 | Net Yield 99% | Date 6/7/79
Heliostats Per Year 25,000 | Starting No. Per Yr. 304,545
Output From Step, Hel. 25,125 | Starting No. Per Hr. 100.7

Line No.	Operation	Required Thruput Pcs/Hr	Pcs/Hr Per Mach.	Machine Time Hrs/Pc	Machine Requirements: Min	Spare	Total	Cost, $K: Per Mach.	Cost, $K: Total	Life, Yrs	Depr Cost Per Pc	Operators: No. Per Shift	MH/Pc	Class	Rate, $/Hr	Direct Labor Cost/$/Pc	Floor Space: Per Mach	Total	Type
	Mirror																		
	Receive & Store	101	1000		1	-	1	50	50	15		1							
	Storage to Line	101	1000		1	-	1	(1)	-	-		-							
	Transfer	101	300		1	-	1	50	50	15		1							
	Inspect	101	300		1	-	1	200	200	10		1							
	Clean	101	300		1	-	1	100	100	15		1							
	Back Lite																		
	Receive & Store	101	1000		1	-	1	(1)	-	-		-							
	Storage to Line	101	1000		1	-	1	(1)	-	-		-							
	Transfer	101	300		1	-	1	(1)	-	-		-							
	Inspect	101	300		1	-	1	50	50	15		1							
	Clean	101	300		1	-	1	100	100	15		1							
	Apply Glue	101	300		1	-	1	150	150	10		1							
	Assembly																		
	Join	101	300		1	-	1	150	150	15		1							
	Press	101	300		1	-	1	1000	1000	20		1							
	Inspect Bond	101	300		1	-	1	100	100	10		1							
	Inspect Mirror Fig	100	300		1	-	1	300	300	10		(2)							
	Inspect Visual	100	300		1	-	1	25	25	10		1							
	Store	100	300		1	-	1	(1)	-	-		-							
	Total								2275			11							

(1) Use forklift from other stations

(2) One inspector does all inspection.

Fig. 4-1. EXAMPLE MANUFACTURING COST WORKSHEET

Table 4-1. SUMMARY OF DIRECT MATERIAL COSTS FOR MANUFACTURING

	Dollars per Heliostat at Given Annual Production Rate		
	25,000	100,000	250,000
Mirror Module[a]	(911.20) 624.40	(879.92) 612.68	(848.74) 601.18
Support Structure	361.16	353.00	345.03
Azimuth Drive	280.72	270.91	264.49
Elevation Drive	703.67	670.59	639.66
Motors	174.56	146.86	140.96
Pedestal	77.22	74.87	72.52
Controls[a]	(342.72) 150.00	(315.05) 140.00	(296.52) 130.00
Allowance for Materials Not Detailed and Yield	50.00	50.00	50.00
Total Direct Materials, Mfg.	$2,421.73	$2,319.31	$2,243.84

[a]Numbers in parentheses are based on quotations or estimates today. Reduction to the number actually used is based on forecasts for a continuing plant operation in the early 1980s.

Table 4-2. DIRECT MATERIALS COST ESTIMATE FOR EACH PRODUCTION LEVEL

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate 25,000	100,000	250,000
MIRROR MODULE						
E-21203-D	Mirror Panel, 48 x 132, silvered	12	48.40 46.20 44.00	580.80	554.40	528.00
E-21204-D	Glass Panel, Float, 48 x 132	12	24.20 23.96 23.72	290.40	287.52	284.64
E-27301	Adhesive, Mirror Module	2	20.00 19.00 18.05	40.00	38.00	36.10
	Subtotal, Mirror Module			911.20	879.92	848.74
E-21205-D	Mirror Module Components (Forecast for continuing plant operation. Other mirror module component values provided for reference only.)			624.40	612.68	601.18
SUPPORT STRUCTURE						
E-23203-D	Outboard Cross Beam	2	14.61 14.32 14.03	29.22	28.64	28.06
E-23202-D	Inboard Cross Beam, McD-D Prototype	2	43.77 42.89 42.04	87.54	85.78	84.08
E-23404-D	Diagonal Beam, McD-D Prototype	4	20.49 20.08 19.68	81.96	80.32	78.72
E-23206-D	Hat Section Stiffener, McD-D Prototype	24	4.54 4.45 4.36	108.96	106.80	104.64
E-23207-D	Outboard Angle - McD-D Prototype	4	0.09 0.09 0.09	0.36	0.36	0.36
E-23208-D	Inboard Angle - McD-D Prototype	4	0.23 0.22 0.21	0.92	0.88	0.84
E-23209-D	Gusset Angle - McD-D Prototype	4	3.47 3.40 3.33	13.88	13.60	13.32
E-27201-D	Clinch Nut - 1/4"	48	0.04 0.04 0.04	1.92	1.92	1.92
E-27202-D	Bolt, 1/4 x 3/4, UNC-20	48	0.04 0.04 0.04	1.92	1.92	1.92
E-27203-D	Washer, SAE Flat, 1/4	48	0.01 0.01 0.01	0.48	0.48	0.48
E-27302-D	Adhesive, Mirror to Hat Section, McD-D Prototype	1.7	20.00 19.00 18.05	34.00	32.30	30.69
	Subtotal, Support Structure			361.16	353.00	345.03

Table 4-2. (Cont'd)

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate 25,000	100,000	250,000
AZIMUTH DRIVE						
E-22401-D	Main Cylinder, AZ DR HSG, 16 OD x .5 wall x 5.5, Raw Stock	1	7.82 7.58 7.35	7.82	7.58	7.35
E-22402-D	Retainer, AZ DR HSG, 14 ID x 20 ID x 1.25 Rolled from Bar Stock	1	11.53 11.19 10.85	11.53	11.19	10.85
E-23003-D	Top, AZ DR HSG, 16 D x 1/2 t,	1	8.56 8.31 8.07	8.56	8.31	8.07
E-22404-D	Motor Mount, AZ DR HSG, 1/2 x 4 x 8 Raw Stock	2	0.89 0.87 0.84	1.78	1.74	1.68
E-22405-D	Motor Mount, AZ DR HSG, 1/2 x 4 x 7 Raw Stock	2	0.79 0.77 0.74	1.58	1.54	1.48
E-22406-D	Shaft Mount, AZ DR HSG, 3.25 OD x 1.75 ID x 3, Raw Stock	1	5.04 4.82 4.61	5.04	4.82	4.61
E-23007-D	Ears, AZ DR HSG, 1 1/4 x 5 x 9	2	3.74 3.64 3.55	7.48	7.28	7.10
E-23008-D	Ears, AZ DR HSG, 1 1/4 x 8 x 14	2	8.56 8.32 8.08	17.12	16.64	16.16
E-22409-D	Membrane, AZ DR, 10 OD x .156 Raw Stock	1	1.10 1.07 1.03	1.10	1.07	1.03
E-22410-D	Tube, AZ DR, 10 OD x .156 x 8 Raw Stock	1	4.56 4.33 4.10	4.56	4.33	4.10
E-22411-D	Spline, AZ DR, 10 OD x .312 x 3 Raw Stock	1	6.20 5.93 5.67	6.20	5.93	5.67
E-22412-D	Doubler, AZ DR, 6.5 OD x .375 Raw Stock	2	1.06 1.03 1.00	2.12	2.06	2.00
E-22413-D	Plug, AZ DR, 7.0 OD x 1.5, Raw Stock	1	5.53 5.37 5.20	5.53	5.37	5.20
E-22414-D	Drive Shaft, AZ DR, 1.75 OD x .75 ID x 10.75, Raw Stock	1	4.26 4.08 3.90	4.26	4.08	3.90
E-22415-D	Retainer-Outer, AZ DR, 19.625 OD x 15.1875 ID x 1.25, Raw Stock	1	10.61 10.30 9.98	10.61	10.30	9.98
E-22416-D	Pan Oil, AZ DR, 15 OD x .125 Raw Stock	1	1.72 1.67 1.61	1.72	1.67	1.61
E-22417-D	Circular Spline, AZ DR, 15 OD x 10 ID x 2.75, Raw Stock	1	19.10 18.55 18.01	19.10	18.55	18.01

Table 4-2. (Cont'd)

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate 25,000	100,000	250,000
E-22418-D	Tube, Elec. Wire, AZ DR, .688 OD x 0.63 wall x 13, Raw Stock	1	0.20 0.19 0.18	0.20	0.19	0.18
E-22419-D	Cover, AZ DR, 9 OD x .125, Raw Stock	1	0.67 0.65 0.63	0.67	0.65	0.63
E-22420-D	Cover, AZ DR, 8 OD x .125, Raw Stock	1	0.55 0.53 0.51	0.55	0.53	0.51
E-26001-D	Helicon, AZ DR	1	3.00 3.00 3.00	3.00	3.00	3.00
E-26002-D	Pinion, Helicon, AZ DR	1	7.00 7.00 7.00	7.00	7.00	7.00
E-26003-D	Ring, Pinion, Ret., AZ DR, 3/4 external	1	0.09 0.09 0.08	0.09	0.09	0.08
E-26004-D	Shim-gear, AZ DR, 1.50 OD x 1.125 ID	1	0.09 0.09 0.08	0.09	0.09	0.08
E-26005-D	Key-gear, AZ DR, Use 1/4 x 1/4 x 1 square	1	0.06 0.06 0.06	0.06	0.06	0.06
E-26006-D	Nut-gear, AZ DR, Use 1", AFBMA Std W-05	1	1.00 0.95 0.91	1.00	0.95	0.91
E-26007-D	Washer-gear, AZ DR, Use 1", AFBMA Std W-05	1	0.06 0.06 0.06	0.06	0.06	0.06
E-26008-D	Bearing-Drive Shaft, AZ DR, Use 1 ID x 2 1/4 OD x 3/4 L	1	2.59 2.46 2.34	2.59	2.46	2.34
E-26009-D	Ring, Bearing Ret., AZ DR, 2 1/4 OD internal	1	0.10 0.10 0.09	0.10	0.10	0.09
E-26010-D	Bushing, Pivot, AZ DR, KJS-1616060	2	0.22 0.21 0.20	0.44	0.42	0.40
E-26011-D	Bearing, AZ DR, BB-2151	1	78.24 77.56 77.04	78.24	77.56	77.04
E-26012-D	Bearing, AZ DR, BB-2149, Turret	1	36.04 35.78 35.57	36.04	35.78	35.57
E-27001-D	Nut, AZ DR, 1/2	8	0.03 0.02 0.02	0.24	0.16	0.16
E-27002-D	Bolt, AZ DR, 1/2 x 2, Class 5	8	0.09 0.09 0.08	0.72	0.72	0.64
E-27003-D	Bolt, AZ DR, 1/2 x 3, Class 5	8	0.12 0.11 0.11	0.96	0.88	0.88

Table 4-2. (Cont'd)

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate		
				25,000	100,000	250,000
E-27004-D	Washer, AZ DR, 1/2	16	0.01 0.01 0.01	0.16	0.16	0.16
E-27005-D	Screw, AZ DR, 1/2 L, FH	8	0.01 0.01 0.01	0.08	0.08	0.08
E-27006-D	Bolt, AZ DR, High Strength	12	1.08 0.92 0.86	12.96	11.04	10.32
E-27007-D	Nut, AZ DR, High Strength	12	1.60 1.36 1.28	19.20	16.32	15.36
E-28001-D	Clamp, AZ DR, Wire Tube	1	0.10 0.09 0.08	0.10	0.09	0.08
E-27009-D	Screw, AZ DR, Cover to Drive	4	0.01 0.01 0.01	0.04	0.04	0.04
E-28002-D	Grommet, AZ DR	1	0.02 0.02 0.02	0.02	0.02	0.02
	Subtotal, Azimuth Drive			280.72	270.91	264.49
ELEVATION DRIVE						
E-23021-D	Sides, Drag Link, EL DR, 8 x 24 x 3/4 blank	2	10.24 9.80 9.55	20.48	19.60	19.10
E-23022-D	Ears, Drag Link, EL DR, 4 x 14 x 3/4 blank	2	3.36 3.28 3.21	6.72	6.56	6.42
E-23023-D	Top, Drag Link, EL DR, 15 x 20 x 1/2 blank	1	8.88 8.62 8.37	8.88	8.62	8.37
E-22432-D	Tube, EL DR, 16 OD x .105 x 81 1/2, Raw Coil	1	24.79 24.01 23.23	24.79	24.01	23.23
E-23025-D	Tab, Actuator, EL DR, .5 x 10 x 10 blank	2	3.29 3.21 3.12	6.58	6.42	6.24
E-23026-D	Tab, Hinge, EL DR, .5 x 9 x 9 blank	4	2.76 2.69 2.62	11.04	10.76	10.48
E-22427-D	Flange, EL DR, .625 x 18 x 18 Raw Stock	2	12.31 11.96 11.62	24.62	23.92	23.24
E-22428-D	Tube, Clevis, EL DR, 1 OD x 3/4 ID	2	0.16 0.15 0.14	0.32	0.30	0.28
E-26013-D	Bushing, EL DR, KJS 1620060	2	0.23 0.22 0.21	0.46	0.44	0.42
E-26014-D	Bushing, EL DR, KJS 1624060	2	0.25 0.24 0.23	0.50	0.48	0.46

Table 4-2. (Cont'd)

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate 25,000	100,000	250,000
E-26015-D	Bushing, EL DR, 1612060	4	0.21 0.20 0.19	0.84	0.80	0.76
E-26016-D	Seal, EL DR, 1 x 1 1/12	4	0.20 0.19 0.18	0.80	0.76	0.72
E-26017-D	Seal, EL DR, 1 1/2 x 2 x 1/8	8	0.20 0.19 0.18	1.60	1.52	1.44
E-26018-D	Seal, EL DR, 1 1/2 x 2 x 1/4	2	0.20 0.19 0.18	0.40	0.38	0.36
E-26019-D	Shim, EL DR, 3/4 ID x 1 1/2 OD x 1/8	4	0.13 0.12 0.12	0.52	0.48	0.48
E-26020-D	Shim, EL DR, 1 ID x 1 1/2 OD x 1/16	4	0.07 0.07 0.06	0.28	0.28	0.24
E-26021-D	Shim, EL DR, 1 ID x 1 1/2 OD x 1/8	6	0.10 0.10 0.09	0.60	0.60	0.54
E-27010-D	Bolt, EL DR, 3/4 x 5, Class 5	2	0.43 0.42 0.42	0.86	0.84	0.84
E-26022-D	Thrust Bearing, EL DR, KTM 1628063	4	0.21 0.20 0.19	0.84	0.80	0.76
E-27011-D	Nut, EL DR, .75	2	0.26 0.26 0.25	0.52	0.52	0.50
E-27012-D	Bushing, Clamp Up, EL DR, .75 Dia x 5 long, Class 8	2	0.10 0.10 0.09	0.20	0.20	0.18
E-27013-D	Bolt, Rod End, EL DR, 3/4 x 3 1/4, Class 8	2	0.35 0.34 0.33	0.70	0.68	0.66
E-27014-D	Nut, Rod End, EL DR, 3/4	2	0.26 0.26 0.25	0.52	0.52	0.50
E-27015-D	Bushing, Clamp Up, EL DR	2	0.10 0.10 0.09	0.20	0.20	0.18
E-26023-D	Jack, Screw, EL DR	2	293.00 278.35 264.43	586.00	556.70	529.26
E-26024-D	Shaft, Pivot, EL DR, 1 1/8 T, 1" Shaft, 2 LG	4	1.00 0.95 0.91	4.00	3.80	3.64
E-26025-D	Washer, EL DR, AN=960-416L, Lawrence Eng.	4	0.10 0.10 0.09	0.40	0.40	0.36
	Subtotal, Elevation Drive			703.67	670.59	639.66

Table 4-2. (Cont'd)

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate 25,000	100,000	250,000
MOTORS						
E-28003-D	Motors, Tracking, 1/4 HP	1	55.29 44.50 43.30	55.29	44.50	43.30
E-28004-D	Motors, Stowage, 1/4 HP	1	55.29 44.50 43.30	55.29	44.50	43.30
E-28005-D	Motors, Azimuth	1	63.74 57.62 54.12	63.74	57.62	54.12
E-27016-D	Bolts, Motor, 1/4 x 1, Class 2	8	0.01 0.01 0.01	0.08	0.08	0.08
E-27017-D	Nuts, Motor, 1/4	8	0.01 0.01 0.01	0.08	0.08	0.08
E-27018-D	Washer, Motor, 1/4	8	0.01 0.01 0.01	0.08	0.08	0.08
	Subtotal, Motors			174.56	146.86	140.96
PEDESTAL						
E-22433-D	Tube, Pedestal, 24" OD x .105 wall x 123.5 Coil Stock	1	56.35 54.58 52.81	56.35	54.58	52.81
E-23030-D	Cap, Pedestal, .375 x 30 x 30 blank Raw Stock	1	20.42 19.85 19.28	20.42	19.85	19.28
E-23031-D	Cover, Pedestal, .0396 x 30 x 30 blank	1	0.45 0.44 0.43	0.45	0.44	0.43
	Subtotal, Pedestal			77.22	74.87	72.52
CONTROLS						
E-28201-D	Microprocessor, INTEL 8748, 3030204	1	59.00 56.00 51.00	59.00	56.00	51.00
E-28202-D	Quad Diff Line Driver, DS 1488 National, 3030205	2	0.69 0.66 0.62	1.38	1.32	1.24
E-28203-D	Quad Diff Line Receiver, National DS 1489, 3030206	2	0.69 0.66 0.62	1.38	1.32	1.24
E-28204-D	Hex D Flip Flop, T.I. 74174, 3030207	3	0.45 0.44 0.43	1.35	1.32	1.29
E-28205-D	Capacitor, .1 uf @ 50V Sprague, (Cramer) 3030208	3	0.12 0.11 0.10	0.36	0.33	0.30
E-28206-D	Power Supply, Semiconductor CKT, MP 1.5, 750/2.15.100, 3030209	1	40.90 40.90 40.90	40.90	40.90	40.90

Table 4-2. (Cont'd)

Cost Account No.	Descriptive Name	Quant Per H	Unit Price	Dollars per Heliostat at Given Annual Production Rate 25,000	100,000	250,000
E-28207-D	Plastic Box, Mac Dac, 3030210	1	1.00 0.95 0.90	1.00	0.95	0.90
E-28208-D	24 Pin Connector, Cramer-Amphenol 24-28P 3030211	1	5.21 5.21 5.21	5.21	5.21	5.21
E-28209-D	Optical Transceiver, Spectronics, WPX-4141 Trans, SPX-4140 Receiver, 3020204	1	99.90 95.00 90.00	99.90	95.00	90.00
E-28210-D	Earom, 128 x 8, Nitron NC7053PC	8	9.00 7.00 6.35	72.00	56.00	50.80
E-28211-D	Uart, T.I., TMS 6011	1	5.00 5.00 5.00	5.00	5.00	5.00
E-28212-D	Hall Effect Sensor Microswitch 1AV3A, 2040201	6	3.12 3.05 2.98	18.72	18.30	17.88
E-28213-D	Line Driver, Fairchild 9614, 2040202	3	0.55 0.50 0.48	1.65	1.50	1.44
E-28214-D	Ferrous Metal Disc, Mac Dac 2040203	3	1.20 1.15 1.10	3.60	3.45	3.30
E-28215-D	Line Receiver, Fairchild 9615, 2040301	1	0.55 0.52 0.50	0.55	0.52	0.50
E-28216-D	Opto Triac, Motorola MDC 3011, 2040302	4	0.87 0.85 0.84	3.48	3.40	3.36
E-28217-D	Resistor, Cramer Catalog, 2040303	4	0.25 0.24 0.23	1.00	0.96	0.92
E-28218-D	Capacitor, .1 uf @ 1400 V, Cramer Catalog PKM10P1, 2040304	4	0.29 0.28 0.27	1.16	1.12	1.08
E-28219-D	PC Board, 6" x 6" plated thru electronic layout fabricators, 2040305	1	5.22 4.32 3.60	5.22	4.32	3.60
E-28220-D	Plastic Cover, Mac Dac, 2040306	1	1.00 0.95 0.90	1.00	0.95	0.90
E-28221-D	Connectors for fiber optic couple, estimate, 2050303	2	2.50 2.38 2.25	5.00	4.76	4.50
E-28222-D	PC Board, 4" x 5" plated thru electronic layout fabricators, 3030201	1	5.22 4.32 3.60	5.22	4.32	3.60
E-28223-D	24 Pin Connector, Cramer-Amphenol 24-28 S, 3030203	1	3.64 3.60 3.56	3.64	3.60	3.56
E-28224-D	Central Computer, allow			5.00	4.50	4.00
	Subtotal, Controls			342.72	315.05	296.52
E-28250-D	Control (Forecast for continuing plant operation. Other control component values provided for reference only.)	1		150.00	140.00	130.00

costs were often provided as formal quotations. In cases where an engineering estimate was used, the costs have generally been compared with similar components and are in a reasonable range. In some cases, judgment has been applied to produce a cost believed to be compatible with the "steady state" ground rules.

Costs for raw materials, such as steel, were provided by vendors as the price for the highest quantity bracket. This price was generally used for the 25,000 production level. For the 100,000 and 250,000 levels, it was assumed that modest improvements could be made through negotiation. In practice, it is expected that significant reductions in the total direct materials cost could be made through design improvements and negotiation.

In the case of control components and mirrors, current cost figures were obtained from vendors and reduced to provide for reductions forecast in component cost and to allow for design improvements.

4.2.3 Direct Labor

Typical assumptions for the operating conditions used in the manual analysis are listed below.

• production rate	25,000 heliostats/yr
• operating efficiency	90%
• man-hr/work/day	7
• work days/yr	240
• hr/yr (240 days/yr X 7 man-hr/day-shift X 0.90 operating efficiency)	1512 man-hr/yr-shift
• operation - shifts/day	2
• hr/yr, two shifts	3024

The detailed manpower estimates are based on the number of men required to operate a step, using the 1512 man-hours per shift listed and assuming that a second person is required if the piece rate exceeds 1512. If one person is required, he is paid for 2080 hours. This produces a conservative labor requirement, because if a person is not fully utilized on one step, he may perform other operations.

Direct manpower estimates are summarized in Table 4-3. These estimates are based on preliminary equipment design, estimated crews for commercially available equipment, and judgment. For major operations, a step-by-step, moderately conservative analysis has been made in the Manufacturing Cost Estimate Work Sheet format (see Fig. 4-1). Optimization of processes and equipment for any step might reduce personnel and equipment requirements by 20 to 30%. In the steps that require many operators, optimization might even reduce the personnel needed by 50 to 75%. On the other hand, some processes and equipment might require more people or cost more than this limited

Table 4-3. DIRECT LABOR REQUIREMENTS FOR MANUFACTURING

	Persons Required at Given Annual Production Rate			
	Per Shift		Total 2 Shifts	
Item	25,000	250,000	25,000	250,000
MIRROR MODULE	11	26	22	52
PANEL-SUPPORT STRUCTURE	20	105	40	210
AZIMUTH DRIVE	43	187	86	374
Housing Assy				
Main Cylinder	1	3	2	6
Retainer	1	2	2	4
Shaft Mount	1	1	2	2
Motor Mount	1	1	2	2
Ears (Procured)	-	-	-	-
Welding	6	32	12	64
Machining	7	32	14	64
Flex Spline				
Membrane[a]	1	1	2	2
Tube[b]	1	5	2	10
Spline[b]	-	-	-	-
Flex Spline Assy	5	21	10	42
Drive-Plug				
Plug[b]	-	-	-	-
Drive Shaft[b]	-	-	-	-
Drive Plug Assy	1	2	2	4
Retainer-Outer	3	10	6	20
Circular Spline	6	18	12	36
Doubler[a]	-	-	-	-
Pan-Oil[a]	-	-	-	-
Tube-Elec Wire[b]	-	-	-	-
Cover, 9-in. OD[a]	-	-	-	-
Cover, 8-in. OD[a]	-	-	-	-
Azimuth Drive Assy	9	59	18	118
ELEVATION DRIVE-PEDESTAL	44	188	88	376
Drag Link				
Sides (Procured)	-	-	-	-
Ears (Procured)	-	-	-	-
Top (Procured)				
Drag Link Assy	5	24	10	48
Main Beam				
Tube[c]	3	10[d]	6	20[d]
Tab, Actuator (Procured)	-	-	-	-
Tab, Hinge (Procured)	-	-	-	-
Flange (Procured)	-	-	-	-
Tube, Clevis (Procured)	-	-	-	-
Main Beam Assy	11	32	22	64
Pedestal				
Cap (Procured)	-	-	-	-
Cover (Procured)	-	-	-	-
Tube[c]	-	-	-	-
Pedestal Assy	11	32	22	64
Elevation Drive Assembly	14	90	28	180
CONTROLS, allow	14	60	28	120
CENTRAL QUALITY CONTROL, allow	6	20	12	40
LOAD	4	16	8	32
TOTAL, MANUFACTURING	142	602	284	1204

[a] Labor all shown under flex spline membrane.
[b] Labor all shown under flex spline tube.
[c] Main beam tube and pedestal tube fabricated in same pipe mill.
[d] Goes to high-speed pipe mill.

analysis indicates. While some significant reductions are believed possible through optimization studies, such improvements are considered to be a contingency against unforeseen increases. The overall result is believed to be moderately conservative.

In Table 4-4, the manpower requirements are converted to costs at a straight $12 per hour (which includes fringe benefits), with hours established as follows:

52 weeks/yr X 40 man-hr/week = 2080 man-hr/yr

Production Rate	Man-hr/heliostat per man
25,000	2080 ÷ 25,000 = 0.0832
250,000	2080 ÷ 250,000 = 0.00832

Detailed estimates were based on a production rate of 25,000 heliostats per year, with modification for higher volumes.

Table 4-4. SUMMARY OF MANUFACTURING DIRECT LABOR COSTS FOR EACH PRODUCTION LEVEL

Item	Total No. of Persons at Given Annual Production Rate		Total Man-hr per Heliostat at Given Annual Production Rate		Total Direct Labor Cost per Heliostat at Given Annual Production Rate[a]	
	25,000	250,000	25,000	250,000	25,000	250,000
Mirror Module Assy	22	52	1.83	0.43	21.96	5.16
Panel Support Structure Assy	40	210	3.33	1.75	39.96	21.00
Azimuth Drive	86	374	7.16	3.11	85.92	37.32
Elevation Drive Pedestal	88	376	7.32	3.13	87.84	37.56
Controls	28	120	2.33	1.00	27.96	12.00
Central QC	12	40	1.00	0.33	12.00	3.96
Load	8	32	0.67	0.27	8.04	3.24
TOTAL, MANUFACTURING	284	1204	23.64	10.02	$283.68	$120.24

[a] Figured at $12/hr including benefits.

4.2.4 Manufacturing Equipment and Facility Requirements

Equipment quantities were developed from the Manufacturing Cost Estimate Work Sheets. The basic requirements were developed for the production rate of 25,000 heliostats per year; modifications were made for mechanization at higher volumes. A single design was assumed. Equipment flexibility for other heliostat designs was not considered.

Costs for special machines, such as the support welding jigs, were estimated from an undetailed conceptual sketch by an individual experienced in dealing with similar machines. The costs of standard machines were based on an engineering estimate provided by the supplier for the base machine and judgment estimates for tooling and mechanization. This approach provides estimates which, in summary, are probably within 35%. However, even if they are off by a factor of two or so, the effect on heliostat cost is not great. Equipment costs are summarized in Table 4-5.

Table 4-5. COST SUMMARY FOR MANUFACTURING CAPITAL EQUIPMENT

Item	Thousands of Dollars at Given Annual Production Rate 25,000	250,000
MIRROR MODULE	2,275	8,475
PANEL-SUPPORT STRUCTURE	2,030	14,100
AZIMUTH DRIVE	7,205	35,270
Housing Assy		
Main Cylinder	130	390
Retainer	165	330
Shaft Mount	80	80
Motor Mount	80	80
Ears (Procured)	-	-
Welding	850	6,500
Machining	3,100	10,000
Flex Spline		
Membrane[a]	75	200
Tube[b]	75	1,500
Spline[b]	-	-
Flex Spline Assy	800	3,750
Drive-Plug		
Plug[b]	-	-
Drive Shaft[b]	-	-
Drive Plug Assy	250	350
Retainer-Outer	275	1,050
Circular Spline	650	6,000
Doubler[a]	-	-
Pan-Oil[a]	-	-
Tube-Elec Wire[b]	-	-
Cover, 9-in. OD[a]	-	-
Cover, 8-in. OD[a]	-	-
Azimuth Drive Assy	675	5,040
ELEVATION DRIVE-PEDESTAL	2,820	26,075
Drag Link		
Sides (Procured)	-	
Ears (Procured)	-	-
Top (Procured	-	-
Drag Link Assy	275	2,600
Main Beam		
Tube[c]	500	10,000
Tab, Actuator (Procured)	-	-
Tab, Hinge (Procured)	-	-
Flange (Procured)	-	-
Tube, Clevis (Procured)	-	-
Main Beam Assy	1,150	8,800
Pedestal		
Cap (Procured)	-	-
Cover (Procured)	-	-
Tube[c]	-	-
Pedestal Assy	470	1,150
Elevation Drive Assembly	425	3,525
CONTROLS, allow	500	2,000
CENTRAL QUALITY CONTROL, allow	2,000	6,000
LOAD, allow	100	400
TOTAL, MANUFACTURING	$16,930	$92,320

[a] Equipment all shown under flex spline membrane.
[b] Equipment all shown under flex spline tube.
[c] Equipment all shown under main beam tube.

Although the estimates do not consider it in depth, smooth integration of all the small parts production steps should reduce equipment and plant requirements.

Plant layouts for each of the process steps, such as the example in Fig. 4-2, were prepared based on process descriptions. The balance of the layouts can be found in Appendix C. These layouts were used to provide the requirements for building space and to assist in manpower estimates.

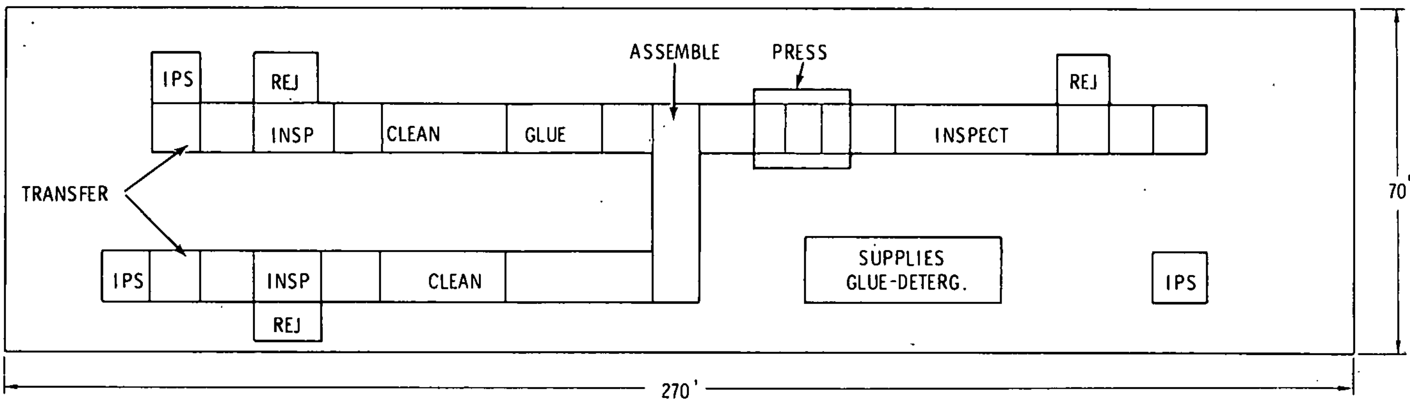


Fig. 4-2. PLANT LAYOUT MIRROR MODULE ASSEMBLY LINE

Table 4-6 summarizes estimates of in-process storage space requirements made to assist in making plant layouts. An intensive effort to integrate and optimize these layouts would significantly reduce overall plant area requirements. Plant areas based on these layouts are summarized in Tables 4-7 and 4-8.

Table 4-6. IN-PROCESS STORAGE SPACE REQUIREMENTS

Item	Hours of In-Process Storage	Square Feet of Plant Space Needed at Given Annual Production Rate	
		25,000	250,000
Reflector Surface	2	42	422
Backlite	2	42	422
Mirror Module	2	42	422
Inboard Cross Beam	2	65	650
Outboard Cross Beam	2	20	200
Diagonal Beam	2	41	410
Hat Section Stringers	2	18	180
Support Structure Angle, allow	2	9	90
Mirror Module w/Stringers	2	147	1,470
Assembled Reflector Panel	2	1,354	13,540

Table 4-7. MANUFACTURING FLOOR SPACE REQUIREMENTS FOR 25,000 HELIOSTATS PER YEAR

Item	Space Requirements, ft^2				
	Hi Bay	Lo Bay	Office	Warehouse	Pad
MIRROR MODULE ASSEMBLY	18,900			2,000	
PANEL-SUPPORT STRUCTURE ASSY	27,300			2,000	18,000
AZIMUTH DRIVE	40,300			2,000	10,000
Housing					
Main Cylinder	5,600				
Retainer	2,500				
Motor Mount	1,200				
Shaft Mount	1,400				
Welding	5,000				
Machining	3,000				
Components					
Lathe	1,800				
Press	1,800				
Flex Spline Assy	3,400				
Plug Assy	1,000				
Circular Spline	3,000				
Outer Retainer	3,000				
Azimuth Drive Assy	7,600				
ELEVATION DRIVE-PEDESTAL	19,750			2,000	10,000
Drag Link Assy	2,200				
Pipe Fabrication	3,250				
Main Beam Assy	4,800				
Pedestal Assy	4,500				
Elev Drive-Ped Assy	5,000			2,000	10,000
CENTRAL QUALITY CONTROL	1,000	2,000		1,000	
CONTROL ASSY AND POWER SUPPLY, allow		3,000		1,000	
LOAD					5,000
Subtotal - Manufacturing	107,250	5,000		10,000	43,000
ENGINEERING, allow	1,000	1,000	1,000	1,000	2,000
SERVICE, allow	2,000	2,000	1,000	1,000	1,000
ADMINISTRATION, allow			5,000		
Subtotal - Support	3,000	3,000	7,000	2,000	3,000
TOTAL ft^2	110,250	8,000	7,000	12,000	46,000
Unit Cost per ft^2	$ 35	$ 30	$ 30	$ 15	$ 5
Total Cost	$3,858,750	$240,000	$210,000	$180,000	$230,000
TOTAL COST	$4,718,750				

Table 4-8. MANUFACTURING FLOOR SPACE REQUIREMENTS FOR 250,000 HELIOSTATS PER YEAR

Item	Space Requirements, ft²				
	Hi Bay	Lo Bay	Office	Warehouse	Pad
MIRROR MODULE ASSEMBLY	56,700			18,000	
PANEL-SUPPORT STRUCTURE ASSY	143,800			5,000	169,000
AZIMUTH DRIVE	164,700			6,000	50,000
Housing					
Main Cylinder	16,800				
Retainer	5,000				
Motor Mount	1,200				
Shaft Mount	1,400				
Welding	25,000				
Machining	27,000				
Components					
Lathe	9,000				
Press	1,800				
Flex Spline Assy	17,800				
Plug Assy	1,500				
Circular Spline	14,200				
Outer Retainer	9,000				
Azimuth Drive Assy	35,000			6,000	50,000
ELEVATION DRIVE-PEDESTAL	97,000				
Drag Link Assy	12,000				
Pipe Fabrication	15,000				
Main Beam Assy	25,000				
Pedestal Assy	15,000				
Elev Drive-Ped Assy	30,000				
CENTRAL QUALITY CONTROL	3,000	6,000			
CONTROL ASSY AND POWER SUPPLY, allow		12,000		10,000	
LOAD					20,000
Subtotal - Manufacturing	465,200	18,000		39,000	239,000
ENGINEERING, allow	3,000	1,000	5,000	2,000	5,000
SERVICE, allow	7,000	5,000	2,000	3,000	3,000
ADMINISTRATION, allow			15,000		
Subtotal - Support	10,000	6,000	22,000	5,000	8,000
TOTAL ft²	475,200	24,000	22,000	44,000	247,000
Unit Cost per ft²	$ 35	$ 30	$ 30	$ 15	$ 5
Total Cost	$16,632,000	$720,000	$660,000	$660,000	$1,235,000
TOTAL COST	$19,907,000				

Building area estimates are based on these layouts for the production level of 25,000 heliostats per year. Estimates for the higher levels were calculated based on higher mechanization. Estimates of the land areas (Table 4-9) are simply an area three times larger than all buildings and pads.

Table 4-9. LAND REQUIREMENTS FOR MANUFACTURING

Heliostats Per Year	Total Bldg Space, ft^2 (Including Pad)	Total Land Area Required		Cost Per Acre Improved, $	Land Cost, Improved, $
		ft^2	Acres		
25,000	183,250	550,000	12	10,000	120,000
250,000	812,200	2,500,000	55	10,000	550,000

4.2.5 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.

4.2.6 Capital Cost Summary

Estimated capital costs are summarized in Table 4-10. These costs were used with a 20% 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. The fixed charge rate includes provisions for amortization of the asset, return on investment, income taxes, property taxes, and capital repairs. In a more detailed manual analysis, different fixed-charge rates, possibly higher, might be used on some equipment. The SAMICS model provides for different equipment lifetimes and thus considers different fixed charge rates.

Table 4-10. SUMMARY OF CAPITAL COSTS FOR MANUFACTURING

Item	Thousands of Dollars at Given Annual Production Rate 25,000	250,000
Land and Roads	120,000	550,000
Buildings	4,718,750	19,907,000
Manufacturing Equipment	16,930,000	92,320,000
Support Equipment, allow	1,000,000	3,000,000
Support Facilities, allow	2,000,000	8,000,000
Subtotal	24,768,750	123,770,000
Engineering, 15%	3,715,300	18,565,500
Contingency, 15%	3,715,300	18,565,500
TOTAL	$32,199,350	$160,901,000
Annualized Capital Cost per Heliostat, 20% Fixed Charges	$ 257.60	$ 128.72

4.2.7 Direct Manufacturing Cost Summary

Direct manufacturing costs are summarized in Table 4-11. These costs were used with company costs and installation costs to arrive at a reasonable cost for the installed heliostat.

Table 4-11. ESTIMATED DIRECT MANUFACTURING COSTS, 1979 DOLLARS

Item	Dollars per Heliostat at Given Annual Production Rate 25,000	250,000
Direct Costs	2,705.41	2,364.08
Direct Materials	2,421.73	2,243.84
Direct Labor	283.68	120.24
Indirect Manufacturing Expense and Contingency	100.00	50.00
Subtotal - Direct and Indirect Manufacturing Costs	2,805.41	2,414.08
Annualized Capital Cost per Heliostat, 20% Fixed Charges	257.60	128.72
TOTAL PER HELIOSTAT	3,063.01	2,542.80
TOTAL PER SQ METER[a]	$ 62.44	$ 51.84

[a] 49,053 m2 per heliostat.

4.3 INSTALLATION

It was assumed that 20 to 21 heliostats would be installed per acre. The greater Los Angeles area was considered the central distribution point for heliostats and construction materials, a travel distance of approximately 100 miles.

Material, labor, equipment costs, and transportation were individually analyzed. These estimates are summarized in Tables 4-12 through 4-15.

Table 4-12. COST SUMMARY OF DIRECT MATERIALS FOR INSTALLATION

Item	Quantity per Heliostat	Unit Price, $	Dollars per Heliostat at Given Annual Production Rate: 25,000	250,000
Land	1/20 acre	700.00	35.00	35.00
Stabilization, allow	1 unit	25.00	25.00	25.00
3-in. Asphalt Cover	24.2 yd^2	2.15	52.03	52.03
Rebar, Foundation	430 lb	0.24 0.22	103.20	94.60
Tapered Pipe, Foundation	98 lb	0.23 0.22	22.54	21.56
Concrete, Foundation	3 yd^3	36.00 21.50	108.00	64.50
Primary Feeder Cable	3 ft	3.45 3.35	10.35	10.05
Secondary Feeder Cable	54 ft	0.89 0.87	48.06	46.98
Miscellaneous Electrical Equipment			108.60	108.60
TOTAL			$512.78	$458.32

Table 4-13. DIRECT MANPOWER FOR INSTALLATION

Item	Persons Needed[a] at Given Annual Production Rate 25,000	250,000
Purchase Site	6	60
Clear/Level Site	3	30
Cover/Stabilize Site, allow[b]	2	20
Drill Foundation Hole	8	66
Fab/Trans Rebar Cage	8	80
Install Rebar Cage	4	22
Fab/Trans Steel Form	4	12
Install Form/Concrete	16	110
Load/Trans Pedestal/Drive	6	60
Install Pedestal/Drive	12	99
Purchase/Trans Primary Cable	5	5
Purchase/Trans Secondary Cable	5	5
Install Cable	6	36
Connect Cable to Heliostats	10	88
Transport Mirror Panels (Unload)	24	234
Install Mirror Panels	30	264
Purchase/Install Power Supply	5	40
Electrical Checkout	12	99
Heliostat Alignment	15	132
Subtotal - Transportation	30	253
Subtotal - Site	151	1209
TOTAL	181	1462

[a] Multiple shift production (total manpower including all shift requirements).

[b] The term "allow" means that this item has not been estimated in detail and a number which is partly or all judgment is used.

Table 4-14. CAPITAL EQUIPMENT COST FOR INSTALLATION

Item	Thousands of Dollars at Given Annual Production Rate 25,000	250,000
Purchase Site	-	-
Clear/Level Site	500	5,000
Cover/Stabilize Site, allow	500	2,000
Drill Foundation Hole	240	1,980
Fab/Trans Rebar Cage	153	1,530
Install Rebar Cage	200	1,100
Fab/Trans Steel Form	28	84
Install Form/Concrete	100	12,210
Load/Trans Pedestal/Drive	140	1,400
Install Pedestal/Drive	340	2,805
Purchase/Trans Primary Cable	96	96
Purchase/Trans Secondary Cable	96	96
Install Cable	44	264
Connect Cable to Heliostats	-	-
Transport Mirror Panels (unload)	460	4,460
Install Mirror Panels	850	7,480
Purchase/Install Power Supply	10	60
Electrical Checkout	14	112
Heliostat Alignment	60	528
Subtotal	$3,831	$41,205
Contingency, 15%	575	6,181
Engineering, 15%	575	6,181
TOTAL	$4,981	$53,567

Table 4-15. ESTIMATED INSTALLATION COSTS, 1979 DOLLARS

Item	Dollars per Heliostat at Given Production Rate	
	25,000	250,000
Direct Costs	755.04	696.71
Direct Material	512.78	458.32
Direct Labor (includes overhead)	242.26	238.39
Equipment Costs	99.85	102.85
Equipment, at 20% Fixed Charges	39.85	42.85
Equipment Operation, allow	60.00	60.00
Subtotal - Direct and Equipment Costs	854.89	799.56
General Contractor Contingency and Fee	85.49	79.96
TOTAL, INSTALLATION	$940.38	$879.52

Material costs include land and materials for soil stabilization. These costs are not always included in heliostat cost estimates. They do not greatly affect the total cost, but are a requirement. The land cost is based on values provided by real estate agents in the Barstow area.

An optimum method of soil stabilization has not been determined; hence this value is simply an allowance.

Labor charges were taken from the 1979 Means Cost Manual[5] based on straight time only and stated in dollars per hour. All labor charges include two rate values. The first is a base rate plus fringe benefits. The second is the burden rate reflecting overhead and profit. Equipment costs are estimated on the basis that all equipment, including transportation equipment, will be purchased by the heliostat supplier and installer. Much of this equipment will be designed and built especially for this operation.

Operating costs are based on values from the Means Cost Manual. The incremental cost of truck operation was based on government figures for a diesel vehicle averaging 6 miles/gal, with a cost of fuel at $0.60/gal (May, 1979 figure).

The general contractor contingency and fee is estimated at 10%. This cost might be lower in a routine operation.

4.4 COST SUMMARY

Company costs for manufacturing are summarized in Table 4-16 for the 250,000 heliostat/year case. The table includes all manufacturing costs in a business, summarized in the format of an IRS corporate income tax form.

Table 4-16. MANUFACTURING COMPANY COST ELEMENTS (ILLUSTRATIVE PROFIT AND LOSS STATEMENT) FOR 250,000 HELIOSTATS PER YEAR

Item	Dollars per Heliostat
INCOME	
Gross Receipts, Less Returns and Allowances	3,114
Less Cost of Goods Sold (includes indirect manufacturing expenses)	2,414
Gross Profit	700
Other Income	-
Total Income	700
DEDUCTIONS	
Compensation of Officers	20
Salaries and Wages (not deducted elsewhere)	50
Repairs	20
Bad Debts	9
Rents, Light, and Heat	30
Taxes / Interest / Amortization / Depreciation	129[a]
Working Capital Interest	20
Contributions	5
Advertising	5
Pension, Profit-Sharing, etc.	20
Employee Benefit Programs	20[b]
Other Deductions	10
Legal and Accounting Fees	5
Consultants	5
Travel	10
Product Development	42
Total Deductions	400
Taxable Income	300
Income Tax	150
Net After Taxes	150

[a] Equipment only, construction interest on heliostat field not included.

[b] Direct labor benefits included in $12/hr.

In Table 4-16, the cost of goods sold and fixed-charge costs 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.

Installation costs are summarized with manufacturing costs in Table 4-17. The addition of installation costs to manufacturing costs provides a total estimated installed cost of $3,993.52 per heliostat, or $81.42 per square meter for the 250,000 heliostat/year case.

Table 4-17. TOTAL INSTALLED HELIOSTAT COST FOR 250,000 HELIOSTATS PER YEAR

	Cost per Heliostat, $		
	Manufacturing	Installation	Total
Direct Material	2,243.84	458.32	2,702.16
Direct Labor	120.24	238.39	358.63
IME & Contingency	50.00	60.00	110.00
Annualized Capital	128.72	42.85	171.57
OH and Profit	571.20	79.96	651.16
TOTAL	3,114.00	879.52	3,993.52

4.5 COMPARISON WITH McDONNELL DOUGLAS ESTIMATES

One of the objectives of this analysis was to provide an independent, presumably objective estimate. The approach to this, with respect to the McDonnell Douglas information, was to read through their document, including production methods, then proceed independently with reference only to the design information. There was little effort to evaluate or even to understand the production scenarios used by McDonnell Douglas. We started with a part design and used our own conceptual approach for process, equipment, and labor.

In the course of obtaining estimates for materials and components, we frequently encountered vendors who had already prepared quotations for McDonnell Douglas. Thus several materials cost estimates are likely to be the same, with adjustment for inflation. Often, we obtained an estimate for the specified part from a different vendor. While our materials costs have not been cross-checked against McDonnell Douglas materials costs item by item, we found several items, such as motors, that had prices in the same general range from different vendors.

Because of the independence of our approach, it was with some surprise that we found such close agreement between our manual calculations for the 250,000 unit per year case and McDonnell Douglas's 250,000 unit per year 10th-year case. This is illustrated in Table 4-18.

TABLE 4-18. COMPARISON OF HELIOSTAT COMPONENT COSTS
-McDonald Douglas, 250,000 Heliostats per Year[a]
-Manual, 250,000 Helistats Per Year

	Labor Man Hours Per Heliostat			Materials Cost, Dollars Per Heliostat		
	McDonnell Douglas	Manual	Difference	McDonnell Douglas	Manual	Difference
Total, Heliostat	23.8	22.2	-1.6	2070	2703	+633
Total, Manufacturing	5.0	10.1	+5.0	1700	2245	+545
Reflective Surface	0.4	0.4	0.0	424	601	+177
Mirror Support Structure	1.0	1.8	+0.8	308	345	+37
Azimuth Drive	1.4	3.1	+1.7	2-7	265	+58
Elevation Drive Pedestal	0.9	3.1	+2.2	409	713	+304
Motors	0.0	0.0	0.0	153	141	-12
Controls and Power supply	1.3	1.0	-0.3	199	130	-69
Central QA and Loading, Allow	-	0.6	+0.6	-	50	+50
Installation, Field Assembly and Checkout	18.8	12.2	-6.6	370	458	+88

[a] Easton, C. R., Solar Central Receiver Prototype Heliostat. MDC-G-7399; McDonnell Douglas Corporation; August 1978; pp. 9-24.

While the estimates are not directly comparable because of differences in make-or-buy, it is apparent that adjusting for one year of inflation would bring them very close together.

From Table 4-18 it is apparent that if we escalate 10% from the McDonnell Douglas 1978 estimates the only significant differences in materials costs are in the reflective surface ($424 plus 10% = $466 vs. $601), the elevation drive-pedestal ($409 plus 10% = $450 vs. $713), the controls ($199 plus 10% = $219 vs. $130), and installation ($370 plus 10% = $407 vs. $458). These differences are readily explained. We have used purchased mirrors and McDonnell Douglas used an in-house mirroring process. Our estimated cost for elevation drive jack screws is $264.43 each, while the McDonnell Douglas estimated cost is

$141.75. We have been slightly more optimistic about the potential for cost reduction in the control package. We have included land cost and site work at $112 per heliostat and this is not included in the McDonnell Douglas estimates. We feel that with further investigation on our part these differences would very likely be reduced. While the overall man-hours for heliostat production and installation are very close, there are significant differences in the man-hours between manufacturing and installation. This is apparently partly because we have included some operations in manufacturing which are included in installation in the McDonnell Douglas estimate and partly because we have used a higher degree of mechanization for field operations and a lower degree of mechanization in production. Also, McDonnell Douglas has estimated on the basis of procuring some finished parts that we have estimated as raw stock, with manufacturing operations in-house.

Overall, we feel the general agreement of the estimates is much more significant than the differences.

SECTION 5.0

SAMICS COST ESTIMATE

5.1 SAMICS DESCRIPTION

The description in this section has been extracted almost verbatim from Chamberlain's report on the normative price for a manufactured product.[3]

SAMICS provides standard formats, data, assumptions, and procedures for determining the price a hypothetical manufacturer would have to obtain in the market to realize a specified after-tax rate of return on equity for a specified level of production.

SAMICS was first applied to solar cell array manufacturing. In order to apply the SAMICS methodology to other industries, it is necessary to replace the standard industry structure data with data that is appropriate to other industry. It is also necessary to develop the relevant process descriptions. These are straightforward procedures.

The approach taken by SAMICS is conceptually very simple and fundamental: describe the direct requirements of each manufacturing process; determine the personnel, facilities, utilities, materials, supplies, and number of machines needed to produce a specified annual amount of the final product; then infer the facilities, indirect personnel, and other necessary support requirements. To obtain a realistic result, many practical complications are carefully modeled. These complications, however, are internal to the model; a user need only describe the manufacturing process sequence and apply SAMICS to produce an estimate of the market price that must be received to obtain a specified profit. Detailed manufacturing cost breakdowns are developed along the way.

The SAMICS methodology is very general and is expected to be usable in virtually any manufacturing industry. SAMICS can be used to estimate the manufacturing costs and product prices associated with process alternatives for complete manufacturing sequences. It can also be used to assess the impact of changes in financial parameters, such as costs of input goods or services, inflation rates, tax policies, interest rates, and required return on equity. Economies of scale can also be investigated, as all costs and indirect requirements are described as functions of annual quantities.

SAMICS is limited by a number of underlying assumptions. Perhaps the most important of these is that the market interaction of supply and demand is ignored: demand is assumed to be known, steady over time, and unaffected by the resultant SAMICS price estimate. That is, the SAMICS price is what the hypothetical industry would have to be able to charge if it were to recover all of the costs of manufacturing and make a profit. There is no guarantee that this price would ever actually occur in the market. A second major limiting assumption is that all factories in the industry operate in a production-line mode. The operating costs (and revenues) of real companies vary widely from year to year, especially in the first few years of operation. In order to calculate a unique annual cost rate, SAMICS assumes that the modeled factories have reached a steady-state operating condition, but that they are still paying off the expenses of getting started. The eventual factory shutdown is assumed to be so far in the future that its effects on costs are negligible. The resultant smoothing of annual costs does take into account escalation rates and each company's discount rate.

An extensive body of standardized data is a part of SAMICS. This standard data includes indirect requirements (such as how much building space is needed for each square meter of factory floor space), price information for all direct and indirect requirements, capital cost estimating relationships for each of the facilities parameters, and economic parameters (such as the general rate of inflation and the corporate income tax rate schedule). The casual user of SAMICS need not concern himself with any of this standard data.

It will generally be the case that the most difficult, time-consuming activity in the application of SAMICS will be the development of an initial set of process descriptions. A detailed understanding of the direct requirements for each of the processes in the hypothetical companies is essential for the preparation of any detailed cost estimate.

Augmentation of the standardized data base is required. Price information must be obtained for any new kinds of direct or indirect requirements. Capital cost estimating relationships are needed for any new kinds of facilities parameters, and relationships among indirect requirements must be developed for every new kind of direct and indirect requirement.

5.2 MATERIALS INPUT

Direct materials are prepared for entry to SAMICS in the format of Fig. 5-1. Expense items entries to SAMICS for this analysis are summarized in Appendix D.

Materials cost estimates were entered for four production rates: 2,500, 25,000, 100,000, and 250,000 heliostats per year. The primary reason for providing the 2,500 (not shown in Fig. 5-1) and 100,000 cases for materials was to establish additional data points for SAMICS extrapolation. SAMICS interpolates or extrapolates from the values entered to produce costs for the production rates of interest.

In SAMICS, the program selects the direct materials costs for the production rate selected. Hence, the direct materials costs should be the same for a given production rate even though equipment, labor, and other costs will vary with the type of equipment and process used.

Referent Number (Cost Acct No.)	Descriptive Name	Unit of Measure	Price Year	Inflation Rate	Quant Per H	Price Per Quantity Relationships: Quantity	Unit Price	Quantity Price
E-23001-D	Main Cylinder, AZ DR HSG, 16 OD x .5 wall x 5.5	Cylinder	1979	11%	1	25,000	12.82	320,500
						100,000	12.58	1,258,000
						250,000	12.35	3,087,500
E-23002-D	Retainer, AZ DR HSG, 14 ID x 20 ID x 1.25	Retainer	1979	11%	1	25,000	41.72	1,043,000
						100,000	40.79	4,079,000
						250,000	39.86	9,965,000
E-23003-D	Top, AZ DR HSG, 16 D x 1/2 t	Top	1979	11%	1	25,000	8.56	214,000
						100,000	8.31	831,000
						250,000	8.07	2,017,500
E-23004-D	Motor Mount, AZ DR HSG, 1/2 x 4 x 8	Mount	1979	11%	2	50,000	1.09	54,500
						200,000	1.07	214,000
						500,000	1.04	520,000
E-23005-D	Motor Mount, AZ DR HSG, 1/2 x 4 x 7	Mount	1979	11%	2	50,000	.99	49,500
						200,000	.97	194,000
						500,000	.94	470,000
E-23006-D	Shaft Mount, AZ DR HSG, 3.25 OD x 1.75 ID x 3	Mount	1979	11%	1	50,000	6.04	302,000
						200,000	5.82	1,164,000
						500,000	5.61	2,805,000
E-23007-D	Ears, AZ DR HSG, 1 1/4 x 5 x 9	Ear	1979	11%	2	50,000	3.74	187,000
						200,000	3.64	728,000
						500,000	3.55	1,775,000
E-23008-D	Ears, AZ DR HSG, 1 1/4 x 8 x 14	Ear	1979	11%	2	50,000	8.56	428,000
						200,000	8.32	1,664,000
						500,000	8.08	4,040,000
E-23009-D	Membrane, AZ DR, 10 OD x .156	Membrane	1979	11%	1	25,000	1.30	32,500
						100,000	1.27	127,000
						250,000	1.23	307,500
E-23010-D	Tube, AZ DR, 10 OD x .156 x 8	Tube	1979	11%	1	25,000	5.56	139,000
						100,000	5.33	533,000
						250,000	5.10	1,275,000
E-23011-D	Spline, AZ DR, 10 OD x .312 x 3	Spline	1979	11%	1	25,000	8.20	205,000
						100,000	7.93	793,000
						250,000	7.67	1,917,500
E-23012-D	Doubler, AZ DR, 6.5 OD x .375	Doubler	1979	11%	2	50,000	1.26	63,000
						200,000	1.23	246,000
						500,000	1.20	600,000
E-23013-D	Plug, AZ DR, 7.0 OD x 1.5	Plug	1979	11%	1	25,000	6.53	163,250
						100,000	6.37	637,000
						250,000	6.20	1,550,000

Fig. 5-1. SAMICS COST ACCOUNT ENTRIES-EXPENSE ITEMS

5.3 PROCESS, FACILITIES, AND LABOR INPUT - FORMAT A

The information developed above was used in the preparation of SAMICS input data sheets [6], as Figs. 5-2 and 5-3 illustrate. Complete sets of SAMICS "Format A" data are contained in Appendices E and F. Fig. 5-4 summarizes the Format A process description sheets and the relationship of each to the other.

SAMICS data were prepared based on the manual estimate for production rates of 25,000 units per year and 250,000 units per year. At the 25,000 unit per year rate, equipment, process, and personnel estimates were based on the assumption that 25,000 units per year would be produced. This case is referred to as the 25,000 unit per year process. At the 250,000 unit per year rate, the equipment, process, and personnel requirements assumed a production rate of 250,000 units per year. This case is referred to as the 250,000 unit per year process. SAMICS uses the equipment throughput rates and personnel requirements of either case to produce requirements for other production rates. Because equipment, process, and personnel requirements are different for the two processes, slightly different results will be obtained at any given production rate estimated by the two processes.

Chamberlain [6] provides a line-by-line explanation of the standard Process Description for entry in Format A. This explanation is given nearly verbatim in the remainder of this section.

Manufacturing technology, as described by a Format A for each process, is a major part of the manufacturing industry's input to the model used in SAMICS to estimate the prices of the products of that technology. Fabrication of a company's product(s) generally requires the performance of a sequence of operations or processes. The purpose of Format A is to describe the economically important characteristics of one of these processes.

Segregation of the process sequence into separate processes is, at least in some cases, somewhat arbitrary. In those cases, separate machines or separate pieces of apparatus should be distinguished. Format A usually describes a particular kind of equipment but sometimes Format A describes a collection of equipment, such as a quality control inspection station or part of a materials handling system. At other times, Format A describes a processing step performed by special facilities, such as storage between manufacturing operations.

5.3.1 Part 1 - Product Description

Part 1 of Format A describes the product produced by the process. This part provides a product name, which may be the same name as the process, a brief description of the product and the units of measure for the product.

5.3.2 Part 2 - Process Characteristics

Process characteristics specify the operating parameters of a single machine. This part provides the output rate of the machine, which

FORMAT A

PROCESS DESCRIPTION

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Dr. / Pasadena, Calif. 91103

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS III computer program.

A1 Process [Referent] MIROR BOND

A2 [Descriptive Name] MIRROR PANEL BONDING TO BACKLITE, INCLUDING RECEIVING INSPECTION AND CLEANING

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] MIRORBOND

A4 Descriptive Name [Product Name] MIRROR MODULE ASSEMBLY

A5 Unit Of Measure [Product Units] MODULE

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 5 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 15 Calendar Minutes (Used only to compute In-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .90 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	BONDER	MIRINSP	MIRPRESS
A9a	Component [Descriptive Name] (Optional)	Cleaning, Glue Apply, Convey	NDT and Other	Plywood Type Press, Modified
A10	Base Year For Equipment Prices [Price Year]	1979	1979	1979
A11	Purchase Price ($ Per Component) [Purchase Cost]	525,000	650,000	925,000
A12	Anticipated Useful Life (Years) [Useful Life]	15	10	20
A13	[Salvage Value] ($ Per Component)	50,000	10,000	10,000
A14	[Removal and Installation Cost] ($/Component)	75,000	25,000	75,000

Note: The SAMIS III computer program also prompts for the [payment float interval], the [inflation rate table], the [equipment tax depreciation method], and the [equipment book depreciation method]. In the LSA SAMICS context, use 0.0, (1975, 6.0), DDB, and SL.

Fig. 5-2. FORMAT A: PROCESS DESCRIPTION, PAGE ONE

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) MIRORBOND

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
[Facilities and Personnel Requirements]

A16 Catalog Number [Expense Item Referent]	A18 Amount Required Per Machine (Per Shift) [Amount per Machine]	A19 Units	A17 Requirement Description
A-2097D	18,900	Sq Ft	Manufacturing Space, Hi Bay
B-3752-D	7	Person/Shift	Production Machine Operator
B-3720D	4	Person/Shift	Inspector/Quality Control

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE
[Byproduct Outputs] and [Utilities and Commodities Requirements]

A20 Catalog Number [Expense Item Referent]	A22 Amount Required Per Machine Per Minute [Amount per Cycle]	A23 Units	A21 Requirement Description
C-1032B	1.0	kWh	Electricity
C-1016B	0.125	Cu ft	Water
C-1048B	0.117	Gallons	Fuel Oil
C-2032D	3.0	Cu ft	Compressed Air
C-40101D	0.17	Lb	Detergent
E-21201D	5.02	Mirror	Mirror Panel
E-21202D	5.02	Lite	Glass Panel
E-27301D	0.85	Gallons	Adhesive

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED [Required Products]

A24 [Product Reference]	A28 [Yield]* (%)	A26 [Ideal Ratio]** Of Units Out/Units In	A27 Units Of A26***	A25 Product Name
			/	
			/	
			/	

Prepared by K Drumheller Date 6/29/79

* 100% minus percentage of required product lost.
** Assume 100% yield here.
*** Examples: Modules/Cell or Cells/Wafer.

Fig. 5-3. FORMAT A: PROCESS DESCRIPTION, PAGE TWO

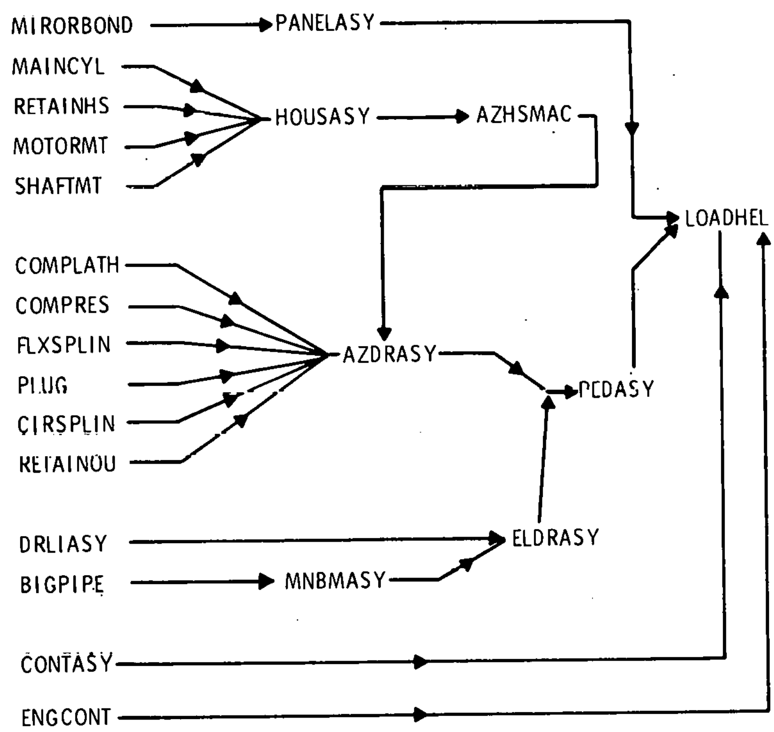


Fig. 5-4. SAMICS FORMAT A SUMMARY-25,000 PROCESS

determines the number of machines required. It also provides the time at the station for calculation of in-process inventory working capital requirements and the operating efficiency of the station.

5.3.3 Part 3 - Equipment Cost Factors

When different components of the "machine" have different lifetimes, equipment cost factors must be provided for each component, though pieces of equipment with the same lifetimes may be treated as a single component. Columns are provided in Part 3, lines A9 through A14, for entering the component data.

5.3.4 Part 4 - Direct Requirements Per Machine (Facilities) or Per Machine Per Shift (Personnel)

Some of the direct requirements of the process depend not on the operation of the machine, but on the existence of the machine in the production area. The best example of this is the floor space requirement, which clearly exists even if the machine is completely idle. Other facilities parameters and direct personnel requirements depend on the number of machines assumed to be in continuous operation.

5.3.5 Part 5 - Direct Requirements Per Minute

Some of the direct requirements of the process depend upon the extent to which the machine is operated, especially utilities, by-products, and commodities.

5.3.6 Part 6 - Intra-Industry Product(s) Required

Products are distinguished from commodities by the fact that products are produced by processes within the modeled industry, while commodities are produced outside the modeled industry. Part 6 of Format A provides a reference to the input product(s) processed by the process being described.

5.4 SAMICS RESULTS

SAMICS output for the 25,000 and 250,000 unit per year cases are found in Appendices G and H. As illustrated in Fig. 5-5, a SAMICS output summary for a 25,000 unit per year production rate using a 25,000 unit per year process, SAMICS summarizes

- capital
- materials
- labor
- indirects.

COMPANY: HELIO25K, COMPANY TO MANUFACTURE HELIOSTATS AT 25K BASE LEVEL
PRODUCTS: LOADHEL
QUANTITY: 2.500E+04
PRICE: 3566.629 $(1979)/ HELIOSTAT
COMPANY MARKUP = 1.368 TIMES (DIRECT EXPENSES PLUS EXTERNAL PRODUCT COSTS)

CAPITAL VALUES

	INFLATOR (1979 TO 1979)= 1.0000			DEFLATOR (1979 TO 1979)= 1.0000		
	IN $(1979)			IN $(1979)		
	INITIAL	BOOK	TAXABLE	INITIAL	BOOK	TAXABLE
FACILITIES	6437633.	1595245.	1327895.	6437633.	1595245.	1327895.
EQUIPMENT	19148992.	6902686.	3624779.	19148992.	6902686.	3624779.
WORKING	14041130.	14041130.	14041130.	14041130.	14041130.	14041130.
LAND	218729.	218729.	218729.	218729.	218729.	218729.
TOTAL	39846464.	22757776.	19212528.	39846464.	22757776.	19212528.

FINANCIAL PARAMETERS

COST OF CAPITAL -CALCULATED-	RATE OF RETURN ON EQUITY -INPUT-	DEBT INTEREST RATE -INPUT-	LEVERAGE (TOTAL/EQUITY) -INPUT-	INCOME TAX RATE -CALCULATED-
17.50%	20.00%	10.00%	1.200	49.91%

TIME PARAMETERS
CONSTRUCTION LEAD TIME = 0. YEARS, STARTUP PERIOD = 0. YEARS
RAW MATERIAL INVENTORY TIME (INPUT) = .083 YEARS (30.4 DAYS)
INPROCESS INVENTORY TIME (CALCULATED) = .004 YEARS (575.0 MINUTES)
(MULTIPLIED BY 1.0 FOR WORKING CAPITAL CALCULATION)
FINISHED GOODS INVENTORY TIME (INPUT) = .120 YEARS (43.8 DAYS)
ACCOUNTS RECEIVABLE TURNOVER TIME (INPUT) = .120 YEARS (43.8 DAYS)
ACCOUNTS PAYABLE TURNOVER TIME (INPUT) = .120 YEARS (43.8 DAYS)

ALL COMPANY EXPENSES ARE IN $(1979)

COMPANY DIRECT EXPENSES	65,201,904.	
COMPANY DIRECT LABOR EXPENSES		4,403,575.
COMPANY DIRECT MATERIALS AND SUPPLIES		60,695,472.
COMPANY DIRECT BYPRODUCT EXPENSES		0.
COMPANY DIRECT UTILITIES EXPENSES		102,893.
COMPANY INDIRECT EXPENSES	2,602,883.	
COMPANY INDIRECT LABOR EXPENSES		2,306,792.
COMPANY INDIRECT MATERIALS AND SUPPLIES		196,338.
COMPANY INDIRECT BYPRODUCT EXPENSES		1,737.
COMPANY INDIRECT UTILITIES EXPENSES		98,019.
COMPANY BYPRODUCT INCOME	(0.)	
COMPANY CAPITAL EXPENSES	7,586,508.	
COMPANY EQUIPMENT REPLACEMENT		1,544,805.
COMPANY FACILITIES REPLACEMENT		214,587.
COMPANY AMORTIZED ONE-TIME COSTS		0.
COMPANY INTEREST ON DEBT		376,550.
COMPANY RETURN ON EQUITY		3,765,505.
COMPANY NON-INCOME TAXES		99,952.
COMPANY INSURANCE PREMIUMS		1,585,109.
COMPANY INCOME TAXES	3,028,182.	
COMPANY MISCELLANEOUS	9,846,628.	
COMPANY EXTERNAL PRODUCT COST	0.	
COMPANY TOTAL ANNUAL EXPENSES	89,165,680.	

Fig. 5-5. SAMICS OUTPUT SUMMARY - 25,000 Units per Year
25,000 Units per Year Process

The capital summary includes equipment and buildings described in the Format A forms plus facilities included in SAMICS as requirements to support the specified operations. The working capital requirements are calculated on the basis of inventories, interest, salaries, and other items normally required to keep the business operating.

Materials requirements are calculated directly from the entries in Format A and the cost account catalog. SAMICS calculates total materials requirements on the basis of the initial requirements plus the yields incorporated in each process step.

Labor requirements are calculated based on the manpower indicated in Format A and the salaries indicated in the cost account catalog. Labor calculations in SAMICS assume that operators are at the machine only as required to meet the specified production. When required production is completed at a particular machine, the operator moves to another machine. Specified yields and machine up time (operating efficiency) are considered in labor calculations.

The cost of labor, materials, and capital as a percentage of the total manufacturing cost and as a function of production rate is illustrated in Fig. 5-6.

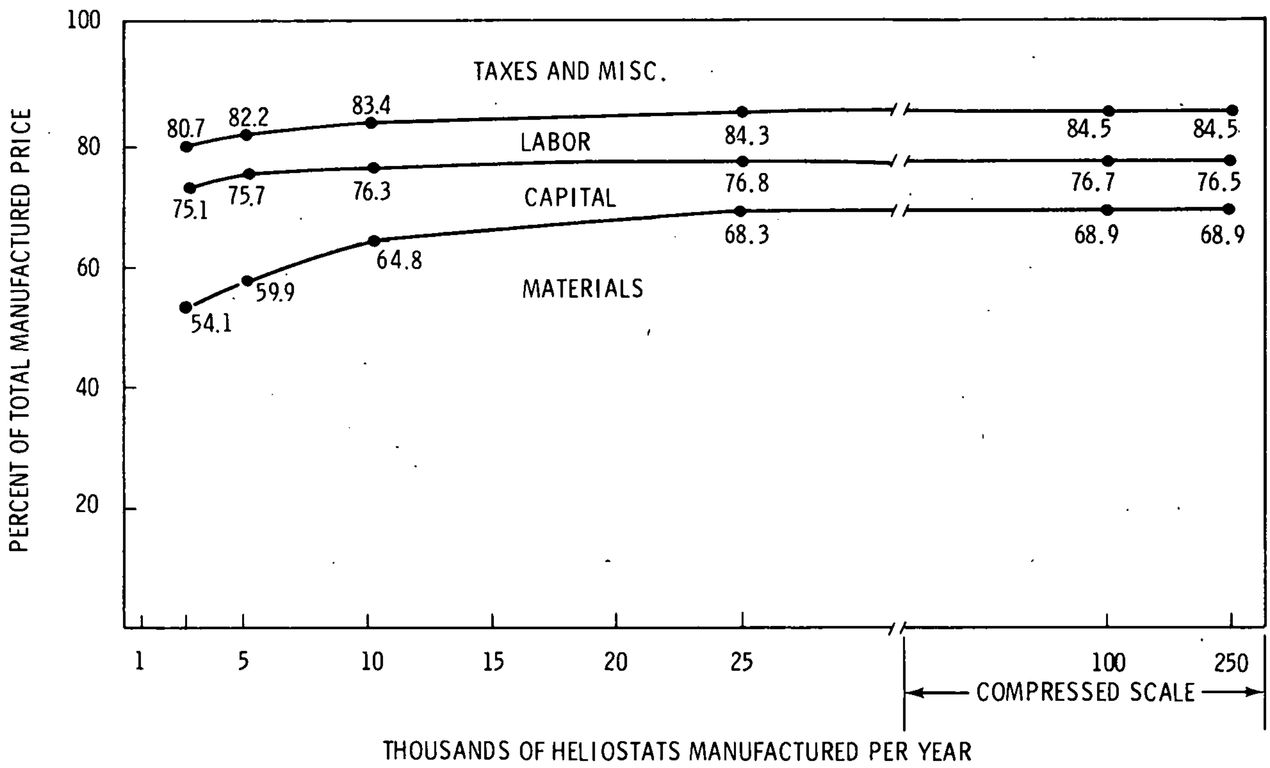


Fig. 5-6. PERCENTAGE OF TOTAL FACTORY COST VS. QUANTITY MANUFACTURED (25K Plant)

One of the principal advantages of SAMICS is illustrated in Table 5-1. Once information is input, production costs for different production rates can be established very quickly. For this analysis, the process information developed for production rates of 25,000 heliostats per year and 250,000 heliostats per year was used. Once these processes were input, estimated costs for other production rates were produced with a few minutes of computer time. Table 5-1 summarizes estimated costs for production rates from 2,500 units per year to 1,000,000 per year. These results are shown graphically in Fig. 5-7. Results summaries for each of the cases in Table 5-1 are found in Appendices I and J.

An interesting point from Table 5-1 and Fig. 5-7 is that the costs obtained at the 25,000 unit per year production rate are lower with the process and equipment data for the 250,000 unit per year production rate. If the plant design were optimized, it would be expected that the 25,000 process parameters would produce the lower cost at 25,000 units per year. There are several reasons for this anomaly, the principal one is probably that the processes and equipment are not optimized.

Figure 5-7 is derived from the parametric resizing of the plant facilities and shows the impact of distributing plant overheads over a larger volume of product. However, this curve is a static cost curve and should not be interpreted as the cost-volume curve which would be seen in a growing industry. SAMICS has the ability to vary production rate independently of the processes used, while in a growing industry (and most cost studies conducted to date) the processes are coupled to the production volume. The sequence of decisions which leads to a trajectory of prices over time or production quantity were not modeled in this study nor are they explicitly contained in the SAMICS methodology.

Table 5-1. SAMICS ESTIMATED COSTS FOR HELIOSTATS, FOB FACTORY[a]

	Dollars per Heliostat at Given Annual Production Rate	
Number of Heliostats Produced per Year	25,000/yr Process	250,000/yr Process
2,500	$6,518.47	$7,274.69
5,000	4,874.63	5,136.25
10,000	4,038.92	4,093.92
25,000	3,566.63	3,485.84
100,000	3,380.83	3,188.19
250,000	3,270.79	3,068.83
500,000		3,027.52
1,000,000		3,009.82

[a] 49,053 m^2 per heliostat.

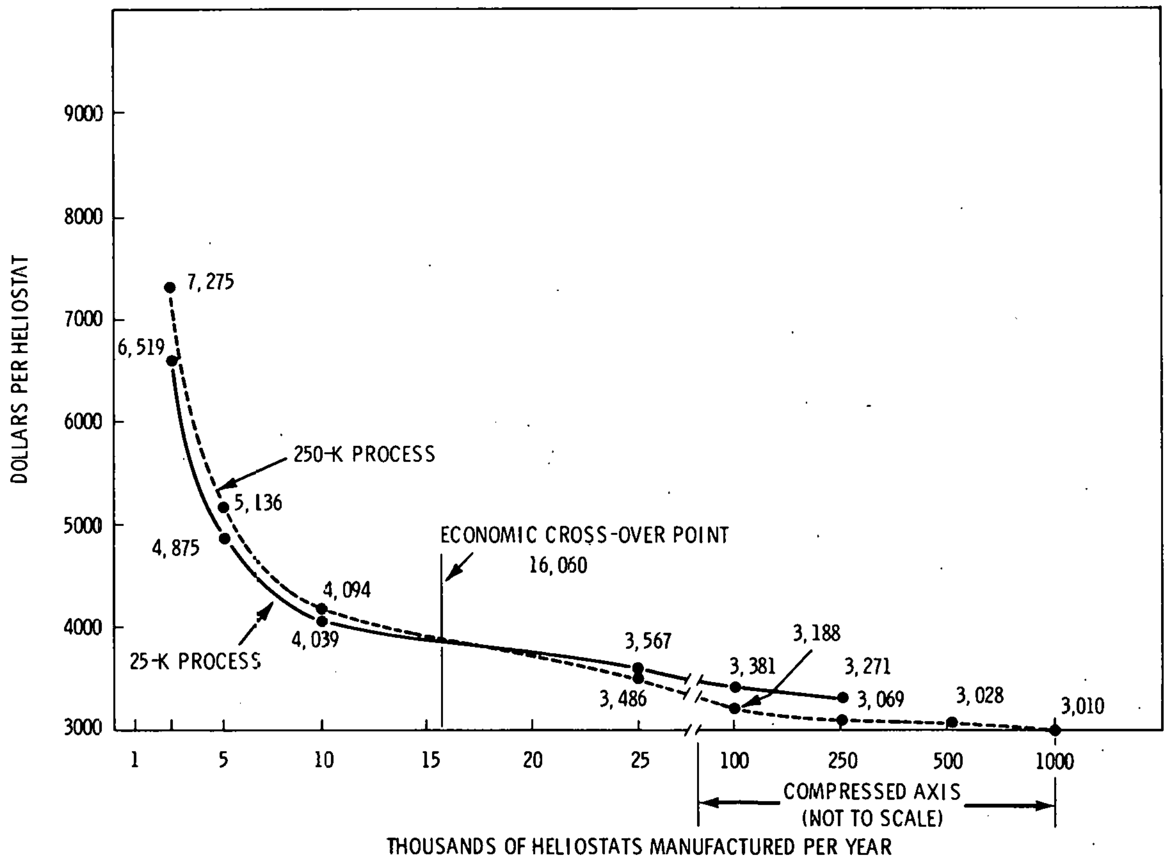


Fig. 5-7. HELIOSTAT PRICE-QUANTITY RELATIONSHIPS

In producing the data for these curves, SAMICS selects a proper material cost for the production rate, using the proper number of machines for the particular production rate and specified process and applying the proper number of people to operate the machines. It also adds the overheads. At the 25,000 unit per year production rate using the 25,000 unit per year process, most operations require only one machine. If the production rate is reduced to 5,000 units per year and the 25,000 unit per year process is used, almost the same number of machines will be required. With the 250,000 unit per year process, one of each machine is needed at the 5,000 unit per year production rate, but the machines would, in total, be more highly mechanized and thus more costly. Hence the equipment cost for a production rate of 5,000 units per year would usually be greater with a 250,000 unit per year process than with a 25,000 unit per year process. At production rates of 1 or 1000 units per year, there would be almost enough machines to produce 25,000 units in either case, so the equipment cost per heliostat would be very large. At a production rate of 50,000 units per year, two pieces of equipment would be required for several operations with the 25,000 unit per year process, but because of higher speeds, fewer pieces of equipment might be required for a production rate of 50,000 units per year with the 250,000 unit per year process. Thus the equipment cost for a production rate of 50,000 units per year might be less with a 250,000 unit per year process than with a 25,000 unit per year process.

Fig. 5-8 summarizes the results of the 250,000 unit per year case using the 250,000 unit per year process. The full results of this case, found in Appendix G, illustrate the extent of SAMICS input to support facilities and overhead functions.

Indirect costs for the 250,000 unit per year process - 250,000 unit per year production rate are shown in Fig. 5-9. The indirect costs in SAMICS were not reviewed in depth in this analysis. A review of indirects in comparable industries and development of a new data base for indirect costs could result in a different total cost. However, it is unlikely that such a review would result in cost changes of more than 25% .

The estimated cost of a heliostat manufactured with the 250,000 unit per year process at a production rate of 250,000 units per year is \$3068.83 (Table 5-2). With estimated installation costs of \$879.52 (from Table 4-15), this provides a total cost of \$3948.35, or \$80.49/m^2 for a 528-ft^2 (49.053-m^2) heliostat.

5.5 SAMICS - MANUAL COMPARISON

A comparison of the total manufacturing company costs arrived at manually and with SAMICS for the 250,000 units per year case is shown in Table 5-3.

There is close agreement between the estimate obtained by SAMICS and the manual calculations. Both methods used identical starting numbers for the direct labor, materials, and equipment costs. In the manual calculations, the direct labor requirements were based on the assumption that if a person

COMPANY: HELIO250K, COMPANY TO MANUFACTURE HELIOSTATS AT 250K BASE LEVEL
PRODUCTS: LOADHEL2
QUANTITY: 2.500E+05
PRICE: 3068.831 $(1979)/ HELIOSTAT
COMPANY MARKUP = 1.309 TIMES (DIRECT EXPENSES PLUS EXTERNAL PRODUCT COSTS)

CAPITAL VALUES

	INFLATOR (1979 TO 1979)= 1.0000			DEFLATOR (1979 TO 1979)= 1.0000		
	---------- IN $(1979)----------			---------- IN $(1979)----------		
	INITIAL	BOOK	TAXABLE	INITIAL	BOOK	TAXABLE
FACILITIES	29098080.	7210506.	6002082.	29098080.	7210506.	6002082.
EQUIPMENT	109194992.	39786912.	20986688.	109194992.	39786912.	20986688.
WORKING	124299200.	124299200.	124299200.	124299200.	124299200.	124299200.
LAND	829920.	829920.	829920.	829920.	829920.	829920.
TOTAL	263422192.	172126528.	152117888.	263422192.	172126528.	152117888.

FINANCIAL PARAMETERS

COST OF CAPITAL -CALCULATED-	RATE OF RETURN ON EQUITY -INPUT-	DEBT INTEREST RATE -INPUT-	LEVERAGE (TOTAL/EQUITY) -INPUT-	INCOME TAX RATE -CALCULATED-
17.50%	20.00%	10.00%	1.200	50.06%

TIME PARAMETERS
CONSTRUCTION LEAD TIME = 0. YEARS, STARTUP PERIOD = 0. YEARS
RAW MATERIAL INVENTORY TIME (INPUT) = .083 YEARS (30.4 DAYS)
INPROCESS INVENTORY TIME (CALCULATED) = .004 YEARS (575.0 MINUTES)
(MULTIPLIED BY 1.0 FOR WORKING CAPITAL CALCULATION)
FINISHED GOODS INVENTORY TIME (INPUT) = .120 YEARS (43.8 DAYS)
ACCOUNTS RECEIVABLE TURNOVER TIME (INPUT) = .120 YEARS (43.8 DAYS)
ACCOUNTS PAYABLE TURNOVER TIME (INPUT) = .120 YEARS (43.8 DAYS)

ALL COMPANY EXPENSES ARE IN $(1979)

COMPANY DIRECT EXPENSES	586,041,600.	
COMPANY DIRECT LABOR EXPENSES		24,705,120.
COMPANY DIRECT MATERIALS AND SUPPLIES		560,587,264.
COMPANY DIRECT BYPRODUCT EXPENSES		0.
COMPANY DIRECT UTILITIES EXPENSES		749,273.
COMPANY INDIRECT EXPENSES	14,232,344.	
COMPANY INDIRECT LABOR EXPENSES		12,311,386.
COMPANY INDIRECT MATERIALS AND SUPPLIES		1,074,619.
COMPANY INDIRECT BYPRODUCT EXPENSES		5,752.
COMPANY INDIRECT UTILITIES EXPENSES		840,603.
COMPANY BYPRODUCT INCOME	(385.)	
COMPANY CAPITAL EXPENSES	52,050,176.	
COMPANY EQUIPMENT REPLACEMENT		8,591,550.
COMPANY FACILITIES REPLACEMENT		969,936.
COMPANY AMORTIZED ONE-TIME COSTS		0.
COMPANY INTEREST ON DEBT		2,858,348.
COMPANY RETURN ON EQUITY		28,583,504.
COMPANY NON-INCOME TAXES		543,179.
COMPANY INSURANCE PREMIUMS		10,503,689.
COMPANY INCOME TAXES	29,504,752.	
COMPANY MISCELLANEOUS	85,388,416.	
COMPANY EXTERNAL PRODUCT COST	0.	
COMPANY TOTAL ANNUAL EXPENSES	767,208,448.	

Fig. 5-8. SAMICS OUTPUT SUMMARY - 250,000 Units Per Year
250,000 Units Per Year Process

INDIRECT REQUIREMENTS

QUANTITY	PRICE	COST	REFERENT	DESCRIPTIVE NAME	QUANTITY	PRICE	COST	REFERENT	DESCRIPTIVE NAME
1.533E+05	17 30	2664223.	A2272I	WAREHOUSE SPACE	9.861E+04	19.57	1939962.	A2176I	PLANT MAINTENANCE AND
6.509E+04	29 23	1902715.	A2128I	OFFICE SPACE-ADMINISTR	1.468E+04	94.29	1384117.	A1112I	ELECTRICAL SERVICE FAC
1.509E+04	73 33	1106213.	A2256I	TOILET AND LOCKER ROOM	1.145E+06	.94	1080139.	A1096I	LANDSCAPING AND IRRIGA
5.530E+04	17 37	960479.	A2160I	PASSAGES AND CORRIDORS	2.305E+06	.36	829920.	A1080I	LAND
2.660E+04	26.02	692309.	A2192I	QUALITY CONTROL LABORA	1.246E+04	55.37	689687.	A2016I	CAFETERIA AND LUNCHROO
1.299E+04	27.99	363560.	A2040I	EXTERIOR WALLS	1.403E+05	1.17	163603.	A1368I	WALKS, CURBS AND GUTTE
1.690E+05	.46	78020.	A1272I	PAVING (LIGHT DUTY) FO	1.763E+04	3.96	69885	A1032I	FIRE LOOP AND SECONDAR
1.597E+04	4.08	65212.	A1208I	STORM DRAINS	5.333E+03	7.89	42066	A2200I	SHIPPING AND RECEIVING
2.613E+03	14.60	38152.	A2032I	ELECTRICAL EQUIPMENT R	6.696E+02	49.35	33050	A2024I	COMPUTER ROOM
2.458E+04	1.17	28675.	A1352I	SITE LIGHTING	2.305E+06	.01	26547	A1048I	GRADING
2.442E+03	11.36	27732.	A1224I	TELEPHONE LINES	1.009E+03	26.82	27056	A2144I	OFFICE SPACE-MANUFACTU
1.593E+03	16.14	25721.	A2112I	MECHANICAL EQUIPMENT R	7.544E+02	31.01	23393	A2040I	HEALTH SERVICE FACILIT
3.073E+04	.74	22819.	A1256I	PAVING (HEAVY DUTY) FO	4.049E+03	5.25	21251	A1016I	FENCING
3.343E+03	4.08	13649.	A1192I	SANITARY SEWERS	6.276E+03	1.17	7320	A1304I	SIGNS AND FLAGPOLE
4.885E+03	1.17	5697.	A1288I	SECURITY CONTROL FACIL	2.284E+02	22.02	5029	A2240I	TELEPHONE EQUIPMENT RO
1.815E+03	1.75	3176.	A1336I	STORAGE SPACE	2.063E+03	1.28	2647	A2020I	COMPRESSED AIR FACILIT
3.375E+02	7.58	2559.	A1240I	WATER SERVICE FACILITI	1.704E+02	14.00	2385	A1320I	STORAGE AREA WALLS
2.053E+03	.12	239.	A1128I	FUEL OIL SERVICE FACIL	6.604E+00	.86	6	A2008I	AIR CONDITIONING FACIL
4.469E-03	.08	.	A2056I	HEATING FACILITIES	1.560E-03	.12		A1144I	NATURAL GAS SERVICE FA
4.854E-06	2.33	.	A2263I	VENTILATION FACILITIES	5.198E+05	0.	0.	A3032I	TOTAL MANUFACTURING FL
9.584E+05	0.	0.	A3016I	TOTAL FACTORY FLOOR SP	4.386E+05	0.	0.	A3040I	TOTAL SUPPORT FLOOR SP
5.822E+01	29999.99	1,746,480.	B3400I	MACHINE SHOP FOREMAN	1.980E+01	30000.00	594131	B3512I	QUALITY CONTROL FOREMA
3.834E+01	15000.00	575066.	B1192I	JANITOR	1.029E+01	35000.00	360284.	B1128I	EMPLOYMENT INTERVIEWER
1.029E+01	35000.00	360284.	B1448I	SUPERVISOR, TRAINING	1.029E+01	35000.00	360284.	B2208I	PURCHASING AGENT
2.321E+01	15000.00	348214.	B1160I	GUARD (SECURITY)	1.658E+01	20000.00	331616.	B1444I	SECRETARY III (UPPER M
2.059E+01	15000.00	308815.	B1352I	PERSONNEL CLERK	9.703E+00	30000.00	291080.	B3480I	PRODUCTION MACHINE SHO
1.764E+01	15000.00	264609.	B1144I	GROUNDSKEEPER	1.029E+01	25000.00	257346.	B2008I	ACCOUNTANT
1.273E+01	20000.00	254611.	B1272I	MAINTENANCE MAN (PLANT	1.675E+01	15000.00	251219.	B1432I	SECRETARY I (LOWER MAN
7.762E+00	29999.99	232847.	B3320I	ASSEMBLY FOREMAN	1.029E+01	20000.00	205877.	B2032I	BOOKKEEPER
1.029E+01	20000.00	205877.	B2160I	PROCUREMENT CLERK	5.147E+00	35000.00	180142.	B1416I	SAFETY ENGINEER
5.147E+00	35000.00	180142.	B3208B	ELECTRONICS ENGINEER	5.147E+00	35000.00	180142.	B3224B	INDUSTRIAL ENGINEER
5.147E+00	35000.00	180142.	B3240B	MECHANICAL ENGINEER	5.147E+00	35000.00	180142.	B3256B	PRODUCTION PLANNER
5.147E+00	35000.00	180142.	B3272B	QUALITY CONTROL ENGINE	5.147E+00	35000.00	180142.	B3208I	RESEARCH ENGINEER (ELE
5.726E+00	30000.00	171772.	B1256I	MAINTENANCE FOREMAN (P	1.215E+00	129999.94	157922.	B1384I	PRESIDENT
1.029E+01	15000.00	154407.	B1048I	CLERK GENERAL OFFICE (	1.029E+01	15000.00	154407.	B1240I	MAIL CLERK
1.029E+01	15000.00	154407.	B2144I	PAYROLL CLERK	9.637E+00	15000.00	144550.	B1440I	SECRETARY II (MIDDLE M
3.529E+00	40000.00	141142.	B3496I	PRODUCTION SUPERINTEND	6.863E+00	20000.00	137251.	B1336I	NURSE, PROFESSIONAL (G
2.430E+00	55000.00	133677.	B2048I	CONTROLLER AND CHIEF A	1.781E+00	74999.94	133587.	B2272I	VICE PRESIDENT, FINANC
5.147E+00	25000.00	128673.	B3192I	DRAFTSMAN, MECHANICAL	1.698E+00	74999.94	127324.	B3304I	VICE PRESIDENT, MANUFA
3.431E+00	34999.99	120095.	B2096I	FINANCIAL ANALYST	3.431E+00	34999.99	120095.	B2240I	SYSTEMS ANALYST
3.431E+00	34999.99	120095.	B3128B	CHEMICAL ENGINEER	3.431E+00	34999.99	120095.	B3352I	ASSISTANT PRODUCTION S
1.593E+00	74999.94	119511.	B1464I	VICE PRESIDENT, ADMINI	2.288E+00	49999.98	114376.	B1080I	DIRECTOR OFFICE ADMINI
2.002E+00	55000.00	110087.	B3144I	DIRECTOR, MANUFACTURIN	3.431E+00	30000.00	102938.	B2176I	PROGRAMMER, BUSINESS
1.716E+00	54999.98	94360.	B1016I	ADMINISTRATIVE ASSISTA	1.716E+00	49999.99	85782.	B1112I	DIRECTOR PUBLIC RELATI
1.716E+00	49999.99	85782.	B2256I	TREASURER	1.716E+00	49999.98	85782.	B1064I	DIRECTOR INDUSTRIAL RE
1.787E+00	45000.00	80420.	B2192I	PURCHASING ADMINISTRAT	2.002E+00	39999.99	80063.	B1304I	MANAGER, PERSONNEL
3.869E+00	20000.00	77381.	B1176I	GUARD CHIEF	1.716E+00	40000.00	68625.	B1208I	LAWYER, CORPORATE (BUS
3.431E+00	19999.99	68625.	B2080I	DIGITAL COMPUTER OPERA	1.599E+00	40000.00	63965.	B1320I	MANAGER, SECURITY AND

Fig. 5-9 SAMICS OUTPUT-INDIRECTS- 250,000 Units per Year Process
250,000 Units per Year Rate

Fig. 5-9 . (Cont'd)

1.225E+00	50000.00	61,228.	B316CI	DIRECTOR, QUALITY CONT	1.430E+00	40000.00	57180.	B1208I	MANAGER, COMPENSATION,
5.147E+00	11000.00	56616.	B3216I	ENGINEERING AIDE	2.200E+00	25000.00	55012.	B3520I	QUALITY CONTROL SUPERV
3.431E+00	15000.00	51469.	B2112I	KEY PUNCH OPERATOR	1.716E+00	30000.00	51469.	B1032I	AUDITOR, INTERNAL
1.716E+00	30000.00	51469.	B2016I	ACCOUNTING SUPERVISOR	1.191E+00	35000.00	41700.	B2128I	MANAGER, DATA PROCESSI
1.716E+00	20000.00	34313.	B1368I	PERSONNEL CLERK, SUPER	8.578E-01	40000.00	34313.	B3176I	DIRECTOR, RESEARCH AND
5.330E-01	49999.99	26652.	B1096I	DIRECTOR PLANT MAINTEN	1.061E+00	25000.00	26522.	B3440I	MECHANICAL MAINTENANCE
8.624E-01	29999.99	25072.	B3336I	ASSEMBLY OPERATIONS SU	1.716E+00	15000.00	25735.	B1400I	RECEPTIONIST
8.578E-01	25000.00	21445.	B2224I	PURCHASING SUPERVISOR	5.719E-01	24999.99	14297.	B2064I	DATA PROCESSING SUPERV
8.578E-01	15000.00	12867.	B1224I	LEGAL SECRETARY	1.179E-01	25000.00	2947.	B3464I	PROCESS MAINTENANCE SU
1.029E+03	0.	0.	B5016I	TOTAL DIRECT PERSONNEL	7.861E+02	0.	0.	B5064I	TOTAL MAINTENANCE PERS
4.795E+02	0.	0.	B5048I	TOTAL STAFF PERSONNEL	1.509E+03	0.	0.	B5032I	TOTAL PERSONNEL
9.053E+02	440.59	398006.	C2016I	CAFETERIA SERVICE	7.957E+06	.03	250578.	C1032B	ELECTRICITY
1.413E+07	.01	120580.	C1016B	DOMESTIC WATER	2.628E+02	155.75	40927.	C1112I	TELEPHONE SERVICE
3.430E+05	.08	26183.	C2144B	SOLID WASTE MATERIAL	2.353E+06	.00	6408.	C2064B	SEWAGE AND PROCESS WAS
3.589E-02	.02	.	C1064B	NATURAL GAS	3.546E+02	0.	0.	C2048B	POWER SUPPLY
1.677E+07	0.	0.	C2080B	WATER SUPPLY	1.123E+01	0.	0.	C2096B	AIR CONDITIONING
3.700E+01	0.	0.	C2112B	HEATING	2.412E+00	0.	0.	C2128B	VENTILATED ROOM SPACE
1.128E+08	0.	0.	C2160I	LIGHTING					
1.677E+07	00	4992.	D1048B	POLLUTED WATER	2.058E+06	.00	761.	D1080I	SEWAGE WASTE
1.929E+01	0	0.	D1016B	FUMES	3.430E+06	-.00	-386.	D1096B	SOLID WASTE
7.544E+05	1 19	896357.	E1432I	OFFICE SUPPLIES	1.509E+05	1.19	179271.	E1256B	EXPENDABLE TOOLS
3.121E+07	0.	0.	F1016B	ENERGY	1.677E+07	0.	0.	F1080B	WATER
6.314E+03	0.	0.	F1032B	FUEL OIL	3.589E-02	0.	0.	F1048B	NATURAL GAS

THIS COMPANY, HELIO250K, BUYS THE FOLLOWING PRODUCTS FROM OTHER COMPANIES:
(NONE)

Table 5-2. INSTALLED HELIOSTAT COST FOR 250,000 HELIOSTATS PER YEAR, USING SAMICS VALUES

Item	Dollars per Heliostat
Cost of Manufacturing	3,068.83
Cost of Installation	879.52
Total Cost, Installed	$3,948.35
Installed Cost per Sq Meter	$ 80.49

Table 5-3. COMPARISON OF TOTAL MANUFACTURING COSTS

Manual, 250,000 Heliostats per Year Process
SAMICS, 250,000 Heliostats per Year Production Rate

Item	Dollars per Heliostat Manual	Dollars per Heliostat SAMICS
INCOME		
Gross Receipts, Less Returns and Allowances	3114	3069
Less Cost of Golds Sold	2414	2401
Direct Materials	2244	2242
Direct Labor	120	99
Indirect Manufacturing Expenses and Contingencies	50	60
Gross Profit	700	668
Other Income	-	-
Total Income	700	668
DEDUCTIONS		
Compensation of Officers	20	
Salaries and Wages (not deducted elsewhere)	50	43
Repairs	20	
Bed Debts	9	
Rent, Light, and Heat	30	
Taxes		
Interest		
Amortization	129	94
Depreciation		
Working Capital Interest	20	
Contributions	5	
Advertising	5	
Pension, Profit-Sharing, etc.	20	
Employee Benefit Programs	20	
Other Deductions	10	
Legal and Accounting Fees	5	
Consultants	5	
Travel	10	
Product Development	42	
Miscellaneous	-	299
Total Deductions	400	436
Taxable Income	300	232
Income Tax	150	118
Net After Taxes	$ 150	$ 114

were required to operate a machine he would work the full shift. The SAMICS program was based on the assumption that if a person were required only part time at a machine he would move to other operations when he was finished at the first machine. Thus, the SAMICS program indicated a slightly lower direct labor requirement than the manual calculation.

In the manual estimate, indirects and profits were added manually, often as percentages only. In SAMICS, indirects were added from the detailed data base of SAMICS, with financial parameters provided by SERI.

In SAMICS, an overall yield loss of 1% was used. In the manual calculations, yield was considered only in the "allowance for materials not detailed." SAMICS also provided more specific allowances for tools. Thus, SAMICS materials costs are slightly higher.

Capital costs are lower with SAMICS because SAMICS considers the plant to be an operating plant and does not include removal, salvage value, and installation in the capital cost. These were included in the manual calculations. The engineering and contingency costs could have been further increased to compensate for this difference but were intentionally left in the same range because the detailed overhead calculations of SAMICS are believed to provide more realistic steady-state costs in this way.

5.6 SAMICS SENSITIVITY ANALYSIS

The price estimates produced by SAMICS are derived from estimates of the price of materials and components used in heliostat manufacture and from estimates of the labor and capital required to convert those materials into a finished product. To determine how sensitive the heliostat price is to variations in the cost of materials, capital, and labor, some sensitivity studies were performed on selected costs.

The sensitivity analysis was performed by varying the prices input to SAMICS and rerunning the program. This approach was taken in order to capture all of the indirect effects of cost changes. As an example, the price of the elevation jack screw was changed from $293 to $100. The direct savings are $193 per unit or $386 per heliostat. However, the total savings are $474 per heliostat. The difference results from additional savings in the capital cost (the debt required to buy the jack screws) and in taxes (value of inventory and total revenue) and miscellaneous expenses which are computed as a percentage of the total cost.

The breakdown is as follows:

Direct Materials	$389.00
Interest on Debt	1.34
Return on Equity	13.44

Insurance Premiums	3.23
Income Taxes	13.49
Miscellaneous	53.54
	$474.04

The indirect savings can vary depending on the requirements needed by a product or process. As a result, the only way to correctly compute the savings of a reduced input cost or process change is to rerun the program.

Table 5-4 is a summary of the sensitivity runs which were performed and the results are displayed graphically in Figure 5-10. The most sensitive element among those tested is the price of the elevation jacks. The least sensitive is the allowance for engineering and contingency. However, the conclusion from these sensitivity tests is that the SAMICS price estimates are remarkably robust. That is, large variations in the cost of individual components are required to product an appreciable change in the selling price. For example, a reduction of 67% in the price of the jack screw produces a 7% change in the manufactured price or a 6% reduction in the installed price. Since components and materials can be priced reasonably accurately (probably ±10% in total) for this application, it appears that the SAMICS price estimates are relatively insensitive to random errors in the pricing of labor, capital, or materials.

Table 5-4. SENSITIVITY ANALYSIS OF SAMICS PRICE ESTIMATES (AT 25,000 HELIOSTATS PER YEAR, NOT INSTALLED)

Item	Cost Category	Dollars per Item	Dollars per Heliostat
Mirror Panel (12/Heliostat)	High	75.00	4189
	Nominal	33.00	3567
	Low	15.00	3300
Jack Screw (2/Heliostat)	High	400.00	3850
	Nominal	293.00	3567
	Low	100.00	3092
Azimuth Motor (1/Heliostat)	High	100.00	3622
	Nominal	55.29	3567
	Low	10.00	3511
Control (1/Heliostat)	High	500.00	3998
	Nominal	150.00	3567
	Low	50.00	3444
Direct Labor/Shift	High	158[a]	3614
	Nominal	142[a]	3567
	Low	139[a]	3558
Engineering Contingency	Nominal	240,000.00	3567
	Low	1,000.00	3514

[a] Persons per shift - not dollars.

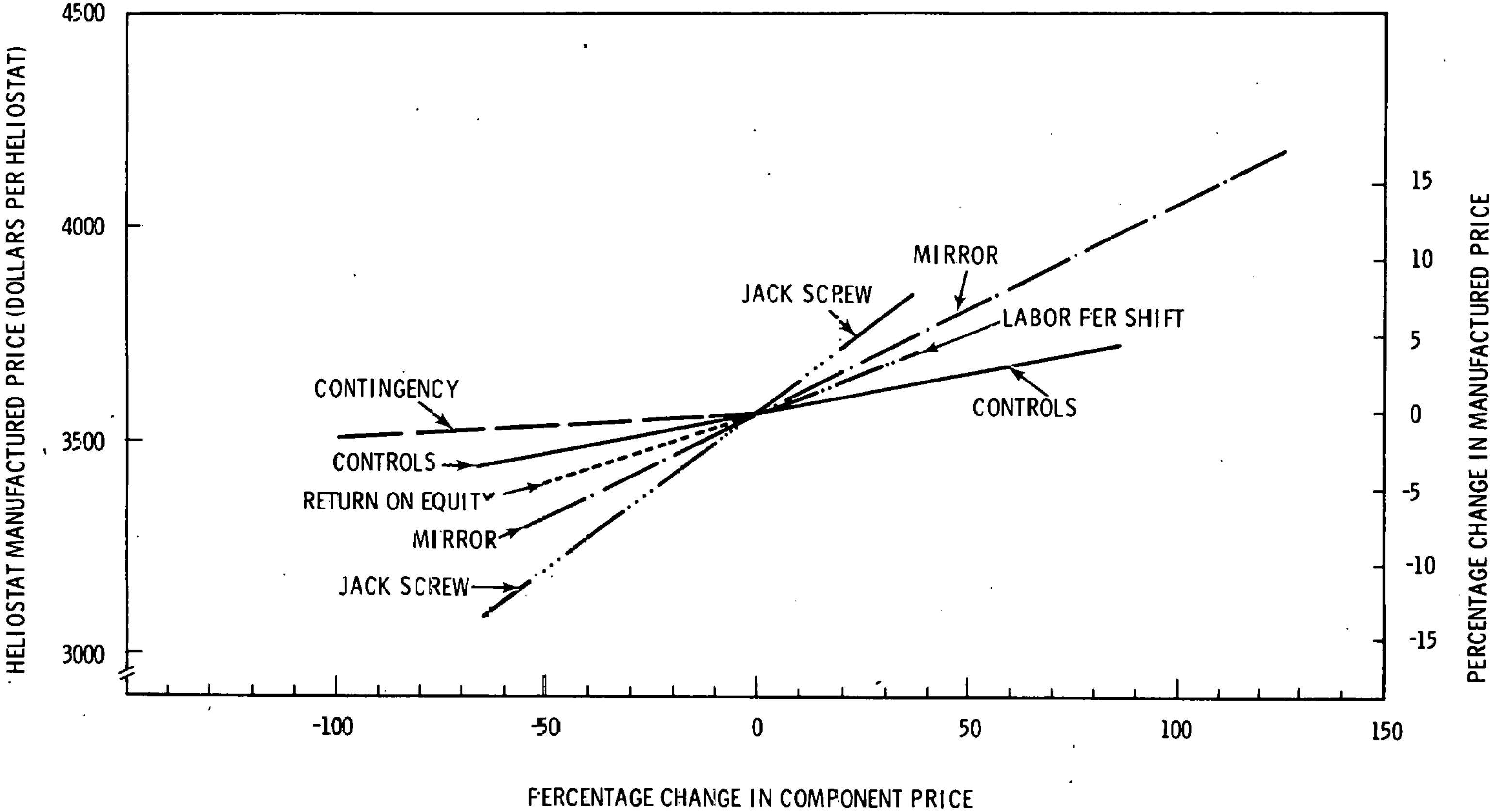


Fig. 5-10. SENSITIVITY OF MANUFACTURED PRICE TO INDIVIDUAL COSTS AT 25,000 HELIOSTATS PER YEAR PRODUCTION RATE

SECTION 6.0

CONCLUSIONS

The primary conclusion of this study is that the second generation of heliostat designs should cost approximately $100/m^2 at volumes of 25,000 units/year. This price falls to approximately $80/m^2 at volumes of 250,000 units/year.

A second conclusion is that cost reduction begins at relatively low production volumes and that many production benefits can be obtained at production rates of 5,000 to 15,000 units/year. This conclusion, if supported by further study, could have significant implications for the penetration of intermediate markets and for government commercialization programs.

A third conclusion is that the SAMICS model and the SAMIS III program can be useful tools in heliostat manufacturing, costing, and economics studies.

Costs of $80 to $100/m^2

This study, a previous study by Pacific Northwest Laboratory [7], studies by heliostat designers [2], and a study by Arthur D. Little [8] all indicate that $80/m^2 to $100/m^2 is a realistic range.

In high-volume production, the costs of materials are a majority of the total cost. Materials costs for a given design can be estimated quite accurately for a particular time. It is usually possible to obtain quotations or vendor estimates on all materials. This does not mean that some cost reduction cannot be achieved through redesign of purchased components or serious negotiation with raw material suppliers. It does not mean that all estimators will arrive at exactly the same number, for different estimators may use different suppliers or different interpretation of specifications. Different estimators may also use different process yields, different procured components or different specific times. It does mean that properly prepared estimates of materials costs which use the same definition of materials are likely to be in reasonably close agreement and that a manufacturer can make an estimate for material costs and can then produce a product at a materials cost within that estimate. However, a manufacturer cannot always accurately predict inflation. Normally, both the supplier and seller will include clauses to provide for inflation effects.

Plant cost estimates and labor cost estimates are subject to wider variation between estimators because, particularly at the conceptual process design stage, the judgment of the estimator is a significant factor. In this study, approximately 50% of the plant cost and 50% of the labor cost are based on the judgment of the estimator. However, even if the judgment part of the estimate is off by $\pm$ 50%, the effect on the estimated cost of the heliostat would be small.

Indirect costs, overheads, and return on investment are also subject to significant variation. These costs will depend to a large extent on the character of the heliostat business. A review of overhead costs for a number of different businesses indicates that the costs in this study are in a reasonable range. However, a 50% different in overhead costs would cause only 9.5% difference in the total cost estimate.

The modest effect of changes in plant, labor, and overhead costs on total cost is illustrated in Table 6-1 and is further illustrated in the SAMICS sensitivity analysis of Section 5.6.

As the business matures, it may be that requirements beyond those embodied in the present design will evolve. Undoubtedly some design changes that tend to increase cost will be made as a result of operating and maintenance experience. Also, some changes that will tend to reduce costs will result from production experience. In balance, heliostat costs may vary in practice. It seems unlikely that such variation will greatly shift the economic position of heliostat energy.

Cost Reductions Begin at Low Volume

One of the fundamental reasons why cost reductions begin at low volume is that, particularly in the design used for this analysis, much of the heliostat is produced by high-volume methods even at low volumes. With roll-formed shapes, a custom roll former will charge for tooling and setup, but the actual production rate will be high. Float glass will be produced on a float line at a very high rate whether you are buying 20,000 ft^2 or 20,000,000 ft^2. A modern, numerically controlled lathe can be programmed in a matter of minutes to a produce many of the parts in this design at high-volume rates.

In this analysis, reductions in cost between the 25,000 and the 250,000 units per year production rates are not large. This is partly because much of the heliostat cost is in elements produced with high-volume techniques and partly because 250,000 units per year is not a high enough production rate to utilize greatly different production techniques.

SAMICS--A Useful Tool

Once data is input for a particular design, SAMICS can be used with a minimum of effort to:

- evaluate the effect of specific design changes, production methods, or material changes on heliostat cost
- provide costs for a broad range of production rates
- evaluate the effects of changes in general overheads or specific overhead items on total heliostat cost.

SAMICS also provides a consistent base for comparison of different designs or processes and a standard technique easily learned by people in the business.

Table 6-1. EFFECT OF CHANGES IN LABOR, CAPITAL, AND OVERHEAD COST ON INSTALLED HELIOSTAT COST - 250,000 PER YEAR MANUAL CASE

	Cost per Heliostat $	Cost per Heliostat with 50% Increase in Direct Labor, $	Cost per Heliostat with 50% Decrease in Capital Cost, $	Cost per Heliostat with 50% Increase in Overheads, $
Direct Material	2702	2702	2702	2702
Direct Labor	359	539	359	359
Annualized Capital Cost	172	172	86	172
Overheads	761	761	761	1142
Total Cost	3994	4174	3908	4375
% Change from Original		+4.5	-2.2	+9.5

SECTION 7.0

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16. Abstract (Limit: 200 words)

This study has two primary objectives. The first is to provide a detailed cost evaluation of the second generation of DOE heliostats, from which repowering heliostat designs are likely to be derived. A second objective is to provide an analytical foundation for the evaluation of future heliostat designs. The approach taken for this study was to produce a cost estimate for the production of the McDonnell Douglas prototype design by generating estimates of the materials, labor, overhead, and facilities costs for two different production scenarios, 25,000 heliostats per year and 250,000 heliostats per year.

The primary conclusion of this study is that the second generation of heliostat designs should cost approximately $100/m^2$ at volumes of 25,000 units/year. This price falls to approximately $80/m^2$ at volumes of 250,000 units/year. A second conclusion is that cost reduction begins at relatively low production volumes and that many production benefits can be obtained at production rates of 5,000 to 15,000 units/year. A third conclusion is that the SAMICS model and the SAMIS III program can be useful tools in heliostat manufacturing, costing, and economics studies.

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