SAMICS VALIDATION

SAMICS SUPPORT STUDY
PHASE III FINAL REPORT

JET PROPULSION LABORATORY

TB&A Theodore Barry & Associates

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The Solar Array Manufacturing Industry Costing Standards are a part of the LSA Project Analysis and Integration Activity and are intended to provide a standard procedure and data base for estimating, from descriptions of the manufacturing processes, the price at which solar modules would have to be sold to realize a specified after-tax return on equity.

ACKNOWLEDGMENTS

We extend our sincere appreciation for the courtesy and cooperation we received from the many individuals who participated in this study for the Low-Cost Solar Array Project at the Jet Propulsion Laboratory. Mr. Robert Chamberlain deserves special recognition for his efforts to develop the Solar Array Manufacturing Industry Costing Standards. We would also like to extend a special thanks tc Mr. Dale Burger for his valuable counsel regarding the revisions to the Cost Account Catalog.

PHASE III

SAMICS SUPPORT STUDY

FINAL REPORT

JET PROPULSION LABORATORY

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VOLUME I

SAMICS III

COMPUTER PROGRAM VALIDATION

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A - EVALUATION

EXECUTIVE SUMMARY

This is a report of Theodore Barry & Associates' review and validation of the SAMICS model. The purposes for this review were the following:

a. To test the computational validity of the computer model by comparison with preliminary TB&A hand calculations based on conventional cost estimating techniques.

b. To review and improve the accuracy of the cost relationships being used by the model.

c. To provide an independent verification to users of the model's value in decision making for allocation of research and development funds and for investment in manufacturing capacity.

TB&A's conclusion is that the SAMICS model is a flexible, accurate, and useful tool for managerial decision making. Our comparison of model results with TB&A calculations shows close correlation. This report provides the basis for our conclusions. It also contains recommendations for increasing the usefulness of SAMICS.

The purpose of SAMICS is to provide a consistent basis for estimating array costs and comparing production technology costs. The user of SAMICS provides detailed process information for calculating direct costs. To these are added indirect and overhead expenses. Although thorough documentation of direct processes requires a significant initial effort, the process gives SAMICS its primary strength. A complete accounting of direct process resource requirements establishes an audit trail that will help to monitor the realism of assumptions before production and to later identify variations from forecasted operating parameters after production begins.

SAMICS will be valuable to the LSA Project in monitoring program objectives. It integrates all the production processes involved in module manufacturing. Thus, technology transfer from task to task and to manufacturers under

contract, followed by audits of operations, should help JPL's decision makers to allocate research funds more effectively to the lowest cost technologies.

Some limitations of SAMICS should be noted. There are three components of profit that the model calculates. The first is the conventional profit after tax in the accounting sense. The other two are amortized one-time costs and return on equity. Output formats should indicate that all three of these are returns on the capital investment.

The SAMICS model calculates annual operating expense based on a steady state condition following a number of years of operation. In addition to these steady state operating costs, initial start-up costs are computed and amortized over the economic life of the facilities. The user inputs the useful life of equipment which can be either the physical life or the expected life of the technology. In reality, technological obsolescence will probably occur before physical obsolescence. The user should be aware of the difference that the two lifetimes may have on product price.

The model also assumes that the duties of the staff can be divided so that all direct and indirect workers are fully utilized. For example, .5 people may be required on one process, and .5 on another. The program would call for 1.0 person for the two operations. For large plants, this is reasonable. For small operations, it understates personnel requirements, because it will be difficult to obtain high utilization of staff in these facilities. At least one person per operation should be assigned in small plants.

The model should also be expanded to better serve financial analysts Cash flow projections for each year of operation should be added for more flexibility.

The model can also provide additional support to manufacturing and industrial engineers for planning operations. Added model output reports would help plan facilities, provide production schedules, and define material requirements. These would be of great value to plant operations staff in administering module manufacturing operations.

VALIDATION PROCESS

The purpose of the validation is to verify that the program is working correctly and to substantiate the results. To do this, the SAMICS program results were compared with conventional estimates provided by TB&A.

These conventional estimates were performed manually by facilities engineers and cost analysts independently of the computer model development. Three solar array plant sizes corresponding to annual production levels of .50, 15, and 500 Megawatts were used. The estimates are presented in the SAMICS Support Study Final Report, Volume III: Conceptual Plant Designs.

For the validation, the program was run with input data for each of the three test case factories. Any differences in results were reconciled by explaining how to eliminate them or by explaining why they cannot or should not be eliminated. Part B of this report is a detailed comparison of computer- and hand-calculated results by account.

Based on the model review conducted during the validation process, changes in the cost account catalog, the indirect requrements matrix, the capital cost estimating relationships, and the submodel equations are recommended. Finally, the results are compared after implementation of the recommended changes.

ASSUMPTIONS AND RESULTS

The conceptual plant design assumed Springfield, Illinois, for the site location. Capital costs for construction vary widely from one location to another. Costs in Springfield, however, are typical of the national average. The following paragraphs describe the other key assumptions and their impact of the results.

- Manufacturing Process

  A manufacturing process sequence using ion implantation was selected as the automated assembly design for the conventional estimates. This

sequence of 14 process steps was chosen by JPL for two reasons. First, because it is very similar to processing which is well developed and widely used in the semi-conductor industry. Second, at the time the conventional estimates were made, ion implantation was a highly viable condidate for the newly developing photovoltaic industry. However, now several other superior candidates have emerged so that the exact numerical values presented in this report would no longer be cost competitive.

Nevertheless, this process sequence provides a true baseline for the validation comparisons. The production operations start with silicon wafers as input and end with packaged solar array modules as output. The overall process yield is approximately 70%. Appendix B contains descriptions for each process step. The same size equipment is used in all plant sizes, however, the number of machines may vary.

- Solar Array Design

The solar array module design consists of 224 circular solar cells connected in series on a 14.6 square foot panel. The cells are three inches in diameter with a nominal efficiency of 15%. The panels have a power rating of 160 watts and weigh approximately 55 pounds. Different module sizes and performance factors would have a great impact on the results because the price estimates are expressed as manufacturing cost per peak watt of capacity and the capacity is directly proportional to the cell efficiency.

- Financial Parameters

The most critical financial factors are the cost of capital, 18.37%, and the required rate of return on equity of 21%. The companies are not highly leveraged. Total debt is 20% of net worth by assumption.

This is typical of the electronics industry in general. A recent Value Line Survey of 16 leading electronics firms showed an average debt to equity ratio of 21%, indicating a marked propensity for equity financing. The inflationary rates are also important due to the time value of money. All costs are inflated to a steady state manufacturing year. Different rates are applied to different accounts. However, all exceed 6%, the rate at which the final price estimates are deflated to current year dollars.

- Capital Investment Requirements

The construction lead times and production startup times, which vary with plant size, determine when construction financing activities would have to begin, in order to meet the design year production goals.

Annual Production Level (MW)	.50	15	500
Construction Lead Time (Years)	1.75	2.00	3.00
Production Start-Up Period (Years)	.25	.75	1.50
Steady State Manufacturing Year	1980	1982	1986

- Personnel Staffing

In the SAMICS model fractional numbers of people are considered to provide realistic estimates of labor costs. At least two plausible mechanisms can be used in the actual staffing of the factory: part-time workers are hired at the specified pay rate, or fractional jobs are combined, so that some personnel perform multiple functions at the weighted average pay rate. Indirect requirements for parking lots, cafeteria space and other items that depend upon the actual number of people are based on the implicit assumption that fractional jobs are combined.

However, it appears that this labor efficiency assumption is unrealistic for capital intensive processes at low levels of production.

For example, the direct labor requirement computed for the .50 MW plant is 1.8. Yet, it is assumed that four shifts of manufacturing personnel are required for continuous operation seven days per week. Theoretically, this implies less than one person per shift (.45 to be precise), which is clearly impossible in the real world.

The problem is that the model assumes a constant productivity at all levels of production while productivity actually increases with the division of labor. Productivity also decreases with the number of functions that one person must perform. In small plants less division of labor is possible because the same people are requred to perform multiple functions. Consequently, they are less productive at any one function as a result of a host of factors such as delays, set-up times, learning and movement from one place to another.

- Factory Operating Schedule

The model currently assumes that all factories operate 345 days per year with three shifts per day. This continuous operation requires approximately four shifts of production personnel. This is not practical and results in excess capacity in the smaller plants. The effect of reducing the number of operating shifts would increase costs for large plants, but reduce costs for small plants.

The operating schedule is a key factor in designing a facility which is expected to produce a given level of output per year. Fewer operating shifts require a larger facility to achieve the same output.

Although the validation results presented in Volume I are based on a fixed operating schedule: 24 hours per day and 7 days per week for 345 days per year, Volume II of this report presents a model for SAMICS to vary the factory operating schedule.

This feature will enhance the SAMICS model, allowing users to test the impact of different operating strategies. The input parameters are the number of production shifts and the number of operating days per week both of which may vary by manufacturing process.

- One-Time Cost Model

Under the SAMICS steady-state assumption, the volume of production is exactly equal to the specified fraction of design capacity, and the real value of the hypothetical firm's capital is kept constant. Furthermore, annual expenses (including profit) are exactly equal to annual revenues because of the required rate of return on equity condition.

During the plant construction period, expenditures are made for capital goods. This capital is obtained from debt and equity investors according to the firm's leverage. The capital goods, such as land, facilities, and equipment, are retained by the company, and depreciated in value to recover their cost. The acquisition of this capital requires some additional "one-time" expenditures during the construction phase. These one-time costs are amortized and recovered by increasing the required revenue cash flows during steady-state operation.

During the initial period of operation or production start-up, the output is less than capacity as unit operating costs follow a learning curve.

The major factor causing operating costs per unit during startup to be lower than steady state is the difference in yield on direct materials. More materials --estimated at 25% -- are scrapped. Overhead costs, on the other hand, are essentially the same with the exception of income taxes. Revenues are substantially lower, due to lower production volume. The result is a net operating loss for the start-up period.

This imbalance is reflected in the price of the company'a product by amortizing one-time costs over the life of the facility to recover them through steady state operating revenues. These amortized one-time costs represent 2% to 5% of the solar array price and directly impact several other financial parameters, such as income taxes and return on equity.

B - COMPARISON OF ACCOUNTS

In Volume III of the SAMICS Support Study, Conceptual Plant Designs, TB&A developed the requirements for a representative manufacturing process. The initial designs included documentation of direct requirements followed by the development of additional indirect requirements. These inputs were provided to facilities engineers who completed the plant designs with utilities, waste disposal, restrooms, and other facility requirements. These conceptual designs were used to estimate product prices.

The validation process involves a comparison between the conceptual design and the SAMICS program results for a plant with identical direct requirements. The results of this comparison are shown in three parts. The first is the Direct Requirements. These should be identical because they define the basic processes from which other requirements are developed. The second part of the comparison is the Indirect Requirements.

Since TB&A's Conceptual Plant Design is based on engineering estimates of requirements rather than computed relationships, the comparison of Indirect Requirements will be close, but not exact.

The third and last part of the comparison is the Capital Expenses, including the financial model of the firm, income taxes, and miscellaneous expenses. Differences in comparison are caused by minor differences arising from differing indirect requirements and from differences in the method of calculating the expenses.

Tables 1, 2, 3 and 3A in Appendix C show the overall results of the comparison. The cost per peak Watt in 1975 dollars for the TB&A Conceptual Design and the current SAMICS program is shown below:

Production	Old TB&A	Revised TB&A	Old SAMICS	Revised SAMICS	% DIFFERENCE*
0.5 MW	$5.61	$5.49	$5.68	$5.31	-3.3%
15 MW	2.13	2.11	2.10	1.86	-11.8%
500 MW	.86	.89	1.04	.85	-4.5%

All Prices are in 1975 $/Watt

$$*\text{DIFFERENCE} = \frac{(\text{Revised SAMICS} - \text{Revised TB\&A})}{\text{Revised TB\&A}}$$

Tables 1, 2, and 3 reflect results from the Original SAMICS program (labeled "Old SAMICS") compared to the "Revised TB&A" estimates. Revisions were made to correct minor errors and items overlooked in the initial TB&A estimates. The "Revised SAMICS" column is from Table 3A. These results are based on the implementation of recommendations made during the validation. The recommendations are detailed below under the "Financial Data Comparison" heading.

The discrepancy of 11.8% for the 15 MW case is largely due to a SAMICS data base error in the inflation and deflation of the standardized price for silicon wafers.

The following sections cover each part of the comparison. Detailed item-by-item comparisons are shown. One of the benefits of the comparison process has been a thorough review of the Indirect Requirements recommended in TB&A's original support study. From this review, modifications to indirect requirements are recommended. These are documented in Volume II of this report.

DIRECT REQUIREMENTS COMPARISON

Tables 4, 5, 6 and 7 in Appendix C compare TB&A and SAMICS results for the three plant sizes. The categories of direct requirements are as follows:

Table 4 -- Direct Labor
Table 5 -- Direct Materials
Table 6 -- Direct Byproducts
Table 7 -- Direct Utilities and Plant Services

The quantities of personnel directly required to operate and maintain the machines and to transport and inspect materials are specified as inputs by the model user. Since

the same inputs were applied, the SAMICS program agrees quite closely with the conventional estimates for direct personnel. However, factory operations require more staff than those directly required to produce the product.

These indirect personnel are generally needed to operate any manufacturing plant. Examples are supervisors, managers, engineers, accountants, janitors, and guards. These support personnel are referred to as indirect requirements whose amounts can be determined as functions of certain direct and other indirect requirements.

Direct labor and direct material categories are the same to the third or fourth significant digit. The difference in direct materials is due to the way SAMICS inflates and deflates the price of wafers. When this is fixed, the correspondence will be even closer.

The tables show that the Direct Requirements are sufficiently close to provide a basis for comparing Indirect Requirements and Capital Expenditures generated by the model.

INDIRECT REQUIREMENTS COMPARISON

Table 8 in Appendix C compares Indirect Personnel for the three plant sizes showing the requirements in people for each job title. Also identified is the relationship between the job category and the facilities design. For example, the Training Supervisor staffing is not at all dependent on facilities, so a "0" appears. A Secretary III has a third order relationship since some manager staffing will depend on the facility size. This is indicated by a "3". Guards and Janitors are directly related, so a "1" appears.

This presentation enables the reader to compare items that would be expected to differ (those with 1, 2, and 3 relationships), and those which would not ("0" relationship). Since the "2" and "3" items vary from the "1", the differences in indirect requirements arise from the "1"'s. Differences in these categories do not invalidate the model, but suggest that certain capital and indirect requirements will be site and location specific and that the model can only approximate these. Specific recommendations for changes in indirect requirements and costs are the topic of Volume II.

The determining items for most indirect personnel are based on an organizational structure developed during Phase I of the support study. This structure indicates the immediate needs for supervisory and managerial support. Other types of indirect personnel depend on the total number of direct labor personnel or the total size of the factory.

Examples of the former include assembly operations supervisors, accounting supervisors, and the vice president of manufacturing. Examples of the latter are mail clerks, personnel clerks, nurses and bookkeepers.

The determining items are tabulated in Appendix D for all indirect personnel, along with numerical parameters defining the relationships.

These relationships are based on standard industrial engineering staffing assumptions that are used for conventional cost estimates. However, the conventional estimates developed for SAMICS are considerably more detailed than for most manufacturing cost estimates. Normally, personnel are estimated by functional groups or departments whereas the SAMICS relationships estimate numbers of people for each job position in the organization.

The similarity of the results compared in Table 8 in Appendix C is due to the fact that this well established procedure was then used to generate the indirect requirements matrix. Thus, the SAMICS program uses the same relationships that were used for the conventional estimates.

In the TB&A Conceptual Design, indirect materials and utilities were estimated as 5% of total direct costs. This is a conventional estimate of these costs. The SAMICS program makes explicit calculations from indirect requirements relationships. Although the percentage difference is large, the impact of the difference on module cost is small and SAMICS uses a more detailed and accurate approach.

FINANCIAL DATA COMPARISON

Of the categories of financial expenses, three play a primary role in determining overall costs. These are Equipment Replacement, Facilities Replacement, and Amortized One-Time Costs. Other factors, such as Interest on Debt and Income Tax are driven by these factors. Table 11 in Appendix C is a comparison of TB&A and SAMICS results. The major difference apparent in the comparison is between Amortized One-Time Costs (AOC).

Because of differences, TB&A has carefully reviewed the SAMICS calculation of AOC and made the following recommendations to JPL regarding modifications to the equations.

- Material required during startup should be based on start-up volume, not steady-state volume.
- Expenses during start-up should not include steady-state AOC, investment tax credit and income tax.
- A tax saving will result from start-up losses and from initial higher depreciation and should be included in the model.

Another difference between SAMICS and the conventional TB&A estimates is the capital recovery factor used to amortize one-time costs.

The TB&A results are based on the standard capital recovery factor formula used in engineering economic studies:

$$CRF\ (K,L) = \frac{K\ (I + K)^{L}}{(I + K)^{L} - 1}$$

where

K = Cost of Capital
L = Recovery Period

For K = 18.374% and L = 40 years, the capital recovery factor is .183956 which is the value applied by TB&A.

The SAMICS program uses a generalized capital recovery factor which is a modification of the conventional capital recovery factor to account for growth of the annual payment at the rate of inflation. It can be defined as the numerical value of the first term in a growing stream of L annual cash flows which start at the beginning of the first amortization year (Design Manufacturing Year for SAMICS) and has a present value of unity.

The generalized capital recovery factor can be derived by equating the present value of a stream of inflating cash flows with an initial value of GCRF to unity and solving:

$$GCRF\ (K,L,g) = \frac{1}{1 + \sum_{i=1}^{L-1} \frac{\prod_{t=T}^{T+i-1} (1+g)}{(1+K)^i}}$$

The complexity of this equation results from allowing the inflation rate to vary from year to year. If the inflation rate is zero, this expression reduces to the conventional capital recovery factor.

The SAMICS program results are based on a generalized capital recovery factor of .1045 compared to .1837 for the conventional TBA estimates.

Tables 9 and 10 in Appendix C compare initial capital costs for facilities. Since the TB&A costs were the result of a conceptual design rather than a computer program, there should be differences in some component requirements. Where large differences exist, the indirect requirement relationships have been reviewed. Where appropriate, modifications are recommended. These are documented in Volume II. Those facilities requirements for which changes are recommended are footnoted in Tables 9 and 10.

C - SUMMARY OF RECOMMENDATIONS

Several recommendations made here will improve the usefulness of the model. Some have already been mentioned in the prior sections, but are reiterated here to provide a consolidated list.

Provide Indoctrination for Potential Users. To the uninitiated, SAMICS' demand for complete process documentation presents a formidable task. JPL should provide special training sessions for users. The course should describe the program's logic, how to collect data, and how to interpret results.

An Edit Routine Should Monitor Input Data Validity. Most production operations will be expected to have predictable operating parameter ranges. These critical parameters should be identified and reasonable ranges established for comparison purposes. An output listing should compare the user's parameters with the established ranges as a check on input and assumption validity.

Validate the Model Using a Real Facility. As larger operations come into production, JPL will have an opportunity to further validate SAMICS assumptions. Model parameters should be compared with actual parameters from an operating facility after operations have commenced.

Provide Cash Flow by Year. The model contains the information required to generate cash flow projections. These are useful for financial analysis and corporate investment decision-making. They could be a useful supplement to current reports.

Combine Some Output Figures. Some costs are allocated to the processes. These should be summed by the computer to provide overall costs. Also, profit after tax, amortized one-time costs, and return of equity should be summed because they all represent return of capital.

Integerize Direct Staff Requirements. To eliminate distortions for small operations, each process should have at lease one person per shift assigned.

VOLUME II

INDIRECT REQUIREMENTS MATRIX

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A - INTRODUCTION

This section documents modifications to the Indirect Requirements Matrix. The SAMICS simulation model will use the matrix to compute the indirect needs of the solar array firm from the items required directly by its manufacturing processes.

The key assumption is that the indirect requirements can be determined from the direct requirements for any manufacturing process, while the direct requirements can only be obtained from a knowledge of the process.

The user of the SAMICS model describes the direct requirements of the manufacturing processes by specifying the quantities of facilities, personnel, utilities, commodities, byproducts, and equipment from the cost account catalog. However, factory operations require more staff, facilities, and supplies than those directly required to operate. These items are generally needed to support any manufacturing plant, and are generated by the SAMICS model, using the indirect requirement relationships which constitute a standardized factory design.

Three types of modifications have been made to the original matrix:

- Improvements have been recommended as a result of the SAMICS III computer program validation discussed in Volume I.
- The matrix has been expanded to allow for a variable number of factory operating shifts. The original matrix is based on the operating assumption of three shifts and 24 hours per day for 345 days per year.
- All units of measure have been converted from the FPS system to the metric system for use with the Phase II Cost Account Catalog, which is metric.

The following sections describe the matrix changes regarding the revised relationships, variable operating shifts, and metric system units. The new matrix data is listed in Appendix D.

B - RECOMMENDED IMPROVEMENTS

One purpose of the validation process was to verify the correctness and appropriateness of the indirect requirements relationships recommended in Volume II of the SAMICS Support Study. This process involved comparison of results from the SAMICS program with parameters for independently designed manufacturing facilities. The results of the two are compared in this section. Where significant differences have occurred, a recommendation is made to either (1) retain the recommended relationship or (2) modify the relationship to correspond with the independent design, or (3) a combination of the above.

The following exhibits summarize the recommended changes with an accompanying explanation of the reason for the change. Two recommendations--those for parking and passages/corridors--will add space requirements to the parameters in the model. The recommended figures are more appropriate and should be adopted. The remaining recommendations have the impact of setting a limit on the minimum size of the facility. For maintenance and quality control facilities, a maximum is appropriate since many of these workers are on the production floor, not in the support facility. In the case of the minimum limits, some facility requirement exists regardless of the plant size. The minimum requirement makes this provision.

Each indirect requirement relationship has been reviewed and the changes just recommended are the result. Despite the differences, it is felt that the newly recommended parameters are the best alternative. The impact on cost per peak watt is shown in the table below.

SAMICS SOLAR ARRAY PRICE ESTIMATES*
REVISED PROGRAM

Annual Production	.50 MW	15 MW	500MW
Original Matrix	$5.31	$1.86	$.85
New Matrix	$5.66	$1.91	$.92

*Stated in 1975 dollars

INDIRECT REQUIREMENTS MATRIX ANALYSIS

FACILITIES: EXTERNAL SITE PARAMETERS

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Industrial Waste Clarifiers and Hold Tanks (GAL)	Polluted Water (GAL/YR) Poisonous Acid (GAL/YR) Used Solvent (GAL/YR)	Change facilities capital costs to the following: Q_1= 29,000 P_1= 1,000 Q_2= 110,250 P_2= 4,500 Q_3=3,000,000 P_3=20,000 This reduces excessive costs; indirect requirements O.K. 15 GAL capacity per 345 GAL/YR.
Electrical Service Facilities (KW)	Electricity (KW-HR/YR)	No change in Matrix or Facilities cost function
Liquid Nitrogen Facilities (CU FT)	Liquid Nitrogen (GAL)	No change in Matrix or Facilities cost function
Liquid Oxygen Service Facilities (CU FT)	Liquid Oxygen (GAL)	No change in Matrix or Facilities cost function
Storm Drains (CFM)	Total Factory Space Paving for Roads Paving for Parking	No change 1 CFM/60 SQ FT
Water Service Facilities (CFM)	Water Supply (CU FT)	No change 1 CFM per 49680 CU FT/YR
Paving for On-Site Roads (SQ FT)	Total Factory Space (SQ FT)	No change
Paving for Parking Lots (SQ FT)	Total Direct Personnel Total Staff Personnel (PRSN*YR)	Change SQ FT/ person from 200 to 325 to allow for circulation
Storage Space (SQ FT)	Total Factory Space (SQ FT)	No Change
Site Lighting ($)	Total Factory Space (SQ FT)	Change determining item to parking lot size (SQ FT) with an indirect requirement for electricity (KW-HR)

INDIRECT REQUIREMENTS MATRIX ANALYSIS

FACILITIES: LAND DETERMINANTS

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Land (SQ FT)	Total Factory Floor Space (SQ FT)	Change to 1.2 SQ FT/SQ FT 20% is allowance for other land requirements
	Paving for Parking Lot (SQ FT)	Add the relationship 1 SQ FT/SQ FT
	Paving for Roads (SQ FT)	Add the relationship 1 SQ FT/SQ FT
	Liquid Nitrogen Service Facilities (Ft^3)	Implicit in 20% allowance
	Liquid Oxygen Service Facilities (CU FT)	Implicit in 20% allowance
	Natural Gas Service Facilities (CU FT)	Implicit in 20% allowance
	Security Control Facilities ($)	Implicit in 20% allowance
	Storage Space (SQ FT)	Implicit in 20% allowance
	Walks, Curbs and Gutters ($)	Implicit in 20% allowance
	Compressed Air Facilities (CFM)	Implicit in 20% allowance
	Fuel Oil Service Facilities (CU FT)	Implicit in 20% allowance
	Industrial Waste Clarifiers (GAL)	Implicit in 20% allowance
	Chemical and Solvent Storage (SQ FT)	Implicit in 20% allowance

INDIRECT REQUIREMENTS MATRIX ANALYSIS

FACILITIES: LANDSCAPING

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Landscaping & Irrigation	Land (SQ FT)	Delete the relationship 1 SQ FT/SQ FT* (SQ FT)
	Total Factory Space (SQ FT)	Change from -1 SQ FT per SQ FT to .20 SQ FT/SQ FT
	Storage Space (SQ FT)	Delete the relationship -1 SQ FT/SQ FT
	Paving for Parking (SQ FT)	Delete the relationship -1 SQ FT/SQ FT
	Paving for Roads (SQ FT)	Delete the relationship -1 SQ FT/SQ FT

INDIRECT REQUIREMENTS MATRIX ANALYSIS

FACILITIES: INTERIOR BUILDING SPACE PARAMETERS

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Cafeteria and Lunch (SQ FT)	Total Personnel	No Change, Volume II O.K.
Electrical Equipment Room (SQ FT)	Electricity (KW-HR/YR)	No Change, Volume II O.K
Health Service Facilities (SQ FT)	Total Personnel	No Change, Volume II O.K.
Mechanical Equipment Room (SQ FT)	Total Personnel	Set minimum space requirement of 400 SQ FT for up to 25 people
Office Space, Administration (SQ FT)	Total Staff Personnel	No Change, Volume II O.K.
Office Space, Manufacturing (SQ FT)	Total Direct Personnel	No Change, Volume II O.K.
Passages and Corridors (SQ FT)	Office Space, Administration Office Space, Plant, Manufacturing Space	To allow for more circulation than 5%, 6%, 10% apply 30%, 25%, 20% factors to the respective areas
Compressed Air Facilities (CFM)	Compressed Air	No Change
Plant Maintenance Shop (SQ FT)	Maintenance Personnel	Set maximum size at 50,000 SQ FT for 300 or more maintenance personnel
Quality Control Laboratory (SQ FT)	Quality Control Personnel	For 200 or more quality control personnel, set maximum size at 8,000 SQ FT and change from 100 SQ FT per person to 40 SQ FT to recognize that 60% of quality control personnel are on production floor and do not require lab space

INDIRECT REQUIREMENTS MATRIX ANALYSIS

FACILITIES: INTERIOR BUILDING SPACE PARAMETERS

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Solvent and Chemical Storage (SQ FT)	Industrial Waste Clarifiers (GAL/YR)	Capital cost function O.K., change Matrix
Telephone Equipment Room (SQ FT)	Telephone Service	No Change, Volume II O.K.
Toilet and Locker Room (SQ FT)	Total Personnel	Set minimum space requirement of 500 SQ FT for up to 15 people
Warehouse Space (SQ FT)	Manufacturing Floor Space (SQ FT)	No change, space utilization is not as good in small plants

INDIRECT REQUIREMENTS MATRIX ANALYSIS

FACILITIES: EQUIPMENT

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Computer ($)	Total Personnel (PRSN*YRS)	New item: require $0 or no computer for less than 25 people, $250 per PRSN*YR for up to 250 people, $180 per PRSN*YR for up to 1000 people and $120 per PRSN*YR for 2500 employees Add to catalog at cost of $1/$
Forklift Truck (Trucks)	Warehouse Space (SQ FT)	New item: require zero trucks for 500 SQ FT or less, 1 truck per 10,000 SQ FT for up to 160,000 SQ FT, and .75 trucks per 10,000 SQ FT for 160,000 SQ FT or more
	Shipping and Receiving Dock (SQ FT)	Included in warehouse requirement Add to catalog at $20,000/truck
Scrubber	TCE Fumes (CFM)	Scrubbers must be specified as direct equipment requirements on the user input formats because of extreme variations in scrubber requirements and costs depending on the specific type and concentration of the fumes (note that "the fumes" and "fumes" are different items)

INDIRECT REQUIREMENTS MATRIX ANALYSIS

PERSONNEL

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Groundskeeper (PRSN*YRS)	Land (SQ FT)	Groundskeeper requirement is excessive. Change determining item from land to landscaping and irrigation with one groundskeeper per 150,000 SQ FT

INDIRECT REQUIREMENTS MATRIX ANALYSIS

UTILITIES AND PLANT SERVICES

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Domestic Water (CU FT/YR)	Total Direct Personnel Total Staff Personnel	Combine to total personnel with 1040 CU FT per PRSN*YR
	Landscaping and Irrigation (SQ FT)	10.8 CU FT/YR per SQ FT
	Process Waste Disposal (CU FT/YR)	.08 CU FT/YR per CU FT/YR
	Air Conditioning (KW-HR/YR)	.88 CU FT/YR per KW-HR/YR
	Cooling Water (KW-HR/YR)	.94 CU FT/YR per $\frac{\text{KW-HR}}{\text{YR}}$
Electricity (KW-HR/YR)	Total Factory Floor Space (SQ FT)	33 KW-HR/YR per SQ FT (for lighting)
	Heating (CU FT/YR)	Require 5 KW-HR/YR per 100 CU FT/YR
	Air Conditioning (KW-HR/YR)	No change, 1 KW-HR/YR per $\frac{\text{KW-HR}}{\text{YR}}$
	Ventilated Room Space (CU FT/YR)	.05 KW-HR/YR per CU FT/YR
	Paving For Parking (SQ FT)	This is for Site Lighting 1 KW-HR/YR per SQ FT based on an average of 11 hrs/day
	Cooling Water (KW-HR/YR)	Add new requirement of 1 $\frac{\text{KW-HR}}{\text{YR}}$ per $\frac{\text{KW-HR}}{\text{YR}}$
	Compressed Air (CU FT/YR)	Add new requirement of 3.5 $\frac{\text{KW-HR}}{\text{YR}}$ per $\frac{\text{CU FT}}{\text{YR}}$
	Lighting (lumens)	Remove; lighting included in floor space electric requirement
Cafeteria Service (PRSN*YRS)	Total Direct Personnel Total Staff Personnel (PRSN*YRS)	O.K. at 60% for both direct and staff personnel

INDIRECT REQUIREMENTS MATRIX ANALYSIS

UTILITIES AND PLANT SERVICES

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Air Conditioning (KW-HR/YR)	Total Factory Space (SQ FT)	Change to 50 KW-HR/YR per SQ FT
Heating (CU FT/YR)	Total Factory Space (SQ FT)	1000 CU FT/YR per SQ FT This is equivalent to 50 KW-HR/YR per SQ FT.
Ventilated Room Space (CU FT/YR)	Total Factory Space (SQ FT)	Change to 1000 CU FT/YR per SQ FT from 1 CU FT/YR per 397440 SQ FT
	Fumes (CU FT/YR)	New requirement for fumes 3 CU FT/YR per CU FT of fumes
Lighting	Total Factory Space (SQ FT)	Remove: Lighting electric requirements are determined directly from Total Factory Floor Space

INDIRECT REQUIREMENTS MATRIX ANALYSIS

BY-PRODUCTS

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Sewage Waste (GAL)	Total Direct Personnel Total Staff Personnel	Same for both direct and staff (1035 GAL/YR per PRSN*YR) change determining item to total personnel
Solid Waste (LBS)	Total Direct Personnel Total Staff Personnel	Same for both direct and staff (1725 LBS/YR per PRSN*YR) change determining item to total personnel

COMMODITIES

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Expendable Tools ($)	Total Personnel	Change to $100/YR per PRSN for total personnel
Office Supplies ($)	Total Staff Personnel	Change to $500/YR per PRSN for total staff personnel

INDIRECT REQUIREMENTS MATRIX ANALYSIS

RESOURCES

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Silicon (KG/YR)	Rejected Cells (Cells)	Negative resource requirement -3.96×10^{-3} KG/cell
	Rejected Wafers (Wafers)	Negative resource requirement -3.96×10^{-3} KG/cell
	Silicon, Metallurgical Grade	+ 1 KG/YR per KG
	Silicon, Polycrystalline (KG)	+ 1 KG/YR per KG
	Silicon, Ribbon (KG)	+ 1 KG/YR per KG
	Silicon, Ingot (KG)	+ 1 KG/YR per KG
	Cells, Solar (Cells)	3.96×10^{-3} KG/cell
	Wafers, Solar (Wafers)	3.96×10^{-3} KG/wafer
	Silicon, Polycrystalline $10/KG $15/KG $20/KG $25/KG $30/KG $35/KG $40/KG $45/KG $50/KG $55/KG $60/KG $65/KG $70/KG $75/KG	Add the following grades of polycrystalline with a one-to-one resource requirement

INDIRECT REQUIREMENTS MATRIX ANALYSIS

RESOURCES

INDIRECT ITEM	DETERMINED BY	RECOMMENDATION
Energy (KW-HR)	Electricity (KW-HR)	O.K. 1 KW-HR/KW-HR
	Fuel Oil (GAL)	O.K. 39.102 KW-HR/GAL
	Natural Gas (CU FT)	O.K. .291 KW-HR/CU FT
Fuel Oil (CU FT)	Fuel Oil (GAL)	O.K. .13369 CU FT/GAL
Natural Gas (CU FT)	Natural Gas (CU FT)	O.K. 1 CU FT/CU FT
Water (CU FT)	Domestic Water (CU FT)	O.K. 1 CU FT/CU FT
	Deionized Water (CU FT)	O.K. 1 CU FT/CU FT
	Cooling Water (KW-HR/YR)	Delete: cooling water requires domestic water and is also recycled, therefore, does not directly require any of the resource water.

C - VARIABLE FACTORY OPERATING SHIFTS

ANALYSIS

This section presents the indirect requirements relationships and the manufacturing process equations which vary with the factory operating schedule.

For the initial version of SAMICS, these indirect relationships and process equations were based on a fixed operating schedule: 24 hours per day and 7 days per week for 345 days per year.

This continuous operation requires approximately four shifts of production personnel. Clearly, this is not practical and results in excess capacity in smaller plants. The effect of reducing the number of operating shifts would increase costs for larger plants, but reduce costs for smaller plants.

The operating schedule is a key factor in designing a facility which is expected to produce a given level of output per year. Fewer operating shifts require a larger facility to achieve the same output.

The model contains provisions for determining these short-run cost variations quite easily. To accomplish this, several indirect requirements relationships and process equations must be allowed to vary with the operating schedule.

The operating schedule is essentially defined by two factors:

S = Number of production shifts that are operated each week

A = Number of factory operating days per week

Together, these two variables determine a third factor, the number of discrete shifts to cover the production schedule. Table 1 contains the crew production function.

C = Number of production personnel crews

TABLE #1
PRODUCTION CREW FUNCTION

SHIFTS/DAY S/A	NUMBER OF CREWS C
$0 < S/A < 1$	Impossible
$S/A = 1$	$C = 1$ if $A < 5$ $C = 2$ if $A \geq 5$
$1 < S/A < 2$	$C = 2$
$S/A = 2$	$C = 2$ if $A < 5$ $C = 3$ if $A \geq 5$
$2 < S/A < 3$	$C = 3$
$S/A = 3$	$C = 3$ if $A < 5$ $C = 4$ if $A \geq 5$
$3 < S/A$	Impossible

The number of crews is limited to 1, 2, 3, or 4. There cannot be more days per week (A) than shifts/week (S), so the number of shifts per day S/A must be greater than or equal to one. There cannot be more than 3 shifts/day, so S/A must also be less than or equal to 3.

For example, suppose that the user specifies:

S = 21
A = 7

This would correspond to continuous operation 24 hours/day for 7 days per week. Then, the number of crews would be found by computing

S/A = 3

and, searching the table with

A $\geq$ 5

therefore,

C = 4.

An analysis of the indirect requirements matrix resulted in a list of 47 relationships, which could potentially be affected by the factory operating schedule. These are listed in the following exhibits.

Each item on this initial list was investigated to determine whether or not it should actually change and why.

This narrowed the list down to 17 items which depend on the operating schedule.

The final list of matrix changes is presented in the next section. There are no personnel, commodities, by-products, or resources on the list. The only relationships which vary with the number of shifts are facilities and utilities.

VARIABLE OPERATING SHIFT ANALYSIS
ACCOUNT A: EXTERNAL SITE FACILITIES

Indirect Requirement	Determining Item	Change/Reason
Industrial Waste Clarifiers	Polluted Water Poisoned Acid Used Solvent	No Change
Land	Total Factory Floor Space	Change to Determine by Parking Space Land = (paving and floor space) *Variable
Electrical Service Facilities	Electricity	No Change
Fuel Oil Service Facilities	Fuel Oil	$I = \frac{15}{345} * \frac{7}{A}$ *(fuel oil) where A = operating days/week
Natural Gas Service Facilities	Natural Gas	$I = \frac{15}{345} * \frac{7}{A}$ *(natural gas)
Liquid Nitrogen Service Facilities	Liquid Nitrogen	No Change
Liquid Oxygen Service Facilities	Liquid Oxygen	No Change
Sanitary Sewers	Sewage and Process Waste Disposal	Multiply current relationship by 21/S where S = shifts/week
Telephone Lines	Office Space, Administration Office Space, Manufacturing Total Factory Floor Space	No Change; current model reflects economics of lower densities
Water Service Facilities	Water Supply	Multiply current relationship by 21/S where S = shifts/week; assume no fixed components
Paving for Parking	Total Direct Personnel = D_1	$.85(\frac{D1}{C} + D2)*200$ for $\frac{S}{A}=1$
	Total Staff Personnel = D_2	$.85(\frac{2D1}{C} + D2)*200$ for $\frac{S}{A}>1$
		C = Number of crews
Site Lighting	Total Factory Floor Space	Change to depend on paving; site light = (paving)* factor

VARIABLE OPERATING SHIFT ANALYSIS
ACCOUNT A: INTERNAL BUILDING SPACE FACILITIES

Indirect Requirement	Determining Item	Change/Reason
Air Conditioning Facilities	Air Conditioning	No Change
Cafeteria and Lunchroom	Total Personnel	Change to depend on D1, D2, and C. $I=(D1+D2)*.60 * \begin{cases} 15 \text{ for } D<500 \\ 25 \text{ for } D\geq 500 \end{cases}$ Where D = D1 + D2
Compressed Air Facilities	Compressed Air	Multiply by 21/S
Electrical Equipment Room	Electricity	Multiply variable portion by 21/S; fixed portion unchanged
Heating Facilities	Heating	No Change; consumption is based on operating schedule
Mechanical Equipment Room	Total Direct Personnel Total Staff Personnel	Multiply current relationship by 21/S where S = shifts/week and divide direct by C
Office Space, Manufacturing	Total Direct Personnel	No Change; all supervisors have their own office in current model
Telephone Equipment Room	Telephone Service	No Change; room size is determined by number of phone lines, and the ratio remains the same
Toilet and Locker Room	Total Personnel	Change to depend on direct crews C; substitute $di=\begin{cases} \frac{D1}{C} \text{ for } i=1 \\ D2 \text{ for } i=2 \end{cases}$
Ventilation Facilities	Ventilated Room Space	No Change; ventilation consumption is based on operating schedule

VARIABLE OPERATING SHIFT ANALYSIS
ACCOUNT B: PERSONNEL

Indirect Requirement	Determining Item	Change/Reason
Guard (Security)	Total Factory Floor Space	No Change. This is a patrol model (24 Hours/day, 7 days/week), not a police model (breaking fights, catching thieves): independent of operating schedule
Janitor	Total Factory Floor Space	No Change; once per day cleaning; 5 days/week; one person per 25,000 feet
Maintenance	Total Factory Floor Space	No Change
Maintenance Foreman (Plant)	Groundskeeper Maintenance Man (Plant) Janitor	No Change; all determining items are tied to floor space and will change with operating schedule
Production Planner	Total Direct Personnel	One Planner per 200 direct; no change in number; does job differently
Assembly Foreman	Chassis Assembler Electronics Assembler Encapsulator General Assembler Module Assembler Semi-Conductor Assembler Wire Worker	Fractional people reflect change in costs, but no change in number required for different operating schedules. No change in ratio 1:12 or salary anticipated from specialization of labor
Chemical Process Foreman	Chemical Operator	No Change. Same reason for all of following foremen
Electronics Maintenance Foreman	Electronics Maintenance Electronics Technician	No Change
Machine Shop Foreman	Machine Shop Operator Welder	No Change
Materials Handling Foreman	Materials Handler Materials Clerk Forklift Truck Operator	No Change
Mechanical Maintenance Foreman	Maintenance Mechanic Maintenance Man	No Change

VARIABLE OPERATING SHIFT ANALYSIS
ACCOUNT B: PERSONNEL

Indirect Requirement	Determining Item	Change/Reason
Quality Control Foreman	Tester Systems Tester Components Inspector Systems	No change
Warehouse Foreman	Inventory Clerk Packager, Hand Packager, Machine	No change

VARIABLE OPERATING SHIFT ANALYSIS
ACCOUNT C: UTILITIES AND PLANT SERVICES

Indirect Requirement	Determining Item	Change Reason
Electricity	Total Factory Floor Space	No change
Telephone Service	Total Direct Personnel Total Staff Personnel	No change
Cafeteria Service	Total Direct Personnel Total Staff Personnel	No change
Power Supply	Electricity	No change
Water Supply	Domestic Water	No change
Air Conditioning	Total Factory Floor Space	No change
Heating	Total Factory Floor Space	No change
Ventilated Room Space	Total Factory Floor Space	No change

VARIABLE OPERATING SHIFT ANALYSIS
ACCOUNT D: BY PRODUCTS

Indirect Requirement	Determining Item	Change/Reason
Fumes	Total Factory Floor Space	No Change; assuming that non-process fumes are independent of personnel
Sewage Waste	Total Direct Personnel Total Staff Personnel	No Change; total waste is same for any operating schedule
Solid Waste	Total Direct Personnel Total Staff Personnel	No Change; total waste is same for any operating schedule

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT C

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

INDUSTRY DESCRIPTION

C1 Industry Referent SOLAR

C2 Description (Optional) SOLAR ARRAY MODULE MANUFACTURING INDUSTRY

INDUSTRY OBJECTIVE

C3 Industry Result NEW PHOTOVOLTAIC POWER CAPABILITY

C4 Quantity Produced .5E6, 15E6, 500E6 PEAK-WATTS/YEAR

DESCRIPTION OF THE FINAL PRODUCT OF THE INDUSTRY

C5 Reference PSAM Name PACKAGED SOLAR ARRAY MODULES

C6 Production is Measured in MODULES/YEAR

C7 Hardware Performance 160 PEAK-WATTS/MODULE (C4 per C6)

C8 Product Design Description (Optional) THE SOLAR ARRAY MODULES CONTAIN 224 CIRCULAR SILICON CELLS, 3 INCHES IN DIAMETER, WEIGHING 3.96 GM. THE MODULES ARE 14.6 SQUARE FEET AND 2 INCHES THICK.

MAKERS OF THE FINAL PRODUCT OF THE INDUSTRY

C9 Company Reference SAMCO Market Share 100%

Company Reference _____ Market Share _____

Company Reference _____ Market Share _____

Prepared by THEODORE BARRY & ASSOCIATES Date 2/22/79

JPL 8039-S 11/77

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT B

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

COMPANY DESCRIPTION

B1 Company Referent SAMCO

B2 Description (Optional) SOLAR ARRAY MODULE MANUFACTURING COMPANY. ITS FINAL PRODUCT IS PACKAGED SOLAR ARRAY MODULES, PSAM, MEASURED IN MODULES/YEAR. IT PURCHASES NO OTHER PRODUCTS FROM OTHER FIRMS IN THE MODEL INDUSTRY.

B3 Product Produced PSAM

B4 B5

		Process	PACKER
Intermediate Product	MODULE		
		Process	PASSEM
Intermediate Product	TSCT		
		Process	STRTES
Intermediate Product	STRING		
		Process	CONNEC
Intermediate Product	CCELLS		
		Process	ARCOAT
Intermediate Product	TCELLS		
		Process	CELTES
Intermediate Product	AGCELL		
		Process	AGFRNT
Intermediate Product	AGWAFR		
		Process	AGBACK
Intermediate Product	INWAFR		
		Process	INSPEC
Intermediate Product	LDWAFR		
Intermediate	DIWAFR	Process	LOADER
Intermediate Product	WFRBOT	Process	DIFUSE
Intermediate	IONWFR	Process	TRANS
Intermediate Product	CLNWFR	Process	IONIMP
		Process	CLEANR

B6 Purchased Product (NONE)

B7 Supplier Company Reference _____ Percent Supplied _____

Supplier Company Reference _____ Percent Supplied _____

Prepared by THEODORE BARRY & ASSOCIATES Date 2/22/79

JPL 3038-S 11/77

MATRIX CHANGES

- Land

The model currently determines the land area required from the total area of the building. The ratio varies from 3.8 for small buildings less than 11,318 square feet to 2.0 times the building size over 250,000 square feet.

However, this relationship is based on continuous operation, 345 days per year. For fewer operating shifts, a smaller portion of the land around the building is required for parking for a given building size, the amount of land required actually varies with the number of operating shifts. Thus, there are really three dependent variables in this relationship rather than just building size.

Indirect Item: I = Land (SQ FT)
Determined by: D_1 = Total Factory Space (SQ FT)
D_2 = Paving for Parking Lot (SQ FT)
D_3 = Paving for On Site Roads

$$I = 1.2 * D_1 + D_2 + D_3$$

- Fuel Oil Service Facilities

Fuel oil storage tank(s) should be sized for 15 days of full plant operation for use during natural gas supply interruption. The determining item in this relationship is the annual amount of fuel oil in cubic feet.

The model currently assumes the plant is operated for 345 days per year, and, thus, divides the annual amount by 345 to obtain the daily consumption rate.

To vary the operating schedule, the relationship should be changed to the following:

Indirect Item: I = Fuel Oil Service (CU FT)

Determined By: D = Fuel Oil (CU FT)
A = Number of Factory Operating Days per Week

$$I = \frac{(15)}{345} * \frac{(7)}{A} * D$$

Indirect Item: I = Sanitary Sewers (CFM)

Determined By: D = Sewage and Process Waste Disposal (CU FT)
S = Number of Production Shifts per Week

$$I = \left(\frac{3}{496800}\right) * \left(\frac{21}{S}\right) * D$$

- Water Service

The capacity of water service facilities is determined by the annual water supply required. The model currently assumes

$$496{,}800 \text{ minutes/year} = (345 \frac{\text{days}}{\text{year}}) * (24 \frac{\text{hours}}{\text{day}}) * (60 \frac{\text{minutes}}{\text{hour}})$$

to convert the annual amount to an average per minute. This is based on 21 shifts per week. For other operating schedules, this should be adjusted by S/21, where S is the number of shifts per week.

Indirect Item: I = Water Service Facilities (CFM)

Determined By: D = Water Supply (CU FT)

$$I = \left(\frac{1}{496{,}800}\right) * \left(\frac{21}{S}\right) * D$$

- Paving for Parking Lots

The amount of parking space required depends on the total number of personnel. However, there are differences in the requirements among personnel. These differences are related to the factory operating schedule.

Support staff personnel, such as accountants, system analysts, and personnel clerks, are assumed to work one and only one shift per day for five days per week.

Direct production staff are divided into equal crews for shift operations. The number of shifts per week (S), and the number of days per week (A).

- Natural Gas Service

At low levels of consumption, gas should be stored in tanks outside the building. Above 1,000,000 CU FT/YR, natural gas lines will be connected to the gas company lateral at the property line. The tanks should be sized in cubic feet to hold the amount of gas required for 15 days of plant operation.

The model currently assumes 345 days of operation per year. The relationship should be modified by the actual number of days per week.

Indirect Item: I = Natural Gas Service Facilities (CU FT)

Determined By: D = Natural Gas (CU FT)
A = Number of Factory Operating Days per Week

$$I = \frac{(15)}{345} * \frac{(7)}{A} * D \quad \text{for } D < 1{,}000{,}000$$

$$I = 0 \quad \text{for } D \geq 1{,}000{,}000$$

- Sanitary Sewers

Sewers carry sanitary effluent from the building line to a sewer lateral at the property line. Manholes are provided for clean-out when the distance exceeds 100 feet. The PVC pipe is sized in cubic feet per minute (CFM) for the calculated sewage flow and adjusted by 3 for peaking.

To convert the amount of waste per year to an average per operating minute, the model currently assumes

$$496{,}800 \text{ minutes/year} = (345 \frac{\text{days}}{\text{year}}) * (24 \frac{\text{hours}}{\text{day}}) * (60 \frac{\text{minutes}}{\text{hour}})$$

This is based on 21 shifts per week. The operating minutes per year for other schedules can be approximated by multiplying this function by S/21, where S is the number of shifts per week.

With 3 operating shifts per day and 7 days per week, 4 crews of direct personnel are required. The total parking area must accommodate both of the two largest groups.

Approximately 15% of the people can be expected to use car pools, public transportation, or some other means of getting to and from work. Thus, the total number of parking spaces required can be computed as follows (assuming a nominal area of 200 square feet per vehicle):

Indirect Item: I = Paving for Parking Lots (SQ FT)

Determined By: D_1 = Total Direct Personnel (PRSN*YRS)
D_2 = Total Support Personnel (PRSN*YRS)
C = Number of Production Personnel Crews
S = Number of Production Shifts/Week
A = Number of Factory Days/Week

$$I = .85*\left(\frac{D1}{C} * D_2\right) * 325 \text{ for } \frac{S}{A} \leq 1$$

$$I = .85*\left(\frac{2D1}{C} + D_2\right) * 325 \text{ for } \frac{S}{A} > 1$$

- Site Lighting

The model currently computes the amount of site lighting in dollars as a function of the total plant size.

However, for a given plant size the amount of lighting required will vary with the size of the parking lot, which in turn depends on the operating schedule. Thus, the amount of site lighting should be computed as a function of the parking lot size.

Indirect Item: I = Site Lighting (1977 dollars)

Determined By: D = Paving for Parking (SQ FT)

$$I = .400*D \text{ for } 0 \leq D \leq 50{,}000$$
$$I = 19445 + .001*D \text{ for } 50{,}000 < D \leq 500{,}000$$
$$I = .050*D \text{ for } 500{,}000 < D$$

- Cafeteria and Lunchroom

Cafeteria space is determined by the total number of personnel.

For plants with less than 500 employees, a vending machine cafeteria will be provided. This is typically a breakeven operation.

For plants employing 500 personnel or more, full cafeteria facilities are justifiable. The cafeteria service will be contracted out and subsidized.

The model currently assumes that:

- 60% of all personnel can be expected to use the facilities.
- the cafeteria must be large enough to accommodate all staff personnel users and one shift of direct personnel users.
- four shifts of direct personnel.
- the space required is 15 SQ FT per user for less than 500 personnel and 25 SQ FT for more than 500.

To allow for variable operating shifts, the total number of direct personnel should be divided by the number of crews.

Indirect Item: I = Cafeteria Space

D_1 = Total Direct Personnel

D_2 = Total Staff Personnel

C = Number of Production Personnel Crews

$I = (.60 * (D_{1/C} + D_2) * 15$ for $(D_1 + D_2) < 500$

$I = (.60 * (D_{1/C} + D_2) * 25$ for $(D_1 + D_2) \geq 500$

- Compressed Air Facilities

The capacity of compressed air facilities is determined by the annual amount of compressed air consumed. The capacity is expressed in cubic feet per year.

To convert the annual amount to an average flow rate per minute, the model currently assumes

$$496{,}800 \text{ minutes/year} = (345 \frac{\text{days}}{\text{year}})(24 \frac{\text{hours}}{\text{day}})(60 \frac{\text{minutes}}{\text{hour}})$$

This is based on 21 production shifts per week. For other operating schedules the relationship should be factored by S/21, where S is the number of production shifts per week.

Indirect Item: I = Compressed Air Facilities

Determined By: D = Compressed Air (CU FT/YR)
S = Number of Production Shifts per Week

$$I = \left(\frac{1}{496{,}800}\right) * \left(\frac{21}{S}\right) * D$$

- Electrical Equipment Room

The size of the electrical equipment room required is proportional to the total annual amount of electricity consumed.

The current model consists of fixed and variable portions. The variable portion should be factored by 21/S to allow for variable operating shifts.

Indirect Item: I = Electrical Equipment Room (SQ FT)

Determined By: D = Electricity (KW-HR/YR)
S = Number of Production Shifts per Week

$$I = 0.00 + (1.1250E\text{-}3) * \frac{21}{S} * D \text{ for } 0 \leq D \leq 200{,}000$$

$$I = 210.53 + (7.2368E\text{-}5) * \frac{21}{S} * D \text{ for}$$

$$200{,}000 < D \leq 4{,}000{,}000$$

$$I = 166.67 + (8.333E\text{-}5) * \left(\frac{21}{S}\right) * D$$

$$\text{for } 4{,}000{,}000 < D \leq 10{,}000{,}000$$

- Mechanical Equipment Room

The mechanical equipment room contains a boiler, hot water pump, chiller, cold water pump, air

compressor, and humidifiers. For large plants, a cooling tower is constructed on the roof. The amount of space required is determined by the maximum number of personnel present at any time.

The capacity of these facilities is directly proportional to the number of operating shifts per week. The model currently assumes 21 shifts per week. Consequently, the relationship should be factored by 21/S, where S is the number of shifts per week.

Indirect Item: I = Mechanical Equipment Room (SQ FT)

Determined By: D_1 = Total Direct Personnel (PRSN*YRS)
D_2 = Total Staff Personnel
S = Number of Production Shifts per Week
C = Number of Production Personnel Crews

$$I = \begin{cases} 0.0 + 16.00*\left(\frac{21}{S}\right)*D & \text{for } 0 \leq D < 25 \\ 225.0 + 7.00*\left(\frac{21}{S}\right)*D & \text{for } 25 \leq D < 75 \\ 705.9 + .588*\left(\frac{21}{S}\right)*D & \text{for } 75 \leq D < 500 \\ 625.0 + .750*\left(\frac{21}{S}\right)*D & \text{for } 500 \leq D \end{cases}$$

$$\text{Where } D = \left(\frac{D1}{C} + D_2\right)$$

- Toilet and Locker Room

Toilet and locker rooms include the facilities required for personal cleanliness and sanitation: lavatories, lockers, toilets, and washrooms. Restrooms, including toilet and lavatory facilities, should be located in areas free of heavy operational traffic, but centrally available to work areas to avoid excessive loss of time by employees from their assigned duties in traveling to and from the facilities.

In general, separate facilities should be provided for each sex and for each type of work being performed. It is normally not a good policy to mix production and office facilities. The quantity of facilities required can be determined from the maximum number of employees present at any time.

The current model should be changed to allow for variable operating shifts of direct personnel.

Indirect Item: I = Toilet and Locker Room (SQ FT)

Determined By: D_1 = Total Direct Personnel
D_2 = Total Staff Personnel
C = Number of Production Personnel Crews

$$I = \begin{cases} 0.00 + 33.330*di & \text{for } 0 \leq di < 15 \\ 312.50 + 12.500*di & \text{for } 15 \leq di < 35 \\ 330.00 + 12.000*di & \text{for } 35 \leq di < 110 \\ 783.75 + 7.875*di & \text{for } 110 \leq di < 190 \\ 435.10 + 9.710*di & \text{for } 190 \leq di \end{cases}$$

For i = 1,2 -- where $d_1 = D_{1/C}$ and $d_2 = D_2$

- Cafeteria Service

Cafeteria service is a utility expressed in PRSN*YRS to capture the cost of food served in the cafeteria.

The quantity required is determined by the total number of personnel. For plants with less than 500 employees, a vending machine cafeteria will be provided. This is typically a breakeven operation.

For plants employing 500 personnel or more, full cafeteria facilities are justifiable. The cafeteria service is assumed to be contracted out and subsidized.

In either case, the capital cost of the facilities is computed from the size of the cafeteria and lunchroom, which is a facilities account determined by total personnel.

The model currently assumes that 60% of all personnel use the cafeteria service.

Cafeteria Service (PRSN*YRS) = $.60 * (D_1 + D_2)$
Where D_1 = Total Direct Personnel
D_2 = Total Staff Personnel

The cost of this service is computed from the following price-quantity pairs in the cost account catalog.

Q PRSN*Yrs.	P 1977 $	Rate $/PRSN*YRS
249	0	$ .00
250	6985	$ 27.94
500	139750	$279.50

A survey of restaurant consultants indicated that there is not a significant difference in the subsidy required per person across different shifts. Also, the average cost per person is $1.25 per day, based on 1979 dollars. This is consistent with the current model, so that no change is required.

- Air Conditioning[1]

Air conditioning is a utility measured in KW-HR with zero cost in the catalog.

The quantity required is determined indirectly by the amount of factory floor space. The model currently uses the following relationship.

$$\text{Air conditioning (KW-HR)} = \frac{50 \text{ KW-HR/YR}}{\text{SQ FT}} * (\text{Floor Space})_{\text{SQ FT}}$$

Air conditioning has two indirect requirements: a facility to establish the initial capital cost and a utility to compute the annual operating expense. These are air conditioning facilities and electricity, respectively.

$$\text{Air Conditioning Facilities}_{\text{(Tons)}} = \frac{1.7 \text{ tons}}{\text{KW-HR/YR}} * (\text{Air Conditioning})_{\text{KW-HR/YR}}$$

$$\text{Electricity (KW-HR/YR)} = \text{Air Conditioning (KW-HR/YR)}$$

The capital cost of the facilities is computed with the following relation:

$$\text{Air Conditioning Facilities Cost}_{\text{(1977\$)}} = (\$860/\text{ton}) * (\text{Air Conditioning Facilities})_{\text{(Tons)}}$$

[1] The use of heating, ventilation, and air conditioning will be highly dependent on local weather conditions. The model assumes that the use of these utilities is independent of the number of shifts. This provides the most conservative (highest) estimate of cost, since the utility load will probably be less than fewer shifts.

- Heating[1]

  Heating is a utility measured in cubic feet per year with zero cost in the catalog. The energy required is estimated to be that required to maintain comfortable temperatures in the Springfield plant.

  The quantity required is determined indirectly by the amount of factory floor space. The model currently uses the following relationships.

  $$\text{Heating} = \frac{(1000 \text{ CU FT/YR})}{\text{SQ FT}} * \text{Floor Space (SQ FT)}$$

  Heating has two indirect requirements: a facility to establish the initial capital cost and a utility to compute the annual operating expense. These are heating facilities and electricity, respectively.

  $$\underset{\text{(BTU/HR)}}{\text{Heating Facilities}} = \frac{(1 \text{ BTU/CU FT})}{8280 \text{ HRS/YR}} \text{ Heating (CU FT/YR)}$$

  $$\underset{\text{(KW-HR/YR)}}{\text{Electricity}} = \frac{(5 \text{ KW-HR})}{100 \text{ CU FT/YR}} * \text{Heating (CU FT/YR)}$$

  The capital cost of the heating facilities is computed as follows:

  $$\underset{\text{(1977\$)}}{\text{Heating Facilities Cost}} = \left(\frac{\$850}{12{,}000 \text{ BTU/HR}}\right) * \underset{\text{(BTU/HR)}}{\text{(Heating Facilities)}}$$

- Room Space Ventilation[1]

  This is the normal requirement for ventilating a facility. It is not to be confused with process requirements for removal of fumes. Ventilation is a utility measured in cubic feet per year with zero cost in the catalog. The energy required is estimated to be that required to maintain adequate air flow in the plant.

  The quantity required (CU FT/YR) is determined by the amount of factory floor space (SQ FT). The model currently assumes the following relationship.

  $$\underset{\text{Space}}{\text{Ventilated Room}} = \frac{(1000 \text{ CU FT/YR})}{\text{SQ FT}} * \text{Floor Space (SQ FT)}$$

[1]See footnote on Page II-32.

Ventilation has two indirect requirements: a facility to establish the initial capital cost and a utility to compute the annual operating expense. These are ventilation facilities and electricity, respectively.

$$\text{Ventilation Facilities (CFM)} = \frac{1\ \text{YR}}{496{,}800\ \text{Minutes*}} * \text{Room Space Ventilation (CU FT/YR)}$$

$$\text{Electricity (KW-HR/YR)} = \frac{0.05\ \text{KW-HR}}{\text{CU FT}} * \text{Room Space Ventilation (CU FT/YR)}$$

The capital cost of the ventilation facilities is computed as follows:

$$\text{Ventilation Facilities Cost (1977\$)} = (\$2/\text{CFM}) * (\text{Ventilation Facilities (CFM)})$$

The ventilation flow rate per square foot of floor space is based on an average room height of 15 feet.

SUMMARY OF
INDIRECT REQUIREMENTS MATRIX CHANGES
FOR VARIABLE OPERATING SCHEDULE

Account A: Faciliites

• Land	SQ FT	Paving for Parking Lots Total Factory Floor Space
• Fuel Oil Service Facilities	GAL	Fuel Oil (GAL)
• Natural Gas Service	CU FT	Natural Gas (CU FT)
• Sanitary Sewers	CFM	Sewage and Waste Disposal (CU FT)
• Water Service	CFM	Water Supply (CU FT)
• Paving for Parking Lots	SQ FT	Total Direct Personnel Total Staff Personnel
• Site Lighting	$	Total Factory Floor Space
• Cafeteria and Lunchroom	SQ FT	Total Direct Personnel Total Staff Personnel
• Compressed Air Facilities	CFM	Compressed Air (CU FT)
• Electrical Equipment Room	SQ FT	Electricity (KW-HR)
• Mechanical Equipment Room	SQ FT	Total Direct Personnel Total Staff Personnel
• Toilet and Locker Room	SQ FT	Total Staff Personnel

Account B: Personnel

No Change

Account C: Utilities and Plant Services

• Cafeteria Service	PRSN*YRS	Total Staff Personnel Total Direct Personnel
• Air Conditioning	KW-HRS	Total Factory Floor Space
• Heating	CU FT	Total Factory Floor Space
• Ventilated Room Space	CU FT	Total Factory Floor Space
• Lighting	Lumens	Total Factory Floor Space

Account D: By-Products

No Change

Account E: Commodities

No Change

Account F: Resources

No Change

MANUFACTURING PROCESS MODEL

The manufacturing process model computes the number of machines required, based on the machine characteristics, the direct process requirements, the process yields, and the array performance factor. To do this, the model currently assumes:

496,800 operating minutes/year

this is equivalent to 345 days with 24 hours per day.

- Required Operating Minutes

  $R = Q/T$

  Where R = Required number of machine operating minutes to produce Q

  Q = Annual production quantity (units/year)

  T = Machine capacity (units/minute)

- Actual Operating Minutes

  $A = K*F*P$

  Where A = Actual number of minutes that one machine operates per year

  K = Number of plant operating minutes per year

  F = Process usage fraction

  P = Fraction of capacity at which the plant is operating

  The process usage fraction is the fraction of the time that the plant is operating that a particular machine would operate if at full capacity. This factor allows for set-up time, warm-up/cool-down time, cleaning, required and preventive maintenance.

- Plant Operating Minutes

  $K = NS*H*M*(D*W-E)$

  Where K = Number of plant operating minutes per year

NS = Number of plant operating shifts per day (either 1, 2, or 3)

H = Number of hours the company operates per shift (typically 8)

M = Number of minutes the company operates each hour (60)

D = Number of days the company operates per week (normally 5 or 7)

W = Number of weeks the company operates per year (normally 52)

E = Number of Plant holidays per year (may be none)

- Number of Machines

N = Actual number of machines needed to produce Q allowing for down-time

N = R/A (round up to integer)

Since it is usually impossible to purchase a fraction of a machine, N should be rounded up to the next larger integer. If the machine is available in many sizes, making small increments to capacity possible, then fractional numbers of machines would be conceivable, but machine prices per unit of output capacity would have to be roughly constant. Realistically, most companies would add the extra capacity for future expansion.

M = Ideal number of machines required if there were no down-time and no excess capacity

M = R/(NS*H*M*(D*W-E))

I = Number of idle machines

I = N - M

NUMBER OF DIRECT PERSONNEL

$$q = r * n * SM$$

where

q = number of direct personnel of a particular type required

r = input number of persons of this type required directly per shift

n = actual number of machines required to produce Q (before rounding up to an integer)

N = R/A

SM = Shift Multiplier expressed in persons required per person shift required

$$SM = (NS*H*(D*W-E))/(FN*NS*h*(d*W-e-v-a))$$

where

S, NS, H, D, W, and E were defined above

FW = Company working minutes per hour and divided by personnel working minutes per hour (normally 1.0)

WS = Persons per working day (normally 1.0)

h = Person working hours per shift (normally h = H = 8)

d = Personnel working days per working week (normally 5, perhaps 4 or 6)

w = Personnel working weeks per year (normally 52)

e = Paid personnel holidays per year (typically 6 to 10)

V = Paid personnel vacation days per year

a = Paid absenteeism days per year primarily for sick leave

For round-the-clock operation 24 hours per day for 345 days per year, the model currently uses the following standard values for these parameters:

NS = 3 shifts/day	h = 8 hours/shift
H = 8 hours/shift	d = 5 days/week
D = 7 days/week	w = 52 weeks/year
W = 52 1/7 weeks/year	e = 8 days/year
E = 20 days/year	v = 13.5 days/year
	a = 19.0 days/year

Based on these values, the shift multiplier SM is 4.7 persons required per person shift required.

SM = 4.7 persons/person shift

These variables are related to the shift parameters as follows:

S = Number of production shifts that are operated each week
S = NS*D
A = Number factory operating days per week
A = D
C = Number of production personnel crews

C is determined by entering Table #1 on page II-16 (the Production Crew Function) with

$\frac{S}{A} = NS$

D - METRIC SYSTEM UNITS CONVERSION

During Phase III of the SAMICS Support Study, the data contained in the first version of the cost account catalog was completely converted to the metric system units of measure and expanded to encompass all promising manufacturing processes associated with the JPL Technology Development Tasks.

Now, for the computer program to use the new catalog, the matrix must also be expressed in metric units.

The matrix listed in Appendix D is the new recommended matrix which is consistent with the original Phase I matrix and compatible with the Phase III catalog. It is compatible in the sense that the units of measure are metric and the catalog numbers are the same as those used in the new Phase III matrix.

Table #2 contains the metric conversion factors.

The matrix has been entered on a computer data file and combined with the Phase III Cost Account catalog.

TABLE 2
METRIC CONVERSION TABLE

1 atmosphere	= 1.01×10^5 newtons per square meter
1 BTU	= 1055.87 joules
1 calorie	= 3.9683 BTU
1 cubic centimeter	= .061025 cubic inches
1 cubic meter	= 35.3156 cubic feet
1 gram	= .03527 ounces
1 kilogram	= 1000 grams
1 kilogram	= 2.2046 pounds
1 kilowatt	= 1.3405 horsepower
1 kilowatt hour	= 3.6×10^6 joules
1 liter	= .26418 U.S. gallons
1 meter	= 100 centimeters
1 meter	= 3.2809 feet
1 centimeter	= .3937 inches
1 metric ton	= 1.1023 tons
1 metric ton	= 1000 kilograms
1 newton/square meter	= .000145 PSIA
1 square meter	= 10.76410 square feet
1 thermal ton	= 1160 kilowatt hours

VOLUME III

PHASE III

COST ACCOUNT CATALOG

Table of Contents

A - INTRODUCTION

This section documents revisions and corrections that have been made to the Phase II Cost Account Catalog. The catalog contains standard prices (as functions of annual quantities) and inflation rates for all facilities, personnel, utilities, plant services, commodities, and by-products.

Following are the changes that were made to the catalog as a result of the reorganization during the Phase II SAMICS Support Study.

- The direct requirements were separated from the indirect requirements in each account.
- The commodity items were reorganized into a 4-level functional classification.
- The prices versus quantity relationships were reviewed and updated as necessary for all items.
- The units of measure were converted to the metric system for all quantities.
- All items within a given account were arranged alphabetically.
- The number of items and the scope of the catalog were expanded to include the manufacturing requirements for all of the JPL project task groups.
- The facilities capital cost estimating relationships were incorporated in Account A of the catalog.
- The catalog was renumbered.

Appendix A lists the JPL reference document numbers for both the Phase I and Phase II catalogs.

During Phase III, additional changes have been made to the catalog. These changes fall into three categories:

- Format Changes: The format, item descriptions, catalog numbers have been restructured to make the catalog easier to use.

- Validation Corrections: New items, catalog prices and indirect requirement relationships have been corrected or added as a result of the SAMIS computer program validation.

- Data Extensions: New items supplied by JPL and SAMICS users have been added and many of the price versus quantity relationships have been updated.

The following paragraphs describe these recent changes to the Phase II Cost Account Catalog. The revised Phase III catalog is stored in a computer file, the format of which is also described below.

B - CATALOG REVISIONS

FORMAT CHANGES

To make the Phase II Catalog and indirect requirements relationships easier to use, the computer data file, referred to as the "Phase III Cost Account Catalog", was revised as follows:

1. The descriptive names of catalog items have been modified so that the generic noun (or noun phrase, as in "FLOOR SPACE") appears first and descriptive adjectives, in order of increasing specificity and separated by commas, follow. (For example, "OTHER FLASH TANK" was changed to "TANK, FLASH, OTHER".) In addition, the names of some items have been changed to make them more meaningful or more easily understood. For example, "MANUFACTURING SPACE (TYPE A)" has been changed to MANUFACTURING SPACE, TYPE A, TYPICAL PRODUCTION ROOM and "VENTILATION" to "VENTILATED ROOM SPACE".

2. Generic identifications have been added to the descriptive names of those items which did contain sufficient generic information in the Phase II Cost Account Catalog. For example, one of the two items named "XT-375" was changed to "Acrylic Sheet, XT-375". The resulting names conform with the style defined in (1.) above.

3. The catalog has been sorted, first by account (the first character of the item referent), then alphabetically by the revised descriptive names. Referents, (catalog numbers) have been reassigned, whenever possible, to correspond to the referents in the Phase I Cost Account Catalog. However, the following suffixed alphabetic character has been dropped.

   D = Direct Requirement
   I = Indirect Requirement
   B = Both Direct and Indirect

4. Personnel in Account B have been divided into direct and indirect and sorted separately. Personnel which were labeled "B" for both Direct and Indirect were placed in both groups with similar descriptive names. For example, "Chemical Engineer" has been changed to "Chemical Engineer, Indirect Staff" and "Chemical Engineer".

   The new referent numbers for these items are listed below under "DATA EXTENSIONS".

5. For those items that may result in the production of potential pollutants, a parenthetical list of pollutant referents has been added to the descriptive name. All of the potential pollutants are contained in Account D: By-Products.

6. To make the catalog easier to use by those who are unfamiliar with the metric system, conversion factors have been included in the new catalog. The FPS-Metric conversion formula appears for each item. For example, the descriptive name for "LAND" has been changed to "LAND; 0.09290*FT**2 = M**2". These conversion factors have been expressed to at least four significant digits.

7. Each catalog item's references to indirect requirements have been changed to correspond to the new catalog numbers described in (3.) above.

8. The asterisks which terminate the inflation rate tables were replaced with inflation class code characters. The codes are defined below.

Class Code	Class Description	Inflation Rate
A	Raw Materials	7.0%
B	Labor	7.5%
C	Industrial Chemicals	5.5%
D	Commodities	5.5%
E	Energy	8.0%
F	Natural Resources	9.0%
G	Land	4.0%
H	Facilities	8.0%
I	Construction	8.0%
J	Equipment	6.0%

Not all facilities have an 8% inflation rate. Most facilities that were added to the Phase II Catalog, such as Distillation Columns, have a 5.5% rate.

This updated version of the cost account catalog was combined with the indirect requirement matrix file to form the expense data file in a format acceptable to the SAMIS computer program.

The Phase III Cost Account Catalog contains the following information:

- Reference Numbers with an Alpha Prefix indicating the following accounts:
  - A. Facilities
  - B. Personnel
    1. Direct Personnel
    2. Indirect Personnel
  - C. Utilities and Plant Services
  - D. By-Products
  - E. Commodities
  - F. Resources
- Description
  - Name
  - Pollutant Referents
  - FPS--Metric Conversion Formula

- Metric System Units of Measure
- Inflation Rate Table
- Inflation Class Code
- N Price -- Quantity Pairs

  Q_1 Q_2 Q_3 . . . QN
  P_1 P_2 P_3 . . . PN

- M Indirect Requirements
  - Referent
  - R Quantity -- Quantity Pairs

    I_1 I_2 I_3 . . . IR
    D_1 D_2 D_3 . . . DR

VALIDATION CORRECTIONS

1. New facilities items:

   Forklift trucks, at a cost of $20,000/truck.
   Determining item - - Warehouse Space.

Warehouse Space (SQ FT)	# Trucks
499	0
500	.05
10,000	1
160,000	12

   No separate requirement for shipping & receiving dock.

   Assumptions:

   Truck activity rate = 200 sec/move/pallet
   Pallet Size = 48" x 48"
   Operating Schedule = 345 days/yr - 24 hrs/day
   Availability = 80%

   1 move = Time to reach load and time to reach dumping site + loading time + unloading time.

   # Forklift truck operators: Input to model.

Computer:

Total Personnel	Computer ($)
24	$ 0
25	250
250	62,500
1000	180,000
2500	300,000

Scrubber: Will be a direct requirement.

2. Modified Facility Items:

Industrial Waste Clarifiers (Gallons)
Capital costs changed to:

Q_1	Q_2	Q_3
29,000	110,250	3,000,000
P_1	P_2	P_3
1,000	4,500	20,000

Land (SQ FT):
Determinants changed to

(i) Total Factory Floor Space	1.2	SQ FT/SQ FT
(ii) Parking Lots	1	SQ FT/SQ FT
(iii) Paving for Roads	1	SQ FT/SQ FT

Other facilities requiring land are implicit in the 20% allowance in Total Factory Floor Space.

Landscaping & Irrigation:
Determinant changed to

Total Factory Floor Space 0.2 SQ FT/SQ FT

Passage & Corridors
Requirements changed to

Office Space, Administration	- 30%
Office Space, Manufacturing	- 25%
Plant Manufacturing Space	- 20%

Plant Maintenance Shop:
Maximum size set at 50,000 sq. ft. for 300 or more maintenance personnel.

Quality Control Laboratory:
Maximum size set at 8,000 sq. ft. for 200 or more quality control personnel. 60% of quality control personnel are on the production floor and do not require laboratory space.

Industrial Waste Clarifiers;
Determinant changed to

Solvent & Chemical Storage (D)

	D_1	D_2	D_3
gallons	29,000	110,250	3,000,000
sq. ft.	100	200	800

	I_1	I_2	I_3

3. Modified Personnel Items:

Groundskeeper:
Determining item changed to

Landscaping & Irrigation--1 groundskeeper/150,000 sq. ft.

4. Modified Utilities Items:

Electricity:

Determining items changed to:

- Total Factory Floor Space
- Heating
- Ventilated Room Volume

- Paving for Parking
- Cooling Water
- Compressed Air

Air Conditioning:
Determinant changed to:

- Total Factory Floor Space

Room Space Ventilation
Determining Items changed to

Total Factory Floor Space 7762.5 CU FT/YR/SQ FT

Fumes 3 CU FT/YR/CU FT

Heating (CU FT/YR):
Determining item changed to

Factory Floor Space 1000 CU FT/YR per SQ FT

5. Modified Resource Items

Silicon:
Determining items changed to

Polycrystalline Silicon (all grades) 1 kg/kg
Silicon, Metallurgical grade 1 kg/kg
Silicon Ribbon 1 kg/kg
Solar Cells .22 kg/sq. m.
Solar Wafers .22 kg/sq. m.
Reject Cells -.22 kg/sq. m.
Rejected Wafers -.22 kg/sq. m.

4. UTILITIES

REFERENT	ITEM DESCRIPTION
C2172	Outside Engineering Services

5. BY PRODUCTS

REFERENT	ITEM DESCRIPTION
D1192	Used Lubricant
D1224	Reusable Polysilicon
D1240	Miscellaneous By Product Chemicals

6. COMMODITIES

The following numbers were assigned to different grades of Polycrystalline Silicon. The prices varied from $10 to $75 per kg, in steps of $5.

E1586, E5128, E5144, E5160, E5176, E5192, E5208, E5224, E5240, E5256, E5272, E5288, E5304, E5320.

REFERENT	ITEM DESCRIPTION
E6000	Silica Spin On
E6016	Silicon Dopaut
E6032	Shellac, Clear Spray
E6048	Epory Paste
E6064	Graphite Beam Mount
E6080	Collant Rust Lick
E6096	Blade Dressing 1X1X6 Alumina Sticks
E6112	Blade Dressing 1/2X1/2X6 Alumina Sticks
E618	Tensioning Fluid
E6144	Purified Polysilicon
E6160	Thinner
E6176	Diffusion Source
E6192	MEK
E6208	Silicon Seed Crystal
E6224	Pre-Assembled Pan
E6240	Caston
E6256	Terminal Bus Wire
E6272	PVC Coated Fiber Glass Screen
E6288	Miscellaneous Panel Material

E6304	Terminal Block Sets
E6320	Frame Material
E6336	MOO_3/Tin Paste
E6352	Polycrystalline Wafers
E6368	Polycrystalline Wafers
E6352	Polycrystalline Wafers
E6400	Ceramic Block
E6416	Aluminium Powder Suspension
E6432	High Tension Wire
E6448	Multiwax
E6464	Micarta 30 mil.
E6480	Micarta 62 mil.
E6496	Expendable Paper Belt
E6512	Palladium Paper Belt
E6528	Sealing Glass
E6544	Copper Foil Interconnects
E6560	Boron Trifluoride
E6576	Tetrafluoromethane
E6592	EFG Dies
E6608	EFG Insulation Material
E6624	EFG Heating Element
E6640	EFG Cartridge Material
E6656	Aluminium Paste
E6672	Dichlorosilane
E6688	Texture etch
E6704	Vacuum Pump Oil
E7000	Metal Paste

C - FILE DESCRIPTION

This section describes the format of the Phase III Cost Account Catalog data file. The file was created by combining the updated catalog with the new recommended indirect requirements matrix. The matrix data is presented in Appendix D. The file format is acceptable to the SAMICS III Computer Program.

The combined catalog/matrix data base has been entered on the NCSS computer via a terminal and stored on a disc under the title "Expense Data". The information on each entry is stored on two consecutive lines with format shown in Exhibit III-1.

```
* A2048
 HEALTH SERVICE FACILITIES; .09290*FT**2=M**2
 M**2
       1977
  1977.0000      8.0000  H
  14.00       0.5775E+04   18.50       0.7000E+04   28.00       0.9240E+04
  47.00       0.1400E+05  *
  A3048
  1.000        1.000       *
     1.00000
  *
* A4416
 HEATER, 4.16 M**2, CS/CS; .09290*FT**2=M**2
 HEATER
       1977
  1977.0000      5.5000  D
  10.00       0.1300E+05  *
  *
* A4400
 HEATER, 2.8 M**2 1723500 N/M**2  SHELL, SS/SS; 6894.7572*PSI=N/M**2
 HEATER
       1977
  1977.0000      5.5000  D
  10.00       0.2300E+05  *
  *
* A4424
 HEATER, OTHER
 DOLLARS
       1978
  1978.0000      5.5000  D
  1.000        1.000       *
  *
* A2056
 HEATING FACILITIES; 1055.87*BTU=J
 J
       1977
  1977.0000      8.0000  H
 0.1270E+08   850.0       *
  *
* A2192
 LABORATORY, QUALITY CONTROL; .09290*FT**2=M**2
 M**2
       1977
  1977.0000      8.0000  H
  14.00       0.3875E+04   28.00       0.7050E+04   70.00       1.7025E+04
  140.0       0.3375E+05  *
  A3048
  1.000        1.000       *
     1.00000
  *
* A1080
 LAND; .09290*FT**2=M**2
 M**2
       1977
  1977.0000      4.0000  G
 0.4045E+04 0.1899E+05  0.0095E+04 0.3746E+05  0.2024E+05 0.9191E+05
 0.4047E+05 0.1506E+06  0.2023E+06 0.6991E+06  *
```

1. PROJECT BACKGROUND

The Jet Propulsion Laboratory (JPL) is managing the Low-Cost Solar Array (LSA) Project, funded by the Department of Energy (DOE), to develop and transfer to industry lower cost processes for the manufacture of flat-plate photovoltaic solar modules. JPL has contracted the technology research and development to over 80 universities and commercial firms.

Prior to the development and implementation of the Solar Array Manufacturing Industry Costing Standards (SAMICS), the subcontractors' cost estimates were not comparable because of differences in accounting standards, economic assumptions, and financial parameters, and because processes had not been considered in the context of an integrated process sequence in a factory environment.

Consequently, the development of SAMICS is an important part of the LSA project. These standards unify economic and financial accounting assumptions providing comparable cost estimates for the alternative manufacturing technologies under development by the subcontractors.

The costing standards have been formulated as a mathematical model to simulate the design and operation of a hypothetical solar factory. To facilitate the use of this rather complex model, a computer simulation program called SAMIS (Solar Array Manufacturing Industry Simulation) has been written. Given a proper description of the manufacturing technology as input, the program computes the manufacturing price for solar arrays over a broad range of production levels.

2. SUPPORT STUDY WORK

Theodore Barry & Associates (TB&A), a management consulting firm, has been contracted to support the development and implementation of the SAMIS program. This support study work has been performed in three phases.

Phase I involved critiquing the model, collecting cost account catalog data, developing the indirect requirements matrix, and formulating the facilities capital cost estimating relationships.

The critique of the SAMICS model was documented separately during the initial stage of the Phase I study. The other support study results are documented in a 3-volume report:

Volume I contains the COST ACCOUNT CATALOG. This standard data base includes prices and inflation rates for all exogenous inputs to the SAMICS model. The inputs which will describe the manufacturing processes and factory requirements are divided into six categories: facilities, personnel, utilities, by-products, commodities, and resources.

Volume II presents several SUBMODEL ANALYSES, including the indirect requirement relationships, facilities capital cost estimating relationships, standard financial parameter values, and a model for estimating one-time costs. The one-time cost model refers to the construction and production start-up phases and includes procedures for estimating construction lead time and production start-up time.

The user of the SAMICS model describes the direct requirements of the manufacturing processes by specifying the quantities of facilities, personnel, utilities, commodities, by-products, and equipment from the cost account catalog. However, factory operations require more staff, facilities, and supplies than those directly required to operate the machines. These items are generally needed to operate any manufacturing plant and are generated by the SAMICS model, using the indirect requirement relationships, which constitute a standardized factory design.

Volume III contains CONCEPTUAL PLANT DESIGNS and the corresponding Solar Array price estimates for three alternative levels of production: .50, 15, and 500 megawatts per year by 1980, 1982, and 1986, respectively. The plant designs are based on an ion implantation process sequence, which starts with silicon wafers and ends with packaged solar modules.

The work performed during the Phase III study focused on three areas:

- Cost Account Catalog
- Marketing Model
- Distribution Model

The data contained in the first version of the Cost Account Catalog was completely converted to metric system units of measure and expanded to encompass all promising manufacturing processes associated with JPL's Technology Development Tasks.

The Marketing Model estimates selling expenses and the size of the sales force required as a function of the demand. The model does not attempt to forecast demand; rather, it is assumed to be known. The country is divided into seven marketing regions with up to three types of customers in each region. Marketing costs vary with the type of customer as well as the annual production level, reflecting the fact that residential installations, for example, imply different sales requirements than commercial power generating plants.

The Distribution Model computes the cost of transporting, warehousing, and delivering solar arrays from the manufacturer to the customer. The factory location and demand distribution are specified as inputs; the number and size of regional warehouses and the modes of transportation are determined by an optimization algorithm.

This volume of the Phase III study documents the SAMIS III computer program validation. To do this, the program was run for three test cases corresponding to the Phase I Conceptual Plant Designs. The results are compared with the manual computations performed during the Phase I study and the differences are reconciled. Adjustments in the cost account catalog, the indirect requirements matrix and the facilities capital cost estimating relationships are recommended.

Other Phase III work involved critiquing the computer program output reports, recommending improvements in format and content for easier interpretation of the results by the general industrial audience as well as the JPL technology development subcontractors. The indirect requirements matrix is updated and converted to metric system units of measure in Volume II. Volume III documents revisions and corrections that have been made for the new Phase III Cost Account Catalog. The changes include both validation implied corrections and JPL supplied extensions. Listed below JPL reference document numbers for the Phase I and Phase II support study reports by Theodore Barry & Associates.

3. REFERENCES

Theodore Barry & Associates (TB&A), A Critical Review of the Solar Array Manufacturing Industry Costing Standards, ERDA/JPL-954800/1, July 1977.

Theodore Barry & Associates (TB&A), Phase I SAMICS Support Study Final Report, ERDA/JPL-954800/2, September 1977.

Volume I: Cost Account Catalog
Volume II: Submodel Analyses
Volume III: Conceptual Plant Designs

Theodore Barry & Associates (TB&A), Phase II SAMICS Support Study Final Report, SAMICS Cost Account Catalog, DOE/JPL 954909-78/1, April 1978.

Theodore Barry & Associates (TB&A), Phase II SAMICS Support Study Final Report, SAMICS Marketing & Distribution Model, DOE/JPL 954909-78/2, January 1979.

This appendix contains the input data for the SAMIS computer program validation. The data describes:

- Format C: Structure of the Modeled Industry
- Format B: Input, Output, and Intermediate Products of the Modeled Company
- Format A: Manufacturing Processes of the Modeled Factory
- Financial Parameter Values

The manufacturing technology as described by the set of FORMAT A's is the major input required to estimate the solar module prices. These inputs include the economically important machine operating and cost parameters, and the direct process requirements.

The manufacturing process sequence described here consists of 14 steps. The sequence starts with silicon wafers and ends with packaged solar array modules, using the ion implantation step to form the junction. The automated assembly equipment is designed for high volume production.

The same input data was used to generate solar array costs for three levels of production: .50, 15, and 500 Megawatts per year.

COMPUTER INPUT DATA OUTLINE

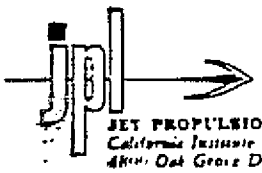
FORMAT C: Industry Descriptions
FORMAT B: Company Description
FORMAT A: Process Description

1. CLEANR — System "Z" Wafer Cleaning
2. IONIMP — ION Implantation: 2 sides
3. TRANS — Transportation: Wafer Boats
4. DIFUSE — Diffusion
5. LOADER — Transfer: Wafer Loader/Flipper
6. INSPEC — Post Diffusion Inspection
7. AGBACK — Silver Metalization: Back
8. AGFRNT — Silver Metalization: Front
9. CELTES — Cell Test
10. ARCOAT — Anti-Reflective Coating
11. CONNEC — Interconnect: GAP Welding
12. STRTES — String Test
13. PASSEM — Double Glass Panel Assembly
14. PACKER — Array Module Packaging

Financial Parameter Values

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A



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PROCESS DESCRIPTION

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

A1 Process [Referent] CLEANR

A2 [Descriptive Name] SYSTEM Z WAFER CLEANING: WAFERS CLEANED IN A SULFURIC ACID/HYDROGEN PEROXIDE MIXTURE

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] CLNWFR

A4 Descriptive Name [Product Name] CLEANED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 125 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 8.0 Calendar Minutes (Used only to compute In-process Inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .8075 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	SYSTEM Z		
A9x	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	45,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	-0-		
A14	[Removal and Installation Cost] ($/Component)	-0-		

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, (19 6.0), DDB, and SL.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) CLEANP

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
A2064D	200	SQ. FT.	MANUFACTURING SPACE (TYPE A)
B3672D	.7278	PRSN/SHIFT	CHEMICAL OPERATOR
B3736D	.0434	PRSN/SHIFT	MAINTENANCE MECHANIC
B5080D	.0364	PRSN/SHIFT	CHEMICAL ENGINEER
B3624D	.2043	PRSN/SHIFT	MATERIAL HANDLER
B3608D	.0688	PRSN/SHIFT	MATERIAL CLERK
B3752D	.01	PRSN/SHIFT	MACHINE SHOP OPERATOR

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
D1048B	4.455	GAL.	POLLUTED WATER
E1640D	.0644	LBS.	SULFURIC ACID
E1336D	.0575	LBS.	HYDROGEN PEROXIDE
C1032B	.5838	KW-HR.	ELECTRICITY
C1144D	.56	CU. FT.	DEIONIZED WATER
E1590D	133.226	WAFERS	WAFERS, SINGLE CRYSTAL SILICON
D1016B	360	CU. FT.	FUMES
D1032B	.067	GAL.	POISONOUS ACID
D1064D	1.684	WAFERS	REJECTED WAFERS

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
NONE			1	
			1	
			1	

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

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A

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PROCESS DESCRIPTION

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

A1 Process [Referent] IONIMP

A2 [Descriptive Name] ION IMPLANTATION: A DOUBLE IMPLANTER IS USED TO IMPLANT THE FRONT SIDE OF ONE WAFER AND THE BACK OF ANOTHER

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] IONWFR

A4 Descriptive Name [Product Name] IONIZED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 33.333 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1.0 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] 0.85 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	IONIMP		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	700,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) IONIMP

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
A2064D	850	SQ. FT.	MANUFACTURING SPACE (TYPE A)
B3096D	0.312	PRSN/SHIFT	SEMICONDUCTOR ASSEMBLER
B3736D	.0867	PRSN/SHIFT	MAINTENANCE MECHANIC
B3752D	.02	PRSN/SHIFT	MACHINE SHOP OPERATOR

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
C1032B	.667	KW-HR	ELECTRICITY
C1080D	.006	CU.FT.	LIQUID NITROGEN
C1128D	.0107	KW-HR	COOLING WATER
E1280D	.0008	UNITS	FILAMENTS/INSULATORS
E1112D	.274	CU.FT.	ARGON GAS
D1064D	.45	WAFERS	REJECTED WAFERS
D1080I	.033	GAL.	SEWAGE WASTE

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
CLNWFR	99	1.0	WAFERS/WAFER	CLEANED WAFERS
			/	
			/	

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

FORMAT A

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PROCESS DESCRIPTION

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

A1 Process [Referent] TRANS

A2 [Descriptive Name] WAFERS ARE PLACED IN 12" SILICON BOATS TO BE CARRIED TO THE DIFFUSION PROCESS

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] WFRBOT

A4 Descriptive Name [Product Name] WAFERS IN 12" SILICON BOATS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6	[Output Rate] (Not Thruput)	0.6	Units (given on line A5) Per Operating Minute
A7	Average Time at Station [Processing Time]	.943	Calendar Minutes (Used only to compute in-process inventory)
A8	Machine "Up" Time Fraction [Usage Fraction]	.94	Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	BOATS		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	500		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) TRANS

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
B3624D	.00047	PRSN/SHIFT	MATERIAL HANDLER
B3608D	.00016	PRSN/SHIFT	MATERIAL CLERK

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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

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
IONWFR	100	1.0	WAFERS /WAFER	IONIZED WAFERS
			/	
			/	

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

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A

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PROCESS DESCRIPTION

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

A1 Process [Referent] LIFUSE

A2 [Descriptive Name] DIFFUSION: DOPANTS ARE DRIVEN INTO THE WAFERS BY HEAT TREATMENT IN A FURNACE

PART 1 -- PRODUCT DESCRIPTION

A3 [Product Referent] DIWAFER

A4 Descriptive Name [Product Name] DIFFUSED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 -- PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 150 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1.00 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .95 Operating Minutes Per Minute

PART 3 -- EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	LINDBERG		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	72,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A · Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) DIFUSE

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
A2064D	800	SQ.FT.	MANUFACTURING SPACE (TYPE A)
B3096D	.78	PRSN/SHIFT	SEMICONDUCTOR ASSEMBLER
B3736D	.087	PRSN/SHIFT	MAINTENANCE MECHANIC
B3752D	.02	PRSN/SHIFT	MACHINE SHOP OPERATOR

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
C1032B	1.667	KW-HR	ELECTRICITY
C1128D	.222	KW-HR	COOLING WATER
C2096B	.0059	KW-HR	AIRCONDITIONING
E1416	.027	CU.FT.	NITROGEN GAS
D1064D	2.021	WAFERS	REJECTED WAFERS

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
WFRBOT	99	1.0	WAFERS / WAFER	WAFERS IN 12" SILICON BOATS
			/	
			/	

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

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PROCESS DESCRIPTION

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

A1 Process [Referent] LOADER

A2 [Descriptive Name] LOADER-FLIPPER TRANSFER OF DIFFUSED WAFERS INTO WAFER CASSETTES

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] LDWAFR

A4 Descriptive Name [Product Name] LOADED DIFFUSED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 50 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1.0 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .95 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	FLIPPER		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	20,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	-0-		
A14	[Removal and Installation Cost] ($/Component)	-0-		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) LOADER

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
B3736D	.029	PRSN/SHIFT	MAINTENANCE MECHANIC
B3752D	.0067	PRSN/SHIFT	MACHINE SHOP OPERATOR

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

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
DIWAFR	100	1.0	WAFERS/WAFER	DIFFUSED WAFERS

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

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PROCESS DESCRIPTION

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

A1 Process [Referent] INSPEC

A2 [Descriptive Name] POST DIFFUSION INSPECTION: WAFERS ARE INSPECTED BY MEASURING RESISTIVITY WITH A 4-POINT PROBE

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] INWAFR

A4 Descriptive Name [Product Name] INSPECTED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 24,167 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 20.5 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .8 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	SORTPROBE		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	150,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) INSPEC

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
A2064D	200	SQ.FT.	MANUFACTURING SPACE (TYPE A)
B3768D	.214	PRSN/SHIFT	ELECTRONICS COMPONENTS TESTER
B3688D	.171	PRSN/SHIFT	ELECTRONICS MAINTENANCE MAN

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
C1032B	.08333	KW-HR	ELECTRICITY
D1064D	.326	WAFERS	REJECTED WAFERS

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
LDWAFER	99	1.0	WAFERS/WAFER	LOADED DIFFUSED WAFERS

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

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A

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PROCESS DESCRIPTION

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

A1 Process [Referent] AGBACK

A2 [Descriptive Name] THICK AG METALIZATION —BACK: A SCREEN PRINTING AND FIRING SYSTEM SINTERS A CONDUCTIVE NETWORK ON THE BACKS OF WAFERS

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] AGWAFR

A4 Descriptive Name [Product Name] BACK METALIZED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 30 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .8 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	PRINTFIRE		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	265,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) AGBACK

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
A2064D	1616	SQ. FT.	MANUFACTURING SPACE (TYPE A)
B3096D	.156	PRSN/SHIFT	SEMICONDUCTOR ASSEMBLER
B3736D	.174	PRSN/SHIFT	MAINTENANCE MECHANIC
B3688D	.0085	PRSN/SHIFT	ELECTRONICS MAINTENANCE MAN
B3752D	.04	PRSN/SHIFT	MACHINE SHOP OPERATOR

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
D1080I	.00086	GAL.	SEWAGE WASTE
D1096B	.0043	LBS.	SOLID WASTE
E1128D	.0084	LBS.	INK SOLVENT
E1064D	2.25	GRAMS	SILVER INK PASTE
E1696D	.0182	DOLLARS	THERMOCOUPLE
E1576D	.0014	SCREENS	SCREENS
E1624D	.0168	SQUEEGEES	SQUEEGEES
C1032B	.485	KW-HR	ELECTRICITY
D1064D	.4043	WAFERS	REJECTED WAFERS

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
INWAFR	99	1.0	WAFERS / WAFER	INSPECTED WAFERS
			/	
			/	

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

FORMAT A

PROCESS DESCRIPTION

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

A1 Process [Referent] AGFRNT

A2 [Descriptive Name] THICK AG METALIZATION — FRONT: A SCREEN PRINTING AND FIRING SYSTEM SINTERS A CONDUCTIVE NETWORK ON THE WAFER FRONTS

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] AGCELL

A4 Descriptive Name [Product Name] BACK AND FRONT METALIZED WAFERS

A5 Unit Of Measure [Product Units] WAFERS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 30 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1.0 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .79 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	PRINTDRYR	PRINTFIRE	
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977	1977	
A11	Purchase Price ($ Per Component) [Purchase Cost]	190,000	265,000	
A12	Anticipated Useful Life (Years) [Useful Life]	10	10	
A13	[Salvage Value] ($ Per Component)	0	0	
A14	[Removal and Installation Cost] ($/Component)	0	0	

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) AGFRNT

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
A2064D	3232	SQ. FT.	MANUFACTURING SPACE (TYPE A)
B3064D	.3396	PRSN/SHIFT	SEMICONDUCTOR ASSEMBLER
B3688D	.0085	PRSN/SHIFT	ELECTRONICS MAINTENANCE STORE
B3736D	.1735	PRSN/SHIFT	MAINTENANCE MECHANIC
B3752D	.0401	PRSN/SHIFT	MACHINE SHOP OPERATOR

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
D1096D	.0043	LBS.	SOLID WASTE
C1032B	.7183	KW-HR	ELECTRICITY
E1576D	.0035	SCREENS	SCREENS
E1624D	.00333	SQUEEGEES	SQUEEGEES
E1128D	.0177	LBS.	INK SOLVENT
E1696D	.0364	DOLLARS	THERMOCOUPLE
E1064D	2.256	GRAMS	SILVER INK PASTE
D1080I	.404	GAL.	SEWAGE WASTE
D1064D	.00086	WAFERS	REJECTED WAFERS

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
AGWAFR	99	1.0	WAFERS /WAFER	BACK METALIZED WAFERS
			/	
			/	

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

REVERSE SIDE JPL 3037-S R 10/78

FORMAT A

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PROCESS DESCRIPTION

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

A1 Process [Referent] CELTES

A2 [Descriptive Name] CELL TEST: WAFER ELECTRICAL TEST

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] TCELLS

A4 Descriptive Name [Product Name] TESTED SOLAR CELLS

A5 Unit Of Measure [Product Units] CELLS

PART 2 – PROCESS CHARACTERISTICS

A6	[Output Rate] (Not Thruput)	20	Units (given on line A5) Per Operating Minute
A7	Average Time at Station [Processing Time]	20	Calendar Minutes (Used only to compute in-process inventory)
A8	Machine "Up" Time Fraction [Usage Fraction]	.644	Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	SORTER		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	175,000		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

JPL 3037-5 R10/78

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) CELLTES

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
A2096D	200	SQ.FT.	MANUFACTURING SPACE (TYPE C)
B3768D	.214	PRSN/SHIFT	ELECTRONICS COMPONENTS TESTER
B3688D	.171	PRSN/SHIFT	ELECTRONICS MAINTENANCE MAN
B5172D	.0855	PRSN/SHIFT	QUALITY CONTROL ENGINEER

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
C1032B	.083333	KW-HR	ELECTRICITY
D1176D	5.9123	CELLS	REJECTED CELLS

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
AGCELL	80	1.0	CELLS /WAFER	BACK AND FRONT METALIZED WAFERS

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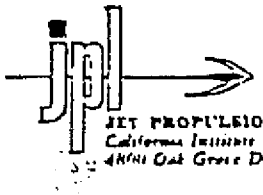
* 100% minus percentage of required product lost.
** Assume 100% yield here.
*** Examples: Modules/Cell or Cells/Wafer.

FORMAT A



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PROCESS DESCRIPTION

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

A1 Process [Referent] ARCOAT

A2 [Descriptive Name] ANTI-REFLECTIVE COATING: CELLS ARE SPRAYED WITH AN ANTI-REFLECTIVE COATING AND BAKED

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] CCELLS

A4 Descriptive Name [Product Name] COATED CELLS

A5 Unit Of Measure [Product Units] CELLS

PART 2 – PROCESS CHARACTERISTICS

A6	[Output Rate] (Not Thruput)	90.0	Units (given on line A5) Per Operating Minute
A7	Average Time at Station [Processing Time]	1.00	Calendar Minutes (Used only to compute in-process inventory)
A8	Machine "Up" Time Fraction [Usage Fraction]	.8075	Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	COATER	RFLCTOMTR	
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977	1977	
A11	Purchase Price ($ Per Component) [Purchase Cost]	120,000	20,000	
A12	Anticipated Useful Life (Years) [Useful Life]	10	10	
A13	[Salvage Value] ($ Per Component)	0	0	
A14	[Removal and Installation Cost] ($/Component)	0	0	

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.

Format: A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) ARCOAT

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
A2080D	116	SQ.FT.	MANUFACTURING SPACE [TYPE B]
B3096D	.78	PRSN/SHIFT	SEMICONDUCTOR ASSEMBLER
B3736D	.217	PRSN/SHIFT	MAINTENANCE MECHANIC
B3688D	.0427	PRSN/SHIFT	ELECTRONICS MAINTENANCE MAN
B3752D	.050	PRSN/SHIFT	MACHINE SHOP OPERATOR

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
E1080D	.0095	LITERS	ANTI-REFLECTIVE COATING
C1032B	.1667	KW-HR	ELECTRICITY
C2128B	1.667	CU.FT.	VENTILATION
E1416D	.0036	CU.FT.	NITROGEN GAS
D1176D	6.6513	CELLS	REJECTED CELLS

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
TCELLS	95	1.0	CELLS / CELL	TESTED SOLAR CELLS
			/	
			/	

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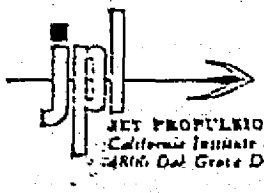
* 100% minus percentage of required product lost.
** Assume 100% yield here.
*** Examples: Modules/Cell or Cells/Wafer.

FORMAT A



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PROCESS DESCRIPTION

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

A1 Process [Referent] CONNEC

A2 [Descriptive Name] INTERCONNECT ... GAP-WELDING: SOLAR CELLS ARE INTERCONNECTED USING PARALLEL GAP TECHNIQUES WITH AUTOMATED MATERIAL HANDLING EQUIPMENT

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] STRING

A4 Descriptive Name [Product Name] INTERCONNECTED SOLAR CELLS

A5 Unit Of Measure [Product Units] CELLS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 63.333 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1.0 Calendar Minutes (Used only to compute in-process inventory)

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

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	INTERCON		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	271,000 -		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) CONNEC

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
A2064D	130	SQ.FT.	MANUFACTURING SPACE (TYPE A)
B3096D	.2599	PRSN/SHIFT	SEMICONDUCTOR ASSEMBLER
B3736D	.0868	PRSN/SHIFT	MAINTENANCE MECHANIC
B3080D	.08662	PRSN/SHIFT	MODULE ASSEMBLER (REWORK)
B3752D	.02	PRSN/SHIFT	MACHINE SHOP OPERATOR

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
D1176D	.6257	CELLS	REJECTED CELLS
E1072D	.3475	FT.	SILVER-PLATED COPPER WIRE
E1240D	.0914	DOLLARS	ELECTRODES
C1032B	.1333	KW-HR	ELECTRICITY

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
QCELLS	99	1.0	CELLS/CELL	COATED CELLS
			/	
			/	

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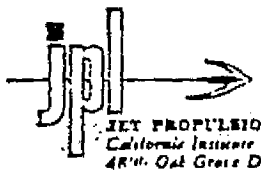
* 100% minus percentage of required product lost.
** Assume 100% yield here.
*** Examples: Modules/Cell or Cells/Wafer.

FORMAT A



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PROCESS DESCRIPTION

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

A1 Process [Referent] STRTES

A2 [Descriptive Name] SOLAR CELL STRINGS SUBMITTED TO ELECTRICAL TESTING

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] TSCT

A4 Descriptive Name [Product Name] TESTED SOLAR CELL STRINGS

A5 Unit Of Measure [Product Units] CELLS

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) 126.67 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .86 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A9	Component [Referent]	TESTEQUIP		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	80,000 -		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) PASSEM

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
A2064D	110	SQ.FT.	MANUFACTURING SPACE (TYPE A)
B3768D	.1712	PRSN/SHIFT	ELECTRONICS COMPONENTS TESTER
B3688D	.0855	PRSN/SHIFT	ELECTRONICS MAINTENANCE MAN

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE PER OPERATING 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
C1032B	.05	KW-HR	ELECTRICITY
D1176D	1.2485	CELLS	REJECTED CELLS

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
STRING	99	1.0	CELLS /CELL	INTERCONNECTED SOLAR CELLS
			/	
			/	

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

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PROCESS DESCRIPTION

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

A1 Process [Referent] PASSEM

A2 [Descriptive Name] DOUBLE GLASS PANEL ASSEMBLY

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] MODULE

A4 Descriptive Name [Product Name] ARRAY MODULES

A5 Unit Of Measure [Product Units] MODULES

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) .2771 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] .85 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A9	Component [Referent]	PANASMBLY	FINASMBLY	
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977	1977	
A11	Purchase Price ($ Per Component) [Purchase Cost]	103,000 -	125,000	
A12	Anticipated Useful Life (Years) [Useful Life]	10	10	
A13	[Salvage Value] ($ Per Component)	0	0	
A14	[Removal and Installation Cost] ($/Component)	0	0	

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.

A15 Process Referent (From Page 1 Line A1) PASSEM

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
A2064D	680	SQ.FT.	MANUFACTURING SPACE (TYPE A)
B3752D	.0236	PRSN/SHIFT	MACHINE SHOP OPERATOR
B3080D	.4330	PRSN/SHIFT	MODULE ASSEMBLER
B3688D	.0855	PRSN/SHIFT	ELECTRONICS MAINTENANCE MAN
B3736D	.0867	PRSN/SHIFT	MAINTENANCE MECHANIC
B3764D	.430	PRSN/SHIFT	SYSTEMS TESTER
B3624	.091	PRSN/SHIFT	MATERIALS HANDLER
B3608	.0305	PRSN/SHIFT	MATERIAL CLERK

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
C1032B	.08	KW-HR	ELECTRICITY
E1812D	6.146	SQ.FT.	FLOAT GLASS
E1272D	.0311	LBS.	CELL ADHESIVE
E1160D	.1242	UNITS	PANEL CONNECTOR
E1232	.2427	DOLLARS	EDGE SEAL
E1250D	.0428	LBS.	EPOXY POTANT
E1128D	.248	LBS.	INK SOLVENT
D1080I	.0255	GAL.	SEWAGE WASTE

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
TSCT	100	.0044643	MODULES/CELL	TESTED SOLAR CELL STRINGS
			/	
			/	

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

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PROCESS DESCRIPTION

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

A1 Process [Referent] PACKER

A2 [Descriptive Name] ARRAY MODULE PACKAGING

PART 1 – PRODUCT DESCRIPTION

A3 [Product Referent] PSAM

A4 Descriptive Name [Product Name] PACKAGED SOLAR ARRAY MODULES

A5 Unit Of Measure [Product Units] MODULES

PART 2 – PROCESS CHARACTERISTICS

A6 [Output Rate] (Not Thruput) .8333 Units (given on line A5) Per Operating Minute

A7 Average Time at Station [Processing Time] 1.2 Calendar Minutes (Used only to compute in-process inventory)

A8 Machine "Up" Time Fraction [Usage Fraction] 1 Operating Minutes Per Minute

PART 3 – EQUIPMENT COST FACTORS [Machine Description]

A9	Component [Referent]	PKGEQUIP		
A9a	Component [Descriptive Name] (Optional)			
A10	Base Year For Equipment Prices [Price Year]	1977		
A11	Purchase Price ($ Per Component) [Purchase Cost]	25,000 -		
A12	Anticipated Useful Life (Years) [Useful Life]	10		
A13	[Salvage Value] ($ Per Component)	0		
A14	[Removal and Installation Cost] ($/Component)	0		

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.

Format: A: Process Description (Continued)

A15 Process Referent (From Page 1 Line A1) PACKER

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
A2064D	100	SQ.FT.	MANUFACTURING SPACE (TYPE A)
B3656D	.9021	PRSN/SHIFT	MACHINE PACKAGER
B3624D	.5107	PRSN/SHIFT	MATERIAL HANDLER
B3608D	.172	PRSN/SHIFT	MATERIAL CLERK

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
E 1180 D	2.7	CU.FT.	WOODEN CRATES

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
MODULE	100	1.0	MODULES/MODULE	ARRAY MODULES

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

FINANCIAL PARAMETER VALUES

The following financial paramater values were used for the SAMIS computer program validation:

1)	Operating minutes per year	= 496,800
2)	Calendar hours per year	= 8,280
3)	Depreciation half life fraction	= 0.5
4)	Deinflation rate table	= 1974, 6%; 1975, 7.1%; 1976, 6%
5)	Percent of capacity	= 100%
6)	Federal income tax table (income, %)	= 0, 20%; 25,000, 22%; 50,000, 48%
7)	State income tax table (income, %)	= 0, 4%
8)	Leverage	= 1.2
9)	Debt interest rate	= 10.5%
10)	Other tax rate	= 2%
11	Insurance rate	= 4%
12	Insurable percentage of working captial	= 100%
13	Facility life (years)	= 40
14)	Capital recovery time	= Infinity
15)	Rate of return on equity	= 21%
16)	Base year	= 1975

NO.	ANNUAL PRODUCTION	.5 MW	15 MW	500 MW
17)	Construction leadtime (yrs)	1.75	2.00	3.00
18)	Startup period (yrs)	0.25	0.75	1.50
19)	Manufacturing year	1980	1982	1986

20) Miscellaneous factory costs (% of op. expenses) = 5%

21) Miscellaneous G&A expenses (% of book value) = 5%

22) Miscellaneous selling expenses (% of revenue) = 0

23) Tax life fraction (facilities) = 2/3

24) Investment tax credit (ITC) rate = 11 %

25 ITC top tax life (yrs) = 7

26) ITC middle tax life (yrs) = 5

27) ITC bottom tax life (yrs) = 3

28) ITC maximum percentage = 50

29) ITC lower fraction = 1/3

30) ITC upper fraction = 2/3

31) Facilities tax depreciation method = DDB

32) Facilities book depreciation method = SL

33) Facilities inflation rate table = 1975, 8%

34) Raw materials inventory time (yrs) = .12 (43 days)

35) Processing time multiplier = 2

36) Finished goods inventory time (yrs) = 0.08 (29 days)

37) Accounts receivable turnover time (yrs) = 0.15 (55 days)

38) Accounts payable turnover time (yrs) = 0.08 (30 days)

TABLE 1
TOTAL ANNUAL COST COMPARISON
.50 MW PLANT

	TB&A (1980 $)	SAMICS (1980 $)	Difference* 1975 $ Per Watt
Direct expenses:			
Direct labor	$24,123	$24,142	-.000
Direct materials	1,678,248	1,678,163	+.000
By-product expenses	85	76	+.000
Direct utilities	5,596	5,520	+.000
Total direct expenses	$1,708,052	$1,707,901	+.000
Indirect expenses:			
Indirect labor	$43,365	$52,399	-.013
Indirect materials and indirect utilities	86,117	17,530	+.101
Total indirect expenses	$129,482	$69,939	+.088
By-product income	($48,059)	$(48,057)	-.000
Capital expenses:			
Equipment replacement	$292,632	$300,291	-.011
Facilities replacement	15,399	15,776	-.001
Amortized one-time cost	56,691	483,164	-.631
Interest on debt	55,944	24,739	+.046
Return on equity	559,437	272,138	+.425
Non-income taxes	39,062	12,987	+.039
Insurance	127,871	154,308	-.039
Total capital expenses	$1,146,936	$1,263,403	-.172
Income taxes	$615,775	$708,460	-.137
Miscellaneous income	159,839	136,061	+.035
Total annual cost	$3,712,025	$3,837,707	-.186
Price estimate (1975 $)/Watt	$5.49	$5.68	-.19

Price deflator = .7396

*Difference = (TB&A - SAMICS) * .7396/500,000.

TABLE 2
TOTAL ANNUAL COST COMPARISON
15 MW PLANT

	TB&A (1982 $)	SAMICS (1982 $)	Difference* 1975 $ Per Watt
Direct expenses:			
Direct labor	$768,744	$768,756	.000
Direct materials	32,447,127	32,387,474	+.003
By-product expenses	1,564	1,378	-.000
Direct utilities	212,613	212,093	-.000
Total direct expenses	$33,430,048	$33,369,701	+.003
Indirect expenses:			
Indirect labor	$586,217	$630,027	-.002
Indirect materials and indirect utilities	1,662,925	263,283	+.061
Total indirect expenses	$2,249,142	$893,310	+.059
By-product income	($862,463)	($862,417)	-.000
Capital expenses:			
Equipment replacement	$904,471	$902,714	+.000
Facilities replacement	45,951	77,504	-.001
Amortized one-time cost	1,075,503	3,958,055	-.126
Interest on debt	372,473	141,307	+.010
Return on equity	3,724,731	1,423,073	+.101
Non-income taxes	348,881	43,074	+.013
Insurance	851,367	657,845	+.008
Total capital expenses	$7,323,377	$7,203,572	+.005
Income taxes	4,807,840	5,400,294	-.026
Miscellaneous expenses	1,064,209	1,962,916	-.037
Total annual cost	$48,012,153	$47,907,376	+.005
Price estimate (1975 $)/Watt	$2.11	$2.10	+.01

Price deflator = .6582

*Difference = (TB&A - SAMICS) * .6582/15,000,000.

TABLE 3
TOTAL ANNUAL COST COMPARISON
500 MW PLANT

	TB&A (1986 $)	SAMICS (1986 $)	Difference* 1975 $ Per Watt
Direct Expenses:			
Direct Labor	$34,958,320	$34,954,890	+.000
Direct Materials	446,201,167	442,277,000	+.004
By-Product Expenses	59,579	59,167	+.000
Direct Utilities	11,496,546	11,489,012	+.000
Total Direct Expenses	$492,715,612	$488,780,069	+.004
Indirect Expenses:			
Indirect Labor	$23,323,620	$26,044,465	-.003
Indirect Materials and Indirect Utili es	23,075,169	14,318,579	+.009
Total Indirect Expenses	$46,398,789	$40,363,044	+.006
By-Product Income	($6,770,509)	($6,770,207)	-.000
Capital Expenses:			
Equipment Replacement	$30,232,129	$30,199,127	+.000
Facilities Replacement	1,047,056	2,584,572	-.002
Amortized One-Time Cost	34,623,889	156,935,422	-.128
Interest On Debt	8,090,892	3,397,977	+.005
Return Of Equity	80,908,921	33,979,815	+.049
Non-Income Taxes	6,702,686	1,439,882	+.005
Insurance	18,498,468	18,881,925	-.000
Total Capital Expenses	$180,104,041	$247,418,720	-.071
Income Taxes	$115,379,998	$192,049,285	-.080
Miscellaneous Expenses	23,116,834	32,806,818	-.010
Total Annual Cost	$850,944,765	$994,647,729	-.151
Price Estimate (1975$)/Watt	$.887	$1.037	-$.15

Price Deflator = .5214

*Difference = (TB&A - SAMICS) * .5214/500,000,000.

TABLE 3A
TOTAL ANNUAL COST
REVISED SAMICS PROGRAM
WITH ORIGINAL INDIRECT REQUIREMENTS MATRIX

	.5MW (1980 $)	15MW (1982 $)	500MW (1986 $)
Direct expenses:			
Direct labor	$ 24,143	$ 768,753	$ 34,954,592
Direct materials	1,676,752	32,387,424	442,277,376
By-product expenses	75	1,322	59,105
Direct utilities	5,520	214,974	11,350,344
Total direct expenses	$1,706,490	$33,372,480	$488,640,768
Indirect expenses:			
Indirect labor	$52,392	$629,881	$26,036,976
Indirect materials and indirect utilities	17,530	262,900	14,307,444
Total indirect expenses	$69,922	$892,777	$40,344,336
By-product income	($48,057)	($862,417)	($6,770,207)
Capital expenses:			
Equipment replacement	$ 300,288	$ 902,715	$ 30,199,088
Facilities replacement	15,137	74,970	2,539,648
Amortized one-time cost	386,515	1,573,742	68,607,472
Interest on debt	24,911	143,150	3,426,074
Return on equity	249,114	1,431,498	34,260,816
Non-income taxes	13,140	43,831	1,465,137
Insurance	153,290	653,788	18,810,032
Total capital expenses	$1,142,393	$4,823,692	$159,308,256
Income taxes	612,275	3,014,557	103,645,344
Miscellaneous income	148,530	1,905,244	32,885,664
Total annual cost	$3,679,578	$44,008,560	$824,829,952
SAMICS price estimate (1975 $)/Watt	$5.31	$1.86	$.846
Price deflator	.7396	.6582	.5214
TB&A price estimate (1975 $/Watt)	$5.49	$2.11	$.887
Percent difference[1]	3.2%	11.8%	4.67%

[1] $\frac{\text{TB\&A} - \text{SAMICS}}{\text{TB\&A}}$

[2] Columns do not add because of rounding errors.

TABLE 3B
TOTAL ANNUAL COST
REVISED SAMICS PROGRAM
WITH RECOMMENDED INDIRECT REQUIREMENTS MATRIX

	.50MW (1980 $)	15MW (1982 $)	500MW (1986 $)
Direct expenses:			
Direct labor	$ 24,143	$ 768,753	$ 34,954,592
Direct material	1,676,752	32,387,424	442,277,376
By-product expenses	74	1,312	59,048
Direct utilities	5,519	214,973	11,350,334
Total direct expenses	$1,706,487	$33,372,464	$488,640,768[2]
Indirect expenses:			
Indirect labor	$ 37,645	$ 541,959	$23,395,840
Indirect materials and indirect utilities	110,861	1,200,971	51,788,800
Total indirect expenses	$148,505	$1,544,921	$75,183,920
By-product income	($48,057)	($862,417)	($6,770,207)
Capital expenses:			
Equipment replacement	$300,288	$902,715	$30,199,088
Facilities replacement	23,625	101,350	3,915,056
Amortized one-time cost	434,757	174,864	80,279,296
Interest on debt	26,290	148,262	3,702,920
Return on equity	262,901	47,395	37,029,248
Non-income taxes	14,310	47,395	1,659,203
Insurance	167,267	699,288	21,186,400
Total capital expenses	$1,229,437	$5,130,490	$177,971,200
Income taxes	679,674	3,257,612	118,970,256
Miscellaneous income	156,057	1,949,062	35,211,264
Total annual cost	$3,920,147	$45,255,056	$895,998,720
SAMICS price estimate $\frac{(1975\ \$)}{Watt}$	$5.66	$1.91	$.920
Price deflater	.7396	.6582	.5214
TB&A price estimate (1975 $/Watt)	$5.49	$2.11	$.887
Percent difference[1]	-3.10%	9.48%	-3.72%

[1] $\frac{TB\&A - SAMICS}{TB\&A}$

[2] Columns do not add because of rounding errors.

TABLE 4
ANNUAL DIRECT LABOR COSTS (1976 $)

Annual Production	.50MW		15MW		500MW	
	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Chemical Operator II	$357	$357	$10,657	$10,711	$707,700	$707,859
Maintenance Mechanic I	2,513	2,520	75,072	75,112	2,541,248	2,541,177
Materials Handler	1,872	1,879	23,652	23,652	672,960	672,961
Material Clerk	502	502	6,373	6,374	181,720	183,167
Semi-Conductor Assembler	2,812	2,815	84,162	84,163	2,553,314	2,553,220
Electronics Components Tester	1,984	1,976	56,613	56,594	1,879,768	1,878,263
Electronics Maintenance Man	2,939	2,939	87,608	87,455	2,916,320	2,915,151
General Assembler	1,034	1,034	30,974	31,033	1,031,940	1,031,996
Machine Shop Operator	472	473	14,946	14,927	472,416	472,555
Module Assembler	1,286	1,289	38,912	38,904	1,312,200	1,312,221
Systems Tester	426	417	13,153	13,106	442,800	442,324
Packaging Machine Operator	392	392	8,898	8,821	313,600	313,648
Chemical Engineer	38	48	1,219	1,200	80,880	80,854
Quality Control Engineer	1,104	1,104	32,200	32,396	1,085,600	1,085,522
Total Direct Labor Cost	$17,731	$17,745	$484,439	$484,448	$16,192,466	$16,190,915
Manufacturing Year $	$24,123	$24,142	$768,744	$768,756	$34,958,320	$34,954,890
Year	1980		1982		1986	

Assumed 8% inflation rate

TABLE 5
ANNUAL DIRECT MATERIALS EXPENSES (1977 $)

Annual Production Level			.50 MW		15 MW		500 MW	
	Units	Inflation	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Sulfuric Acid	lbs.	8%	$205	$202	$5,177	$5,125	$171,463	$171,462
Hydrogen Peroxide	lbs.	13%	120	119	3,816	3,777	101,816	100,800
Filaments/ Insulators	units	8%	8,001	8,004	24,002	24,004	560,038	560,267
Argon Gas	cu.ft.	13%	8,051	8,059	33,801	33,462	1,126,720	1,126,721
Nitrogen Gas	cu.ft.	13%	16	16	393	393	16,235	16,239
Solvent (Butyl Acetate)	lbs.	13%	1,320	1,304	31,344	31,275	1,040,887	1,038,264
Silver Ink Paste	gm	13%	69,367	69,347	1,630,204	1,630,205	54,725,925	54,726,416
Thermocouple	$	8%	1,731	1,715	51,953	51,432	1,731,729	1,714,397
Screens	screens	8%	770	770	23,175	23,140	771,199	771,197
Squeegees	squeeges	8%	634	629	19,053	19,053	635,066	630,909
Anti-Reflective Coating	liters	13%	753	753	22,555	22,553	751,907	751,898
Silver Plated Copper Wire	ft.	13%	1,022	1,022	30,648	30,655	1,021,763	1,021,591
Electrodes	$	8%	1,020	1,020	30,611	30,306	1,020,525	1,021,590
Cell Adhesive (FEP Teflon)	lbs.	13%	4,628	4,657	136,919	136,916	4,565,012	4,563,865
Window and Substrate Glass	sq.ft.	13%	18,077	18,077	457,356	457,347	15,250,562	15,249,518
Panel Connector	1000 units	13%	4,164	4,163	123,277	123,277	4,110,489	4,110,445
Edge Seal	$	8%	2,733	2,737	82,110	82,112	2,737,865	2,737,055
Epoxy Potant	lbs.	13%	1,855	1,829	54,880	54,880	1,829,901	1,829,335
Wafers, Single Crystal	1000 units	8%	1,191,876	1,191,856	18,680,472	18,641,350	88,537,878	87,644,000
Total Direct Materials Expense			$1,316,343	$1,316,279	$21,441,746	$21,401,262	$180,706,980	$179,790,000
Manufacturing Year $			$1,678,248	$1,678,163	$32,447,127	$32,387,474	$446,201,167	$442,277,000
			1980		1982		1986	

(See Volume I for a comparison of accounts.)

TABLE 6
ANNUAL DIRECT BY-PRODUCT EXPENSES AND INCOME
(1977 $)

Annual Production Level			.50 MW		15 MW		500 MW	
	Units	Inflation	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Fumes	1000 cu.ft.		0	0	0	0	0	0
Poisonous Acid	lbs.	15%	29	27	182	137	4,256	4,410
Polluted Water	gal.	15%	19	16	397	347	9,310	9,158
Rejected Wafers	wafers	8%	-8,699	-8,699	-139,344	-136,349	-646,202	-646,229
Sewage Waste	gal.	15%	1	1	21	16	468	463
Solid Waste	lbs.	15%	7	6	178	185	2,902	2,788
Rejected Cells	cells	8%	-29,452	-29,450	-450,634	-450,598	-2,740,738	-2,740,560
By-Product Expenses	(1977 $)	15%	56	50	778	685	16,936	16,819
By-Product Income	(1977 $)	8%	-38,151	-38,149	-586,978	-586,947	-3,386,940	-3,386,789
Total Net By-Product Expense	(1977 $)		-38,095	-38,099	-586,200	-586,261	-3,370,009	-3,369,970

Manufacturing Year Dollars	1980		1982		1986	
By-Product Expenses	$85	$76	$1,564	$1,378	$59,579	$59,167
By-Product Income	-$48,059	-$48,057	$862,463	-$862,417	-$6,770,509	-$6,770,207

TABLE 7
ANNUAL DIRECT UTILITIES EPENSES
(1977 $)

Annual Production Level			.50 MW		15 MW		500 MW	
	Units	Inflation	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Electricity	Kw-Hr	12%	$2,293	$2,248	$68,310	$68,422	$2,298,496	$2,297,418
Deionized water	Cu.ft.	13%	175	170	5,230	5,090	174,346	174,325
Ventilation	1000 Cu.ft.	12%	0	0	0	0	0	0
Liquid nitrogen	1000 Cu.ft.	13%	984	980	29,703	29,406	990,113	990,112
Cooling water	KW-Hr	15%	462	462	13,854	13,898	461,799	460,526
Total Direct Utilities expense (1977$)			$3,914	$3,860	$117,097	$116,816	$3,924,754	$3,922,381
Manufacturing year $			$5,596	$5,520	$212,613	$212,093	$11,496,546	$11,489,012
			1980		1982		1986	

TABLE 8
INDIRECT PERSONNEL REQUIREMENTS

Annual Production Level			.50 MW		15 MW		500 MW	
		Salary	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Secretary III	3	$11,350	.033	.335	.881	.842	26.94	27.85
Training Supervisor	0	20,360	.017	.018	.480	.494	15.92	16.43
Vice President, Administration	3	52,500	.005	.005	.075	.082	2.37	2.60
Accountant	0	14,000	.017	.018	.480	.494	15.92	16.43
Accounting Supervisor	0	20,600	.003	.003	.080	.082	2.65	2.74
Bookkeeper	0	10,000	.017	.018	.480	.494	15.92	16.43
Controller	3	35,300	.004	.004	.110	.117	3.65	3.88
Data Processing Supervisor	0	17,700	.001	.001	.026	.028	.88	.91
Computer Operator	0	10,600	.006	.006	.160	.165	5.31	5.48
Financial Analyst	0	19,500	.006	.006	.160	.165	5.31	5.48
Keypunch Operator	0	8,800	.006	.006	.160	.165	5.31	5.48
Manager, Data Processing	3	26,500	.002	.002	.055	.057	1.84	1.90
Payroll Clerk	0	8,260	.017	.018	.480	.494	15.92	16.43
Purchasing Clerk	0	9,800	.017	.018	.480	.494	15.92	16.43
Programmer, Business	0	17,700	.006	.006	.160	.165	5.31	5.48

*Salary stated in 1977$.

TABLE 8, Continued
INDIRECT PERSONNEL REQUIREMENTS

Annual Production Level			.50 MW		15 MW		500 MW	
		Salary	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Purchasing Administrator	0	30,000	.003	.003	.083	.086	2.76	2.85
Purchasing Agent	0	20,000	.017	.170	.480	.497	15.92	16.43
Purchasing Supervisor	0	17,500	.001	.001	.039	.041	1.32	1.37
Systems Analyst	0	19,500	.006	.006	.160	.165	5.31	5.48
Treasurer	0	32,960	.003	.003	.080	.082	2.65	2.74
Vice President, Finance	3	52,000	.003	.003	.081	.086	2.72	2.84
Chemical Engineer	0	24,000	.006	.006	.160	.165	5.31	5.48
Director, Manufacturing Engineering	0	32,000	.003	.004	.096	.100	3.37	3.48
Director, Quality Control	0	32,000	.010	.010	.286	.289	9.63	9.67
Director, R&D	0	28,000	.002	.002	.040	.041	1.33	1.37
Draftsman, Mechanical	0	12,700	.009	.009	.240	.247	7.97	8.22
Electrical Engineer	0	23,500	.009	.009	.240	.247	7.97	8.22
Engineering Assistant	0	11,000	.009	.009	.240	.247	7.97	8.22

*Salary stated in 1977 $.

TABLE 8, Continued
INDIRECT PERSONNEL REQUIREMENTS

Annual Production Level			.50 MW		15 MW		500 MW	
		Salary	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Industrial Engineer	0	23,000	.009	.009	.240	.247	7.97	8.22
Mechanical Engineer	0	23,500	.009	.009	.240	.247	.797	8.22
Production Planner	0	23,000	.009	.009	.240	.247	7.97	8.22
Quality Control Engineer	0	23,000	.009	.009	.240	.247	7.97	8.22
Research Engineer	0	20,000	.009	.009	.240	.247	7.97	8.22
Vice President, Manufacturing	3	52,500	.004	.004	.175	.115	3.89	2.84
Assembly Foreman	0	14,000	.053	.053	1.585	1.585	50.39	50.39
Assembly Operating Supervisor	0	17,000	.006	.006	.186	.186	6.22	6.22
Assistant Production Supervisor	0	20,000	.006	.006	.160	.165	5.31	5.48
Chemical Process Forman	0	13,000	.003	.003	.085	.085	5.62	5.62
Electronics Maintenance Foreman	0	13,500	.022	.022	.664	.663	22.09	22.08
Machine Shop Foreman	0	13,500	.004	.004	.132	.132	4.19	4.19

*Salary stated in 1977 $.

TABLE 8, Continued
INDIRECT PERSONNEL REQUIREMENTS

Annual Production Level			.50 MW		15MW		500MW	
		Salary	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Materials Handling Foreman	0	13,500	.017	.017	.219	.219	6.23	6.25
Mechanical Maintenance Foreman	1	13,500	.040	.080	1.194	.673	40.04	20.20
Administrative Assistant	0	37,600	.003	.003	.080	.082	2.65	2.74
Internal Auditor	0	21,200	.003	.003	.080	.082	2.65	2.74
General Office Clerk	0	8,260	.017	.018	.480	.494	15.92	16.43
Director, Industrial Relations	3	32,960	.003	.003	.080	.082	2.65	2.74
Director, Office Administration	3	32,960	.004	.004	.105	.110	3.53	3.65
Director, Plant Maintenance	2	32,960	.011	.014	.029	.054	.35	1.15
Director, Public Relations	0	32,960	.003	.003	.080	.082	2.65	2.74
Employment Interviewer	0	20,360	.017	.018	.480	.494	15.92	16.43
Groundskeeper	1	8,800	.357	.435	.931	1.736	14.58	38.19
Guard	1	7,100	.433	.559	1.267	2.569	5.55	49.56

*Salary stated in 1977 $.

TABLE 8, Continued
INDIRECT PERSONNEL REQUIREMENTS

Annual Production Level			.50 MW		15 MW		500 MW	
		Salary	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Guard Chief	2	11,000	.072	.093	.211	.428	.92	8.26
Janitor	1	8,800	.520	.671	1.520	3.082	38.00	84.32
Corporate Lawyer	0	23,500	.003	.003	.080	.082	2.65	2.74
Legal Secretary	0	10,600	.002	.001	.040	.041	1.32	1.37
Mail Clerk	0	8,260	.017	.018	.480	.494	15.92	16.43
Maintenance Foreman (P&U)	2	15,600	.127	.162	.306	.546	5.43	12.47
Maintenance Man (P&U)	1	8,800	.650	.838	1.225	1.713	12.62	27.10
Manager, Compensation	3	26,500	.003	.003	.067	.069	2.21	2.28
Manager, Personnel	3	26,500	.003	.003	.092	.096	3.09	3.20
Manager, Security and Maintenance	2	26,500	.033	.042	.086	.162	1.06	3.46
Nurse	0	12,900	.012	.012	.320	.330	10.62	10.95
Personnel Clerk	0	8,260	.035	.036	.959	.989	31.86	32.86
Personnel Clerk Supervisor	0	12,500	.003	.003	.080	.082	2.65	2.74
President	3	88,300	.003	.003	.070	.064	2.04	2.11
Receptionist	0	10,600	.003	.003	.080	.082	2.65	2.74

*Salary stated in 1977 $.

TABLE 8, Continued
INDIRECT PERSONNEL REQUIREMENTS

Annual Production Level			.50 MW		15 MW		500 MW	
		Salary	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Safety Engineer	0	23,500	.009	.009	.240	.247	7.97	8.22
Secretary I	2	9,750	.048	.051	1.140	1.184	38.00	39.38
Secretary II	3	10,400	.026	.028	.738	.579	18.39	18.98
Process Maintenance Supervisor	2	16,500	.007	.012	.207	.148	6.90	4.70
Production Machine Shop Supervisor	0	16,500	.001	.001	.022	.022	.70	.70
Plant Manager	2	23,500	.006	.007	.512	.138	5.03	4.52
Quality Control Foreman	0	13,500	.024	.024	.709	.708	23.60	23.58
Quality Control Supervisor	0	16,500	.003	.002	.079	.079	2.62	2.62
Warehouse and Material Handling Supervisor	0	16,500	.002	.002	.033	.033	1.00	0.99
Warehouse Foreman	0	13,500	.003	.003	.076	.075	2.67	2.67
Total Indirect Personnel			2.90	3.86	250.76	289.47	538.15	692.52
Total Direct Personnel			1.74	1.79	47.99	49.44	1,592.81	1,643.00
Total Personnel			4.64	5.65	298.75	338.91	2,130.96	2,335.52

Salary stated in 1977 $.

See Volume I for a comparison of accounts.

TABLE 9
INITIAL CAPITAL COSTS
FOR INTERIOR BUILDING FACILITIES
(Stated in 1977 $)

Annual Production Level	.5 MW		15 MW		500 MW	
	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Manufacturing Space (Type A)	141,795	169,247	369,638	369,636	8,359,560	8,359,529
Manufacturing Space (Type B)	17,400	17,400	17,400	17,400	278,400	278,400
Manufacturing Space (Type C	10,000	10,000	40,000	40,000	944,000	943,994
Total Space	169,195	196,647	427,038	427,036	9,581,960	9,581,923
Cafeteria*	17,100	109	32,250	21,418	360,000	967,598
Computer Room	0	-	10,560	10,560	33,440	33,288
Electrical Equipment*	4,298	238	7,280	11,042	15,850	165,976
Health Service Facilities*	5,775	-	7,000	1,006	10,010	31,665
Mechanical Equipment Room*	7,640	109	10,920	12,982	39,625	28,048
Office Space - Administration	90,958	1,256	144,855	113,495	1,020,855	2,842,063
Office Space - Plant	5,000	-	11,750	1,211	69,000	36,631
Passages and Corridors*	10,822	389	18,112	38,516	118,575	879,196
Plant Maintenance Shop*	10,900	232	64,200	42,552	855,000	1,390,388
Quality Control Laboratory*	0	-	7,050	25,347	33,750	834,953
Shipping Dock	4,775	1,013	9,400	23,122	23,700	94,311
Chemical Storage*	2,240	14,112	4,320	538,571	13,920	14,027,945
Telephone Room	955	-	2,730	1,236	7,925	547
Toilets	35,000	859	65,000	82,381	845,000	967,639
Warehouse Space	8,925	97	178,500	10,164	4,350,000	2,342,551
Support Space	204,388	18,414	573,927	933,603	7,796,650	24,612,799
Total Factory	373,583	215,061	1,000,965	1,360,639	17,378,610	34,194,722

Inflation rate: 9% for internal site facilities.

*Change recommended in Volume II.

TABLE 10
INITIAL CAPITAL COSTS
FOR EXTERNAL SITE FACILITIES
(Stated in 1977 $)

Annual Production Level	.50 MW		15 MW		500 MW	
	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Fencing	9,500	2,859	15,500	5,760	52,000	26,809
Fireloop and Secondary Water	0	0	0	0	150,000	15,000
Grading	4,410	2,285	4,280	5,521	25,340	49,491
Industrial Waste Clarifiers*	1,000	15,026	4,500	110,231	20,000	2,899,411
Landscaping and Irrigation*	8,300	24,670	23,180	105,558	195,384	2,099,688
Electrical Service*	1,500	12,708	2,000	226,143	6,250	7,369,905
Fuel Oil Service	1,500	0	2,500	0	5,000	0
Liquid Nitrogen Service*	3,250	135	6,500	2,234	35,000	4,061
Liquid Oxygen Service*	3,250	0	6,500	0	35,000	0
Sanitary Sewers	1,090	707	3,050	1,572	25,845	19,307
Storm Drains*	1,000	978	2,500	4,495	20,000	122,965
Telephone Lines	450	552	1,400	2,220	10,000	49,518
Water Service*	1,500	40	2,000	193	6,250	4,050
Paving (heavy duty)*	9,800	7,894	13,600	12,086	20,930	28,409
Paving (light duty)*	2,400	396	11,592	4,278	189,504	112,856
Security Control	0	0	0	0	3,500	8,078
Storage Space	100	113	270	372	2,900	5,788
Signs and Flagpole	2,000	2,000	2,000	2,000	5,000	11,995
Storage Area Walls	400	417	650	756	2,100	2,981
Site Lighting*	1,500	4,190	5,000	10,397	50,000	36,080
Walks, Curbs, and Gutters	8,500	10,850	15,750	29,286	120,000	274,558
Total Facilities Cost	$62,450	$85,820	$124,772	$523,102	$986,253	$13,140,950

Inflation rate: 8% for external site facilities.

*Change recommended in Volume II.

TABLE 11
ONE-TIME COST MODEL COMPARISON*

Annual Production	.50 MW		15 MW		500 MW	
	TB&A	SAMICS	TB&A	SAMICS	TB&A	SAMICS
Capital Charges, Insurance and Non-Income Taxes during Construction	217,272	908,852	673,690	4,827,049	23,959,718	355,927,976
Loss on Start-Up Operations	39,690	595,255	5,027,546	15,470,930	162,484,703	753,412,390
Income Taxes for Depreciation of Assets to Steady-State Book Values	(69,877)	—	(215,367)	—	(6,327,177)	—
Capital Charges (for Depreciation of Assets to Steady-State Book Values	120,975	3,109,450	368,799	10,303,000	8,363,373	392,003,000
Total One-Time Costs	308,060	4,613,557	5,854,668	30,600,979	188,480,617	501,343,366
Capital Recovery Factor	.1837	.1045	.1837	.1045	.1837	.1045
Amortized One-Time Costs	56,591	483,164	1,075,503	3,958,055	34,623,889	156,935,422
Manufacturing Year	1980		1982		1986	

*All costs are expressed in steady-state manufacturing year dollars.

See Volume I for an analysis of the variations, including the difference in capital recovery factor.

This section contains a list of all relationships for the indirect requirements matrix. The relationships are tabulated with the description of the immediate or one-step determining items for each indirect requirement item. Since these relationships may depend numerically upon the amount of the determining item, the table provides the data for a piecewise non-linear (power) approximation.

The table columns contain the following information:

- o I = Indirect Requirement Cost Account Catalog Number and Description
- o D = Determining Item Cost Account Catalog Number and Description
- o N = Number of coordinate pairs needed to define the piecewise non-linear approximating function
- o C = Exponent of power to which the determining item quantity is raised to compute the indirect item quantity
- o D_i= Amount of direct item at the ith break point in the piecewise non-linear approximating function
- o I_i= Amount of direct item needed for an amount D_i of the determining item

'i' is the index for the pairs of points that define the piecewise non-linear approximating function (i = 1, 2, . . . , N). The function is illustrated graphically on the following page for N = 4.

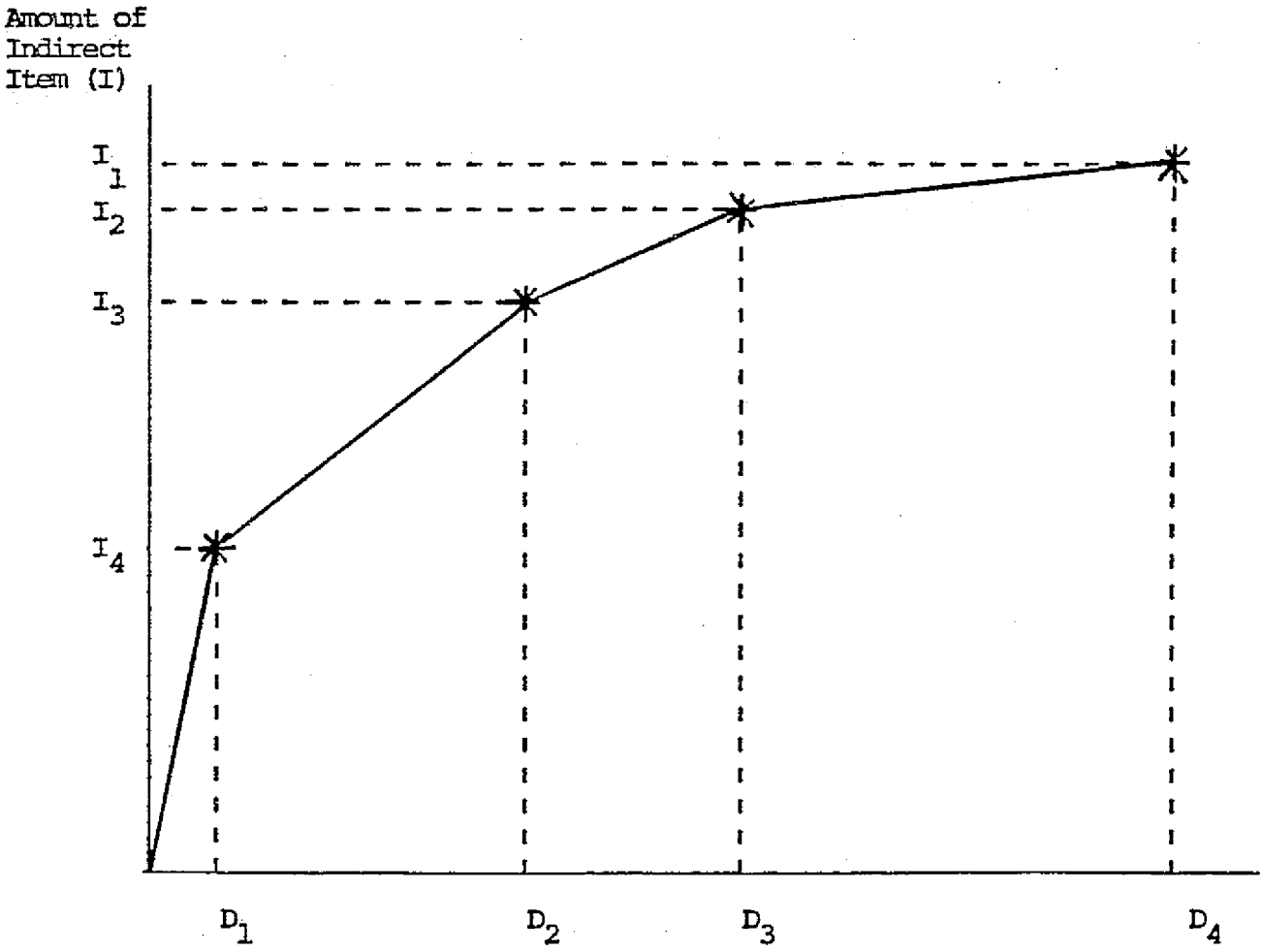
The following table lists the abbreviations used for units of measure.

The matrix presented here is the new recommended matrix which has been incorporated in the Phase III Cost Account Catalog. Three types of modifications have been made to the original matrix:

- o Improvements recommended as a result of the SAMICS computer program validation discussed in Volume II.
- o Corrections of errors found by JPL.
- o Changes of account numbers, descriptions, and metric units of measure to be consistent with the PHase III Cost Account Catalog documented in Volume III.

INDIRECT REQUIREMENTS MATRIX

PIECE-WISE NONLINEAR APPROXIMATING FUNCTION



$$l_i = a_i + b_i * D_i$$

ABBREVIATIONS TABLE

B.T.U.	=	British Thermal Unit
cm	=	centimeter
cm**2	=	square centimeter
(cm**3)/2	=	cubic centimeter per second
CS	=	Carbon Steel
D	=	Diameter
EXT*YRS	=	Extension Years (telephone)
g	=	gram
H	=	Height
inf.	=	infinity
J	=	Joule
Kg	=	Kilogram
Kw	=	Kilowatts
Kw Hr	=	Kilowatt Hours
L	=	Length
m	=	meter
m**2	=	square meter
m**3	=	cubic meter
(m**3)/min	=	cubic meter per minute
mil	=	one thousandth of an inch
mm	=	millimeter
n/m**2	=	newtons per square meter
PSIA	=	Pounds per square inch Atmospheric
PRNS*YRS	=	Person Years
SS	=	Stainless Steel
S.T.P.	=	Standard Temperature and Pressure for gases. 0° C and 1 atmosphere

INDIRECT REQUIREMENTS MATRIX DATA

Indirect Requirement Number	Indirect Requirement Description (I)	Determining Item Number	Determining Item Description (D)	N	C	D_1	I_1	D_2	I_2	D_3	I_3	D_4	I_4	D_5	I_5
A1112	Electrical Service Facilties	C1032	Electricity	2	1	500,000	0	1E06	2000						
A1016	Fencing	A1080	Land	1	5	.8361	2.44								
A1032	Fireloop & Secondary Water Supply	A3016	Total Factory Floor Space	3	5	18,580	0	18,581	230.0	46,450	336				
A1048	Grading	A1080	Land	1	1	1	1								
A1064	Industrial Waste Clarifiers & Hold Tanks	D1048	Polluted Water	1	1	1,342	58.34								
		D1032	Poisonous Acid	1	1	1,342	58.34								
		D3016	Used Solvent	1	1	1,342	58.34								
A1080	Land	A3016	Total Factory Floor Space	1	1	1.00	1.20								
		A1272	Paving for Parking Lots	1	1	1.00	1.00								
		A1256	Paving for Roads	1	1	1.00	1.00								
A1096	Landscaping & Irrigation	A3016	Total Factory Floor Space	1	1	1	.2								
A1160	Liq. Nitrogen Service Facilities	C1080	Nitrogen (Liq)	1	1	1	1								
A1176	Liq. Oxygen Service Facilites	C1096	Oxygen (Liq)	1	1	1	1								
A1144	Natural Gas Service Facilities	C1064	Natural Gas	1	1	1	1								
A1256	Paving (Heavy Duty) for On-site Roads	A3016	Total Factory Floor Space	5	1	929	696.76	1,858	1,226	4,645	1,394	9,290	1,858	46,450	2,323
A1272	Paving (Light Duty) for Parking Lots	B5016	Total Direct Personnel	1	1	1	30.19								
		B5048	Total Staff Personnel	1	1	1	30.19								
A1192	Sanitary Sewers	C2064	Sewage & Process Waste Disposal	1	1	14,067	1,419								
A1288	Security Control Facilities	A3016	Total Factory Floor Space	3	1	9,197	0	9,290	2,500	92,901	5,000				

INDIRECT REQUIREMENTS MATRIX DATA

Indirect Requirement Number	Indirect Requirement Description (I)	Determining Item Number	Determining Item Description (D)	N	C	D_1	I_1	D_2	I_2	D_3	I_3	D_4	I_4	D_5	I_5
A1352	Site Lighting	A1272	Paving for Parking Lots	5	1	1,850	5,000	3,716	7,000	9,290	12,500	46,450	20,000	92,901	25,000
A1304	Signs and Flagpole	A3016	Total Factory Floor Space	3	1	2,000	9,197	9,197	2,000	27,870	3,000				
A1320	Storage Area Walls	A1336	Storage Space	2	.5	30.48	3,716	3,048	37.16						
A1336	Storage Space	A3016	Total Factory Floor Space	3	1	929	4.65	4,645	18.58	46,450	9,290				
		A2272	Warehouse Space	3	1	929	-4.65	4,645	-18.58	46,450	-92.9				
A1208	Storm Drains	A3016	Total Factory Floor Space	1	1	5.57	473								
		A1256	Paving, Heavy Duty	1	1	5.57	473								
		A1272	Paving, Light Duty	1	1	5.57	473								
A1224	Telephone Lines	A2128	Office Space-Administration	1	1	92.9	8								
		A2144	Office Space-Manufacturing	1	1	92.9	4								
		A3032	Total Mfg. Space	1	1	92.9	2								
A1368	Walks, Curbs & Gutters	A1080	Land	6	1	4,645	10,000	6,968	13,125	11,613	18,750	23,225	31,250	46,451 (D_6)92,901	50,000 (I_6)75,000
A1240	Water Service Facilities	C2080	Water Supply	1	1	1,046.74	473								
A2008	Air Conditioning Facilities	C2096	Air Conditioning	1	1	17	10								
A2016	Cafeteria & Lunch Room	B5032	Total Personnel	4	1	1.00	23.72	100	45.99	500	299.9	501	383.2		
A2020	Compressed Air Facilities	C2032	Compressed Air	3	1	5.6	0	5.6	.0945	56.6	.4729				
A2024	Computer Room	B5032	Total Personnel	4	1	25	0	26	18.58	75	18.58	100	18.58	2,500	92.90
A2032	Electrical Equipment Room	C1032	Electricity	3	1	200,000	20.90	4E06	46.45	1E07	92.90				
A2040	Exterior Walls	A3016	Total Factory Floor Spc	2	.5	9.29	12.19	92.90	121.91						
A2048	Health Service Facilities	B5032	Total Personnel	3	1	1	13.39	70	18.58	2,000	46.45				
A2056	Heating Facilities	C2112	Heating	1	1	234.46	.947								

Indirect Requirement Number	Indirect Requirement Description (I)	Determining Item Number	Determining Item Description (D)	N	C	D_1	I_1	D_2	I_2	D_3	I_3	D_4	I_4	D_5	I_5
A2112	Mechanical Equipment Room	B5032	Total Personnel	3	1	1	37.16	25	37.16	75	69.68				
A2128	Office Space-Administration	B5048	Total Staff Personnel	1	1	1,000	12,611								
A2144	Office Space-Manufacturing	B5016	Total Direct Personnel	1	1	1	18.58								
A2160	Passages & Corridors	A2128	Office Space - Adm	1	1	3	1								
		A2144	Office Space - Mfg	1	1	4	1								
		A3032	Total Mfg Floor Space	1	1	5	1								
A2176	Plant Maintenance & Machine Shop	B5064	Total Maint Personnel	6	1	30	278.7	31	1394	50	2322.5	100	2787	300 (D_6) 1000	4645 (I_6) 4645
A2192	Quality Control Lab	B6000I	Total Q.C. Personnel	3	1	1	3.72	200	744	2000	744				
A2208	Shipping & Receiving Dock	A2272	Warehouse Space	5	1	46.45	9.29	929.0	92.90	4645	311.22	9290	464.5	46450.7	696.76
		A2224	Solvent & Chemical Storage	5	1	45.45	9.29	929	92.9	4645	311.22	9290	464.5	46450.7	696.76
A2224	Solvent & Chemical Storage	A1064	Industrial Waste Clarifiers & Hold Tanks	3	1	1.0977E5	9.29	4.1733E5	18.58	11.3559E7	74.32				
A2240	Telephone Equipment Room	C1112	Telephone Service	3	1	1.00	4.65	50	13.94	1000	46.65				
A2256	Toilet and Locker Room	B5032	Total Personnel	6	1	1.00	46.45	15	46.45	16	69.68	110	153.29	190 (D_6) 1500	211.8 (I_6) 1395
A2263	Ventilation Facilities	C2128	Ventilation	1	1	14067	473								
A2272	Warehouse Space	A3032	Total Mfg Floor Space	4	1	1858	46.45	4645.1	697	9290	2323	92901	27870		
A3016	Total Factory Floor Space	A3032	Total Mfg Floor Space	1	1	1	1								
		A3048	Total Support Floor Space	1	1	1	1								
A3032	Total Mfg Floor Space	A2064	Mfg Space (Type A)	1	1	1	1								
		A2080	Mfg Space (Type B)	1	1	1	1								
		A2096	Mfg Space (Type C)	1	1	1	1								
A5000	Forklift Trucks	A2272	Warehouse Space	5	1	500	0	501	1	10000	1	160000	16	170000	16.75
A5016	Computer	B5032	Total Personnel	5	1	24	0	25	250	250	62500	1000	100000	2500	300,000

INDIRECT REQUIREMENTS MATRIX DATA

Indirect Requirement Number	Indirect Requirement Description (I)	Determining Item Number	Determining Item Description (D)	N	C	D_1	I_1	D_2	I_2	D_3	I_3	D_4	I_4	D_5	I_5
A3048	Total Support Floor Space	A2016	Cafeteria & Lunchroom	1	1	1	1								
		A2024	Computer Room	1	1	1	1								
		A2032	Electrical Equipt. Rm.	1	1	1	1								
		A2048	Health Svc Facilities	1	1	1	1								
		A2112	Mech. Equipt. Room	1	1	1	1								
		A2128	Office Space - Adm	1	1	1	1								
		A2144	Office Space - Mfg	1	1	1	1								
		A2160	Passages & Corridors	1	1	1	1								
		A2176	Plant Maint & Machine Shop	1	1	1	1								
		A2192	Quality Control Lab	1	1	1	1								
		A2208	Shipping & Recvg Dock	1	1	1	1								
		A2224	Solvent & Chem Storage	1	1	1	1								
		A2240	Telephone Equipt Room	1	1	1	1								
		A2256	Toilet & Locker Room	1	1	1	1								
		A2272	Warehouse Space	1	1	1	1								
B1016	Administrative Asst.	B5016	Total Direct Personnel	1	1	600	1								
B1032	Internal Auditor	B5016	Total Direct Personnel	1	1	600	1								
B1048	General Office Clerk	B5016	Total Direct Personnel	1	1	100	1								
B1064	Director, Industrial Relations	B1304	Manager, Personnel	1	1	2	1								
		B1288	Manager, Compensation, Insurance & Medical Service	1	1	2									
B1080	Director, Office Adm.	B1048	General Office Clerk	1	1	12	1								
		B1400	Receptionist	1	1	3	1								
		B1240	Mail Clerk	1	1	12	1								
B1096	Director, Plant Maint. & Security	B1320	Mgr, Security & Maint	1	1	3	1								
B1112	Director, Public Relns.	B5016	Total Direct Personnel	1	1	600	1								
B1128	Employment Interviewer	B5016	Total Direct Personnel	1	1	100	1								
B1144	Groundskeeper	A1096	Landscaping & Irrigation	1	1	13935	1								
B1160	Guard (Security)	A3016	Total Factory Floor Space	2	1	11148	4	55741	15						