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**Technology Transfer from NASA to
Targeted Industries**

Volume II

Prepared by:

**Wayne McCain
Bernard J. Schroer
William E. Souder
Mary S. Spann
Harry Watters
M. Carl Ziemke
University of Alabama in Huntsville
Huntsville, Alabama 35899
(205) 895-6243
FAX(205) 895-6733**

Prepared for:

**Technology Utilization Office
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
(205) 544-0553
FAX(205)544-3151**

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ABSTRACT

This volume contains the following materials to support Volume I:

- 1.0 Survey of Metal Fabrication Industry in Alabama
- 2.0 Survey of Electronics Manufacturing/Assembly Industry in Alabama
- 3.0 Apparel Modular Manufacturing Simulators
- 4.0 Synopsis of a Stereolithography Project
- 5.0 Transferring Modular Manufacturing Technology to an Apparel Firm
- 6.0 Letters of Support
- 7.0 Fact Sheets
- 8.0 Publications
- 9.0 One Stop Access to NASA Technology Brochure

1.0 Survey of Metal Fabrication Industry in Alabama

THE METAL FABRICATION INDUSTRY IN ALABAMA

Mary S. Spann, Ph.D.
Department of Management and Marketing
College of Administrative Science
University of Alabama in Huntsville

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INTRODUCTION

This report details the first steps in an ongoing University of Alabama in Huntsville program designed to facilitate technology transfer to specific industries in the state of Alabama. These first steps involve (1) selecting a target industry via standard industrial classification (SIC) codes using the Alabama Industrial Directory, (2) surveying the target industry via a mail questionnaire and (3) analyzing responses to the survey. This report documents the survey results for the metal fabrication industry in Alabama and describes characteristics of the sample firms, their technology practices and plans, and their training practices and plans. In general, data are presented for the aggregate sample. Where significant differences exist between firms of different sizes, these statistics are also reported.

RESEARCH METHODOLOGY

Using the Alabama Industrial Directory for 1991-1992, 520 firms were identified by Standard Industrial Classification (SIC) codes as manufacturing companies in the metal fabrication industry. The business unit defined as an independent business or a division or subsidiary of a parent firm was the unit of analysis in this study. A questionnaire was mailed to each firm. About one month later, each non-respondents received a duplicate questionnaire and a second appeal to participate in the study. In general, respondents identified themselves as presidents, chief executive officers, or general managers. Table 1 below indicates the number of responses obtained. The response rate was about 18%.

Table 1
Status of Mailed Questionnaires and Response Rate

Number of firms in identified population	520
Undelivered questionnaires	5
Firms designated as "not electronic manufacturers"	15
Size of adjusted population	500
Total completed questionnaires returned	92
Response rate (92/500)	18%

FIRM CHARACTERISTICS

Lines of Business

Machine shops (SIC #3599) constituted 35% of the sample firms; 24% of the sample firms were classified as miscellaneous metal fabricators (SIC #3441), 21% worked with ventilators (#3444), 15% worked in steel plate (SIC #3443), 2% in valve fittings (SIC #3494) and 1% in missile spare parts (#3812).

Firm Size

Firm size is typically measured by number of employees and by revenues. Here revenue objectives are used as a surrogate for actual revenues. Firms are more willing to reveal objectives rather than actual revenues. Past research has indicated that the objectives and actual revenues are highly correlated.

The vast majority of sample firms were small firms by either definition. Fifty percent of the sample were firms with less than 20 employees. Another 27% had between 20 and 50 employees; 10% had between 51 and 100, 6% between 101 and 250, 5% between 251 and 500, and 1% had 1000 to 2000 employees. Six percent of the sample firms had revenue objectives of less than \$100,000 this year; 17% had revenues objectives of between \$100 and \$500 thousand; 10% between \$500 thousand and \$1 million; 51% between \$1 and \$10 million and 15% greater than \$10 million.

Markets

In general, the metal fabrication industry serves primarily business and government customers. Only 5% of industry revenues, on average, came from individual consumers. On average, sales to small businesses (under 100 employees) accounted for 28% of industry revenues, revenues from medium sized businesses (100 to 500 employees) 23%, revenues from large businesses (over 500 employees) 31% and revenues from government organizations 13%. Table 2 summarizes these statistics.

When the sample is divided into three subgroups based on size, some market differences are apparent. On average, firms with less than 20 employees serve more individual consumer than larger firms. The smallest firms received 10% of revenues from this market segment whereas

firms with more than 20 employees receive less than 1% of their revenues from individual consumers. Additionally, the smallest firms (less than 20 employees) make significantly fewer sales to large businesses (22% of revenues) whereas firms with 20-50 employees get 31% of their revenues and firms with more than 50 employees get 48% of their revenues from large businesses. No statistically significant differences between the three subgroups exist for average revenues from small businesses, medium businesses and government.

Table 2
Percent Revenues from Various Types of Customers

Type of Customer	Mean	Standard Deviation	Minimum	Maximum
Individual Consumers	5.06%	13.60	0%	95%
Small Businesses	28.38%	30.86	0%	100%
Medium Sized Businesses	22.78%	22.95	0%	98%
Large Businesses	30.52%	31.40	0%	100%
Government Agencies	13.26%	26.34	0%	100%

Geographically, the industry primarily serves state (52% of revenues) and regional (22%) markets; on average, only 3% of industry revenues came from international markets. Table 3 summarizes the distribution of average revenues from state, regional, national and international markets.

Firm size makes a difference in the geographic dispersion of the firm's markets. Firms with less than 20 employees do 75% of their business within the state. Firms with more than 50 employees serve more geographically dispersed markets with 44% of their revenues coming from the USA outside of the Southeast (See Table 4 for more details.)

Table 3
Percent Revenues from Geographic Markets Served

<u>Geographic Market</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>Minimum</u>	<u>Maximum</u>
Alabama	52.29%	37.58	0%	100%
Southeast USA Outside Alabama	22.44%	22.16	0%	85%
USA Outside Southeast	22.13%	28.56	0%	95%
International	3.44%	9.39	0%	70%

Table 4
Percent Revenues from Geographic Markets Served by Size Subgroups

Firm Size by Number of Employees				
<u>Geographic Market</u>	<u>< 20</u>	<u>20 - 50</u>	<u>> 50</u>	<u>*</u>
Alabama	74.77%	41.48%	19.95%	**
Southeast USA Outside Alabama	19.05%	25.70%	29.32%	
USA Outside Southeast	5.54%	28.15%	43.63%	**
International	0.64%	7.10%	6.58%	**

** Statistically significant differences between subgroups at $p < 0.02$

Problems

Dealing with government regulations is the industry's biggest problem. This result may be related to the fact that most of the sample firms are small businesses. A common complaint among many small businesses is that government regulations are overly burdensome. Finding and retaining qualified workers is also problematic. Financing growth and dealing with technological change are rated as the least problematic. These data are presented in Table 5. No size subgroup differences exist in the problems facing metal fabricators.

Table 5
Potential Problem Areas

Problem Areas	Mean*	Standard Deviation
1. Government Regulations	3.35	1.360
2. Finding & Retaining Qualified Workers	3.22	1.907
3. Competition	3.03	1.277
4. Marketing	2.74	1.241
5. Technological Change	2.45	1.228
6. Financing Growth	2.33	1.646

* Rate the difficulty your firm has with each of the potential problem areas. Degree of Difficulty: 1 (Not A Problem) to 5 (Critical Problem).

Competitive Advantage

The sample firms rely on product quality as an important source of their competitive advantage (Table 6). The firms also compete on the basis of better service and better delivery. A competition advantage based on a specialized product or a low cost position was used less often.

Table 6
Sources of Competitive Advantage

Basis for Competitive Advantage	Mean*	Standard Deviation
Better Product Quality	3.977	1.005
Better Service	3.895	1.117
Better Delivery	3.593	1.110
Specialized Product	3.202	1.210
Low Cost	3.200	0.961

* Rate your firm's advantage over its competitors. Scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

Relationships With Suppliers

Most firms in the industry develop long-term relationships with their suppliers. However, these long term relationships appear not to be as beneficial as they should be. One would expect

that a long-time supplier would be a source of ideas for new products as well as for improvements in processes and quality. The fact that firms in the industry tend to have numerous suppliers may dilute these potential benefits. Table 7 summarizes relationships with suppliers.

Table 7
Characteristics of Relationships With Suppliers

Characteristic	Mean*	Standard Deviation
1. Source of Ideas for Improving Quality	2.750	1.241
2. Source of Process Improvement Ideas	2.988	1.256
3. Source of New Product Ideas	3.202	1.297
4. Numerous Suppliers	3.500	1.177
5. Long term Relationships	3.940	1.123

* Indicate your agreement with each items describing your relationships with your suppliers. Scale of 1(Strongly Disagree) to 5 (Strongly Agree).

TECHNOLOGY PLANS AND PRACTICES

Success in Adopting New Technology

The majority of firms reported that they are usually to always successful in adopting new technologies (Figure 1). No difference in the successful adoption of new technology exists among firms of varying sizes.

Barriers to Implementing New Technologies

The cost of implementing new technologies is a strong barrier to the implementation of new technology. The need to educate workers in new technologies is also a barrier to implementation. Firms tend to disagree that resistance to change is a barrier to the implementation of new technology. No significant differences in barriers to new technology implementation exist between firms of different sizes.

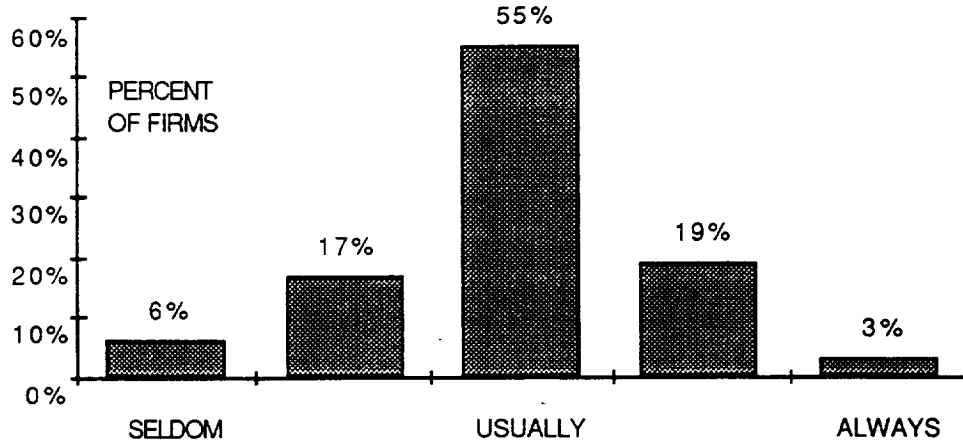


Figure 1
Success in Adopting New Technology

Table 8
Barriers to Implementing New Technologies

Barrier	Mean*	Standard Deviation
1. Cost	3.718	1.259
2. Education	3.500	1.197
3. Resistance to Change	2.821	1.328

* A barrier to implementing new technology in my firm is: _____ .
Scale of 1(Strongly Disagree) to 5 (Strongly Agree).

Use of Computer-Integrated Manufacturing (CIM) and Other Engineering Tools

Table 9 lists current and planned usage of computer-integrated manufacturing (CIM) for all firms in the study. Table 10 lists current usage of CIM broken down by firm size. CNC is used by almost one-half of the sample firms. Roughly 40% of the sample use CAD, whereas approximately one-third use CAE and CAM. Forty percent of all firm plan to link their CAD and CAM systems within the next 5 years. About one-third plan to adopt CAD, CAM, CAE and MRP and engineering data management within the next 5 years. Cellular manufacturing, flexible manufacturing systems, robotics, DNC and EDI are least used and less likely to be used.

Current use of the most popular CIM tools is highly related to firm size. CNC, CAD, CAM, CAE and networks are used by 50% to 83% of the larger firms. Only 10% to 20% of firms with fewer than 20 employees employ these tools. Forty to sixty percent of firms with 20 to 50 employees use CNC, CAD, CAM and CAE. It appears that most firms must have at least 20 employees before adopting the most popular CIM tools (CNC, CAD, CAM and CAE).

Table 9
Use of Computer-Integrated Manufacturing (CIM)

Type of CIM	Percent of All Sample Firms		
	Use Now	Use In 5 Years	Neither Use or Plan to Use
Computer Numeric Control (CNC)	48.81%	21.43%	29.76%
Computer-aided Design (CAD)	44.71%	34.12%	21.18%
Computer-aided Engineering (CAE)	35.71%	34.52%	29.76%
Computer-aided Manufacturing (CAM)	31.22%	36.14%	32.53%
Firm-Wide Information Networks	20.24%	22.62%	57.14%
Materials Requirement Planning (MRP)	21.95%	32.93%	45.12%
Computer-Supported SPC	17.50%	22.50%	60.00%
Computer-Aided Process Planning (CAPP)	15.66%	25.30%	59.04%
Automated Testing/Inspection (Vision)	14.81%	25.93%	59.26%
Engineering Data Management	12.50%	33.75%	53.75%
Linking CAD to CAM	12.20%	40.24%	47.56%
Bar Coding/Automated Data Collection	11.11%	29.63%	59.26%
Data Network Control (DNC)	10.00%	16.25%	73.75%
Electronic Data Interchange (EDI)	9.88%	23.46%	66.67%
Cellular/Modular Manufacturing	7.50%	15.00%	77.50%
Flexible Manufacturing Systems	6.49%	24.68%	68.83%
Robotics	4.88%	26.83%	68.29%

Table 10
Current Use of Computer-Integrated Manufacturing (CIM) by Firm Size

Type of CIM	Percent of Firms With		
	<20 employees	20-50 employees	>50 employees
Computer Numeric Control (CNC)	22.22%	60.00%	70.59%**
Computer-aided Design (CAD)	16.67%	55.00%	83.33%**
Computer-aided Engineering (CAE)	11.11%	50.00%	64.71%**
Computer-aided Manufacturing (CAM)	13.89%	42.11%	52.94%**
Firm-Wide Information Networks	14.29%	28.57%	57.14%**
Materials Requirement Planning (MRP)	8.57%	30.00%	35.29%**
Computer-Supported SPC	11.11%	22.22%	31.25%
Computer-Aided Process Planning (CAPP)	12.78%	21.05%	27.78%**
Automated Testing/Inspection (Vision)	18.18%	27.27%	54.55%**
Engineering Data Management	2.86%	16.67%	29.41%**
Linking CAD to CAM	37.50%	37.50%	25.00%
Bar Coding/Automated Data Collection	5.56%	5.56%	29.41%**
Data Network Control (DNC)	0.00%	11.11%	31.25%**
Electronic Data Interchange (EDI)	16.67%	50.00%	33.33%
Cellular/Modular Manufacturing	0.00%	5.56%	25.00%**
Flexible Manufacturing Systems	0.00%	5.56%	25.00%**
Robotics	2.78%	0.00%	11.76%**

**Statistically significant differences at $p < 0.05$.

Of interest in Table 11 is the heavy current use and planned use of quality inspection and the limited use of SPC and TQM as systems for managing quality. Additionally, more than 50% of the firms plan never to use JIT, DFM, or concurrent engineering -- techniques which along with SPC and TQM receive many favorable reviews in both the engineering and business press as means of improving American quality and productivity. These are areas where theory and practice fall particularly short of one another.

Differences in current use and planned use of SPC, TQM and JIT exist between firms of different sizes with smaller firms (fewer than 20 employees) less likely to have currently adopted these practices and less likely to adopt these practices.

Table 11
Use of Other Engineering Tools

Tool	Percent of All Sample Firms		
	Use Now	Use In 5 Years	Neither Use or Plan to Use
Quality Inspection	72.29%	30.77%	18.07%
Total Quality Management (TQM)	20.51%	30.77%	48.72%
Just-in-Time Inventory (JIT)	27.50%	21.25%	51.25%
Design for Manufacturing (DFM)	18.42%	21.05%	60.53%
Concurrent Engineering	14.86%	22.97%	62.16%
Statistical Process Control (SPC)	12.99%	27.27%	59.74%
Theory of Constraints	2.78%	19.44%	77.78%

Quality Management Transition

Almost all of the larger firms with more than 50 employees collect customers feedback as do the majority of the sample firms, regardless of their size. Almost all of these larger firm have communicated their quality values and have a written mission statement stating their quality values. More than one-half of the larger firms have begun a total quality management transition and have instituted human resource planning. These practices are also reflected to some degree by the small firms in the sample as detailed in Table 12. Again firm size is a critical factor in the adoption of quality management philosophy and practices.

Table 12

Quality Management Practices by Firm Size

<u>Practice</u>	Percent of Firms		
	<u><20 employees</u>	<u>20-50 employees</u>	<u>>50 employees</u>
Collect and Use Customer Feedback	73.68%	90.48%	94.74%
Communicate Program for Quality Values	36.84%	76.19%	84.21%
Quality Values in Written Mission	32.43%	61.90%	84.21%
Begun TQM Transition	21.05%	25.00%	68.42%
Benchmarking	18.92%	52.38%	31.58%
Human Resource Planning	7.89%	47.62%	57.89%

TRAINING PLANS AND PRACTICES

Despite the implementation of human resource planning, including training, as reported in Table 12, the great majority of the sample firms actually provide very little training for experienced production workers at the current time. Eight hours of training per month is presently considered average for production workers. Figure 2 shows that only 13 percent of the firms are providing more than 8 hours of training per month. Seventy percent of the firms provide very little, if any, training. Amount of training is unrelated to firm size, larger firms are provided no more training than smaller firms.

The sample firms were generally unfamiliar with state-supported training programs and institutions. About 17% had used the services of AIDT (Alabama Industrial Development Training), 2% of ACATT (Alabama Center for Advanced Technology Transfer) and none of the sample was familiar with ACIST (Alabama Center for Information Systems Transfer). Figure 3 summarizes the types of training received by employees of sample firms and whether or not that training was taken through AIDT, ACATT or ACIST. About half of the firms had employees who had training in CNC; about 40% of firms had employees with training in quality control, management and fabrication.

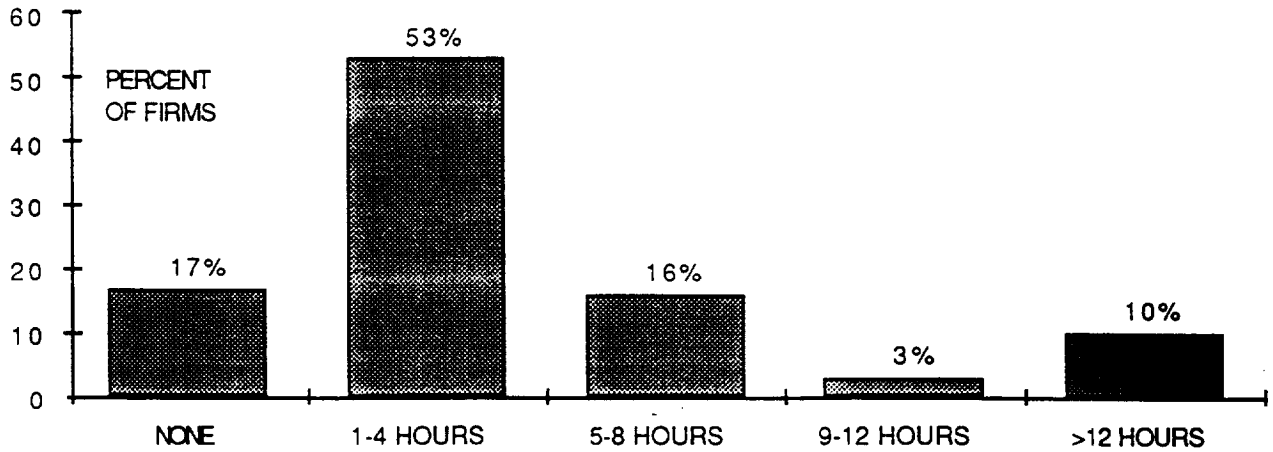


Figure 2
Investments in Training Experience Production Workers

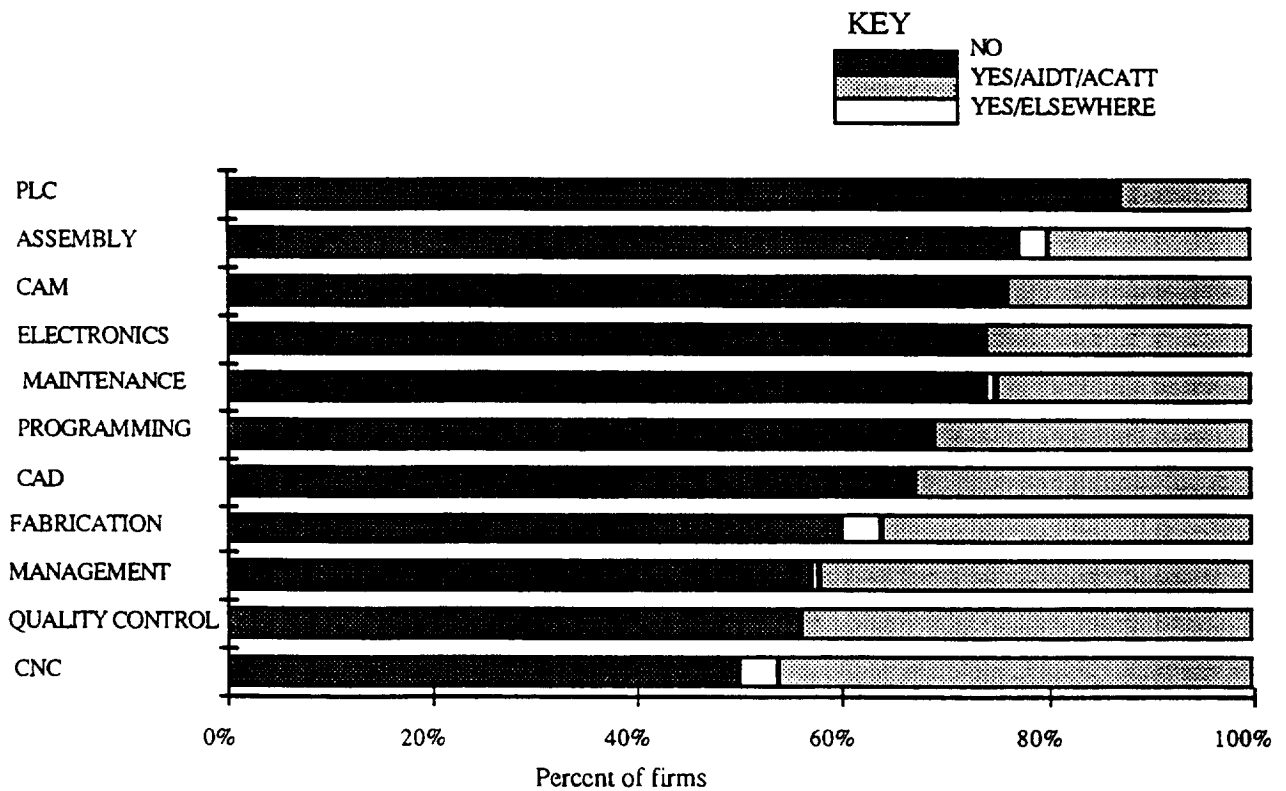


Figure 3
Kinds and Sources of Training

Figure 4 outlines potential training needs over the next five years by listing the kinds of technology the sample firms plan to adopt in this time frame. Thirty to thirty-five percent of the sample firms plan to adopt MRP, EDM, CAD, CAE, and CAM while 40% plan to link their CAD and CAM systems.

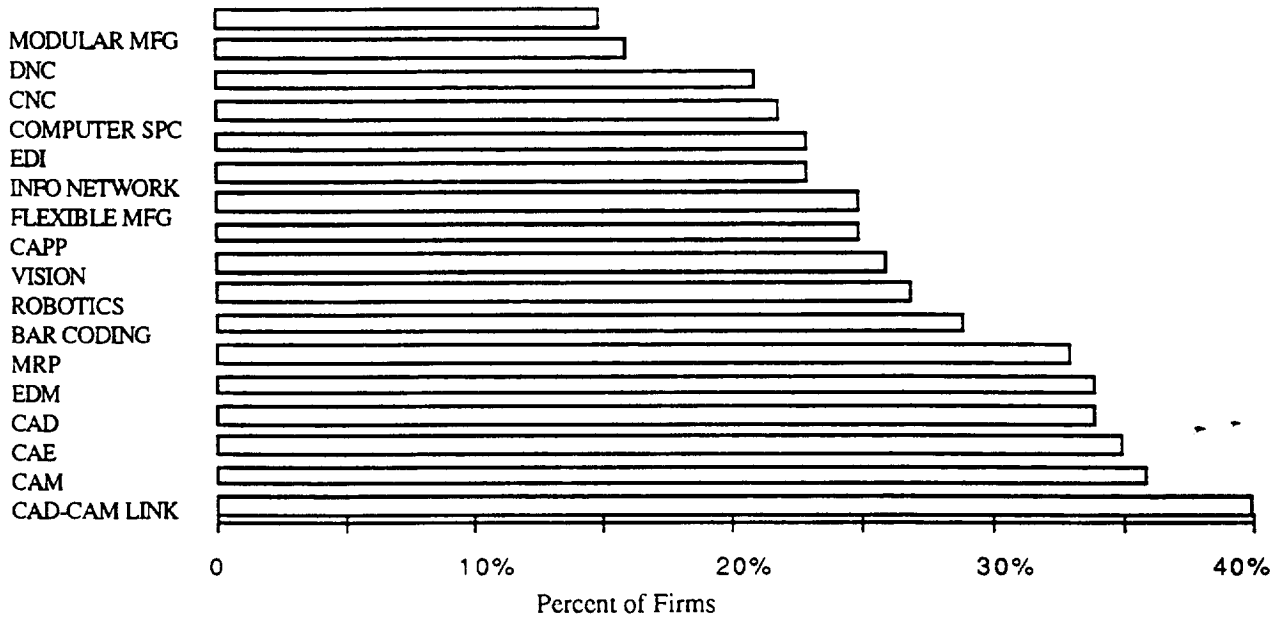


Figure 4
Plans to Use Computer-Integrated Manufacturing Within Five Years

Investments in the Equipment

While investment in training do not correlate with firm size, investments in equipment do ($r = 0.47$). Larger firms have plans for larger investments in equipment than smaller firms. Larger firms do not, however, do significantly more training. Table 13 summarizes planned investments in equipment over the next 3 years.

Table 13
Planned Investments in Equipment During Next Three Years

Amount of Planned Investment	Percent of Firms
< \$100,000	39.08%
\$100,000 to \$500,000	43.68%
\$500,000 to \$1,000,000	9.20%
More than \$1,000,000	8.05%

CONCLUSIONS

The data presented provide a global picture of the average firm in the metal fabrication industry. Such averages blur differences which we know exist -- differences in size, capabilities, strategies, objectives, etc. Some of these differences between firms of different sizes have been reported.

Nevertheless, a few things stand out. Ninety-nine percent of Alabama metal fabricators are small businesses using the Small Business Administration's definition of a small business as one with 500 or fewer employees. Additionally, the majority of these firms are very small businesses with 50% having less than 20 employees and another 27% with 20 to 50 employees. These size differences are important. The data demonstrate that the size of the business influences the scope of the marketing effort, the adoption of technology and plans for the future.

Alabama metal fabricators operate almost entirely in the industrial segment of the market targeting other businesses (80% of revenues) within the State (52%) and Southeast (22%). The smaller fabricators tend to make fewer sales (22%) to large businesses than do the larger fabricators (48%). Additionally, smaller fabricators rely more heavily on sales to other businesses within Alabama (75%).

The sample firms compete on the basis of quality, delivery and service rather than with specialized products or low cost. General consensus in the industry is that competition is strong with expectation that it will be somewhat stronger in the future. Fairly typical for small businesses, Alabama's small metal fabricators define dealing with government regulation as their most serious problem. Finding and retaining qualified workers is the second largest problem yet

training for experienced workers is generally neglected with 70% of these firms provide 4 or fewer hours of training per month. Larger firms do not do significantly more training than small ones. The vast majority of Alabama metal fabricators fail to use the services of the state-support training programs and institutions like ADIT, ACATT, and ACIST

The majority of the firms report that they are usually to always successful in adopting new technologies but that cost and education are serious barriers to implementing new technologies. CNC and CAD are used by almost half and CAE and CAM by about one-third of all the sample firms. Again size makes a big difference in the adoption of these CIM technologies. Fifty to eighty percent of firms with more than 50 employees use CNC, CAE, CAD and CAM whereas only 10 to 20% of firms with fewer than 20 employees do.

Almost 80% of the sample firms reported they emphasis quality products and 74% reported that quality is an important source of their competitive advantage, yet quality is largely assured by inspection. Modern engineering and management practices for the implementation of quality management are largely unused in the industry. Only 20% of the industry use TQM and 13% use SPC. Firms with more than 50 employees have done more in implementing quality management transitions than firms with fewer than 20 employees. Almost all of these larger firms have written mission statements and inhouse programs to communicate their quality values to customers and employees alike. Almost all firms, regardless of size, collect customer feedback.

Certainly opportunities for training exist within the metal fabrication industry. Clearly with the emphasis on quality as a major source of competitive advantage, training in quality management is critical to Alabama's metal fabrication industry. Other training opportunities based on the industry's plans for technology adoption within the next five years include training in MRP, EDM, CAD, CAM, CAE and linking CAD to CAM. With cost and education as serious barriers to technology implementation, training institutions have an opportunity to overcome these barriers with low cost training programs. Size is also key here. Based on current and planned use of CIM and emphasis on implementing TQM, firms with more than 20 employees are most likely targets for training programs. Firms with fewer than 20 employees appear to have too few resources to implement CIM or TQM at the present time.

2.0 Survey of Electronics Manufacturing/Assembly Industry in Alabama

CAS Research Report No. 91-11-1

**LINKING TECHNOLOGY AND STRATEGY
IN THE ELECTRONIC INDUSTRY
IN ALABAMA
DESCRIPTION OF THE INDUSTRY**

**Center for Management and Economic Research
College of Administrative Science**

The University of Alabama in Huntsville

**LINKING TECHNOLOGY AND STRATEGY
IN THE ELECTRONIC INDUSTRY
IN ALABAMA**

DESCRIPTION OF THE INDUSTRY

**Mary S. Spann, Ph.D.
Assistant Professor**

November 13, 1991

**This report was prepared as part of a grant from the
Center for Management and Economic Research
College of Administrative Science, University of Alabama in Huntsville.**

INTRODUCTION

Concerns About the Electronic Industry

Concern over American competitiveness in a global economy is widespread. The concern over American competitiveness in the electronic industry is based on two factors. First, the electronic industry is important because its estimated size is hundreds of billions of dollars per year worldwide (Gilder, 1991). The second concern is that Americans have already lost the consumer electronic segment of the industry to the Japanese (Gilder, 1991).

Alabama firms have a share in this market and face the risk of foreign domination of the industry. In the state of Alabama, over 45,000 people, in about 350 businesses, work in the electronic assembly industry. In 1988, the Governor of Alabama established a task force to identify industries in the State in need of technical assistance. The task force identified the apparel manufacturing industry as the first target industry. The electronic assembly industry is a likely candidate for another state-assisted program. One purpose of this study was to characterize the state-of-the-industry in Alabama and to identify areas of concern. This report presents those initial findings.

Characterizing the Industry in Alabama

The type of preliminary information collected on the electronic industry included market definition (customer size and location), perceptions of competition, relationships with suppliers, sources and uses of technology, emphasis on quality, problem areas, investments in the future, business strategy, and channels of communication. The results are described below.

Acknowledgement: This work was supported by the Center for Management and Economic Research of the College of Administrative Science and the Johnson Research Center of the University of Alabama in Huntsville.

RESEARCH METHODOLOGY

Using the Alabama Industrial Directory for 1990-1991, 350 firms were identified by Standard Industrial Classification (SIC) codes as manufacturing companies in the electronic industry. The unit of analysis was the business unit defined as an independent business or a division or subsidiary of a parent firm. A survey instrument designed following the guidelines of Dillman (1978) was mailed to each firm. Ten days later, a postcard was sent to each firm indicating that a questionnaire had been mailed. One month later, a duplicate questionnaire was mailed to each of the non-respondents with a second appeal to participate in the study. Respondents identified themselves as presidents, chief executive officers, or general managers.

Early on, officers of some firms indicated that they could not participate in the study because their firms were not electronic manufacturers or assemblers. These responses indicate that the SIC codes were not an exact classification and that the sample frame contained some firms not in the desired population. Consequently, the cover letter of the second mailing asked principals of firms that were mis-classified to return the questionnaire unanswered but with the notation "not an electronic manufacturer." Many complied. Table 1 below indicates the number of responses obtained. The response rate was 25%.

Table 2 compares the size (in terms of number of employees) of the firms in the sample against those in the population identified through the Alabama Industrial Directory. Reasonable correspondence exists between firms in the sample and the population.

Table 1
Status of Mailed Questionnaires and Response Rate

Number of firms in identified population	350
Undelivered questionnaires	44
Firms designated as "not electronic manufacturers"	46
Size of adjusted population	260
Total completed questionnaires returned	66
Response rate (66/260)	25%

Table 2
Comparison of Size of Sample Firms to Population

Number of Employees	Population	Sample
Less than 50	65.2%	58.3%
51 - 100	12.3%	20.0%
100 - 500	17.2%	15.0%
More than 500	5.3%	6.7%

FINDINGS: STATE-OF-THE-INDUSTRY

Industry Structure

According to management guru, Michael Porter, (1980) the definition of the structure of any industry involves 5 forces: the industry rivals, buyers, suppliers, barriers to entry and threat of substitution. The electronic manufacturing/assembly industry in Alabama (hereafter, the industry) was characterized, in this preliminary analysis, according to markets served (buyers), perceptions of competition (rivalry), and relationships with suppliers.

Markets. Seventy-five percent of the industry served only business and government organizations. Only 5% of industry sales, on average, were to individual consumers. On average, sales to small businesses (under 100 employees) accounted for 21% of industry sales, sales to medium sized businesses (100 to 500 employees) 18%, sales to large businesses (over 500 employees) 30% and sales to government organizations 26%. Table 3 summarizes these statistics.

Geographically, the industry primarily served domestic markets; on average, only 10% of sales were international. Almost 50% of the firms had no international sales. Table 4 summarizes the distribution of average sales in domestic and international markets.

Table 3
Percent Revenues from Various Types of Customers

Type of Customer	Mean	Standard Deviation	Minimum	Maximum
Individual Consumers	5.03%	17.96	0%	100%
Small Businesses	21.04%	31.77	0%	100%
Medium Sized Businesses	18.45%	24.37	0%	100%
Large Businesses	29.71%	32.33	0%	100%
Government Agencies	25.76%	38.34	0%	100%

Table 4
Percent Revenues from Geographic Markets Served

Geographic Market	Mean	Standard Deviation	Minimum	Maximum
Alabama	27.74%	32.53	0%	100%
Southeast USA Outside Alabama	22.37%	24.74	0%	100%
USA Outside Southeast	39.69%	31.82	0%	100%
International	9.95%	17.01	0%	85%

Competition. Table 5 summarizes the means by which firms compete while Tables 6 and 7 concerns perceptions of competition in the industry. In general, the sample firms reported that they do not compete on the basis of low cost but rather seek some differential advantage based on delivery, specialized products, quality or service. Top managers in Alabama firms believe that the greatest competition comes from national competitors rather than from regional or international competitors. Perceptions are that competition is quite strong and will get somewhat stronger in the next 3 to 5 years.

Table 5
Sources of Competitive Advantage

Basis for Competitive Advantage	Mean*	Standard Deviation
Low Cost**	3.076	1.154
Better Delivery	3.727	1.075
Specialized Product	3.803	1.218
Better Product Quality	4.152	0.899
Better Service	4.152	0.996

* Rate your firm's advantage over its competitors. Scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

** Low Cost is significantly different from all others at $p = 0.001$.

Table 6
Sources of Competition

Source of Competition	Mean*	Standard Deviation
Local Domestic Firms	2.348	1.376
International Firms Located in USA	2.712	1.367
Offshore International Firms	2.884	1.218
National Domestic Firms**	3.394	1.251

* In the next 3-5 years, where do you expect the greatest competition? Scale of 1 (Strongly Disagree) to 5 (Strongly Agree).

** Significantly larger than all others at $p < 0.05$.

Table 7
Perceptions of Strength of Competition

Degree of Competition	Mean*	Standard Deviation
Currently	3.894	1.125
In 3-5 Years**	4.121	1.060

* Scale of 1 (Very Cooperative) to 5 (Very Competitive).

** Significant difference at $p < 0.05$

Relationships With Suppliers. Most firms in the industry develop long-term relationships with their suppliers. However, these long term relationships appear not to be as beneficial as they should be. One would expect that a long-time supplier would be a source of ideas for new products as well as for improvements in processes and quality. The fact that firms in the industry tends to have numerous suppliers may dilute these potential benefits. Table 8 summarizes relationships with suppliers.

Table 8
Characteristics of Relationships With Suppliers

Characteristic	Mean*	Standard Deviation
1. Source of Process Improvement Ideas	2.84	1.177
2. Source of New Product Ideas	2.92	1.168
3. Source of Ideas for Improving Quality	2.97	1.109
4. Numerous Suppliers**	3.63	1.132
5. Long term Relationships***	3.98	0.850

* Indicate your agreement with each items describing your relationships with your suppliers. Scale of 1(Strongly Disagree) to 5 (Strongly Agree).

** Significantly greater than 1, 2, 3, and 4 at $p = 0.05$.

*** Significantly greater than 1, 2 and 3 at $p = 0.004$.

Sources and Uses of Technology

Both internal and external sources of technology appear to be important to the industry with firms relying somewhat more on their own internal R&D capabilities. These firms value proprietary technology achieved through firm-owned patents over standard, non-proprietary, public domain technology. Extremely little technology is transferred from the government sector. These data are summarized in Table 9. Preliminary analysis, not shown here, indicates that there may be two distinct subgroups of firms in the sample, one group which relies on numerous internal and external sources and a second group which relies on very few sources of technology.

Table 9
Sources of Firm Technology

	Mean*	Standard Deviation
1. Technology Transferred from Government**	0.985	1.353
2. Public Domain Technology***	1.708	1.548
3. Firm Owned Patents	2.485	1.833
4. Externally Developed Technology	2.592	1.610
5. Internal R&D	2.864	1.727

* In relationship to the technology of your firm, to what extent does your firm employ the following? Scale of 0 (Not At All) to 5 (Very Extensively).

** Used significantly less than all others at $p = 0.001$.

*** Used significantly less than 3, 4, & 5 at $p = 0.004$.

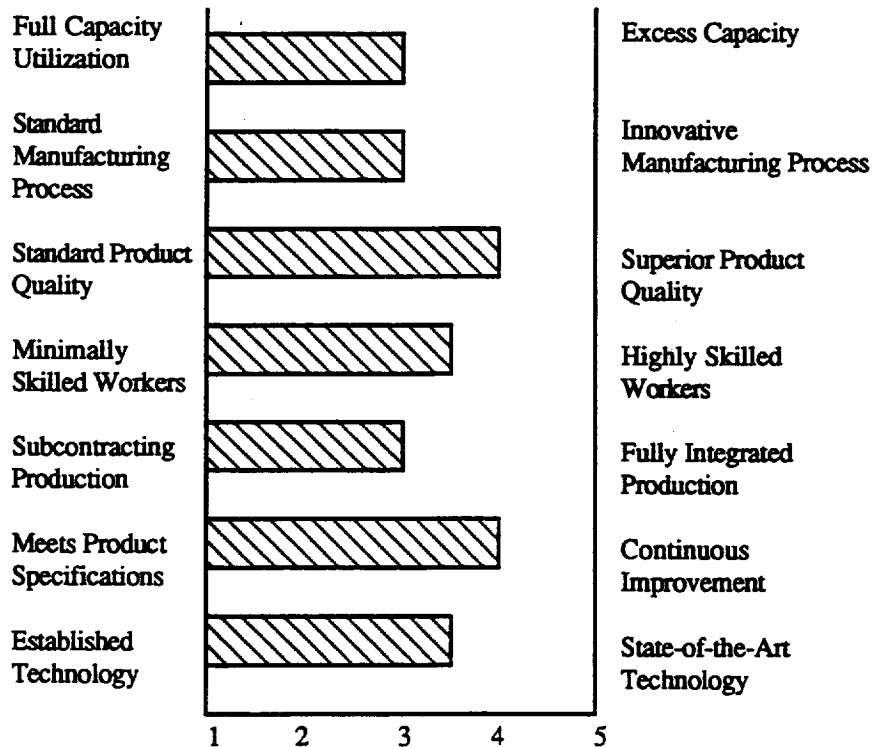
Table 10 lists usage of engineering tools and techniques. Special fixture and attachments on production equipment are most widely used while industrial robots are least used. At least 40% of the sample firms use some fairly sophisticated technology -- from computer-aided design (CAD) to computer simulation of processes. Firm size correlates positively and significantly with the use of CAD, CAM, computer simulations, surface mount technology and robots.

Table 10
Use of Engineering Tools and Techniques

Tool or Technique	Percent of Firms
Special Fixtures on Production Equipment	84.8%
Special Attachments on Production Equipment	77.3%
Computer-aided Design (CAD)	77.3%
Systems Engineering	62.1%
Automated Production Equipment	54.5%
Computer-aided Manufacturing (CAM)	40.9%
Computer Simulation of Processes	40.9%
Surface Mount Technology	36.9%
Industrial Robots	10.6%

Correspondingly, the firm's production processes emphasize superior product quality, highly skilled workers, continuous improvement and state-of-the-art technology. The data are summarized in Table 11.

Table 11
Emphasis in Production Processes



Emphasis on Quality

Emphasis on quality within the industry shows up as a basis for the firm's competitive advantage (Table 5) and as an emphasis in production (Table 11). Table 12 summarizes some techniques and tools used to assure product quality. Almost 90% of the firms inspect to assure quality. Only two of the 66 firms have no quality programs. The other firms that do not inspect for quality use statistical process control. About half of the firms have initiated total quality management programs while over 40% use statistical process control to monitor their production

processes. Certification by government agencies and government contractors is often an indication of quality, and slightly over 50% of the firms report that they are certified suppliers (Table 13).

Table 12
Use of Quality Management Tools and Techniques

Tool or Technique	Percent of Firms
Quality Control by Inspection	86.4%
Total Quality Management (TQM)	51.5%
Statistical Process Control (SPC)	43.9%

Table 13
Certification As A Supplier

Certifying Organization	Percent Firms Certified
Prime Contractor to Government	54.5%
US Government (Any Branch)	56.1%

Problems

Competition is ranked as the industry's biggest problem. Finding and retaining qualified workers is also somewhat problematic. Financing growth and dealing with technological change are rated as the least problematic. These data are presented in Table 14.

Table 14
Potential Problem Areas

Problem Areas	Mean*	Standard Deviation
1. Competition**	3.09	1.057
2. Finding & Retaining Qualified Workers	2.98	1.157
3. Marketing	2.89	1.204
4. Government Regulations	2.86	1.251
5. Technological Change	2.62	1.034
6. Financing Growth	2.50	1.304

* Rate the difficulty your firm has with each of the potential problem areas. Degree of Difficulty: 1 (Not A Problem) to 5 (Critical Problem).

** Competition is significantly a greater problem than 5 & 6 at $p < 0.05$.

Channels of Communication

The results emphasize the eclectic nature of the industry's markets and market segments. Top managers indicated that they read trade journal related to their particular market segment more so that generic electronic industry journals like Electronic Business, Electronic Times and Electronic News. Thus, the reading habits of top managers in the sample firms focused on customers rather than competition. As might be expected, trade show attendance also focused on customers.

Investments in the Future

We were also concerned with how well the industry was preparing itself for the future by making investments in human resources (Table 15) as well as equipment (Table 16). Fifty percent of the firms are doing very little training (4 hours or less per month) for experienced production workers. About 30% of the firms are providing what is considered to be an average amount of training (5 - 8 hours per month). Only 3% are doing considerable training. Training appears to be weakness in the industry.

Investments in equipment correlate very strongly ($r = 0.7$) with firm size. Larger firms have plans for larger investments in equipment. Larger firms do not, however, do significantly more training.

Table 15
Investments in Training Experience Production Workers*

<u>Average hours/month/worker</u>	<u>Percent of Firms</u>
0	13.6%
1 - 4	36.4%
5 - 8	28.8%
9 - 12	3.0%
12 or more	13.6%

* On average, how much training do your experienced production workers receive on company time?

Table 16
Planned Investments in Equipment During Next Three Years*

<u>Amount of Planned Investment</u>	<u>Percent of Firms</u>
< \$100,000	33.3%
\$100,000 to \$500,000	37.8%
\$500,000 to \$1,000,000	9.1%
More than \$1,000,000	18.2%

* Estimate the total cost of new equipment you plan to purchase in the next 3 years for use in this business.

Business Strategy and Objectives

Business strategy is defined as the means by which a firm competes in a given product market. Numerous ways exist to describe business strategy. Porter has suggested that there are three generic strategies: cost leadership, differentiation, and focus (1980). Ansoff's (1965) classic matrix characterizes business strategy along two dimensions: products (present and new) and markets (present and new). Thus, Ansoff defines four business strategies: market penetration (present products and present markets), product development (new products and present markets),

market development (present products and new markets) and diversification (new products and new markets).

The sample firms use differentiation strategies and focus or niche strategies more than low cost strategies. These firms have also adopted market development and market penetration strategies more than product development or diversification. Thus, the emphasis tends to be on offering existing products to current or new customers rather than developing and offering new products. These data are summarized in Table 17.

Table 17
Business Strategy

Strategy	Mean*	Standard Deviation
Lost Cost**	2.78	1.544
Differentiation	3.39	1.299
Focus (Niche)	3.50	1.303
Diversification***	3.15	1.361
Product Development	3.39	1.299
Market Penetration	3.47	1.205
Market Development	3.54	1.026

* To what extent does your company emphasize the following strategies? Scale from 0 (Not At All) to 5 (Very Extensively).

** Lost cost strategies emphasized significantly less than differentiation or focus.

*** Diversification strategies emphasized significantly less often than market development strategies.

Table 18 summarizes firm objectives for this year and for 5 years hence. The data tend to show that firms have expectations of growth in sales over the next 5 years. About 90% of the firms expect that their sales will be over \$1 million with almost 55% of the firms expecting sales of over \$10 million in 5 years. Only 26% of the firms expect sales revenues to exceed \$10 million in the current year.

Correlational data provide some clues as to where this growth is expected as well as some characteristics of firms with growth expectations. Firms with higher five-year sales objectives tend to be larger firms ($r = 0.46$). These firms do not focus on sales to small businesses ($r = -0.31$) but concentrate on sales to government agencies ($r = 0.31$) and on international sales ($r = 0.32$). These firms use external sources of technology ($r = 0.32$) and emphasize continuous improvement ($r = 0.36$) and state-of-the-art technology ($r = 0.39$) in their manufacturing processes. Strategically, firms with high long-term growth objectives have adopted new product strategies, developing new products for current customers ($r = 0.37$) and for new customers ($r = 0.31$). Additionally, firms with high five-year sales growth goals plan to make considerable investments in equipment in the next three years ($r = 0.49$).

Table 18
Sales Objectives

Sales Objective	Percent Firms this Year*	Percent of Firms in 5 Years**
Less than \$50,000	3.0%	0.0%
\$51,000 - \$99,999	0.0%	1.5%
\$100,000 - \$499,999	10.6%	4.5%
\$500,000 - \$999,999	10.6%	3.0%
\$1 Million - \$10 Million	50.0%	36.4%
> \$10 Million	25.8%	54.5%

*Which of the following best matches your sales revenue objective for this year? **In 5 years?

CONCLUSIONS

Conclusions are necessarily preliminary and brief at this time. Some late responses are still arriving. Two questionnaires have arrived recently and are not include in the above analysis. We have looked at very few inferential statistics and at few sub-group statistics. The data presented provide a global picture of the average firm in the industry. Such averages blur differences which we know exist -- differences in size, capabilities, strategies, objectives, etc.

Nevertheless, a few things stand out. Alabama electronic manufacturers operate almost completely in the industrial, not the consumer, segment of the market. Furthermore, these firms largely target firms and government organizations in the USA. The firms compete on the basis of differentiation (delivery, service, quality and specialized products), not cost. There is general consensus in the industry that competition is strong with expectation that it will be somewhat stronger in the future. The sample firms define competition as their most serious problem.

Another conclusion is that Alabama electronic assemblers largely ignore the government as a source of technology. Much of the industry (about 70%) is located in the North and North Central part of the state operating in close proximity to government agencies like NASA, SDC, and MICOM, all of which have established programs, mandated by federal legislation, for the transfer of government technology to the private sector. Furthermore, electronic technology abounds in the space and defense programs sponsored by these agencies. Yet the industry almost universally ignores these sources of technology.

Somewhat surprising, on the positive side, is the reasonably widespread use of some fairly sophisticated technology such as CAD, systems engineering and computer simulations. On the downside, it appears that Alabama firms do not use their suppliers as well as they could and that training for experienced workers is generally neglected.

Based on these preliminary analysis, possible areas of assistance could include:

1. Business-to-business (industrial) marketing.
2. International marketing.
3. Improving quality, deliver, and service.
4. New product development.
5. Federal technology and technology transfer programs.
6. Managing relationships with suppliers.
7. Assessing training needs.

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3.0 Apparel Modular Manufacturing Simulators

DESCRIPTION OF SIMULATORS SSE#3, SSE#6, AND SSE#5

B. J. Schroer
M.C. Ziemke
University of Alabama in Huntsville
Huntsville, AL 35899
(205)895-6243
FAX (205)895-6733
December 1992

1.0 MODULAR MANUFACTURING SIMULATOR (SSE #3)

1.1 System Description

The modular manufacturing simulator SSE#3 can be used for designing and evaluating modular manufacturing systems with the following operational characteristics:

- one line with a maximum of 18 stations (all stations in a series)
- each station may have a maximum of eight machines with each machine performing the identical operation (machines at each station are in parallel)
- all operators are cross-trained and able to work at any station at the same efficiency
- maximum of 26 operators
- unlimited space for work-in-process (WIP) in front of each station
- always enough items (WIP) in front of the first station so there is never a delay waiting on an item
- work is done in lots. A lot may be one or many items
- no machine breakdown.

It should be noted that this simulator probably has very little value for modeling real world manufacturing modules. Instead this simulator is an ideal tool for the first time user of simulation to understand the operation and potential of simulators.

1.2 Model Inputs

The following inputs are necessary for the simulator to construct a model:

- name of model
- number of stations
- number of machines at each station
- cycle time distribution at each station. The simulator supports the following distributions: constant, uniform, normal, exponential, and triangular.

1.3 Operator Movement Rules

All operators are moveable and are not fixed at a specific machine. The specific rule for the movement of operators between the stations is as follows. The operators always attempt to pull items from the module starting at the last station. Once an operator finishes an operation at a machine, the operator will join the back of an operator queue. The operator at the front of the operator queue is always checking, starting with the last station, to determine if a machine at the station is available and if there is WIP in front of that station. If so, the operator will move to an available machine at the station and perform the operation. Once the operation is complete, the operator will return to the operator queue.

If there is no available machine at the last station, or there is no WIP in front of the last station, the operator will check the next to last station and continue to check upstream stations until an idle machine is found and there is WIP in front of that station. When both of these conditions are satisfied, the operator will move to the available machine and perform the operation.

2.0 **MODULAR MANUFACTURING SIMULATOR (SSE #6)**

2.1 System Description

The modular manufacturing simulator SSE#6 is based on the Toyota Sewing System (TSS) developed by Aisin Seiki Co., Ltd., Aichi, Japan. The operational characteristics of SSE#6 are:

- work is done in lots of only one part
- one line with a maximum of 18 stations (all stations in a series)
- each station may have a maximum of eight machines with each machine performing the identical operation (machines at each station are in parallel)
- all operators are cross-trained and able to work at any station at the same efficiency
- maximum of 26 operators
- unlimited space for work-in-process (WIP) in front of each station
- always enough items (WIP) in front of the first station so there is never a delay waiting on an item
- no machine breakdown
- first station must consist of only one machine
- last station must consist of only one machine

2.2 Model Inputs

The following inputs are necessary for the simulator to construct a model:

- name of model
- number of stations
- number of machines at each station

- cycle time distribution at each station. The simulator supports the following distributions: constant, uniform, normal, exponential, and triangular.

2.3 Operator Movement Rules

This simulation is based on the Toyota Sewing System (TSS) and has the following operator movement rules:

- Parts move counterclockwise in the manufacturing module. Operations move counterclockwise with the part and also move clockwise for additional work.
- An operator performs an operation at a station and will move counterclockwise with the part to the next station and performs the operation until the operator reaches an operator at a station. The part is then placed in front of the station, or passed directly to the operator, if the operator is free.
- If an operator is not busy, the operator will move clockwise until there is an available part. If there is no waiting part, the operator will interrupt the first operator reached. The interrupted operator will then move clockwise to either find an available part or another busy operator to interrupt. The interrupting operator will then complete the interrupted operation.

If a station has more than one machine, the operator movement rule for that station is as follows:

- If the operator number, who has just completed working on a part, is greater than the other operator numbers at that station, the operator will attempt to move forward to the next station with the part. If the next station is busy, the operator will interrupt one of the other operators at the current station.
- If the operator number, who has just completed working on a part, is less than the other operator numbers at that station, the operator will move backwards for more work. If the backwards station is busy, the operator will interrupt the operator.

The SSE#6 has an additional rule governing the movement of an operator. The selection of this rule is controlled by the "TYPE" column in Option 3, "Input/Edit Stations". The description of each type is:

- Type 1– the operators move following the previously defined rules.
- Type 2– the operator will stay at the station if the WIP in front of this station is not empty and the WIP at the station is greater than the WIP at the next station. The operator will move to the next station if the WIP in front of this station is less than the WIP at the next station. If the operator cannot move to the next station because that station is occupied or the WIP in front of the current station is empty, the operator will move backwards to find work.

A note of warning to the user. After a number of test runs of the SSE#6, it has been observed that the coded rules do not operate exactly as the real world operation of the manufacturing module. To compensate for the difference, the above Type 2 rule has been added to SSE#6. Generally, the station with the largest cycle time may need to be a Type 2 rather than a Type 1. It has been found that overall production of the module more closely approximates the theoretical production when the Type 2 rule is added to the station with the largest cycle time.

3.0 MODULAR MANUFACTURING SIMULATOR (SSE #5)

3.1 System Description

The modular manufacturing simulator SSE#5 can be used for designing and evaluating modular manufacturing systems with the following operational characteristics:

- one line with a maximum of 18 stations (all stations in a series)
- each station may have a maximum of eight machines with each machine performing the identical operation (machines at each station are in parallel)
- some operators may be fixed at a specific machine
- some operators may be moveable and work on a defined set of stations. These moveable operators are assigned to a home station and to other stations based on a priority sequence. Operator efficiency may vary between stations. The movement of the operators is governed by a set of defined rules
- maximum of 26 operators
- unlimited space for work-in-process (WIP) in front of each station
- always enough items (WIP) in front of the first station so there is never a delay waiting on an item
- work is done in lots. A lot may be one or many items
- no machine breakdown.

3.2 Model Inputs

The following inputs are necessary for the simulator to construct a model:

- Name of model
- Number of stations
- Number of machines at each station
- Cycle time distribution at each station. The simulator supports the following distributions: constant, uniform, normal, exponential, and triangular.

The input parameters for a fixed operator are:

- Priority = 1
- Operator efficiency (%) = value 1 to 150
- Other parameters = unused

The input parameters for a moveable operator are:

- Priority = 1, 2, 3, ... (1 = home station)
- Operator efficiency (%) = value 1 to 150
- Lower WIP limit at this station = 0, 1, 2, 3, ... lots
- Upper WIP limit at this station = 0, 1, 2, 3, ... lots
- Bundle limit at this station = 0, 1, 2, 3, ... lots
- Time limit operator spends at this station = any positive number

3.3 Operator Movement Rules

The rules for the movement of a moveable operator are:

Rule 1: Operator will attempt to move to another station in the priority list when the operator has worked more than the "Time Limit" at the current station, or when the operator has completed, or exceeded, the "Bundle Limit" at the current station and the operator has completed a lot of garments.

Rule 2: If Rule 1 is satisfied, the operator will move from the current station to the first station in the priority list that satisfies one of the following conditions:

Rule 2a: WIP at current station is LESS than the upper WIP limit and the WIP at a station in the priority list is GREATER than the upper WIP limit.

Rule 2b: WIP at current station is LESS than the lower WIP limit and the WIP at a station in the priority list is GREATER than the lower WIP limit

If the operator cannot move and the WIP in front of the current station is zero, the operator will be idle. The operator will attempt to move every time the system changes state. When a state change occurs, the system will first check if the "Upper WIP Limit" has been exceeded at any station in the priority list, and second, will check if the "Lower WIP Limit" has been exceeded at any station in the priority list. If any of these two conditions occurs, the operator will go to that station. If both of these conditions are not satisfied, the operator will attempt to move to a station in the priority list that has WIP greater than zero.

The above rules always check the parameters in the assigned priority sequence. For example, if the operator is at Station 4 and the priority sequence is Station 2, Station 3, Station 4, and Station 5, the rules are always fired starting with Station 2, then Station 3 and then Station 5.

It should be noted that some of the parameters may be set to zero. For example, if the "Time Limit" and "Bundle Limit" are zero, then Rule 1 is always true and Rules 2a and 2b are tested after the operator has completed every lot.

4.0 **COMPUTER REQUIREMENTS**

All the simulators require the following hardware:

- IBM/PC compatible
- VGA monitor (640 x 480 graphics mode)

4.0 Synopsis of a Stereolithography Project

CAR Report
No. 93-03

**Synopsis of a Stereolithography
Project**

**Prepared for
Morgan Research Corporation
2707 Artie Street, Suite 17
Huntsville, Alabama 35805**

**by
Kristy Haught
Industrial and Systems Engineering
University of Alabama in Huntsville
Huntsville, Alabama 35899**

November 1992

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This project was funded in part by the AIDT Alabama Center for Advanced Technology Transfer (ACATT) and the NASA Marshall Space Flight Center (MSFC).

1.0 INTRODUCTION

A request was received by the University of Alabama in Huntsville (UAH) to produce a StereoLithography Apparatus (SLA) generated mock-up of an electronics assembly for a rapid prototyping project. The assembly, shown in Figure 1, is comprised of seven parts and a housing. The individual piece parts consist of three different spools, an LED, two different covers, and an accelerator block. The housing is actually a representation of the housing and eight attached electronic components made as one solid piece (Figures 2 and 3). The requesting party provided UAH with hand drawn sketches of the required parts and resolved questions as they arose.

2.0 RAPID PROTOTYPING WITH THE SLA PROCESS

The SLA rapid prototyping process is accomplished through a fairly rigid process. This process is shown in Figure 4.

2.1 Generation of the CAD Model

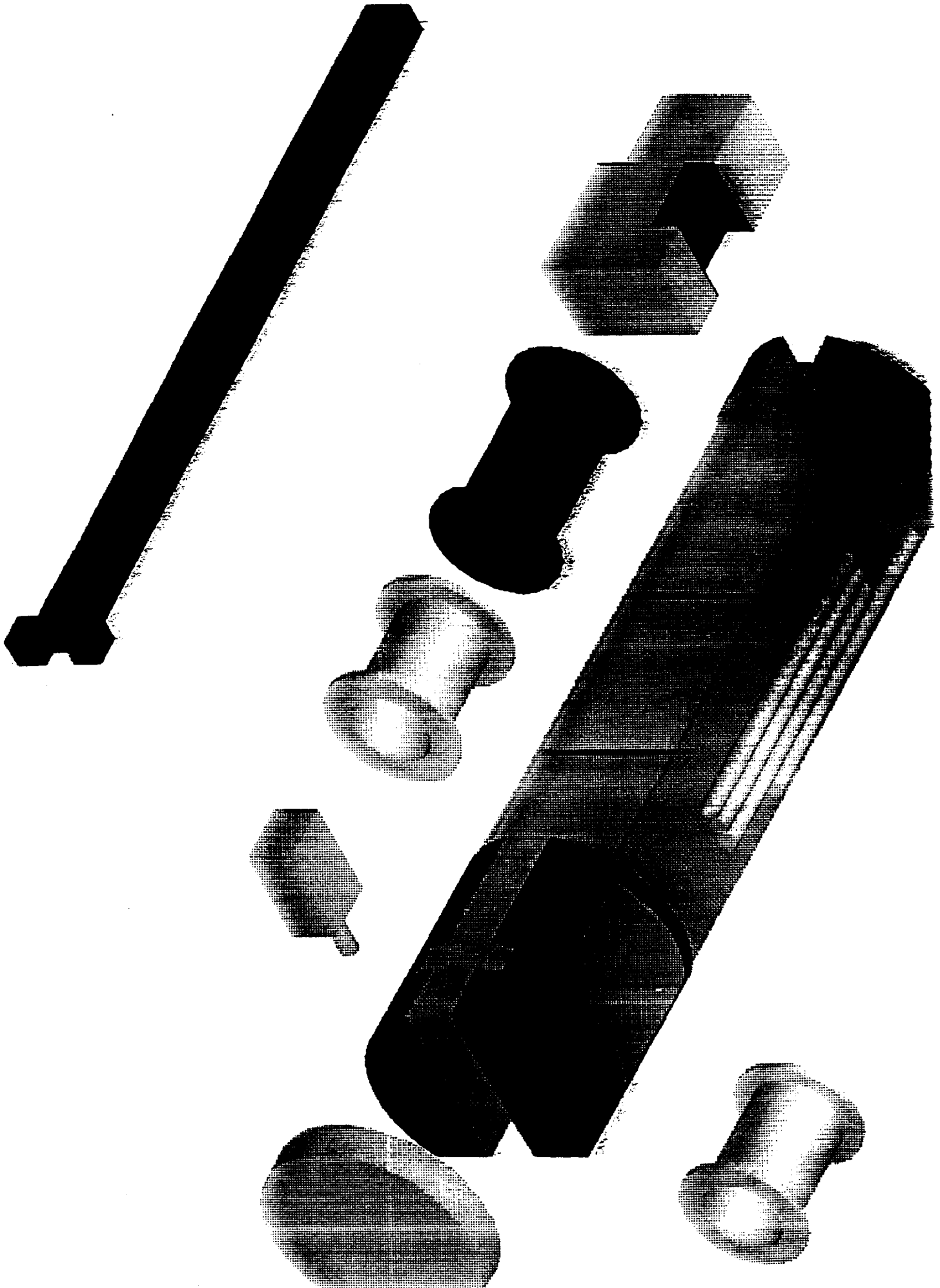
The first step in this process is the development of a 3-D solid model CAD database of the prospective part. The designer needs to consider three aspects of the CAD model, the part, the base support, and the secondary supports (Figure 5).

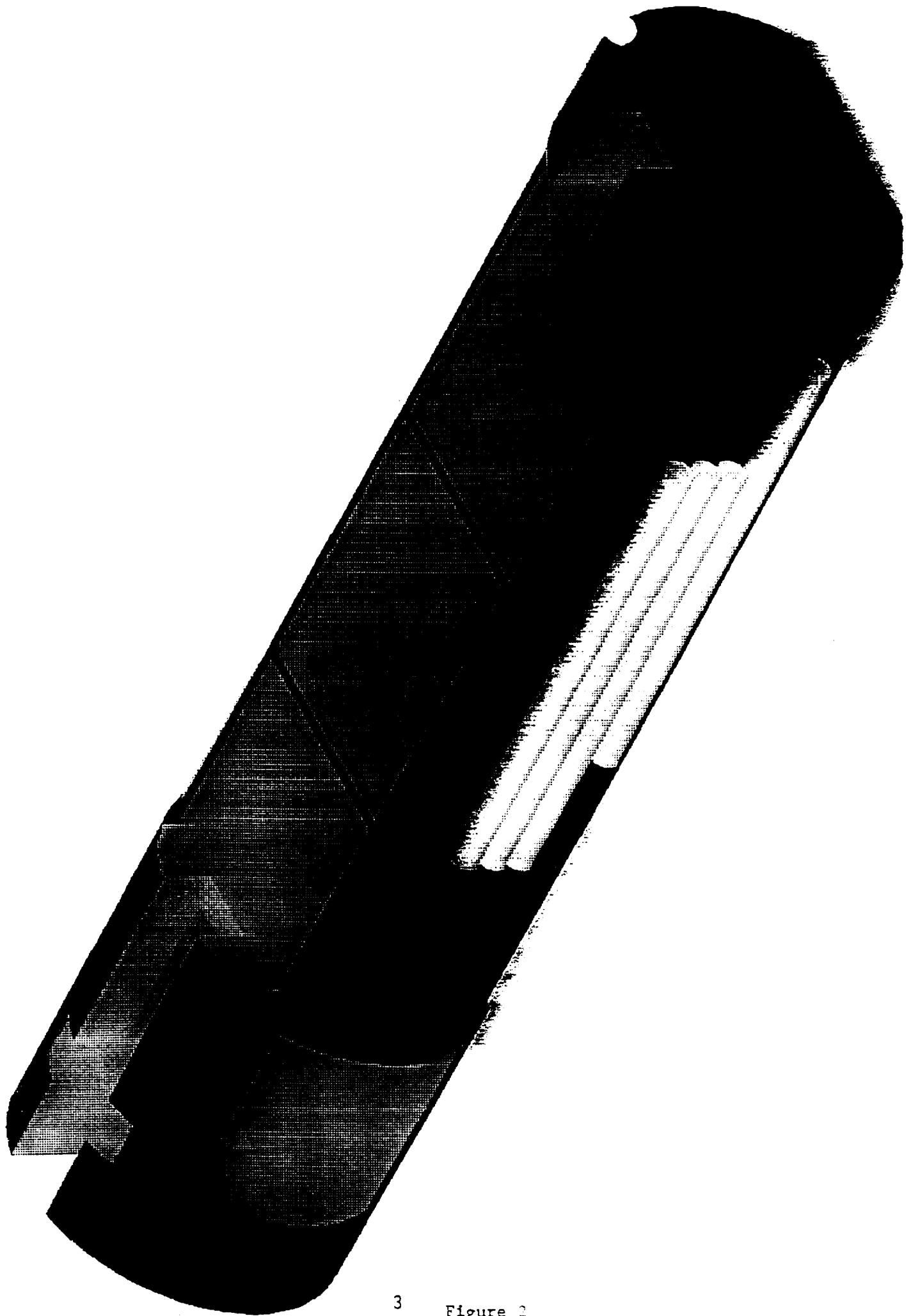
- The Part - The part itself, seen in Figure 6, must be defined as a three dimensional solid. The part will sit on a base support at least 0.250" off the construction platform. The construction platform is a steel plate with a series of 1/4" holes on approximately 1/2" centers (to facilitate drainage during the build process).

- The Base Support - The purpose of this support (seen with the secondary supports in Figure 7) is to prevent irregularities and/or warpage in the construction platform from effecting the finished part. This support should be a separate solid from the part closely approximating (without undercutting) the footprint. It should overlap the part 0.050"-0.060" in the direction of the Z axis to ensure full support.

- The Secondary Supports - In addition to the base support at the bottom, secondary supports (also seen in Figure 7) may be required within and about the part itself for the building process. These additional supports are generally required where there are unsupported overhangs. They should overlap the part in all contact direction by 0.050"-0.060" to ensure good support. [Aside: Although it was not available for this project, a third party software package called Bridgeworks exists that will automatically generate all the supports.]

The party requesting the mock-up had no electronic drawings available. They had the ability to create Autocad databases and were willing to do so if





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OF POOR QUALITY

SLA RAPID PROTOTYPING PROCESS

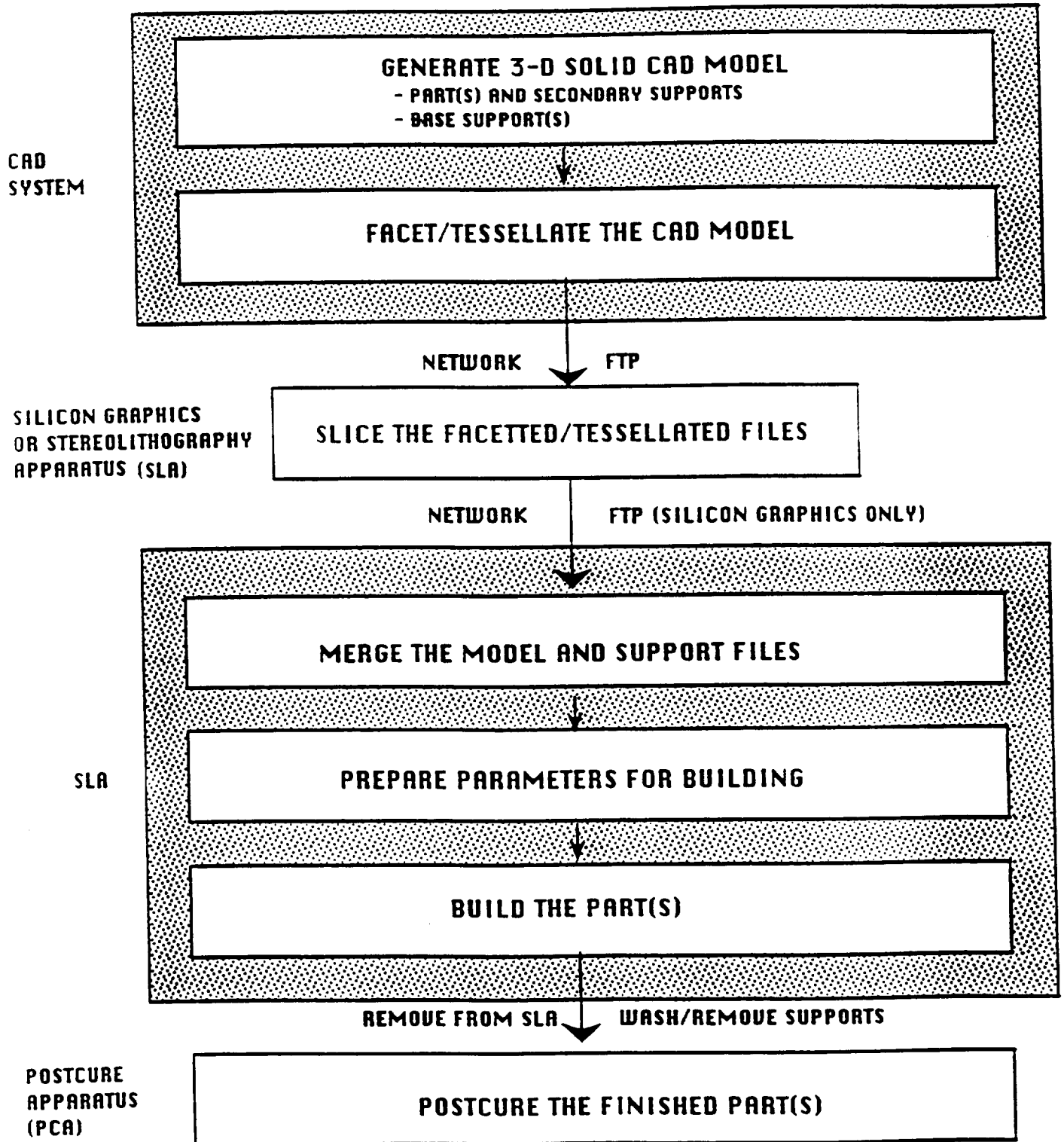


FIGURE 4



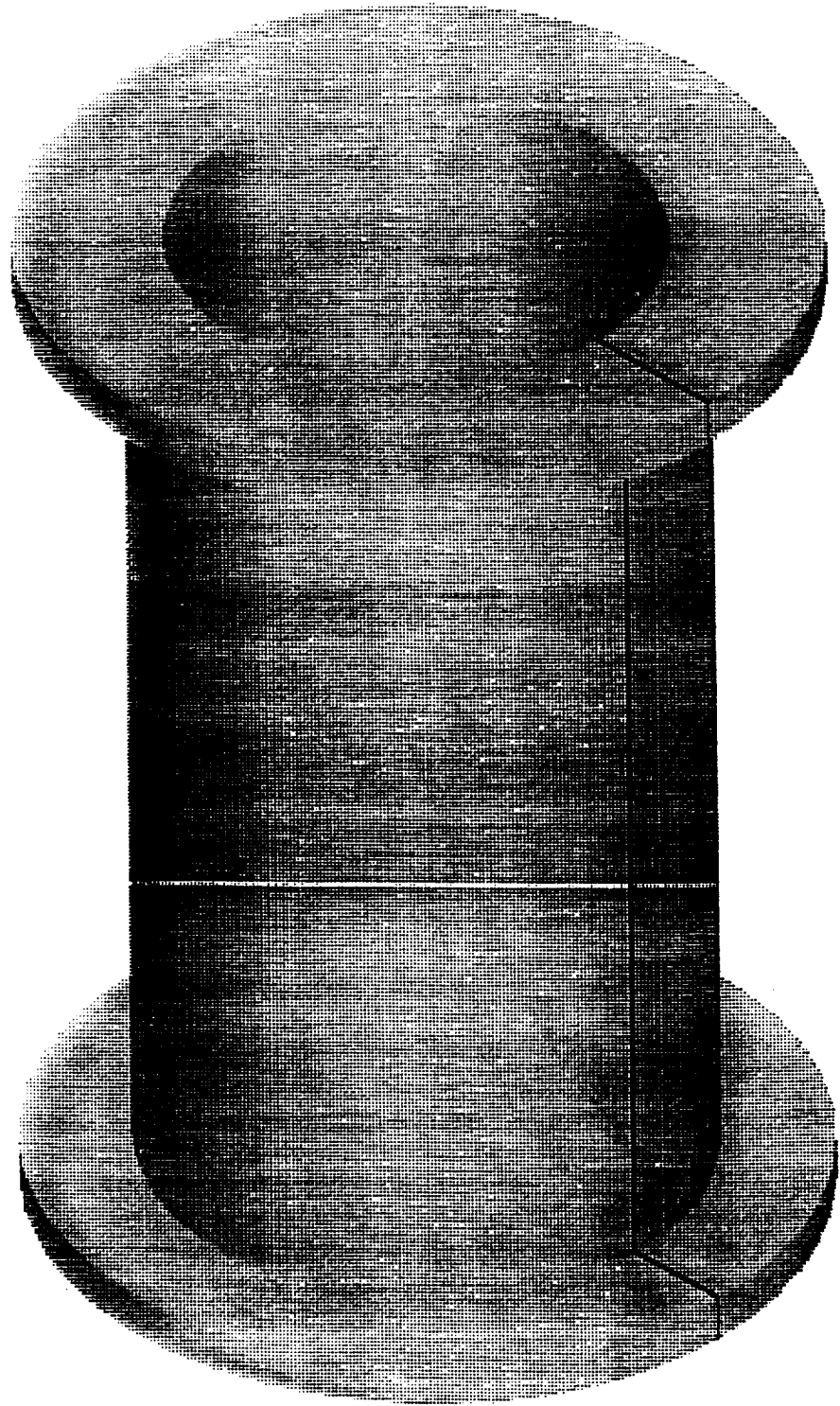


Figure 6

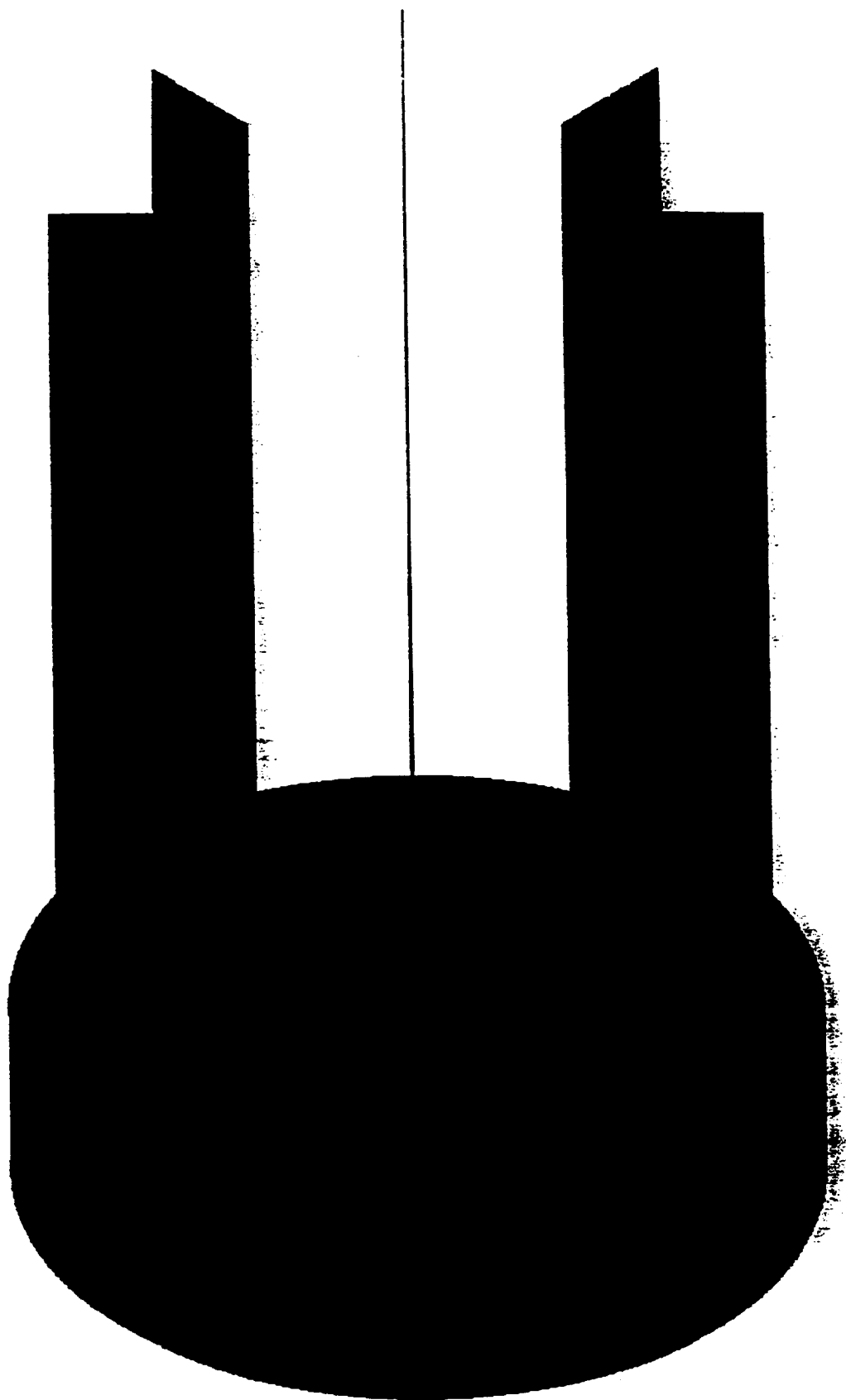


Figure 7

necessary. The equipment available for use at Alabama Center for Advanced Technology Transfer (ACATT) requires the database to be in Intergraph solids in order to get it into the faceted format necessary for delivery to the SLA. After some preliminary research, it became apparent that it would be at least as easy to originate the database on the Intergraph system as it would be to get an acceptable translation from an Autocad database (had one existed). This phase of the project went well.

2.2 Facetting/Tessellating the CAD Model

Using software resident on the CAD system, the model and supports are faceted (Intergraph terminology)/tesellated (general terminology) as seen in Figure 8. This process breaks all of the boundary surfaces down into triangles. As surfaces grow in complexity, the triangles defining them become smaller. Very complex surfaces generate very large data files. Chord height may be set for this procedure (generally recommended at 0.010"). It will also effect triangle size and file size. Two files, the model file and the support file, will be generated separately using the facetting/tessellation procedure:

- **The Model File** - This file contains the model(s) of the part(s).

- **The Support File** - This file contains the model(s) of the base support(s) and any secondary supports. Having separate files for the base and the model allows the developer to set different parameters (i.e., honeycombing for the supports, larger overcure values, etc.) later in the build process and improve build efficiency. [*N.B.* The entire CAD model must be in positive space for the building process. It is recommended that, by this point in the process, the bottom of the base supports be at +.001" in Z to avoid any possible problems.] The facetting phase was also accomplished easily on the Intergraph system. All the parts for the mock-up assembly were small and would all have fit on the SLA platform (approximately a 10" X 10" area). It would have been feasible to make all the parts in one run. This was deemed undesirable because of the complexity of the housing and the need to gain experience in the system operation. The project was broken down into two runs. The first run was the seven piece parts (three coils, two covers, an LED, and an accelerator block). The intent was for the first run to provide insight on how the system behaved and on how the secondary supports should be configured for the housing. Subsequent run(s) would be made to refine the piece parts and to build the housing.

2.3 Slicing the Files

This procedure slices the tessellated models into horizontal layers. The model and support files are handled separately because it is desirable that the slice parameters for the model differ from those for the base supports. The slice parameters effect the quality level of the final part. This is the point at which the hatching (laser pattern) is defined. The supports will be defined using a honeycomb tight enough for good support and loose enough for easy removal prior to the post cure operation. The slicing procedure is accomplished on the

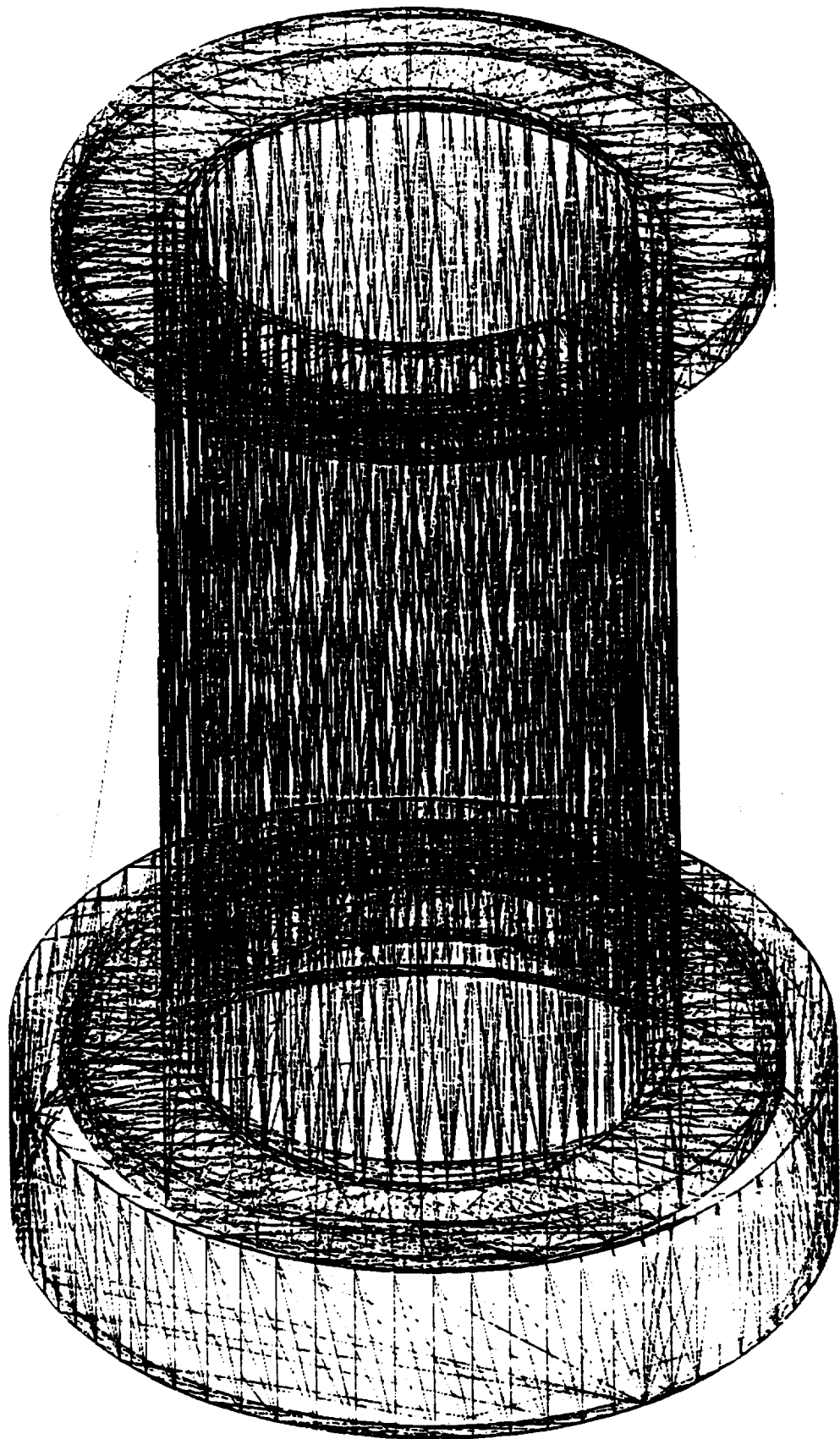


Figure 8

SLA system or on the Silicon Graphics system after transfer of the model and support files over the network.

- Slicing On the SLA System - For slicing on the SLA system, simply set the parameters, slice and go on to the file merge step. For reasons given below, it is preferable to use the Silicon Graphics system.

- Slicing On the Silicon Graphics System - This system is faster than using the SLA PC and it permits graphical review of the sliced files for previously undetected database anomalies. At the time of this project, this system was not fully available to the network. Files could be transferred to the system, but not from it (i.e., to the SLA after slicing). Files for this project were sliced on both systems using the same parameters. After graphical review of Silicon Graphics sliced for correctness, the SLA sliced files were used to complete the procedure.

2.4 Merging the Files

After slicing is complete, the model and support files are merged into a single build file.

2.5 Preparation

During this phase, the merged model can be defined as a series of ranges along the Z axis. It is frequently desirable to set different parameters for different depths. Some areas may be more critical or more fragile than others, requiring special treatment. Several build parameters, such as shrinkage and cure depths, are all set at this point in the process. The system may also be operated using default values. It is generally recommended that the resin (polymer) specific parameters be used be entered into the computer unless they are known to coincide with the system defaults.

2.6 Building

This is the phase where the part is actually generated. A helium cadmium laser emitting UV light is used to trace the shape of the part, at each slice, on the polymer, partially curing and partially trapping minute amounts of polymer. This is followed by dipping, recoating, and leveling of the part in the resin filled vat followed by curing of the next layer of the part. The process repeats itself based on the specified parameters until the complete part has been generated or the process is stopped through error or interruption.

2.7 Postcuring Process

Once the build process is completed, excess polymer is drained from the part back into the resin tank prior to removing the part from the SLA. Any excess resin remaining on the part is removed using a solvent and the supports are removed from the part. As mentioned earlier, there is still uncured resin trapped within the part structure. Additional curing is required and is accomplished

using a Post Cure Apparatus (PCA), a UV oven. Setting the part in direct sunlight will also cure the part, but it will require a much longer period of time. The PCA or sunlight can be used in the treatment of resinous waste from this process. In its uncured state, the resin is considered toxic waste; cured, it becomes inert plastic waste.

3.0 REMARKS

- The first run, with just the piece parts, showed a major problem with the base supports. They did not overlap the parts sufficiently in the Z axis and were not strong enough to prevent warpage or curling. Database errors in the accelerator block were also discovered and corrected at this time.
- The housing was added to the second run. The housing peeled as it grew. The piece parts were scrapped as well because loose cured polymer interfered with their growth. Database anomalies in the housing were the suspected cause of this problem. The housing database was, therefore, rebuilt from scratch.
- Meanwhile, a separate build run was made for the piece parts with good results. It was noted that many of the dimensions were approximately 0.010" oversized using the shrink factor recommended for the resin. While this is a concern, the difference in size did not cause a problem for the customer, and time did not permit a thorough investigation. It has since been learned that this was due to a lack of beam width compensation during the build process. With proper compensation, this problem is easily eliminated.
- Several more build runs were made on the housing with approximately the same results (i.e., continued to peel as it grew). Different strategies were tried to alleviate this problem (e.g., the part was re-oriented, pauses were increased, sweeper blade gap was increased, overcure was increased) without success. What did become apparent was that the problem was predictable and repeatable. Although literature available at the time indicated that 0.050" thick vertical walls (approximately 1.200" tall) should not require supports, they do. Once supports were added to the thin wall areas, the part ran without difficulty.
- The end result of this project was that the customer was pleased with the SLA generated parts. The experience gained by the technician indicated that additional investigation might be warranted on shrinkage, secondary supports, the impact of weave patterns, and resin specific properties.

4.0 BIBLIOGRAPHY

SLA-250, User Reference Manual, p. 6-9, Software Release 3.60, September 1989, Document Number 50043001-04, Valencia, CA: 3D Systems, Inc.

Jacobs, Paul F. (editor), Rapid Prototyping and Manufacturing: Fundamentals of Stereolithography, Dearborn, Michigan: Society of Manufacturing Engineers, 1992.

5.0 Transferring Modular Manufacturing Technology to an Apparel Firm

CAR Report 93-04

**Transferring Modular Manufacturing Technology
to an Apparel Firm**

Prepared for:

**Hilton Active Apparel
Simplex Textile Products Division
608 Tallahatta Springs Road
Thomasville, AL 36784**

Prepared by:

**Xiaomu Ye
Bernard J. Schroer
M. Carl Ziemke
University of Alabama in Huntsville
Huntsville, AL 35899
(205) 895-6243**

February 1993

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ABSTRACT

This report summarizes the technical assistance provided Hilton Active Apparel in Thomasville, Alabama. Hilton Apparel is interested in changing several of its manufacturing lines from the progressive bundle system to modular manufacturing. This assistance was supported in part by contracts from the Alabama Industrial Development Training's (AIDT) Alabama Center for Advanced Technology Transfer (ACATT) and the NASA Marshall Space Flight Center (MSFC) NCC8-18

1.0 INTRODUCTION

Hilton Active Apparel has an interest in applying the concepts of modular manufacturing in their facility in Thomasville, Alabama. As a result, the following technical assistance was provided Hilton:

- Mailed copies of three modular manufacturing simulators SSE3, SSE6, and SSE5. These simulators were mailed after Hilton's request for technical assistance from the NASA Marshall Space Flight Center (MSFC). Appendix A contains a copy of the request and the corresponding MSFC response (MSFC #608)
- Conducted on-site seminar on modular manufacturing
- Analyzed several garment lines using the modular manufacturing simulators

The latter two activities are discussed in detail in the following sections.

2.0 MODULAR MANUFACTURING

The seminar on modular manufacturing consisted of two parts:

- Introduction to modular manufacturing
- Application of simulation for designing and analyzing modular manufacturing systems

The topics covered in the introduction to modular manufacturing included:

- Features of modular manufacturing
- Advantages and disadvantages of modular manufacturing
- Group work ethics
- Solving problems on sewing floor
- Conducting a work group meeting
- Brainstorming during group problem solving
- How to give and receive constructive criticism
- Planning the project
- Forming the module

Appendix B outlines the basic steps in implementing modular manufacturing. The presentation documentation is bound in a separate report.

The topics covered in the application of simulation included:

- Introduction to simulation

- Simulation languages
- Simulation case studies
- Modular manufacturing simulators

3.0 MODULAR MANUFACTURING SIMULATION

3.1 Garment A

Figure 1 gives the process flow for making Garment A. The line consists of seven stations with one machine at each station. The exception is Station 3 which is a manual operation not requiring a machine. The line has six operators.

3.1.1 Maximum Production

If it assumed that all operators can move to any machine in any order and there are extra machines at each station, then:

1. Sum of operators times =
1.95 + 2.43 + 0.40 + 1.31 + 1.60 + 0.53 + 1.85 = 10.07 minutes
2. Average time each operator spends on a garment =
10.07 min/6 op = 1.68 min/op
3. Maximum production per day =

$$\frac{480 \text{ min}}{\text{day}} \times \frac{1}{1.68 \text{ min}} = 286 \text{ garments}$$

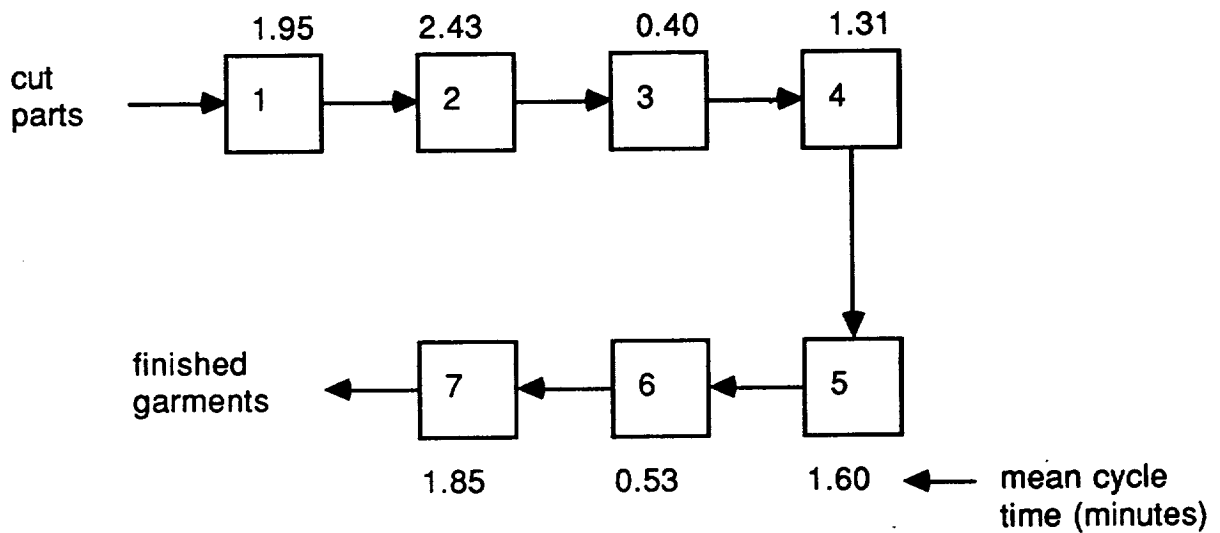
This maximum production can be validated by using SSE3. Figure 2 gives the layout for this modified line. Assuming only the mean station times and no distributions, the production is 286 garments per day.

3.1.2 Module Modifications (SSE6)

One common method of module operation is the Toyota Sewn System (TSS). Figure 3 gives the operator movement rules for the TSS. The simulator SSE6 has been written specifically for evaluating TSS modules. Figure 4 gives the layout of the TSS module for Garment A.

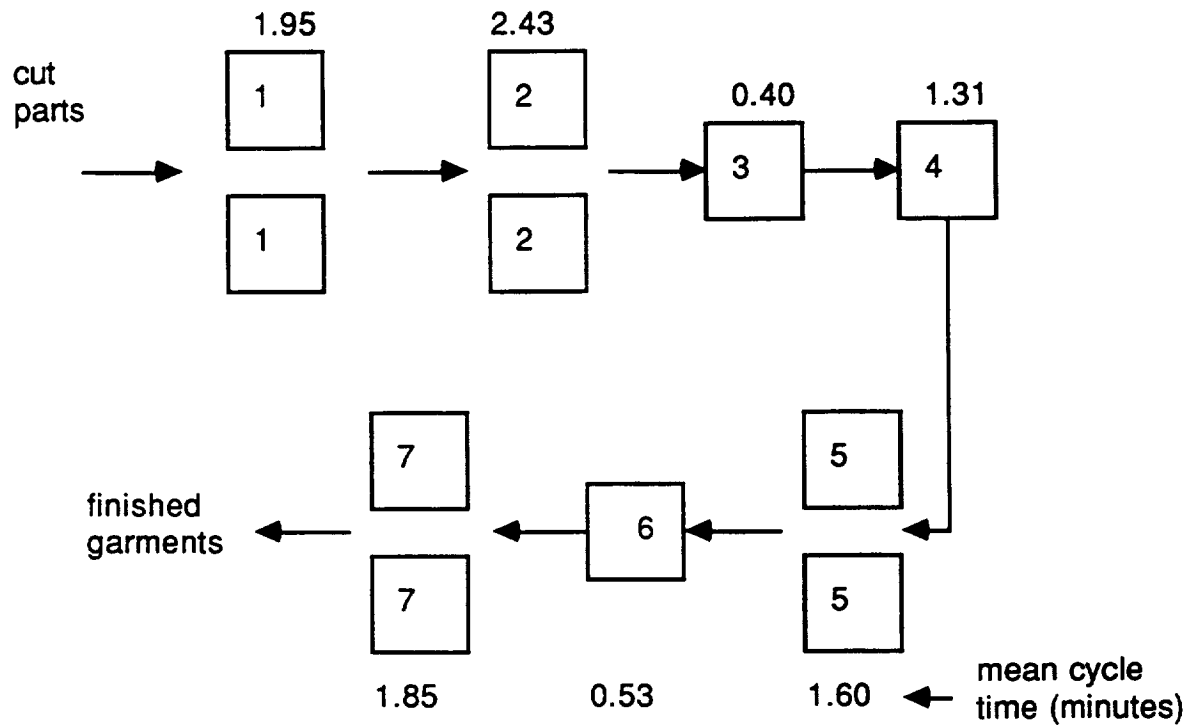
Figure 5 gives the production per day and production per operator as a function of the number of operators with only one machine at each station. Figure 6 gives the corresponding work-in-process (WIP) as a function of the number of operators. Table I gives the percent of time each operator was idle.

Note that the production did not increase above 169 by adding a fifth or sixth operator. WIP remained around 95 garments. Also, by adding a fifth operator, one operator was idle 100 percent of the time. By adding a sixth operator, two operators were idle 100 percent of the time (see Table I).



Station	Description	Machine
1	set pocket	single needle lockstitch
2	front merrow, close shoulder, and side seam	top feed safety stitch
3	mark for collar	no machine
4	set collar	top feed safety stitch
5	topstitch fronts	single needle lockstitch
6	tail merrow	top feed safety stitch
7	hem sleeve and tail	single needle lockstitch

Figure 1. Initial module layout for Garment A



Station	Machines	Description	Machine description
1	2	set pocket	single needle lockstitch
2	2	front merrow, close shoulder, and side seam	top feed safety stitch
3	1	mark for collar	no machine
4	1	set collar	top feed safety stitch
5	2	topstitch fronts	single needle lockstitch
6	1	tail merrow	top feed safety stitch
7	2	hem sleeve and tail	single needle lockstitch

number of operators = 6

Figure 2. Module modification using SSE3

The SSE6 has the following operator movement rules:

- Parts move forward in the manufacturing module. Operations move forwards with the part and also move backwards for additional work.
- An operator performs an operation at a station and will move forwards with the part to the next station and performs the operation until the operator reaches an operator at a station. The part is then placed in front of the station, or passed directly to the operator, if the operator is free.
- If an operator is not busy, the operator will move backwards until there is an available part. If there is no waiting part, the operator will interrupt the first operator reached. The interrupted operator will then move backwards to either find an available part or another busy operator to interrupt. The interrupting operator will then complete the interrupted operation.

If a station has more than one machine, the operator movement rule for that station is as follows:

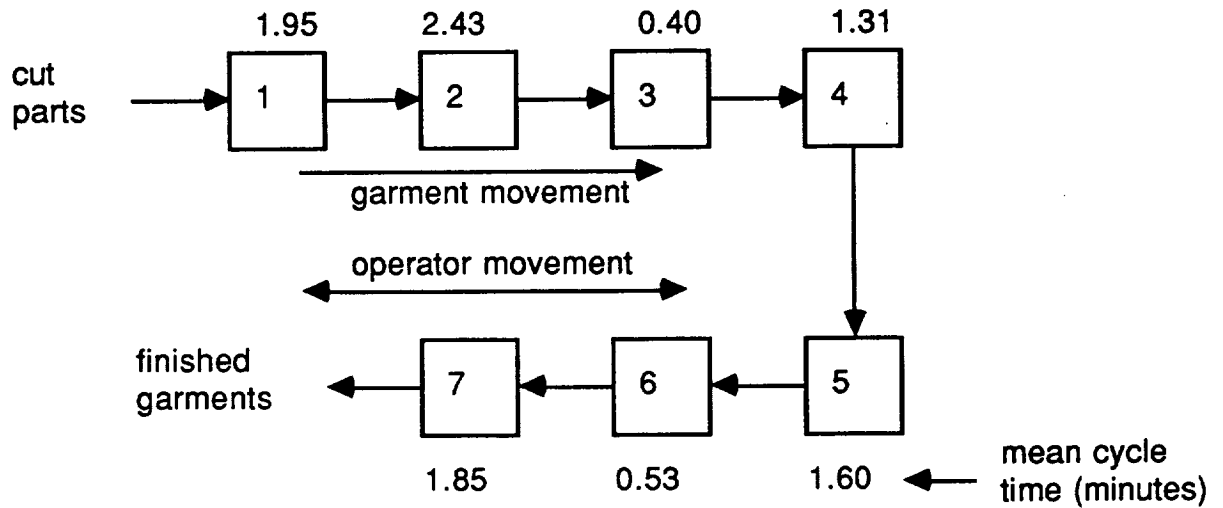
- If the operator number, who has just completed working on a part, is greater than the other operator numbers at that station, the operator will attempt to move forward to the next station with the part. If the next station is busy, the operator will interrupt one of the other operators at the current station.
- If the operator number, who has just completed working on a part, is less than the other operator numbers at that station, the operator will move backwards for more work. If the backwards station is busy, the operator will interrupt the operator.

The SSE6 also has a TYPE column in Option 3, Input/Edit Stations. The description of each type is:

- Type 1– the operators move following the previously defined rules.
- Type 2– the operator will stay at the station if the WIP in front of this station is not empty and the WIP at the station is greater than the WIP at the next station. The operator will move to the next station if the WIP in front of this station is less than the WIP at the next station. If the operator cannot move to the next station because that station is occupied or the WIP in front of the current station is empty, the operator will move backwards to find work.

A note of warning to the user. After a number of test runs of the SSE6, it has been observed that the coded rules do not operate exactly as the real world operation of the manufacturing module. To compensate for the difference, the above Type 2 rule has been added to SSE6. Generally, the station with the largest cycle time may need to be a Type 2 rather than a Type 1. It has been found that overall production of the module more closely approximates the theoretical production when the Type 2 rule is added to the station with the largest cycle time.

Figure 3. SSE6 Operator Movement Rules



Station	Description	Machine
1	set pocket	single needle lockstitch
2	front merrow, close shoulder, and side seam	top feed safety stitch
3	mark for collar	no machine
4	set collar	top feed safety stitch
5	topstitch fronts	single needle lockstitch
6	tail merrow	top feed safety stitch
7	hem sleeve and tail	single needle lockstitch

Figure 4. Module modification using SSE6

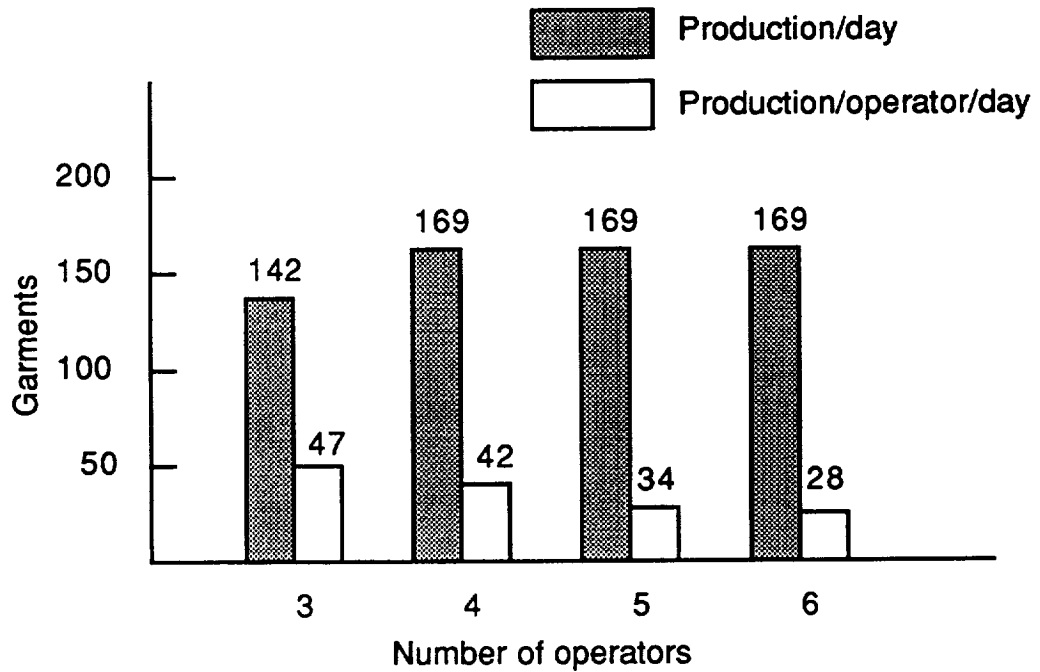


Figure 5. Daily production as function of number of operators

One machine/station
 Station 2 is Type 2
 Data collected after running model for 480 minutes and
 a warmup of 100 minutes

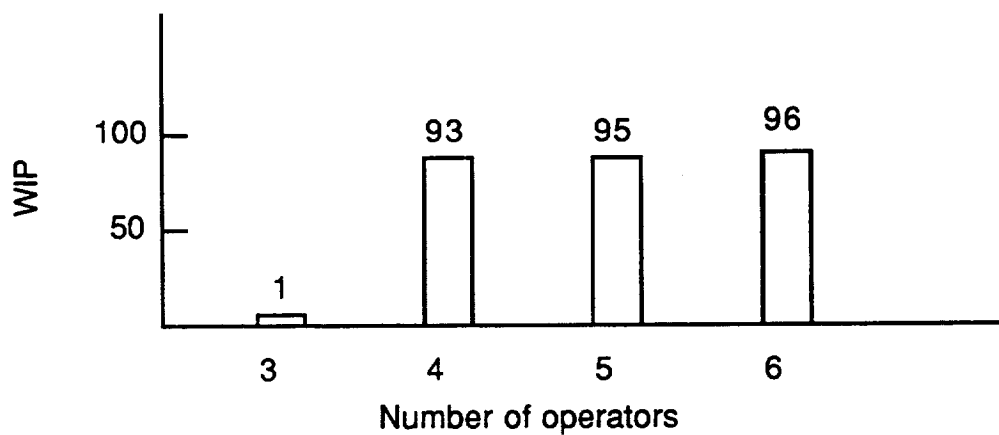


Figure 6. WIP after eight hours as function of number of operators

Table I Operator idle time (%)

Run	Number of operators	Operator					
		1	2	3	4	5	6
1	3	8	11	0	-	-	-
2	4	0	0	22	0	-	-
3	5	100	0	0	22	0	-
4	6	100	100	0	0	22	0

Station	Machines/ station	SSE6 station type
1	1	1
2	1	2
3	1	1
4	1	1
5	1	1
6	1	1
7	1	1

Data collected after running model 480 minutes and a warmup of 100 minutes

One approach to increase module production is to add duplicate machines at selected stations. The stations with long cycle times are logical selections. These stations are Stations 1 and 2. Table II gives the results by adding more machines. Run 5 consisted of four operators and two machines at Station 2. The production increased to 190 garments per day. Run 6 consisted of four operators and two machines at both Stations 1 and 2. The production remained at 190 garments per day.

Run 7 consisted of adding a fifth operator and a second machine at Station 2. Production increased to 234 garments per day. Run 8 consisted of five operators and two machines at both Stations 1 and 2. Production remained at 238 garments per day. Note that adding additional machines not only increased production, but also reduced the WIP to less than five garments. Also, average operator utilization was 95 percent for Run 8 (Reference Table III).

Table IV gives the percentages each operator spent at each station for Run 8. Note that the operators worked in zones. For example, Operators 1 and 2 worked at Stations 1 and 2. Operator 3 worked at Stations 2, 3, and 4. Operator 4 worked at Stations 4, 5, and 6. Operator 5 worked at Stations 6 and 7.

3.1.3 Module Modifications (SSE5)

It is generally impossible in most real world modules to have the operators move freely in the module as given in Sections 3.1 and 3.2. Instead, some operators are fixed at machines while others are cross trained and work on several machines. The simulator SSE5 can be used to evaluate various operator movement rules. The operator movement rules are given in Figure 7.

Figure 8 is a layout of a modified module. Two machines are placed at Station 2 because of the large cycle time. All cycle times are normally distributed with the standard deviations ten percent of the means.

The following runs were made:

Run 1 (See Table V)

Operator

- | | |
|---|------------------------------|
| 1 | fixed at STA1 |
| 2 | moves between STA2, 3, and 4 |
| 3 | moves between STA4, 3, and 2 |
| 4 | moves between STA5 and 6 |
| 5 | moves between STA7 and 6 |

Run 2 (See Table VI)

Operator

- | | |
|---|--------------------------|
| 1 | fixed at STA1 |
| 2 | moves between STA2 and 3 |

Table II. Machines at each station

Run	Station							Operators	Production/ day	Module WIP after one week
	1	2	3	4	5	6	7			
5	1	2	1	1	1	1	1	4	190	0
6	2	2	1	1	1	1	1	4	190	2
7	1	2	1	1	1	1	1	5	234	0
8	2	2	1	1	1	1	1	5	238	4

Table III. Operator idle time (%)

Run	Operator					Average operator utilization
	1	2	3	4	5	
5	19	15	13	0	-	88
6	8	7	13	0	-	93
7	31	28	16	12	0	83
8	6	4	16	0	0	95

SSE5 Run 8 file name: SIMTSS

Data collected after running model 2400 minutes (4 hours)
and a warmup of 300 minutes

Station 2 is a Type 2 for all runs

Table IV. Percent time operator worked at each station for Run 8

Station	Machines	Operator				
		1	2	3	4	5
1	2	75	22	0	0	0
2	2	19	65	27	0	0
3	1	0	9	10	0	0
4	1	0	0	59	5	0
5	1	0	0	0	74	1
6	1	0	0	0	5	7
7	1	0	0	0	0	92
idle		6	4	4	16	0

The input parameters for a fixed operator are:

- Priority = 1
- Operator efficiency (%) = value 1 to 150
- Other parameters = unused

The input parameters for a moveable operator are:

- Priority = 1, 2, 3, ... (1 = home station)
- Operator efficiency (%) = value 1 to 150
- Lower WIP limit at this station = 0, 1, 2, 3, ... lots
- Upper WIP limit at this station = 0, 1, 2, 3, ... lots
- Bundle limit at this station = 0, 1, 2, 3, ... lots
- Time limit operator spends at this station = any positive number

The rules for the movement of a moveable operator are:

Rule 1: Operator will attempt to move to another station in the priority list when the operator has worked more than the "Time Limit" at the current station, or when the operator has completed, or exceeded, the "Bundle Limit" at the current station and the operator has completed a lot of garments.

Rule 2: If Rule 1 is satisfied, the operator will move from the current station to the first station in the priority list when one of the following conditions is satisfied:

Rule 2a: WIP at current station is LESS than the upper WIP limit and the WIP at a station in the priority list is GREATER than the upper WIP limit.

Rule 2b: WIP at current station is LESS than the lower WIP limit and the WIP at a station in the priority list is GREATER than the lower WIP limit

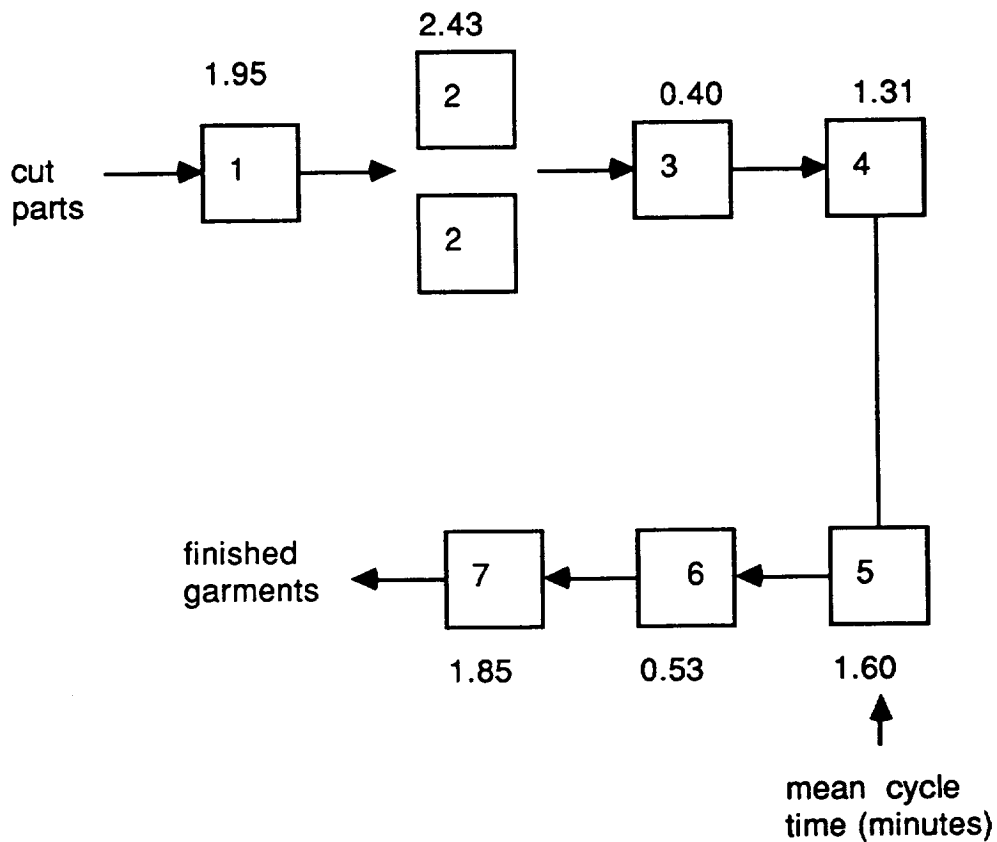
If Rule 1 is satisfied and both Rules 2a and 2b are not satisfied, then the operator will stay at the current station and do another lot. After each lot the operator will try to move depending on Rules 2a or 2b.

When the operator can no longer do work at the current station because there is no WIP and Rules 2a and 2b are not satisfied, the operator will attempt to go to the first station in the priority list that has WIP greater than zero, rather than remain idle at the current station. However, if the operator still cannot move, the operator will remain at the current station and be idle. Note that the operator will attempt to move every time the system changes state.

The above rules always check the parameters in the assigned priority sequence. For example, if the operator is at Station 4 and the priority sequence is Station 2, Station 3, Station 4, and Station 5, the rules are always fired starting with Station 2, then Station 3 and then Station 5.

It should be noted that some of the parameters may be set to zero. For example, if the "Time Limit" and "Bundle Limit" are zero, then Rule 1 is always true and Rules 2a and 2b are tested after the operator has completed every lot.

Figure 7. SSE5 Operator Movement Rules



Station	Machines	Description	Machine description
1	1	set pocket	single needle lockstitch
2	2	front merrow, close shoulder, and side seam	top feed safety stich
3	1	mark for collar	no machine
4	1	set collar	top feed safety stitch
5	1	topstitch fronts	single needle lockstich
6	1	tail merrow	top feed safety stitch
7	1	hem sleeve and tail	single needle lockstitch

Figure 8. Module modification (using SSE5)

Table V. SSE5 Run 1 results

Operator movement sequence (1 = home station)

Operator	Station						
	1	2	3	4	5	6	7
1	1						
2		1	2	3			
3		3	2	1			
4					1	2	
5						2	1
Machines	1	2	1	1	1	1	1

Production/week: 1159 garments

Production/day: 232 garments

Module WIP at end of week: 86 garments

Largest WIP in front of Station 2: 83 garments

Operator	% idle
1	0
2	0
3	0
4	7
5	1

Data collected after running model for 2400 minutes (4 hours)
and a warmup of 300 minutes

Table VI. SSE5 Run 2 results

Operator movement sequence (1 = home station)

Operator	Station						
	1	2	3	4	5	6	7
1	1						
2		1	2				
3		1	2				
4				1			
5					2	1	
6						2	1
Machines	1	2	1	1	1	1	1

Production/week: 1125 garments

Production/day: 225 garments

Module WIP at end of week: 121 garments

Largest WIP in front of Station 5: 121 garments

Operator	% idle
1	0
2	28
3	28
4	33
5	0
6	14

- 3 moves between STA2 and 3
- 4 fixed at STA4
- 5 moves between STA6 and 5
- 6 moves between STA7 and 6

Run 3 (See Table VII)

Operator

- 1 fixed at STA1
- 2 moves between STA2, 3, and 1
- 3 moves between STA3, 2, and 1
- 4 moves between STA4, 5, and 6
- 5 moves between STA6, 5, and 4
- 6 fixed at STA7

The results of each run are given in Tables V, VI, and VII. Figure 9 summarizes the results. Production was 232 for Run 1 with five operators, 225 for Run 2 with six operators, and 259 for Run 3 with six operators. Production increased from Run 2 to Run 3 by only changing the operator movement rules. As production increased, operator utilization also increased to 100 percent for Run 3.

3.2 Garment B

Figure 10 gives the process flow for making Garment B. The line consists of nine stations with one machine at each station. Station 5 is a manual operation not requiring a machine.

Figure 11 gives the layout of the modified module. Two machines are placed at Station 3 because of the large cycle time. All cycle times are normally distributed with the standard deviations ten percent of the means. Seven operators are placed in the module.

Table VIII gives the results of the SSE5 simulator. The operator assignments are:

Operator

- 1 fixed at STA3
- 2 moves between STA2 and 1
- 3 fixed at STA3
- 4 fixed at STA4
- 5 moves between STA5 and 6
- 6 moves between STA7, 8, and 9
- 7 Moves between STA8 and 9

Hourly production was 503 garments. The WIP in the module at the end of the day was 12 garments. Average operator utilization was 93.2 percent.

Table VII. SSE5 Run 3 results

Operator movement sequence (1= home station)

Operator	Station						
	1	2	3	4	5	6	7
1	1						
2	3	1	2				
3	3	2	1				
4				1	2	3	
5				3	2	1	
6							1
Machines	2	2	1	1	2	1	1

Production/week: 1296 garments
 Production/day: 259 garments
 Module WIP at end of week: 241 garments
 Largest WIP in front of Station 5: 206 garments
 WIP in front of Station 7: 35 garments

Operator	% idle
1	0
2	0
3	0
4	0
5	0
6	0

SSE5 file name: SIMPLX3

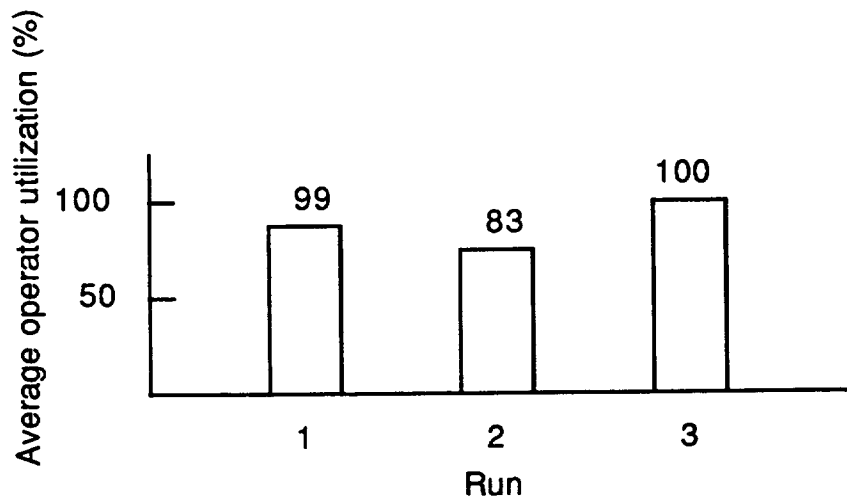
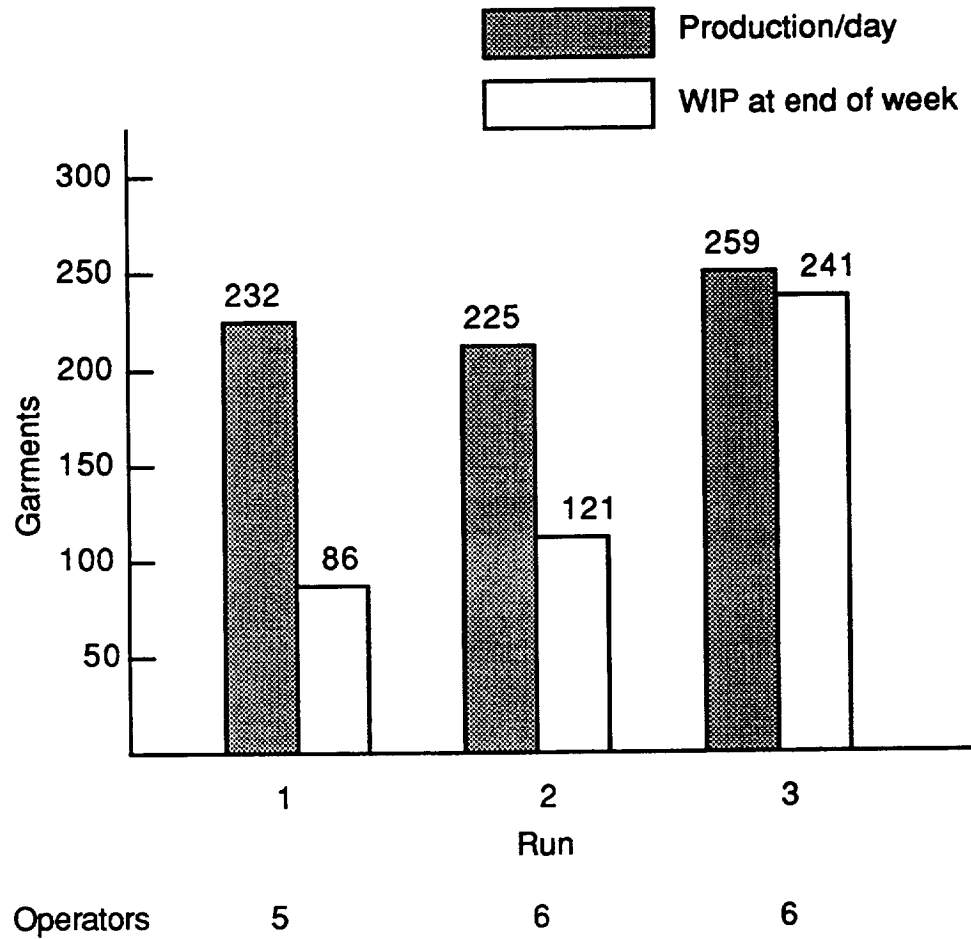
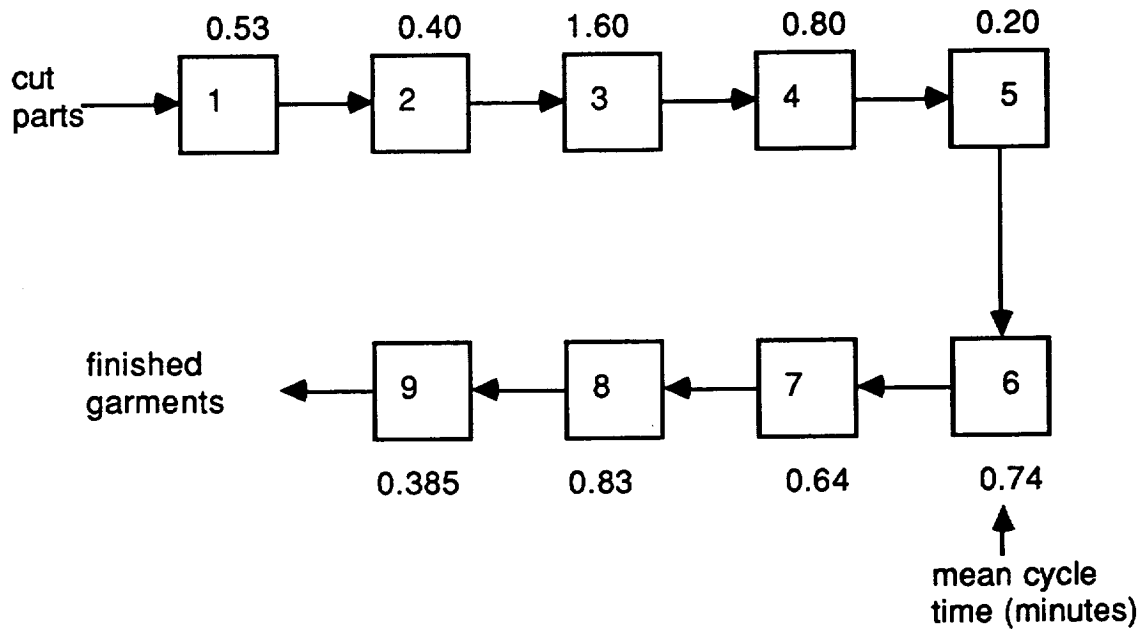
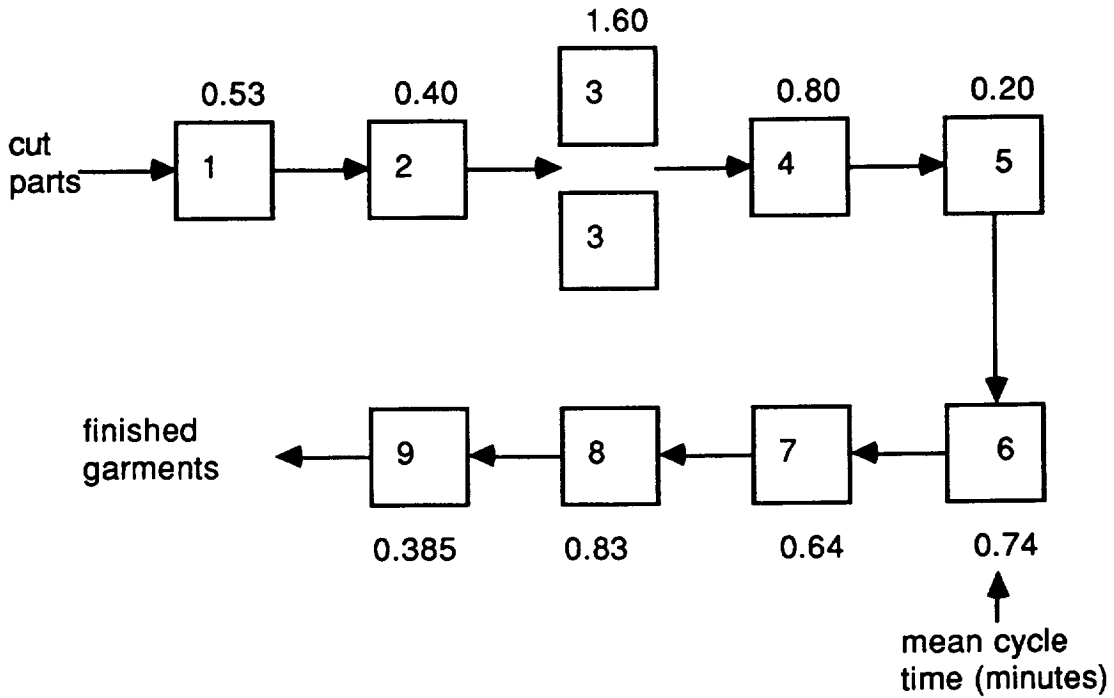


Figure 9. Comparison of results for SSE5



Station	Machines	Description
1	1	close shoulder
2	1	stitch shoulder
3	1	set sleeve and close
4	1	set collar
5	1	turn and mark collar
6	1	close collar
7	1	topstitch plackard
8	1	close unit tail
9	1	label sew

Figure 10. Initial module layout for Garment B



Station	Machines	Description
1	1	close shoulder
2	1	stitch shoulder
3	2	set sleeve and close
4	1	set collar
5	1	turn and mark collar
6	1	close collar
7	1	topstitch plackard
8	1	close unit tail
9	1	label sew

Figure 11. Module layout for Garment B (using SSE5)

Table VIII. SSE5 results for Garment B

Operator	Station								
	1	2	3	4	5	6	7	8	9
1			1						
2	2	1							
3			1						
4				1					
5					1	2			
6							1	2	3
7								1	2
Machines	1	1	2	1	1	1	1	1	1

Production/day: 503 garments
 Module WIP at end of day: 12 garments

Operator	% idle
1	14.6
2	0.0
3	14.5
4	13.8
5	0.0
6	0.8
7	4.2

SSE5 file name: GARMB

Data collected after running the model for 480 minutes and
 a warmup of 100 minutes

4.0 ANALYSIS

4.1 Garment A

Hilton Apparel has indicated a maximum production of 288 garments per day with six operators. This production is achievable using the SSE3 simulator provided the operators are all cross trained and can move to any station in any sequence and there is always an available machine at a station. The model using the SSE3 simulator resulted in a production of 286 garments per day. However, to achieve this production, a set of unrealistic rules were used by the SSE3. The model using the SSE6 simulator was based on the Toyota Sewn System (TSS) and resulted in a maximum module production of 169 garments per day with only four operators. Adding more than four operators did not increase production. A greater production of 234 garments/day was achieved by adding a second machine at Station 2 and a fifth operator.

The model using the SSE5 simulator was based on a set of rules that permitted some operators fixed while other operators move between a defined number of machines. A production was achieved of 259 garments with six operators and two machines at Stations 1, 2, and 5. However, there was a large WIP buildup of 241 garments.

One method to increase production is to improve the method. This may include changing the operations, adding special attachments to the machines, and purchasing more automated machines. Station 2 is a logical place to start since this station has the largest cycle time. Station 1 also has a large cycle time as well as Station 7.

Another method to increase production is to assign the most efficient operators to those stations with the largest cycle times. For example, if an operator is fixed at each of the seven stations and all operators work at 100 percent efficiency, the production would be $480 \text{ minutes/day} / 2.43 \text{ minutes}$ for the longest cycle time = 198 garments/day. If the operator is fixed at Station 2 and works at 110 percent the production would be $480 \text{ minutes/day} / (2.43 \text{ min} / 1.1) = 217 \text{ garments/day}$.

4.2 Garment B

The model using the SSE5 simulator achieved a production of 503 garments per hour. The WIP at the end of the day was only 12 garments. Average operator utilization was 93 percent.

5.0 REFERENCES

"Simulation Support Environment for Modular Manufacturing Systems SSE4 and SSE5", B. Schroer and J. Wang, Research Report 92-03, June 1992.

"Simulation Support Environment for Modular Manufacturing Systems SSE3 and SSE6", B. Schroer and J. Wang, Research Report 92-04, June 1992.

APPENDIX A

MSFC Problem Statements

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812
AC(205)544-2121

Reply to Airmail:

AT01

Mr. Roger Digmon
Simplex Industries
608 Tallahatta Rd
Thomasville, AL 36784

DEC 11 1992

Dear Mr. Digmon:

In reference to your request (Problem Statement #608) for apparel manufacturing simulation software, we have attached copies of the following apparel simulators:

1. SSE#3 and SSE#6 with users manual and software
2. SSE#5 with users manual and software

The SSE#3 probably cannot be used to model a real world apparel manufacturing module. Instead, this simulator is an excellent training tool for the first-time user of computer simulation.

The SSE#6 can be used to model apparel manufacturing modules that are based on the TSS (Toyota Sewing System) where all operators stand and move between stations. Work is done in lots of one garment.

The SSE#5 can be used to model manufacturing modules where some operators are fixed at machines while other operators can move between several machines. The moveable operators move based on a defined set of rules such as a time limit, bundle limit, lower WIP, and upper WIP. This simulator has been used by a number of apparel firms in Alabama.

For example, to execute the SSE#5 simulator, first load DOS and then load the simulator disk in drive A. Next, enter SSE5. If you have any questions concerning the use of the simulators, please call Dr. Bernard J. Schroer at (205) 895-6256.

Also enclosed is a set of recent publications by B. Schroer and M. Ziemke on modular manufacturing and simulation. The article "Home Grown Modular Manufacturing" outlines a small firm's success in implementing modular manufacturing.


The article "A Look at TSS Through Simulation" gives the development of a simulation model for studying the operation of a manufacturing module where all operators are cross trained and move like a chain between stations. Note that in this article, five operators are optimal in terms of maximum production and minimum work-in-process. Adding more operators do not increase production but do increase work-in-process. The SSE#6 can be used to model these types of manufacturing modules.

The article "Manufacturing's New Crystal Ball" gives a brief introduction into computer simulation, the different types of simulation systems, and a sample simulation model of a manufacturing module.

The article "Technology Transfer To a Major Manufacturing Industry: Case Study of a State's Approach" outlines Alabama's approach to technology transfer to the apparel industry.

Thank you for your interest in Marshall Space Flight Center's Technology Transfer program. If we can be of any further assistance, please call my office at (205) 544-0962.

Sincerely,


Ismail Akbay, Director
Technology Utilization Office

Enclosures

cc: AT01/Nell Massey
UAH/Bernard Schroer

11/23

Disclaimer

This information was assembled by the United States Government acting through the National Aeronautics and Space Administration. Neither the United States Government nor any agency or person acting on behalf of the United States Government assumes any liability resulting from the use of the information. In addition, the United States Government does not represent or warrant that use of the information will be free from privately owned rights.

Technical Request/Problem Statement

Date: 12/1/92

Name: Roger Dignon

Organization/Company: Simplex Industries

Address: 608 Tallahatche Rd Phone: (205) 636-5446
Thommsville AL 36784 Fax: () _____

Problem Title: Modular Manufacturing

Definition of Problem:
Responding to short lead time orders
Quick response manufacturing

Desired results:

Action to date:

What you expect from NASA/Marshall or other federal laboratory:
copies of apparel manufacturing
simulators developed by UAH.

Schedule - Date needed: ASAP

Return form to:

Director, Technology Utilization
Code AT01
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
(205) 544-2223
Fax (205) 544-3151

APPENDIX B

Ten Basic Steps to Modular Manufacturing (Self-Directed Work Teams)

During the past three years, the authors have written several articles about getting started in modular manufacturing. Although these pieces have proven useful to some clients, it has become obvious that many managers would prefer a “cookbook” approach to the subject. Thus, a paradigm is presented for converting to a dedicated work team approach from whatever work management method had been used previously.

The approach is based almost entirely upon experience with apparel manufacturing. However, the basic concept is applicable to several other manufacturing industries, including electronic or electrical assembly work. The point here is that the new discipline to be taught is not the actual manufacturing skills. Instead, it is the philosophy of shared group effort to achieve common production goals. For this reason, certain common elements of work can be taught irrespective of the product produced. These include: problem-solving, goal-sharing, team-building, etc. In Alabama, the state will provide free in-plant orientation courses on these types of subjects. This training is important. Most of the productivity and quality improvements achieved from dedicated work teams is attributable to their improved work attitudes.

Steps to modular manufacturing (MM)

1. Obtain management commitment
 - a. write down goals and objectives
 - b. have management sign off on plan

2. Get smart on modular manufacturing
 - a. visit plants that have implemented MM
 - b. attend MM seminars and workshops
 - c. read trade journals about MM
 - d. learn from other's mistakes

3. Start small
 - a. select one garment or style
 - b. understand operation of current manufacturing of selected garment
 - c. develop process flow of existing system
 - d. determine standard times for existing system
 - e. determine existing resources such as number of operators, bundle handlers, maintenance, supervisors, etc

4. Develop straw man MM
 - a. develop process flow of proposed MM
 - b. determine machines for each operation
 - c. determine operations that may be combined on same machine
 - d. determine required resources (operators and machines)
 - e. determine MM production goal
 - f. develop employee pay plan
 - f. develop simulation model of MM
 - g. use model to balance line, optimize staffing, and allocate resources

5. Find willing workers
 - a. solicit employee participation
 - b. screen and select employees for module

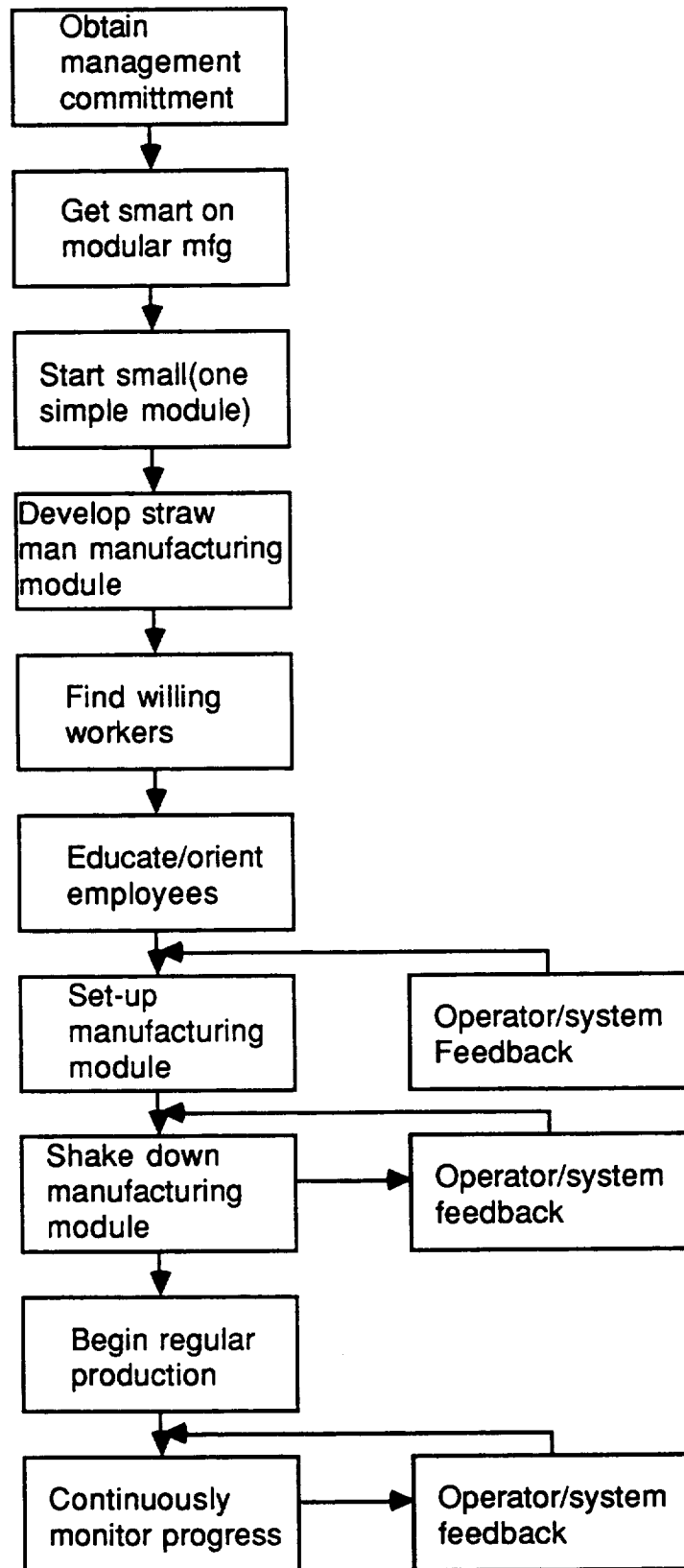
6. Educate/orient employees
 - a. schedule training sessions on company time
 - b. company's plans for modular
 - c. features of MM
 - d. example of other firms' pay plans
 - e. advantages of progressive bundle system (PBS)
 - f. disadvantages of PBS
 - g. advantages of MM
 - h. disadvantages of MM
 - i. quality through MM
 - j. group work ethics
 - k. solving problems on the sewing floor
 - l. conducting a work group meeting
 - m. brainstorming during group problem solving
 - n. reasons to avoid destructive criticism
 - o. benefits of constructive criticism
 - p. how to give constructive criticism
 - q. how to receive constructive criticism

7. Set-up MM
 - a. ensure employee participation
 - b. hold meeting with module on company time
 - c. have module select leader and group name
 - d. install sign of module name
 - e. help module develop reporting procedure such as the use of blackboard to record production per hour
 - d. solicit suggestions
 - e. use suggestions to modify and improve module (management needs to respond to suggestions quickly, such as within one week)

8. Shake down MM
 - a. compensate operators for lost pay during shakedown
 - b. hold meeting with module on company time
 - c. solicit suggestions
 - d. modify and improve module

9. Begin regular production
 - a. may still need to compensate operators for lost pay based on average earnings under old progressive bundle system
 - b. Experiment with machine setups and/or work methods better suited to MM

10. Continuously monitor progress
 - a. hold meeting with module on company time (weekly)
 - b. solicit suggestions
 - c. modify and improve module



Ten basic steps to modular manufacturing

6.0 Letters of Support



MORGAN
RESEARCH CORPORATION

FILE - Letters

October 30, 1992

The Honorable Bud Cramer
U.S. House of Representatives
1431 Longworth House Office Building
Washington, D.C. 20515

Dear Congressman Cramer:

I would like to inform you of the success Morgan Research Corporation has had accessing the technology transfer program at the NASA Marshall Space Flight Center. Several months ago Morgan Research submitted a problem statement to MSFC for assistance in a technology call sterolithography for the rapid prototyping of parts.

Through relationships with the University of Alabama in Huntsville and the Alabama Center for Advanced Technology Transfer, MSFC was able to "grow" a prototype assembly for Morgan Research (an exploded view of the assembly is attached). Thanks to the efforts of MSFC, I was able to use this prototype part to successfully market Morgan Research's concepts with another governmental agency in Huntsville.

As a small company, I am most pleased and gratified that the federal government is supporting the transfer of technology from the federal laboratories to the private sector. I want to thank you for your support and strongly encourage your continued support of technology transfer.

Sincerely,

Timothy D. Morgan
Vice President

cc J. Lee, Director MSFC

tdm/lsp

NOV 16 1992 08:37AM LEBOUT #18

P.2:3

Mar. 16 11/10



De Company
10 Hwy 5 & Bland Rd
Baton Rouge
LA 70803
November 13, 1992

Jack Lee
Director
George C Marshall Space Flight Center
DA01 Bldg. 9200
Marshall Space Flight Center, AL 35812

Dear Mr. Lee,

I want to thank MSFC and its Technology Utilization Office for its response to my simulator software request in August 1992. I have used the software to evaluate several manufacturing alternatives at Lee Apparel Co.

During the years of 1986-91, while we were developing Modular Manufacturing in our Bayou La Batre, Al. facility, the staff at the University of Alabama in Huntsville responded to numerous questions from me, and I feel that the simulator is a new peak in industrial technology assistance.

I want to commend MSFC and UAH for their initiative in providing technology to the apparel industry, and have recommended strongly to my successor at the Bayou La Batre, Al. facility, that we continue to utilize this invaluable resource.

Sincerely,

Michael Pickron
Area Engineering Manager

bh

ORIGINAL PAGE IS
OF POOR QUALITY

C-2

Phone (205) 259-3000
FAX (205) 259-3165

ANDOVER TOGS, INC.

October 23, 1992

Mr. Jack Lee, Director
George C. Marshall Space Flight Center
DA01 Bldg. 4200
Marshall Space Flight Center, AL. 35812

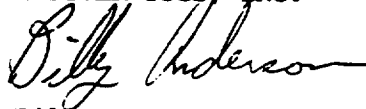
Dear Mr. Lee:

Andover Togs has been experimenting with modular manufacturing here in North Alabama. Through the technology transfer program with MSFC and the University of Alabama in Huntsville, Andover requested assistance in the conceptual development of simulation models to design and evaluate manufacturing modules. As a result, MSFC provided us with some simulation software for modeling our systems. We are currently implementing several manufacturing modules in our Distribution Center in Scottsboro.

I want to thank MSFC for its rapid response to our request and certainly hope you continue this valuable service to industry in Alabama.

Sincerely,

ANDOVER TOGS, INC.



Billy Anderson
Distribution Engineer

BA:gf

cc: G. Daugherty, Andover Togs
B. Schroer, UAH
C. Zienke, UAH

7.0 Fact Sheets



**The University
Of Alabama
In Huntsville**

Huntsville, Alabama 35899

Center for Automation
and Robotics

July 1992

Fact Sheet

Access to NASA Technologies

Alabama Industrial Development Training (AIDT) and the University of Alabama in Huntsville (UAH) have developed a technology transfer program to assist Alabama firms access technology available within the NASA Marshall Space Flight (MSFC) in Huntsville. Some of the services available from AIDT and MSFC are:

- NASA Tech Briefs Magazine
- COSMIC software library
- Database searches
- Technical assistance

Of special interest to firms such as yours are the AIDT/UAH technical assistance teams that are available to assist firms with technical problems and to access NASA technologies. If you have a specific technical problem, just complete the attached Technical Assistance/Problem Statement form and return to either AIDT or MSFC. If you would like a site visit and assistance in accessing AIDT and MSFC please call:

M.C. Ziemke, UAH
(205) 895-6408

Jeff Sica, AIDT
(205) 461-7550

The AIDT Alabama Center for Advanced Technology Transfer (ACATT) has weekly tours every Thursday at 5:00 p.m. Please call for a reservation.

This project is funded in part by Cooperative Agreement NCC8-18 from the NASA Marshall Space Flight Center (MSCF) Technology Utilization Office, Mr. Ismail Akbay, Director and Mr. John R. Richardson, Program Manager; and Alabama Industrial Development Training (AIDT), George Howard, Director.



HOW TO DO BUSINESS WITH THE GOVERNMENT

A common question is how to do business with the government. This Fact Sheet answers this question.

Small Business Offices in Alabama

Anniston

Anniston Army Depot
ATTN: SDSAN-SB
36201-5003
Ms. Kathy Harvey
(205) 235-7346

USACML&MPCEN&FM

ATTN: ATZN-DC
Bldg. 241-C
Fort McClellan
36205-5000
Mrs. Brenda Furlow
(205) 848-5126

Birmingham

Small Business Administration
2121 Eighth Avenue, North
Suite 200
35203-2376
Mr. James Barksdale 731-1341
Ms. Donna Glenn 731-0706

Daleville

Directorate of Contracting
U.S. Army Aviation Center
ATTN: ATZQ-C
Fort Rucker
36362-5000
Mr. Peter Polivka
(205) 255-3404/3407

Huntsville

U.S. Army Missile Command
ATTN: AMSMI-SB
Redstone Arsenal
35898-5150
Dr. Rex Conners 876-5441
Mr. Lee A. Ford 876-2561
Mr. Dwight Kimbrell 876-2376
Ms. Bertie Lipscomb 876-5318

U.S. Army Strategic Defense Command
P.O. Box 1500
35807-3801
Mrs. Virginia B. Wright
(205) 955-3412

George C. Marshall Space Flight Center
Procurement Office, Attn: AP16
35812
Conrad Walker 544-0254
David Brock 544-0267

U.S. Army Engineer Division
Huntsville CEHND-DD
P.O. Box 1600, West Station
35807-4301
Mr. Ed Lewis
(205) 955-5743

Mobile

Supply Officer
U.S. Coast Guard Aviation
Training Center
36608-9682
(205) 694-6312

U.S. Army Engineer District
P.O. Box 2288
36628-0001
Ms. A.E. Cotton
(205) 690-3597

Montgomery

U.S. Department of Agriculture
Forest Service
Contracting Office
1765 Highland Avenue
36107
Ms. Charlotte Flitcraft
(205) 832-4470

SSC/PK

Building 501
Maxwell AFB
Gunter Annex, AL
36114-6343
Mr. Melvin Carr
(205) 416-5614

National Guard

c/o USPFO, Alabama
P.O. Box 3715
36109-0715
Col. Max S. Bowdoin
(205) 271-7316

Supply Officer

Veterans Administration Hospital
215 Perry Hill Road
36109
(205) 272-4670

Tuskegee

Supply Officer
Veterans Administration Medical Ctr
36083
(205) 727-0550

Each federal procurement office has a small business specialist for assisting small firms sell to that agency. Contact this person for assistance and to get on the bidding list.

Federal Solicitation Mailing List

To get on the bidding list, complete attached form SF129 and send to each of the above procurement offices.

Small Business Procurement System

Bid information from the *Commerce Business Daily* is entered into the states computer system and then to the Small Business Development Centers (SBDCs). The SBDC matches your specific capabilities with bid opportunities and mails you a notice so you can call the appropriate federal agency for a bid package. Complete the attached form to receive this service.

Small Business Development Centers (SBDCs)

For more information contact the following SBDC nearest you:

Auburn

Auburn University
Small Business Development Center
226 Thach Hall
Auburn University, AL 36849-5243
205-844-4220

Birmingham

The University of Alabama at
Birmingham
Small Business Development Center
901 South 15th Street
MCJ Building, Room 143
Birmingham, AL 35294
205-934-6760

Florence

The University of North Alabama
Small Business Development Center
Box 5017, Keller Hall
Florence, AL 35632-0001

Huntsville

Northeast Alabama Regional SBDC
Alabama A&M University and The
University of Alabama in Huntsville
P.O. Box 343
255 Church Street, N.W.
Huntsville, AL 35804-0343
205-535-2061

Jacksonville

Jacksonville State University
Small Business Development Center
113B Merrill Hall
Jacksonville, AL 36265
205-231-5271

Livingston

Livingston University
Small Business Development Center
Station 35
Livingston, AL 35470
205-652-9661, ext. 439

Mobile

The University of South Alabama
Small Business Development Center
College of Business/Management
Studies
BMSB 101
Mobile, AL 36688
205-460-6004

Montgomery

Alabama State University
Small Business Development Center
915 South Jackson Street
Montgomery, AL 36195
205-269-1102

Troy

Troy State University
Small Business Development
Center
Sorrell College of Business
Troy, AL 36082-0001
205-566-7665

Tuscaloosa

The University of Alabama
Small Business Development
Center
Box 870397, 400 S. Martha
Parham West
Tuscaloosa, AL 35487-0397
205-348-7011

Call Donna Bass • ACATT/AIDT • 2903 Wall Triana Hwy Suite 1 • Huntsville, AL 35824 • (205) 461-7550 • Fax (205) 461-8153

This project is funded in part by Cooperative Agreement NCC8-18 from the NASA Marshall Space Flight Center (MSFC) Technology Utilization Office, Mr. Ishmail Akbay, Director and Mr. John R. Richardson, Program Manager; and the Alabama Industrial Development Training (AIDT), George Howard, Director.

SOLICITATION MAILING LIST APPLICATION

1. TYPE OF APPLICATION INITIAL REVISION 2. DATE

FORM APPROVED
OMB NO.
3090-0009

NOTE—Please complete all items on this form. Insert N/A in items not applicable. See reverse for instructions.

3. NAME AND ADDRESS OF FEDERAL AGENCY TO WHICH FORM IS SUBMITTED (Include ZIP code)

4. NAME AND ADDRESS OF APPLICANT (Include county and ZIP code)

5. TYPE OF ORGANIZATION (Check one)
 INDIVIDUAL NON-PROFIT ORGANIZATION
 PARTNERSHIP CORPORATION, INCORPORATED UNDER THE LAWS OF THE STATE OF _____

6. ADDRESS TO WHICH SOLICITATIONS ARE TO BE MAILED (If different than Item 4)

7. NAMES OF OFFICERS, OWNERS, OR PARTNERS

A. PRESIDENT	B. VICE PRESIDENT	C. SECRETARY
D. TREASURER	E. OWNERS OR PARTNERS	

8. AFFILIATES OF APPLICANT (Names, locations and nature of affiliation. See definition on reverse.)

9. PERSONS AUTHORIZED TO SIGN OFFERS AND CONTRACTS IN YOUR NAME (Indicate if agent)

NAME	OFFICIAL CAPACITY	TELE. NO. (Include area code)

10. IDENTIFY EQUIPMENT, SUPPLIES, AND/OR SERVICES ON WHICH YOU DESIRE TO MAKE AN OFFER (See attached Federal agency's supplemental listing and instructions, if any)

11A. SIZE OF BUSINESS (See definitions on reverse) <input type="checkbox"/> SMALL BUSINESS (If checked, complete items 11B and 11C) <input type="checkbox"/> OTHER THAN SMALL BUSINESS	11B. AVERAGE NUMBER OF EMPLOYEES (Including affiliates) FOR FOUR PRECEDING CALENDAR QUARTERS	11C. AVERAGE ANNUAL SALES OR RECEIPTS FOR PRECEDING THREE FISCAL YEARS \$
12. TYPE OF OWNERSHIP (See definitions on reverse) (Not applicable for other than small businesses) <input type="checkbox"/> DISADVANTAGED BUSINESS <input type="checkbox"/> WOMAN-OWNED BUSINESS	13. TYPE OF BUSINESS (See definitions on reverse) <input type="checkbox"/> MANUFACTURER OR PRODUCER <input type="checkbox"/> REGULAR DEALER (Type 1) <input type="checkbox"/> CONSTRUCTION CONCERN <input type="checkbox"/> SURPLUS DEALER <input type="checkbox"/> SERVICE ESTABLISHMENT <input type="checkbox"/> REGULAR DEALER (Type 2) <input type="checkbox"/> RESEARCH AND DEVELOPMENT	

14. DUNS NO. (If available)

15. HOW LONG IN PRESENT BUSINESS?

16. FLOOR SPACE (Square feet)		17. NET WORTH	
A. MANUFACTURING	B. WAREHOUSE	A. DATE	B. AMOUNT \$

18. SECURITY CLEARANCE (If applicable, check highest clearance authorized)

FOR	TOP SECRET	SECRET	CONFIDENTIAL	C. NAMES OF AGENCIES WHICH GRANTED SECURITY CLEARANCES (Include dates)
A. KEY PERSONNEL				
B. PLANT ONLY				

CERTIFICATION — I certify that information supplied herein (Including all pages attached) is correct and that neither the applicant nor any person (Or concern) in any connection with the applicant as a principal or officer, so far as is known, is now debarred or otherwise declared ineligible by any agency of the Federal Government from making offers for furnishing materials, supplies, or services to the Government or any agency thereof.

19. NAME AND TITLE OF PERSON AUTHORIZED TO SIGN (Type or print)	20. SIGNATURE	21. DATE SIGNED
---	---------------	-----------------

INSTRUCTIONS

Persons or concerns wishing to be added to a particular agency's bidder's mailing list for supplies or services shall file this properly completed and certified Solicitation Mailing List Application, together with such other lists as may be attached to this application form, with each procurement office of the Federal agency with which they desire to do business. If a Federal agency has attached a Supplemental Commodity list with instructions, complete the application as instructed. Otherwise, identify in Item 10 the equipment, supplies and/or services on which you desire to bid. (Provide Federal Supply Class or Standard Industrial Classification Codes if available.) The application shall be submitted and signed by the principal as distinguished from an agent, however constituted.

After placement on the bidder's mailing list of an agency, your failure to respond (submission of bid, or notice in writing, that you are unable to bid on that particular transaction but wish to remain on the active bidder's mailing list for that particular item) to solicitations will be understood by the agency to indicate lack of interest and concurrence in the removal of your name from the purchasing activity solicitation mailing list for the items concerned.

SIZE OF BUSINESS DEFINITIONS
(See Item 11A.)

a. Small business concern—A small business concern for the purpose of Government procurement is a concern, including its affiliates, which is independently owned and operated, is not dominant in the field of operation in which it is competing for Government contracts and can further qualify under the criteria concerning number of employees, average annual receipts, or other criteria, as prescribed by the Small Business Administration. (See Code of Federal Regulations, Title 13, Part 121, as amended, which contains detailed industry definitions and related procedures.)

b. Affiliates—Business concerns are affiliates of each other when either directly or indirectly (i) one concern controls or has the power to control the other, or (ii) a third party controls or has the power to control both. In determining whether concerns are independently owned and operated and whether or not affiliation exists, consideration is given to all appropriate factors including common ownership, common management, and contractual relationship. (See Items 8 and 11A.)

c. Number of employees—(Item 11B) In connection with the determination of small business status, "number of employees" means the average employment of any concern, including the employees of its domestic and foreign affiliates, based on the number of persons employed on a full-time, part-time, temporary, or other basis during each of the pay periods of the preceding 12 months. If a concern has not been in existence for 12 months, "number of employees" means the average employment of such concern and its affiliates during the period that such concern has been in existence based on the number of persons employed during each of the pay periods of the period that such concern has been in business.

TYPE OF OWNERSHIP DEFINITIONS
(See Item 12.)

a. "Disadvantaged business concern"—means any business concern (1) which is at least 51 percent owned by one or more socially and economically disadvantaged individuals; or, in the case of any publicly owned business, at least 51 percent of the stock of which is

owned by one or more socially and economically disadvantaged individuals; and (2) whose management and daily business operations are controlled by one or more of such individuals.

b. "Women-owned business"—means a business that is at least 51 percent owned by a woman or women who are U.S. citizens and who also control and operate the business.

TYPE OF BUSINESS DEFINITIONS
(See Item 13.)

a. Manufacturer or producer—means a person (or concern) who is operating, or maintaining a store, warehouse, or other establishment that produces, on the premises, the materials, supplies, articles, or equipment of the general character of those listed in Item 10, or in the Federal Agency's Supplemental Commodity List, if attached.

b. Service establishment—means a concern (or person) which owns, operates, or maintains any type of business which is principally engaged in the furnishing of nonpersonal services, such as (but not limited to) repairing, cleaning, redecorating, or rental of personal property, including the furnishing of necessary repair parts or other supplies as part of the services performed.

c. Regular dealer (Type 1)—means a person (or concern) who owns, operates, or maintains a store, warehouse, or other establishment in which the materials, supplies, articles, or equipment of the general character listed in Item 10, or in the Federal Agency's Supplemental Commodity List, if attached, are bought, kept in stock, and sold to the public in the usual course of business.

d. Regular dealer (Type 2)—In the case of supplies of particular kinds (at present, petroleum, lumber and timber products, machinery tools, raw cotton, green coffee, hay, grain, feed, or straw, agricultural liming materials, tea, raw or unmanufactured cotton linters and used ADPE), Regular dealer means a person (or concern) satisfying the requirements of the regulations (Code of Federal Regulations, Title 41, 50-201.101(a)(2)) as amended from time to time prescribed by the Secretary of Labor under the Walsh-Healey Public Contracts Act (Title 41 U.S. Code 35-45). For coal dealers see Code of Federal Regulations, Title 41, 50-201.604(a).

- **COMMERCE BUSINESS DAILY**—The Commerce Business Daily, published by the Department of Commerce, contains information concerning proposed procurements, sales, and contract awards. For further information concerning this publication, contact your local Commerce Field Office.



FACT SHEET

CHARACTERIZING THE METAL FABRICATION INDUSTRY IN ALABAMA

Mary S. Spann, Ph.D.
College of Administrative Science
University of Alabama in Huntsville

Data Collection and Sample Size

Questionnaires were mailed to 520 firms classified as metal fabricators in Alabama by Standard Industrial Classification codes listed in the *Alabama Industrial Directory*. Of the 500 questionnaires delivered, 92 were completed for a response rate of 18 percent. This report summarizes the findings of this study.

Ninety-nine percent of the sample firms are small businesses using the Small Business Administration's definition of a small business as one with 500 or fewer employees. Additionally, the majority of these firms are very small businesses with 50 percent having less than 20 employees and another 27 percent with 20 to 50 employees. These size differences are important. The data demonstrate that the size of the business influences the scope of the marketing effort, the adoption of technology and plans for the future.

Findings

Markets

Alabama metal fabricators operate almost entirely in the industrial segment of the market targeting other businesses for 80 percent of the industry's revenues. Fifty percent of industry revenues come from other businesses within Alabama and an additional 22 percent come from southeastern states outside Alabama. The smaller fabricators (less than 20 employees) tend to make fewer sales (22 percent) to large businesses whereas firms with 20-50 employees get 31 percent of their revenues and firms with more than 50 employees get 48 percent of their revenues from large businesses. Additionally, smaller fabricators rely more heavily on revenues from other businesses within Alabama (75 percent).

Competition and Other Problems

The sample firms compete on the basis of quality, delivery and service rather than with specialized products or low cost. General consensus in the industry is that competition is strong with expectation that it will be somewhat stronger in the future.

Fairly typical for small businesses, Alabama's metal fabricators define dealing with government regulation as their most serious problem. Finding and retaining qualified workers is the second largest problem. Financing growth and dealing with technological change are rated as the least problematic.

Relationships with Suppliers

Most firms in the industry develop long-term relationships with their suppliers. However, these long-term relationships appear not to be as beneficial as they should be. One would expect that a long-time supplier would be a source of ideas for new products as well as for improvements in processes and quality. This is not the case for the sample firms. The fact that firms in the industry tend to have numerous suppliers may dilute these potential benefits.

Technology

The majority of the firms report that they are usually to always successful in adopting new technologies but that cost and education are serious barriers to implementing new technologies. Computer Numeric Control (CNC) and Computer-Aided Design (CAD) are used by almost half and Computer-Aided Engineering (CAE) and Computer-Aided Manufacturing (CAM) by about one-third of all the sample firms. Again size makes a big difference in the adoption of these technologies. Fifty to 80 percent of firms with more than 50 employees use CNC, CAE, CAD and CAM whereas only 10 to 20 percent of firms with fewer than 20 employees do.

Almost 80 percent of the sample firms reported they emphasis quality products and 74 percent reported that quality is an important source of their competitive advantage, yet quality is largely assured by inspection. Over 70 percent of these firms inspect for quality. Modern engineering and management practices for the implementation of quality management are largely unused in the industry. Only 20 percent of the industry use TQM and 13 percent use SPC. Firms with more than 50 employees have done more in initiating quality management transitions than firms with fewer than 20 employees. Almost all of these larger firms have written mission statements and inhouse programs to communicate their quality values to customers and employees alike. Almost all firms, regardless of size, collect customer feedback.

Training

Training for experienced workers is generally neglected in the industry with 70 percent of these firms providing four or fewer hours of training per month. The larger fabricators do not do significantly more training than small ones. In today's complex work environment, eight hours of training per month is considered average training for experienced production workers. The vast majority of Alabama metal fabricators fail to use the services of the state-support training programs and institutions like Alabama Industrial Development Training (AIDT) and Alabama Center for Advanced Technology Transfer (ACATT).

Certainly the need for training exists within the metal fabrication industry. With the emphasis on quality as a major source of competitive advantage, training in quality management is critical to Alabama's metal fabrication industry. Other training needs, based on the industry's plans for technology adoption within the next five years, include training in Materials Requirement Planning (MRP), Engineering Data Management (EDM), CAD, CAM, CAE and linking CAD to CAM. Cost and education are serious barriers to technology implementation, but Alabama's metal fabricators have an opportunity to overcome these barriers by utilizing state-supported training programs.



**The University
Of Alabama
In Huntsville**

August 1992

FACT SHEET

NASA Track Record on Free Technical Assistance

During the past four years, the NASA Marshall Space Flight Center in Huntsville has received more than 100 inquiries for free technical assistance from the private sector. As seen in Figure 1, these requests cover a wide range of technologies. Although MSFC has capability in all of these areas, when they fail to find the proper expertise in Huntsville, they call on other NASA centers or the Federal Laboratory Consortium for additional help. Thus most requests for services are eventually satisfied. This fact may be seen in Figure 2, a study made at the midpoint of the third quarter of calendar year 1992. As would be expected, most requests for services during this six-week period were still open and being worked on. Dropping back to requests received during April-June 1992, we see that half have been closed by MSFC or referred to other sources. The bar for January - March 1992 shows only a small number of requests still being worked on while most have been closed or referred. There were no open items carried over from 1991.

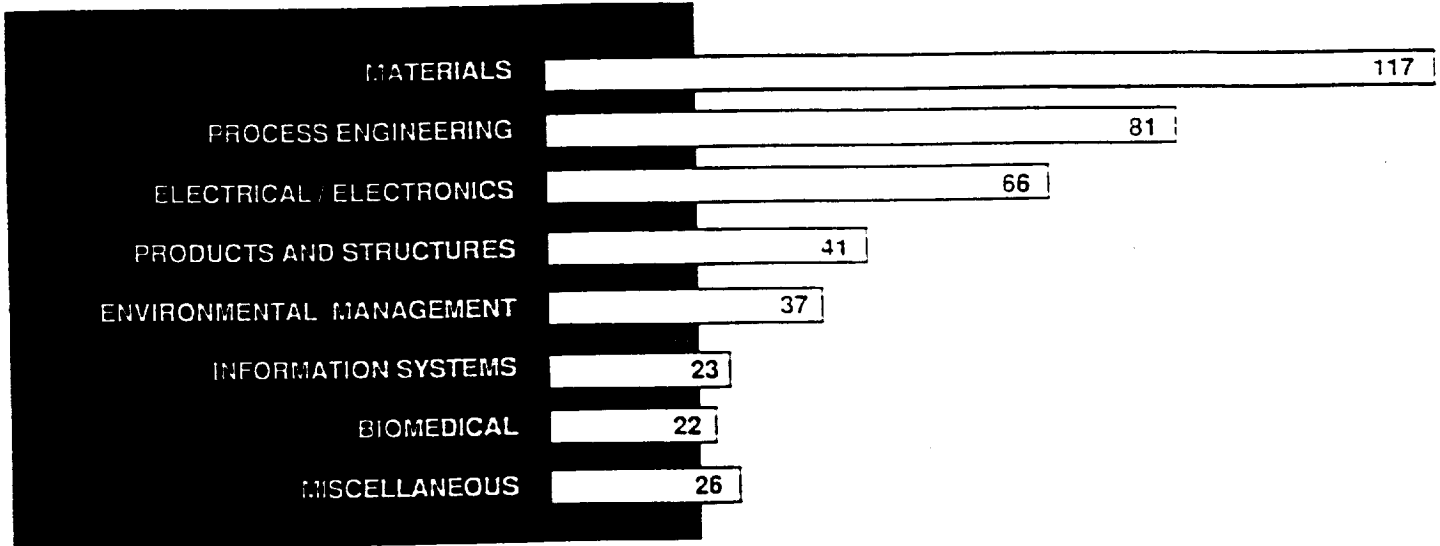
What this means is that a request for technical assistance to MSFC will most likely be satisfied by that organization within four months of receipt. This is a good batting average for a free service that depends on engineers and scientists who answer requests for assistance on a time-available basis. Also, it should be appreciated that requests for technical assistance are sharply up in volume over last year. Reflecting this fact, MSFC has recently contracted with UAH for services of their scientists and engineers to help reduce the backlog of work. In turn, UAH is recruiting technical assistance from TVA, Alabama Power and the Beville Center to help Alabama industries with technical problems.

Thus this is now a good time for Alabama industries to seek solutions to their technical problems from the MSFC/UAH Technology Transfer team. During the past three months, the apparel manufacturing industry alone has submitted more than 25 requests for assistance involving both hardware and software.

This project is funded in part by the NASA Marshall Space Flight Center Technology Utilization Office, Mr. Ismail Akbay, Director and the Alabama Industrial Development Training (AIDT), Mr. George Howard, Director.

FIGURE 1

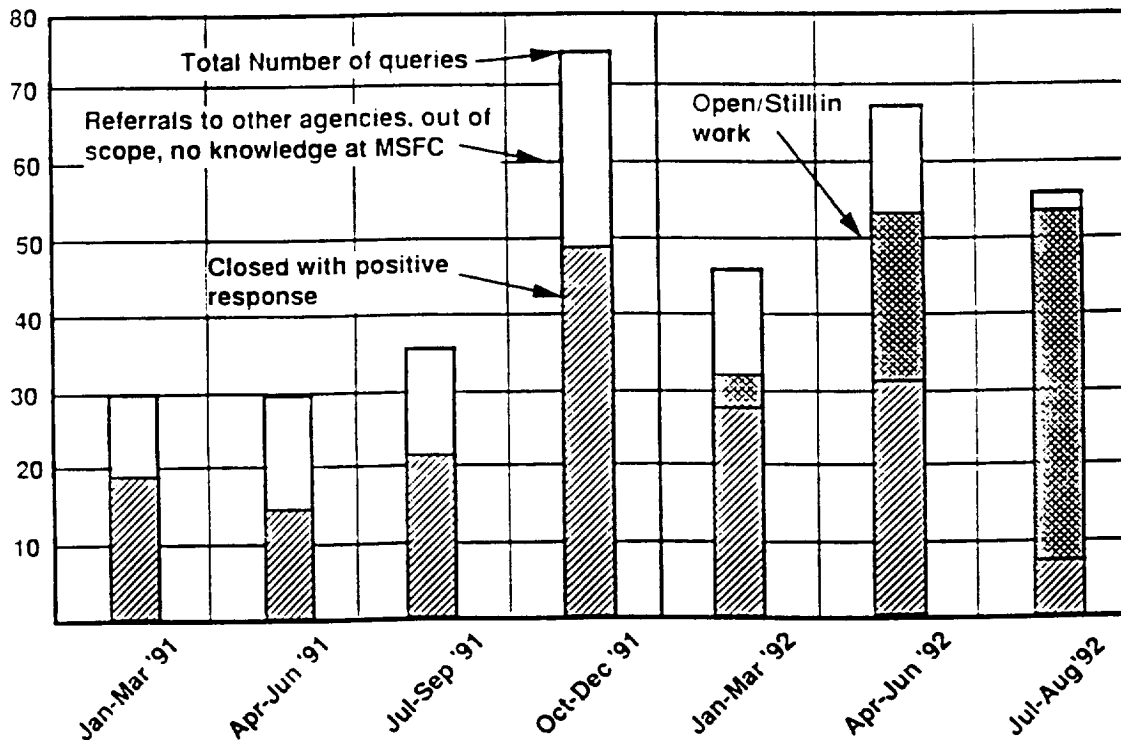
Inquiries from the private sector cover a range of technical disciplines at MSFC



Technical inquiries by discipline through August, 1992

FIGURE 2

Most technical queries from the private sector receive positive responses from MSFC





The University
Of Alabama
In Huntsville

TECHNOLOGY TRANSFER IN ALABAMA

NASA Technology

The Marshall Space Flight Center (MSFC) has developed a technology transfer program to assist Alabama firms access technologies from NASA. Some of the services available are:

- *NASA Tech Briefs* magazine – monthly magazine containing short abstracts describing NASA-developed technologies (free)
- COSMIC software library – 1,200 software programs developed with NASA funds (small charge for each program)
- Database searches – specialists available to assist firms access over 1,000 computerized databases throughout the world; typical examples of database searches are information on new technologies, patent searches, and information on competitors (small fee for each search)
- Technical assistance – technical teams available to assist firms with specific problems (free)

Of special interest to firms such as yours are the MSFC/UAH technical assistance teams that are available to assist firms with technical problems and to access NASA technologies. If you have a specific technical problem, just complete the attached Technical Assistance/Problem Statement form and return it to MSFC.

For more information contact:

Technology Utilization Office, Code AT01
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
(205) 544-2223 Fax (205) 544-3151

AIDT Services

Alabama Industrial Development Training (AIDT) provides comprehensive workforce recruiting and training to manufacturing start-up firms and to manufacturing firms that are expanding and upgrading their workforce. Some of the services available from AIDT are:

- Seminars on manufacturing technologies
- Demonstrations of manufacturing technologies at one of its three regional centers. AIDT's Alabama Center for Advanced Technology Transfer (ACATT) in Huntsville has weekly tours every Thursday at 5:00 PM
- Training – in such areas as CAD, CAM, CIM, PLC, TQM, SPC, C, Unix, and Ada
- Technical Assistance – a team of engineers will visit your plant, provide assistance, and help you complete the problem statement forms

All of the above services are free to qualified firms in Alabama. For more information contact:

Alabama Center for Advanced Technology Transfer (ACATT)
2903 Wall Triana Highway, Suite 1
Huntsville, AL 35824-1537
(205) 461-7550 Fax (205) 461-8153

Contacts

Bernard Schroer, UAH (205) 895-6256
Carl Ziemke, UAH (205) 895-6408
Jeff Sica, ACATT (205) 461-7550

Harry Waters, MSFC (205) 544-0553
Roger Black, MSFC (205) 544-1822

This project is funded in part by the NASA Marshall Space Flight Center Technology Utilization Office, Mr. Ismail Akbay, Director and the Alabama Industrial Development Training (AIDT), Mr. George Howard, Director.

8.0 Publications

BY THE CASE**TECHNOLOGY TRANSFER TO A MAJOR MANUFACTURING INDUSTRY: CASE STUDY OF A STATE'S APPROACH**

M. Carl Ziemke and Bernard J. Schroer

The paper presents the state of Alabama's approach to the transfer of technology to the apparel-manufacturing industry. The technology-transfer program has been under way for three years. This paper summarizes the highlights of the program, the approach to transferring technology, and the lessons learned.

The importance of technology transfer to industries has become widely recognized. In some of the larger industrial states, organizations, such as the Ohio Technology Transfer Organization (OTTO), have been formed to serve the major industries. However, in some of the more poorly financed states, such as Alabama, there is no such organization designated to provide needed technology to industries. As a consequence, the state administration in Alabama provides technology transfer to industries on a selective basis, using state-university contractors that have an established track record in technology outreach, both to the general public and to selected target groups. In March 1989, the authors were named co-principal investigators on a contract to provide technology transfer to apparel manufacturers, a major state industry that provided employment to approximately 56,000 people. This was initially a one-year contract that has received two one-year extensions.

While working on the technology-transfer contract, we encountered and shed light on several questions of general interest to the technology transfer community:

- Is it best to be an able communicator or

M. Carl Ziemke is a research scientist at the University of Alabama in Huntsville (UAH). He has 42 years of combined industry and university experience in management and technology, with more than 45 publications in those fields.

Bernard J. Schroer is chair of The Industrial and Systems Engineering Department at UAH and a fellow in the IIE Society. He holds a Ph.D. in industrial engineering from Oklahoma State University and has just published a book (with Carl Ziemke) on modern-apparel-manufacturing management and technology.

to be highly knowledgeable about the technology to be transferred?

- Is it practical to originate technology while being primarily concerned with the transfer of that technology?
- Should business-related topics such as marketing and tax information be included with the truly technological information being transferred to the clientele?
- Is it beneficial to the targeted clientele as a whole if a select few receive technical/business consulting services from technology-transfer agents?
- Are selected members of the targeted clientele a logical source of technology valuable to most of the other members of the group?

These issues are discussed in detail in this paper. Also discussed is a general methodology for technology transfer to a major industrial sector that should have broad application in similar state-assistance efforts.

CHOOSING THE TARGET INDUSTRY

Because Alabama has a diverse industrial base, the state administration had inadequate funds for a technology-transfer effort that would support all major industrial sectors. In 1988, the Alabama Department of Economic and Community Affairs (ADECA) began evaluating state industrial sectors in terms of size, competitive position, and geographic distribution. Forest products is the state's largest industrial employer and is well distributed throughout all 67

counties. However, this industry exhibits steady growth and is secure from foreign competition through its huge reserves and local standing timber.

Next in size is apparel manufacturing, equally well-distributed but threatened by global competition. Unlike the forest-products industry, apparel manufacturing has no permanent state-agency representation and no strong internal-trade organization to look after its interests. Therefore, it was chosen for special state technology-transfer assistance. Technology transfer represented the most cost-effective method to assist an industry that had already received the maximum possible benefits of state-tax forgiveness, low-interest industrial bonds, and related assistance.

This technology-transfer program deviated from the industrial-development efforts of previous state administrations that had concentrated almost entirely on attracting new industrial plants rather than on supporting existing plants that were vulnerable to competition. A whole new industrial-support strategy had to be developed by the technology-transfer team at the University of Alabama in Huntsville (UAH).

CHARACTERIZING THE INDUSTRY

The state chose as team leaders two experienced engineer/managers who had long associations with state technical-outreach programs, some of which were distinguished by national awards. Because these team leaders did not have extensive experience with apparel manufacturing, the initial efforts on the contract were to survey and characterize the industry.

Nation-wide, the industry is notable for its diversity in both products and firms. Products include shoes, belts, gloves, shirts, blouses, hats, dresses, tailored suits, sleepwear, trousers, outerwear, socks, and hosiery.(1) This diversity complicates the transfer of technology to the industry. However, the team was able to narrow targeted firms in terms of their products. We first investigated a major segment of Alabama apparel manufacturing: knitted socks. Several thousand people in northeast Alabama are engaged in sock production. After visiting several plants, we found that the industry was

doing well with 1920s-vintage automatic sock-knitting machines and had little incentive to modernize except where labor supplies were tight.

Another major apparel-industry segment in

Figure 1. Eight phases of technology transfer and specific tasks associated with each

Phase I:	Select target industry a. Select Standard Industrial Classification (SIC) codes that correspond to target industry. b. Select firms listed in Alabama Industrial Directory that correspond to SIC codes.
Phase II:	Survey target industry a. Prepare survey instrument, or questionnaire. b. Mail survey questionnaires to firms. c. Conduct second mailing of questionnaires one month later. d. Develop database of respondents, or clients.
Phase III:	Analyze responses to survey a. Profile firms responding. b. Identify needs of firms. c. Prepare report of survey results. d. Send fact sheet summarizing survey results to clients.
Phase IV:	Conduct site visits to responding firms a. Meet with person completing survey questionnaire. b. Discuss state's technology-transfer program. c. Discuss survey results. d. Discuss firm's needs. e. Identify followup on-site seminars on selected technologies. f. Identify technical-assistance project and point-of-contact.
Phase V:	Conduct on-site seminars a. Present seminar to top management on selected technologies. b. Identify technologies to be demonstrated. c. Identify technical-assistance project and point-of-contact.
Phase VI:	Demonstrate technologies a. Firms visit a state center and/or federal laboratories for demonstration of selected technologies. b. Conduct technical sessions on selected technologies.
Phase VII:	Conduct specialized training a. Firms attend a state center for specialized training.
Phase VIII:	Provide technical assistance a. Establish state and university team. b. Work with firm in solving problem. c. Prepare report on project. d. Send fact sheet summarizing project to clients.

north Alabama produces disposable garments, such as hospital gowns, from non-woven fabrics. This is mostly a cottage industry built around such standard sewing equipment as second-hand single-needle machines and sergers. This industrial segment is not threatened by imports because of the low cost of production and high-bulk, low-value products that are uneconomical to ship great distances.

We ultimately determined that our major targeted industrial sector produced sewn products from conventional knitted or woven fabric. Within this sector, we defined small contractors and subcontractors as the primary groups to be assisted. The fabric employed in this industrial segment moves from the textile manufacturer to apparel jobbers or manufacturers, both of whom may use independent contractors or subcontractors for production. These two latter types of firms typically work on fabric owned and supplied by the jobbers or manufacturers.⁽²⁾ They provide finishing operations such as stone-washing, pressing, or embroidering. The completed garments go to apparel wholesalers and retailers who determine the volume and type of production orders.

In characterizing the apparel-manufacturing industry, we were struck by the large numbers of small producers (mostly contractors and subcontractors). In 1986, there were 1.1 million employees in this industry working for 22,525 domestic firms—an average of only 48 employees per firm.⁽³⁾ These numbers can be misleading, however. The industry is roughly divided into two equal parts. One consists of large manufacturers, each of whom employs from about 500 to several thousand workers. The other part includes small contractors and

subcontractors with from three to 300 employees. We initially targeted the small firms because they had raw resources with which to cope with today's dynamic global apparel market.

The larger firms were not targeted because their experienced, college-trained managers and engineers might not need or accept assistance from those new to apparel manufacturing. This theory proved to be incorrect. We now provide direct consulting support to the three largest firms in the state (40% of the apparel-manufacturing jobs), two of which have started experiencing financial difficulties due to reduced orders for garments since we started the program. We have visited five of their 30 plants at least once. In contrast, we visited more than 40 small apparel plants more than once. (Generally, assistance to the large firms is more technical than that given to small ones.)

RESULTS OF INDUSTRY SURVEY

While we were characterizing the apparel manufacturing industry, both nationally and locally, we were circulating a three-page survey instrument among the state apparel-manufacturing sector, about 500 firms. While only about 10% of those surveyed responded, the data revealed major problems (Table I) and caused us to reconsider our basically technical approach to aiding this industry through technology transfer. After making subsequent plant visits, we listed the typical limitations of small apparel firms (Table II).

As can be seen in Tables I and II, many problems were associated with operating these small apparel-manufacturing firms that were not primarily technical in nature. Nevertheless, we found solutions for most of them. In this effort, we were assisted by our state sponsors (ADECA), who recognized that the primary goal

Table I Problems Common to Apparel Manufacturing
<ul style="list-style-type: none"> • A general shortage of skilled operators (primarily female sewing workers) • The current level workforce is typically unskilled and difficult to train • Lack of nearby vocational training forces extensive, expensive use of in-plant training • The existing workforce exhibits high rates of turnover and absenteeism • The smaller firms (primarily contractors) often have marketing problems

Table II Typical Limitations of Small Apparel Firms
<ul style="list-style-type: none"> • Small workforces (often less than 75 people) • Often, managers and key employees are not college-educated • Managers may lack knowledge of current technology • Rarely is marketing done by a full-time expert • High-productivity machines are unsuited to small workforces • In-plant training is often impractical or inefficient

of their technology-transfer contract with us was to assist a major industrial segment to be more profitable and competitive. Thus we were permitted to transfer any useful types of information, including those involving management, marketing, and training.

IMPACT OF GLOBAL COMPETITION

Although, as a major apparel producer, Alabama manufactures considerably more clothing than it purchases, much of the clothing bought in Alabama is produced outside of the country. Thus the state apparel producers operate in a national and a global market. This is true even of small state producers who contract with large jobbers or manufacturers whose home offices and primary markets are typically out-of-state.

Despite the inroads of foreign production on the domestic apparel market, US producers still supply about 5% of American purchases. This market share has an annual retail value of \$73-billion.(5,6) Alabama's share of this market is roughly \$4-billion. Apparel production is the lowest-paid major manufacturing industry in the US. Wage levels averaged \$6.59/hour in 1990, and are estimated to be little more than \$7.00/hour in 1991.(7) Yet most foreign apparel workers make only 10-25% of this hourly wage, so US plants cannot compete solely on the basis of labor cost. Because US workers are not necessarily forced to compete with foreign workers, only about 50% of the US apparel market has been lost to foreign producers.

The salient characteristic of the American apparel market in the last decade was *diversity*. Styles changed as often as six times per year.(8) In addition, within each major clothing group there is now a very wide range of fabric types, textures, and colors. Formerly plain garments are being individualized with screen printing, embroidery, appliques, sequins, fancy buttons, and other add-ons. Major consequences of this revolution in clothing styles are much shorter production runs and style life-cycles. Also, sewing tasks tend to be more complex.

Due to the ability of American producers to adapt quickly to change, these circumstances favor them over foreign producers. This answer of the domestic US apparel producers to low-cost

Table III. Characterization of Quick Response

- | |
|--|
| <ul style="list-style-type: none"> • Delay of orders to reflect latest consumer preference • Fast response to production orders • Economical production of small lots • Greater flexibility in product type, style, and fabric • Minimum in-process inventory (WIP) • Improved quality assurance (Q/A) |
|--|

foreign competition is known as quick response (QR). This technique recognizes and seeks to satisfy the needs of the volatile, diverse apparel market (see Table III).(9,10,11)

The UAH technology-transfer team sought solutions to the industry-wide problem of meeting QR requirements. One of these solutions was our promotion of a more effective basic-production system called modular manufacturing (MM). This innovation is a partial solution to the general shortage of skilled operators and the high turnover and absenteeism rates.

DEVELOPING CLIENTELE

It might be assumed that when the state announced the availability of free technical and business assistance to a hard-pressed industry with over 500 member firms, developing a sizable clientele would be no problem. This assumption is incorrect because:

- Much of the industry consists of small, independent, family-owned firms.
- Small Alabama businesses tend to distrust governmental organizations.
- Many firms do not believe in intra-industry cooperation.
- Apparel contracting is highly competitive.
- Most firms do not belong to trade associations.

Expanding the Survey Base

As indicated earlier, we got a positive response to our industry survey from about 40 apparel-producing firms. It was decided to arrange plant visits to all of these firms and almost all of the visits were accomplished within the first contract year. The authors learned much about the problems of the industry and also how individual plants operated. We also

encountered some useful solutions to common problems. In some cases, the plant managers referred us to other firms with which they had good relations. This allowed us to expand the original survey base. Also useful were referrals by colleagues in the state-university system. These researchers had their own list of favorite firms in the industry.

Attending Industry Meetings

Although apparel firms are not major joiners of apparel-manufacturing associations, many attend industry meetings such as the annual Bobbin Show in Atlanta each September. We attended this show in 1989, 1990, and 1991, and met more firm owners or managers at each visit. We also attended special technical seminars co-sponsored by Georgia Tech. Through these meetings, we came to know many of the key players in the industry, including consultants, academics, and the trade media. These contacts have proven quite useful in several aspects of the state technology-transfer contract.

APPROACH TO TECHNOLOGY TRANSFER

An eight-phase approach (Figure 1) has been defined for transferring technology to the apparel-manufacturing industry in Alabama. The specific tasks associated with each phase are outlined in Figure 1. It should be noted that not all technology-transfer projects have eight phases or follow the same sequence of phases. For example, many projects never go beyond the site visit, Phase IV. On the other hand, many projects combine Phase IV with the on-site seminar, Phase V, and then proceed with a technical-assistance project, Phase VIII. Some technical-assistance projects begin when one client reads a Fact Sheet about another client and therefore start with Phase VIII. The following are ways of working through some of the phases:

Fact Sheets

Fact Sheets are an excellent medium to keep in contact with clients. They are used to:

- Publicize seminars, workshops, and trade shows.

- Introduce new technologies such as modular-manufacturing systems, quality-improvement tools, and use of computer simulation.
- Summarize results of technical-assistance projects with clients.

An average of two Fact Sheets are mailed to over 120 clients monthly.

Alabama Apparel Producers Directory

Early in the program it became obvious that apparel firms, especially small and medium-size ones, did not communicate with each other. As a result, it was not uncommon for a firm to go out of state to locate a contractor when a firm in the same county was lacking work. To alleviate this problem, the Alabama Apparel Producers Directory was established, and currently lists 88 firms with excess capacity. It is updated annually and distributed at the Alabama booth at the Bobbin Show. The directory also is advertised in several trade publications.

Seminars

After we surveyed the industry and made numerous site visits, it became apparent that many firms had similar problems. As a result, the following seminars were developed:

- Modern apparel-manufacturing systems with emphasis on modular manufacturing.
- Pre-employment screening concepts.
- Computer simulation as a tool for designing and evaluating manufacturing systems.
- Human-resource management.

An average of eight seminars are conducted annually. Many seminars are held at a centrally located apparel firm. Also, a number of seminars are given only for employees of selected firms.

Since the project team did not have expertise on all these subjects, agreements were made with several consulting firms to assist in presenting the seminars. As an incentive, the consultants were made aware of the apparel firm's needs and

ould respond to them.

Publication in Trade Journals

An interesting finding was that most of the apparel clientele read the trade journals. Therefore, the project team published articles in four journals between April 1990 and January 1992 (12,13,14,15) This effort greatly improved the credibility of the team and aided in the acquisition of new industrial clients.

Technical-Assistance Projects

During the three years of the technology-transfer program, a total of 11 technical-assistance projects were conducted by the project team. A final report was prepared containing the results of each project.(16) The results of the projects were then summarized into a Fact Sheet and distributed to all clients in the database. Some of the projects were:

- Evaluation of proposed unit-production system (UPS)
Camptown Togs, Clanton, AL
- Design of modular-manufacturing system
Kappler USA, Guntersville, AL
- Evaluation of standup modular-manufacturing system
Lee Company, Bayou LaBatre, AL
- Design of a simulation-support environment for rapidly modeling manufacturing modules
Vanity Fair, Monroeville, AL
- Re-design of finishing workstation
Andover Togs, Scottsboro, AL
- Benchmarking a cut-and-sew firm
Florence Sportswear, Florence, AL

Four of the above technical-assistance projects consisted of developing simulation models of the firms' manufacturing processes. The models were developed using the conceptual framework

of the simulation-support environment and simulation macros presented in two NASA Tech Briefs. (17,18) Copies of the computer software for these Tech Briefs are available from the NASA Computer Software Management and Information Center (COSMIC) at the University of Georgia.

Using Tech Briefs as a foundation, we developed a general-purpose simulation system specifically for modeling apparel-manufacturing modules. This simulator allows an apparel firm to rapidly model a manufacturing module without writing a simulation model in a commercial language such as GPSS/PC, SIMAN, or WITNESS. Copies of the software and documentation are available at no cost to Alabama apparel firms. Regional seminars are held to train firms in the use of the simulator.

Figure 2 is a layout of a typical manufacturing module that was modeled with the apparel simulator. The module consists of 13 stations and five operators. All operators are cross-trained and can work at any station. To input this module into the simulator, the user must enter the number of stations, the number of operators, the number of machines at each station, and the cycle time for each station. The simulator then automatically constructs the simulation model. Finally the model is executed and animated on the computer screen, and statistical reports are generated.

Demonstrations

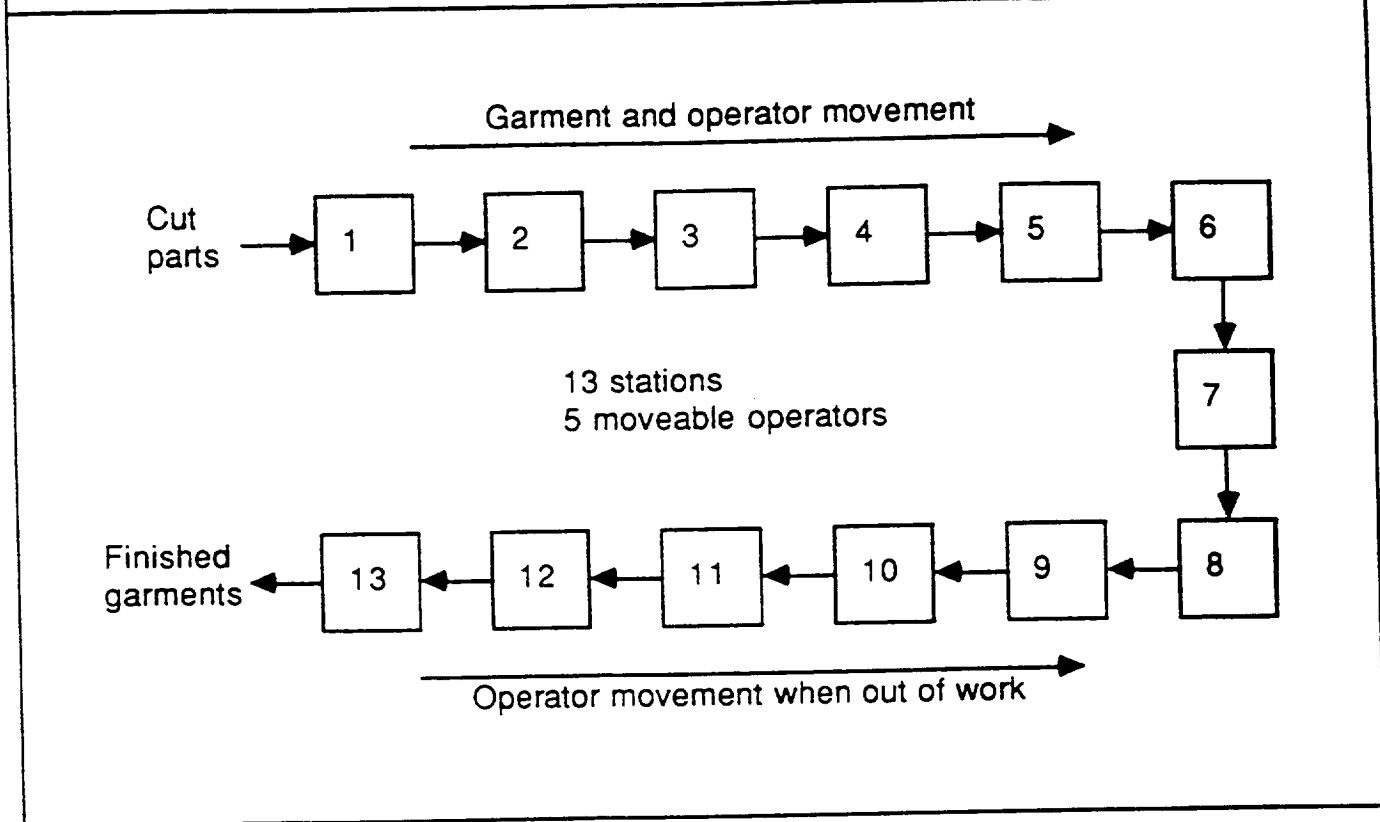
One of the most effective methods of technology transfer is demonstration. The project team took many firms (often at their request) to other firms in Alabama that had implemented a technology. One of the most requested demonstrations was the implementation of modular-manufacturing systems.

LESSONS LEARNED

After working with the apparel-manufacturing industry for three years, we have learned the following lessons:

- Technology-transfer processes can be slow, with months of little or no activity between many phases.

Figure 2 Typical Manufacturing Module Using the Apparel Simulator



- The team needs to be technically competent in order to establish credibility with clients.
- Publishing technology-transfer results in trade journals also enhances the team's credibility and at the same time is an excellent method of dissemination.
- It is often difficult to determine the success of technology transfer; the results of one transfer were uncovered six months later in a trade journal.
- The team needs to maintain continual contact with clients; one approach is through monthly Fact Sheets.
- The use of industrial consultants is an excellent approach in implementing a technical-assistance project.

CONCLUSIONS

The approach used to transfer technology to the apparel industry has proven successful and is applicable to other large, diverse industrial sectors, such as electronic manufacturing and

metal fabrication. These industries in Alabama, like apparel manufacturing, consist of many small firms in the 30-to-300-employee range. Similarly, smaller firms sell primarily to larger manufacturers, jobbers, or the federal government. Our survey of the metal-fabrication and electronic-manufacturing industries in Alabama is not complete. However, the initial results indicate that the use of the same technology-transfer approach is applicable.

Human nature is the same in all industries. Plant-management personnel are most impressed by technology-transfer agents who are willing to work with them personally, not just mail them third-party materials that were developed for another purpose. However, once a relationship has been established, certain technology-based materials developed for other purposes can be useful. Currently, upon request, useful consumer-oriented information is being provided to 10,000 Alabama apparel workers because their management thought that this would be a morale-building public service. This

situation shows that a technology-transfer program's success is dependent upon the ability to adapt quickly to the needs of its clientele.

The information being provided to the state apparel industry by the program varies from high-tech to low-tech to no-tech because the program continues to follow its state charter of supporting the industry with any and all types of information and assistance. The program is now serving 25% of the eligible firms in the state apparel industry. However, in terms of employees being served, that number has increased to about 50%. Yet in none of the three contract years have either of the two team members charged more than 70% of their time to the program.

In summary, we offer the following conclusions:

- The approach, or model, used to transfer technology to the apparel industry in Alabama should also apply to other industries. For example, the project team is currently applying this approach to the electronics-assembly/manufacturing industry and the metal-working industry in the state.
- The survey is an excellent method for initially identifying a cooperative subset of a targeted industry. Furthermore, this subset probably contains firms that are most interested in new technologies and receptive to change.
- It is important that a successful technology transfer is achieved early to give the program credibility and to expand the number of clients.
- The larger apparel firms have a much greater interest in new manufacturing technologies than smaller firms, since most of them have either engineering departments or technical staff responsible for evaluating new technologies.
- The Alabama booth at the annual Bobbin trade show in Atlanta is beneficial to the apparel firms that participated in the booth, and, more importantly, it reflects the state's support and commitment to the apparel industry. The

Alabama Apparel Producers Directory is distributed to manufacturers visiting the booth.

- The assistance requested by apparel firms required that the project team have a thorough understanding of various technologies. Much of the assistance could not have been provided without the engineering and manufacturing background and experience of the project team.

This project was funded in part by the Alabama Department of Economic and Community Affairs (ADECA), Alabama Industrial Development Training (AIDT), and the NASA Marshall Space Flight Center (MSCF).

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A Closer Look At Modular Manufacturing And Deming Management

By Bernard J. Schroer
M. Carl Ziemke

University of Alabama, Huntsville

Today, almost all U.S. managers have heard something about Dr. W. Edwards Deming and his unique approach to a theory of management for improving quality, productivity and a company's competitive position. This theory of management has been a major factor in the competitive advantage demonstrated by Japan over the United States in several key industries. The Deming concept is usually cited with respect to such high-tech industries as camera manufacturing, digital electronics production and the manufacturing of advanced automotive products, but often forgotten is the fact that textile and apparel manufacturing were among the first major industries revived in postwar Japan. These industries have benefited directly from the utilization of Deming's principles. One manifestation of these principles was the development of modular manufacturing in Japanese apparel production, as well as in other resurgent Japanese industrial sectors.

The Deming theory for management applies to small organizations as well as large companies and to the service sector as well as the industrial sector. Currently, Deming's principles are being studied for possible implementation in many of America's major manufacturing industries. Of special interest is the application of Deming's theory of management to the apparel industry. Interestingly, many of the concepts of modular manufacturing closely correspond to the Deming's theory of management.

As part of a contract with the state of Alabama that has been ongoing since March 1989, the authors engaged in the process of transferring information on modern management and technology to apparel manufacturers and contractors in

Alabama. During this period, 34 firms were visited, and managers from four firms employing modular manufacturing were met with while two of the plant sites were visited to analyze this process first-hand. These two firms were H.D. Lee in Bayou La Batre and Sandra Sportswear in Anniston, Ala. Consequently, the basic Deming principles can be compared with those of the modular manufacturing process. Given the impressive success of the many Japanese industries that have adopted the Deming principles, these similarities can be considered to be a strong recommendation for the adoption of modular manufacturing.

Deming's 14 points

Some of the reasons that have hindered the implementation of Deming's management principles:

- Short-sightedness in planning for the future;
- Failure to adequately evaluate external forces such as competition, shifts in markets and the introduction of new technologies;

- Focus on short-term profits;
- No consistent long-range focus that does not change over time; and
- Turnover of management.

Unfortunately, many persons who have heard of Deming's work are only aware of a few aspects such as statistical quality control and quality circles. Deming calls for an almost complete revision of management thinking and operations from top to bottom, as identified from Deming's 14 points (Figure 1).

The apparel manufacturing industry in the United States is generally managed along conservative and conventional lines. Therefore, Deming's 14 point approach for improving management may seem revolutionary in the context of apparel manufacturing. However, it is worthwhile to compare the Deming principles with the growing trend toward modular manufacturing of apparel.

Modular manufacturing

Modular manufacturing has been defined as a process rather than a prescribed set of rules of operation. The

The 14 Points Of The Deming Approach

1. Create constancy of purpose of improvement of product and service.
2. Adopt new philosophy.
3. Cease dependence on inspection to achieve quality.
4. End practice of awarding business on basis of price tag alone.
5. Improve constantly and forever every process for planning, production and service.
6. Institute training on the job.
7. Adopt and institute leadership.
8. Drive out fear.
9. Break down barriers between staff areas.
10. Eliminate slogans, exhortations, and targets for workforce.
11. Eliminate numerical quotas for workforce and numerical goals for management.
12. Remove barriers that rob people of pride of workmanship. Eliminate annual rating or merit system.
13. Institute a vigorous program of education and self-improvement for everyone.
14. Put everybody in company to work to accomplish transformation.

Figure 1

American Apparel Manufacturers Association (AAMA) has defined modular manufacturing as "a contained, manageable work unit of five to 17 people performing a measurable task. The operators are interchangeable among tasks within the group to the extent practical, and incentive compensation is based upon the team's output of first quality products."

The modular approach is rather new to U.S. apparel production, although it

has been in use in Japan's apparel industry for decades, as well as in Sweden, where it is principally applied to automobile assembly. Like the Deming approach, modular manufacturing represents a major break with conventional authoritative top-down management as exemplified by Douglas McGregor's Theory X management style. McGregor also described a Theory Y style of management in which management's interaction is more consultative and worker participation is en-

Principles Of Modular Manufacturing

- Production employees are formed into well integrated work groups of 5-30 persons.
- Modular groups choose a natural leader who is their principal interface with next level of supervision.
- Modular groups are given considerable latitude in performing specific work tasks and in machine and work assignments.
- Most inspections are done within modular group which corrects most sewing errors.
- Groups have weekly meetings on company time and have access to top management when required.
- Modular group is paid fixed salary, sometimes augmented by production bonuses.
- Group members are credited only with defect-free production.
- In general groups are configured to complete specific type of garment.

Figure 2

couraged. One positive result of this approach is job enrichment or improved quality of work life. These concepts undergird the specifics of modular manufacturing (Figure 2).

A number of apparel firms have implemented or are experimenting with modular manufacturing. A recent article in *Apparel Industry* magazine described the experiences of five companies with modular manufacturing: Lee Apparel Co., The Arrow Co., Jaymar-Ruby Group.

Operational Characteristics

- All work is done in lots of 36 garments.
- If an operator has started a lot, she is not interrupted until lot is finished. The exception to this rule is for operators 8, 10 and 14. These operators, who are assigned to assembly operations may interrupt lot being worked on, prior to completion. These three operators are also capable of performing subassembly, or part operations, as those parts are required. Parts operations however, will not be interrupted until completion. When parts lot is completed, the operator will return to complete interrupted assembly operation.
- Two utility operators can perform any operations 2, 3, 9, 11, 12 or 13. However, cycle time to perform these operations is 80 percent of standard.
- Module makes only one garment type.
- All operators at a station can perform task at same cycle times, with exception of utility operators.
- If an operator has to select between two stations, she will select station that has most completed lot waiting in buffer. This is lot that has completed most operations.
- First portion of operation 14, attach leather patch, is done in lots of 36, before lot is trimmed, which is the second opinion of operation 14. Consequently, if operator 19 at operation 15 is out of work, she will assist in second opinion of operation 14 and complete lot. After lot has been completed, operator 19 will then perform operation 15 on lot.
- Operators 2 and 22 only work four hours a day.
- Operator 20 at operation 16 will also assist at operation 17 by completing another lot, when buffer at operation 18 is empty and buffer at operation 17 is not empty.
- Buffer space exists between each operation.

Figure 3

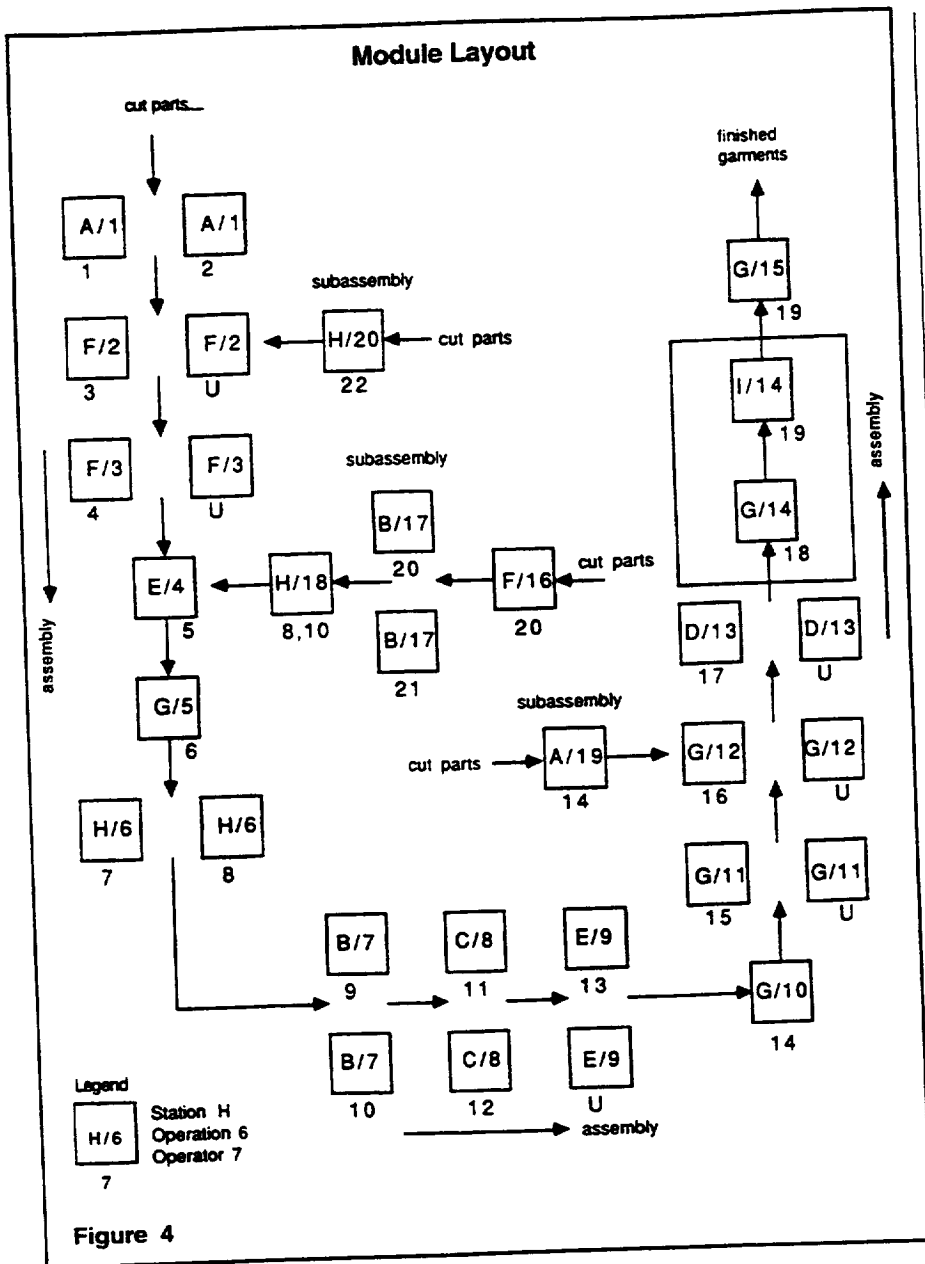


Figure 4

Woolrich and Jostens Graduation.

Figure 4 is a schematic of one of the modular manufacturing modules at the H.D. Lee plant in Bayou La Batre, Ala. The module consists of 22 standard operators, two utility operators, 26 assembly stations and six subassembly stations. The plant manufactures denim jeans and has been operating four modules since 1986, with each module averaging 1,100 pairs of jeans a day. To fully explain the actual operation of the module and to observe the influences of modular manufacturing within the module, a list of operational characteristics is also given in Figure 3.

A photograph (page 58) of the H.D. Lee plant that still operates using the standard progressive bundle method of apparel manufacturing. Operators are at every machine, with the machines arranged in a line with large amounts of partially sewn garments accumulating between the machines. Contrast this

method of manufacturing with the modular manufacturing at the H.D. Lee plant. This module features spare machines and a minimum accumulation of work in progress. (See page 58.)

Deming vs. Modular Mfg.

Despite the wide application of Deming's principles within several major Japanese manufacturing industries, he does not limit the use of his concept to manufacturing alone, much less modular manufacturing. Nevertheless, when Figures 1 and 2 are compared, some striking points of similarity are seen. In the company training sessions that are almost always required to form a new modular manufacturing work group, virtually all of the Deming 14 points with the exception of 4, 9 and 10, are covered in some form. Also, a major feature of the weekly meetings of the modular manufacturing groups is quality improvement. Thus, these

ORIGINAL FACE IS
OF POOR QUALITY



Progressive bundle method of apparel manufacturing



Modular method of apparel manufacturing

groups can be said to comprise quality circles.

In a recent article, M. Fralix stated that a shrinking, more highly educated labor force and demographic changes, such as an aging population, coupled with changing customer needs and the world economy necessitate changes in the apparel industry. This statement directly addresses Deming's point 2.

Point 4 is not normally a matter of module group discussion. However, many apparel manufacturers are awarding contracts to fabric suppliers based on quality rather than price. With respect to point 9, institution of modular manufacturing has not necessarily resulted in the breakdown of barriers between staff areas, although the Deming concept of total

work force commitment to plant performance is very beneficial. As for point 10, some plants have found it desirable to constantly post updated modular manufacturing group performance records as useful information to the work group. However, rarely do specific goals or targets accompany these figures.

It is interesting to consider Deming's point 3 in the context of modular manufacturing. To cease dependence on inspection to achieve quality does not mean abandonment of 100 percent final inspection. Under conventional apparel production, formal inspection is done by persons other than production workers and often occurs days or even weeks after the garment was sewn. Given that there is about 15 percent error rate in garment produc-

tion, it is obvious that a sizeable portion of these defective garments must inevitably slip by 100 percent final inspection. The Deming philosophy is to strive to eliminate errors in the first place. The modular manufacturing system does this by making module members primarily responsible for error detection and correction. For example, an error due primarily to machine adjustment is caught quickly and the problem is promptly corrected. At H.D. Lee, the modular manufacturing approach reduced initial garment defects from 15 to three percent. Thus, in some cases, the output of modular manufacturing groups may receive only audit type inspection.

In an apparel module, the group generally selects its own leader. Also, many modules set their own hours, keep their own time cards, approve leave and even select who should be laid off. Is this not adopting a new philosophy and driving out fear (Deming's points 2 and 8)? As a result, apparel firms that have implemented modular manufacturing have reported significant reductions in employee turnover and absenteeism. For example, the annual employee turnover at H.D. Lee was reduced from 20 to 11 percent. An even greater reduction in absenteeism was observed at H.D. Lee.

As indicated by Figure 2, the overall efficiency of a module should continually increase (Deming's point 5). This is true because it is in the best interest of the employee in the module to improve the process, increase production and improve quality. The resulting benefits to the employees are a shorter work week, a higher hourly rate, and more job satisfaction. In addition, work in process (WIP) is greatly reduced. For example, at H.D. Lee, WIP was reduced from a period of one week to one day.

Modular manufacturing requires extensive and continuous employee training, which is consistent with Deming's points 6 and 13. Employees in a module must be cross trained on multiple machines. For a module to function, employees must be trained in communication skills and the module leader must have some basic management skills. This necessary training also points to several negatives for modular manufacturing. First, multiple backup machines are needed in a module, and, second, employee training is expensive.

Conclusions

In summary, it has been shown that the specific practices within modular manufacturing in apparel production are generally supported by Deming's management principles and vice versa. This

fact is certainly a boost for the choice of modular manufacturing over the other methods available to apparel production. Whereas wholesale adoption of Deming's 14 points for the modular groups has been accepted by numerous firms and appears to be successful, the same cannot yet be said of operations within company management. At these levels, it is a major deviation from long established policy to eliminate numerical goals and thus the annual rating or merit system (Deming's points 11 and 12). In this investigation of the adoption of modular manufacturing in apparel manufacturing, the adoption of these points at the management compensation level have yet to be seen. However, recent U.S. studies have shown that a combination of numerical goals and incentive studies has often proven to be counterproductive, just as Deming has claimed. In Japan, company loyalty is much more a matter of tradition and pride than is currently the case in the United States, where few executives lose face by changing employers.

A final confirmation of the basic validity of many of the features of both the Deming principles and modular manufacturing is resident in the work of many U.S. management theorists such as Douglas McGregor. Since the end of World War II, these theorists have pointed out the need to abandon the strictly authoritarian management styles prevalent in U.S. manufacturing industries and instead adopt practices that cause workers at all levels to internalize company goals and objectives. One aspect of this approach is job enrichment, which often takes the form of providing the production worker with greater control over the work and also with the opportunity for a change in work assignments to avoid boredom. Interestingly, this last work aspect has been suggested as a means to help avoid the damaging effects of carpal tunnel syndrome. Possibly the two features of the Deming concept most emphasized in modular manufacturing are job enrichment and quality assurance.

When modular manufacturing is compared with its chief rival — unit production systems — for quick response, modular manufacturing has a definite advantage in the area of job enrichment, which is inherent in several of Deming's 14 points. Thus, it can be said that modular manufacturing is supported both by Deming's principles and the basic philosophies of many other leading experts in management.

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Bernard J. Schroer is director of the Johnson Research Center and a professor in the Department of Industrial and Systems Engineering at the University of Alabama in Huntsville. He has a Ph.D. in industrial engineering from Oklahoma State University and is a registered professional engineer. Dr. Schroer is a fellow of IIE and a member of SME/RE, SCS, AAI, NSPE, and Sigma Xi. **M. Carl Ziemke** is a research scientist in the College of Administrative Science at the University of Alabama in Huntsville. He had 30 years of experience in high technology industries before joining the university. Mr Ziemke has published extensively in high technology management, technology transfer and robotics applications. He has a B.S. in mechanical engineering and a M.S. in administrative science and is a registered professional engineer.

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Manufacturing's New Crystal Ball

Using simulation can provide inexpensive insurance against costly mistakes.

by Bernard Schroer

THERE IS increasing interest in using computer simulation for modeling modern apparel manufacturing systems. Because simulation can increase productivity, improve quality and, at the same time, reduce costs, it is a technology that can improve an apparel company's competitive edge, not only in domestic markets, but also in international ones.

Computer simulation facili-

tates rapid evaluation of various manufacturing alternatives and strategies. It allows for studying these alternatives and strategies in a controlled environment by varying only selected parameters. Furthermore, simulation is becoming widely accepted by management as inexpensive insurance against costly mistakes. In the apparel industry, there is a continual effort to improve the process, minimize system vari-

ability, improve quality and reduce cost. Simulation provides an approach to support this effort.

What is Computer Simulation?

Simulation can be defined as studying essence without reality. It consists of developing a representation (or model) of a real-world process or system, and then experimenting with the model to study the operation of the system over time.

Models of very simple systems often can be solved mathematically. However, most models of complex,

real-world systems cannot, and instead must be solved using simulation. In these instances, a computer model of the system is developed. The computer model is generally written or programmed using commercially available simulation software that runs on a personal computer (PC).

With simulation, it is possible to manipulate the model rather than the real-world system. In an apparel environment, such real-world manipulation is often too expensive and impractical, opening opportunity for the use of simulation.

The following outlines uses for simulation in a manufacturing environment:

- ▼ understanding the operational behavior of a system;
- ▼ conceptualization of various system configurations and the comparison of these configurations or alternatives with the existing real-world system;
- ▼ analyzing the behavior of the real-world system in a controlled environment by selectively varying parameters;
- ▼ predicting the impact of various changes to the system; and
- ▼ studying various proposals during the system design stage, before actually purchasing equipment or starting construction.

Steps in Using Simulation

Figure 1 outlines the steps in a computer simulation. First, the user must define the manufacturing system (problem). Quite often, this first step is the most difficult, but the most beneficial to management.

Next, the user develops a model of the manufacturing system. For example, the model can be in the form of one of the following: a process flow diagram of garments within the manufacturing system, the steps in sewing a garment, the processing of an order through various departments or the operations in the cutting room. During this second step, the user also begins col-

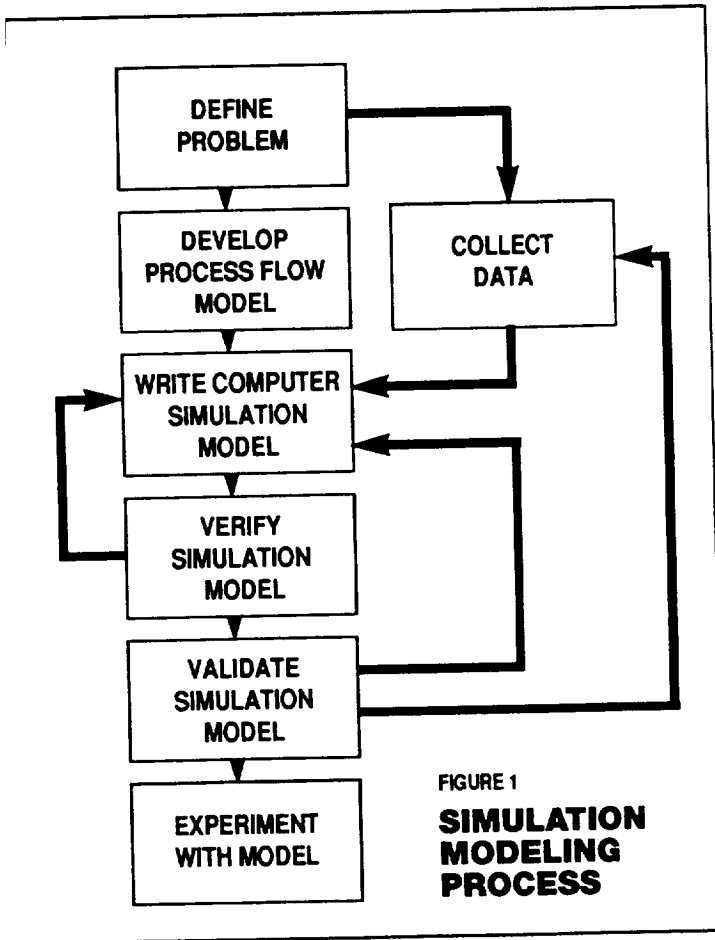


FIGURE 1
SIMULATION MODELING PROCESS

TABLE 1

ADVANTAGES AND DISADVANTAGES OF SIMULATION SOFTWARE

SOFTWARE CATEGORY	ADVANTAGES	DISADVANTAGES
General Purpose Simulation Languages	<ul style="list-style-type: none"> ▼Ability to model in detail complex system characteristics ▼Good set of diagnostics 	<ul style="list-style-type: none"> ▼Thorough knowledge of simulation language required ▼Long time needed to write and debug model ▼Generally, user must program animation
Simulators	<ul style="list-style-type: none"> ▼Easy to use ▼Reduced development time ▼Minimum user training ▼Increased productivity ▼Built-in animation 	<ul style="list-style-type: none"> ▼Domain specific ▼User may not be able to model unique system characteristics ▼Requires large PCs
Front-Ends	<ul style="list-style-type: none"> ▼Easy to use ▼Reduced development time ▼Rapid prototyping ▼Includes custom statistical reports ▼Reduces knowledge of simulation language ▼Continuous documentation ▼Increases user's productivity 	<ul style="list-style-type: none"> ▼Very domain specific ▼User may not be able to model unique system characteristics

ecting the necessary data for the model. Typical examples of the data needed for a simulation model of an apparel system are process times, distribution types, bundle sizes, number of operators, number and types of machines, operator efficiencies and operator movement rules between stations.

The third step is to develop a computer simulation model of the manufacturing process. The simulation model is generally written using commercially available simulation software. Most commonly used simulation software has been ported to PCs. Moreover, much of the software has elaborate graphics and animation capabilities.

The fourth step is to verify that the simulation model, or code, is correct. A number of techniques exist for verifying codes, such as running the model with no distributions, running only one transac-

tion through the model and testing each logic branch separately.

It is then necessary to validate that the model does in fact accurately represent the real-world problem, or manufacturing system. For example, the model outputs, such as daily production, work-in-process and operator utilization, are compared with the actual system. The last step is experimentation with the model. Here, various system alternatives can be simulated and compared to the baseline run.

Simulation Software

Simulation software can be divided into three categories: general purpose simulation languages, simulators and front-ends.

General purpose simulation languages are

very similar to conventional programming languages. A user writes a model using the statements, or blocks, of the simulation language. Several common simulation languages are GPSS/PC, SLAM, SIMAN and SIMSCRIPT.

A simulator is a computer system that permits a user to model a specific class of problems with almost no programming. An example of a simulator is WITNESS, a visual, interactive tool designed specifically for manufacturing problems. With WITNESS, the user does not have to program in a language. Instead, the modeling process is object oriented and consists of the following phases: define, detail and display.

In the define phase, the user creates and names each of the physical elements in the model. For example, some of the elements are machine and buffer. Associated with each element is a set of user defined attributes, or characteristics, which is entered in the detail phase. In the display phase, the user places each of the physical elements on the screen. WITNESS has a library of predefined icons for the physical elements, which can be modified or added to by the user. In the detail phase, the user responds to a series of questions for each physical element. Lastly, the model logic is defined in the form of IF-THEN-ELSE rules.

Front-ends are interface programs that operate between the user and a general purpose simulation language. Front-ends also have been developed for simulators. They are domain specific and generally consist of a user interface program and an automatic

code generator program. The user interface program assists the user in defining the problem through the development of a problem specification file. This file is then input to an automatic code generator program that creates the program

Simulation can be defined as studying essence without reality.

code in the target simulation language.

Currently, there are very few commercially available front-ends. [TC] has developed a front-end system for modeling modular apparel manufacturing systems. This front-end generates SIMAN simulation code. Other front-ends within the apparel domain include a modular manufacturing system with

all operators standing and a modular manufacturing system with operators sitting and standing. Both, which were developed by researchers at the University of Alabama in Huntsville, generate WITNESS simulation code.

Table 1 summarizes the advantages and disadvantages of each simulation software category. Simulation languages are still the most frequently used of the three categories. However, simulators are gaining acceptance because of their built-in graphics and animation features. Front-end systems are just beginning to gain acceptance and combine the features of both simulation languages and simulators.

Critical Issues

"A little knowledge is dangerous" is a true statement in simulation.

Computer simulation programs, while offering rapid evaluation of manufacturing alternatives, generate reams and reams of output. Without a thorough understanding of a simulation model's operation and its limitations, the user may draw erroneous conclusions or receive invalid results from the model.

Several critical simulation issues requiring observation by the user are:

- Model verification and validation;
- starting and stopping conditions;
- system steady state analysis; and
- output analysis.

An overview of these issues will assist you in developing a functional simulation model for use in an apparel

The utilization of a simulation model without a thorough understanding of its operation and limitations may yield invalid results and erroneous conclusions.

manufacturing environment.

Model Verification and Validation

One of the most important and difficult tasks in simulation is the verification and validation of the simulation model. Commonly addressed questions during verification are:

1. Is the model represented correctly in the simulation code?

2. Are the input parameters and logic structure of the model correctly represented in the simulation code?

Commonly used model verification methods include:

- Using the trace feature in the simulation software to trace a transaction through each model segment.
- Replacing all distributions with mean values only.
- Turning on the built-in animation features, which are valuable in observing abnormalities during model execution, such as large work-in-process (WIP) buildup, resources (i.e., machines and operators not being utilized) and transactions moving through various model segments.

● Running a single transaction through the model and observing its path, computing the time the transaction was in the system, and then comparing the results with the actual real world data.

Model validation consists of determining if the model is an accurate representation of the real world system. Validation is usually achieved through an interactive process of comparing the model's

behavior to the actual system's behavior. Typically, the validation process incorporates a series of discussions between the plant manager, manufacturing engineer and the model developer.

The result of each discussion provides greater insight into the actual operation of the system, a sharper definition of the system's operational characteristics and a model that closely represents the actual system.

Commonly used model validation methods are as follows:

● Remove all model variation; replace with mean values; run a transaction through the model; and compare transaction time in the system with actual data.

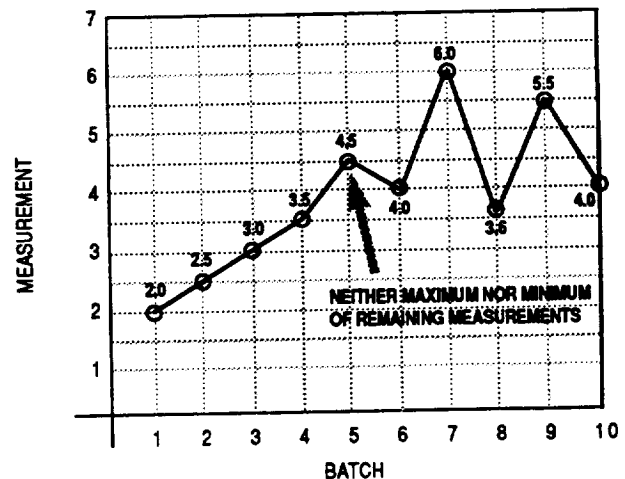
● Sit down with the plant manager and manufacturing engineer and run the model with the animation features on. Often, plant personnel notice abnormalities in the model execution not apparent to the modeler.

Starting and Stopping Conditions

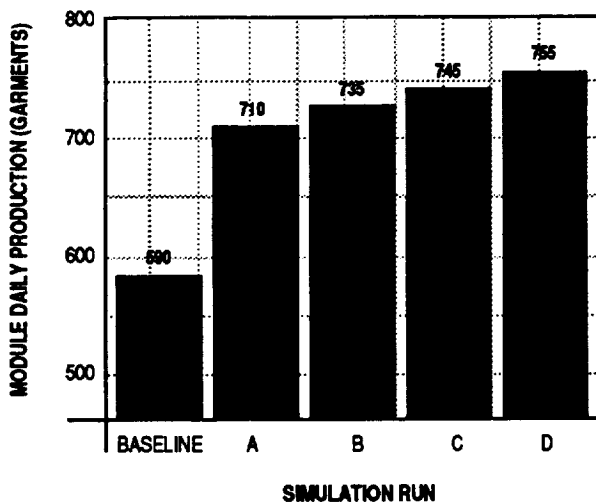
The time required to obtain the probability distribution depends on the system's starting conditions. Three approaches used in starting a simulation model are:

- Start the system empty and idle;

FIGURE 2
EXAMPLE OF CONWAY RULE
FOR DETERMINING EQUILIBRIUM



**FIGURE 3
PRODUCTION FOR VARIOUS SIMULATION RUNS**



- Set the starting conditions as close to steady state mode as possible; and

- Set the starting conditions as close to the steady state mean as possible.

The first approach is most commonly used in apparel manufacturing systems because of its simplicity. Using this method, all queues (buffers) start empty and facilities (machines) start idle. A simulation can be terminated by stopping the creation of new events and then allowing the system to return to an empty and idle state. It is important to note that including the measurements collected after terminating new events also introduces a bias which can be serious, especially if the total run time is short.

Two approaches commonly used in apparel manufacturing models to determine stopping conditions are to stop the system after a given amount of production and to stop the system after a given time (i.e., after an eight-hour shift). By using either of these approaches, no limit is placed on the number of transactions, or garments, entering the system. Therefore, at the completion of the simulation, garments are still in the system and machines are still being utilized.

determining equilibrium in apparel manufacturing systems is to execute the model for a long enough period of time to ensure the system's performance does not depend on the starting condition of the model. This is often done when the model and running times are both small.

However, in most situations, the error resulting from the initial conditions must be taken into consideration. Several approaches have been studied to determine the truncation point beyond which the system is in steady state and statistical data can be collected, including time series analysis, queuing theory models and heuristic rules of thumb.

The results from time series analysis and queuing theory are rigorous and precise; however, the results have rather limited applicability. On the other hand, many of the heuristic rules

System Steady State Analysis

Generally, there is no single point during the execution of the simulation model beyond which the system is in steady state (i.e., equilibrium). Therefore, there is a problem in finding the point beyond which the modeler is willing to neglect the error made by considering the system in equilibrium.

One common approach in determining equilibrium in apparel manufacturing systems is to execute the model for a long enough period of time to ensure the system's performance does not depend on the starting condition of the model. This is often done when the model and running times are both small.

have much broader applicability, but are not precisely mathematically formulated. Several heuristic rules to estimate system steady state are as follows: Conway rule; modified Conway rule; crossing of the mean rule; cumulative means rule; and deletion rule.

Here, we briefly will look at the Conway rule. It consists of ignoring all observations of a response variable until the first observation is neither the maximum nor the minimum of the remaining observations.

For example, Figure 2 is a plot of 10 batch means with each batch having a sample size of 25 observations. These batches are obtained by running the simulation model for a time period sufficient to complete 25 garments for each batch. The response variable, such as production per hour, is then measured. The model continues to run, and the response variable is measured after the completion of each set of 25 garments. Applying the Conway rule, the fifth batch mean is neither the maximum nor the minimum of the remaining five means. Therefore, it is assumed that the system required four batches, or 100 observations, to reach steady state.

Output Analysis

There are several commonly used techniques to analyze the output from

**FIGURE 4
AVERAGE WIP FOR VARIOUS SIMULATION RUNS**

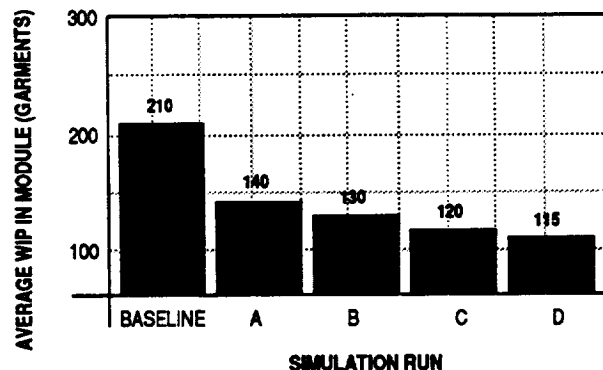
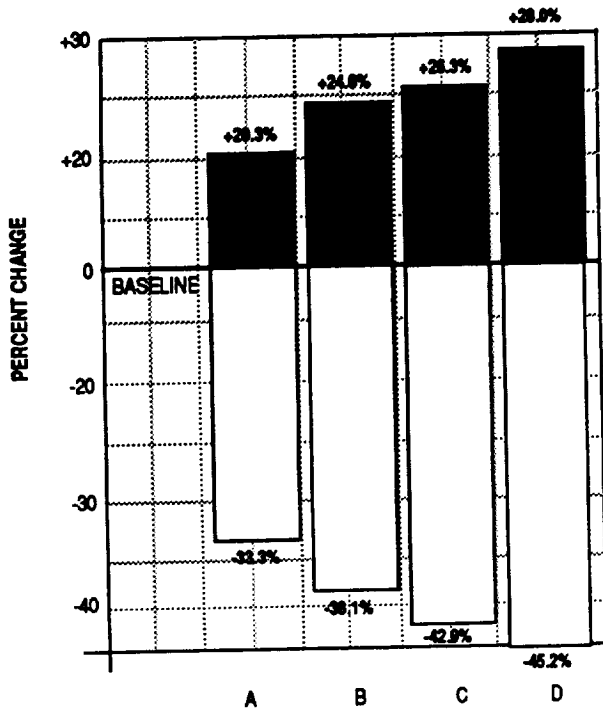


FIGURE 5
PERCENT CHANGE IN PRODUCTION
AND AVERAGE WIP



The baseline statistics can also identify low operator and machine utilizations, excessive WIP, low daily production and system bottlenecks.

Graphical Analysis

An analysis of the statistics from the baseline run should result in the identification of several parameters that could be changed in further simulation runs. One approach in evaluating the effect of these parameters on the system is to only vary one parameter at a time, and then compare the system's results as a function of this parameter.

For example, Figure 3 gives the simulation results for the

simulation. The first run of the simulation model is to validate that the model approximates the real world system as closely as possible. This simulation run is often called the baseline run. This baseline run gives output statistics such as: machine utilization, operator utilization, work-in-process (WIP) in front of various stations, production, production per operator and the time a garment is in the system. These baseline statistics often identify potential abnormalities or problems in the system. For example, at the end of a simulation, if the WIP in front of a station is also the maximum WIP during the simulation, then the system is probably unstable. That is, the queue length is continually increasing and the queue is approaching an infinite queue. As a result, other parameters will also continually increase, such as the time in the system or the time to produce a garment.

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increased production 24.6% over the baseline. On the other hand, alternative A decreased WIP 33.3% and alternative B decreased WIP 38.1%.

Alternatives C and D also show an increase in production and a decrease in WIP. However, these changes are not as great relatively when compared to alternative B. On the other hand, alternative B shows a much greater percent change compared to the baseline run.

In summary, additional analysis should be made of alternative A concerning its impact on the system, the requirements to implement this alternative and its cost effectiveness.

Statistical Analysis

Machine (or operator) utilization and production rates are two standard simulation outputs. The question with regard to these results is: "What confidence do we have in these simulation results?" In other words, what is the confidence interval for machine utilization and production rate?

Additional accuracy can be achieved by increasing the run length of each replication or the number of replications. For example, doubling the accuracy requires quadrupling the sample size or number of replications. An often overlooked question is how large of a sample is needed to have some level of confidence in the simulation statistics.

For instance, assume you intend to estimate the average daily production to plus or minus five garments per day with a 95% level of confidence. How large of a sample or number of replications is needed to satisfy this requirement? Standard statistical techniques can provide the answers to these questions. And while statistics is too broad a topic to discuss here, other resources, such as *Discrete Event System Simulation*, a book by Banks and Carson, can be valuable tools in furthering your efforts to achieve reliable results.

Analysis of a Model

Simulation models provide the apparel industry a method of evaluating today's complex manufacturing alternatives, such as unit production systems and

modules.

Once equipped with a good understanding of simulation software and its capabilities, you are ready to undertake the design of a computer model for the apparel manufacturing environment. But before you make the decision to pursue simulation, the examination of an apparel manufacturing simulation model will help you better understand what is involved. A model using GPSS/PC simulation language is used herein to illustrate the development process.

Figure 6 is a process flow diagram of a modular manufacturing system. The operational characteristics of the hypothetical module are as follows:

- ◆ Seven machines and seven operators with an operator fixed at each machine.
- ◆ All work is done in lots of 12 garments.
- ◆ Operator efficiency is 100%.
- ◆ Unlimited space is available in front of each machine for work-in-process.
- ◆ There is no machine breakdown.
- ◆ An unlimited amount of cut parts is available in front of machine one.
- ◆ Cycle times are normally distributed with the standard deviation equal to 10% of the means.

Figure 7 is a listing of the GPSS/PC model for the apparel module in Figure 3. The simulation model is started in the empty and idle states. That is, all buffers are empty and all machines idle at simulation time 0.0. The model is run for a simulated time of 800 seconds to reach steady state. The statistical outputs are then reset and the model continues to run for an additional 4,000 seconds.

The machines in Figure 7 are labeled STA1, STA2A... STA4, and the queues, or buffers, before each station are labeled similarly STA1, STA2, STA3 and STA4.

Blocks 80-110 of the model allow a part to enter the module whenever the queue STA1 before station STA1 is empty. Block 110 will split a duplicate transaction and send it to the queue block labeled BEGIN when the logic switch, SWITCH1, is reset at block 180. With this logic, there are always cut parts in the first buffer waiting to enter

the module. The simulation of many parts at each station is modeled by the following GPSS/PC blocks: QUEUE, SEIZE, DEPART, ADVANCE and RELEASE.

The QUEUE and DEPART blocks collect the queue statistics, while the SEIZE and RELEASE blocks simulate a garment occupying a machine. The ADVANCE block indicates the amount of time to perform the operation on the garment.

For example, the GPSS/PC equation for the cycle time at station STA1 is:
 $V\$TIME1 = 20 + FN\$SNORM\#2$

This expression equates:

$$\text{cycle time at station STA1} = \text{mean of 20 seconds} + (z \text{ value from standard normal}$$

distribution \times standard deviation of 2 seconds)

The z value varies between -5.0 and +5.0 following the standard normal cumulative distribution given in block 10. For example, a random number of 0.5 will give a z value of 0.0. Therefore, the cycle time will be:

$$V\$TIME1 = 20 \text{ seconds} + (0.0 \times 2 \text{ seconds}) = 20 \text{ seconds}$$

The following GPSS/PC statements are used to execute the model:

◆ CLEAR; 580 ADVANCE 800; START 1, NP; RESET; 570 GENERATE ,,1; 580 ADVANCE 4000; START.

The first start is used to run the model for 800 seconds to reach equilibrium. The NP option in the first start state-

FIGURE 6
**SAMPLE APPAREL
 MANUFACTURING
 MODULE**

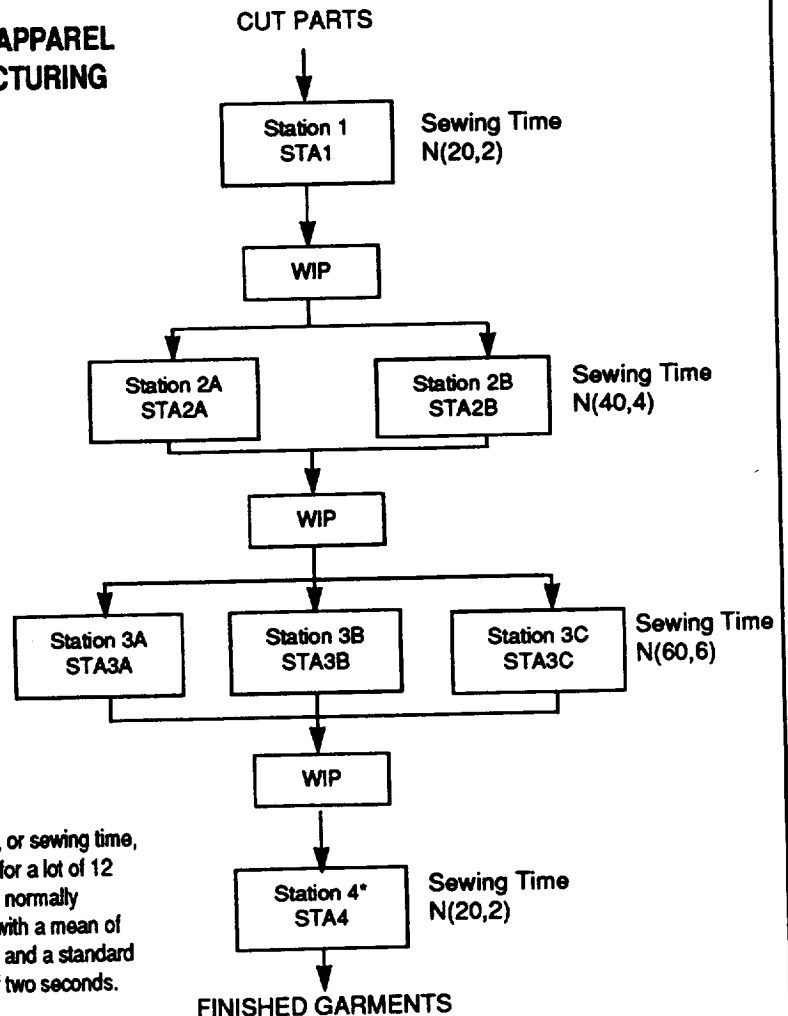


FIGURE 7
GPSS/PC Model for Sample Problem

```

10 SNORM      FUNCTION      RN1.C25
0, -.5/.00003, -.4/.00135, -.3/.00621, -.25/.02275, -.2
.06681, -.15/.11507, -.12/.15866, -.1/.21186, -.8/.27425, -.6
.34458, -.4/.42074, -.2/.50/.37926, .2/.65542, .4
.72575, .6/.78814, .8/.84134, .1/.88493, .12/.93319, .15
.97725, .2/.99379, .25/.99865, .3/.99997, .4/.15
20 *
30 TIME1      FVARIABLE      20+FNSSNORM#2
40 TIME2      FVARIABLE      40+FNSSNORM#4
50 TIME3      FVARIABLE      60+FNSSNORM#6
60 TIME4      FVARIABLE      20+FNSSNORM#2
70 *
start simulation with one garment always waiting to enter system

80
90 BACK1      GENERATE      ...1
100           GATE LR      SWITCH1
110           LOGIC S      SWITCH1
120           SPLIT      1, BACK1, BEGIN
130 *
140 BEGIN     QUEUE      STA1
150           SEIZE      STA1
160           DEPART     STA1
170           ADVANCE    VSTIME1
*
resetting SWITCH1 will cause another garment to seize station 1

180           LOGIC R      SWITCH1
190           RELEASE    STA1
200 *
210 QUEUE     SEIZE      STA2
220           TRANSFER   BOTH, NEXTA, NEXTB
230 NEXTA     SEIZE      STA2A
240           DEPART     STA2
250           ADVANCE    VSTIME2
260           RELEASE    STA2A
270           TRANSFER   .NEXTC
280 NEXTB     SEIZE      STA2B
290           DEPART     STA2
300           ADVANCE    VSTIME2
310           RELEASE    STA2B
320 NEXTC     QUEUE      STA3
330 *
340           SEIZE      STA3
350 NEXTD     TRANSFER   ALL,NEXTD,NEXTE,5
360           SEIZE      STA3
370           DEPART     STA3
380           ADVANCE    VSTIME3
390           RELEASE    STA3A
400 NEXTG     TRANSFER   .NEXTF
410           SEIZE      STA3B
420           DEPART     STA3
430           ADVANCE    VSTIME3
440           RELEASE    STA3B
450 NEXTE     TRANSFER   .NEXTF
460           SEIZE      STA3C
470           DEPART     STA3
480           ADVANCE    VSTIME3
490           RELEASE    STA3C
500 *
510 NEXTF     QUEUE      STA4
520           SEIZE      STA4
530           DEPART     STA4
540           ADVANCE    VSTIME4
550           RELEASE    STA4
560           TERMINATE
570 *
580 AA       GENERATE      ...1
590           ADVANCE    4,000
           TERMINATE    1

```

ment will suppress the printing of the statistical reports. The reset statement clears the statistics. The redefining of the generate block will cause another transaction to enter block 580 and the model to run for an additional 4,000 seconds.

onds. The last start statement will cause the model to stop at:

**time = 800 seconds +
4,000 seconds, or 4,800 seconds.**

Figures 8 and 9 contain the standard

GPSS blocks, facility and queue statistical reports. Station utilization varied from 93.7% for station four (STA4) to 100% for station one (STA1). Maximum buffer content reached five lots in the queue at station three (STA3), three lots for station two (STA2) and two lots for station four (STA4).

Because of the previously stated model design constraints, the maximum buffer was only one lot in the queue at STA1. Facility STA4 had 233 entries and had one lot, or transaction, at the facility when the model was terminated at time 4,800 seconds. Therefore, a total of 233 minus one, or 232 lots, was made during the simulation. The end time on the clock was 4,800 seconds. However, the system was run the first 800 seconds to reach equilibrium. The 232 lots were made in 4,800 seconds minus 800 seconds, or 4,000 seconds. This equates to an hourly production of 209 lots.

The average work-in-process in the module is given in column AVE.CONT in Figure 9. It is 1.19 lots plus 2.04 lots plus 0.49 lots, or 3.72 lots, in buffers STA2, STA3 and STA4. An additional seven lots are being worked on at the machines, giving an average total work-in-process in the module of 10.72 lots, or approximately 11 dozen garments.

Model output such as this is valuable in anticipating the efficiency of production lines, and computer simulation models similar to this example have been or are being used by a number of apparel manufacturing firms. For example, several recent apparel applications of simulation include:

- ◆ Evaluation of a stand-up modular manufacturing system at Lee Co., Bayou La Batre, AL (Software: WITNESS).

- ◆ Evaluation of a proposed unit production system at Camptown Togs Inc., Clanton, AL (Software: GPSS/PC).

- ◆ Design of a modular manufacturing system at Kappler USA Inc., Guntersville, AL (Software: WITNESS).

- ◆ Progressive bundle system simulation at Hart, Schaffner & Marx, Chicago, IL (Software: Front-End and SIMAN).

- ◆ Unit production system simulation at Sara Lee Knit Products (Software:

FIGURE 8
GPSS/PC Block Outputs

START_TIME	END_TIME	BLOCKS	FACILITIES	STORAGES	FREE_MEMORY
0	4800	46	7	0	174880
LINE	LOC	BLOCK_TYPE	ENTRY_COUNT	CURRENT_COUNT	RETR
80		GENERATE	1	0	0
90	BACK1	GATE	246	0	0
100	3	LOGIC	246	0	0
110	4	SPLIT	246	0	0
130	BEGIN	QUEUE	246	0	0
140	6	SEIZE	246	0	0
150	7	DEPART	246	0	0
160	8	ADVANCE	246	1	0
180	9	LOGIC	245	0	0
190	10	RELEASE	245	0	0
210	11	QUEUE	245	0	0
220	12	TRANSFER	245	3	0
230	NEXTA	SEIZE	122	0	0
240	14	DEPART	122	0	0
250	15	ADVANCE	122	1	0
260	16	RELEASE	121	0	0
270	17	TRANSFER	121	0	0
280	NEXTB	SEIZE	120	0	0
290	19	DEPART	120	0	0
300	20	ADVANCE	120	1	0
310	21	RELEASE	119	0	0
320	NEXTC	QUEUE	240	0	0
340	23	TRANSFER	240	3	0
350	NEXTD	SEIZE	80	0	0
360	25	DEPART	80	0	0
370	26	ADVANCE	80	1	0
380	27	RELEASE	79	0	0
390	28	TRANSFER	79	0	0
400	NEXTG	SEIZE	80	0	0
410	30	DEPART	80	0	0
420	31	ADVANCE	80	1	0
430	32	RELEASE	79	0	0
440	33	TRANSFER	79	0	0
450	NEXTE	SEIZE	77	0	0
460	35	DEPART	77	0	0
470	36	ADVANCE	77	1	0
480	37	RELEASE	76	0	0
500	NEXTF	QUEUE	234	1	0
510	39	SEIZE	233	0	0
520	40	DEPART	233	0	0
530	41	ADVANCE	233	1	0
540	42	RELEASE	232	0	0
550	43	TERMINATE	232	0	0
570	44	GENERATE	1	0	0
580	45	ADVANCE	1	0	0
590	46	TERMINATE	2	0	0

FIGURE 9
GPSS/PC Statistical Reports

FACILITY	ENTRIES	UTIL.	AVE_TIME	AVAILABLE	OWNER	PEND	INTER	RETRY	DELAY
STA1	246	1.000	19.51	1	248	0	0	0	0
STA2A	122	0.992	39.06	1	243	0	0	3	0
STA2B	120	0.981	39.26	1	244	0	0	3	0
STA3A	80	0.985	59.14	1	238	0	0	3	0
STA3B	90	0.979	58.77	1	239	0	0	3	0
STA3C	77	0.975	60.82	1	237	0	0	3	0
STA4	233	0.937	19.30	1	233	0	0	0	1

QUEUE	MAX	CONT.	ENTRIES	ENTRIES (0)	AVE.CONT.	AVE.TIME	AVE.(0)	RETRY
STA1	1	0	246	246	0.00	0.00	0.00	0
STA2	3	3	245	27	1.19	23.38	26.28	0
STA3	5	3	240	21	2.04	40.74	40.74	0
STA4	2	1	234	42	0.49	9.98	9.98	0

Front-End and SIMAN).

And while computer knowledge is required to program in general simulation languages, it does not mean the technology is out of reach for the average apparel manufacturer. **B**

Bernard J. Schroer is a professor in the Dept. of Industrial and Systems Engineering at the University of Alabama in Huntsville. He has a Ph.D. in Industrial Engineering from Oklahoma State University and is a registered professional engineer.

Schroer is co-author of a handbook on Modern Apparel Manufacturing Systems and Simulation which is available for purchase by calling the University of Alabama at Huntsville at 205-895-6243.

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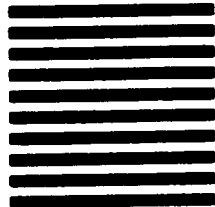
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