NISTIR 4786

Shop of the 90's
The Automation of Small Machine Shops Using Existing and Affordable Technology

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Chief, Fabrication Technology Division

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Technology Administration
National Institute of Standards and Technology
Manufacturing Engineering Laboratory
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EXECUTIVE SUMMARY

Today's competitive market forces are compelling reasons for small manufacturers to speed up their rate of automation. During the 1970's and 1980's small manufacturers were slow to automate and as a result their ability to compete in the market place steadily declined. The major thrust of the Shop of the 90's project is to reverse the negative trends (i.e., non-competitiveness and poor quality) which are eroding the basic fabric of our manufacturing infrastructure. The Shop of the 90's project has created a model from which we are developing information, recommendations, and procedures for increasing the productivity and competitiveness of small manufacturing firms. We have selected automation technology that is appropriate for small manufacturers. The appropriateness of this technology depends on: (1) affordability of the hardware and software, (2) the attitude of management and employees with respect to change, (3) the training of the employees, and (4) the ability and willingness to add in incremental and manageable modules. We address the affordability issue by advocating commercially available "off-the-shelf" PC based hardware and software technology. This type of hardware and software has a shorter training time and corresponding lower training cost.

Within the Shop of the 90's context we recognize any change that improves the monitoring and controlling of the manufacturing processes to produce a product that is economical and of consistent high quality as a positive step toward automation. For example, automation could be as simple as installing digital readouts on a manual machine tool, if the result of that installation leads to consistent high quality products. Another example is that a 1960 style job shop, with all manual machines, needs to create a new image, therefore they could retrofit their manual milling machine with a PC-based CNC controller at one-fifth the cost of a new CNC machine of similar capability. This type of automation not only allows the user to perform current jobs at a faster production rate and higher quality, but opens opportunities for new markets in which they could not compete before.

A modular approach consisting of upgrades, retrofits, and add-ons allows the small manufacturer to automate at a rate that is appropriate for a company's budget for purchasing new technology and providing employee training.

The Shop of the 90's project includes three major tasks: (1) evaluation of existing in-house equipment, (2) implementation of a PC-based shop network, and (3) employee training. Although all three of these tasks are very important, Task 1 is the most important area and should be conducted first; it is the easiest and can be handled by shop personnel. Tasks 2 and 3 may require expertise not found within the shop, therefore management should adequately budget for these tasks.

The Shop of the 90's project focuses on automation that improves the management and productivity of the shop. Both types of automation will decrease product cycle time and improve product quality. The potential improvements that are derived from both types of automation technology are significant and neither should be overlooked.

This report documents, in a chronological and anecdotal format, the Shop of the 90's project's experiences gained from the NIST main instrument shop in the Fabrication Technology Division and our beta site, the Ray V. Watson Company located in Baltimore, MD during the period of June 1988 to October 1991.

The Shop of the 90's project is dynamic. A future automation path is planned. The plan includes the following: (1) in-process gauging, (2) statistical feedback into the manufacturing process, (3) improved machine tool metrology information and a knowledge base for evaluating the performance of machine tools, and (4) better interfaces for exchanging information.

At various stages of automation the flow of information to small manufacturers is vital if these manufacturers are to be encouraged to follow a smooth and continuous progression toward automation. Therefore, this document lists federal and state organizations that can provide information to small manufacturers.

ACKNOWLEDGMENT

The author would like to acknowledge Denver Lovett, Mechanical Engineer, Manufacturing Engineering Laboratory, for his help in preparing this report. Mr. Lovett assisted with interviews, gathered information, and helped edit and review this report.

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I. INTRODUCTION

Automation is the means of controlling and improving a manufacturing process.

Automation does not necessarily mean robots, computers, or numerically controlled machining.

It does mean identifying, using, or creating the materials and solutions to produce a product that is of consistent high quality and employing production methods that are economical.

The National Institute of Standards and Technology (NIST), is well known for its research at the forefront of automation technology and is helping small shops deal with the automation techniques that exist today. The Shop of the 90's (SoN) is not the factory of the future, it's the factory of the here-and-now. The primary goal of the SoN project is to develop and transfer recommendations, information, and procedures for increasing the productivity and competitiveness of small machine shops in the United States (U. S.).

Studies conducted by the Department of Commerce (DoC) and the National Science Foundation (NSF) show that:

- Of the 150,000 metal fabrication facilities within the United States 85% are small machine shops, approximately 127,500 operations.
- These facilities employ 50 or fewer employees.
- They are producing parts in lot sizes of 50 or less.
- They account for approximately 75% of all United States metal fabrication.
- They are running substantially behind their overseas competitors in the use of modern technology.
- Their adoption of computerized automation is much too slow by today's business standards and needs.

The adoption of computerized automation is the key to restoring United States competitiveness in manufacturing but the rate of implementing automation to enhance quality and shorten product through put time has seriously lagged behind the availability of automation products that can help accomplish these results.

The DoC and NSF studies, along with studies conducted by the John F. Kennedy School of Government, have shown that:

- In Japan, approximately 30% of all machine tools are computer controlled.
- In the U. S., fewer than 11% are computer controlled.
- Sweden and Germany each have more computer controlled equipment than the U. S.
- In recent years 85% of the total investment in new equipment, of any type, occurred in 26% of all facilities.
- In firms with fewer than 50 employees the chances are less than 50-50 that management has installed any type of computer controlled equipment.
- The chances are 18 to 1 that you will find some form of computerized automation in plants with less than 500 employees which are part of a multi plant corporation.
- In non-automated facilities only 1 in 10 production managers plan to invest in new technology in the future.

The main reasons given by shop management for not investing in or using automation are:

- Insufficient payback on short runs of parts.
- Batches of parts are too small and too specialized.
- The short term return on investment is insufficient.

If modernization in small machine shops is too slow, the larger manufacturing firms run the risk of falling even further behind their competitors in Japan and Europe on quick response to market demands, cost savings, and quality improvements. Small firms that fail to carry out an effective automation program face a threat from both foreign and domestic companies. It can become a vicious cycle. As large firms lose out in world markets, the network of small supplier firms that depends on them will also suffer. Large firms are making some gains in implementing automation strategies but their supplier base of small machine shops is adopting automation at too slow a pace. Small shops that do not adopt new technology run the risk of losing out to foreign suppliers. If small machine shops do not have the capacity to turn out high quality parts, at lower costs with quick turn around times, large companies have no choice but to take their business elsewhere.

Keeping small machine shops in business and making them more productive is essential to a strong United States economy.

According to the DoC and NSF studies the small firms that have failed to adopt even one computer controlled machine employ approximately 22% of the work force. This equates to nearly 3.1 million jobs and covers 21 different types of industries.

For firms that continue this trend of making little or no effort to modernize their manufacturing technology the window of opportunity is closing fast. We could not only lose these jobs but many more.

There are wide variations in the effectiveness with which the new tools are integrated into and used within the manufacturing system. Lack of experience with new technology is a possible deterrent to adoption and further postpones potential gains from its use. Reliance on market forces and trends to stimulate and encourage the adoption of automation technology is inefficient, and, therefore, a policy to stimulate the use of this technology must be considered as a viable option.

What is needed to change this situation:

- A change in business strategy.
- A shift to making a more diverse mix of products in a broader range of batch sizes.
- A greater awareness of the available and reliable existing technology.

It is the mission of NIST to support United States industry. It is the mission of the Manufacturing Engineering Laboratory (MEL) to bring resources to bear on mechanical manufacturing industries. In pursuit of this MEL mission we established the SoN technology implementation program. This program focuses NIST resources on problems that are impeding the diffusion of automated technology to the small machine shop.

These problems are:

- A lack of the knowledge and capabilities that automation can provide.
- Apprehension about the implementation of automated equipment.
- Technology shock associated with the installation and use of automated equipment.

II. SHOP OF THE 90's - PHASE ONE - THE PROJECT

A. PROJECT GOAL

The goal of SoN is to develop and transfer recommendations, information, and procedures for increasing the productivity and competitiveness of small and medium sized machine shops within the United States.

What modern technology is affordable and useful to the small machine shop? How is it best introduced? What return on investment might be expected? To help answer these questions, NIST used its own machine shop to conduct an experiment in the practical implementation of these technologies to improve productivity and cost efficiency. These questions are addressed in this section.

B. THE FABRICATION TECHNOLOGY DIVISION'S MACHINE SHOP

NIST's Fabrication Technology Division (FTD) is a good example of a small machine shop. The division designs and manufactures specialized instruments and other equipment for NIST's laboratories. Other duties include tool and material inventory and management, cost estimating, and shop service billing. The workload is comparable to that of many small machine shops in high technology industries.

FTD employs 60 people within its main shop, on-site contact (satellite) shops, and office. The staff uses a wide variety of NC and manual machine tools of varying vintages.

FTD is supported in its main shop with:

- Numerical control machines (3 lathes and 7 mills).
- Manual machines (11 lathes and 8 mills).
- A grinding shop (8 grinders).
- An electrical discharge machining shop (2 ram and 1 wire).
- An inspection room.
- A welding/sheetmetal shop (1 NC punch press).

FTD has a complete tool crib and manages the Metal Storeroom for NIST. FTD has seven contact (satellite) shops, throughout NIST, to handle on-site manufacturing and repair. Equipment within these contact shops brings the total pieces of equipment within FTD to 256.

C. PROJECT DESCRIPTION

Beginning in July 1988, FTD implemented a project to modernize and improve its own operations, thus creating SoN.

To make the project applicable to small private sector machine shops advanced experimental hardware and software from NIST laboratories was not used. Only affordable, commercially available, off-the-shelf hardware and software were used. The software used in the project had to be easy to load and operate by trades and craft people. The cost of purchases and changes was justified by a reasonable return on investment.

For the small machine shops PC based systems seem to be the answer to high cost mainframe and engineering workstation based systems. There are drawbacks to these systems though. They are not efficient at number crunching complex programs and some of the programs they run are limited in their functionality. Even though there are drawbacks, PC based systems can perform the work required by the small shops within a reasonable amount of time and with a reasonable amount of accuracy to be effective, efficient, and economical.

The project was carried out by using NIST's FTD as a test bed.

This project was broken down into three tasks:

1) Evaluate all machine tools within FTD's Main Shop as to their condition and need for repair. Repair, replace, or surplus any machine tool as cost justification warrants.

2) Structure and set up a PC network that covered the Main Shop, Tool Crib, Inspection Room, Metal Storeroom, and the foremen's offices. This network included a Computer Aided Design (CAD) and Computer Aided Machining (CAM) system, a Computer Aided Cost Estimating (CACE) system, a Computer Aided Process Planning (CAPP) system, a tool room management system, and Distributed Numerical Control (DNC) system.

3) Train on new equipment and cross train on existing equipment. All equipment necessary to make FTD productive is of little or no use without the trained personnel to operate it properly (the same is true in the private sector). It was therefore necessary that shop personnel be trained on the hardware, software, and machine tools that were incorporated into SoN.

D. SPECIFICS OF THE PROJECT TASKS

1. TASK 1: EQUIPMENT EVALUATION

This task, though the most time consuming, was the most essential part of the project. Without knowing the condition of its equipment a shop will be unable to evaluate its existing and future workload capacity.

Once shop equipment is evaluated, a return on investment can be calculated to allow the shop owner to make repair or replace decisions on defective or outmoded equipment.

Following is a sample equipment evaluation form developed during the project. Even though the form seems simple, it contains all the information necessary to assist shop management in making sound decisions and calculating the return on investment on any piece of equipment within a shop.

Although the equipment evaluation was conducted on the 256 pieces of equipment within FTD the evaluation statistics are based on the 118 within the Main Shop.

We found that 30 pieces of equipment were listed in fair to poor condition (74.5% good to excellent and 25.5% fair to poor). The most common cause of the fair to poor rating was AGE and WEAR DUE TO USE.

To illustrate how to use this type of form refer to the following information:

- Blank Equipment Evaluation Form.

- Completed Equipment Evaluation Form.

  This form represents an actual evaluation of the NC machines in the Main Shop. It contains all necessary information and a completed return on investment calculation.

- Instructions on filling out the Equipment Evaluation Form.

EQUIPMENT EVALUATION FORM

GENERAL MACHINE INFORMATION:

MACHINE #____

MANUFACTURER____

MODEL #____

TYPE OF MACHINE [] MANUAL [] N/C

[] MILL [] LATHE [] GRINDER [] EDM

[] OTHER____________________________

YEAR OF MANUFACTURE (OR AGE)__________________

H.P. RATING__________________

WORK AREA X______________ [] IN. [] M.M.

Y______________

Z______________

A______________

B______________

C______________

W______________

MAX. WORK PIECE WEIGHT____________________LBS.

ESTIMATED USE THROUGHOUT THE YEAR (%)__________

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EQUIPMENT CONDITION INFORMATION:

CONDITION OF MACHINE [] EXCELLENT [] GOOD [] FAIR [] POOR

If FAIR or POOR explain.

If POOR should this machine be:

[] SURPLUSED [] REPAIRED []OTHER

If REPAIRED or OTHER explain.

WHAT TYPE OR CATEGORY OF JOBS SHOULD THIS MACHINE BE USED FOR?

WHAT TYPE OR CATEGORY OF JOBS SHOULD THIS MACHINE NOT BE USED FOR?

OTHER COMMENTS:

THIS PAGE INTENTIONALLY LEFT BLANK

RETURN ON INVESTMENT INFORMATION:

ORIGINAL COST OF MACHINE $________________________________

YEARS OF DEPRECIATION ______________
(SUGGESTED 5 MIN. TO 10 MAX.)

ANNUAL DEPRECIATION (COST / YEARS) $______________________

ANNUAL MAINTENANCE COST $_________________________________
(CONTRACT COST OR SET ASIDE)

ADDITIONAL MAINTENANCE COST $_____________________________
(ADDITIONAL CHARGES [PARTS, ETC.] + LABOR +
DOWNTIME COST [DOWN HRS. X SHOP RATE])

ACTUAL ANNUAL MAINTENANCE COST $__________________________
(ANNUAL COST + ADDITIONAL COST)

ANNUAL SET ASIDE FOR REPLACEMENT $________________________
(SUGGESTED SET ASIDE = 10% OF ORIGINAL COST PER YEAR)

AMOUNT OF REVENUE GENERATED ANNUALLY BY MACHINE $____________
(2080 HRS. / % OF USE X SHOP RATE)

INCOME DERIVED FROM MACHINE $_____________________________
(REVENUE GENERATED - ANNUAL DEPRECIATION - ACTUAL MAINTENANCE
COST - REPLACEMENT SET ASIDE)

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EQUIPMENT EVALUATION FORM

GENERAL MACHINE INFORMATION:

MACHINE # **BM4**

MANUFACTURER **Burgmaster Inc.**

MODEL # **111-25**

TYPE OF MACHINE [] MANUAL [X] N/C

[X] MILL [] LATHE [] GRINDER [] EDM

[] OTHER______________________________

YEAR OF MANUFACTURE (OR AGE) **1972**

H.P. RATING **5**

WORK AREA X **40** [X] IN. [] M.M.

Y **20**

Z **10**

A **10**

B______________

C______________

W______________

MAX. WORK PIECE WEIGHT **2000** LBS.

ESTIMATED USE THROUGHOUT THE YEAR (%) **80**

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EQUIPMENT CONDITION INFORMATION:

CONDITION OF MACHINE [] EXCELLENT [] GOOD [] FAIR [X] POOR

If FAIR or POOR explain.
Because of the age of this machine it has many small problems; spindle runout, override switches, tapers, etc.

If POOR should this machine be:

[X] SURPLUSED [] REPAIRED []OTHER

If REPAIRED or OTHER explain.
The cost of repair and upgrade of this machine is in excess of its market value or cost of replacement.

WHAT TYPE OR CATEGORY OF JOBS SHOULD THIS MACHINE BE USED FOR?
Roughing work, work with tolerances of +/- .005 or greater, nonprecision work, drilling.

WHAT TYPE OR CATEGORY OF JOBS SHOULD THIS MACHINE NOT BE USED FOR?
Precision work, tolerances of +/- .005 or less.

OTHER COMMENTS:

THIS PAGE INTENTIONALLY LEFT BLANK

RETURN ON INVESTMENT INFORMATION:

ORIGINAL COST OF MACHINE **$72,222**

YEARS OF DEPRECIATION **15**
(SUGGESTED 5 MIN. TO 10 MAX.)

ANNUAL DEPRECIATION (COST / YEARS) **$4,815**

ANNUAL MAINTENANCE COST **$1,896**
(CONTRACT COST OR SET ASIDE)

ADDITIONAL MAINTENANCE COST **$23,000**
(ADDITIONAL CHARGES [PARTS, ETC.] + LABOR +
DOWNTIME COST [DOWN HRS. X SHOP RATE])

ACTUAL ANNUAL MAINTENANCE COST **$24,896**
(ANNUAL COST + ADDITIONAL COST)

ANNUAL SET ASIDE FOR REPLACEMENT **$2,889**
(SUGGESTED SET ASIDE = 10% OF ORIGINAL COST PER YEAR)

AMOUNT OF REVENUE GENERATED ANNUALLY BY MACHINE **$49,920**
(2080 HRS. / % OF USE X SHOP RATE)

INCOME DERIVED FROM MACHINE **$18,216**
(REVENUE GENERATED - ANNUAL DEPRECIATION - ACTUAL MAINTENANCE
COST - REPLACEMENT SET ASIDE)

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MACHINE INFORMATION

MACHINE # **BM4**

[This can be any number that the shop chooses. It should be a number that has some meaning. This number within the Main Shop corresponds to the electric panel breaker for FTD emergency shutoff.]

MANUFACTURER **Burgmaster Inc.**

[This is the maker or brand name of the machine.]

MODEL # **111-25**

[This is the manufacturer's model number.]

TYPE OF MACHINE **[X] N/C [X] MILL**

[This machine is a numerical control mill. For the purposes of the machine evaluation report there is no distinction between computer numerical control and numerical control.]

YEAR OF MANUFACTURE (OR AGE) **1972**

[This is the year in which the machine was manufactured.]

H.P. RATING **5**

[This is the horse power rating of the spindle motor.]

WORK AREA **X 40 Y 20 Z 10 A 10 [X] IN.**

[This is the usable work area and axis travel of the machine table and other axis. In this case they are measured in inches.]

MAX. WORK PIECE WEIGHT **2000 LBS.**

[This is the total weight that the machine table will hold. Exceeding this weight can cause damage to the machine.]

ESTIMATED USE THROUGHOUT THE YEAR (%) **80**

[This is the estimated use of the machine at the time of the initial report. Estimated use includes all the time that a machine is scheduled for work. It also includes setup time, cleanup time, and downtime, if any, due to machine breakage or malfunction. This number will be used in the return on investment calculations on page three of the report.]

CONDITION INFORMATION

CONDITION OF MACHINE **[X] POOR**

[This is the condition that shop management determines the machine is in when the report is being prepared.]

If FAIR or POOR explain.

Because of the age of this machine it has many small problems; spindle runout, override switches, tapers, etc.

[Once a conditional assessment has been made, explain the reasoning behind the assessment.]

If POOR should this machine be: [X] SURPLUSED

[At this point, based on previous information, make a management decision. What will be done with this machine? If the machine will be repaired or any other action taken, the return on investment calculations must backup the decision.]

If REPAIRED or OTHER explain.

The cost of repair and upgrade of this machine is in excess of its market value or cost of replacement.

[Explain the reason behind the decision.]

WHAT TYPE OR CATEGORY OF JOBS SHOULD THIS MACHINE BE USED FOR?

Roughing work, work with tolerances of +/- .005 or greater, non-precision work, drilling.

[Explain what types of jobs the machine should be used for.]

WHAT TYPE OR CATEGORY OF JOBS SHOULD THIS MACHINE NOT BE USED FOR?

Precision work, tolerances of +/- .005 or less.

[Explain what types of jobs the machine should not be used for.]

OTHER COMMENTS:

[This space is for any comments that are pertinent to the evaluation of the machine or any comments that are necessary.]

RETURN ON INVESTIMENT INFORMATION

ORIGINAL COST OF MACHINE **$72,222**

[This is what the machine cost new.]

YEARS OF DEPRECIATION **15**

[It is suggested that five years minimum to ten years maximum be used. Most machines have an average life of ten to fifteen years. An average of seven is the norm when depreciating machinery. This allows for three to eight years of profit on each machine.]

ANNUAL DEPRECIATION **$4,815**

[This is the original cost of the machine divided by the number of years the machine was depreciated.]

ANNUAL MAINTENANCE COST **$1,896**

[This is the amount of a maintenance contract for this machine or for all machines divided by the number of machines. If no maintenance contract is in force it is suggested that at least one percent of the original machine cost be set aside, in an escrow account, each year to cover maintenance.]

ADDITIONAL MAINTENANCE COST **$23,000**

[This is the salary of a maintenance person divided by the number of machines. Calculated into this number is the downtime costs of the machine. This is the time the machine is not working because of maintenance problems and there is a job on or scheduled for the machine. It is calculated by taking the downtime hours times the shop rate.]

ACTUAL ANNUAL MAINTENANCE COST **$24,896**

[This is the annual maintenance costs plus the additional maintenance costs, cited previously.]

ANNUAL SET ASIDE FOR REPLACEMENT **$2,889**

[There should be some money set aside each year to cover replacement costs of the machine or money to cover the rebuilding of the machine at the end of its useful life. It is suggested that at least ten percent of the original cost be set aside each year, in an escrow account.]

AMOUNT OF REVENUE GENERATED ANNUALLY BY MACHINE **$49,920**

[This is the income generated by the machine. It is the number of shop hours (2080 hours per shift), divided by the estimated use (from page one), times the shop rate.]

INCOME DERIVED FROM MACHINE **$18,216**

[This is the actual money that the machine made for the shop. It is the amount of revenue generated, minus the annual depreciation, minus the actual maintenance cost, minus the replacement cost set aside.]

It must be pointed out that in filling out the form for machines within FTD certain important information came to light.

1) The suggested depreciation time was exceeded on occasion because when the machine was purchased there was no standard or suggested time.

2) The set aside is low, only four percent, because at NIST this is a fixed rate.

3) The annual maintenance cost is a fixed amount because there is a maintenance contract in force to cover all shop equipment. This contract is a three year contract.

It is suggested that a copy of page one and two be put into a manual and placed in the planning/estimating office. This way the planner/estimator is not bidding on jobs or creating process plans for jobs that exceed the capabilities of shop equipment.

Another use we have found for this form is to complete the first page and circulate it among the other shops in the area and encourage them to do the same. This is not giving away any shop secrets or giving your competitors any advantage. Most of them already know what type of equipment you have and what shape it is in. However, the next time shop management wants to bid on a job but can not because it does not have the necessary equipment, they will know where that equipment is located. The bid can then be issued and the necessary work can be subcontracted out, thus allowing more contracts to be won in the local business community and allowing all shops to become more competitive and economically sound.

2. TASK 2: THE PERSONAL COMPUTER NETWORK

A PC network was set up within FTD for CACE, CAPP, CAD, CAM, tool room management, and job tracking.

A job cost tracking system will be installed at a later date. The job cost tracking system will use existing, in-use, dBASE-III+ software. Using this software program will show how in-place software can be used to increase productivity and will allow FTD to interface with its existing cost accounting system. This interface will issue more accurate time and cost charges on jobs performed within the shop.

This task also investigated computer aided inspection (CAI) and machine tool retrofits and upgrades.

FTD encouraged private sector participation through industrial partners, to assist in the networks installation.

Following is a list of the industrial partners that participated in the project. These industrial partners were requested to supply necessary hardware and software (free or at a nominal cost) that is available to the general public. The partners benefited by being able to have their hardware and software tested and evaluated and by participating in the process.

Shop of the 90's Partners

Applied CIM Technology
15150 25th Avenue, North
Minneapolis, MN 55447

Control of tool crib inventory; maintain control over gages and fixtures; provide capability to create tool assemblies and kits.

Autodesk, Inc.
2320 Marinship Way
Sausalito, CA 94965

Computer Aided Design (CAD); design engineering; drafting.

Brown and Sharpe Manufacturing Company
Precision Park
N. Kingstown, RI 02852

Computer Aided Inspection (CAI); reverse engineering (digitizing of parts to produce the CAD drawing).

CADCAM Integration, Inc.
80 Winn Street
Woburn, MA 01801

Direct Numerical Control (DNC); CAD/CAM integration and shop floor data acquisition; upload and download NC programs to NC machine tools; provide editing capability.

CADKEY, Inc.
440 Oakland Street
Manchester, CT 06040

Computer Aided Design (CAD); design engineering; drafting.

CNC Software, Inc.
45 Industrial Park Road
Tolland, CT 06084

Computer Aided Manufacturing (CAM); generation of NC code through the use of post processors; graphical verification of NC code.

Digital Manufacturing Systems
P. O. Box 1079
Rogers, AR 72757

Automated Programmed Tool (APT) language for the PC.

DynaPath Systems, Inc.
12843 Greenfield Road
Detroit, MI 48227

CNC machine tool controllers; machine tool upgrades.

FASTCUT
550 Carson Plaza Drive
Suite 107
Carson, CA 90746

Inactive third party package, for PC CAD software, for creating surfaces.

International Business Machines Corporation
6705 Rockledge Drive
Bethesda, MD 20817

PC hardware and Local Area Network; sharing of files; transferring files between PC computers; uploading and downloading files between the DNC unit and computers.

Kramer Consulting Inc.
6175 Shamrock Ct.
Dublin, OH 43017

Software for integrating CAD and CAM.

Management Systems Applications, Inc.
4900 Seminary Road
Suite 210
Alexandria, VA 22311

Installation of Local Area Network for sharing of files and transferring files between PC computers.

Manufacturers Technologies
59 Interstate Drive
West Springfield, MA 01089

Software for CACE and concurrent CAPP.

Microcompatibles, Inc.
301 Prelude Drive
Silver Spring, MD 20901

Software for verifying NC code.

Novell, Inc.
555 Herndon Parkway
Herndon, VA 22070

Local Area Network software.

Servo Products Company
433 N. Fair Oaks Ave.
Pasadena, CA 91109

PC-based machine tool controller to retrofit manual machines to CNC machines.

Zenith Data Systems
8521 Leesburg Pike
Suite 700
Vienna, VA 22182-2414

PC computer hardware for manufacturing work cells. Local Area Network; sharing of files; transferring files between PC computers; uploading and downloading files between the DNC unit and the computers.

a. SOFTWARE ELEMENTS OF TASK 2

(1) COMPUTER AIDED COST ESTIMATING

CACE is an essential part of today's shop. Using manual cost estimation is time consuming and ineffective. The possibility of overcharging a customer for the same job done in the past is very high. With a computer data base of past jobs one can search for known fields and retrieve past jobs for comparison. This data base can also be used to calculate proper feeds and speeds for cutting materials. This will allow a more accurate machine time estimate than is possible by manual methods. While the computer is calculating job costs, based on the operations needed to produce a product, it is also building a CAPP. This cost estimate is then presented to the customer for approval. If changes are necessary only a few key strokes are needed to recalculate the estimate, it does not need to be done from scratch.

(2) COMPUTER AIDED PROCESS PLANNING

The CAPP that is produced as part of a CACE operation is another vital component in today's shop floor work procedures. It tells the machinist what operations need to be performed and what needs to be done to perform these operations to produce a part in a timely and cost efficient manner. When the process plan is generated at the same time as the cost estimate the entire estimating process becomes efficient.

(3) TOOL ROOM MANAGEMENT

Tool room management helps ensure that the right tool for the job is in stock, when needed. While the cost estimator and process planner are bidding on jobs they can look at the tool room inventory data base and generate processes around tools that are in stock. If the tool needed is not in inventory, the process can be changed or altered to compensate. It also allows the shop to eliminate tools from the tool room that are not used frequently enough to warrant keeping them in stock. When the tool room management data base is queried the data base will show what tools are checked out and to whom, the most recent cost paid for tools, and expected delivery times based on past orders. This allows a shop to secure the proper tool at the best price, in the least amount of time.

(4) PROJECT MANAGEMENT

After a job bid is accepted, there must be some way of keeping track of that job through its production cycle. Project Management (PM) and job tracking helps the shop foreman to be aware of a job's status and any potential bottlenecks within the shop, before they occur. It also allows the foreman to use a what-if situation to move jobs and personnel from machine to machine to see how different situations will affect shop productivity, before the part is placed into production. This will increase productivity and efficiency within the shop.

(5) COMPUTER AIDED DESIGN AND COMPUTER AIDED MACHINING

In many shops, including FTD, most of the jobs that are worked on come through the door on paper (e.g., blueprints, notebook paper, lunch bags, napkins, etc.). This may have been acceptable when shops used only manual machines. Now that CNC machines are in use, a better form of communicating part information to the shop floor is needed. There is also a need to produce better part programs for these CNC machines. Manual programming is ineffective and nonproductive. With the installation of a CAD and CAM system two problems can be solved at once. Using this system, shop personnel can provide better customer design information to the shop floor and program CNC machines in a more accurate and economical manner.

In most situations the installation of both a CAD and CAM system is not necessary. The primary objective is to produce an economical part that is of good quality. If a shop is subcontracting to major manufacturers, most of the design work has already been done. These design files can be imported into a CAM system using neutral format data base part files. This eliminates the need to redraw the part and possibly introduce errors. Most CAM systems today have some minimal design capabilities but it must be remembered that the CAM programs were written to do CNC programming, not part design. If a shop is involved with customer part design or prototyping, then the installation of a CAD system is essential.

(6) DISTRIBUTED NUMERICAL CONTROL

Distributed NC (DNC) is a combination of hardware and software used to send NC programs from the programing computer to the machine tool control. The type of computer and type of machine tool control will determine the configuration of the DNC system.

Most DNC systems consist of a PC and RS-232, or RS-422, cables connecting the computer to the machine tool control. The software that is used varies widely. Some software is built into the CNC programing software and allows for the downloading of programs to one machine tool at a time. Some software is a separate package altogether and allows for the downloading and uploading of programs to between 60 and 100 machine tools at a time. Some software allows for the uploading of shop floor data collection (e.g. Statistical Process Control information and data).

The type of system that is right for the small machine shop depends on the shop layout, number of machine tools, and management's desire.

(7) COMPUTER AIDED INSPECTION

CAI helps the small shop reduce labor costs, and increase productivity, while tightening performance standards. Coordinate measuring machines (CMM's) are a cost effective tool for ensuring that manufactured products meet design specifications. They also facilitate the reporting of inspection results. CMM's are simple to use, flexible, and require less setup time than conventional methods. CMM's have become affordable by most small shops. In addition to the traditional inspection of piece parts, CAI gives the small machine shops the capability to digitize parts and to do reverse engineering. This is an important function in building prototypes and in doing repair work.

(8) MACHINE TOOL RETROFITS

Machine tool retrofitting allows small machine shops to upgrade an existing manual machine to a CNC machine. Retrofitting can also be used to upgrade an existing NC machine and bring it up to modern CNC standards. This will allow uploading, downloading, easy editing, and generation of part programs. This is an essential and economic step for the effective use of CAM software.

The main reason to consider upgrading existing NC machines is that the newer controls are more dependable, faster, and have greater control capabilities. The standard operations built into the new controls allow for more flexibility in part programs, better program manipulation, easier machine operation, and canned cycles that are almost transparent to the operator.

The newer controls support higher spindle speeds, faster feed rates, quicker changes in feed rates during program operation, tool changes, and multiple axis operation.

With the proper retrofit the need for a CAM system can almost be eliminated, but not completely.

The first consideration before retrofitting a machine tool is to determine if the retrofit is cost justified. If you have completed the Equipment Evaluation Form you should have the answer. Most reputable machine rebuilders will help in the justification process. These rebuilders are good sources for information on the proper axis drives and spindle motors for a given machine. These rebuilders can perform the retrofit for you or you can have your maintenance mechanic perform the task.

If a machine tool is to be upgraded efficiently it is recommended that it have ball screws and chrome ways. This is to ensure that a high degree of accuracy is achieved and maintained.

Also be sure that the selected control can be upgraded in the future. That way when the next generation of control comes out you will not have an overtaxing expense or effort to bring the machine up to standards. This is called planned non-obsolescence.

3. TASK 3: TRAINING AND CROSS TRAINING OF SHOP PERSONNEL

The personnel within FTD are trained as instrument makers and machinists. They were not trained to operate the hardware and software within SoN. It was, therefore, necessary that all shop personnel be trained on the new hardware, software, and machine tools that were incorporated into the project and shop.

This training began with the cross training of existing CNC machinists so each one of them was able to run any CNC machine in the shop.

The reason for training CNC machinists first was:

- o They already know the basics of CNC operation.
- o The training curve was shorter.
- o It was more economical.

After that a two stage training operation was put into place:

1) CNC machinists were trained on the PCs. They learned CAD and CAM systems.

2) Other shop personnel were trained on the CNC machines.

Eventually all shop personnel will be able to operate all the machines and computer systems within the shop.

The training program was the most expensive task undertaken. It must be remembered that money must be set aside to cover salaries, travel, and meals if necessary, and down time for all personnel involved in this task.

Information gathered from CAD, CAM, and machine tool vendors indicates that the average training curve in the manufacturing industry is approximately six months. This is after the installation of any new machine tool, piece of hardware, or software package. This training curve is the time necessary for an individual to return to a production ratio of 1 to 1. A 1 to 1 production ratio means that the individual has returned to the production ratio achieved before the installation of any new equipment. After that, the individual should achieve a ratio of at least 2 to 1 for CAD/CAM and at least 40 to 1 for NC machines. We have seen and heard of production ratios higher than these, but these are rare and should not be anticipated.

III. SHOP of 90's BETA TEST SITE

A. The Ray V. Watson Company

NIST concluded, early on, that a beta site was needed to test the transfer of technology from the project to private sector. A beta site is a private sector company that performs manufacturing work, is willing, under a Cooperative Research and Development Agreement (CRDA), to allow NIST to examine their business and make recommendations for automation and changes, and is willing to give feedback to NIST on the technology transfer and recommendations. This feedback would include why they implemented or did not implement technology and recommendations and what the results were.

Since November of 1989, NIST and the Ray V. Watson Company (RVW) have been working together to transfer SoN automation technology to small machine shops within the private sector. During January of 1990 we developed a work plan to be included in a CRDA. This agreement was officially approved by all parties on April 11, 1990.

Following is a chronological report of the efforts to accomplish the task of technology transfer. This report was submitted by the SoN staff.

<u>**December 11, 1989**</u>

The SoN staff visited RVW to obtain first hand information about their operations. Topics that were discussed included:

- Organization of staff and employees.
- Cost Estimating.
- Diversity of work load.
- Need for improved process planning.
- Need to maximize the capabilities of their machine.
- Need to acquire machinists with NC programming ability.
- Need to acquire more modern equipment, NC machines, and possibly a CMM.

RVW is about fifty years old. In September of 1989 the company was purchased by the Link Brothers (Robert, Richard, and Ron). The management is very receptive to change and is eager to improve the production efficiency of the business by acquiring new technology, both in the office and on the shop floor. For example, when we first met with RVW in early November we learned that they had no computers in their office or on the shop floor. However, during our visit RVW explained how they were using their two new computers. One was being used for clerical and accounting purposes and the other was being used for cost estimating and job routing/process planning. We had previously given them a spreadsheet overlay for cost estimating, and were delighted to see that they were putting it to good use. They informed us that they had purchased the PM software package which they had seen operate at NIST. The completion of SoN Equipment Evaluation Forms for about forty percent of their machines is another example of their eagerness to follow through on suggestions we made during their visit to our SoN facility. We were pleased with their fast start in trying to make automation work in their shop.

RVW has a unique capability of producing a diverse mix of gears which are used throughout industry. Some of their gears are used for repairing newspaper presses, Bureau of Engraving presses, and for repairing Navy machinery. Manufacturing of gears is about twenty five of their business. It was evident from our tour that gear manufacturing is their unique niche. Although they make several types of gears, they usually make just one or two gears at a time and they do not have a diverse range of lot size, which would provide an economy of scale. Their gear department is struggling under adverse odds of aging and obsolete equipment that needs repair. Hiring of machinists with NC experience, and cross training younger employees with older employees is a priority that the owners are starting to address.

The welding fabrication and repair area has the potential for significant growth. About twenty percent of the company's revenue from last year came from this area. We noticed that the company was building storm grates that were designed for bicycle safety. This job had variation in part sizes and lot sizes. Welding fabrication is an area that they hope to expand.

The new owners are very aggressive in finding new work and they are building a large backlog of work. However, completing quality work in a timely manner is a problem. On some of the jobs success was obtained only after several costly iterations. Their company's production rate is suffering from:

- Old and inefficient equipment.
- Old production methods.
- A lack of NC machines.
- The company's inspection department is severely lacking many of the basic inspection tools and gages

and could use a CMM.

During our tour we noticed four problems that need to be addressed:

- o Poor process planning. One job was a trial and error approach, another suffered from the wrong ordering of the processes.

- o In the milling area the programming capability of one of the machines is not being used. It had been fitted with Digital Readout/NC upgrade about two years before.

- o In the lathe area, where a backlog exists, there are no NC lathes.

- o In the inspection area there is no capability to do Reverse Engineering. For many of their jobs, they only have a broken part to work with.

We suggested that regular production meetings among their cost estimators and the foreman may help to improve their process planning. Also feedback from the machinists and the foreman on how well the actual time spent on the job agreed with the estimated time could help to improve both the their cost estimating and process planning.

We agreed that a CRDA with RVW and NIST would be written to identify RVW as our first Beta Site. The suggested time frame for this agreement was eighteen months. During this time NIST would visit the company once every two months to discuss problems of mutual interest.

December 12, 1989

A meeting at NIST to discuss:

- o Problem areas, and target one for improvement. (lathe, gear cutting, and inspection are potential candidates.)

- o Group Technology (GT) and how it helps improve process planning, cost estimating, and operation sheets.

- o Sources of outside expertise including the Association of Retired Executives, and Catonsville Community College.

February 15, 1990

We visited RVW to evaluate their progress in automating functions in the production office and on the shop floor.

We noticed remarkable improvements in the general appearance of the shop. The shop walls were visibly more pleasing, in that it was freshly painted and some cleanup had been performed.

The amount of work in the shop had noticeably increased and lot size apparently had increased.

Office automation in the clerical/accounting area and in the production office was well received by their employees and significant progress had been made in the last two months.

For example:

- They modified a spreadsheet overlay written for cost estimation to include materials and a markup for their margin on the materials.

- Significant progress was made in job tracking. Improved job tracking is very helpful because they often have about one hundred jobs in the shop at one time.

- Posting the work-in-process is being done on a weekly basis (manually).

- They have eliminated repetitive job data entry using their recently purchased office automation/accounting modular software.

- They are using their spreadsheet overlay to perform gear formula calculations. They experience some success and a few minor problems with this approach. We mentioned to them that there are relatively inexpensive software packages for performing gear calculations and we would supply them with sources for this software.

Their chief estimator, who is sixty-two and who has had no prior computer experience, has demonstrated that age is no barrier when it comes to putting computers to good use in reducing the backlog of job cost estimations. After about four months of training he loves using his spreadsheet overlay package for doing cost estimations and he indicated that he couldn't do without it. Their cost estimation software has allowed them to examine many more jobs. This is very significant because the shop usually gets only three out of every ten jobs which they are requested to provide estimates on. The success in speeding up cost estimation has moved the critical bottleneck from the production office to the shop floor.

They have installed PM software but are not currently using it to track jobs through their production shop. They are tracking jobs manually. They are trying to find the right person, one who has enough experience in managing the jobs in the shop and enough slack time to learn the software package.

Our suggestion is that the foreman or an assistant to the foreman may be the right person for this job. Making the best use of the PM software for job tracking is a task that we can provide some immediate help on. Clarifying the lines of responsibility for this task needs to be done. We will provide input on how we are using this software package and we will develop a simplified synopsis on what will be the best way to get them started.

RVW made it clear that the job completion rate in the shop is not keeping up with their tremendous marketing effort of attracting new jobs. The major bottleneck is the lathe area. They are subcontracting some of their lathe work, with limited success. Their subcontractor is using an NC lathe to make parts for them. RVW is making a reasonable profit by subcontracting. However, this is not their preferred way of doing business.

We suggested that the installation of an NC lathe would:

- Shorten the manufacturing lead time on several parts that they are currently making.
- Help them to achieve consistent high quality.
- Allow them to more aggressively go after new business that they would not pursue if they had only manual machines.

Our analysis suggests that the first step of automation for their shop should start with an NC lathe, followed by an introduction of CAM then CAD. The lack of an NC lathe is a barrier that is impeding the adoption of planned automation strategies on the shop floor. The second area of automation should be in the inspection area.

If the estimators and the shop foreman know the capabilities of the machines on the shop floor, this knowledge can prevent them from taking on jobs that are unrealistic for their shop's capabilities. During our tour, there was discussion concerning jobs in which the drawings for the job call for tolerances that exceed the capabilities of the machines.

The company had completed the machine survey forms. Some of the information from this survey should help them to assess the capabilities of their machines. Since they are using spreadsheet based software for their cost estimation, it may be prudent to build a database for the capabilities of the machines so that these capabilities can be retrieved during cost estimations and process planning. This may be an area that we may be able to help them with. Jobs that are not a good match for the machine shop's capabilities can cause serious delays in order to achieve the desired quality or may result in not meeting the drawing's specifications. These delays can hinder the orderly progression of other jobs.

We presented RVW with a draft of a CRDA. The statement of work was discussed. RVW stated that they had no problems with the proposed statement of work.

This statement of work is:

> The objectives of this program are to identify barriers in transferring hardware and software technologies from the "SHOP OF THE 90's" to small machine shops, and to develop strategies that will facilitate the transfer of commercially available technologies which enhance the productivity of small machine shops.
>
> The program shall include, but not necessarily be limited to:
>
> (a) Identifying problem areas.
>
> (b) Providing demonstrations and operational guidance to facilitate technology transfer.
>
> (c) Developing a methodology for evaluating improvements.
>
> (d) Loaning equipment as may be appropriate for achieving program objectives and for accomplishing the elements above.

RVW stated, later by telephone, that the company accepted the CRDA. The CRDA was sent through the NIST management levels for approval signatures.

SoN will open channels of communication and use its contacts to identify potential equipment loans and other "soft" equipment programs which may be required to eliminate barriers to the orderly progression of our strategies for technology transfer. We have recently talked to the National Tooling and Machining Association (NTMA), the American Gear Making Association (AGMA), the National Machine Tool Building Association (NMTBA), the Brown & Sharpe Company, and the Defence Industrial Plant Equipment Center (DIPEC).

Their net staff has increased by one machinist. In fact, two new machinists were hired, but one of their senior machinist retired, giving them an increase of one. One of the two new people hired has NC programming experience.

Their only machinist with bevel gear experience was recently put on "light duty" by his doctor. This has put them in somewhat of a bind. The company is trying to hire a machinist with bevel gear experience. They have recently discovered that one of the former owner's sons has bevel gear experience and he is willing to work with them in training someone on their staff. This offer from the son of the original owners of the company will temporarily help them solve their manpower shortage in the gearing department.

RVW recognizes that attracting highly qualified machinists with NC programming experience is an ongoing challenge for them.

During a recent telephone conversation with RVW, we suggested that RVW work to develop a cooperative education agreement with Catonsville Community College to facilitate training and the gaining of practical experience in the machining of gears.

AGMA and the NTMA are aware of the critical shortage of machinists with gear cutting experience. In developing a cooperative educational agreement it might be prudent that NIST and RVW hold discussions with these two associations.

May 4, 1990

SoN wrote a letter on May 4, 1990 to Allison Gas Turbine. This letter initiated discussions on the possible consignment of machine tools to RVW to perform work for the General Motors' Allison Gas Turbine Division.

May 7 and 8, 1990

A Brown and Sharpe Micro Validator was installed at RVW and training was begun.

Our partnership with Brown & Sharpe increases our capability to put appropriate emphasis on maintaining quality in a small machine shop.

One of the anticipated benefits from automation is consistent high quality. A properly focused quality assurance program will not only assure that parts not meeting specification are rejected, but can help identify flaws and problems in the manufacturing process. Both of these affect the ability of a company to provide a product that meets specifications. Increasing the speed and the quality of inspection is a recommendation that we made to RVW during our last meeting. To implement this recommendation, we encourage the Brown & Sharpe Manufacturing Company to loan one Micro Validator to NIST and one to our beta site.

After about three weeks experience with the Micro Validator NIST was ready to install the Micro Validator at RVW and provide some training for the inspector. This installation and training occurred on site. On May 7, 1990 at 7:30 a.m. the equipment was uncrated and inspected. The components were moved to the inspection room and set up. At 1:00 p.m. the system was started up with the remainder of the day spent checking it out. Starting at 7:30 a.m. on May 8, 1990 the entire day was spent training their inspector on the system. It should be noted that their inspector is a part-time employee with no previous experience with computers or CMMs. Although he was eager to learn, the one day of training time only allowed for the basics to be reviewed.

May 11, 1990

An announcement of the CRDA was made at a media briefing at NIST. Robert Link, President of RVW, attended the briefing. Mr Link announced the CRDA and informed the media about the work that is being carried out under this agreement.

May 17, 1990

Training was begun for the project management software at RVW.

The training session was performed by NIST on site at RVW. Early into the training session we realized that the person being trained had not been previously exposed to the PM software, this was a prerequisite. Considerable time was spent explaining such basics as sign-on/sign-off, location of menu, and the like. Because of time restraints, loading of resources, construction of layouts, use of menus, and setting of dependencies were the areas covered. Because of previous commitments by RVW staff there time at RVW was not fully utilized.

Job tracking software provides an automated method of job entry and job tracking and it helps the user to catch bottlenecks before they happen. This software tool allows the user to try different combinations of jobs and machines to find the most productive distribution of work by allowing the user to ask what-if questions.

May 18, 1990

A meeting was held between the SoN staff and RVW at NIST.

Automating the manufacturing operations often requires changes in organizational structures in order to support the automation strategies. RVW requested advice on alternative organizational structural.

The primary purpose of the meeting was to discuss different ways for RVW to reorganize their existing personnel to achieve better communication throughout their company. A specific area, discussed in detail, was how to improve communications between planning and estimating staff and the shop floor staff. Organizational charts were drawn up showing alternative approaches to the problem areas. One was selected as the most appropriate for their operation. Minimal time was spent discussing management problems in general.

June 18, 1990

A meeting was held at RVW with a focus on the need for NC machine tools that could be supplied by Cincinnati Milacron. Attending the meeting were the SoN staff, Bob Link and Rick Link from RVW, and Cincinnati Milacron staff.

The prelude or "groundwork" for this meeting was a letter from NIST to Cincinnati Milacron. In response to this letter, we received a letter from the manager of Cincinnati Milacron's Government Systems Group. In his letter he discussed Cincinnati Milacron's involvement in the Machining Initiative for Aerospace Subcontractors and their Intelligent Machinist Workstation. He stated that our SoN project is very interesting and addresses a very real need in getting advanced and available technology to the small machine shop base. Milacron is addressing this need. Possibly there is a way we can work together in this area.

After discussions with Cincinnati Milacron's Government Systems Group it was concluded that there was significant interest in working with SoN and that a plant inspection of our beta site should be the next step.

NIST gave an overview of the computer systems and software that were implemented in the SoN project. We discussed the progress in automating the production office and the inspection room at RVW. We told Milacron that our plan for implementing automation on the shop floor is stalled because of the lack of NC machining centers and NC turning centers.

RVW discussed the backlog of orders and mentioned several potentially new customers for which they were providing bids. He discussed the workload currently in the shop and how the spreadsheet overlay for cost estimation has reduced the time of providing quotes to their customers. He stated that he is working on getting better feedback of actual time spent from the shop foreman to the estimators. He recently made some changes in his organization to improve communications and to support their CAI. Bob expressed his appreciation for having the opportunity to participate in a CRDA with NIST and said that he highly values the media recognition from the association with NIST.

Cincinnati Milacron asked a series of questions to ascertain what type of machine tool would better serve the needs of RVW. Their questions focused on the following factors:

- The physical size of their workpieces.
- The frequencies of these sizes.
- Workpiece material.
- Horsepower requirements.
- Tooling requirements.

RVW and their foremen gave the Milacron team a workcenter-by-workcenter tour of their plant. During the tour they spent sufficient time at some of the stations to point out the range in size of the workpieces, the range in lot size and the diversity of work type. They also gave them names of some of the customers connected with the various jobs.

During the tour Milacron had gathered enough information to assess the machine tool needs of RVW.

During the concluding discussion we focused on:

- Future direction for the company.
- Bringing work back in-house vs. continuing to subcontract.
- NC program training and the choice between an NC lathe or NC milling machine.

The Milacron team stated that companies like RVW represent an opportunity to increase their share of the market in the low price end of the market. They are holding still in this part of the market now, but fairly soon their competition may come out with a product that may "burst their bubble" or threaten their share of the market. Milacron said that they would make a favorable proposal to their Manager.

Milacron was impressed with RVW management and their significant backlog of work. Their very effective marketing effort, which resulted in a substantial workload at their subcontractor and within their own shop was regarded as very significant justification for NC machine tools. They see a significant future market in low priced NC machine tools for companies like RVW.

August 2, 1990

A meeting with General Motors' Allison Gas Turbine Division was held and focused on:

- Equipment needs that could possibly be supplied by the General Motors' Allison Gas Turbine Division.

- o A review of some inspection work that is currently being performed with the Brown & Sharpe Micro Validator.

Attending the meeting were staff from NIST, Allison Gas Turbine, and RVW.

The prelude or "groundwork" for this meeting was initiated with a letter to Allison's Plant Manager. Subsequent discussions focused on alternative ways to utilize some of Allison's surplus equipment effectively. The decision made during these discussions was to use RVW as a supplier and to loan/consign the equipment required to do the job. To initiate this relationship usually requires a site inspection.

RVW gave an overview of computer systems and equipment implementation that has improved the operation of their production office and inspection department. We discussed the lack of NC machine tools that is currently limiting our automation strategy.

RVW discussed the orders that they received from their new customers and some of the orders from their existing customers. Especially important for them was a 400 gear order that they received from a new customer.

It was stated that RVW has programmed the gear formulas for helical, bevel, and spur gears. They used spreadsheet software to program the gear formulas. Using the computer has reduced gear design time by seventy-five percent compared to the manual system. The benefits are time saving and a significant reduction in error rate.

Allison Gas Turbine briefed us on their modernization program:

- o Flexible automation cells are causing a lot of problems because too many sensors and gages are required. Problems with any one of these usually would force a shutdown of the spindle.

- o They are backing away from the flexible automation systems.

- o They use their NC programmers to produce NC codes, and are currently not using CAM software to generate NC codes for their NC machines.

- o The Allison plant consists of eighty-eight acres under roof, and has four thousand machine tools, of which three hundred are NC machines.

- Multi-vendor machine tool controllers are causing some problems in their union shop. Therefore, they have started standardizing their machine tool controllers. They chose the GE Fanuc 15 as their NC controller.

- Their repair gears are class 8 to 10 and are mostly made from 4340 or 8260 material.

- Most of their gears require grinding, but some require honing.

- NC machine tools require an operator. One operator per NC machine is not cost effective for them. Their cost effective way of operating is to have two machines "back-to-back" and to have one operator servicing both machines.

- One of Allison's former employees is an expert in gears. This expert will not accept compensation when he is requested to do special jobs for Allison. It was indicated that this expert service could be made available to RVW.

RVW and their foreman conducted a tour of the shop. Allison was impressed with the range of gears that they were making and with the diversity of other work that was being processed in the shop.

Allison stated that RVW was similar to some of the companies that they were doing business within the Indianapolis area, and he felt that RVW was capable of manufacturing some of the gears that they are using to repair their equipment.

Allison Gas Turbine Division said they could provide help in the following areas:

- Use RVW as a supplier of some gears that are used in the repair of their machines.

- Put RVW on the bid list for other work.

- Loan some instruments for inspecting gears.

- Put on consignment some bevel gear machines and other gear making equipment that is needed to process the orders that they will give to RVW.

Unfortunately, it is not likely that Allison will locate any surplus NC machine tools.

We reviewed some of the functions that their inspector was performing. During this review, we observed that they had gained familiarity with the operation of the machine. However, there are some gaps in their operation that need to be addressed. We were able to answer most of their questions concerning the angular function they were attempting to use.

Allison Gas Turbine Division was pleased with the site inspection. They talked with RVW management, shop foreman, estimator, and some of the workers, and received a reasonably good overview on how the company operates. They seemed to be very impressed with RVW management and, therefore, the opportunity for future business looks good. The expected outcome from this meeting is a series of new orders of medium lot size. If this scenario materializes, these projected orders from General Motors may be used to structure a financial loan package for the procurement of new NC machine tools.

October 25, 1990

RVW wanted to get a head start on training their quality control inspector to use CAI software. They sent three of their people here for training on CAI and a tour of our inspection area and tool crib. The people who visited from RVW were Marty Downey, John Hentz, and Tony Woodward. Their inspector, John Hentz, was very enthusiastic about the additional capabilities that CAI would provide to their company.

Marty Downey discussed the record keeping for FTD's inspection jobs with Gene Morgan, FTD inspector. Marty and Tony also toured our tool crib and had a discussion about our tool tracking system.

November 7, 1990

SoN staff made a site visit to RVW to install CAD software and CAI software. SoN staff made the connection between the Micro Valve CMM and the CAI system. The SoN staff gave an hour of introductory training on CAD and performed some additional training on Micro Valve. They specifically directed the training to those areas where they had experienced some difficulties. RVW's overall progress with the Micro Validator System is very good. They presented training objectives for the new software.

January 4, 1991

SoN staff made a site visit to RVW to install the latest version of CAI software on their computer system. The SoN staff pointed out some of the bugs that they had found with the system and showed John Hentz how to perform some testing in those areas in which bugs had been found. During this visit, they were asked to participate in a production meeting to discuss some new organizational changes that were implemented to support the automation that is occurring in their shop.

B. Ray V. Watson Company / SHOP OF THE 90'S

Situation Report, August 31, 1990

The SoN staff asked RVW to submit a report on their view of the results of the technology transfer efforts between RVW and NIST. Following is a report submitted by BoB Link, President of RVW.

Background:

The Link (Robert, Richard, and Ron) brothers purchased RVW Company September 1, 1989. The company is a machine job shop with sub-specialties of gear cutting, manufacture of machinery replacement parts, and custom steel fabrications.

The company has a wide customer base with 90% of its business related to the Maryland/District of Columbia market. It serves a wide spectrum of industrial sectors, including: printing, food, paper, defense, steel, and machinery manufacturers.

Sales revenues are approximately $1.2 million per annum. The company occupies a 13,500 square foot facility, located in a stable, attractive area of Baltimore city. It employees 20 full time and 5 part time staff.

The shop contains approximately 70 machine tools, including mills, lathes, grinders, gear hobs, shapers, generators, broaches, drill presses, and welding machines. At the time of purchase, the technology was of the 1950's vintage.

Mission Statement/Business Strategy:

The Links sensed a growing need for local manufacturing that could provide quality products on time. Their objective was to acquire a small manufacturing business, and apply management principles and modern technology so as to benefit from their perceived sense that the Maryland region and the United States have a need for an efficient manufacturing base, which could compete in a world economy.

The market opportunities would be based on local demand for products, including the manufacture of products/parts currently imported from abroad. They believe that the future health of the United States economy is dependent on a competitive manufacturing base. The Links have backgrounds in international business and finance, accounting, and industrial sales.

National Institute of Standards and Technology / SHOP OF THE 90's:

Shortly after acquisition of the company RVW contacted NIST's SoN for help and assistance. RVW learned about the program through a newspaper article. NIST's philosophy and mission of technology transfer matched the needs and objectives of RVW. After several on-site meetings a CRDA was signed in January 1990 between NIST and RVW.

In management's opinion, interaction with NIST has resulted in the following actions and results:

Plant/Work Space:

- Machinery assessment completed with identification of machinery for disposition. **Benefit:** Creation of 2000 square feet in the shop for new machinery and improved shop efficiency.

- Shop cleanup and fresh paint. **Benefit:** Improved morale among employees and favorable impact on customers during shop tours.

- Machinery tune ups. **Benefit:** Better quality parts; improved machinists' performance; improved morale. NIST has also provided a list of recommended machine rebuilders for conversions to CNC.

- Introduction to Cincinnati Milacron executives and initiation of negotiations for a CNC lathe and milling machine. Outcome expected to be resolved in September 1990.

- Location of two used milling centers available through DIPEC. Decision to proceed pending Cincinnati Milacron outcome.

Administration:

- Staff inventory/appraisal completed. **Benefit:** Evaluation of in-house skills for better manpower utilization and identification of needs for training. Key to recruitment needs and for wage reviews.

- Establishment of job descriptions for shop based on SoN recommendations. **Benefit:** Assist manpower appraisal and recruitment. Improved productivity in shop.

- Reorganization of supervisory responsibilities. **Benefit:** Better coordination of purchasing of metal inventory and tools with shipping, receiving, and manufacturing process.

Quality Control/Inspection:

- Greatly improved technology for inspection with introduction of Brown and Sharpe Micro-Val CMM in May 1990. This is on loan with the option to purchase. SoN staff coordinated this agreement and provided on-site training. **Benefit:** Inspection time reduced by 70%. Improved customer confidence with emphasis on quality.

- Introduction of in process inspection. **Benefit:** Reduction of rework.

Management Systems:

- Introduction of two Packard Bell A/T computers used for estimating, production scheduling, job analyses, calculations of gear formulas, and word processing. **Benefits:** Estimating and process plans now generated on hard copy. Systemized approach uses spreadsheet based software, resulting in reduced errors and better records for future referral. Completed jobs are analyzed and compared with estimates. Feedback provided to estimators and foremen.

- Gear formula calculations now performed by computer, resulting in 75% time saving and significant reduction of error rate.

- Production scheduling now utilizes spreadsheet based software which tracks hours remaining in backlog by machining function. This system significantly reduces non-productive shop time and improves delivery schedule.

- Office Writer software is used for word processing. This has significantly improved correspondence preparation.

  Special Note: Computers were introduced by the Links in November of 1989. At that time none of RVW staff had any computer experience. On the job training and NIST's on-site support have transferred several of our key staff to experienced and active users of our two computer systems.

Other:

NIST's relationship has assisted RVW in many other areas. Staff have assisted us in locating sources of MIL-SPEC materials which enabled us to bid on a job for manufacturing weather instruments.

NIST has advised RVW on technology for the manufacture of cams, under consideration as a new product. NIST has been a source of referral for the manufacture of gears.

Future Needs:

Through aggressive business development efforts RVW has been highly successful in developing new customers and larger lot sizes for gears and other machine parts. For example, the company has recently been awarded two purchase orders in excess of $90,000 for manufacturing over 500 gears. In addition we have recently bid on a contract in excess of $100,000 for manufacturing of parts for weather instruments. Customers have also requested that we manufacture cams. This would require a CNC machining center.

The lack of automated machinery is resulting in competitive pricing pressures and customer concerns about uniformity of parts on repeat orders. During the past nine months RVW has subcontracted out over $45,000 to a CNC shop for lathe and milling services. A CNC lathe and machining center would greatly enhance our production and marketing image.

RVW's staff receives frequent requests to manufacture parts and gears from samples. This is currently done through manual measurement and the creation of sketches. An Automated Reverse Engineering system and CAM to program the machines would significantly expand our quality and efficiency and lead to increased business opportunities. Consultations and demonstrations at NIST have made us aware of available technology in this area.

In addition to the above items, the Allison Gas Turbine Division of General Motors was introduced to RVW through SoN. As an outcome of Allison's visit, RVW has been placed on Allison's list for replacement gear requirements for their machinery. Allison is also searching for any spare gear inspection machinery as well as a spiral bevel gear generator to place on loan.

The company is optimistic about its ability to market effectively and source new business. During its past 12 months of operation at least 25 new customers have been landed, including: Solor Cup, General Motors, Washington Metropolitan Transit Authority, Washington Suburban Sanitation Commission, Mitsubishi Corrugating Machine, Genstar, Voest Alpine, and Holiday Tyler Printing. Management believes there are many opportunities for growth but improved technology will be essential.

Summary:

RVW management and staff believe that NIST's SoN has been a substantial contributor of knowledge and technology transfer. Their input has positively impacted our level of technology, improved controls, and increased productivity. We hope to continue our association in what has been a very rewarding relationship. Our primary focus needs to be on automated machinery and related support systems.

This, by no means, is the end of the work NIST will be doing with RVW, or any other beta sites. As the CRDA draws to a close a report will be forthcoming. This report will cover all aspects of technology transfer between NIST and the private sector.

IV. PRODUCTIVITY AND QUALITY IMPROVEMENTS WITHIN THE FABRICATION TECHNOLOGY DIVISION

Interviews were held with the Shop supervisors and other shop personnel involved with the implementation of the SoN project within FTD. This section discusses the results of these interviews.

The purpose was to receive and evaluate feedback on the implementation of the SoN project. From this feedback we can make changes in the implementation process and decide what the next steps in the project will be.

The questions asked were:

1) What is the most significant improvement that can be contributed to SoN's automation? Please comment on the following areas:

   A) Time savings; give examples of actual cases of time savings. Are there any examples for which the time required for the job was longer than the time for manual operation?

   B) Improvement of quality and reduction of rejects.

   C) Improvement of reporting and documentation.

   D) How has automation changed your job? Has it made your job more interesting, more challenging, or more difficult? Give some specific examples.

   F) Are there any additional capabilities that automation has provided that were not possible to do under the manual system? Give some examples.

G) Other comments.

2) Has automation resulted in a reduction in response time, i.e., the reduction in time between job entry and job completion? Can you quantify or give examples of reductions in response times?

3) Has there been a reduction in the idle time on the machine? Can you give specific values for reduction in machine idle time or can you estimate the reduction in machine idle time?

5) Has there been a reduction in rejects as a result of SoN automation? Do you have data that support the reduction in rejects, or can you provide estimates and specific examples?

6) Has automation reduced the total time the job spends in the shop? Can you provide specific examples?

7) Does automation provide better utilization of machine tools?

8) Has automation resulted in better documentation, improved tracking, quicker retrieval of job information?

9) Has automation resulted in greater customer satisfaction? Could you give specific examples?

10) If you had your own shop, which one of SoN's technologies would you implement?

Each person was given the questions ahead of time. Following are the remarks made by each person:

Remarks by Jeff Kelley, Foreman, Main Shop:

Project Management allows us to get better reports and better retrieval of data. However it takes more time to input data and to keep the system updated. The overall contribution is a little to the plus side.

CAM contributes to improved quality. Better machine tool controllers (ease of programming and conversational graphics) has contributed to improved quality. CAM has provided the capability to generate more difficult programs faster than before. For simple to medium complexity parts, the part programs are entered at the machine tool controller, by the machinist. For medium to complex parts, CAM is used to generate the part program. The machinists view CAM as a love-hate situation. The problem is that when CAM is used to generate the Numerical Control code some people feel that they are no longer an entity. They feel that they are not using their skills and someone else is doing the technical work. The more of their technical skills that they use in doing their job, the greater value they feel they are to you. If they are not using their machinist skills they feel insecure.

Response time: CAD/CAM has improved response time to our customers. However, the tool room is operating at a slower rate. It simply takes longer to get the tools. The machinists make comments weekly about the slow operation of the tool room.

CAM alone does not result in a reduction in rejects. The machinists know that they are being audited. This quality audit challenges our machinists to make the part right the first time.

Automation has reduced the time the parts spend in the shop. This is true for the more complex parts, but it is not true for the simpler parts.

Our NC machines have a higher utilization and therefore little, if any, idle time.

Automation has resulted in better documentation, improved job tracking, quicker retrieval of job information.

Automation has resulted in greater customer satisfactions for jobs involving complicated geometry but probably no change in customer satisfaction for simple type jobs.

If I were the owner of a machine shop, I would have machine tools with powerful machine tool controllers. I would use CAD/CAM for the more complicated jobs. I would install job tracking and scheduling software. I would also install a Micro-VAL CMM. I would also try to identify a good tool management system, one that is proven. I would give the employees more responsibility.

Remarks by Dana Strawbridge, Assistant Foreman, Main Shop:

The degree of complexity of the part will determine if part geometry will be entered into a CAM system or if the NC program for the part will be developed elsewhere and then entered at the machine tool controller.

When CAM is used for the average complexity part, approximately two hours time savings is achieved. However, when doing production parts the time savings could be several months.

When the NC part program is developed using the CAM software, there is an improvement of quality and a reductions in rejects. This is especially true if the machinist is thoroughly familiar with the operation of CAM and frequently use the CAM software.

Automation has made the job more interesting and challenging. There have been only minor difficulties in terms of frequent distractions in providing the service of hardware and software support. Automation has given us the capability to do very complex parts.

Automation has reduced our response time to our customers and the idle time on the NC machines has not increased.

A reduction in rejects has occurred during the last year. Some of the reduction in rejects may be attributed to CAM.

CAM has contributed to better utilization of the NC machines.

CAM has provided for faster retrieval and modification of part programs, and allows better verification of part programs.

Automation has resulted in fewer errors which contributes to a reduction in response time. Both of these contribute to greater customer satisfaction.

If I were the owner of a machine shop, I would definitely have CAM. Depending on the size of the shop, I would probably not have tool room management software. Our experience has shown that our tool room is not working well. The main problem is that the response time is too slow; people have to wait. I would not use Project Management software.

Remarks by Bob Wantz, Instrument Maker/Numerical Control Programer:

Some small jobs can be done faster with a machine tool that has a smart controller. Other jobs can be done faster with CAM. If each machinist develops their NC part program by using CAM this can lead to less productivity because the machine is idle while the machinist is doing part programing. This is especially true when you have a series of different operations to be performed on that machine. Under this condition it would be better to have a person dedicated to CAM to produce programs for the various machines. This would lead to greater utilization of the machines. But, on the other hand, this approach leads to under utilization of machinist skills. Some machinists feel that CAM does not allow them to fully use their skills or to fully use their smart controllers. I suspect that some machinists have quit because they feel that the CAM type automation would render their job to "part loaders" and "button pushers."

Our tool room software is not saving time; it takes longer. They are still using the "paper-work" system and are not using the system the way it is suppose to be used. It takes longer to get tools.

Remarks by Bob Lach, Senior Fabrication Technologist:

With CAM we now have the capability to machine more complex parts. The combination of CAD/CAM has reduced the total through-put time and reduced reject rates, especially for the more complex parts. The reject rates for all types of parts have been greatly reduced. Some of this reduction in rejects may be attributed to having a dedicated full-time inspector. The idle time on the machine tools depends on the workload. Under heavy workload condition, the idle times on the machines are greatly reduced with the use of CAM.

My priority for the implementation of automation would be: 1) CAM, 2) CAD, 3) cost estimation, 4) reverse engineering, and 5) job tracking.

Remarks by Sherman Reeder, Foreman, Special Shops:

The Project Management software package is being used to keep track of job entries and job completions. We have a lot of little jobs. Using Project Management software for these little jobs would be time consuming and would be a waste of time. Project Management allows me to be more organized. I can easily determine which jobs are a day or so behind schedule.

Tool Room Management software has not improved the management of the shop.

Computer Aided Cost Estimation has shown there is a need for more help in the cost estimation office.

Remarks by Ken Wiltshire, Foreman, Support Activities:

Computer Aided Cost Estimation for complex jobs can be performed faster and more accurately as compared with doing it manually. If Computer Aided Cost Estimation was used for a lot of the small jobs it would take longer. Even for the simpler jobs we "log" the job in the system. In the future, backlog reports will be generated by the system. The data from the system will be exported to DBASE-III to produce the backlog report.

From management's viewpoint the Tool Room Management Software is providing better inventory control. We have achieved better accountability for our tools. Our people feel more responsible for the tools since their employee identification number is entered in the computer as compared with signing a little piece of paper. We can also keep better transactions record.

We are realizing a time savings with the installation of a computer network. Looking up material in the storeroom catalog makes the job easier and is saving time. Using the network to acquire the time and materials balance on a job order is an additional convenience that is saving some time.

CAM is reducing idle time on the machines. This is especially true when there is a well trained person doing most of the programming. The machine idle time can increase, if each machinist performs his own NC programming. This is because the machine stands idle when the machinist is on the computer doing the programming for his job.

CAM can provide a reduction in response time to the customer. This is especially true for the moderate to more complex parts.

The combination of various types of automation used within SoN and NIST's automated storeroom catalog achieves better utilization of machine tools and a reduction in response time to the customers.

If I were a shop owner I would implement automation in the following order: 1) CAD and CAM, 2) a CMM, and 3) depending on the size of the shop, I would install Job Tracking and Tool Room Management.

V. SUMMARY - PHASE ONE

By the end of fiscal year 1989 (9/30/89) FTD had an integrated manufacturing system in operation geared to the small machine shop. This system does computerized cost estimating, computerized process planning, and computerized tool room management and there is an intergraded system for CAD and machining. This system eliminated the inefficiencies that occur within the shop today and made the manufacturing process more productive and cost efficient. This system transmitted better customer information to the shop floor and allowed the NC machine to be programmed more efficiently.

Although this project is being carried out within the NIST machine shop, all the information and techniques are available to interested private or public sector organizations. NIST's FTD further encourages the participation of guest workers, industries, and academic institutions in developing the tools and techniques for SoN.

VI. THE FUTURE--PHASE TWO--TECHNOLOGY TRANSFER

A. GOALS

Through lectures and seminars allow small machine shops to investigate the benefits of using automation. To provide hands-on experience with installed personal computer based equipment, software, and machine tools. To retrofit and rebuild manual machine tools to NC capabilities.

B. BACKGROUND

Over the past three years FTD has installed SoN within it's main instrument shop. FTD has done extensive work within its shop to bring the existing equipment up to present day standards. FTD has started an extensive training program to cross train its machinists. The SoN staff have given seminars and lectures at NIST Regional Manufacturing Technology Centers, to state and local governments, universities and community colleges, and to numerous visitors and guests at NIST.

FTD has set up a demo and seminar center where all the lessons learned in the past three years can be put into practice and viewed by private sector. This center is used for continuing and on-going SoN projects. It is a testbed to investigate new technology and determine what is applicable to the small machine shop. If it is applicable, how should it be implemented, and what will be the results of the implementation.

Ways of doing this are:

- o Develop a SoN technology implementation program that focuses NIST resources on problems that are impeding the diffusion of automated technology to the small machine shops.
- o Developing and implementing training aids and equipment.
- o Conducting a series of workshops, seminars, and demonstrations.
- o Establishing a network of linkages among Regional Manufacturing Technology Centers, government laboratories and small manufacturing firms. These linkages and interactions will serve as a catalyst to strengthen business-to-business ties that promote the transfer of technologies, particularly between large and small firms.

C. SPECIFICS OF THE FUTURE PROJECT

1. INPROCESS GAUGING AND STATISTICAL FEEDBACK

In phase two the need to investigate and implement inprocess gauging is the next rational step. Without some form of quality control all the lessons learned in phase one are useless. This inprocess gauging will consist of touch probing for the NC machines, and associated software.

Statistical feedback will consist of software that will analyze input from the inprocess gauging, monitor the machine tool, and operator input. From this feedback information will be gathered to determine proper machine usage, machine reliability, tool usage, and other pertinent information needed to improve a manufacturing process.

2. SEMINARS

FTD has been giving lectures and seminars locally and throughout the United States and at the Regional Manufacturing Technology Centers. During the next few years there will be a need to continue this practice as it is difficult for NIST to spread the word from within its own walls. It is difficult for most of the small shops that we are targeting, the ones that need our help the most, to travel to us, so we must go to them.

3. TRAINING

Training is still the number one priority within FTD. The fabrication Technology Division still has machinists within the shop that need training on how to work with the new technology. During the next few years the amount of training will increase two-fold over the past three years.

4. APPROACH

FTD will adapt the latest technology to the skills of the trades craftsman. These technologies will come from existing NIST projects and industrial partners and be tailored to the small machine shop.

At the shop floor level there are knowledge gaps in the following areas that need to be addressed and standardized:

- A lack of basic machine tool metrology information directed at a level that can be easily understood by craftsmen.

- A lack of strategies for implementing effective in-process inspection while the part is still fixtured on the machine.

Solution: Develop and implement a process using technology and information received from NIST's Quality In Automation project. This process will be used to design and build software and hardware that will allow for in-process metrology using the NC machine in the quality control and inspection phases of manufacturing.

- A lack of suitable interface programs for running and exchanging data between multi-software packages.

Solution: Develop and implement a process using technology from the Product Data Exchange Standard and Computer Aided Logistics System projects that will allow for the exchange of part file and NC programming information within the personal computer based software environment. This will allow for the exchange of information between large and small manufacturers.

- A lack of readily accessible data-bases on machine tools and machining capabilities.

Solution: Along with industrial partners and information from the Automated Manufacturing Research Facility project develop a process that allows the small shops to take advantage of Group Technology and Machining Technology.

- A lack of a knowledge-base for evaluating the performance of machine tools.

Solution: Using information, derived from the Quality in Automation project, develop a method for evaluating the performance of machine tools within small machine shops.

- A lack of a suitable linkage for data exchange between CACE, CAD and CAM systems and programs.

Solution: Along with industrial partners, and using information and methods derived from the Automated Manufacturing Research Facility, develop methods and processes for creating an automated manufacturing environment that has its focus on the small machine shop.

VII. PROGRAMS FOR ADVANCED MANUFACTURING (FEDERAL, STATE, AND LOCAL)

Following is a list of Federal, State, and local Government contacts. This list was submitted to the SoN project by the Small Business Administration (SBA). The contacts on this list have programs either fashioned after or similar to SoN. For further help or information contact them directly.

A. FEDERAL PROGRAMS FOR ADVANCED MANUFACTURING

Department of Commerce

SHOP OF THE 90'S

The Shop of the 90's program is designed to help small machine shops upgrade their manufacturing capabilities. The program uses off-the-shelf software and hardware packages in combination with personal computers.

Contact: Mr. Adrian Moll, Chief
Fabrication Technology Division
National Institute of Standards and Technology
Building 304, Room 136
Gaithersburg, Maryland 20899
(301) 975-6504

Automated Manufacturing Research Facility (AMRF)

The AMRF offers a basic array of manufacturing equipment and systems as a "test-bed" that researchers from NIST, industrial firms, universities, and other government agencies can use to experiment with new standards and to study new methods of measurement and quality control for automated factories. While this facility may be beyond the needs of most small firms it does provide basic research and techniques which small firms will find useful in the future.

Contact: Dr. Phillip Nanzetta
AMRF Project Manager
National Institute of Standards and Technology
Building 220, Room B124
Gaithersburg, Maryland 20899
(301) 975-3414

Clearinghouse for State and Local Initiatives on Productivity, Technology, and Innovation.

The 1988 Trade Bill established the Clearinghouse for State and Local Initiatives on Productivity, Technology, and Innovation in the Department of Commerce's Office of Technology Commercialization.

Contact: Dr. Elizabeth Robertson
Clearinghouse for State and Local Initiatives on Productivity, Technology, and Innovation
Technology Administration
U.S. Department of Commerce
Room 4418
14th and Pennsylvania Avenue, NW
Washington, DC 20230
(202) 377-0825

Interagency Working Group on Advanced Manufacturing

This working group was established to coordinate federal efforts on advanced manufacturing.

Contact: Mr. Ted Lettes
Director
Advanced Manufacturing
Office of Technology Commercialization
14th and Constitution Avenue, NW
Room 4418
Washington, DC 20230
(202) 377-8111

Department of Defense

Manufacturing Technology Program

The Manufacturing Technology Program (also called the ManTech Program) is a decentralized program administered by the services and the Defense Logistics Agency to encourage firms to use efficient means to produce products for defense.

Contact: Dr. Loyd Lehn
(703) 694-4783

Industrial Modernization Incentives Program

The Industrial Modernization Incentives Program (IMIP) motivates industry to make investments that enhance productivity, and improve product quality and reliability, through implementation of new or improved manufacturing technology.

Contact: James W. Woodford, Director
Industrial Modernization and Technology Implementation
OASD (PR)
Pentagon, Room 3B253
Washington, DC 20301
(703) 695-0292

Army:
Stephen French
HQDA SARD-ER
Pentagon, Room 2E673
Washington, DC 20310-0103
(703) 697-2615

Navy:
Steve Linder
OASN (R, D&A) PI-PA
Washington, DC 20360
(703) 602-1505

Air Force:
Major Bob Hartzell
SAF/AQXM
Pentagon, Room 4C283
Washington, DC 20330-1000
(703) 695-3235

Defense Logistics Agency:
Don Obrien
DLA-PR
Cameron Station
Alexandria, Virginia 22304-6100
(703) 274-6445

Computer-aided Acquisition and Logistics Program

One of DoD's data automation efforts to make the job of creating, controlling, and storing data more efficiently is the Computer-aided Acquisition and Logistics (CALS) program.

Contact: Dr. Mike McGrath
OASD (P&L), DASD(S) CALS
Pentagon, Room 2B322
Washington, DC 20301-8000
(202) 697-0051

Department of Energy

Advanced Manufacturing Initiative

The Department of Energy's (DoE) Advanced Manufacturing Initiative (AMI) is a pivotal element of the Defense Program's Technology Transfer Initiative. The AMI forges an alliance between DoE's defense programs, the defense complex's, and the United States manufacturing industry that will advance the manufacturing capabilities of both defense programs and United States industry.

Specialty Metals Processing Consortium

The DoE has also established the Specialty Metals Processing Program to perform unclassified research to advance the state of the art in this critical field. This program will provide hands-on training for interns and/or university graduate students through project research.

Contact: John Hnatio
Defense Programs
Technology Transfer
Department of Energy
Washington, DC 20585
(202) 586-8446

Industrial Technologies Program

The Industrial Technologies Program has several different energy-oriented components which focus on energy efficient processes and big energy production or savings opportunities.

Contact: Charles J. Glasser
Implementation and Development Division CE-223
Office of Waste REduction
Conservation and Renewable Energy
U.S. Department of Energy
Washington, DC 20585
(202) 586-1298

National Aeronautics and Space Administration

Industrial Applications Centers

The National Aeronautics and Space Administration (NASA) has established several industrial applications centers across the country. These centers have access to many types of databases and may offer other types of assistance, such as productivity analysis.

Contact: Mr. Leonard Ault
Office of Commercial Programs
Technology Utilization Division
National Aeronautics and Space Administration
Main Transportation Building
400 7th Street, SW
Room 5415
Washington, DC 20024

B. STATE AND LOCAL PROGRAMS FOR ADVANCED MANUFACTURING

Alabama

Industrial Modernization Program

The Industrial Modernization Program is designed to facilitate the prompt implementation of new technology by Alabama industries.

Industrial Modernization Program
Alabama Research Institute
Alabama Department of Economic and Commercial Affairs
3465 Norman Bridge Road
Montgomery, Alabama 36130
Contact: Mr. Mark Worsham
(205) 263-0048

Alabama Research Institute

The Alabama Research Institute provides research grants to institutes, colleges, universities, and individual faculty members to pursue both basic and applied research.

Institutional Challenge Grants/Research Project Grants
Alabama Research Institute
Alabama Department of Economic and Commercial Affairs
3465 Norman Bridge Road
Montgomery, Alabama 36130
Contact: Mr. Mark Worsham
(205) 263-0048

Arkansas

Center for Technology Transfer

The Center for Technology Transfer includes a Center for Robotics and Automation, a Productivity Center, and a Center for Interactive Technology.

Center for Technology Transfer
College of Engineering
University of Arkansas at Fayetteville
Engineering Research Center, Room 49
Fayetteville, Arkansas 72701
Contact: Mr. William H. Rader
(501) 575-3747

California

California Aerospace Supplier Improvement Program

The California Aerospace Supplier Improvement Program will develop a curriculum focusing on the various principles of Total Quality Management (TQM), including innovations such as computer-aided manufacturing, "just-in-time" procurement, and team work and communication skills.

California Aerospace Supplier Improvement Program
California Department of Commerce
1121 L Street, Suite 600
Sacramento, California 95814
Contact: Mr. Warren Rashleigh
(916) 324-8213

California Competitive Technology Program

The California Competitive Technology Program assists California companies to commercialize technology developed in public, non-profit research institutions.

Competitive Technology Program
California Office of Competitive Technology
200 East Del Mar Avenue
Suite 204
Pasadena, California 91105
Contact: Dr. Thomas L. Walters
(916) 324-5853

Florida

Florida High Technology and Industry Council

The Florida High Technology and Industry Council brings into focus issues of importance to high-technology communities, identifies solutions, and provides accountability; focuses the resources of the private business community in the identification and resolution of issues; and, involves the private business community in the identification and resolution of issues.

Applied Research Grants Program
Florida High Technology and Industry Council
Collins Building, Room 501A
107 West Gaines Street
Tallahassee, Florida 32399-2000
Contact: Ray Iannucci
(904) 487-3134

Georgia

Georgia Research Consortium

The Georgia Research Consortium is a state program to fund university research initiatives that have potential for stimulating high technology development.

Centers of Excellence
Georgia Research Consortium
Office of the Governor
State Capitol
Atlanta, Georgia 30334
Contact: Mr. Tom Lewis
(404) 656-6870

Indiana

Indiana Corporation for Science and Technology

The Indiana Corporation for Science and Technology is a partnership of businesses, government, and universities. The major thrust of the CST funding program supports Indiana's small and medium sized manufacturing and business communities, largely by providing research and development funds.

Applied Research Grants
Indiana Corporation for Science and Technology
One North Capital Avenue
Suite 925
Indianapolis, Indiana 46204
Contact: Delbert Schuh II
(317) 635-3058

Technical Assistance Program, Purdue University

The Technical Assistance Program was established in 1986 with the mission of helping Indiana business, industry, and government institutions adopt appropriate technologies for the improvement of their operations.

Technical Assistance Program
Purdue University
Civil Engineering Building, Room G175
W. Lafayette, Indiana 47907
Contact: Dr. Ben M. Hillberry
(317) 494-6258

Kansas

Center for Research in Computer Controlled Automation

The Center focuses on research in the area of automated design and manufacturing systems.

Center for Research in Computer Controlled Automation
Durand Hall #302
Kansas State University
Manhattan, Kansas 66506
Contact: Dr. John Ulrich
(913) 532-5617

Kansas Technology Enterprise Corporation

KTEC provides grants to academic/business partnerships for the purpose of stimulating technological innovation.

Applied Research Matching Grant Program
Kansas Technology Enterprise Corporation
112 West 6th Street, Suite 400
Topeka, Kansas 66603
Contact: Dr. William Brundage
(913) 296-5272

Institute for Aviation Research

The Institute was created in response to the research and advanced technology requirements of the aviation industry.

Institute for Aviation Research
Wichita State University
Campus Box 146
Wichita, Kansas 67208
Contact: Dr. W. H. Wentz, Jr.
(316) 689-3525

Kentucky

Center for Robotics and Manufacturing Systems

The Center for Robotics and Manufacturing Systems conducts manufacturing related research; provides technical assistance to state manufacturers; and establishes curriculum in manufacturing systems engineering.

Center for Robotics and Manufacturing Systems
Breckenridge Hall
University of Kentucky
Lexington, Kentucky 40506
Contact: Mr. William A. Gruver
(606) 257-6262

Massachusetts

Center for Applied Technology

The Center for Applied Technology, part of the Massachusetts Centers of Excellence, is devoted to improving the transfer and utilization of new technology in small and medium-sized manufacturing firms.

Center for Applied Technology
Massachusetts Centers of Excellence Corporation
9 Park Street
Boston, Massachusetts 02108
Contact: Mr. Frank Emspak
(617) 727-7430

Research Grants/Massachusetts Centers of Excellence Corporation

The Massachusetts Centers of Excellence Corporation promotes new technologies or new applications of existing technologies, through partnerships among academia, industry, and government.

Research Grants
Massachusetts Centers of Excellence Corporation
9 Park Street
Boston, Massachusetts 02108
Contact: Ms. Megan Jones
(617) 727-7430

Maryland

Technology Initiatives Program

The Technology Initiatives Program (TIP) supports technology efforts at the University of Maryland by augmenting or creating capabilities which are important to industrial interaction.

Technology Initiatives Program
Wind Tunnel Building, Room 2104
University of Maryland
College Park, Maryland 20742
Contact: Mr. David Barbe
(301) 405-3902

Michigan

Industrial Technology Institute

The Industrial Technology Institute (ITI) seeks to enhance the productivity and competitiveness of Michigan's industry through coordinated programs of R & D, computer integration, and implementation.

Industrial Technology Institute
P. O. Box 1485
Ann Arbor, Michigan 48106
Contact: Mr. George Kuper
(313) 769-4000

Technology Deployment Service

The Technology Deployment Service assists small and medium sized firms considering the adoption of new, computer based technology. It can provide its clients with the following services at no cost: a structured review of firm operations and technology, a site visit and written technology assessment by a field representative who has a background in private industry and manufacturing technology, and technical assistance in designing a customized labor training program to support implementation of new technology.

Technology Deployment Service
Michigan Modernization Service
Industrial Technology Institute
2901 Hubbard
Ann Arbor, Michigan 48109
Contact: Mr. John Cleveland
(313) 769-4664

Michigan Modernization Service

The Michigan Modernization Service provides direct, customized, consultation to small and medium sized manufacturers in the areas of technology deployment, work force development, and market analysis.

Michigan Modernization Service
Michigan Department of Commerce
106 West Allegan Street, Suite 212
Lansing, Michigan 48913
Contact: Mr. John Cleveland
(517) 373-7411

Product Development Program

The Product Development Program enables the Michigan Strategic Fund (MSF) to finance the commercialization of promising new products in return for royalty rights. Funds are available to small, under financed companies which have developed product prototypes.

Product Development Program
Michigan Strategic Fund
Michigan Department of Commerce
P. O. Box 30234
Lansing, Michigan 48909
Contact: Mr. Peter Plastrik
(517) 373-7550

Research Excellence Fund

The Research Excellence Fund provides funds to academic researchers at the state's public universities to conduct basic and applied research.

Research Excellence Fund
Michigan Strategic Fund
P. O. Box 30234
Lansing, Michigan 48909
Contact: Dr. Jamie Kenworthy
(517) 373-7550

Workforce Development Group

The Workforce Development Group is a joint effort between the Governor's Office for Job Training and the Michigan Modernization Service. It provides, not only customized training programs to clients, but also information and assistance in applying for grants from two funds specifically for assisting small manufacturing firms with their training strategies.

Workforce Development Group
Governor's Office for Job Training
201 North Washington Street
P. O. Box 30039
Lansing, Michigan 48933

<u>Minnesota</u>

Minnesota Manufacturing Assessment Program

A division of Minnesota Advanced Manufacturing Technology Centers, this program was established to provide manufacturers with appropriate advice and information regarding those manufacturing technologies and techniques which can cost-effectively improve their operations.

Minnesota Manufacturing Assessment Program
Advanced Manufacturing Technology Centers
511 11th Avenue
Suite 216
Minneapolis, Minnesota 55415
Contact: Mr. Bruce Hardman
(612) 338-7722

Minnesota Manufacturing Institute

The Minnesota Manufacturing Institute serves as MAMTC's manufacturing technology center at the Minneapolis Business Technology Center in the Minneapolis Technology Corridor. A full time technical staff provides technology needs assessment and assistance, develops pilot projects, and undertakes proprietary cooperative applied research and development under contract with industry.

Minnesota Manufacturing Institute
Minnesota Advanced Manufacturing Technology Centers
P. O. Box 1148
Minneapolis, Minnesota 55458
Contact: Mr. Bruce Hardman
(612) 332-7883

The Productivity Center/Office of Research & Technology Transfer

The Productivity Center provides a focus for research and education in advanced manufacturing technologies and productivity.

The Productivity Center
Office of Research and Technology Transfer
University of Minnesota
1919 University Avenue
St. Paul, Minnesota 55104
Contact: Dr. Tony Potami
(612) 624-1648

<u>Missouri</u>

Centers for Advanced Technology

The Centers for Advanced Technology program encourages the interaction of Missouri's academic, business, and industrial communities to develop and commercialize new technologies.

Centers for Advanced Technology
Missouri Corporation for Science and Technology
P. O. Box 118
Jefferson City, Missouri 65102
Contact: Mr. Gary Taylor
(314) 751-3906

Missouri Enterprise Business Assistance Center

This center has made application of existing technology a primary objective.

Missouri Enterprise Business Assistance Center
Missouri IncuTech Foundation
800 West 14th Street
Rolla, Missouri 65401
Contact: Mr. Dennis Roedemeier

<u>**New Jersey**</u>

Center for Manufacturing Engineering Systems

This center seeks to advance the science and practice of manufacturing engineering by means of research in that discipline, primarily collaborative research with industry and also through technology extension services.

Center for Manufacturing Engineering Systems
New Jersey Institute of Technology
323 Dr. Martin Luther King Boulevard
Newark, New Jersey 07102
Contact: Dr. Michael Pappas
(201) 596-3338

Center for Computer Aids for Industrial Productivity

This center conducts applied research, conducted in close liaison with industry, through educational programs that facilitate technology transfer between the research community and industrial organizations.

Center for Computer Aids for Industrial Productivity
Rutgers University
P. O. Box 1390
Piscataway, New Jersey 08855
Contact: Dr. Herbert Freeman
(201) 932-4208

Ohio

Edison Industrial Systems Center

The Industrial Systems Center is trying to meld engineering technologies with business systems to achieve large scale systems integration.

Edison Industrial Systems Center
1700 N. Westwood Avenue
Suite 2286
Toledo, Ohio 43607-1207
Contact: Mr. Charles G. Depew
(419) 531-8610

Edison Materials Technology Center

This center is a consortium of industrial, academic, government, and civic members; headquartered at the Miami Valley Research Park. The center works closely with nine universities and five major government laboratories. Through the combined strength of its members, it applies expertise to solve problems defined by industry.

Edison Materials Technology Center
3171 Research Boulevard
Kettering, Ohio 45420
Contact: Ernest Moore
(513) 259-1365

Institute of Advanced Manufacturing Sciences

The Institute concentrates on improving manufacturing quality, productivity, and innovation.

Institute of Advanced Manufacturing Sciences
3220 Forrer Street
Cincinnati, Ohio 45209
Contact: Mr. Charles F. Carter, Jr.
(513) 841-8803

Edison Technology Centers

There are eight Edison Technology Centers performing research, technology transfer, and education and training. The centers give member companies, large and small, access to university and special R&D capabilities, technical consulting, training, and education programs, and forums for sharing problems and ideas.

Edison Technology Centers
Thomas Edison Program
77 South High Street
26th Floor
Columbus, Ohio 43266
Contact: Mr. Christopher Coburn
(614) 466-3086

Oklahoma

Center of Excellence/Oklahoma Center for the Advancement of S&T

The Oklahoma Center for the Advancement of S&T has developed three centers: the Center of Excellence in Molecular Medicine, the Center for Integrated Design and Manufacturing, and the Center for Laser Development and Applications.

Center of Excellence
Oklahoma Center for the Advancement of S&T
205 N.W. 63rd
Suite 305
Oklahoma City, Oklahoma 73116-8209
Contact: Dr. Carolyn Smith
(405) 848-2633

Tennessee

Center for Industrial Services

The Center provides technical and managerial assistance to existing manufacturers in Tennessee.

Center for Industrial Services
The University of Tennessee
226 Capitol Boulevard Building
Suite 401
Nashville, Tennessee 37219
Contact: Mr. T. C. Parsons
(615) 242-2456

Tennessee Technological University

One of 27 Research Centers for Excellence, a program of the Tennessee Higher Education Commission, this center for manufacturing research helps industry utilize rapidly developing technologies.

Tennessee Technological University
P. O. Box 5007
Cookeville, Tennessee 38505
Contact: Angelo Volpe
(615) 372-3241

Texas

Advanced Technology Program

The Advanced Technology Program is a competitive grant program in science and engineering for university faculty in public and private higher education institutions.

Advanced Technology Program
Texas Higher Education Coordinating Board
P. O. Box 12788
Austin, Texas 78711
Contact: Mr. Roger Elliott
(512) 483-6150

Utah

Centers of Excellence Program/Utah Centers of Excellence

The Centers of Excellence Program provides state funds for research and development based at Utah universities.

Centers of Excellence Program
Utah Centers of Excellence
Utah Department of Community & Economic Development
324 South State, Suite 200
Salt Lake City, Utah 84111
Contact: Mr. G. Michael Alder
(801) 538-8770

Washington

The Washington Technology Center

The Washington Technology Center is the statewide industry-university program for commercially promising research and technology development. Center programs include: (1) Technology Transfer Program; (2) Research Centers (seven) with offices and laboratories at the University of Washington, Washington State University, and Tri-Cities University Center; (3) the Industry Fellow and Industry Associate Programs; and (4) the Technology Assistance Program of the WTC.

The Washington Technology Center
376 Leow Hall, FH-10
University of Washington Campus Office
Seattle, Washington 98195
Contact: Dr. Edwin B. Stear
(206) 546-1920

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