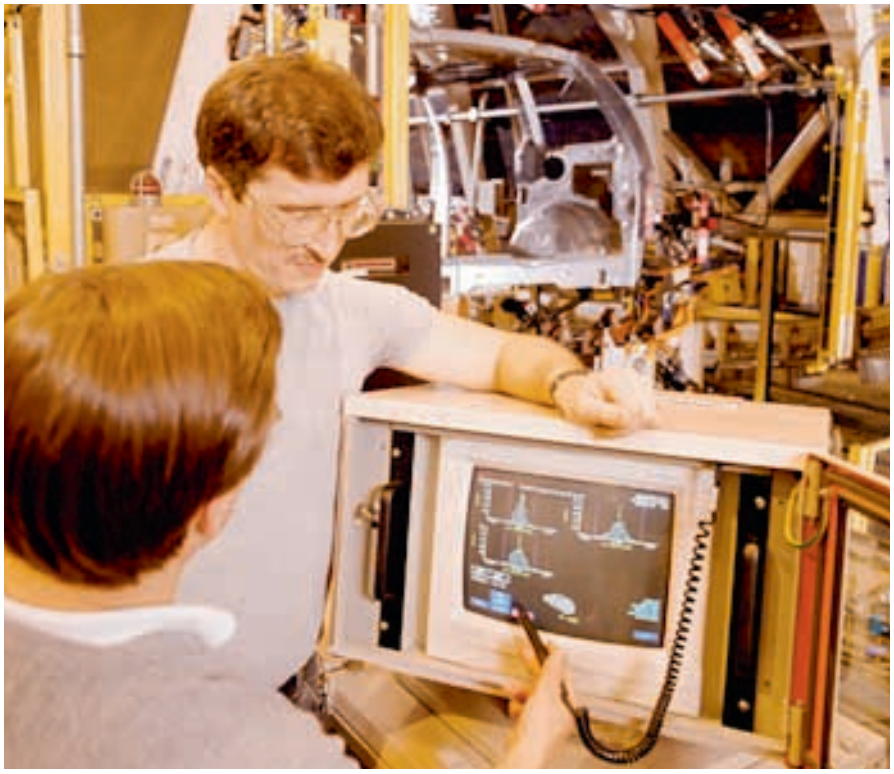
Chapter 4

Discrete Manufacturing

Auto Body Consortium (Joint Venture, formerly 2mm Auto Body Consortium)

A Systems Solution to a Quality Problem in Auto Body Manufacturing

Just a few millimeters make a big difference on an automated assembly line as doors, hood, windshield, wheel housings and other parts are installed on a body-in-white (BIW), the partially completed body of an automobile. If BIW openings are slightly off kilter or parts vary much from specifications, the overall fit and finish of the completed car suffers. When dimensions vary more radically, a BIW may have to be custom-assembled by hand. In addition, if the variations grow too large, the entire BIW may be pulled from the assembly line and junked.



Assembly plant staff members monitor operations using real-time analysis tools developed in the ATP project.

Toward a Tightly Fitted Car Body

In contrast, a tightly fitted car means fewer defects, less time and money for factory repairs, better appearance and performance for the owner, and lower long-term maintenance costs. And the quicker assembly-line changeovers can be made while retaining tightness of fit, the faster new models can be introduced at reasonable cost.

A U.S. Problem Overcome

The problem of "dimensional variation" has cost the U.S. automotive industry dearly in product quality, wasted materials, increased production time and lost sales. While European auto makers were building cars with dimensional variations less than 2.5 mm and Japanese manufacturers were achieving results at or below 2 mm, U.S. producers were assembling cars with as much as 5- or 6-mm variation. But with completion of ATP's "2mm Project" in 1995, American auto makers have shown a marked increase in their ability to assemble cars with world-class precision. In all five Chrysler and General Motors (GM) auto assembly plants where the new methods were tested, overall dimensional variation was brought down to, or below, the 2 mm standard. In addition, other technologies developed by the project have yet to reach the assembly line, and their full implementation in auto body plants promises to reduce dimensional variation even further.

The project has published a manual for use in extending the procedures developed during the project.

Lower Production Costs

With an investment of $4.9 million from the ATP and $9 million from the automobile industry, the 2mm Project developed a number of interrelated technologies and processes that have already cut net production costs (actual costs less the cost of implementing 2mm technologies) by $10 to $25 per vehicle in plants where they have been tested.[1] When full

PROJECT:

To develop improved measurement technology and process control needed to achieve tighter fit — as well as better quality and lower costs — in auto bodies and other products assembled from sheet metal parts.

Duration: 9/1/1992 — 10/31/1995
ATP number: 91-01-0177

FUNDING (IN THOUSANDS):

ATP	$4,487	43%
Companies	6,048	57%
Total	$10,535	

ACCOMPLISHMENTS:

The project achieved the R&D goal of developing measurement and process control technology, which participating companies verified in several in-plant tests. Widespread adoption of the technology is now underway in auto assembly plants. Indicative of progress, the companies:

- cut dimensional variation in auto body assembly to a world-class standard of 2 mm or less and demonstrated the reduction with existing workforces in all five plants initially targeted by the project;
- reduced production costs by $10 to $25 per vehicle at two plants initially adopting the technology, savings that are expected, according to consortium staff, to be applied eventually in plants which produce all 6.5 million cars and light trucks produced annually by Chrysler and General Motors;
- reduced expected future maintenance costs by an estimated $50-$100 per vehicle;
- published several papers in professional journals;
- published *The Capture and Communication of Knowledge: A Lessons-Learned Approach*, a manual that will speed the adoption of the technologies and processes developed during the ATP project by showing how to implement them;
- worked with the University of Michigan to begin transferring the technology to other GM and Chrysler assembly plants beyond the original five, implementing it thus far in 22 plants in the United States and Canada;
- generated via ISI Automation Group (formerly ISI Robotics) the spin-off development of a new type of clamp, called the SofTouch, for holding sheet metal parts during assembly; and
- provided member auto assembly companies a "quality" peg on which to hang marketing literature — Chrysler highlights the fact that its new Concorde "literally has a two-millimeter body."

COMMERCIALIZATION STATUS:

Some supplier companies have incorporated the new measurement and process technology in assembly line equipment, and the new approach to tighter fit has been put into use in six of 10 Chrysler plants and 16 of 31 GM plants in the United States and Canada. Net production cost reductions of $10 to $25 per vehicle are estimated to have already been achieved using the new approach, meaning millions of dollars saved per year. Higher-quality vehicles from these plants are becoming available to consumers, and U.S. manufacturers are expected to increase their market share.

OUTLOOK:

Because the technology is being used and being systematically transferred to additional plants, the outlook is excellent. It is now being transferred to all Chrysler and GM plants, and through the supply chain, to Ford Motor Company. The technology is expected also to be adopted or adapted for use by other discrete manufacturers in, for example, the appliance and furniture industries. Auto assembly companies that adopt this new technology can expect to save hundreds of millions of dollars annually in production and maintenance costs. Consumers will benefit from higher-quality vehicles and will likely see some of the manufacturing cost savings. Producers and consumers are expected to benefit from yearly savings of up to $650 million in auto maintenance costs. Quality improvements resulting from the project have been projected to boost U.S. industrial output by the automotive and related industries by more than $3 billion in the year 2000 and to create thousands of new jobs. To the extent the quality improvements extend to other manufacturing industries, the output and employment effects will be even greater.

COMPANIES:

Auto Body Consortium (joint venture lead; formerly 2mm Auto Body Consortium)
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Joint venture participants: CDI-Modern Engineering; Classic Design, Inc.; Detroit Center Tool, Inc.; ISI Robotics; Perceptron, Inc.; Pioneer Engineering & Manufacturing; Progressive Tool & Industries, Inc.; Weber Technologies, LLC; Chrysler Corporation; General Motors Corporation (GM), Technical Center; University of Michigan, Mechanical Engineering and Applied Mechanics.

Subcontractor: Wayne State University

adoption by all GM and Chrysler assembly plants is achieved — probably by the year 2000 — annual production cost savings are projected in the range of $65 million to $160 million on the current production volume of 6.5 million vehicles, which amounts to 48 percent of the cars and light trucks sold in the United States. Some of the cost savings are likely to be passed on to consumers as a result of competition among U.S. and foreign producers in the new vehicle market in the United States.

ATP's financial contribution helped small- and medium-supplier companies pay for an expanded university effort while large assemblers provided most of the industry cost share, which covered their own expenses and joint venture overhead.

Less Maintenance, Faster Launch

Cars and trucks built with 2mm Project innovations should also cost less to maintain as better body fit results in reduced wear, less rust and fewer other problems. These savings are estimated to range from $50 to $100 per vehicle over its useful lifetime. Several years after GM and Chrysler have fully implemented the 2mm Project results, total maintenance savings are expected to reach $325 million to $650 million per year based on current production volume. And, although a dollar value has not yet been estimated, the new technology is expected to decrease the time required to launch new auto models.

Higher Quality and Lower Costs Mean Increased Market Share and Jobs

In addition, assuming the 2mm Project quality and cost improvements lead to at least a 1 percent increase in market share for GM and Chrysler (at the expense of vehicles built abroad), economic projections show an overall increase in U.S. economic output in the year 2000 of more than $3 billion and the creation of around 70,000 new jobs. These estimates take into account the impact of an increase in vehicle sales on related sectors, but they do not include any increases due to adoption of 2mm technologies by companies outside the auto industry.

Collaborative Research to Solve a Complex Systems Problem

The 2mm Project was initiated by the Auto Body Consortium (eight small- and medium-size companies that provide tooling and engineering services for auto body assembly lines), two big auto manufacturers (Chrysler and General Motors) and two universities, one a joint venture partner, and the other a subcontractor. The joint venture treated BIW dimensional variation as a systems problem, selecting 11 subprojects, or tasks, to be accomplished in four general areas. Separate task groups, with staff from various joint venture members, worked on each subproject. After the operational tasks were completed, the final task of the 2mm Project was to synthesize the information, processes and lessons learned from the research and incorporate the results into a user-friendly database to help companies adopt the new technologies and methodologies

The computer display for one of the many diagnostic procedures provided by the new dimension control system.

and establish an infrastructure for future improvements.

The 2mm Project would have been difficult to achieve without the involvement of the ATP for several reasons. Dimensional variation in auto body production is a systems problem that could not have been solved by any one of the 11 project members alone. The ATP encourages formation of joint ventures like the Auto Body Consortium to solve complex systems problems. The public/private partnership was helpful in the face of a long history of federal antitrust enforcement that has left auto makers fearful of cooperating with each other without federal government involvement. Assembly line suppliers are generally small- or medium-size companies without research budgets large enough to fund work of the type undertaken by the 2mm Project, and auto makers have been reluctant to fund research by their suppliers. The fact that development risks were unevenly born by consortium member firms was another obstacle that ATP participation helped to overcome.

ATP's participation in the 2mm Project proved critical to the formation of this research joint venture. The ATP provided the catalyst needed to overcome multiple barriers. ATP's financial contribution helped small- and medium-supplier companies pay for an expanded university effort while large assemblers provided most of the industry cost share, to cover their own expenses and joint venture overhead.

The 2mm Project shows how small- and medium-size supply companies, large auto producers, and universities were able to cooperate in the development of an integrated system to reduce dimensional variation in body assembly and to improve the quality of the final product. It also demonstrates the unique role that comparatively modest investments of money and leadership by ATP can play in catalyzing complex, cooperative research ventures that pay off handsomely in technological and economic returns.

Widespread Adoption Underway in Auto Plants

The new approach to tighter dimensional fit has been put into use in six of 10 Chrysler plants and 16 of 31 GM plants in the U.S. and Canada, and it is being transferred to the remaining GM and Chrysler plants and to Ford Motor Company through the supplier chain.

. . . organized meetings to share results with interested people from the aerospace, appliance and metal furniture industries, as well as other industries that use automation to assemble metal parts.

HelpMate Robotics, Inc. (formerly Transitions Research Corporation)

Robot Navigation Technology

Robots are frequently seen as exotic, make-believe objects in science fiction movies. They walk, talk, crack jokes and worry about whether they are human or have souls. Real robots are much more mundane, but they are becoming increasingly useful in industry. They do work too tedious or dangerous for humans, enduring tedium without erring and danger without harm. They paint cars in factories without needing protective masks. They transport radioactive materials in power plants without suffering from radiation.

Using Robot Technology for Deliveries in Hospitals

Robots are also delivering medicines in hospitals faster and more reliably than humans can. "Do you really see hospitals and nursing homes starting to use that kind of technology?" an interviewer asked Paul Hoffman of *Discover* magazine after he demonstrated robot technology on CBS Good Morning America in May 1996. Replied Hoffman: "They do. This company, HelpMate Robotics in Danbury, is already using it in hospitals, right now."

Improved Navigation Capabilities

HelpMate Robotics, using ATP funds, has indeed developed the navigational technology needed to create mobile robots that can scurry around a hospital or other industrial environment. And with other funding, it has built them. This advance, set on the technical foundations laid by robotics pioneer and company CEO Joseph Engelberger, has helped to expand the use of mobile robots throughout the country.

These robots do some of the ambulatory work traditionally done by humans. To work well, the robots must have dependable vision systems that can use light from many different sources and recognize light-shading differences. They have to be trainable (programmable). They must make quasi-intelligent decisions — "Go around the gurney with the patient on it." And they have to be able to report to their human supervisor and ask for help when encountering problems they cannot handle — "There is no one here to sign for the parts."

Specifically, HelpMate researchers successfully developed an improved light direction and range (LIDAR) scanner. LIDAR is a device in the "eyes" of the robot that senses light, calculates direction and determines the range to objects in its path. This is a clear advance over previous technology, which used sonar to detect shapes. Researchers also developed navigation capabilities based on new sensing systems and ways of combining data from different sensors. These capabilities permit the control of robots in quasi-structured environments — places with predefined components such as doorways, light fixtures, windows and elevators that are fixed in place and definable from photos or engineering drawings — and among objects that are not predefined, such as a patient on a gurney and human workers moving about the space.

They do work too tedious or dangerous for humans, enduring tedium without erring and danger without harm.

Drugs are loaded on the HelpMate robot by a hospital pharmacist for delivery to staff in one of the hospital's wards.

HelpMate in Hospitals

Most of the ATP-funded technology has been embedded in the hospital version of the HelpMate robot. More than 150 HelpMate robots have been rented by scores of hospitals in Europe, Japan, Canada and the United States. Purchased outright, the robots cost about $110,000. Most are rented for $4 to $6 an hour. If a robot is used 100 hours a week, the annual rental fee is about $25,000.

HelpMate Robots are delivering medicines, supplies, prepared food, x-ray images and other material in about 100 hospitals in the United States and Canada.

Marketing Agreements for Distribution Abroad

Company officials say that ATP funding enabled HelpMate to achieve its research and development results much sooner than it would otherwise have been able to do. The award also helped it develop strategic marketing arrangements abroad. The company has signed an agreement for Otis Elevator to distribute HelpMate hospital robots exclusively in Europe. It has also developed marketing arrangements with other parties in Europe and Japan.

HelpMate raised $6 million through an initial public stock offering in 1996 and used the money to build production and sales capabilities. A second offering of $5 million did not go through, and the company had to downsize temporarily. New funding, however, has been committed, which should enable rebuilding of staff and marketing, as well as further work on a home-service version of the robot. In addition, the population of HelpMate robots in the field continues to serve well and will back up the company's renewed sales effort.

PROJECT:

To develop the technology for intelligent, autonomous mobile robots, or "robot carts," that can find their way around a factory, hospital or similar place by sensing and avoiding obstacles and taking alternative routes if a path is blocked. Such robots could reduce costs for delivering materials and supplies in many different environments.

Duration: 6/15/1992 — 3/31/1994
ATP number: 91-01-0034

FUNDING (IN THOUSANDS):

ATP	$699	44%
Company	875	56%
Total	$1,574	

ACCOMPLISHMENTS:

The company achieved the target navigation capabilities, including successful development of a specialized LIDAR (light direction and range) scanner. Evidence of progress includes the following:

- The company incorporated the new navigation capabilities into its original HelpMate robot and is now producing and selling the upgraded version.
- HelpMate raised $6 million through an initial public stock offering in 1996, and used it to build production and sales capabilities. (A second offering did not go through, and the company temporarily downsized in 1997. New funding commitments are expected to rebuild staff and marketing.)
- The upgraded HelpMate robot was named one of 36 finalists in the *Discover* magazine competition for technology of the year for 1996.
- CEO Joseph Engelberger, the principal investigator for the ATP project, received the Japan Prize in "systems engineering for an artifactual environment" in 1997 from the Science and Technology Foundation of Japan.
- The company and Otis Elevator entered into an alliance in which Otis is to be the exclusive distributor of HelpMate hospital robots in Europe.

COMMERCIALIZATION STATUS:

Robots incorporating the new navigational technology have been rented or sold to about 100 hospitals in the United States and Canada, and the company has entered marketing arrangements with parties in Europe and Japan.

OUTLOOK:

Since the robots are already in use commercially, the outlook for the technology is excellent, despite a temporary downsizing at HelpMate. The company now plans to expand the use of the technology by developing robots that can provide assistance in the home to infirm and elderly persons, a venture that potentially could save billions of dollars by eliminating some need for hospitalization or professional help in the home. Opportunities exist for applying these mobile robots in factories, warehouses and many other environments. Thus, the potential for future utilization of the technology is high.

COMPANY:

HelpMate Robotics, Inc.
(formerly Transitions Research Corporation)

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Number of employees:
27 at project start, 14 at the end of 1997

HelpMate plans to expand the use of the ATP-funded technology by developing robots that can assist infirm and elderly persons at home.

Benefits From Robots

Hospitals using HelpMate robots are benefiting. HelpMate Robots are delivering medicines, supplies, prepared food, x-ray images and other material in about 100 hospitals in the United States and Canada. They have lowered the cost and improved the quality of these delivery services. One hospital pharmacy director, for example, reported net annual savings of around $10,000 per robot per year. In addition, the robots made the deliveries faster than humans did. There are about 150 HelpMate robots in these hospitals, according to company officials. If the savings for each robot to the hospital is $5,000 to $10,000 per year, then these hospitals are already realizing an annual savings of $750,000 to $1.5 million. The cost savings at the 100 hospitals alone over 10 years would be in the millions. These are savings above the rental cost of the robots. As more hospitals, factories and other facilities adopt these robots, cost savings will multiply.

In addition to these cost savings, benefits accrue to hospitals, physicians and patients through improved delivery service. Not only is robot delivery faster than human delivery, but it is also frequently more reliable, according to hospital officials, because of fewer delivery mistakes.

Robots to Serve the Elderly and Infirm

The analysis above is only for robots already employed in hospitals. For in-home nursing services, the use of robots could generate much larger savings. HelpMate plans to expand the use of the ATP-funded technology by developing robots that can assist infirm and elderly persons at home. But for this application, the company must first solve additional technical problems. These robots must have highly functional arms, improved vision, more sophisticated programming and some speech recognition capabilities. The company has estimated that, if successful, this development could substantially reduce health care costs by eliminating some of the need to hospitalize or hire home help for the frail elderly.

Other Potential Uses

Two industrial applications currently being explored are in computer chip fabrication and clinical laboratory work. In clinical labs, vials containing substances, such as the human immunodeficiency virus, that are highly dangerous to human workers could be moved from one workstation to another by robot. In a chip fabrication plant, robots could move supplies to the fabrication line in response to specific orders from operators. For these applications to be realized, capital will have to be raised to support the additional engineering required to tailor robots to the specific needs of each environment. Lab robots, for example, will need to be built to work without bumping into delicate research instruments and materials, and chip-plant robots must be engineered to operate so cleanly they do not contaminate the superclean rooms where chips are fabricated.

In addition to these applications, company officials say, the ATP-funded technology is expected to be used for mobile robots in all kinds of factories and has potential applications in warehouses, maintenance facilities, mail distribution centers and shopping malls (for delivery, maintenance and cleaning services). As in hospitals, the use of robots in these environments is expected to lower costs substantially and improve service.

Two industrial applications currently being explored are in computer chip fabrication and clinical laboratory work.

PreAmp Consortium (Joint Venture)

New Models to Speed the Development of Electronics Components

Printed circuit boards are ubiquitous. Most people know that boards are in computers, and that each computer actually contains several boards. They are also found in televisions, VCRs and the hand-held controls for these devices, as well as in printers, airplanes, thermostats, automobiles, appliances, calculators, garage-door openers, industrial controls, communications satellites and numerous other devices.

Data Sharing Speeds Component Development

In this ATP project, the PreAmp consortium developed common parts identifiers (a standard "product model" for components) and fabrication procedures (a generic "manufacturing process model" for making components) that can be shared among producers and users of printed circuit boards and other electronics components all along the production chain. These models will enable true concurrent (simultaneous) engineering of component design and manufacturing processes, an arrangement that will reduce the cost of developing components, improve their quality and decrease their time-to-market. These improvements, in turn, will lead to similar improvements in finished electronics products that incorporate printed circuit boards and other components developed via this new technology.

PreAmp is a joint venture of the South Carolina Research Authority (SCRA) and four large companies that use printed circuit boards in their finished products. Funding from ATP enabled the consortium to conduct research that it otherwise would have been unable to do. It also facilitated the formation of alliances among the research partners, helping them to demonstrate technology-enhanced concurrent engineering concepts to industry.

These models will enable true concurrent (simultaneous) engineering of component design and manufacturing processes . . .

The research involved four major tasks: the design of software architecture for electronically sharing component specifics; the development of software prototypes; the implementation, analysis, evaluation and demonstration of a component database and access mechanism; and the refinement of the manufacturing capability database, its software architecture and manufacturing process planning.

Easier to Share Information

The PreAmp "product model" for electronics components was successfully developed. It is a complete standards-based, data-sharing framework for automating the design and manufacture of electronic components such as printed circuit boards. It is an extension to the electronics industry of STEP (Standard for Exchange of Product Model Data), an international standard that defines a standard product model for automation systems in order to facilitate the capture and use of all information relevant to product design and manufacture. This extension will speed the development of electronics components (and, ultimately, finished electronics products) by greatly easing the sharing of information among the engineers who design electronics components and those who design the processes for manufacturing these components.

In addition, the PreAmp generic model of manufacturing processes was designed to further aid manufacturing engineers by capturing all relevant data on the manufacturing capabilities of a particular plant, information such as shop-floor equipment capabilities, equipment layout, and operating requirements and limits. As part of this effort, researchers developed a knowledge-based software system that can extract process "rules" from the manufacturing process data — for example, "Given current equipment, interconnects may not be spaced closer than X." Such rules will improve the functioning of the system.

The combination of the full product and manufacturing models allows concurrent (simultaneous) engineering of component design, process design and component manufacturing. Studies cited by the consortium suggest the new technology can reduce time-to-market by 50 percent or more, double component quality levels and reduce development costs by 30 percent to 70 percent. The project's commercialization work is still underway, so it is not yet known whether these expectations will be matched by improvements in the quality of actual component design and manufacturing processes.

Initial Commercialization

Some of the technology developed by the PreAmp consortium has been adapted and incorporated in software tools by STEP Tools, Inc., an informal participant in the ATP project. STEP Tools developed a prototype STEP

PROJECT:

To develop a standards-based data-sharing framework for automating the design and manufacture of electronics components. The framework will enable true concurrent (simultaneous) engineering of component design and manufacturing, which will reduce the cost of developing components, increase their quality and decrease their time-to-market. Such improvements will lead to similar improvements in finished electronics products that incorporate these components.

Duration: 7/1/1992 — 7/31/1996
ATP number: 91-01-0267

FUNDING (IN THOUSANDS):

ATP	$5,166	37%
Consortium	8,625	63%
Total	$13,791	

ACCOMPLISHMENTS:

PreAmp successfully completed all technical goals, including development of a knowledge-based software system that can extract process "rules" from manufacturing process data. Other accomplishments include:

- STEP Tools, an informal participant in the project, developed prototype software to validate a standard data access interface library that has since become part of its ST-Developer product. ST-Developer has been distributed to more than 100 customers worldwide and is being used to build and maintain STEP (Standard for Exchange of Product Model Data) applications and databases.
- Researchers presented several papers at professional conferences, including the
  - Design and Automation Conference,
  - National Electronics Packaging Conference, and
  - Reliability in Agile Manufacturing Symposium.
- PreAmp hosted a "Vendor Opportunity Forum" to give software vendors opportunities to commercialize the technology developed by the project.

COMMERCIALIZATION STATUS:

A modest amount of commercialization is under way via the product introduced by STEP Tools, but the main commercial goals of the consortium have so far not been accomplished. Boeing is conducting a pilot project, and SCRA continues to develop the technology and promote commercialization.

OUTLOOK:

The core technology developed by the project may be commercialized in several years, after additional R&D work. Thus, there is some prospect of benefits to eventual users. If commercialization does occur, the spillover benefits could be large, since so much of the work of this project is in the development and promulgation of data-sharing standards.

COMPANIES:

PreAmp Consortium
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Other consortium members: Boeing Company, Defense & Space Group; Hughes Aircraft Company; Martin Marietta Corporation, Electronics Information & Missiles Group; and Rockwell International Corporation, Collins Avionics & Communication Division

Informal participants: Rensselaer Polytechnic Institute and STEP Tools, Inc.

data application interface for the project. Afterward, the company enhanced the prototype to make it suitable for commercial use and incorporated it in the ST-Developer™, an application that already has several hundred customers.

The principal "test-bed" implementation of the models developed during the ATP project was carried out by PreAmp members. Boeing is conducting a pilot project to determine whether it can use the new software technology in its internal operations to increase the productivity of printed circuit board design work. The company is working with an ATP-project subcontractor in developing software to translate existing database information to work in the new "product model" system. It will probably be known by 1999 whether the Boeing effort succeeds. If it does, the creation of commercial products will be much more likely.

Three members (Boeing, Hughes and Rockwell) have arranged with SCRA for it to serve as the PreAmp agent with vendors interested in creating commercial software systems that include the ATP-funded technology. Consortium members, with the help of SCRA, proposed the enhanced STEP procedures to the International Standards Organization for registration, which is expected to be issued as STEP Application Protocol 210.

Reorganization and company upheavals among consortium members, however, seem to be hindering further progress toward commercialization. Organizational energy has been siphoned off to deal with mergers and acquisitions. In addition, reductions in national defense work have caused turmoil in three of the four corporate members of the consortium that have been very active defense contractors. But if energy can be refocused on further developing the ATP-funded technology, it could be commercialized in several years.

Studies cited by the consortium suggest the new technology can reduce time-to-market by 50 percent or more, double component quality levels and reduce development costs by 30 percent to 70 percent.

Large Potential Benefits From Data-Sharing Standards

The new technology was intended for use in the production of printed circuit boards, and it has potential applications in the manufacture of other electronics components as well. If widely adopted, the product and manufacturing process models would provide a "common language" for the production process. In that case, the economic spillover benefits from widespread use of the technology could be large since so much of it involves data-sharing standards. Given the hundreds of millions of printed circuit boards produced for use in the United States each year, the benefits from this kind of standardization would be extremely large.

Saginaw Machine Systems, Inc.

Better Precision for Machine Tools Through Thermal-Error Correction

Machine tools are used in hundreds of thousands of plants and shops to cut and shape metal parts and pieces. The interface between the cutting or shaping tool and the material being worked almost always gets hot. In most cases, a coolant is directed onto the interface area to take away enough heat to allow the job to be performed.

High Heat Degrades Machining Quality

Even with the coolant, the machine tool itself often becomes warm enough to change shape slightly, and the accuracy of the machining operation degrades. The result can be a finished part that fails to meet specifications. What would have become a salable part becomes scrap metal, and some high-precision parts cannot be made at all.

Thermal-Error Compensation

With ATP funding, Saginaw Machine Tools — a small, privately held company founded in 1983 to build precision computer-controlled machine tools for high-volume manufacturing — together with researchers at the University of Michigan, developed a solution to the heat problem. Their technology monitors the temperature gradients in computer numerically controlled (CNC) machine tools and alters the control process dynamically (while the machine is working) to compensate for heat-related changes in the machine tool as the part is being worked. When the new technology is incorporated into machine tools, the result is higher-quality parts.

A new high-precision vertical lathe which incorporates the new thermal-error compensation technology, first delivered to customers in 1998.

The technology uses a laser system to measure machine geometric and thermal errors and heat sensors to monitor temperatures near the interface between the cutting tool and the metal being worked. A computer program, using a thermal volumetric error model, processes the laser and sensor data and sends corrective instructions to the machine tool in real time, as it shapes the metal. Use of this thermal-error compensation technology enhances the accuracy of CNC machine-tooled products by fourfold to fivefold as measured by spindle drift (shifting of the shaft, in a lathe or other machine tool, that holds the piece being formed), at a commercially viable cost.

Customers manufacturing high-precision parts realize productivity improvements of 10 percent to 30 percent . . .

First Products to Market

At the end of the ATP funding period, additional development work not originally foreseen by the company remained to be done. Saginaw continued to advance the technology and has invested as much of its own funds since the close of the project as the ATP put in at the beginning.

Since completing the development work, the company has begun to move its first product, which uses the Accu-System incorporating the ATP technology, into commercialization. By early 1998, Saginaw had developed prototype tools. One prototype was tested by an independent laboratory and pronounced ready for market. Another tool from Saginaw was subjected to a competitive evaluation process by a large tool buyer, in which the Saginaw tool was pitted against tools from seven other suppliers. The results showed that the Saginaw machine with the Accu-System was the most accurate. All in all, 30 characteristics of machine performance were measured, and the Saginaw machine had a weighted average score that was 50 percent higher than the next best machine. On the critical characteristic of spindle drift, the Saginaw machine achieved a two-thirds reduction in drift compared with the next best machine.

PROJECT:

To develop an easily adaptable thermal-error correction technology for enhancing the accuracy of computer numerically controlled machine tools.

Duration: 4/15/1991 — 11/16/1993
ATP number: 90-01-0232

FUNDING (IN THOUSANDS):

ATP	$540	84%
Company	100	16%
Total	$640	

ACCOMPLISHMENTS:

Saginaw, working closely with researchers at the University of Michigan, accomplished the project's technical goals by developing a generic mathematical model of thermal errors, as well as the sensor and computer-control systems for a thermal-error correction technology. The company also

- developed several prototype tools incorporating the new technology;
- submitted a prototype, as did seven other manufacturers, for testing by an independent laboratory, which found that the Saginaw machine was the most accurate of the eight machines, with an overall score 50% higher than the next best machine; and
- developed the Accu-System, which incorporates the ATP-funded technology, offered commercially for the first time in a machine tool in early 1998.

COMMERCIALIZATION STATUS:

Commercial products were introduced to the market in early 1998.

OUTLOOK:

The outlook for this technology is very promising. Saginaw started receiving orders in early 1998 for machine tools that incorporate the new technology. Machine tools that could benefit from the improved accuracy are used in plants and shops throughout the nation. Other tool producers are likely to imitate the technology, which is not expected to receive patent protection. Users of the tools that incorporate the new technology will benefit from a substantial improvement in machine tool accuracy, increasing the overall precision of the pieces produced by the machines.

COMPANY:

Saginaw Machine Systems, Inc.
301 Park St.
Troy, MI 48083

Contact: Gerald J. Romito
Phone: (248) 583-7200

Number of employees:
120 at project start, 120 at the end of 1997

Subcontractor: University of Michigan

. . . most machine tools that make high-precision parts are likely to be improved in the long run.

If Saginaw had not received the ATP award, company officials say, it would not have done the project.

By March 1998, Saginaw had received orders from other companies for eight machines priced at more than $200,000 each. Orders for several dozen additional machines of the same type were expected over the next several months.

Productivity Improvements

Users of the technology are able to take advantage, at reasonable cost, of a substantial increase in the accuracy of their machine tools, improving the precision of the workpieces the machines produce. Customers manufacturing high-precision parts realize productivity improvements of 10 percent to 30 percent because of reduced requirements for part testing and rework.

The number of potential applications is large. Because the Saginaw equipment is now in use, other manufacturers may imitate the technology. The company has concluded that none of the technology is patentable, and it is likely that competitors will be able to imitate its methods. Consequently, most machine tools that make high-precision parts are likely to be improved in the long run.

If Saginaw had not received the ATP award, company officials say, it would not have done the project. Being primarily a manufacturing company, it did not have a substantial research and development capability. While working on the ATP project, Saginaw collaborated with the University of Michigan on a subcontractor basis to extend the company's research capabilities. In addition, officials say, having the ATP award helped Saginaw win a subsequent $1 million award from the Defense Advanced Research Projects Agency for a related project.