A Profile of ATP Manufacturing Investments

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Good ideas can come to anyone, anywhere. But innovation requires much more than a good idea; it requires the ability to make that idea workable in, and beneficial to, the real world. Few challenges are more daunting. The transition from idea to innovation depends on a solid plan, dedicated champions, and adequate capital. The Advanced Technology Program (ATP) at the National Institute of Standards and Technology seeks to provide federal help to support U.S. innovations in all sectors that have the potential for broad benefits for the people and economy of the nation.

Innovation lies at the heart of U.S. manufacturing leadership and success. Manufacturing advances create more efficient processes and higher quality products to meet consumer demands and customer service expectations. Successful manufacturers are always striving to make improvements in manufacturing technologies to reduce cost and lead-times and achieve 'six-sigma' quality levels. Many of these advances are being pursued by suppliers for original equipment manufacturers—small or mid-size companies that are shouldering more of the costs of technology development to improve manufacturing abilities and outputs.

There are risks to pursuing early-stage manufacturing technology development. A new processing technology may offer dramatically higher yields in the lab but little guarantee that scale-up to commercial production levels will produce similar results. The perceived risks may be so high that companies are not willing to invest in these innovations. A body of evidence, however, suggests that in terms of innovation in manufacturing, the returns to the nation far exceed the costs of the investment. A June 2003 study by Joel Popkin for the National Association of Manufacturers, Securing America's Future: The Case for a Strong Manufacturing Base, points out that U.S. manufacturing generates large benefits to the American economy.

This study found that:

- The manufacturing sector, more than any other, helps to generate increased economic activity in other industries (every dollar of goods produced generates an additional $1.43 in economic activity in other industries or sectors).
- Manufacturers' investments in innovation account for almost two-thirds of all private-sector research and development; this investment in turn leads to advances in other manufacturing sectors and spillover into non-manufacturing activities in the United States.
- Gains associated with increased productivity from process improvements or other innovations are traditionally higher for the manufacturing sector.

Since 1990, the Advanced Technology Program (ATP) has been encouraging companies to pursue the development of high-risk, enabling technologies that would otherwise not be developed or that would be developed too slowly to take advantage of market opportunities. ATP partners with industry to provide funding for early-stage technologies that are viewed by private sector funding sources as too technically risky or undeveloped but that nonetheless have the potential to deliver broad-based economic benefits for the United States.

(continued inside)

ATP accepts proposals from U.S. companies that operate in all industries and fields of science and technology. Awards are based on the results of peer-reviewed competitions—open to all technology areas—and adhere to a demanding set of technical and business criteria.

ATP has invested more than $600 million in 200-plus projects that directly involve manufacturing technologies, and more than $250 million in 80-plus projects that indirectly involve manufacturing technologies. The investment in these technically risky projects is already proving to be worthwhile. One case study examined ATP's "2mm Project" funded in 1991 and involving the Auto Body Consortium. The study found that economic benefits from this project (cost reductions in automobile production and maintenance, and increased market share due to quality improvements) generated a return of about $200 million, or about 20 times the total project cost. ATP looks for this kind of potential high rate of return in each project it considers. A few recent manufacturing projects are highlighted in this brochure.

Enhancing U.S. Competitiveness

All projects receiving awards from ATP are expected to be innovative and contribute to entire industrial sectors and/or cut across multiple sectors. Some, however, hold special significance for helping U.S. firms and industries to regain global market share.

High-speed Scrap Metal Sorter

The Challenge: Each year, U.S. industry discards tens of billions of pounds of potentially reusable nonferrous metals as waste or mixed scrap. These metals from trash, packaging, appliances and other home products, cars, trucks, and aircraft continue to pile up in junkyards and landfills across the country—or they're shredded and sent overseas for hand sorting, which is a slow and inaccurate process. As this valuable metal goes to waste, more aluminum and other metals are mined. Production of metal from ore creates more pollutants and consumes more energy than production from recycled scrap metals.

The Innovation: A recycling company, wTe Corporation of Bedford, Massachusetts, together with National Recovery Technologies, Inc., of Nashville, Tennessee, proposed to apply high-speed optoelectronic technology to scrap sorting. The result was a high-speed sorter for crushed and ground nonferrous scrap. Called Spectramet®, the new technology uses a number of optical recognition techniques to whisk ground-up, mixed metals via conveyor belt through analysis and sorting. The sorting technology allows very precise specifications for the sorted alloys, significantly raising the economic value of the scrap.

Mountains of scrap metal piling up in the United States or shipped overseas for recycling can now be recycled using a new high-speed optoelectronic sorting system created by a joint venture team with funding from ATP. Piles of sorted scrap are shown here prior to further processing.

The venture partners are planning for Spectramet, LLC to be operational in 2005 to shred and sort automobile metals and recover nonferrous metals from waste-to-energy facilities in the northeastern United States. The ability to recycle aluminum alloys (in lieu of mining and manufacturing new aluminum) could mean billions of dollars in savings to U.S. manufacturers. Potential environmental benefits are also impressive. Recycling reduces the need to landfill; it also yields important energy savings in comparison to the production of new aluminum. The technology could soon be applied to copper, zinc, and superalloys from discarded aircraft and appliances. It could also benefit the construction industry, which is the second-largest market for nonferrous metal alloys.

Whole Genome Shuffling

The Challenge: Bioprocesses such as fermentation convert renewable feedstocks to chemicals, antibiotics, vitamins, and other products with a combined market value of almost $40 billion. To continually improve yields from these processes, researchers follow a traditional path—mutating the micro-organisms and then screening the mutant strains for increased productivity. This method achieves a maximum improvement of only about 10 percent annually. The challenge involves greatly increasing the yield.

The Innovation: Maxygen, Inc., of Redwood City, California, proposed its proprietary technology, "genome shuffling," to double the existing rate at which desired traits and products are generated. The company was awarded $1.24 million from ATP in 1998 to fund this idea. Also called "directed evolution," Maxygen's technology shuffles populations of cells that have already been improved through mutation, generating new

Zyvex Corporation is developing new low-cost, computer-controlled, microscale assemblers that could mass produce 3-D micro and nanoscale components for medical and scientific instrumentation, fiber optics, and photonics.

cells that contain many more beneficial genetic modifications in combination. For U.S. manufacturers this means more pharmaceutical and industrial products and enzymes produced with higher quality and at lower costs.

Maxygen used the technology to improve Eli Lilly's production of tylosin, an antibiotic used to treat livestock and household pets. In a 12-month demonstration, genome shuffling produced a strain of tylosin that performed as well as the commercial strain that had been developed the "old way"—20 rounds of strain improvement over 20 years. In a second study with Cargill Dow, LLP, genome shuffling was used to produce a three-fold increase in lactic acid in a commercial strain of lactobacillus. Both studies were summarized in journal articles. In 2002, Maxygen spun off a subsidiary, Codexis, to commercialize the genome shuffling technology.

Assemblers for Nanotechnology Applications

The Challenge: The burgeoning field of nanotechnology, which holds extraordinary promise in many areas, has been limited by the fact that working on the scale of MicroElectroMechanical Systems (MEMS) and NanoElectroMechanical Systems (NEMS) is a time-consuming and often high-cost endeavor.

The Innovation: Zyvex Corporation of Richardson, Texas, is developing a new manufacturing technology that will drive innovation in the world of silicon micro–machines. Zyvex sought to develop NEMS for prototype nanoscale assemblers by using MEMS-scale tools, then extending these capabilities to the nanometer scale. The result would be adaptable, affordable, and molecularly precise manufacturing. Zyvex, along with Honeywell International, Inc. (Morris Township, New Jersey), Rensselaer Polytechnic Institute Center for Automation Technologies (Troy, New York), the University of Texas at Dallas, and the University of North Texas, will produce highly parallel microassembly and nanoassembly systems for real-world, high-volume applications in medical and scientific instrumentation, fiber optics, photonics, and more.

Success with this project could accelerate the technical, economic, and societal benefits of nanotechnology and assist the United States in achieving leadership in the emerging nanotechnology arena.

Creating New Industries

ATP embraces innovative ideas that can revolutionize industries and perhaps go further—spurring entirely new manufacturing sectors that create jobs, improve lives, and strengthen the U.S. economy.

Overcoming Organ Rejection

The Challenge: For the recipient, organ transplants can mean longevity and dramatically improved quality of life. Many on waiting lists are not so fortunate; thousands of Americans die each year waiting for an organ to become available. The medical community has long sought to use organs from animals to fill the shortage of human organs, but the human body's immediate rejection of animal organs has made this impossible.

The Innovation: PPL Therapeutics, Inc. (now Revivicor, Inc.), of Blacksburg, Virginia, sought to revolutionize the field of transplant medicine by altering the genes of a pig, "knocking out" the enzyme that results in hyperacute rejection (HAR) in the human body and making it practical to transplant these organs into humans. If successful, this genetics technology could enable a major manufacturing sector—large-scale production of engineered organs for transplantation—that could save lives, create jobs, and reduce the tens of billions of dollars now spent annually caring for patients with organ failure.

By August 2002, Revivicor had produced piglets with the gene in question completely inactivated. Organs and cells from these pigs will be tested in pivotal transplantation studies at the University of Pittsburgh's Thomas E. Starzl Transplantation Institute, which will look for the elimination of HAR and the long-term survival of xenografts. Cells from these genetically modified pigs will soon be tested for the treatment of type 1 diabetes, first in animals, and then in humans. Testing of genetically altered organs (hearts and kidneys) could follow after the first cell experiments, with human clinical trials in two to four years.

The goal of Revivicor, Inc., is to develop technology that can produce cloned pigs with a specific gene inactivated or "knocked out," potentially eliminating the automatic human immune response to transplanted pig organs and tissues. The result could be a new industry that saves the lives of thousands awaiting transplants.

Improving Processes and Quality

Product quality is a key requirement in today's marketplace, and low production costs are essential to remaining competitive. Congress created ATP in large part to infuse the U.S. manufacturing infrastructure with innovations that will reduce costs and time to market while increasing quality. Here are a few of the challenges being tackled by the nation's innovators.

Real-time, High-speed Machine Balancing

The Challenge: The precision balancing of high-speed tools is critical for their durability, the quality of the finished parts they produce, and worker safety. These tools, used to make automobile engine blocks and other products, can run at more than 40,000 rpms—speeds that far surpass tolerances for effective static balancing. Excessive vibration results, causing bearing damage, broken tools, and poor surface finish.

The Innovation: BalaDyne Corporation of Ann Arbor, Michigan, proposed leveraging its RealTime™ vibration control technology to enable balancing of high-speed machining tools. The company (acquired by Lord Corporation of Cary, North Carolina following conclusion of the project) partnered with the University of Michigan to develop mathematical models to predict the balancing requirements for high-speed machinery in an unsteady state. The BalaDyne system uses sensors to monitor vibration levels and a counterweight system to correct imbalances in a matter of seconds.

The technology can return hundreds of millions of dollars in savings for U.S. industry in reduced downtime and safety hazards, extended bearing and machinery life, and increased quality and precision of machined parts. The technology is also being applied to other rotating machinery, such as industrial fans, turbo-machinery, pumps, power generation equipment, and propeller-driven aircraft.

Molds for Engine Parts from 3D Printing Technology

The Challenge: The automobile industry increasingly uses aluminum engine components to reduce the weight of vehicles, resulting in lower energy consumption. Lost-foam casting allows manufacturers to use Styrofoam patterns in casting molds for the sophisticated aluminum cylinder heads used today. Unfortunately, the tools used to create the foam patterns are expensive, and the lead time in production is prohibitively lengthy.

Three-dimensional printing process technologies created by Extrude Hone Corporation could enable low-cost manufacture of Styrofoam patterns for complex engine components from a parts-design database. In this conceptual image, print heads selectively deposit micro droplets of binding solution with extreme precision only on the powder to be printed, bonding each layer until all cross-sections have been built.

The Innovation: Extrude Hone Corporation of Irwin, Pennsylvania, proposed to apply aspects of its ProMetal™ three-dimensional printing process (known as 3DP) to the creation of Styrofoam molds for aluminum engine components. 3DP uses a layering technique like ink-jet printing to build copper molds one layer at a time with metal powder. For the ATP project, the 3DP process would use Styrofoam and resin to build a highly accurate 3-D pattern that is then placed in dry sand. Hot copper poured into the pattern vaporizes the plastic form to create a highly detailed cylinder head that is faster to produce and much less expensive than molds made the old way.

The software-based 3DP approach creates a precise prototype that meets GM standards and can be altered cost effectively as needed. Other benefits include the possibility that products can be taken to market faster and that the process can be adapted to other applications, such as the manufacture of turbine components and chassis for consumer electronics.

Flexible Manufacturing of Large Plastic Molds

The Challenge: The traditional process used by U.S. auto parts manufacturers to create molds for large plastic parts, such as doors and bumpers, is expensive and complex and can take many months. This problem hampers the $20 billion U.S. tooling and machining industry as it struggles to compete with low-cost Asian firms.

The Innovation: Stewart Automotive Research, LLC of Houston, Texas, a small company, sought to redesign this cumbersome scenario by adapting and optimizing water-jet cutting and electron-beam welding in a rapid-manufacturing process. Such a breakthrough would, for example, enable a U.S. auto parts manufacturer to order a complex metal mold for an automobile bumper or hood and take delivery in several weeks rather than the standard six months or more.

The risk and complexity of combining these technologies into a viable, cost-effective process made private sector investment unlikely. Working with ATP for funding, Stewart teamed with Flow International Corp. (Kent, Washington), an expert in abrasive water-jet cutting, and several high-speed machining companies to develop a process for internal and external rough-cutting of slices or "plates" of a large metal mold, rather than machining the entire mold at once. Sciaky, Inc. (Chicago,

The HotEye™ system uses imaging technology to inspect newly forged metals while withstanding their intense heat. It can cut waste of forged metal product by 90 percent and reduce burn injuries, with a resulting savings to U.S. industry in the billions.

Illinois), an expert in electron-beam welding, developed a welding process to rejoin the stack of slices into a monolithic tool.

The project not only developed the proposed mold manufacturing process, but also created a new generation of electron beam welding equipment, attracting $2 million in additional private sector investment and generating technical and economic benefits for a variety of industrial and military applications. Stewart Automotive Research predicts that its new flexible manufacturing technology could yield $6.8 billion per year in faster cycle times (more parts created per machine) and better capital equipment utilization, $1.4 billion per year in reduced lead-time costs, and $200 million per year in reduced scrap during mold creation. These quality, quantity, time, and cost efficiencies could offset the low-labor-cost advantage of overseas competitors and possibly return market share and jobs to the United States in mold production.

Imaging-based, High-temperature Process Control

The Challenge: Accurate inspection of products during the manufacturing process can lead to significant manufacturing productivity gains. But, for "hot" industries like steel production and forging, in-process inspection has not been possible; neither sensors nor humans could withstand the 1850°C heat. Resulting high-scrap rates cost billions of dollars annually to steel mills and their customers.

The Innovation: OG Technologies, Inc., of Ann Arbor, Michigan, developed an image sensor capable of monitoring defects at the extremely high temperatures involved in steel manufacturing, metal forging, and other hot metal processes. However, the company realized that its innovative imagers were of limited economic value without the ability to quickly and accurately analyze the resulting images. OG Technologies approached ATP for help in tackling the challenge of converting raw images into useful manufacturing process knowledge.

Through ATP financial support and partnerships with other firms, OG Technologies created a new system, HotEye™, that can spot tiny surface defects on rolled steel bars passing below the sensors at speeds of up to 225 miles per hour.

For the forging industry, HotEye monitors process steps and quickly and accurately measures critical dimensions, helping to achieve new levels of cost-effective quality and allowing a significant jump in "good part" machine operating time. The result can save billions of dollars in rejected parts and wasted energy costs. Data can be monitored, recorded, and analyzed, indicating when critical parameters are drifting out of specification. As a bonus, this method also reduces the risk of burn injuries associated with manual inspections.

Snapshots of profiled projects

High-speed Scrap Metal Sorter
Sponsor: wTe Corporation, Bedford, MA
ATP funding: $2.0 million
Nov. 1, 2000 to Oct. 31, 2003
Other participant: Massachusetts Institute of Technology, Cambridge, MA

Whole Genome Shuffling
Sponsor: Maxygen, Inc., Redwood City, CA
ATP funding: $1.3 million
Dec. 1, 1998 to Nov. 30, 2001

Assemblers for Nanotechnology Applications
Sponsor: Zyvex Corporation, Richardson, TX
ATP funding: $12.2 million*
Oct. 1, 2001 to Dec. 16, 2006
Other participants: Honeywell International, Inc., Morris Township, NJ; Rensselaer Polytechnic Institute Center for Automation Technologies, Troy, NY; University of Texas at Dallas; University of North Texas, Denton, TX

Overcoming Organ Rejection
Sponsor: Revivicor, Inc. (formerly PPL Therapeutics), Blacksburg, VA
ATP funding: $2.0 million
Nov. 1, 1999 to Oct. 31, 2002

Real-time, High-speed Machine Balancing
Sponsor: BalaDyne Corporation, Ann Arbor, MI
ATP funding: $2.0 million
Oct. 1, 1997 to Sept. 30, 2000
Other participant: University of Michigan at Ann Arbor

Molds for Engine Parts from 3D Printing Technology
Sponsor: Extrude Hone Corporation, Irwin, PA
ATP funding: $3.2 million*
Dec. 19, 1997 to Dec. 18, 2002
Other participants: General Motors Powertrain Group, Pontiac, MI; Massachusetts Institute of Technology, Cambridge, MA

Flexible Manufacturing of Large Plastic Molds
Sponsor: Stewart Automotive Research, LLC, Houston, TX
ATP funding: $2.0 million
Nov. 1, 2000 to Oct. 31, 2003
Other participants: Flow International Corp., Kent, WA; Sciaky, Inc., Chicago, IL; Rice University, Houston, TX

Imaging-based, High-temperature Process Control
Sponsor: OG Technologies, Inc., Ann Arbor, MI
ATP funding: $2.0 million
Nov. 1, 2000 to April 30, 2004
Other participants: Ohio State University, Columbus, OH; University of Michigan at Ann Arbor

*Joint venture

Fueling economic growth

More than half of U.S. economic growth depends on advances in technology. We'd live in a different and less prosperous nation without them. NIST's Advanced Technology Program (ATP) helps to fuel the engine of economic growth by providing vital funding for high-risk, enabling technologies.

From its inception in 1990 through September 2004, ATP has awarded $2.3 billion in funding to companies for 768 innovative projects. Industry matched this funding with $2.1 billion in cost-sharing. Half of the projects funded in this time frame have been successfully completed. Many more are in the works. ATP's portfolio of investments to date is expected to return at least $17 billion in benefits to the American people, delivering broad quality-of-life improvements, consumer savings, and productivity gains, adding to Treasury receipts (through taxes), and spurring whole new industries.

ATP's unique and vital role

It takes capital to turn ideas into new products and industries. Yet for many high-risk research efforts, initial investments will not be recovered for years or even decades, making them unattractive to private-sector companies. New ideas often fall into a "valley of death" between basic research and product development, a void where risk aversion and a resulting lack of investment capital kills innovations.

ATP funding plays a critical role in bridging this investment gap. With venture capital firms, state governments, and universities contributing only 8 to 16 percent toward early stage technology development, federal programs, such as ATP, account for between 21 and 25 percent. By sharing the costs of innovation, ATP catalyzes private-sector investment and risk taking.

New products benefit the economy

Of the first 120 ATP projects completed, two out of three brought new products or processes into the marketplace, and many are expected to deliver far-reaching benefits to our society. Consider a few examples: a data storage technology that could return $3.7 billion in consumer benefits; flow-control machining that might increase returns in the auto industry by $142 million annually; and, component-based software projected to yield $840 million in public and private returns. These projects have also spurred company growth and job creation. Three out of five small, single-applicant companies have at least doubled in size, and 13 percent have grown by more than 1,000 percent. The bottom line: The projected economic impact of a handful of these early ATP projects would pay for every ATP project funded since 1990.

Putting private-sector ingenuity to work

ATP partners with companies of all sizes as well as universities and nonprofits, encouraging these organizations to take on and overcome national technical challenges that they could not or would not accept alone. In this way, ATP seeks to reap major potential benefits for the nation—benefits that extend well beyond the participating organizations themselves to broad applications that benefit society.

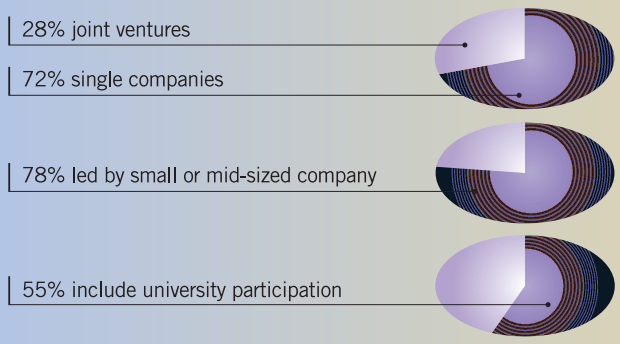
ATP accepts proposals in all industries and fields of science and technology, and awards funding as the result of open, peer-reviewed competitions. In 44 competitions to date, 768 winning projects have been selected from 6,924 submitted proposals. Proposals are evaluated by one of several technology-specific boards that are staffed with experts in particular fields. Proposals are assured an appropriate, technically competent review even if they involve a broad, multidisciplinary mix of technologies. Awards are made based on high-risk technologies that:

- Extend their benefits well beyond the companies involved in the project.
- Have broad potential applications, particularly across different industrial sectors.
- Open new potential markets or make possible wholly new products or industrial processes.

The eight innovative manufacturing technologies profiled in this brochure represent the mission of ATP to bridge the gap between the research lab and the marketplace, stimulating prosperity through innovation.

ATP at a Glance

768 projects funded from 1990 to September 2004, resulting in nearly 1,200 new patents. At the time of award:



To innovate or not to innovate?

What would have happened without ATP funding? In many cases, innovation would have been slower or nonexistent. A survey of companies that submitted non-winning proposals to ATP in 2000 reveals that more than 40 percent did not proceed with their proposed projects in any way. An additional 40 percent went ahead on a smaller scale. Time to market, a critical success factor for new technologies, also suffers without ATP funding. Surveys indicate that ATP funding accelerated the R&D cycle for nine out of ten awardees. Reduction in time to market by two years or more is anticipated for about 60 percent of planned commercial applications by ATP awardees.

Contact ATP at:

Advanced Technology Program
NIST
100 Bureau Drive, Stop 4701
Gaithersburg, MD 20899-4701

Phone: 1-800-ATP-FUND or 1-800-287-3863
Fax: 301-926-9524
E-mail: atp@nist.gov
Website: www.atp.nist.gov

The Advanced Technology Program is part of the Department of Commerce's National Institute of Standards and Technology. ATP's mission is to accelerate the development of innovative technologies for broad national benefit through partnerships with the private sector.

ADVANCED TECHNOLOGY PROGRAM

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