GEM: a brief, non-technical, description that demonstrates the value of NIST impacts on companies, industry sectors, academia, and the public

NIST GEMs for Manufacturing Engineering

October, 2004

MEL innovation & productivity

NIST National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

The Manufacturing Engineering Laboratory's

GEMs

October 2004

NIST
National Institute of Standards and Technology
Technology Administration
U.S. Department of Commerce

Why are GEMs important?

- Emphasize measurable impacts on the economy and quality of life.
- Show impacts on particular industry/market sectors.
- Justify taxpayer's investment in NIST.
- Can be the only NIST information that our stakeholders review.
- Interest industry and universities in further collaborations.
- Promote NIST activities to third party investors.
- Improve internal communications.

How are GEMs used?

- As talking points for NIST leadership in meeting with key stakeholders in government and the private sector.
- To educate our stakeholders (i.e. Congress, Department of Commerce leadership, Administration leadership, the media, and others) about NIST impacts.
- As talking points for Secretarial or Congressional speeches.
- As background information for Secretary of Commerce travel to specific organizations or regions.
- In response to ad-hoc media inquiries.

MEL GEMs

NIST Helps Improve Dimensional Metrology System Interoperability Leading to Cost Savings

Partnering Organizations:

- Automotive Industries Action Group (AIAG), Southfield, MI 48034-7100
- DaimlerChrysler, Auburn Hills, MI 48326-2766
- Ford Motor Company, Dearborn, MI 48126
- Tecnomatix, Morgan Hill, CA 90035
- The Boeing Company, Seattle, WA 98124
- Wilcox Associates, Inc., Alpine, UT 84004

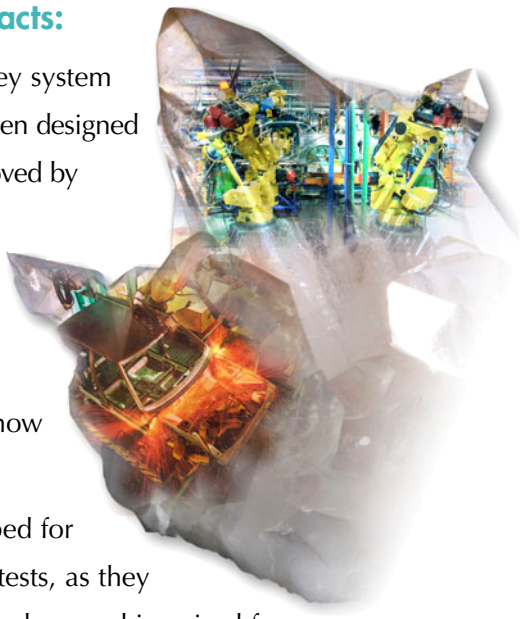
Problem Statement:

Large manufacturers use many types of dimensional measuring machines to perform measurements of parts and assemblies at their U.S. and international factories. Measuring machines are composed of several internal systems. Measuring machines also need to communicate with several external systems. The problem is that these systems typically do not communicate well with one another unless they all come from the same vendor. This is called the "interoperability problem," and is known to cause large, unnecessary costs to both users and vendors.

NIST Response:

NIST is working with the measuring machine industry to ensure that measuring machine systems talk fluently to one another, no matter where the systems come from. NIST is helping industry develop common interface "languages" (specifications), and once a common specification is agreed upon, NIST designs and develops tests that are used to verify whether implementations of the specification actually conform to the specification.

Results and Impacts:



- Tests for several key system interfaces have been designed by NIST and approved by industry.
- Tests for the equipment interface have been released and are now in use worldwide.
- A distributed testbed for conducting these tests, as they emerge, is now in place and is poised for active testing in the coming years.
- NIST input in standards gap and overlap analysis has provided key overall guidance.
- NIST input in specification analysis has reduced ambiguity in a specific interface specification for the equipment interface.

Lockheed Martin Gets in STEP with Streamlined Data Exchange

Partnering Organizations:

- Lockheed Martin Aeronautics Company, Fort Worth, TX 76101

Problem Statement:

A majority of total aircraft cost today comes from suppliers of raw material, fabricated parts, entire subsystems, and support equipment. Traditionally, Lockheed Martin Aeronautics Company manually transmitted large volumes of engineering data via hard-copy bid packages to potential suppliers. This presented storage, shipping, and document control problems. Data often had to be interpreted and re-entered into different systems, resulting in lengthy time delays and numerous errors.

NIST Response:

NIST has been a leader in the quest to create a universal, unambiguous language for exchanging product information. As the secretariat for the International Organization for Standardization (ISO) Subcommittee on Industrial Data, NIST provided leadership and direction in developing standard exchange protocols.

The Standard for Exchange Protocol (STEP) evolved from this collaboration. Lockheed Martin's data is now quickly and accurately sent electronically to first-tier suppliers and in some cases, retransmitted to lower-tier suppliers without concern for compatibility with diverse proprietary software. NIST still participates in STEP's evolution and implementation by developing testing methodologies for and making technical contributions to ISO.

Results and Impacts:

- Lockheed Martin's data is now quickly and accurately sent electronically to first-tier suppliers and retransmitted to lower-tier suppliers.
- During Lockheed Martin's rebid of F-16 machined parts that involved about 2,300 part numbers and 50 potential suppliers, use of STEP provided a 95 percent reduction in procurement costs and a 52 percent reduction in labor required to provide information to suppliers by the prime contractor with similar savings predicted for suppliers.

NIST Performs Critical Mass Measurements for Accountability of Nuclear Materials

Partnering Organizations:

- United States Enrichment Corporation (USEC), Piketon, OH 45661

Problem Statement:

Monitoring and accountability of nuclear materials requires accurate and precise measurements. The standards used to trace the accuracy of these measurements to the International System (SI) of Units of mass range from 1300 pounds to 32000 pounds. The equipment and expertise required to perform such measurements are only available at NIST. In addition, mass calibrations are performed at regular intervals defined by the particular application requirements. A calibration expires when the end of the calibration interval is reached before a new calibration is performed. This is particularly important for regulatory purposes such as monitoring of nuclear materials, and a company was faced with the imminent expiration of the calibration of the mass standards used to monitor nuclear materials.

NIST Response:

NIST provided precision mass measurements (0.01% - 0.0014% uncertainty) with direct traceability to the SI unit of mass to the United States Enrichment Corporation prior to the expiration of the calibration of the mass standards.

Results and Impacts:

- The nuclear industry can use these precision measurements to develop a mass measurement assurance program to help monitor inventory of their nuclear materials.

NIST Helps Small Businesses Integrate Engineering Analysis Tools

Partnering Organizations:

- Carco Electronics, Pittsburgh, PA 15238-2932
- Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA 15213-3890

Problem Statement:

Carco Electronics manufactures complex devices that simulate and test missile guidance and tracking systems for military applications. These devices place missile components in a yoke that can be rotated in all directions to simulate missile flight. Carco engineers were not able to perform detailed analyses of proposed designs for new simulation and test systems in time to meet proposal submission deadlines because the company had no in-house computer-aided engineering (CAE) analysis capabilities. In fact, only their finished designs were analyzed by outside consultants, who spent most of their time converting Carco's designs from computer-aided design (CAD) files to the format needed by the CAE systems.

NIST Response:

As part of the Technology Insertion Demonstration Evaluation (TIDE) program administered by the Software Engineering Institute at

Carnegie Mellon University, NIST researchers participated in a team that helped Carco engineers install a new 3-Dimensional CAD system, acquire a CAE system, gain the expertise in performing analyses with the CAE system, and integrate the CAD and CAE systems so as to optimize there products and their design processes. NIST also developed two self-assessment tools to help small manufacturers select appropriate engineering environments and problem-solving tools for their business.

Results and Impacts:

- Significantly improved overall design quality.
- Significantly increased number of contracts by analyzing and optimizing designs at the proposal stage.
- Reduced control system design costs by 50 percent.
- Reduced design errors by 25 percent.
- Totally eliminated redesigns of completed product designs by analyses throughout the entire design process.
- Reduced total engineering cycle time by 40 percent.

NIST Helps to Accelerate Research in Robotic Search and Rescue Efforts

Partnering Organization

- Defense Advanced Research Projects Agency (DARPA), Information Processing Technology Office, Mobile Autonomous Robot Software, Arlington, VA 22203-1714
- American Association for Artificial Intelligence (AAAI), Menlo Park, CA 94025-3442
- RoboCup American Open, Pittsburgh, PA 15213
- Carnegie Mellon University, Pittsburgh, PA 15213
- University of Pittsburgh, Pittsburgh, PA 15260
- University of South Florida, Tampa, FL 33620
- University of Massachusetts, Lowell, MA 01854
- University of New Orleans, New Orleans, LA 70148

Problem Statement:

Robotic systems can help minimize risk to rescue personnel while increasing victim survival rates in dangerous applications, such as urban search and rescue. However, research in urban search and rescue robotic technologies was not progressing fast enough due to the lack of tangible goals and measures of effectiveness in a controlled and repeatable environment.

NIST Response:

NIST responded to requests from the robotic research community to provide reference test arenas for robotic search and rescue. The arenas were designed to isolate a variety of challenges that robots would need to overcome in order to

begin to address search and rescue in realistic scenarios. The arenas contain simulated victims, hazards, and a variety of mobility, mapping, perception, and planning challenges. The arenas are used annually at the American Association for Artificial Intelligence Robot Competitions (starting in 2000), will be replicated to host the American Open Rescue Robot Competition, and have been adopted by the RoboCup Rescue League (starting in 2002) for international replication. The intent is to accelerate robotic rescue technologies, and provide researchers from various academic institutions the opportunity to test and evaluate their own robotic implementations and sensors.

Results and Impacts:

- Since the arenas are available at NIST year-round and reproducible worldwide, researchers can compare and contrast technical approaches and understand what constituent technologies, such as sensors and planning algorithms, work best under given conditions. This allows the teams to become more competitive in national and international competitions.
- The research community has access to a common basis for evaluating foundational technologies for robotic search and rescue.
- The arenas provide an opportunity for accelerating development and deployment of robotic rescue technologies.
- NIST-designed versions of the arenas reside year-round in Japan, Italy, Pittsburgh, and Virginia. By the end of 2004, additional arenas will exist in Portugal, Germany, New Orleans, and Nashville.
- Researchers have used the arenas to create high-fidelity models within simulation programs. This provides developers world-wide access to "virtual" versions of the arenas to facilitate even more widespread initial testing of algorithms.

- A body of data collected focusing on human-robot interaction is becoming available to the human factors and human-machine control development communities. Other data, such as operator interface screens, robot videos, tracking information, and workload measures, is captured at the annual competitions and at the NIST site.
- Several aspects of the arenas are applicable to other indoor robotic domains, such as homeland security, office transport, and military reconnaissance. In fact, the National Institute of Justice has funded NIST to extend the current arenas to support performance evaluation of bomb-disposal robots.
- NIST is working with DARPA, AAAI, RoboCup, Carnegie Mellon University, the University of Pittsburgh, the University of Massachusetts, and other organizations to develop metrics for measuring the performance of robots facing search and rescue challenges.
- DARPA has provided multi-year funding to support this work and its dissemination.

NIST Brings Critical Measurement Expertise to Semiconductor Manufacturing

Partnering Organizations:

- International SEMATECH, Austin, TX 78741-6499

Problem Statement:

Automated scanning electron microscopes (SEMs) are used on-line in U. S. semiconductor production facilities to inspect critical dimensions of integrated circuits and photomasks. As the features to be measured become smaller, the resolution limits of these SEMs make it harder to provide measurements and calibration standards with the uncertainties needed to keep pace with Moore's Law. This law has been an essential ingredient in the strength of the semiconductor industry until now.

NIST Response:

Atomic force microscopes (AFMs) are useful as reference tools for the calibration of SEMs, but the AFMs themselves must be calibrated to be useful for this purpose. NIST sent an expert in AFM calibration to SEMATECH to develop calibration procedures that would enable their AFM to be used as a reference tool for other measurements. This effort required the use of samples that had been measured at NIST and the adaptation of calibration methods used at NIST to establish traceability and uncertainty budgets for the measurements. SEMATECH's industrial constituents have quickly come to regard SEMATECH's AFM as the "reference measurement system" for similar measurements by SEMs and other instruments.

Results and Impacts:

- Enabled improvement in the internal consistency of measurements on photomasks.
- Reduced the uncertainty of step height measurements at SEMATECH.
- SEMATECH's AFM used for quality control of new linewidth standards for the semiconductor industry.

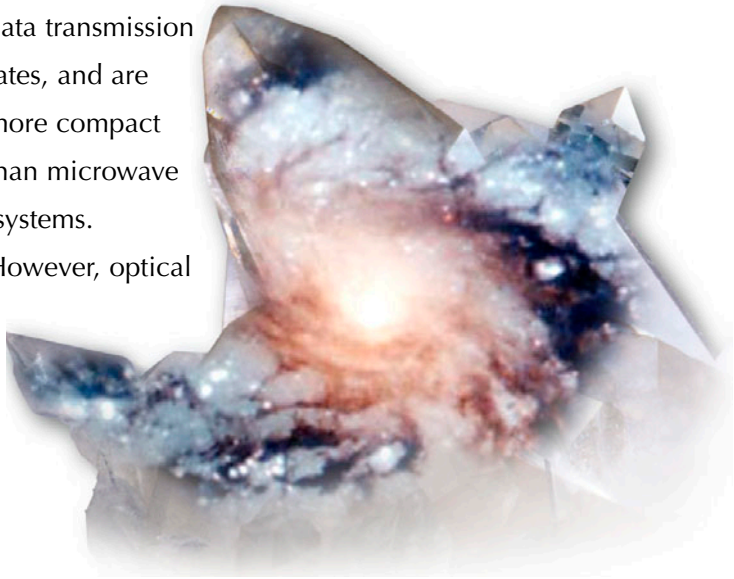
NIST Helps Ensure Accurate Deep Space Communications

Partnering Organizations:

- The Johns Hopkins University Applied Physics Laboratory (JHU-APL), Laurel, MD 20723-6099

Problem Statement:

Microwave communications systems have long been used to send data between spacecraft and ground stations. Newer optical communications systems have much higher gain, much greater data transmission rates, and are more compact than microwave systems. However, optical



spacecraft communication systems must be very accurately pointed to work properly, especially for communications with potential future spacecraft that may travel far beyond our solar system.

NIST Response:

NIST staff invented a new technology called "Parallel Cantilever Biaxial Micro-Positioning," (PCBMP) which enables highly accurate positioning for assembly and alignment of micro-scale and nano-scale devices. NIST staff in collaboration with researchers from the Johns Hopkins University recently concluded that the technology could be used for extremely accurate positioning of lenses to steer a laser beam for optical communications with future spacecraft operating in deep space. The NIST micro-positioning technology can meet the demanding limitations on size, mass, and power requirements in a deep space explorer.

Results and Impacts:

- Enables spacecraft communication terminals with higher gain and data rates.
- Enables communication with potential future spacecraft operating in deep space many billions of miles from earth.
- Makes interactive control of spacecraft possible.
- Enables commercial and military applications of this technology.
- Successfully tested one-dimensional tracking of a target under simulated spacecraft operation.

NIST Helps to Develop Knowledge Bases for Smarter Robots

Partnering Organizations:

- The Boeing Company, Seattle, WA 98124-220
- DCS Corporation, Alexandria, VA, 22314
- Defense Advanced Research Projects Agency (DARPA), Information Processing Technology Office, Mobile Autonomous Robot Software, Arlington, VA 22203-1714
- General Dynamics Robotics Systems, Inc., (GDRS), Westminster, MD 21157
- Perceptek Inc., Littleton. CO 80125
- U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC), Warren, MI 48397-5000

Problem Statement:

Robotic systems rely on an internal world model to represent and reason about their perception of the world. This works in much the same way that the human brain makes decisions about actions to perform based upon what the person senses in the environment and based upon that person's prior knowledge and experience. Though much effort has been put into enhancing the sensing and action components of robots, relatively little has been applied to enhancing the world model, which would allow the robot to "think" better. Not only does the robot have to be able to perceive based on new sensed inputs, but it must also be able to leverage knowledge it has previously acquired. It also should be able to learn from past knowledge so it can properly address similar situations in the future.

Without advancement in the world modeling area, robotic capabilities will be limited to fairly simplistic behaviors and the field will not reach a level of performance commensurate with public needs and expectations.

NIST Response:

NIST has responded to this need by taking the lead role in working with industry and other government agencies to define and develop the methodologies, data structures, and knowledge bases necessary to achieve the level of intelligence that is being requested and expected by the community at large. NIST has developed a methodology for extracting the knowledge pertinent to robotic applications and has applied this methodology to the domains of on-road driving and military tactical behaviors. The knowledge that was uncovered by applying this methodology was captured formally in software using ontological approaches and has been used by organizations carrying out robotic development efforts around the country. In all of these efforts, the introduction of this additional knowledge will allow the systems to perform at much higher levels than previously achieved.

Results and Impacts:

- The data structures resulting from the methodology have been used by numerous organizations to enhance their robotic efforts, including PercepTek Inc., Boeing, U.S. Army Tank Automotive Research, Development, and Engineering Center (TARDEC), and the Defense Advanced Research Projects Agency (DARPA). Use of these data structures has resulted in a more formal and structured approach for identifying and implementing knowledge within the world model, which has allowed these organizations to accelerate their efforts in developing robotic software and/or a higher level of performance within the robotic system.
- The use of ontological approaches in defining the data structures has reduced the ambiguity associated with the meaning of the knowledge in efforts within TARDEC.Boeing is using NIST-developed software infrastructure and ontologies of road and vehicles in its autonomous systems research program.
- The use of ontological approaches in defining the data structures has resulted in an increased level of functionality of the robotic software within Boeing.
- The research community has access to a common set of data structures to allow for greater knowledge reuse, enabling accelerated robotic development.
- DARPA has used this methodology as part of a formal information gathering, structuring and evaluation process to scope the effort needed to achieve autonomous on-road driving. This methodology has also provided detailed results that are being used as a benchmark to drive future programs in this technology area.

NIST Helps Design High Resolution Scanning Electron Microscope Stage

Partnering Organizations:

- E. Fjeld Company, North Billerica, MA 01862

Problem Statement:

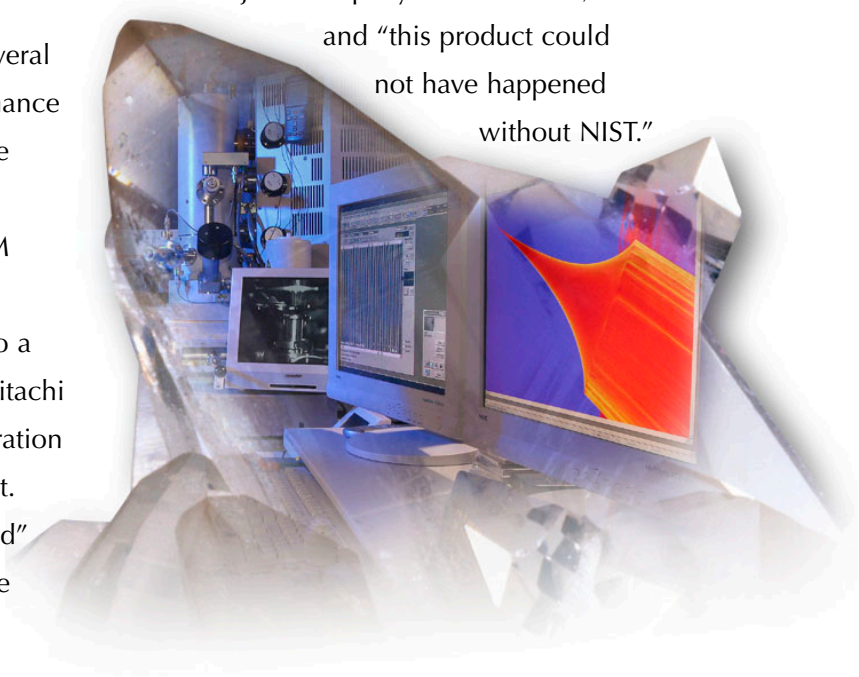
Inspecting and testing semiconductor devices requires the use of high-resolution field emission scanning electron microscopes. The sample stages of these microscopes must be able to accurately move extremely small distances with unprecedented control.

NIST Response:

NIST worked with E. Fjeld Company for several years to design and develop a high-performance scanning electron microscope (SEM) sample goniometer stage. The result was a high performance stage adaptable to several SEM instruments. In collaboration with the Fjeld company, this stage was recently adapted to a new NIST high-resolution state-of-the-art Hitachi S-4700 microscope. This was the first integration of this type of stage into the new instrument. The S-4700 is an all-digital "Windows-based" system and adaptation required new sample stage software and other modifications to make it fully compatible. Additionally, the newly developed stage locking system and drift compensation software was also tested on the NIST instrument following installation. This new stage and stage locking system and software enable a much more stable sample mounting and motion platform enabling magnifications to 500,000 times with sharpness unable to be attained with the regular stage.

Results and Impacts:

- The SEM sample stage was developed as a new product for this small business and several have been sold and installed in other U.S. companies.
- The new sample stage, control software, and stage lock system is now commercially available and benefits U.S. semiconductor companies by enabling higher magnification images (now up to 500,000 times) with unparalleled image sharpness, unable to be attained with the regular stage.
- The company stated the product was going to be excellent, collaboration between NIST and Fjeld Company was excellent, and "this product could not have happened without NIST."



NIST Helps Industry Improve Ship Repair and Conversion Operations

Partnering Organizations:

- Atlantic Marine, Inc., Jacksonville, FL 32226
- Atlantic Marine, Inc., Mobile, AL 36652

Problem Statement:

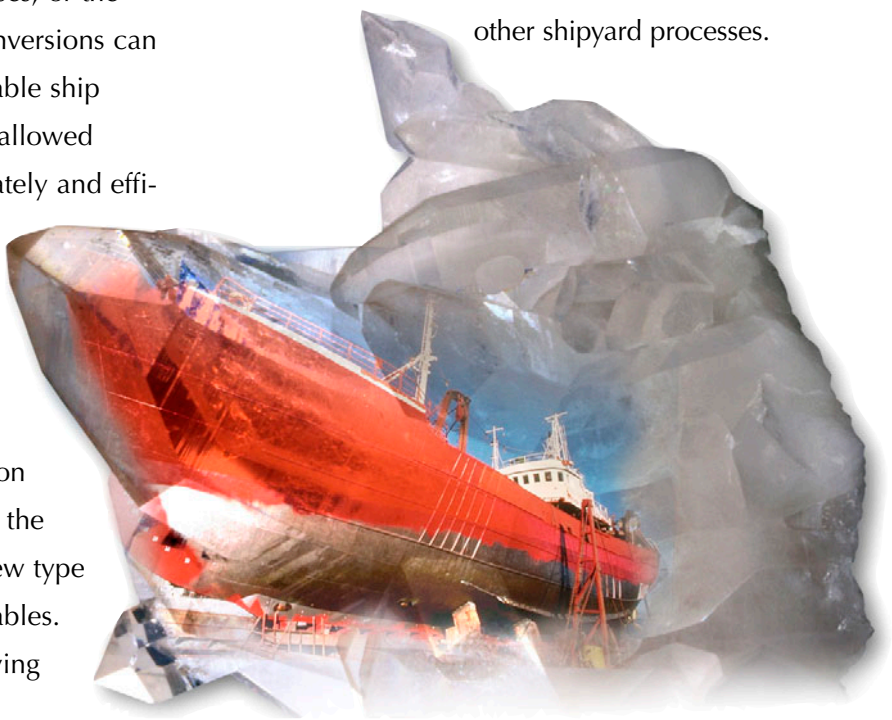
Atlantic Marine, a U.S shipbuilder, wanted to improve their competitiveness in the global marketplace. The company needed to improve overall quality, as well as reduce costs and cycle times of their ship repair and conversion business to obtain a competitive edge.

NIST Response:

NIST led an effort to apply precision metrology techniques to ship repair and conversion operations at Atlantic Marine's Jacksonville, Florida, and Mobile, Alabama, facilities. This effort developed and implemented a system that improved Atlantic's reverse engineering processes, or the means by which ship repairs and conversions can be engineered in the absence of reliable ship design information. The new system allowed measurement data to be lifted accurately and efficiently from ships, translated measurement data into production information, and it provided the basis for produced parts and assemblies to fit properly on ships. NIST also led an effort to improve work performance on shipyard drydocks that demonstrated the feasibility of using a revolutionary new type of working platform suspended by cables. This new concept, known as the "Flying Carpet," permits workers and equipment to be precisely positioned and moved for efficient access to large surfaces, such as ships in drydocks. The Flying Carpet also makes available more valuable drydock space for other craft and improves the efficiency and safety of drydock operations.

Results and Impacts:

- NIST's efforts enable the transfer of research results to American shipyards on an industry-wide basis.
- The metrology system increases Atlantic Marine's throughput for measurement and other dependent activities.
- The metrology system increases measurement data integrity and versatility by capturing measurement data electronically.
- The electronic data capture capability of the metrology system also means that reverse engineering processes are documented in a complete, consistent, and nearly automatic manner that facilitates their integration with other shipyard processes.



- The metrology system provides better opportunity for increased fabrication of parts prior to a vessel's arrival in the shipyard.
- The Flying Carpet increases personnel safety and can decrease the cycle time in steel renewal and other types of material repair during drydockings.
- The Flying Carpet decreases the cost and can increase the speed of ship hull cleaning and painting.

NIST Measurements Enable New Nanoscale Calibration Specimen by Industry

Partnering Organizations:

- VLSI Standards, Inc., San Jose, CA 95134-2006

Problem Statement:

The semiconductor industry depends on scanning electron microscopes (SEMs) to measure submicroscopic features on computer chips and other devices to ensure the devices can be manufactured efficiently and meet performance specifications. Standards with accuracy approaching the size of individual atoms are needed to calibrate the SEMs. VLSI Standards, a metrology supplier to the semiconductor industry, wanted to develop a calibration standard for these SEMs. The company had the technique for manufacturing the standard as a fine grating with uniform pitch spacing but needed to trace the calibrated pitch spacing to an appropriate standard.

NIST Response:

NIST conferred with VLSI Standards and outlined a procedure for the company to calibrate their grating specimen by basing the traceability of the proposed standard on pitch measurements of a similar, master artifact obtained with the Calibrated Atomic Force Microscope at NIST. VLSI Standards used the NIST measurements as the basis for calibration and released the new pitch standard in the spring of 2002.

Results and Impacts:

- The new pitch standard, called the NanoLattice, will be used primarily for calibration of the magnification and scan linearity of critical dimension SEMs used as high magnification inspection tools in the semiconductor industry.
- The NIST work provides metrology support for the progressive reduction in manufactured semiconductor feature sizes according to Moore's Law.
- VLSI Standards' product and the NIST supporting work were highlighted in an article by A.E. Braun in the April 2002 issue of Semiconductor International Magazine.

NIST and SPECTEL Research Develop an SEM Monitor and Reference Material to Optimize SEM Performance

Partnering Organizations:

- SPECTEL Research, Mountain View, CA 94043

Problem Statement:

Automated scanning electron microscopes (SEMs) are used on-line in U.S. semiconductor production facilities to inspect critical dimensions of integrated circuits. The performance of these SEMs degrade over time. A measurement drift of a few nanometers could result in a substantial loss of product and company profit. A quantitative method for determining the performance of the SEM was needed.

NIST Response:

In collaboration with SPECTEL Research, NIST first developed an algorithm to optimize the performance of SEMs. In order for the algorithm to work effectively, an appropriate sample material needed to be imaged. As part of this collaborative effort, NIST developed and released a Reference Material as an appropriate sample to be used in the sharpness analysis process during semiconductor production. In addition, NIST and SPECTEL developed an SEM Monitor, which is the first technology to qualitatively and quantitatively measure a scanning electron microscope's performance, astigmatism, and image quality.

Results and Impacts:

- The new Reference Material is available to the U.S. semiconductor industry as a sample to be used in sharpness and SEM performance analysis.
- Improved performance of critical dimension scanning electron microscopes currently being used on semiconductor production lines.
- The new SEM Monitor makes measurements in less than a tenth of a second, enabling its users to adjust and align a microscope in real time and optimize performance.
- SEM manufacturers are adopting this technology and building it into their new instruments.
- The SEM Monitor received the R&D 100 Award from Research and Development Magazine as one of the 100 most innovative technologies of 1998.

NIST Helps Semiconductor Manufacturers Improve Accuracy of Critical Dimension Measurements

Partnering Organizations:

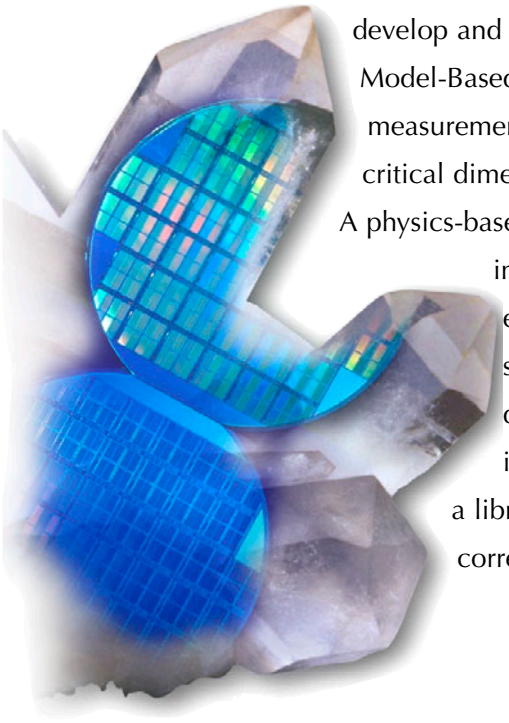
- International SEMATECH, Austin, TX 78741-6499
- Soluris, Inc., Concord, MA 01742

Problem Statement:

During production, semiconductor electronics manufacturers use scanning electron microscopes (SEMs) to monitor the size of critical features, such as transistor gates, in order to react quickly to changes that would otherwise reduce yield. In addition, as critical features shrink in size below 100 nanometers, measurement accuracy is even more important to help ensure faster computer processors and denser memories.

NIST Response:

NIST collaborated with International SEMATECH (ISMT), a consortium of semiconductor electronics manufacturers, to develop and test a new, Model-Based Library SEM measurement algorithm for critical dimension (CD) SEMs. A physics-based model of the interaction of electrons with samples was developed and is used to build a library of images corresponding to a range of sample shapes close to the shape targeted by the manufacturing process. The measured image is matched to the library to determine the sample's size and shape. After the test results were published, NIST consulted with Soluris, Inc. (then Schlumberger Verification Systems), a manufacturer of CD-SEMs, to incorporate a version of this measurement technique into their products.



Results and Impacts:

- Improves accuracy (i.e., smaller measurement bias) for critical dimension measurements in semiconductor manufacturing.
- Improves repeatability for critical dimension measurements needed for continued reduction of feature size that produces faster computer processors and denser memories.
- Provides more information (e.g., elements of feature shape, such as sidewall angles) than previous methods that measured only feature widths.
- Incorporation of this technology into a commercial CD-SEM makes it available to semiconductor manufacturers in a form they can use.

NIST Works with American Petroleum Institute to Ensure Integrity of Oil Drilling Equipment

Partnering Organizations:

- American Petroleum Institute, Washington, DC 20005-4070

Problem Statement:

Petroleum exploration and drilling require uniform equipment fittings to avoid costly mistakes including injury to humans or environmental harm.

NIST Response:

NIST works with the American Petroleum Institute (API) to establish dimensional measurements that can be traced to NIST's standard for length. Dimensional conformance ensures that equipment fittings will mate properly and perform according to specifications. With help from NIST, API has established a system of three levels of traceable measurements. This system ensures that whether measurements are made in the field, in the lab, or on the manufacturing floor, they are consistent and accurate.

Results and Impacts:

- Interchangeability of fittings for oil drilling operations throughout the world ensures proper operation.
- The risks of unanticipated environmental impacts and human injury are reduced.

NIST Helps Microelectronics Industry Automate On-Chip Wire Bond Testing

Partnering Organizations:

- Idaho National Engineering and Environmental Laboratory, Idaho Falls, ID 83415
- Simpex Technologies, Inc., Brea, CA 92821
- The Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723-6099

Problem Statement:

One of the most difficult and costly quality control challenges facing the microelectronics industry is ensuring the integrity of microscopic connections between chips and the wires that carry data into and out of the chip. Existing methods for testing the integrity of these wire bonds involve pulling and shearing the bond destroying the samples tested. Better quality control of bond integrity could lead to broad advances in products that use microelectronics, including longer-life pacemakers, sturdier cell phones, and space station components needing fewer repairs.

NIST Response:

NIST collaborated with Simpex Technologies and other research organizations to develop a high-speed nondestructive system for testing wire bond integrity. The new Micro Laser Ultrasonic Bond Detection System uses a pulsed laser to create ultrasonic waves in the bond, which travel into the chip surface where they are detected by a second continuous wave laser system. A strong bond results in a strong ultrasonic wave in the chip surface, while a weak bond results in a weak or absent signal. The system includes customized 3-dimensional signal processing software to convert the detected signals into information about bond strength. In addition to being nondestructive, the system also operates at least 30 times faster than the standard destructive mechanical pulling method.

In a multi-year Cooperative Research and Development Agreement with Simpex Technologies, NIST provided expert advice on ways to analyze the detected waves to determine bond integrity.

Results and Impacts:

- Allows for the rapid nondestructive evaluation of electronic chip bond integrity.
- Increases product reliability.
- Product cited for a 2002 R&D 100 Technology Innovation Award.
- System automation can yield large cost savings.

NIST Helps Boeing Improve Spare Parts Production Time

Partnering Organizations:

- Boeing Company, St. Louis, MO 63166

Problem Statement:

Boeing Company facilities have faced increased pressure to reduce the production time for small batch manufacturing of spare parts for military aircraft, in particular the F-15, F-18, C-17, and AV-8 Harrier aircraft. The turn-around time for spare parts production is affected by the flexibility and capability of the equipment and personnel to accommodate the many different requirements of multiple jobs without a production line dedicated to a particular type of part.

NIST Response:

In collaboration with Boeing engineers, NIST introduced new high-speed machine tool controller technology, computer-aided manufacturing software, a simple Ethernet network, and new machining methodologies into a Boeing spare parts machine shop.

Results and Impacts:

- Use of high-speed machining operations enabled cost-effective production of spare parts from single-piece materials, many times eliminating dozens of parts required to build corresponding assemblies from simpler components.
- Boeing fundamentally changed the operation of its two-shift, eight-person spare parts machine shop and drastically reduced the turn-around time for spare parts production.
- Successes achieved in the Boeing spare parts machine shop have driven similar improvements at other Boeing facilities, including two process research facilities and a tooling shop.

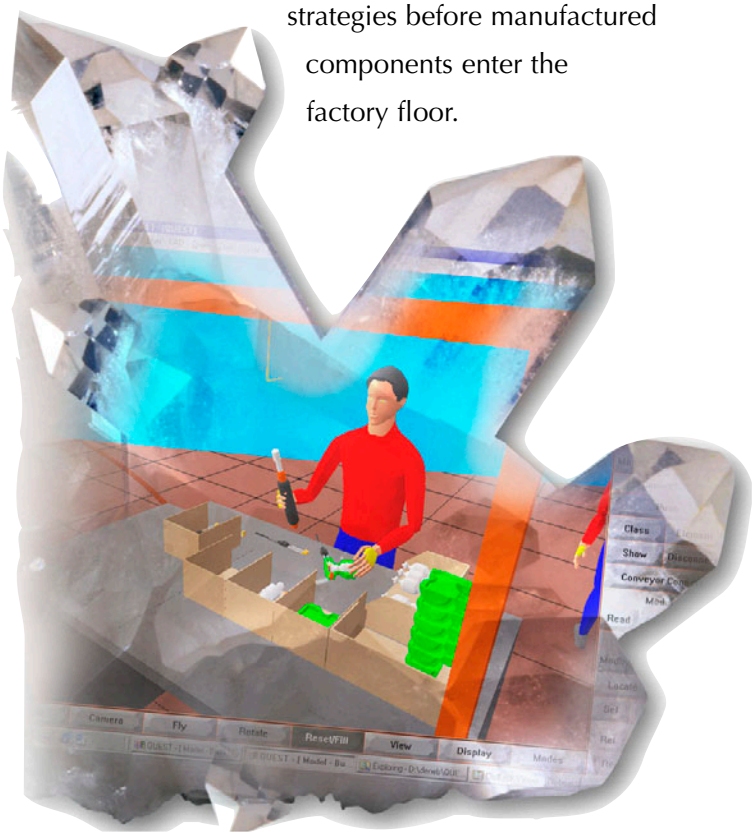
NIST Research Leads to Factory Computer Simulation Software

Partnering Organizations:

- MetroSage LLC, Volcano, CA 95689-9610

Problem Statement:

Efficient and accurate measurements are key to manufacturing autos, aircraft, heavy equipment and other products requiring high precision machining. Manufacturers need to use complex measuring instruments such as coordinate measurement machines (CMMs) and other measurement devices to verify that parts are properly made, but use of these instruments can be time-consuming and expensive. Manufacturers need a method to develop and test measurement strategies before manufactured components enter the factory floor.



NIST Response:

NIST has been developing mathematical algorithms to help manufacturers optimize the use of their measurement instruments. Recently NIST developed computer simulation methods used to estimate the accuracy of measurements in manufacturing applications. NIST's publication of the results caught the attention of MetroSage LLC, a developer of software for factory applications

Results and Impacts:

- MetroSage used NIST research to develop their "PUNDIT/CMM" software system that allows computer simulation of factory measurements without requiring a slowing or stoppage of the production line. The software became commercially available in January, 2004.
- Several U.S. manufacturers, including Ford, Boeing, and Caterpillar, have pre-purchased PUNDIT/CMM software to assist in their manufacturing measurements.
- The U.S. Air Force and the Department of Energy have acquired PUNDIT/CMM for defense related measurements.

NIST Helps Develop Repository for Data Exchange Standards

Partnering Organizations:

- Advanced Technology Institute, North Charleston, SC 29418
- Boeing, Commercial Airplane Group, Seattle, WA 98124-2207

Problem Statement:

STEP, the Standard for the Exchange of Product Model Data, allows companies to effectively exchange product data information with their worldwide partners, customers, and suppliers. STEP is widely used in a variety of industries, including aerospace, automotive, and shipbuilding. However, the cost of developing a STEP data exchange specification for a particular industrial application is huge, and the standards development process is very long. STEP's continued success requires that an organizationally and geographically diverse standards development team have the tools needed to quickly and cost-effectively develop new high quality specifications for particular applications as well as maintain existing specifications

NIST Response:

NIST collaborated with PDES, Inc., an industry/government consortium aimed at accelerating the development and implementation of STEP, to build a standards development environment called the STEP Modules Repository.

The repository enables standards developers to reuse existing specifications and supports collaboration over the Internet. STEP specifications are written using the Extensible Markup Language (XML), a standard syntax for structured information that is able to capture both the natural language and computer-interpretable aspects of STEP. The XML-encoded STEP specifications reside on a secure, Internet-accessible central server employing state-of-the-art software tools to manage updates and track revision histories.

Results and Impacts:

- Reduced cost and improved quality of STEP standards.
- Standards developers can now more easily create new specifications and search for information in existing specifications.
- Standards developers successfully used the repository to develop modular STEP standards for Product Data Management and Configuration-Controlled 3D Design.

NIST Laser Ball Step Gage Used to Ensure Performance of Large Coordinate Measuring Machines

Partnering Organizations:

- Caterpillar, Inc., Mossville, IL 61552

Problem Statement:

Coordinate measuring machines (CMMs) are used in manufacturing facilities to perform dimensional measurements of parts and assemblies. Ensuring proper performance of CMMs is critical to effective manufacturing performance. Evaluating the performance of moderate to large CMMs is a complicated task because large calibrated dimensional artifacts are hard to maintain, unwieldy to use, and difficult to calibrate.

NIST Response:

In response to a request from the Caterpillar Technical Center, NIST redesigned the Laser Ball Step Gage (LBSG) for use on moderate size (1.6 X 3 X 2 meter volume) coordinate measuring machines (CMMs). The original design of the NIST LBSG, intended for much larger machines, used large rigid tripods to support a long (greater than 3 meter) calibrated length in various positions in the CMM work zone.

The redesigned version of the LBSG uses a new support structure that allows implementation on moderate size work volumes. As proof of concept, NIST also participated in the performance evaluation testing of a new Caterpillar CMM.

Results and Impacts:

- U.S. industry now has an invaluable tool for assessing the measurement performance of this class of CMMs.
- Caterpillar supports the inclusion of LBSG as a valid artifact for testing CMMs per standards issued by the International Organization for Standardization (ISO).
- Caterpillar uses LBSG for testing larger CMMs as part of periodic evaluation and for acceptance purposes. For example, Caterpillar used this technology to successfully validate the performance of a CMM purchased in Brazil.

NIST and EPRI Team Help Identify Power Quality Effects on Machine Tools

Partnering Organizations:

- Electric Power Research Institute (EPRI), Palo Alto, CA 94304-1395
- EPRI-PEAC Corporation, Knoxville, TN 37932

Problem Statement:

Millions of dollars are lost annually when industrial machining equipment inadvertently shuts down or malfunctions due to voltage sags on the electrical system. Such failures can result in production downtime and damaged or unusable parts that must be scrapped or reworked. Furthermore, the resultant financial and scheduling impacts can affect the ability to meet production and profitability goals.

NIST Response:

NIST was subcontracted by the Electric Power Research Institute (EPRI) to work on a cooperative project with EPRI and EPRI-PEAC Corporation to characterize the sensitivity of machine tools to voltage sags that can occur on a utility grid. In this collaborative effort, EPRI and NIST designed and carried out tests on three different classes of machine tools ranging from ultra-precision to general purpose to measure their accuracy under varying power conditions. Input power to machine tools was adjusted using the EPRI-PEAC developed power sag generating equipment. Based on these tests, NIST published a joint paper with EPRI describing the sensitive components of machine tools and possible remedies to be taken by end users or Original Equipment Manufacturers (OEMs).

Results and Impacts:

- Based on these tests, the power requirements specifications in the ANSI/ASME Standard for Performance Evaluation of Machining Centers were updated.
- Improved productivity by reducing unexpected downtime of machine tools.
- Improved cost savings by eliminating damaged parts and cutting tools caused by unexpected power sag crashes.

NIST Helps with the Calibration of the MIT Pentaflex Micro Positioner

Partnering Organizations:

- Massachusetts Institute of Technology (MIT), Cambridge, MA 02139

Problem Statement:

The Precision Engineering Research Group of MIT developed a pentaflex micro positioner, a new kind of planar XY micro positioning stage based on large compound leaf spring flexures which form parallel kinematic mechanisms. The calibration and testing of this device requires the use of expensive and sophisticated instrumentation, control and analysis software.

NIST Response:

NIST research staff collaborated with MIT to perform the calibration and testing work on this new device. The work was performed in NIST laboratories where the MIT researchers had the opportunity to use NIST hardware and software tools and to interact with NIST researchers with expertise in precision engineering, optics, modeling and control of dynamic systems.

Results and Impacts:

- MIT research staff now has a better understanding of the behavior of complex large compound leaf spring flexures parallel kinematic mechanisms. This required the fabrication of tools and fixtures, which were not available within the university's resources.
- Completion of the experimental work requirements helped an MIT researcher prepare a doctorate degree thesis. The student had the opportunity to interact with NIST researchers with expertise in metrology and optics, which proved to be very valuable for the completion of his thesis work and publications currently under preparation.

NIST Helps Bring Internet Technology to Industrial Robot Systems

Partnering Organizations:

- Robotic Industries Association (RIA), Ann Arbor, MI 48106

Problem Statement:

Industrial robot controllers are being connected to factory data networks in increasing numbers to integrate design, programming, maintenance and diagnostics with production processes such as welding, assembly, and painting. An obstacle to this integration has been the proprietary nature of robot controllers. According to industry members of the Robotic Industries Association (RIA), the costs associated with integrating proprietary robot controllers add between $2 billion - $4 billion annually to the $1 billion industrial robot market.

NIST Response:

NIST established and led an open architecture working group comprised of key end users and vendors of industrial robot systems and the RIA. The working group determined communication requirements based on a three-phase approach, in which Internet standards would be introduced to commercial robot controllers. In addition, NIST participated in the publication of an RIA Technical Report that lists first-phase requirements to be supported by robot vendors.

Results and Impacts:

- The Technical Report is being referenced by end users when contracting for industrial robot systems to help these companies reduce integration costs.

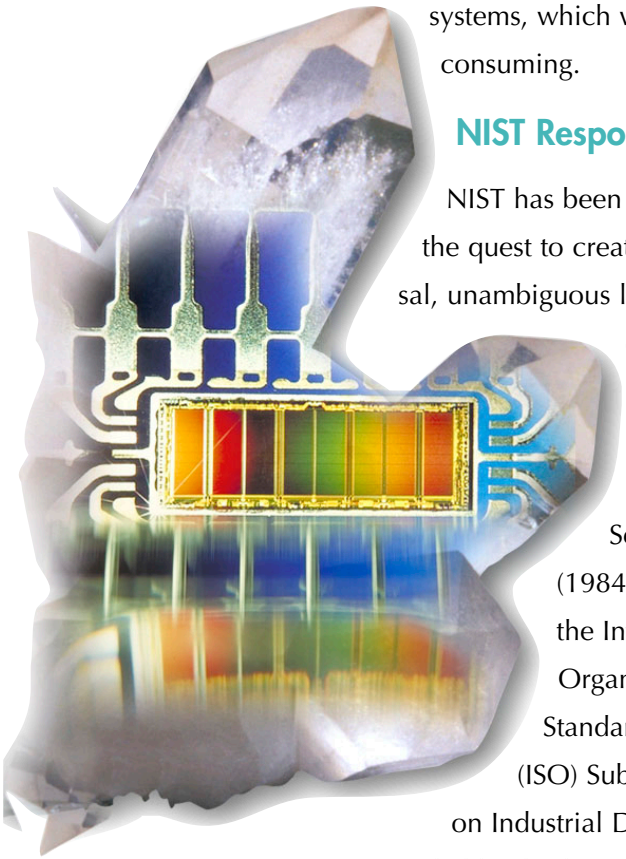
NIST Helps General Dynamics Electric Boat Corporation to Expand its Use of STEP Improve Product Exchange Data

Partnering Organizations:

- General Dynamics Electric Boat, Connecticut

Problem Statement:

Current shipbuilding contracts involve extensive teaming, so the exchange of product model data is essential with vendors, suppliers, partners, and customers. Over the years, these transfers have been done manually, or with proprietary translators, or with national standards. Data often had to be interpreted and re-entered into different systems, which was time consuming.



NIST Response:

NIST has been a leader in the quest to create a universal, unambiguous language for exchanging product information. As the Secretariat (1984-1997) for the International Organization for Standardization (ISO) Subcommittee on Industrial Data (ISO TC 184/SC4), NIST provided leadership and direction in developing standard exchange protocols. ISO 10303, informally known as the STandard for the Exchange of Product model data (STEP), evolved from this collaboration. STEP exchange protocol ISO 10303-227 (Piping) which was developed under technical leadership of NIST and is being used in production at Electric Boat in for shipbuilding design. Electric Boat's data is now quickly and accurately sent electronically without concern for compatibility with diverse proprietary software. NIST continues to participate in STEP's evolution and implementation by developing testing methodologies for and making technical contributions to ISO.

Results and Impacts:

- ISO 10303 STEP application protocol standards have become the tools of choice for many production data transfers at Electric Boat: AP203 (Geometry) is used for the exchange of thousands of solid models per year; AP209 (Analysis) and AP227 (Piping) are routinely used for CAD-CAE integration efforts; and AP227 allows the transfer of an external partner's piping to the PIPESTRESS 2000 program run at Electric Boat for analysis. Availability of the AP227 transfers promotes collaboration and interoperability among platforms and among partners, while alleviating the requirement for manual entry of data into the PIPESTRESS 2000 program.
- STEP is viewed by Electric Boat views STEP as an enabling technology for data exchange and improved product lifecycle management capabilities.
- The use of STEP standards within Electric Boat promotes collaboration and interoperability among platforms and among vendors.

NIST Helps Data Integration in Manufacturing Simulation

Partnering Organizations:

- The Boeing Company, Boeing Commercial Airplanes, Seattle, WA 98124-2207

Problem Statement:

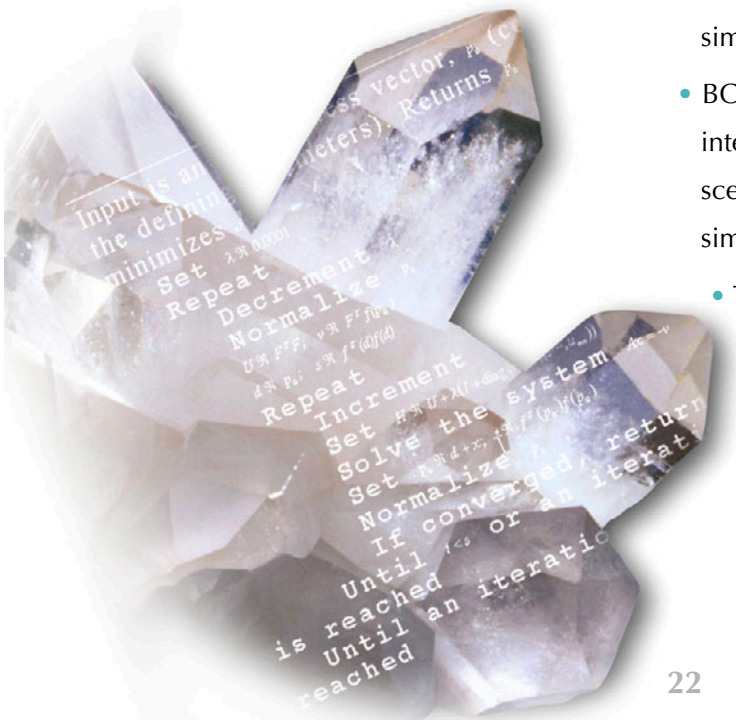
Boeing Commercial Airplane (BCA) Material & Process Technology (M&PT) group has been conducting discrete event simulation modeling projects without a standard specification that is equivalent to the depth and breadth of the eXtensible Markup Language (XML)-based document proposed by NIST. This case study was the first attempt by industry to integrate the NIST's generic specifications to a specific M&PT simulation project.

NIST Response:

The goal of the NIST project was to describe the important information about the manufacturing facilities and processes; to establish a neutral model of shop information, which is based on the XML, to configure simulation models; and to exchange data between simulation and other manufacturing applications.

A case study was performed at BCA, utilizing the XML simulation interface specification.

The simulation model in this case study contains asynchronous servers, multi-input/output buffers, bi-directional cranes, labors (manpower), processes, and machines on different shifts. This model can be executed from a batch control language document, which is derived from the proposed NIST XML-based simulation specification. This case study illustrated a feasible method for using the XML-based NIST specifications in a discrete event simulation model of a manufacturing process.



Results and Impacts:

- This new method of integration has potential for improving efficiencies in BCA M&PT when conducting discrete event simulation projects in the future.
- BCA views NIST's specification as an enabling technology for simulation data transportation, and an innovative method for executing simulation model constructions.
- BCA successfully incubated and tested the new integration process in model modifications and scenario iterations, which improved overall simulation efficiency.
- This case study promotes the use of standard specifications gaining a savings in time and resources for reusability.

NIST Helps Promote Interoperability for EtherNet/IP™ Devices

Participating Organizations:

- ODVA (formerly the Open DeviceNet Vendor Association), Ann Arbor, MI 48108-5002
- Cisco Systems, San Jose, CA 95134-9883,
- Frontline Test Equipment, Charlottesville, VA 22906-7507
- General Motors, Controls, Robotics & Welding, Warren, MI, 48090-9040
- Hirschmann Electronics, Germantown, MD 20874
- HMS Industrial Networks, Chicago, IL 60601
- InterlinkBT, Plymouth, MN 55441,
- Motoman Inc (A Yaskawa Company), West Carrollton, OH 45449
- Network Vision, Newburyport, MA 01950
- Numatics, Inc., Highland, MI 48356
- Phoenix Contact, Harrisburg, PA 17101
- Pyramid Solutions, Beachwood, OH 44122
- Rockwell Automation, Mayfield Heights, OH & Milwaukee, WI 53202

Problem Statement:

EtherNet/IP™ (Ethernet / Industrial Protocol) is one of a growing number of industrial Ethernet standards that have emerged in the last few years that allows real-time communication over Ethernet for industrial data acquisition and control. Since the EtherNet/IP specification is fairly new and the types of products vary widely, it has been difficult for vendors to test and demonstrate interoperability with each other's products.

NIST Response:

NIST helped organize and conduct two EtherNet/IP Interoperability Plug-Fests to test and document the interoperability of EtherNet/IP devices. These plug-fests were organized through ODVA (formerly the Open DeviceNet Vendor Association) and were open to any vendor developing EtherNet/IP products. They involved connecting all of the devices on one network and running them through a series of tests designed to determine their ability to connect to different vendor's products individually and in groups. Performance data was collected to determine the effect of any background network traffic or the number of connections on the real-time communications. The first plug-fest established that the EtherNet/IP standard is functional and provides a basic level of interoperability. The second plug-fest established the degree of interoperability provided by the specification and identified and documented any implementation issues and specification ambiguities.

Results & Impacts:

- The plug-fests provided a valuable source of testing for EtherNet/IP vendors. The events brought together multiple competing vendors to one location in a development environment to test the capabilities of their products.
- The implementation issues and specification ambiguities from the plug-fests were reported to the EtherNet/IP committees and vendors, resulting in improvements to the specification and better, more interoperable products.
- ODVA will use the test results to create a minimum-recommended-features document to help vendors achieve interoperability.

NIST Helps to Accelerate Research in Autonomous Mobility Planning

Partnering Organizations:

- The Boeing Company, Seattle, WA 98124-2207
- Intelligent Innovations, Incorporation , Cecilia, KY, 42724
- Georgetown University, Washington, DC 20057
- George Washington University: Department of Engineering and Applied Science, Washington, DC 20052
- University of Delaware, Newark, DE 19716
- Bremen University: TZI – Center for Computing Technologies, Germany

Problem Statement:

An autonomous mobility system must include a sophisticated reasoning system in order to operate in realistic on- and off-road driving situations. This reasoning system must integrate perceived and *a priori* knowledge about the world with system objectives in order to formulate control decisions.

This requirement places an extremely large burden on the developers of the reasoning system. In addition to developing every aspect of the reasoning system, they must also provide sensor processing to feed the reasoner, a low-level control system to control the autonomous platform, and the autonomous platform itself. In addition, development and debugging of the reasoner may be hampered by errors occurring in other subsystems and the lack of the ability to recreate scenarios in a controlled and measured environment. For all of these reasons, only the largest and best-funded institutions have been able to participate in autonomous mobility research.

The current situation leads organizations to typically implement the entire autonomous system in-house (either in simulation or real hardware), which introduces inefficiencies, slows progress, and excludes smaller organizations from participating in autonomous mobility research. In addition, the majority of these systems are "home-grown" quick solutions to the problem and do not communicate with other vendors' components or allow for easy transition from the simulation world to a real-vehicle.

NIST Response:

NIST responded to requests from the robotic research community to provide a simulation environment in which individual components of a high-level reasoning system may be developed and evaluated. The environment, known as the Mobility Open Architecture Simulation and Tools (MOAST), is designed to remove the burden of developing the infrastructure necessary for this research from the individual scientists. Facilities for the simulation of processed sensor data, low-level vehicle control, storage of a priori data, and visualization of results are provided, as well as a fully functioning modularized reasoning system. All of these components follow the NIST- developed MOAST architecture (which has been adopted by several outside programs and organizations) and communicate over standard messaging channels. The intent of this system is to allow researchers from various academic and commercial institutions to test and evaluate their niche expertise without requiring expertise in every aspect of mobile robotics.

Results and Impacts:

- Organizations no longer have to develop a sophisticated multi-disciplinary infrastructure to explore aspects of reasoning for autonomous mobility systems. This has allowed both large and small companies as well as the government to conduct research within their competency areas.
- Researchers are able to experiment with novel algorithms and techniques without robot or human safety concerns. For example, the real or simulated robotic platform may navigate amongst simulated vehicle and pedestrian traffic.
- Running experiments in the MOAST simulation environment removes safety concerns, eliminating the need for costly safety vehicles and personnel during the initial development and testing phases.
- The research community has access to repeatable well-defined trials to allow for accurate algorithm evaluation. In addition, events can be made to happen "on-command" rather than by chance.
- Research into reasoning systems is accelerated because researchers are not limited by real-robot and sensor-processing availability.
- The design of the environment allows for easy transition from simulation to real robot implementation without the need to recode algorithms. For example; preliminary simulations of laboratory experiments with Magellan Pro robots at University of Delaware could be performed using this architecture.

NIST Software Helps Improve Network Implementation Efficiencies

Partnering Organizations:

- MCI (formerly WorldCom), San Jose, CA 95113

Problem Statement:

Customers of the Customer Network Engineering (CNE) Group within the MCI organization rely on MCI's expertise to design, implement, operate, and manage their network, including customer premise equipment. A typical network rollout requires more than 60 manual verification steps. CNE's goal of rolling out the network to 25 sites per day was difficult to achieve due to aggressive scheduling and additional customer design requirements. Therefore, an automated verification process was needed.

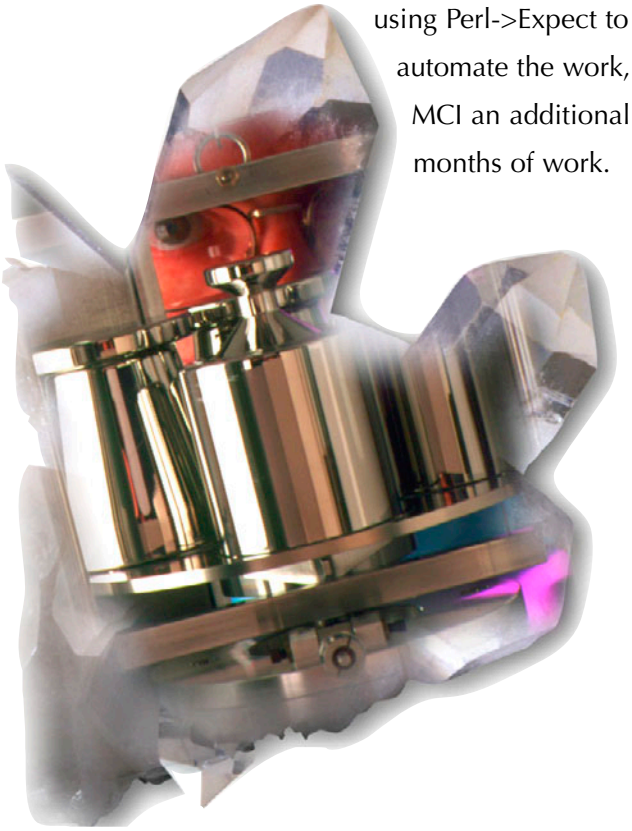
NIST Response:

NIST developed a tool, known as Expect, that enables automation of applications that normally require human interaction. Expect makes it possible to automate these applications, allowing users to speed up tasks and solve new problems through the synergy of combining existing programs in new ways. The CNE Group used Expect over a six-week development and testing cycle to create an automated verification program called WT. Due to the portability of Expect, moving WT to a production machine required only a single source code line change.

Results and Impacts:

Using Expect, the WT script dramatically:

- Reduced engineering time per site from about 74 minutes to an average of 41 minutes, resulting in a savings of 33 minutes.
- Enabled design enhancement of other Expect scripts that configured core Juniper/Cisco routers and terminals servers resulting in additional time reduction of approximately 14 minutes per site.
- Improved consistency and automatic documentation of all results.
- Enabled MCI to save approximately 47 minutes of manual work per customer location per project in 2,157 sites, or more than 9.6 months of work.
- Increased the number of sites that are put on-line by a factor of two (more than 50 sites per day versus the planned 25 sites per day.)
- A design engineer from MCI developed a script using Perl->Expect to fully automate the work, saving MCI an additional four months of work.



NIST Helps Guarantee Uniformity of Mass Measurements

Partnering Organizations:

- State Weights and Measures Laboratories, All States

Problem Statement:

Weights and Measures Laboratories in each State test more than 300,000 mass artifacts each year to establish mass standards. A systematic protocol was needed to guarantee uniformity of mass measurements across the U.S., equity in national trade, and uniform support of the U.S. industry.

NIST Response:

NIST developed and implemented a model framework for a systematic intercomparison protocol to guarantee uniformity of mass measurements across the U.S., equity in national trade, and uniform support of the U.S. industry. This protocol establishes an unbroken traceability chain that links all the State Weights and Measures Laboratories to each other and to the NIST's National Standard of Mass.

Results and Impacts:

- The national comparison of mass standards formally tied together the entire U.S. legal metrology system in the area of mass.
- Results of the national comparison of mass standards have guaranteed the uniformity of mass measurements in the U.S.
- The national comparison of mass standards has provided assurance in equity in national trade.

- The national comparison of mass standards has provided assurance in the more than 300,000 mass measurements conducted per year by the States Weights and Measures Laboratories.

NIST Helps Ensure the Accuracy of Laser Tracking Measuring Machines

Partnering Organizations:

- Naval Surface Warfare Center, Corona Division, Norco, CA 92860

Problem Statement:

Laser tracking measuring machines, known also as laser trackers, are becoming the tool of choice for inspecting large manufactured parts. Using traditional calibration methods to gain confidence in the measurement results of these machines is a time consuming and complicated task. The calibration process, including transit, typically takes approximately five days. Additionally, these calibration procedures are not well described or necessarily complete.

NIST Response:

NIST developed and deployed the Laser Rail Calibration System (LARCS) for calibrating laser trackers. The instrument consists of a laser interferometer rail and support system to set up and measure an in-place calibrated length in any orientation in the laser tracker measurement work volume. The instrument includes a fully functional scripted software program that walks an operator through a set of automated measurement procedures that are designed to be sensitive to common error modes of these measuring systems. The software analyzes the results of the measurements and reports performance quality factors that characterize the laser tracker length measurement capability.

Results and Impacts:

- Reduces the calibration cycle for laser trackers from five days to just over five hours; making it economical to more frequently calibrate these instruments which provides greater confidence in the measurements and their results.
- Provides the utility to calibrate or certify the performance of laser trackers in-house, providing significant savings in both time and cost.
- Reduces the complexity of the calibration process by providing a simple set of automated measurement procedures and automatic data analysis. This eliminates the requirement for a high-level operator to perform the calibration testing, allowing more efficient use of human resources.
- Calibrated laser tracking machines lead to more accurate parts.
- Widely applicable anywhere laser trackers are used, including the aviation, steel, and automotive industries.

NIST and Industry Develop EXPRESS Software for Improved Product Data Applications

Partnering Organizations:

- Boeing, Seattle, WA 98124-2499
- Modulant Solutions, San Francisco, CA 94107

Problem Statement:

Numerous engineering data models are specified in EXPRESS, a modeling language used in the Standard for the Exchange of Product Model Data (STEP). Manufacturers and software vendors need to transform these data models into alternative formats such as the Extensible Markup Language (XML) so they can be more easily integrated with other business applications and with the Web.

NIST Response:

NIST initially developed a parser to convert data from EXPRESS to XML and other formats. After further collaborative development with other researchers on the SourceForge open source development web server, this parser is currently being used both by Boeing and Modulant for product data applications. These companies have contributed to the parser's further development by implementing bug fixes and supplying test data. The parser is also being used in an international open source project to develop a translator from EXPRESS to Web Ontology Language (OWL).

The parser differs from other open source EXPRESS software in that it is optimized for applications involving transformation of EXPRESS to other languages and integration with the Web. Also, the use of state-of-the-art parser technology results in code that is relatively small and easy to maintain.

Results and Impacts:

- Reduced cost of deploying the rigorously defined and internationally agreed-upon data models of the Standard for the Exchange of Product Model Data (STEP).
- Reduced software development costs.

NIST Calibrates Artifacts to Improve Quality Assurance

Partnering Organizations:

- Air Force Primary Standards Laboratory, Heath, OH 43056-6118
- Pratt & Whitney - United Technologies Corporation, East Hartford, CT 06108-0968

Problem Statement:

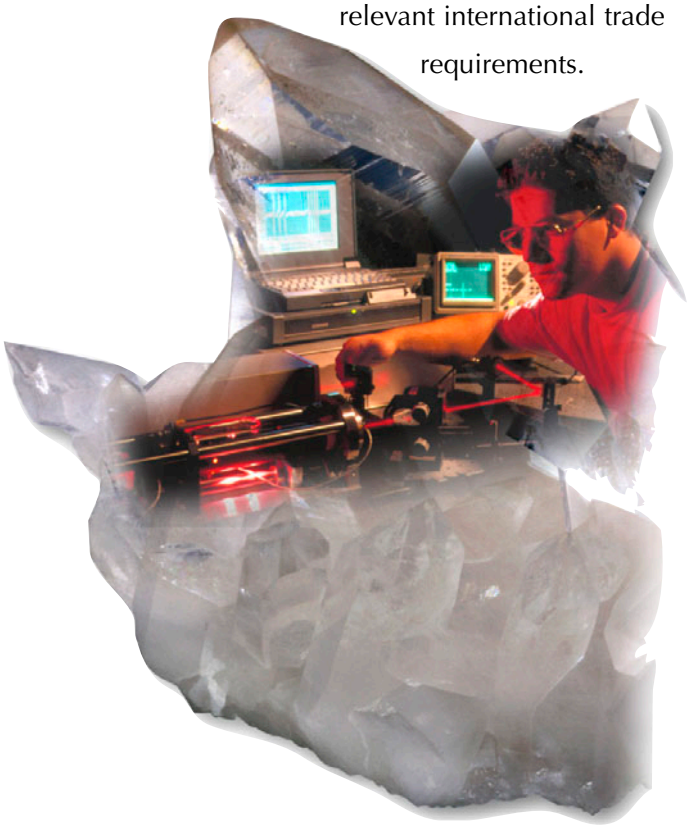
U.S. companies need assurances that the dimensions of manufactured parts conform to design specifications. Production of commercially available products increasingly depend on highly distributed supply chains. To ensure that parts coming from across the globe fit and work together properly, manufactures must know that all suppliers conform to the same dimensional standards.

NIST Response:

NIST performs over 6,000 calibrations annually for over 300 organizations in 40 states. NIST calibrates each of these company's internal standard for length. Companies trace their internal standard to the NIST standard to facilitate commerce with other businesses knowing the dimensions of manufactured parts correlate to each other.

Results and Impacts:

- Parts manufactured with dimensional conformance to the NIST standard work better, last longer, and can be properly assembled with parts manufactured at other conforming companies.
- Manufactured parts that can trace their dimensional conformance to NIST's standard meet relevant international trade requirements.



NIST Helps Develop Smart Transducer Interface Standards

Partnering Organizations:

- Aeptec Microsystems, Inc., Rockville, MD 20855-2604
- Agilent Laboratories, Palo Alto, CA 94304-1317
- Analog Devices, Norwood, MA 02062-9106
- Endevco Corporation, San Juan Capistrano, CA 92675-1798
- Kistler Instrument Corporation, Amherst, NY 14228-2119
- National Instruments, Austin, TX 78759-3504
- Oak Ridge National Laboratory, Oak Ridge, TN 37830-8050
- The Boeing Company, Seattle, WA 98108-3546
- The Modal Shop, Inc., Cincinnati, OH 45212-3520
- Wilcoxon Research, Gaithersburg, MD 20878-1757

Problem Statement:

Transducers (sensors and actuators) are used widely in industries including aerospace, automotive, biomedicine, building automation, industrial automation, manufacturing, process control, and environmental monitoring. It is costly for manufacturers to produce sensors because of the lack of a standardized sensor communication interface, which is used to support numerous proprietary networking protocols for integrating the sensor networks and instrumentation systems.

NIST Response:

Based on the results from a series of workshops and collaborations with industry partners, NIST facilitated the formation of a standards committee and chaired the technical development of a standardized interface for sensors and actuators. This committee was organized through the Institute of Electrical and Electronics Engineers (IEEE) organization, with accreditation from the American National Standards Institute (ANSI). Standards resulting from this committee are designated as the IEEE series of standards for smart transducer interfacing and networking to facilitate sensor, instrument, and network interoperability.

Results and Impacts:

- Two standards have been published by IEEE and accepted by ANSI.
- Provided sensor developers and users with opportunities for interoperability among sensors and networks.
- Reduced the cost of supporting multiple networking protocols, increased smart sensor functionality, and improved competitiveness in industry.
- Accelerated development of smart sensor technologies and created new market opportunities.
- Reduced the total life cycle cost i.e. installation, upgrade, and maintenance of sensor systems, because the sensor can identify itself and contain calibration data enabled by the smart sensor communication interface standards.
- The smart sensor communication interface standards that enable sensors to identify themselves and to enhance their accuracy via the calibration data have reduced the total life cycle cost of sensor systems.
- Provided the enabling technology for easing the integration and networking of sensors and actuators into measurement, control, and monitoring systems.

NIST Helps Design a Precision Controlled Environmental Facility

Partnering Organizations:

- Thermo Richardson Grating Laboratory (RGL), Rochester, NY 14605

Problem Statement:

Thermo RGL manufactures diffraction gratings, a key artifact in spectroscopy used to separate polychromatic light into its monochromatic components. Master gratings are cut, line by line, using a large (approximately 25 cubic meters) stable frame called a "ruling engine." Ruling a master grating is a long, slow, painstaking process, with some forms taking up to six weeks to rule. Environmental factors such as humidity, temperature variation and vibration severely impact the quality of the master grating produced. Thermo RGL wanted to create a new environment (cell) for a recently acquired engine, with tight temperature, vibration, and humidity control.

NIST Response:

NIST collaborated with Thermo RGL on the design of a room-sized precision controlled environmental facility. The new ruling environmental cell has been quite successful, with temperature control initially measured at the required 70 degrees Fahrenheit +/-0.001 degrees Fahrenheit single point stability.

Results and Impacts:

- The new cell is very compact and energy efficient.
- The new cell can recover from a temperature upset in minutes as compared to hours by the other Thermo RGL's cells.