Intelligent Systems Program

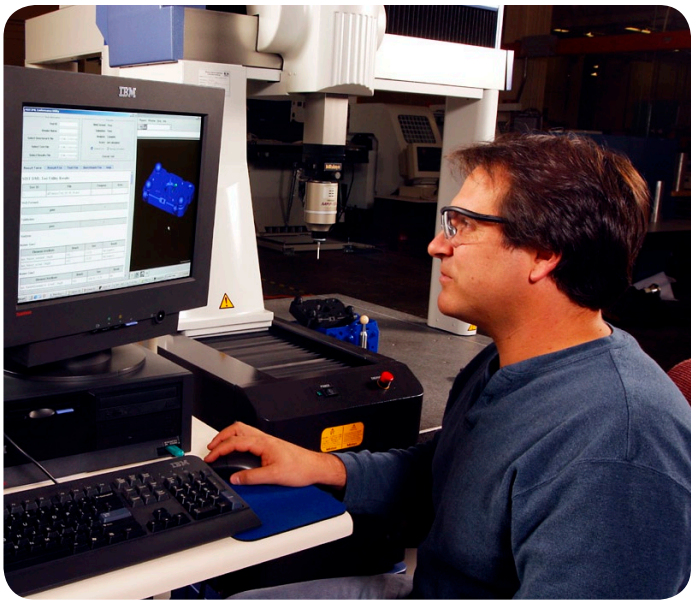
Robotics and Automation Interoperability Standards Program

Annual FTEs: 7 NIST staff
1 guest researcher
8 total FTEs

Challenge:

The increasing pace of technological change and expectations of shorter time-to-market for new products represent growing challenges for U.S. manufacturers. These pressures, combined with the push for distributed manufacturing facilities, create an urgent need for shop floor robots and automation equipment that offer:

- Real-time integration between engineering, production, and business function, which may be geographically dispersed. Information and instructions need to be transmitted and acted upon without the delays that currently occur because of missing or misinterpreted data.
- Faster, more accurate, and more autonomous onboard planning, re-planning, and execution abilities that are driven by product and process models and respond to changes elsewhere in the manufacturing enterprise. Machine tools, robots, and coordinate measurement machines currently require extensive trial-and-error debugging whenever a new program is downloaded. This rework and tuning by human operators results from the hard-coded nature of the programs, which cannot adapt to individual differences in each piece of equipment. The challenge is to provide the necessary information about the part design (features, tolerances, etc.) as well as the machine's own characteristics so that it can automatically adjust for its own motion errors and other variations.
- Interoperability of products from diverse vendors. Manufacturing enterprises must be able to buy the best equipment for their needs and to outsource production of various components. For these options to be economically viable, data must be reliably transferred among machine tools, robots, and coordinate measurement machines. U.S. manufacturers must be able to buy equipment with confidence that it will integrate with the rest of their enterprise.



Testing standard interfaces for dimensional metrology equipment

Overview

The Intelligent Systems Division is working on interoperability standards that will meet the challenges listed above. We are working to achieve a vision of the seamless transfer of "smarter" data. This is an essential prerequisite not only for reliable transfer of information between equipment controllers, but also for providing enough richness in the information to enable the shop floor equipment to make in situ decisions when new programs are received and when conditions change. This vision of seamless smart data transfer presents business and technical challenges. To address the business challenge, which is rooted in resistance to standards, ISD involves vendors and end users in the definition of requirements, standards, and validation. The technical challenges center on the definition of the data models and interface protocols themselves: are they complete, efficient, unambiguous, and correct? MEL is addressing the technical challenges by developing measures of the correctness (syntactic and semantic) of interface language specifications and by implementing standards validation tools and processes.

Thus far, we have focused on interoperability standards for metrology equipment and next generation machine tools. The metrology equipment standards cover interfaces between computer aided-design (CAD) and Product Life Cycle Management Software, Inspection Process Planning Software, Inspection Execution Software, Coordinate Measuring Machines, and Reporting and Analysis Software. In the next generation machine tools interoperability front, NIST has been focusing on the ISO 10103 AP 238 ("STEP NC – Standards for the Exchange of Product model data – Numerical Control") and on the Open Modular Architecture Controller Human-Machine Interface (OMAC HMI).

Key Accomplishments and Impacts:

- With industry partners, NIST has conducted numerous tests and pilot experiments that demonstrate facets of STEP-NC (such as feature-based steps, and the ability to support dynamic optimization and compensation) in action and validate that the data contained in the standard can be interpreted in real-time. Successful tests of this sort are necessary to build industry confidence and participation in these new standards.
- Thanks in great part to NIST efforts in developing validation test suites and bringing the stakeholder community together, several metrology standards are gaining wide acceptance. Examples include the I++ DME (Dimensional Measuring Equipment) specification, the DML (Dimensional Markup Language) specification, and QMD (Quality Measurement Data).

Future Directions and Plans:

Looking ahead, NIST will continue to strengthen its ties to the different communities in the broader metrology landscape and among the users of advanced machining technologies. Additional opportunities for NIST to apply its expertise include interface standards for nanoscale metrology, material transport vehicles, and industrial robots.

Awards and Recognition

Board Membership

Staff	Board Membership
John Horst	• Advisory Board, Quality Expo • Advisory Board, 3D Collaboration and Interoperability Conference • Board of Directors, Dimensional Metrology Standards Consortium Board of Directors

Leadership

Staff	Leadership
Fred Proctor	• Executive Committee of the Computers and Information in Engineering (CIE) Division of the American Society of Mechanical Engineers.
John Horst	• Chair, Dimensional Metrology Standards Consortium High-Level Measurements Process Planning (HIPP) Subcommittee • Executive Committee member, AIAG Metrology Interoperability Project Team
John Michaloski	• Chair, Open Modular Architecture Controller Human-Machine Interface
Hui-Min Huang	• Invited plenary on architectural perspective for a robotics standards technical framework at the OMG Robotics Domain Special Interest Group meeting

Excellence

Staff	Excellence Recognized
Joseph A. Falco John A. Horst Hui-Min Huang Willlam G. Rippey Keith A. Stouffer	• Department of Commerce Bronze Medal Award for Superior Federal Service (2006): For technical leadership and engineering achievement demonstrating outstanding initiative, commitment, and technical competence in developing critically-needed software testing tools for the I++ Dimensional Measurement Equipment and Dimensional Markup Language data exchange standards.
John Horst	• Automotive Industry Action Group (AIAG) Outstanding Achievement Award for efforts to enable metrology systems interface standards in the automotive industry. (2005)
Frederick Proctor, et al.	• Guest Editorial, “STEP-Compliant Process Planning and Manufacturing,” International Journal of Computer Integrated Manufacturing special issue on STEP-NC, Vol. 19, No. 6, September 2006.
John Michaloski	• ISA On-line Webinar, “Integrating CNC and ERP - A Real World Success,” in June 2006
James Albus	• Keynote presentation to International Conference on Smart Machining Systems, 2007
Bill Rippey	• Invited technical coordinator for trade show interoperability demonstrations sponsored by International Association of CMM Manufacturers (iacmm), 2004-2008. The yearly demonstrations at Control involve integration of 8-14 vendor’s products.

Projects

Robotics and Automation Interoperability Standards Program

Metrology Interoperability Project

(Status: to be completed in 2011)

Challenge/Problem Addressed:

The U.S. manufacturing sector is suffering significant interface language incompatibility costs, since products can talk with one another only through translators that are costly to build and maintain. For example, certain dimensional metrology product vendors must build and maintain internal translators for more than *sixty* different upstream and downstream products. All this cost is passed on to the OEM and eventually to the customer. Airbus's recently-reported anticipated $6.1 billion loss over 4 years was in large measure the result of interface language incompatibility. Besides their intrinsic cost, such translation efforts do not add to product value, are detrimental to quality, and stifle innovation.

The ideal solution to this problem is worldwide adoption of correct, complete, and unambiguous interface language standards. For the quality measurement sector of manufacturing, Figure 1 shows the number and types of interfaces along with the current and future standards at each interface.

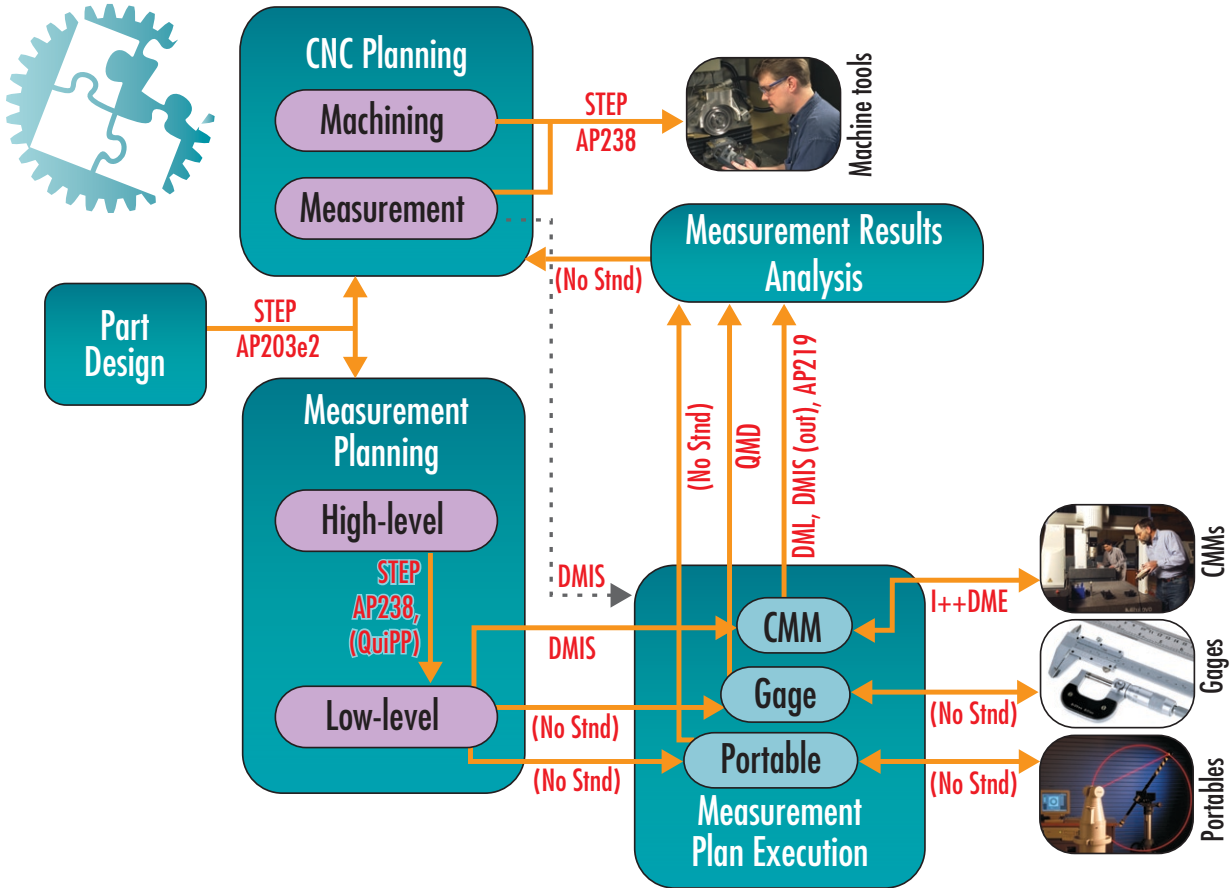


Figure 1: Quality Measurement Information Exchange Standards Infrastructure

Objectives:

- Define and update a standards infrastructure for quality measurement information at the interfaces between product design, product manufacture, measurement planning, measurement execution, measurement equipment, and measurement results analysis.
- Define complete, correct, and unambiguous quality measurement information exchange standards in appropriate information modeling languages and make possible compliant implementations of those standards worldwide.
- Define and develop implementation conformance tests for both sides of each interface defined in the standards infrastructure
- Facilitate regular public demonstrations of interoperability with vendors worldwide for each interface in the standards infrastructure.
- Act as an advocate for U.S. quality measurement systems user corporations (automotive, aerospace, defense, etc) and for quality measurement information exchange standards through meeting organization, conference talks, and board membership.
- Integrate metrology information exchange standards with information exchange standards efforts in the broader manufacturing context, including machining, forging, casting, and assembly.

Accomplishments:

- Achieved worldwide acceptance of key metrology standards through NIST specification analysis, standards development consultation, public interoperability demonstrations, and test suite development. These achievements reduce the need for standalone custom translators and the costs incurred by incomplete or erroneous information transfer. Standards that have benefited from NIST involvement include I++ DME, Automotive Industry Action Group (AIAG) Dimensional Markup Language, Dimensional Metrology Standards Consortium's Dimensional Measuring Interface Standard (DMIS), and AIAG's Quality Measurement Data specification.
- Defined information needed to generate a high-level measurement process plan as well as the high-level process plan itself for use within STEP NC (ISO STEP AP238), allowing for implementation of rich on-machine inspection.
- Organized International Metrology Interoperability Summit in 2006, which elicited input from stakeholders about industry priorities and needs. A Metrology Interoperability Roadmap was published, providing a baseline assessment of interoperability and guidance for future standards efforts.

Vendors demonstrate integration of multi-vendor products

Planned Future Accomplishments:

- Generate DMIS test utilities for all DMIS conformance classes. Generate and update compliance tests for other standards within the standards infrastructure.
- Define product certification for DMIS-generating products as the DMIS test utilities emerge. Introduce the concept of certification for other quality measurement information exchange standards.
- Define a Quality Measurement Process Planning (QuiPP) standard using the Unified Modeling Language (UML)
- Work with the manufacturing machining standards community (including ISO STEP-NC group) to integrate rich and accurate metrology information that will allow correct and complete on-machine coordinate metrology.
- Define standards or modify existing standards for portable metrology systems such as optical metrology systems and portable arm CMMs. The command and results analysis requirements of these systems have some fundamental differences from the same requirements for traditional CMMs.

Customers and Collaborators:

- Ford Motor Company
- Lockheed Martin
- Honeywell FMT
- Boeing
- General Motors
- Chrysler LLC
- Daimler
- Audi
- Volvo
- BMW
- International Association of Coordinate Measuring Machine Manufacturers
- Automotive Industry Action Group (AIAG)
- Society of Manufacturing Engineers
- Longview Associates
- Dimension Metrology Standards Consortium
- Mitutoyo
- Wenzel
- Metromec
- Hexagon Wilcox
- Hexagon Brown & Sharp
- Sheffield
- Helmel Engineering
- Siemens PLM Software
- Dassault
- Renishaw
- Faro
- Applied Precision, Inc.
- Zeiss
- Messtechnik Wetzlar
- Xspect Solutions, Inc.

Robotics and Automation Interoperability Standards Program

Next Generation Machine Tool Control Interoperability

(Status: to be completed in 2010)

"Smart data for smart machines:"

Challenge/Problem Addressed

The challenge is to make possible the development of faster, more accurate, and more autonomous machine tools that are driven by product- and process models and are responsive to the manufacturing enterprise.

Challenges to realizing the vision of smart data for smart machines are the resistance of vendors to standardization (a business challenge) and the development of the data models themselves (a technical challenge). To address the business challenge, we realize that vendors and end users must be involved in the development of standards and pull for their success. Looking at the extent of vendor- and end-user involvement and the potential markets for U.S. companies, we prioritize candidate standards and select those that we think have the most potential. Along the way, we continually assess these markers to decide whether to continue participating. STEP-NC and OMAC HMI have shown growing involvement from vendors and end users (aerospace and automotive) with more impressive demonstrations each year.

Objective(s):

Support industry groups by validating data exchange standards, specifically the ISO 10103 AP 238 "STEP-NC" standard for machine tool programs, and the Open Modular Architecture Controller Human-Machine Interface (OMAC HMI) standard for machine tool status information. Paraphrasing BASF, "We don't make the standards you use, we make the standards you use better."

Accomplishments:

- Developed prototype implementations of STEP-NC based interpreters and controllers to establish the feasibility of benefits to industry, such as:
  - real-time interpretation of STEP-NC data models
  - on-machine compensation for straightness, angularity, and squareness
  - toolpath optimization based on STEP-NC data
- Developed a real-time connection between computer-numerical control and enterprise resource planning for aerospace applications, leading to the OMAC specification. Demonstrated at a series of public tests held by Boeing.

Planned Future Accomplishments:

- Validate extensions to STEP-NC to support traceability and data logging (FY09).

Customers and Collaborators:

- Airbus
- Boeing
- Fanuc
- Gibbs CAM
- Mastercam
- Okuma
- Sandvik
- Siemens
- STEP Tools Inc.
- Unigraphics
- International Organization for Standardization (ISO)
- OMAC