Manufacturing Interoperability

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Program Funding:	$3.9 M
FTEs:	26

Program Goal

Equip U.S. manufacturers with the technical guidance and testing support needed to interoperate in today's global, heterogeneous manufacturing world.

Problem

Globalization is the major trend in manufacturing today — globalization of markets and globalization of partners. Both have led to an explosion in the amount of information sharing that must take place. Nevertheless, humans still provide the bulk of the understanding needed to determine what the information means and the majority of the tacit knowledge needed to make decisions based on that understanding. It is absolutely critical to the success of companies and their suppliers that this sharing is done correctly, efficiently, and inexpensively. Changes in technology are positively impacting the way in which this information sharing takes place.

Approach

We work with industrial partners to overcome the barriers that arise from the increased reliance on electronic information exchange, using a virtual manufacturing environment where vendors and manufacturers can test conformance to existing standards; and researchers can validate the next generation of standards incorporating semantic web technologies. This program focuses on three major thrusts: an interoperability testing and demonstration infrastructure; testing of key integration standards for today's manufacturers; and developing semantic technologies for tomorrow's integration needs.

Typical Customers and Collaborators

Industry:

Accordare, Drake Certivo, Lockheed Martin, Nyamekye Research and Consulting Firm, Covisint, General Motors (GM), Ford, Lear, Lesker Corporation, The Boeing Company, Deere & Company, LK Metrology, Mitutoyo, Pratt & Whitney, DaimlerChrysler, GE, LK, Zeis, Nihon Unisys

Consortium:

Automotive Industry Action Group (AIAG), PDES, Inc., Metrology Automation Association (MAA)

Software Vendor:

AutoSimulation, Inc., EDS, Promodel Corporation, Micro Analysis & Design Incorporated, Softimage, Proplanner, Flexsim Software, Emergis, Fujitsu, QAD, SAP, Sterling Commerce, iConnect, Wolverine Software, Simul8 Corp., Delmia Corporation, Rockwell Software, Sewickley, Knowledge Based Systems, Inc., Technomatix, Delmia, Wilcox, Theorem Solutions

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interoperability

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Equip U.S. manufacturers with the technical guidance and testing support needed to interoperate in today's global, heterogeneous manufacturing world.

Customer Need & Intended Impact

Program Manager:
Steven Ray

Total FTEs:
26

Annual Program Funds:
$3.9M

Globalization is the major trend in manufacturing today — globalization of markets and globalization of partners. The globalization of markets means that the companies want to sell their products all over the world. The globalization of partners means that supply chain members are also located all over the world. Both have led to an explosion in the amount of information sharing that must take place. It is absolutely critical to the success of companies and their suppliers that this sharing is done correctly, efficiently, and inexpensively.

Changes in technology, from faster networks to new programming languages such as XML (EXtensible Markup Language), are impacting the way in which this information sharing takes place. Nevertheless, humans still provide the bulk of the understanding needed to determine what the information means and the majority of the tacit knowledge needed to make decisions based on that understanding. All of this is about to change with the advent of the Semantic Web. Simply stated, the Semantic Web will enable computers to understand the meaning of concepts, to reason about those concepts, and act on those concepts according to the rules they have been given. The resulting programs will operate at the semantic level, not the data level. They will know that purchase orders are different from schedules, which in turn are different from Numeric Control (NC) programs; and they will know how to deal with those differences.

This program addresses the information sharing needs of Original Equipment Manufacturers (OEMs), their Small and Medium Enterprise (SME) suppliers, and software vendors. In addition, we have customers within the federal government, including the Department of Energy (DOE) Oak Ridge National Labs and the Department of Defense (DOD) departments of the Army, Air Force, and Navy. Within NIST, the evolving Interoperability Test Bed (ITB) is already supporting the work of other laboratories. Those laboratories include the Electronics and Electrical Engineering Laboratory (EEEL), Building and Fire Research Laboratory

(BFRL), Chemical Sciences and Technology Laboratory (CSTL) and Information Technology Laboratory (ITL). Finally, we have a number of customers from the international standards-development sector. We actively participate in technical working groups in three *de jure* organizations: American Society of Mechanical Engineers (ASME), Institute of Electrical and Electronics Engineers, Inc. (IEEE), and ISO. We also participate in other industry-led standards development organizations: OMG, OASIS, and W^3C.

To survive in the global economy, our customers repeatedly emphasize the need to get the right information to the right place in the right form at the right time. Succinctly, their goal is information integration anywhere, anytime. Our customers asked NIST to address three specific and important needs that will enable the realization of this goal.

NIST should:

- Provide methods, tools, and data sets for testing conformance to existing international and de facto standards.
- Evaluate: (1) the standards conformance of key implementations – what was implemented agrees with the specification (conformance testing), (2) that the standards meet the business requirements they were intended to address (validation testing), and (3) that sets of business applications can successfully operate together (interoperability testing).
- Propose a new generation of standards technology that is based on formal semantics, to support both the automation of the integration process and the harmonization of existing, conflicting standards.

NIST is uniquely positioned to respond to these needs. Our service to customers is perhaps best illustrated in Figure 2.

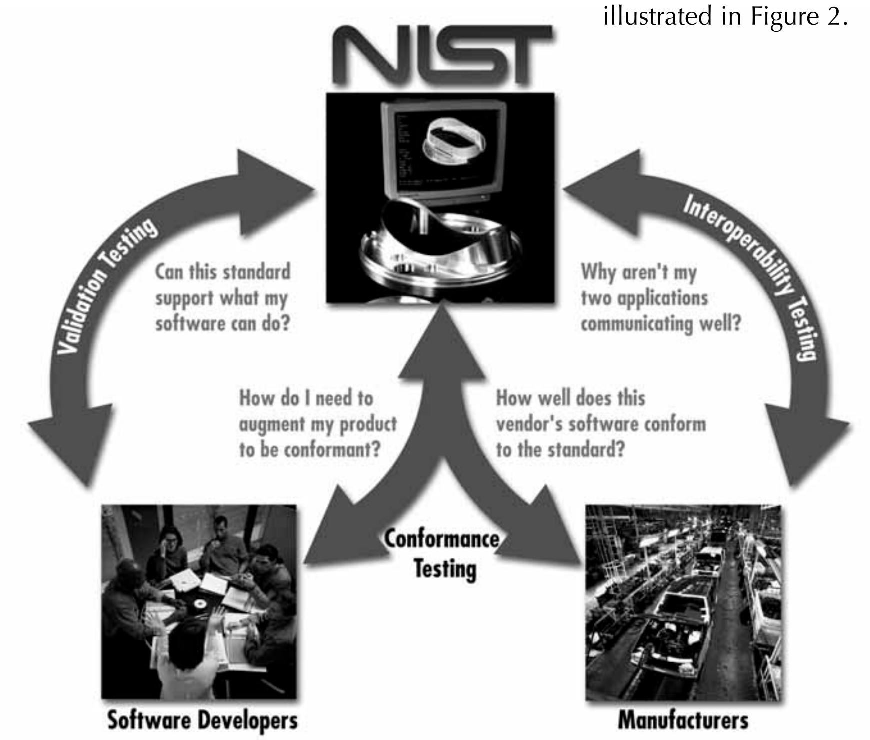

Figure 2. Customer Needs

Technical Approach & Program Objectives

We aim to equip today's manufacturer with the guidance and testing support needed to participate in the global, distributed manufacturing world. We work with industrial partners to overcome the information-handling barriers that have arisen from the increased reliance on electronic information exchange with distant customers and suppliers, using a virtual manufacturing environment where vendors and manufacturers can test conformance to existing standards, and researchers can validate the next generation of standards. A picture of our vision is shown in Figure 3.

Program Thrusts

The Manufacturing Interoperability Program focuses on three major thrusts:

A. An interoperability testing and demonstration infrastructure

B. Testing of key integration standards for today's manufacturers

C. Development of semantic technologies for tomorrow's integration needs

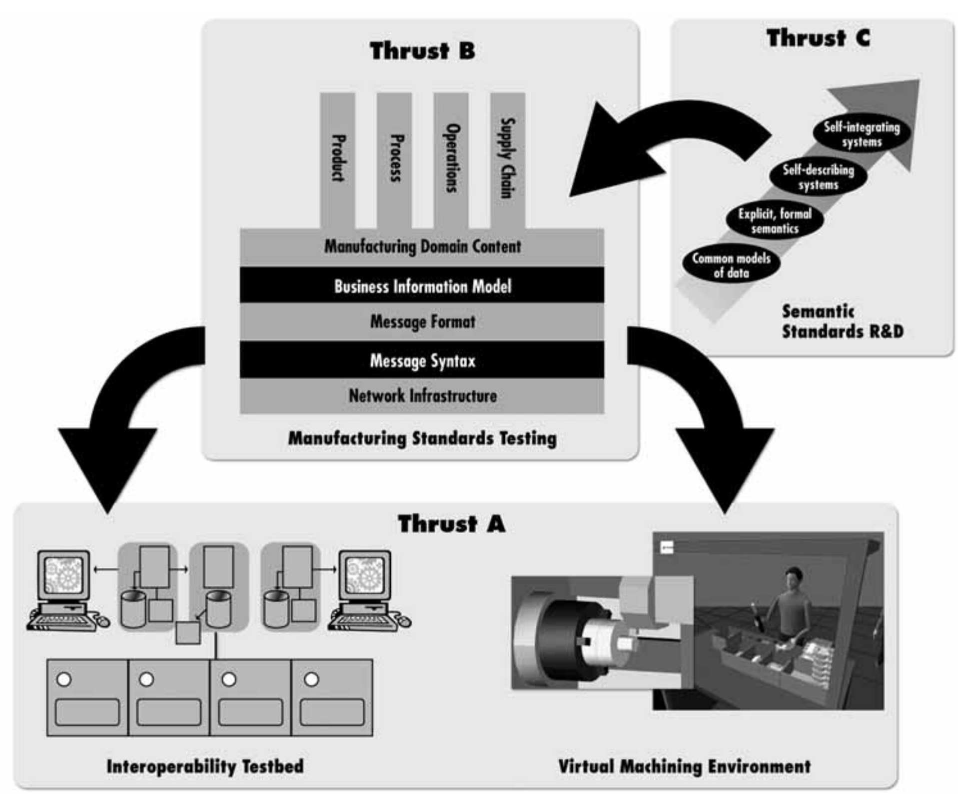

Figure 3. Program Vision

These three thrusts depend on one another to be successful. Integration standards will be identified in concert with industrial partners for key information supporting product, process, operations and supply chains. Pragmatic choices will be made to provide a recommended suite of standards for today's modern manufacturer.

These standards will be supported through the interoperability testing and demonstration infrastructure containing two major components: a testing environment for logging, diagnosis, conformance and interoperability testing focused at the content level, plus a piloting and demonstration environment populated with commercial production software tools to establish the usability of these standards-based approaches in realistic settings. These two components are called the Interoperability Test Bed, and the Virtual Manufacturing Environment, respectively.

Finally, the program is investing in a strong research thrust to support the use of semantic technologies in new standards. It is becoming widely accepted that semantic technology is the correct way to transmit information in an unambiguous and computable fashion, and we are recognized leaders in this arena. The tools within our testing infrastructure will rely upon the semantic research results, and the content-oriented tests will typically use ontologies, either explicitly specified in the standards (most desirable), or reverse-engineered from the standards.

Thrust A - Interoperability Testing and Demonstration Infrastructure

This infrastructure builds upon past efforts and collaborations initiated under earlier MEL programs and projects that addressed interoperability testing and the simulation of manufacturing supply chains, systems, and processes.

Objective #1

Will establish a program Technical Advisory Board (TAB). The Technical Advisory Board will be comprised of leading experts from industry, government, standards organizations, academia, and the research community. The TAB will advise program management on changing industry needs, program directions, collaboration opportunities, evolving technologies, implementation issues, and relevant external activities. It will also document the industry problems, research, development and testing issues within the scope of the program.

> **"NIST is doing what our industry members won't do – providing the infrastructure and testing resources to speed the development and implementation of new specifications."**
>
> **David Connelly, President**
> **Open Applications Group**

Objective #2

Establishes the Interoperability Test Bed (ITB). The Interoperability Test Bed will consist of a testing framework and tools for standards conformance and interoperability demonstration, building on the demonstrated success of the Manufacturing Business- to-Business (B2B) Test Bed and the Metrology Interoperability Test Bed. A report documenting the ITB configuration, tools, methods, and procedures will be produced.

Objective #3

Establishes a Virtual Manufacturing Environment (VME) capability within the NIST laboratories. The Virtual Manufacturing Environment will pilot interoperability solutions, and will be an effective means to communicate the value of this program to decision makers in industry and government. The VME will enable NIST to implement, evaluate, and demonstrate the feasibility of interoperability solutions using real manufacturing software applications, as well as simulations and emulations of manufacturing processes and equipment. VME software systems will be augmented with manufacturing hardware in the MEL Fabrication Technology Division and other laboratories in MEL. Manufacturing hardware may include numerically controlled machine tools, coordinate measuring machines, robots, and other manufacturing equipment. Visualization capabilities within the Advanced Manufacturing Systems And Networking Testbed (AMSANT) Facility will be enhanced to support VME pilot implementations and demonstrations. Web cam and other remote visualization capabilities will be installed to monitor actual physical hardware running at remote locations from the AMSANT. A report documenting the VME configuration, applications, procedures and test data sets will be produced.

Thrust B – Integration Standards Testing

A typical interaction between a manufacturer and a customer or supplier contains a minimal set of information, often called a technical data package. This information includes a specification of a product to be manufactured along with quality specifications and at times processing requirements. The manufacturer in turn must incorporate this manufacturing need into its ongoing operation plans – schedules, inventory, resource and component requirements. By focusing on just this minimal set of requirements, we identified a core set of cross-referencing standards needs to support a majority of manufacturers, especially small manufacturers. These standards – product, process, operations, and supply chain standards as shown in Figure 3 – must be consistent with one another to enable smooth information flow. This program will identify and validate such a consistent standards suite by teaming with industrial partners in the various specializations in an environment of close and frequent communication among the specializations. In this manner we will avoid a disjoint set of standards that cannot support interoperation among them. This is achievable only by virtue of having an interoperability program with the breadth of scope present here at NIST.

The specifications, typical software applications, and associated test data will be validated using testing tools within the Interoperability Test Bed. One or more real world test case data sets will be established for each specification in cooperation with industrial and research collaborators. Test Bed tools will support information modeling, wrapper development, system prototyping, verification, validation, conformance and interoperability testing.

The Virtual Manufacturing Environment (VME) will be used to test-drive the specifications and test data sets with both real and simulated manufacturing software applications. Existing commercial software applications may be used "as-is" or extended to support required interfaces and functionality. If appropriate commercial or research systems are not available, prototype applications may be developed to fill holes in the integration scenario. Due to resource limitations, prototype development will usually only be undertaken as a last resort when it is critical to the effective achievement of an interoperability objective.

Objective #4

Addresses the collaborative identification of a suite of complementary standards supporting the exchange of product, process, operations and supply chain information, with associated testing support. A consistent approach will be used to achieve each interoperability scenario. First, a system architecture and scenario document will be developed. This document will describe industry's requirements, the software applications or functional modules that need to be integrated, and an operational scenario that illustrates how the integrated applications and modules should ultimately function together.

The next steps will be to identify and test interface specifications that will be used to implement the architecture. Working with industry and other research collaborators, test data sets will be assembled that reflect real industry problems. The test data sets will be used to populate software applications, and where appropriate, associated databases. Test data will be used to exercise interfaces, perform various integration tests using tools of the Interoperability Test Bed, and pilot solutions within the Virtual Manufacturing Environment. Demonstrations will be scheduled periodically to show progress towards and completion of integration.

As individual specifications are established or identified, attention will be concentrated on integrating them into larger networks of interconnected systems and interfaces, specifically through the following integrations:

1. Expanded supply chain interoperability through the integration of supply chain business processes specifications with the production management operations specifications
2. Expanded internal engineering data flow through the integration of the engineering product and manufacturing process specifications
3. Full integration across a virtual enterprise through the joining of the combined supply chain specifications with the combined product and process specifications.

The first integration will give supply chain managers and participating suppliers access to both inventory levels and production schedules throughout a supply chain, expanding upon the goals of the Automotive Industry Action Group (AIAG) Inventory Visibility and Interoperability program.

The second integration will provide a consistent, standards-based treatment of the engineering data from concept to manufacturing process execution.

The third integration will provide a consistent set of standards covering the supply chain management, internal production management, production process functions and engineering data flows addressed in earlier work.

Thrust C – Development of New Technologies for Interoperability Standards and Integration

Tools and standards for information system development have gone through a long process of abstraction and layering. Each layer enables individuals to direct these devices in ways closer to how they understand the problem being solved. Early computer systems were programmed by physically wiring computer circuit boards. Machine programming and assembler language raised this to the symbolic level. Later languages such as Fortran and C brought languages closer to simple mathematics, and LISP and Prolog enabled programmers to build intelligent systems that reflected human problem solving techniques.

"Semantics-based integration tools are destined to become increasingly powerful and capable."

From CIO Magazine, August 2002

Despite these improvements, in many respects software standards and technology have changed very little over the last 20 years. The languages have become a bit easier to use, but not vastly different from Fortran of the 1950's. Programmers and architects still sift through libraries of reusable elements, and put them together in a handcrafted way. Many tools are available now, but just as aids in the manual process of software construction. They are comparable to the improvement of a circular saw over a handsaw, rather than robotic and NC manufacturing systems over manually controlled machine tools.

This thrust will complete the fundamental research necessary for information system development to move to a new level of automation and facilitate the integration of industry's next generation of systems. The components will be:

- Identification of semantic approaches
- Ontology development
- New tools and techniques
- Prototype systems

Semantic approaches are the next logical step in bringing computer languages closer to the way business, engineering and manufacturing experts understand their problems. These approaches express the expert's concepts in terms of meaningful, computable statements. The techniques are not oriented toward computational speed, but rather precision of expression. In this way, the specific conclusions or effects that are expected of the system can be recorded, validated with automated reasoning and simulation, and used to verify the performance of the system eventually built. Its semantic description can be searched by others looking for existing functionality to reuse, or can be automatically composed with semantic descriptions of other systems to create newly integrated ones. The semantic description can also be used to present the data present in the system in a way domain experts can understand, and enable automated and semi-automated decision-making.

Ontology capabilities will become a core technology. [...] By 2005, lightweight ontologies (taxonomies) will be part of 75 percent of application integration projects [...] By 2010, ontologies using strong knowledge representations will be the basis for 80 percent of application integration projects.

From Gartner, "Semantic Web Technologies Take Middleware to the Next Level," August 2002

Objective #5

To identify the semantic approaches that are appropriate to manufacturing. The primary concern is that these be understandable by experts at the same time they are rigorous enough to enable computer support. In particular, they must be self-documenting and address concrete instances of concepts, so it does not require the original author or extensive documentation for others to understand the meaning of the information, and so they are amenable to commonly available automatic reasoners. It is also important that the approaches leverage existing or near-term information standards to ensure relevance.

Objective #6

To apply the identified semantic approaches to the primary areas of manufacturing: product, process, operations, and supply chain. These will require a common set of primitive concepts that are reusable as needed in the various areas. The results will be amenable to automatic reasoning, to enable application in complex and diverse systems, coordination of knowledge across organizations and disciplines, enhanced support for enterprise design, integration, and decision-making, unambiguous of interoperability standards, and autonomous agents. MEL's experience in both manufacturing and ontologies will apply to these areas.

Objective #7

To develop tools and techniques for working with the ontologies developed in the previous objective. It will address automation in the capture of the knowledge implicit in interfaces to manufacturing software, the design of inter-system processes using those interfaces, and generation of translation software from these specifications. This will involve the matching of concepts between existing systems and requirements on the integrated process, as well as the expression of those concepts in specific implementations.

Objective #8

Apply and test the tools developed in Objective #3, using actual industry cases drawn from the many incompatible standards currently emerging. Part of the testing will be to ensure that the results of the tools conform to existing tests provided for the standards involved. This objective will also identify those aspects where tool support requires further research in the underlying semantic representations.

Major Accomplishments

Metrology Test Bed Launched

The "test bed" is a group of people and physical resources located at NIST in the Manufacturing Engineering Laboratory that support development and testing of standards for components of dimensional metrology systems. Our primary tie to industry is through the Automotive Industry Action Group Metrology Interoperability Team (AIAG-MIPT). For more information, please visit the test bed website: http://www.isd.mel.nist.gov/projects/metrology_interoperability/NISTactivities.htm#testbed

Simulation Standards Consortium Established

The Manufacturing Engineering Laboratory hosted the Simulation Standards Consortium kick-off meeting at NIST on February 25, 2003. Charles McLean made a presentation on the mission, goals and objectives, and motivations for joining the consortium; and offered a framework of modeling and simulation standards for focusing the efforts of the Consortium. Swee Leong presented the operational plans for this Consortium. A draft Simulation Standards Consortium agreement was distributed to the participants for their review, comments, and approval. Meeting attendance represented 19 organizations from major software vendors, industrial companies, government agencies, and academia. Responses to the Simulation Standards Consortium have been very positive.

"Economic Impact of Inadequate Infrastructure for Supply Chain Integration" Study Completed

This economic impact study examined the current state of supply chain integration, estimated the economic impact of inadequate integration, and identified opportunities for governmental organizations to provide critical standards infrastructures that will improve the efficiency of supply chain communications. A copy is available at http://www.nist.gov/director/prog-ofc/report04-2.pdf.

Process Specification Language (PSL) Becomes an International Standard

ISO 18629-1, Process Specification Language Part 1, "Overview and basic principles," was published as an international standard by ISO. NIST played an integral role in the initial drafting and continued leadership in the development of ISO 18629 and its associated parts. Process data is used throughout the life cycle of a product, from early in the manufacturing process during design, through process planning, validation, production scheduling, and control. The standard is available for purchase via the ISO online catalog: http://www.iso.org/iso/en/ISOOnline.frontpage.

NIST B2B Testbed Demonstration with the Automotive Industry Action Group

NIST staff presented an update of the Object Application Group (OAG)/NIST B2B Testbed capabilities at the AUTOTECH 2004 conference in Detroit, MI. NIST presented the methodology developed for content testing that was applied to the Inventory Visibility and Interoperability (IV&I) project (http://www.aiag.org/whatsnew.cfm#ivi) as part of the IV&I status update, and demonstrated the testbed capability to support Business Object Document (BOD) constraint checking to the representatives of the Standards in Automotive Retail (STAR) consortium. The STAR delegation expressed significant interest to use NIST capabilities for BOD management and testing of business rules and constraints within the STAR community. The NIST team also presented the vision and some technical ideas for a Semantic Web-based approach to develop the next generation OAG specification. For more information regarding the NIST test bed, please visit: http://www.mel.nist.gov/msid/b2btestbed/.

FY2005 Projects

Interoperability Test Bed (Objectives #1 & #2)

Combine existing and emerging MEL & NIST testing capabilities into a coherent, structured interoperability testing environment, with tools, test cases, test bed documentation; hold a demonstration of test bed capabilities at a public open house.

Virtual Manufacturing Environment (Objectives #1 & #4)

Collect the manufacturing applications and simulation tools needed to support the various integration threads. Where possible, commercial applications will be acquired and training completed; otherwise, prototype software will be developed.

Supply Chain Business Systems (Objectives #1 & #4)

Bring together the software applications and interface specifications that will provide capabilities to satisfy industry's priority needs in the integration of supply chain business systems.

Production Management Systems (Objectives #1 & #4)

Bring together the software applications and interfaces specifications that will provide capabilities to satisfy industry's priority needs in the integration of production management systems.

Shop Process Systems (Objectives #1 & #4)

Bring together the software applications and interfaces specifications that will provide capabilities to satisfy industry's priority needs in the integration of process engineering and shop floor hardware systems.

Collaborative Design and Engineering Systems (Objectives #1 & #4)

Bring together the software applications and interfaces specifications that will provide capabilities to satisfy industry's priority needs in the integration of design and engineering systems.

Common Manufacturing Primitives Ontology Specification (Objectives #1, #5, & #6)

Develop formal ontologies using emerging semantic methods such as Process Specification Language (PSL), Web Ontology Language (OWL) and Resource Description Framework (RDF), in support of the integration threads.

Next Generation Integration Technologies (Objectives #1, #5, & #7)

Continue the work begun in the Automated Methods for Integrating Systems (AMIS) project developing tools, methods, and models, and using the ontologies developed for the integration threads, to support the automation of various aspects of the integration process.

Typical Customers and Collaborators

Industrial:

Accordare, Drake Certivo, Lockheed Martin, Nyamekye Research and Consulting Firm, Covisint, General Motor Corp., Ford Motor Company, Lear, Lesker Corporation, The Boeing Company, Deere & Company, LK Metrology, Mitutoyo, Pratt & Whitney, DaimlerChrysler, General Electric, LK, Zeis, and Nihon, Unisys

Consortium:

Automotive Industry Action Group, PDES, Inc., and Metrology Automation Association

Software Vendor:

AutoSimulation, Inc., EDS, Promodel Corporation, Micro Analysis & Design Incorporated, Softimage, Proplanner, Flexsim Software, Emergis, Fujitsu, QAD, SAP, Sterling Commerce, iConnect, Wolverine Software, Simul8 Corp., Delmia Corporation (formerly Deneb Robotics), Systems Modeling – Rockwell Software, Sewickley, Knowledge Based Systems, Inc., Technomatix, Delmia, Wilcox, and Theorem Solutions

FY2005 Standards Participation

Active participation and leadership roles in:

- ANSI/ASME B5 Machine Tools - Components, Elements, Performance, and Equipment
- Foundation for Intelligent Physical Agents ISO/IEC JTC1/SC22/WG11
- ISO/IEC JTC1/SC32 Information Technology Data Management and Interchange
- ISO TC184/SC4 Industrial automation/Industrial data
- ISO TC 184/SC1/WG7 Industrial automation systems and integration/ Physical device control
- ISO TC184/SC5/WG4 Manufacturing Programming Environments
- I++ Group
- OASIS
- Object Management Group
- Open Applications Group
- SISO/IEEE
- US PRO
- W3C Semantic Web

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