# Manufacturing Systems Integration Programs

## Supply Chain Integration

| | |
|---|---|
| Annual FTEs: | 11 NIST FTEs |
| | 10 Guest Researcher FTEs |
| | **21 Total FTEs** |

### Challenge

The manufacturing sector will continue to provide the core of our nation's real wealth creation in the foreseeable future. Innovation and competition within this sector will take place at the level of supply chains or "value chains[3]," however, not at the level of individual companies. These value chains will evolve into a network of global, collaborative partnerships. These partnerships will develop rapidly when new market or technology opportunities appear. They will dissolve just as quickly when those opportunities disappear.

As part of this evolution, manufacturing will become less resource-intensive and more knowledge-intensive. This shift will require a new capability – the ability for all partners to exchange and assimilate information ***instantaneously***. The challenge for the Supply Chain Integration program is to foster and promote that capability by developing and demonstrating an infrastructure for the testing and integration of automated systems that exchange information throughout the supply chain.

### Overview

The Supply Chain Integration program has produced a number of syntax- and quality-based testing and validation tools that are now available as NIST Web services or as free stand-alone tools. To address new challenges, we have begun shifting our focus to content-based testing[4]. This is necessary to ensure that the semantics of the information being exchanged is correctly understood. In addition, the program is pursuing new approaches to manufacturing standards development that facilitate, rather than hinder, the automation process. The foundation for this infrastructure comes from the completed Automated Methods for Integrating Systems (AMIS) project, which provided a fundamental basis for our information exchange and application integration.

3 Adding value to the supply chain, either through the traditional economic model of providing added value to goods, or through innovative aspects of logistics and inventory management, e.g., Dell Computers

4 Validation is a form of testing done to assess the rigor of a developing standard. Syntax-testing is easier and more quantitative than testing the semantics or content of the data. Syntax-testing checks the data, while content-based testing checks the proper use and context of information.

The AMIS project defined a general approach for automating the exchange of information semantics between any two software applications. This approach was demonstrated using a "Request-for-Quote" supply-chain scenario and standards from the Open Applications Group (OAG) and the Chemical Industry Data eXchange (CIDX).

The Inventory Visibility and Interoperability (IV&I) project used the AMIS approach to demonstrate automated exchange of inventory-on-hand data between global automotive suppliers. Working with the Automotive Industry Action Group (AIAG) and with European and Korean collaborators, MSID developed numerous semantic technologies, which provided the initial set of components for our integration infrastructure.

The Materials Off Shore Sourcing (MOSS) project began last year. It is adapting the IV&I testing infrastructure to include business processes[5]. MOSS aims to reduce the uncertainty in door-to-door shipping times by simplifying and integrating the information flow among the dozens of players involved. To date, MSID has developed a conceptual data model for all the information objects, a model for all of the messages, and a number of testing tools.

## Key Accomplishments and Impacts:

- Developed syntax and quality-based tools that are routinely used by developers from both government and industry, resulting in a 30% reduction in the time to develop new e-commerce specifications. AIAG has projected more than $200M savings from suppliers using interoperable IV&I applications.
- Potential savings have not been documented for MOSS, but the impacts of poor interoperability are known. They include a substantial increase in premium shipping costs, more than 20 days of excess inventory maintained, 80% of all information re-keyed with an average cost of $20 each, and more than 40 days difference between best (21 days) and worst (63 days) shipment times from Europe. If successful, the MOSS project will have a significant impact on all of these numbers.

## Future Directions and Plans:

- Enhance existing infrastructure to facilitate the exchange of manufacturing and business data and provide support for testing and validating manufacturing and business specifications. Continue the shift in testing focus from syntax-based to content-based testing. This is necessary to ensure that the content of the information being exchanged is correctly understood.
- Pursue new approaches to manufacturing standards development that will promote/ease, rather than hinder, the automation process. Launch the Virtual Supplier Network project that will enable OEMs (e.g., GM, Ford, DaimlerChrysler) and suppliers to match requirements with capabilities automatically over the Internet through the addition to the MOSS infrastructure of components that will address two important complications: the fact that the applications involved are not known in advance, and the influence of business negotiations on the exchange of technical data.

5 Business process describes a set of activities that are the recommended way to achieve the goal; directs resources and people to work towards a goal, e.g., what activities need to be accomplished to receive 300 widgets by next Wednesday.

## Awards and Recognition:

### Board Memberships

| Staff | Board Membership |
|---|---|
| Jones, Al | • Advisory Board for the Engineering Department at Loyola College, Baltimore, MD<br>• Advisory Board for the Industrial Engineering Department at Morgan State University. |
| Ray, Steve | • European Union INTEROP Network of Excellence Advisory Committee<br>• Intelligent Manufacturing Systems U.S. Delegation<br>• Accreditation Board for Engineering and Technology<br>• University of Maryland Institute for System Research Strategic Advisory Board |

### Leadership

| Staff | Leadership |
|---|---|
| Barkmeyer, Edward | • Voting representative for NIST in the Technical Committees of the Object Management Group (OMG)<br>• Chair of two OMG Revision Task Forces, charged with maintenance and revision of the Product Data Management Enablers interface standard<br>• Chair of two OMG Working Groups in the Manufacturing Domain Task Force, Enterprise Resource Planning and Manufacturing Business Objects<br>• Co-Chair of two OMG independent Working Groups, Web services, and Business Rules, which became formal standards development bodies within the OMG |
| Denno, Peter | • Leader of the System Engineering Tool Interoperability Plugfest. The work is recognized in the plans of INCOSE, OMG and ISO TC 184/SC4<br>• Activity Lead of the Systems Engineering Tool Interoperability effort of INCOSE's Model Based Systems Engineering (MBSE) Initiative, which is a major initiative within INCOSE<br>• Leader of the MOSS validation effort collaborative with the Automotive Industry Action Group and other partners |
| Frechette, Simon | • Co-Chair of the Software Development Productivity Working Group, National Coordination Office for Information Technology Research and Development |
| Morris, KC | • Chartered and led the Working Group on XML Schema Interoperability for the Federal CIO Council's Data Architecture Subcommittee |
| Ray, Steve | • Co-Organizer of the Ontology Forum, Ontology Summit (2006, 2007, 2008)<br>• Committee Chair, National Center for Ontology Research (NCOR) Ontology Evaluation<br>• Chair, IMS Vision Forum study group on "Key Technology for Manufacturing Innovation and Environmental Sustainability", 2006 |

## Leadership (continued)

| Staff | Leadership |
|---|---|
| Wallace, Evan | • Co-Chair of the Ontology Platform Special Interest Group of the OMG<br>• Co-Chair of the Ontology Definition Metamodel Finalization Task Force of the OMG<br>• Representative for NIST in the OWL Working Group of the World Wide Web Consortium (W3C)<br>• Formerly represented NIST in the W3C Semantic Web Best Practices and Deployment Working Group (now closed) |

## Excellence

| Staff | Excellence Recognized |
|---|---|
| Goyal, Puja<br>Lubell, Josh<br>Morris, KC | • Awarded the 2005 Bronze Medal Award for Superior Federal Service for building XML schemas and creating a collection of software tools and test case data sets to support multi-party collaboration work process for the life cycle of facilities equipment |
| Ivezic, Nenad | • Recipient of the 2006 Automotive Industry Action Group (AIAG) Individual Achievement Award for outstanding contributions to the automotive industry<br>• Recipient of the 2007 AIAG Individual Achievement Award for outstanding contributions to the automotive industry |
| Ray, Steve | • Invited Keynote presentation entitled "Standards, Interdependence and Complexity - Developments and Trends in Standards from the Enterprise to the Shop Floor," at the International Conference on Smart Machining Systems (ICSMS), March 13-15, 2007 |

# Projects

## Supply Chain Integration

### Introduction

Supply chain integration enables supply-chain partners to exchange information automatically. This exchange takes place between disparate software applications that need to work together to satisfy a unified manufacturing or business need. These applications likely run on multiple, geographically dispersed computer systems and platforms, and were generally not designed with integration in mind. These and other issues make integration projects complicated and extremely expensive.

Studies have shown that most integration efforts fail to achieve their goals. Successful integration involves four stages: (1) specification creation, (2) specification validation, (3) development of conformance and interoperability test methods, tools, and data sets, and (4) implementation. Each of these stages builds upon results of the previous stages, so problems in any stage can greatly increase the likelihood of overall failure.

MSID researchers have identified a number of such problems, including:

- Inaccurate capture and/or documentation of data interchange rules and constraints – Unreliable manual processes result in a time-consuming and error-prone cycle of interpreting and refining data processing rules and constraints.
- Inconsistent specification design quality – Often caused through lack of consistent practices, even while using formal modeling languages.
- Inadequate content validation – Primarily due to lack of appropriate content validation tools.
- Informal and unstructured specification definition – Leads to ambiguity and misinterpretation.
- Syntax-only integration standards approach – Leading analysts have estimated that 35% to 65% of system integration costs are due to semantic issues that syntax-only standards cannot address.
- Local management of data interchange rules – Results in conflicting standards.
- Non-adaptable, non-extensible implementations – Leads to the proliferation of incompatible dialects.

The Supply Chain Integration program is developing reference models and practical toolkits that will address these issues in innovative ways. Together, the program's products will make possible accurate specification creation, formal validation and testing, and rapid application integration.

### Strategy

The program has two main thrusts: the development of tools for the testing and validation of existing supply-chain interface standards; and the development of an infrastructure to automate application integration.

The first thrust is based on the standards life-cycle activity model of standards, which we presented at our last meeting in 2005. That model addresses the creation, use, and maintenance of any standard. We have used this model to frame our research and the development of tools to support validation and testing of an existing standard (see Figure 1). In the following section, we provide overviews of these tools primarily in the context of the W3C XML Schema, because of its widespread adoption by industry.

The second thrust is based on the approach developed in the AMIS (Automated Methods for Integrating Systems) project, which we also presented in preliminary form in our last meeting in 2005. The AMIS strategy is to derive from the published interface specifications for a software system (application program interfaces, messages, exchange files, protocols, specifications, and documentation) an understanding of the roles in the business processes the system was built to support. That understanding must be captured in formal models that contain definitions of the business entities, properties, processes and rules in a machine-readable form suitable for automated reasoning.

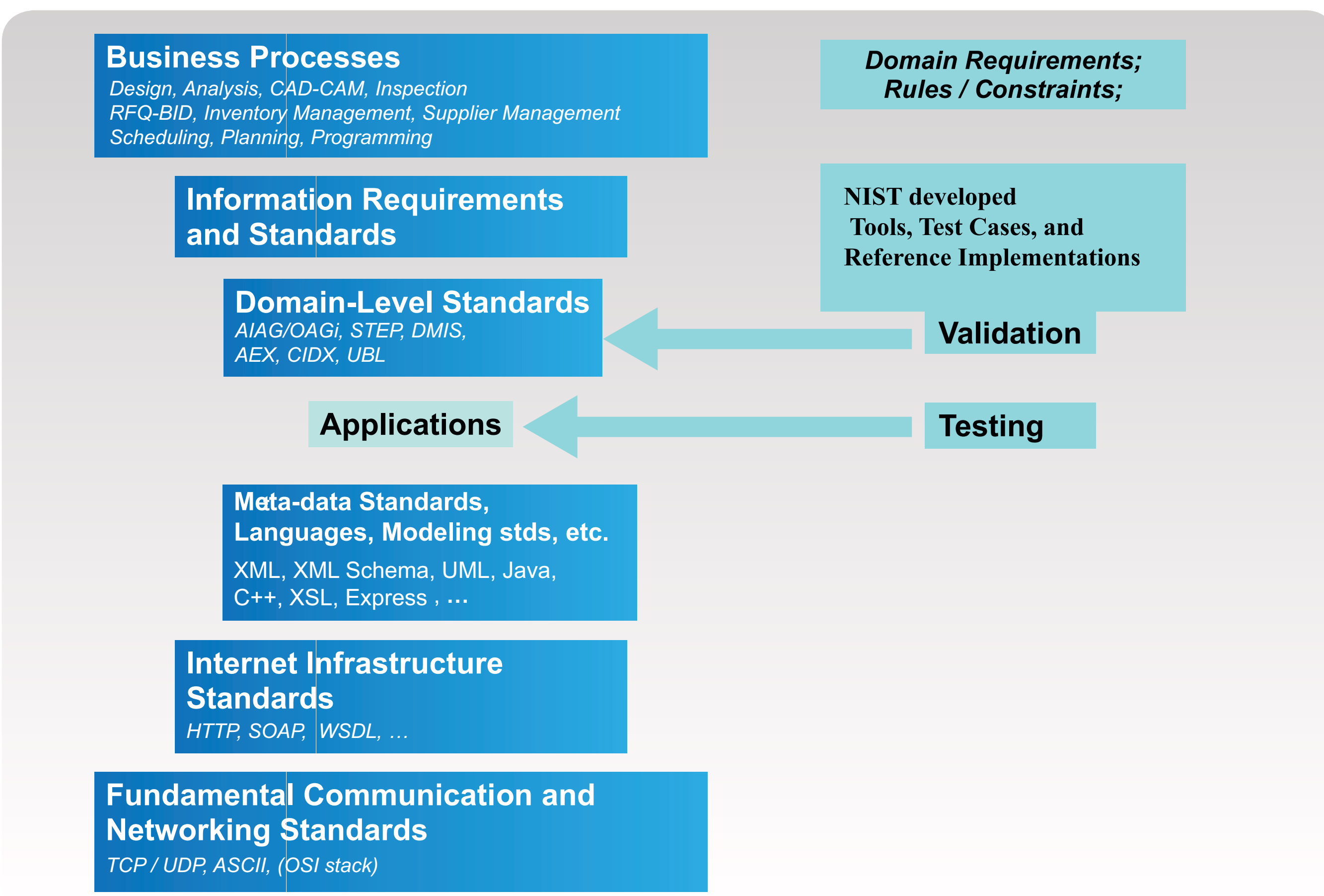


**Figure 1. Conceptual View of the Supply-Chain Integration Stack**

The AMIS project produced a high-level description of the major components of a semantics-based integration infrastructure for supply chains (see Figure 2). That infrastructure contains local ontologies, a reference ontology[6], mappings, translators, and connector transformations. The project also demonstrated how to build those components for a 'request-for-quote' supply-chain scenario and related standards from the automotive and chemical industries.

Lessons/ideas from AMIS became a crucial part of AIAG's Inventory Visibility and Interoperability (IV&I) project, which sought to develop an agreed-upon set of e-Kanban[7] messages that would allow suppliers to communicate inventory data to the rest of the supply chain. MSID's role was to collaborate with European and Korean partners on a semantics validation project designed to show that the automotive industry could lower cost, improve speed to market, and reuse IT investments by using emerging semantic technologies to define and implement messages among suppliers.

This project was important for four reasons. First, it applied the AMIS approach to a real integration problem using real commercial IV&I applications. Second, it demonstrated the potential of using semantic technologies to automate the integration process. Third, it showed that it may be possible to separate that process into two parts: a private part that only the users know about and a public part containing models, tools, and agents that do all the real work. Fourth, it showed the potential to further separate those models, tools, and agents into one collection that is specific to a certain branch of manufacturing and another collection that is generic.

AIAG's Material Off-Shore Sourcing (MOSS) project is an initiative designed to improve business procedures and information drivers controlling the intercontinental shipment of goods. AIAG studies assert that improvements in the accuracy of information conveyed—and agreement in how it is to be interpreted—will result in tangible reductions in overall supply-chain transit times and measurable decreases in the variation of transit times. A direct result will be reductions in buffer-stock inventory and expedited/premium transportation expenditures.

In FY07, MSID began working with MOSS participants from government, AIAG, and the vendor community to develop the necessary recommendations and standards, test associated Electronic Data Interchange (EDI)[8] messages, develop a testing infrastructure, and conduct demonstrations using an ocean-shipment scenario. We will again use the AMIS approach and extend the IV&I infrastructure to evaluate a real business process.

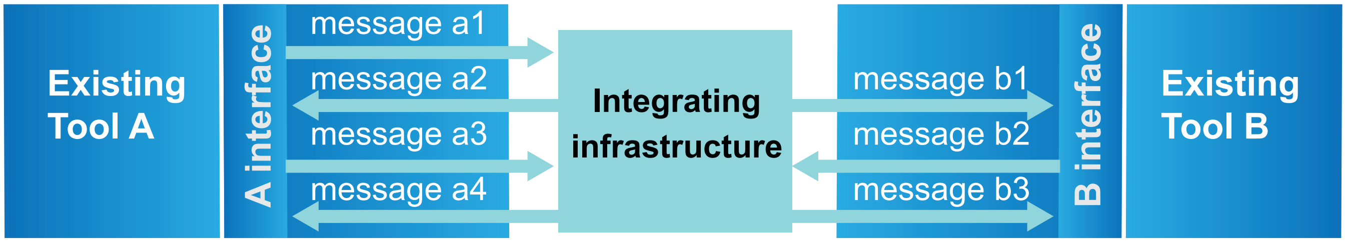


**Figure 2. Conceptual View of Application Integration**

6 Ontology is a representation of a set of concepts within a domain and the relationships between those concepts. It is used to reason about the properties of that domain, and may be used to define the domain.

7 E-Kanban is an electronic signaling system to trigger action. Of Japanese origin, Kanban is a means through which just-in-time production is achieved, originally implemented using physical tokens.

8 EDI (Electronic Data Interchange) is a widely used early set of standards for sharing business data electronically, still heavily used for off-shore shipments.

Supply Chain Integration

## AMIS (Automated Methods for Integrating Systems)

(Status: complete in 2006)

### Challenge/Problem Addressed:

Supply chain integration, even when it is based on existing syntactic interface standards, is an error-prone, costly, time-consuming, repeated, human-intensive engineering activity.

### Objective(s):

- Reduce the effort required to exchange supply chain semantics by devising models, methods, algorithms, and tools to automate engineering activities that are now done by human systems integrators.

### Accomplishments:

- Developed a reference architecture that describes the major components of a semantics-based integration infrastructure for supply chains. That infrastructure contains local ontologies, a joint reference ontology, semantic mappings and translators, and connector transformations.
- Demonstrated the reference architecture based on (1) a request-for-quote supply chain scenario, and (2) ontologies based on two different supply chain standards: one from the automotive industry and one from the chemical industry, and, (3) mappers and translators to go from one standard ontology to the other.

### Customers and Collaborators:

- OAGi (Open Applications Group, Inc.)
- CIDX (Chemical Industry Data eXchange consortium)

Supply Chain Integration

## ATHENA/IV&I (Inventory Visibility and Interoperability)

(Status: complete in 2007)

### Challenge/Problem Addressed:

Integrating off-shore suppliers into an existing supply chain so that inventory levels are visible to all partners is costing billions of dollars a year within the transportation sector.

### Objective:

- Develop and implement an integration infrastructure, based on the AMIS reference architecture, to exchange inventory information automatically between automotive supply-chain partners.

### Accomplishments:

- Developed a monitoring tool to help test and validate supply chain integration implementations that use the Business Process Specification Schema (BPSS) and Collaboration Protocol Agreement (CPA) specifications. The tool checks whether each message has the right sender and receiver, message sequencing, and time constraints. The tool is implemented as a Java applet, which enables it to run in web browsers.

- Industry and government partners have adopted the Content Checker tool to aid the consistent application and validation of supply chain transaction specifications in real manufacturing transactions. This tool precisely specifies and extends conformance testing based on the semantics defined in a transaction schema, or content standard. Currently, the Content Checker works with transaction specifications based on the XML Schema language.
- Developed a collection of ontological models, semantic annotation tools, semantic reconciliation tools, and semantic translation tools based on existing OAG inventory standards and developed jointly with U.S, Korean, and European partners.

## Customers and Collaborators:

- Automotive Industry Action Group
- SAP
- Open Applications Group, Inc
- KORBIT[9]

9 Created in December 2002 in South Korea, KorBIT is an open consortium formed to help enterprises develop interoperability so as to conduct business over the Internet.

Supply Chain Integration

# Materials Off-Shore Supply Chains (MOSS) (Status: complete in 2009)

## Challenge/Problem Addressed:

The complexity of information transfers adds substantial logistics delays forcing OEMs to use premium shipping and warehouse extra inventory, which adds billions of dollars a year in shipping costs.

## Objective(s):

- Propose recommendations and standards
- Define associated EDI messages
- Develop an integration infrastructure
- Conduct demonstrations to show the automated exchange of logistics information across the entire logistics business process

## Accomplishments:

- Developed a MOSS conceptual model of the objects and relationships in ocean-freight transport and messaging supporting the management of ocean-freight manufacturing supply chains.
- Defined the MOSS message type structures, which include the ~100 key properties for the management of ocean-freight manufacturing supply chains, and mappings of this information into EDIFACT[10] messages.
- Developed tools to assess the conformance of MOSS participants' messages to the MOSS recommendation. The current tools check for correct syntax formation and the presence of required information elements.

10 United Nations/Electronic Data Interchange For Administration, Commerce, and Transport (UN/EDIFACT) is the international Electronic Data Interchange standard developed under the United Nations.

- Designed a message metamodel for representing the structure of an EDI- or XML-based message type. Its use in MOSS may demonstrate a strategy for decoupling concerns of message syntax from the task of message processing.
- Built a Queries/Views/Transformations (QVT) mapping engine, which is the major component of the conformance validation tooling. It will be used to map information from EDI messages to a form consistent with the MOSS conceptual model.

## Planned Future Accomplishments:

- Proof-of-concept conformance testing demonstration
- Detailed business process and interoperability demonstration

## Customers and Collaborators:

- Automotive Industry Action Group
- Honda of America Manufacturing
- U.S. Customs and Border Protection
- Bosch
- Daimler Chrysler Corporation
- Ford Motor Corporation
- General Motors Corporation
- Global Commerce Systems

Supply Chain Integration

# Integration Standards Testing Tools

(Status: complete in 2009)

## Challenge/Problem Addressed:

Studies have shown that most integration efforts fail to achieve their goals. Poorly designed interface specifications and inadequate test methods and data are still major causes of these failures.

## Objective(s):

- Provide industry with a suite of open tools and test methods that allow quick and easy assessment of XML-schema based interface standards.

## Accomplishments:

- The Naming Assister tool is used by standards development organizations to evaluate a specification's consistent use of naming. The tool maps terms used to assemble element names or type names against a table of allowable terms. It can also check the construction of compound names against the International Organization for Standardization's ISO 11179 recommended naming convention.
- Extended the use of the Schema Validation tool that allows users to validate transaction schemas and transaction instances against the W3C standard specification for XML schemas.
- Extended the Schematron Editor tool to provide a Java-based GUI tool for business analysts to create, view and modify Schematron files easily.

The tool includes a number of wizards to (1) facilitate specification of constraints and more precise semantic definitions of business-content standards, and (2) test an XML instance file against the constraints defined by the current Schematron file.

## Planned Future Accomplishments:

- Enhance instance validation tool that allows users to validate specific instance data content with either their own uploaded schemas, or from publicly available schemas including OASIS UBL v1.0, Grants.gov v1.0, and OAGIS v9.0.
- Extend the Quality of Design (QOD) tool as a more sophisticated tool suite, introducing Web 2.0 capabilities that allows users to define customized schema testing profiles based upon specific tests defined by them or collected from tests previously defined by others.

## Customers and Collaborators:

- Open Applications Group Inc. (OAGi)
- Automotive Industry Action Group (AIAG)
- FIATECH[11]
- Un/CEFACT
- Navy
- IRS
- GSA
- U.S. Air Force
- OCIO Council

11 FIATECH is a consortium that provides global leadership in identifying and accelerating the development, demonstration and deployment of fully integrated and automated technologies to deliver the highest business value throughout the life cycle of all types of capital projects.

Supply Chain Integration

# Supply Chain Center

(Status: complete in 2011)

## Challenge/Problem Addressed

Supply chain challenges span all industrial sectors, but the solutions are typically addressed within the context of a given sector, even at NIST, resulting in duplication and inconsistency.

## Objective(s):

- Create a NIST-wide interdisciplinary Supply Chain Center where multiple laboratories can come together to share results and enhance each other's work

## Accomplishments:

- Developed a web-based collection point both for sharing efforts across NIST, and to provide one-stop shopping for customers looking for NIST work relevant to supply chain interoperability. All of the tools mentioned above can be accessed through this web site.

## Planned Future Accomplishments:

- Enhance and evolve the web-based collection content and presentation
- Expand the user base of the web-based supply chain center

## Customers and Collaborators:

Other NIST Laboratories, including:

- BFRL
- EEEL
- ITL