Internet-Based Solutions for Manufacturing Enterprise Systems Interoperability – A Standards Perspective

Nenad Ivezic, Boonserm Kulvatunyou, Albert Jones

Manufacturing Engineering Laboratory

National Institute of Standards and Technology

1 Introduction

This chapter reviews efforts of selected standards consortia to develop Internet-based approaches for interoperable manufacturing enterprise information systems. The focus of the chapter is on the efforts to capture common meaning of data exchanged among interoperable information systems inside and outside a manufacturing enterprise.

We start this chapter by giving a general overview of the key concepts in standards approaches to enable interoperable manufacturing enterprise systems. These approaches are compared on the basis of several characteristics found in standards frameworks such as horizontal or vertical focus of the standard, the standard message content definitions, the standard process definitions, and dependence on specific standard messaging solutions.

After this initial overview, we establish one basis for reasoning about interoperable information systems by recognizing key manufacturing enterprise objects managed and exchanged both inside and outside the enterprise. Such conceptual objects are coarse in granularity and are meant to drive semantic definitions of data interchanges by providing a shared context for data dictionaries detailing the semantics of these objects and interactions or processes involved in data exchange.

In the case of intra-enterprise interoperability, we recognize enterprise information processing activities, responsibilities, and those high-level conceptual objects exchanged in interactions among systems to fulfill the assigned responsibilities. Here, we show a mapping of one content standard onto the identified conceptual objects.

In the case of inter-enterprise interoperability, we recognize key business processes areas and enumerate high-level conceptual objects that need to be exchanged among supply chain or trading partners.

Here, we also show example mappings of representative content standards onto the identified conceptual objects.

We complete this chapter by providing an account of some advanced work to enhance interoperability of manufacturing enterprise information systems in the context of the enterprise standards development.

2 A General Overview of Approaches for Interoperable Manufacturing Enterprise Systems

Here, we provide a general overview of the key concepts and selected standards approaches to enable interoperable manufacturing enterprise systems. We compare these approaches with respect to several key characteristics found in interoperable solutions.

2.1 General Concepts

To understand the focus of this chapter, its place within the general interoperability architecture, and to characterize selected approaches, we identify three key characteristics of the approaches: interoperability focus, industry focus, and integration objective. Other important aspects of interoperability solutions related to security, network protocols, trading partner agreements, and registry and repository solutions are issues that transcend all enterprises and are not considered in this discussion.

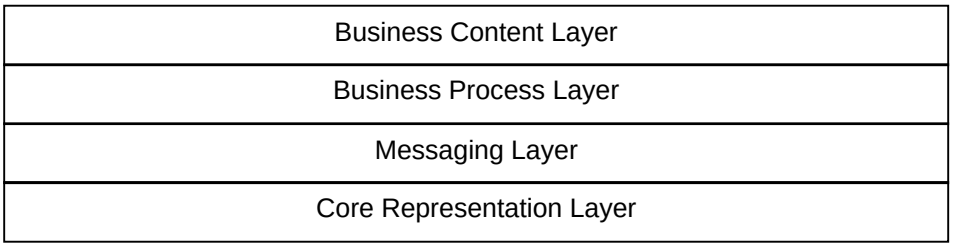

Figure 1. An Abstract Interoperability Stack Defining Scope of Internet-based Interoperable Solutions

Interoperability Focus is the first key characteristic of an interoperable standards solution and identifies the scope of that solution within an interoperability stack. Figure 1 shows one such abstract interoperability stack, based in part on previous studies [Business Internet Consortium, 2002], with four layers typically taken into account when developing current interoperable solutions. A standards approach may develop interoperability specifications in one or more of these layers:

- *Core Representation Layer* defines the syntax of messages, usually as sequence of data fields. The syntax supports specifications in the layers above for defining messages, process, and content. For the Internet-based approaches in this chapter, we assume the W3C standards, such as XML DTD, XSLT,

and XML Schema, that define message structure, document types, and data access within the documents [W3C, 2003].

- *Messaging Layer* includes standardized message and envelope structure definitions. Within this layer, session recording and communication setup for message transport are addressed so that coordination between interacting parties is assured. The issues of reliable and secure messaging are dealt with here. This layer is the foundation of communications among the other layers as it provides support for the message exchange and content packaging.
- *Business Process Layer* defines the way business processes are encoded so that the semantics of these processes may be shared and executed in a repeatable manner. Within this layer, business processes are defined that may be either broadly applicable or specific to an industry. The processes comprise simple interactions such as request/response or complex interactions such as collaborative product development or supply chain planning.
- *Business Content Layer* includes business definitions, data dictionary entries, business documents, and attachments that may constitute the meaning of a business message. Within this layer, one may specify composition of a valid business content – data structures, data types, constraints, and code lists. Also, this layer includes definitions of business terminology and accepted values that may be used in messages in support of many industries. The content covers many application domains such as product development, logistics, finance, and quality.

Industry Focus is the second key characteristic of an interoperability approach and may be either horizontal or vertical. Many of the interoperability approaches originate and are fixed on a specific industry sector – we call them vertical industry standards. Others, to a lesser or greater extent are focused on tying enterprises across industry sectors – we call them horizontal standards. For example, virtually all organization types deal with sales, procurement, and human resources in a generic sense. In addition, manufacturing companies need to exchange data within their respective cross-industry supply chains. This, becomes a significant issue when content standards developed by different organizations within one sector need to be translated and 'understood' by information processing systems in organizations from another sector.

Integration Objective is the third key characteristic of an interoperability approach and may be either architecture/application integration, supply chain integration, or trading network integration. In the architecture/application integration case, the interoperability approach enables interoperability of applications and information processing systems that co-exist within some enterprise architecture. In the supply chain integration case, the interoperability approach supports interactions that take place in an industry specific or cross-industry supply chains. In the trading network integration case, the interoperability approach addresses the needs of advertising the manufacturing or trading capabilities, identifying partners, establishing partnerships, and negotiating terms of trade among involved parties that may take on a wide range of roles such as customers, suppliers, logistics, retailer, broker, and warehouse.

2.2 Selected Approaches

Most of the developments to enhance enterprise interoperability are taking place within voluntary consortia that develop standards for business processes, business content, enabling technologies, and the overall business architectures. We focus on three prominent standardization efforts, summarized in Table 1, that influence manufacturing enterprise interoperability: Open Applications Group, RosettaNet, and ebXML.

2.2.1 Open Applications Group

The Open Applications Group (OAG) is building specifications that define the business object interoperability between enterprise business applications [OAG, 2003]. The OAG Integration Specification (OAGIS) is the common content model needed to represent information objects that enable communication between business applications [Rowell, 2002]. Such a content model provides a common basis of understanding among developers who specify intent of the messages to be processed by enterprise information systems.

OAGIS includes a large set of Business Object Documents (BODs) and integration scenarios that can be used in different business environments, such as application-to-application (A2A) and business-to-business (B2B). BODs are message content definitions that can be used broadly across many different industries (for example, telecommunications and automotive) and aspects of Supply Chain Automation (for example, Ordering, Catalog Exchange, Quotes).

OAGIS implies an architecture/application integration approach enabling interoperability of applications and systems that need to co-exist within some inter- or intra-enterprise architecture.

OAGIS does not specify an implementation architecture and can be utilized over different messaging and transport solutions such as RosettaNet Implementation Framework (RNIF) and ebXML Messaging [RNIF, 2003; EbMS, 2003].

OAGIS have been adopted and used in aerospace, automotive, and telecommunications manufacturing industries. As shown later in this chapter, the OAGIS content standards support interaction among information systems typically found in a manufacturing enterprise Product Data Management system, Enterprise Resource Planning system, and Factory Planning System. The BOD structures can be extended to accommodate alternative integration scenarios. In situations where existing BOD structures are not available for customization, new BODs can be developed. An example is the Standards for Technology in Automotive Retail (STAR) consortium that defines standard XML message for dealer-to-OEM business transactions (i.e., Parts Order, Sales Lead, Credit Application) within the STAR/XML project [STAR, 2003].

OAGIS specifications are currently represented using W3C XML Schema and make use of advanced features such as XSLT, overlays, constraints specification and validation using Schematron [Schematron, 2003].

2.2.2 RosettaNet

RosettaNet is a consortium of Electronic Components (EC), Information Technology (IT) and Semiconductor Manufacturing (SM) companies working to create, implement and promote open e-business process standards [RosettaNet, 2003]. The RosettaNet standards propose solutions for the three layers of the interoperability stack shown in Figure 1: messaging, business processes, and business content. In this manner, the standard is self-sufficient and complete; it can be implemented independent of other standards with exception of core representation standards.

The RosettaNet specifications include RosettaNet Implementation Framework (RNIF) that provides for data exchange protocols; Business Dictionary that defines the properties used in basic business activities; Technical Dictionary that provides common language for defining products and services; and Partner Interface Processes (PIPs) that are system-to-system, XML-based dialogs that define business processes between trading partners.

The Rosettanet specifications can be applied to a variety of supply chain integration scenarios and trading partner data exchanges. The industry focus is mostly vertical (i.e., high-technology) but with plans to be extended horizontally: RosettaNet recently joined Uniform Code Council (UCC) and indications are that additional retail-oriented industries will be included within the scope of the standard [UCC, 2002]. The RosettaNet specification, although complete and independent of other standards, is planning for future interfacing with other messaging and transport solutions such as ebXML Messaging. Also, some advanced business process standards such as ebXML BPSS are planned for use in development of new PIPs [ebBPSS, 2003].

The specification is a supply chain-driven interoperability approach. The standard has been adopted and implemented in a variety of software products in support of high-technology supply chains throughout IT, Electronic Components, and Semiconductor Manufacturing sectors. The primary deliverables, PIPs, provide building blocks for inter-enterprise manufacturing integration. The PIPs are categorized in a number of cluster groups, such as Product Information, Order Management, Inventory Management, Marketing Information Management, Service and Support, and Manufacturing. As shown later in this chapter, these PIPs contain guidelines that prescribe the content of the messages exchanged using the prescribed PIP choreography. Different from BOD structures that are intentionally left to be extensible by the implementers, the PIP structures can only be changed through a RosettaNet sanctioned, and formally managed, change-submission process. When existing PIP structures are not available for customization, new projects are started and PIPs are developed [iHUB, 2002]. RosettaNet specifications are represented using W3C XML DTD specifications.

2.2.3 ebXML

ebXML (Electronic Business using eXtensible Markup Language) is an effort co-sponsored by UN/CEFACT and OASIS to develop a modular suite of specifications that enables enterprises of any size and in any geographical location to conduct business over the Internet [ebXML.org]. ebXML is developing a series of standards specifications to exchange business messages, establish trading relationships, communicate data in common terms and define and register business processes.

ebXML produces a wide range of specifications including Business Process Specification Schema (BPSS), Core Components, Collaboration Protocol Profile and Agreement (i.e., a mechanism for declaring

a trading partner capabilities and agreement), standardized messaging service, and others [ebBPSS, 2003; ebCC, 2003; ebCPPA, 2003]. In addition, ebXML is working on a standardized UML-based modeling methodology for modeling business processes and translating those models into XML documents.

Different ebXML specifications are at different levels of maturity. For example, the messaging specification is well advanced and has been adopted by software vendors. In contrast, due to its sheer complexity, the core component specifications that provide for a methodology leading to a unified, well-defined semantics of message content are only now being validated.

The ebXML specifications could be applied to a variety of supply chain integration scenarios and trading partner data exchanges. The industry focus is definitely horizontal, cutting through virtually all industry sectors. The ebXML effort is a trading-partner-driven interoperability approach supporting the needs of publishing, discovering, and establishing trading agreements for a general trading partner context irrespective of the industry.

The ebXML specification is complete and independent of other standards, in principle. However, with respect to its content-standard development process, the adopted ebXML development process is to recognize a number of existing content standards (such as OAGIS) and, over time, drive its own content standards process based on these existing standards.

The mature parts of the standard (e.g., messaging and business processes) have been adopted by a variety of software product vendors. Pilot efforts, reference implementations, and initial adoptions of ebXML exist in automotive industry with more such efforts advertised for the future [STAR, 2003]. ebXML specifications are represented using UML modeling and XML representations.

	OAG	RosettaNet	ebXML
Date formed	1995	1998	1999
Founders	Enterprise software vendors	Information Technology, Electronic Components, and Semiconductor Manufacturing companies	UN/CEFACT and OASIS
Objectives	To build specifications that define the business object interoperability between enterprise business applications.	To create, implement and promote open e-business process standards in support of supply chain integration.	To provide an open XML-based infrastructure enabling the global use of electronic business information in an interoperable, secure manner by all parties.
Interoperability Focus	Business Content Layer	Messaging Layer, Business Process Layer, Content	Messaging Layer, Business Process Layer, Content

		Layer	Layer
Deliverables	Business Object Document (BOD) specifications; Integration scenarios (non-normative)	RosettaNet Implementation Framework (RNIF), Business Dictionary, Technical Dictionary, Partner Interface Processes (PIPs)	Business Process (BPSS), Core Components (CC), Messaging (ebMS), Collaborative Protocol Profile and Agreement (CPP/A), Registry, and others
Industry Focus	Horizontal (automative, aerospace, logistics, telecommunications)	Vertical to horizontal: High-technologies to also include retail industries	Horizontal
Integration Driver	Architecture/Application Interoperablity	Supply Chain Integration	Trading Partner Network Integration
Interactions	RNIF, ebXML (current)	ebXML (future)	OAG, xCBL, SWIFT (future)
Technology	W3C XML Schema	W3C XML DTD	UML and W3C XML

Table 1. A Comparison of Three Standards Approaches: OAGIS, RosettaNet, and ebXML.

3 Interoperable Information Systems within the Manufacturing Enterprise

We now focus on the semantic issues for interoperable information systems within the manufacturing enterprise. We adopt one proposed **interoperability framework** for describing processing activities, responsibilities, and high-level interface objects in the manufacturing enterprise information systems. Then, we give an objective basis for a possible mapping for the OAGIS manufacturing content standard onto the adopted high-level interface objects. Also, we illustrate how these mapped content standards would be supportive of one interoperable manufacturing enterprise architecture.

3.1 An Intra-Enterprise Manufacturing Interoperability Description Framework

An interoperability framework was proposed to describe features of interoperable information systems within a manufacturing enterprise [OMG, 1998]. This framework outlines high-level processing activities, information-processing responsibilities, and high-level interface objects.

Manufacturing information processing activities include Product Development, Process Design, Process Prototyping, Requirements Planning, Production Planning, Resource Scheduling, Preparation and Setup, Process Operations, Work-in-Process Reporting, and Cost and Usage Reporting.

Information processing responsibilities that are supported by these manufacturing activities include Capture/maintain product specification, Capture/maintain item descriptions, and Capture/maintain Manufacturing Bill of Materials, to name only a few.

Based on the established activities and responsibilities, we can identify conceptual interface objects. An example interface object may be identified from the Manufacturing Process Definition activity. Within this activity, one responsibility is Capture and Maintain Manufacturing Bill of Materials. On the other hand, another information processing activity is Resource Scheduling with a responsibility to Provide Effective Manufacturing Bill of Materials. With the potential to assign the two responsibilities to two different systems (e.g., ERP and PDM systems), there is a need to exchange Bill of Materials. These conceptual objects form context for identification of data dictionaries detailing the semantics of these objects and processes involved in data exchange.

In the previous example, the Bill of Materials (BOM) is a conceptual object necessary for manufacturing systems integration. Such an object provides a context to identify elements of data dictionary such as Batch Size Quantity (i.e., the number of items that can be produced in each run of the BOM) and Effective Period (i.e., the time period during which the BOM is effective). The related interactions that may take place among manufacturing systems for this conceptual object may include requests to get and synchronize a BOM and interactions requesting and showing BOM detail.

Using a similar analysis, a collection of high-level interface objects may be identified to assure interoperability among systems implementing different manufacturing information processing. Table 2 identifies these objects and gives a summary semantics definition for the objects based on [OMG, 1998].

Bill of Material	List of the material items needed to create a particular configuration of a final product in a particular manufacturing facility in a certain time frame.
Cost and Usage Report	Reports from the manufacturing facility to the enterprise management systems on actual costs of operating the production facility and materials and resources used, including relationships to specific orders, products and yields, and work-in-process inventory.
Inventory	Body of business information that tracks the available supply of parts, tools and materials, and possibly the warehousing of finished goods.
Item	Individual instances of the materials -- the pieces or packaged units – that include final products, component parts/products, raw/stock materials, “work-in-process”
Item Description	Specifications for a kind of Item that is used in, or results from, the manufacturing processes. The information describes the properties that are common to all instances, such as its name, part number, its mechanical, electrical or chemical properties, etc
Labor	Information about employee and contractor time and effort expended on fulfillment of a particular order, when the enterprise uses the information to define cost of manufacture.
Labor Resources	Information about individual employees and contract personnel directly related to their use as manufacturing resources.
Lot	A unit of product that is in work in the manufacturing facility. As such it is a collection of product items, possibly accompanied by other materials, in some state of manufacture
Manufacturing Order	Vehicle by which the manufacturing facility is directed to produce a quantity of product items
Master	List of all “Manufacturing Orders” to be fulfilled in a given factory over a certain time

Schedule	period, with target volumes and completion dates.
Plant and Equipment Resources	Information about plant facilities and individual machines and other equipment that is specifically allocated for use, or specifically accounted for, in fulfilling manufacturing orders
Process Specifications	List of operations and steps required in order to manufacture a finished good.
Product Specification	Engineering descriptions of a finished good that results from the manufacturing processes
Purchase Request	Request from the manufacturing systems to the purchasing system to purchase (additional) materials, based on a demand discovered in the factory
Tooling	Items needed for the manufacturing process but not part of the finished goods

Table 2. High-level Interface Objects Supporting Intra-Enterprise Manufacturing Systems Interoperability

3.2 Manufacturing Enterprise Information Systems

The information systems that are found in a manufacturing enterprise include: Product Data Management systems, Enterprise Resource Planning systems, Factory Scheduler/Dispatchers, Factory Planning Systems, Process Control Systems, Human Resources Management Systems, and Manufacturing Execution Systems.

An example architecture supporting manufacturing enterprise information processing activities is shown in Figure 2, based on [OMG, 1998]. The architecture shows information systems communicating using the interface objects identified in Table 2 that are the subjects of the information flows identified on the wires linking the software component boxes. (The unlabeled dashed edges indicate an additional control interface that exists between the Manufacturing Executing and each individual tool Control system.)

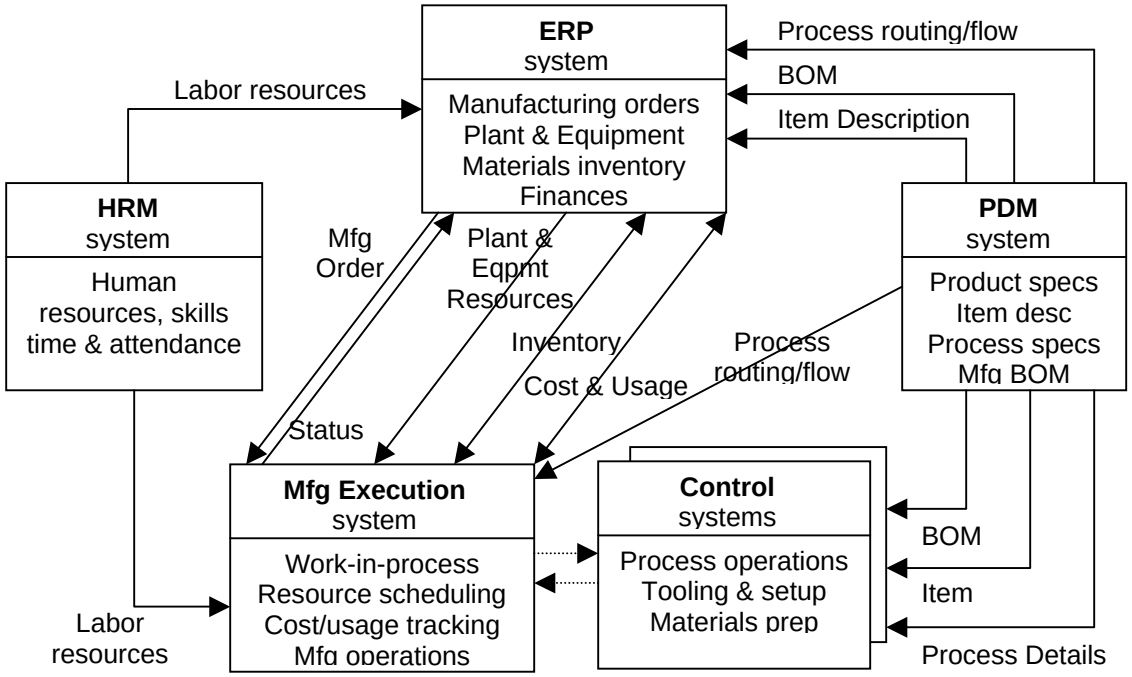

Figure 2. An Example Architecture of a Manufacturing Enterprise Information System

3.3 OAG Semantic Integration Standards in the Manufacturing Sector

Table 3 gives one possible mapping of the OAGIS content standards onto the identified conceptual objects. The OAGIS BODs consist of verb and noun parts (e.g., ProcessPurchaseOrder – verb Process and noun PurchaseOrder). For the purposes of this mapping, we have identified the nouns that constitute the BODs. As can be seen from the table, the mapping is not always one-to-one since OAGIS may have multiple nouns that express semantics of the corresponding conceptual object – for example – Cost and Usage Report is mapped onto Consumption, Costing Activity, and variants of WIP nouns. In addition, a number of OAGIS nouns are included that do not have a mapping onto the proposed high-level objects.

High-Level Concept Object	**OAG Noun**	**OAG Meaning**
Bill of Material	Bill of Material	List of items to be produced in a specified time period. The Bill of Material structure is broken down into three ways to represent the Item. An Item may be included by itself, or may be represented as part of a set of options or as an option within a class of options.
Cost and Usage Report	Consumption	Process whereby a certain amount or quantity of inventory, resources or product is utilized which likely lead to the need for some form of replenishment.
	Costing Activity	Details of the activities in the Manufacturing Application that caused the entries in the Journal.
	WIP Confirm	Work-in-Progress confirmation represents confirmation of the movement of WIP materials. The noun refers to general information about the entire WIP transaction, as well as line item detail about the specific WIP operation or routing step. This may apply to the movement of raw materials or finished products.
	WIP Merge	WIP Merge is used to notify a Manufacturing Application of the creation of a single production lot from multiple production lots of a product being made on a production order.
	WIP Move	WIP Move is used to communicate which processing step the product is coming from and which step it is being moved to, along with the quantity moving and the time this event occurred.
	WIP Recover	WIP Recover is used to notify a Manufacturing Application of the creation of usable production materials from material previously considered unsuitable for production use. This is most often likely to represent a return to production of scrap material.
	WIP Split	WIP Split is used to notify a Manufacturing Application of the creation of multiple production lots from a single production lot of a product being made on a production order.
	WIP Status	WIP Status is used to notify a Manufacturing Application of the progress of a production order at a point in time.
Inventory	Inventory Balance	Stocked items and the quantities of each item by location. Other item-by-location information, such as serial numbers or lot numbers, can also be included.

	Inventory Count	Results of a physical inventory or cycle count of the actual on-hand quantities of each item in each location. Compare to the noun InventoryBalance, which represents system-maintained on-hand quantities.
	Inventory Issue	Request to process an issue or request information about an issue.
	Inventory Movement	Identify items being moved, source, and destination of movement.
	Inventory Receipt	Intended for use in Unplanned Receipt Scenarios.
Item	Item Cross Reference	Item Cross Reference describes both alternate and related items. Alternate items could specify items that have alternative universal identifiers such as EAN, UPC, or party specific identifiers such as supplier part number or customer part number. Related items could be spares, accessories or substitutes.
	Item Master	Represents any unique purchased part or manufactured product. Item, as used here, refers to the basic information about an item, including its attributes, cost, and locations. It does not include item quantities. Item is used as the Item Master.
Item Description	Item Master. Value Class	Grouping to determine the General Ledger accounting effect. These are user defined values, with the exception of the values TOTAL, MATERIAL, LABOR, BURDEN, OVERHEAD, SUBCONTRACT.
Labor	Employee Time	Time sheet information for an employee.
	Employee Work Schedule	Planned work hours for an employee.
Labor Resources	Personnel	Human resource information maintained for each employee. It includes such data as job code, employee status, department or place in the organization, and job-related skills. Although generally maintained in a Human Resource Management System (HRMS), this information may also be needed and updated by manufacturing applications (workforce scheduling) or project management.
Lot	Lot	Manufacturing lot.
Manufacturing Order	Production Order	Document requesting the manufacture of a specified product and quantity.
Master Production Schedule	Sequence Schedule	A Sequence Schedule is used to indicate sequential scheduling of ordered items in the manufacturing process. Commonly, the sequence schedule is generated by a work in process application and transmitted to an order or material planning application.
Plant and Equipment Resources	Resource	An abstract type describing the allocation of persons, equipment or materials, likely in a manufacturing environment.
	Resource Allocation	Identifies the resources that are need for a production order and indicates where they are to be assigned.
Process Specifications	Routing	Description of the resources, steps, and activities associated with a path or routing associated with a manufacturing process. Typically, a routing contains people, machines, tooling, operations, and steps.
Product Specification	Project	A set of tasks with the following attributes: a singular purpose, a start and end date, those that accumulate costs, and those that may have materials and overhead. SYNONYMS: Job, Process Model, WBS.
Purchase Request	Requisition	Request for the purchase of goods or services. Typically, a requisition leads to the creation of a purchase order to a specific supplier.
Tooling	Tool	A tool needed for a given task.
	Dispatch List	A prioritized detail status of orders and operations scheduled or in-process at a specific work center.
	Engineering	A request for a change to a manufactured item. This document allows

	Change Document	the change to progress through the different states from being a request and going through the review process to becoming an approved Engineering Change Order.
	Engineering Work Document	Carries product structure information and information on what is to be changed in it as the result of a project design activity.
	Maintenance Order	Order for a machine, building, tooling or fixed asset to be repaired or for preventive maintenance to be performed.
	Pick List	List of materials to be retrieved from various locations in a warehouse in order to fill a production order, sales order, or shipping order.
	Product Requirement	Request to reserve or allocate a specified quantity of a specified item. Typically, this requirement would be received by an inventory or production system.
	Planning Schedule	Indicates a demand forecast sent from a customer to a supplier, or a supply schedule sent from a supplier to a customer.

Table 3. A Possible Mapping of the OAG Content Standard Nouns Onto the Identified Conceptual Objects

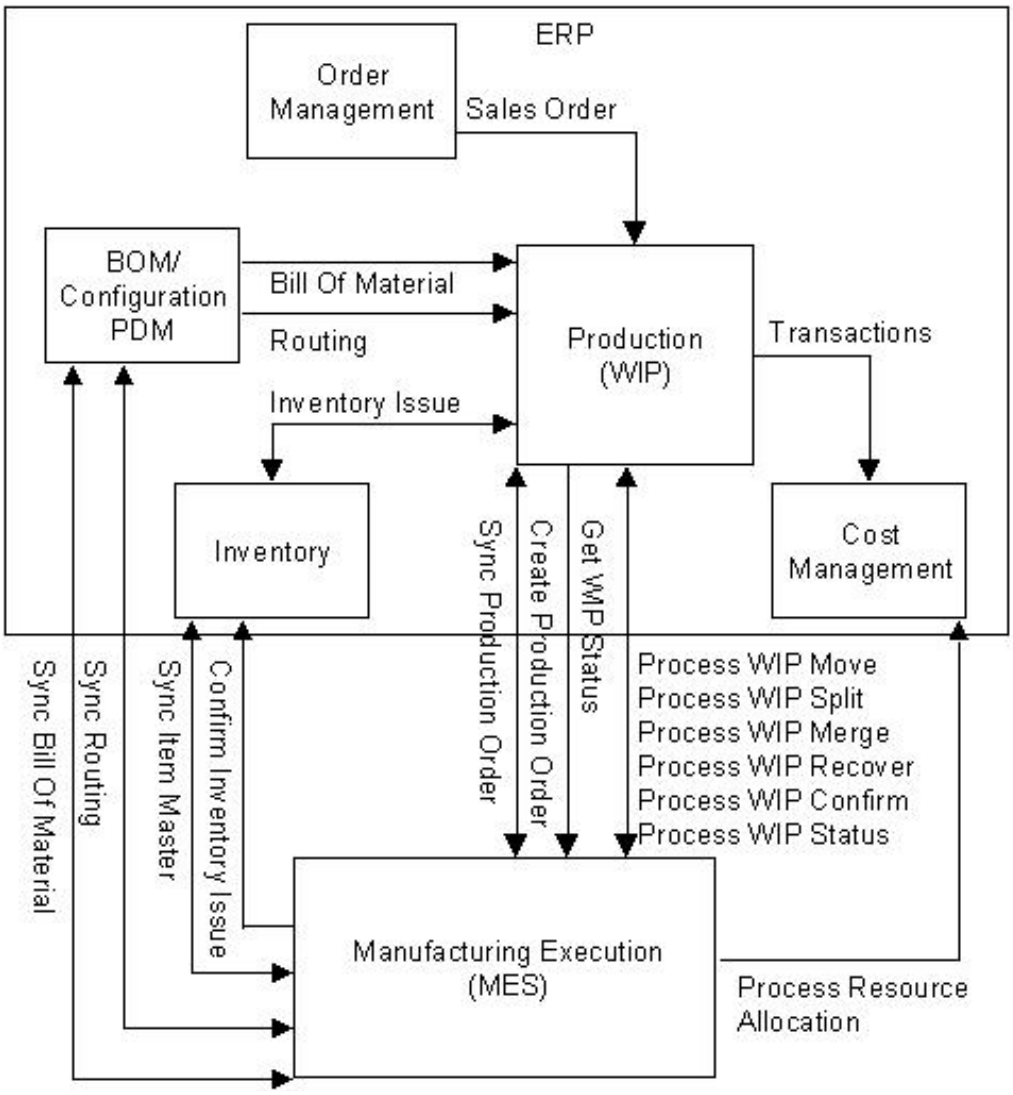

Figure 3. An Example Intra-Enterprise Integration Scenario Using OAG BODs

To supplement the semantic definitions of its BODs, OAGIS includes (non-normatively) possible communications between various software modules as starting points for the OAGIS users to find and adopt to their own needs. (Note that the actual scenarios of integration, that need to include the actual flow control, can be derived from these proposed communications.) Figure 3 shows possible communications using OAG BODs that are similar to the example manufacturing enterprise system architecture shown in Figure 2.

For example, Manufacturing Order in Figure 2 corresponds to Production Order (as indicated in Table 3) in the suggested CreateProductionOrder BOD used in Figure 3. Similarly, BOM and Process Routing/Flow in Figure 2 correspond to BOM and Routing exchanged between BOM/Configuration/PDM component and Production/WIP component in Figure 3.

4 Interoperable Information Systems Outside the Manufacturing Enterprise

In this section, we look at the approaches that support interoperable systems across multiple manufacturing enterprises. Here, without the luxury of an existing high-level manufacturing inter-enterprise interoperability framework, we adapt a proposed classification of enterprise business processes as a starting point for constructing such a framework. We show how two alternative approaches to enable interoperable inter-enterprise manufacturing systems, OAGIS and RosettaNet, may be mapped onto the classification structure. We illustrate two inter-enterprise integration scenarios by using the OAGIS and RosettaNet concept objects.

4.1 An Inter-Enterprise Manufacturing Interoperability Classification Framework

A classification of enterprise business processes has been proposed [ebXML, 2003]. This classification is based on general inter-enterprise activities and includes business areas such as procurement/sales, design, recruitment and training, logistics, and others. The classification is not complete and was meant to be a basis for constructing an evolving framework of a common business processes catalog. Nevertheless, we take this classification as a basis for identifying some high-level interface objects commonly identified in an inter-enterprise activity.

We focus only on a subset of the inter-enterprise information processing activities that fall into the following business areas: procurement and sales, logistics, manufacturing, and financial services. We map

the OAG and RosettaNet higher-level concepts onto the classification categories and arrive at the following table with semantics for the higher-level interface objects.

OAG Noun and Definition	RosettaNet Business Data Entity/PIP and Definition
Procurement/Sales	
Consumption Process whereby a certain amount or quantity of inventory, resources or product is utilized which likely lead to the need for some form of replenishment.	**Consumption Notice** Business document to trading partner that owns consigned product that communicates material, material quantities, and dates the material quantities were consumed
Delivery Receipt Transaction for the receiving of goods or services. It may be used to indicate receipt of goods in conjunction with a purchase order system.	**Receipt Information** The collection of business properties that describes the receipt of a delivery of a quantity of a product.
Electronic Catalog A list of items or commodities. Each item can be classified into one or more categories, and the specifications of each item can be identified. A catalog has at least one publisher and one or many suppliers for the items in the catalog.	**Sales Catalog** The collection of business properties that describe a seller's catalog of products.
Inspection Report on the inspection of items identified in the source document.	**Inspection Results** The collection of business properties that describe the results of a product inspection.
Invoice Invoice document to the customer.	**Invoice** An itemized list of goods or services specifying the price and the terms of sale.
Party Information use by business applications to reference parties that may play different roles within an integration (e.g., Supplier, Customer, Carrier)	**Partner Role Description** The collection of business properties that describe a business partners' role in a partner interface process.
Price List List of items with their base price, price breaks, discounts and qualifiers.	**Price List** The collection of business properties that describe product pricing in a price list document.
Product Availability Information on the availability of a specified item at a specified inventory location for a specified date.	**Product Availability** The collection of properties that describe a product's time frame for being available.
Purchase Order An order to purchase goods from a buyer to a supplier.	**Purchase Order** The collection of business properties that describe a buyer's offer to purchase a quantity of products at an agreed price and schedule.
Quote Document describing the prices of goods or services provided by a vendor. The Quote includes the terms of the purchase, delivery proposals, identification of goods or services ordered, and their quantities.	**Quote** The collection of business properties that describe an offer to supply a quantity of products at an agreed price and schedule.
Request for Quote Document describing goods or services desired from a vendor. The RFQ includes the terms of the purchase, delivery requirements, identification of goods or services ordered, as well as their quantities.	**Request Quote (PIP)**

Sales Order A customer order, a step beyond a Purchase Order in that the receiving entity of the order also communicates Sales Information about the Order along with the Order itself.	**Sales Information** The collection of business properties that describe the sale of a product.
Cart List of items selected for purchase.	**Shopping Cart** The collection of product descriptions, quantities and prices that comprise a buyer's intent to purchase.
Manufacturing	
Bill of Materials List of items to be produced in a specified time period. (Same as in inter-enterprise.)	**Bill Of Material** The collection of business properties that describes a bill of material for a product.
Engineering Change Document A request for a change to a manufactured item. (Same as in inter-enterprise.)	**Engineering Change Request** The collection of business properties that enables a party proposing an engineering change to send an engineering change request to a change review forum.
Inventory Balance Stocked items and the quantities of each item by location. Other item-by-location information, such as serial numbers or lot numbers, can also be included. (Same as inter-enterprise)	**Inventory Report** The collection of business properties that describe a product in inventory at a specific point in time.
Maintenance Order Order for a machine, building, tooling or fixed asset to be repaired or for preventive maintenance to be performed. (Same as inter-enterprise)	**Service Event Information** The collection of business properties that describe the data elements and entities associated with performing repair or maintenance service on a part or unit of product.
Planning Schedule Indicates a demand forecast sent from a customer to a supplier, or a supply schedule sent from a supplier to a customer. (Same as inter-enterprise)	**Forecast** The collection of business properties that describe the advance indication of the opportunity for selling or demand.
Sequence Schedule Sequential scheduling of ordered items in the manufacturing process. (Same as inter-enterprise)	**Product Release Schedule** The collection of business properties that identifies the dates(s), quantity(s) , times(s) and release number for Material Release
Engineering Work Document Carries product structure information and information on what is to be changed in it as the result of a project design activity. (Same as inter-enterprise)	**Engineering Information** The information for engineering purpose, i.e, technical data necessary for process of the device.
Work In Process Movement of material or finished products; also, production order status. (Same as inter-enterprise)	**Work In Process** The collection of business properties that describe the manufacturing steps which must be performed.
Financial Services	
Credit Customer credit information used in the context of credit checking new sales orders.	**Credit Reference** The collection of business properties that describe the current credit status of an account of party.
Credit Status Credit approval status of a customer or a specific customer order.	**Credit Reference** The collection of business properties that describe the current credit status of an account of party.
Exchange Rate Information that applies to the currency exchange rate ratio.	**Currency Conversion** The collection of business properties that describe the exchange of money in circulation.

Logistics	
Shipment A document that identifies and describes a collection of goods to be transported by a carrier and delivered to one or more destinations.	**Shipment** The collection of business properties that describe a consignment tendered for transportation from one point to another.
Shipment Schedule Commonly, a shipment schedule is generated by a material planning application and transmitted to an order or material planning application.	**Shipping Information** The collection of business properties that describe information regarding shipments tendered for transportation.
Carrier Route Describes a scheduled journey that a transportation service provider (freight carrier) is requested to perform for a shipper, customer or coordinator.	**Routing Information** The collection of business properties that describes a leg used in the routing of a shipment.

Table 4. A Mapping Between the OAG Content Standard Nouns and RosettaNet Business Data Entities.

4.2 Example Inter-Enterprise Scenarios of Integration

Figure 4 gives a family of supply chain integration scenarios by identifying communication links (and associated BODs or simpler communication patterns) among software modules. As stated before, OAG doesn't provide control of flow to define integration scenarios in these non-normative specifications.

Software modules are indicated with single-line boxes. The software modules outside of the enterprise are indicated with the dashed-line boxes. The arrows indicate possible communication channels and associated BODs. The double-lined boxes indicate simpler communication patterns that may be found among the other non-normative OAG integration scenarios. In this way, OAG integration scenarios are defined recursively from simpler to more complex scenarios.

Definitions of the OAG BODs used in this figure can be found in Table 4. In the figure, the inter-enterprise conceptual objects (i.e., OAG nouns) identified in Table 4 are used to form BODs such as ProcessPurchaseOrder, AddPurchaseOrder, and others to support the supply chain integration scenario.

One possible scenario of integration may start with the ProcessPurchaseOrder BOD from an external customer order management system into the supplier's order management system. The local order management system may determine whether the items are to come from the inventory and, in that case, the SyncSalesOrder is sent to the shipping module. The shipping module may communicate with the inventory system using GetPickList and ShowPickList pair of BODs. Alternatively, if the items are to be obtained from an external source, the order management system may use AddPurchaseOrder BOD to communicate this decision to the purchasing system that, in turn, can send ProcessPurchaseOrder to the external supplier.

Although in case of RosettaNet, supply chain integration scenarios are supported by identifying Partner Interface Processes (PIPs), one can also identify, in early phases of an interoperability effort, support of these integration scenarios using high-level RosettaNet business data entities such as those recognized in Table 3. For example, the RosettaNet iHUB project was put together to use and further develop PIPs in support of supply and demand planning within a collaborative, dynamic trading network [iHUB, 2002]. One of the high-level conceptual integration diagrams identified the roles in such a trading network and the conceptual objects exchanged between these roles and the network hub. In that way, identification of conceptual objects such as those in Table 4 represents a basis for data exchange among the partners. Table 5, summarizes the roles and objects of interest or exchanged by these roles.

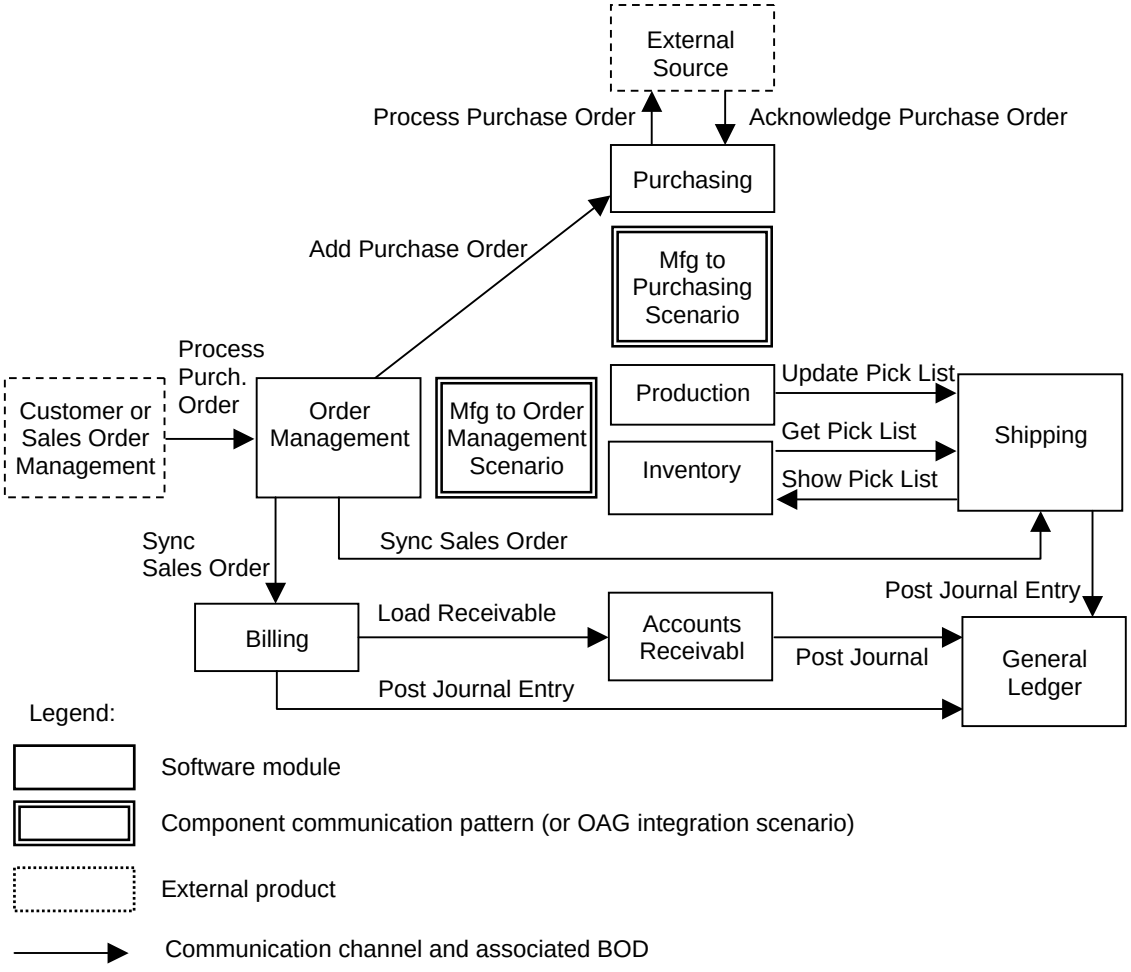

Figure 4. A Possible Supply Chain Integration Scenario Supported By OAG BODs

	Component Manufacturer	Original Equipment Manufacturer	Component Supplier	Distributor
Forecast	+	+	+	+
Inventory Report	+	+	+	+
Replenishment/ Consumption	+			
Purchase Order	+	+		+
Sales Order	+		+	+
Shipment	+	+	+	+
BOM	+			
Product Master	+	+	+	
Work Order	+			
Product Catalog				+

Table 5. The Roles and Objects Exchanged by These Roles in RosettaNet iHUB Project.

5 Advanced Developments in Support of Interoperable Manufacturing Enterprise Systems

We conclude this chapter by giving an account of advanced developments in support of interoperable manufacturing enterprise information systems that are taking place in the standards organizations including ebXML, OAG, RosettaNet, NIST, and W3C.

5.1 OAG

OAG has recently enhanced its OAGIS specifications by adopting W3C XML Schema recommendations to represent its object concepts along with other advanced related technologies such as XSL, XSLT, and Schematron [Schematron]. OAG has also taken steps to ensure that adoption of XML Schema as its representation approach continues to reflect its extensible design and support of other vertical and horizontal industry standards [OAGIS, 2003]. One important practical development is that OAGIS keeps separate the content structure definitions from the content validation specifications to reflect the fact that validation procedures are typically specific to the users of the interoperability standards. Although this practice encourages a common content model within and across different industries, it leaves a lot of room to different interpretations of standards specification meaning and, consequently, may cause interoperability issues. For that reason, researchers are investigating complementary technologies such as RDF and Semantic Web to provide additional rigor and to formally define the meaning of a content model [ISOMA].

OAG is also embarking on collaborative efforts with other standards specification efforts that are focused on either a specific vertical industry sector or addresses a portion of horizontal efforts. An example of the former is a recent inclusion of TranXML specifications within the OAGIS [TranXML, 2003]. TranXML provides specifications for the transportation and logistics industries. An example of the latter is the collaborative effort with HR-XML that provides a cross-industry standard specification for procurement of human resources [HR-XML,2003].

5.2 ebXML

The ebXML effort at UN/CEFACT is developing an advanced approach for content and structure definition named Core Components (CC) to execute business collaborations in complex application contexts [ebCC, 2003]. Presently, the CC specification is at the verification stage under UN/CEFACT Open Development Process (ODP). The CC approach starts with a syntax independent construct of information (using UML class diagrams). The class diagrams of the CC specification together with adopted naming conventions and rules enable serialization of the object class diagrams into data vocabularies. The CC approach starts with a basic vocabulary (called core components) and employs a context mechanism to apply to that vocabulary. The context mechanism defines eight context categories (shown in Table 6), which when applied to the core components results in an application context-specific business object called business information entity (BIE) that is used for actual business data exchange. Different business-specific semantic constraints and restrictions may be applied at the time of creation of BIEs. The context mechanism introduced in this way provides means to narrow down the intended meaning of business terms through a flexible mechanism while allowing an important generality at the basic dictionary level. It is expected that the users of standardized core components will be able to agree on the semantics at the basic dictionary level and, then, arrive at a common meaning of the business information entities (BIEs) by applying the context mechanism to the dictionary (i.e., core components).

Early adoptions of the CC approach have begun by several organizations including OAG, UCC, and ebXML UBL Technical Committee [OAG, 2003; UCC, 2003; UBL, 2003]. A number of issues have been revealed in these initial steps which broadly fall into one of the two categories.

Context category	Description	Example
Business Process	The type of process	Ordering, Delivery
Product Classification	The type of products that the collaboration is about	Parts, Consumer goods
Industry Classification	The sector in which the collaboration takes place	Aerospace, Electronic Components
Geopolitical	The location of the partners	International, Europe
Official constraints	The legislation that applies	US law, EU law
Business Process Role	The roles the partners play in the process	Buyer, Seller
Supporting Role	Roles of relevant parties outside the collaboration	Shipping Agent
System Capabilities	Specific system requirements	SAP, Intuit

Table 6 – The Core Components Context Mechanism Defines Eight Context Categories

The first category of issues deals with the *usage of the CC approach* where one may proceed with a top-down approach or a bottom-up approach to develop core components. The users (such as UCC EAN and SWIFT) that employ a top-down approach attempt to derive core components from the business requirements (as recommended by the CC specifications) without looking back at the existing content models. On the other hand, the users (such as OAG and UBL) who use the bottom-up approach attempt to derive core components from existing content models. A trade-off between the two approaches is obvious.

In the case of top-down approaches, any harmonization of the results among such efforts will be supported well as the business requirements provide a common basis for defining context and common semantics without a regard for backward compatibility. However, breaking the backward compatibility will cause issues for existing users of these standards specifications. On the other hand, in the case of bottom-up approaches, a harmonization of the results among different efforts will not have a common basis and the differences in the starting models may be reflected in the identified core components. However, the backward compatibility may be preserved allowing continuity in the standards adoption.

The second category of issues deals with the *interpretation of the specification and information modeling*. These issues are always present where there is an attempt to model information and information

types need to be determined. Questions such as 'Whether an entity should be an object or a simple type?' or 'Whether an object characteristic should be a contextual property or simple property?' abound in any standards adoption process. A core component primer [CCSD, 2003] has been developed to assist the adopting organizations in the process of addressing these issues.

5.3 RosettaNet

RosettaNet has made a significant investment to enhance interoperability among products implementing RosettaNet specification by developing its own conformance certification program. The RosettaNet Ready program provides tools and services required to measure compliance of a product implementation with RNIF and PIP specifications. In addition, RosettaNet has put in place the RosettaNet Interoperability program to improve implementation interoperability through education and testing activities [RN url]. The program's objective is to drive down the cost of connecting trading partners and especially to enable small and medium enterprises to get involved in trading networks. The initial problems being addressed by the program include the new trading partner transport, routing, and packaging concerns and security issues.

5.4 National Institute of Standards and Technology

The National Institute of Standards and Technology (NIST) has been developing a Manufacturing B2B Interoperability Testbed in collaboration with the Open Applications Group. The main objective for the testbed is to advance available technology for on-demand, highly available, and efficient interoperability demonstration, piloting, and testing [oagnist]. The testbed project has utilized technologies such as Semantic Web and W3C XML technologies and standards specifications such as OAGIS and ebXML to develop tools such as content checking, business process monitoring, and virtual trading partners in support of interoperability testing and demonstration. The OAG/NIST Testbed also collaborates with industry partners and consortia such as OASIS ebXML Interoperability, Implementation, and Conformance (IIC) to advance the state of the art of automated testing facilities that is accessible in a distributed fashion [ebXML IIC, 2003].

Another important activity at NIST addresses the issue of convergence and reuse in developing B2B and other eBusiness standards: The eBusiness Standards Convergence (eBSC) Forum has been initiated to provide a forum for advancing collaboration among different eBusiness initiatives and achieving cross-

industry interoperability and convergence [NIST-eBSC, 2003]. The participating organizations include industry organizations and initiatives (e.g., Aerospace Industries Association, Automotive Industry Action Group), standards development organizations (e.g., OAG, OASIS, ebXML), eBusiness software testing organizations (e.g., Drake Certivo, Drummond Group), and various NIST organization units. The forum has established a work plan that includes a number of deliverables to improve convergence of eBusiness standards including:

- Recommendations on what is needed for the paradigm shift to cross-industry standards convergence;
- Agreement on eBusiness architecture framework and opportunities for convergence;
- A common conceptual model for eBusiness capabilities stack.; and
- Recommendations on Generic Industry Roadmap for industry adaptation.

5.5 Semantic Web Activity

Semantic Web technologies have been put forward by W3C to develop new methods of data encoding on the Web to give well-defined meaning to information. To achieve this, existing formal logic systems are adopted for Web-based representation [SeWeb]. There are two basic ways to employ Semantic Web technologies to enhance enterprise systems interoperability. In the first approach, Semantic Web technologies are used to annotate information and provide semantic formalism to the information exchanged between applications or enterprises. Such annotation enhances clarity of the information at design as well as run times and allows more efficient information integration processes [Peng, AIEDAM].

In the other approach, Semantic Web technologies are used to provide a well-defined meaning for the whole integration task and create ontology service and software modules that can be dynamically composed to achieve certain functionality. An example effort of this kind is Semantic Web for Web Services [DAML-S, 2003]. Obviously, the latter approach is significantly harder but carries a promise of potentially significantly changing the enterprise integration industry.

Disclaimer

Certain commercial software products are identified in this paper. These products were used only for demonstration purposes. This use does not imply approval or endorsement by NIST, nor does it imply that these products are necessarily the best available for the purpose.

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