International Standards for System Integration

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Abstract. Missing from the repertoire of mechanisms for systems integration presented at past INCOSE symposia are the International Standards for process component integration being developed in the context of industrial automation. To improve the efficiency of beneficially constructed interactions between systems and system components, the international community is adopting a wide range of *standards* through formal development and review processes. For this presentation, the focus is on the *standards* efforts for industrial automation conducted by ISO TC184 SC5 working groups. The work products range from shop floor communication structures through enterprise level system concept management – all with a process centric orientation. Of particular interest are the enablers of interoperable supply chain components and support for systems throughout their lifetime.

IMPACT OF STANDARDS ON SYSYEMS ENGINEERING

While many aspects of systems engineering can benefit from the use of International Standards, three benefits immediately come to mind. First, is the role these standards play in tool use. From electrical connectors to CAD files, standards support the creation of reusable parts throughout the product life-cycle. Second, standards generally codify existing practice reinforced by substantial research. And third, standards often represent the best practices a discipline has to offer. A standard emerges only after its subject matter has been carefully crafted to promote a practice that many agree works well in international commerce. INCOSE has participated in standards development but has played a more tentative role in the promotion of standards as a means to accomplish the objective of systems engineering. Knowledge of International Standards and their sphere of use will enable the benefits of use to accrue to the broader system engineering community.

THE INTEROPERATION GOAL

Are we there yet? The success of our industrial age and our emerging information age is critically dependent upon meaningful interactions among elemental system components. While human elements of behaviour will continue to serve central roles in strategic guidance, we are progressing toward systemic component and system interactions across layers of enterprise structure for which human mediation is no longer essential. The use of adopted International Standards enables the uniform selection of interaction mechanisms to drive more efficient and effective system performance.

Central to TC184 SC5, and many other ISO subcommittees, is the effort to bring forward standardization that supports integration and interoperability in manufacturing enterprises.

INCOSE member involvement with ISO 10303 AP233 is one such effort. However, (IDEAS 2003) reports that we are far from achieving the levels of interoperability among manufacturing systems and components that many believe are essential for significant improvement in manufacturing productivity. We continue the exchange of capital and labor to reduce cost and increase output per unit of expense, and we improve the communication channels that are now essential to production systems. However, as reported in (National 2001) our dynamic response to changes in strategy, tactics, and operational needs continues to be limited by the paucity of interoperability between systems, and between components within systems.

The extent to which we are successful in providing useful component and system interaction is expressed in the current International Standards and de-facto industry standards that define information exchange. Having emerged from the automation of tasks and the adoption of information management as a key factor in modern manufacturing, the need for interoperability of the kind we seek is rather new. Reliance upon human mediated interoperation is no longer sufficient. Yet, enabling sophisticated adaptive component and system interoperation is proving to be very difficult.

Interaction Levels. Systems and components thereof interact in different ways ranging along a continuum from isolated action to full interaction. Some interactions are the result of execution or resource dependencies. Others are simply consequential. To guide the development of international standards, we find it helpful to consider three kinds of system interaction.

When all connections between components are direct, almost in a physical sense, we can say that the components of a system are *unified*. A model of this system is a unified model and model components have essentially the same conceptual representation although distinctions in levels of detail resulting from constituent separation or decomposition, and of properties emerging from aggregation or composition, remain. A user oriented view of a unified system is always consistent although it may be incomplete. Unified systems are the conceptual ideal most easily realized on a small scale, and perhaps only on a small scale. However, for the purpose of conceptual modeling, unified systems represented as subsystems or components are often the norm, e.g., a "black box".

When connections between components and systems become indirect, i.e., when a transformation from one representational form or view to another occurs, and system behaviour results from specific knowledge about the means to transfer information, products, and processes, then we can say that the system is *integrated*. The models of this system, often with distinct conceptual representations, form an integrated system model wherein individual components interact using fixed representations known by other components a-priori. Integrated systems and components retain unique identity and interact through static messaging protocols. Because the models involved may have distinct representations, a consistent view of the system may not be possible.

When connections between components and systems become malleable or ad-hoc in their manifestation, then system behaviour must move from static descriptions to incorporate dynamic features that enable *interoperable* interaction. In this case one component, or agent as it is often called, acts as if it were another component while maintaining its own distinct features. Interoperable systems, subsystems and components interact successfully because they are effective communicators and interpreters of system knowledge representation. These components can move beyond reaction to situational adaptation by using capabilities for context awareness and thus enhance opportunities for successful interaction.

Systems integration is now the standard of practice and the area of interest to most practitioners. In fact, the vast majority of our international and de-facto standards effort to date target integration enablement. But interoperability, especially in a heterogeneous setting like a supply chain, goes beyond our methodologies for integration and offers new challenges for system and enterprise understanding. WG1 of SC5 is pursuing the codification of that understanding into new international standards. Along the way we find ourselves addressing the standards for process integration that must serve as the foundation for process interoperation.

Ontology Issues. The three characterizations of interaction given above probably do not resonate with all readers. In addition, the terms *system*, *subsystem* and *component* are only loosely distinguished because the primary consideration is for the terms *unified*, *integrated* and *interoperable*. The emphasis is on the interaction rather than on the things interacting. However, some may feel that the characterization of interaction can only be articulated correctly when the nature of the things interacting is determined. Each community of practice evolves its own sense of appropriate terminology to describe its domain. Since standards, both international and de-facto, are developed by working groups, each standard bears a perspective on word choice and meaning that represents an agreement among those approving adoption of the standard.

And even then, we tend to allow wide latitude in word use. For example, (Kosanke 2004) reports on variation in the use of the term 'resource' that is commonly found in our manufacturing standards. Within TC184 SC5 some groups consider 'resource' to include anything consumed by manufacturing processes, e.g. electrical energy and lubricants, as well as the capital and human resources required to conduct those processes. Other groups, like our WG1, restrict 'resource' to non-consumables, e.g., machines and physical facilities. Some individual participants advocate including processes as a deployable resource. All are valid uses of the term but one must be aware of the usage context. WG1 does not ignore consumables; it just considers them to be a part of the resource rather than distinct from it. Such consideration is consistent with the granularity of its modelling and architectural context.

To be interoperable, components and systems must correctly interpret words and other symbols used as labels and data in an appropriate context. With (ISO10303-1 1994), SC4 of ISO TC184 made significant strides in correct interpretation of product descriptions in the standard more commonly referred to as STEP (STandard for Exchange of Product model data). This standard, a data centric approach to enable integration, is a precursor to process interoperability in its restricted, albeit expanding, domain context. The (ISO18629-1 2004) standard described below uses an ontological approach to bridge the data – process gap with formal rigor.

Unfortunately, as the subject matter of standards becomes less concrete, i.e., further removed from physical phenomena, consistency in interpretation becomes more difficult. Language, idiom, and culture often have profound impact on concept expression and interpretation. While resolving this aspect of interoperability is beyond the charge of SC5 WG1, we are constantly reminded of its importance to our efforts.

One mechanism available to standards authors as they seek to achieve clarity in their work is the distinction between normative and informative subject matter. And over the past couple of years, ISO has focused considerable effort to assure that published standards express criteria for conformance that are testable. We expect conformance language use (shall, should, may/can) to be consistent across normative clauses. But when utilizing multiple standards, users must be careful to consider both the expressed and more subtle distinctions in term meaning – caveat emptor.

ISO TC184 SC5

SC5 Scope. SC5 develops standards for industrial automation. A complete listing of ISO Technical Committees is found at http://www.iso.ch where TC184 is charged with 'Industrial automation systems and integration'. The scope of SC5 is standardization in the field of enterprise architecture, communications and processes to enable manufacturing systems integration, interworking, and interoperability. This standardization includes: an automation glossary; process representations (i.e. exchange/negotiation in manufacturing enterprises); requirements for global programming environment; and manufacturing profiles likely to be utilized by industry (ISO/TC184/SC5 N831 2004).

SC5 is now responsible for six working groups and has working group collaboration in JWG8 with TC184/SC 4 'Industrial data' (see Figure 1.). In addition to the collaborations between ISO committees and sub-committees, ISO partners with other international bodies to promulgate standards of common interest. ISO TC184/SC 5 and IEC TC65 SC65A through its ISA S95 liaison are working together in JWG15 at the boundary between automation control systems and production management systems where the information exchange content necessary to direct and report manufacturing operation and control is standardized in (ISO 62264-1 2003). (SAP 2004) recently announced support for this standard as a basis for integration of their ERP offerings with manufacturing execution systems for the plant floor.

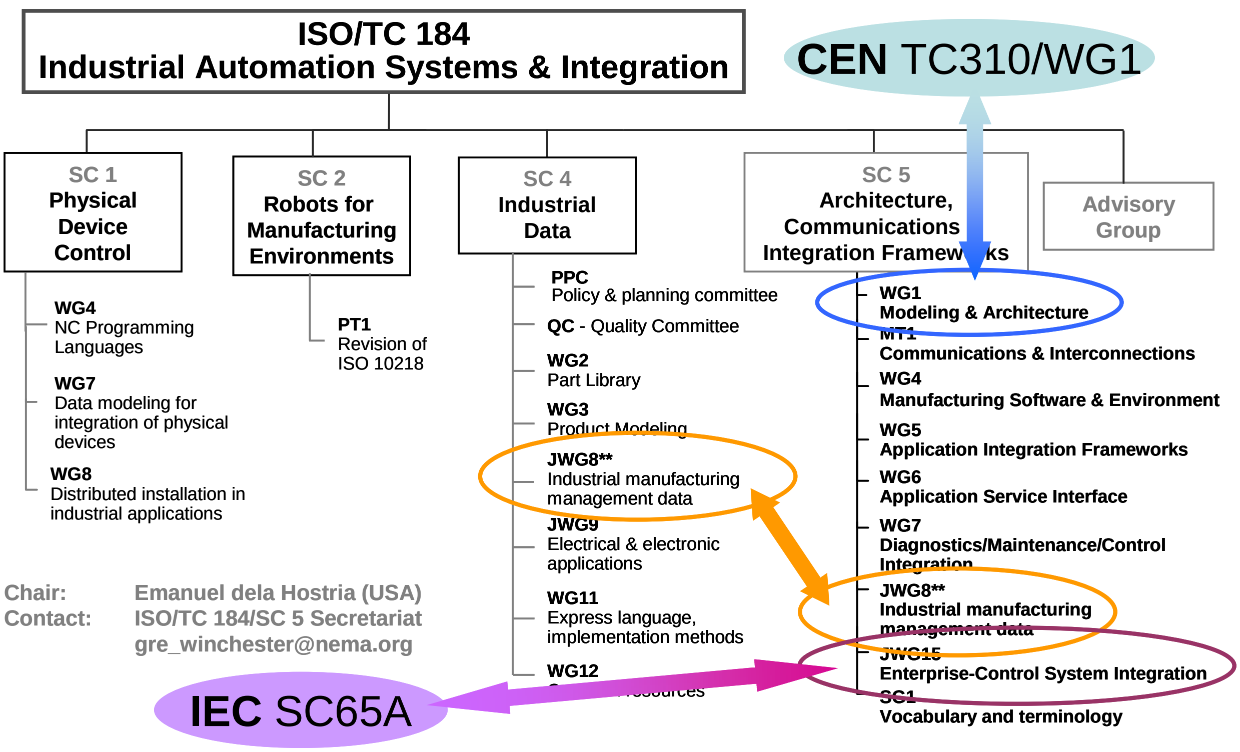

Figure 1. ISO/TC184/SC5 Collaborations

SC5/WG1 is working closely with CEN TC310/WG1 (International 2001) to produce two standards, (ISO/FDIS19439 2004) to articulate a "framework for enterprise modeling" of manufacturing systems targeting executable models and (ISO/DIS19440 2004) to articulate the modeling constructs necessary to achieve a satisfactory description in the framework context. We also expect to receive substantive material from other European efforts including those of the

(EC/FP6 2004) ATHENA project in the area of manufacturing interoperability.

INTEGRATION STANDARDS

Describing Industrial Data. The development of international standards is an evolutionary activity that mimics the evolution of industrial practice as supported by academic and industrial research. One of the most successful standardization efforts toward integration began in 1979 and continues to this day with the activities of TC184/SC4. At that time, NIST (National Institute of Standards and Technology, USA) began work in establishing standards for the exchange of engineering drawing elements, beginning with IGES (Goldstein 1998), that has evolved through several iterations into IS 10303 and its many application protocol (AP) parts (Kemmerer 1999). Today IS 10303, known as STEP by many practitioners, is a robust foundation for the exchange of information about product components and, increasingly, system attributes codified as data elements. IS 10303 continues its evolution with new APs and revisions to established parts. INCOSE maintains a liaison with SC4 and actively participates in the AP233 effort for system engineering data exchange.

The (Gallaher 2002) study commissioned by NIST concludes that the STEP standard accounts for an annual two hundred million dollar benefit for adopting industries in the USA. One key factor in the success of STEP related to that savings is the enablement of information migration between product versions. This reuse of data through changes in operations comprises half of the standard’s benefit to industry.

One feature of IS 10303 is the EXPRESS language (ISO10303-11 1994) and its graphical extension subset that enables the programmatic description of primitives identified in the standard. While EXPRESS has seen use in tool suites for product model exchange, its value has been diminished by the restrictions on access imposed by its distribution provisions. For International Standards with focused practitioner audiences to gain full value, those standards must be distributed at low cost and persistently promoted by the entities responsible for their adoption. When only the largest member of a supply chain has effective access to a standard, it is unlikely that adoption along the supply chain will occur voluntarily.

Describing Industrial Processes. Joint Working Group 8 (SC5/JWG8) is a collaborative effort between SC4 and SC5 to provide the Process Specification Language (PSL) as an interchange mechanism for process definition between systems and system components (ISO18629-1 2004). PSL yields process information representation that is independent of particular processes and models. It is a formal language specification in KIF with a lexicon, ontology, and grammar defined by a core specification, several theory sub-parts, e.g. resource theories stated using core language elements, and sub-part definitional extensions, e.g., temporal and state extensions. This standard codifies appropriate process knowledge as data for exchange between processors. The fragment of Figure 2 details a sequence constraint for an automobile wire harness assembly.

Note that the two language standards, EXPRESS and PSL, go beyond the format definition of descriptive information exchange, e.g., EDI, to allow a more flexible resolution of rule based information exchange for well defined situations. While PSL can be processed very efficiently by machines, it tends to inhibit extensive use by humans to manage content exchange. The expectation is that PSL will serve as the low level intermediary among various process definition and execution systems with its formal rigor allowing for unambiguous conveyance of information. PSL is intended for interaction between machines rather than humans and machines.

```
(forall (?occ)
        (iff (occurrence_of ?occ make_harness_wire)
                (exists (?occ1 ?occ2 ?occ3)
                        (and (occurrence_of ?occ1 extrude)
                             (occurrence_of ?occ2 twist)
                             (occurrence_of ?occ3 jacket)
                             (min_precedes ?occ1 ?occ2 make_harness_wire)
                             (min_precedes ?occ2 ?occ3 make_harness_wire))))

(Source: ISO/CD18629-44 Annex B)
```

Figure 2. PSL assembly sequence constraint

SC5 collaboration with SC4 also involves a multi-part standard for 'Industrial manufacturing management data' known as MANDATE (ISO15531-1 2004). Using EXPRESS, this standard elaborates a data model for the exchange of manufacturing management information, focusing on discrete manufacturing with an emphasis on data structures for time and resource.

Processes Integration. SC5 is producing a series of standards devoted to integration and interoperability. The (ISO15745-1 2003) series targets component to component information exchange protocols as the 'Open System application integration frameworks' multi-part standard. An Application Integration Framework (AIF) of elements and rules for integration requirements provides the basis for application interoperability profiles that are interface specifications detailed as UML models with XML schemas for profile templates.

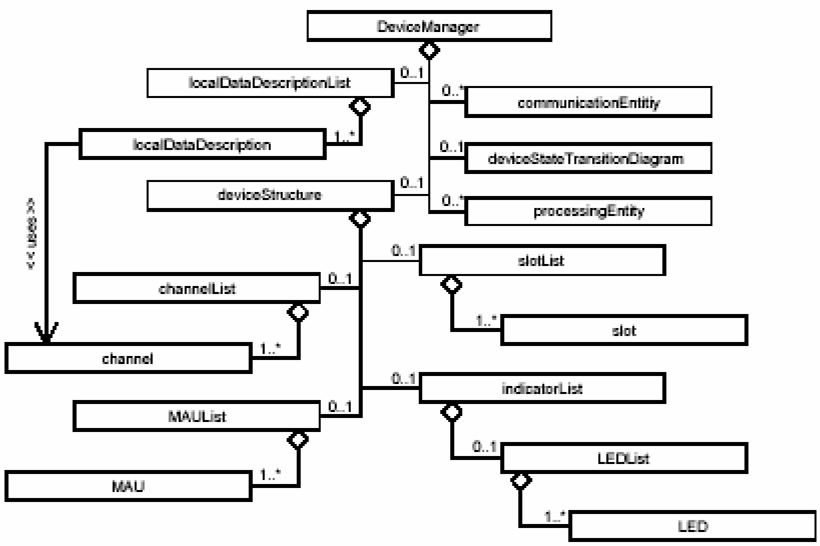

Figure 3. CANopen representation of DeviceManager object

The current publications in the series detail both communication network profiles and the communication related aspects of device profiles specific to IS 11898-based control systems, IEC 61158-based control systems, and Ethernet-based control systems. Figure 3 shows the IS 15745-2 DeviceManager class diagram for CANopen technology, an IS 11898 control system, that is further detailed in a template generated to comply with the AIF of IS 15745. To date, almost a dozen industry specifications have been elaborated under the IS 15745 structure. By using a common integration framework, the various specifications become unified at the descriptive level of that framework even though each technology has distinct characteristics and application.

The (ISO16100-1 2003) standard series targets the computer-interpretable and human readable representation of a software capability profile. The standards provide a method to represent the capability of manufacturing software relative to its role throughout the life cycle of a manufacturing application, independent of a particular system architecture or implementation platform. Software interface requirements are characterized as manufacturing software units (MSU) with capability elements and rules. An IDEF0 schema grounds the UML models and XML profile schemas. Capability classes for manufacturing (domain, application, information, process, resource, activity, function, software unit), software (computing system, environment, architecture, design pattern, datatype, interface/protocol), and roles are specified. Such a class is

```
Common Part
    Template ID
    Capability Class Name
    Software Unit ID
        Vendor Name
        Version Number & History
        Computing Facilities Required
            Processor
            OperatingSystem&Options
            Language
            RuntimeMemory
            DiskSpace
            MultiUserSupport
            RemoteAccess
            AddOns&PlugIns
        Measured Performance of the Unit
            ElapsedTime
            NumberOfTransactionsPerUnitTime
        Reliability Data of the Unit
            UsageHistory
            NumberOfShipments
            IntendedSafetyIntegrityLevel
            CertificationBody
        Support Policy
        Price Data
    Reference Dictionary Name
    NumberOfMethods
    M
Part Specific to Capability Class
M
```

Figure 4. Example template structure for Capability Class (ISO 16100-2)

outlined in Figure 4. Part 3 of this standard intends to provide a means for matching a MSU that is needed for manufacturing with a MSU that is available for manufacturing.

These standards codify existing industry practice and focus industrial efforts on common feature support. IS 15745 and IS 16100 are detailed descriptive standards that can be utilized to enable integration and to support interoperability. (Kosanke 2005) provides a comparison of these two standards and concludes that while they have somewhat different scope, both use profiles to capture information needed to identify the capabilities of entities expected to interact. He also notes a limit in the use of these standards with respect to the human aspects of interoperation where information about the internal structure and dynamics of the application may be more important than information about the potential exchange itself.

Model Architecture. At the other end of the spectrum is (ISO14258 1998) that describes concepts and rules for enterprise models. This SC5/WG1 product provides an overview of the issues that must be considered when modeling in the enterprise context. It establishes system theory as the basis for modeling and introduces primary modeling concepts for life-cycle phases, recursion and iteration, distinctions between structure and behaviour, views, and basic notions of interoperability.

Upon this conceptual foundation, (ISO15704 2000) specifies a more detailed model representation and adds concepts for life history, and model genericity. This standard also begins the elaboration of methodologies to support enterprise modeling. A significant feature of IS 15704 is its informative Annex A that presents the GERAM (Generalised Enterprise Reference Architecture and Methodology) developed by an IFIP/IFAC Task Force on Architectures for Enterprise Integration (see Figure 5.).

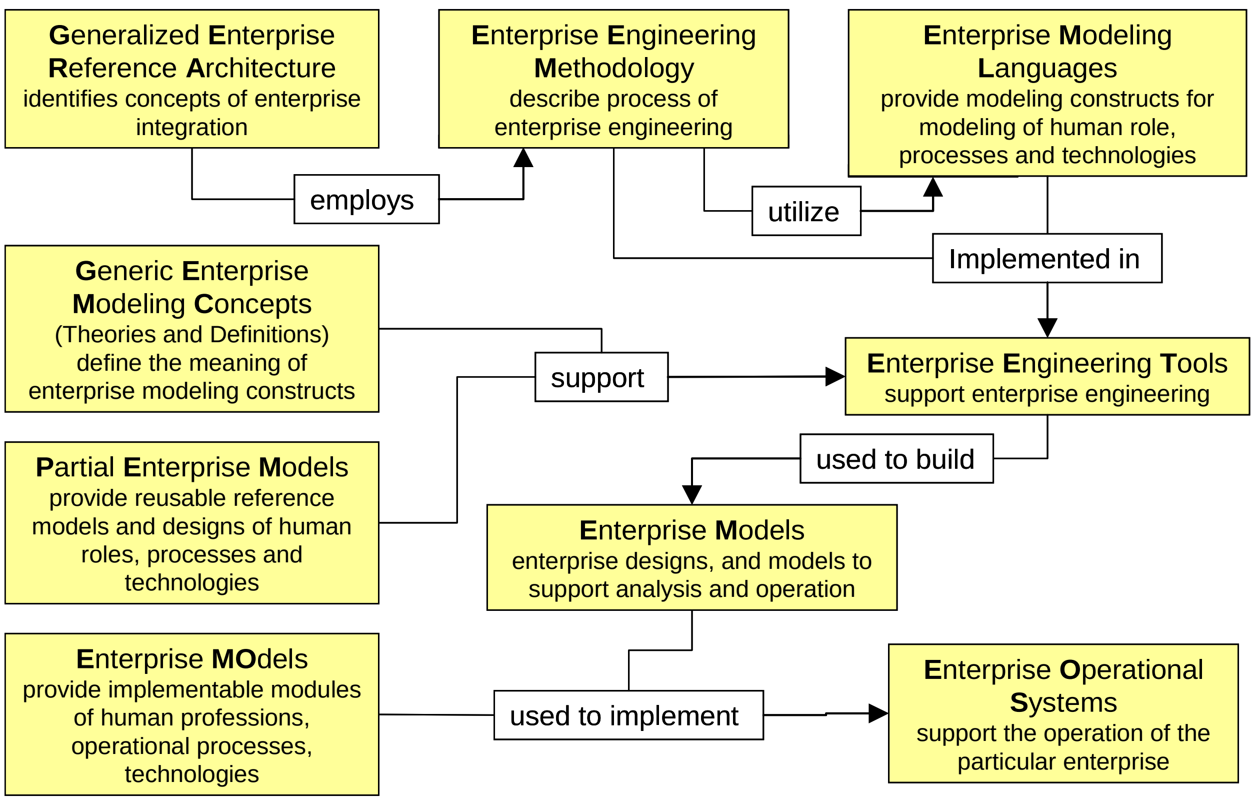

Figure 5. Scope of IS 15704 GERAM annex

The intent of GERAM is to facilitate the unification for methods across disciplines and allow their combined use rather than segregated application. The scope of GERAM includes a description of all elements recommended in enterprise engineering and integration. Each of the components identified in Figure 5, usually abbreviated by the bold capitals, e.g., GERA or EMO, is elaborated to provide criteria that should be satisfied by any set of selected tools and methods.

Currently we are amending IS 15704 to add user centric views, Economic View and Decision View, as informative annexes. IS 15704 identifies the structural features available for further development of model and system interoperability.

(ISO/FDIS19439 2004), in final draft stage, further articulates the concepts of IS 15704 as a framework for enterprise modeling and meets the criteria for a GERA component of GERAM. Three essential dimensions of enterprise modeling are placed in a framework context. The dimension of modeling phase is segmented by life-cycle stage as Domain Identification, Concept Definition, Requirements Definition, Design Specification, Implementation Description, Domain Operation and Decommission Definition. While dependencies between modeling phases exist, there is no assumption of chronology in their articulation. The dimension of model view articulates Function, Information, Resource, and Organization as a minimal group of perspectives for manufacturing enterprises. The dimension of genericity ranges over Generic, Partial, and Particular with increasing specificity. For each defined coordinate in the resulting 3-space, descriptions of the expected model content relative to the intersection is given. An informative annex provides an illustrative example taken from the CIMOSA Technical Baseline (CIMOSA 1996). The goal of this standard is to further the development and deployment of enactable models for enterprise operation by providing a conceptual structure rich enough to support the articulation and maintenance of such models. Enactable models are a precursor to robust interoperability.

Relative to this framework, the draft standard (ISO/DIS19440 2004) details templates for constructs that can be used to build the model. Defined as generic elements, the characteristics of these core constructs necessary for computer-supported modeling of enterprises are: the provision of an explicit model of Business Processes, with their dynamics, functions, information, resources, organization and responsibilities; sufficient detailing and qualification of its components to allow the creation of a representation to enable operational use. The defined constructs include Domain, Business Process, Enterprise Activity, Event, Enterprise Object, Object View, Product, Order, Resource, Capability, Functional Entity, Organizational Cell, Decision Centre, and Organizational Unit. Each construct can be specialized for a unique purpose and additional constructs can be created. The generic constructs can be combined and elaborated to form a partial model of an industrial segment. Partial models and generic constructs can be specialized to meet particular model needs within an enterprise.

The collaboration with IEC SC65A has resulted in (ISO/IEC 62264-1 2003) that articulates the boundary between business process systems of the enterprise and its manufacturing control systems. The scope of this standard is limited to describing the relevant functions in the enterprise and the control domain, and which objects are normally exchanged between these domains (see Figure 6.). Part 2 of the standard defines the interface content between manufacturing control functions and other enterprise functions. The interfaces considered are the interfaces between Levels 3 and 4 of the hierarchical model defined by Part 1. This standard is particularly noteworthy because of its acceptance as a basis for the integration of enterprise resource planning (ERP) systems and manufacturing execution systems (MES). Again, a UML based model is used to represent the information objects that have attributes presented in a tabular format.

In addition to these published standards, each SC5 working group is developing new proposals to address the issues of integration and interoperation in the manufacturing automation domain. We draw upon successful practices wherever we find them and believe that many of our products are of potential benefit to those outside the manufacturing domain.

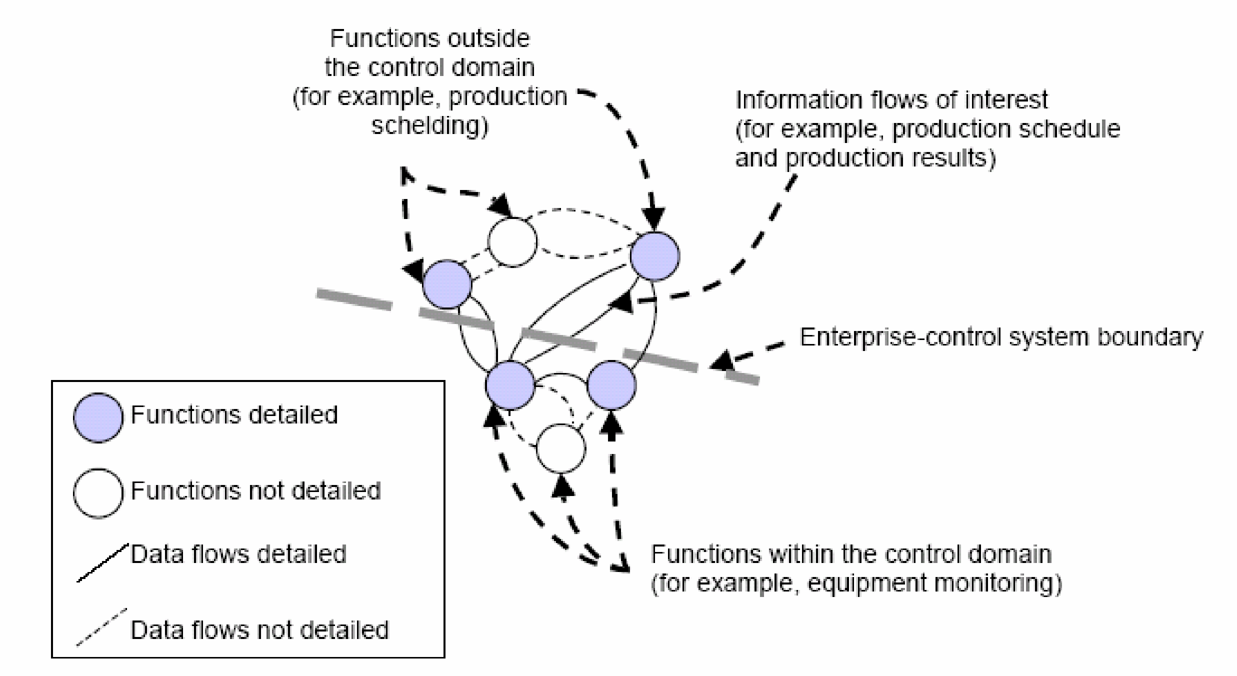

Figure 6. ISO/IEC 62264 Enterprise-control system boundary

STANDARD OPPORTUNITY

All of these standards support the interactions necessary to construct unified manufacturing operations and enhance integration among systems of differing origin. But the difficult tasks of dynamic interoperation are yet to be addressed in a *standard* for the industrial community. The products of ISO TC184 SC5 provide a wide range of opportunity for system engineers to use known solutions for problems in component and system integration. These past efforts lay a solid foundation and begin to articulate the system and component features necessary to achieve robust interoperability in the future. We invite your support for and use of International Standards. Please contact the author if you wish further information or would like to participate with our efforts.

REFERENCES

CIMOSA Association, *Open System Architecture for CIM: Technical Baseline. Version 3.2*, CIMOSA 1996. Available from www.cimosa.de

EC/FP6, "IST-507849 Advanced Technologies for Interoperabilities of Heterogeneous Enterprise Networks and their Applications", 2004. Available at http://www.athena-ip.org

Gallaher, M., O'Connor, A., Phelps, T., "Economic Impact Assessment of the International Standard for the Exchange of Product Model Data (STEP) in Transportation Equipment Industries", RTI International and National Institute of Standards and Technology, Gaithersburg, MD, 2002.

Goldstein, B., Kemmerer, S., Parks, C. "A Brief History of Early Product Data Exchange Standards – NISTIR 6221", National Institute of Standards and Technology, Gaithersburg, MD, 1998.

IDEAS Roadmaps, "Deliverable D2.3 The Goals, challenges, and vision (2nd version) (M8)", Information Society Technologies, European Commission, 2003. Available at www.ideasroadmap.net

International Organization for Standardization and European Committee for Standardization, “Agreement on Technical Co-operation between ISO and CEN (Vienna Agreement). Version 3.3”, 2001.

ISO10303-1 *Industrial automation systems and integration – Product data representation and exchange - Part 1:Overview and fundamental principles*. ISO, Geneva, 1994.

ISO10303-11 *Industrial automation systems and integration – Product data representation and exchange - Part 11: Description methods: The EXPRESS language reference manual*. ISO, Geneva, 1994.

ISO14258 *Industrial automation systems – Concepts and rules for enterprise models*. ISO, Geneva, 1998.

ISO15704 *Industrial automation systems – Requirements for enterprise-reference architectures and methodologies*. ISO, Vienna, 2000.

ISO15531-1 *Industrial automation systems and integration – Industrial manufacturing management data – Part 1: General overview*. ISO, Geneva, 2004.

ISO15745-1 *Industrial automation systems and integration – Open systems application integration framework – Part 1: Generic reference description*. ISO, Geneva, 2003.

ISO15745-2 *Industrial automation systems and integration – Open systems application integration framework – Part 2: Reference description for ISO 11898-based control systems*. ISO, Geneva, 2003.

ISO16100-1 *Industrial automation systems and integration – Manufacturing software capability profiling for interoperability – Part 1: Framework*. ISO, Geneva, 2002.

ISO16100-2 *Industrial automation systems and integration – Manufacturing software capability profiling for interoperability – Part 2: Profiling methodology*. ISO, Geneva, 2003.

ISO18629-1 *Industrial automation systems and integration – Process specification language – Part1: Overview and basic principles.* ISO, Geneva, 2004.

ISO/CD 18629-44 *Industrial automation systems and integration – Process specification language – Part44: Definitional extension: Resource extensions.* ISO, Geneva, 2004.

ISO/DIS19440 *Enterprise integration -Constructs for enterprise modelling.* ISO, Geneva, 2004.

ISO/FDIS19439 *Enterprise integration – Framework for enterprise modelling.* ISO, Geneva, 2004.

ISO/IEC62264-1 *Enterprise-control system integration – Part 1: Models and terminology*. ISO, Geneva, 2003.

ISO/TC184/SC5 N831. “Report of the ISO/TC 184/SC 5 Secretariat For The 2004 TC184 Plenary Meeting in Rosslyn, USA”, 2004. Available at http://forums.nema.org/wb/default.asp?boardid=13

Kemmerer, S, “STEP The Grand Experience NIST Special Publication 939”, Manufacturing Engineering Laboratory, National Institute of Standards and Technology, Gaithersburg, MD, 1999.

Kosanke, K., “ISO Standards for Interoperability: a comparison”, First International Conference on Interoperability of Enterprise Software and Applications, INTEROP-ESA’2005, Geneva, 2005

Kosanke, K., Martin, R., Ozakca, M., “ISO TC 184 SC5 - Vocabulary Consistency Study Group Report, SC 5 Plenary Meeting, 2004-April, AFNOR, St. Denis, France, 2004. Available at http://forums.nema.org/wb/default.asp?boardid=143

National Coalition for Advanced Manufacturing, “Exploiting E-Manufacturing: Interoperability

of Software Systems Used by U.S. Manufacturers”. Washington D.C., 2001.
SAP, “SAP Drives Accelerated Adoption of Manufacturing Industry Standards”, SAPPHIRE’04, New Orleans, USA, 2004.
SC 5 Secretary (2004) Meeting Report SC 5 Plenary Meeting 2004-04-22/23, AFNOR, St. Denis, France. Available at http://forums.nema.org/wb/default.asp?boardid=13

BIOGRAPHY

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