Standards Road Map Project

Standards Classification Strategy and Methodology

A task of the **Manufacturing-Enterprise-Integration Project**

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Table of contents

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Abstract:
This document describes a research project to recommend a decision tool that the Manufacturing Systems Integration Division (MSID) could use during its strategic-planning process to evaluate which standards activities to support. This paper describes how to apply a methodology originally developed to identify relevant standards that could enable shop-floor processes to interoperate more effectively. A classification strategy is presented to categorize the standards identified during the standards-identification process. A vision for a World-Wide-Web based information resource is presented. A road map that relates the methodology to the division strategic-planning process is discussed. Proposals for further work are included.

Key Words:
Enterprise integration, activity models, standards classification, shop-floor-production model

1 Introduction, results, conclusions, and criteria summary

1.1 Introduction

The standards road-map project is part of the Manufacturing Enterprise Integration Project of the Manufacturing Systems Integration Division [THOM97]. MSID is a division of the Manufacturing Engineering Laboratory (MEL), one of the seven National Institute of Standards and Technology (NIST) laboratories. The MSID mission is to promote economic growth by working with industry to develop and apply technology, measurements, and standards for information-based manufacturing. This is accomplished by working with the U.S. manufacturing industry, software suppliers, systems integrators, and standards-development organizations. This project is a task of the FY1998 Manufacturing-Enterprise-Integration Project.

The purpose of this research project is to recommend a domain, relevant to MSID, of enterprise-integration-related standards, and to indicate what is to be included and what is to be excluded from that domain. Enterprise-integration-related standards are those, at any level in the enterprise, that help processes to interoperate. Assume, however, that all standards considered will be in the information-technology category. There are three document deliverables that are required to satisfy the objective. In addition there are written summaries of findings.

The three project documents described below comprise the deliverables of this project.

1. The *Criteria Analysis* describes criteria to help MSID justify participation in a particular standard. [NELL99]
2. A *Standards Baseline* [unpublished] describing current MSID standards activities. This is a logical predecessor to a standards-information resource, called the standards landscape, that would include a list of sources and/or the standards by category in the enterprise-integration-related-standards

domain. The landscape would also include the purpose of the standard, and the status of standard development. This resource could be a database, a World-Wide-Web site, a paper document, or a combination to be determined. The information resource is to be completed in later work.

3. The *Standards Classification Strategy and Methodology* summarizes findings, recommends a methodology to identify needed standards, and recommends a schema to classify relevant standards. [This document]

This document, the *Standards Classification Strategy and Methodology* recommends a standards set and ways to prune the search space. The total search space is considerable larger than the amount of resources available to support such a search task, even when using computer-assisted tools.

Standards development is a labor-intensive process. In the information-technology domain many of the standards that are perceived to be needed to improve enterprise integration are leading technology before that technology has been developed fully. Therefore, the standards-development process is additionally costly because elements of the technology are being developed concomitantly with the standards. With limited resources, choosing which standards activities to support and how much support is appropriate is more difficult without some criteria that would rank the various standards developments with respect to their value to the MSID and, ultimately, its customers.

The Standards Classification Strategy and Methodology will scope the work in terms of the types of standards that apply to MSID activities. MSID is increasing the amount of its effort on the interoperability of entire enterprises. This project was scoped to provide information on standards that apply mostly to shop-floor processes. However, it seemed reasonable that, at some time, the focus of a standards road map such as this would expand to the enterprise, and, perhaps, to an enterprise not in the operations phase of its life cycle. Therefore, any methodology developed or used should establish a basis in an enterprise-reference architecture with sufficient breadth to allow these later extensions. The methodology presented in this report to identify the standards is really a combination of three well-established methodologies.

The first methodology is the GERAM, or Generalized Enterprise-Reference Architecture and Methodology. The GERAM provides a scope that extends to all enterprise processes at any phase of the enterprise-life cycle. However, the enterprise space had to be pruned to a domain relevant to the scope of this project, and the methodology had to have the capability to reach to the lowest-level processes on the shop floor. Another methodology is espoused in the ISO (International Organization for Standardization) TC184 SC5 WG1 report, TR 10314 [ISO 90, 91]. The TR 10314 methodology allows users to navigate inside an operating manufacturing enterprise to the shop floor. Using this methodology, the expert analyst can identify areas where standards exist or are needed to improve intra-process or inter-process communications. Combining these two methodologies allows the standards-extraction process to move from the generic enterprise in any stage of its development, to the manufacturing enterprise, and to the shop floor of that enterprise. Having identified the standards needed, the third methodology offers a way to categorize the standards. For that, the organization scheme presented in the CEN (European Committee for Standardization) M-IT-04 [CEN96] is appropriate for MSID needs.

After presenting the methodologies, the discussion turns to the issues regarding how MSID can apply the results of using the methodologies. There is an analysis of what categories (M-IT-04 categories) of standard would be of interest to other MEL divisions or to the Information Technology Laboratory Divisions. Then there is a vision of what the eventual information resource could be and how it can be used and maintained. An outline of the road-map process is presented showing how MSID can apply the results of this project. Finally, there are some conclusions and opportunities for new work. Projects envisioned are suggested to deal with some of the issues that are raised.

1.2 Results and conclusions

As the Standards Road Map project was being designed, the focus for the work was mostly on creating an information resource of enterprise-integration related standards. The information resource would be tempered by the application of certain criteria that are relevant to improving the responsiveness of MSID to its customer base, the U.S. manufacturing enterprises. The criteria selected, therefore, were those that are in use to help NIST, MEL, and MSID to justify the work that they do.

The *Criteria Analysis* [NELL98] was prepared first. The analysis illuminated the fact that MSID needs to determine very carefully what constitutes meeting a criterion and to assign value to project candidates that ranks the relative worth of a particular standards activity. A scenario was developed to demonstrate how the criteria could be applied. This scenario included some assumptions that users must make to assure that the ensuing ranking properly relates the value intended. The criteria and their meaning were designed to be an input to the MSID strategic-planning process, where other factors, which have been called *filters*, certainly would enter into a final decision. There was no intention to create an algorithmic or deterministic tool that would obviate the human-decision process.

The standards-road-map decision tool would comprise the following components:

- An information resource called the standards landscape
- A mechanism to prune or scope the landscape
- The criteria
- Suggestions to apply the criteria
- A methodology to extract the standards required for process interactions
- A schema to classify the standards
- Filters to evaluate a standards activity from various viewpoints

The road map presented in this document explains these elements and how to navigate through them.

Processes, systems, and technologies enabling improvements in enterprise integration can exist in a wide variety of domains. Technologies ensuing from such topics can either enable significant improvement in integration capability or they can enable some improvements initially but block continued improvement in the future. Applying these improvement technologies can enhance or curtail an enterprise capability to improve. Whether or not this is good depends on the business nature and the goals of the using enterprise. Good standards can help these technologies provide an enterprise with an ability to achieve its maximum capability. To determine whether or not to support a standard or class of standards will require a rather detailed analysis on a case-by-case basis.

A methodology to reveal the standards that apply to interactions among processes should start from a place that includes the entire business entity being analyzed, often referred to as an enterprise. Enterprise models can represent the enterprise and 2.4 advocates a way to achieve this representation. However an enterprise is identical with its processes and process models can represent processes. The link between the enterprise and its processes is therefore very tight. When analyzing one aspect of an enterprise, such as shop-floor production, extending that domain to include another aspect of an enterprise, such as procurement, the enterprise-level models can be a useful tool to represent the new domain and the links between that domain and other domains in a consistent way.

The standards-road-map methodologies and classification schemes are well based in enterprise-analysis research and international standards. The GERAM provides a high-level reference for consistency, extendibility into other domains of the enterprise, and extendibility to other parts of the enterprise life cycle. The project selected a more specific methodology, ISO technical report TR 10314, to identify and extract standards requirements at the lowest process level. This methodology is highly applicable to a significant portion of the MSID work domain, and it appears to be extendible to other areas of MSID concern as well. For classifying the standards, a work originating in the European Committee for Standardization, CEN, is also highly applicable. The CEN M-IT-04 has many categories that fit with MSID work and the schema offers a way to prune out-of-scope standards from the standards landscape.

For the Standards Road Map project, the M-IT-04 and TR 10314 are complementary. The TR 10314 concepts and procedures help with assessing coverage and M-IT-04 provides a helpful classification. Together they represent a classification scheme and a standards identification methodology that could be combined into a useful standards landscape as a component of the overall solution.

Both documents, ISO TR 10314 and CEN M-IT-04, need additional work to update them and to make them more applicable to a standards road map. ISO TR 10314 needs extension beyond the purely shop-floor-production processes. The categories identified in CEN M-IT-04 need updating. Currently the TR 10314 is administered by the ISO TC184 SC5 WG1, Modeling and Architecture, for which NIST is the convenor. The CEN is considering transferring the rights to M-IT-04 to ISO, who in turn would probably assign the responsibility for modifying and maintaining it to TC184 SC5 WG1.

The search for standards needs to be tempered by asking during the extraction process:

- How much does this particular bridge between applications and the associated need for standards matter?
- Will the productivity improvement be worth the effort to achieve the result?

This category of concerns is what has been called a filter. Filters that could help to identify how important a standard is: economic impact, business needs, technology imperative, available resources at NIST, and impact on the product being produced. Filters will apply to the landscape in way that has not yet been determined.

Because business conditions can change rapidly, applicability and weights of the criteria, measures, metrics, and filters will need to be reassessed every time that the criteria are applied to rank standards projects.

Ways to improve industrial coupling must be sought continually. At the same time, MSID must be able to partition needs expressed by industry for operational improvement into workable components of a solution, some of which may be needs for standards.

The information resource should be managed with considerable computer assistance. It should be navigable, maintainable by those standards groups responsible for the information, and World-Wide-Web based with a link to a database.

The methodologies and classification schemes provide a landscape of standards that must be pruned considerably to include only those things relevant to MSID, MEL, and NIST work. Applying the criteria and filters provide the input to the division strategic-planning process. The strategic-planning process assigns specific priorities that translate into MSID work items.

The methodology and classification schemes have been developed for specific purposes and intended for specific users. They are generic enough, however, to be extendible with some expert guidance to other parts of the manufacturing enterprise.

1.3 Criteria summary

The criteria [NELL98] were selected to give priority to the standards activities that NIST and MSID do, or should, support. There are criteria for judging quality of the standard and criteria designed to help MSID determine whether, and how much, to support a standard's development. The criteria have been rephrased below to provide a flavor of the type of information the criteria are intended to provide to the strategic planning process.

Setting Priorities and measuring results

1. (From Criteria 1) Define the nature of the need for the standard. For example, determine whether the need created by a statute, competitive pressure, or something else?

2. (Cr1) Determine the scope of the need for the standard. That is, determine whether the is need for industry in general, an industrial segment, small business, one large company, or something else?

3. (Cr1) Can industry benefit be expected as a result of NIST supporting this standard--in less than three years, in less than five years?

4. (Cr2) What would be the value to be added by NIST--standards development, tools development, interoperability test, conformance test, metrics, capability that uses the standard, or standards administrative activities?

5. (Cr2) Assuming that the standard will help resolve some industrial problem, how much of this problem will be resolved?

6. (Cr3) Can NIST significantly impact the technical transfer to facilitate acceptance of the standard with end users and system integrators through such things as documents, seminars, or mass or focussed publicity?

Relevance for MSID involvement

7. (Cr4) How does the industrial need correspond to the MSID mission with regard to the nature of the need, availability of NIST resources, the nature and size of the anticipated impact?

8. (Cr5) Can NIST participation significantly help improve the state-of-the-art of information technology and the acceptance of open standards in this area?

9. (Cr6) Can NIST involvement be assembled in a timely fashion so as to anticipate infrastructure-technology-implementation needs; that is, is there NIST management commitment, favorable fiscal climate, and is the involvement compatible with current NIST goals?

10. (Cr6) What is the development status of the subject standard and is the status compatible with the timeliness of the need; for example does a committee draft, or equivalent, exist or has work on standards not yet begun?

NIST use of the standard

11. (Cr7) Is there an opportunity for NIST to use the standard to help justify the acceptance process?

Need for NIST resources

12. (Cr8) Which standards-development model is to be used ; such as international standard (ISO or IEC), consortium (CAM-I or NCMS), national (ANSI), major program (NIIIP).

13. (Cr9) How many NIST FTEs are required?

14. (Cr10) Are the NIST resources to be assigned to the standard activity compatible with the size of the impact?

2 Identifying relevant standards

A standard is a documented agreement about rules, guidelines, criteria, or definitions regarding products, processes, or services. ISO asserts in its directives (part 2, clause 5.1) that the objectives for standardization are: mutual understanding; health, safety, protection of environment; interface; interchangeability; fitness for purpose; and variety control. Standards apply to products, processes, or services only in a context and to the extent that the standard serves its function; that is, it is apropos, is of high quality, and is easy to use. For example, a standard specifying process interfaces requiring a user to configure operations in such a way that is not productive for that user, will not have utility and probably will not be used.

There is considerable demand, not just in MSID, for ways to be aware of the standards that exist and their status, discover areas where standards are needed, determine the relative value of participating in a particular standard development, and keep standards data current. Some elements of this project are designed to satisfy these needs.

Identification of the relevant standards requires:

- A detailed knowledge of NIST organizational interests.
- A scheme to categorize the standards.
- Given that classification scheme, a methodology for determining how to evaluate the classified standards in terms of the organizational interest--this will produce a relevant standards landscape.
- A set of criteria for assigning priority combining the NIST organizational interests and customer need.
- A methodology for applying the criteria and converting results into strategic actions for MSID.

2.1 Range of standards to consider, what to include, what not to include

Processes, systems, and technologies enabling improvements in enterprise integration can exist in a wide variety of domains. Technologies ensuing from such topics can either enable continuing and significant improvement in integration capability or they can enable some improvements initially but block continued improvement in the future. Applying these improvement technologies can enhance or curtail the capability of an enterprise to improve. Whether or not this is good depends on the business nature and the goals of the using enterprise. Good standards can help these technologies provide an enterprise achieve its maximum capability. To determine whether or not to support a standard or class of standards will require a rather detailed analysis on a case-by-case basis.

Informal analysis has revealed that integration-improvement standards can be classified into one of five main categories: hardware, software, information format, communications, and architecture. Standards can apply to the real-world items or to the representations and methodology for representing elements of each category. Different standards can apply to the various life-cycle activities of these items. Also different standards can apply to the operating character and methods chosen for each set of processes. The subject matter for these standards is enormously complex. Therefore, to select which standards are applicable, a scenario must be developed that defines the nature and purpose of MSID's work, and what part of this huge domain will further that work for MSID and for its customers.

Several similar standards-mapping efforts have been studied to shed some light on the matter and to help prune the problem space to make the initial road map the most useful to MSID. We have assumed that discrete-part-manufacturing enterprises are of first priority. Of those, we have assumed that standards applying directly or indirectly to detailed-design engineering and manufacturing operations are preferred as opposed to those applying solely to activities such as marketing, financial, facilities, research and development, and logistic support. However, the parts of these functions that interface with or determine the nature of manufacturing operations are to be considered. Note that the scope of MSID's interests includes design engineering, but the current scope of the TR 10314 focuses on the interactions that involve only the shop-floor processes.

2.2 The manufacturing enterprise

This standards road map is intended to provide a way to identify standards that apply to enterprises that manufacture discrete products. This involves many operations that transform material and assemble components into finished goods--the enterprise output. For this analysis the progression through the enterprise models follows a path from the enterprise level to the factory floor (See Figure 1). There is no reason that the analysis cannot be expanded to include other functions such as logistic support or research and development by changing the lower-level models of the methodology so that they are apropos to the specific function about which information regarding applicable standards is being sought.

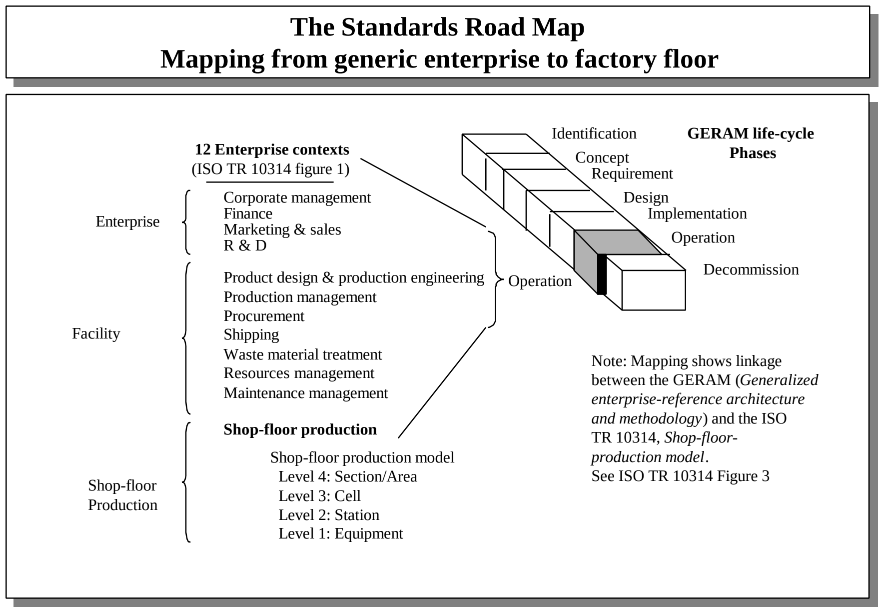


Figure 1 Mapping GERAM to ISO TR 10314

2.3 Enterprise models and shop-floor-production models

A methodology to reveal the standards that apply to interactions among processes should start from a place that includes the entire business entity being analyzed, which this work refers to as an enterprise. Enterprise models can represent the enterprise, and 2.4 advocates a way to achieve this representation. However an

enterprise is equal to the sum of its processes and process models can represent processes. The link between the enterprise and its processes is therefore very tight. If an analyst is concentrating on one domain of an enterprise--such as shop-floor production--and wishes to extend that domain to include another aspect of an enterprise--such as procurement--the enterprise-level models can provide consistency in representing the new domain and the links between that domain and other domains.

There should be provision for processes within that enterprise to communicate with each other and to communicate with processes outside the enterprise. From there the methodology should show clearly how to navigate from the enterprise level to the processes that are to be under consideration. The methodology should provide capability to reveal clearly individual standards applicable to a factory-floor process as well as the standards applicable to design-engineering processes.

The search for a methodology to guide this process concluded that two independently produced pieces of work provided the breadth, depth, and richness required for the standards-identification process. This scope ranged from an enterprise-wide perspective over the enterprise-life cycle, and offered the capability to focus at the bottom level of any particular enterprise activity. The GERAM (see below) and the two-part ISO technical report TR 10314 [ISO90], [ISO91] provide this capability. Any methodology that gets down to the process level, with any degree of completeness, will be complex and will result in enormous amounts of information. The reference model for standardization discussed in the ISO report was developed with this challenge in mind and it offered some useful guidelines. The reference model should be:

- Simply structured
- Based upon readily available and acceptable terminology
- Able to be applied to a wide range of operations and organizations
- Independent of any particular system configuration or implementation
- Independent of any technologies used in enterprises and computer science
- Extendable without invalidating current information

The reference model for shop-floor production is illustrated and discussed in more detail in 2.5.

2.4 The GERAM enterprise-reference architecture

The standards-road-map analysis process began at a high level with an internationally respected and somewhat practiced model of the entire enterprise covering the entire enterprise-life cycle using GERAM. GERAM is the Generalized Enterprise-Reference Architecture and Methodology [GERAM98]. GERAM, developed by a special task force of the IFAC (International Federation of Automatic Control) and the IFIP (International Federation for Information Processing), is the result of a search for a complete enterprise-reference architecture. The task force reviewed the work of several groups that have tried to represent enterprises. The analyses included: PERA (Purdue Enterprise Reference Architecture), the GRAI-GIM (Graphe et Résultats et Activités Interreliés/GRAI Integrated Methodology) architecture of the University of Bordeaux, and the CIMOSA (Computer-Integrated-Manufacturing Open-Systems Architecture) from the AMICE (European Computer-Integrated-Manufacturing Architecture (in reverse)) project of ESPRIT (European Strategic Program for Research in Information Technology). The GERAM representation of life cycle and views are shown in Figure 2. It is in the various views that one can see the influence of the three architectures that contributed to GERAM.

The task force, finding none of the existing enterprise-reference architectures complete, combined the best features of each into a composite architecture and called it the GERAM. An organization tool for standards can use the GERAM components as reference: the architecture, modeling languages, ontological theories, enterprise models, reusable modules, methodologies, and modeling tools. Showing the relationship among these components is the purpose of Figure 3.

GERAM defines a tool kit of concepts for designing and maintaining enterprises for their entire life history. GERAM is not yet another proposal for an enterprise-reference architecture, but is meant to organize existing enterprise-integration knowledge. The framework has the potential for application to all types of enterprise. Individually designed reference architectures can keep their own identity, while identifying through GERAM their overlaps and complementing benefits compared to others.

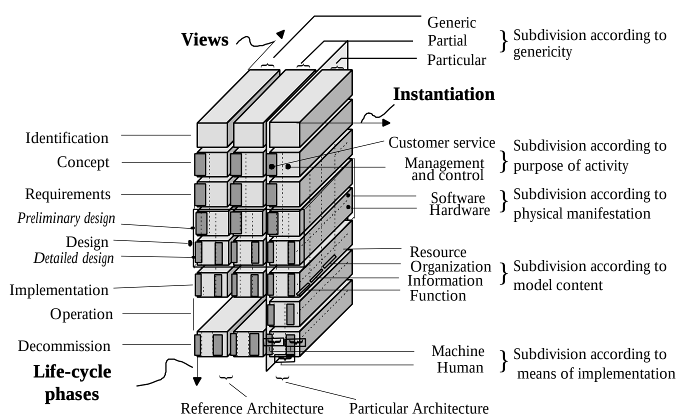
Starting from the evaluation of existing enterprise integration architectures, CIMOSA, GRAI/GIM and PERA, the IFAC/IFIP Task Force has developed an overall definition of a generalized architecture. GERAM refers to those methods, models, and tools that are needed to build and maintain the integrated business entity, be it a part of an enterprise, a single enterprise, or a network of enterprises such as a virtual enterprise or an extended enterprise.

The scope of GERAM encompasses all knowledge needed for enterprise engineering. Thus, GERAM is defined through a pragmatic approach providing a generalized framework for describing the components needed in all types of enterprise engineering processes, such as:

- Major enterprise-engineering efforts such as green-field installation, complete re-engineering, merger, reorganization, formation of virtual enterprise or consortium, and value-chain or supply-chain integration.
- Incremental changes of various sorts for continuous improvement and adaptation.

GERAM is intended to facilitate the unification of methods of several disciplines used in the change process, such as methods of industrial engineering, management science, control engineering, communication and information technology. That is, GERAM allows their combined use, as opposed to segregated application.

GERAM, therefore, provided a starting point but it requires that a more specific methodology be selected for a specific part of the life cycle, product manufacturing, and for detailed analysis at the factory-floor level so that standards applicable to specific activities within a process can be identified. This methodology was found in the ISO TC184 SC5 WG1 Technical Report, ISO TR 10314 [ISO90], [ISO91].



Source: GERAM Generalized Enterprise Reference Architecture and Methodologies (IFAC/IFIP, 1998)

Figure 2 GERAM life cycle and views

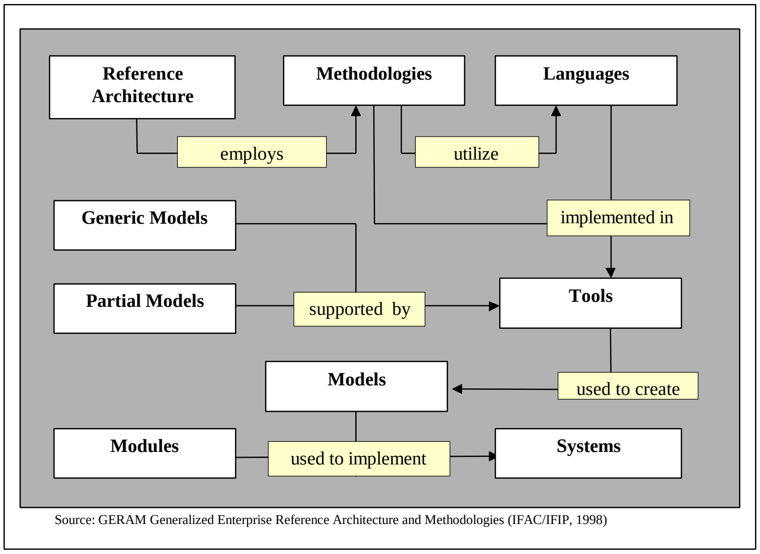


Figure 3 GERAM components

2.5 ISO TR 10314, parts 1 and 2, the manufacturing architecture

ISO TR 10314 is both a classification scheme and a methodology for using the scheme. There are some shortcomings (see 2.5.2) that must be overcome before the methodology is totally suitable for MSID use. ISO TR 10314 describes a reference model that is intended to help coordinate future standards work in the field of industrial automation ; specifically, discrete-parts manufacturing. However, there appears to be no reason, given further analysis, that the methodology is not applicable to other functions in the enterprise. This methodology also provides the ability to identify not only where and what standards exist, but where and what standards or standards areas are missing.

ISO TR 10314 begins with an enterprise in the operations part of its life cycle, and it assumes manufacturing to be all-inclusive, from customer order through to delivery of the product. Twelve manufacturing-enterprise functions are identified. The report concentrates, however, on two types of transactions: among the various levels of shop-floor production, and among shop-floor-production functions and functions that are not shop-floor production.

If using this road-map methodology is to be extended beyond the operations phase of the enterprise life cycle, GERAM can be a consistent way to do that. Figure 1 shows the relationship between the enterprise-operations phase of the life cycle and other enterprise life-cycle phases. A similar methodology to the one used in TR 10314 could be designed for other enterprise life-cycle phases.

Only an outline of the methodology is presented here since the details are available and clearly presented in the referenced works. The reference model for shop-floor production is used as a basis for the methodology to identify and extract relevant areas for standards, whether or not the standards exist. The assumptions used to develop the reference model are presented here because they are consistent with the needs of this
project. The assumptions: (quote)

- The field of interest is the manufacture of discrete parts and in particular the production, the physical realization, of these parts
- The reference model needs to be open ended so that it can be revised to incorporate new technologies
- The reference model needs to be generic in nature so that it can be applied to a wide range of applications and is not directed to a particular organizational structure of manufacturing. (unquote)

2.5.1 Shop-floor-production model

Figure 4 shows how the twelve major enterprise-manufacturing functions are organized into enterprise levels: enterprise, facility, and shop-floor production. The shop-floor-production reference model, in the lower part of the figure 4, organizes the four levels of the shop-floor activities:

- Level 4, section or area, is concerned with overall matching of resources for jobs
- Level 3, cell, is concerned with sequencing and supervising jobs
- Level 2, station, is concerned with supervising the processes
- Level 1, equipment, is concerned with executing the processes

Level 1 is the only level in which material and physical resources exist and in which material is moved or transformed.

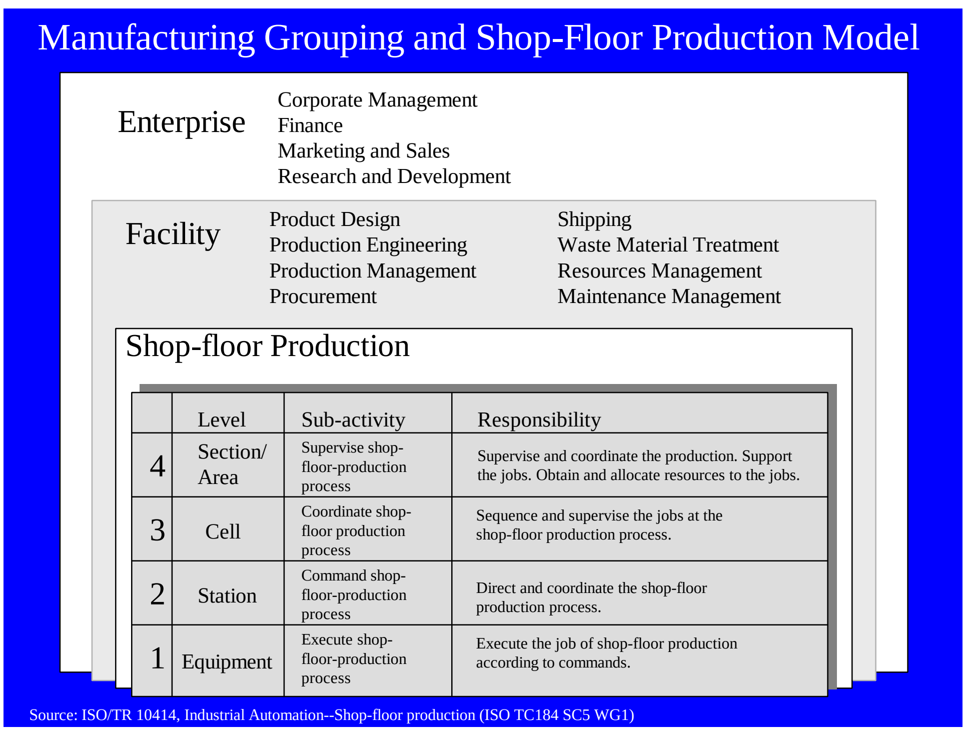


Figure 4 Shop-floor-production model

2.5.2 Generic-activity model

At this point a generic-activity model, Figure 5, is introduced to model the execution of the various activities at each of the four shop-floor production levels. The generic-activity model is loosely based on IDEF-0 but it explicitly recognizes physical and control flows. It provides a general template that is used to consider interrelationships of activities. There are four **subjects** of things that flow through the process interface:

- Control information:
  --Command and status information between SFPM levels
  --Request and response information at the same level (peer to peer)
- Data: All non-control information
- Material: Physical production entities
- Resources: Physical supporting entities.

There are four **actions** that occur in a process:

- Transform: Changing a subject from one form to another
- Transport: Moving a subject from one place to another
- Verify: Assessing compliance of a transformed subject
- Store: Retaining and retrieving a subject

These actions and subjects apply at all four levels, except interactions with actual material and physical resources apply only at level 1.

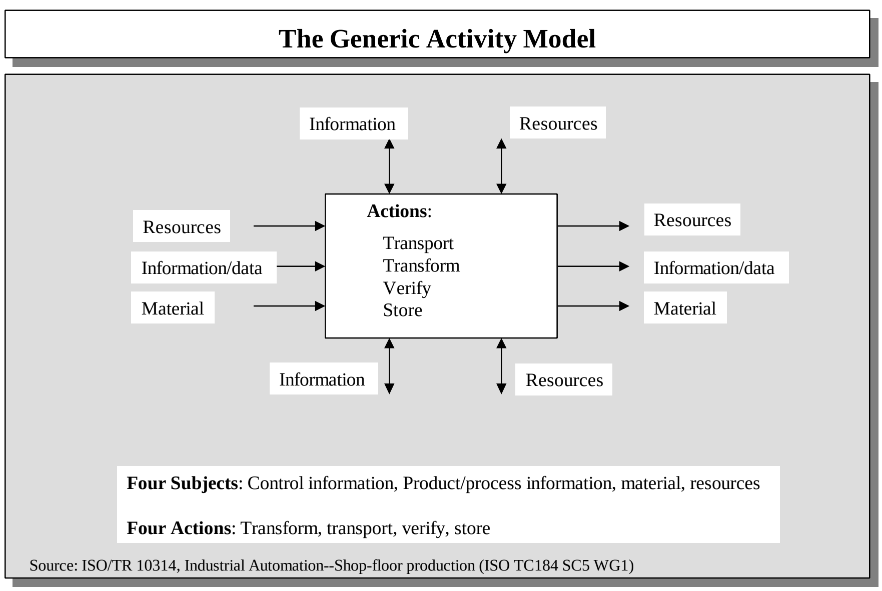


Figure 5 Generic-activity model

2.5.3 Standards-extraction process

To identify areas of standards requirements two types of procedures are developed and called procedures A and B in the TR 10314. Procedures of type A deal with interactions of subjects and actions within one generic activity model on a specific level. Procedures of type B deal with interactions between the shop-floor-production model and the eleven other enterprise-context functions, as well as the adjacent levels of the shop-floor-production model. The procedures in the boxes on the next page exercise the shop-floor-production model to identify and catalog industrial-automation standards. To accomplish this there is a set of structured questions to elicit where standards are needed or whether they already exist at the point of interface to the shop-floor activities.

As each permutation of each procedure is addressed, TR 10314 offers some standards viewpoints to help identify relevant standards. These viewpoints are derived from ISO guidance on standards objectives: performance, safety, compatibility, operability, reliability, maintainability, environment, description, and qualification. TR 10314 also offers some base technology categories into which the standards that ensue from exercising the procedures can be placed. These are information, material and products, product and production, tool and device, instrumentation and control, computer and communication, and human interface. It is these categories that should be harmonized with the categories espoused in the CEN M-IT-04 work, discussed in 2.6.

Exercising all of these procedures will generate an enormous amount of information. Also, to generate the information will require in-depth knowledge about many detailed areas. To accomplish the task properly groups of specialists must be consulted to be sure that the information collected is relevant and current.

2.5.4 Critique of ISO TR 10314

ISO TR 10314 offers a promising tool to extract standards that are needed in a shop-floor-production environment. Following are some comments that can serve as a critique of the methodology. ISO TR 10314 has not been used yet, perhaps for several reasons:

Procedure A1 Subject to Action:
Are there, do we need standards to relate

Transform		Control information		Section	
Transport	**with**	Data	**at the**	Cell	**level?**
Verify		Material		Station	
Store		Resources		Equipment	

Procedure A2 Subject to subject:
Are there, do we need standards to relate

Control information		Control Information		Section	
Data	**with**	Data	**at the**	Cell	**level?**
Material		Material		Station	
Resources		Resources		Equipment	

Procedure A3 Action to Action:
Are there, do we need standards to relate

Transform		Transform		Section	
Transport	**with**	Transport	**at the**	Cell	**level?**
Verify		Verify		Station	
Store		Store		Equipment	

Procedure B1 Horizontal: For each level, consider interactions between:
Are there, do we need standards to relate

		Corporate Management			
		Finance			
		Marketing and Sales			
		Research and Development			
Shop-floor		Product Design, Production Engrg.			Control
Info					
Production	**with**	Production Management	**in terms of**	Data	
		Procurement		Material	
		Shipping		Resources	
		Waste Material Treatment			
		Resources Management			
		Maintenance Management			

Procedure B2 Vertical: For each level, consider interactions between:
Are there, do we need standards to relate

Control information		Section to Cell	
Data	**transported across the**	Cell to station	**Levels?**
Resources		Station to equipment	

(Materials are not transported across levels and it is not clear whether resources are.)

- There is no visibility into clusters of requirements.
- The methodology produces a lot of information with little control on commonality of terms.
- It is difficult to judge the quality of results.
- There is no visibility of de facto standards (except as known by the experts involved).
- It is inward looking--intended for standards makers not users.
- Its effectiveness is not proven.
- Structured in 1989, it did not consider agile, extended, and virtual enterprise concepts.
- It recognizes ISO standards viewpoints but interoperability issues are not highlighted.
- The reference model was felt to be sufficiently general, but only for the shop floor and it only considers interfaces with the larger context of eleven other manufacturing functions.
- The generic activity model works for the shop-floor production model, probably because it encompasses physical aspects; but it is less applicable to other manufacturing business processes. For example in design, the whole of ISO 10303, STEP (Standard for the Exchange of Product Model Data) is identified in only one entry as the interface to the design process.
- Electronic data interchange and Continuous Acquisition and Life-Cycle Support (CALS) issues are not handled.

Major updates to ISO TR10314 must be authorized as an ISO project both by the P-members of TC184 SC5 and by the experts of TC184 SC5 WG1. The document can be revised to accommodate the concerns, to update the methodology to be more generic, to extend its scope, and to merge the categories of standards so that they are congruent with those of M-IT-04 (See 2.6). TC184 SC5 WG1 plans to investigate the feasibility of this based on needs for such a revision among the P-members.

2.6 CEN/CENELEC, M-IT-04, the classification scheme

The M-IT-04 [CEN96] is a joint memorandum from a special-working group of CEN TC310 (European Committee for Standardization) to organize and report on the standards in the information- and the communications-technology domain for advanced-manufacturing-technology (AMT) applications. The standards are classified into categories with the relation shown between the categories. The categories are: enterprise modeling and system architecture, industrial communications, data, information processing for AMT applications, control equipment, human aspects, mechanical equipment, system-operational aspects and multimedia in AMT. For each category there are descriptions: analysis and evaluation of current work, recommended strategy, proposed work program, and testing requirements. (See Appendix)

M-IT-04 defines advanced-manufacturing technology as *the collection of technologies that support the processes of specifying, designing, developing, deploying, operating, and integrating automated-manufacturing systems (hardware and software*). AMT includes other associated research, methods, tools, control, information (data), and communication systems; taking into account physical, human, environmental, and safety aspects to support products throughout their life cycle from concept and design through manufacture to delivery, support, and disposal.

While the ISO TR 10314 offers a classification scheme for the standards that the methodology extracts, MSID feels that for its needs, the classification scheme of M-IT-04 is better. These two schemes should be reviewed by experts in the standards arena with the intent to merge the classifications into one scheme. Perhaps parts of both are relevant and users can select those categories that are most relevant to them.

2.6.1 Relating M-IT-04 to TR 10314

To achieve the standards-road-map mission the standards, once they are identified by the ISO TR 10314 methodology, can be organized into the M-IT-04 categories. For each category, the road map will identify:

- The current situation--how standards apply to what is done in manufacturing enterprises currently
- Requirements--to identify trends and inadequacies

- Recommendations--to move from current situation to meet the stated requirements
- Road map--Plan to get there considering modification to current standards, convergence of existing standards, new standards, or elimination of standards. The road-map time consideration is: the immediate or short term (one year to three years), the medium term (three years to five years), and the long term (five years to seven and more years).

2.6.2 Critique of M-IT-04

M-IT-04 is less inward looking than TR 10314 and is more readily adaptable and can be used by groups other than standards-making groups. Therefore, the methodology of TR 10314 coupled with the classifying scheme of M-IT-04 offers some advantages. The format for the presentation is important because, in its entirety, any updating task would be enormous. For that reason the road-map project envisions a self-maintaining resource. The information presented will not be a paper document or an isolated database. Instead, hopefully, the presentation will be World-Wide-Web based and linked to a database in such a way that standards organizations can access their part of the data by updating the database on-line. The M-IT-04 presentation schema should be placed on-line and organized so that it easy for standards groups responsible for the various standards presented to maintain their own sections and easy for users to see updated contents. The more useful the resource becomes, the more incentive the standards groups will have to keep their portion current. There is some industry support for using M-IT-04. Having an updated Web-based presentation should increase the amount of support. Putting the M-IT-04 on the Web will require a sponsor, such as NIST, to host the effort, design a useful and easy-to-use tool, and to perform maintenance on the schemata.

There is currently no coverage of de facto standards, thus process interoperability will improve only with use of the most pervasive standards, whether or not they are de jure or de facto. The problems are identifying the de facto experts, keeping those sections current, and determining if the same classification scheme will apply to both kinds of standard.

M-IT-04, although it has existed for some time, is still a document in the making. The CEN Information Technology Steering Committee set up the Information Technology Advisory Expert Group and a sub-working group to establish a work program for European standardization in the information-technology domain. There have been six issues of this report over the last eight years and a seventh version is in progress. As has happened in the past, future work of this group probably will significantly reorganize the categories to better reflect work areas needing attention. For this reason the information in this road map should be modularized to enable facile realignments as necessary.

Another issue is whether CEN will continue to support the document. Currently they own the copyright. They are considering whether to offer the document rights to ISO. ISO, in turn, would probably assign responsibility for the document to TC184 SC5 WG1, which NIST convenes. WG1 would have to find the support to maintain the schemata, and that support should come from interested users, such as industry, to make the output most meaningful. The ownership issue probably will be resolved in 1999.

2.7 Matching resources to standards activities, using a standards road map

Part of the Standards Road Map project is to plan a way to identify and categorize the standards in a way that is meaningful to MSID and that helps to enable strategic decisions about MSID standards activities. Research about identification and categorization led to two works of international standards bodies, ISO and CEN, the committee for European Standardization. Documents describing this work [ISO 90] [ISO 91] [CEN96] have proved quite useful. The ISO TC 184 SC5 WG1 Technical Report ISO 10314 provides a clear methodology to identify any relevant standard in the shop-floor manufacturing domain and the CEN M-IT-04 offers a scheme by which the standards identified can be categorized.

To communicate the benefits of using the approach espoused in these documents, the project leader invited Mr. David Shorter, IT Focus, UK, to assist in conducting a workshop for the MSID leadership, Mr. Shorter was heavily involved in the development of both documents. In preparing and conducting the

1998-March-18 workshop Mr. Shorter became familiar with the Standards Road Map project, and, as a result, prepared an informal paper [SHO98] about using the road map. This section is strongly based on that paper, offers some thoughts about the major issues with the project, and offers some potential projects that may mitigate those issues. The paper is organized around what were viewed as the high-level solution components of such a standards road map. The components are formulated to apply specifically to MSID and its industry customers, and where applicable to NIST.

The main objective is that the MEL contribution to standards development should be in balance with industry requirements, taking into account significance and timeliness, and recognizing many subsidiary factors such as effectiveness, and appropriateness. In the standards-road-map workshop attended by the MSID Leadership Committee, a road map was clearly only one part of a solution, albeit a crucial one. Also needed are ways of evaluating and propagating NIST contributions to standards-making activities and aggregating these into an overall contribution to business imperatives. There should also be the capability for two-way propagation--translating an industrial need into *hot spots* for standardization action; and, as standards activities are identified, inform industry how ensuing standards may be applied.

Ideally the aggregation of industry needs, or contributions to business imperatives, or both, should expose patterns of requirements and sets of appropriate standards. This could provide some desirable properties of resilience against changes in individual work items, and of appropriate granularity and visibility for decision-making, both by NIST and industry. If the capabilities, applicability, and relationships of solution components such as standards could be modeled, then model viewpoints might be a way of achieving this. The identification methodology and categorization capability of TR 10314 and M-IT-04, respectively, appear appropriate to show patterns of requirement and high-level-solution components.

The project reports (this one and the *Criteria Analysis* [NELL98]) show the various concerns of developing and using a standards-road map and show how strategic-management decisions can be made using the road map. The workshop introduced the concept of *standards landscape* to distinguish concerns of representing the terrain from the *road map,* which constitutes navigating that *landscape*. The high-level components of the entire road map domain are described below, together with a brief and necessarily partial assessment of the current situation and possibilities for future action. The identified components are:

- MSID concern for standards
- The standards landscape
- Criteria, metrics, measures and filters
- A value system to interpret metrics and measures
- Applying resources
- Managing the complexity

The potential project proposals offered under each component are primarily to resolve basic issues. Implementation issues are not discussed but were touched on in the workshop.

2.7.1 The MSID concern for standards

For the manufacturing enterprise, MSID needs to be able to express the relationships between a particular standard and those standards related to it; between standards and NIST's industrial perspective; and then to be able to map what is happening in the division onto standards. Because enterprise needs and concerns are often directed at business issues and not enabling technology and standards. MSID must strive to translate needs as expressed into capability-improving solutions that include standards and enabling technology.

Patterns of requirement are important. One workshop participant said *: We're not concerned with a standard or sets of standards* [by themselves], *but rather patterns of standards that support a strategic thrust. We're concerned with strategic impact.* The scale of effort must be appropriate and sufficiently comprehensive, and there must be an agreed-to *value policy* for when and where MSID should devote resources to standards-related activities, see Resources item below. This value policy should have its roots in the decision criteria, discussed in the criteria-analysis report [nell98].

Proposal for additional work:

- Produce use-case scenarios for how a standards landscape and related processes could be used in meeting NIST standards concerns. Make sure these cover all the processes and soft issues needed to close the loop. As and when the landscape emerges and processes start to be defined, test the adequacy and effectiveness of these at an early stage.

2.7.2 The standards landscape

M-IT-04 and TR 10314 are complementary. The TR 10314 concepts and procedures help with assessing coverage but need extension beyond the purely shop-floor-production processes, and M-IT-04 provides a helpful classification but one which needs updating. Together they represent a classification and a methodology that could be useful when combined into a standards landscape as a component of the overall solution. Where the application has been limited to shop-floor concerns, the scope should be extended to product and process engineering. Lists of standards information should be augmented with, or replaced by, pointers to other sources such as the National Standards Status Network (NSSN), Subcommittee 4 On-Line Information Service (SOLIS (ISO TC184 SC4)) to reduce duplicated effort and to ease maintenance. The workshop agreed that they could envision the landscape being generated by the identification methodology and classification scheme, and that such a development would form a critical piece of the solution but not the only one. The workshop also agreed that there was no major barrier to the development of a standards landscape.

This standards landscape should include semantic structuring of some kind so that it is not just a flat list but incorporates other information about relationships and dependencies. There was a view that even as it stands, M-IT-04 provides a very useful visualization especially if it where to be extended to link with externally maintained sources containing the necessary information. When augmented by NSSN to populate the classification schema with an up to date list of available standards, it might be sufficient. At this stage the workshop concluded that it is not obvious that re-engineering M-IT-04 into a standards landscape was the most urgent requirement or the best use of resources for this project. Attention should also be paid to economic analyses and industrial trends. Re-engineering M-IT-04 should then be revisited when the role of the standards landscape, within the overall decision-making situation, becomes clearer.

However, note that M-IT-04 is not traversable, and it is not easy, given its present structure, to pull out patterns; for example, what is relevant to manufacturing information, and what standards should one specify and use in a particular domain. Some preliminary pilot work on modeling M-IT-04 and in particular, the ability to propagate and view attributes such as applicability, timeliness, and benefit could be helpful in reducing risk. Selecting attributes is a matter of identifying appropriate criteria, measures, and metrics. Interpreting the results requires deciding how the resulting *value chain* is to be interpreted in terms of benefit to US industry. Even given an adequate standards landscape, one would still need to overlay on that a navigation policy to say how MSID would apply it.

Proposal:

- Given that a proposal is anticipated from CEN that M-IT-04 might be adopted by ISO, there is the opportunity over the next few months for NIST to participate in this activity through their convenorship of the ISO standards committee TC184 SC5 WG1. This would have the advantage of giving NIST a leadership role in reorganizing M-IT-04 to meet future landscape requirements and avoid duplication of effort if M-IT-04 were to be developed elsewhere. Since TC184 SC5 WG1 already is responsible for ISO TR 10314, this is an opportunity to consolidate the matrixes of TR 10314 into the classification schema of M-IT-04 and to extend the concepts (but only as far as needed), thus producing an improved standards landscape.

- Assess and establish appropriate procedures for working with information sources, such as, theme experts, NSSN, and SOLIS.

- If the budget permits, develop a small pilot for representing M-IT-04 as an object model using a commercially available tool, and assess propagation and viewpoint mechanisms.

2.7.3 Criteria, metrics, measures, and filters

The Criteria Analysis (NELL98) demonstrates the complexity of applying criteria and interpreting the answers. A thought here is that standards are often related and used in concert--in which case the rankings for one ought somehow to reflect on the others. Modeling such situations in an object model with inheritance could be one way of reducing complexity.

Some criteria can be developed from the relationships between technologies. A paper prepared for ICEIMT'97 (International Conference on Enterprise Integration and Modeling Technology) [NELL97] has a list based on:

- What amount of format-neutral information at interfaces between applications
- What parts have common semantics
- What are the hardware and software interrelationships
- What is the commonality of communication protocols and semantics

Also, it is not necessary that every application talk to every other application. Some criteria about the relevance of a standard or set of standards can be developed by knowing the relationships among applications and the degree to which particular applications interact .`

Mr. Shorter suggests that measures for these can be defined on the basis of *how much does it matter*; for example, to bridge between two applications, whether this is a once only or continuing requirement, and what is the likely frequency of change in interfaces. This corresponds in some sense to a technological equivalent of the procedures in TR 10314. The problem with standards-extraction methodologies, such as those in ISO TR 10314, is how rapidly they produce an unmanageable volume of detail. This may be appropriate for someone seeking to make a decision in particular circumstances but not for making general strategic decisions. However, the details would apply in the implementation of the strategic decision.

Criteria are also dependent on assumptions prevailing at the time--and these assumptions need to be recorded in such a way that when changes in technology or market situations force a rethink, the implications on the criteria can be seen, and the criteria can be modified and reapplied as appropriate.

Another way of viewing criteria is in terms of filters that can be applied together or in some sequence while evaluating a standards activity. The workshop identified five of these:

- Economic impact
- Business needs
- Technology imperative
- Available resources at NIST. This might well be the dominant consideration because of practical employment practices
- Product impact; that is, assess the current or future market value of those affected and consider the impact on the production processes

How these filters are to be applied to the standards landscape deserves consideration. Some, such as business benefit, might be applicable to sectors of business. Others, such as technology imperatives, may be concerned with quality of service. Working with these filters is beyond the current scope of the Standards Road Map project.

Another difficulty is that some issues and judgements are soft; for example, priorities saying *industry has spoken*, or an evaluation that something is *quite important* and needed *soon* rather than *essential* and needed *now*. In similar situations, expert systems and control systems have used fuzzy logic (see for example: http://www.cms.dmu.ac.uk/People/rij/ fuzzy.html). Is fuzzy logic applicable to propagating benefits over the landscape?

One workshop participant noted that, as with any formal ranking system, users will be tempted to manipulate the scores to achieve the desired result (compare: job-evaluation exercises). One participant suggested that industrial needs *will come out of the road map*. It is difficult to see how this can happen unless *terrain* features are annotated with measures, such as strength of demand, significance, and economic impact. And since these values will change, there should be a separate database for these items with the ability to associate them automatically with attributes in the standards landscape and to calculate derived values.

Another workshop participant noted that NIST should work towards things that aren't there yet; in other words, to anticipate an industrial need. Of course this makes it more difficult to argue an industrial or market justification, even though this type of anticipatory vision is one of the top-level NIST objectives with respect to resolving industry needs.

Proposals

- Extend use-case scenarios to encompass the most effective application of filters and consider the computational implications.

- Consider how best to associate significance and other measures to features of the standards landscape.

- Assess the extent to which soft judgements require special treatment such as fuzzy logic.

- Design information and mapping structures to uncouple demand and timing indicators from the standards landscape.

2.7.4 A value system to interpret metrics and measures

Assume that NIST has successfully defined criteria, measures, and metrics and ways of propagating them among related items in the standards landscape. There is still a problem in deciding how to apply the resulting capability.

- If there is a high score for a standard or an area of standards, is that a good or bad thing, especially if it is related to process rather than to infrastructure?
- If need is critical to industry why don't they do it?
- If industry is not working in a particular area does that mean NIST should or that the standards activity isn't needed?
- If there is a gap in the standards landscape, whether to fill it depends on the relative importance of the thing that filling the gap would support.

This problem illustrates the need for an agreed-value policy for how the road map is to be used. A sample policy is in the Roadmap section of this report.

Proposal

- Investigate the feasibility of drafting criteria and value-chain policies with sufficient clarity that they can be turned into an algorithm.

2.7.5 Applying resources

For MSID, the end point of the exercise is making decisions on where to concentrate; that is, where to put resources in terms of how many full-time equivalents to allocate. There were the following comments from the workshop:

- *We're mostly happy with what we're doing but there's about a 15% annual change in direction or priority*, so not everything needs to be revisited every time.
- Realistically MSID *can have only five or so groups, there is no point in developing a complete model and then saying, well, where are the five groups going to go--because the answer is more or less known beforehand.*
- There is *an audience for everything no matter how obscure. So one could moderate this by recognizing divisional competencies.*

It's not clear how to incorporate these insights. A possible strategic-planning exercise is to produce the landscape map and invite the five MSID groups to characterize their activities. Each group would say which bit of the map they feel should be worked on next, and which bit of the map is missing but will become evident with emerging technology.

The extent to which a group finds it easy or difficult to relate their work to the eventual business benefit may itself provide insights into what might be done to increase the industrial coupling. This would be more applicable if previously endorsed by an industry forum, incorporated into teaching material and codes of practice, delivered to industry in a form that enabled easier, cheaper, lower-risk or incremental implementation. However, such an approach would be less likely to flag gaps in the current program.

Proposal

Use an initial version of the standards landscape in an exercise with one or more group leaders to assess:

- Whether it can provide coupling insights, and/or what modifications would be required to support this
- How clustering of requirements can be overlaid onto the standards landscape, and how new ones can be identified and overlaid in the future

2.7.6 Managing the complexity

The criteria-analysis paper mentions the need to prune the search space. And the workshop envisioned a *spaghetti diagram* showing how quickly the amount of information becomes unmanageable. Attribute inheritance and multiple viewpoints should help here. Another approach is to restrict the depth of treatment to the granularity that is really essential; for example, the top 2 or 3 levels of M-IT-04. Computer assistance is crucial. But merely computerizing the relationships of the road map into a structure is not enough. It needs to be navigable, maintainable, and capable of simplification for specific needs.

Proposal

- Assess the suitability of commercial-modeling tools against the use-case scenarios mentioned in 2.7.1 and other requirements.

2.7.7 Standards of primary and secondary interest to MSID and other NIST groups

The descriptions of the M-IT-04 categories have been reviewed and a preliminary judgement regarding where in NIST the interest in that category would lie. Considered were divisions of the Manufacturing Engineering Laboratory and the Information Technology Laboratory. Further judgement also indicated whether the named MEL division would have a primary or secondary interest in standards in that category, as shown in Table 1.

2.8 Other organization schemes considered

Institute of Electrical and Electronics Engineers: IEEE 1175, a trial-use standard: *Reference Model for Computing System Tool Interconnections* operates from a viewpoint of introducing a new tool into the present enterprise-operating environment. When this happens, there are several changes required to the enterprise. These are: interfaces between the tool and the organization, interconnections to a platform and

Table 1: Advanced manufacturing technology: classification scheme

MEL or ITL Division.	P/S*	Standards Category
		M0 Enterprise Modeling and System Architecture
MSID	P	M0.1 Manufacturing Environment Architecture
MSID	P	M0.2 Methodology
MSID	P	M0.3 Terminology
		M1 Industrial Communications
ITL and MSID	S	M1.1 LAN Basic Standards
ISD and MSID	S	M1.2 MMS and Other Applications
ISD and MSID	S	M1.3 Fieldbus Standards
		M2 Data
MSID	P	M2.1 General Methodology for Definition of Manufacturing Data
MSID	P	M2.2 Product Model Data
MSID	P	M2.3 Manufacturing-Management Data
ITL	P	M2.4 Business Data
MSID	P	M2.5 Standard Parts Libraries
MSID	P	M2.6 Representation of Data
		M3 Information Processing for AMT Applications
MSID	P	M3.1 Information Technology System Structure
ISD	P	M3.2 Application Languages
ITL and MSID	P	M3.3 Applications Programming and Information Support
		M4 Control Equipment
ISD and APTD	?	M4.1 NC Equipment for Machines
ISD and APTD	?	M4.2 Coordinate-Measurement-Machine Controllers
ISD and APTD	?	M4.3 Robot controllers
ISD and APTD	?	M4.4 Programmable controllers
ISD and APTD	?	M4.5 Process-Control Subsystems
ISD and APTD	?	M4.6 Transport-System Controllers
ISD and APTD	?	M4.7 Automatic-Testing Equipment
ISD and APTD	?	M4.8 Data-Entry Terminals
ISD and APTD	?	M4.9 Sensors
ISD and APTD	?	M4.10 Actuators
		M5 Human Aspects
NIST?	S	M5.1 General Ergonomics
MSID and ISD	S	M5.2 Human-System Interface
?	S	M5.3 Human Factors
		M6 Mechanical Equipment
ISD and APTD	?	M6.1 Machines
ISD and APTD	?	M6.2 Industrial Robots
ISD and APTD	?	M6.3 Auxiliary Equipment
		M7 System Operational Aspects
?	S	M7.1 Safety
?	S	M7.2 Operating Environment
?	S	M7.3 Maintenance, Dependability, and Reliability
MSID Related?	S	M7.4 Performance
MSID Related?	S	M7.5 Implementation Guidelines
MSID Related?	S	M7.6 Documentation

MSID Related?	S	M7.7 Engineering
MSID Related?	S	M7.8 Quality
No		**M8 Multimedia in Advanced-Manufacturing Technology**

*P/S refers to Primary/Secondary interest. ITL = NIST Information Technology Laboratory

Then, with this all necessary components in the subject domain, defining methods and mechanisms for information interchange between tools in the subject domain, and the syntax and semantics of the information to be shared. Therefore the standards to be identified are divided into four context categories: the organizational context, the architectural context, the transfer context, and the transfer language.

Electronic Design Automation Companies: The EDAC Standards Road Map is prepared by the Electronic Design Automation Companies, Semiconductor Manufacturing Technology (SEMATECH), Computer-Aided Design (CAD) Framework Initiative. The road map presents standards needs of the electronics manufacturing industry for implementation by the EDA Industry Council. The roadmap is based on the expressed needs of the EDA industry on EDA systems immediately, in the near term, and in the long term. The road map identifies the needs, reviews status and current plans of related standards, identifies standards areas requiring improvement, migration to improved standards, and a road map to produce the required standards. These features provided by the road map are organized into the life cycle activities of an electronic product, such as detailed design and software-design interface. For each activity addressed, the road map presents the current environment, requirements, recommendations, and the road map itself.

3 Vision for the standards-information resource

Originally, a part of the project was to create a standards-information resource that pertains to the enterprise-integration-related-standards domain. This was to include a list of standards by category, the standards organization, the purpose of the standard, and the status of the standard. This resource was to be a database, a World-Wide-Web site, a paper document, or a combination that was to be determined.

The methodology of TR10314 coupled with the classifying scheme of M-IT-04 is applicable to this project because the methodology and structural-design work largely is complete, because the work is based in the international-standards arena, and because it provides a logical look at both the standards-extraction process and the classification schema.

The format for the information-resource presentation is important because the effort required to update the work would be enormous. For that reason the road-map project envisions a self-maintaining resource. The information presented will not be a paper document or an isolated database. Instead, hopefully, the presentation will be World-Wide-Web-based and linked to a database in such a way that standards organizations can access their part of the data by updating the database on-line. The M-IT-04 presentation schema should be placed on-line and organized so that it is easy for standards groups responsible for the various standards presented to maintain their own sections and easy for users to see updated contents. The more useful the resource becomes the more incentive the standards groups will have to keep their portion current.

4 The standards road map

The mission of the standards road map is to:

- Identify MSID interest, level, and role in what NIST does, can do, and should do.
- Identify customer need in the short or immediate term (one to three years), the medium term (three to five years), and long term (five to seven or more years).
- Identify current standards, their status, and their function.
- Identify gaps and overlaps in standards coverage.

The road map is basically an information resource about standards enhanced by some criteria and assumptions that apply to the MSID mission with respect to a particular standard or class of standard. The information resource provides what MSID refers to as the standards landscape.

Then, with this basic information, the results of applying the road-map criteria to the standards landscape should be treated as an input to the division strategic-planning process. The road-map information will enrich the planning process by:

- Helping to define what decisions MSID needs to make to enable better strategic decisions about standards support.
- Improving what MSID is doing with respect to the standards that they currently support.
- Making it easier to determine the level of investment that is prudent and how the investment should be funded.

The criteria and information resource will make it easier to know the nature of the standards that exist or are needed. Knowing the nature of the standard will improve decisions about whether MSID, and NIST, should get involved or disengage. MSID can find itself deciding about standardization in several ways: for example, is MSID involved and should it be or shouldn't it be, is MSID not involved but it should be or still it shouldn't be. Should MSID watch, participate, and/or lead? Alternatively, MSID may recommend that an existing standard be withdrawn or that a non-existing standard be created.

The standards road map is a process that begins with a customer need, usually from industry, and that ends with a decision about NIST applying resources to help develop a particular standard or a family of standards. Figure 6 depicts the process.

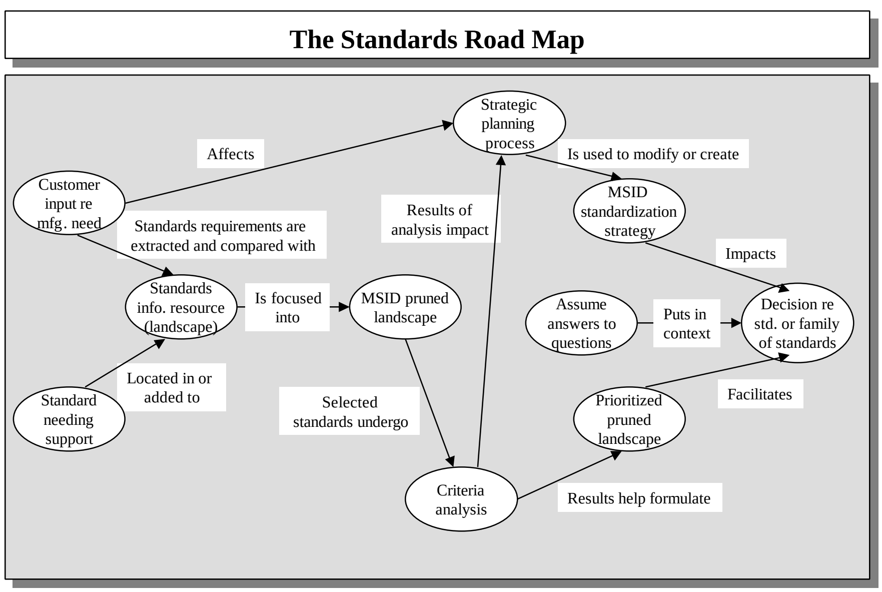


Figure 6 Standards road map

Customer needs are discussed in the criteria-analysis document. The need can arise from within government, industry as a whole, an industry segment, or one company. A standards group can also express the need for support about a standard they are developing. Either way, the standard is located in, or it is placed in, the Standards-Information Resource, also referred to as the standards landscape. An industry need for a standard may be expressed in a variety of ways. If the need is expressed directly as a need for a standard it is easier to analyze. However, most needs expressed by industry will be phrased in terms of improving their performance rather than in terms of a standard, and MSID will need to extract from the need statement the various components necessary to provide a solution. One of those components may be a requirement for a change in the current standards activities.

There is the entire standards landscape and there is that portion of the landscape that is the domain of NIST; and even more focused is the MSID landscape. Standards not in the MSID landscape would not be subject to pressure for MSID to apply resources.

The standards that are in the MSID landscape are analyzed using the criteria developed in this program. The specific analyses are described in the criteria-analysis document. The output of the criteria analysis is designed to be used in the division strategic-planning process, and to create a prioritized and pruned landscape of standards that feed into the MSID-decision process. Keep in mind, the function of the road map is to make the decision process easier by illuminating and ranking the key issues, not to obviate the process.

A decision about whether, and how much, resources should be applied to developing a standard, or a family of standards, should consider three areas of information generated by the standards road map. One is the standardization strategy that emanates from the MSID strategic-planning process. This will use the criteria analysis to develop a plan regarding the standards that are important to MSID customers. A second is the pruned sector of the information resource that contains the standard activities that have survived the criteria analysis. The third component of information is key to the timeliness of a decision and it is perhaps the most difficult to effect. This is the set of assumptions that result from the criteria analysis, the strategic questions [nell98, 3.5], and the MSID-current environment. The output of this process will take the form of an informal scenario of considerations that will affect the decision whether to support a standard now or not.

The methodology described by this road map has been constructed for the shop-floor-production activities of a discrete-parts-manufacturing enterprise, in the operations phase of its life cycle. There appears to be no reason that it cannot be extended to other types of enterprise, other parts of enterprise operation and in other phases of the enterprise-life cycle.

5 Opportunity for new work

- Use an initial version of the standards landscape in an exercise with one or more group leaders to assess:
  - Whether it can provide coupling insights, and/or what modifications would be required to support this.
  - How clustering of requirements can be overlaid on the standards landscape, and how new ones can be identified and overlaid in the future.
- Investigate the feasibility of drafting criteria and value-chain policies with sufficient clarity that they can be turned into an algorithm .
- Given that a proposal is anticipated from CEN for ISO to adopt M-IT-04, there is the opportunity over the next few months for NIST to participate in this activity through their convenorship of the ISO standards committee TC184 SC5 WG1. This would have the advantage of giving NIST a leadership role in reorganizing M-IT-04 to meet future landscape requirements and avoid duplication of effort if M-IT-04 were to be developed elsewhere. Since TC184 SC5 WG1 already is responsible for ISO TR 10314, use this opportunity to consolidate the matrixes of TR 10314 into the classification schema of M-IT-04 and to extend the concepts (but only as far as needed), thus producing an improved standards landscape.
- Produce use-case scenarios for how a standards landscape and related processes could be used in meeting NIST standards concerns. Make sure these cover all the processes and soft issues needed to close the loop. As and when the landscape emerges and processes start to be defined, test the adequacy and effectiveness of these at an early stage.

  - Assess the suitability of commercial-modeling tools against the use-case scenarios mentioned in 2.7.1 and other requirements.
  - Extend use-case scenarios to encompass the most effective application of filters and consider the computational implications.
- Consider how best to associate significance and other measures with features of the standards landscape.
  - How much does this particular bridge between applications and the associated need for standards matter?
  - Will the productivity improvement be worth the effort to achieve the result?
- Assess the extent to which soft judgements require special treatment such as fuzzy logic.
- Design information and mapping structures to uncouple demand and timing indicators from the standards landscape.
- Assess and establish appropriate procedures for working with information source ; such as theme experts, NSSN, and SOLIS.
- Develop a small pilot for representing M-IT-04 as an object model using a commercially available tool, and assess propagation and viewpoint mechanisms.

6 References

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[ISO90] International Organization for Standardization, *Reference Model for standardization and methodology for identification of requirements*, TR 10314 1, 1990-October

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[NELL97] James G. Nell, NIST, *A Standardization Strategy that Matches Enterprise Operation*, NISTIR 6049, 1997-September

[NELL99] James G. Nell, Neil B. Christopher, NIST, *Criteria Analysis*, Standards Road Map Project

[SHO98] David N. Shorter, IT Focus, UK, *Matching Resources to Standards Activities, Using a Standards Road Map*, Unpublished report, 1998-March

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Appendix: Standards categories in the information resource (M-IT-04)
M0 Enterprise Modeling and System Architecture.

M0.1 Manufacturing Environment Architecture includes representations of entire enterprises in the form of frameworks and architectures. They make no distinction or definition regarding the terms "framework and architecture". Reference is to CEN ENV 40 003, Framework for enterprise modeling, and the standards to support the ESPRIT EMEIS, Enterprise model execution and integration services.

M0.2 Methodology is a controversial area to standardize, and, to date, there are very few. Could consist of reports of recommended practices and codes of usage on how to apply other standards. This category also could include formal languages with which to accomplish enterprise representation.

M0.3 Terminology includes glossaries, vocabularies, and formal ontologies.

M1 Industrial Communications

M1.1 LAN Basic Standards (Provisional title**)**

M1.2 MMS (Manufacturing message systems) and Other Applications (Provisional title**)**

M1.3 Fieldbus Standards (Provisional title)

M2 Data

M2.1 General Methodology for Definition of Manufacturing Data This category includes the open-edi reference model, the basic semantic repository, EXPRESS, and work on VHDL, the VHSIC, or very high speed integrated circuit, hardware-description language. This category would include group technology if standardization work existed on the topic.

M2.2 Product Model Data Product-data representation and exchange, mostly the domain of STEP ISO 10303.

M2.3 Manufacturing-Management Data This category includes data used to run a manufacturing enterprise, including links to enterprise-modeling data. Although enterprise modeling is in the M0 category the data for the enterprise models is covered in M2.3. This includes production data for external exchange, say, using edi methods; manufacturing resources; usage-management data ; and manufacturing flow-management data.

Production data for external exchange includes data exchanged between commercial and manufacturing areas, information required for manufacturing planning, information needed from manufacturing orders, information needed from purchasing, information required to monitor suppliers and subsidiaries, and information required to support receiving and delivering products.

Manufacturing resources management data includes performance metrics, input an output resources definition, capacity and capability, tools and application software, capacity of internal controls and intelligence, information input and output capability and capacity, standard references for resources, maintenance scheduling and monitoring, and cost elements.

Manufacturing flow-management data includes definition of production levels, production control, manufacturing planning, and source-requirements planning, just in time, optimized-production technology (OPT), planning-evaluation and review techniques (PERT), production monitoring, cost accounting, process planning, bills of materials, and process plans.

M2.4 Business Data This area includes the business-data exchange and links to the Basic Semantic Repository, coordination of data-element standardization, and edi messages pertaining to manufacturing.

M2.5 Standard Parts Libraries Note: This topic is not about standard parts but about part libraries that conform to a standard format and exchange protocol. This is primarily the domain the ISO 13584 standard.

M2.6 Representation of Data This category includes computer graphics, image processing, office-document architecture (ODA), office-document-interchange format (ODIF), structured-text representations, numeric-table representations, and markup languages (SGML)

M3 Information Processing for AMT Applications

M3.1 Information Technology System Structure The information-technology support for the Enterprise Model Execution and Integration Services (EMEIS) architecture defined in Section M0.1. This includes the integrating infrastructure, application of open-distributed processing, and reference models for computer-integrated, manufacturing-system modules.

M3.2 Application Languages Standardized high-level languages for computer and/or microprocessor-controlled equipment commonly applicable to control devices and applications. Includes languages that facilitate programming, operating, servicing, and training on device controllers and their integration into automation systems. Topics: Manufacturing-automation-programming-language environment, numerical-control languages, manipulating industrial robots, intermediate control for robots, programming languages for robots, CMM-control language, programmable-control language, and FMS cell-control language.

M3.3 Applications Programming and Information Support Includes portable operating system interface, remote-database access, description languages, and information technology security. Topics: software portability, system software interface, standard software modules, general programming languages, operating systems, database systems, software tools and methodologies, knowledge-based techniques, and data security.

M4.0 Control Equipment

M4.1 NC Equipment for Machines Includes information and hardware technologies such as control codes, formats, and command languages device controllers, direct data exchange with CAD/CAM systems, independent sources for geometry, technology processing, tools, and commands. Topics: Equipment characteristics, axis and motion nomenclature, program format and address words, NC of machines, electrical interfaces between NC equipment and electrical equipment, and interfaces to open-systems environment.

M4.2 Coordinate-Measurement-Machine Controllers (same topics as M4.1, see M7.4)

M4.3 Robot controllers (same topics as M4.1)

M4.4 Programmable controllers (same topics as M4.1)

M4.5 Process-Control Subsystems (same topics as M4.1)

M4.6 Transport-System Controllers (same topics as M4.1)

M4.7Automatic-Testing Equipment (same topics as M4.1)

M4.8 Data-Entry Terminals (same topics as M4.1)

M4.9 Sensors (same topics as M4.1 plus response format)

M4.10 Actuators (same topics as M4.1 plus response format including dynamic aspects)

M5 Human Aspects

M5.1 General Ergonomics Standardizing ergonomic principles for visual display terminals, keyboards and workplaces

M5.2 Human-System Interface Includes image, voice, and sound input and output.

M5.3 Human Factors The above categories are considered "basic ergonomics". This category was created to include "meta-level ergonomics"; that is, identifying minimal knowledge and skills requirements; strategy for qualifying the workforce; guidelines for assessing and introducing new technologies into existing manufacturing processes and organizational structures; identifying communications requirements between and within distributed and independent working groups.

M6 Mechanical Equipment

M6.1 Machines Standards for the configuration, dimensions, and mechanical-interface capabilities of machines. Topics such as performance are covered in M7.4, safety in M7.1, ergonomics M5, and human interface M5.2.

M6.2 Industrial Robots Standards for mechanical interfaces and presentation of characteristics of robots. Includes plates, shafts, automatic end- effector-exchange systems, and grasp-type grippers.

M6.3 Auxiliary Equipment Standards for tooling, fixtures, and handling equipment, such as shanks, automatic tool changers, retention knobs for shanks, tapers, faces of spindle holders, automatic press tool changing equipment, modular units (pallets)

M7 System Operational Aspects

M7.1 Safety General safety and safety of manufacturing equipment and cells.

M7.2 Operating Environment Includes operating conditions such as temperature, relative humidity, power supply, and electromagnetic compatibility.

M7.3 Maintenance, Dependability, and Reliability Includes inspection and diagnosis.

M7.4 Performance Includes test and acceptance conditions for various types of machines and machine tools, performance criteria and related testing methods for robots, and evaluation of system properties.

M7.5 Implementation Guidelines

M7.6 Documentation Includes electrotechnical symbols and documentation, product documentation, CAD techniques, software documentation (symbols, flow charts, program and data documentation).

M7.7 Engineering Includes products, process, systems design, CAE techniques, concurrent and simultaneous engineering, configuration management, software engineering methods and processes (project management; software validation, verification, and evaluation; formal design reviews; software-development models, and data description).

M7.8 Quality Comprises primarily the ISO 9000 standards.

M8 Multimedia in Advanced-Manufacturing Technology This category is not well defined yet.