Tinwisle Corporation

Industrial automation process and process model interoperability: an ISO viewpoint

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Convener ISO TC 184/SC 5/WG 1

Industrial automation process and process model interoperability: an ISO viewpoint

- Context of interoperation
- Integration standards
- Architecture standards
- Interoperability standards
- Future Efforts

Who's standards

Context
Integrate
Architect
Interop.
Future

ISO/TC 184
Industrial Automation Systems & Integration

CEN TC310/WG1

SC 1
Physical Device Control

- **WG7** Data modeling for integration of physical devices
- **WG8** Distributed installation in industrial applications

SC 2
Robots for Manufacturing Environments

- **PT1** Revision of ISO 10218

SC 4
Industrial Data

- **PPC** Policy & planning committee
- **QC** - Quality Committee
- **WG2** Part Library
- **WG3** Product Modeling
- **JWG8**** Industrial manufacturing management data
- **WG11** Express language, implementation methods
- **WG12** Common resources

SC 5
Architecture, Communications Integration Frameworks

- **WG1** Modeling & Architecture
- **MT1** Communications & Interconnections
- **WG4** Manufacturing Software & Environment
- **WG5** Application Integration Frameworks
- **WG6** Application Service Interface
- **WG7** Diagnostics/Maintenance/Control Integration
- **JWG8**** Industrial manufacturing management data
- **JWG15** Enterprise-Control System Integration
- **SC1** Vocabulary and terminology

Advisory Group

SC5 Chair: Emanuel delaHostria (USA)
Contact: ISO/TC 184/SC 5 Secretariat
gre_winchester@nema.org

ISA SP95/**IEC** SC65A

NACFAM E-Manufacturing

- Interoperability problem is more complex because it requires agreement on certain common principles and features before truly interoperable solutions can emerge.
- Solutions must…have the trust and acceptance of the industrial and software communities.
- Requires a mechanism to convene the right decision makers to produce the necessary agreement.

The supply chain effect

- High costs of interoperability particularly impact small and medium sized suppliers
- They often have to maintain redundant and costly software packages in order to communicate with their large EOM customers.
- Large manufacturing companies have pushed costs onto SME's by requiring "standardization" around their preferred systems.

Source: Exploiting E-Manufacturing: Interoperability of Software Systems Used by U.S. Manufactures, NACFAM, Feb. 2001

Industrial Data – SC4

- ISO 10303 - STEP (Standard for the exchange of product model data)
  - EXPRESS language and bindings
  - Conformance and testing
  - Common resources
  - Industry specific application protocols
- Over 100 documents with more coming – including AP233 for system engineering information

STEP success*

- Potential $928 million (2001$) savings per year by reducing interoperability problems in the automotive, aerospace, and shipbuilding industries in US
- ~ 17% ($156 million) of potential benefits quantified within scope of study are being realized
- Expect 75% benefit by 2010

(* 2002 Gallaher study results)

Why STEP succeeds

- Avoidance cost savings accounted for approximately half of the potential benefits of STEP
- 80% of avoidance costs were labor costs associated with the use and support of redundant CAx systems
- Mitigation costs resulting from file transfer and data reentry accounted for the balance of benefits

From data to process

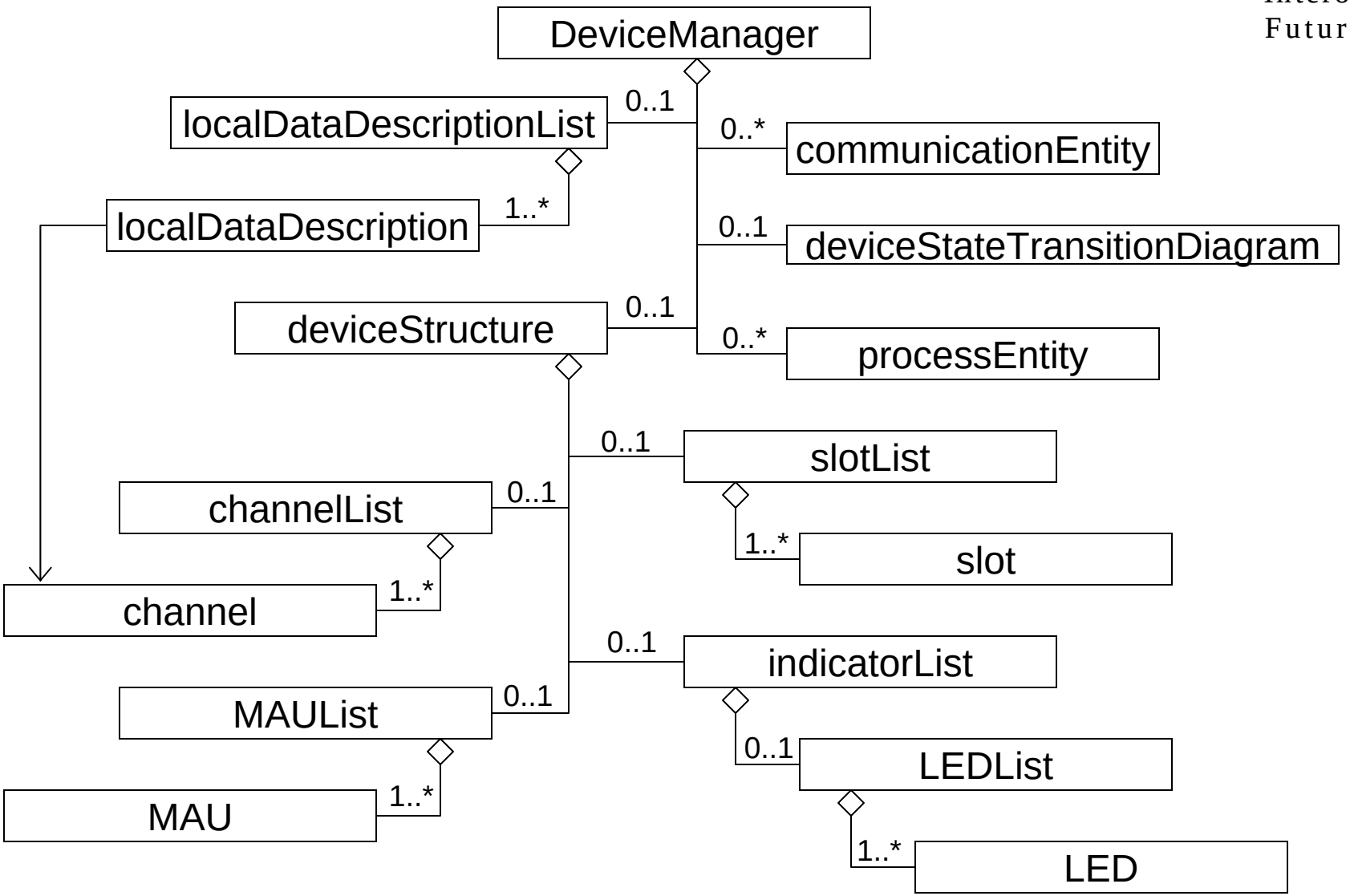
- The STEP domain is primarily data about a product's physical or logical structure
- Whereas SC4 has a data orientation, SC5 has a process orientation – how is the product created?
- SC5 focus is on process interoperability
  - Exchange of process specifications
  - Characterization of process elements
  - Integration of process features

Application integration

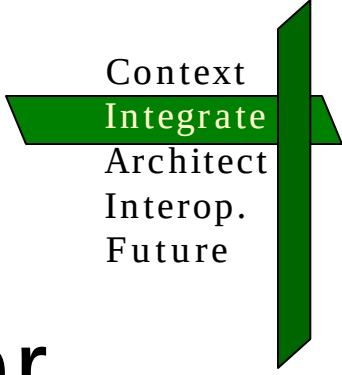
ISO 15745 – Industrial Automation system and integration - Open systems application integration framework

- Framework identifies:
  - Elements and rules for integration requirements using integration models
  - Application interoperability profiles as interface specifications
- UML based integration models
- XML schemas for profile templates

CANopen DeviceManager



Software capability

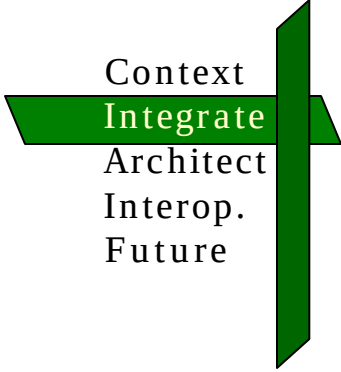


ISO 16100 – Manufacturing software capability profiling for interoperability

- Characterization of software interface requirements
- Software unit capability elements & rules
- IDEF0 process descriptions, UML models and XML profile schemas

"Manufacturing software units shall interoperate with one another, in support of a manufacturing activity, when the services requested by the former can be provided by the latter, using the same operating environment."

Capability classes

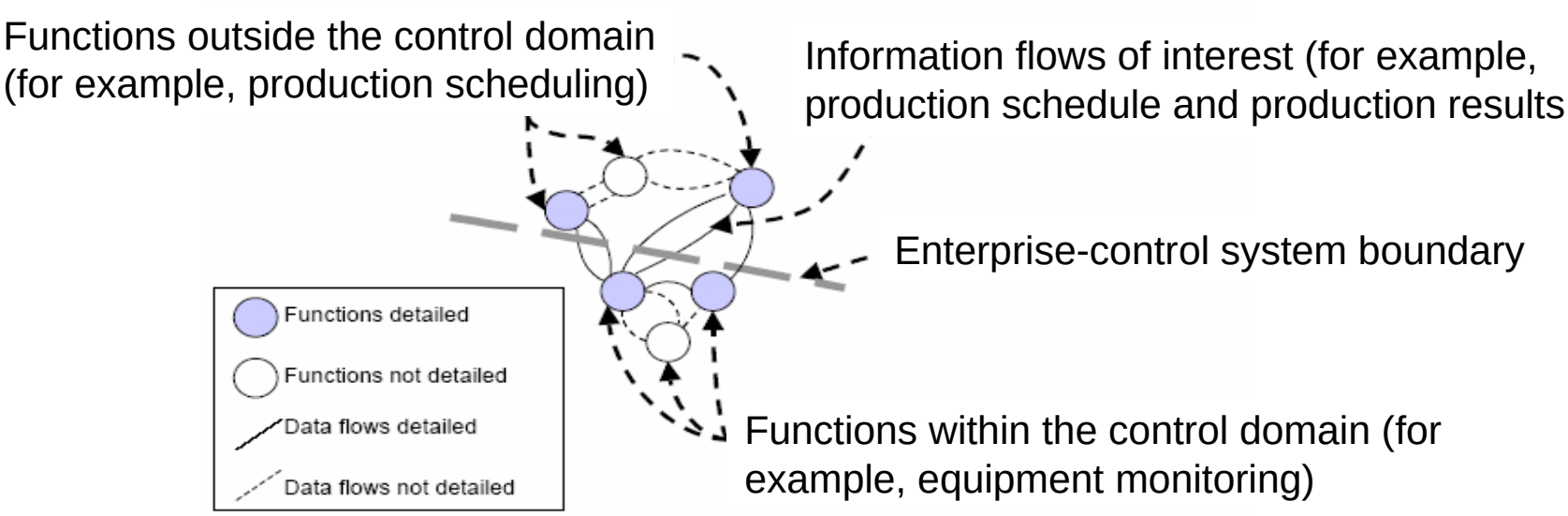


- Manufacturing Capability classes
  - Domain, Application, Information, Process, Resources, Activity, Function, Software Unit
- Software Capability classes
  - Computing system, Environment, Architecture, Design Pattern, Datatype, Interface/Protocol
- Role Capability class

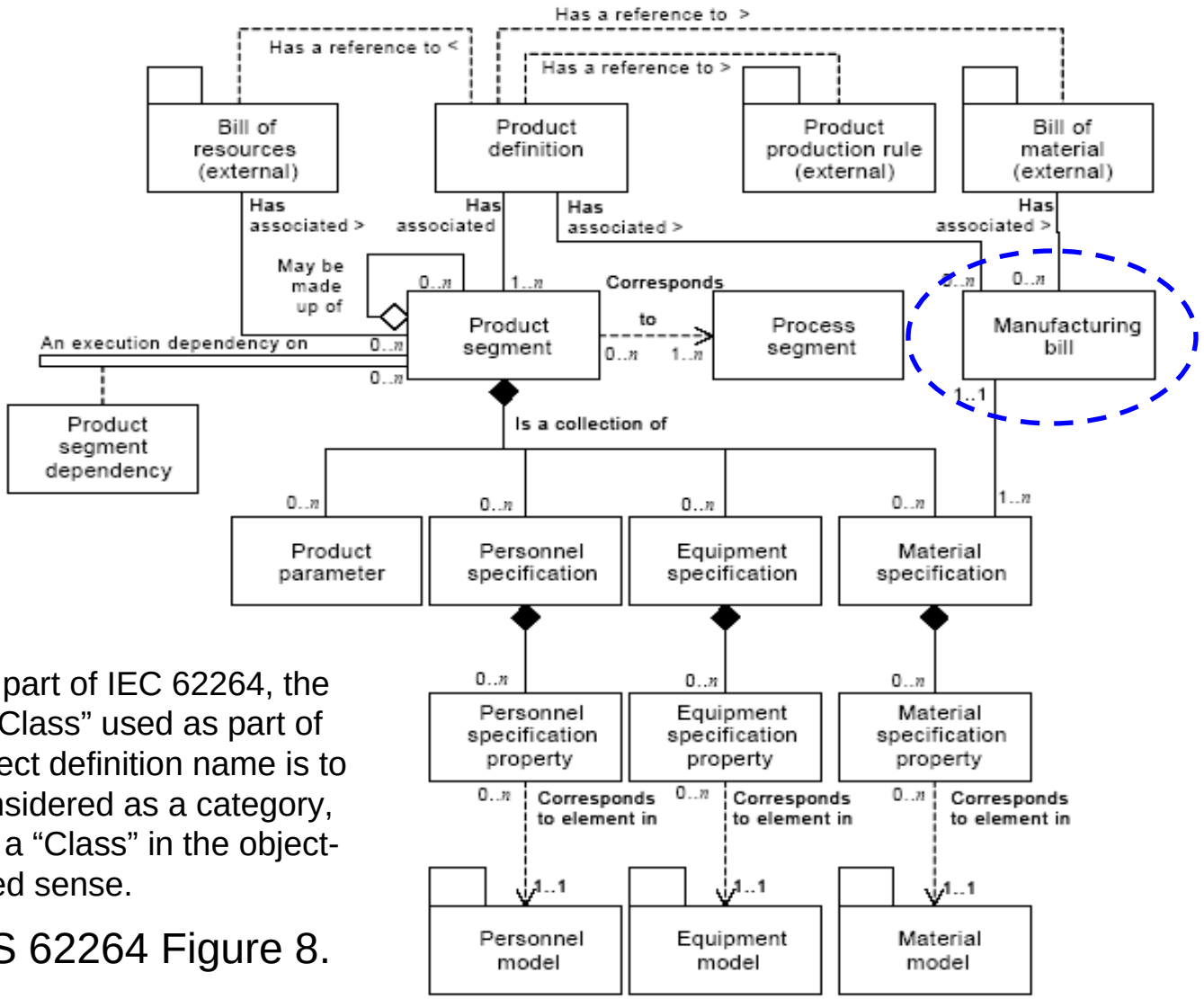
A boundary standard

ISO 62264 Enterprise-control system integration

- Object models for interfaces between enterprise business systems and manufacturing control systems



Product definition model



In this part of IEC 62264, the word “Class” used as part of an object definition name is to be considered as a category, not as a “Class” in the object-oriented sense.

IS 62264 Figure 8.

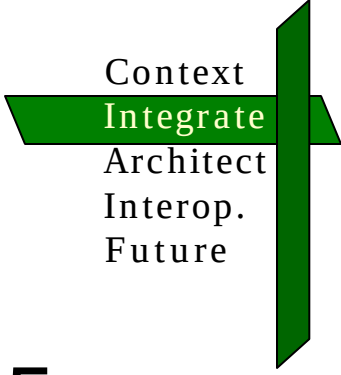
Class model attributes

Table 51 – Attributes of manufacturing bill

Attribute name	Description	Example
ID	A unique identification of a *manufacturing bill*.	10000827
Description	Contains additional information of the *manufacturing bill*.	"All materials required in the manufacturing process for a single widget."
Material class	Identifies the associated *material class* or set of *material classes* required for production. Only the material class or the material property is usually defined.	{Polymer sheet stock 1001A, rivets}
Material definition	Identifies the associated *material definition* or set of *material definitions* required for production.	{Sheet stock 1443a , rivet-10002}
Quantity	Specifies the amount of resources required for production.	{1.0, 26}
Quantity unit of measure	The unit of measure of the associated quantity, if applicable.	{Sheets/piece, number/piece}

Notice in the examples that there is an implied ordering of the set members. The standard makes no provision for enforcement of correspondence for this ordering between attributes.

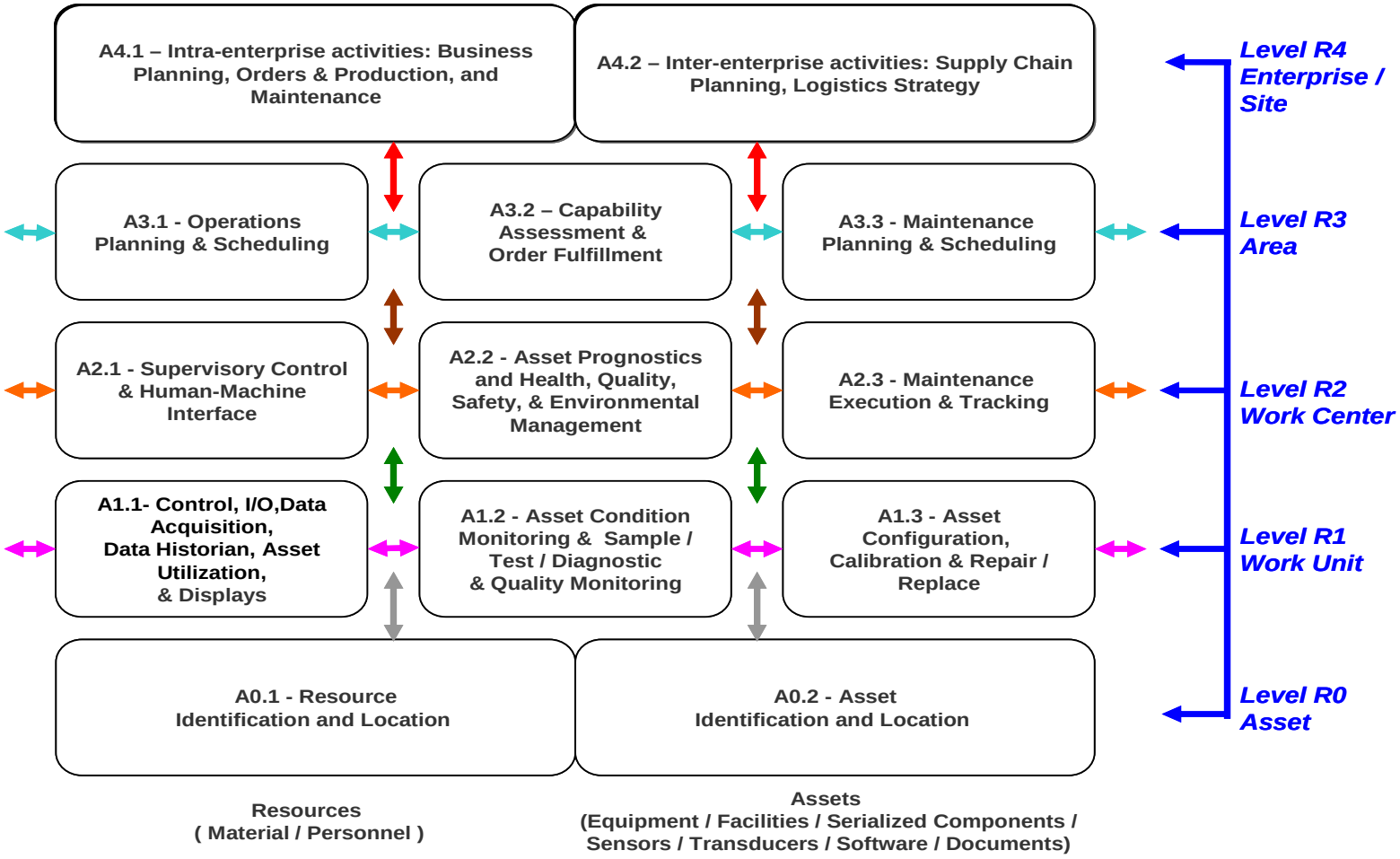
MES & ERP integration



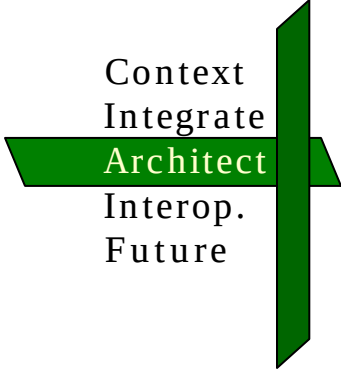
- IS 62264 is better known as ISA95
- Selected by SAP and others as basis for MES to ERP information integration
- But, Part 3 : Models of manufacturing operations, is slower to emerge
- Diversity in implementation results in incompatibility among vendor solutions
- A middle-ware market will evolve

Operation levels

Context
Integrate
Architect
Interop.
Future



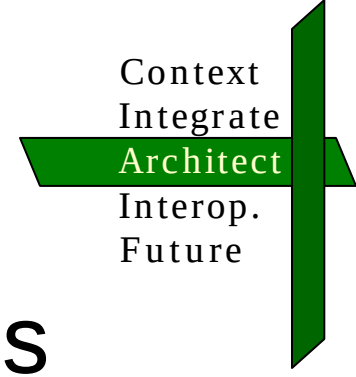
Basic concepts & rules



ISO 14258:1998 Industrial automation systems - Concepts and rules for enterprise models

- Identifies basic concepts for: life-cycle, recursion, and iteration
- Identifies concepts for structure and behavior representation using views
- Places focus of standards for interoperability on inter-process communication.

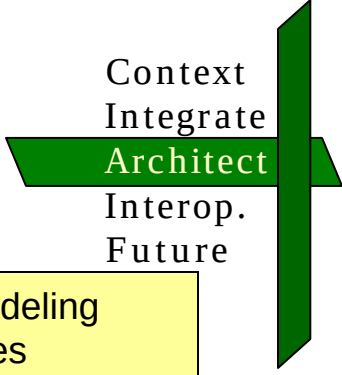
Generalizing standards



ISO 15704:2000 – Requirements for enterprise-reference architectures and methodologies

- Merging of previous work - PERA, IEM, GRAI GIM, CIMOSA, and GERAM
- Presents principles for enterprise architecture
- Extends ISO 14258 with concepts for life history and genericity.

Scope of GERAM



Generalized **E**nterprise **R**eference **A**rchitecture
identifies concepts of enterprise integration

employs

Enterprise **E**ngineering **M**ethodology
describe process of enterprise engineering

utilize

Enterprise **M**odeling **L**anguages
provide modeling constructs for modeling of human role, processes and technologies

implemented in

Generic **E**nterprise **M**odeling **C**oncepts
(Theories and Definitions)
define the meaning of enterprise modeling constructs

support

Enterprise **E**ngineering **T**ools
support enterprise engineering

used to build

Partial **E**nterprise **M**odels
provide reusable reference models and designs of human roles, processes and technologies

Enterprise **M**odels
enterprise designs, and models to support analysis and operation

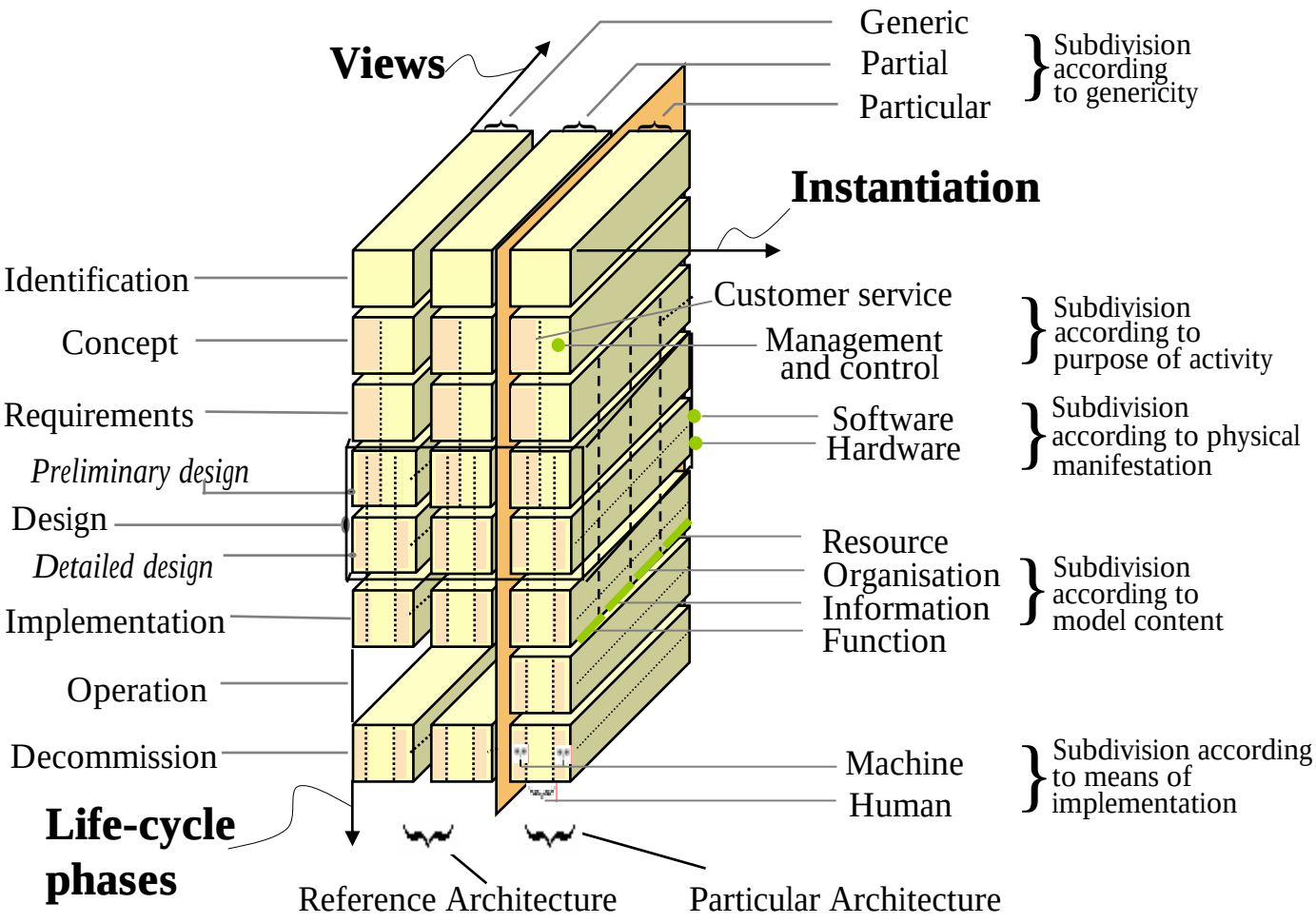
Enterprise **MO**dels
provide implementable modules of human professions, operational processes, technologies

used to implement

Enterprise **O**perational **S**ystems
support the operation of the particular enterprise

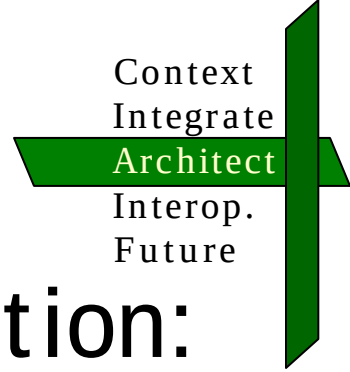
(Adapted from ISO 15704)

GERA framework



Source: ISO 15704:2000 Annex A and Figure 10, The GERA modelling Framework of GERAM [GERAM V1.6.3 http://www.cit.gu.edu.au/~bernus](used with permission)

Unified model framework

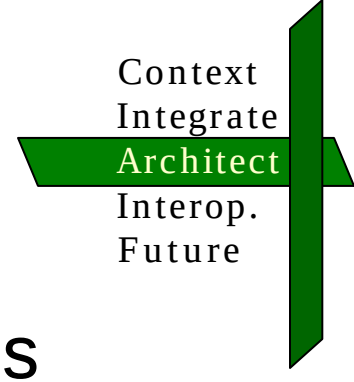


ISO 19439 - Enterprise integration: Framework for enterprise modelling

- Based upon CEN ENV 40003:1990
- Objective is to further enable model based execution using enactable models
- Aligned with IS 15704 (a GERA model)
- Articulates 3 dimensions of enterprise modeling as a framework:

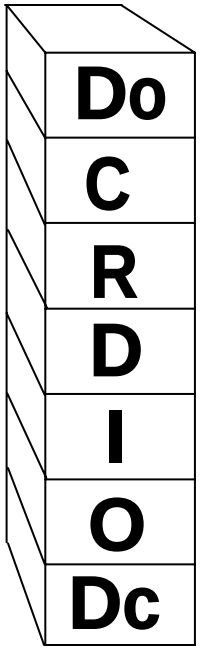
  Phase, View, and Genericity

Model phase -



the purposive ordinant dimension ordered by coordinates corresponding to the phases of the enterprise model life-cycle.

Enterprise **model phase**:



- **Domain** identification
- **Concept** definition
- **Requirements** definition
- **Design** specification
- **Implementation** description
- domain **Operation**
- **Decommission** definition

Identify

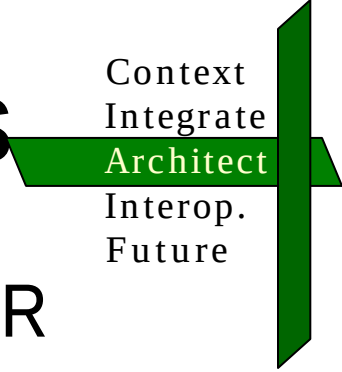
Elaborate

Use

Dispose

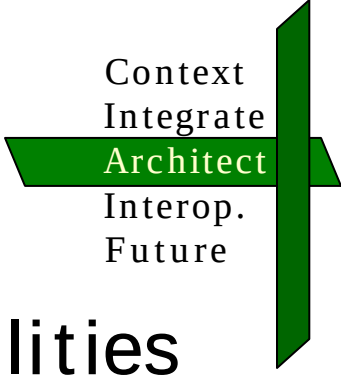
Emphasize model development process for process oriented modeling.

Many possible coordinates



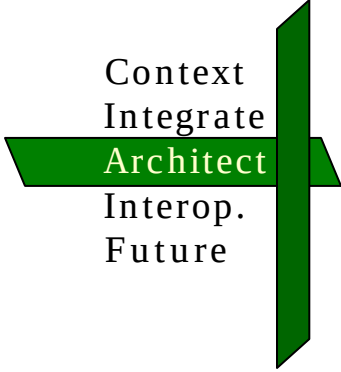
15288 Stage	19439 Phase	C4ISR Guidance
Concept	**Domain**	**Focus**
	Concept	**Scope**
Development	**Requirement**	**Characterize**
	Design	**Determine**
Production	**Implementation**	**Build**
Utilization / **Support**	**Operation**	**Use**
Retirement	**Decommission**	

Early phases



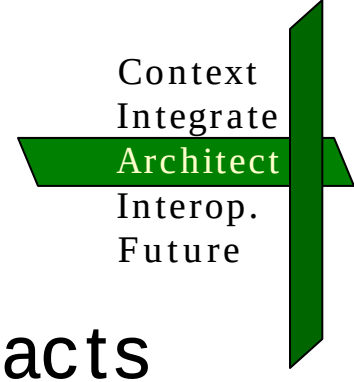
- **Domain identification**
  - Business objectives, functions, capabilities
- **Concept definition**
  - Enablers of objectives & operations
  - Means for achievement of functions & capabilities
- **Requirements definition**
  - Functional, behavioral, informational, and capability for service, manufacturing, management and control
- **Design specification**
  - Processes with all components necessary to satisfy requirements

Post-design phases



- **Implementation description**
  - All information needed for all tasks of operational system
- **Domain operation**
  - Operational usage of model released from implementation
- **Decommission definition**
  - Tasks and resources for retraining, redesign, recycling, preservation, transfer, disbanding, disassembly, disposal

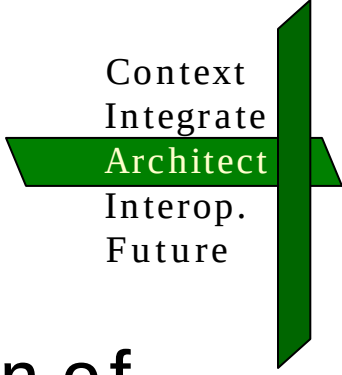
Model View -



an unordered ordinant dimension with pre-defined coordinates that partition facts in the unified model relevant to particular interests and context.

- A prescriptive partition of model content with distinct aspects considered sufficient for most discrete manufacturing
- View content varies with life-cycle model phase
- Function, Information, Resource, and Organization views

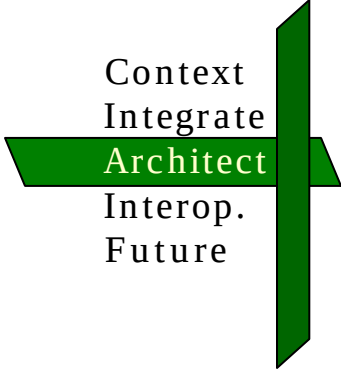
Function view of 19439



Function

- Enables representation and modification of the processes of the enterprise, their functionalities, behaviors, inputs and outputs
- Emphasis on system behavior, mutual dependencies, and influence of elements during function execution
- Includes decisional, transformational and support activities
- Identifies all entities (material, information, resources and control) required for function execution

Other views of 19439



Information

- The material and information related objects used and produced in the course of operations

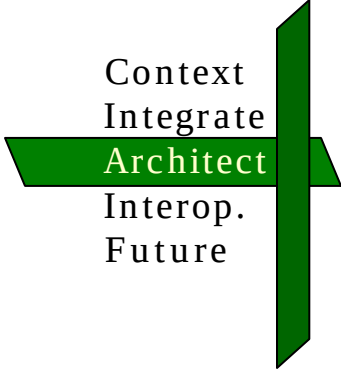
Resource

- Capabilities of people and technological component assets

Organization

- Authority and responsibility during operations
- Expresses decision support structure

Model Genercity -



an ordered ordinant dimension that reflects 19439 as a "standard" framework.

Enterprise **genericity level**:

- **Generic** - reusable modeling language constructs
- **Partial** - prototype models of industry segment or industrial activity

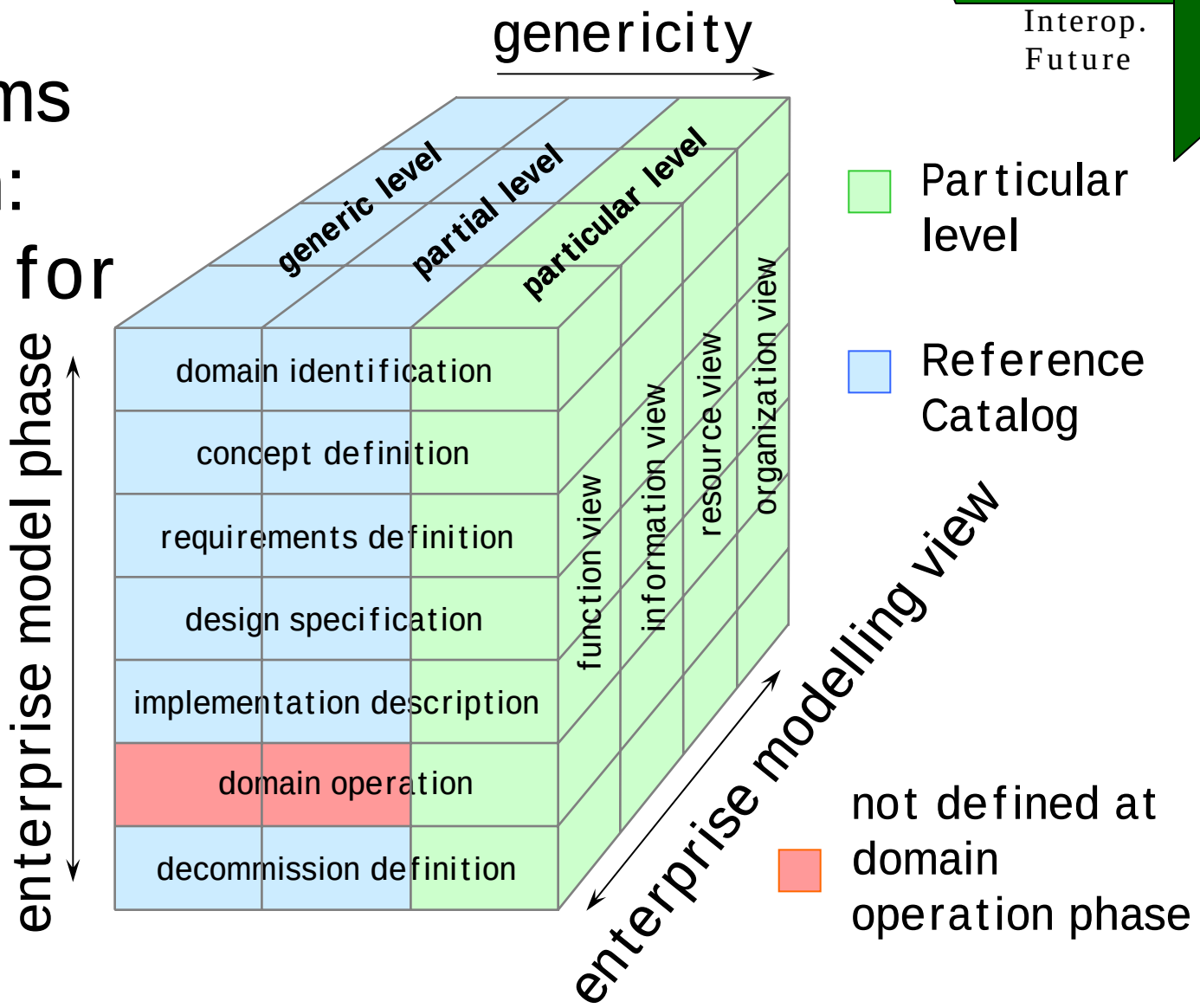
Reference catalog

- **Particular** - models of a particular enterprise domain

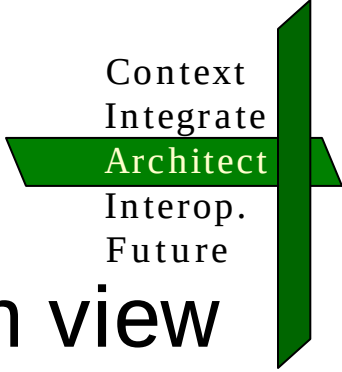
Graphic 19439 dimensions

Context
Integrate
Architect
Interop.
Future

CIM Systems Integration: Framework for Enterprise Modelling

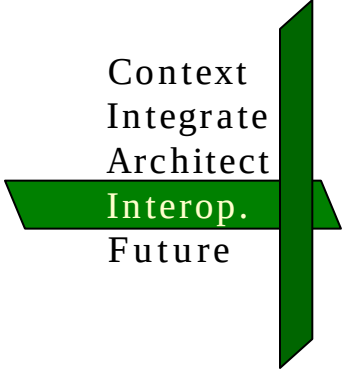


Conformance to 19439



- Shall have function and information view
- Shall be able to derive resource and organization view
- Shall provide distinct model phases
- Shall provide for derivation of partial and particular model from generic constructs
- Shall propagate model changes to all views

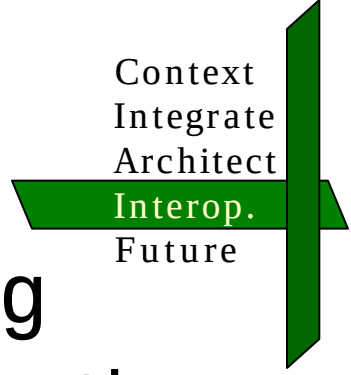
Modelling constructs



ISO/DIS 19440 Enterprise integration – Constructs for enterprise modelling

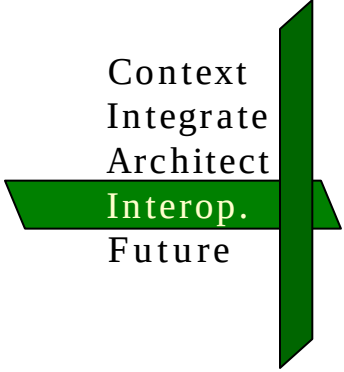
- Based upon CEN ENV 12204:1996
- Aligned with 15704 (an EML artifact)
- Articulates modeling constructs for manufacturing automation
- Elaborates the CIMOSA Baseline example of 19439 with constructs

ISO/DIS 19440 (cont.)



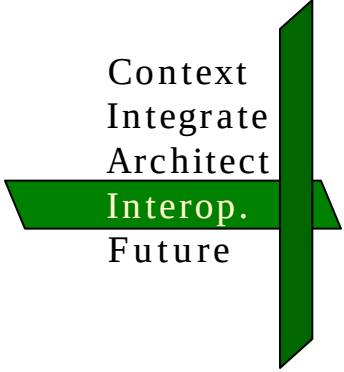
- Constructs for enterprise modelling
  - common semantics enable model unification
  - usable across phases of model development
  - support process-oriented approach
- Arrangement and specialization using templates into structures for a specific purpose
- No mapping between functional operations and capabilities
- No explicit versioning mechanism

Construct template



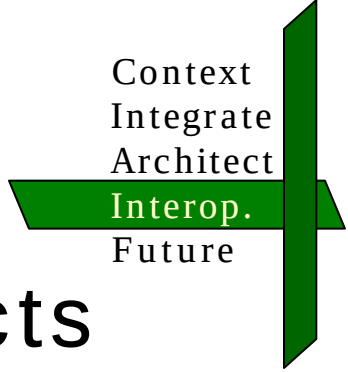
- Common format
  - Header
    - Type label
    - Identifier unique to model
    - Name
    - Authority for design of construct
  - Body
    - Descriptives in textual form
    - Relationships specified by reference

Construct descriptives



- Predefined for each construct
- User-defined by extension
- May be qualified (e.g. mandatory or optional)
- Possibly XML schemas or EXPRESS notation
- Attributes
  - Name (meaningful in domain)
  - Data type (simple or complex)
- Complementary Concepts

Complementary concepts

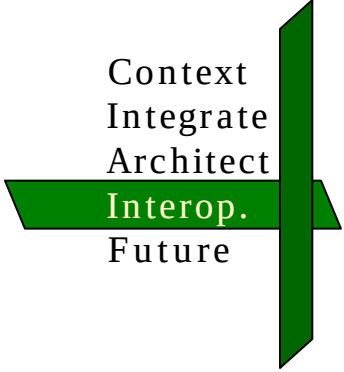


are not fully developed as constructs but have particular significance and semantics for the purpose of enterprise modeling

- Behavior rule
- Constraint
- Declarative rule

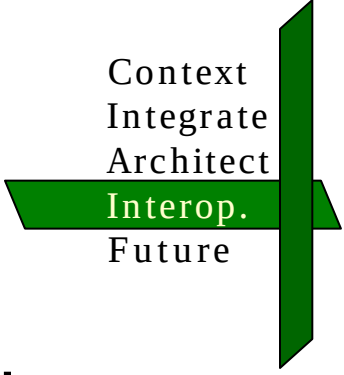
- Functional operation
- Integrity rule
- Objective
- Performance indicator

Construct relationships



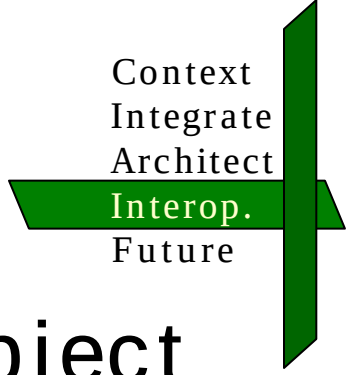
- Model the dynamics between run-time instances
- Types of relationship
  - Operational authority and responsibility
  - Membership in specialization
  - Part of an aggregation
  - Consist of an aggregation
  - Other associations
- Possibly reflexive

Construct and roles



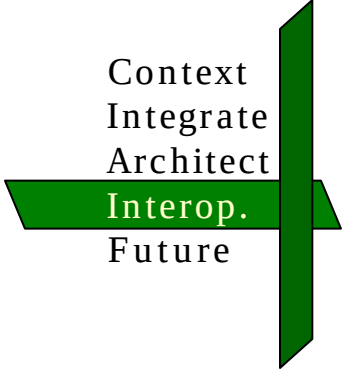
- Human organizational role captures assigned responsibilities and required capabilities (skills)
- Human operational role captures the operational capabilities of person assigned to a task
- Machine operational role captures the operating capabilities of machine assigned to a task
- Machine product role captured by attributes that describe input and output of activities to change state.

Constructs of 19440



Domain	Enterprise Object
Business Process	Object View
Enterprise Activity	Product
Event	Order
Resource	Operational Role
Functional Entity	Organizational Unit
Capability	Organizational Role
Person Profile	Decision Centre

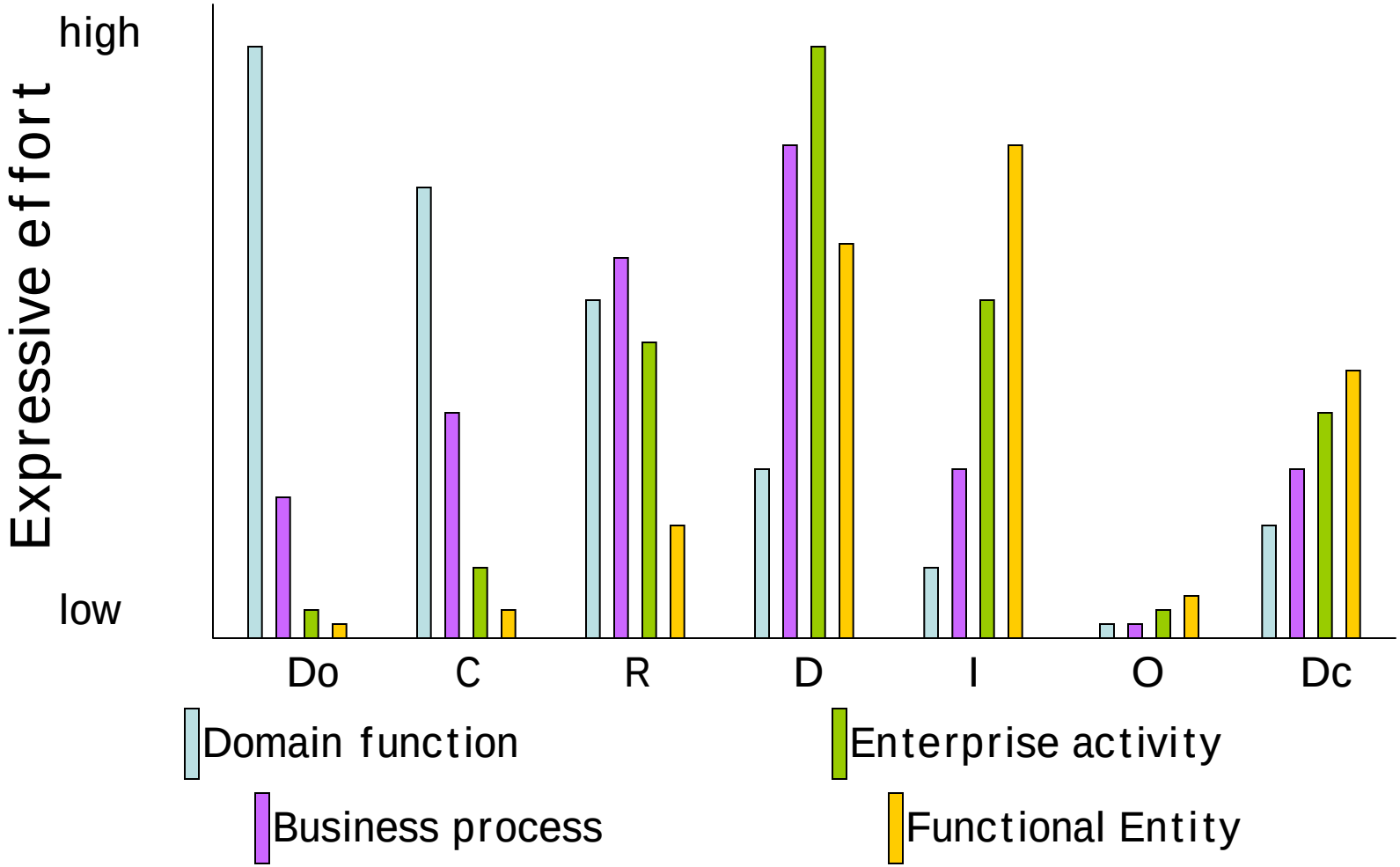
Construct across phases



Construct label	EO (Enterprise Object)
Identifier	<model-unique string>
Name	name of the Enterprise Object instance
Design Authority	[<identifier> "/" <name>] of Organizational Role or Organizational Unit with authority to design or maintain this particular instance
Body ***A1 Descriptives relevant for all enterprise model phases***	
Description	short textual description
Nature	PHYSICAL | INFORMATION
Attributes	[<property_name><property_value>]* – elements representing properties and their values for the entity represented by the Enterprise Object instance
Constraints	[<constraint>]* imposed on selected named Attributes of the Enterprise Object instance
A2 Descriptives relevant for different enterprise model phases	
A2.1 applicable at concept definition and later phases	
Not applicable	
A2.2 applicable at requirements definition and later phases	
Integrity Rules	[<integrity rule>]* applicable to ATTRIBUTES of the Enterprise Object instance in the requirements definition phase

Life-cycle expression

Context
Integrate
Architect
Interop.
Future



Process behaviour

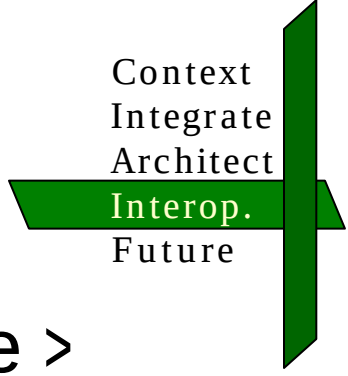
- "shall be described in its behavioural rule set attribute by a set of *behavioural rules*, which control the sequence of constituent Business Processes and Enterprise Activities."
  - well-structured is completely defined
  - semi-structured is known at run-time
  - ill-structured is non-deterministic

Behaviour rules

- Shall enable
  - the capturing of all the conditions that control the sequencing and the dynamic behaviour of Business Processes
  - their presentation in both human and machine understandable form
- Apply only to Business Processes

  (internal behaviour of an Enterprise Activity, the sequencing of its set of *functional operations,* is considered to be an implementation issue)

Formal syntax in BNF



<behavioural rule set> ::=

<behavioural rule set> | <behavioural rule >
<behavioural rule set> ;

<behavioural rule> ::=

WHEN" "<situation>" "DO" "<action> ";" ;/* a behavioural rule is terminated with a semicolon */

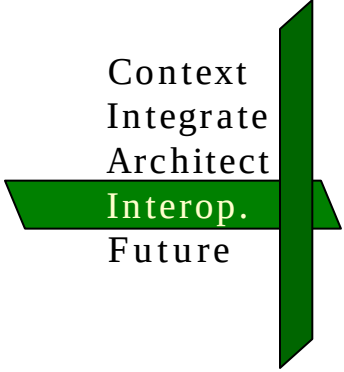
<situation> ::=

<condition> | <and_condition_set>;

<and_condition_set> ::= /* and-rendezvous */

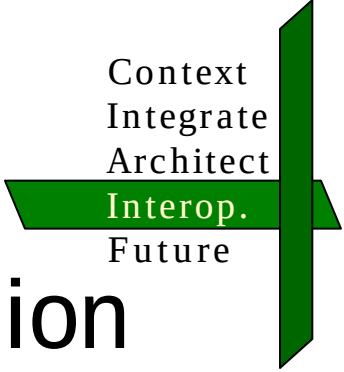
<condition> | <condition>" "AND" "<and_condition_set>;

Conformance to 19440



- Shall either use the constructs as defined or be able to map to the constructs
- Can claim qualified compliance by using a subset of constructs or mapping to a subset of constructs
- Be a valid construction of a compliant modeling language
- Shall identify construction and model execution testing levels

Process description

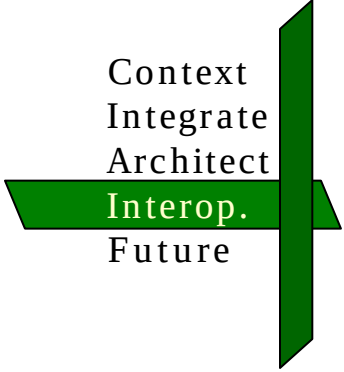


ISO 18629 - Industrial Automation system and integration – Process specification language

- TC184 SC4/SC5 collaboration in JWG8

- Target is process information exchange
- Process information representation
- Process and model independence
- Lexicon, ontology, and grammar form PSL
- Different approach than ISO 10303
- 8 documents in various approval stages

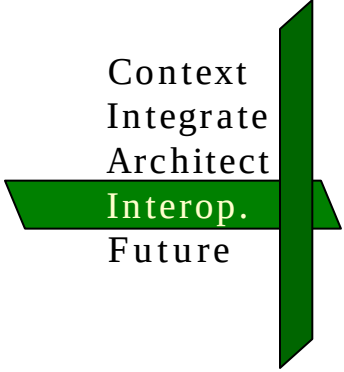
A very ‘formal’ process




```
(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))))
```

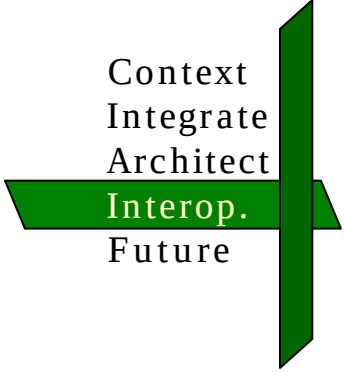
(Source: ISO/CD18629-44 Annex B)

Modeling challenges - 1



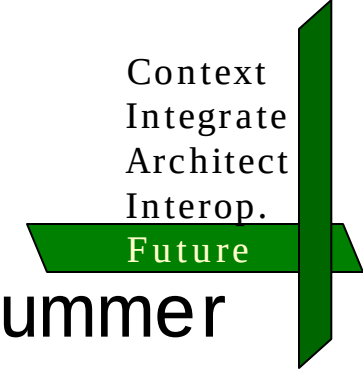
- Operationalizing the constructs
  - Representing the same thing at different phases as a unified construct: the endurant vs. perdurant distinction
  - Transforming the behavioral rules of a business process into executables
  - Maintaining proper relationships as constructs are decomposed along life-cycle
  - Ensuring consistency of aggregations and Complementary concept use

Modeling challenges - 2



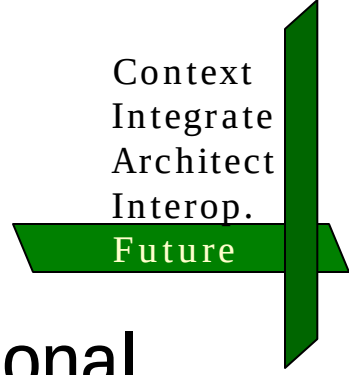
- Identifying tool ready meta-models
  - Validate the meta-model of Annex B
  - A robust meta-model for Object View creation and use in real-time
  - Matching required functional operations with capabilities of a Functional Entity
- Transcribing existing partial models into 19440 terms and syntax
- Articulating a methodology for use

Future actions



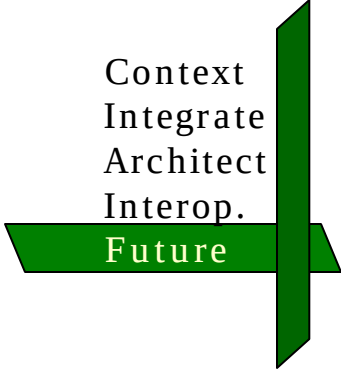
- ISO/FDIS 19440 to enter ballot this summer - comment resolutions to occur 2006 – 2007 & publication in 2007
- ISO 15704 systematic review begins this summer with revision target 2008
- NWIP for System integration using process modeling methods consistent with a reference methodology
- NWIP for Requirements for enabling enterprise interoperability in manufacturing-enterprise processes and their models

NWIP Process Integration



- This standard specifies those informational characteristics that a process model must exhibit in order to enable:
  1. assessment of manufacturing process efficiency
  2. support process improvement
  3. extraction of process operational information relevant to process performance
  4. enhance comprehension and communication between enterprise manager, process experts, and process analyzer.

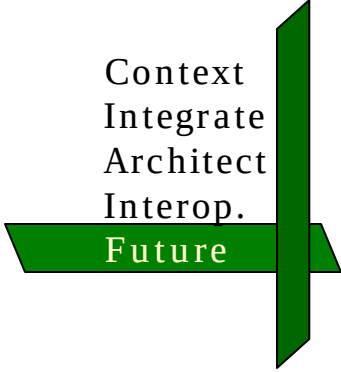
Process characterization



- **Requirements**
  - Characterization of processes

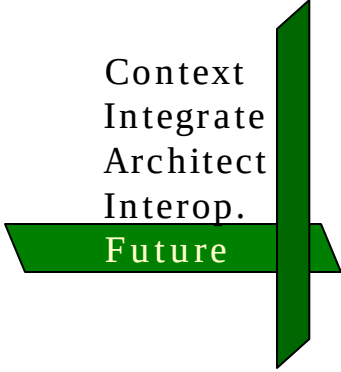
Inputs	Activities
Outputs	Logical decisions
Logical relationships/rules	Time and sequence
Resources	Mechanisms/Control
Organizational role	MoE/MoP
Process categories	Process hierarchy
Recursive notations	Object state transition
Context/scenario	Exceptions
Transactions	Process evolution
Documentation	

Only conceptual integration



- Does not include descriptions of process composition or otherwise aggregate into larger frameworks or architectures.
- Not a process characterization language but rather characterizes the range of processes so that suitable languages are developed to support process characterizations.

NWIP
Enterprise interoperability



- Establishes a base for interoperation in unified, integrated and federated operational environments of manufacturing enterprises
- Defines an interoperability framework and specifies processes and underpinning metadata that must be in place to establish or to negotiate and enable enterprise-interoperability solutions for Manufacturing-Enterprise-Processes (MEPs) and their models
- Focus on enabling the communication rather than defining the communication itself

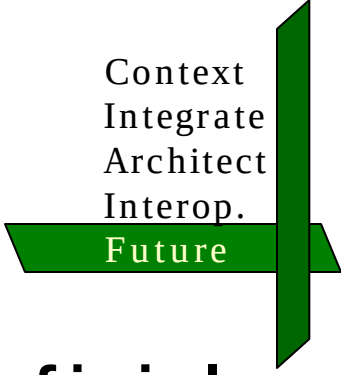
Interoperability Framework

- Interoperability framework defines operational levels (data, service, process, business) of the enterprise at which interoperability is anticipated
- Identify conceptual, technical, and organizational barriers to interoperability at these enterprise levels that currently exist
- Solutions to overcome those barriers are presented as parts of this standard.

Interoperability approach

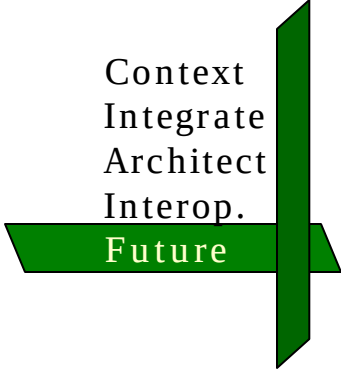
- Unified and Integrated
  - Have common meta-model and representation (19439 & 19440)
  - Allow normative requirements to barrier solutions
- Federated
  - Require *a priori* knowledge about information to exchange
  - Require more elaborate negotiation

Collaboration



- Identify aspects of ISO work beneficial to BMIDTF efforts
- Submit BMIDTF work products as input to ISO working groups in TC184/SC5 and perhaps ISO/IEC JTC1
- Formalize liaisons or identify appropriate representatives to allow comment submissions

Future SC5 Efforts



- Simulation tool integration requirements and criteria
- Use case for multiple standard use
- Coordinated asset registry
- Activity integration across levels
- Terminology harmonization
- Database of software unit capability
- Automation security