Tinwisle Corporation

Interoperation in Industrial Automation: an ISO viewpoint

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Convener ISO TC 184/SC 5/WG 1

Interoperation in Industrial Automation: 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 and robotic devices

- **PT1** Revision of ISO 10218

SC 4
Industrial Data

- **PPC** Policy & planning committee
- **QC** - Quality Committee
- **WG2** Standard parts library
- **WG3** Product Modeling
- **JWG8**** Manufacturing process and management information
- **WG11** Express language, implementation methods
- **WG12** Common resources
- **WG13** Industrial data quality

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**** Manufacturing process and management information
- **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

SC5 Working Groups

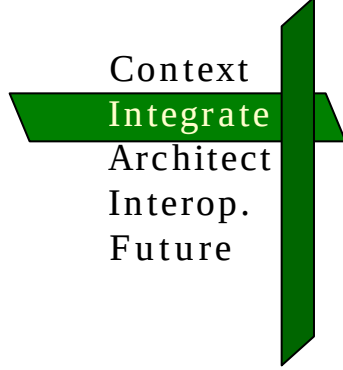
Context
Integrate
Architect
Interop.
Future

- WG1 – Richard Martin (USA)
- WG4 – Michiko Matsuda (Japan)
- WG5 – Graeme Meyer (New Zealand)
- WG6 - Robert Patzke (Germany)
- WG7 – Charles Hoover (USA)
- JWG8 – Jean-Jacques Michel (France)
- JWG15 – Dennis Brandl (USA)

Interoperability approaches

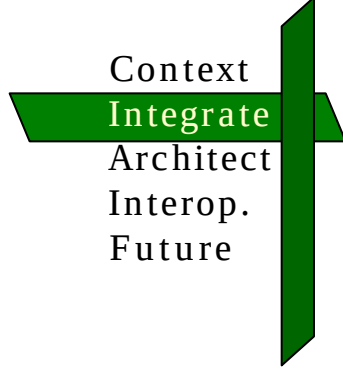
- **Integrated** – common format for all models agreed by all parties necessary
- **Unified** – common format at a meta-level to enable mapping between models using semantic equivalence
- **Federated** – no common format requires accommodation through a shared ontology

SC5/WG6



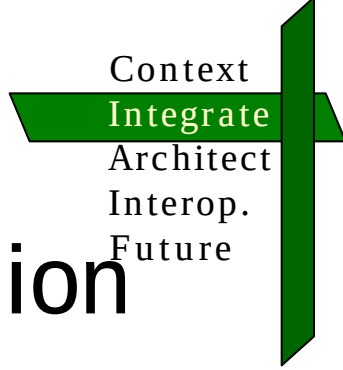
- ISO 20242 a series of 6 parts:
  - Overview of **Service Interface** for Testing Applications
  - Resource Management Service Interface
  - **Virtual Device** Service Interface
  - Device Capability Profile Template
  - Application Program Service Interface
  - Conformance test methods
- First is published, 2nd in CD
- Strong link to **ASAM GDI** specifications

SC5/WG 5



- ISO 15745 series of 5 parts: Generic description and 4 specific to shop floor communication protocols
- Uses a framework and profiles approach
- Work now complete with last amendment approved recently
- Systematic reviews will begin 2009

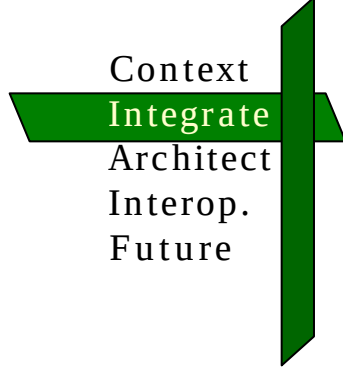
Application integration



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

SC5/WG4

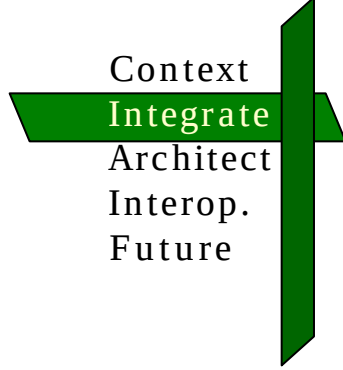


ISO 16100 Manufacturing software capability profiling for interoperability series of 5 parts:

- Framework description (ISO 15745 kind)
- Profiling Methodology
- Interface protocols
- Conformance testing
- Profile matching methodology

- First 4 published

Software capability

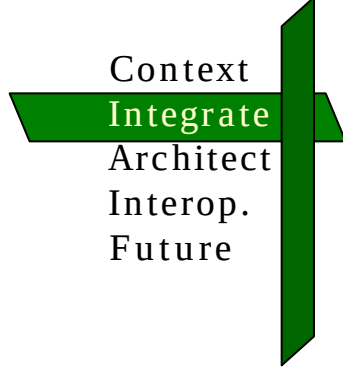


ISO 16100 –

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

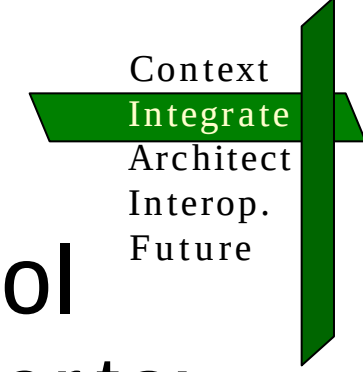
"Manufacturing software units shall interoperate with one another, in support of a manufacturing activity, when the services requested by the former can be provided by the latter, using the same operating environment."

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

SC5/JWG15

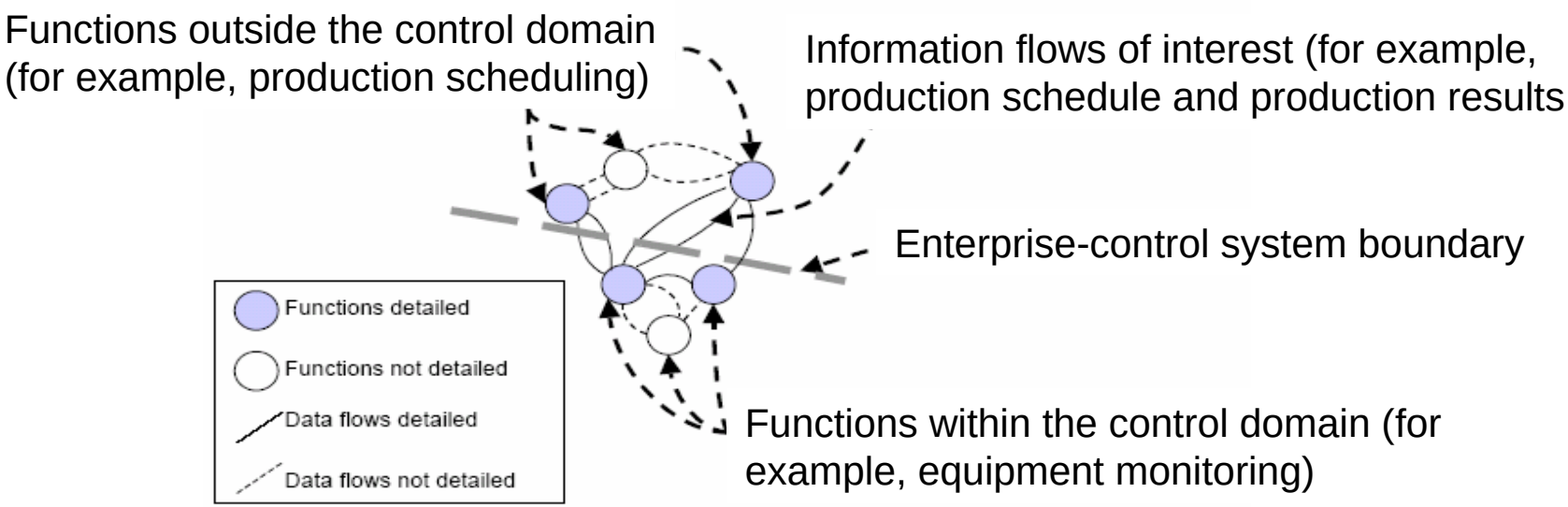


- ISO/IEC 62264 Enterprise-control system integration series of 5 parts:
  - Models and terminology
  - Object models and attributes
  - Activity models of manufacturing operations management
  - Object models and attributes of manufacturing operations management activities
  - Business to manufacturing transactions
- First 3 parts published

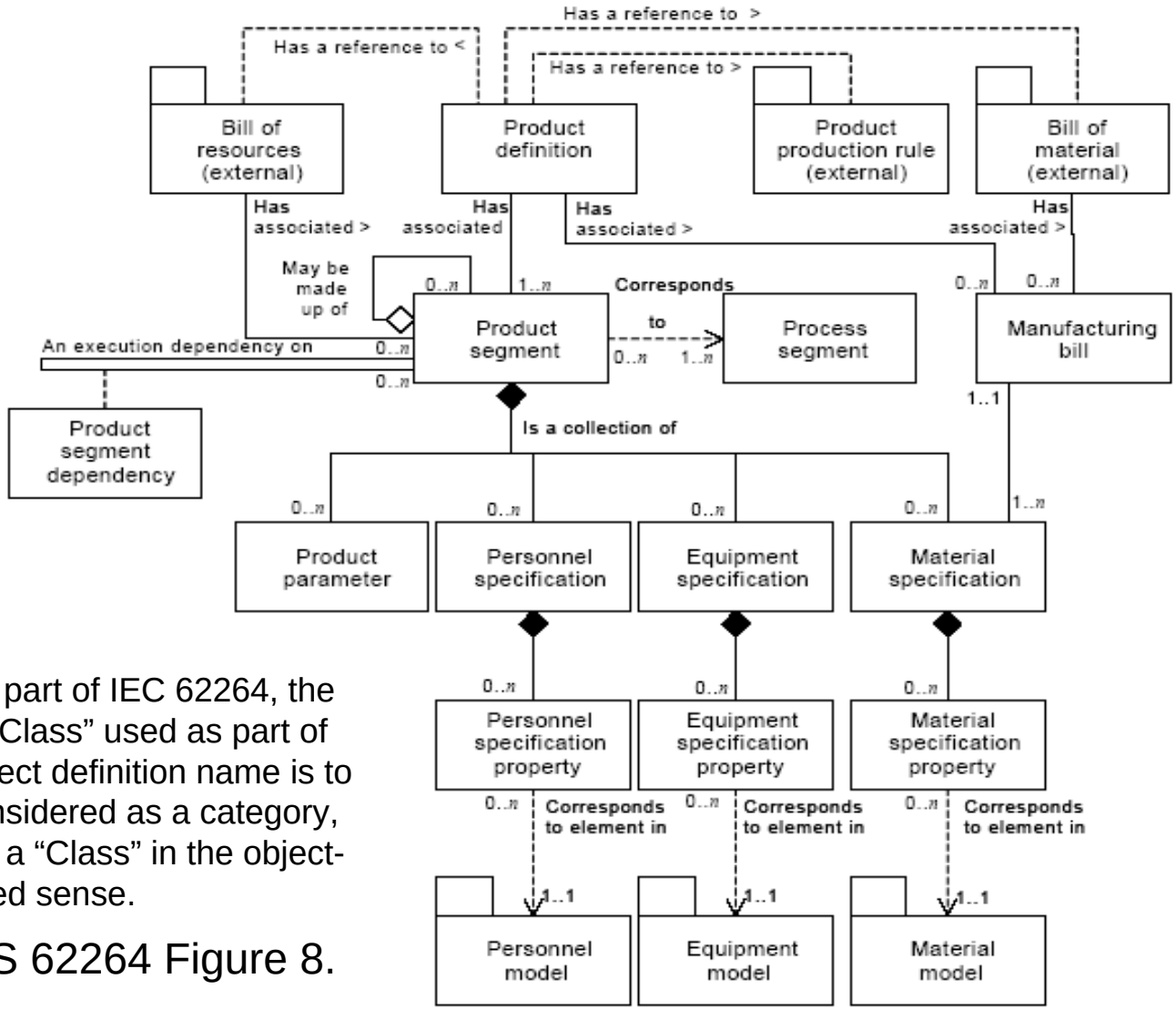
A boundary standard

ISO/IEC 62264 Enterprise-control system integration

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



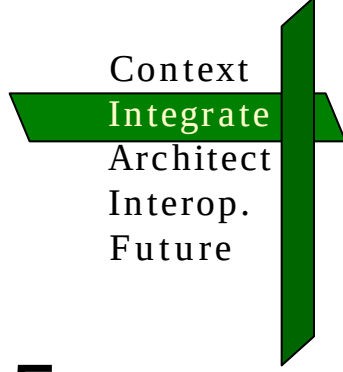
Product definition model



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.

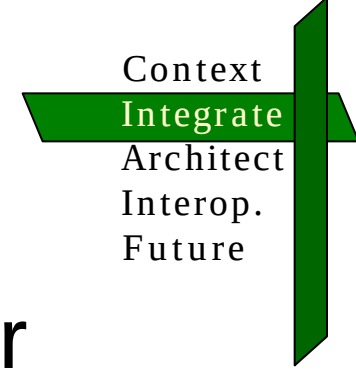
IS 62264 Figure 8.

MES & ERP integration



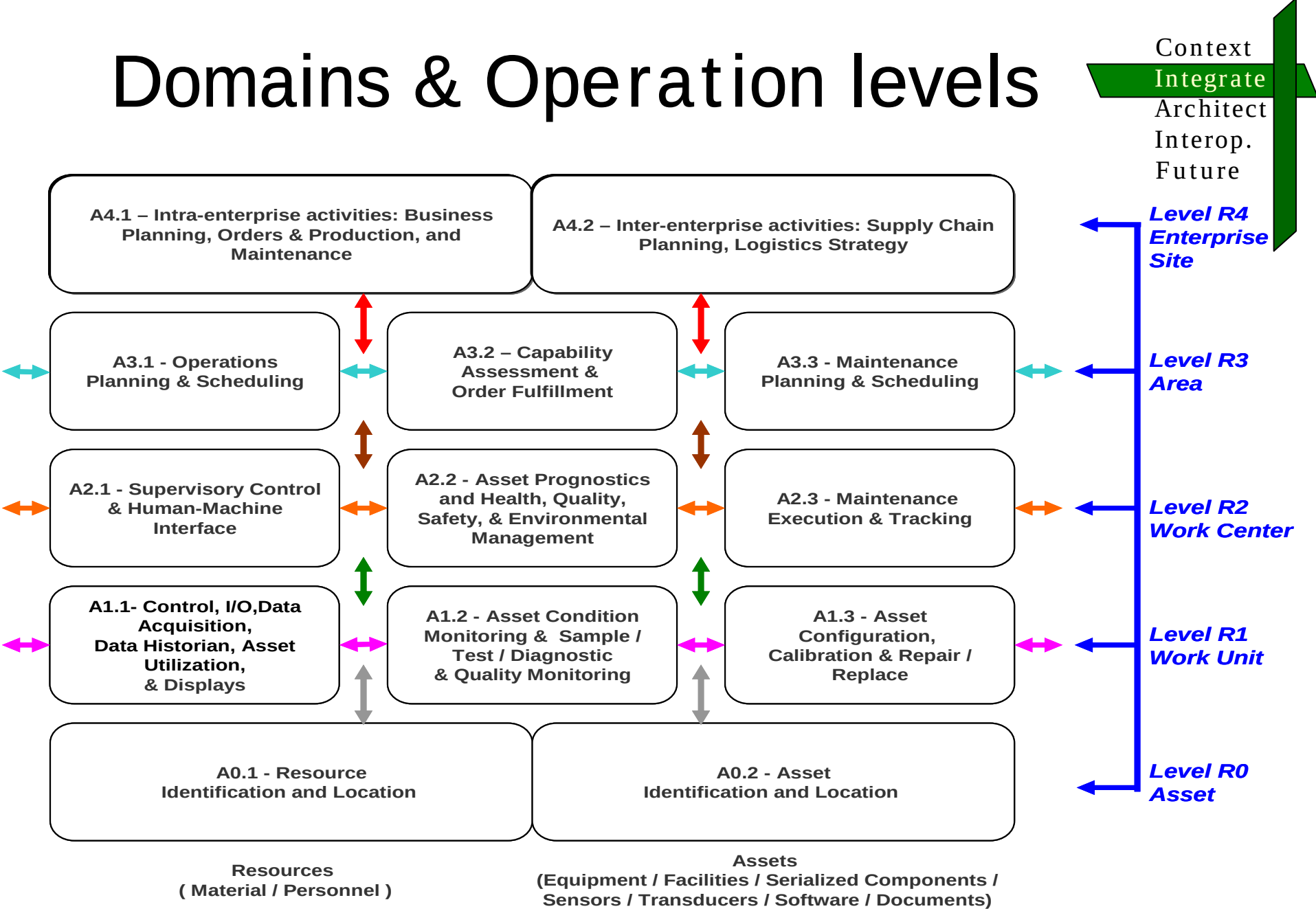
- IS 62264 is better known as ISA95
- Selected by SAP and others as basis for MES to ERP information integration
- Part 4 and 5 are slower to emerge
- Diversity in implementation results in incompatibility among vendor solutions
- A middle-ware market will evolve

SC5/WG7

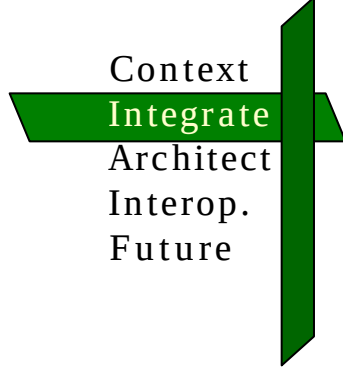


- ISO 18435 a series of 3 parts for diagnostic and maintenance of manufacturing assets:
  - Overview and general requirements
  - Descriptions and definitions of application domain matrix elements
  - Application integration description methods
- First is in CD stage
- Strong link to MIMOSA OSA

Domains & Operation levels

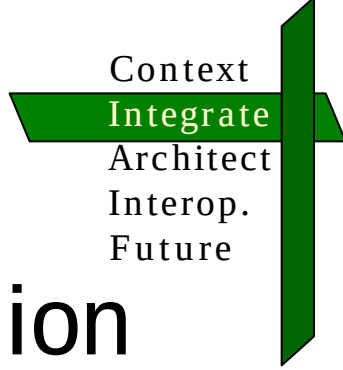


SC5/JWG8



- An SC4 lead joint effort
- ISO 15531 (MANDATE) series of 5 parts related to resource and flow management data
- ISO 18629 (PSL) series of 9 parts
- Current work items complete

Process description

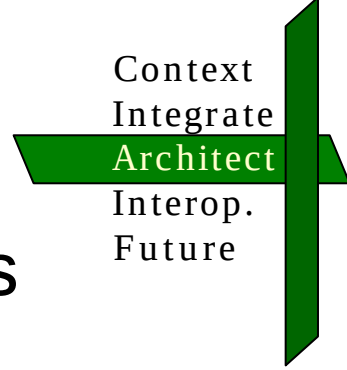


ISO 18629 - Industrial Automation system and integration – Process specification language

- TC184 SC4/SC5 collaboration in JWG8

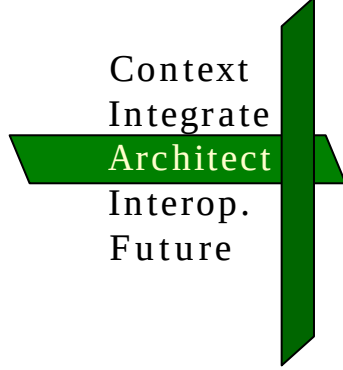
- Target is process information exchange
- Process information representation
- Process and model independence
- Lexicon, ontology, and grammar form PSL
- Different approach than ISO 10303

SC5/WG1



- **ISO 14258:1998** – Concepts and Rules
- **ISO 15704:2000** – Requirements for enterprise-reference architecture and methodology
- **EN/ISO 19439:2006** – Framework for enterprise modeling
- **EN/ISO/FDIS 19440** – Constructs for enterprise modeling
- **ISO/CD 27387** – Characterization of model-based manufacturing processes
- **NWIP** – Requirements for manufacturing enterprise process interoperability

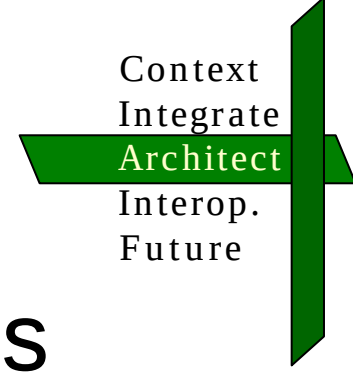
Basic concepts & rules



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.

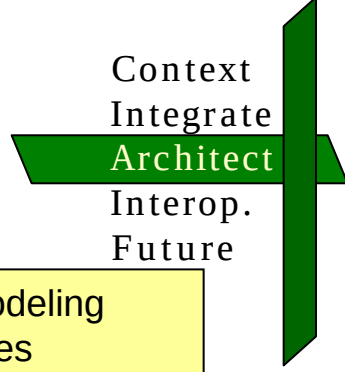
Generalizing standards



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

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

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

employs

utilize

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

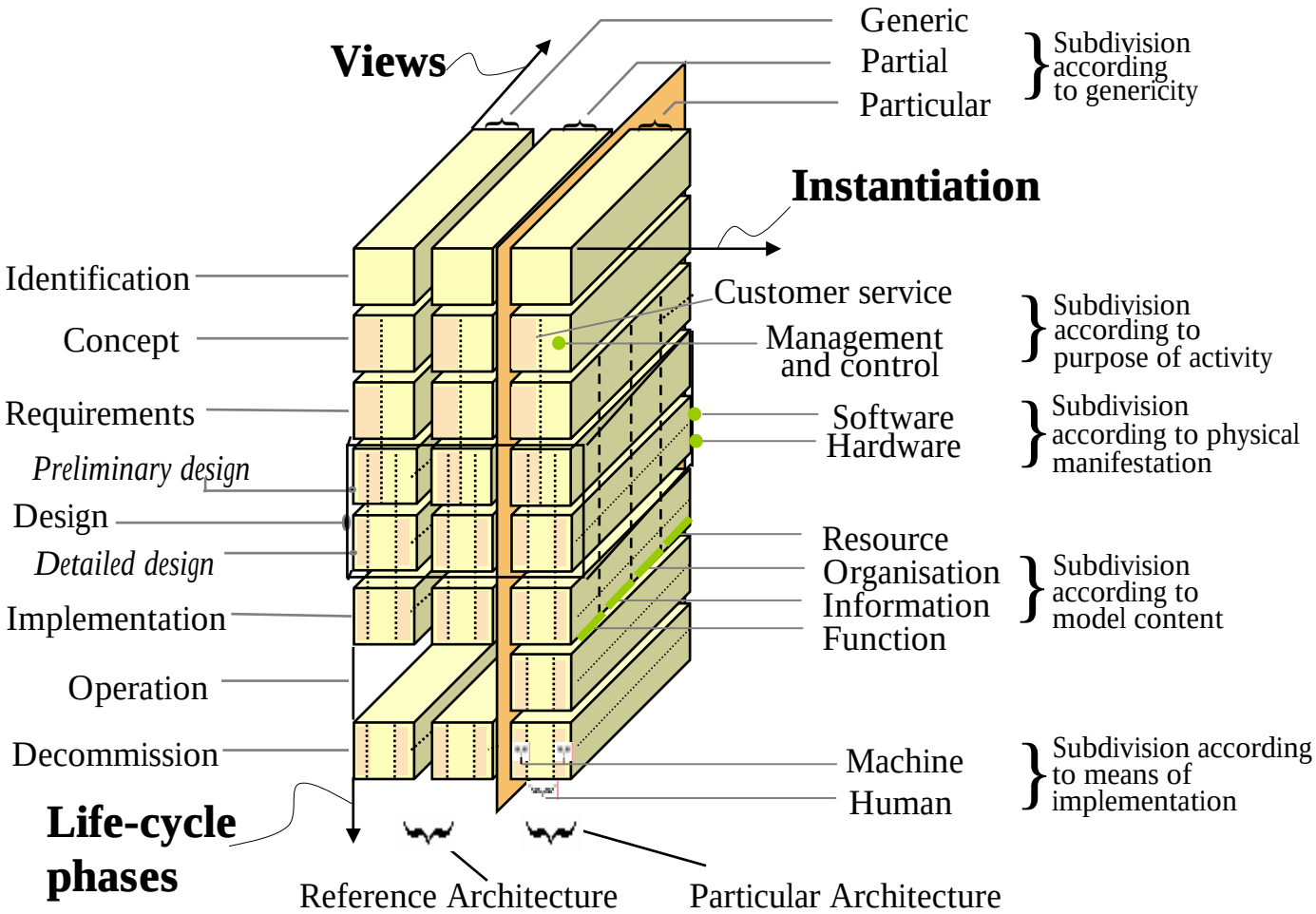
Enterprise **MO**dels
provide implementable modules of human professions, operational processes, technologies

used to implement

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

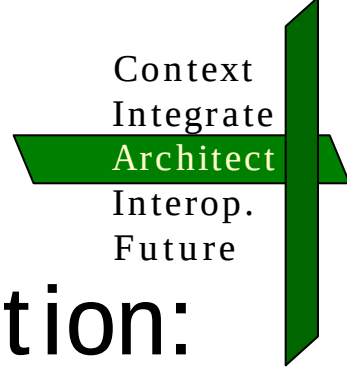
(Adapted from ISO 15704)

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

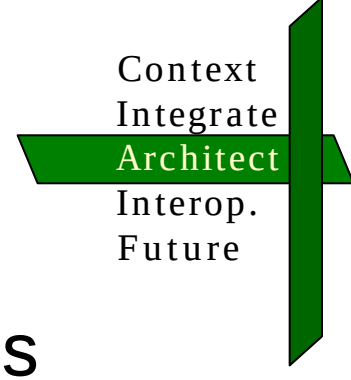


ISO 19439 - Enterprise integration: Framework for enterprise modelling

- 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:

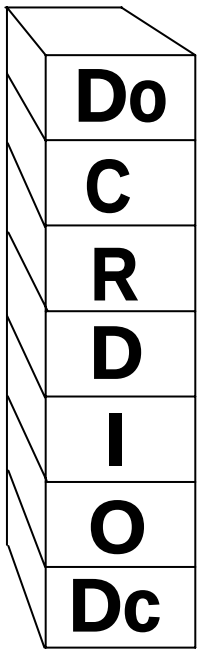
  Phase, View, and Genericity

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

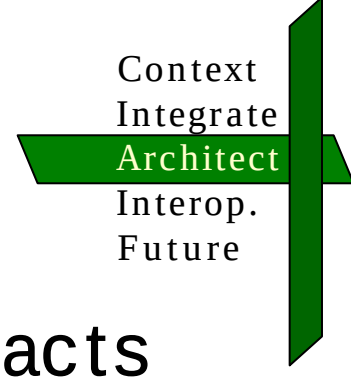
Elaborate

Use

Dispose

Emphasize model development process for process oriented modeling.

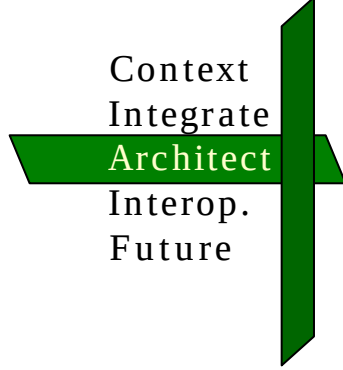
Model View -



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

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

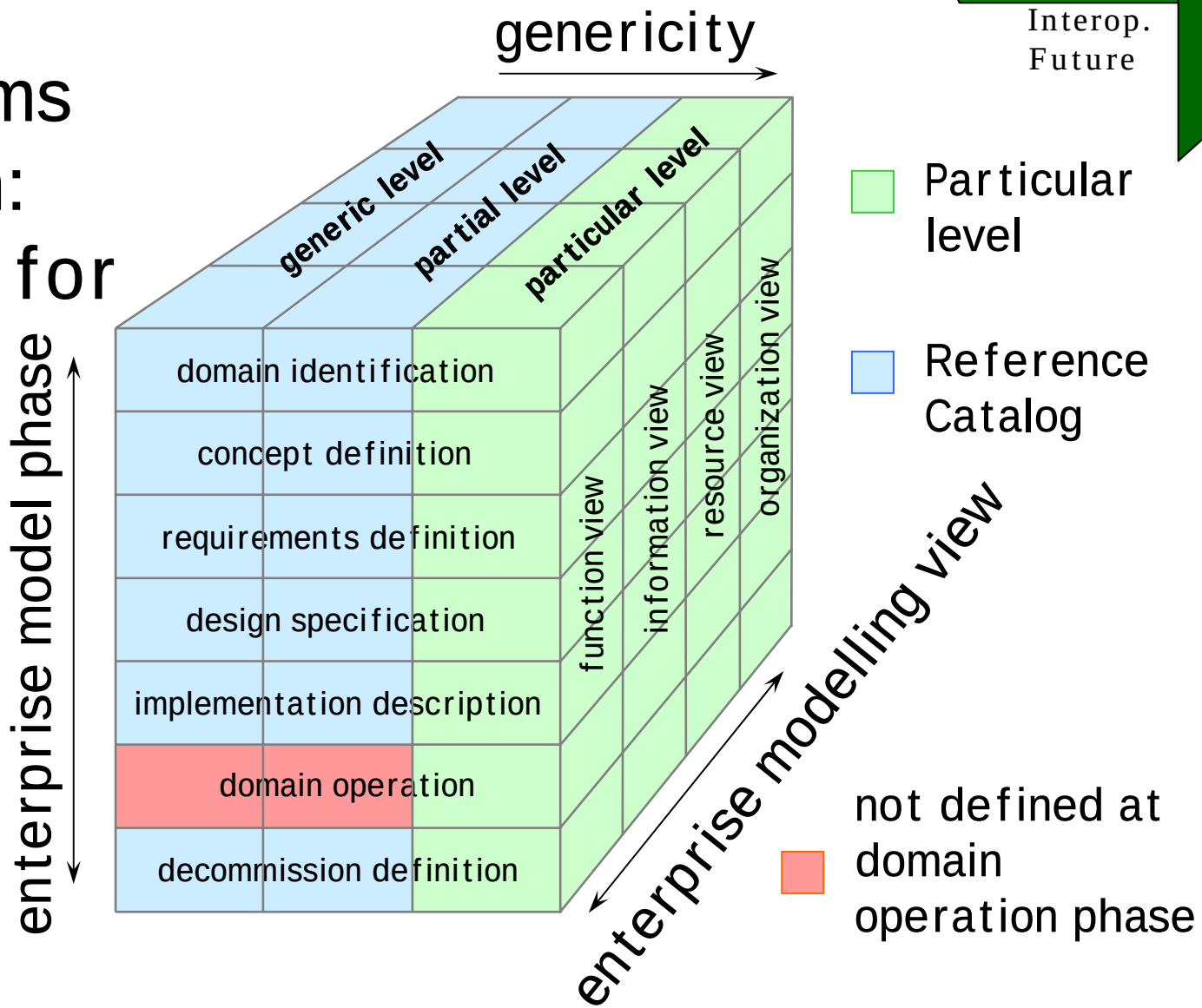
Reference catalog

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

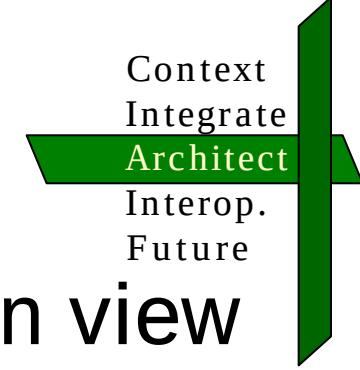
Graphic 19439 dimensions

Context
Integrate
Architect
Interop.
Future

CIM Systems Integration: Framework for Enterprise Modelling

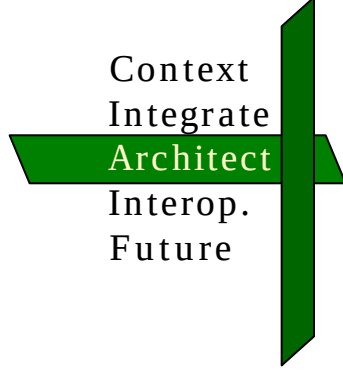


Conformance to 19439



- 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

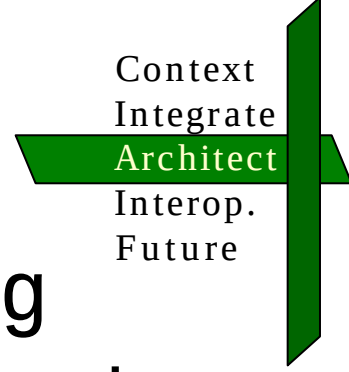
Modelling constructs



ISO/FDIS 19440 Enterprise integration – Constructs for enterprise modelling

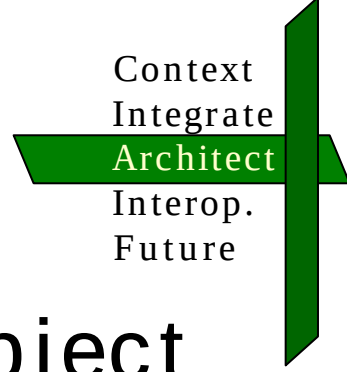
- Based upon CEN ENV 12204:1996
- Aligned with 15704 (an EML artifact)
- Articulates modeling constructs for manufacturing automation
- Elaborates the CIMOSA Baseline example of 19439 with constructs

ISO/FDIS 19440 (cont.)



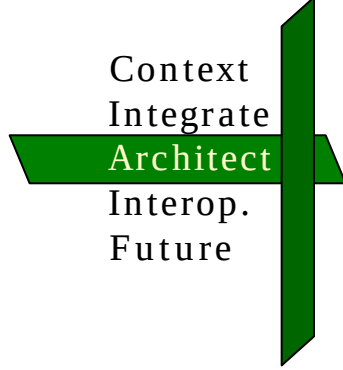
- Constructs for enterprise modelling
  - common semantics enable model unification
  - usable across phases of model development
  - support process-oriented approach
- Arrangement and specialization using templates into structures for a specific purpose
- No mapping between functional operations and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

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
Decision Centre	Person Profile

Construct across phases



Construct label	EO (Enterprise Object)
Identifier	<model-unique string>
Name	name of the Enterprise Object instance
Design Authority	[[<identifier> "/" <name>] [NIL | :" <identifier> "/" <name>]] of Organizational Role and Organizational Unit respectively, having authority to design or maintain this particular instance

Body*A1 Descriptives relevant for all enterprise model phases*

Description	short textual description
Nature of Object	PHYSICAL | INFORMATION
Properties	[<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

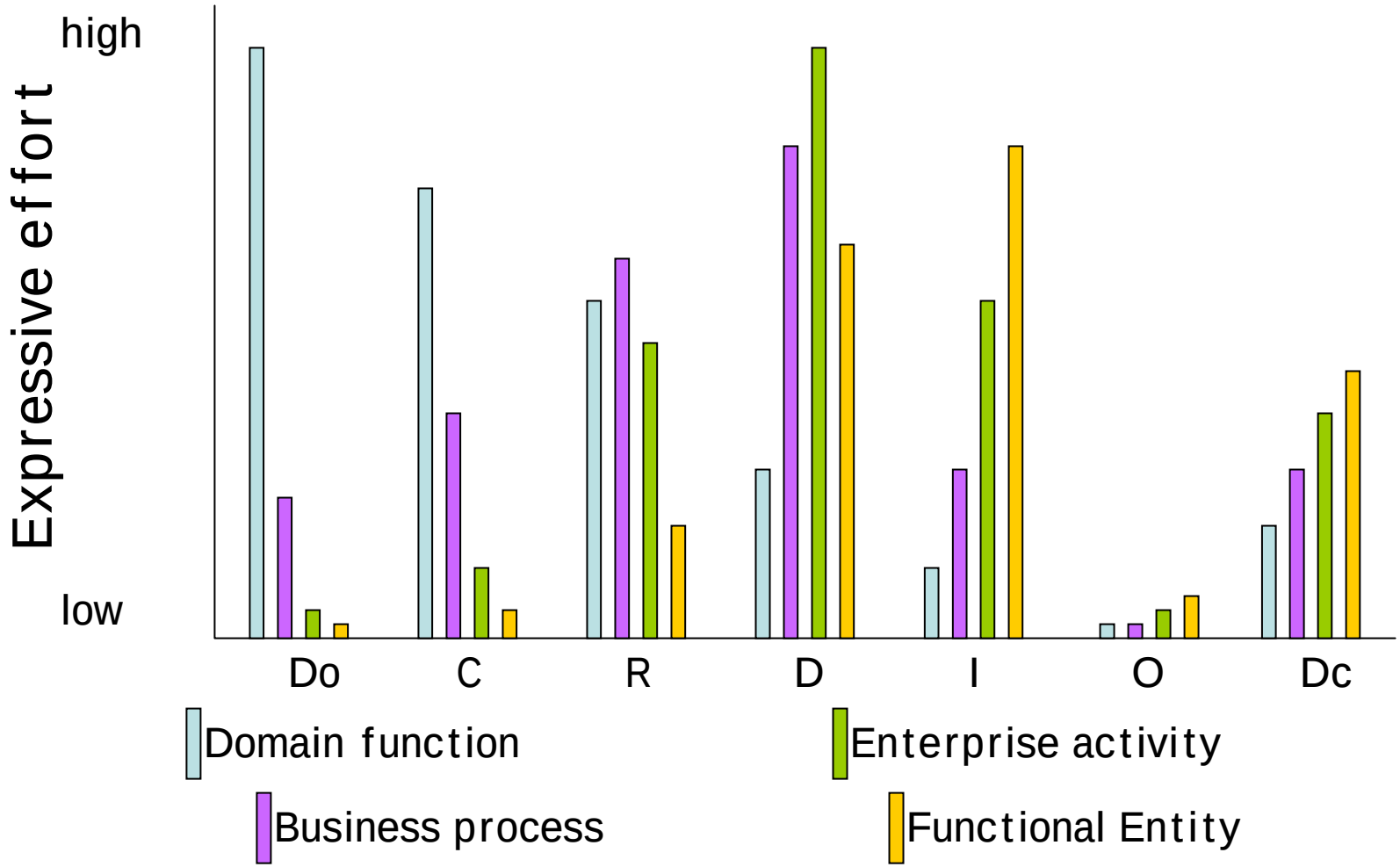
A2.1 applicable at concept definition and later phases

Not applicable

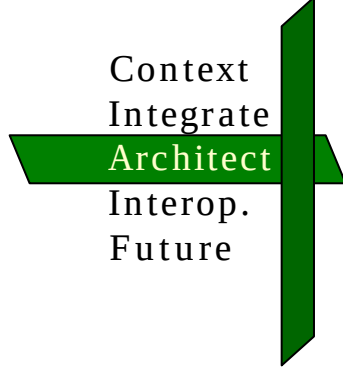
A2.2 applicable at requirements definition and later phases

Integrity Rules	[<integrity rule>]* applicable to attributes of the Enterprise Object instance in the requirements definition phase

Life-cycle expression

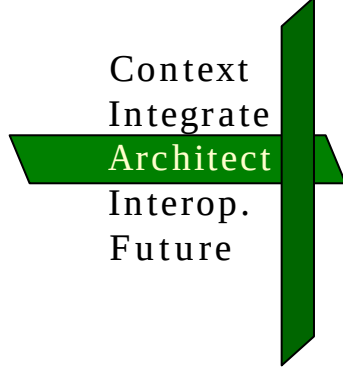


Conformance to 19440



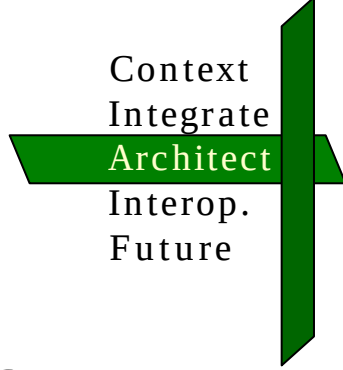
- Shall either use the constructs as defined or be able to map to the constructs
- Can claim qualified compliance by using a subset of constructs or mapping to a subset of constructs
- Be a valid construction of a compliant modeling language
- Shall identify construction and model execution testing levels

Modeling challenges - 1



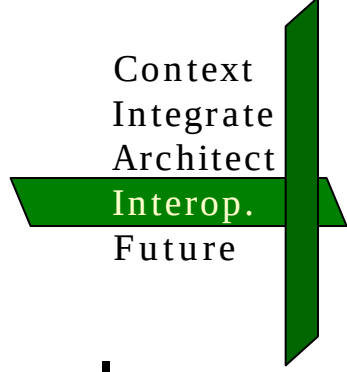
- Operationalizing the constructs
  - Representing the same thing at different phases as a unified construct: the endurant vs. perdurant distinction
  - Transforming the behavioral rules of a business process into executables
  - Maintaining proper relationships as constructs are decomposed along life-cycle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

Modeling challenges - 2



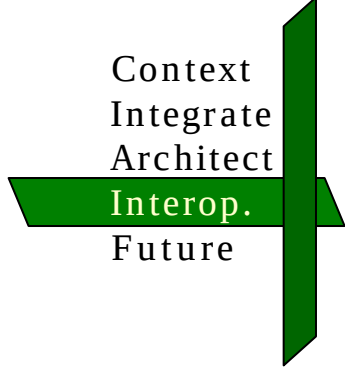
- Identifying tool ready meta-models
  - Validate the meta-model of Annex B
  - A robust meta-model for Object View creation and use in real-time
  - Matching required functional operations with capabilities of a Functional Entity
- Transcribing existing partial models into 19440 terms and syntax
- Articulating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

NP 27387 Process Characterization



- 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.

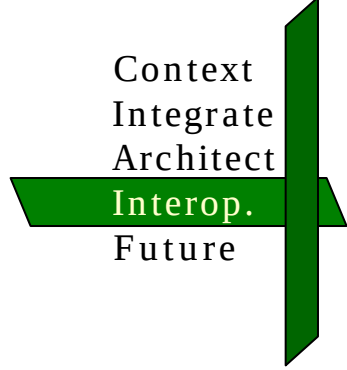
Process characterization



- **Requirements**
  - Characterization of processes

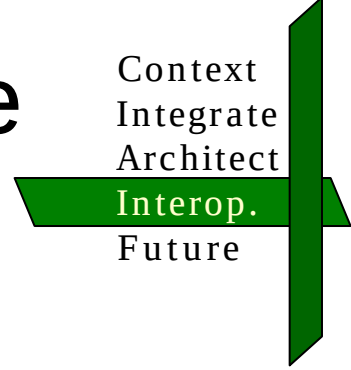
Inputs	Activities
Outputs	Logical decisions
Logical relationships/rules	Time and sequence
Resources	Mechanisms/Control
Organizational role	MoE/MoP
Process categories	Process hierarchy
Recursive notations	Object state transition
Context/scenario	Exceptions
Transactions	Process evolution
Documentation	

Only conceptual integration



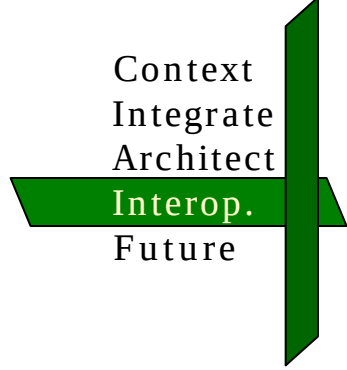
- Does not include descriptions of process composition or otherwise aggregate into larger frameworks or architectures.
- Not a process characterization language but rather characterizes the range of processes so that suitable languages are developed to support process characterizations.

NWIP Manufacturing enterprise process interoperability



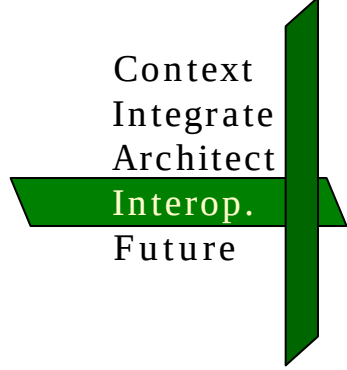
- Establishes a base for interoperation in unified, integrated and federated operational environments of manufacturing enterprises
- Defines an interoperability framework and specifies processes and underpinning metadata that must be in place to establish or to negotiate and enable enterprise-interoperability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

NWIP – MEPI (cont.)



- Focus on enabling the communication rather than defining the communication
- CEN lead effort utilizing results from EU FP6 programs InterOP and Athena
- 3 parts expected:
  - Interoperability Framework
  - Requirements for unified and integrated
  - Requirements for federated environment

Interoperability Framework



- Defines operational levels (data, service, process, business) of the enterprise at which interoperability is anticipated
- Identifies current conceptual, technical, and organizational barriers to interoperability at these enterprise levels
- Solutions to overcome those barriers are presented as parts of this standard.

Interoperability Framework

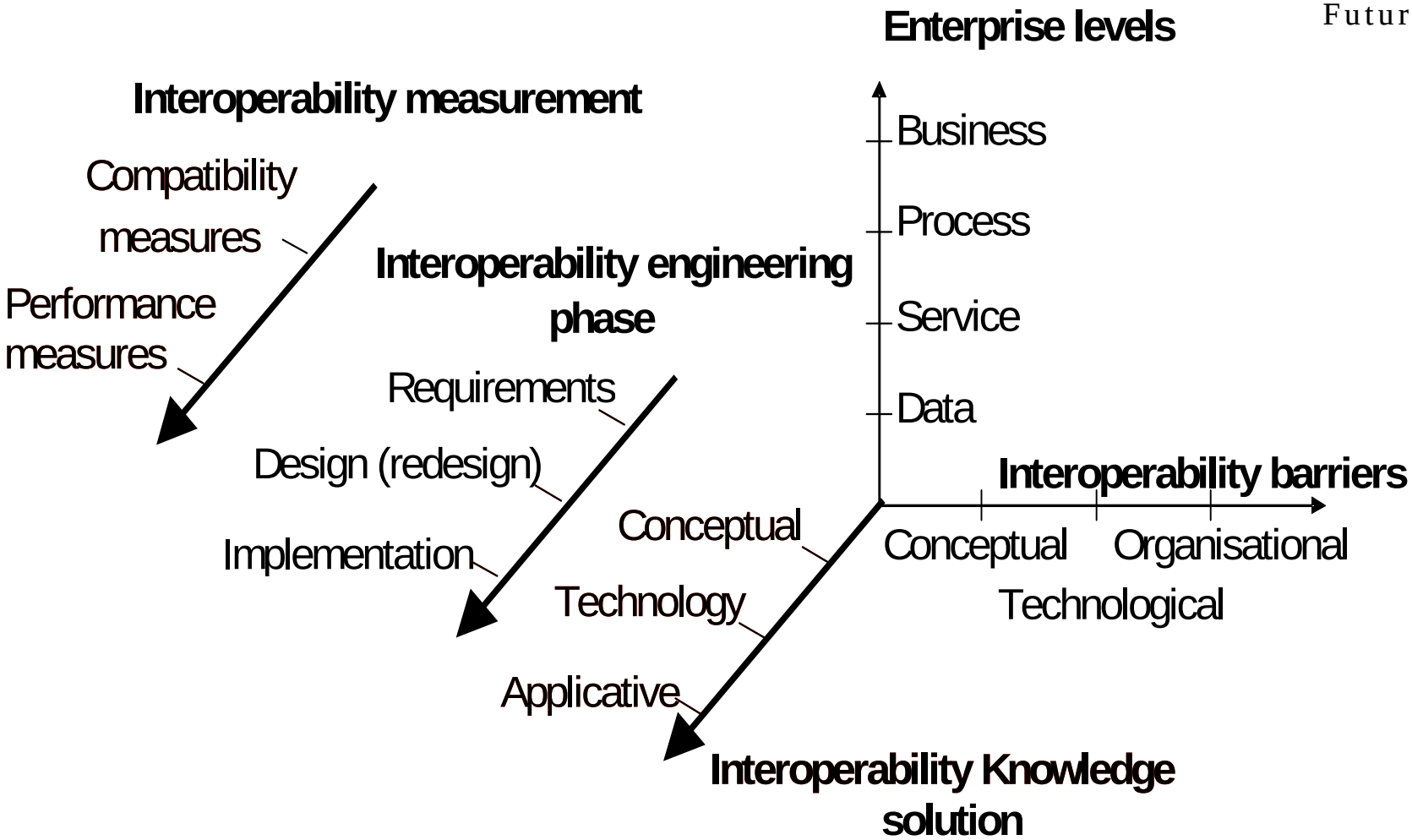
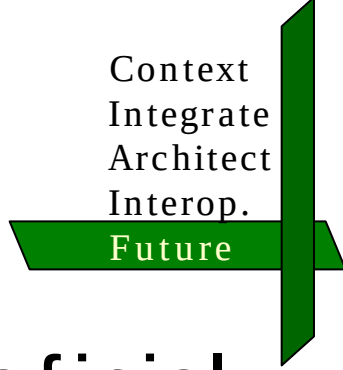


Figure courtesy of Kurt Kosanke

Interoperability approach

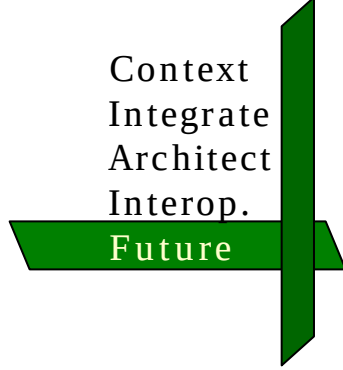
- Unified and Integrated
  - Have common meta-model and representation (19439 & 19440)
  - Allow normative requirements to barrier solutions
- Federated
  - Require *a priori* knowledge about information to exchange
  - Require more elaborate negotiation

Collaboration



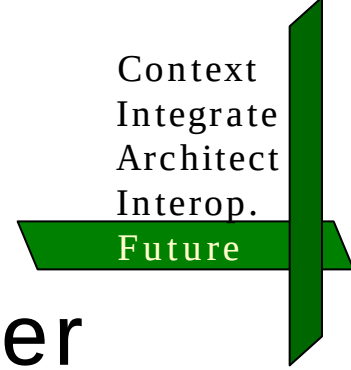
- Identify aspects of ISO work beneficial to ManTIS and SE DSIG efforts
- Submit OMG work products as input to ISO working groups in TC184/SC5 and perhaps ISO/IEC JTC1
- Formalize liaisons and identify appropriate representatives to allow comment submissions (Sandy Friedenthal is OMG Liaison to SC5)

Future SC5 Efforts



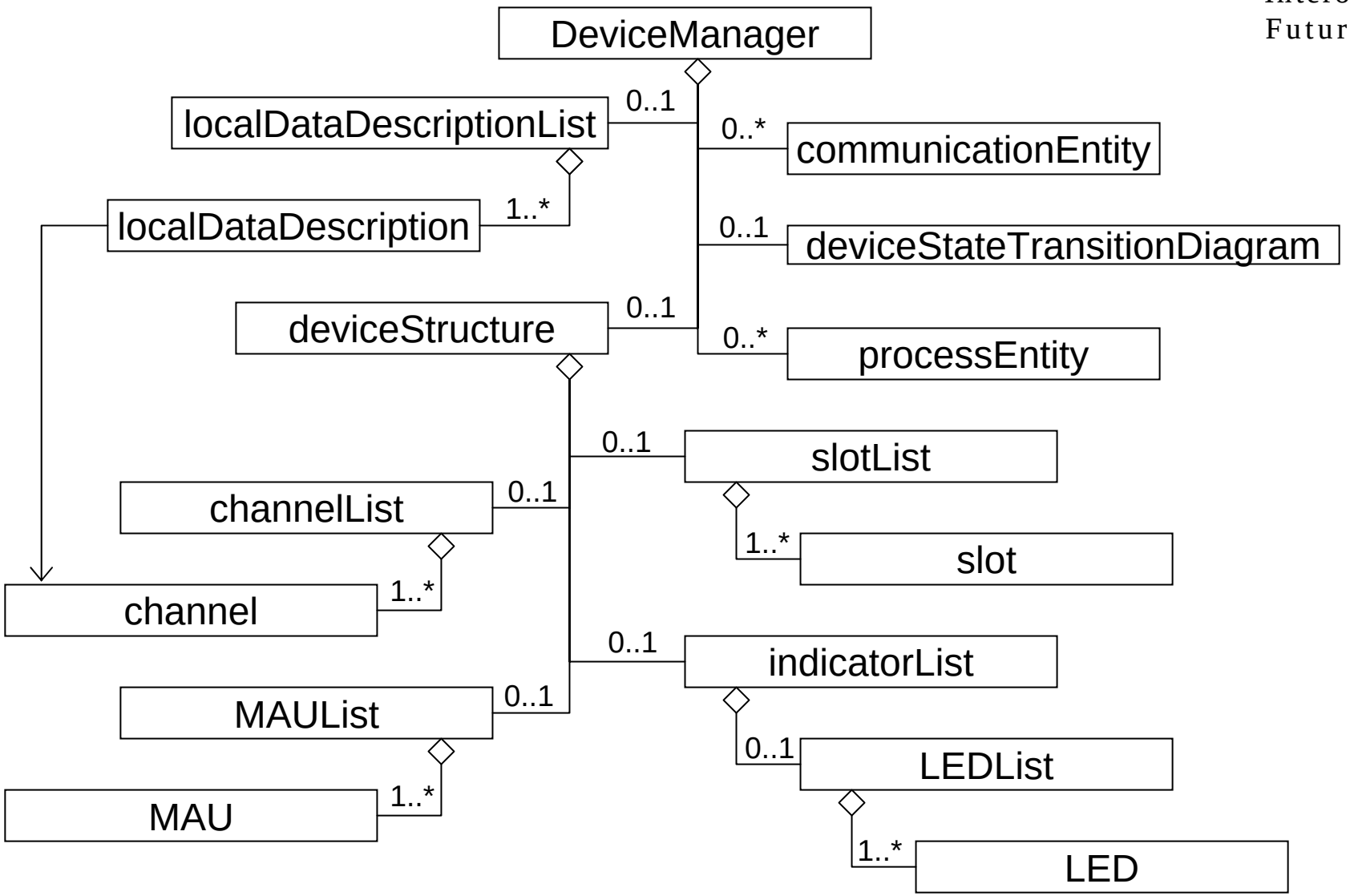
- Simulation tool integration requirements and criteria
- Use case for multiple standard use
- Coordinated asset registry
- Activity integration across levels
- Terminology harmonization
- Database of software unit capability
- Automation security

Contacts



- Richard Martin – SC5/WG1 Convener
  richardm@tinwisle.com
- SC5 Web site –
  http://forums.nema.org/wb/default.asp?boardid=143
- WG1 Web site –
  http://forums.nema.org/wb/default.asp?boardid=13
- OMG Liaison to ISO TC184/SC5 –
  Sandy Friedenthal
  sanford.friedenthal@lmco.com

CANopen DeviceManager



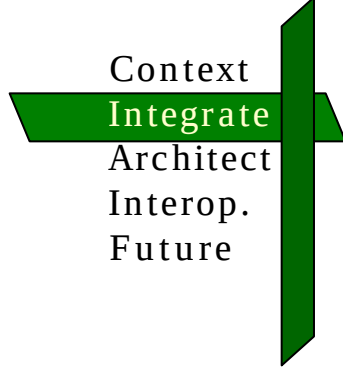
Class model attributes

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.

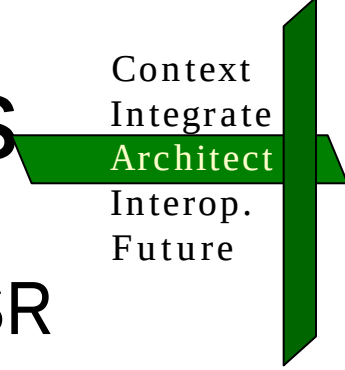
A very 'formal' process




```
(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))))
```

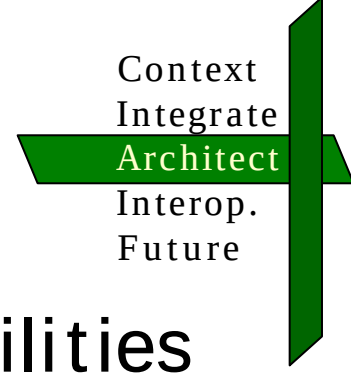
(Source: ISO/CD18629-44 Annex B)

Many possible coordinates



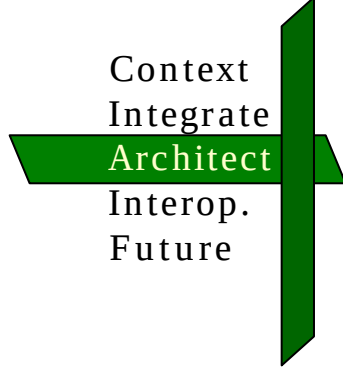
15288 Stage		19439 Phase		C4ISR Guidance
Concept		**Domain**	⟷	**Focus**
		Concept	⟷	**Scope**
Development		**Requirement**	⟷	**Characterize**
		Design	⟷	**Determine**
Production	⟷	**Implementation**	⟷	**Build**
Utilization				
Support		**Operation**	⟷	**Use**
Retirement	⟷	**Decommission**		

Early phases



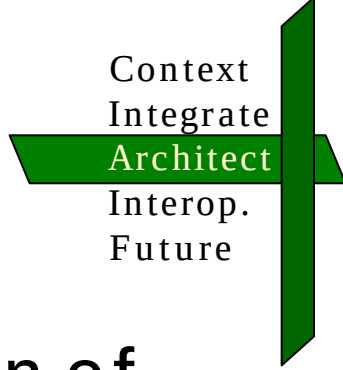
- **Domain identification**
  - Business objectives, functions, capabilities
- **Concept definition**
  - Enablers of objectives & operations
  - Means for achievement of functions & capabilities
- **Requirements definition**
  - Functional, behavioral, informational, and capability for service, manufacturing, 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

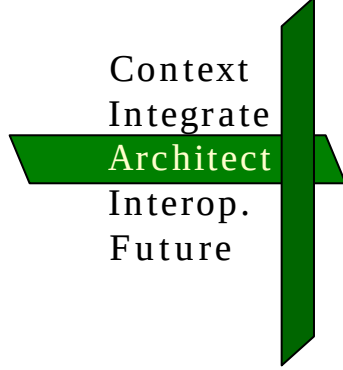
Function view of 19439



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

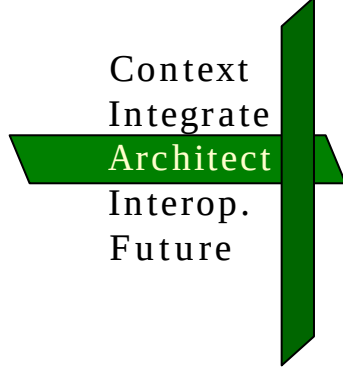
Resource

- Capabilities of people and technological component assets

Organization

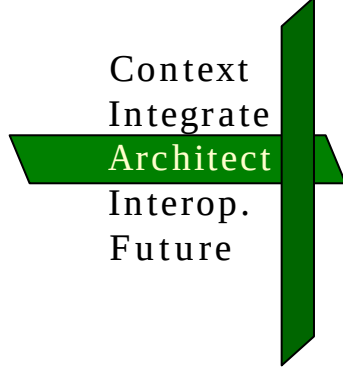
- Authority and responsibility during operations
- Expresses decision support structure

Construct template



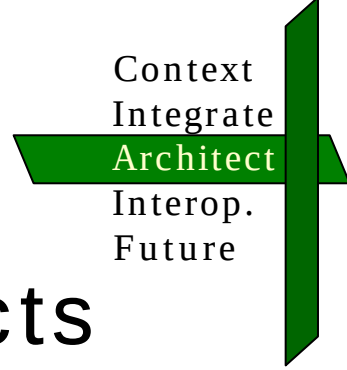
- Common format
  - Header
    - Type label
    - Identifier unique to model
    - Name
    - Authority for design of construct
  - Body
    - Descriptives in textual form
    - Relationships specified by reference

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

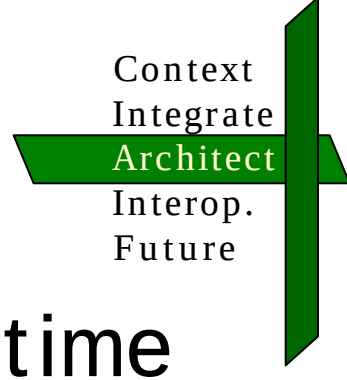
Complementary concepts



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

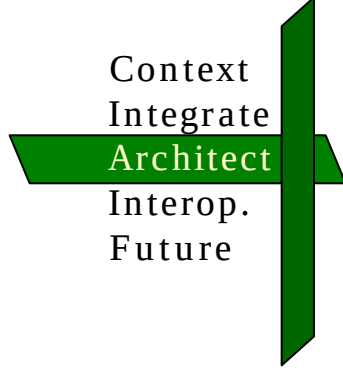
- Behavior rule
- Constraint
- Declarative rule
- Functional operation
- Integrity rule
- Objective
- Performance indicator

Construct relationships



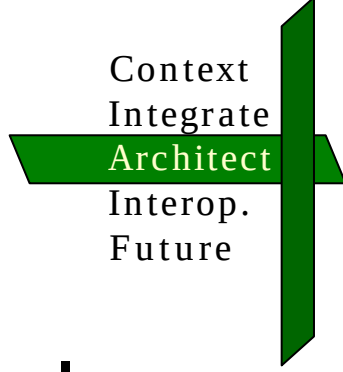
- Model the dynamics between run-time instances
- Types of relationship
  - Operational authority and responsibility
  - Membership in specialization
  - Part of an aggregation
  - Consist of an aggregation
  - Other associations
- Possibly reflexive

Construct and roles



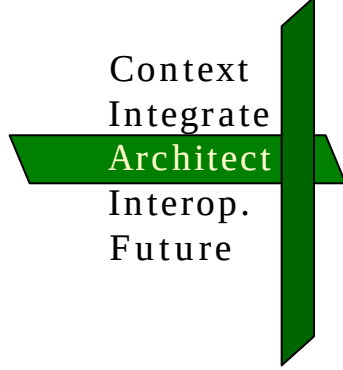
- Human organizational role captures assigned responsibilities and required capabilities (skills)
- Human operational role captures the operational capabilities of person assigned to a task
- Machine operational role captures the operating capabilities of machine assigned to a task
- Machine product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

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

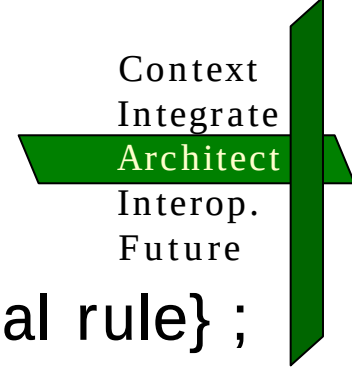
Behaviour rules



- 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 {behavioural rule} ;

behavioural rule = WHEN condition DO action ";"

condition = condition term
| condition term {AND condition term}
| condition term {OR condition term} ;

condition term = single condition | (condition) ;

single condition = event occurrence | action completion ;

event occurrence = event | start | exception ;

event = ev ; (*the named Event needs to be included in the containing Business Process's list of Event Inputs *)