ISO Enterprise Architecture for Intelligent Enterprises:

An INCOSE International Symposium 2007 tutorial

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Why are we here?

Architecture is a people thing we often associate with design intelligence.

We believe all built systems have it.

Understanding architecture helps us understand better the world we build.

Standards are a people thing as well.

Standards form an architectural pattern.

We believe standards help build better systems for use in the real world.

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What will we accomplish?

- Promotion of architecture as an aid in communication among people to enable better understanding of systems
- Identify the prominence of people in architecture and the systems they build for enterprises
- Use of a standards collection from ISO TC184/SC5/WG1 for architecting enterprise systems in general and unified systems in particular

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Tutorial Approach

- Frame the four ISO TC184/SC5/WG1 architectural standards in the enterprise context
- Convey two of the standards with significant detail, often with content from the other two
- Along the way, discuss the interpretation of the standards to craft architectural artifacts for enterprises, projects, and systems

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Architectural Discord

Discussions about architecture of any kind are metaphor-rich and consequently subject to much misinterpretation.

Since architecture is pervasive (in good, bad, and ugly forms) context is critical.

The enterprise context ranges from two people in a garage through tens of thousands cooperating in a global supply chain to millions governed by nation states.

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Architectural Harmony

- Common concepts – we are all doing very similar things even though we are not using the same words or methods.
- Those concepts are independent of methodology and range across many domains of practice.
- We recognize the value of "good" architecture and want to encourage its use.

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Architectural Value

- Architecture is the means by which enterprise mission and objectives are represented.
- Architecture representations are critical communication vehicles for managers and engineers, especially in large, complex, and dispersed enterprises and programs
- Architectural standards facilitate completeness and consistency of representation.

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Many Architectures

Many diverse perspectives result in many views and viewpoints about architecture - at least as many as lecturers on the topic – after all it is a human thing

Characterized with aspects for:

- Form of realization
- Functions to enable or perform
- Objective (or subjective) experience in use

our focus

Derived from principles and patterns

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Architecture definitions

IEEE 1471 (ISO 25961) -

3.5 architecture: The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution.

INCOSE IEWG Knowledge Claims -

Architecture concerns the arrangement of function and feature that maximizes the objective of the system structure.

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My working favorite

ISO 15704:2000

3.2 architecture

a description (model) of the basic arrangement and connectivity of parts of a system (either a physical or a conceptual object or entity)

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Only two types

There are two, and only two, types of architectures that deal with enterprise integration

a) system architectures (referred to as "type 1" architectures) that deal with the design of a system, e.g. the computer control system part of an overall enterprise integration system;

b) enterprise-reference projects (referred to as "type 2" architectures) that deal with the organisation of the development and implementation of a project such as an enterprise integration or other enterprise development programme.

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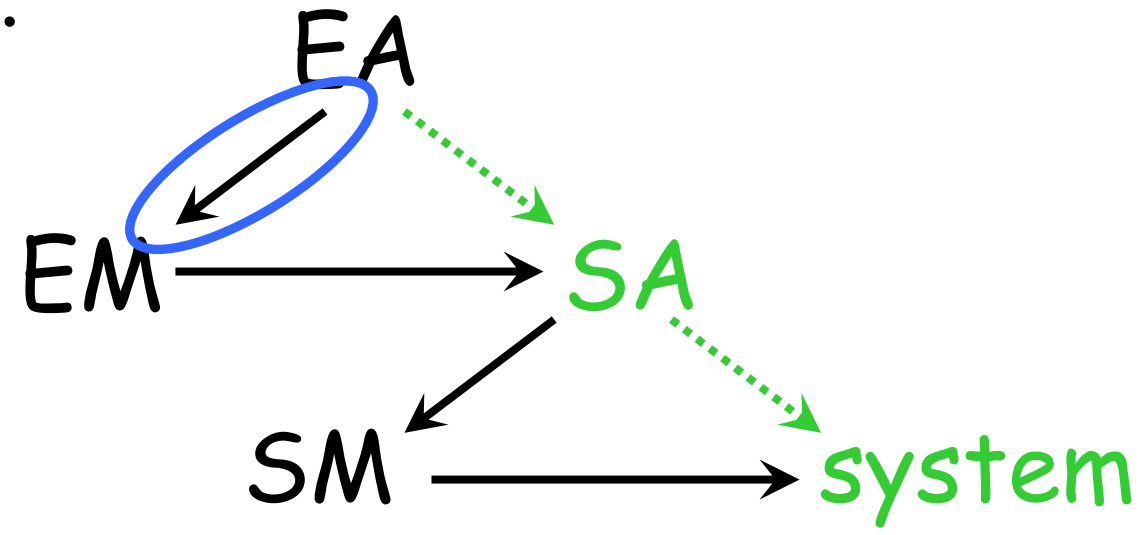
Models and architecture

Architectural intent is embodied in models.

Architectural realization is embodied in instance manifestations of those models.



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Abstraction quiz

$\pi/4 = .78539816339744830961566608\ldots =$

$\sum(1, -1/3, +1/5, -1/7, +1/9, -1/11, +1/13, -1/15, \ldots)$

"…phenomena which appear mostly as chaotic randomness until we select some significant events, and abstract from their particular, irrelevant circumstances so that they become idealized…we choose to ignore certain things as irrelevant and we thus partially select the content of the message by a free choice…some aspects may be completely unknown to us but they may reveal themselves to an observer with a different system of abstractions."

Gregory - 1671, Leibniz - 1674, Jauch - 1973, Hofstader - 1979

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How do we proceed?

- Tutorial part 1
  - Introduction of ISO TC184/SC5 standards and practice
  - Reference points
    - Liaisons and harmonization
    - Principles for EA and modeling
  - ISO 14258:1998 Industrial automation systems - Concepts and rules for enterprise models

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And continuing

- Tutorial part 2
  - ISO 15704:2000 Industrial automation systems - Requirements for enterprise-reference architectures and methodologies
    - Generalized Enterprise Reference Architecture and Methodologies
    - Economic view and Decision view
    - With material drawn from ISO 19439:2006 Enterprise integration – Framework for enterprise modelling and ISO/FDIS 19440:2007 Enterprise integration – Constructs for enterprise modelling

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Who's standards

ISO JTC1/SC7/WG42

CEN TC310/WG1

ISO/TC 184
~~Industrial~~ Automation Systems & Integration

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 (reorganizing)

- **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
- **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
- **SG1** Vocabulary and terminology

Advisory Group

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

ISA SP95/**IEC** SC65E

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SC5 Working Groups

- 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)

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Harmonizing standards

The great thing about standards is that there are so many from which to choose.

Internationally, the interoperation of standards is a BIG concern.

Culture, language, and use domain are all barriers to interoperation.

Breaking down standard silos requires cooperation and accommodation.

- TC184/SC5/WG1 & JTC1/SC7/WG42

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ISO's EA Groups

ISO/TC184/SC5/WG1: Developing enterprise architecture standards based on manufacturing industry for international architecture applications

ISO/IEC/JTC1/SC7/WG42: Developing a systems and software architecture standard

ISO/IEC/JTC1/SC7/WG19: Developing frameworks and languages for distributed processing (ODP)

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Related EA activity

ISO/TC184/SC4/WG3: Developing Data Standards including ISO 10303, 100s of standards including AP233

ISO/TC184/SC5/SG1 & ISO/IEC/SC7/WG22: identifying vocabulary overlaps/conflicts and recommending commonality via "Harmonization"

+ many other indirectly related efforts

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E-A standards

ISO/IEC 42010 Recommended Practice for Architectural Description of ~~Software-Intensive~~ Systems (IEEE 1471)

ISO 14258 Rules and Guidelines for Modelling
ISO 15704 Requirements for Enterprise Reference Architectures
(Needs for Frameworks, Methodologies, Languages, Tools, Models, Modules)

Frameworks	*Languages*	*Modules*
CEN/ISO 19439 Framework for Modelling	*CEN/ISO 19440 Constructs for Modelling*	*ISO 16100 Mfg. Software Capability Profiling*
ISO 15745 Framework for Application Integration	*ISO 18629 Process Specification Language*	*IEC/ISO 62264 Control Systems Integration*
ISO 15288 Life Cycle Mgmt.	*ISO/IEC 15414 ODP Enterprise Language*	
OMG MDA Model Driven Architecture	*BPML (2001). Business Process Modelling Language*	
	ebXML Electronic Business using eXtensible Mark-up Language	

SC5 & WG1

K. KOSANKE and M. ZELM (CIMOSA Association)
D. CHEN (LAPS, University Bordeaux 1)

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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.

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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.

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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 ISO 15704 (a GERA model)
- Articulates 3 dimensions of enterprise modeling as a framework:

  Phase, View, and Genericity

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Modeling constructs

ISO/FDIS 19440 Enterprise integration – Constructs for enterprise modelling

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

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ISO/FDIS 19440 (cont.)

- Constructs for enterprise modeling
  - 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

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Standards reflect practice

WG1 standards reflect industrial modeling practice of the 1990's

- **P**urdue **E**nterprise **R**eference **A**rchitecture
- **C**omputer **I**ntegrated **M**anufacturing **O**pen **S**ystems **A**rchitecture
- **G**raphe a **R**esultats et **A**ctivite **I**nter-relies

Do they harmonize with current practice?

- DoDAF/MoDAF, Zachman, TOGAF, Dual-Vee, etc., and other gallery members

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Zachman framework

ENTERPRISE ARCHITECTURE - A FRAMEWORK ™

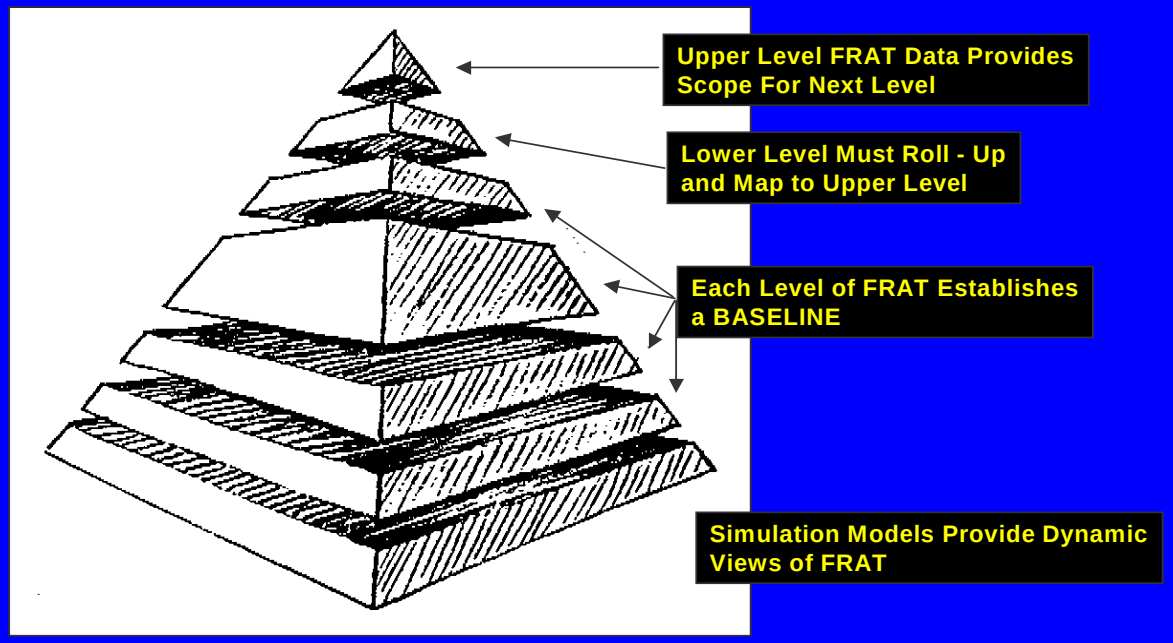
	DATA *What*	FUNCTION *How*	NETWORK *Where*	PEOPLE *Who*	TIME *When*	MOTIVATION *Why*	
SCOPE (CONTEXTUAL) *Planner*	List of Things Important to the Business ENTITY = Class of Business Thing	List of Processes the Business Performs Function = Class of Business Process	List of Locations in which the Business Operates Node = Major Business Location	List of Organizations Important to the Business People = Major Organizations	List of Events Significant to the Business Time = Major Business Event	List of Business Goals/Strat Ends/Means=Major Bus. Goal/ Critical Success Factor	SCOPE (CONTEXTUAL) *Planner*
ENTERPRISE MODEL (CONCEPTUAL) *Owner*	e.g. Semantic Model Ent = Business Entity Reln = Business Relationship	e.g. Business Process Model Proc. = Business Process I/O = Business Resources	e.g. Logistics Network Node = Business Location Link = Business Linkage	e.g. Work Flow Model People = Organization Unit Work = Work Product	e.g. Master Schedule Time = Business Event Cycle = Business Cycle	e.g. Business Plan End = Business Objective Means = Business Strategy	ENTERPRISE MODEL (CONCEPTUAL) *Owner*
SYSTEM MODEL (LOGICAL) *Designer*	e.g. Logical Data Model Ent = Data Entity Reln = Data Relationship	e.g. "Application Architecture" Proc .= Application Function I/O = User Views	e.g. "Distributed System Architecture" Node = I/S Function (Processor, Storage, etc) Link = Line Characteristics	e.g. Human Interface Architecture People = Role Work = Deliverable	e.g. Processing Structure Time = System Event Cycle = Processing Cycle	e.g., Business Rule Model End = Structural Assertion Means =Action Assertion	SYSTEM MODEL (LOGICAL) *Designer*
TECHNOLOGY MODEL (PHYSICAL) *Builder*	e.g. Physical Data Model Ent = Segment/Table/etc. Reln = Pointer/Key/etc.	e.g. "System Design" Proc.= Computer Function I/O = Screen/Device Formats	e.g. "System Architecture" Node = Hardware/System Software Link = Line Specifications	e.g. Presentation Architecture People = User Work = Screen Format	e.g. Control Structure Time = Execute Cycle = Component Cycle	e.g. Rule Design End = Condition Means = Action	TECHNOLOGY CONSTRAINED MODEL (PHYSICAL) *Builder*
DETAILED REPRESEN-TATIONS (OUT-OF-CONTEXT) *Sub-Contractor*	e.g. Data Definition Ent = Field Reln = Address	e.g. "Program" Proc.= Language Stmt I/O = Control Block	e.g. "Network Architecture" Node = Addresses Link = Protocols	e.g. Security Architecture People = Identity Work = Job	e.g. Timing Definition Time = Interrupt Cycle = Machine Cycle	e.g. Rule Specification End = Sub-condition Means = Step	DETAILED REPRESEN-TATIONS (OUT-OF CONTEXT) *Sub-Contractor*
FUNCTIONING ENTERPRISE	e.g. DATA	e.g. FUNCTION	e.g. NETWORK	e.g. ORGANIZATION	e.g. SCHEDULE	e.g. STRATEGY	FUNCTIONING ENTERPRISE

Zachman Institute for Framework Advancement - (810) 231-0531 Copyright - John A. Zachman, Zachman International

Role by **Interrogative** grid of cells containing models of the enterprise. A proto-typical **Framework**!

FRAT

Systems thinking -
each of the FRAT views can be described with



Function
Requirements
Answers
Test

Detail elaboration adds both depth and breadth to the system description

Source: B. W. Mar, B. G. Morais, FRAT – A Basic Framework for Systems Engineering, INCOSE 2002

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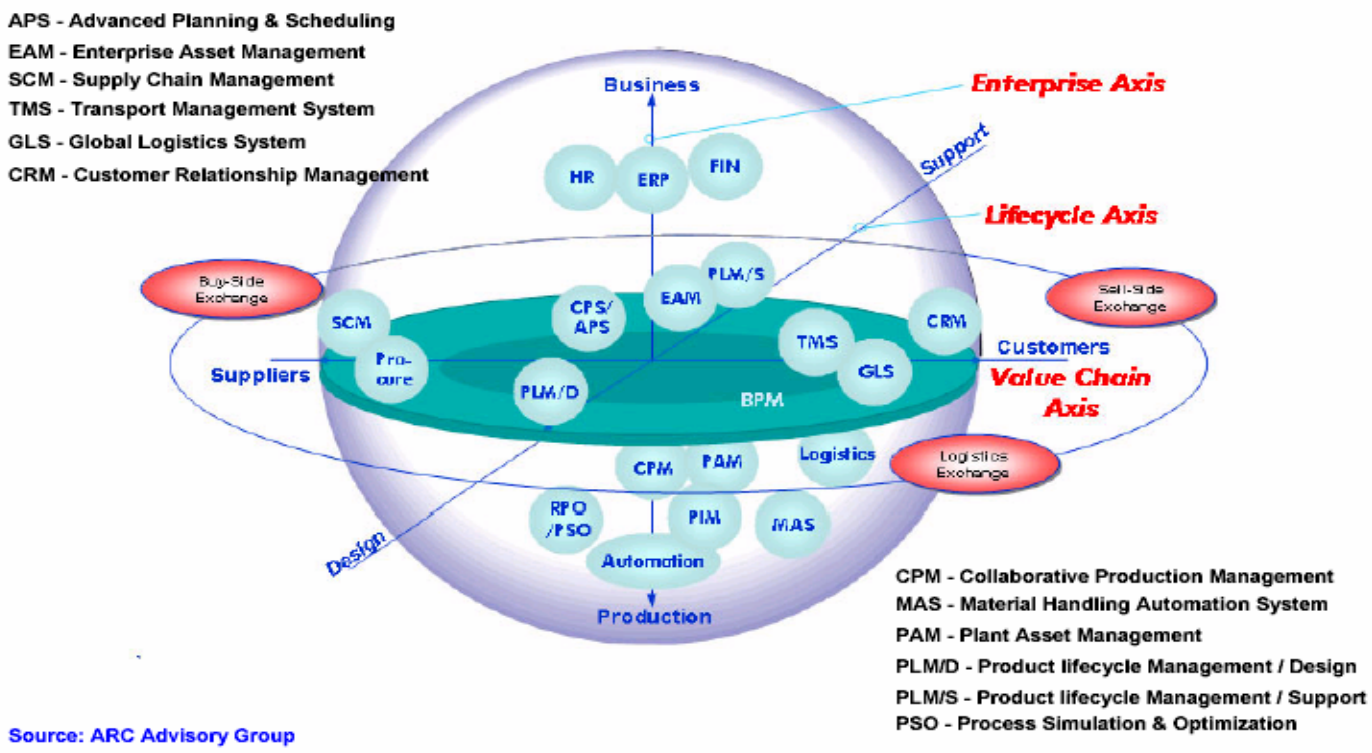
ARC CMM

ISO/TC 184/SC 5
Architecture, Communications, Integration Frameworks

ARC Collaborative Manufacturing Management



E. delaHostria - 020528

Aligning functional applications along axis to identify dimensions of the global manufacturing enterprise

Source: ISO/TC 184/SC5 N913, E. delaHostria, Chairman, and ARC Advisory Group (used with permission)

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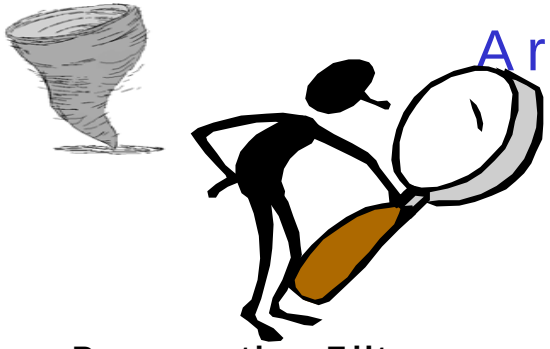
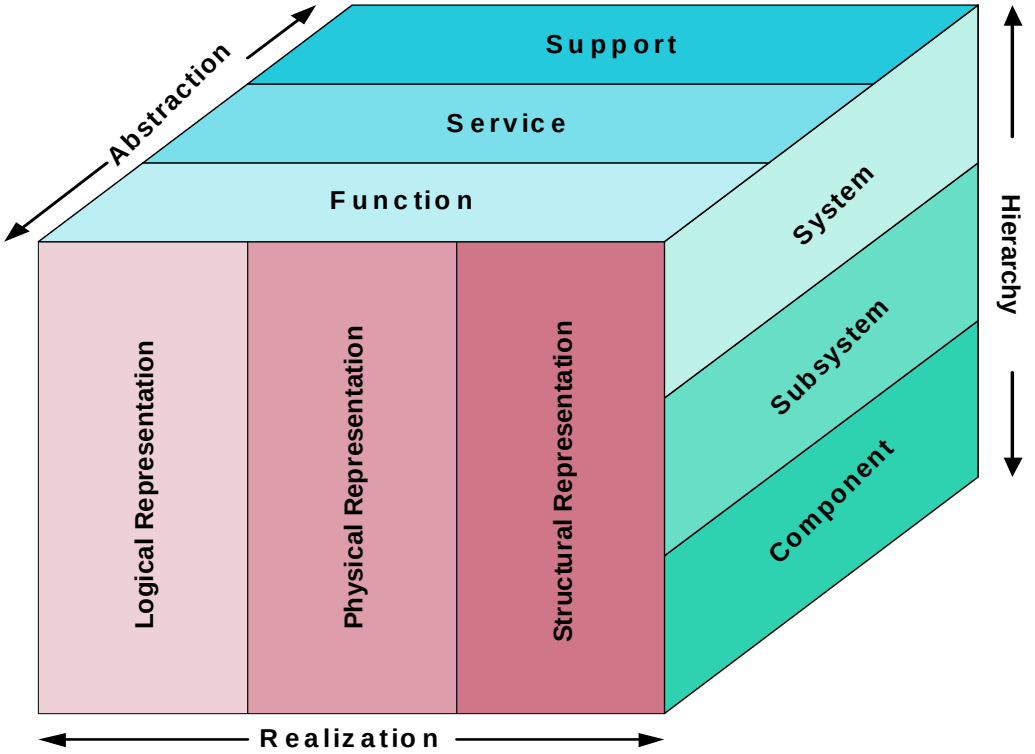
Architectural Perspectives



Perspective Filters:

- Development & Verification
- Manufacturing & Production
- Storage & Transportation
- Installation & Deployment
- Simulation & Training
- Operational
- Maintenance & Support
- Disposal
- Project
- Safety
- Functional
- Physical
- Information/ Data Flow



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Source: R. W. Jorgensen, Architectural Abstractions, INCOSE 2002. Copyright © 2001 Rockwell Collins, Inc. All Rights Reserved.

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Purdue Enterprise Reference Architecture

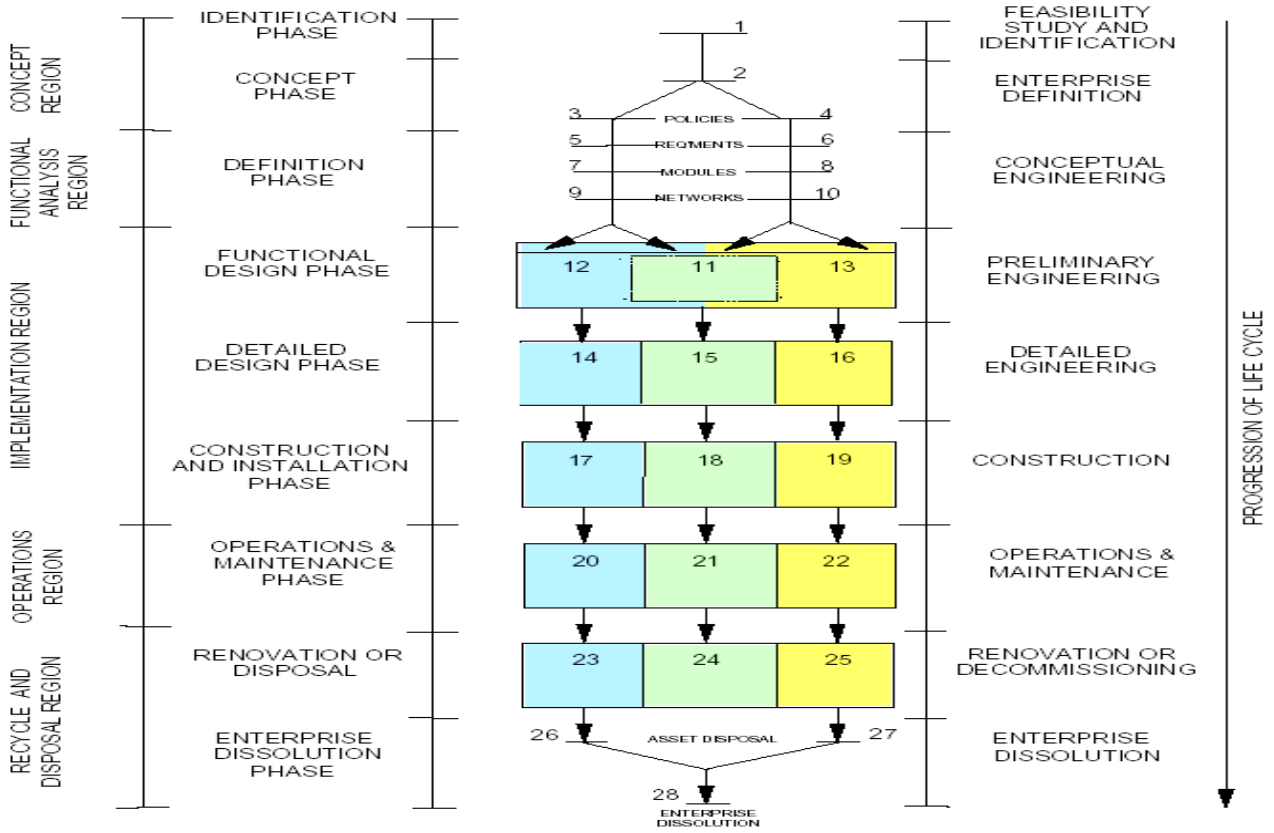

FIGURE 2 - OVERALL FORM OF THE PURDUE ENTERPRISE REFERENCE ARCHITECTURE DIAGRAM SHOWING VARIOUS FORMS OF THE LIFE CYCLE

Source: T. J. Williams, A Handbook on Master Planning and Implementation for Enterprise Integration Programs, Institute for Interdisiplinary Engineering Studies, Purdue Univ.

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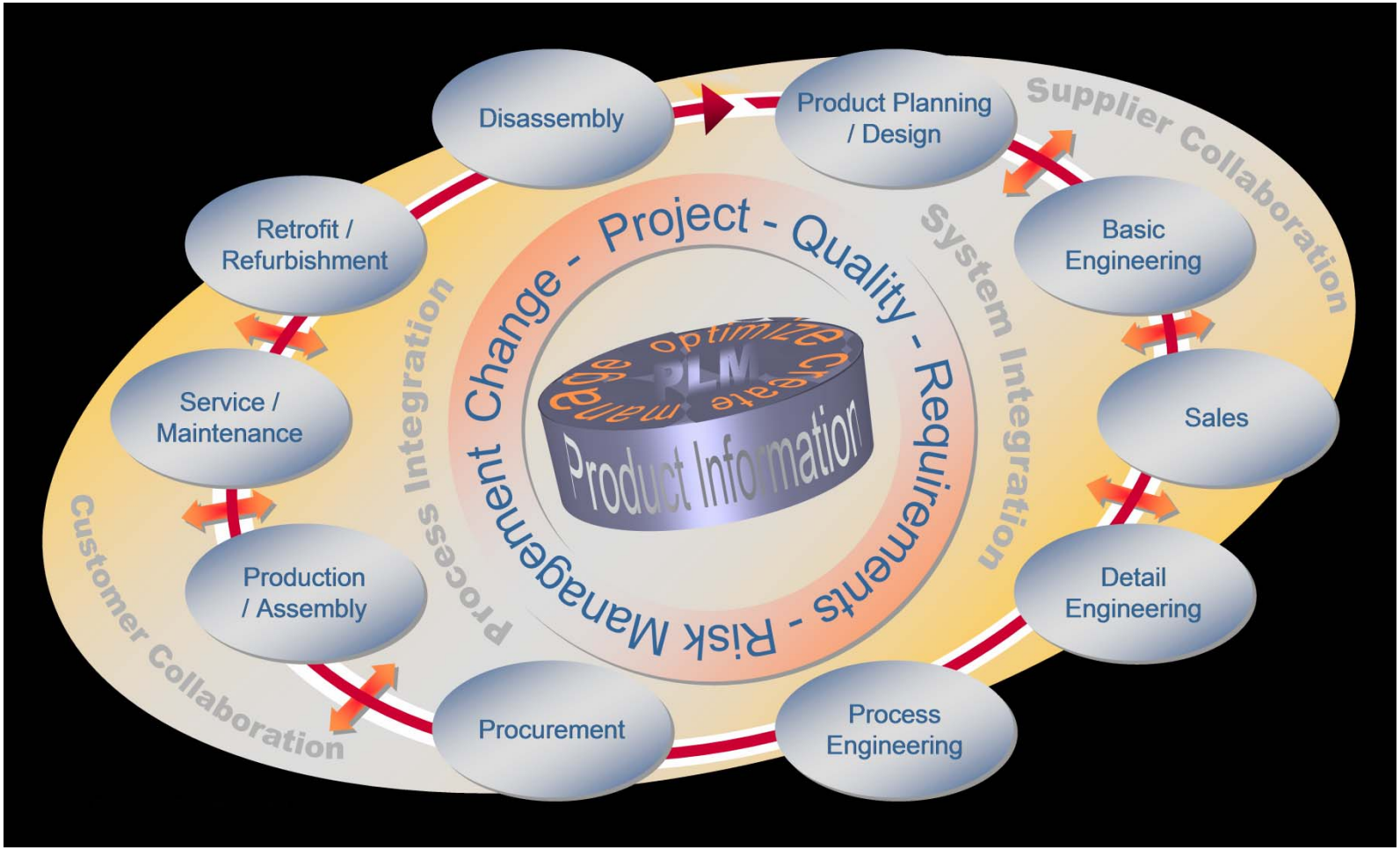
CSC_PLM



Verband Deutscher Maschinen- und Anlagenbau - German Engineering Federation

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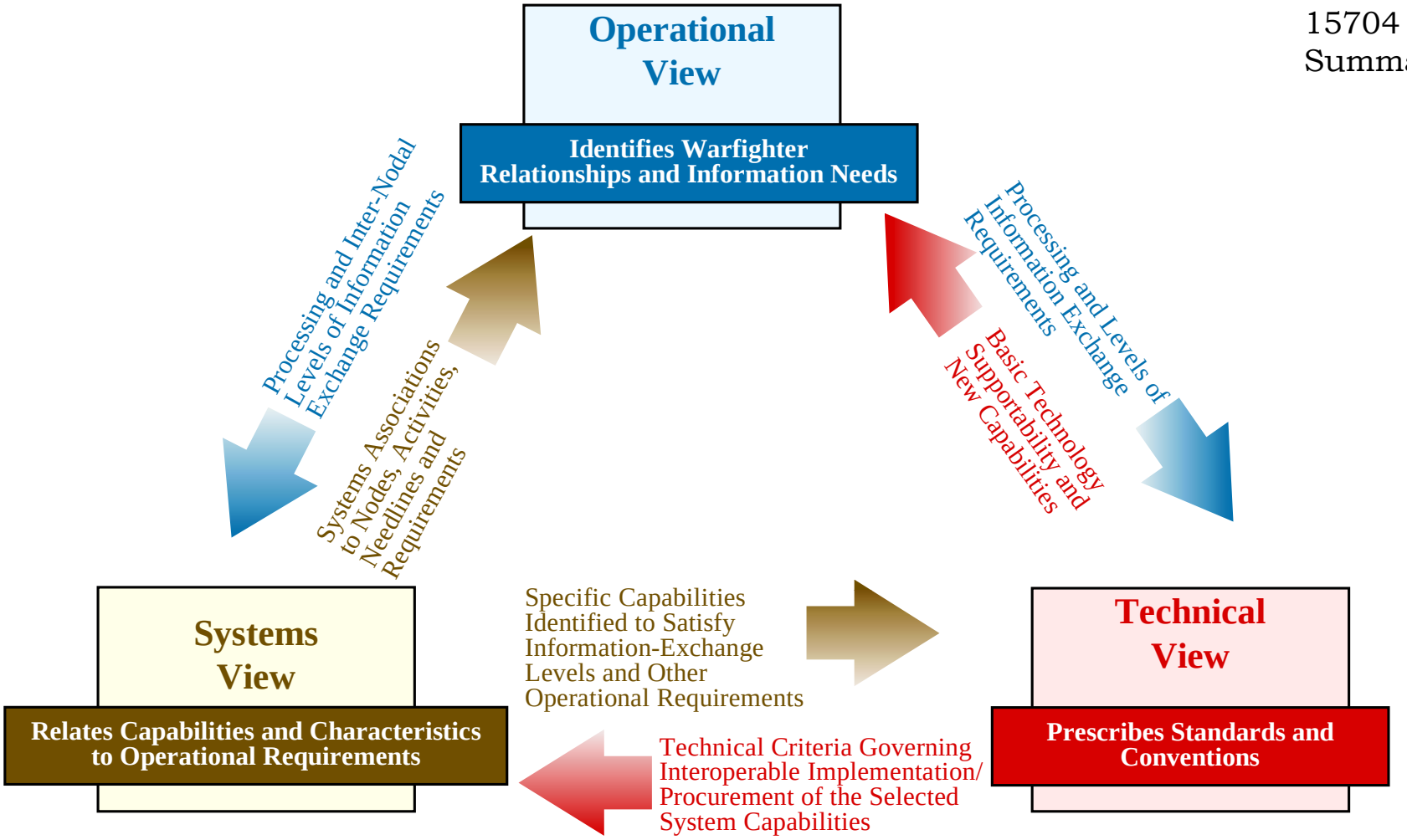
DoDAF



Source: Architecture Working Group, C4ISR Architecture Framework Version 2.0, 1997

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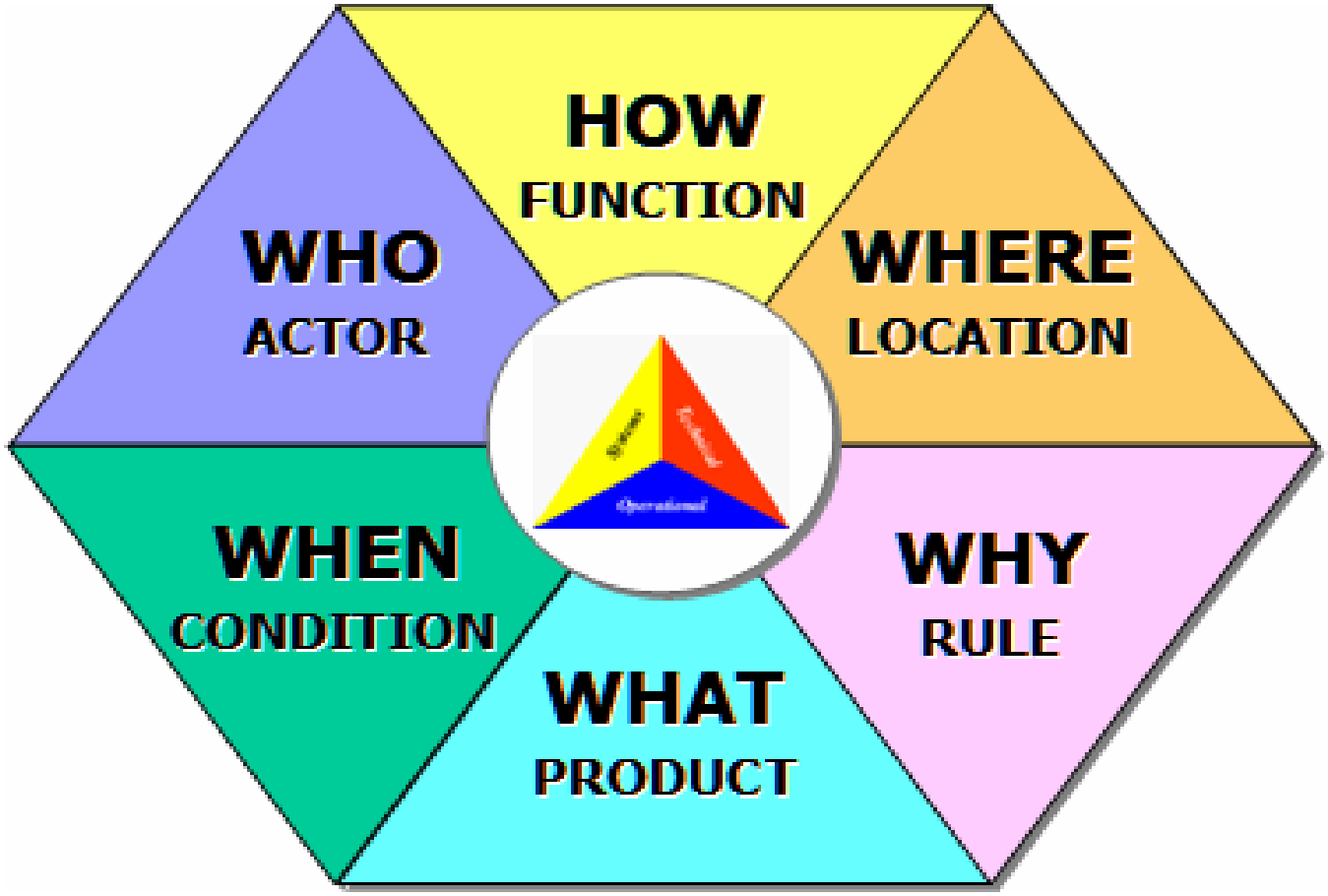
DoDAF redux



DoDAF v2.0 Architecture Conceptual Data Model

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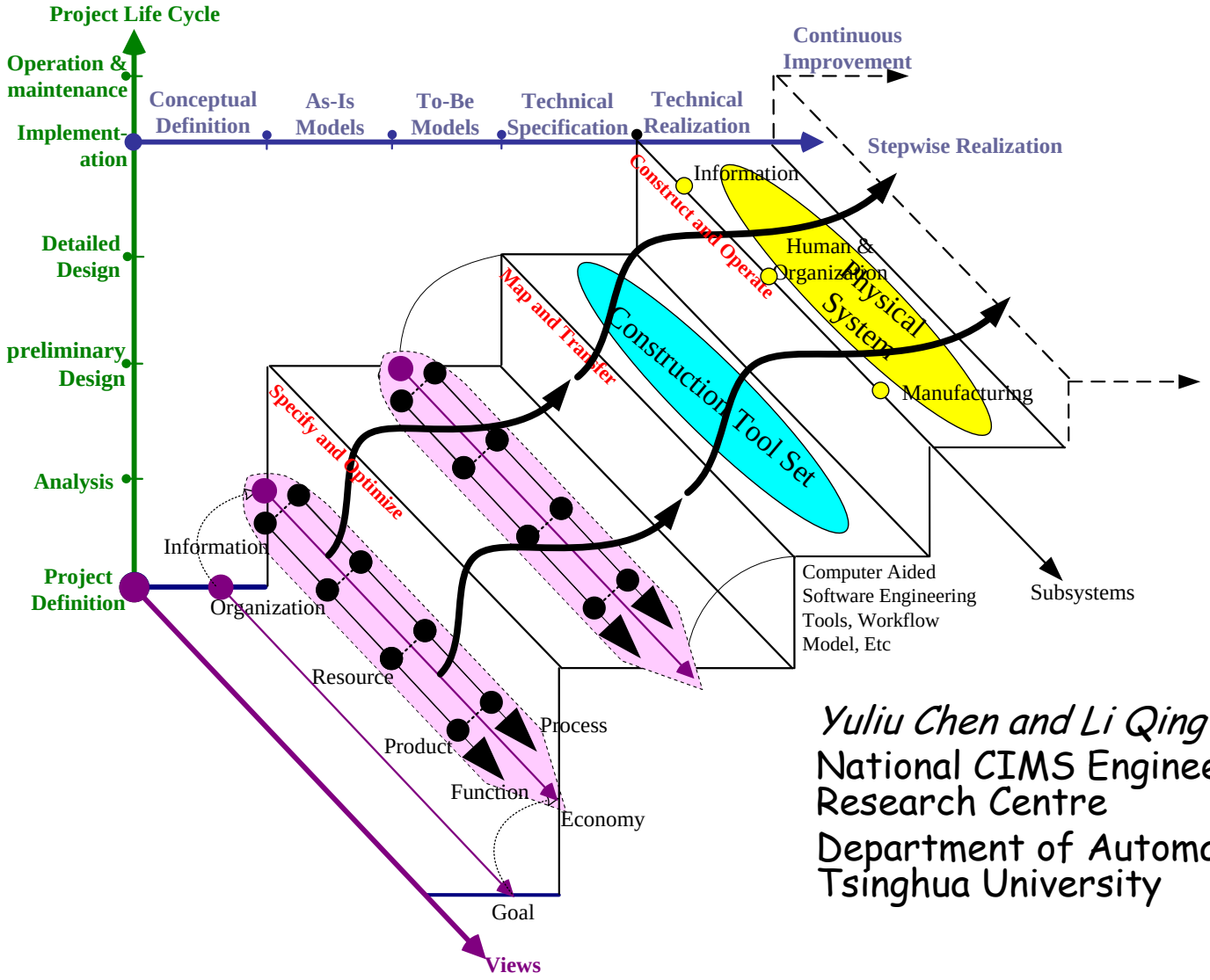
Stair-like Architecture



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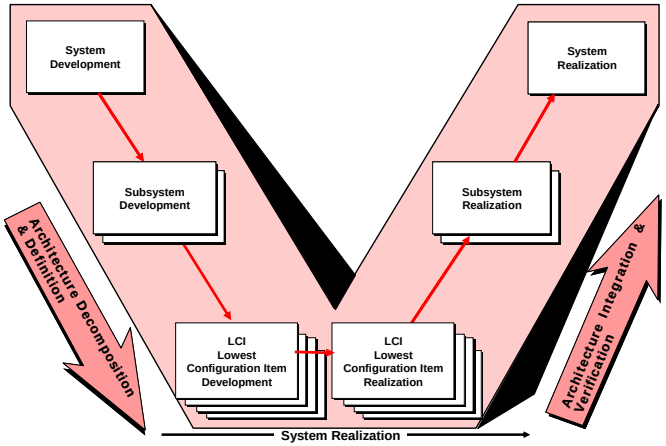
Mooz and Forsberg

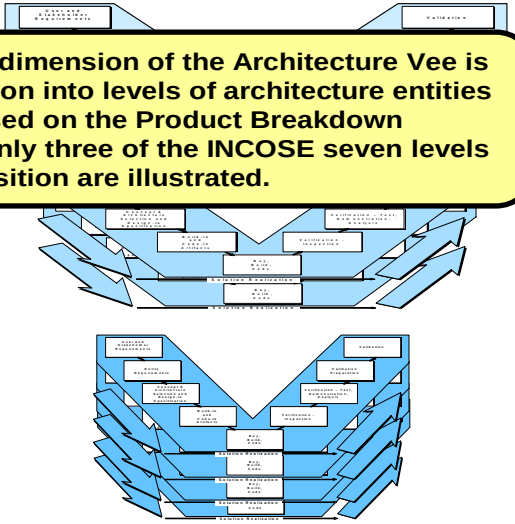
Dual Vee Model

Architecture Vee
for architecture management



Depicts architecture baseline evolution. Vertical dimension is architecture decomposition. Horizontal dimension is system realization. Third and normal dimension is quantity of entities and their interfaces.

Entity Vee
for entity management



The vertical dimension of the Architecture Vee is decomposition into levels of architecture entities which is based on the Product Breakdown Structure. Only three of the INCOSE seven levels of decomposition are illustrated.

The vertical dimension of the Entity Vee is extent of elaboration detail at the decomposition level of interest such as Subsystem or Lowest Configuration Item. The elaboration includes the baselines of concept, architecture, design-to, build-to, code-to, as-built, etc.

CSM THE CENTER FOR SYSTEMS MANAGEMENT

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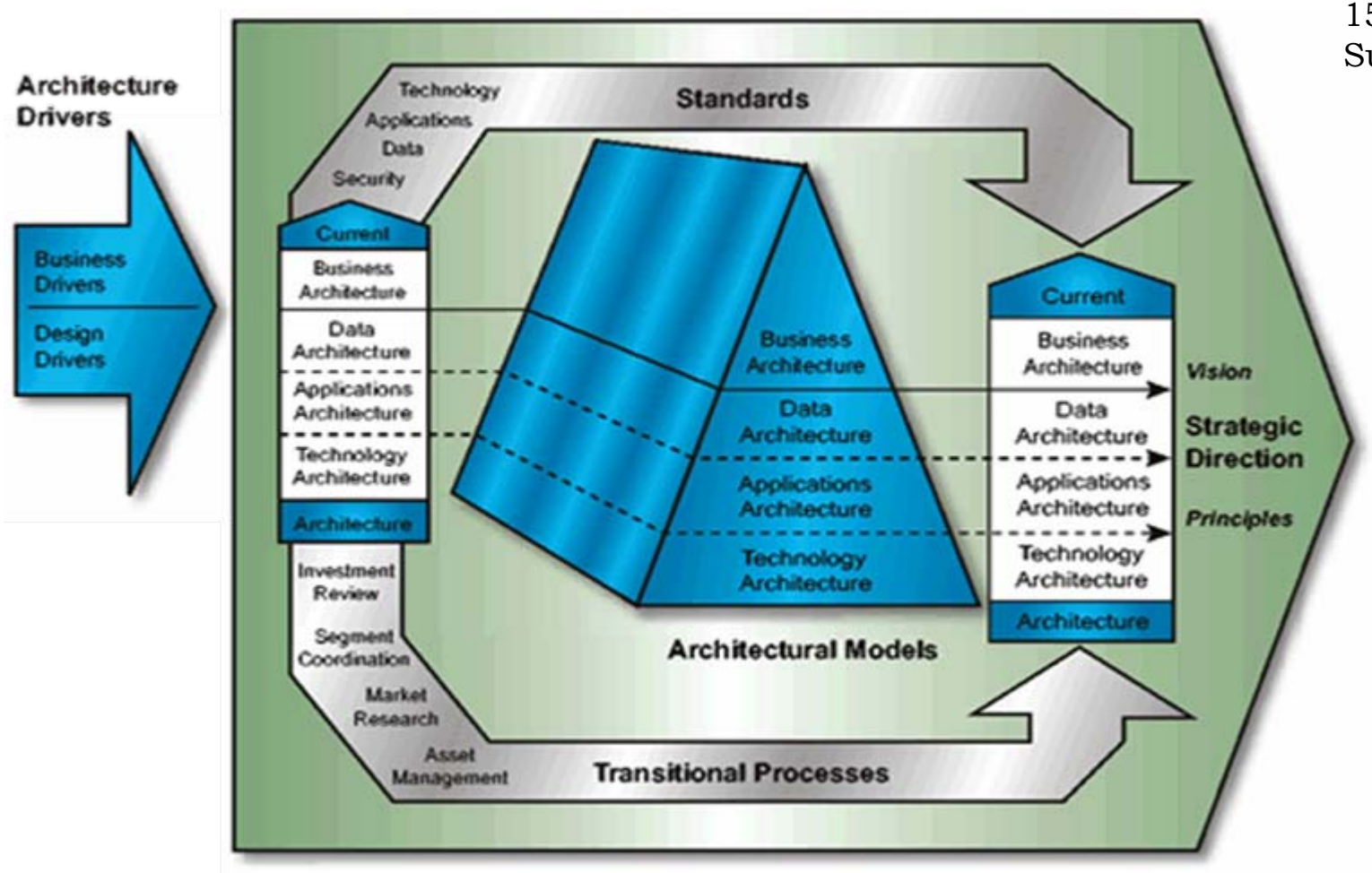
FEAF



Federal Enterprise Architecture Framework

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Synergetic efforts

Liaison

– a channel for communication between groups

Observation - a critical pattern within the architecture of international standards

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Liaisons

Liaisons help to expand the reach for input and validation

Internal (within ISO, like SC4 & JTC1)

External (beyond ISO national bodies)

- IEC, CEN, etc.
- INCOSE, OMG, ISA, OASIS
- Experts from industry and academia

A place for anyone who wants to participate

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INCOSE liaison

- INCOSE Standards Tech Committee (STC)
  - Coordinate INCOSE WG involvement, tasks, etc.
  - STC Liaisons: JTC1/SC7 & TC184/SC5
- Other INCOSE WGs involved:
  - Architecture - Charles Dickerson
  - Integration & Interoperability - John Nallon
  - Model Based SE- Phil Spiby
- INCOSE Connect webpage established
- INCOSE INSIGHT articles (Jan & Apr 07)

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INCOSE Liaison future

- Evaluating 15704/GERAM & liaison w/ IEEE 1471
- Developing plan for 15704 revision
- Reviewing 15704/GERAM comments
- Terminology & definition issues
- Next ISO TC184/SC5/WG1 Mtg:
  - Oct 07, Vienna
- Special EA workshop @ Jan '08 IW

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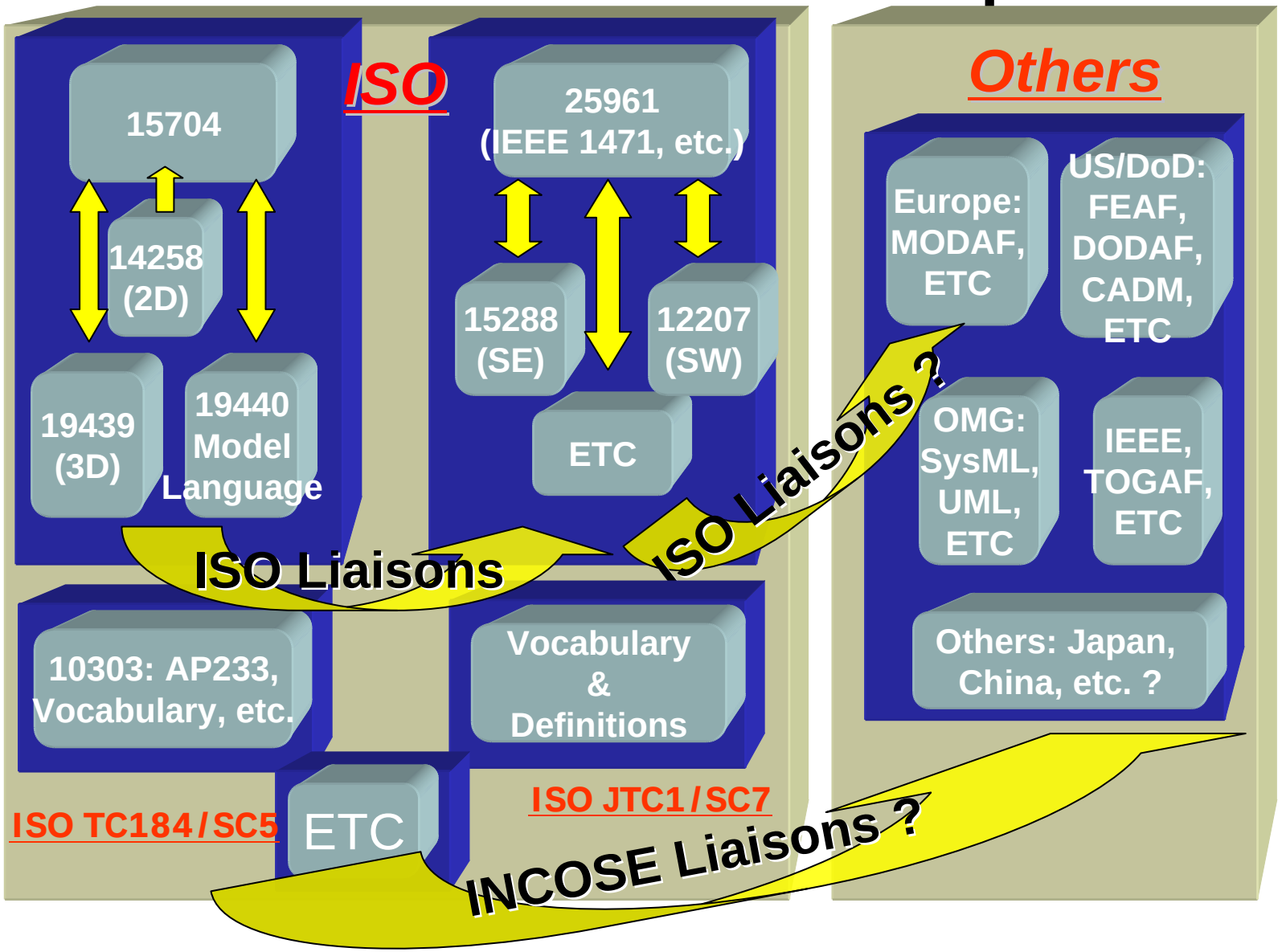
INCOSE Relationships



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Mindful of Principles

General Principles

1. Models are formal artifacts developed and used by people.
2. A complexity tradeoff exists between modeling medium and model instances in that medium.
3. Naming serves as the bridge between the formal and the human.
4. Separate model and instance decompositions – do not confuse meta-levels.
5. Dependency is not chronology
6. Don't hide architecture in methodology.

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More Principles

Framework Principles

7. Frameworks organize artifacts to facilitate understanding.
8. To improve quality, distinguish structure from connectivity.
9. Separate policy from mechanism.
10. Both grid (ordinant) and tree (decomposition) structures appear in models.
11. Scale dimensions include:
    abstractness (abstract to concrete),
    refinement (coarse to fine) and
    scope (general to special)

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More Principles - 2

12. Within a framework, use of components are driven along one ordered dimension.
13. Along this ordered dimension, all prior context is relevant.
14. Refinement is recursive using iteration.
15. Connections can be of arbitrary arity.
16. Views are important in standards and methodologies.
17. Views are used both to "see" contents and to "create" contents.
18. Separate model and instance constraints.

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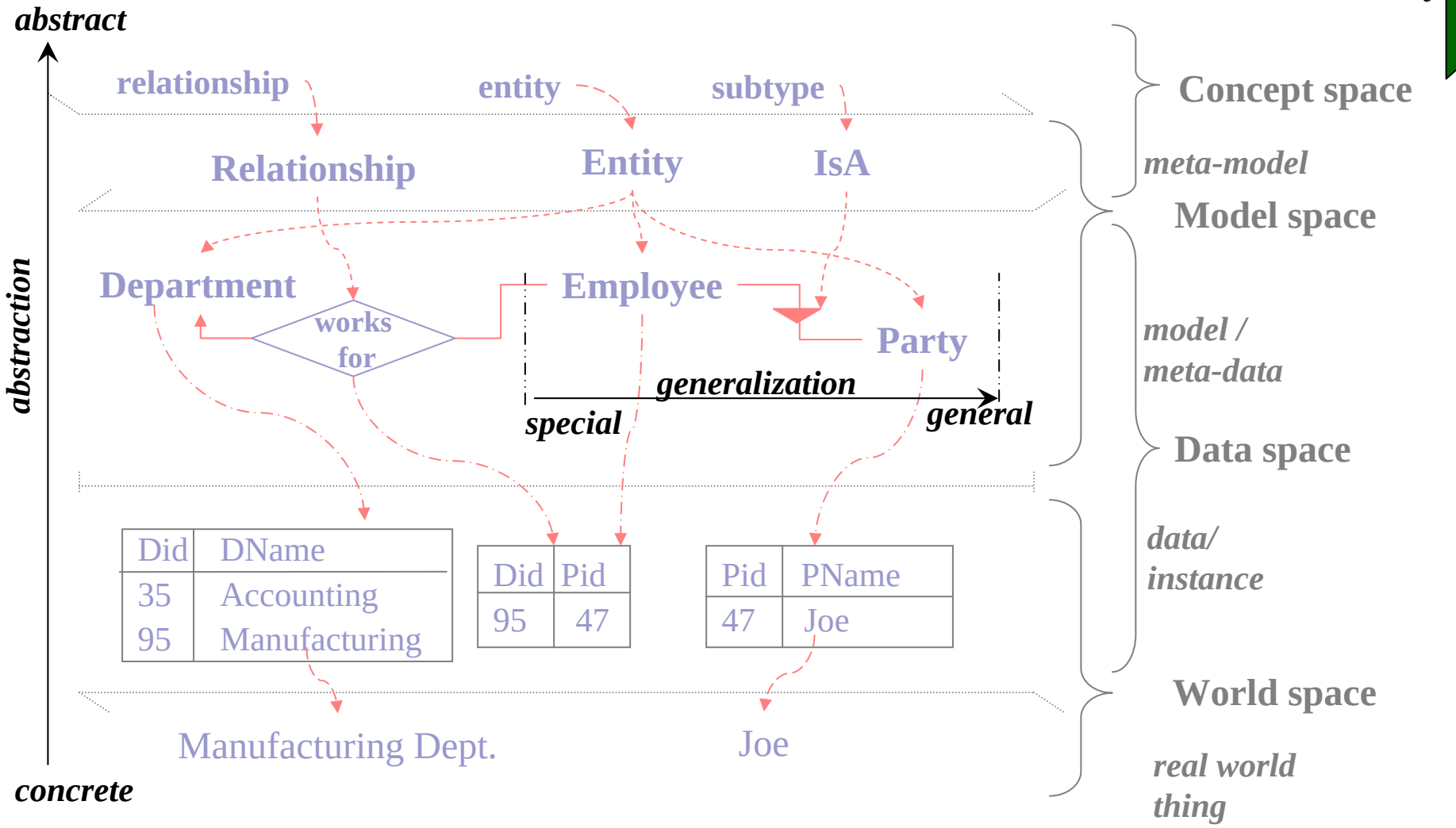
Scope & Meta-confusion



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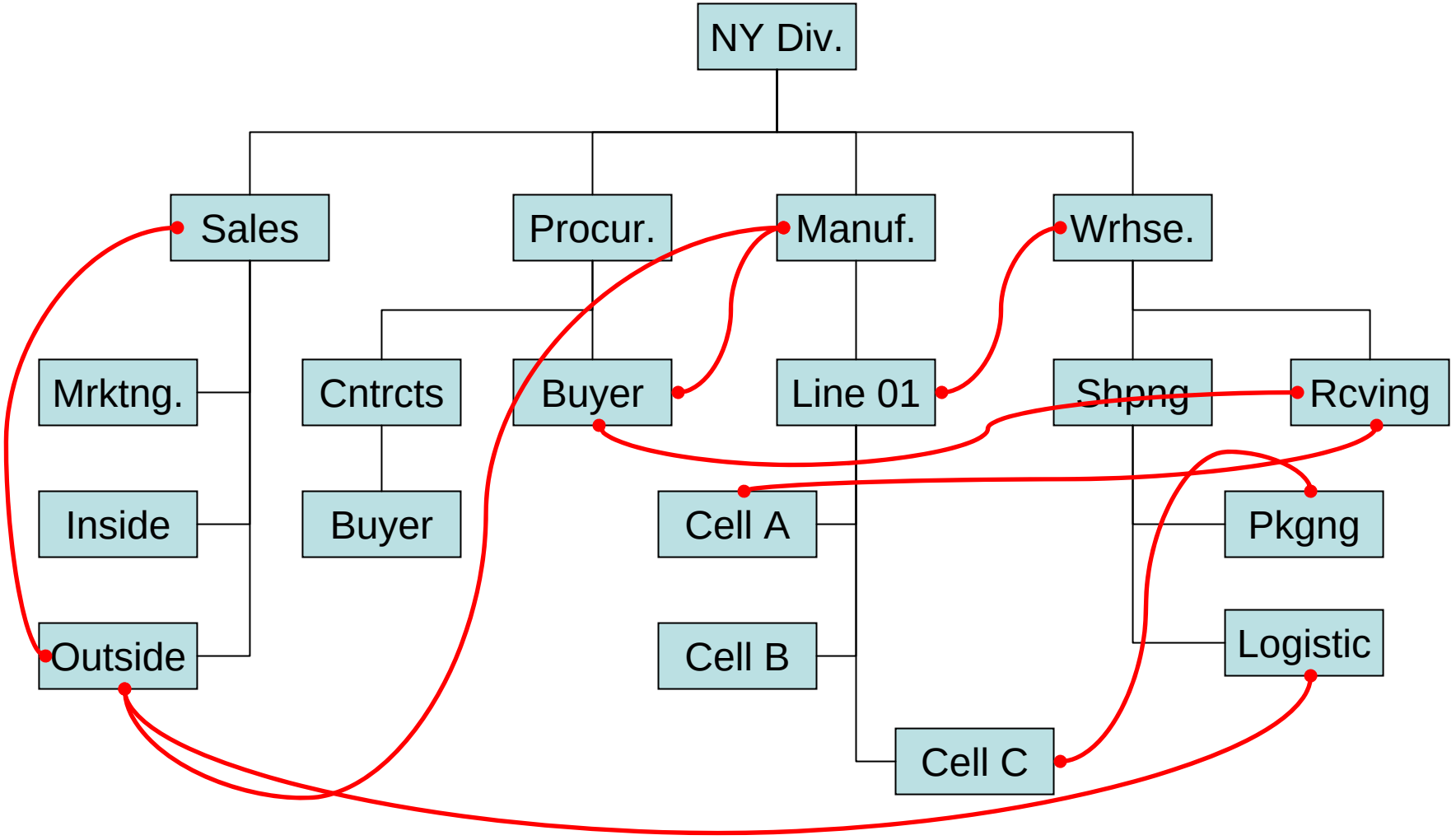
Distinguish structure from connectivity



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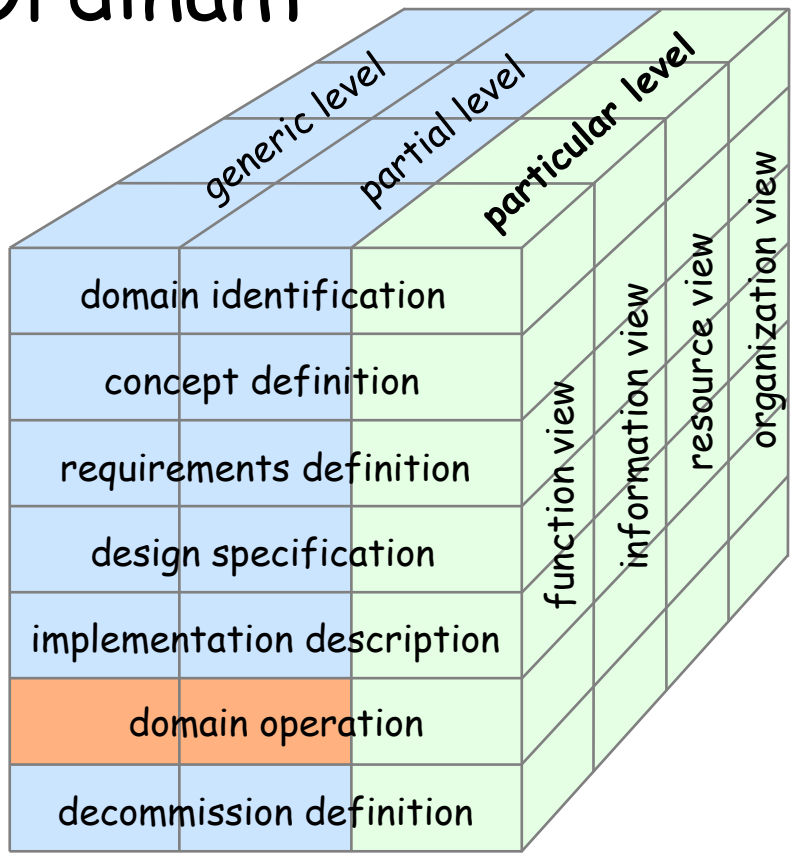
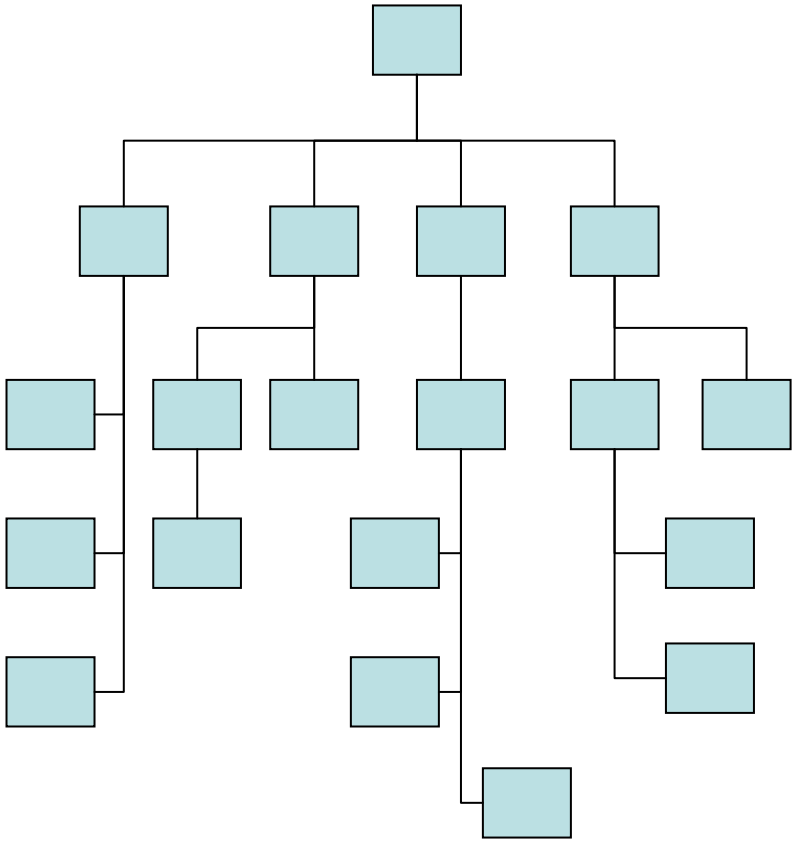
Two structural aspects

Ordinant





Decomposition

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Purposeful dimensions

Zachman: **Role**

{Context, Owner, Designer, Builder, Out-of-context}

ISO 19439: **Model Phase**

{Domain, Concepts, Requirements, Design, Implementation, Operation, Decommission}

ISO 15288: **Process Group**

{Agreement, Enterprise, Project, Technical}

C4ISR/DoDAF: **Guidance**

{Focus, Scope, Characterize, Determine, Build, Use}

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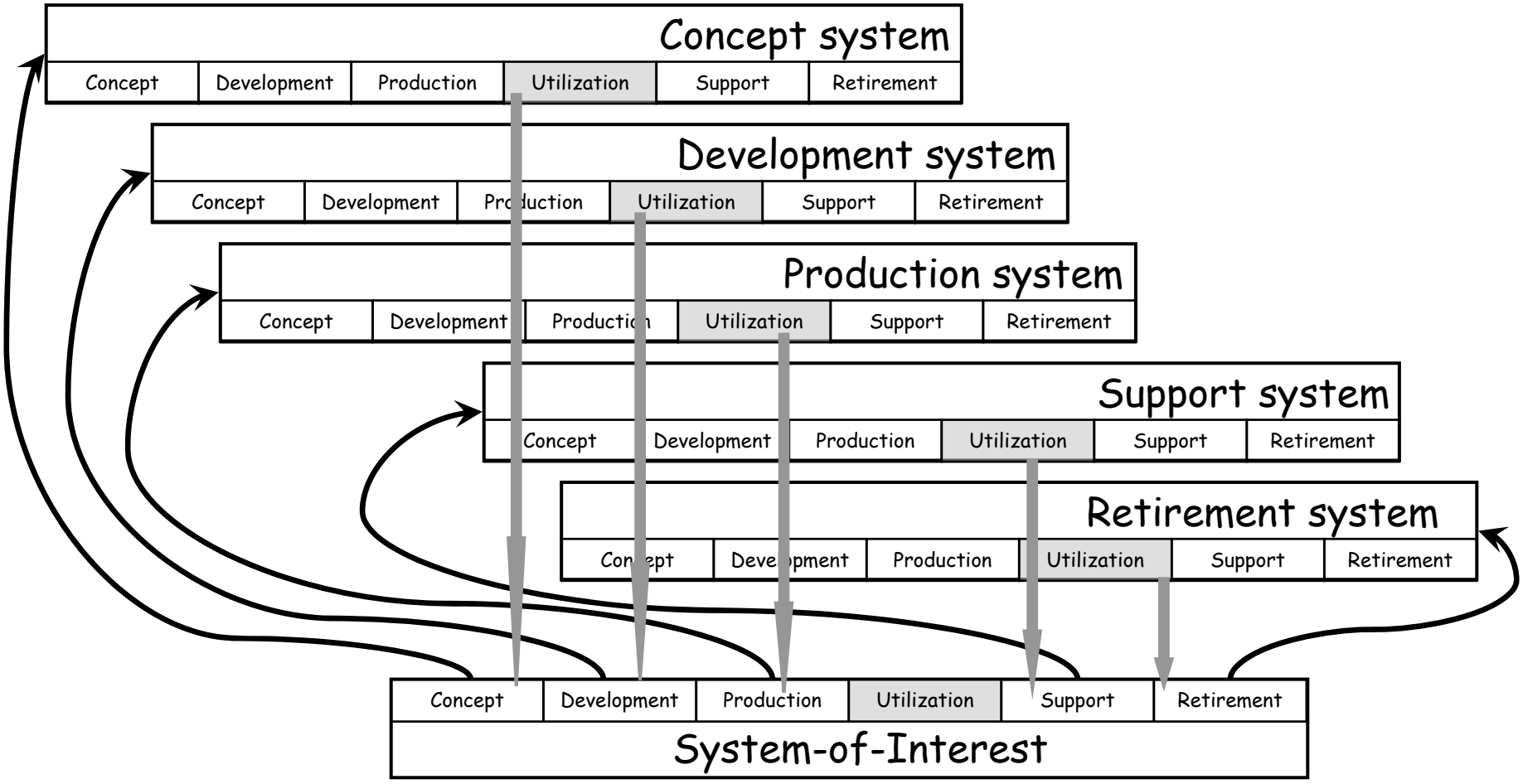
Recursive refinement

cf. ISO 15288



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Views

Views are for communication and analysis.

A static collection of views is insufficient.

Views exist at all meta-levels.

View of structure is meta with respect to view of data.

View update often crosses meta-levels.

Standards sometimes specify a view using a viewpoint.

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Observation points

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Terminology wars

No one speaks the way you do

- Different training
- Different disciplines
- Different customs
- Different translations

A large global upper ontology is a myth

Local taxonomies and meaningful phrases are achievable standards

Precision is more important than recall

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ISO 14258:1998

Adopted after 14 year effort

- Over 300 documents reviewed
- Focus on manufacturing systems architecture
- Lead by National Institute of Standards and Technology - USA

A consensus predicate to on-going reference model effort

10 basic definitions (some still contentious)

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Systems theory aspects

structural – elements have multiple interdependencies leading to emergent qualities

behavioral – identification of variable and functional relationships

hierarchical – systems within systems and levels of abstraction embodied in emergent qualities

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Levels of abstraction

Lower levels reveal detail and the means to achieve purpose – more concrete

Higher levels reveal the role of system within environment – more abstract

Each level has structure and behavior

Observation - enterprise architecture (EA) is manifest in enterprise models (EM) as a pattern. Constraints on the EM are the EA.

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Need for life-cycle

EM shall address what happens to the factors of production (such as people, capital, material, information, energy, and tools) during the phases of the enterprise or product life-cycle.

- Products, processes, projects, and enterprises are systems.
- Systems have a life cycle that can be partitioned into phases such as plan/build, use/operate, and recycle/ dispose.

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Broad model scope

EM shall define relevant aspects of the enterprise necessary to

- conceive, design, procure for, and construct an enterprise consisting of any set of related chosen processes
- manage and operate an enterprise so that it can meet its objectives
- support an enterprise to modify, redesign, dismantle and rebuild it

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Must be accessible

As architectural representations of enterprises, models shall exhibit syntax and semantics so that contents of the model are understandable to human users.

- The syntax of a model refers to the permissible kinds of relations.
- The semantics of a model encompass the meanings of the elements and relations with respect to enterprise-model concepts.

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Manageable parts

Enterprise models shall be designed in such a way as to allow their constituent parts to be managed by an automated configuration-management system.

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Issue-solving activities

Three types of activities are required to solve issues found within each high-level system life-cycle phase. These types are:

- find out what to do (W activity),
- find out how to do it (H activity),
- do it (D activity).

W, H, and D activity models shall have the capability to interoperate.

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ISO 14258:1998 Figure 1

Phase \ Issue-solving activities	"What" Activities	"How" Activities	"Do" Activities
Plan and Build Phase (e.g., before sell/buy title transfer)	•Develop goals •Define strategy •Define product needs	•Develop Requirements •Define concept •Design product •Plan to produce product •Plan to support product	•Procure parts •Produce product •Test product •Ship product
Use and Operate Phase (e.g., after sell/buy title transfer)	•Define support needs •Define Use	•Define Use Requirements •Define Support Requirements	•Use the product •Support product
Dispose and Recycle Phase (e.g., after product is No longer useful)	•Define recycle/dispose needs	•Define recycle/dispose requirements	•Recycle product •Dispose product

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Another way to view it

Context Reference
14258
15704
Summary

ISO 14258:1998 Figure 1 Transposed

Issue-solving activities \ Phase		Plan and Build Phase (e.g., before sell/buy title transfer)	Use and Operate Phase (e.g., after sell/but title transfer)	Dispose and Recycle Phase (e.g., after product is no longer useful)
		w| How |w|w|w|w	w| How |w|w|w|w	w| How |w|w|w|w
Specify	"What" Activities	•Develop goals •Define strategy •Define product needs	•Define support needs •Define Use	•Define recycle/dispose needs
Design	"How" Activities	•Develop Requirements •Define concept •Design product •Plan to produce product •Plan to support product	•Define Use Requirements •Define Support Requirements	•Define recycle/dispose requirements
Build Operate	"Do" Activities	•Procure parts •Produce product •Test product •Ship product	•Use the product •Support product	•Recycle product •Dispose product

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Life-cycles of systems

Different life-cycle phases may have different models.

These models shall have the capability to interoperate where it has been determined that processes need to communicate with each other.

- Feeding modeled information forward and backward in life-cycle activities enables value-added iteration of enterprise processes that improves product quality.

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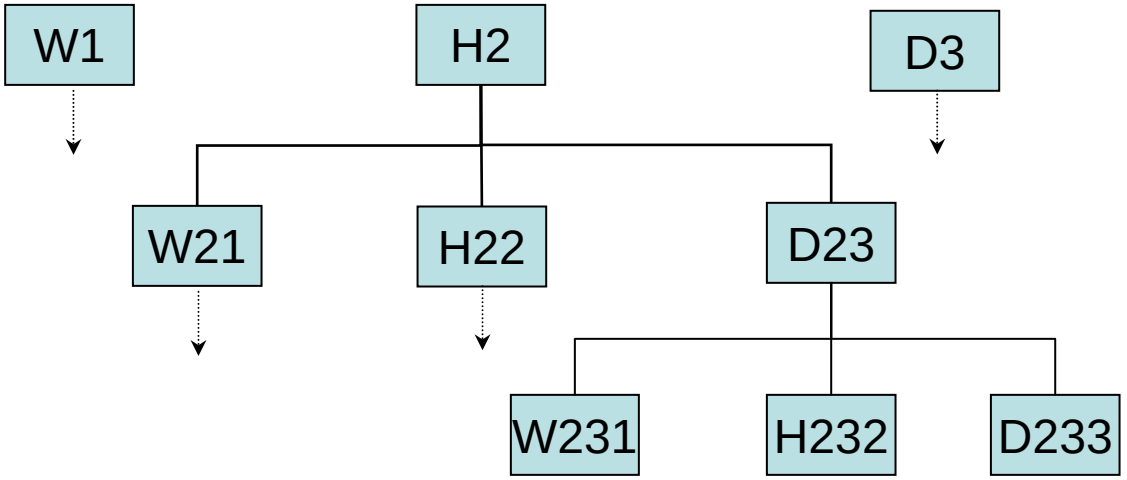
Recursion (structural)

The W, H, and D activities are recursive and decomposable.

Activities can be divided into sub-activities, and these sub-activities will consist of another set of W, H, and D activities.



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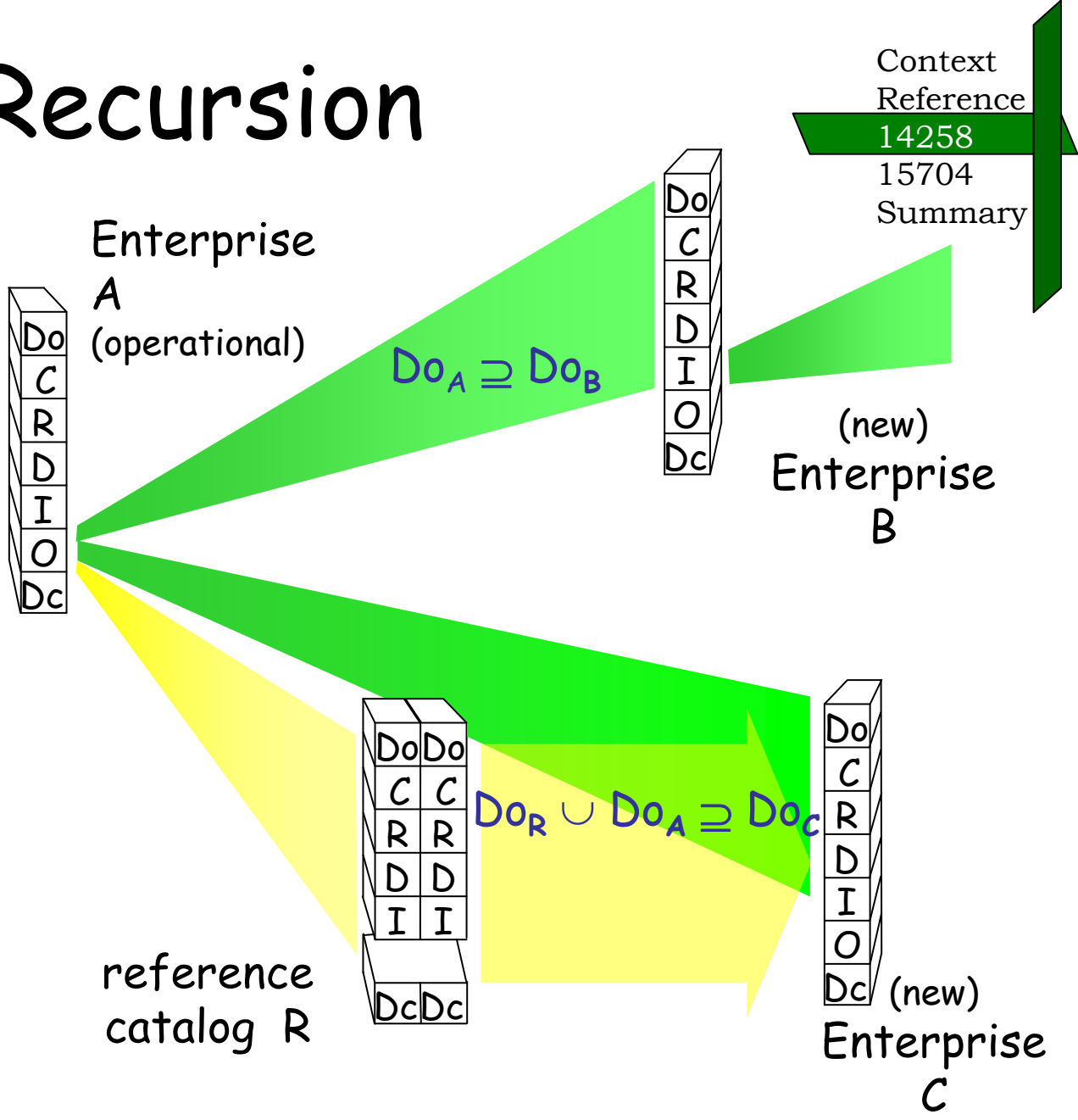
19439 - Recursion

Enterprise operations can model new enterprises either from its own particular models or using reference constructs and partial models.



Sub-activities interact

Sub-activities may be represented by different types of models.

These models shall be able to interoperate where it has been determined that these sub-activities need to communicate with each other.

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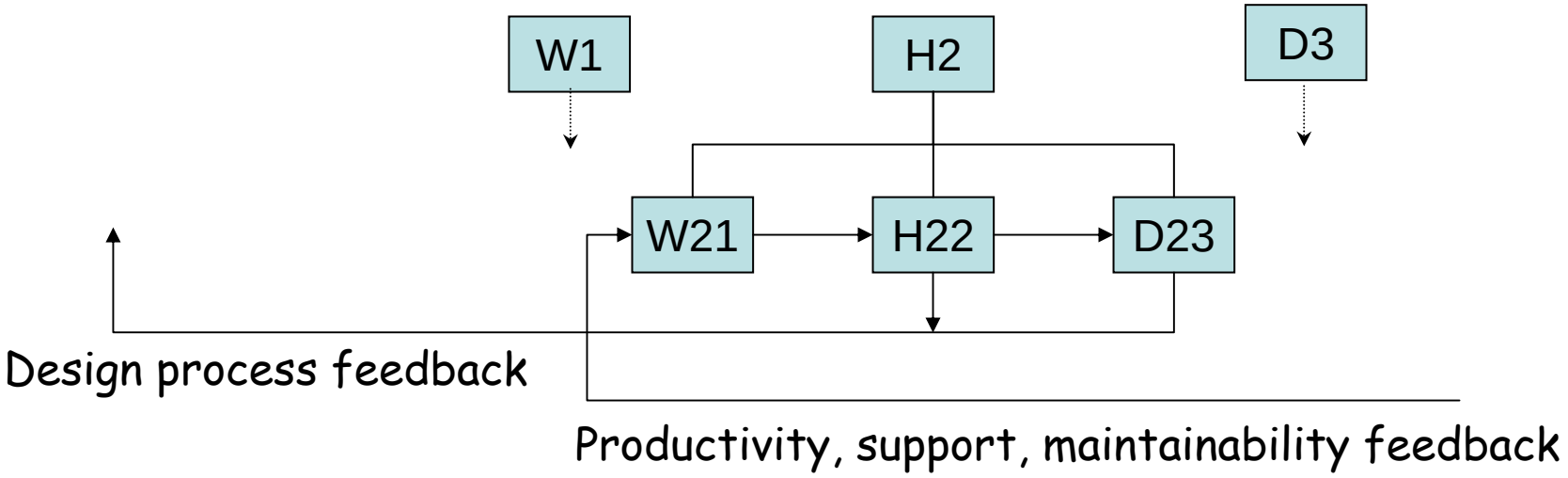
Iteration (behavioral)

The W, H, and D activities are iterative.

- There is no fixed sequence of activities.
- It is possible to return to previous activities to repeat them with updated input.



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Manage change

Each performance of each model-making activity may result in a different model.

Every one of these different models shall be subject to both change and version management.

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Hierarchy types

Classification (Kind-of) hierarchies shall be used within models to classify building blocks for entities to be modeled.

Composition (Part-of) hierarchies shall be used to link models of different scope and detailing granularity of decomposition.

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Structure concept types

1. Activities correspond to elements and objects correspond to relations.
   - E.g., a value-adding process where the output objects (considered as relations) of one activity (considered as an element) are the input objects of another action (considered as an element).
2. Activities correspond to relations and objects correspond to elements.
   - E.g., the structure of a process plan where two objects (considered as elements) are linked by an activity (considered as a relation).

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Compatible structures

The type of structuring shall be unambiguous to whatever facility is interpreting the models, either human or machine.

The enterprise modeler shall ensure that models obtained by the two structuring approaches are able to interoperate.

Observation – two views of the same underlying conceptual or actual model

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Behavioral concepts

An enterprise is a social hybrid system, determined by properties of humans and machines.

Humans (modeled as objects or resources) in the enterprise have a different behavior (e.g. learning and problem solving) from machines (e.g. acting and reacting) and sometimes need a different kind of information.

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Representing behavior

The set of models for an enterprise shall have the capability to describe behavior with respect to

- sequentiality, events, actions, condition
- states, state changes, start states, end states,
- sequencing relationship between actions,
- description of transformation functions.

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Time concepts

Time is relative to the observer.

- Static representations are devoid of time
- Dynamic representations express time sensitive properties and dependencies
- Change is immediate (short-term) or continual (long-term)

Describing behavior requires sequentiality.

- Sequential cycles are similar states being traversed at different times.
- Measuring sequence in time enables discrimination between similar cycles progressing at different rates.

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Representing time

To trace individual elements, sequence properties shall be modeled to describe short-term changes.

EM shall be able to represent time duration, dynamic performance of processes, and sequential phenomena after specific units of time.

EM used to analyze enterprise performance or to simulate processes shall be able to represent effects of sequential phenomena and the time duration of each sequence step.

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Modeling purpose

Models describe essential and relevant parts of an area of concern.

Models do not duplicate reality but are limited approximations of the subset of reality under consideration.

Extent of model detail is relative to its purpose.

Full model description includes purpose, assumptions, and constraints.

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Observers ≈ Viewpoints

- Observers perceive and analyze with attribution of meaning.
- Observer filter is continually modified by experience, personality, politics, society, and situation.
- Enterprise modeler is observer whose purpose is to create an enterprise model.
- The modeler shall define unambiguously the purpose for the model.
  - Model user is observer with task in area of concern addressed by the model.

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Views

Views enable observation using assumptions and constraints.

Views are used to verify completeness, consistency, and integratability of EM.

Two views are of primary importance in representing the structure and behavior of a real world system.

- The information view reveals structure.
- The function view reveals behavior

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Model description

A full, integratable description of any model shall include statements and descriptions of its purpose, assumptions, and constraints.

This shall be done by including a minimum set of modeler views that ensure adequate completeness and consistency, and provide the potential for integrating multiple models of the same enterprise.

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Many models, one solution

- There are as many ways to represent in models as there are reasons to model.
- Users want to reuse models across applications and not be dependent on specific application and tool configuration.
- Users want the many forms to appear as and operate as one solution for their enterprise modeling needs.
- Many models must interoperate to be one solution.

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Way to interoperate - 1

Integrated - bottom up

- Diverse models using common template
- Enormous difficulties associated with standardizing large numbers of models
- Standard or reference models must be as rich as the constituent models
  - Stored in standard form filtered or translated by application, e.g., IRDS
  - Standard models agreed by constituent model owners, e.g., STEP

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Way to interoperate - 2

Unified - top down

- Template provides a common meta-level structure across constituent models to enable mapping between models using semantic equivalence.
- Template is the meta-model for all models but, therefore, is not executable.
- Normalized semantics is established by model owners. (OMG UPDM)
- Then interoperation is straight forward.

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Way to interoperate - 3

Federated - chaotic reality

- No agent imposes requirements for semantic equivalence across models of the enterprise.
- Template is at the meta-level and is not executable.
- Interoperation requires dynamic accommodation rather than predetermined meta-model.
- A shared ontology is very helpful.

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Communication essential

Integrated depends upon standard protocols.

Unified depends upon mediation.

Federated success is highly dependent upon skills and capabilities of humans and machines.

Observation - Interoperation is the exchange of information, material, and energy between entities.

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ISO 15704:2000

- Adopted in 2000 after 15 year effort to consolidate existing knowledge and practice in the area of industrial automation
- Lightweight standard, only 8 pages, and middleweight annex A of 31 pages with heavyweight content
- References normative content from ISO 14258

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ISO 15704:2000 (cont.)

- Primary input is annex A produced by an IFIP-IFAC task force
- Annex A, known as GERAM, articulates a compliant approach and expands context
- Amended in 2005 with 2 new user views
  - Economic view that introduces a new dimension of detail
  - Decision view that introduces a way to articulate operational decisions in time

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Informative introduction

Two primary concerns for enterprise integration base of reference

- Model the whole life history of an enterprise-integration project
- Encompass the people, processes and equipment involved in achieving the enterprise mission

EA is about enterprise project structure.

SA is about system that is part of EA.

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Eight key principles

1. Issues of enterprise integration are ubiquitous and apply to any enterprise, regardless of its size and mission or other attributes.
   - Integration goes beyond information and control systems to encompass culture and mission.
   - Manufacturing is a customer service.
2. Enterprise identification and mission definition are essential.

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Key principle 3

3. Separate mission-fulfillment functions from mission-control functions
   - Fulfillment includes process operation to produce the product or service
   - Control includes the use of information to manage processes and maintain operations
   - Interconnection between fulfillment and control is operational data to control and operational commands to fulfillment.

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Key principles 4 & 5

4. Operations consists of the many transformations of material, energy, and information performed by processes.
   - Processes executed concurrently or sequentially
   - Combination of processes define functionality of the enterprise
5. Evolutionary integration of modules is essential.

evolving

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Key principle 6

6. Three kinds of processes
   - Information and control activities that can be automated by control devices
   - Mission activities that can be automated by mission-fulfillment equipment
   - Activities carried out by humans, whether for information and control or mission-fulfillment
     - Desire a simple way of showing where and how humans fit in the enterprise and how the distribution of functions between humans and machines is accomplished

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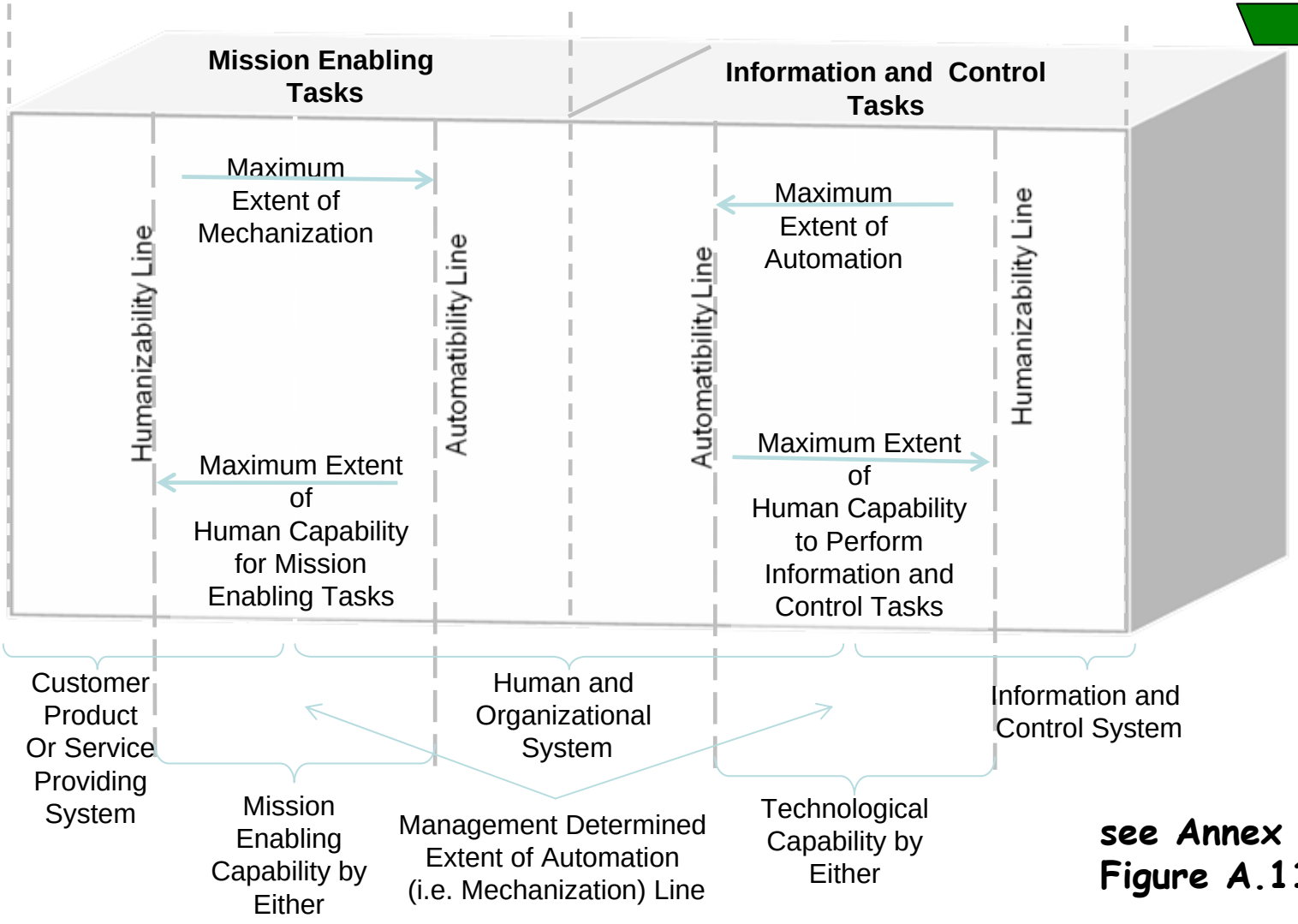
Function distribution



see Annex A, Figure A.11

Adapted from: T. J. Williams, Institute for Interdisiplinary Engineering Studies, Purdue University

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Key principles 7 & 8

7. Every enterprise and product has a life-cycle.
   - A life-cycle can be partitioned
     - Partitioning is specific to purpose
     - Partitioning does not imply strict sequence
   - One enterprise can be embedded within the life-cycle of another's operational phase.
8. Modularity should be enforced whenever possible.

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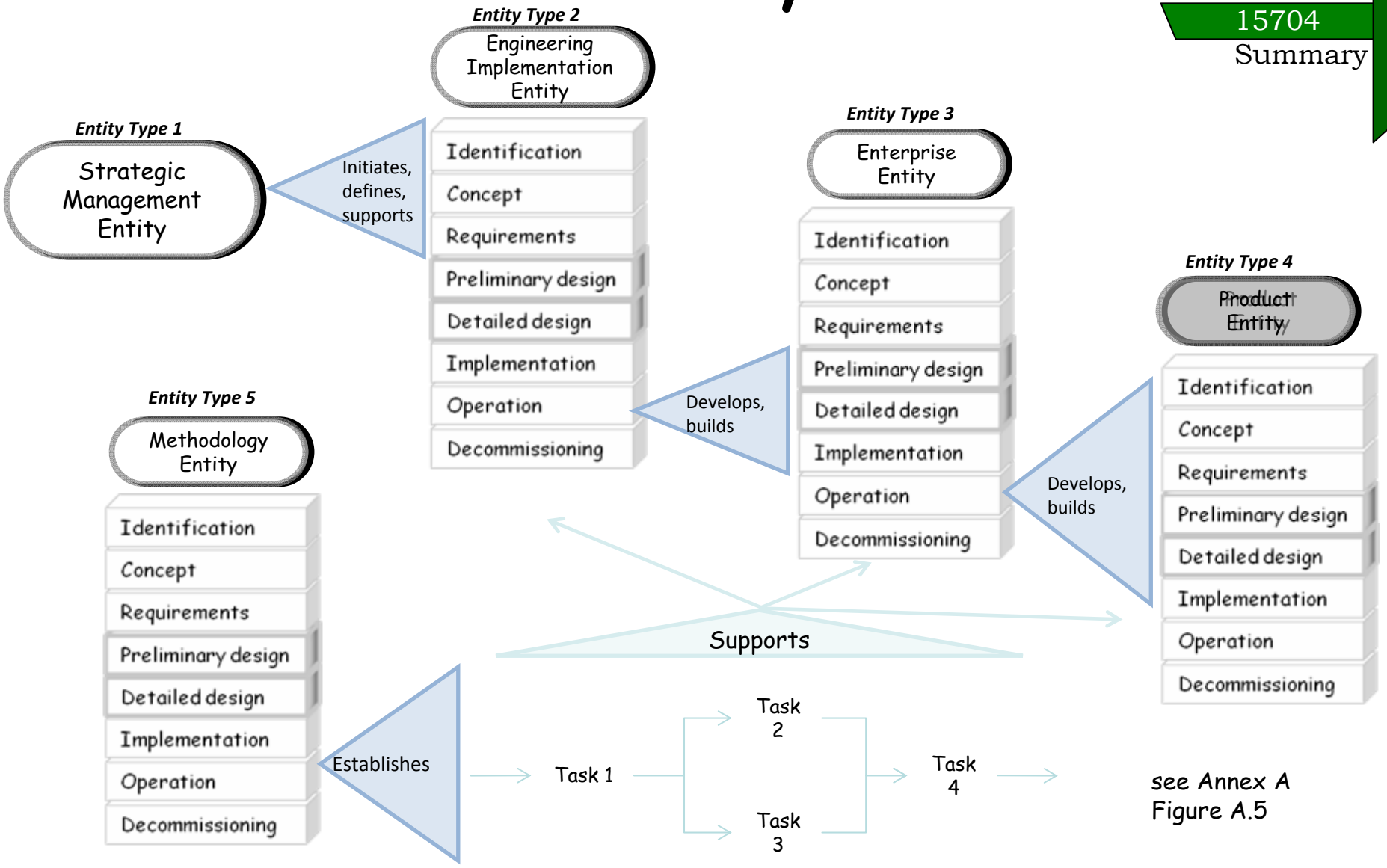
Embedded life-cycles



see Annex A Figure A.5

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Stakeholder concerns

The standard enables an enterprise-integration-planning team to:

- Describe the tasks required
- Define the necessary quantity and quality of information
- Specify relationships among humans, processes, and equipment in the integration considered
- Address management needs

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More concerns

- Address relevant economic, cultural, and technological factors
- Detail the extent of computer-support required
- Support process-oriented modeling that can model the whole life history of an enterprise
- Checking for completeness with respect to ERAM current and future purpose

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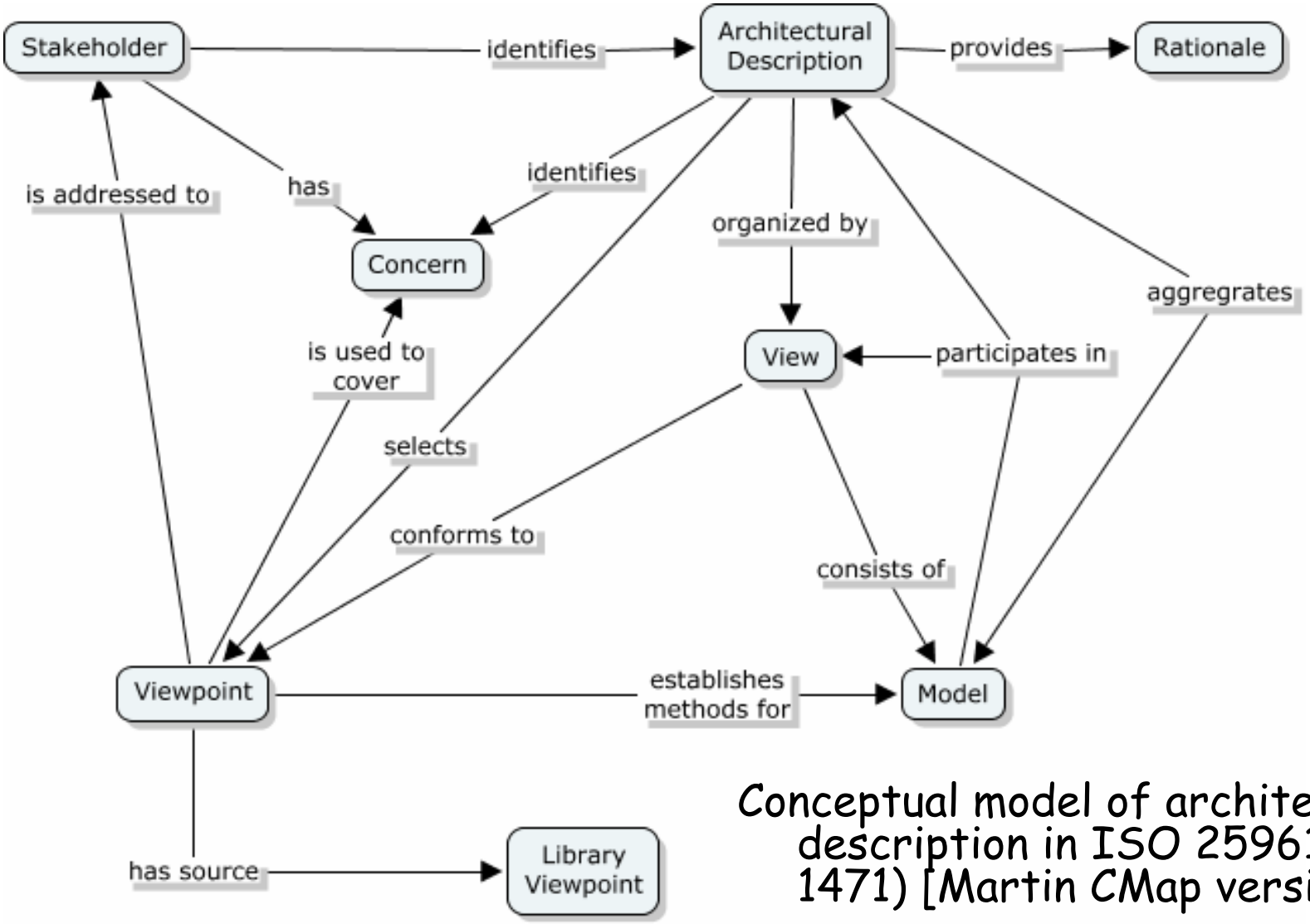
Viewpoints and views



Conceptual model of architectural description in ISO 25961 (IEEE 1471) [Martin CMap version]

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ISO 15704 Scope

Enterprise-reference architectures and methodologies (ERAM) covers those constituents deemed necessary to carry out all projects required by the enterprise throughout the whole life of the enterprise, including:

- enterprise creation
- major enterprise restructuring efforts
- incremental changes affecting only parts of the enterprise-life cycle

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Requirements of 15704

Enterprise-reference architectures and methodologies (ERAM) shall be capable of assisting and structuring the description, development, operation, and organization of any conceivable enterprise entity, system, organization, product, process, and their supporting technology.

Areas covered by ERAM shall be clearly identified.

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General usage

The methodology associated with a reference architecture shall provide the necessary guidelines and management techniques for the initiation and pursuit of a project or program of development and operation of an enterprise or entity.

Such a methodology may or may not be model-based, i.e., the enterprise engineering process may or may not result in a specific enterprise model.

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Many potential ways

ERAM need not be based on any one single methodology and its accompanying architecture or framework. Many different methodologies and/or frameworks may be used for it.

The primary consideration shall be applicability and capability in relation to these requirements.

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Design and operation

ERAM shall identify

- concepts and components
- activities to manage, conceive/define, describe, design, implement, maintain, and decommission any enterprise entity
- activities to use the results of enterprise engineering in the operation itself
  - Such use may include model-based decision support and model-driven operation monitoring and control.

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Conceptually broad

Throughout the life-cycle of the enterprise, the ERAM shall address the

- role of humans
- description of processes (function and behavior)
- representation of supporting technologies

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Human oriented

ERAM shall exhibit the capability to represent human aspects, such as:

- Organizational and operational roles
- Capabilities, skills, know-how, competencies
- Responsibilities, authorization
- Relations to the organization.

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Process oriented

ERAM shall exhibit the capability to represent the enterprise operation.

Such representations shall cover both the functionality and behavior of the operation.

The representations shall recognize the life cycle and life-history concepts of enterprise-entity types and shall support process-oriented operations.

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Technology oriented

ERAM shall exhibit the capability to represent all technologies employed in the enterprise operation.

Such representation shall provide for the use of integration-technology infrastructures to support

- enterprise engineering and operation of business processes, models of enterprise resources, facility layout models, information-system models, communication-system models and logistics models.

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Mission oriented

ERAM shall exhibit the capability to represent any process and its constituent activities involved in

- performing the established mission of the enterprise
- accomplishing management and control of the established mission of the enterprise according to the criteria established by enterprise management

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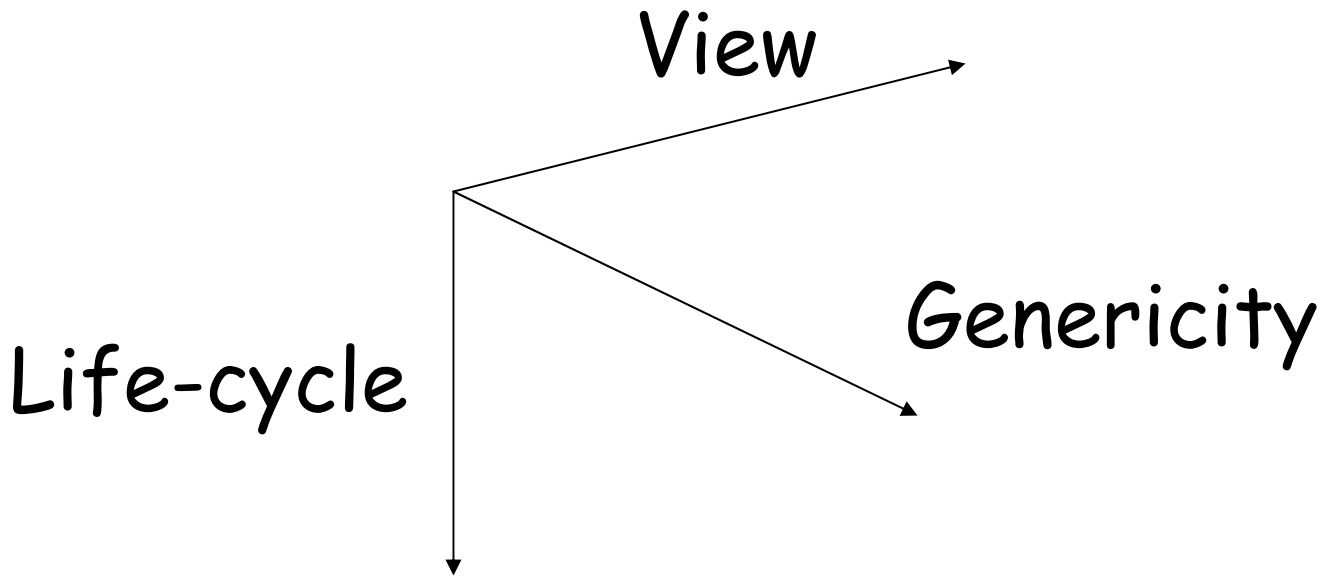
Framework for modeling

ERAM that are model-based shall exhibit the capability to model entities within the conceptual space defined by three dimensions.



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Genericity

ERAM that are model-based shall provide the capability for representing

- Generic-enterprise elements that are reusable modeling language constructs
- Partial-enterprise models that are prototype models of industry segment or industrial activity
- Particular enterprise models that are models of a particular enterprise domain

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Life-cycle & life-history

ERAM shall identify and represent the life-cycle phases pertinent during the life of any enterprise entity.

ERAM shall be capable of representing the life history of any enterprise entity, i.e., the representation in time of activities carried out on any enterprise entity (traceability)

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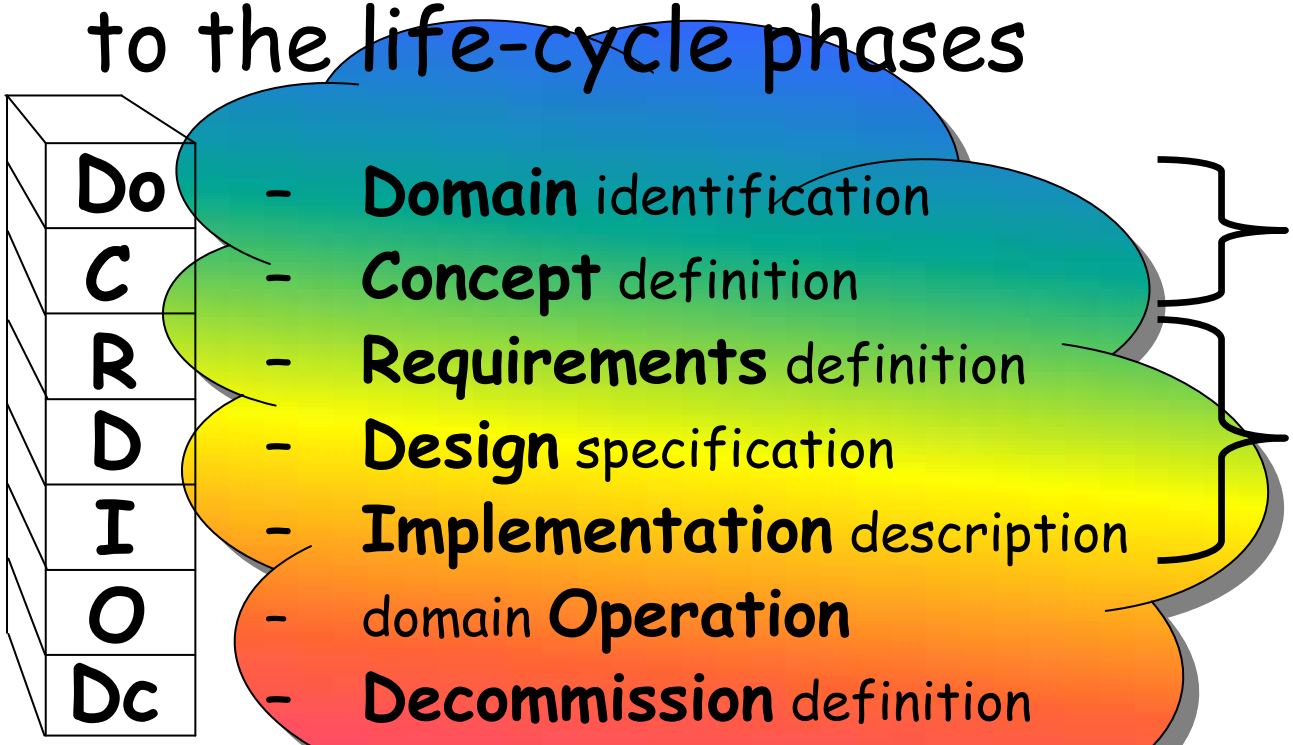
ISO 19439 Model phase

The purposive ordinant dimension ordered by coordinates corresponding to the life-cycle phases



Emphasize model development process for process oriented modeling.

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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, capability for service, manufacturing, management and control

Design specification

- Processes with all components necessary to satisfy requirements

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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

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Many possible coordinates

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

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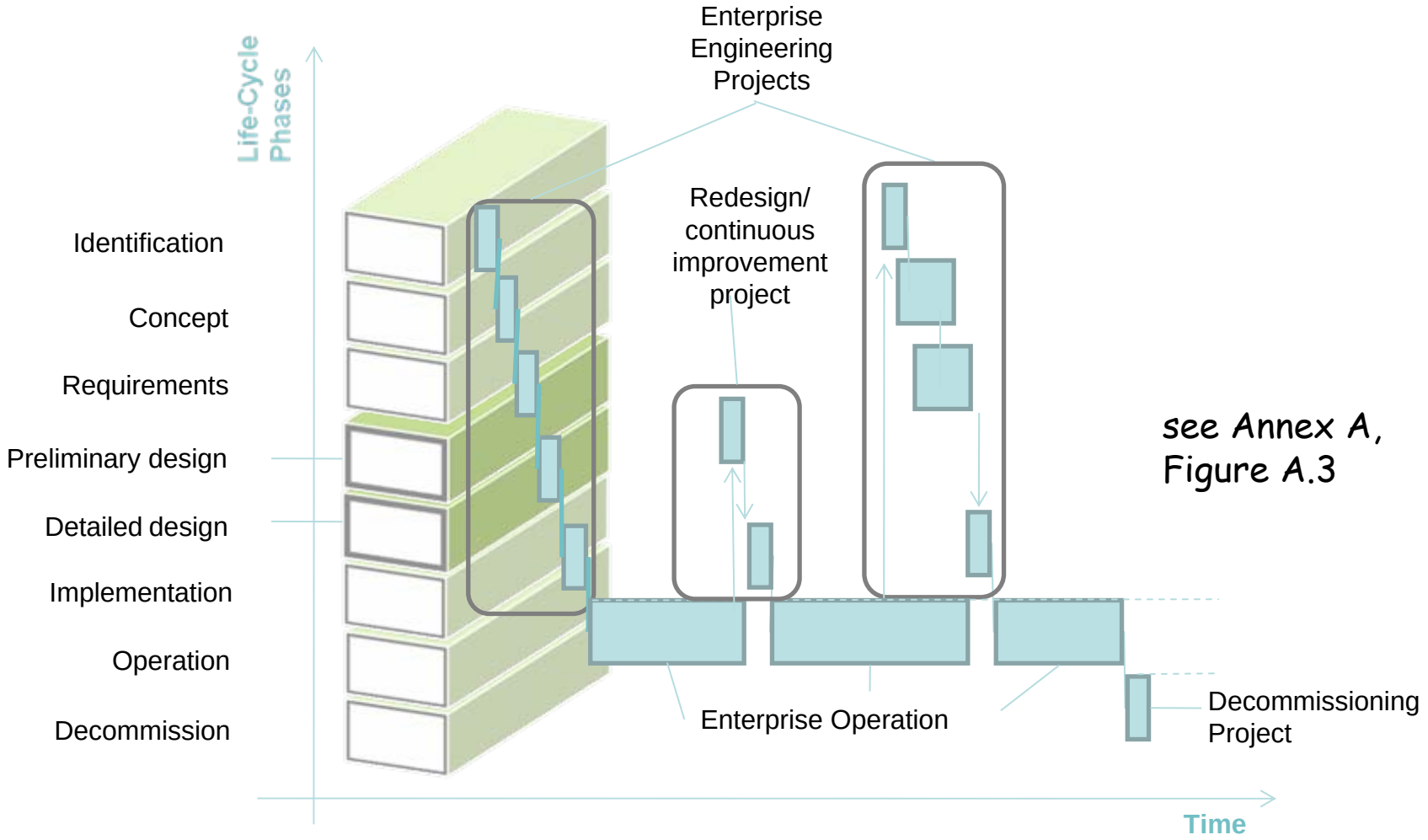
Life history



see Annex A, Figure A.3

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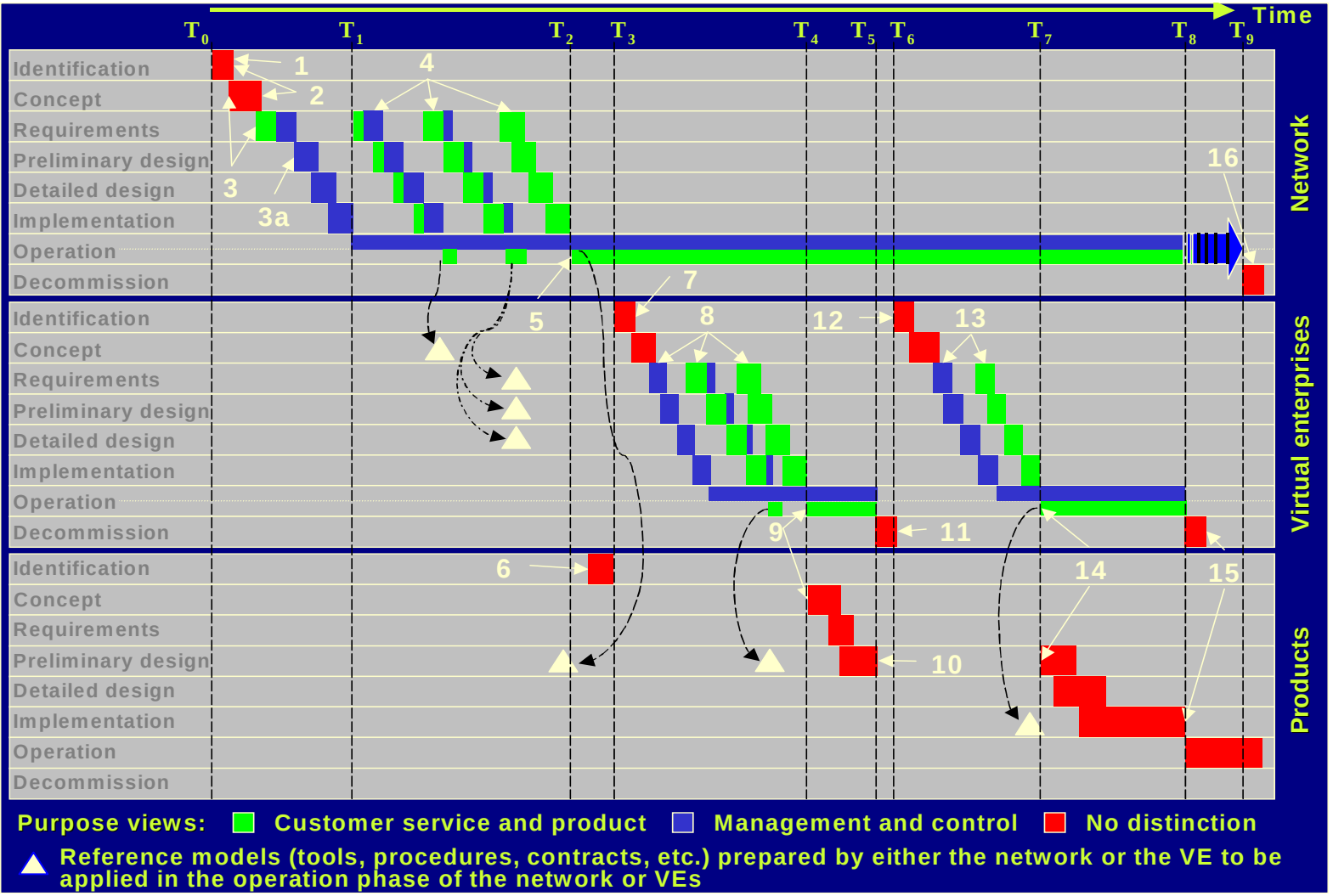
Life history example



3 GERAM instances linked by response to events and reference models

Source: J. Vesterager, P. Bernus, J. Pedersen & M. Tolle, The what and why of a Virtual Enterprise Reference Architecture, in E-work and E-commerce: Novel solutions and practices for global networked economy. B. Stanford-Smith and E. Chiozza (Eds) IOS Press, Amsterdam (2001) Used with permission

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Model "view"

ERAM that are model-based shall provide concepts for representing views of a model to allow it to be described as an integrated model but presented to users in different subsets.

- Views contain subsets of facts present in the integrated model
- Concentrate on relevant questions respective stakeholders may wish to consider.
- The concept of view is applicable to models of all entity types across their life cycle.

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Four views required

Different views may be made available highlighting certain aspects of the model and hiding others.

ERAM that are model based shall include four model-content views:

Function

Information

Resource

Organization

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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

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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

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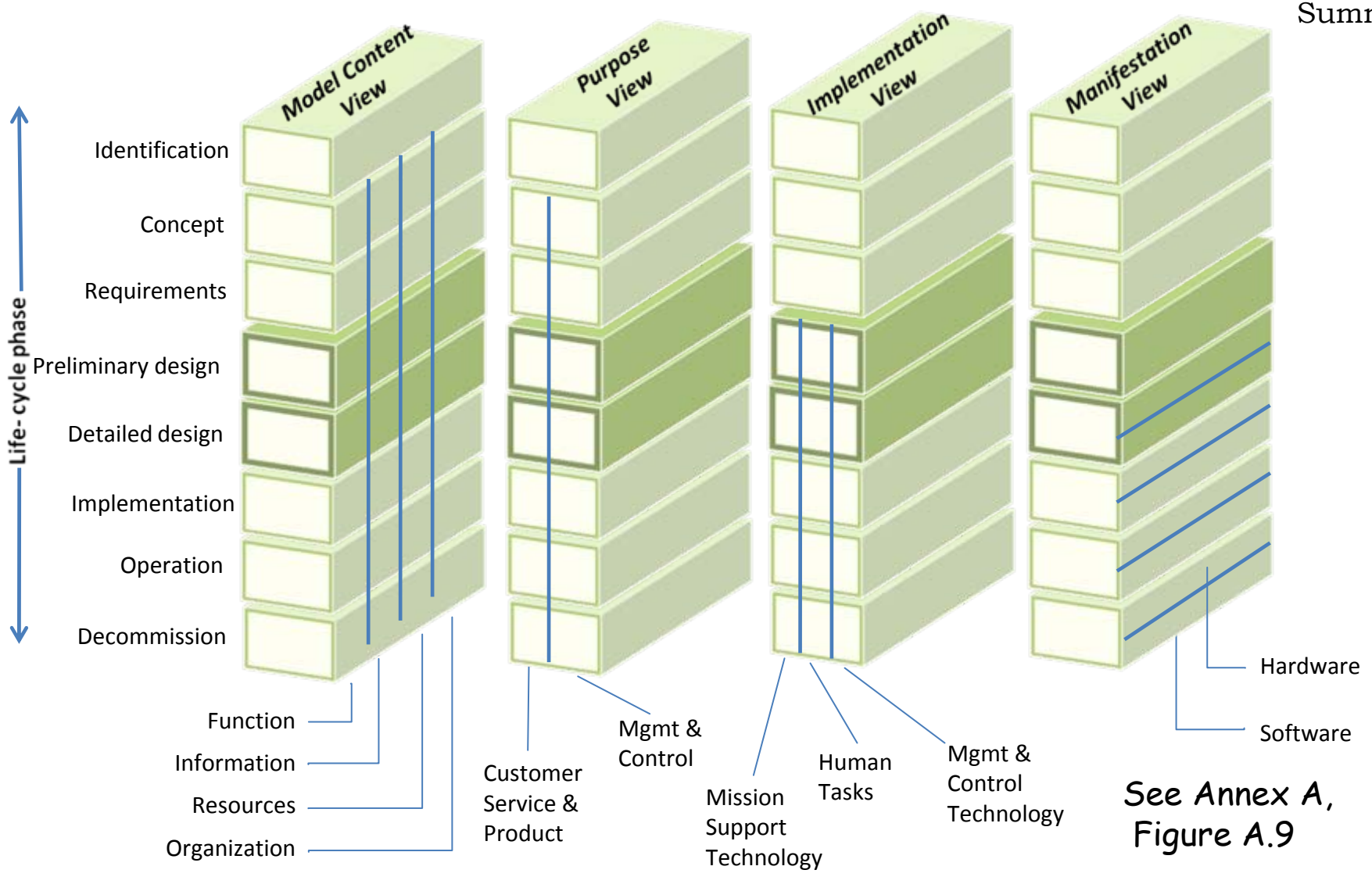
Many views possible



See Annex A, Figure A.9

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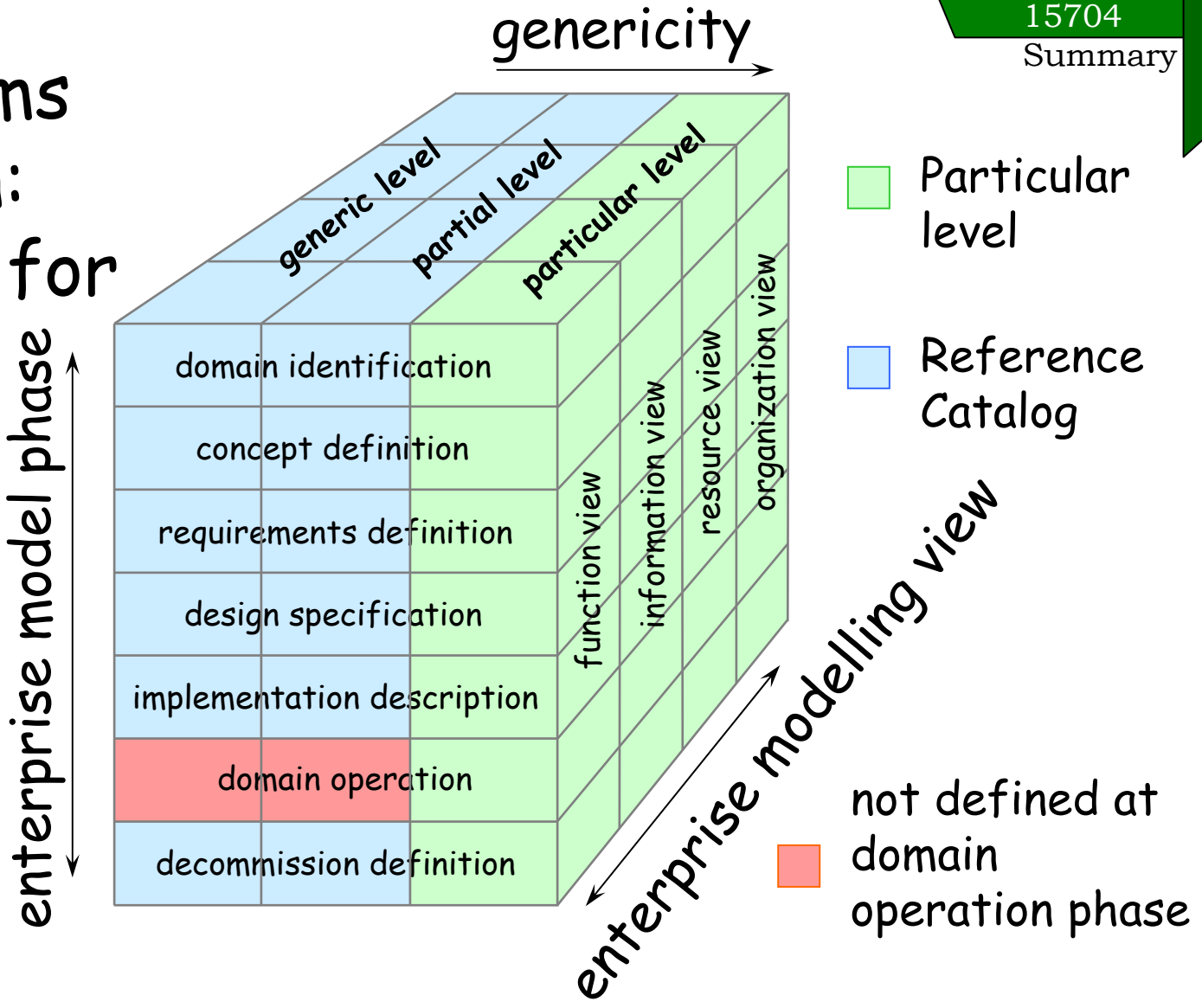
Graphic 19439 dimensions

CIM Systems Integration: Framework for Enterprise Modelling



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Architecture components

- Enterprise-engineering methodologies (EEM) for every type of life-cycle activity for any enterprise-entity type.
- Enterprise modeling languages (EML) or modeling constructs that allow the enterprise operation to be described.
  - Constructs shall allow users to represent the different elements and thereby improve both efficiency and understanding

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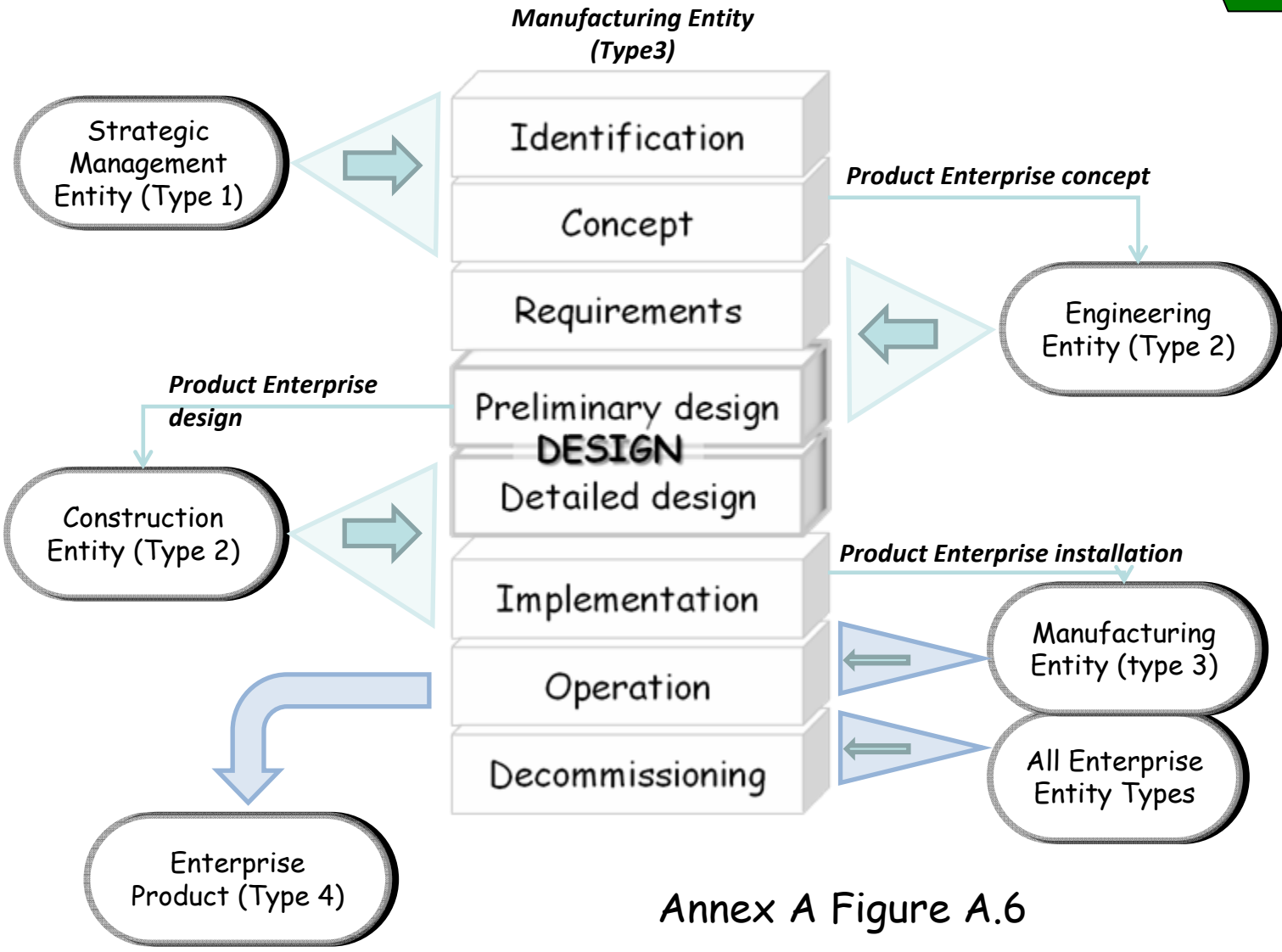
GERA entity types



Annex A Figure A.6

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Languages for people

The form of modeling constructs shall be adapted to the needs of people creating and using enterprise models.

EML shall be expressive enough to model human roles, operational processes and their functional contents and support

EML semantics can be described in terms of ontological theories but the definition of the formal semantics shall be supported by natural language explanations of the concepts.

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Constructs of 19440

Domain

Business Process

Enterprise Activity

Event

Resource

Functional Entity

Capability

Decision Centre

Enterprise Object

Object View

Product

Order

Operational Role

Organizational Unit

Organizational Role

Person Profile

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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

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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

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Complementary concepts

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

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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

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Constructs 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

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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

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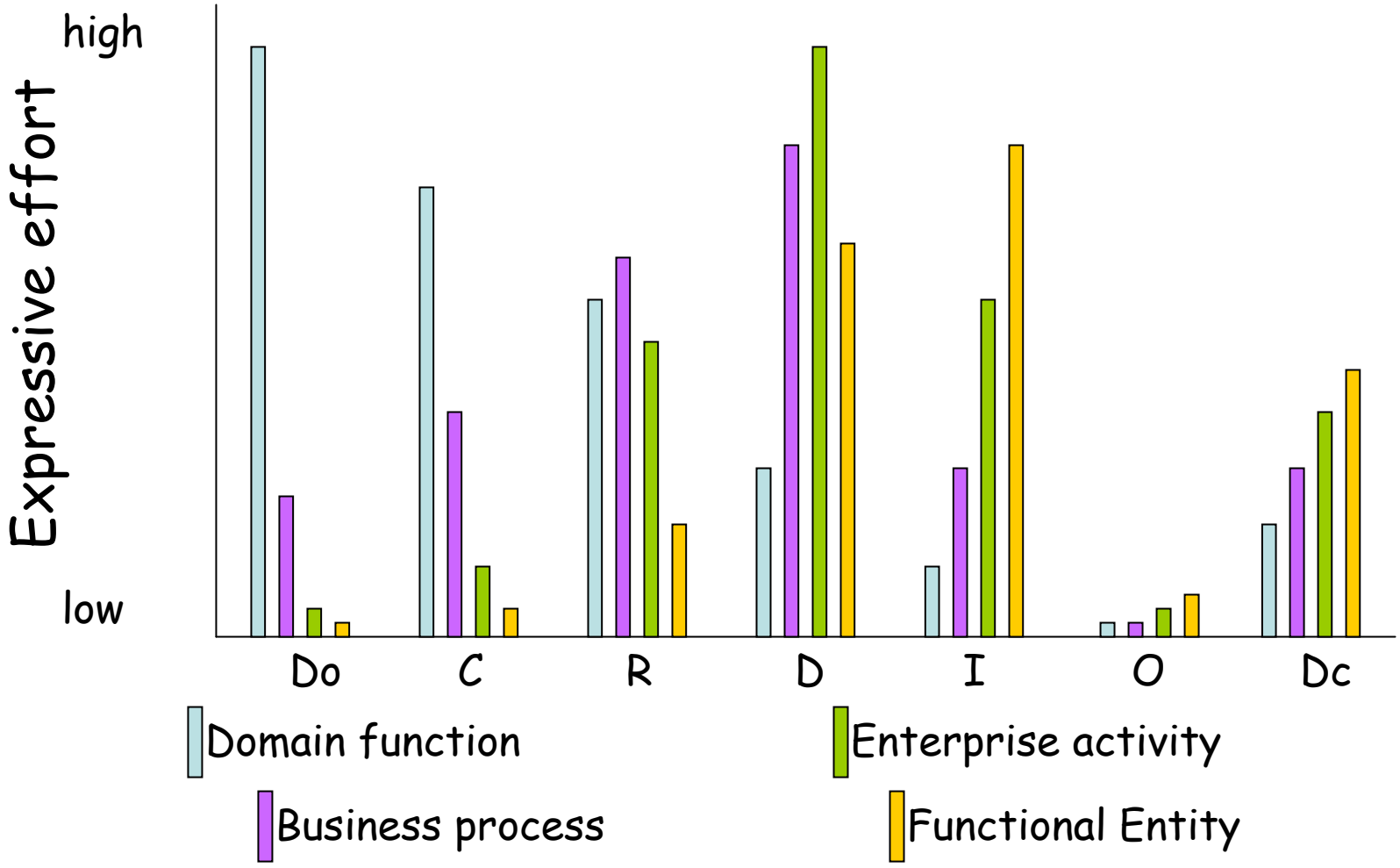
Life-cycle expression



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Process behavior

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

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Behavior 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.

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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 *)

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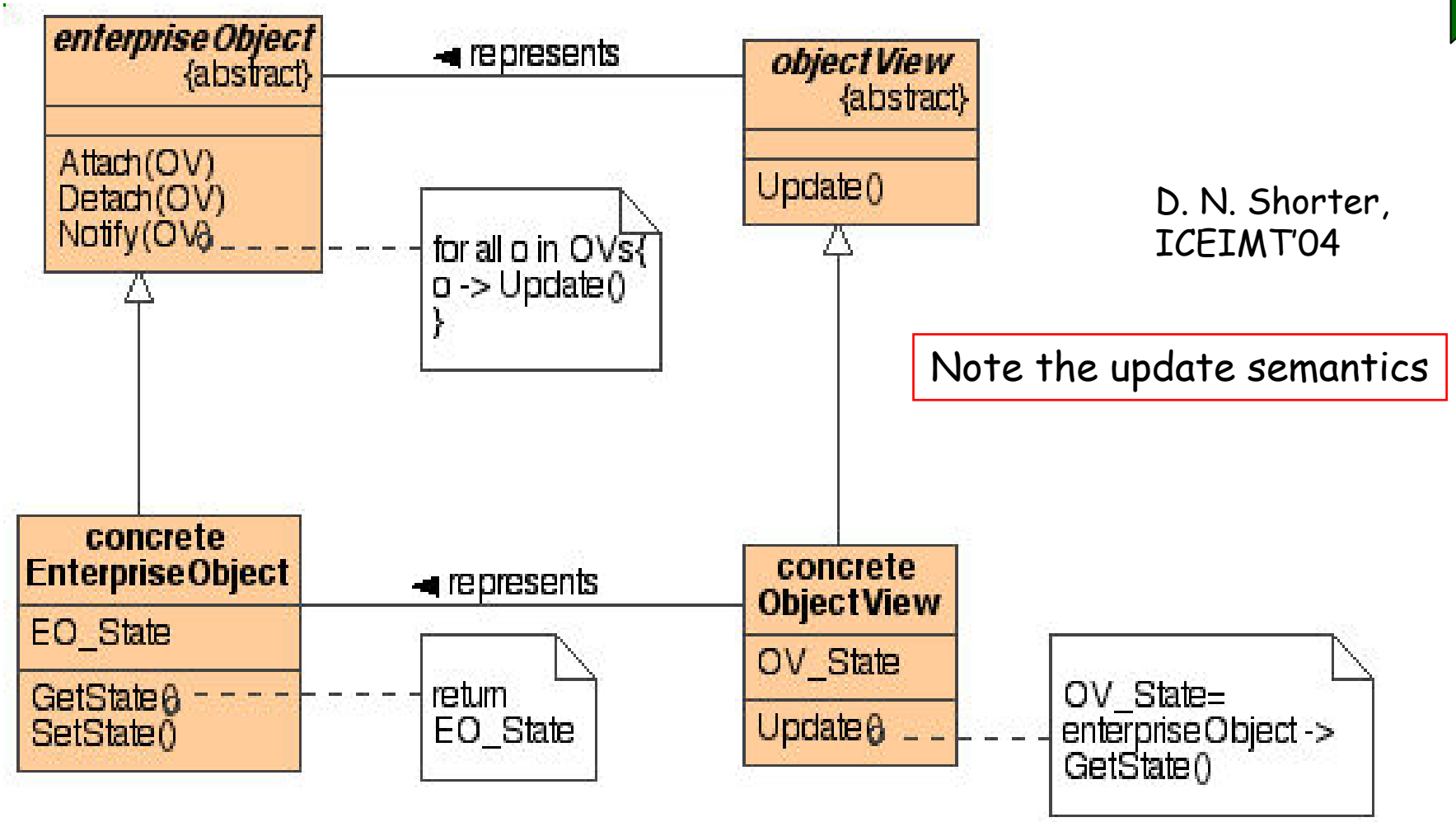
Object view as pattern



D. N. Shorter, ICEIMT'04

Note the update semantics

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Module representation

ERAM shall be able to represent the concept of enterprise modules, building blocks or systems (products, or families of products) for use as common resources in enterprise engineering and enterprise integration.

- One important set of enterprise modules is the integrating infrastructure or the set of integration-technology services required for enterprise engineering and operation in heterogeneous environments.

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Operational system

One result of the enterprise-engineering process shall be a design or model for the enterprise-operational system (EOS).

The enterprise operational system shall consist of the hardware and software needed to fulfill the enterprise objectives and goals.

The content of the operating system is derived from enterprise requirements.

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Glossary a must

To promote understanding about projects and other co-operative efforts, ERAM shall provide

- consistent glossary and a semantics and syntax for use in enterprise-engineering and integration efforts, or
- reference to other suitable glossaries.

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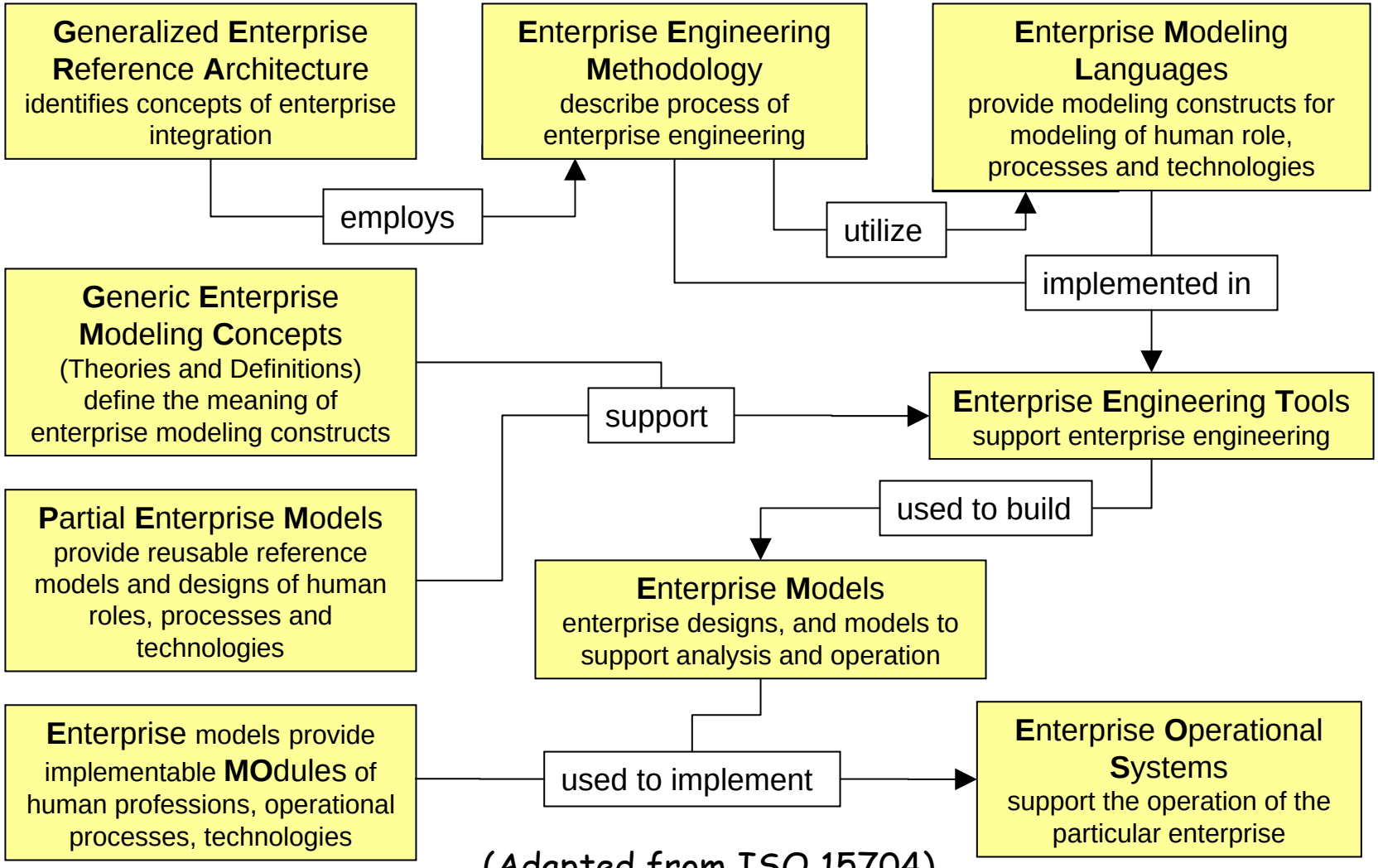
Scope of GERAM



(Adapted from ISO 15704)

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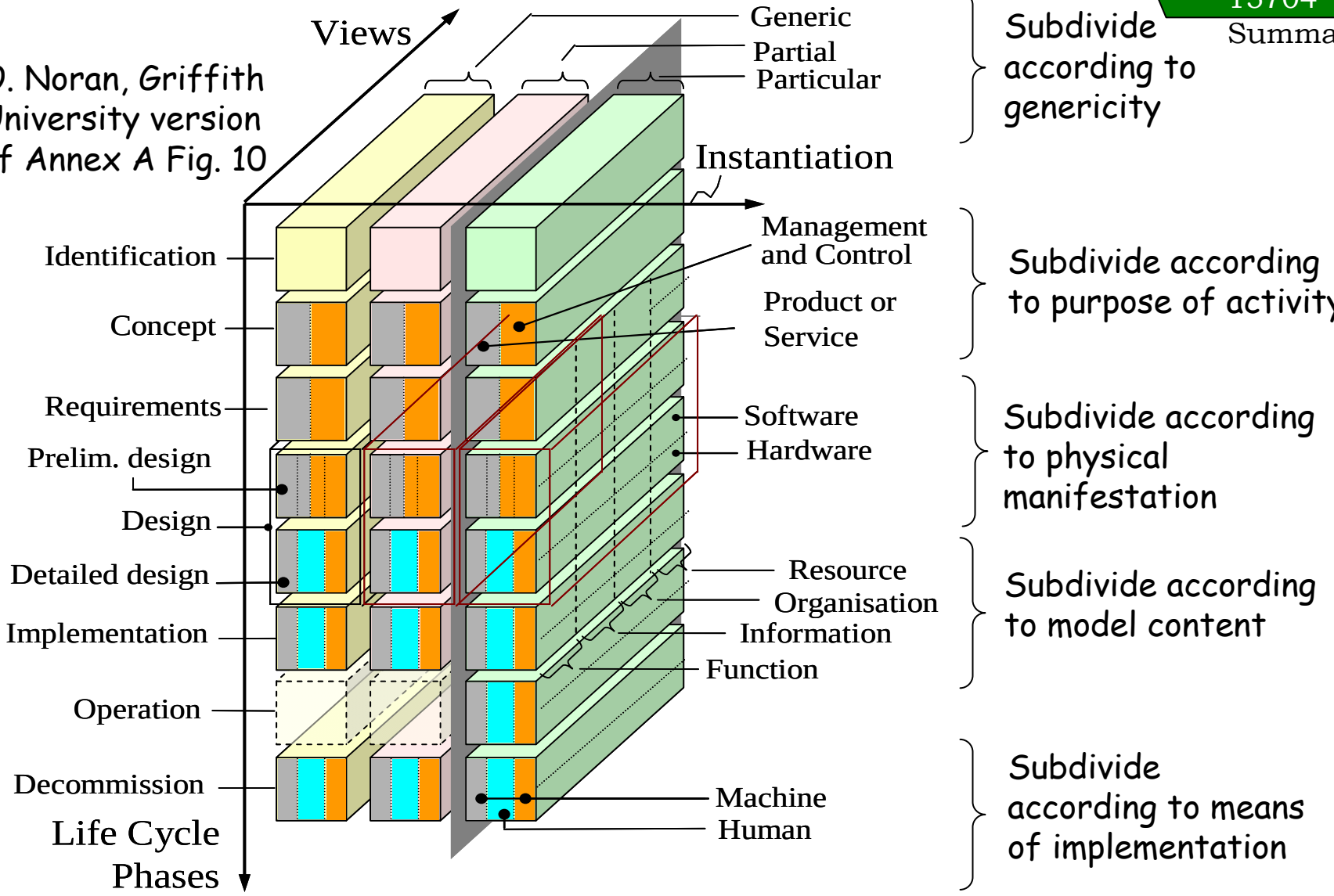
GERA modeling framework

O. Noran, Griffith University version of Annex A Fig. 10



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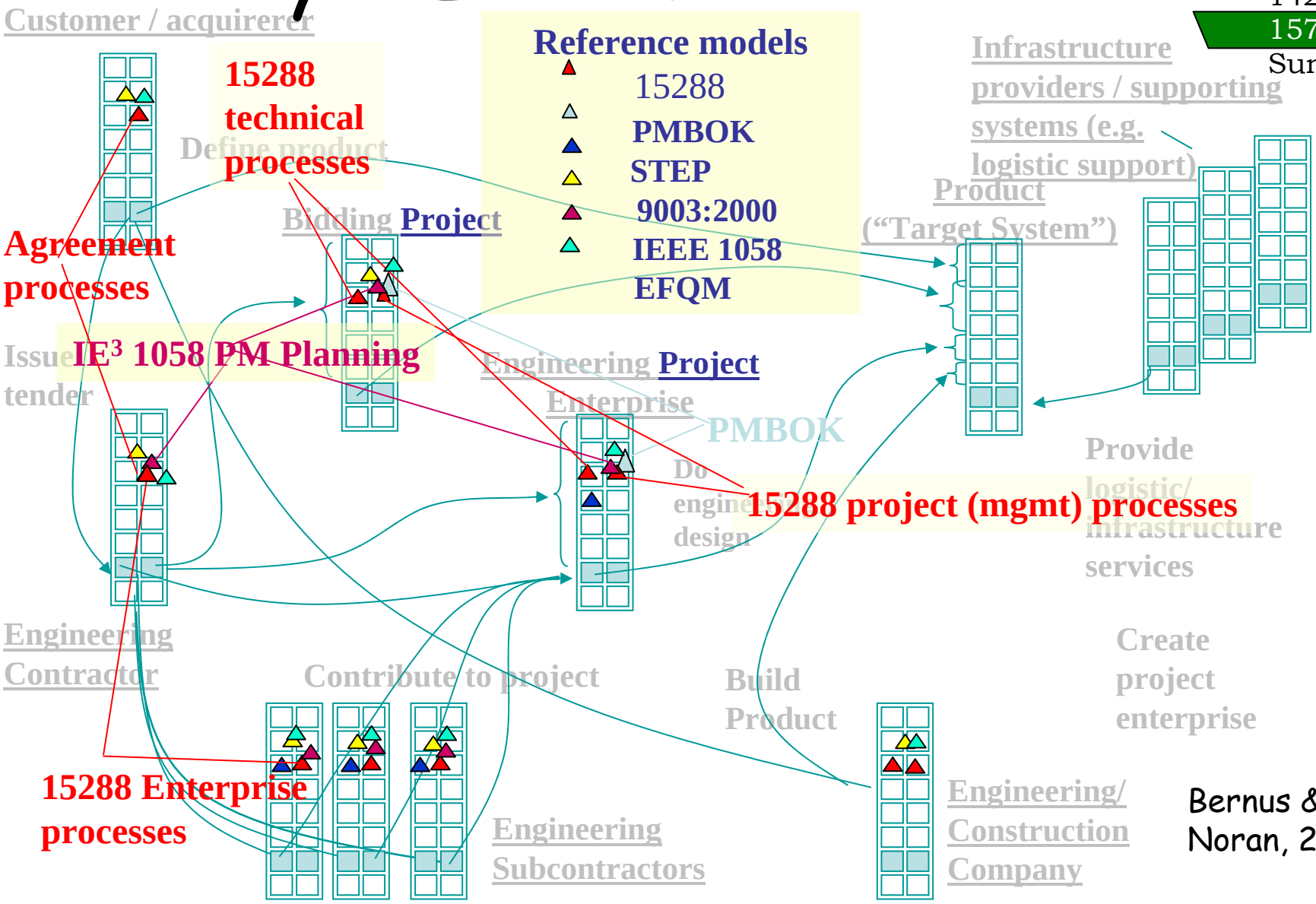
Many GERA & standards



Bernus & Noran, 2004

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ISO 15704 Compliance

Any assessment of the degree of compliance of a candidate architecture and methodology shall be qualified by the following:

- a preliminary statement as to whether or not they are model based;
- a statement of the degree to which they then conform partially or totally to the appropriate requirements

In the event of partial compliance, areas of non-conformance shall be explicitly identified.

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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

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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
- Can be a valid construction of a compliant modeling language
- Shall identify construction and model execution testing levels

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WG1 standards status

ISO 14258:1998 - systematic review completed in 2005 with retention until essential content can be moved to revised ISO 15704

ISO 15704:2000 - systematic review completed in 2007 and revision project commencing

EN/ISO 19439:2006 – published May, 2006

pEN/ISO/FDIS 19440 - ballot to end July, 2007 with publication to follow

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Overall Assessment 1

- Many semi-independent international architecture standards & activities
- Too many conflicting terms, many perspectives, varied applications
- US/DoD architecture perspectives (DODAF, CADM, FEAF) – DODAF 2.0 coming in '08
- INCOSE Architecture related WGs biased towards DoD/US Gov't perspectives/needs
- ISO TC184/SC5 EA Standards biased to Int'l & Manufacturing Industry Architecture Perspectives

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Overall Assessment 2

- Harmonization is critical, but harmonizing these diverse international enterprise architecture points of view together is a major challenge
- Being involved provides an opportunity to contribute toward and learn about the future enterprise architecture for more intelligent enterprise realizations

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