Systems Engineering

Standards landscape

Jay Ganguli
Boeing
Agenda

• Context & approach
• The dimensions of analysis
• The sources of information
  • SEBok, NSF, INCOSE 2025 SE Vision
• Overlap of some standards.
• Implications of some current directions
  • FutureSTEP, MoSSEC, AP209
• Future influencers..disruptors..
  • BigData- Distributed Graph databases, InMemory computing
  • Research via NSF Systems Engineering grants.
• The problem…

• Initial discussion at PDES Inc.
  • PDES Systems Engineering team
  • Landscape…needs to show multidimensional data.
  • Implementation techniques …OSLC…REST, Linked Data
  • Product Life Cycle
  • SysML, AADL, MoSSEC, AP233, ReqIF, FMI, Modelica………..etc
  • Standards bodies…PDES..INCOSE, OASIS, ProSTEP..OMG
  • How choosing one path…restricts/ opens up other options

• Consultancy with Industry Subject Matter Experts
  • Sandy Friedenthal- “Father of SysML”
  • Axel Reichwein - Koneksys
  • Nigel Shaw – Eurostep
  • Garry Roedler- Lockheed Martin Fellow, INCOSE Fellow and Founder Recipient;

Dimension - Evolution over time
Dimension: The Use Case

2025- Sys Engg Vision -INCOSE– S.Friedenthal et al..
Dimension: The Stakeholder view
Dimension: The SE Bok

Relevant Standards

Alignment and Comparison of the Standards

Application of Systems Engineering Standards

Descriptive Models

- Functional Flow Block Diagram (FFBD) [Oliver, Keilier, and Keegan 1997]
- Integration Definition for Functional Modeling (IDEF0) [NIST 1993]

Analytical Models and Simulations

- Systems Modeling Language (SysML) [OMG 2010a]
- Unified Profile for United States Department of Defense Architecture Framework (DoDAF) and United Kingdom Ministry of Defense Architecture Framework (MODAF) [OMG 2011e]
- Web ontology language (OWL) [W3C 2004b]
- Distributed Interactive Simulation (DIS) [IEEE 1998]
- High-Level Architecture (HLA) [IEEE 2010]
- Modelica [Modelica Association 2010]

Modeling Standards

Data Exchange Standards

- Semantics of a Foundational Subset for Executable Unified Modeling Language (UML) Models (FUML) [OMG 2011d]
- Application Protocol for Systems Engineering Data Exchange (AP 233) [ISO 2005]
- Requirements Interchange Format (ReqIF) [OMG 2011c]
- Extensible Markup Language (XML) Metadata Interchange (XMI) [OMG 2003a]
- Resource Description Framework (RDF) [W3C 2004a]
- Query View Transformations (QVT) [OMG 2011b]

Model Transformations for Semantic interoperability

- Systems Modeling Language (SysML)-Modelica Transformation [OMG 2010c]
- OPM-to-SysML Transformation (Grobshofer and Don 2011)
- Model-driven architecture (MDA) [OMG 2003b]

General Modeling Standards (Frameworks)


Other Domain-Specific Modeling Standards

- These standards apply to modeling application software and/or embedded software design:
  - Architecture Analysis and Design Language (AADL) [SAE 2009]
  - Modeling and Analysis for Real-Time and Embedded Systems (MARTE) [OMG 2009]
- Unified Modeling Language (UML) [OMG 2010b]

Software Design Models

- These standards apply to modeling hardware design:
  - Very High-Speed Integrated Circuit (VHSIC) Hardware Description Language (VHDL) [IEEE 2008]
- These standards apply to modeling business processes:
  - Business Process Modeling Notation (BPMN) [OMG 2011a]
Dimension: Layered Standards

Figure 1.9 – from Sandy's Book
Dimension: Standards influencing each other

SOURCE: Analysis of PLM Standards for US Army - NIST
Dimension: Theoretical foundations of Systems Engineering

The INCOSE Vision

2025 - Sys Engg Vision - INCOSE - S. Friedenthal et al.
Dimension: Theoretical foundations of Systems Engineering
National Science Foundation – Systems Science

Theoretical Framework for SE & Design
Explanatory Models Supported by Empirical Evidence

SE&D Practice
- Concept Definition
- System Architecting
- Functional Analysis
- Risk Management
- Requirements Engineering
- Interface Definition
- Tradespace Analysis

Theoretical Explanatory Models
- Systems Theory
- Probability Theory
- Organizational Theory
- Behavioral Economics
- Decision Theory
- Economics
- Psychology

Improved Methods & Tools
Empirical Charact. / Falsification

NSF – Theoretical Framework for SysEng – Paredis
Dimension: Complexity...and its roots

The roots for growing levels of systems complexity

- Increasing complexity, cumulative ambiguity, "lack of control"
- Mechanical and electrical elements
- Electronic, isolated islands of software
- Software intensive
- Network intensive
- Enterprise, organizational governance (decentralized)
- System of systems

2025 - Sys Engg Vision - INCOSE - S. Friedenthal et al.
Dimension: Consortia / Business priorities and drivers

Radar screen

Available external standards

Monitor external development

Adopted

Candidate

Track

Participate in external development

ASD development

STEP
ASD S-Series
TSCP
3D visualisation
LOTAR

BiP available
BiP in preparation
Current ASD SSG actions

Version: V1.7
Intended Relationships of Key System & Software Engineering Process Standards After Alignment

Used with permission from Garry Roedler, LM Fellow / Engineering Outreach Program Manager INCOSE Fellow and Founder Recipient; IEEE Golden Core
Growing collaboration

Standardization
Goals, Objectives, Needs

ISO/IEC JTC1/SC7
• Systems & software engineering standards
• Some coordination between committees

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Compementary And Supplementary

IEEE-CS
• Large number of standards combined or fast-tracked
• Coordinated development

INCOSE
• SE References, including SE Handbook

Other
For specific resources

• TechAmerica – EIA-632A
• ISO/IEC JTC1 SC27
• ISO TC 184
• CMMI – Some PAs (e.g., M&A)

SEBoK
SWBoK
• SE Body of Knowledge
• SW Body of Knowledge

Vocabularies
• SE & SW Process es - SEVOCAB

Influence other key SE & SW resources

Reference Curricula
• Grad Ref Curriculum for SE - GRCSE
• Grad Ref Curriculum for SW

Used with permission from Garry Roedler, LM Fellow / Engineering Outreach Program Manager
INCOSE Fellow and Founder Recipient; IEEE Golden Core
Dimension : Churn in STEP

AP233/PLCS

AP233
- Classification
- Product Structure
- Activities
- Change Management
- Approvals, Security, Status
- Schedule
- Requirements Management
- V & V
- Risk Management
- Environment
- Systems
- Organizations
- Property

PLCS e2
- Maintenance
- Support Tasks
- APSI
- Support History
- Messaging

They share a common core!
Dimension: Churn in STEP...Requirements domain

Relationship of RIF to OMG Standards (Concepts)
AP209 and MoSSEC – Scope comparison

Key Question: I am an Architect. What data is available to support my decision and where did it come from?

Key Question: I am a Simulation Analyst. What data is available to execute my simulation and what results did it produce?

Used with permission from Nigel Shaw, Director EuroSTEP
AP209 and MoSSEC – together

MoSSEC is analysis type agnostic and only records meta data about Models

The detail can be described using AP209 (and/or other formats including system specific formats)

Used with permission from Nigel Shaw, Director EuroSTEP
The “Why” and the “What”

» AP209 has no concept of why the analysis is being performed or even if it needs to be performed or not.
  - AP209 has all the details for What analysis is/was to be performed

» MoSSEC deals with recording everything is that has been or will be done and where the data used came from
  - MoSSEC has little of the details for What analysis is/was to be performed except by reference to associated documents
    » Which can be AP209 datasets

Used with permission from Nigel Shaw, Director EuroSTEP
Challenges for distributed systems engineering: MoSSEC

- **Distributed Infrastructure**
  - Secure Collaboration for:
    - Locations
    - Organisations
    - Software Platforms

- **Distributed Processes**
  - Multitude of Modelling and Simulation tools
  - Simulation driven design changes traced and under PLM control

- **Distributed Data**
  - Modelling and Simulation data
  - V-cycle meta-data
    - (who what when where how why etc)
  - Efficient sharing, synchronisation and integration

Remain Compliant with existing Standards (e.g. AP233, AP239, AP242)
Collaboration vs Modelling & Simulation Data

- Modelling and Simulation data
  - Managed in the PLM/M&S systems
  - Exchanged with technical standards

- Collaborative SE context data
  - Managed by MoSSEC Compliant Tools
  - Exchanged with MoSSEC services

- Together they enable the distributed dataset

Technical standards:
- e.g. AP242, AP209

MoSSEC
MoSSEC & AP233, and PLCS

AP239 templates used

- What templates used in plcs_psm mapping are for planned v1 of MoSSEC
Evolution of “interoperability” in the Product Data space (STEP context)

The primary driver for interoperability in the STEP world was aimed at building new APs faster.

Figure 4-8: Mapping AP #1 requirements to AP #2 requirements

Fig. 2 Modular Architecture vs. Initial STEP Architecture
STEP on the Lifecycle

Global Product Data Interoperability Summit | 2015

Process & use cases

Information

Multi-disciplinary Analysis & design
Systems Engineering

AP 233 ed1
Function diagram
State machine
Issues management

AP 209 ed2
Structural Analysis
Comput. Fluid Dynamic

AP 242 ed2
Additive Manufact., (ed2)
Composite design
Process planning

AP 243 ed1
Requirement management
Project management

AP 238 ed1
Analysis shape
Idealized Analysis shape

AP 210 ed1
Analysis model
Interconnect substrate
Electronic assembly

AP 235 ed1
Electronic assembly, interconnect & packaging design.

Support

Suite of AIA - ASD
ILS Specs (SX000)
Based on PLCS

Product Life Cycle Support

Support tasks
Support history
Maintenance
Messaging
APS1

Risk management
Validation & Verif.
Schedule

Cutting tools
Turning
Milling
Workpiece
Tools paths

State
Substance

Engineering Properties
for product design & verification

Analysis TB done.

STEP Future Architecture Workshop - 29-30 June 2015
Toulouse

Modular STEP standard
NON Modular STEP standard

Only contained in AP 242 ed2
AP = Application Protocol

Global Product Data Interoperability Summit | 2015

DRAFT (May 2015)
Multi-layered information models...based on Standards –

PLCS Information Architecture

“Business/Domain” layer

Concept model

“Core/standard” Information layer

ISO 10303-239
ARM EXPRESS

PLCS PSM
EXPRESS

PLCS PSM
SysML

PLCS PSM
OWL

Templates

Maps

Maps

Maps

Specializes

OWL
Ref. Data

STEP Future Architecture Workshop - 29-30 June 2015
- Toulouse
FutureSTEP: recent developments

Old STEP
- AAM & Conceptual model
  - interpretation
- Express ARM
- Mapping
- Express AIM

Modular STEP
- Conceptual model
  - interpretation
- Express Modular ARM
- Mapping
- Express Modular AIM

DEXlib
- Conceptual picture
  - Layered ARM
  - Mappings
  - DEXlib
  - transformation
- Express Modular ARM
- Mapping
- Express Modular AIM

PLClibrary
- Conceptual picture
  - Layered ARM
  - Mappings
  - PSM SysML
  - Derivation
- Express Modular ARM
- Mapping
- Express Modular AIM

AP242 ed1
- Capability picture
  - Layered ARM
  - Mappings
  - PSM SysML
  - Express BO Model
  - Partial mapping
- Express Modular ARM
- Mapping
- Express Modular AIM

Goal
- Conceptual model
  - Layered ARM
  - Mappings
  - CORE SysML

Integration?
- Express Modular ARM
- Mapping
- Express Modular AIM

STEPS phase 1: Monolithic Aps
- divergences between teams
  - Ex: 203 vs 214 => PDM Schema

But Logic layer and implementation layer got more dependant

PLC version 1: new business needs on lifecycle, request for XML implementation method, introduction of a higher level development framework with inputs from semantic web, based on the modular architecture but inefficient XML implementation

ARM implementation

Underlying concepts of the PLC framework are aligned with the STEP philosophy

PLC version 2: for PLC stakeholders, difficulties to maintain strong integration with STEP modules.

The SysML PSM is the integration layer

AP242 ed1 BO Model:
- requirements close from PLCs: XML implementations with associated documentation
- Plus strong requirement of full integration to the modular architecture
- Fail to provide complete mapping from BO Model to Modules
- Harmonization started between BO Model and PSM

Ensure consistency and integration on the whole stack and across AP

Model based

Allow extensions from other domains and technologies
FutureSTEP recent developments

Multi Information Model layer and associate stakeholders

- **Level 5**: Company specific Aerospace & Defence
- **Level 4**: European OR American or Asian Aerospace & Defence, European OR American Or Asian Automotive
- **Level 3**: International Aerospace & Defence, International Automotive
- **Level 2**: AP 209, AP 242, AP 239
- **Level 1**: Core model
- **Core model**: simulation, Elec, Geometry, PDM, REQ, ILS block

Example: MOSSEC would be a new information model at level 2 referencing the Core model objects

We have a global consistent information model

The core model is one specific layer of the information model shared by all the stakeholders

Worldwide multisector ISO consensus
Dimensions- what does a Pragmatic user need?

- Scope of standards
- Ease of adoption by vendors + users + developers
  - Vendors attends standards mtgs…
- Existing tool support
- Existing adoption
- Alignment with technical trends – Linked data. Is the std compatible with linked data, communication protocol
- Documentation quality, accessible, examples to get started
- Stds:
  - Std ways to access info: AP233, SysML, AADL, FMI, Modelica, Simulink,
  - Std protocol: OSLC is domain independent..
- Quantify the complexity…the number of relationships
- Assess the impact..is it in a domain used by 90% of engineers.
- W3C: Dublin Core, RDFontologies,

Courtesy : Axel Reichwein - Koneksys
Users can work seamlessly across their tools (complex and fragile synchronization schemes not required)

Architecture of the Web
Linked Data
Increased reuse
Decreased maintenance costs
Standard Interfaces
Linked Lifecycle Data (OSLC)
“Just Enough” integration
Increased traceability
Better visibility

OSLC is an open and scalable approach to lifecycle integration. It simplifies key integration scenarios across heterogeneous tools.

http://www.w3.org/DesignIssues/LinkedData.html
What co-existence may mean...

- Mapping conceptual notions of APs – ARM (Application Reference Module) to linked data
- OSLC resource structure, maps to STEP notions of modularity?
- How does OSLC influence Future STEP architecture?
- Can OSLC domain linking features be used to test STEP AP modularity?

As a research assistant at OCLC, I have had the opportunity to be involved in a variety of industry initiatives to help modernize library infrastructure and prepare them for the eventual coming of Linked Data. Two of these projects help underscore the fundamental changes that the library industry needs to undergo in order to support the adoption of Linked Data. The first is the redevelopment of the MODS data model as an RDF ontology and the second is the conversion of the Getty vocabularies from a traditional controlled string-based thesaurus into a Linked Data dataset that uses URIs as identifiers for people, organizations, places, concepts etc. The two projects each address different but equally important types of changes that will need to occur in order for libraries to create Linked Data and integrate it into their everyday workflows.

Source: http://hangingtogether.org/?p=4096
**OSLC & SysML experience**

Interoperability beyond SysML

- From linked Data user perspective: SysML concepts can be used to define cross-domain relationships

Courtesy: Axel Reichwein, Koneksys
OSLC Tool Interoperability

Tool Interoperability through Standardized RDF Vocabularies

- Interoperability between tools is based on common standards
- OSLC specifications provide RDF vocabularies for specific domains for the purpose of supporting interoperability

OSLC Resources in RDF/XML

Data exchange through neutral format

Tool A

OSLC Adapter for Tool A

HTTP

OSLC Adapter for Tool B

Tool B

Courtesy: Axel Reichwein, Koneksys
OSLC Resource and Resource Shapes

Additional RDF resources for defining constraints on RDF resources: OSLC Resource Shapes

- **RDFS Vocabulary** cannot define constraints on RDF data
- **OSLC Core vocabulary** includes additional RDFS classes and RDF properties for defining constraints on RDF data such as:
  - RDFS class oslc:ResourceShape
  - RDFS class oslc:AllowedValues
  - RDF property oslc:occurs
  - RDF property oslc:allowedValue
- **OSLC resource shapes** are RDF resources that define constraints on RDF data by using the OSLC Core vocabulary

Courtesy: Axel Reichwein, Koneksys
One way to think of the landscape
The Positive influence of Consortia Projects: UK’s CONGA: PLCS/MoSSEC/OSLC

Conga
Configuration Optimisation of Next Generation Aircraft

• OSLC supported Conga in the sharing of requirements in the Conga Tool Net.

• OSLC was demonstrated to work well with another standard (BDA) which was already being use for requirements.

• The delegated UI allowed other tools to access requirements in DOORS.

"The aim was to identify how requirements in OSLC could be made available to other partners. The other tools in the tool net were already BDA compliant and so a re-work to OSLC consumers wasn’t desirable."

"The solution was to create BDA requirement objects on the collaboration hub and embed the link to the DOORS requirement inside. Using the link to the delegated UI it was possible for existing consumers of BDA resources to access the requirements in DOORS without having to develop their own OSLC consumer adapters."

(Source: OSLC Community Update – OSLC with PLCS and MoSSEC (June 10, 2015))
The need to Collaborate..
People…

Global Product Data Interoperability Summit | 2015
• Standards Lead At INCOSE (Ken Zemrowski) & Sandy Friedenthal working on 2 near term task
  • Focus on developing a domain specific SE vision for automotive
  • INCOSE will encourage other domains to do something similar.
• NSF – Theoretical Framework for SysEng engagement. The standards roadmap is critical here too.
• INCOSE engagement with standards bodies like PDES, OASIS- OSLC
  • ‘MBSE for OSLC ‘working group is working with OSLC. (Mark Sampson and Sandy F – Co-Chairs)
  • ‘Tools Interop WG’ is also collaboration on standards.
• INCOSE’s new strategy ‘Accelerate the Transformation to a MB Discipline’ has a ‘Technical objective that requires engagement with other standards bodies.
• MBSE wiki would be a good place to show links to other standards working groups
• ALM-PLM working group leaders invited to FutureSTEP sessions
  • Axel Reichwein to present OSLC view at PLCS meet.
• Importance of Standardizing Interaction patterns and Webservices
• Linked Data…Resource Shapes..
• Could provide early clues on Interoperability needs for STEP.
Collaboration with other Organizations

A cornerstone to make OSLC a success is to collaborate with other organizations

- Recently announced: Partnership with ProSTEP iViP (www.prostep.org)
- ProSTEP iViP Association is an international association committed to develop innovative approaches for modern standards for product data management and virtual product creation
- ProSTEP iViP has created the CPO initiative (Code of PLM Openness) to establish a common understanding on openness for IT systems in PLM between IT customers, IT vendors and IT service providers; OSLC and associated standards are seen as the approach to implement CPO.
- Joint activities are planned, e.g. 1st ProSTEP iViP – OASIS OSLC Conference October 20th, 2015 hosted by Daimler AG in Stuttgart http://www.prostep.org/en/events/topic-specific-events/oslc.html
- Relaunch of the ALM-PLM Interoperability Working Group on open-services.net http://open-services.net/workgroups/alm-plm-interoperability/
ProSTEP and OSLC

Seamless Lifecycle Integration - based on open Standards

Held jointly with: 4th Interoperability Conference

Location: Daimler Auditorium, Stuttgart-Möhringen
Epplestraße 225, 70567 Stuttgart
Date: 20 October 2015 / 10:00 – 16:00

One day full of information under the lead-theme ALM – PLM Interoperability. Impulses for enabling information flows between different engineering disciplines will be given. In industry-relevant talks possibilities of OSLC will be discussed and demonstrated. Target-audience are people interested in solving systems engineering challenges in smart ways – experts and new-comers.

The keynote will be held by Prof. Martin Eigner, TU Kaiserslautern.

Registration and more information at:

Seamless Lifecycle Integration

20 October 2015

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
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<tr>
<td>10:00</td>
<td>Welcome Dr. Steven Vettemann, ProSTEP iViP &amp; Rainer Ersch, Siemens AG</td>
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| 10:15 | OSLC: Introduction & Overview
Rainer Ersch, OASIS-OSLC Steering Committee Member |
| 10:30 | Keynote: OSLC - Bridge between Model-based Systems Engineering and PLM?
Prof. Dr. Martin Eigner, University Kaiserslautern |
| 11:15 | OSLC as an Opportunity to Compose IT Solutions in an existing Application Landscape
Frank Wagenknecht, Bombardier Transportation |
| 11:45 | Co-simulation in technical software development
Gerold Eggum, Philips Healthcare |
| 12:15 | Lunch Break |
| 13:30 | Aerospace: Industrial Use Case Demonstrator
Andreas Klen, Airbus |
| 14:20 | Coffee Break |
| 14:40 | Automotive: Industrial Use Case Demonstrator
Bzd., Daimler |
| 15:30 | Questions & Answers from the Audience Closing Remarks & Outlook
Rainer Ersch, Siemens AG & Dr. Steven Vettemann, ProSTEP iViP |
| 16:00 | Anticipated end |
BACKUP
• Ensures consistency between the system model and domain models
• AADL profile enables import of SysML elements into AADL model.

SysML (Rhapsody)

AADL (OSATE)