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SysML v2 – Next-generation, Scalable, Enterprise-ready, Open Standard for MBSE

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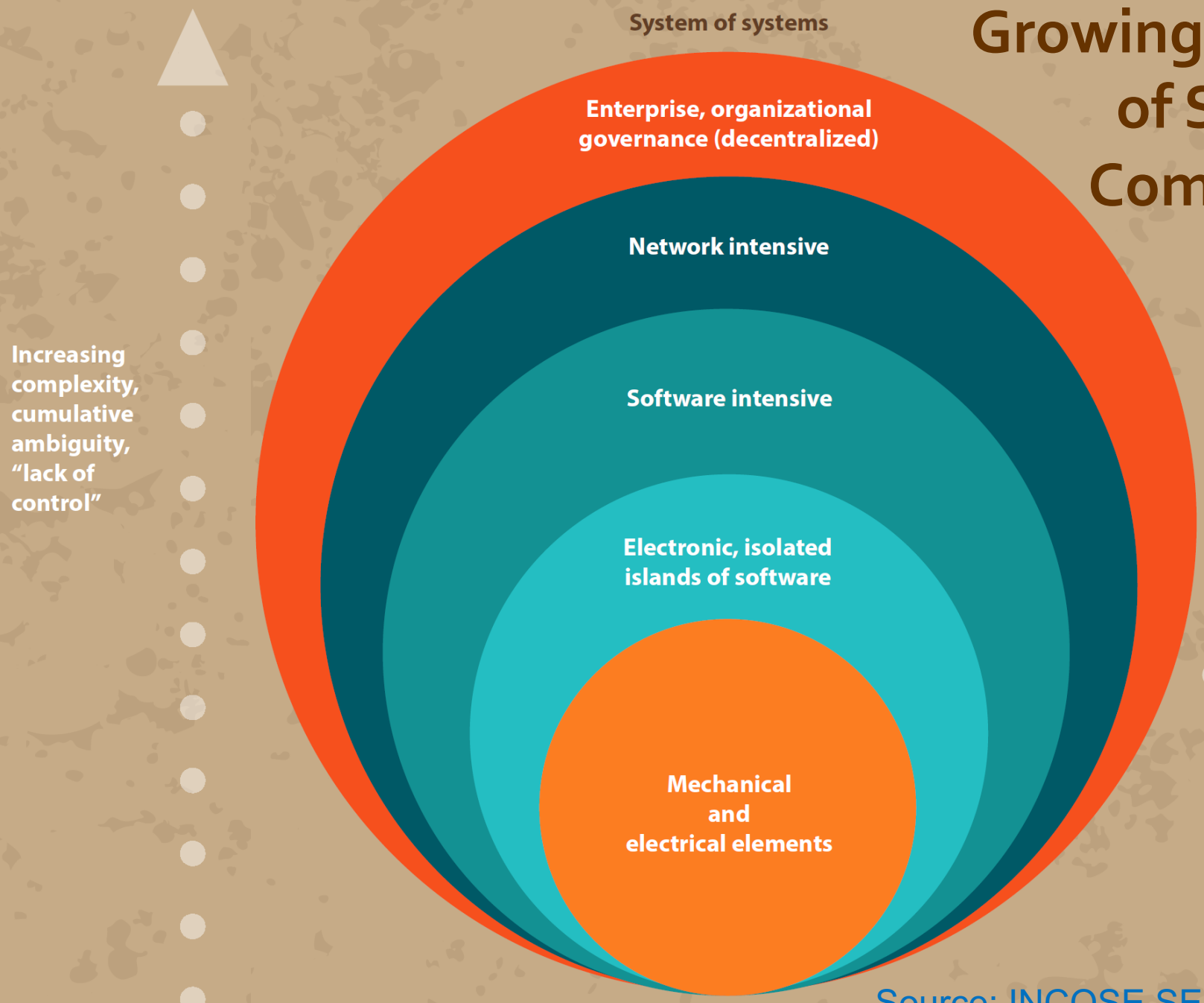
Growing Levels of System Complexity



Source: INCOSE SE Vision 2025

System Model Facilitates Management of Complexity

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A specification and architecture model that abstracts the detailed design and captures rich data about the system elements and their inter-relationships

- Systems, subsystems, and components
- Operational & enabling systems (e.g., verif, mfg, support)
- Integrates with multi-disciplinary design & analysis models
- Supports variant designs, patterns, and reuse

INCOSE SE Vision 2025
MBSE: Standard SE Practice

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F R O M

- Model-based systems engineering has grown in popularity as a way to **deal with the limitations of document-based approaches**, but is still in an early stage of maturity similar to the early days of CAD/CAE.

T O

- Formal **systems modeling is standard practice** for specifying, analyzing, designing, and verifying systems, and is **fully integrated with other engineering models**. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. **The use of internet-driven knowledge representation** and immersive technologies enable highly efficient and **shared human understanding of systems in a virtual environment** that span the full life cycle from concept through development, manufacturing, operations, and support.

Systems Modeling Language (SysML) SST

www.omgsysml.org

- SysML v1 adopted in 2006
- Continued evolution to address user and vendor needs
  - SysML v1.5: current version
  - SysML v1.6: in process
- Facilitated awareness and adoption of MBSE
- Much learned from applications of MBSE using SysML

Goal: Develop next generation of SysML to support MBSE over next 10+ years

SysML v2

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- OMG issued 2 Request-For-Proposals (RFPs)
  - SysML v2 Language RFP (2017-12, OMG Burlingame)
    - https://www.omg.org/cgi-bin/doc?ad/2017-12-02
  - SysML v2 API and Services RFP (2018-06, OMG Boston)
    - https://www.omg.org/cgi-bin/doc?ad/2018-06-03
- SysML v2 Submission Team (SST)
  - Formed in Dec 2017 to respond to SysML v2 Language RFP, and API & Services RFP
- Submission
  - Initial Submission: Jun 2020
  - Revised (Final) Submission: Jun 2021

SysML v2 Effectiveness Measures

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- Enable a model-based approach to improve systems engineering productivity, quality, and management of complexity and risk
  - *Expressive:* Ability to express key system concepts
  - *Precise:* Concise representation that enables unambiguous human and computer interpretation that supports model checking, execution/solvers, and reasoning
  - *Visualization:* Ability to effectively communicate with diverse stakeholders
  - *Interoperable:* Ability to exchange and transform data with other models
  - *Manageable:* Ability to efficiently manage change to models
  - *Usable*: Ability for stakeholders to efficiently and intuitively create, maintain, interpret, and use the model
  - *Adaptable/Customizable:* Ability to extend models to support domain specific concepts and terminology
  - *Scalable:* Ability to scale from small to large models
  - *Compatibility with SysML v1:* Maintain a migration path for SysML v1 models

SysML v2 Submission Team (SST) *SST*

- SysML v2 Submission Team (SST) formed December 2017
  - Leads: Sandy Friedenthal, Ed Seidewitz
- A broad team of end users, vendors, academics, and government liaisons
  - Currently 120 members from 63 organizations
- Developing submissions to both RFPs
- Driven by RFP requirements and user needs

Track Leads

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1. Project Management – Ed Seidewitz, Sandy Friedenthal
   - Infrastructure – John Watson
2. Requirements V&V – Sandy Friedenthal
3. Profile Development – Yves Bernard, Tim Weilkiens
4. Metamodel Development – Chas Galey
5. API/Services Development – Manas Bajaj
6. Pilot Implementation – Ed Seidewitz

SST Participants
63 orgs, 120 members

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- Aerospace Corp
- Airbus
- ANSYS medini
- Aras
- ARDEC
- Army Aviation & Missile Center
- BAE
- BigLever Software
- Boeing
- CEA
- Contact Software
- Draper Lab
- Elbit Systems of America
- European Space Agency
- Ford
- Fraunhofer FOKUS
- General Motors
- George Mason University
- GfSE
- GTRI
- IBM
- Idaho National Laboratory
- IncQuery Labs
- Intercax
- Itemis
- Jet Propulsion Lab (NASA JPL)
- John Deere
- Kenntnis
- LieberLieber
- Lightstreet Consulting
- Lockheed Martin
- LSST
- Maplesoft
- MITRE
- ModelAlchemy Consulting
- Model Driven Solutions
- Model Foundry
- NIST
- No Magic
- OAR
- Obeo
- OOSE
- Ostfold University College
- Phoenix Integration
- PTC
- Raytheon
- Rolls Royce
- SAF Consulting *
- SAIC
- Siemens
- Sierra Nevada Corporation
- Simula
- System Strategy *
- Tata Consultancy Services
- Thales
- Thematix
- Tom Sawyer
- University of Cantabria
- University of Alabama in Huntsville
- University of Detroit Mercy
- University of Kaiserslautern / VPE
- Vitech
- 88solutions

INCOSE rep *

Academia/Research
End User

Tool Vendors
Government Rep

Key Elements of SysML v2

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- New Metamodel that is not constrained by UML
  - Grounded in formal semantics
- Robust visualizations based on flexible view & viewpoint specification and execution
  - Graphical, Tabular, Textual
- Standardized API to access the model

Integrated Views of a System
SysML v2 Enhancement over SysML v1

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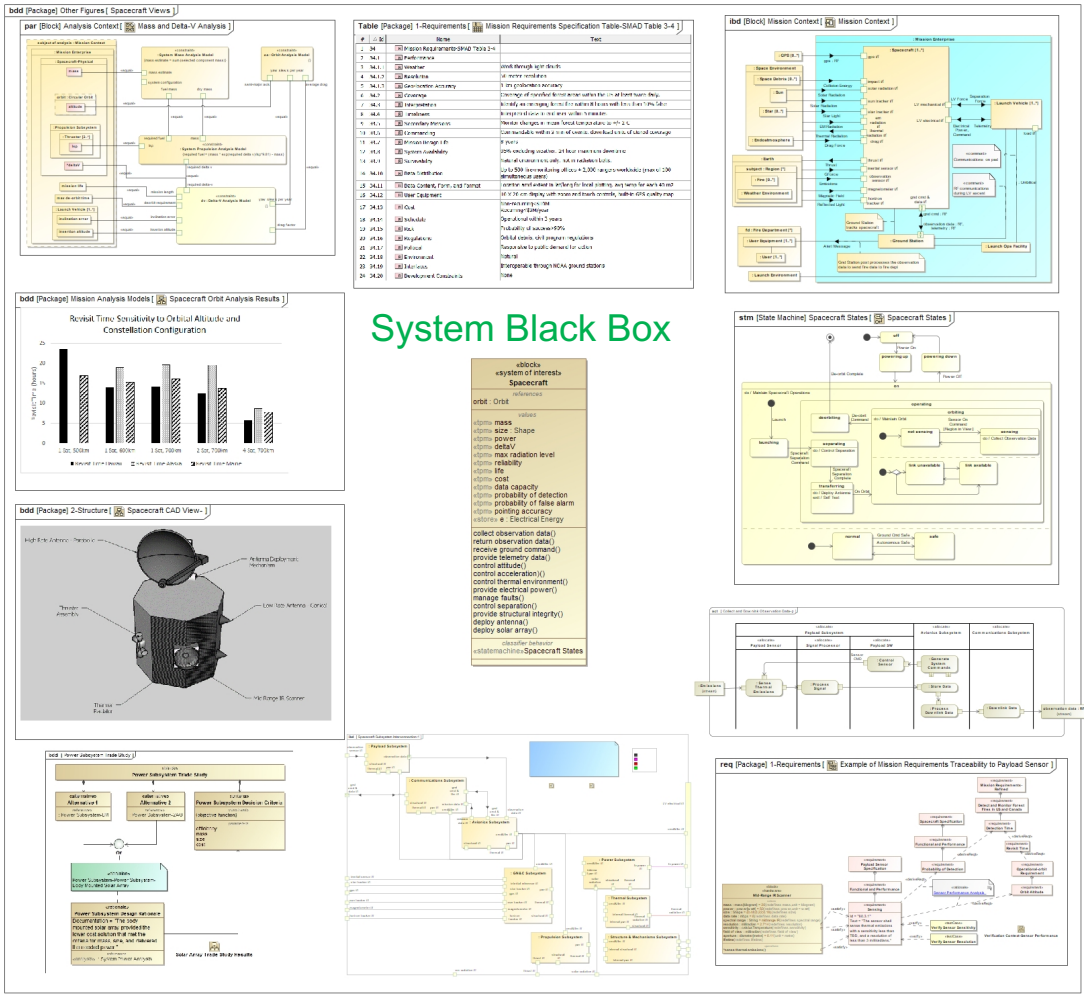
Improved integration with Analysis

Variant Modeling & Design Configurations



Geometric View

Improved integration between Behavior & Structure

Trade Studies

Property-based requirements

Source: Architecting Spacecraft with SysML

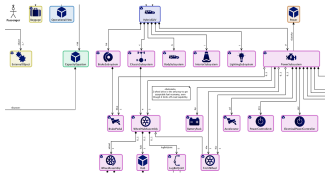
SysML v2 Visualization Concept

Source: C. Schreiber, J. Feingold, M. Sarrel

Textual Syntax

```
part vehicle_C1: VehicleDefinitions.Vehicle {
        part frontAssembly: AxleAssembly {
                part frontWheel: Wheel[2];
                part frontAxle: Axle;
        }
        part rearAssembly: AxleAssembly {
                part rearWheel: Wheel[2];
                part rearAxle: Axle;
        }
}
```

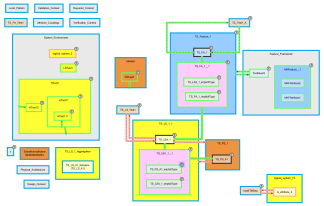
SysML Diagrammatic



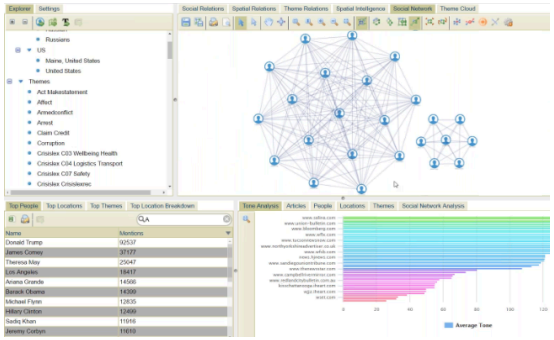
Tabular Data View

Name	Thread pitch (mm)	Minor diameter tolerance	Nominal diameter (mm)	Head shape	Price for 50 screws	Available at factory outlet?	Number in stock	Flat or Phillips head?
M4	0.7	4g	4	Pan	$10.08	Yes	276	Flat
M5	0.8	4g	5	Round	$13.89	Yes	183	Both
M6	1	5g	6	Button	$10.42	Yes	1043	Flat
M8	1.25	5g	8	Pan	$11.98	No	298	Phillips
M10	1.5	6g	10	Round	$16.74	Yes	488	Phillips
M12	1.75	7g	12	Pan	$18.26	No	998	Flat
M14	2	7g	14	Round	$21.19	No	235	Phillips
M16	2	8g	16	Button	$23.57	Yes	292	Both
M18	2.1	8g	18	Button	$25.87	No	664	Both
M20	2.4	8g	20	Pan	$29.09	Yes	486	Both
M24	2.55	9g	24	Round	$33.01	Yes	982	Phillips
M28	2.7	10g	28	Button	$35.66	No	1067	Phillips
M36	3.2	10g	36	Pan	$41.32	No	434	Both
M50	4.5	10g	50	Pan	$44.72	No	740	Flat

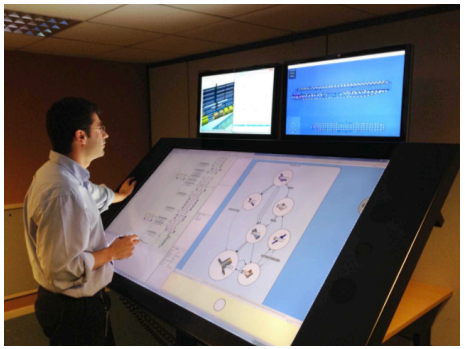
Model Differencing



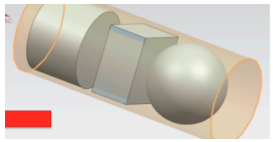
Dynamic Visualization



Interactive Display



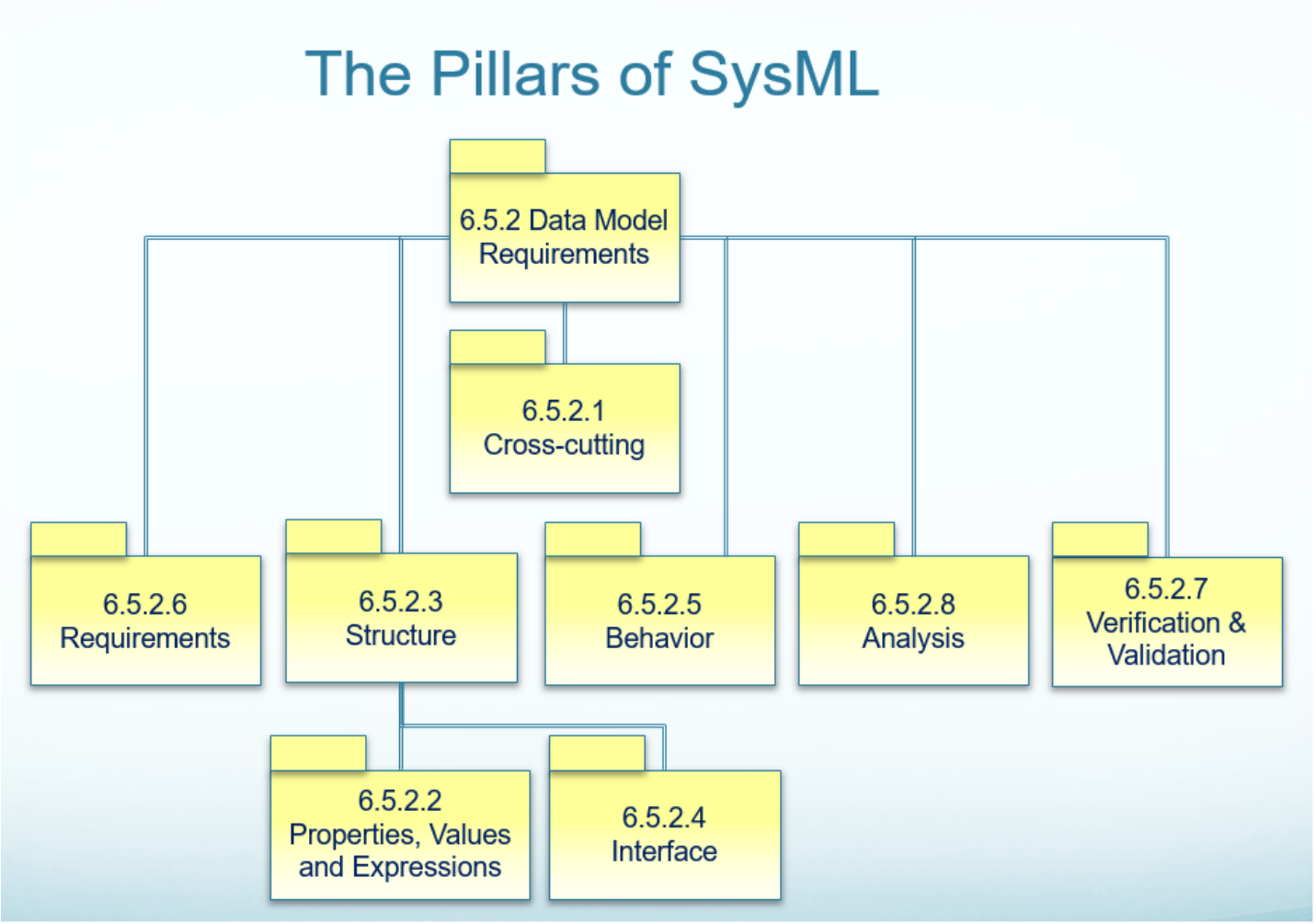
Physical Envelope



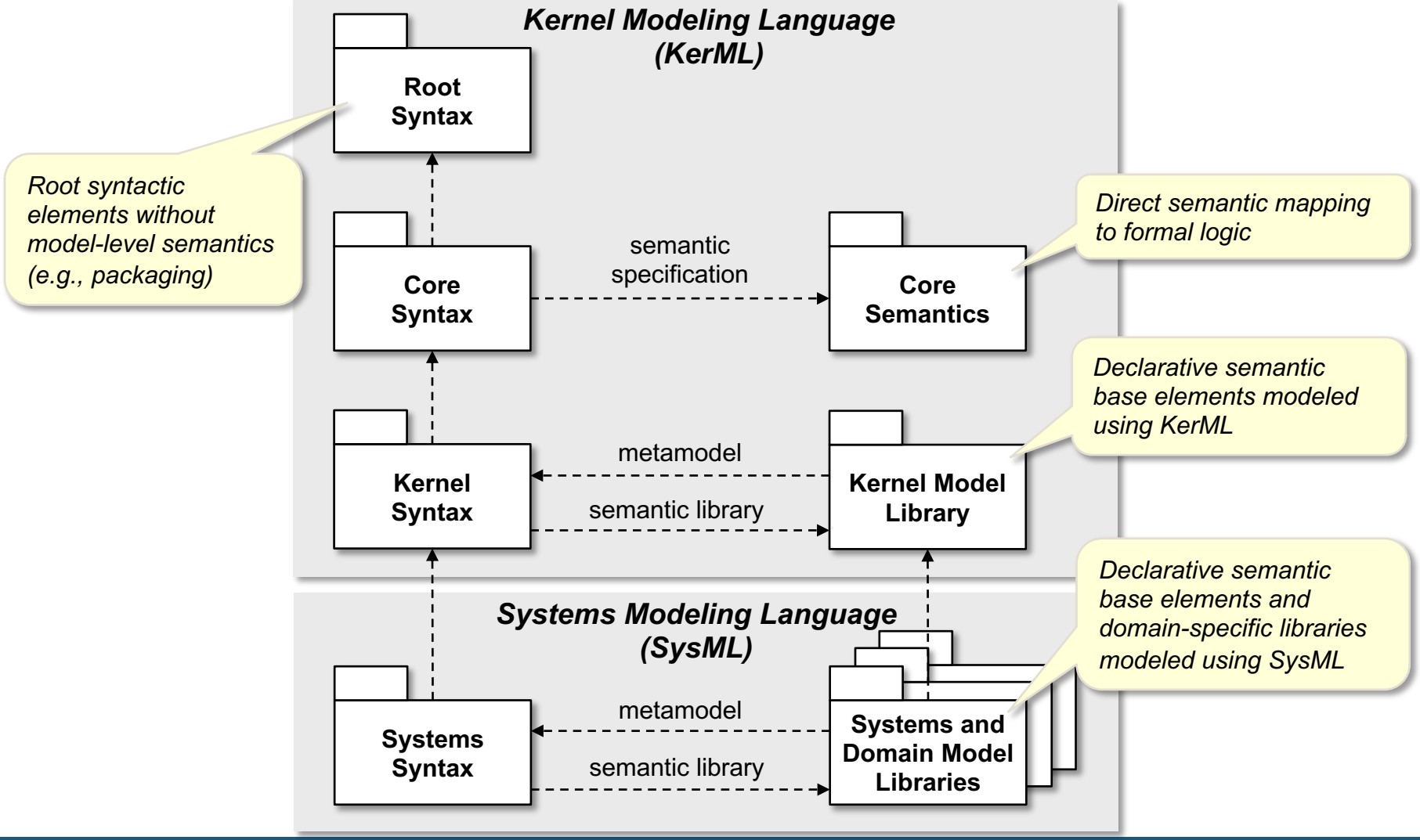
SysML v2 Language

SysML v2 Modeling Concepts

Source: SysML v2 RFP



SysML v2 Language Architecture SST



SysML v2 Textual Notation

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```
part vehicle_b :> vehicle_a {
    port fuelCmdPort;
    port vehicleToRoadPort {
        port wheelToRoadPorts[2];
    }

    part engine {
        port fuelCmdPort;
        port drivePwrPort;
    }

    part transmission {
        port clutchPort;
        port shaftPort;
    }

    part driveshaft {
        port shaftPort_a;
        port shaftPort_b;
    }

    part rearAxleAssembly :>> vehicle_a::rearAxleAssembly {
        part differential {
            port shaftPort;
            port axlePorts[2];
        }
        part rearAxle :>> vehicle_a::rearAxleAssembly::rearAxle {
            part halfAxles[2] {
                port axleToDiffPort;
                port axleToWheelPort;
            }
        }
        part rearWheels[2] :>> vehicle_a::rearAxleAssembly::rearWheels {
            port wheelToAxlePort;
            port wheelToRoadPort;
        }

   }

}
```

SysML v2 API & Services

SysML v2 API and Services RFP Scope

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- Mandatory Services
  - Model Navigation, Creation, Update, Deletion Services
  - External Relationship Management Service
- Non-Mandatory Services
  - Model Query Service
  - Advanced Model Construction Services
  - Model View and Viewpoint Management Services
  - Model Analysis Services
  - Model Management Services
  - Model Transformation Services
  - General Services – Timestamp and UUID generation, API Call Back

API Architecture – PIM and PSM

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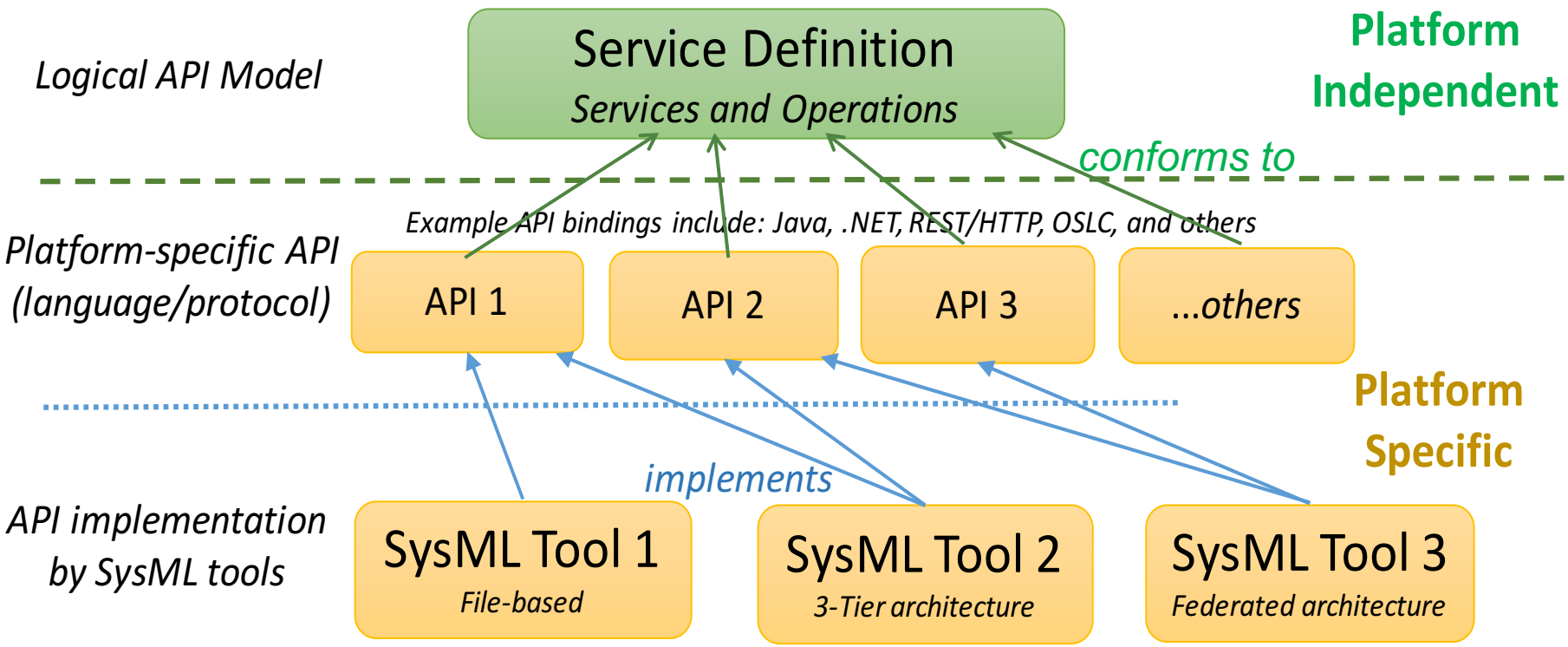
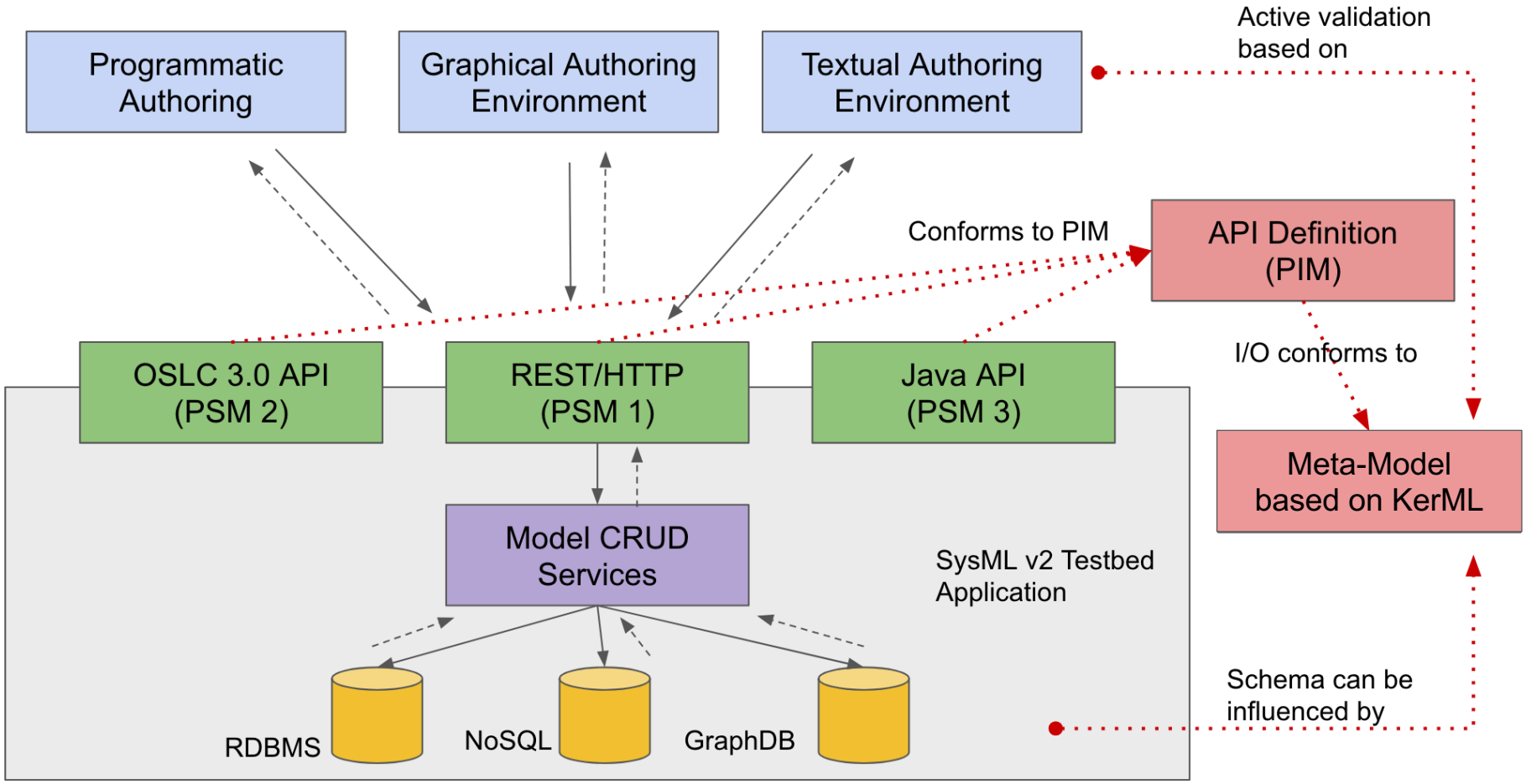


Pilot Implementation

High-Level Architecture of SysML v2 Testbed



Summary

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- Systems engineering practice must evolve to address evolving challenges of system complexity and be relevant to diverse application domains
- MBSE is part of the digital engineering transformation to improve SE and manage complexity and risk, and reuse
- SysML v1 was adopted in 2006 and facilitated awareness and adoption of MBSE
- Using the system model as an integrating framework is a constant
- SysML v2 facilitates increased adoption and effectiveness of MBSE over SysML v1 through enhanced:
  - Precision & expressiveness
  - Consistency and integration among the language concepts
  - Interoperability with other engineering models and tools
  - Usability by model developers and consumers

Questions & Comments

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