

#### SysML and the On-going SysML v2 Evolution

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European Space Agency

#### OMG SysML v2 Timeline



Request for Proposal Initially two submission teams Including SE Since end 2018 **Concept Model** merged into one Started 2015 Started Jan 2018 Language RFP on language released Dec 2017 • API RFP on API released May 2018 Includes open source prototype implementation OMG SysML Portal Recent Changes Media Manager Silemap Trace: - sysmil\_assessment\_and\_roadmap\_working\_group Table of Contents SysML v2 RFP Working Group SysML v2 RFP Working Group The SysML v2 Requirements are available on the SysML v2 Requirements Review page · Previously System Modeling Assessment and Roadmap Working Group' Description System Modeling Environment Scope of the System Previously 'System Modeling Assessment and Roadmap Working Group' Modeling Environment (SME) Capabilities of the System
 Modeling Environment (SME) Mailing list: mbse-roadmap-wg@omg.org Working Group Objectives: MG Wiki on SvsML v2 RFP \* Assess effectiveness of system modeling \* Develop the concept for the next gener Derive the requirements for SysML v2 to a support appoint for model, apoption and

#### **Submission**

Started June 2018

Initial submission of spec

•Language & API Scheduled June 2020



•v2.0 Expected summer 2021 Also first production tool implementations

Public overview SysML v2 approach by Ed Seidewitz Copyright @ 2018 Model Driven Solutions, Inc.

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Ed Seidewitz

Chief Technology Officer

Model Driven Solutions

Indel

**Driven Solutions** 

SvsML v2 and MBSE: The Next Ten Years

16 October 2018

Business Meets Technolo MBSE Meeting at MODELS 2018, Copenhagen

#### SysML v2 Requirements and Constraints



- Extensive RFP (<u>http://www.omgsysml.org/SysML-2.htm</u>)
  - Also very relevant input to MB4SE / future harmonisation
- SysML v2 shall be based on SMOF (Semantic Meta Object Facility)
  - Provides support for temporal aspects and multiple classifications
- Must provide migration path from SysML v1 that can be automated

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# SysML v2 Objectives

- Increase adoption and effectiveness of MBSE by enhancing...
- Precision and expressiveness of the language
- Consistency and integration among language concepts
- Interoperability with other engineering models and tools
- Usability by model developers and consumers

Substantially reduce learning curve for systems engineers



- SysML v2 Submission Team (SST) formed December 2017
  - Leads: Sandy Friedenthal, Ed Seidewitz
- A broad team of end users, vendors, academics, and government liaisons
  - $\,\circ\,$  Currently 110 members from 61 organizations
- Developing submissions to both RFPs
- Driven by RFP requirements and user needs



### **Tracks & Leads**

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



### **SST** Participating Organizations

# SST

• 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

End User		
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#### Tool Vendors

- Idaho National Laboratory
- IncQuery Labs
- Intercax
- Itemis

Academia/Research

- Jet Propulsion Lab
- John Deere
- Kenntnis
- LieberLieber
- Lightstreet Consulting
- Lockheed Martin
- LSST
- Maplesoft
- MITRE
- ModelAlchemy Consulting
- Model Driven Solutions
- Model Foundry
- NIST
- No Magic
- Obeo
- OOSE

Government Rep

#### INCOSE rep \*

- 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
- Vitech
- 88solutions



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







## SysML v2 Validation Cases

#### \_\_\_\_\_

#### • The following 15 validation cases capture initial required language functionality

0 1-Parts Tree

Ο

- $\circ$  2-Parts Interconnection
- 3-Function-based Behavior
- 4-Functional Allocation
- 5-State-based Behavior
- O 6-Individuals and Snapshots
- 7-Variant Configuration

- 9-Verification
- $\,\circ\,$  10-Analysis and Trades
- 11-View and Viewpoint
- 12-Cause-Effect and Failures
- 13-Model Containment
- 0 14-Language Extension
- 15-Properties, Values, & Expressions
- 8-Requirements Reflects 60% of the SysML v2 RFP requirements
- Additional validation cases are being defined to validate the API & Services requirements – in process





- Initial comparison highlights the following intended benefits
  - Additional functionality (e.g., variants, trade-off, ..)
  - Integrated concepts (e.g., between structure and behavior)
  - Ease of use (e.g., built in redefinition at every level of nesting)
  - Clarification of concepts (e.g., individuals/snapshots vs instances)





A paradigm shift to make SysML v2 more precise and intuitive to use

- Emphasizes modeling of localized usages (e.g., parts on an ibd)
   Decompose, connect, relate, and group usages
- Supports other language requirements
   variant design configurations, individuals, analysis, verification, ...
- Facilitates creating and modifying design configurations including structure and behavior to satisfy their requirements



## Usage Focused Modeling Approach Multiple Views of a System





## SysML v2 vs SysML v1 Redefinition



Vehicle mass is redefined with different values



# Function-based Behavior SysML v1 Activity Decomposition





# Function-based Behavior SysML v2 Action Decomposition



SS7



## Function-based Behavior SysML v1 Functional Allocation



# Function-based Behavior SysML v2 Functional Allocation



# SysML v1 Instance vs SysML v2 Individual/Snapshot





## Variant Configurations General Concepts



SS7

# API & Services Validation Cases



# SysML v2 API and Services RFP Requirements in Sections 6.5, 6.6

#### Mandatory Requirements

- API and Services Architecture and Conformance
- Service Scope, Conditions, and Response
- Model Navigation, Creation, Update, Deletion Services
- External Relationship Management Service

#### Non-Mandatory Requirements

- 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

#### OMG Document #: ad/2018-06-03



# **Pilot Implementation**



#### High-Level Architecture of SysML v2 Testbed



#### Example of ESA contributions

# **Properties, Values and Expressions**

#### PRP 1: Properties, Values and Expressions Requirements Group

The requirements in this group provide a unified representation of the type of properties, variables, constants, operation parameters and return types as well as literal values and value expressions. This includes types to represent variable size collections, compound value types, and measurement units and scales.



### Status RFP PRP Requirements 1/4

ID	Title	Requirement	Satisfied?
PRP 1.01	Unified Representation of Values	Proposals for SysML v2 shall include a capability to represent any value-based characteristic in a unified way, called a value property, which shall include representation of a constant, a variable in an expression or a constraint, state variable, as well as any formal parameter and the return type of an operation.	Yes
PRP 1.02	Value Type	Proposals for SysML v2 shall include a capability to represent a Value Type as a named definition of the essential semantics and structure of the set of allowable values of a value-based characteristic.	Yes
PRP 1.03	Value Expression	Proposals for SysML v2 shall include a capability to represent a value as a literal or through a reusable Value Expression that is stated in an expression language. A Value Expression shall include the capability to represent opaque expressions.	Yes Note: Textual SysML (evolution of Alf) is proposed as primary expression language.
PRP 1.04	Logical Expressions (non-mandatory)	Proposals for SysML v2 may include a capability to represent, as part of the Expression language, logical expressions that support as a minimum the standard boolean operators AND, OR, XOR, NOT, and conditional expressions like IF-THEN-ELSE and IF-AND-ONLY-IF, in which symbols bound to any characteristics (e.g. value properties or usage features) may be used.	Yes Supported by Textual SysML expressions. Concrete (graphical) syntax TBD.
PRP 1.05	Unification of Expression and Constraint Definition	Proposals for SysML v2 shall include a capability to represent a reusable constraint definition in the form of an equality or inequality of value expressions which can be evaluated to true or false.	Yes Note: Textual SysML (evolution of Alf) is proposed as primary expression and constraint definition language. Concrete (graphical) syntax TBD.



### Status RFP PRP Requirements 2/4

ID	Title	Requirement	Satisfied?
PRP 1.06	System of Quantities	Proposals for SysML v2 shall include a capability to represent a named system of quantities that support definition of numerical Value Types in accordance with the ISO/IEC 80000 standard.	Yes Note: Arbitrary system of quantities can be defined.
PRP 1.07	System of Units and Scales	Proposals for SysML v2 shall include a capability to represent a named system of measurement units and scales to define the precise semantics of numerical Value Types in accordance with the [ISO/IEC 80000] standard.	Yes Note: Also includes all concepts to support automated scale/unit conversion, US Customary Units or other non-SI units.
PRP 1.08	Range Restriction for Numerical Values	Proposals for SysML v2 shall include a capability to represent a value range restriction for any numerical Value Type.	Yes Note: Also for String.
PRP 1.09	Automated Quantity Value Conversion (non- mandatory)	Proposals for SysML v2 may include a capability to represent all information necessary to perform automated conversion of the value of a quantity (typed by a numerical Value Type) expressed in one measurement scale to the value expressed in another compatible measurement scale with the same quantity kind.	Yes All information to do automated quantity value conversion is captured. Conversion algorithm will be defined in Textual SysML.
PRP 1.10	Primitive Data Types	Proposals for SysML v2 shall include a capability to represent the following primitive data types as a minimum: signed and unsigned integer, signed and unsigned real, string, Boolean, enumeration type, ISO 8601 date and time, and complex.	Yes Note: All numerical data types inherit from NumericalValue, which is the generalization of Number and QuantityValue. Signed vs unsigned number types are specializations of Real, Integer, etc.



### Status RFP PRP Requirements 3/4

ID	Title	Requirement	Satisfied?
PRP 1.11	Variable Length Collection Value Types	Proposals for SysML v2 shall include a capability to represent variable length value collections where each member of the collection is typed by a particular Value Type and is referable by index, and where the collection may be one of the established collection types: sequence (ordered, non-unique), set (unordered, unique), ordered set (ordered, unique) or bag (unordered, non-unique).	Yes Note: Is even generalized for any Object or Value type, i.e. Anything. Textual SysML supports collection types out-of- the-box, using multiplicity as well as {unique} and {ordered} qualifiers.
PRP 1.12	Compound Value Type	Proposals for SysML v2 shall include a capability to represent both scalar and compound Value Types, where a scalar Value Type represents elements with a single value, and compound Value Type represents elements with a fixed number of component values, where each component value is typed in turn by a scalar Value Type or another compound Value Type.	Yes Note: Textual SysML supports compound types out-of-the-box through the feature concept.
PRP 1.13	Discretely Sampled Function Value Type (non-mandatory)	Proposals for SysML v2 may include a capability to represent variable length sets of values that constitute discrete time series data, frequency spectra, temperature dependent material properties, and any other datasets that can be represented through a discretely sampled mathematical function.	Yes
PRP 1.14	Discretely Sampled Function Interpolation (non-mandatory)	Proposals for SysML v2 may include a capability to represent an interpolation scheme for a Discretely Sampled Function Value Type for derivation of the function's range values for domain values that are in-between sampled values.	Yes



### Status RFP PRP Requirements 4/4

ID	Title	Requirement	Satisfied?
PRP 1.15	Probabilistic Value Distributions	Proposals for SysML v2 shall include a capability to represent the value of a quantity with a probabilistic value distribution, including an extensible mechanism to detail the kind of distribution, i.e. the probability density function for continuous random variables, or the probability mass function for discrete random variables.	To be completed Note: Exploring possibility extend unit/scale annotation to probalistic value distributions.
PRP 1.16	System Simulation Models (non- mandatory)	Proposals for SysML v2 may include a capability to represent signal flow graph models and lumped parameter models as well as combinations thereof.	In principle Note: Through parametric constraint blocks with bindings similar to SysML v1. Details TBD.
PRP 1.17	Across and Through Value Properties (non- mandatory)	Proposals for SysML v2 shall include a capability to define across and through properties of flows on Interface Ends that participate in representing physical interactions in lumped parameter models.	In principle Note: 'Across- and Through- ness' to be defined on ConstraintBlock, not at Quantity level.
PRP 1.18	Basic Geometry (non- mandatory)	Proposals for SysML v2 may include a capability to represent basic two- and three-dimensional geometry of a structural element, including a base coordinate frame as well as relative orientation and placement of shapes through nested coordinate frame transformations, where the basic shape definitions are provided in a model library.	To be completed Note: Generic concepts for 3D Shape and AxisPlacement in library. Examples TBD. Propose to model after ISO 10303-242 (STEP), JT, 3D PDF and verify mappability.
PRP 1.19	Materials with Properties	Proposals for SysML v2 shall include a capability to represent named materials with their material properties in a model library and assignment of such materials to physical elements such as hardware components.	To be completed Note: Generic concept for Material in library. Examples TBD.



- Started identifying use of Values, ValueTypes, Expressions, Quantities, ... in Track 2 Validation Cases
- Not so easy to define sensible / manageable set of Validation Cases covering all required details
- Value, Quantity, etc., concepts are well understood, do not need extensive refinement
- Therefore, first elaborated a V&V table covering:
  - Examples in Track 2 Validation Cases
  - Concepts in Track 4 Meta-model
  - Proposed implementations in Track 6 Pilot Implementation



#### PRP V&V Table (Excerpt)

		P	c					
-	000.1	Dreportion Values and	The requirements in this group provide a unified representation of the tune of	U			0	
	PRPA	Properties, values and Expressions	properties variables constants operation parameters and return type of					
		Requirements Group	as literal values and value expressions. This includes types to represent variable					
		nequirements broup	size collections, compound value types, and measurement units and scales					
			size conections, compound value types, and measurement units and scales.					
2								
3	Id	Name	Text	Compliance	Track 2 Validation Case	Track 4 Concept	Track 6 Textual Language	Track 6 Library
	PRP 1.01	Unified Representation	Proposals for SysML v2 shall include a capability to represent any value-based	Mandatory				,
		of Values	characteristic in a unified way, called a value property, which shall include					
			representation of a constant, a variable in an expression or a constraint, state					
			variable, as well as any formal parameter and the return type of an operation.					
			Supporting Information:					
			A classification of invariant" can be attached to a value property to assert that is					
			does not vary over time. A constant is an invariant value property of some higher-					
			level context (ultimately the "universe" in case of fundamental physics					
			constants).					
			Provisions should be made to distinguish between a fundamental physical or					
			mathematical constant (i.e., Pi) from a constant value within the context of a					
4			particular model or model execution (i.e., amplifier gain)."			4		
	PRP 1.02	Value Type	Proposals for SysML v2 shall include a capability to represent a Value Type as a	Mandatory	• mass	Value	• datatype	abstract datatype Value
			named definition of the essential semantics and structure of the set of allowable		• steeringAngle	(In sysmul metamodel:: Libraries::	<ul> <li>feature // typed by a datatype</li> </ul>	reacure value roperty: value[0*]
			values of a value-based characteristic.		(in 1a-Parts free, 10-Parts free	base)		(in systily sicy notally/base.an)
					• engineTorque : Torque			
					(in 2a-Parts Interconnection			
					Example)			
5								
	PRP 1.03	Value Expression	Proposals for SysML v2 shall include a capability to represent a value as a literal	Mandatory	<ul> <li>time duration &lt;= 1 second</li> </ul>			
			or through a reusable Value Expression that is stated in an expression language.		<ul> <li>out torque=fn(fuel demand)</li> </ul>			
			A Value Expression shall include the capability to represent opaque expressions.		(in 3b-Function-based Behavior			
6					Example-with Constraints)			
	PRP 1.05	Unification of Expression	Proposals for SysML v2 shall include a capability to represent a reusable	Mandatory	<ul> <li>time duration &lt;= 1 second</li> </ul>			
		and Constraint Definition	constraint definition in the form of an equality or inequality of value expressions		<ul> <li>out torque=fn(fuel demand)</li> </ul>			
			which can be evaluated to true or false.		(in 3b-Function-based Behavior			
7					Example-with Constraints)			a desta de la construction
	PRP 1.06	system of quantities	Proposals for SySML vz shall include a capability to represent a named system of	Mandatory		SystemOrQuantitiesUnitsAndScales		abstract datatype QuantityValue
			the ISO/IEC 80000 standard			Quantities:: )		(in sysmil/sre/library/Quantitias alf)
			the restrict advancements.			SystemOfQuantitiesUnitsAndScales		nackage ISO // International System of Quantities
			Supporting Information: The typical Systems of Quantities is the ISO/IEC 20000			(in SysML Metamodel:: Libraries:		(in sysml/src/library/ISO.alf)
			International System of Quantities (ISQ) with seven base quantities: length.			Quantities:: ISO IEC 80000)		package USCustomaryUnits
			mass, time, electric current, thermodynamic temperature, amount of substance			,		(in sysml/src/library/USCustomaryUnits.alf)
8			and luminous intensity.					(
	PRP 1.07	System of Units and	Proposals for SysML v2 shall include a capability to represent a named system of	Mandatory		SystemOfQuantitiesUnitsAndScales		See above
		Scales	measurement units and scales to define the precise semantics of numerical			(in SysML Metamodel:: Libraries::		
			Value Types in accordance with the [ISO/IEC 80000] standard.			Quantities::)		
			Supporting Information: Similar to SysML v1 QUDV, SysML v2 should include					
			model libraries representing the [ISO/IEC 80000] units, as well as the conversion					
9			to US Customary Units defined in [NIST SP 811] Appendix B.					
				teres and the second				

#### Information Model Approach and Textual Syntax



- Started from <u>KerML (Kernel Model Language)</u>
  - Minimalistic meta-model (M2)
  - Normative / informative model libraries (M1, M0)
  - Feature (similar to UML property) is a 'first class citizen' and can be nested
    - Self-standing features can be defined
    - Addresses the deeply nested feature inconveniences of SysML v1
    - E.g. mass defined as feature mass: MassValue[1..1] can be used on a block directly: MyBlock.mass = 24@[kg]
- New textual syntax based on <u>fUML ALF</u>
  - Very powerful and concise alternative for graphical notation
  - Main work in Track 6 Prototype Implementation

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#### Summary



- SysML v2 on quite promising route
- Many serious improvements
  - Properly based on formal semantics
  - Usage focused modelling will make tools much more SE-friendly
  - Same for unification of structure and behavior modelling
  - Standardized technology-independent API
    - Can also be used by non-SysML tools
  - Substantial European influence (Experience from ECSS, RangeDB, Capella)
- All major vendors participate in SST
- > Will take another 2 years before becoming available in tools

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