Progress on SysML v2

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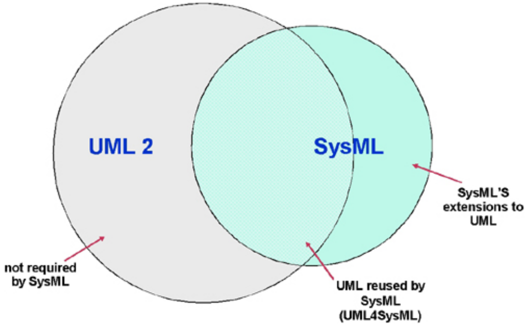
ESA/ESTEC – Noordwijk – The Netherlands

What is SysML?

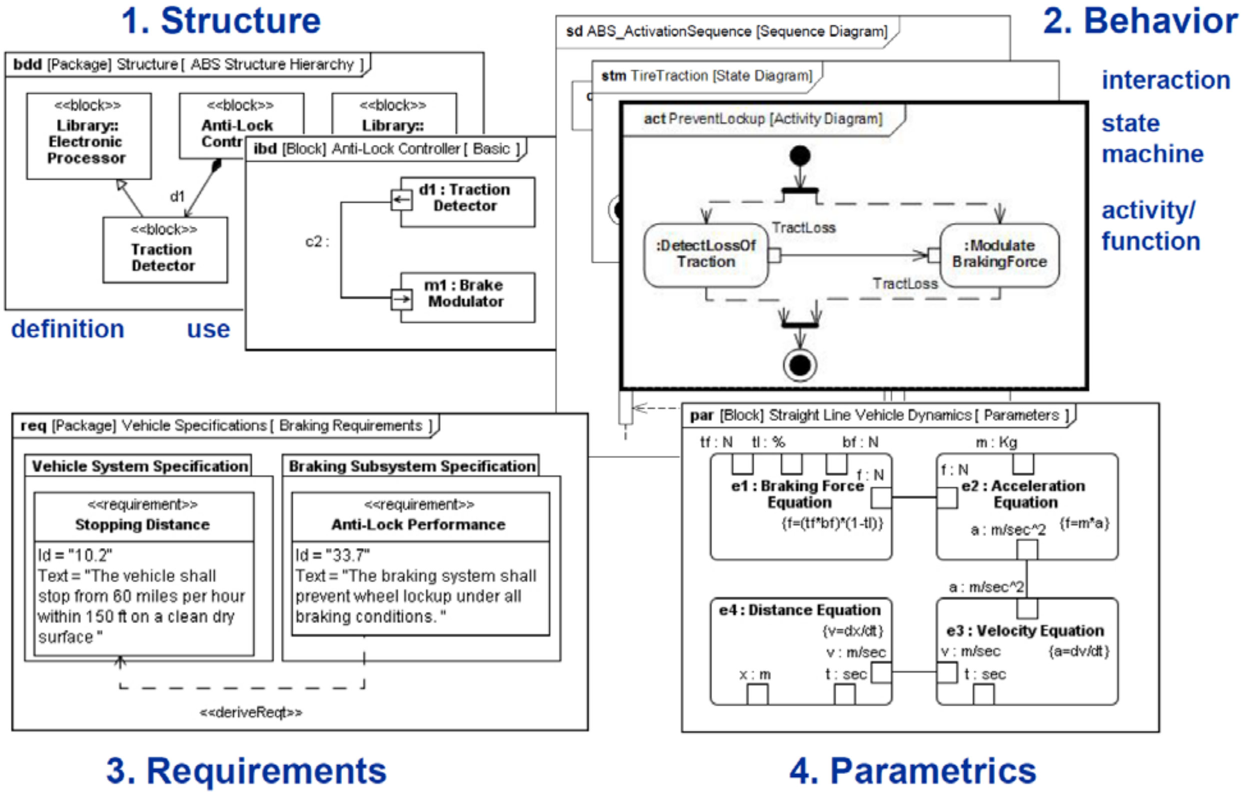
- Systems Modeling Language – profile / extension of UML



> general-purpose graphical modeling language for specifying, analyzing, designing, and verifying complex systems that may include hardware, software, information, personnel, procedures, and facilities
> from http://www.omgsysml.org/

- OMG standard since 2007 – v1.0
- In real industrial use since 2010 – v1.2
- Currently v1.5 – released May 2017
- v1.6 almost published – v1.7 in development

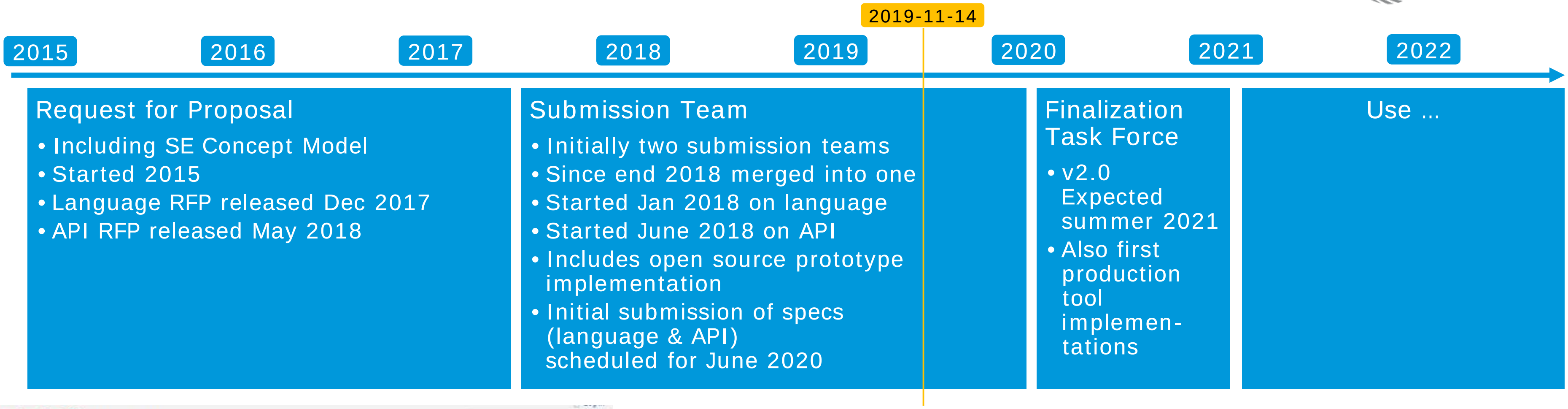
The four pillars of SysML


1. Structure
bdd [Package] Structure [ABS Structure Hierarchy]
<<block>> Library:: Electronic Processor
<<block>> Anti-Lock Contr
<<block>> Library::
d1
<<block>> Traction Detector
ibd [Block] Anti-Lock Controller [Basic]
d1 : Traction Detector
c2 :
m1 : Brake Modulator
definition
use
2. Behavior
sd ABS_ActivationSequence [Sequence Diagram]
stm TireTraction [State Diagram]
act PreventLockup [Activity Diagram]
:DetectLossOf Traction
TractLoss
:Modulate BrakingForce
TractLoss
interaction
state machine
activity/ function
req [Package] Vehicle Specifications [Braking Requirements]
Vehicle System Specification
Braking Subsystem Specification
<<requirement>> Stopping Distance
Id = "10.2"
Text = "The vehicle shall stop from 60 miles per hour within 150 ft on a clean dry surface"
<<requirement>> Anti-Lock Performance
Id = "33.7"
Text = "The braking system shall prevent wheel lockup under all braking conditions."
<<deriveReqt>>
3. Requirements
par [Block] Straight Line Vehicle Dynamics [Parameters]
tf : N
tl : %
bf : N
m : Kg
f : N
e1 : Braking Force Equation
{f=(tf*bf)*(1-tl)}
f : N
e2 : Acceleration Equation
a : m/sec^2
{f=m*a}
a : m/sec^2
e4 : Distance Equation
{v=dx/dt}
v : m/sec
x : m
t : sec
e3 : Velocity Equation
v : m/sec
{a=dv/dt}
t : sec
4. Parametrics

All diagram types:

- Requirement
- Structure
  - Block Definition
  - Internal Block
  - Parametric
  - Package
- Behavior
  - Activity
  - Sequence
  - State Machine

OMG SysML v2 Timeline



Request for Proposal

- Including SE Concept Model
- Started 2015
- Language RFP released Dec 2017
- API RFP released May 2018

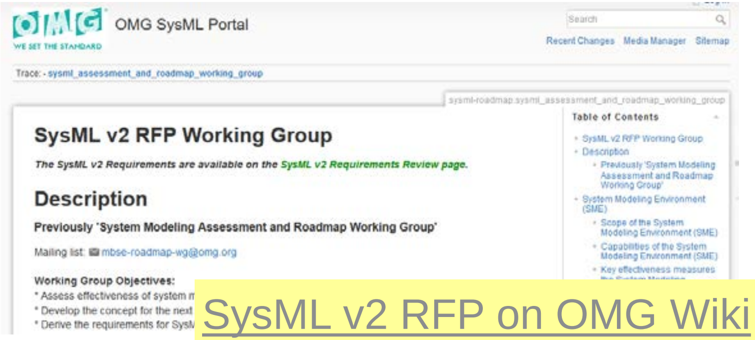
Submission Team

- Initially two submission teams
- Since end 2018 merged into one
- Started Jan 2018 on language
- Started June 2018 on API
- Includes open source prototype implementation
- Initial submission of specs (language & API) scheduled for June 2020

Finalization Task Force

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

Use ...



OMG SysML Portal

Trace: - sysml_assessment_and_roadmap_working_group

sysml-roadmap:sysml_assessment_and_roadmap_working_group

SysML v2 RFP Working Group

The SysML v2 Requirements are available on the SysML v2 Requirements Review page.

Description

Previously 'System Modeling Assessment and Roadmap Working Group'

Mailing list: mbse-roadmap-wg@omg.org

Working Group Objectives:

* Assess effectiveness of system m
* Develop the concept for the next
* Derive the requirements for SysM

Table of Contents

- SysML v2 RFP Working Group
- Description
  - Previously 'System Modeling Assessment and Roadmap Working Group'
- System Modeling Environment (SME)
  - Scope of the System Modeling Environment (SME)
  - Capabilities of the System Modeling Environment (SME)
  - Key effectiveness measures

SysML v2 RFP on OMG Wiki

MBSE Meeting at MODELS 2018, Copenhagen

SysML v2 and MBSE: The Next Ten Years
16 October 2018

Ed Seidewitz
Chief Technology Officer
Model Driven Solutions

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Public overview SysML v2 approach by Ed Seidewitz

SysML v2 Requirements and Constraints

- Extensive RFP (http://www.omgsysml.org/SysML-2.htm)
  - 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

SysML v2 Objectives

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- 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)

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 110 members from 61 organizations
- Developing submissions to both RFPs
- Driven by RFP requirements and user needs

Submission Team Tracks

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- Track 1: Project Management – Ed Seidewitz, Sandy Friedenthal
- Track 2: Requirements V&V
- Track 3: Profile Development
- Track 4: Metamodel Development
- Track 5: API/Services Development
- Track 6: Pilot Implementation

SST Participating Organizations

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Academia/Research | End User | Tool Vendors | Government Rep | INCOSE rep *

- 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
- John Deere
- Kenntnis
- LieberLieber
- Lightstreet Consulting
- Lockheed Martin
- LSST
- Maplesoft
- MITRE
- ModelAlchemy Consulting
- Model Driven Solutions
- Model Foundry
- NIST
- No Magic
- 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
- Vitech
- 88solutions

61 in total – many aerospace – most major vendors on board

Key Elements of SysML v2

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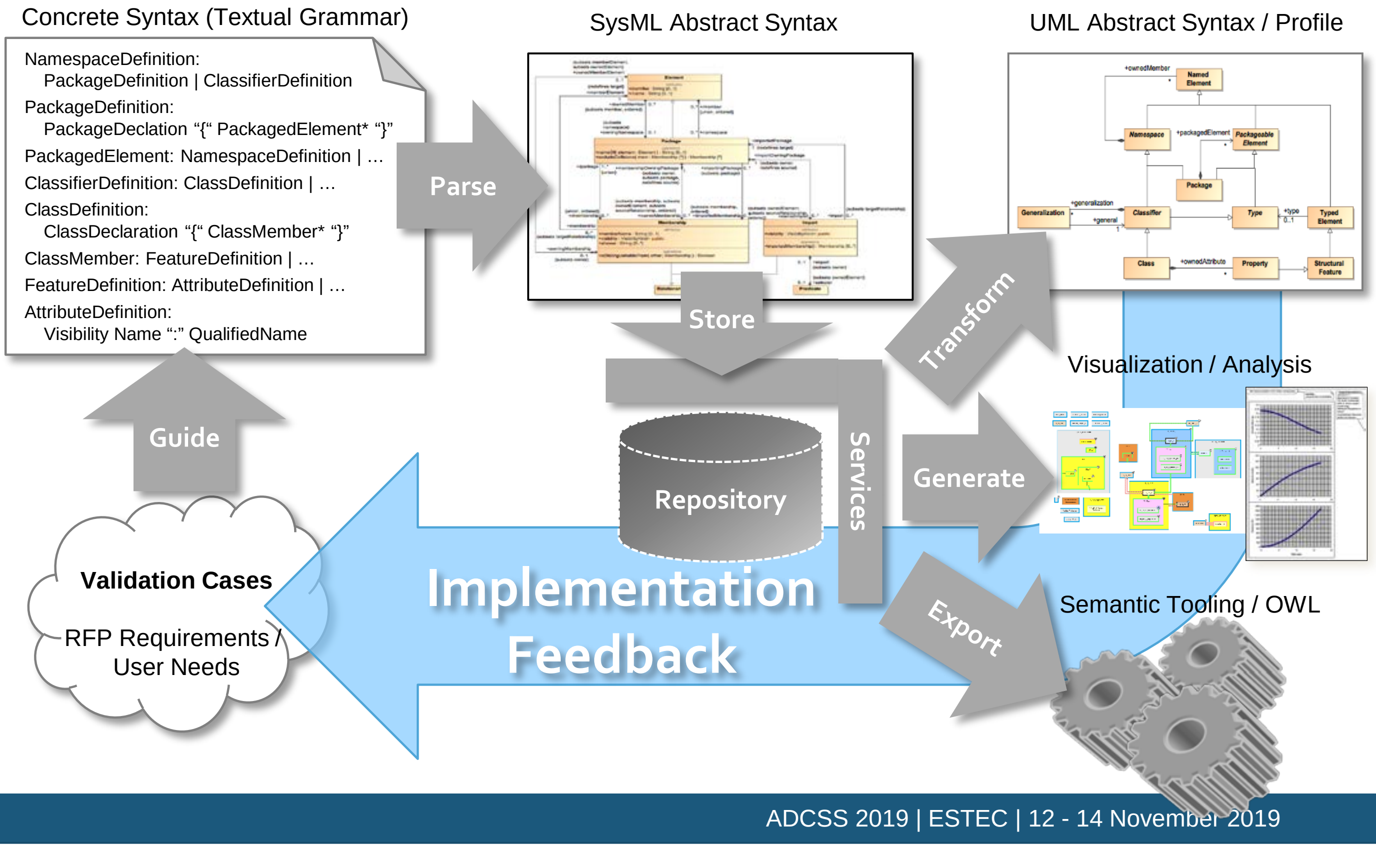
- New Metamodel that is not constrained by UML
  - Grounded in formal semantics
- Robust visualizations based on flexible view & viewpoint specification and execution
  - Graphical, Tabular, Textual
- Standardized API to access the model

SST Agile Collaborative Approach



Concrete Syntax (Textual Grammar)

```
NamespaceDefinition:
   PackageDefinition | ClassifierDefinition
PackageDefinition:
   PackageDeclation “{“ PackagedElement* “}”
PackagedElement: NamespaceDefinition | …
ClassifierDefinition: ClassDefinition | …
ClassDefinition:
   ClassDeclaration “{“ ClassMember* “}”
ClassMember: FeatureDefinition | …
FeatureDefinition: AttributeDefinition | …
AttributeDefinition:
   Visibility Name “:” QualifiedName
```

SysML v2 versus SysML v1 Comparison

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- 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)

Usage Focused Modeling Approach

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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

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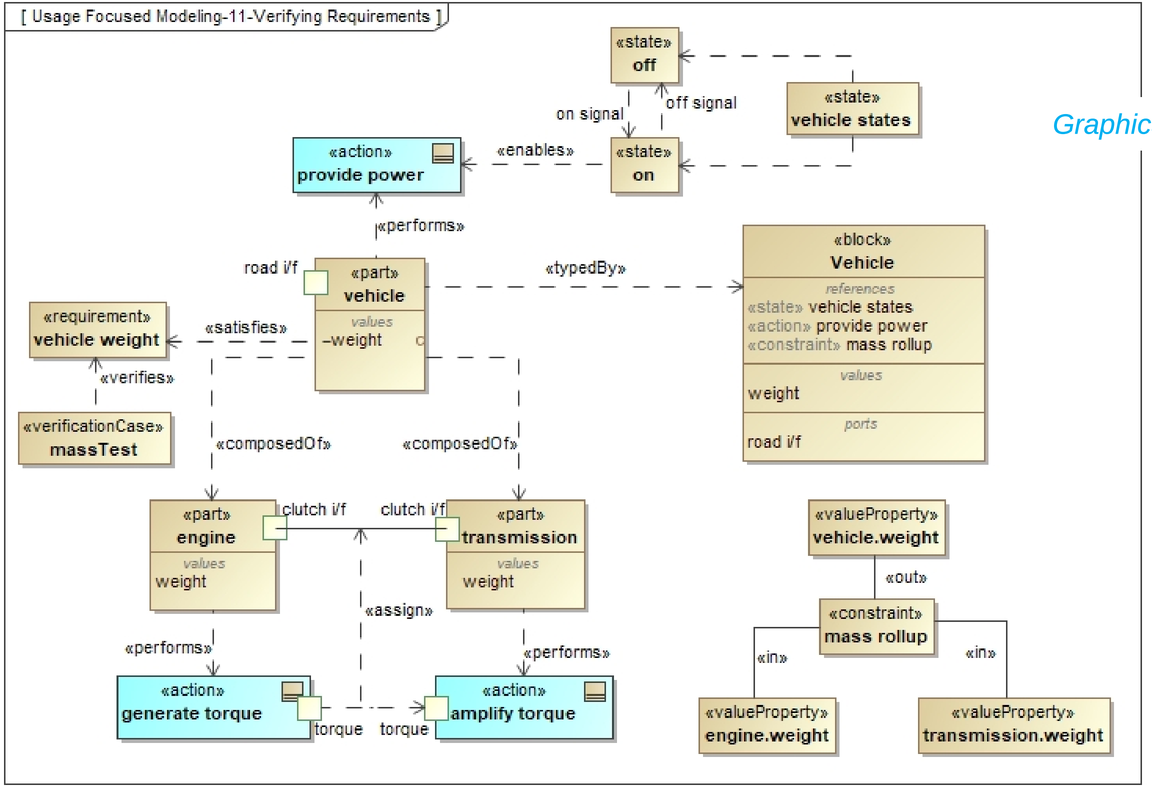

Graphical notation for illustrative purposes only

Function-based Behavior
SysML v2 Functional Allocation

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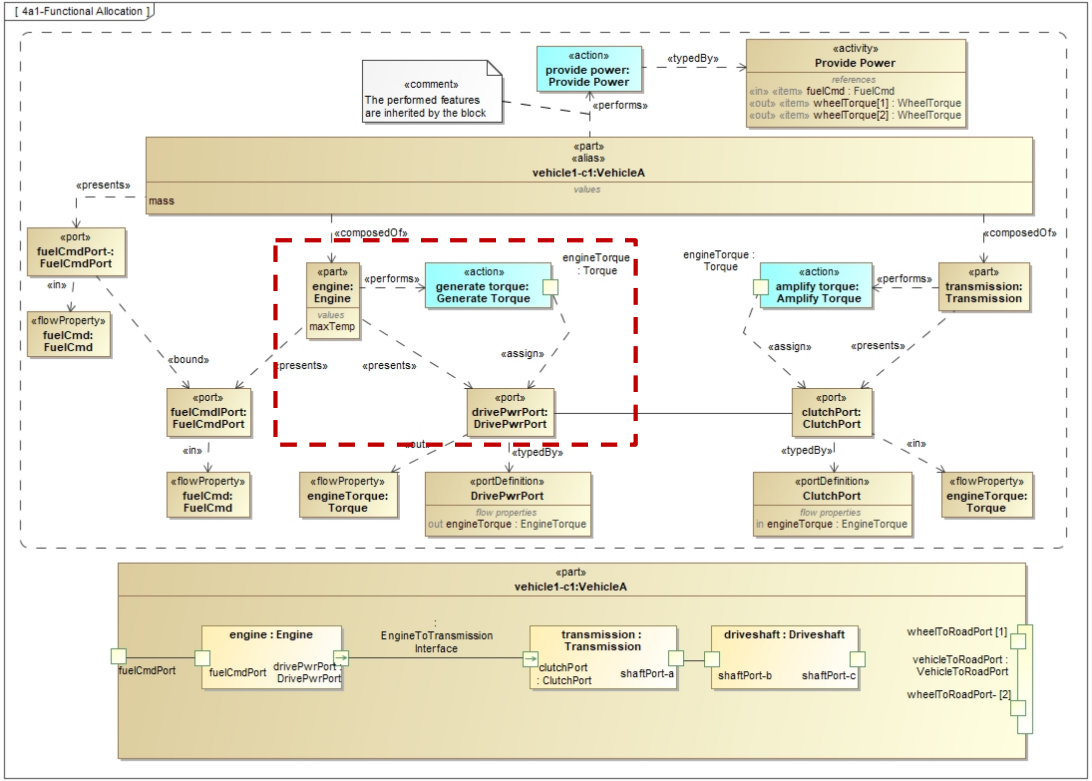

Information Model Approach and Textual Syntax

- Started from KerML (Kernel Model Language)
  - 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 fUML ALF
  - Very powerful and concise – alternative for graphical notation
  - Main work in Track 6 Prototype Implementation

Textual Language Examples Packages

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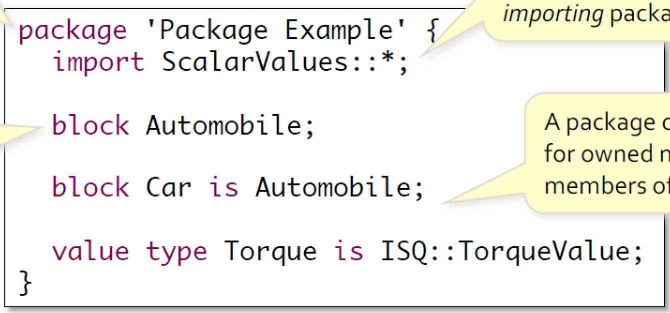
A *package* acts as a *namespace* for its members and a *container* for its owned members.

ⓘ A name with spaces or other special characters is surrounded in singe quotes.

An *import* adds all the members of the *imported* package to the *importing* package.



```
package 'Package Example' {
  import ScalarValues::*;

  block Automobile;

  block Car is Automobile;

  value type Torque is ISQ::TorqueValue;
}
```

The *owned members* of a package are elements directly contained in the package.

A package can introduce *aliases* for owned members or individual members of other packages.

ⓘ A *qualified name* is a package name (which may itself be qualified) followed by the name of one of its members, separated by :: .

Courtesy Ed Seidewitz, Model Driven Solutions

Textual Language Examples
Blocks and Value Types

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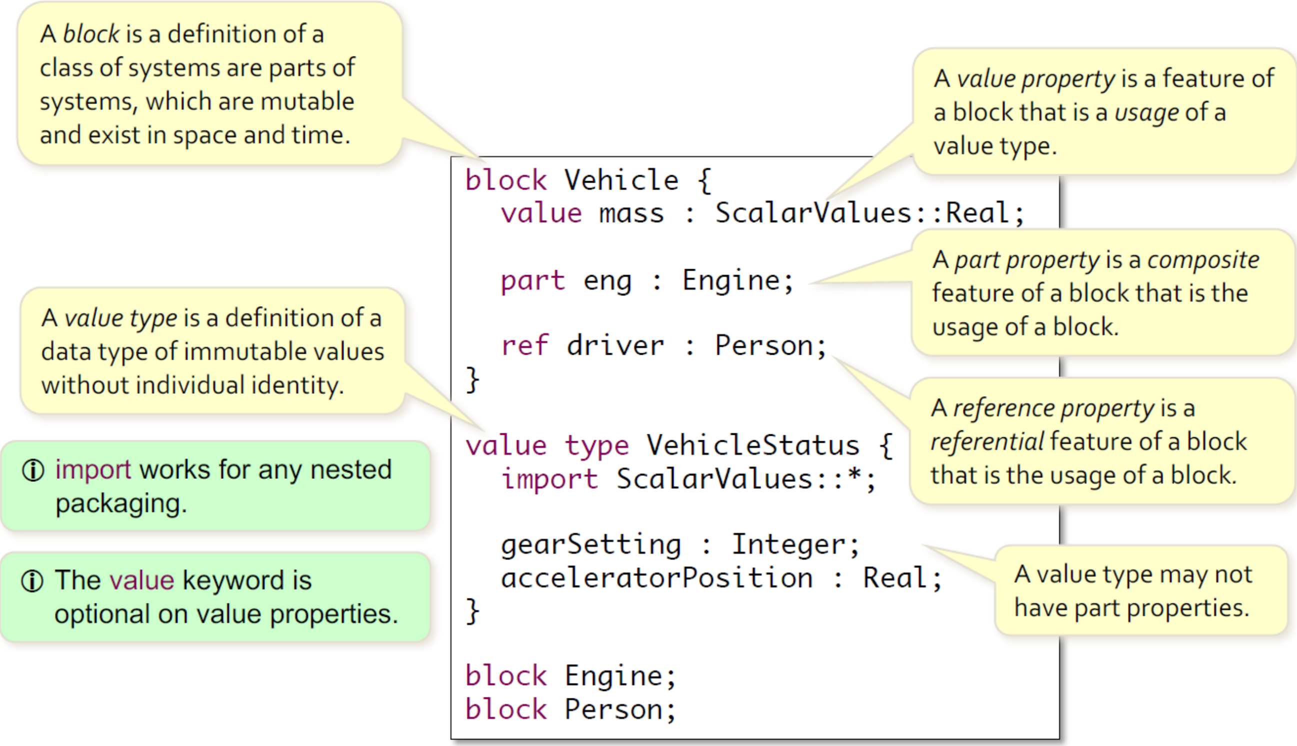

```
block Vehicle {
  value mass : ScalarValues::Real;

  part eng : Engine;

  ref driver : Person;
}

value type VehicleStatus {
  import ScalarValues::*;

  gearSetting : Integer;
  acceleratorPosition : Real;
}

block Engine;
block Person;
```

A *block* is a definition of a class of systems are parts of systems, which are mutable and exist in space and time.

A *value type* is a definition of a data type of immutable values without individual identity.

ⓘ import works for any nested packaging.

ⓘ The value keyword is optional on value properties.

A *value property* is a feature of a block that is a *usage* of a value type.

A *part property* is a *composite* feature of a block that is the usage of a block.

A *reference property* is a *referential* feature of a block that is the usage of a block.

A value type may not have part properties.

Courtesy Ed Seidewitz,
Model Driven Solutions

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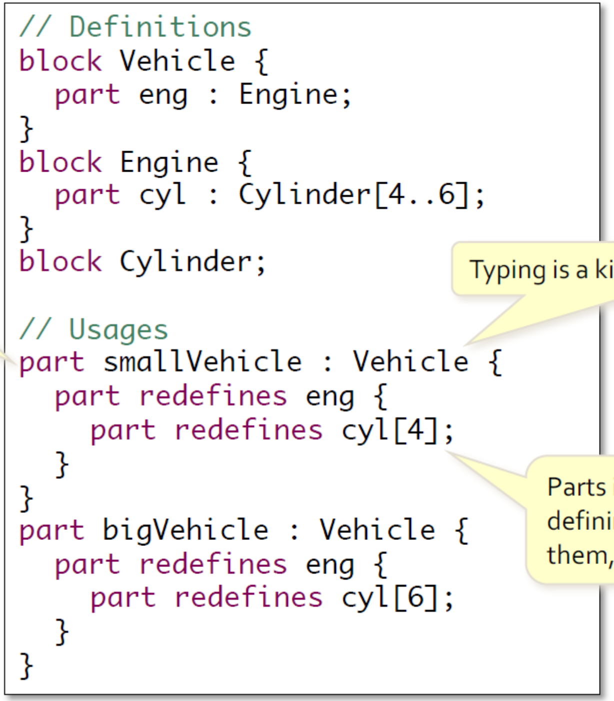
Textual Language Examples
Parts (and nested redefinitions)

Parts can be specified outside the context of a specific block.



```
// Definitions
block Vehicle {
  part eng : Engine;
}
block Engine {
  part cyl : Cylinder[4..6];
}
block Cylinder;

// Usages
part smallVehicle : Vehicle {
  part redefines eng {
    part redefines cyl[4];
  }
}
part bigVehicle : Vehicle {
  part redefines eng {
    part redefines cyl[6];
  }
}
```

Typing is a kind of generalization.

Parts inherit properties from their defining blocks and can redefine them, to any level of nesting.

Courtesy Ed Seidewitz, Model Driven Solutions

Textual Language Examples Interface Decomposition

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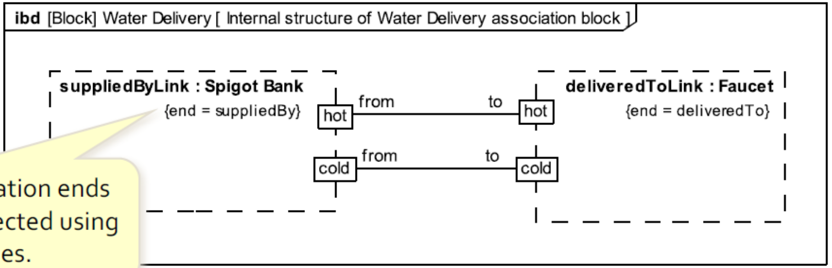
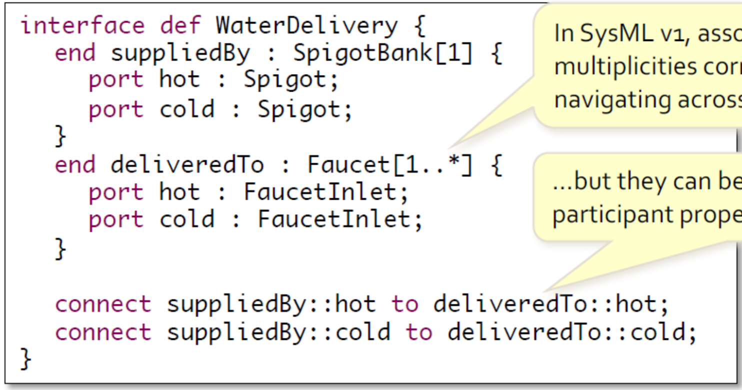
From SysML v1.5 spec



ibd [Block] Water Delivery [Internal structure of Water Delivery association block]
suppliedByLink : Spigot Bank
{end = suppliedBy}
hot
cold
from
to
from
to
hot
cold
deliveredToLink : Faucet
{end = deliveredTo}

In SysML v1, association ends could only be connected using participant properties.



```
interface def WaterDelivery {
   end suppliedBy : SpigotBank[1] {
      port hot : Spigot;
      port cold : Spigot;
   }
   end deliveredTo : Faucet[1..*] {
      port hot : FaucetInlet;
      port cold : FaucetInlet;
   }

   connect suppliedBy::hot to deliveredTo::hot;
   connect suppliedBy::cold to deliveredTo::cold;
}
```

In SysML v1, association ends have multiplicities corresponding to navigating across the association…

…but they can be interconnected like participant properties.

Courtesy Ed Seidewitz, Model Driven Solutions

Textual Language Examples
Activities/Functions (control flow / item flow)

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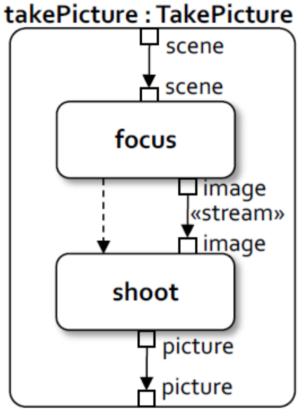

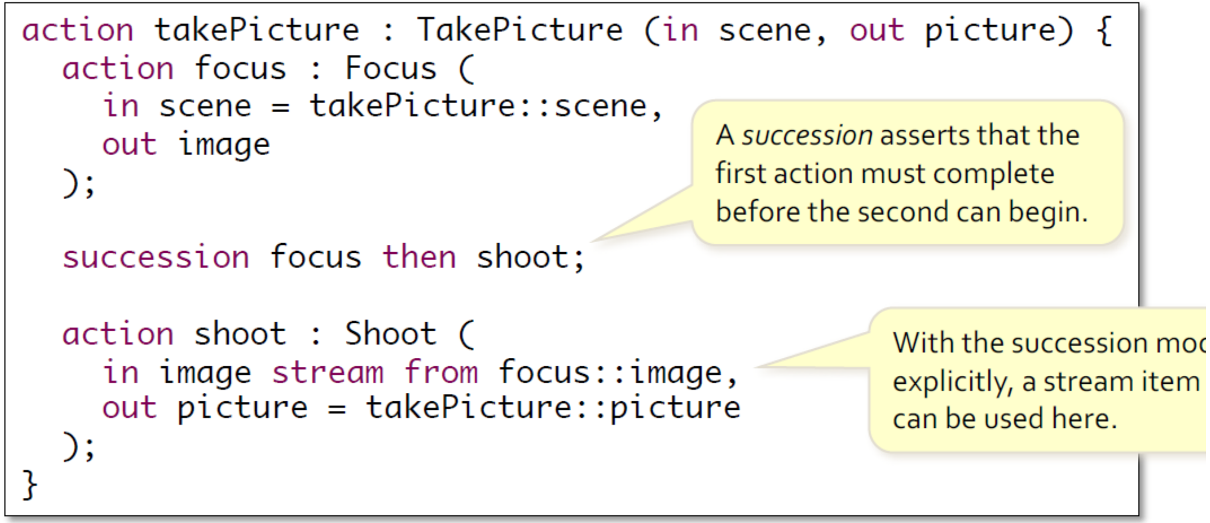

```
action takePicture : TakePicture (in scene, out picture) {
  action focus : Focus (
    in scene = takePicture::scene,
    out image
  );

  succession focus then shoot;

  action shoot : Shoot (
    in image stream from focus::image,
    out picture = takePicture::picture
  );
}
```

A *succession* asserts that the first action must complete before the second can begin.

With the succession mod explicitly, a stream item can be used here.

Courtesy Ed Seidewitz,
Model Driven Solutions

Textual Language Examples Quantities, Units and Scales

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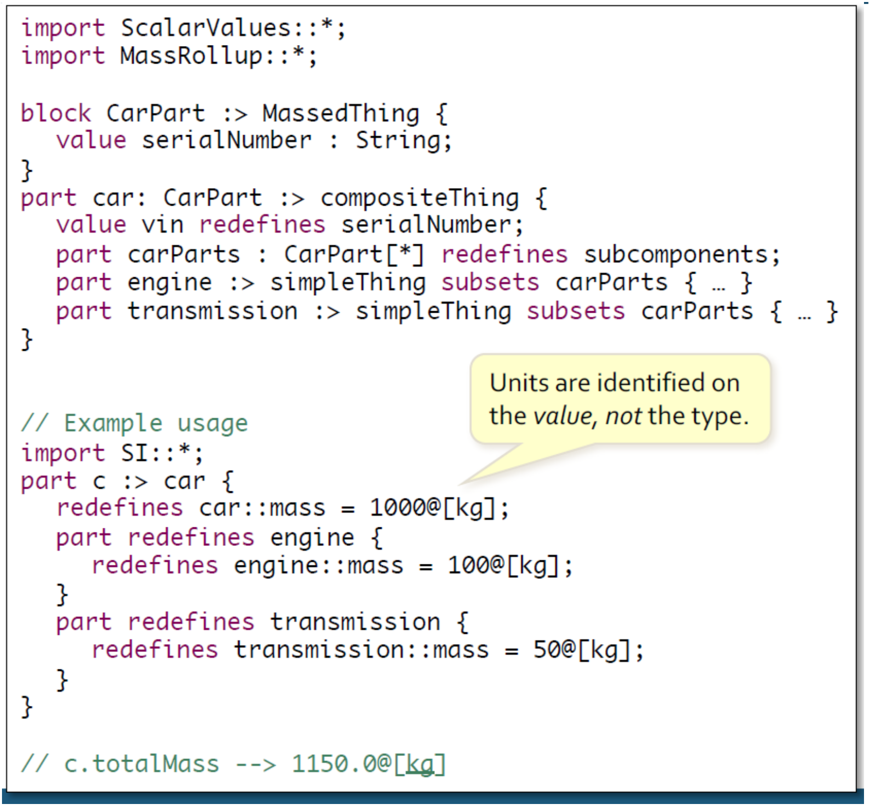

```
import ScalarValues::*;
import MassRollup::*;

block CarPart :> MassedThing {
   value serialNumber : String;
}
part car: CarPart :> compositeThing {
   value vin redefines serialNumber;
   part carParts : CarPart[*] redefines subcomponents;
   part engine :> simpleThing subsets carParts { … }
   part transmission :> simpleThing subsets carParts { … }
}


// Example usage
import SI::*;
part c :> car {
   redefines car::mass = 1000@[kg];
   part redefines engine {
      redefines engine::mass = 100@[kg];
   }
   part redefines transmission {
      redefines transmission::mass = 50@[kg];
   }
}

// c.totalMass --> 1150.0@[kg]
```

Units are identified on the *value*, *not* the type.

- Full ISO/IEC 80000 semantic model
- US Customary Units as well
- Implemented as extensible model library
- Automated conversion between any compatible units/scales
- Build on SysML v1 QUDV
- Compatible data model with ECSS E-TM-10-23 & E-TM-10-25, EGS-CC
- Quantity value definition will be extended in 2020-Q1 to probabilistic values with probability distributions, uncertainties, etc.

Pilot Implementation

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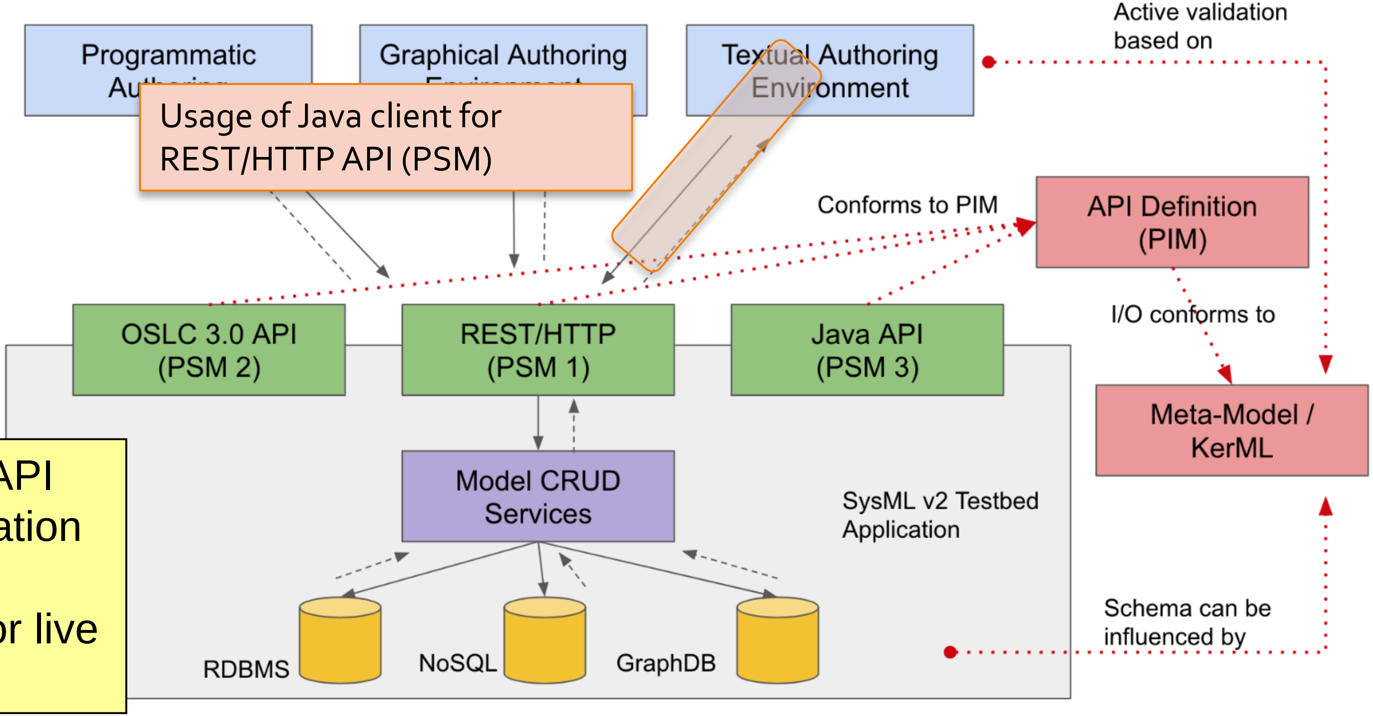
High-Level Architecture of SysML v2 Testbed



Usage of Java client for REST/HTTP API (PSM)

- Prototype API implementation
- REST API available for live testing

Summary

- SysML v2 on a very promising track
- First SysML v2 Public Incremental Release 2019-09 made 11 Oct 2019
  - See http://openmbee.org/sysml-v2-release/2019-09
  - Running textual prototype on Jupyter Notebook with REST API
    and Tom Sawyer auto-layout graphical language visualisation in web-browser
- Many serious improvements
  - Properly based on formal semantics – including mapping to OWL/RDF
  - Usage-focused modelling & unification of structure and behavior: much more SE-friendly
  - Standardized technology-independent API – Can also be used by non-SysML tools
  - Substantial European influence (Experience from ECSS, RangeDB, Capella)
- Will take another ~1.5 years before becoming available in tools