OMG Standards Development Organization

SYSML V2: WHERE WE ARE AND HOW WE GOT HERE

OMG MEETING
ORLANDO, FLORIDA
JUNE 21, 2023

SANFORD FRIEDENTHAL & ED SEIDEWITZ
CO-LEADS SYSML V2 SUBMISSION TEAM (SST)

Agenda

- Part 1 – S. Friedenthal*
  - Background
  - Comparing SysML v2 with SysML v1
  - Considerations for transitioning from SysML v1 to SysML v2
  - Summary
- Part 2 – E. Seidewitz
  - SysML v2 Submission Team
  - Key language design principles
  - Rational and trade offs for some key language design decisions
  - Conclusion

* **Reference:** Friedenthal S., Seidewitz E., "SysML v2: Highlighting the Differences with SysML v1, Project Performance International (PPI)", *Systems Engineering Newsletter,* PPI SyEN 123, April 2023 https://www.ppi-int.com/systems-engineering-newsjournal/ppi-syen-123/

OMG Standards Development Organization

PART 1
WHERE WE ARE

SANDY FRIEDENTHAL

SysML v2 Examples
Open-Source Pilot Implementation

- Examples of the SysML v2 textual syntax were created using the open-source pilot implementation that was developed as part of the SysML v2 submission development effort
- The graphical views of the SysML v2 model were created using a prototype visualization tool integrated with the pilot implementation, based on an open-source application called Plant UML
  - Note: Some SysML v2 views created in draw.io application
- The quality of the graphical visualization is limited but will be substantially improved when commercial tools become available

OMG Standards Development Organization

BACKGROUND

The Future of Systems Engineering is Model-Based

- Part of the digital transformation
- Full life cycle from SoS to component level
- Agile system development including automated workflow and CM of the digital thread
- Model patterns and reuse

- Facilitates
  - managing complexity & risk
  - more rapidly respond to change
  - reuse and design evolution
  - reasoning about & analyzing systems
  - shared stakeholder understanding
  - automated documentation & reporting

Source: INCOSE SE Vision 2035

Systems Modeling Language™ (SysML®)

Supports the specification, analysis, design, and verification and validation of complex systems that may include hardware, software, information, processes, personnel, and facilities

SysML has evolved to address user and vendor needs
v1.0 adopted in 2006; v1.7 adopted 2022

SysML v1 has facilitated awareness and adoption of MBSE

Much has been learned from using SysML v1 for MBSE

SysML v2 is the next generation systems modeling language intended to address some of the limitations of SysML v1

SysML v2 Status

February 2023	Submitted Alpha Specifications
March 2023	Formed Finalization Task Forces
June 2023	Adopted by OMG Board of Directors Published Beta Specifications
December 1, 2023	Public Comment Deadline
March 2024	Deliver Finalized Specifications Establish Revision Task Forces
Mid 2024	Publish Formal Specifications

COMPARING SYSML V2 WITH SYSML V1

SysML v2 Objectives

Increase adoption and effectiveness of MBSE with SysML 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
- Extensibility to support domain specific applications
- Migration path for SysML v1 users and implementors

Key Elements of SysML v2

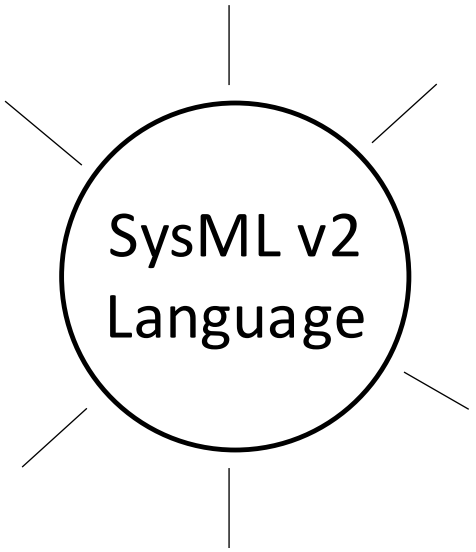
- New Metamodel that is not constrained by UML
  - Preserves most of UML modeling capabilities with a focus on systems modeling
  - Grounded in formal semantics
- Robust visualizations based on flexible view & viewpoint specification
  - Graphical, Tabular, Textual
- Standardized API to access the model

SysML v2 Language Capabilities

Requirements

Behavior
- function-based
- state-based
- sequence-based
- use cases

Structure
- decomposition
- interconnection
- classification



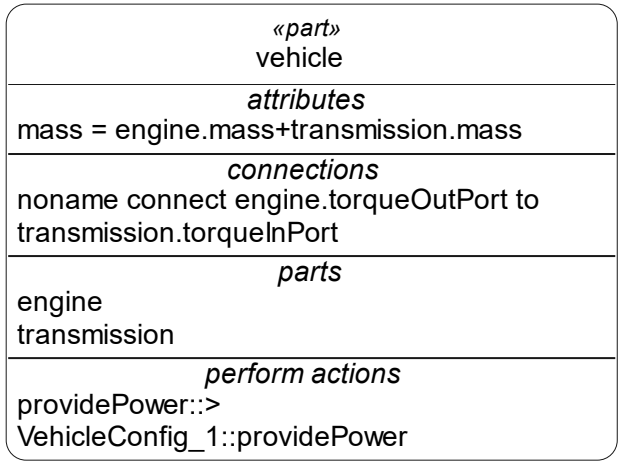
Analysis
- analysis cases
- expression language

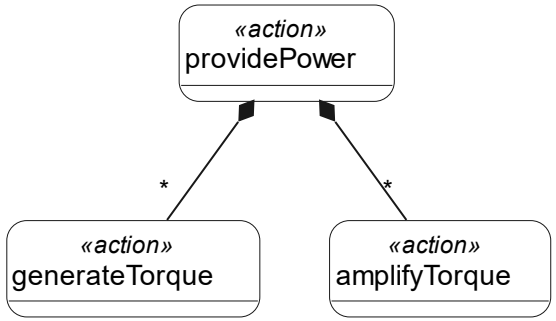
Verification
- verification cases

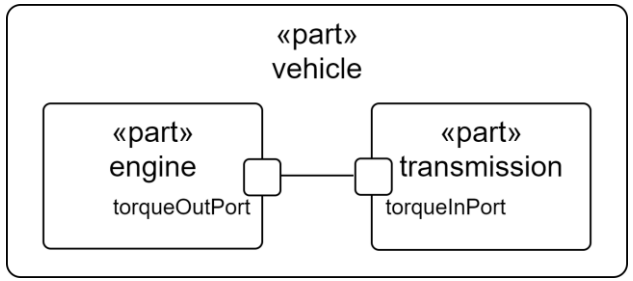
View & Viewpoint

Simple Vehicle Model
SysML v2 Textual and Graphical Syntax

```
part vehicle{
    attribute mass = engine.mass+transmission.mass;
    perform providePower;
    part engine{
        attribute mass;
        port torqueOutPort;
        perform providePower.generateTorque;
    }
    part transmission{
        attribute mass;
        port torqueInPort;
        perform providePower.amplifyTorque;
    }
    connect engine.torqueOutPort to transmission.torqueInPort;
}
action providePower{
    action generateTorque;
    action amplifyTorque;
}
```







OMG Standards Development Organization

Definition and Usage
SysML v2 vs. SysML v1

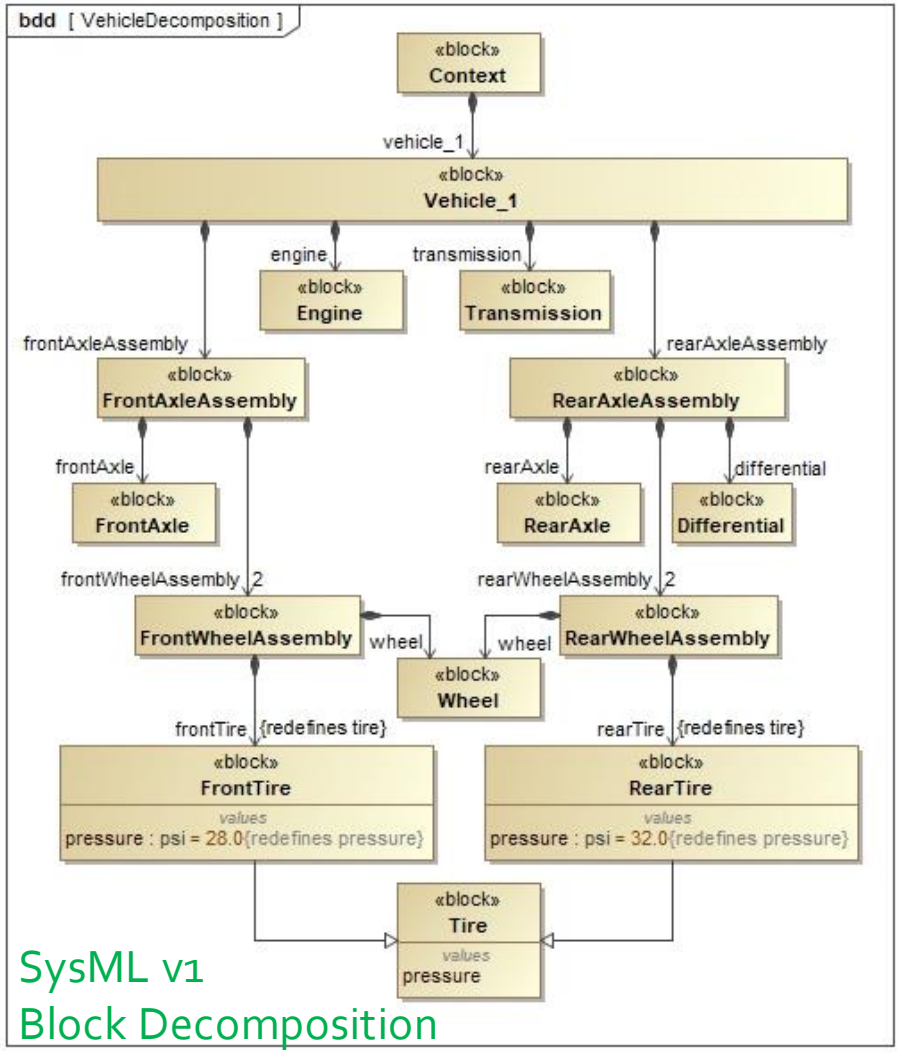
- Reuse concept to define an element once and use it in different contexts
- SysML v1 informally introduces the concept of definition and usage (e.g., block and part property)
  - It is applied inconsistently across the language (e.g., blocks, activities, requirements)
- Definition and usage elements are formally part of SysML v2
  - Applies to virtually all elements (e.g., attributes, parts, ports, connections, actions, states, requirements, constraint, cases, views, ….)
  - Supports consistent pattern of decomposition and specialization
- Benefits
  - Enables effective reuse
  - Facilitates learning and using the language
  - Enables automation

Terminology (partial)
SysML v2 vs. SysML v1

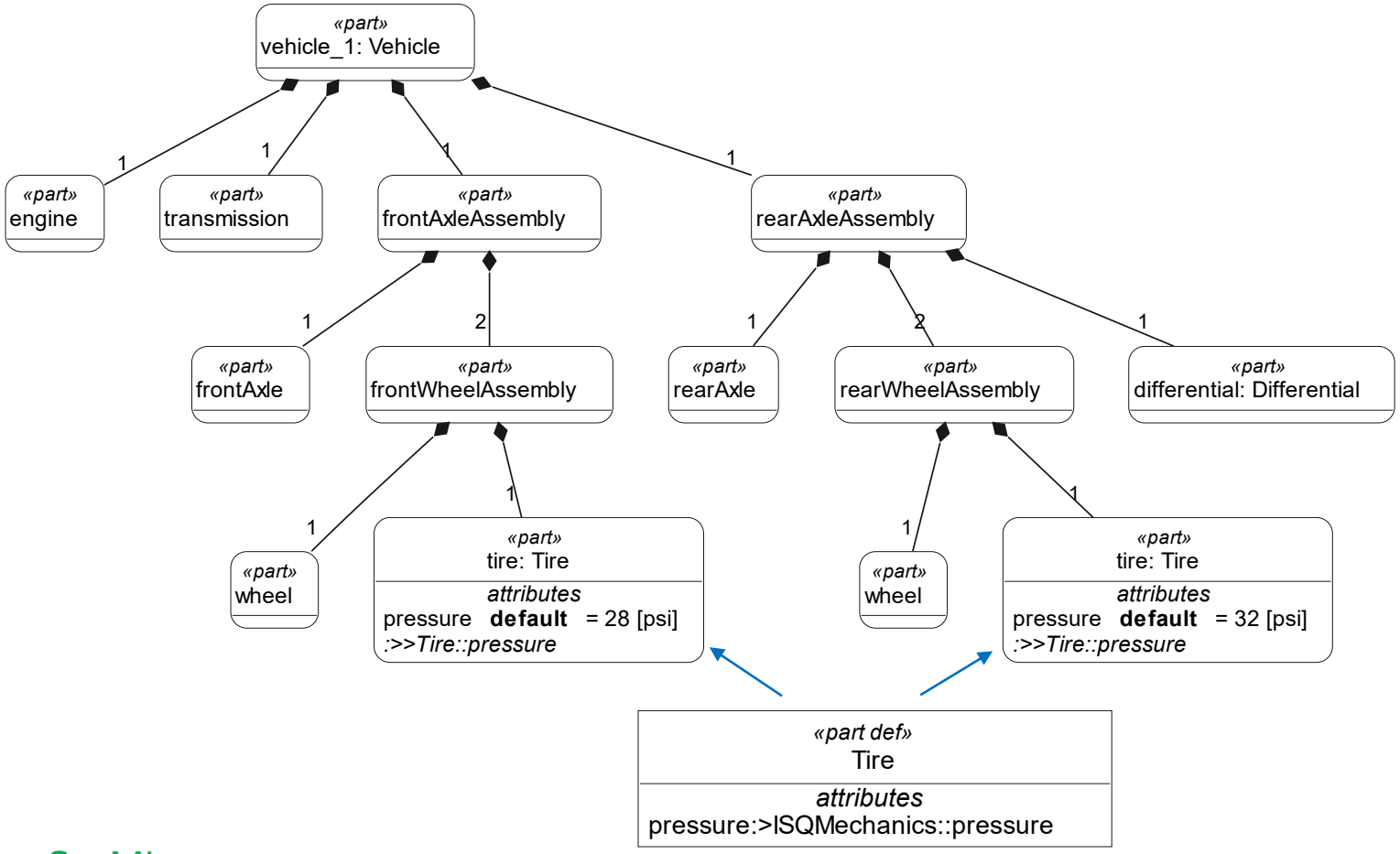
SysML v2	SysML v1
part / part def	part property / block
attribute / attribute def	value property / value type
port / port def	proxy port / interface block
action / action def	action / activity
state / state def	state / state machine
constraint / constraint def	constraint property / constraint block
connection / connection def	connector / association block
requirement / requirement def	requirement
view / view def	view

SysML v2 applies a consistent pattern of definition and usage

SysML v1 and v2
Vehicle Block vs Part Decomposition



SysML v1
Block Decomposition

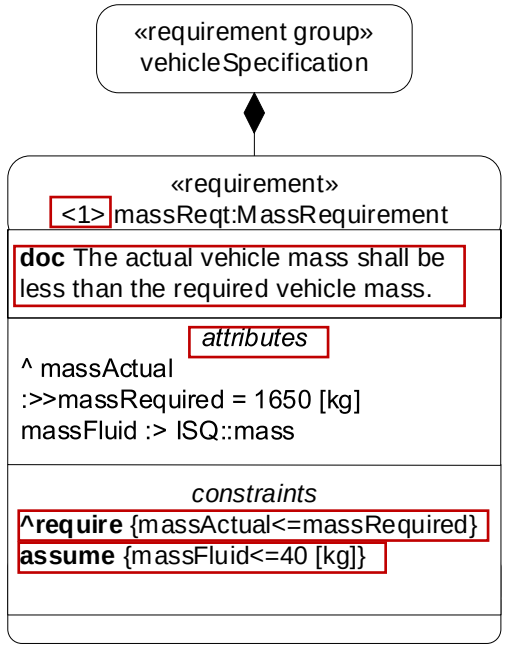


SysML v2
Part Decomposition

OMG Standards Development Organization

SysML v2 Requirement

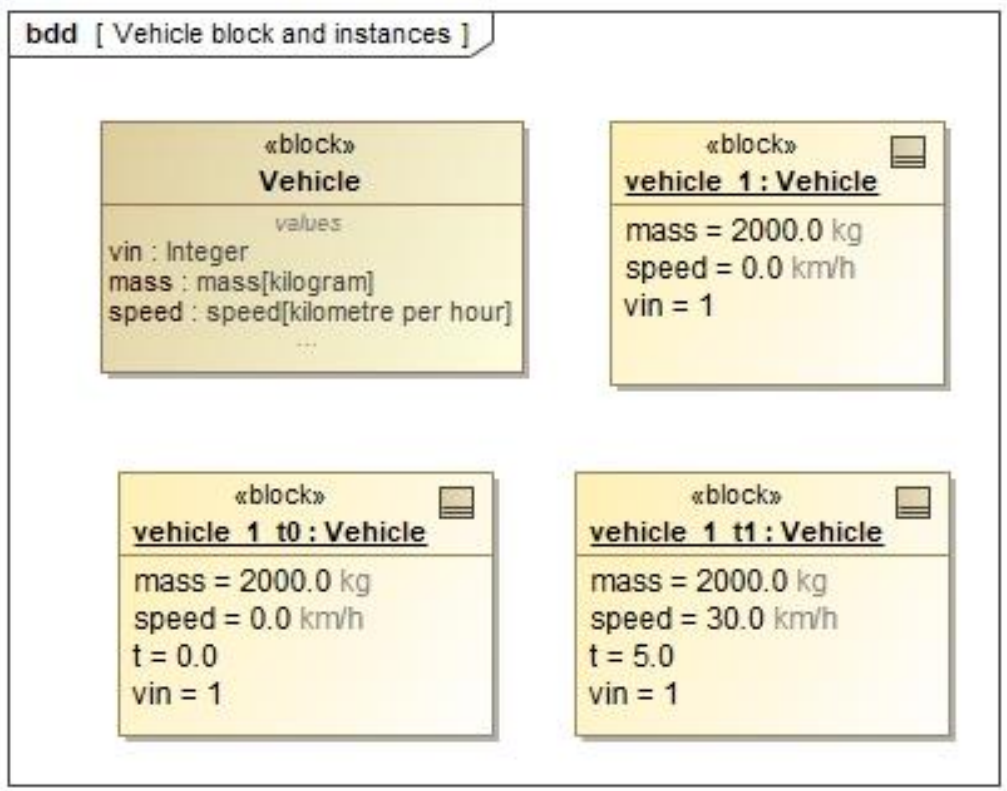
- Builds on SysML v1 concept of a property-based requirement
- A constraint definition that a valid design solution must satisfy that can include:
  - Identifier
  - Shall statement
  - Constraint expression that can be evaluated to true or false
  - Attributes of the constraint expressions
  - Assumed constraint expression must be true for the requirement to be applicable



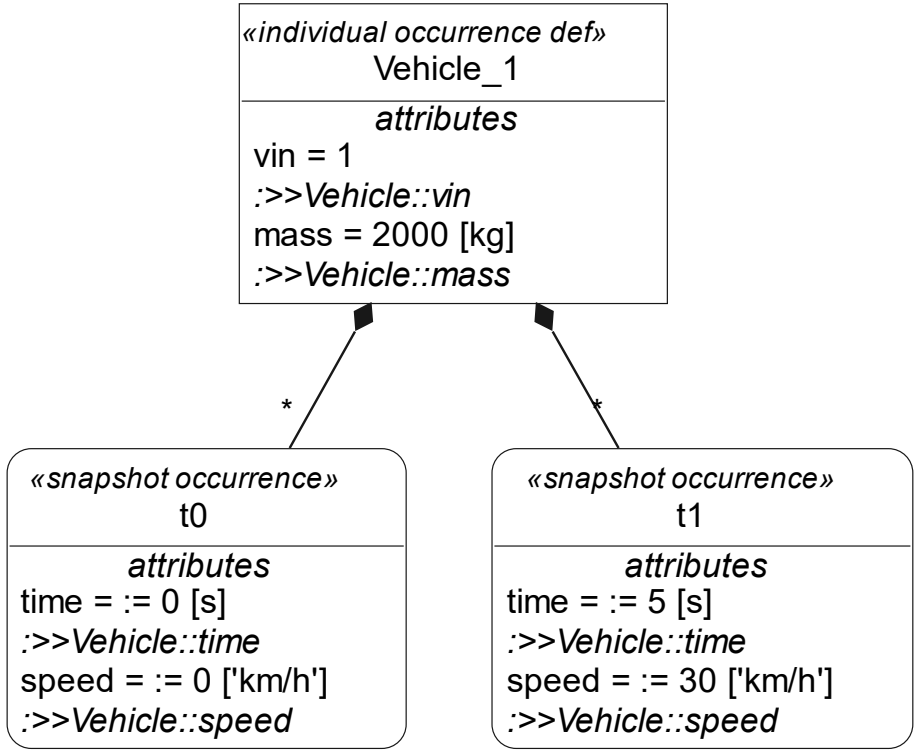
A SysML v2 Requirement Can be Evaluated by a Solver as Pass or Fail

SysML v1 Instances vs. SysML v2 Individuals and Snapshots

SysML v2 distinguishes the concept of an individual from a snapshot of an individual at a point in its lifetime

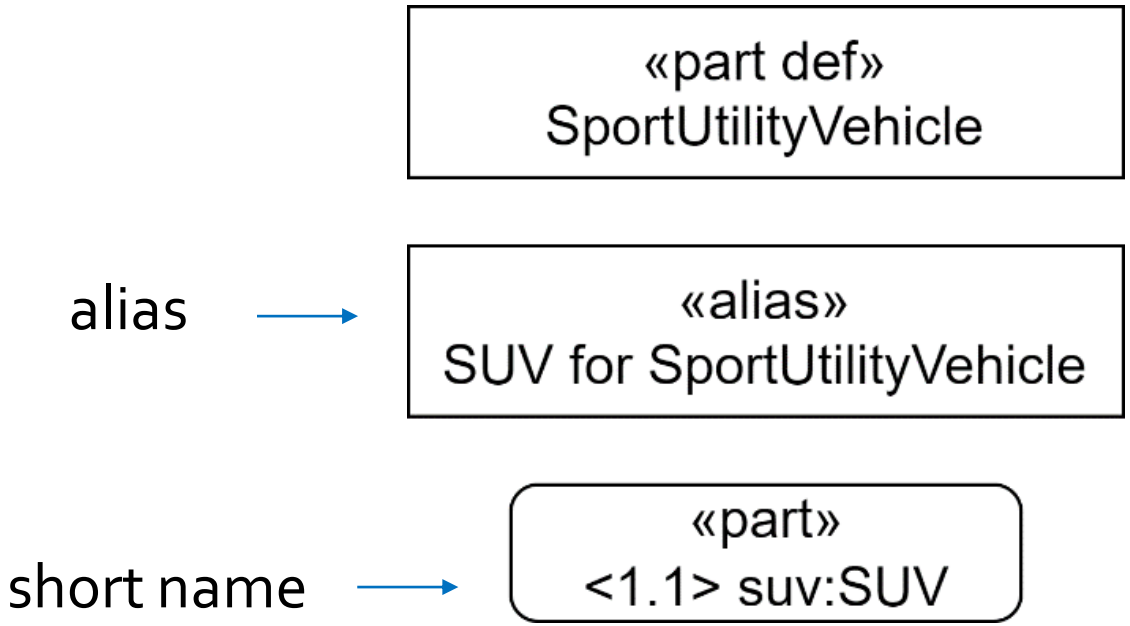


SysML v1



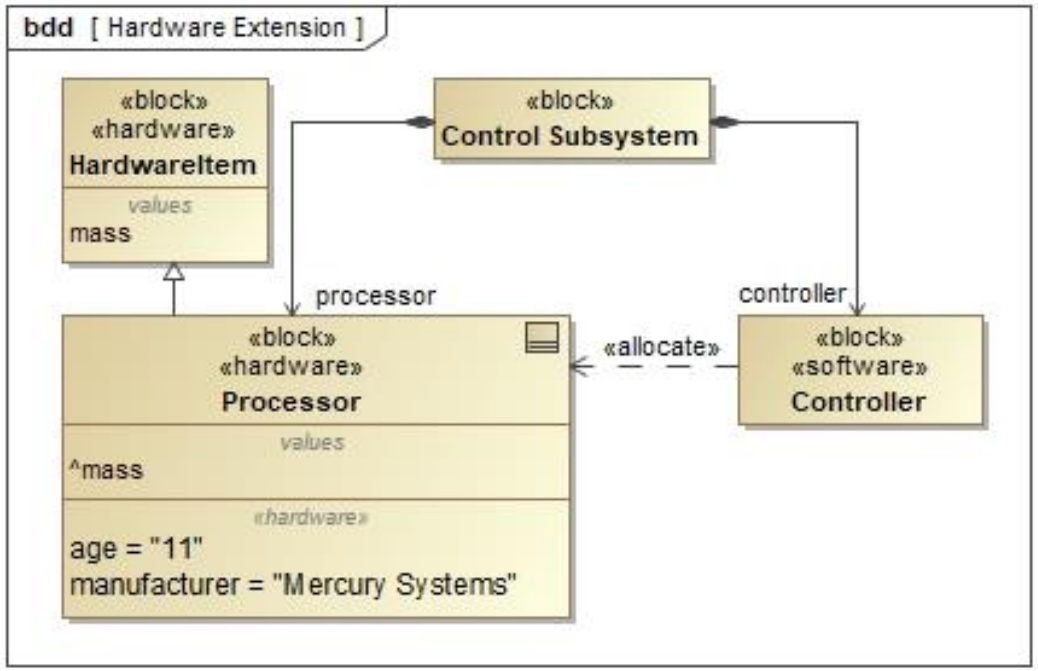
SysML v2

SysML v2 Alias and Short Name

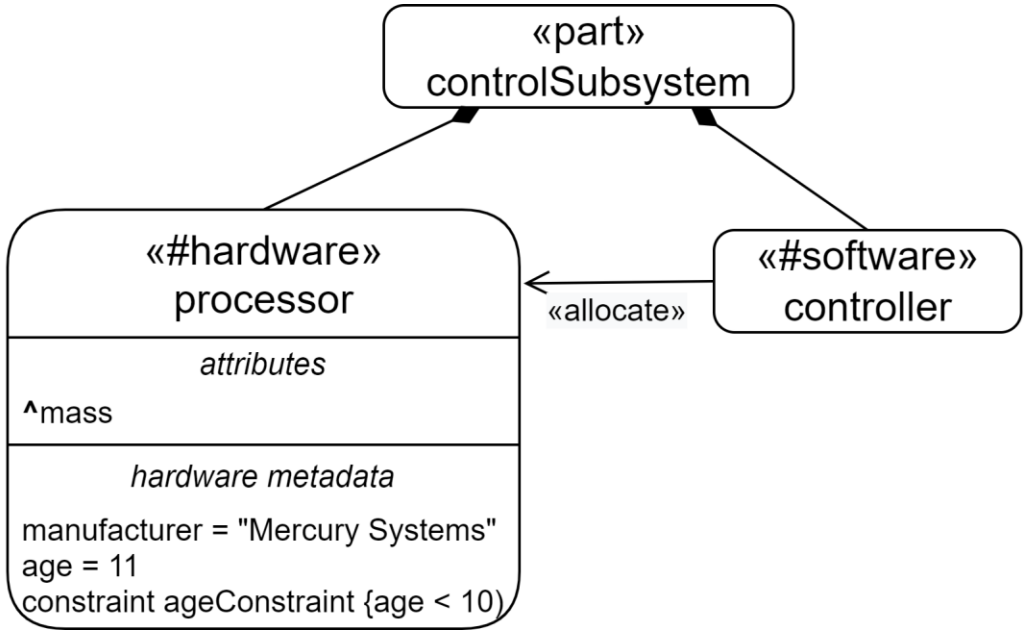


Language Extension
SysML v2 vs SysML v1

Library extension mechanism in SysML v2 can automatically combine the capability of specialization with stereotypes

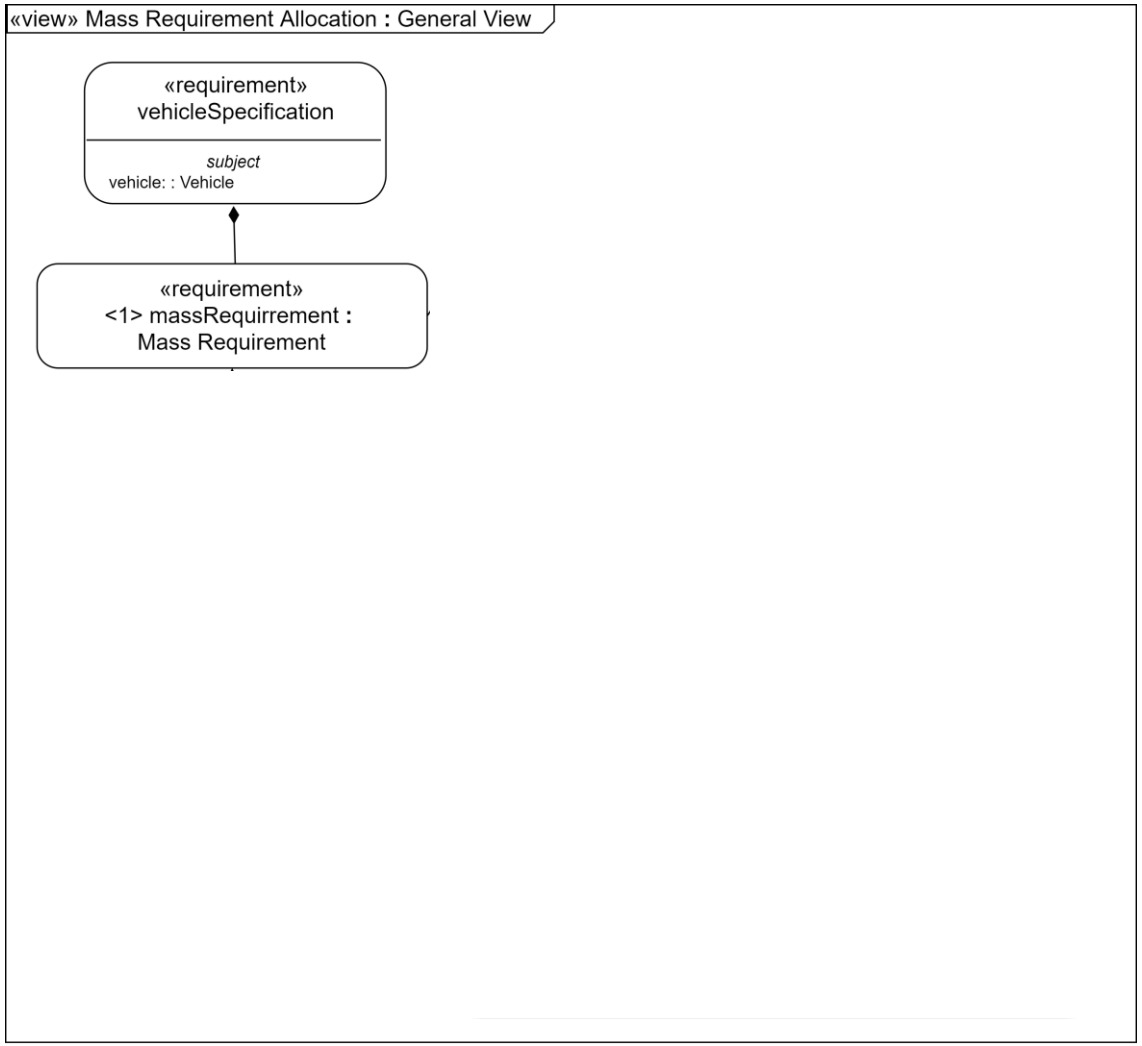


SysML v1

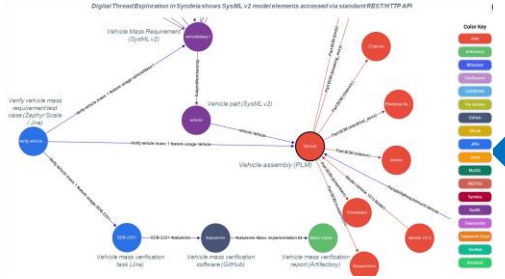


SysML v2

Simple Vehicle Model

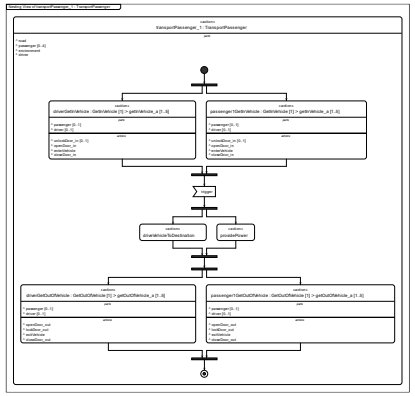


Connecting SysML v2 through the standard API



CM of the Digital Thread

Source: Syndeia with SysML v2



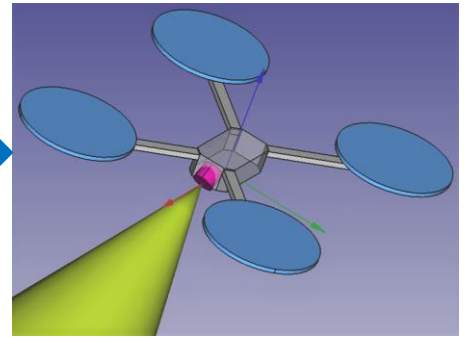
Graph Visualization

Source: Tom Sawyer with SysML v2

Systems Modeling API

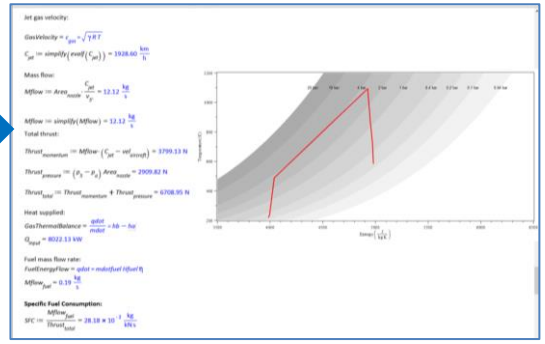
SysML v2

- Structure
- Behavior
- Requirements
- Analysis
- Verification
- View & Viewpoint



CAD/CAD Viewer

Source: FreeCAD with SysML v2



Analysis Solver

Source: Maple with SysML v2

Comparing SysML v2 with SysML v1

- ✓ Simpler to learn and use
  - ➢ Systems engineering concepts designed into metamodel versus added-on
  - ➢ Consistent application of definition and usage pattern
  - ➢ More consistent terminology
  - ➢ Ability to decompose parts, actions,
  - ➢ More flexible model organization with package filters
- ✓ More precise
  - ➢ Textual syntax and expression language
  - ➢ Formal semantic grounding
  - ➢ Requirements as constraints
- ✓ More expressive
  - ➢ Variant modeling
  - ➢ Analysis case
  - ➢ Trade-off analysis
  - ➢ Individuals, snapshots, time slices
  - ➢ More robust quantitative properties (e.g., vectors, ..)
  - ➢ Simple geometry
  - ➢ Query/filter expressions
  - ➢ Metadata
- ✓ More extensible
  - ➢ Simpler language extension capability
    - ▪ Based on model libraries
- ✓ More interoperable
  - ➢ Standardized API

TRANSITIONING TO SYSML V2

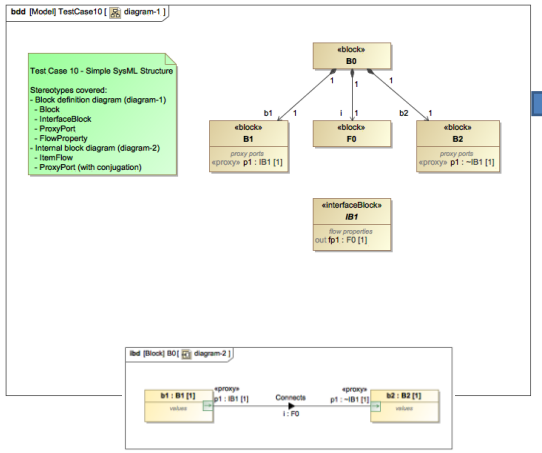
SysML v1 to v2 Transition Planning

- Integrate transition planning with existing MBSE/DE initiatives
  - MBSE improvement teams and community of practices
- Initiate pilots using the Jupyter environment to begin impact assessment
- Initiate tool vendor discussions on roadmap
- Prepare incremental plans
  - MBSE practices
  - Tool infrastructure
  - Training
  - Metrics
  - Reference models and reuse repositories
  - MBSE Community of Practice website
  - Criteria for project deployment

Transition Guidance being developed by DoD office of DE, Modeling & Simulation

SysML v1 to SysML v2 Transformation

SysML v1 Model



SysML v2 XML

SysML v2 Textual Notation

```
package eVehicleLibrary {
  attribute def ElectricEnergy;
  attribute def BatteryCapacity :> ScalarValues::Integer;
  attribute def Speed :> ScalarValues::Integer;
  port def PowerOutPort { out energy : ElectricEnergy;
  }
  interface def PowerInterface {
    end supplierPort : PowerOutPort;
    end consumerPort : ~PowerOutPort;
  }
}
package eVehicleDefinitions {
    import eVehicleLibrary::*;
  part def Wheel {
    value size : ScalarValues::Integer;
  }
  part def Battery {
    value capacity : BatteryCapacity;
  }
  part def Engine;
}
....
```

Source: SST Track 3 Presentation
Yves Bernard, Tim Weilkiens
08 February 2022

SysML v2
Creating a Culture of Model Quality

- Transition to SysML v2 provides an opportunity to improve model quality
  - Bring more rigor to MBSE to ensure model satisfies its intended purpose
  - Applies if transforming a SysML v1 model or developing a new model
- The need for rigor
  - Consistent high quality training material
  - Practitioner and instructor certifications
  - Modeling guidelines, patterns, practices, and metrics
  - Validation suites and correct by construction
  - Review processes
  - Validated reference models
  - …

SUMMARY

Summary

- SysML v1 is based on UML which was originally designed as a software modeling language
- SysML v2 was designed to address the SysML v1limitations and improve MBSE adoption and effectiveness
  - New metamodel with both graphical and textual syntax and standardized API to access the model
  - More precise, expressive, usable, interoperable, and extensible
  - Consistent definition and usage pattern enables reuse, usability, and automation
- Progress/Plans
  - Awaiting OMG approval for SysML v2 beta specifications leading to final adopted specification in 2024
  - Will continue to evolve specification with domain specific extensions
- Organizations should begin SysML v2 transition planning to advance their MBSE capabilities
  - Treat as an opportunity to improve model quality

PART 2
HOW WE GOT HERE

ED SEIDEWITZ

Second-System Effect

"The tendency of small, elegant, and successful systems to be succeeded by over-engineered, bloated systems, due to inflated expectations and overconfidence."

https://en.wikipedia.org/wiki/Second-system_effect

http://catb.org/jargon/html/S/second-system-effect.html

Fred Brooks, *The Mythical Man-Month,* Chapter 5

SYSML V2 SUBMISSION TEAM

SysML v2 Submission Team (SST)

SysML v2 Requests for Proposals

Language : December 2017

API and Services : June 2018

SST formed December 2017

Leads: Sandy Friedenthal, Ed Seidewitz

A broad team of end users, vendors, academics, and government liaisons

Grew to 200+ members from 80+ organizations

Developed submissions to both RFPs

Final submission: February 2023

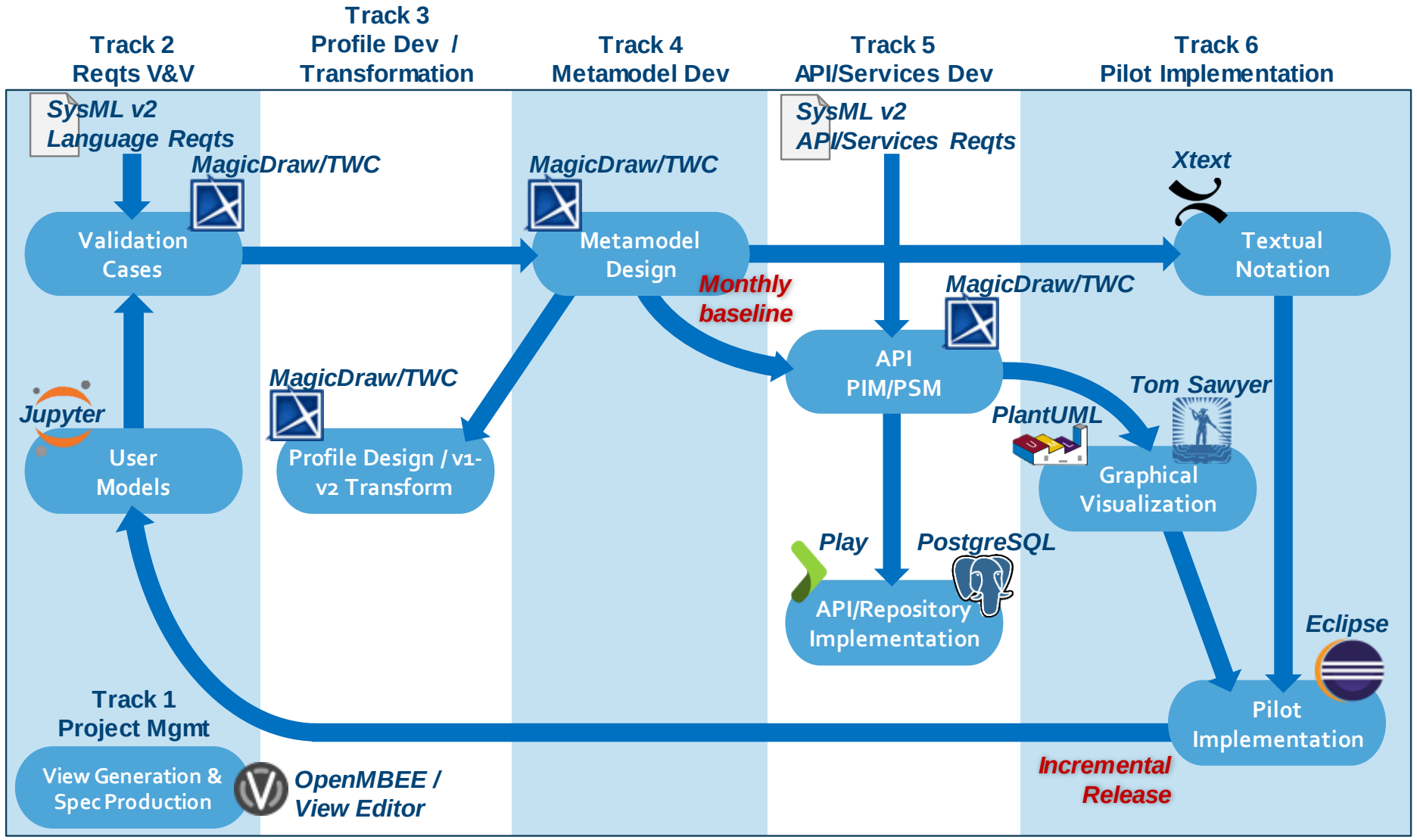
SST Participating Organizations

- Aerospace Corp
- Airbus
- ANSYS medini
- Aras
- Army Aviation & Missile Center
- Army CBRND
- BAE
- BigLever Software
- Boeing
- U.S. Army DEVCOM Armaments Center
- CalTech CTME
- CEA
- Contact Software
- Defence Science and Technology Group
- DEKonsult
- Delligatti Associates
- Draper Lab
- ESTACA
- Ford
- Fraunhofer FOKUS
- General Motors
- George Mason University
- GfSE
- Georgia Tech/GTRI
- IBM
- Idaho National Laboratory
- IncQuery Labs
- Intercax
- Itemis
- Jet Propulsion Lab
- John Deere
- Kenntnis
- KTH Royal Institute of Technology
- LieberLieber
- Lightstreet Consulting
- Lincoln Lab
- Lockheed Martin
- MathWorks
- Maplesoft
- Mercury Systems
- Mgnite Inc
- MID
- MITRE
- ModelAlchemy Consulting
- Model Driven Solutions
- Model Foundry
- NIST
- No Magic/Dassault Systemes
- OAR
- Obeo
- OOSE
- Ostfold University College
- Phoenix Integration/ANSYS
- PTC
- Qualtech Systems, Inc (QSI)
- Raytheon
- Rolls Royce
- Saab Aeronautics
- SAF Consulting *
- SAIC
- Siemens
- Sierra Nevada Corporation
- Simula
- Space Cooperative
- Sodius Willert
- System Strategy *
- Tata Consultancy Services
- Thales
- Thematix
- Tom Sawyer
- Twingineer
- UFRPE
- University of Western Switzerland (Rosas Center)
- University of Cantabria
- University of Alabama in Huntsville
- University of Detroit Mercy
- University of Kaiserslautern / VPE
- Vera C. Rubin Observatory
- Vitech
- 88solutions

Academia/Research
Tool Vendor
Government Rep
End User
INCOSE rep *

OMG Standards Development Organization.

SST Incremental Approach



OMG Standards Development Organization

SST Milestones

December 2017	SysML v2 RFP issued; SST formed
June 2018	SysML v2 API & Services RFP issued
August 2019	**Internal Review**
August 2020	Initial Submission
February 2021	**Stakeholder Review**
August 2021	1st Revised Submission
November 2021	2nd Revised Submission
September 2022	**Specification Review (2½ days)**
November 2022	3rd Revised Submission
December 2022	**Established Change Board**
February 2023	Final Submission

OMG Standards Development Organization

KEY DESIGN PRINCIPLES

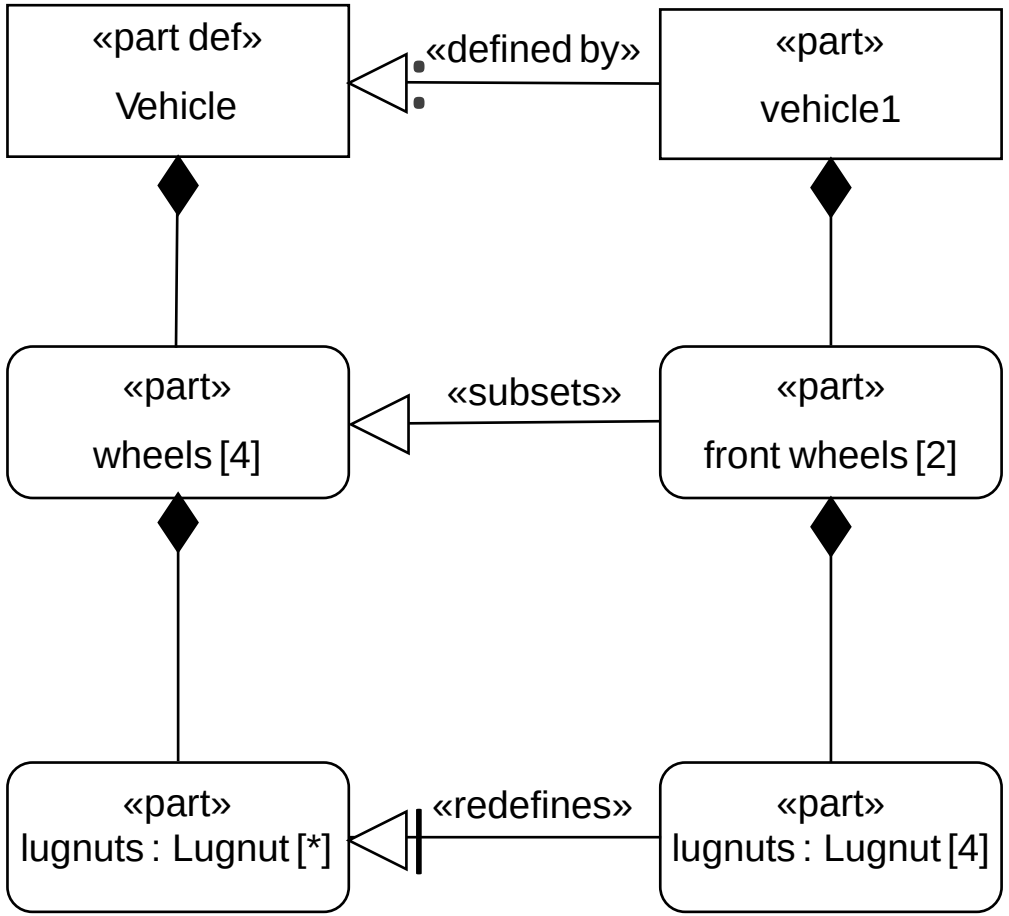
Consistency

For example, consistent pattern of definition and usage

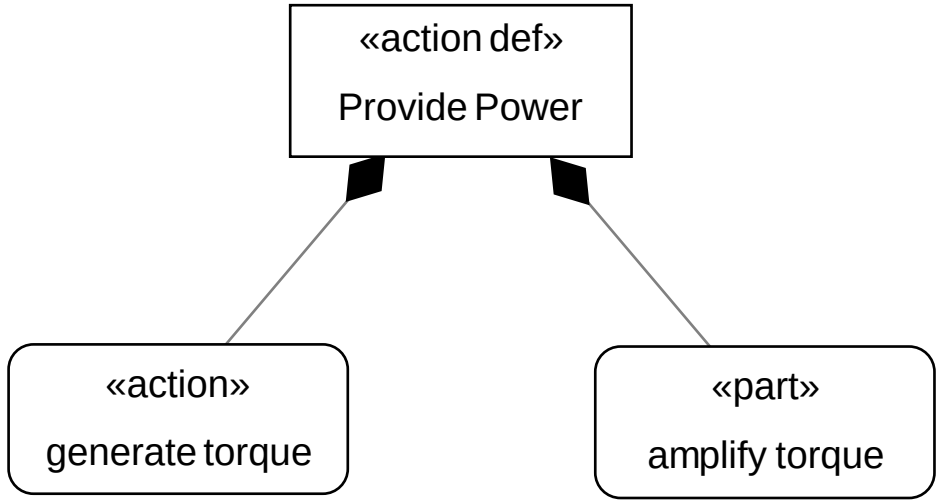
SysML v2	SysML v1
part / part def	part property / block
attribute / attribute def	value property / value type
port / port def	proxy port / interface block
action / action def	action / activity
state / state def	state / state machine
constraint / constraint def	constraint property / constraint block
connection / connection def	connector / association block
requirement / requirement def	requirement
view / view def	view

Unification of Concepts

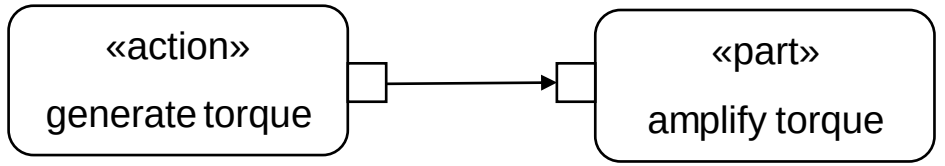
Feature typing (definition), subsetting and redefinition are all kinds of specialization.



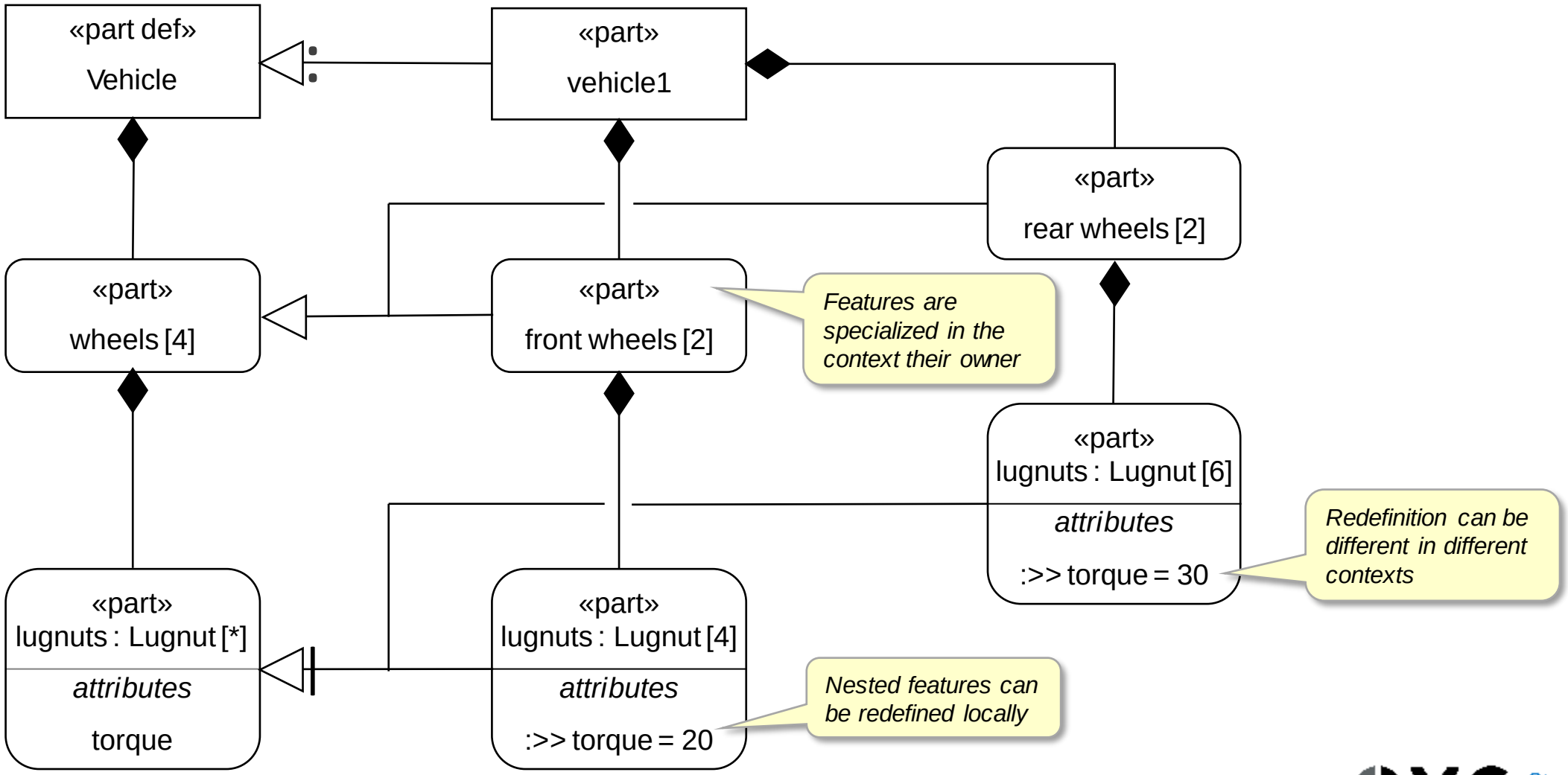
Actions and subactions are related by feature membership, just like parts and subparts.



Object flows are the same as information flows.



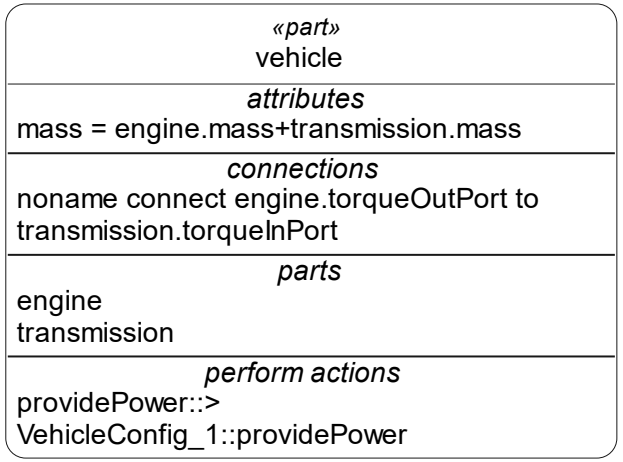
Specialization in Context

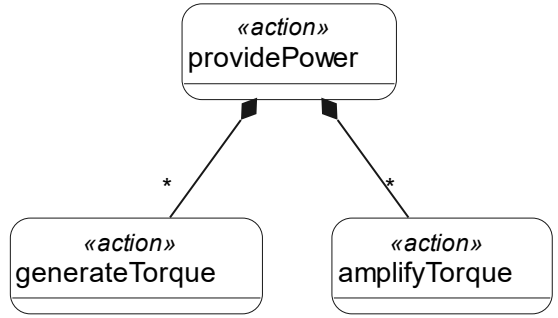


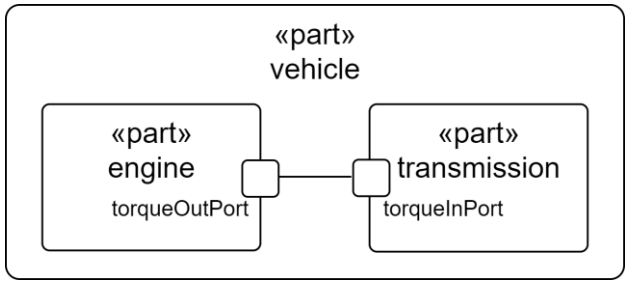
Textual and Graphical Notation

- *There are corresponding textual and graphical notations for each language construct.*
- *There is a comprehensive expression language.*
- *Textual notations can be used consistently on graphical diagrams.*

```
part vehicle{
    attribute mass = engine.mass+transmission.mass;
    perform providePower;
    part engine{
        attribute mass;
        port torqueOutPort;
        perform providePower.generateTorque;
    }
    part transmission{
        attribute mass;
        port torqueInPort;
        perform providePower.amplifyTorque;
    }
    connect engine.torqueOutPort to transmission.torqueInPort;
}
action providePower{
    action generateTorque;
    action amplifyTorque;
}
```





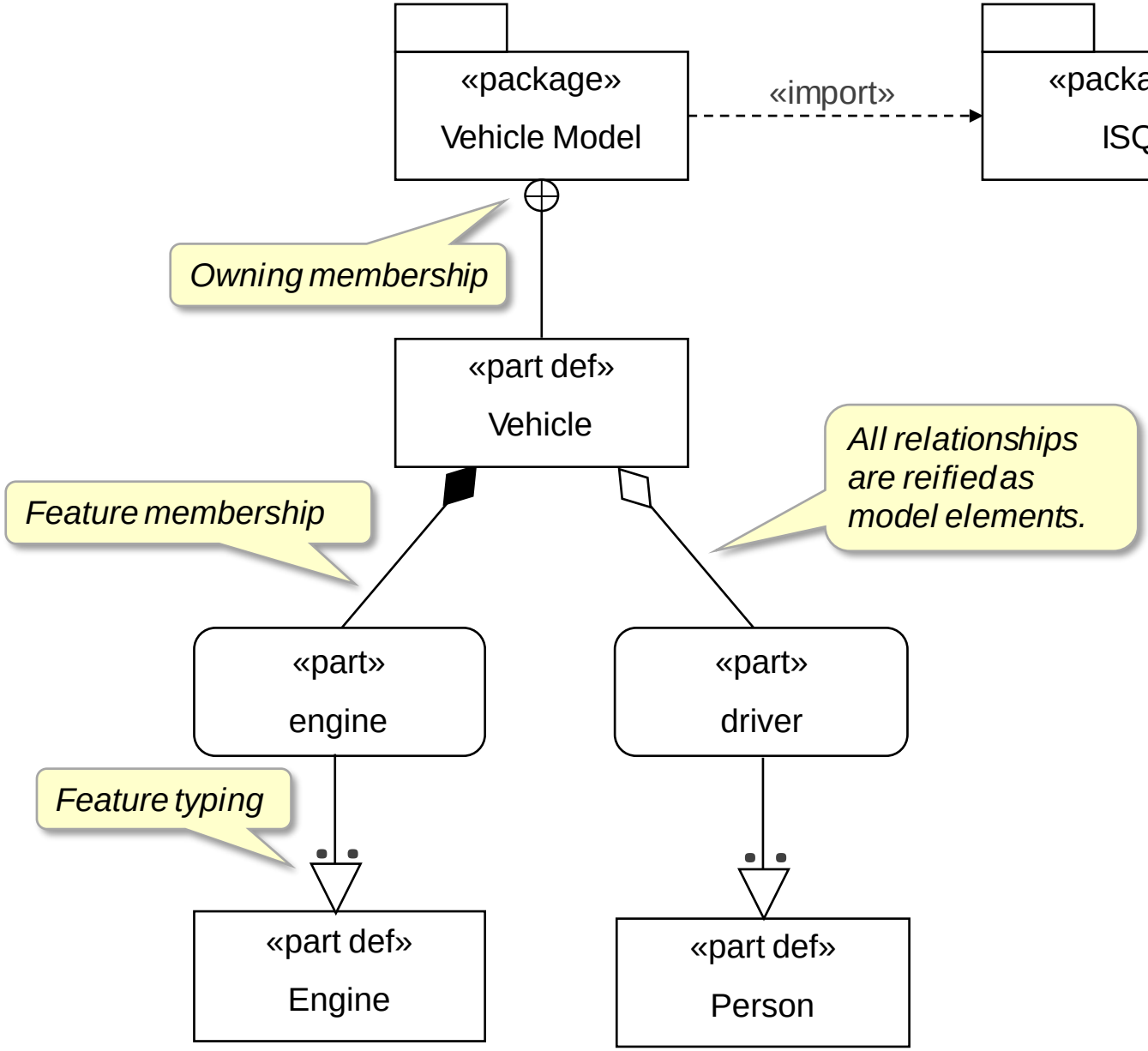


OMG Standards Development Organization

OMG Standards Development Organization

DESIGN DECISIONS: RATIONALE AND TRADE OFFS

Reified Relationships



Rationale

Allows consistent graph-oriented navigation across a model

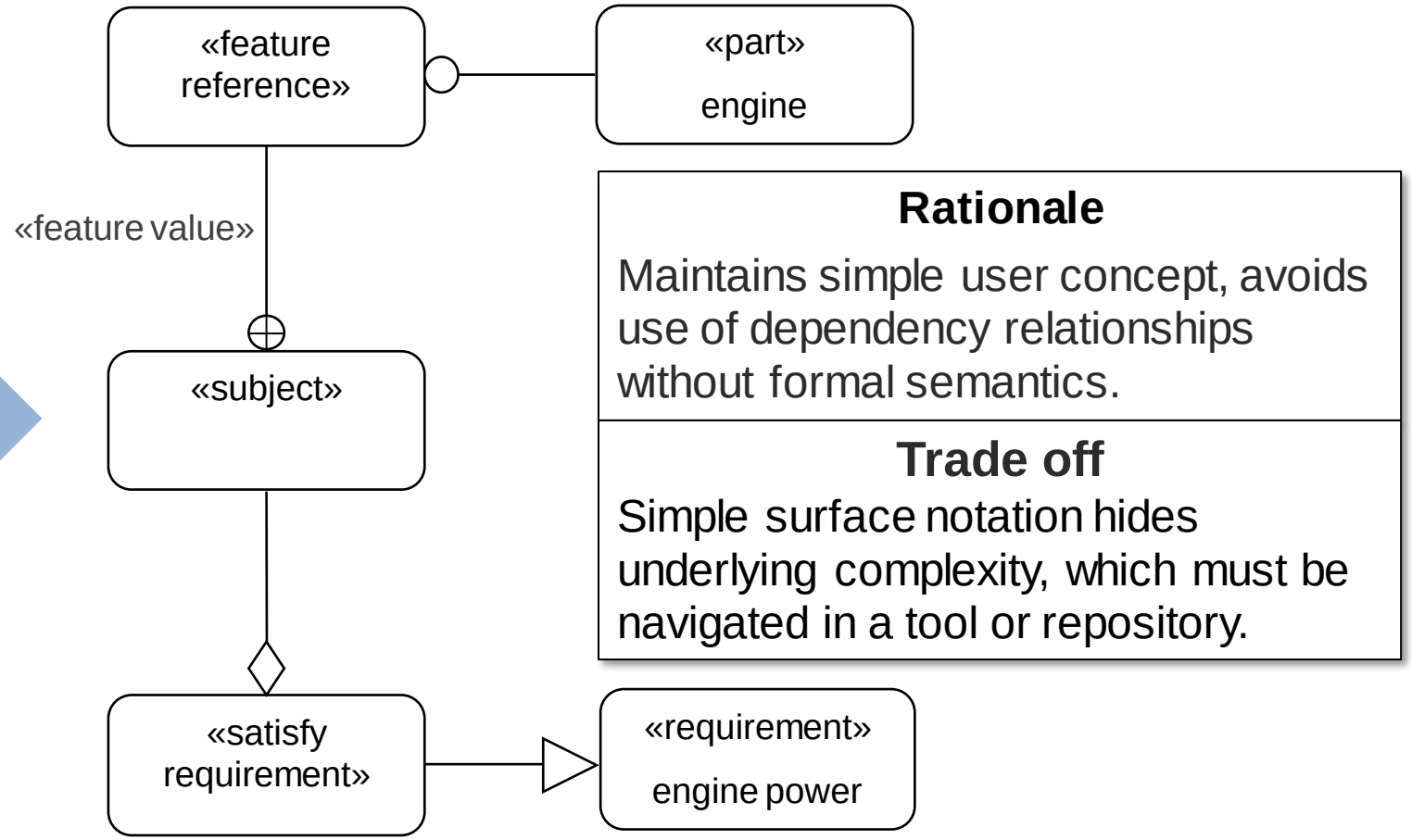
Trade off

Essentially doubles the number of model elements needed to represent a model

Compact Notation

User Conception

Actual Meaning



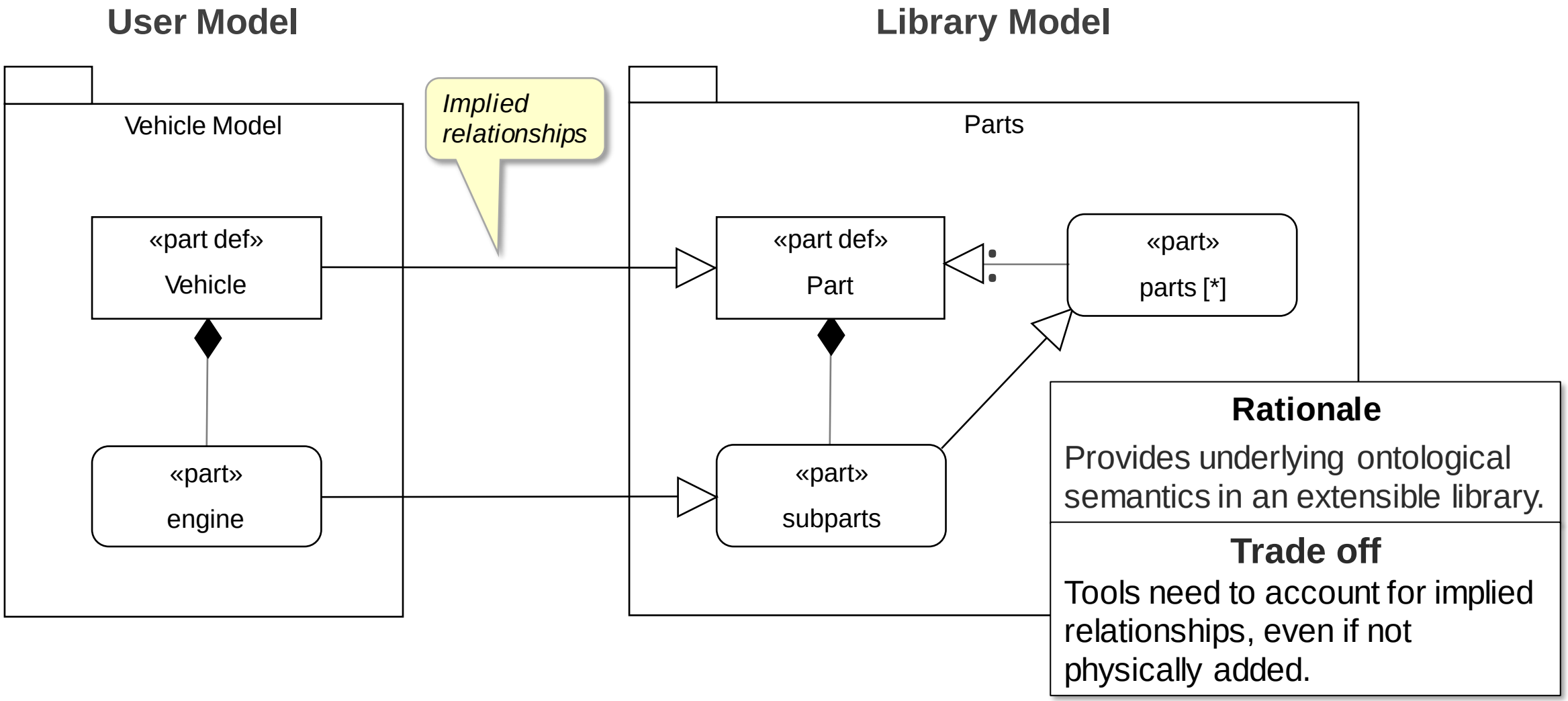
Rationale

Maintains simple user concept, avoids use of dependency relationships without formal semantics.

Trade off

Simple surface notation hides underlying complexity, which must be navigated in a tool or repository.

Semantic Library Models



OMG Standards Development Organization

CONCLUSION

Conclusion

- The SST ran for over 5 years, with no significant conflict, losing no participating organizations
- Pilot implementation was released (almost) every month from November 2018 to February 2023.
- Submitted specifications met their objectives and about 90% of the RFP requirements.
- There is already a SysML v2 user community, and there is great interest in moving to SysML v2 in the wider MBSE community.

But There are Trade-Offs

- SysML v2 is not just a simple evolution from SysML v1
  - New foundation not based on UML
  - Reified and implied relationships
  - Textual in addition to graphical notation
- SysML v2 is bigger than SysML v1
  - New functionality
  - Extensive model libraries
- SysML v2 is not easy to implement

Nevertheless…Many Implementations in Progress!

Dassault/3DS
Cameo

IBM
Rhapsody

PTC
Windchill Modeler

Sparx
Enterprise Architect

Intercax
Syndeia

Siemens

Ansys

SST Public Repositories
Current Release: 2023-02

- Monthly release repository
  - https://github.com/Systems-Modeling/SysML-v2-Release
- Release content
  - Specification documents (for KerML, SysML and API)
  - Training material for SysML textual notation
  - Training material for SysML graphical notation
  - Example models (in textual notation)
  - Pilot implementation
    - Installer for Jupyter tooling
    - Installation site for Eclipse plug-in
  - Web access to prototype repository via SysML v2 API
  - Web access to Tom Sawyer visualization tooling
- Open-source repositories
  - https://github.com/Systems-Modeling
- Google group for comments and questions
  - https://groups.google.com/g/SysML-v2-Release
    (to request membership, provide name, affiliation and interest)

THANK YOU!