



SST

Introduction to the SysML v2 Language Graphical Notation

(2021-11-06)

This presentation of the SysML v2 language uses the proposed graphical modeling notation that complements the textual syntax. The graphical notation is being formally specified in the SysML v2 specification. It is still in process, and there are potential errors and inconsistencies since the notation is generated manually with Visio.

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Updates since 2021-09-18

- 9-21-21: Slide 83 – changed include on use case
- 9-23-21: Slide 69 - refer to default
- 9-23-21: Slide 70 – changed body to result
- 9-23-21: Slide 77 – changed body to expression
- 9-23-21: Slide 99 – updated view (PartUsage) and viewpoint (stakeholder)
- 9-30-21: Slides 99-102 – updated view/viewpoint based on discussion at joint track lead session on 9/30
- 11-02-21 Slides 81-82 – replace square brackets with angle bracket on req't id
- 11-02-21 New Slide 18 – element import notation
- 11-06-21 Slide 19 – updated alias notation
- 11-02-21 Slide 37 – added binding connection
- 11-02-21 Slide 39 – updated interfaces compartment
- 11-02-21 Slide 50 – updated input/output flows
- 11-02-21 Slide 51 – updated parallel notation
- 11-03-21 Slide 70 – changed '=>' to '='
- 11-04-21 Slides 49-50 – change parameter notation – change from flow to binding on delegations
- 11-04-21 Slides 57-59 – remove slash from entry, do, and exit actions
- 11-06-21: Slide 19 – added reference to filter criteria for package import

- | | |
|-----------------------------|--|
| 1. Packages & Element Names | 13. Expressions & Calculations |
| 2. Definition Elements | 14. Quantities & Units |
| 3. Usage Elements | 15. Constraints |
| 4. Part Decomposition | 16. Requirements |
| 5. Part Interconnection | 17. Use Cases |
| 6. Variability | 18. Analysis Cases |
| 7. Actions | 19. Verification Cases |
| 8. Action Flow | 20. Dependency & Allocation Relationships |
| 9. States | 21. Annotations |
| 10. Interactions | 22. Element Filters |
| 11. Individuals | 23. View & Viewpoint |
| 12. Timeslices & Snapshots | 24. Language Extension (not implemented yet) |

General Caveats

- The graphical representation is intended to complement the textual notation
 - The textual notation has been formally specified
 - The graphical notation is being formally specified using graphical BNF
 - The graphical visualization in this presentation is captured in Visio, but will need to be rendered in a more precise way to reflect the specification in the future
 - Two visualization prototypes are under development (Tom Sawyer and PlantUML)
- SysML v2 Marker
 - Some of the more significant SysML v2 changes in functionality and terminology relative to SysML v1 are designated with the SysML v2 marker **v2**

Overview



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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
- 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 and execution
 - Graphical, Tabular, Textual
- Standardized API to access the model

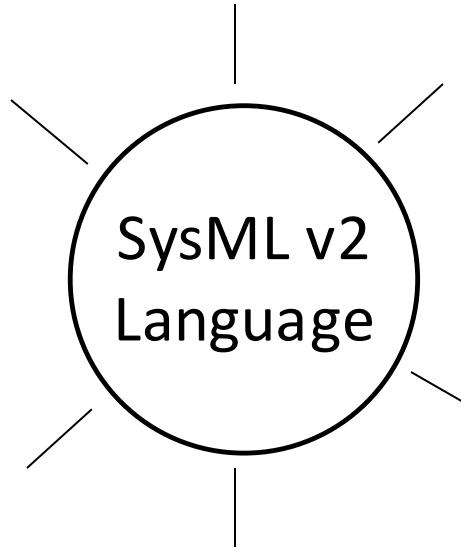
Behavior

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

Structure

- decomposition
- interconnection
- classification

Requirements



Analysis

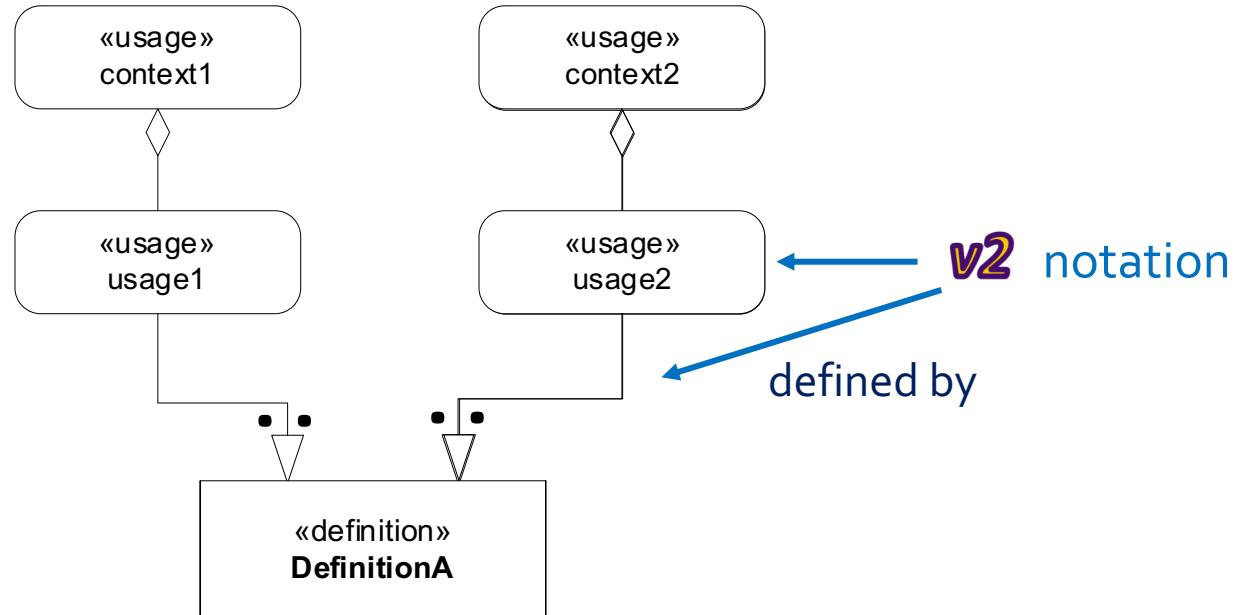
- analysis cases
- expression language

Verification

- verification cases

Definition and Usage Reuse Pattern

- A definition element defines an element such as a part, action, or requirement
- A usage element is a usage of a definition element in a particular context
 - There can be different usages of the same definition element in either different contexts or the same context
- Pattern is applied consistently throughout the language v2



SysML v2 to v1

Terminology Mapping (partial)

- SysML v2 includes consistent usage/definition terminology

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
requirement / requirement def	requirement
connection / connection def	connector / association block

SysML v2 Notation (1 of 2)

Textual and Graphical

```
package 'Vehicle Parts Tree' {
```

v2

```
    part vehicle {
```

```
        attribute mass;
```

```
        perform providePower;
```

```
    part engine {
```

```
        attribute mass;
```

```
        perform generateTorque;
```

```
        part cylinders [6];
```

```
}
```

```
    part transmission {
```

```
        attribute mass;
```

```
        perform amplifyTorque;
```

```
}
```

```
}
```

```
package 'Vehicle Action Tree'{
```

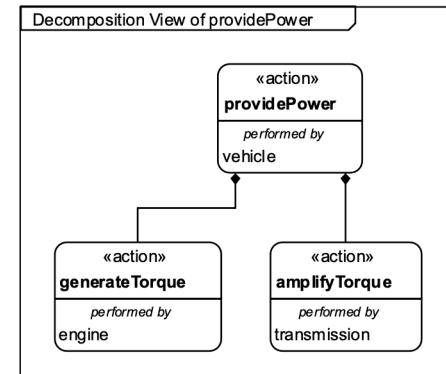
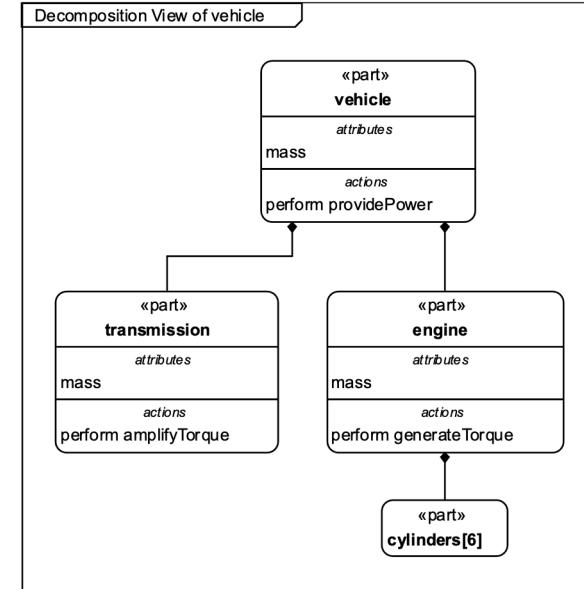
```
    action providePower {
```

```
        action generateTorque;
```

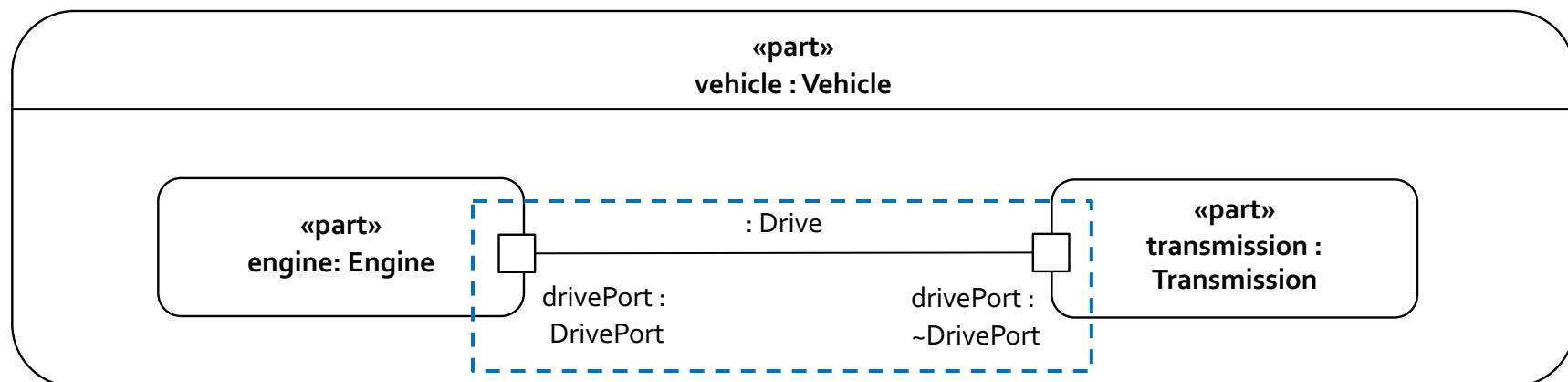
```
        action amplifyTorque;
```

```
}
```

```
}
```



```
interface def Drive {  
    end enginePort : DrivePort;  
    end transmissionPort : ~DrivePort;  
}  
  
part vehicle : Vehicle {  
    part engine : Engine { port drivePort : DrivePort; }  
    part transmission : Transmission { port drivePort : ~DrivePort; }  
    interface : Drive  
        connect engine.drivePort to transmission.drivePort;  
}
```



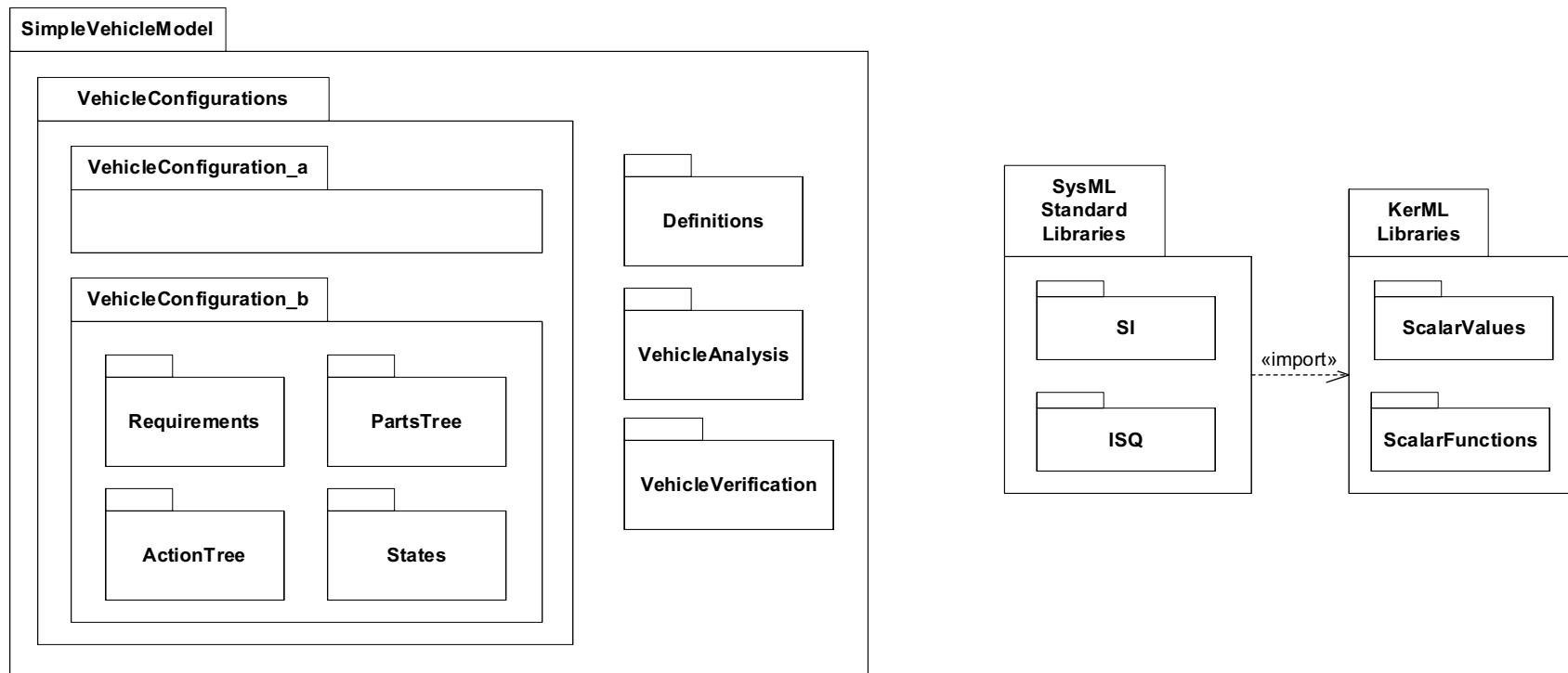
Tom Sawyer Visualization Prototype

Module 1

Packages & Element Names

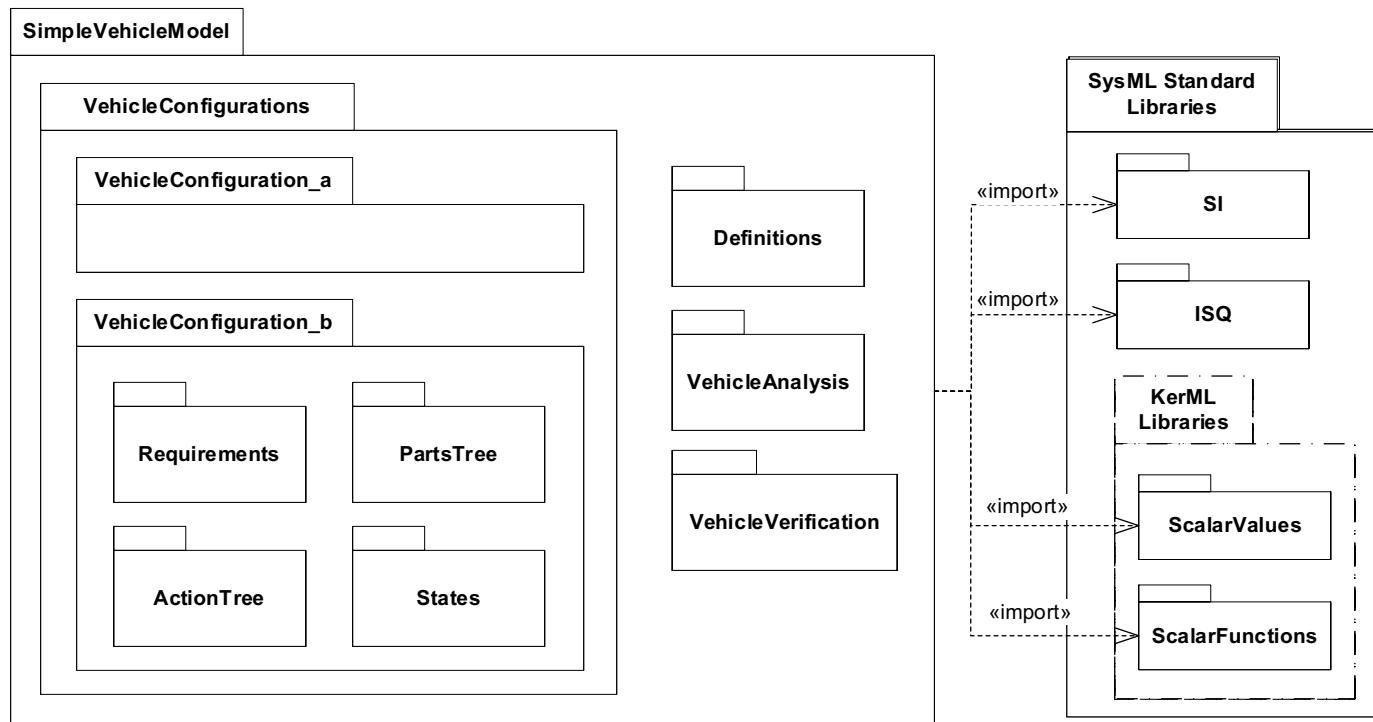
Model Organization [1 of 3]

- A hierarchy of packages, where packages can contain other packages and elements
- Packages are namespaces that contain member elements that may be owned or unowned
- A package can import members of another package as unowned members, where deletion semantics do not apply, and they can be referred to by their local name



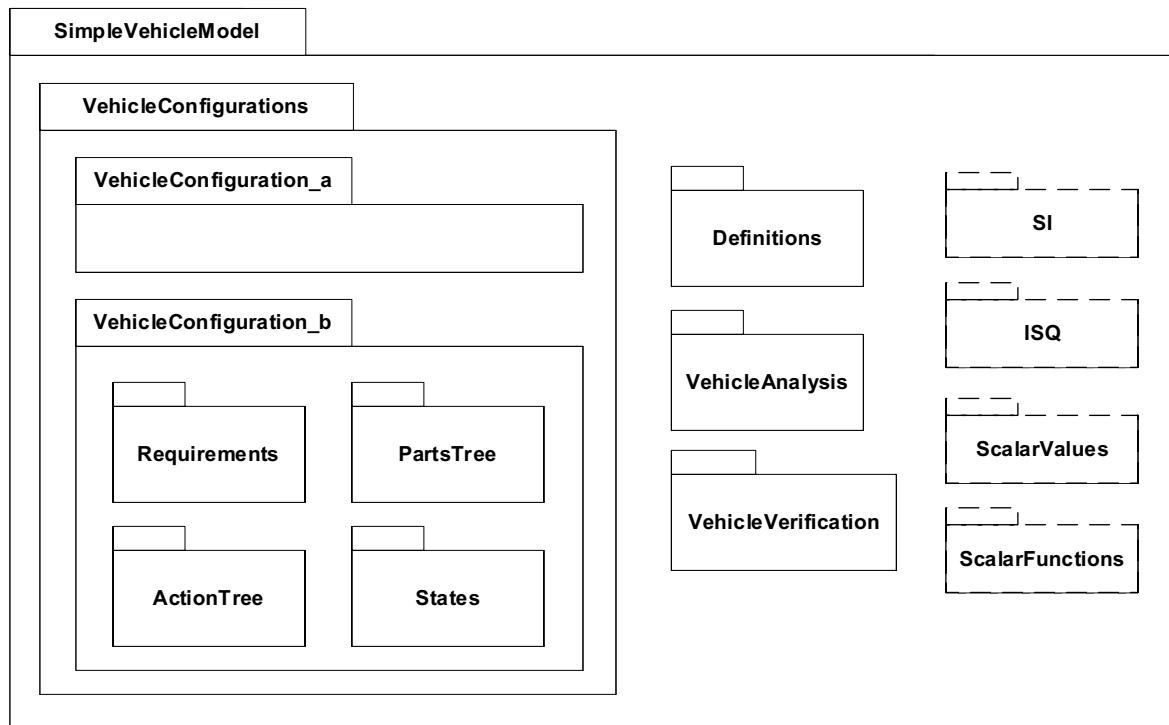
Model Organization [2 of 3]

- A hierarchy of packages, where packages can contain other packages and elements
- Packages are namespaces that contain member elements that may be owned or unowned
- A package can import members of another package as unowned members, where deletion semantics do not apply, and they can be referred to by their unqualified name
 - Nested import notation enables flexible organization **v2**



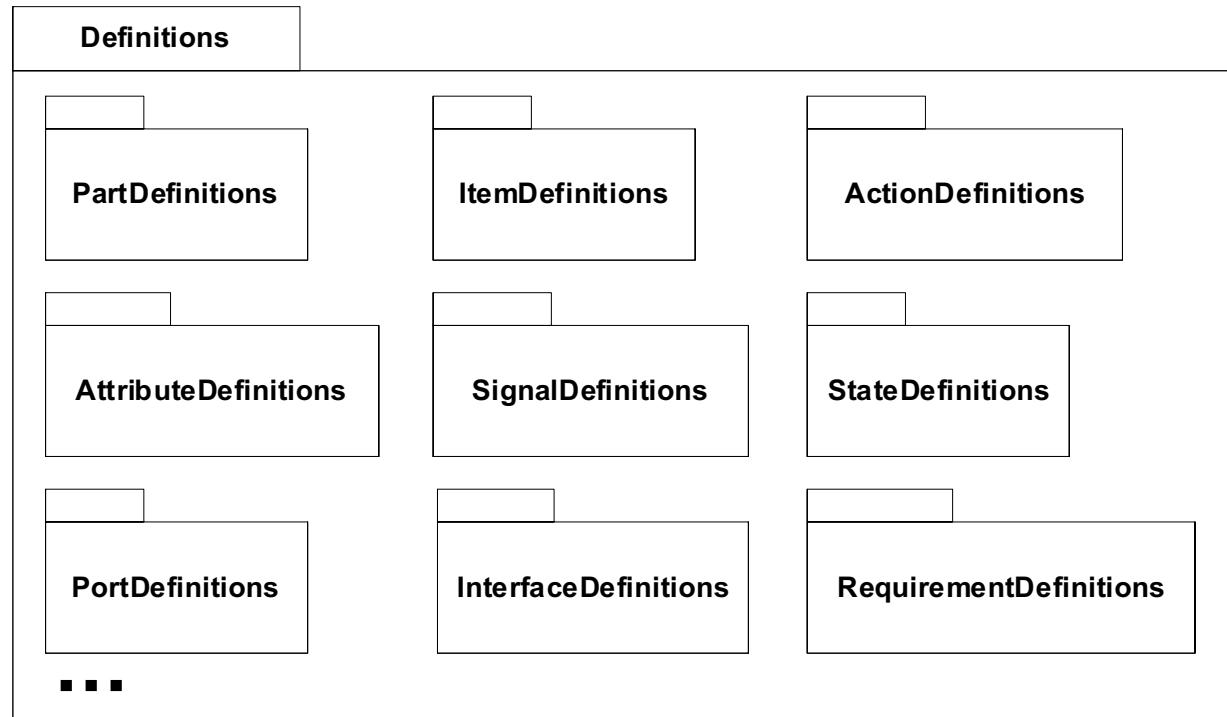
Model Organization [3 of 3]

- A hierarchy of packages, where packages can contain other packages and elements
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 - Nested import notation enables flexible organization **v2**



Definitions Package

- Example: Definitions package contains packages to define different kinds of elements
 - Ellipsis indicates there is more content



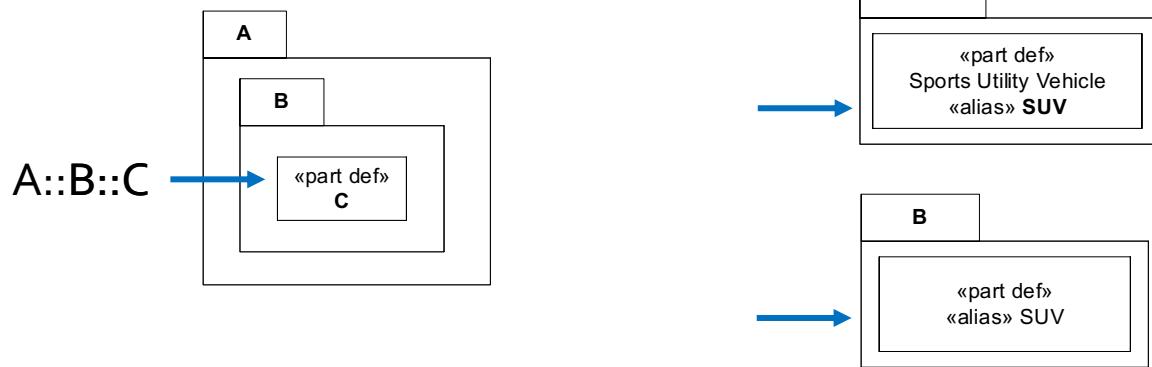
Import Notation

- no star is element import
 - single star is package import (content of package)
 - double star is recursive including outer package
-
- Imports can apply to any namespace, but packages are most commonly used
 - A package import can include filter criteria to select elements based on their metadata



Element Names

- A qualified name of a model element is prepended by the name of its owner followed by a double colon (::)
- A fully qualified name is prepended by the concatenated names of its owners in its containment hierarchy separated by double colons (::)
- An element can have one or more aliases **v2**
- Each element includes a UUID and optionally other id's, such as a URI and a **v2** human-readable id
 - UUID: universally unique identifier
 - URI: Uniform Resource Identifier



Module 2

Definition Elements

Part Definition

- A Part Definition can contain features such as attributes, ports, actions, and states
 - A modular unit of structure

<p>«part def»</p> <p>Vehicle</p>
<p><i>attributes</i></p> <p>mass:>ISQ::mass</p> <p>dryMass</p> <p>cargoMass</p> <p>electricalPower</p> <p>position</p> <p>velocity</p> <p>acceleration</p> <p>...</p>
<p><i>ports</i></p> <p>pwrCmdPort</p> <p>vehicleToRoadPort</p> <p>...</p>
<p><i>perform actions</i></p> <p>providePower</p> <p>provideBraking</p> <p>controlDirection</p> <p>...</p>
<p><i>exhibit states</i></p> <p>vehicleStates</p>



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Other Kinds of Definition Elements

Terminology v2

- Each kind of definition element can contain specific kinds of features
 - Attribute definition
 - Data type that defines a set of data values
 - Primitive attribute definitions include integer, Real, Complex, Boolean, String,
 - Can include quantity kinds such as Torque with units
 - Can include complex data types such as vectors
 - Port definition
 - Defines a connection point on parts that enable interactions
 - Contain kinds of features including directed features with in, out, and in/out
 - Ports can be conjugated (i.e., reverse direction of directed features)
 - Item definition **v2**
 - Defines kind of entity that may be acted on, such as a flow, or a stored item
 - Action definition
 - Defines kind of behavior that transforms inputs and outputs
 - State definition
 - Defines kind of behavior that responds to events
 - Enables entry, exit, and do actions

«attribute def»
Real

«attribute def»
Torque

«port def»
FuelCmdPort

directed features
in item fuelCmd:FuelCmd

attributes
x:Real

«item def»
FuelCmd

«item def»
Fuel

attributes
fuelMass:>ISQ::mass

«action def»
ProvidePower

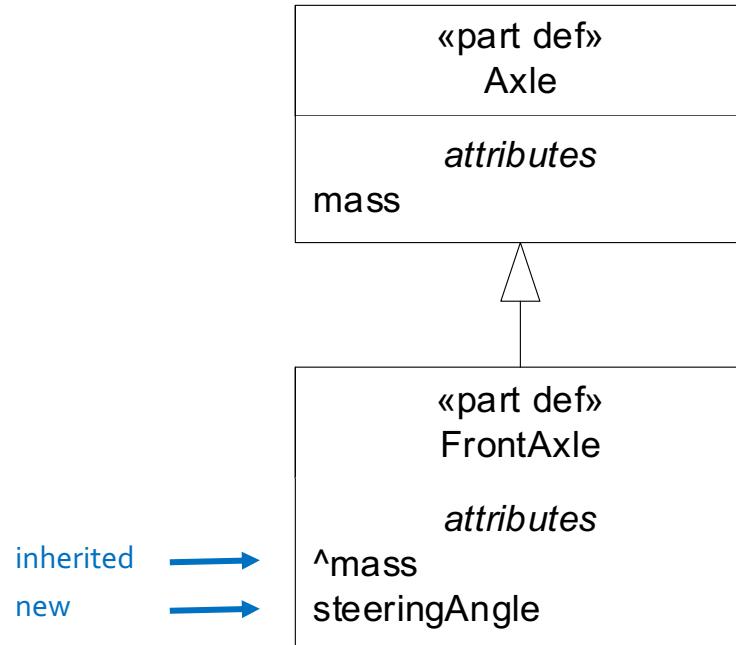
parameters
in pwrCmd:PwrCmd
out torqueToWheels:Torque [*]

«state def»
VehicleStates

actions
do providePower

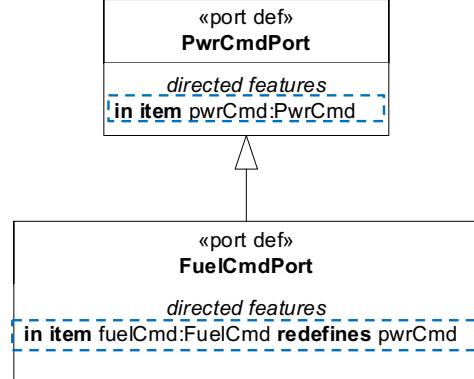
Specialization

- Definition elements can be specialized
 - Subclass inherits features of superclass and can add new features
 - Can be subclassed by more than one superclass (i.e., multiple inheritance)

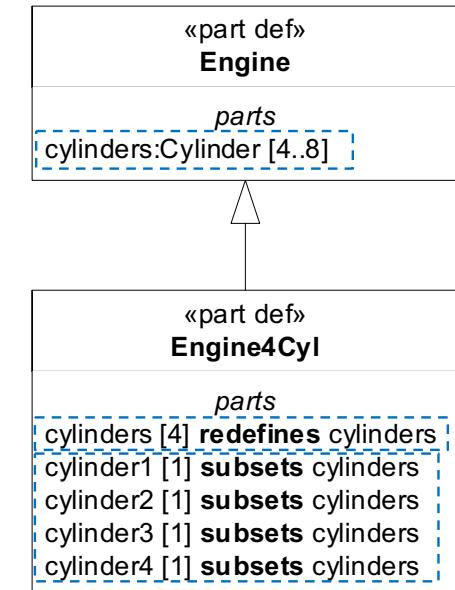


Redefinition and Subsetting

- An inherited feature can be **redefined** by a feature whose definition is more specialized
 - The more specialized feature overrides the inherited feature
 - Symbol for redefines (:>>) v2



- An inherited feature can be **subsetted** by one or more features with a more constrained multiplicity
 - The Engine4Cyl contains a subset of the cylinders contained by Engine
 - First redefine multiplicity to 4
 - Then identify the subsetting features
 - Symbol for subsets (:>) v2

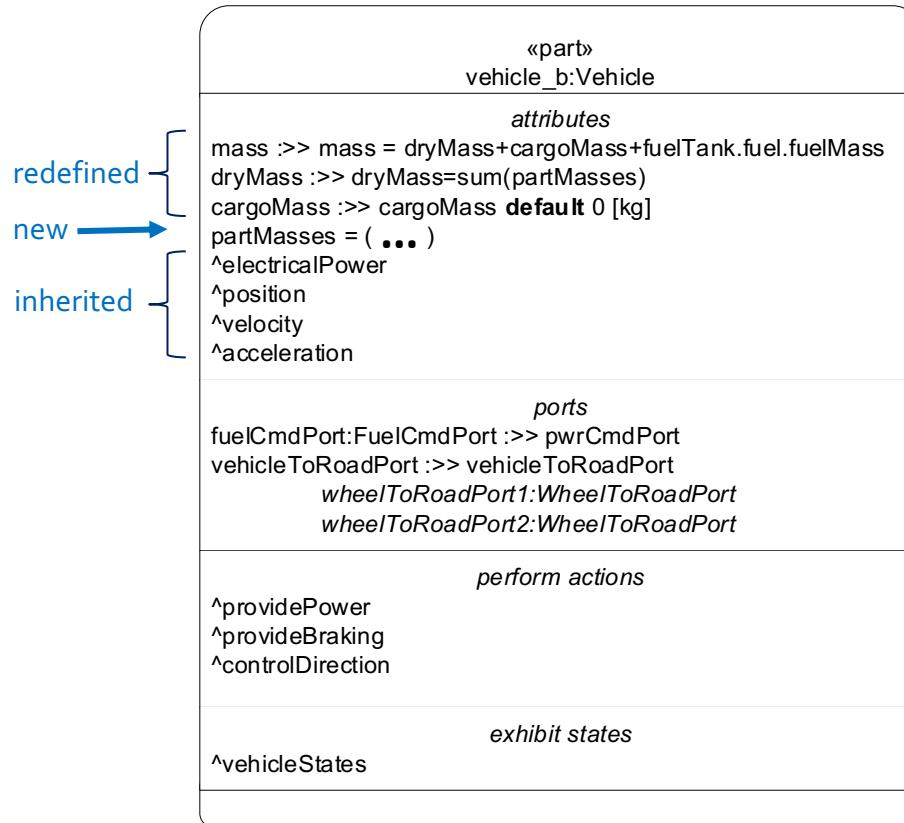


Module 3

Usage Elements

Part

- A part is a usage of a part definition
- Part inherits its features from its definition **v2**
- Inherited features can be redefined or subsetted, and new features can be added



Other Usage Elements

Terminology v2

- Other kinds of usage elements are defined by specific kinds of definition elements
 - Attributes defined by attribute definition
 - Ports defined by port definition
 - Items defined by item definition v2
 - Actions defined by action definition
 - States defined by state definition

Enumeration

- A data type whose range is restricted to a set of discrete values

- Without units

- Definition: **enum def Colors {red; blue; green;}**
 - Usage: **attribute color1: Colors = blue;**

«enum def»	Colors
	enums
	red
	blue
	green

- With units:

- Definition: **enum def DiameterChoices > ISQ::LengthValue {**

- enum = 60 [mm];**

- enum = 70 [mm];**

- enum = 80 [mm];**

- }**

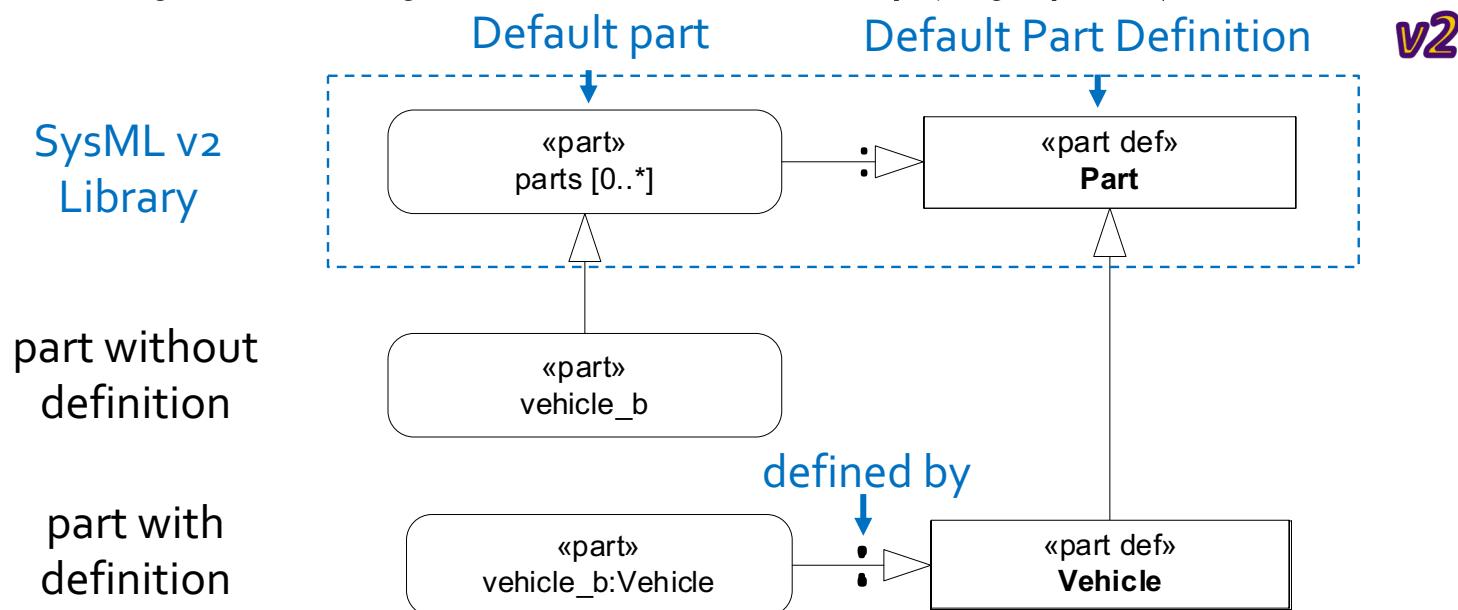
- Usage: **attribute cylinderDiameter: DiameterChoices = 80 [mm];**

«enum def»	DiameterChoices
	enums
	=60 [mm]
	=70 [mm]
	=80 [mm]

v2

Usage Elements Defined By Default Definition Elements

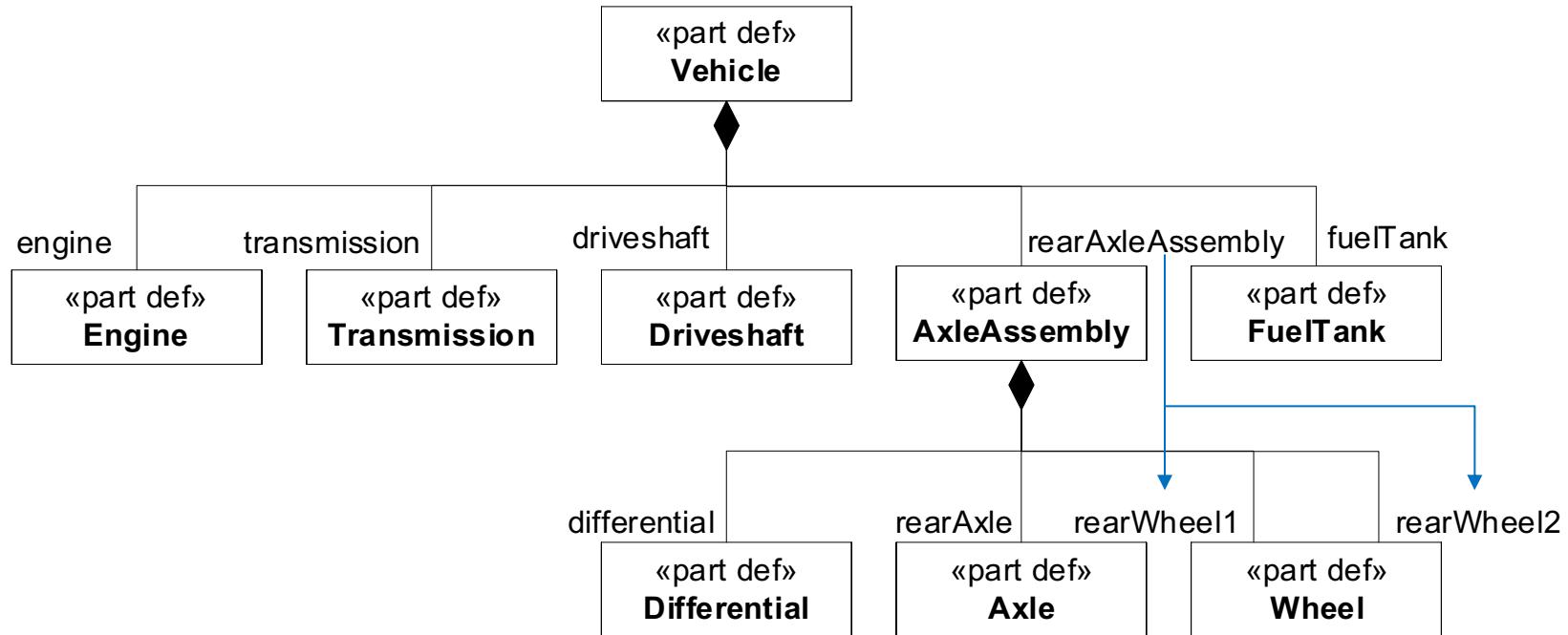
- A definition element is a subclass of the most general definition element in the SysML v2 library (e.g., Part) **v2**
- A usage element is defined by a definition element
 - *defined by* is a kind of specialization
- A usage element that is not provided a definition by the modeler is a subset of the most general usage element in the library (e.g., parts)



Module 4

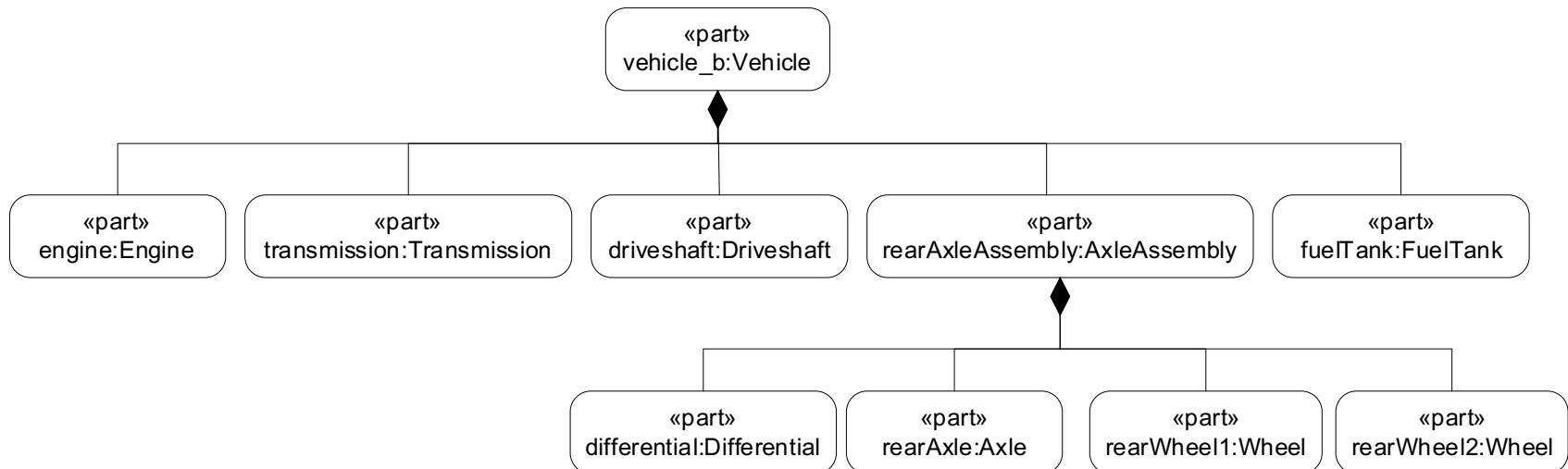
Part Decomposition

- Can create the equivalent of SysML v1 block decomposition using part definitions
 - No part to part relationships in SysML v1



Parts Decomposition

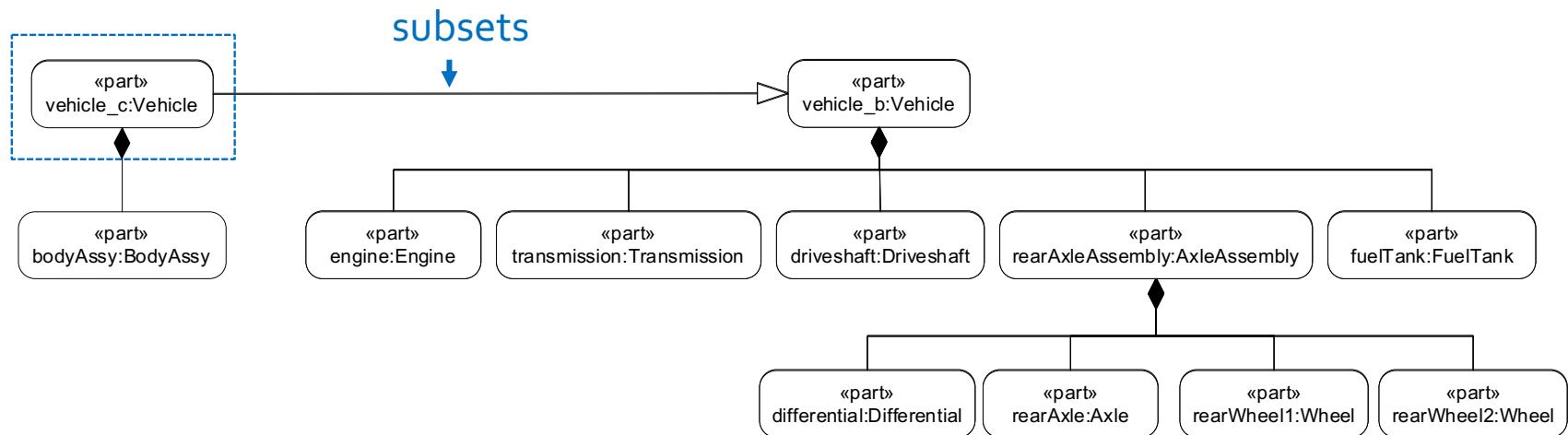
- A parts tree is a composition of a part from other parts **v2**
 - SysML v1 only supports block decomposition
 - Definition element can serve as black-box specification that is not decomposed
 - Does not commit to an internal structure (e.g., decomposition)
 - Can provide significant advantages (more intuitive, less ambiguous, easier to modify a design configuration)



Parts Tree Reuse & Modification

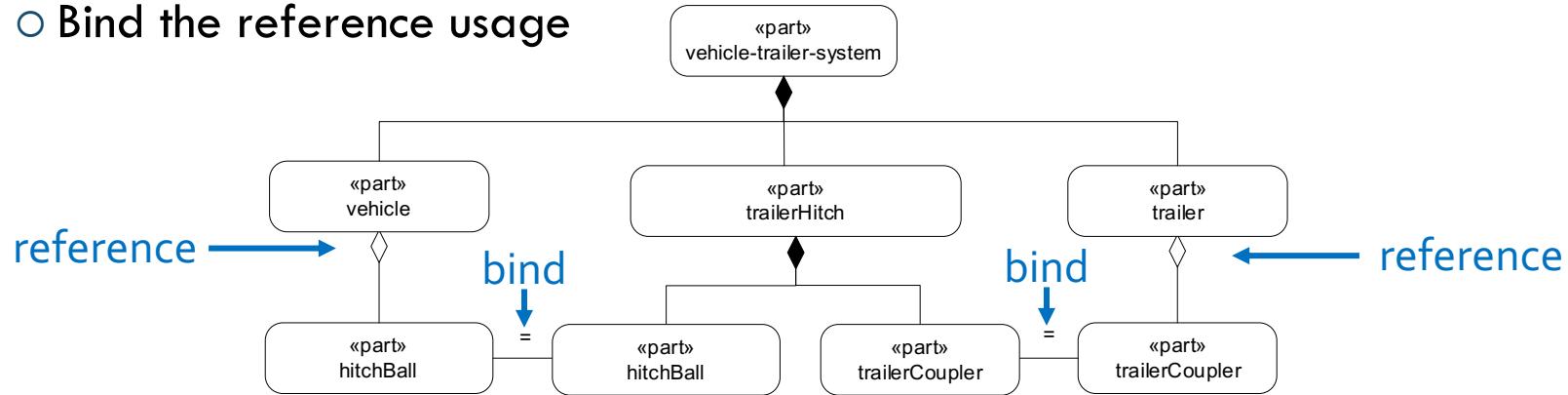
Subsetting a Part

- A part can be a subset of another part
 - Equivalent to specializing a part **v2**
 - Inherits the part decomposition and other features
 - Can modify inherited parts and features through redefinition and subsetting
 - Can add new parts **v2**

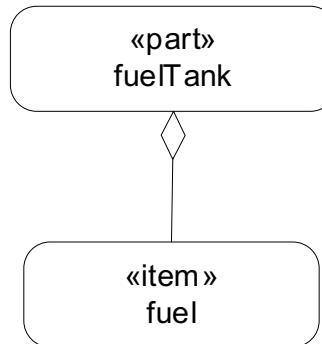


References

- A part can refer to other parts that are part of another decomposition v2
 - Not composite (i.e., lifetime semantics do not apply)
 - Bind the reference usage

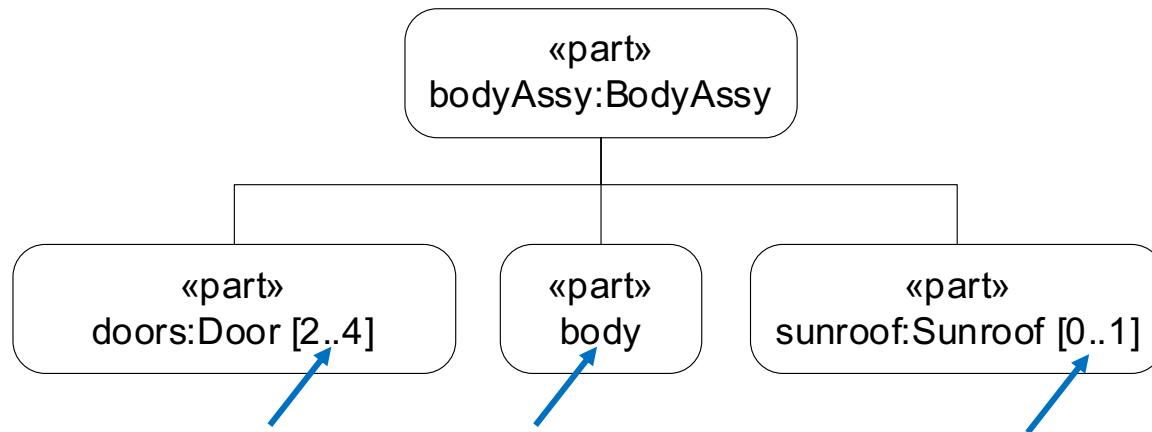


- A part can refer to an item that it stores v2



Multiplicity

- Defines the number of features (e.g., parts) in a particular context
 - Defines a range with a lower bound and upper bound
 - Lower and upper bounds are integers
 - Default multiplicity is [1..1]
 - Optional multiplicity [0..1]

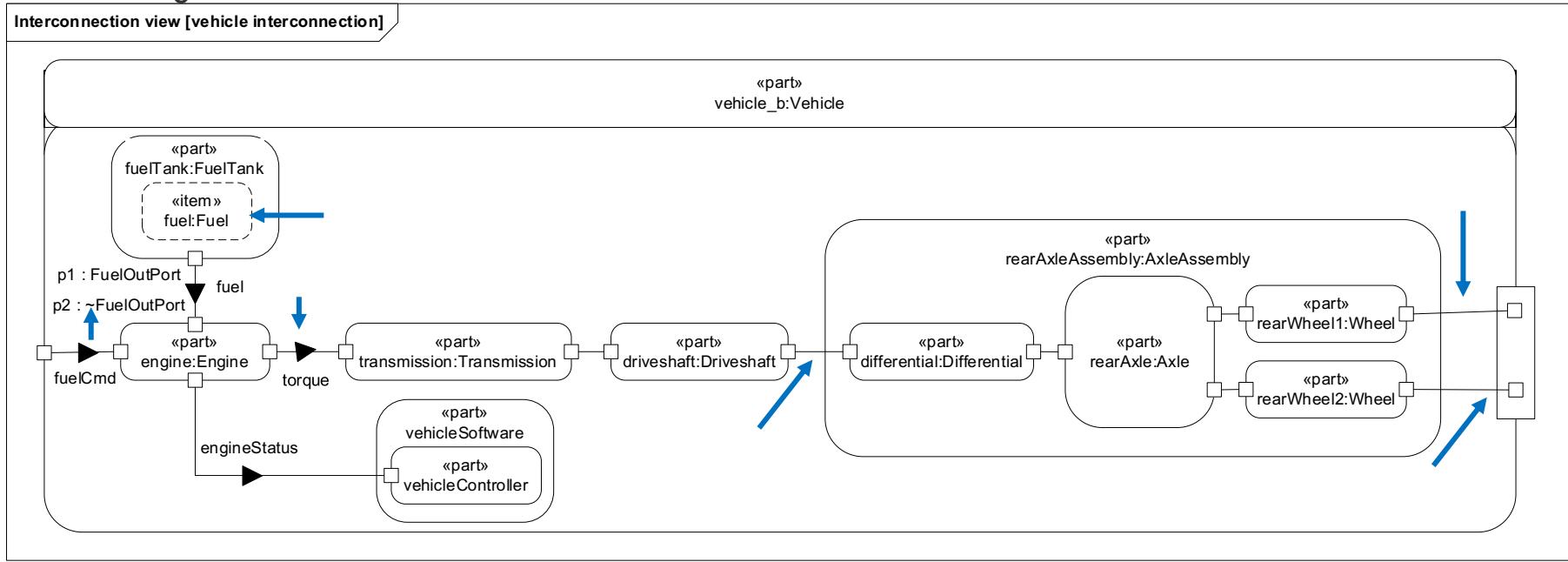


Module 5

Part Interconnection

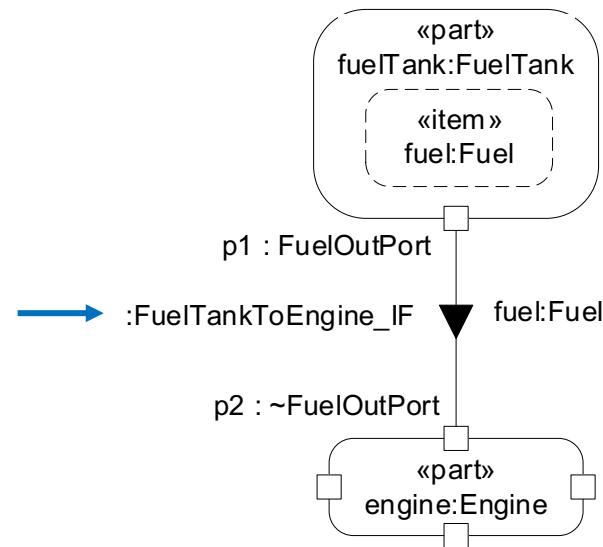
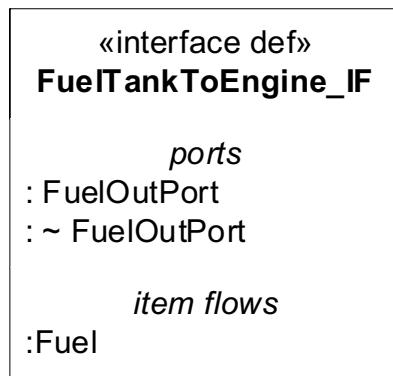
Connecting Parts

- Parts can be connected via their ports or without ports
 - Parts can be connected directly without connecting to the composite part
 - Ports can contain nested ports
 - Flows can be shown on connections
 - References are dashed
 - Conjugate port
 - Binding connection



Interfaces [1]

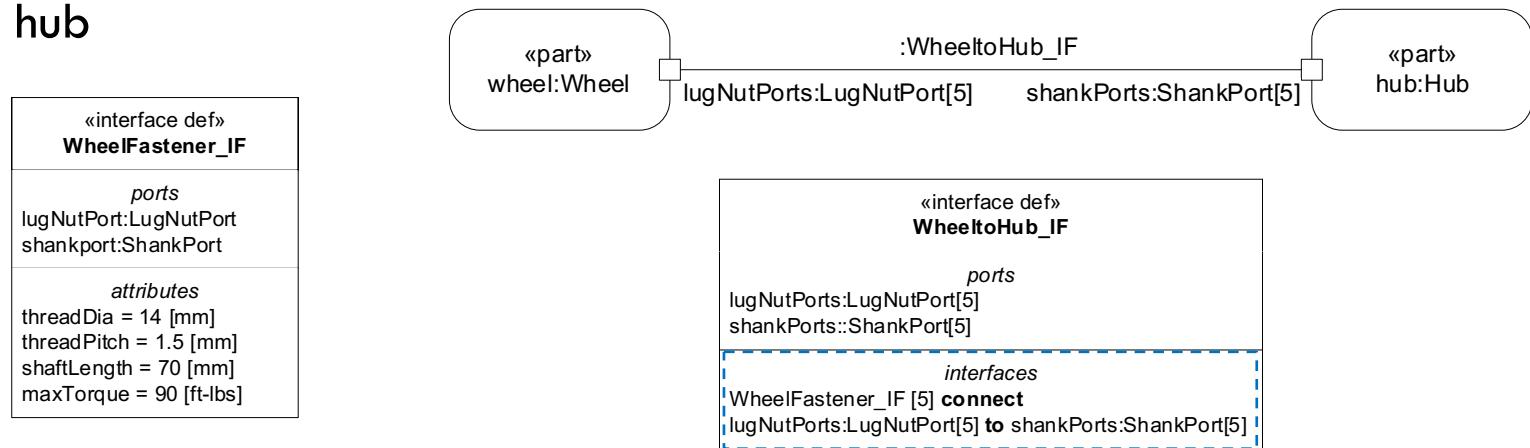
- A connection definition connects two usage elements (e.g., two parts)
- An interface definition is a connection definition whose ends are compatible ports
 - Can contain item flows
 - Can contain other kinds of features
- An interface defined by an interface definition is used to connects parts
 - Ports on parts must be compatible with the interface definition



Interfaces [2]

Connecting a Wheel to a Hub

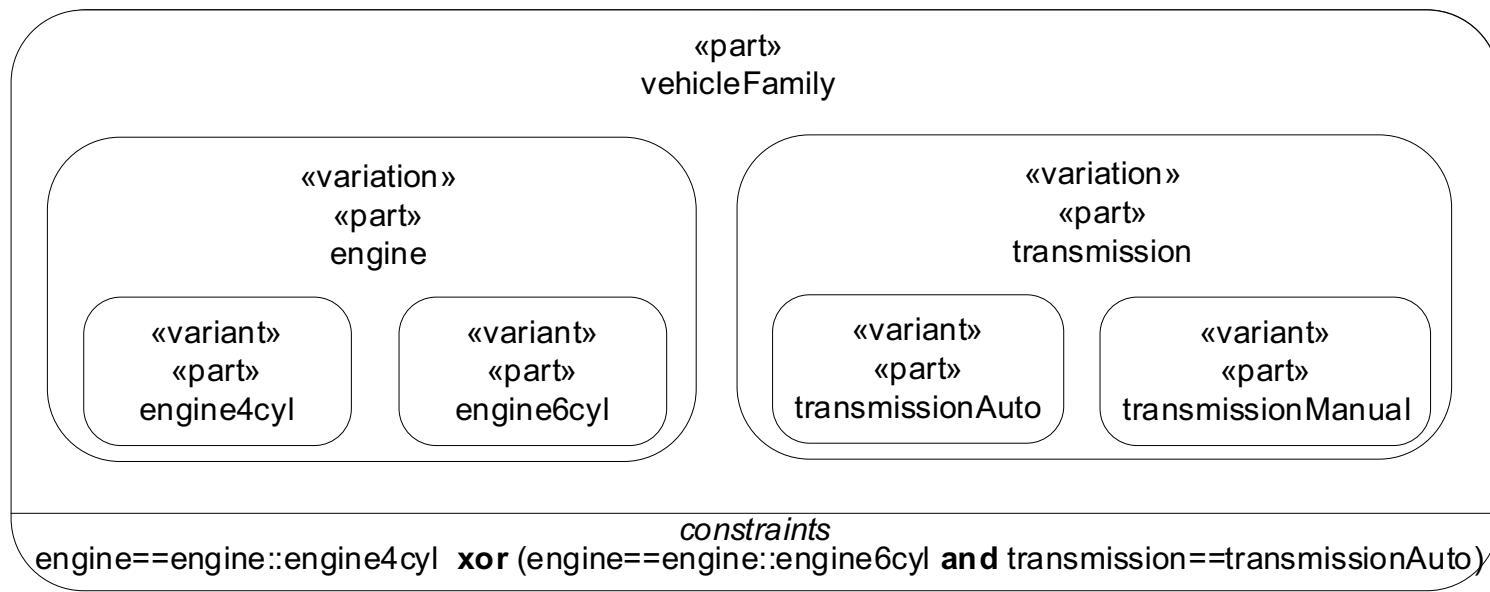
- Wheel Fastener interface specifies a compatible connection between a lug nut and shank
 - Specifies attributes needed for a compatible connection
- Wheel to Hub interface specifies a compatible connection between a wheel and hub (i.e., 5 lug nuts and 5 shanks)
 - Decomposes into 5 Wheel Fastener interfaces
- Usage of Wheel to Hub interface definition connects wheel to hub



Module 6

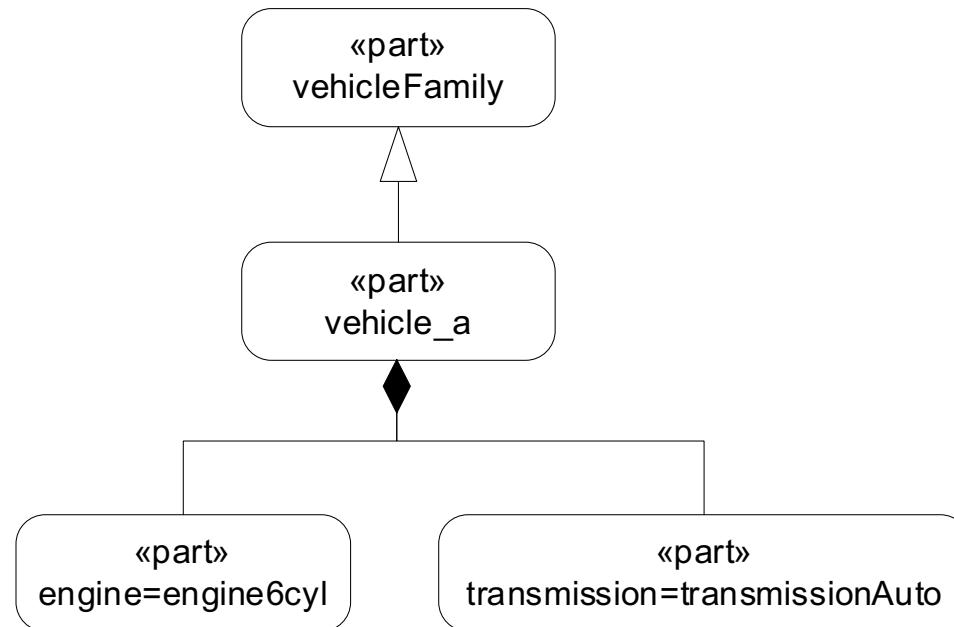
Variability

- Vehicle family is the superset model (150%)
- Variation points represent elements that can vary
 - Can be applied to all definition and usage elements
- A variant represents a particular choice at a variation point
- A choice at one variation point can constrain choices at other variation points
- A system can be configured by making choices at each variation point



Selected Vehicle Configuration

- vehicle_a subsets vehicleFamily to represent a particular design configuration
- parts are selected that conform to variability constraints
 - model is invalid if constraints are not satisfied
 - Variability modeling applications can automate the selection of valid configurations



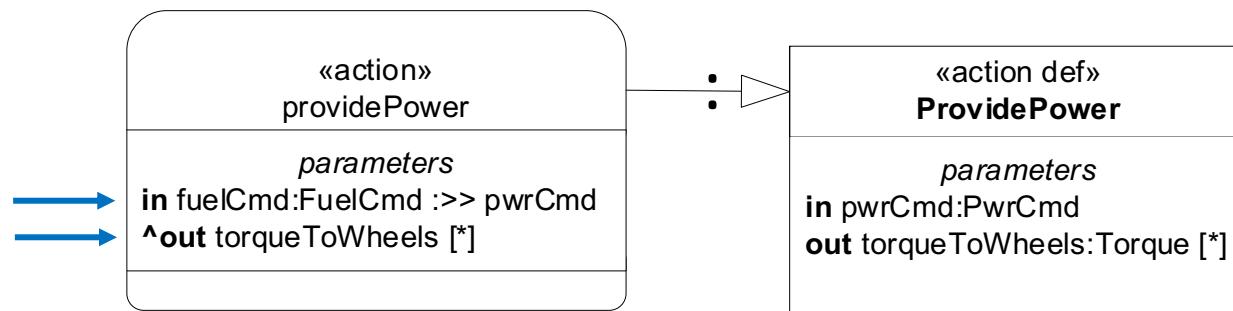
Behavior

Module 7

Actions

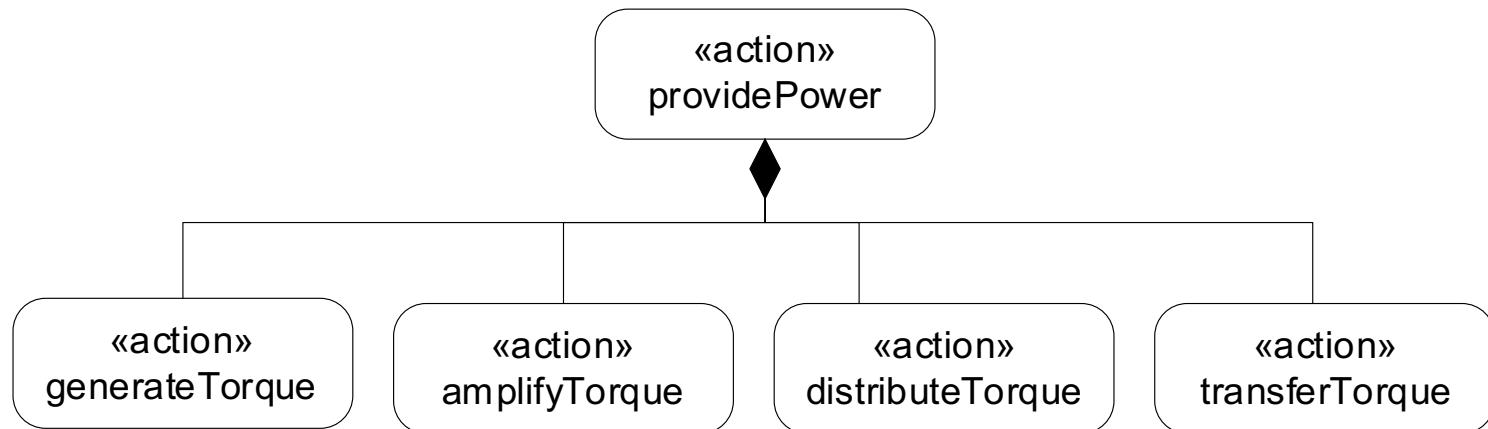
Actions

- Actions are defined by action definitions **v2**
 - Inherit features (e.g., input and output parameters)
 - Features can be redefined



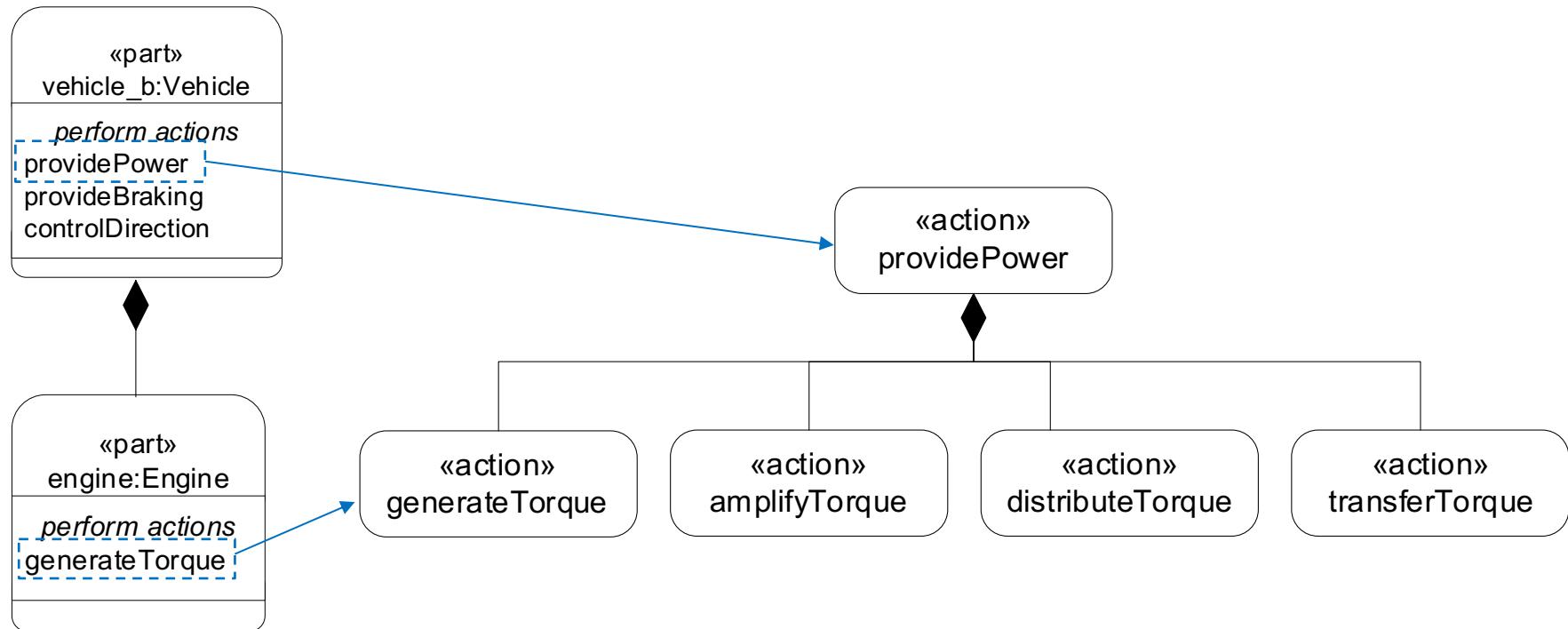
Action Decomposition

- Actions can be decomposed in a similar way as parts **v2**



Part Performs Actions

- A part that performs an action can refer to an action in an action tree

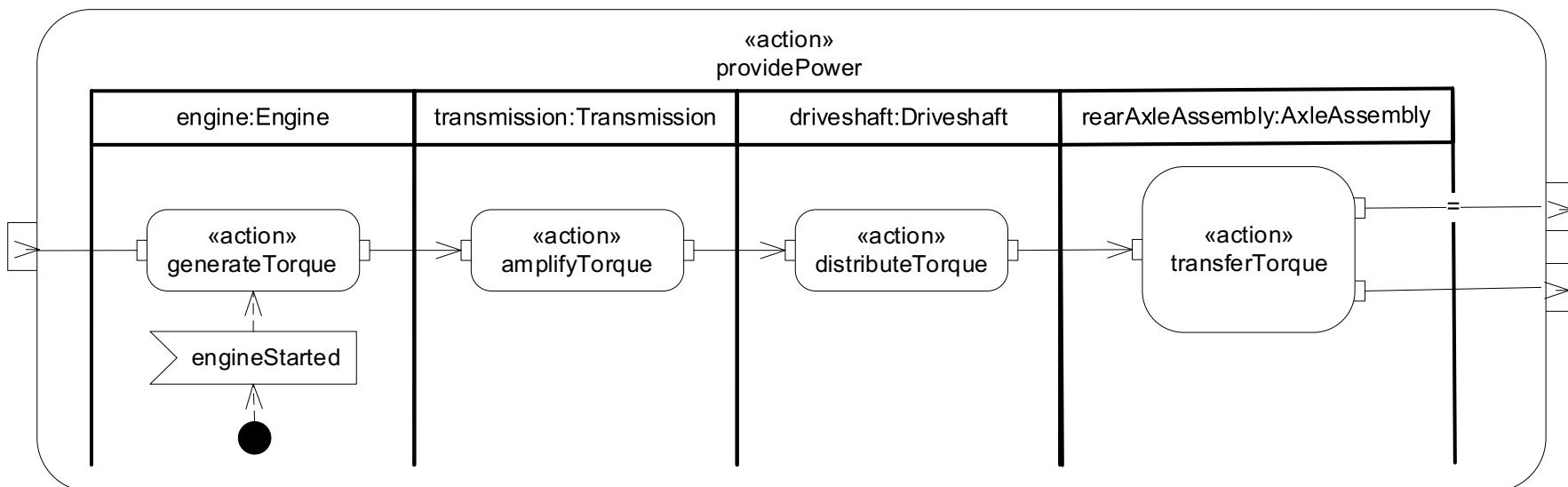


Module 8

Action Flow

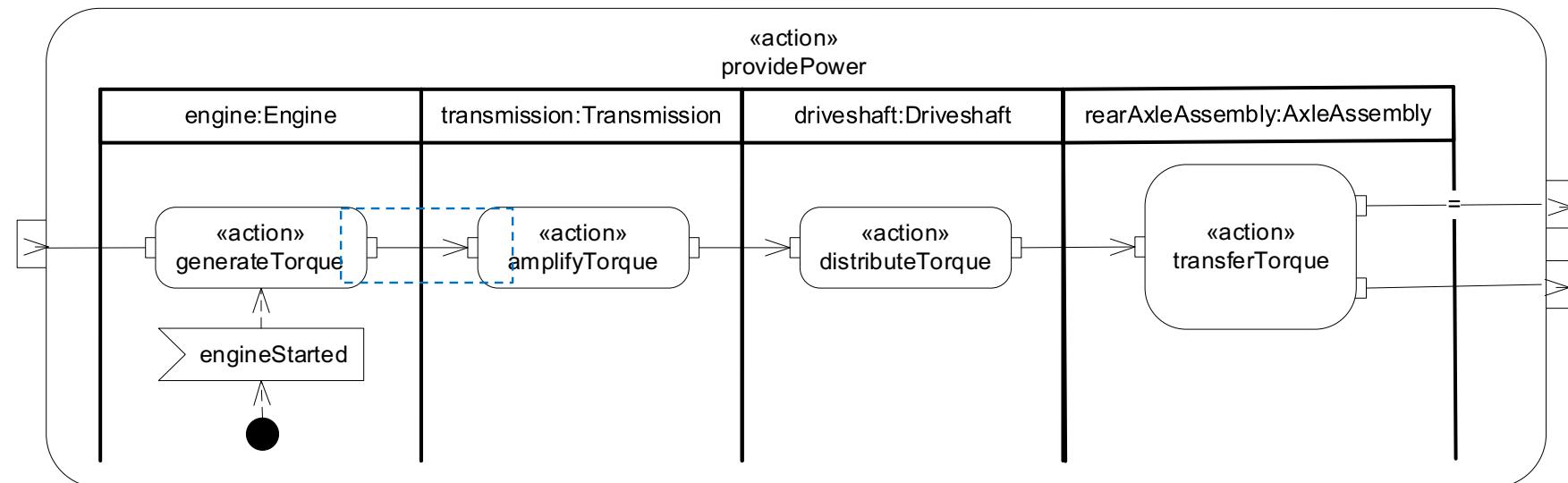
Action Flows

- Action flows can include control flows and input/output flows
- Control nodes include decision, merge, fork, and join nodes
- Actions can include send and accept actions
- Swimlanes represent performers of actions



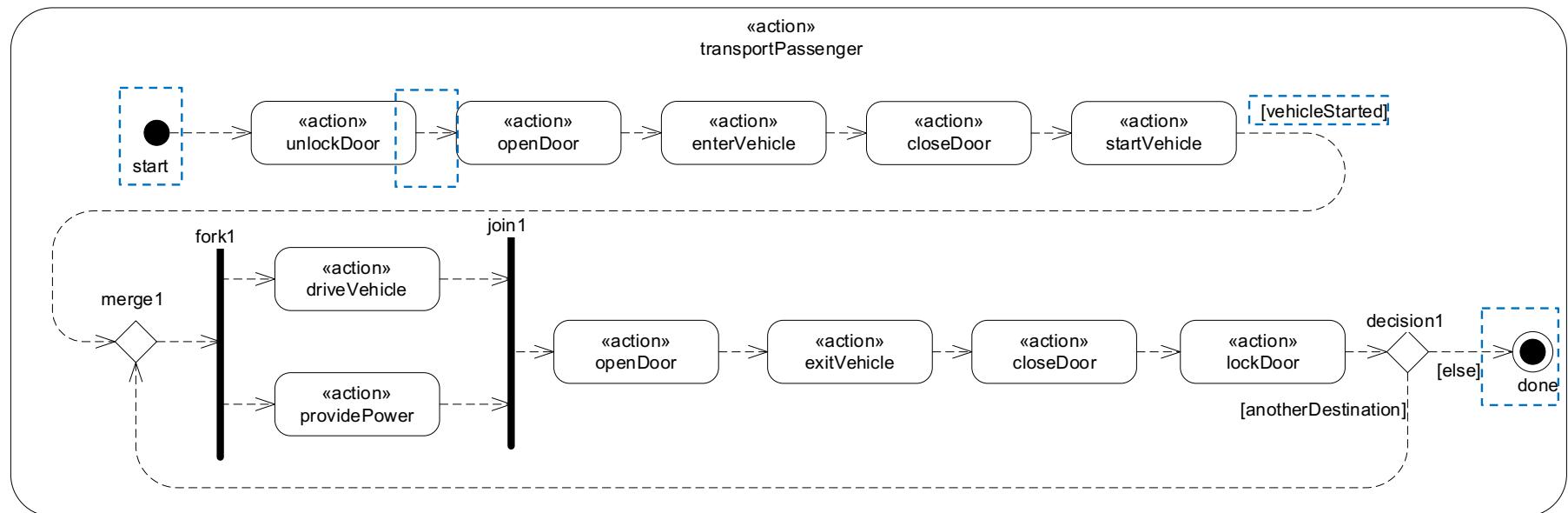
Input/Output Flows

- A flow is a kind of connection that transfers items from a source output to a target input
 - A flow is a transfer that continues while the source and target actions execute (this is the default)
 - A succession flow is a transfer that only occurs after the source action ends and before the target action starts



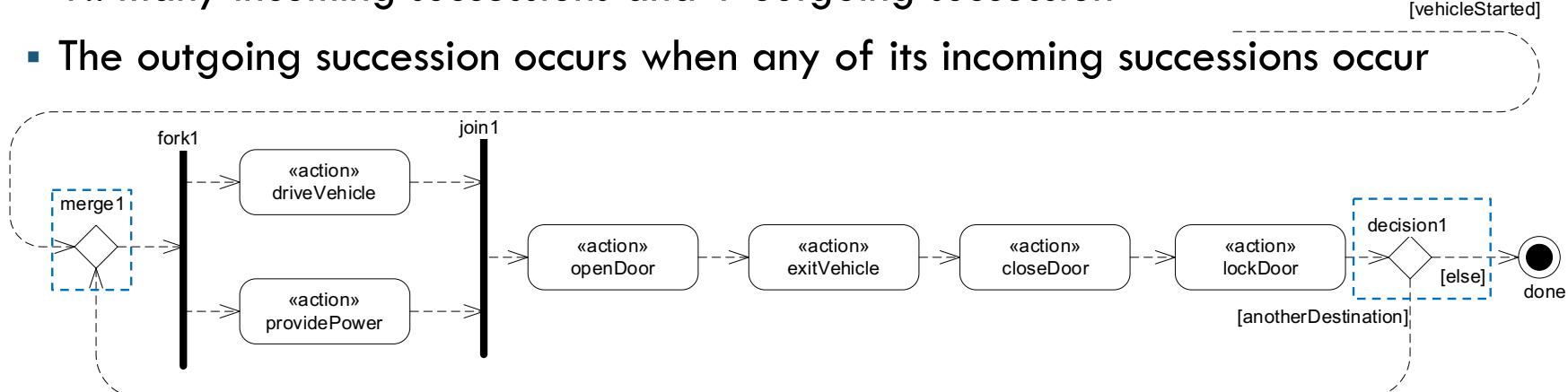
Controlling Actions [1]

- A start action and done action represent the start and end of an action sequence
- A succession asserts that the target action can start execution only after the source action ends execution **v2**
- A conditional succession asserts that the target action can start only if the guard condition is true (if...then). If the guard is false, the target action cannot start



Controlling Actions [2]

- Control nodes are kinds of actions (with names) that control outgoing successions in response to incoming successions **v2**
 - Decision node
 - 1 incoming succession and 1.. many outgoing successions
 - One outgoing succession is selected based on the guard condition that is satisfied (“else” condition is the complement of all other guard conditions)
 - Merge node
 - 1.. many incoming successions and 1 outgoing succession
 - The outgoing succession occurs when any of its incoming successions occur



Controlling Actions [3]

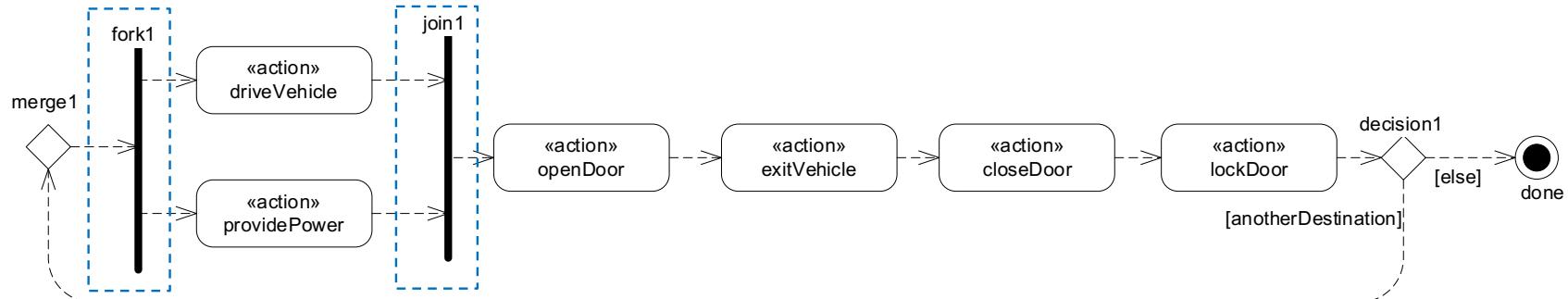
○ Fork node

- 1 incoming succession and 1.. many outgoing successions
- All outgoing successions occur when its incoming succession occurs

○ Join node

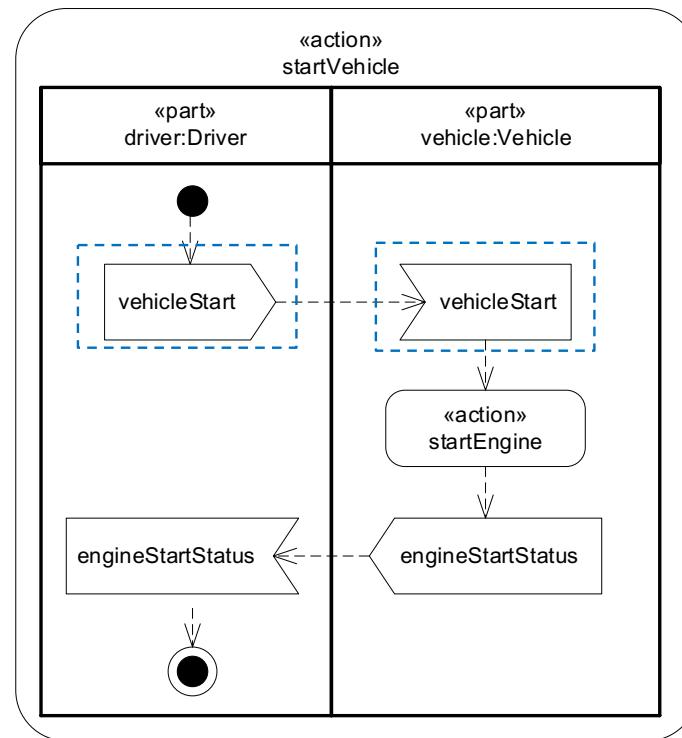
- 1.. many incoming successions and 1 outgoing succession
- Outgoing succession occurs when all its incoming successions occur

Note: Control nodes cannot currently be applied to input/output flows



Controlling Actions [4]

- Accept actions and send actions
 - When a send action executes, it transfers an item to a target part
 - When a triggering input item is received, an accept action executes and can transfer the input item to another action

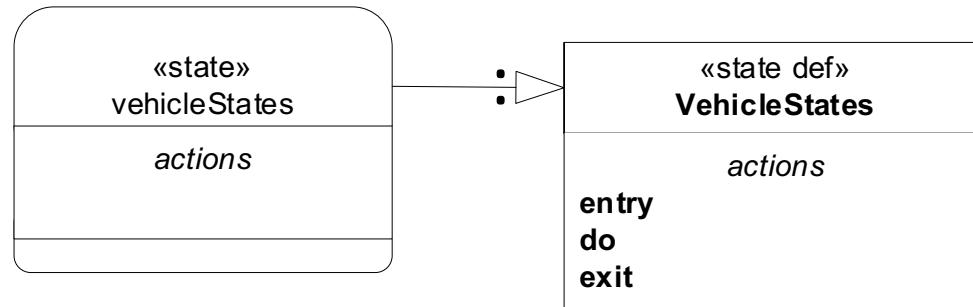


Driver and vehicle are in a shared context

Module 9

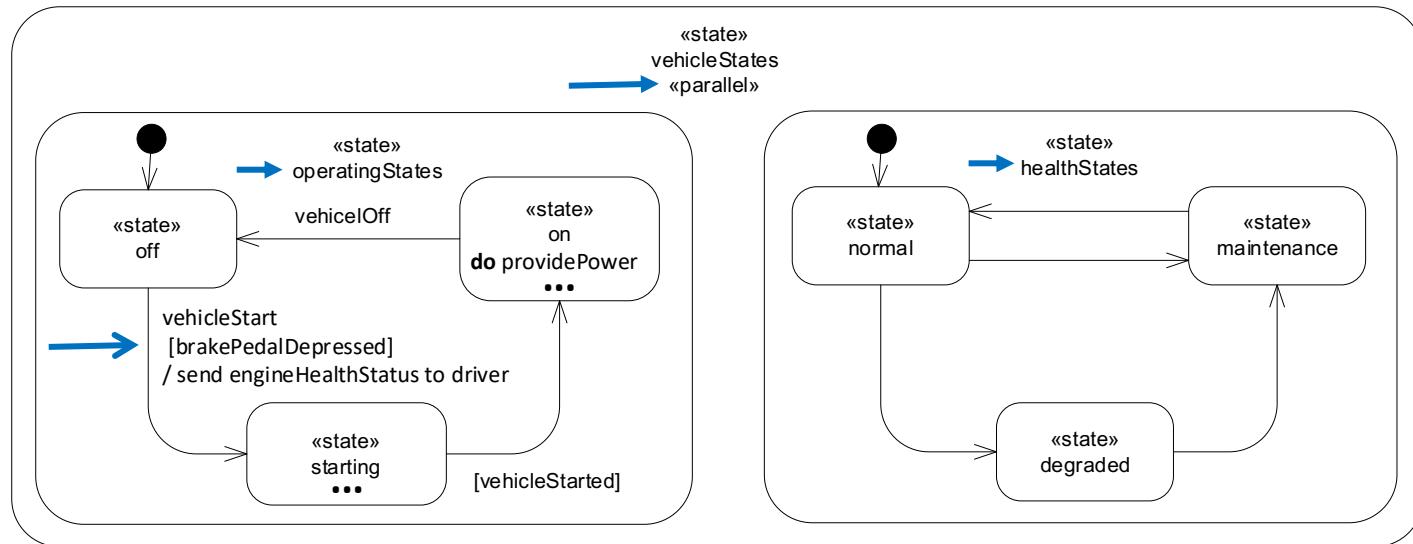
States

- States are defined by state definitions **v2**
 - Inherit features (e.g., entry, exit, and do actions) from its state definition
 - Features can be redefined



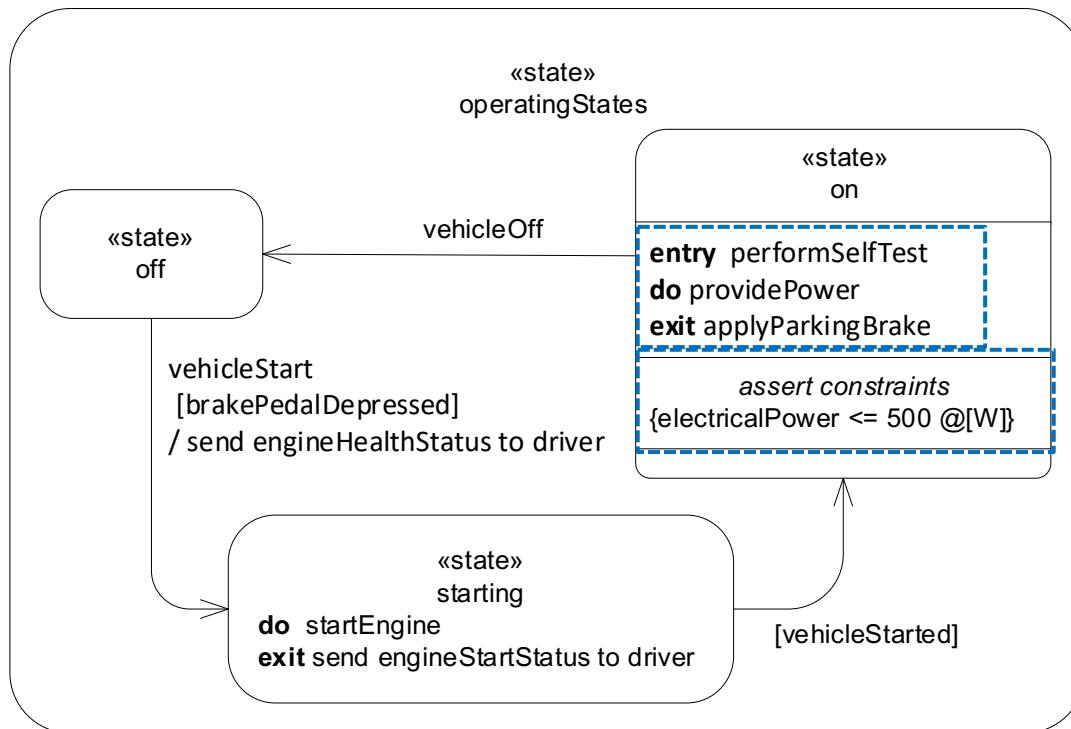
State-based Behavior [1]

- States decompose into nested states (*without regions, which were in SysML v1*) v2
 - A parallel state decomposes into concurrent states
 - A non-parallel state (default) decomposes into sequential/exclusive states
- Transitions between sequential states
 - Triggered by events
 - Can include guard and action



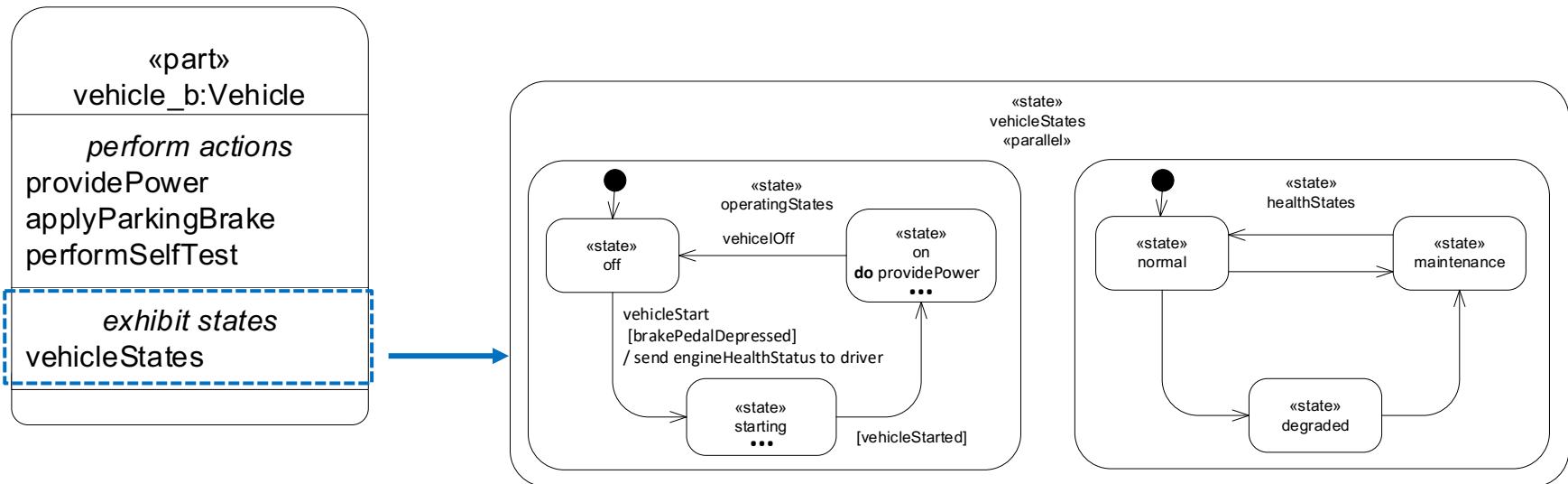
State-based Behavior [2]

- States can have entry, exit, and do actions that can refer to actions in action trees or be defined locally
- States can include constraints (i.e. SysML v2 state invariants)



Part Exhibits States

- A part that exhibits states can refer to state-based behavior v2

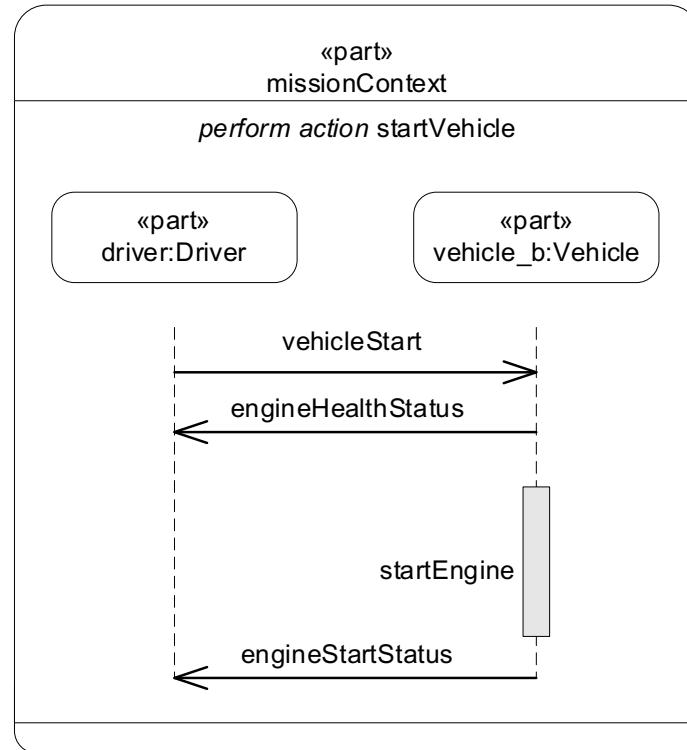


Module 10

Interactions

Sequences

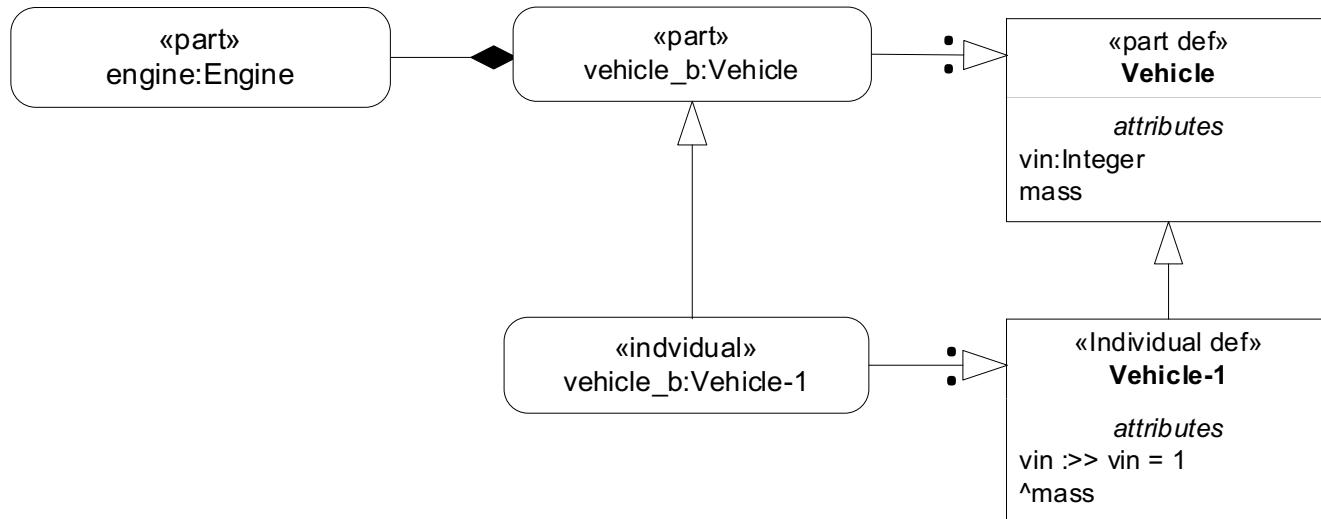
- Represents a sequence of messages between send and accept actions
 - Asynchronous – sender does not wait for reply
 - Synchronous – sender waits for reply (**under discussion**)



Module 11

Individuals

- An individual definition is a unique member of a class with identity
 - A specialization of a class, having only one member
 - Has a unique lifetime
- An individual is a usage that is defined by an individual definition
 - Can subset a part to represent a particular configuration
 - Can have different configurations across Vehicle-1 lifetime

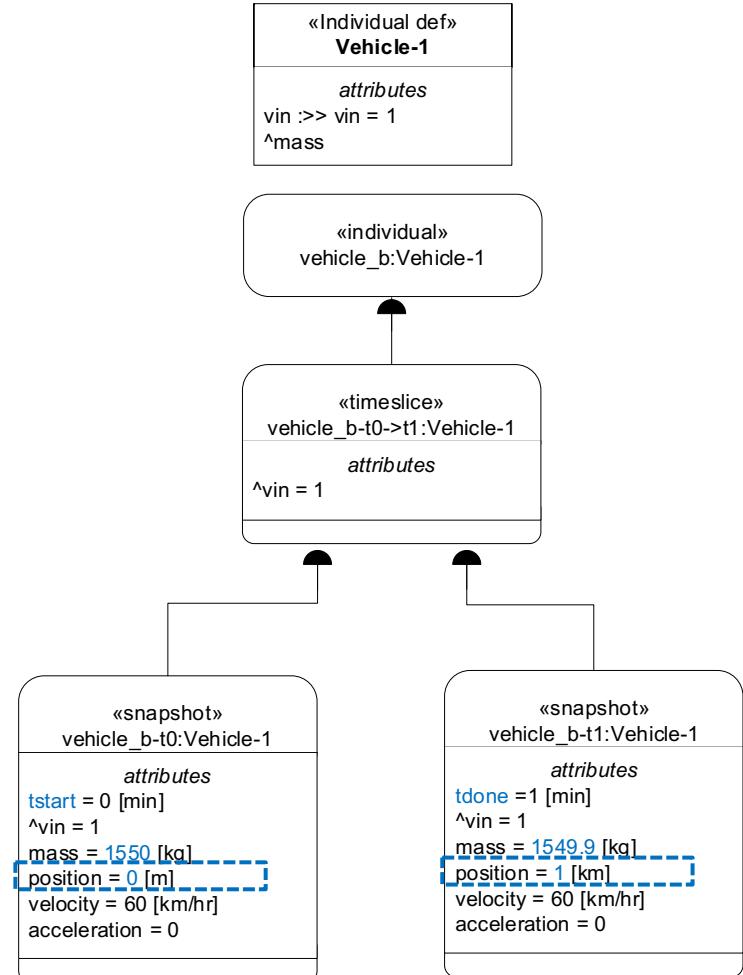


Module 12

Timeslices & Snapshots

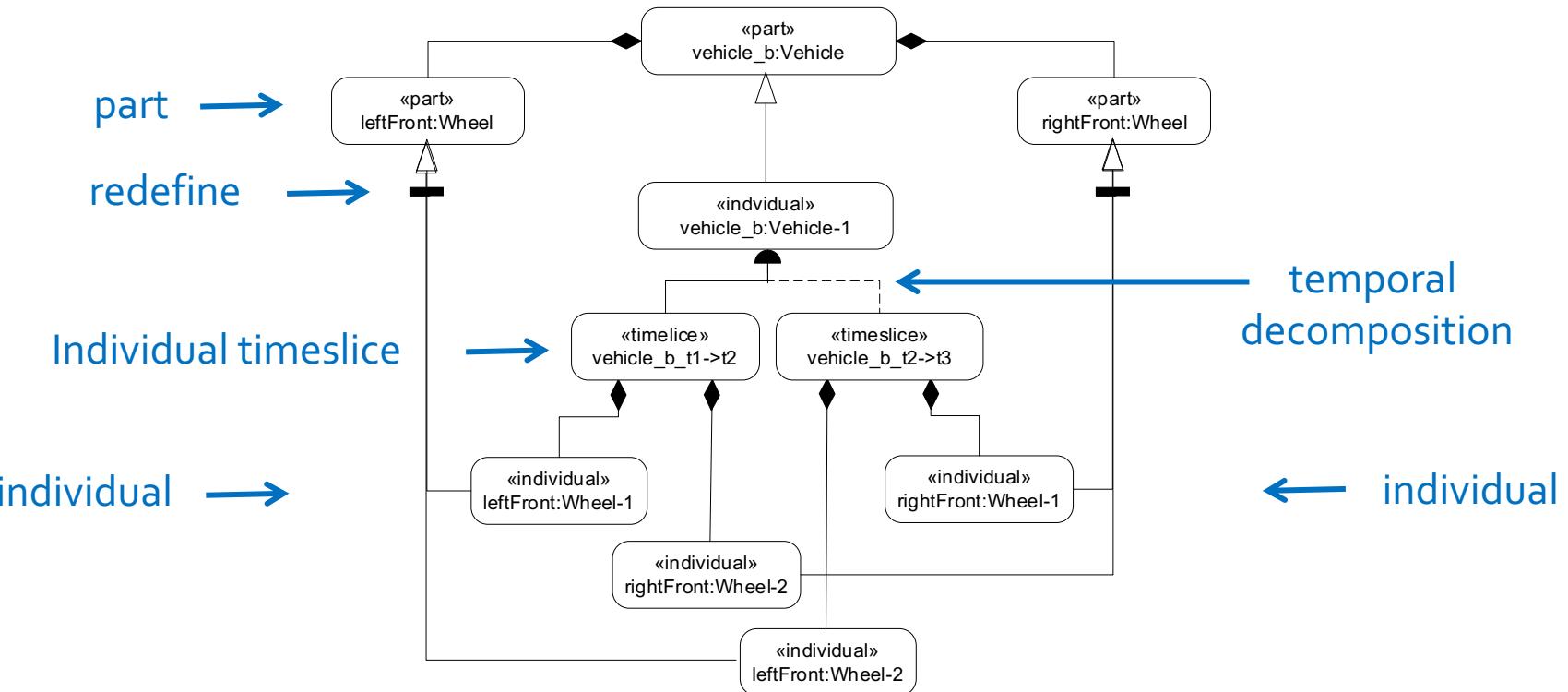
Lifetime with Snapshots and Time Slices v2

- Each individual definition has a unique lifetime
 - Begins when it is created
 - Ends when it is destroyed
- Individual usage exists over some portion of Vehicle-1 lifetime
- Individual lifetime can be segmented into timeslices (i.e., durations of time)
- A timeslice whose duration is zero is a snapshot
 - Beginning and ending snapshot of a time slice is designated as start and done snapshot
- The condition of an individual for a timeslice or snapshot can be specified in terms of the values of its features



Individuals Playing Different Roles v2 SST

- An individual can play different roles and have different configurations in different timeslices
 - Individual wheel (wheel-1) is left front wheel during vehicle_b_t1-t2 timeslice
 - Individual wheel (wheel-1) is right front wheel during vehicle_b_t2-t3 timeslice



Module 13

Expressions and Calculations



Expressions v2

SST

- Used to compute a result
- Default value means value can be over-ridden using redefinition
- Library of mathematical functions (e.g., sum, max, ...)
 - Includes arithmetic operators that also apply to vectors and tensors

```
«part»  
vehicle_b:Vehicle  
  
attributes  
mass ::>> mass=dryMass+cargoMass+fuelTank::fuel::fuelMass  
dryMass :>>dryMass=sum(partMasses)  
cargoMass >> cargoMass default 0 [kg]  
partMasses=(fuelTank.mass,frontAxleAssembly.mass,rearAxleAssembly.mass,engine.mass,transmission.mass,driveshaft.mass)
```

- A kind of behavior generally used to represent reusable mathematical functions

- Inputs
- Expression
- Returns a single result

```
«calc def»
Force

parameters
in m :> ISQ::mass
in a :> ISQ::acceleration
return :> ISQ::force

result
m*a
```

```
«calc»
force:Force

parameters
in m=1500 [kg]
in a=9.806 [m/s^2]
return :> ISQ::force

result
m*a
```

```
«calc»
force:Force

parameters
in m=1500 [kg]
in a=9.806 [m/s^2]
return :> ISQ::force = m*a
```

*Do not repeat expression
in usage if in definition*

- Represent a calculation using the textual notation
 - **calc def** Force (m :>ISQ::mass, a :>ISQ::acceleration) :>ISQ::force = (m * a);
- Evaluate usage
 - Bind values to input parameters. Then evaluate expression and return a result
 - **calc** force : Force (m=1500 [kg], a=9.806 [m/s²]) f;
 - f = Force (m=1500 [kg] , a = 9.806 [m/s²])
- Usage can be owned by a part, action, constraint, package,

Binding Connection

- A binding is a kind of connection where both sides of the connection are asserted to be equal at all times
 - Symbol is «bind» or =
 - If both sides are not equal, the model is invalid (e.g., $3=4$) is invalid
 - A tool could make both sides equal if the values are not the same
 - In the above example, the values can be set to $(3=3)$ or $(4=4)$
 - For $y = x+3$, when x is 1, then y can be set to 4 so that both sides are equal
 - Different from the Boolean operator ‘==’, which evaluates whether both sides of the ‘==’ have the same value or not, and returns a value of true or false (e.g., $\{3==4\}$ returns a value of false)
- Binding is used more broadly to establish equality of any kind of feature
 - A part can be set to be the same value (e.g., engine = engine4cyl)
 - A port on a composite part can be bound to a port on a nested part to constrain them to have equal values

Module 14

Quantities & Units

Quantities and Units

- Quantity is an attribute (e.g., mass) **v2**
- Quantity is defined by an attribute def of a quantity kind (e.g., MassValue)
- Units conform to the quantity kind
- Units are associated with the value **v2**
- A change in a unit will apply the unit conversion factor (if a tool supports this)
 - **attribute** *m*:MassValue = 25 [kg] (if kg is changed to lbs, the value is changed to 55.1 [lbs])
 - In SysML v1, a change in unit requires a change in the value type
- Complex quantities and units can be derived from primitive quantities and units
- Libraries
 - International System of Quantities (ISQ)
 - International System of Units (SI)
 - US Customary Units (USCustomaryUnits) **v2**

Module 15

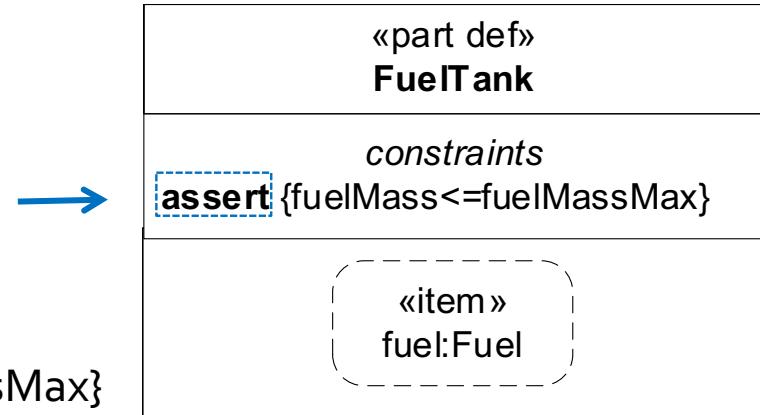
Constraints

Constraint Expression [1]

- A Boolean expression that evaluates to true or false, which includes
 - Constraint operators ($==$), ($>$), (\geq), ($<$), (\leq), (\neq)
 - Used to compare expressions (e.g., $\{a < b\}$)
 - Boolean operators include **and** ($\&$), **or** (\mid), **xor** (\wedge), **not** ($!$)
 - Used to logically combine expressions (e.g., $\{A \text{ and } B \text{ or } C\}$)
- Asserting a constraint to be true means the evaluation must be true for the model to be valid

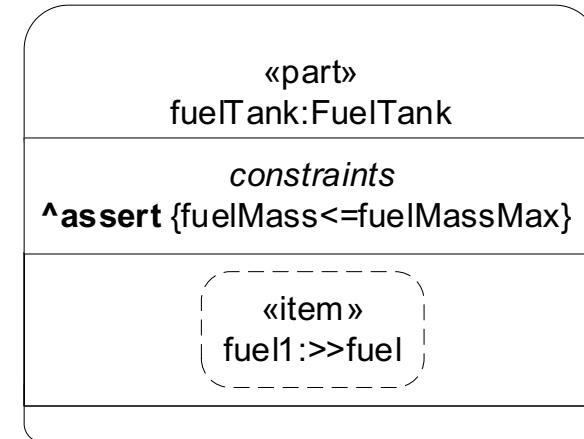
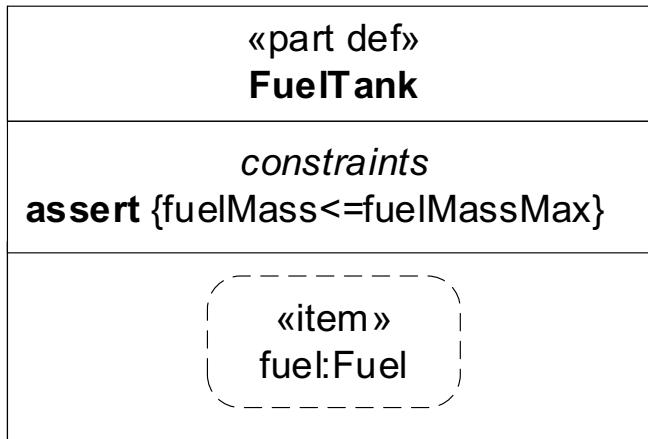
v2

```
part def FuelTank {  
    attribute mass :> ISQ::mass;  
    ref item fuel:Fuel{  
        attribute redefines fuelMass;  
    }  
    attribute fuelMassMax:>ISQ::mass;  
    → assert constraint {fuel.fuelMass≤fuelMassMax}  
}
```



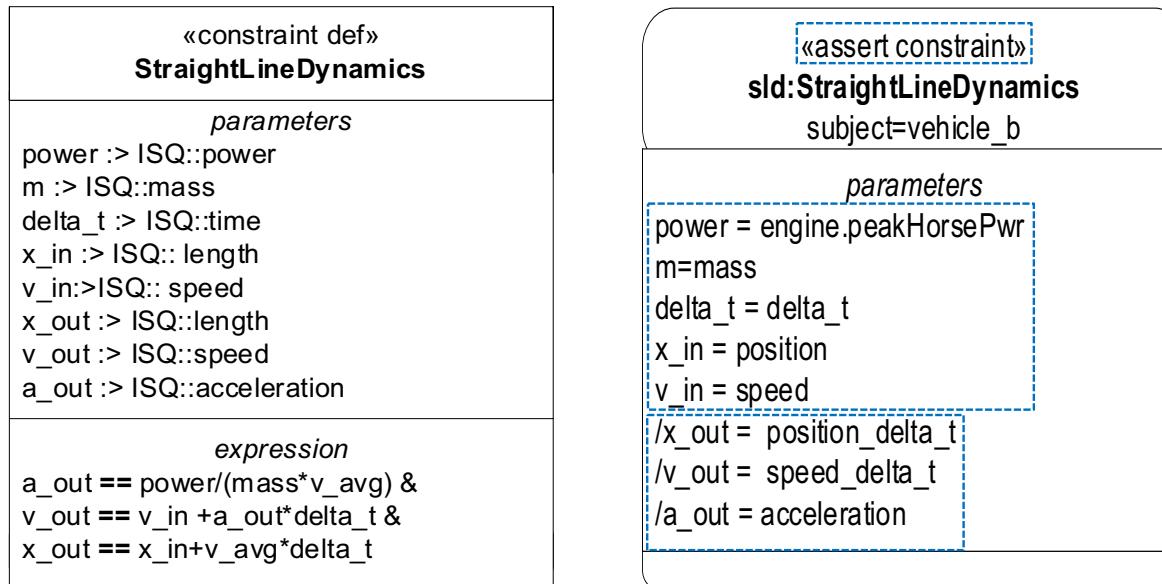
Constraint Expression [2]

- Usage inherits constraint expression



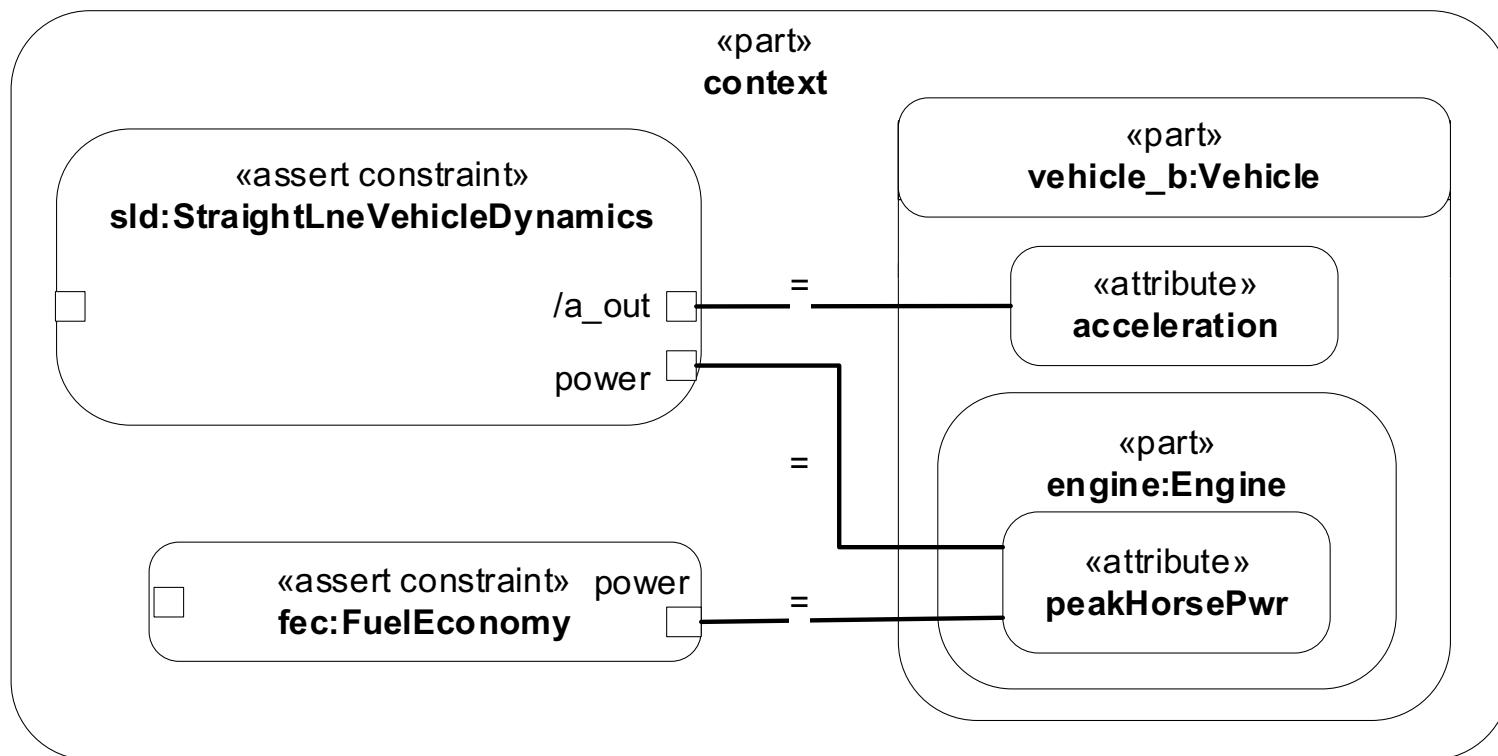
Constraint Definition

- A reusable constraint expression
- Default parameter direction is ‘in’
- Can assert a constraint on the usage
- Bind parameters on the usage
- Identify dependent parameters as derived



Binding Constraints

- Equivalent to SysML v1 parametric diagram

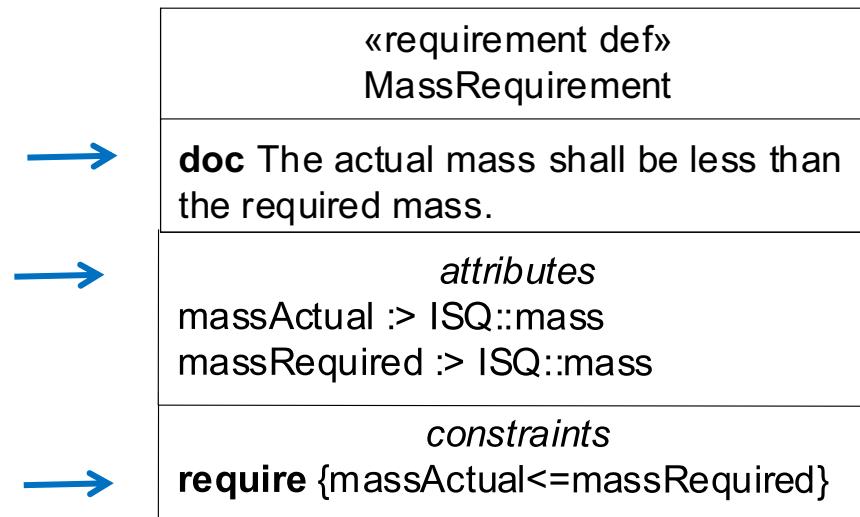


Module 16

Requirements

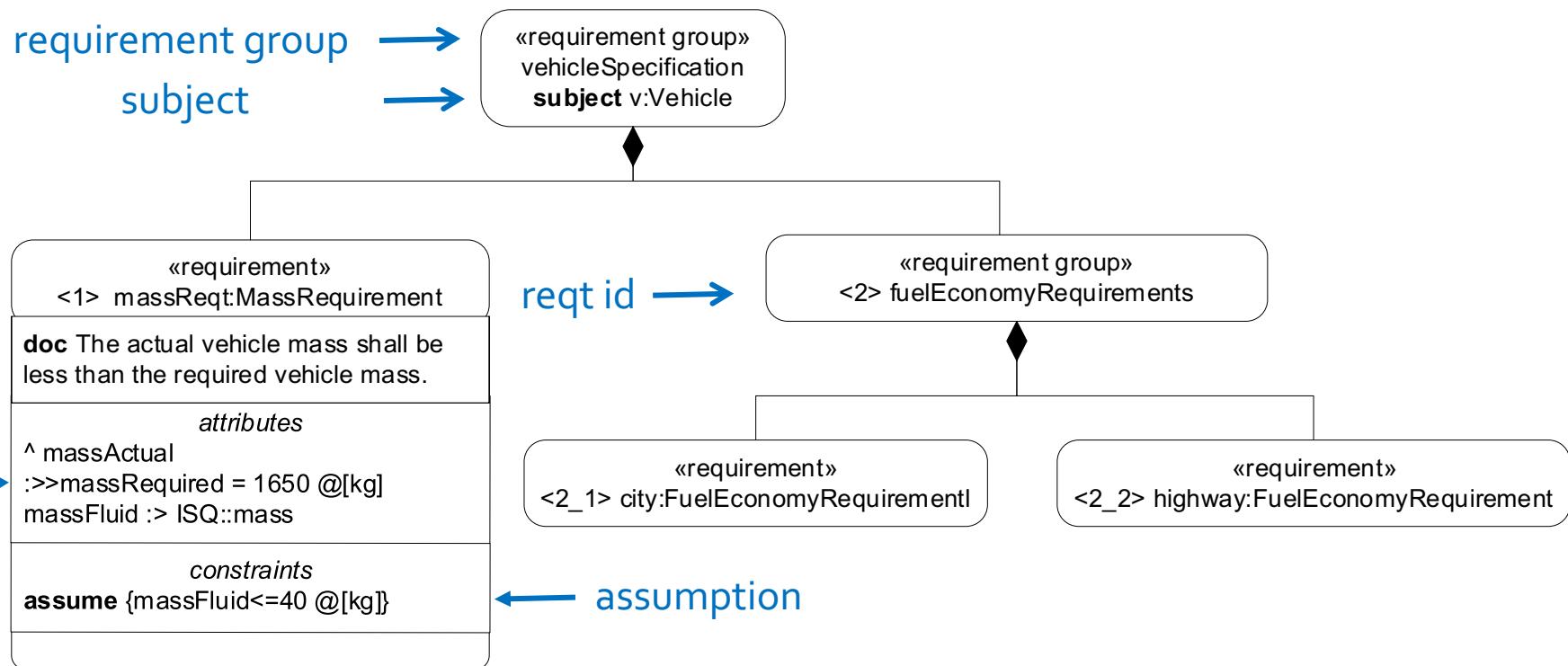
Requirement Definition

- 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
 - can apply to performance, functional, interface and other kinds of requirements if desired
 - Assumed constraint expression that is asserted to be true for the requirement to be valid
 - Attributes of the constraint expressions



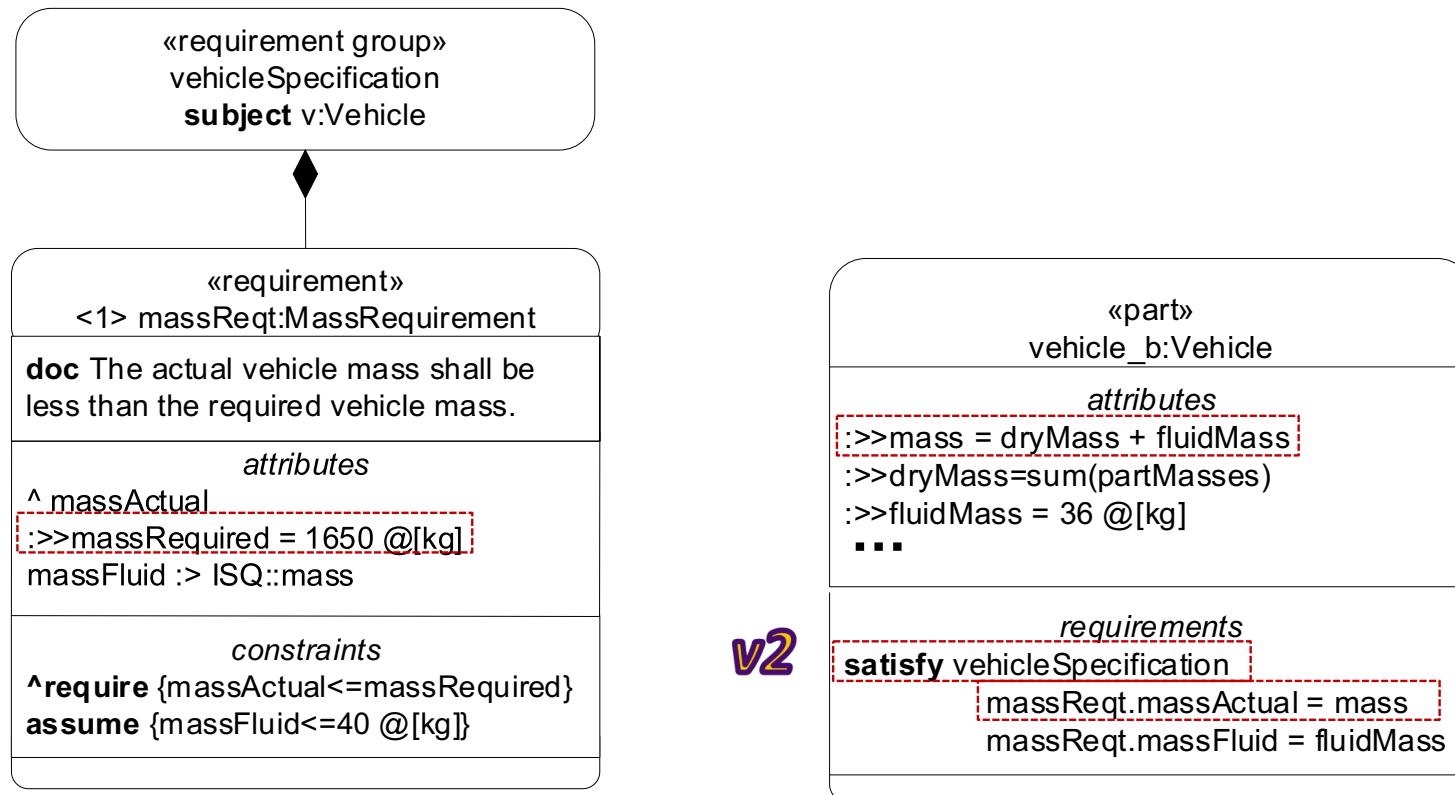
Requirement Specification

- A tree of requirements that contains nested requirement usages **v2**
- Requirement group can own or reference other requirements
- Subject of nested requirements is the kind of entity being specified
- Requirement features can redefine features of the requirement definition



Satisfying a Requirement

- The vehicleSpecification is used to impose constraints on the vehicle
 - The modeler can assert the vehicle mass satisfies the mass requirement
 - Bind the vehicle mass to massActual of the requirement



Module 17

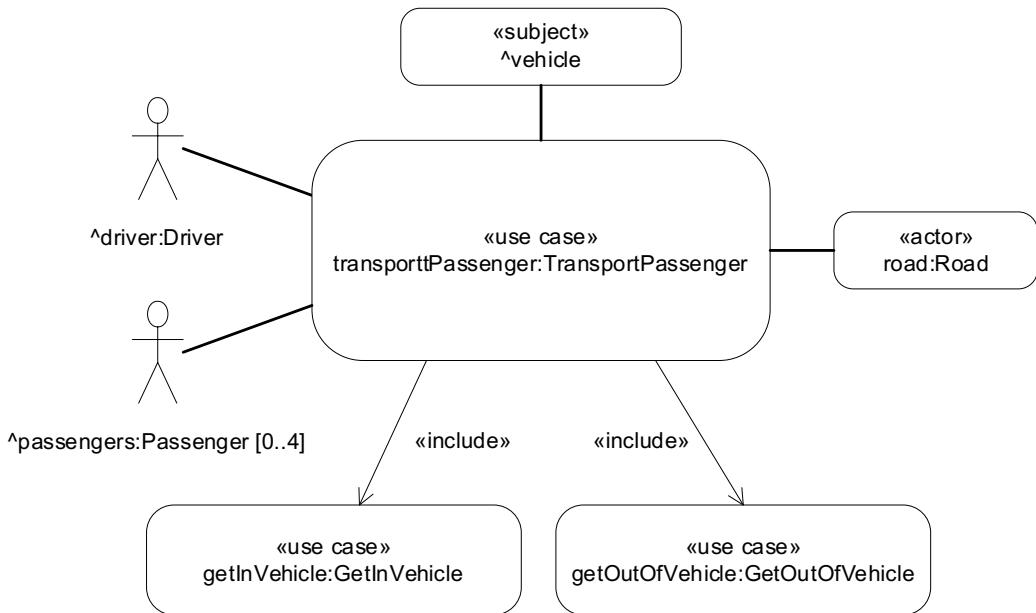
Use Cases

Use Case

- A kind of case

- Subject of the use case (often the system of interest)
- Objective is to provide value to one or more stakeholders
 - Stakeholders are typically external to the system of interest referred to as actors
- Actions/steps performed by actors and subject are required to achieve the objective
- Include use cases are always performed as part of the base use case

«use case def» TransportPassenger subject vehicle:Vehicle
<i>objective</i> doc Driver passenger to destination safely, comfortably, and within acceptable time
<i>actors</i> driver:Driver passengers:Passenger [0..4]
<i>include use cases</i> getInVehicle:GetInVehicle getOutOfVehicle:GetOutOfVehicle
<i>conditions</i> precondition vehicle.position=startingLocation postcondition vehicle.position=endingLocation invariants

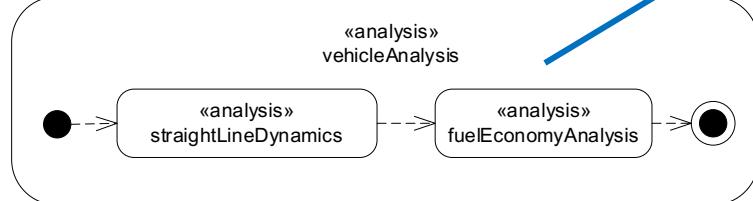


Module 18

Analysis Cases

Analysis Case v2

- A set of steps with an objective to evaluate a result about a subject of the analysis
 - A kind of behavior
 - Each step can be an action, calc, or an analysis case that can contain
 - subject
 - objective
 - input and output parameters
 - Single return parameter (i.e., the result)
 - Attributes bound to calculations and/or constraints to be solved by a solver
 - Bind input & output parameters to the subject



```

<<analysis>>
fuelEconomyAnalysis
subject v = vehicle_b

objective
doc Determine whether the vehicle design configuration can satisfy
the fuel economy requirements

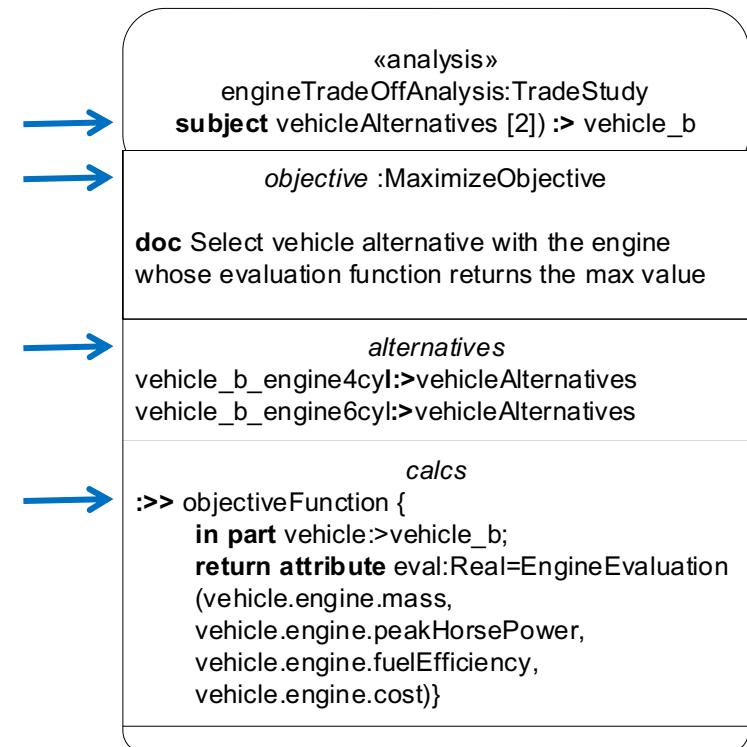
parameters
in scenario:Scenario
return calculatedFuelEconomy :> km/l

attributes
distance = TraveledDistance(scenario)
tpd_avg = AverageTravelTimePerDistance(scenario)
bsfc = ComputeBSFC(vehicle_b::engine)
f_a = BestFuelConsumptionPerDistance(vehicle_b::mass, bsfc,
tpd_avg, distance)
f_b = IdlingFuelConsumptionPerTime(vehicle_b::engine)
calculatedFuelEconomy=FuelConsumption(f_a, f_b, tpd_avg)
  
```

convert to liters / 100 km

- A kind of analysis case

- Trade study objective is to select preferred solution that maximizes or minimizes some objective function
- Subject of the trade study are the vehicle alternatives with different engines
 - Alternatives can be modeled as variants
- Evaluate objective function for each alternative
 - Criteria are parameters of objective function
 - Each criteria may require separate analysis
- Rationale is a kind of annotation

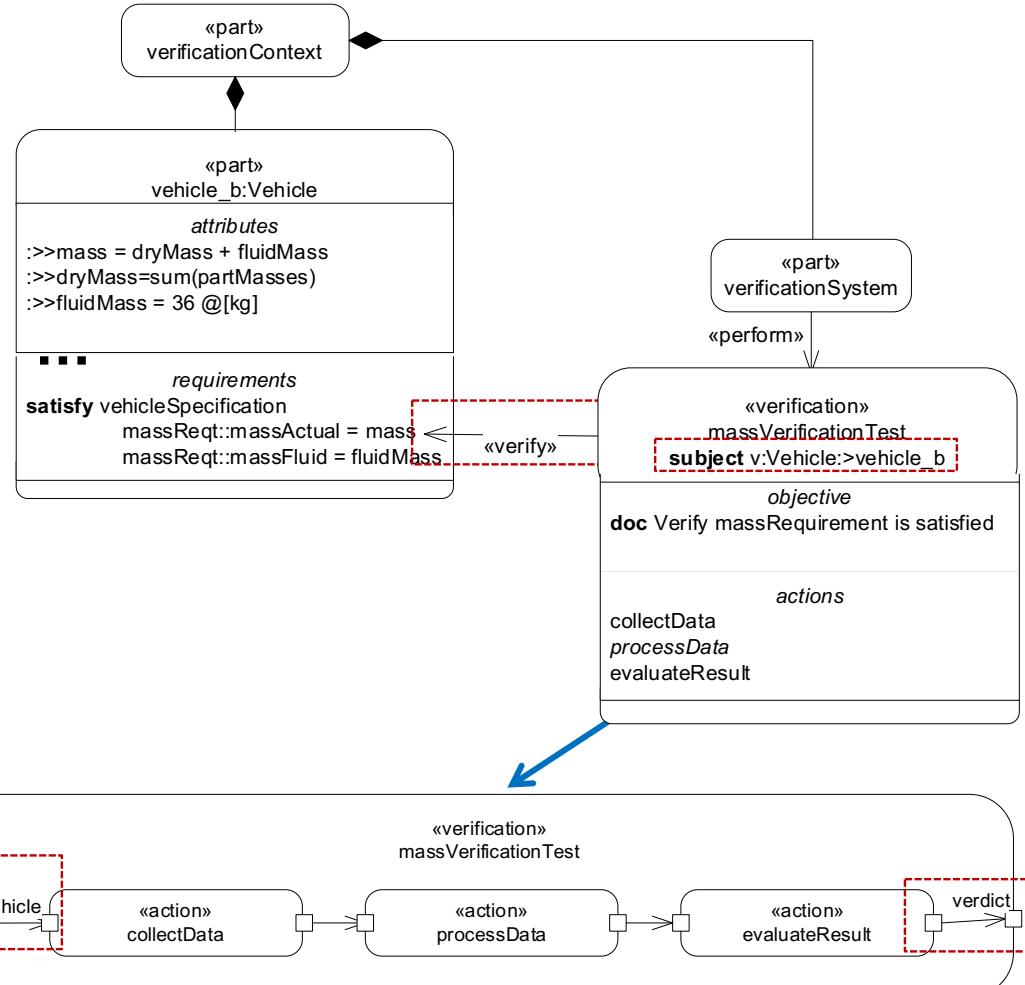


Module 19

Verification Cases

Verification Case

- A set of steps with an objective to evaluate whether the subject of the verification satisfies one or more requirements
 - A kind of behavior
 - Steps typically include collect data, process/reduce data, evaluate result
 - Input is the subject of the verification
 - Returns a result called a verdict whose value is pass, fail, inconclusive, or error
 - Verify relationship binds verification case to subject
 - Verification case is performed by verification system in a context

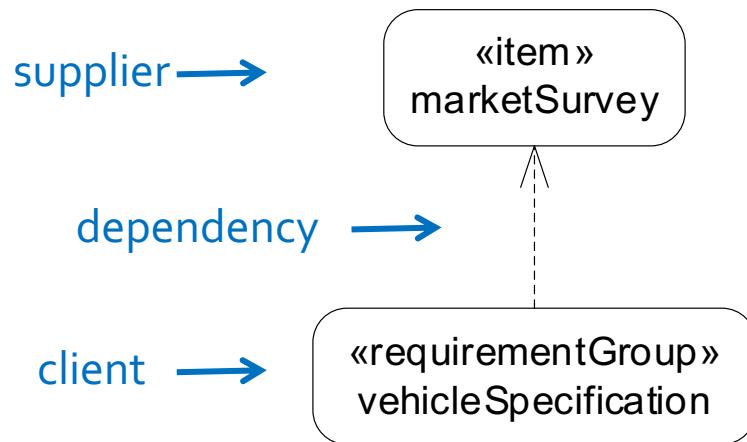


Module 20

Dependency and Allocation Relationships

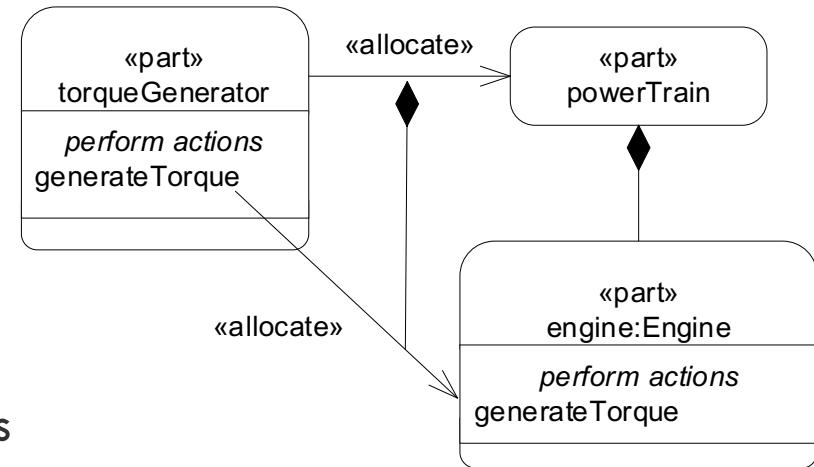
Dependency

- A directed relationship where the element on the client end may be impacted when the element on the supplier end changes
 - Example: Use of dependency to represent traceability between specification and source document
 - Can have 1.. many clients and 1.. many suppliers



Allocation

- A statement of intent that assigns responsibility from one set of elements to another set of elements
 - A kind of mapping (1 to n)
 - Includes definition and usage **v2**
 - Can include suballocations **v2**
- Examples
 - Actions to components
 - Logical components to physical components
 - Logical connections to physical connections
 - Budget allocation (e.g. weight budget)
 - Software to hardware
 - Requirements to design elements
 - ...



The torque generator
is allocated to the powertrain,
and realized by the engine

Module 21

Annotations

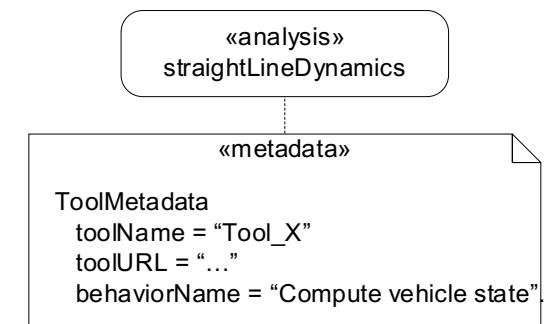
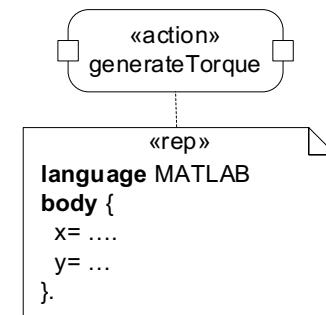
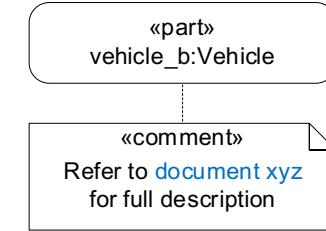
Annotations

- An Annotating Element is an Element that is used to provide additional information about other elements
 - Can be named
 - Can apply to 0.. many elements
- An annotation is a kind of relationship that relates the annotating element to the element being annotated
- Kinds of annotating elements
 - Comment
 - Documentation is an owned comment
 - Textual representation (e.g., opaque expression)
 - Includes name of language and body
 - Annotating feature
 - Used to add structured metadata

v2

v2

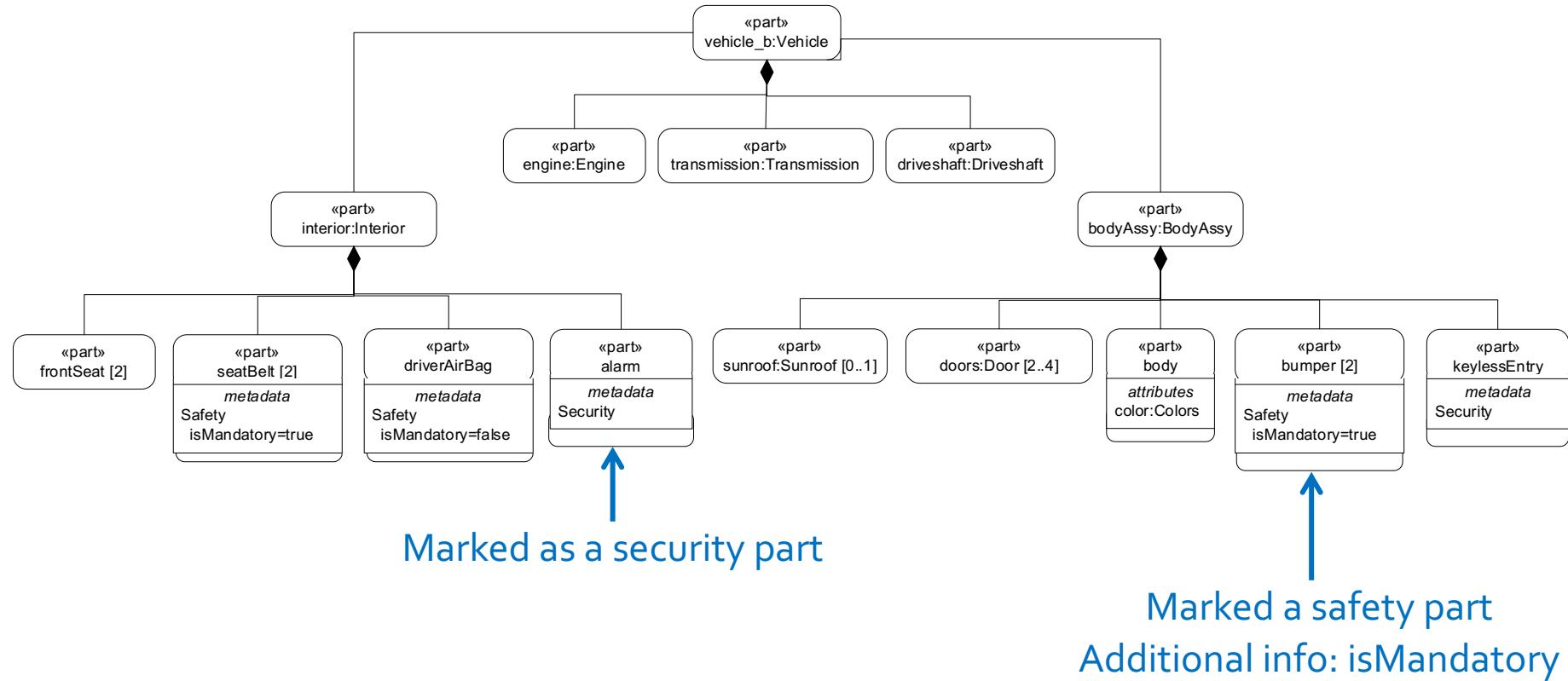
v2



Metadata

- Use metadata to mark elements **v2**

- Identify parts that are Security or Safety parts (e.g., members of Security or Safety group)
- Can add additional security and safety information

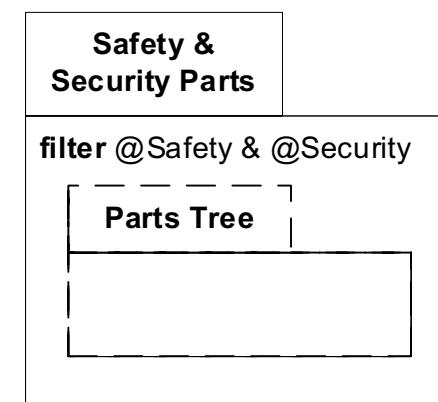
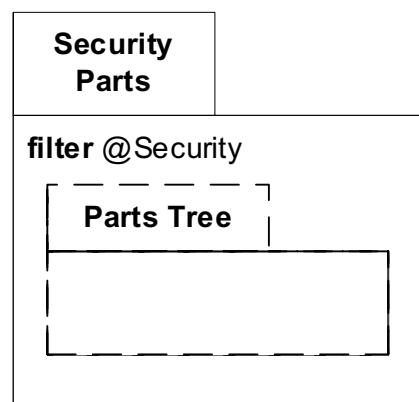
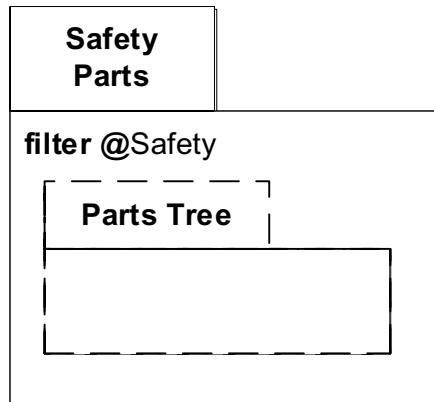


Module 22

Element Filters

Element Filters

- Used to select elements from a group of elements
 - Create a package
 - Import the part of the model that contains the elements of interest
 - Use a recursive import to include all nested elements
 - Define the filter expression to select the imported elements based on the selection criteria



Filter selects parts marked with Safety metadata

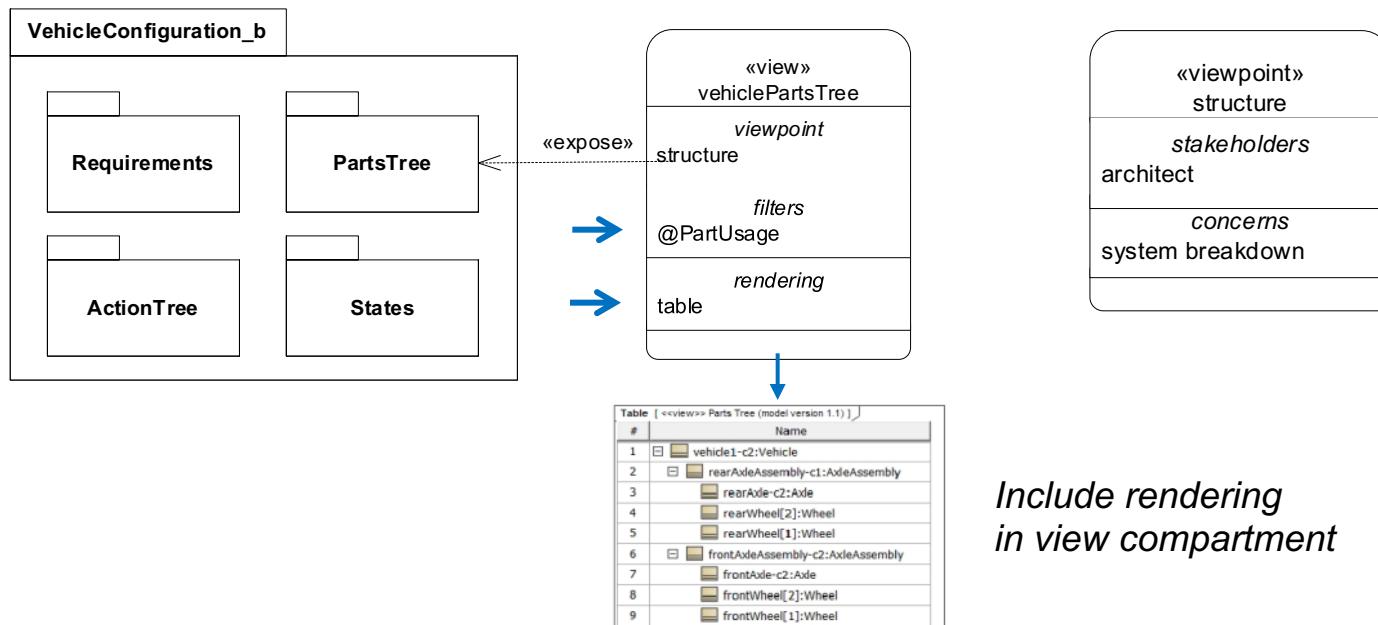
Module 23

View & Viewpoint

View and Viewpoint

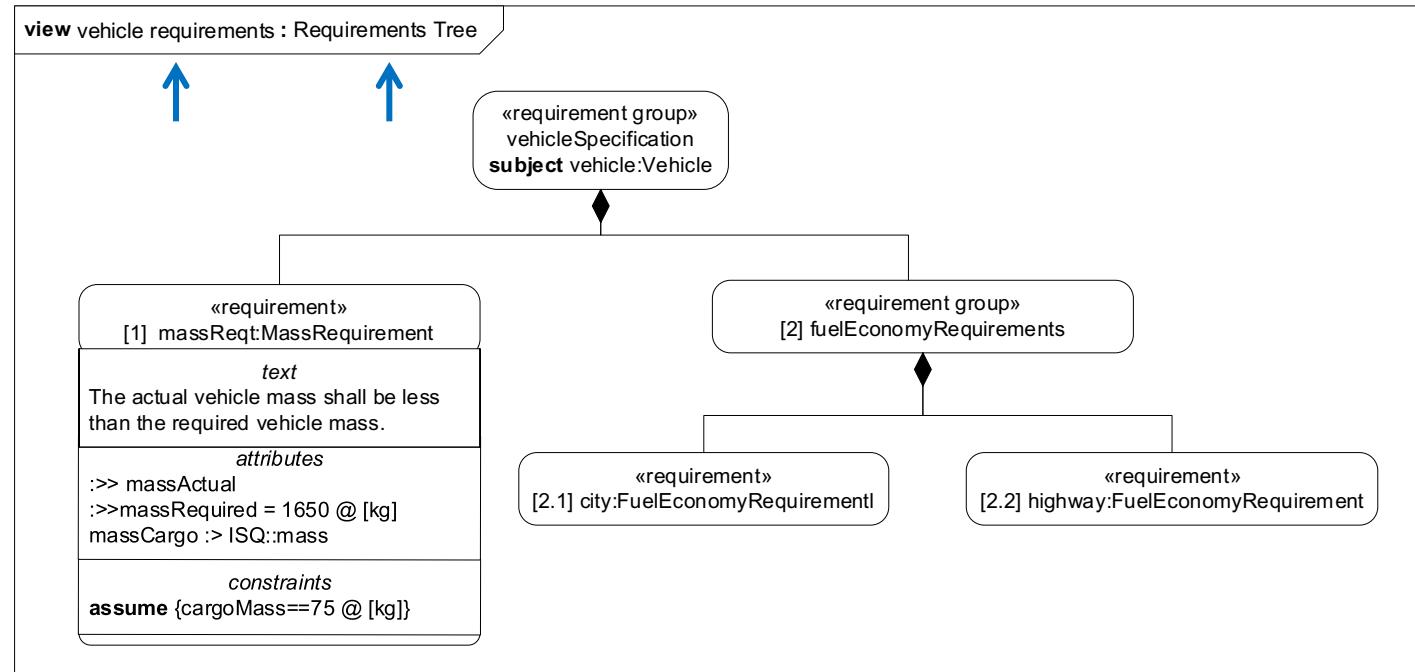
- A Viewpoint reflects the concerns of one or more stakeholders in terms of what they care about relative to a domain of interest
- A View specifies an artifact to present to a stakeholder to satisfy their viewpoint
 - Exposes the scope of the model to be viewed
 - Filters the model to select a particular subset based on a scope and filter criteria
 - Renders the filtered results using a particular presentation form and style
 - Intended to support document generation (e.g., OpenMBEE)

v2



SysML v2 Views and Diagrams

- A view artifact (e.g., diagram, table, document) is a rendering of a set of model elements that is specified by a view usage
 - Frame represents a view that renders model elements which are exposed and filtered
 - View definition (e.g., diagram kind)
 - View name (e.g., diagram name)
 - View content



- Standard diagram kinds / view definitions (topology and filter)
 - Relationship view (general graph with navigable nodes and edges)
 - Tree/ hierarchy view (i.e., a relationship view that filters on membership)
 - Nested/interconnection view
 - Tabular/Matrix view
 - Textual view
 - Additional constraints (temporal, spatial ordering, swim lanes)
- A diagram/view can contain nested diagrams/views (e.g., sub views)
- User defined views and view definitions
 - Users are not constrained by the standard views

SysML v2 Compartments

- Compartments are views of the element represented by the node
- Compartment names represent view definitions
- Standard compartments / view definitions
 - List view of contained elements of a particular kind (e.g., attributes, actions, ports)
 - List view of elements at the other end of relationships (e.g., allocation, specialization, ...)
- A compartment can be rendered using textual (e.g., list view) or graphical notation
- Nested view is a kind of graphical compartment where elements are represented as graphical symbols
- Ports are connectable nodes on the boundary of a part

«part def»
Vehicle
attributes
mass:>ISQ::mass
dryMass
cargoMass
electricalPower
position
velocity
acceleration
...
ports
pwrCmdPort
vehicleToRoadPort
...
perform actions
providePower
provideBraking
controlDirection
...
exhibit states
vehicleStates

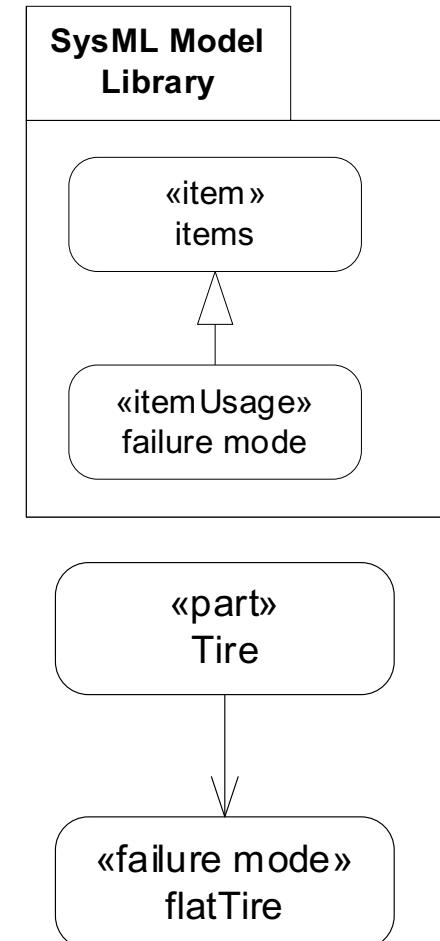
Module 24

Language Extension

Language Extension

In Process

- Provides ability to extend concepts in SysML v2 to address domain-specific concepts and terminology
- Define concept by subclassing an element in the SysML Model Library **v2**
- Apply the concept to an element **define the concept →**



apply the concept →

Summary



SST

Contrasting SysML v1 with SysML v2

- **Simpler to learn and use**

- Systems engineering concepts designed into metamodel versus added-on
- Consistent definition and usage pattern
- More consistent terminology
- Ability to decompose parts, actions, ...

- **More precise**

- Textual syntax and expression language
- Formal semantic grounding
- Requirements as constraints
- Reified relationships (e.g., membership, annotation)

- **More expressive**

- Variant modeling
- Analysis case
- Trade-off analysis
- Individuals, snapshots, time slices
- More robust quantitative properties (e.g., vectors, ..)
- Filter expressions

- **More extensible**

- Simpler language extension capability
 - Based on model libraries

- **More interoperable**

- Standardized API

References

- Monthly Release Repository (release 2021-08)
 - <https://github.com/Systems-Modeling/SysML-v2-Release>
- SysML v2 Specification (revised submission)
 - Note: refer to Annex B for Example Vehicle Model using textual notation
- Introduction to the SysML v2 Language Textual Notation (release 2021-08)
- Friedenthal S., Seidewitz E., A Preview of the Next Generation System Modeling Language (SysML v2), Project Performance International (PPI), [Systems Engineering Newsletter, PPI SyEN 95 27 November, 2020](#)