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Using Model-based Product Line Engineering for Decision Making and to Guide Product Development

Matthew Hause
PTC Engineering Fellow

Andreas Korff
PTC Director Business
Development MBSE



Agenda

- The Evolution of Systems
- Orthogonal Variability Modeling
- Product line Engineering
- Trade-off Analysis
- Conclusions

The Evolution of Systems

- Normally we start with this....



The Evolution of Systems

- Which becomes this....



The Evolution of Systems

- And eventually this....



The Evolution of Systems

- So, why not start with this?



The Evolution of Systems

- Or at least this?



The Evolution of Systems

- However, we certainly don't want this.



System Product Line Engineering (PLE) Challenges

- Increasing number of product families
- Increasing number of products in families
- Understanding product similarity
- Maximizing reuse
- Understanding product variations
- Deciding between options
- Development cycle time
- Commercial product needs
 - Customize existing capabilities to suit client requirements
 - Redeploy common systems & software to the Market



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The Four Pillars of SysML



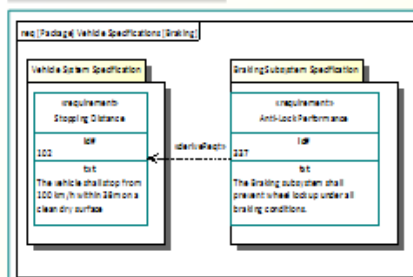
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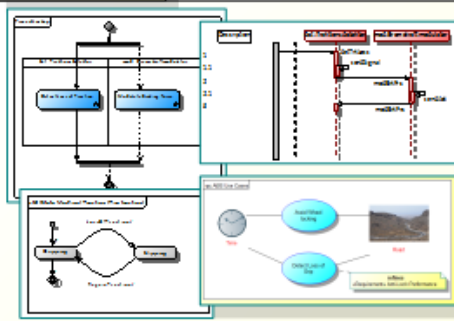
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pkg [Package] the 4 Pillars of SysML [Overview]

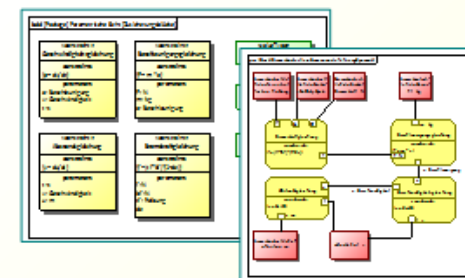
System Requirements



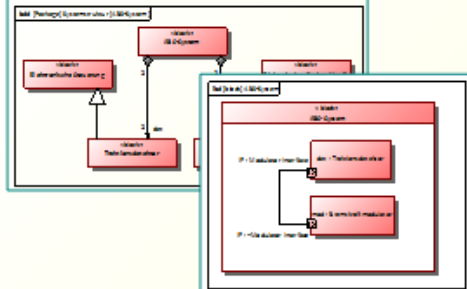
System Behavior



Parametric View



System Structure

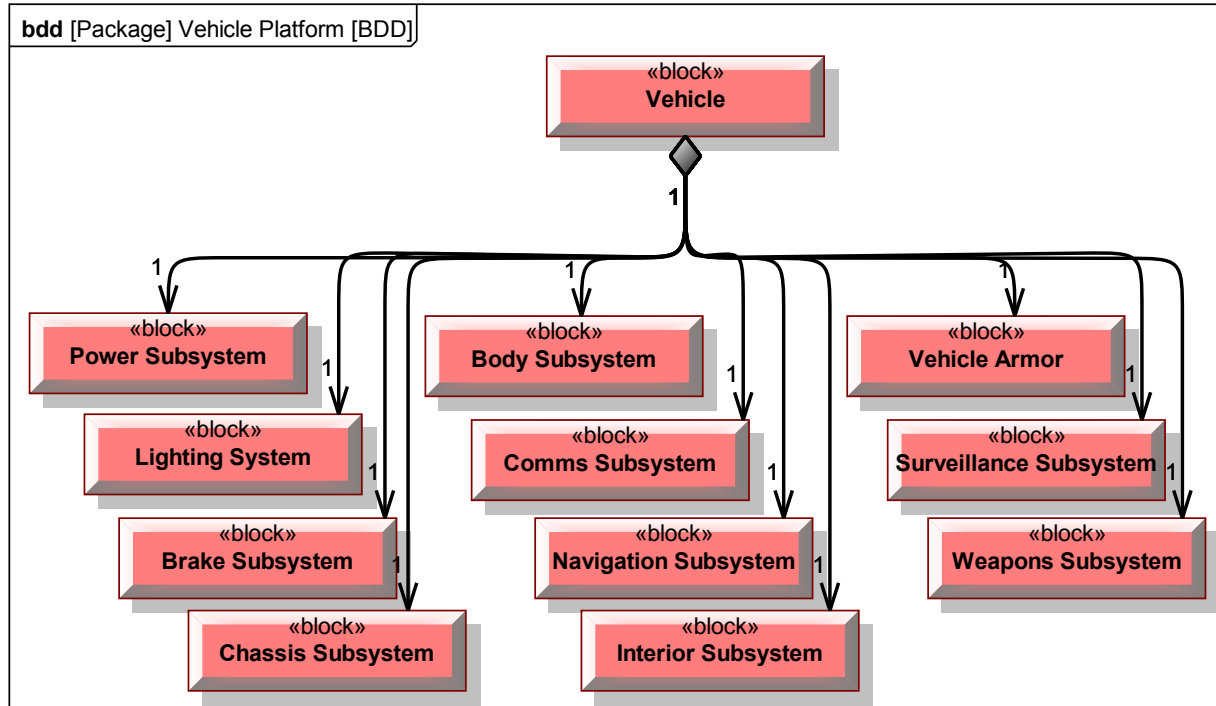


Vehicle Breakdown Structure

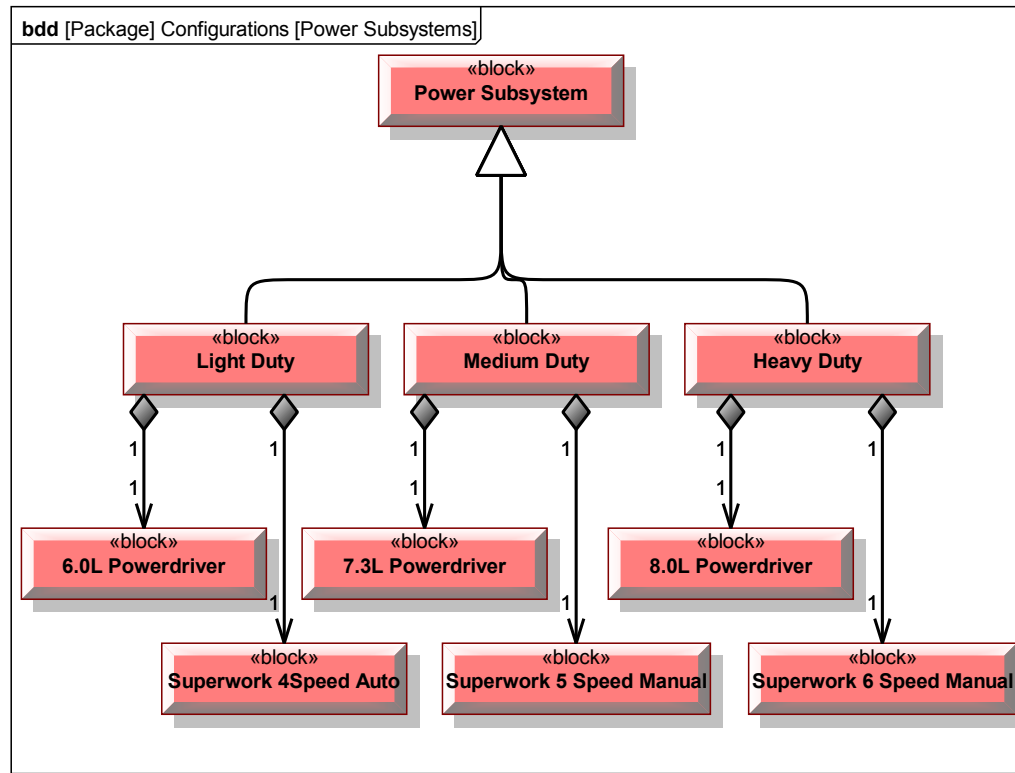


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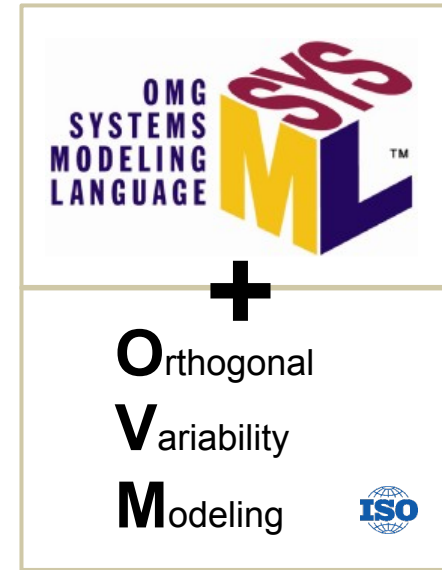
Power Subsystem Options



The Solution ... Model-Based Product Line Engineering

Designing a single system platform rather than as creating a multitude of products

- MBSE + Modular Design + Variation
 - Common language improves
 - Communication
 - Collaboration
 - Stakeholder buy in
 - Architected modular design & reuse
 - System product lines designed up front
- Maximum commonality & minimal variation
 - Less duplicated effort with optimized reuse
 - Parallel working through 'design by contract'
 - More commonality between designs and implementations
 - Managed product line complexity



Decisions, decisions, decisions



- Decision based modeling
 - Investigate the choices
 - Establish the decision framework
 - Define the corresponding choices
 - Determine the trade-off criteria
 - Generate the product models
 - Analyze the product model(s)
 - Repeat as necessary
- Basically, figure out where you want to go before you start the journey

Variant Modeling in OVM

- Variant Diagram
- Variation on all Diagrams
- Simple Notation



Variation Point

Variant

Variability Dependency

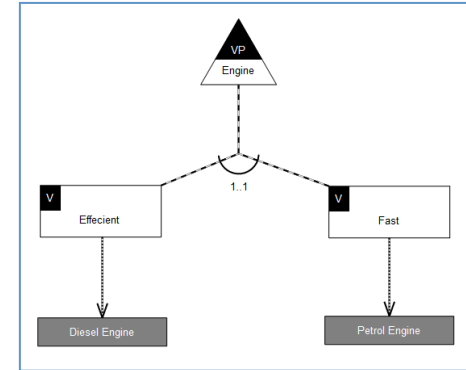
Mandatory/Optional

Requires Dependency

Excludes Dependency

Artifact Dependency

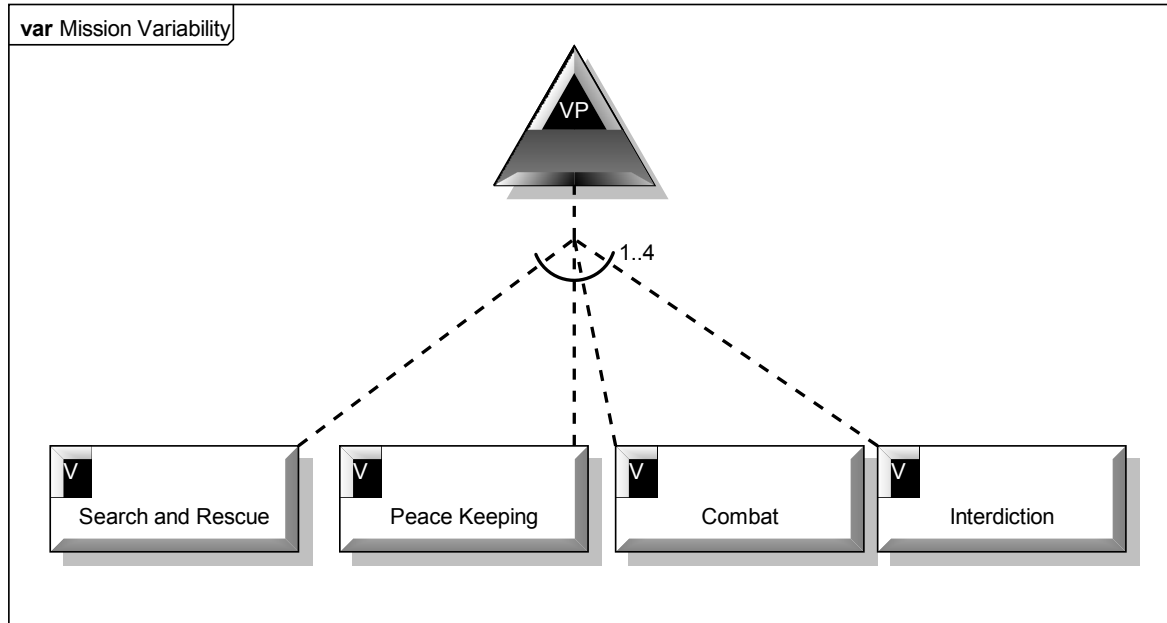
Alternate Choice



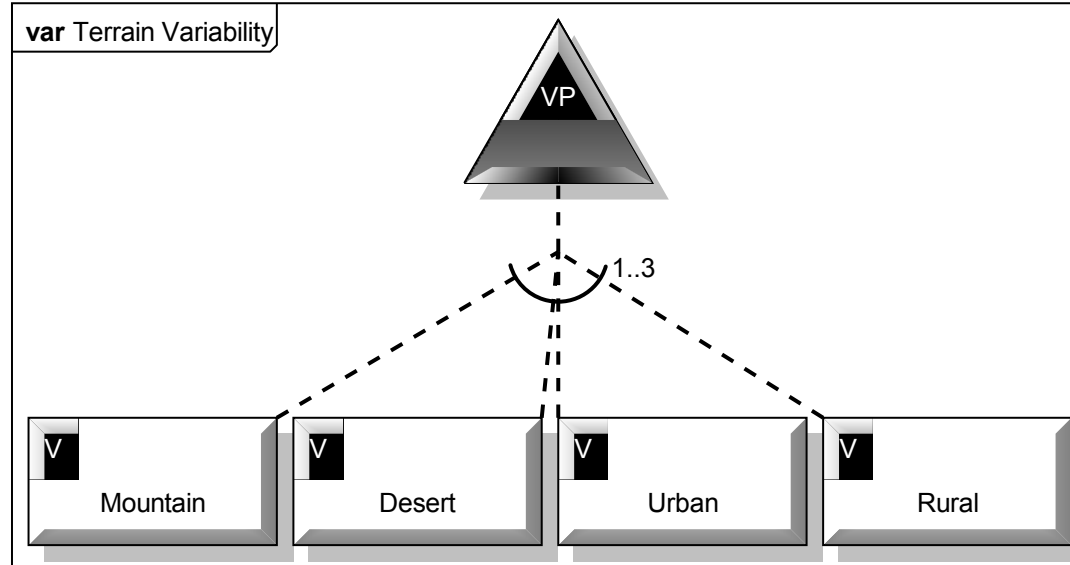
- OVM

PALUNO, The Ruhr Institute of Software Technology
Software Product Line Engineering (Pohl et al - Springer 2005)

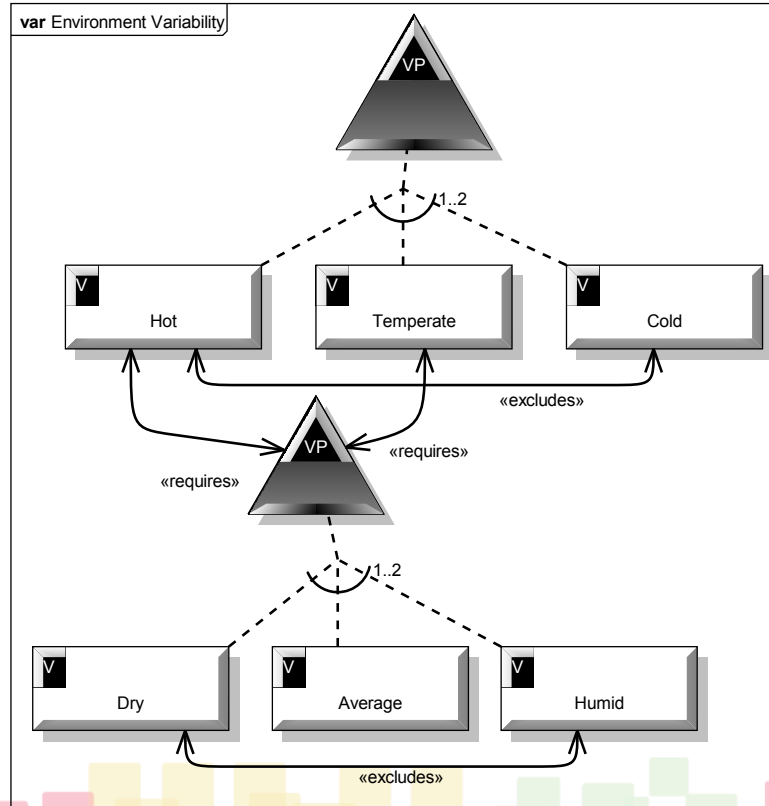
The Mission Purpose



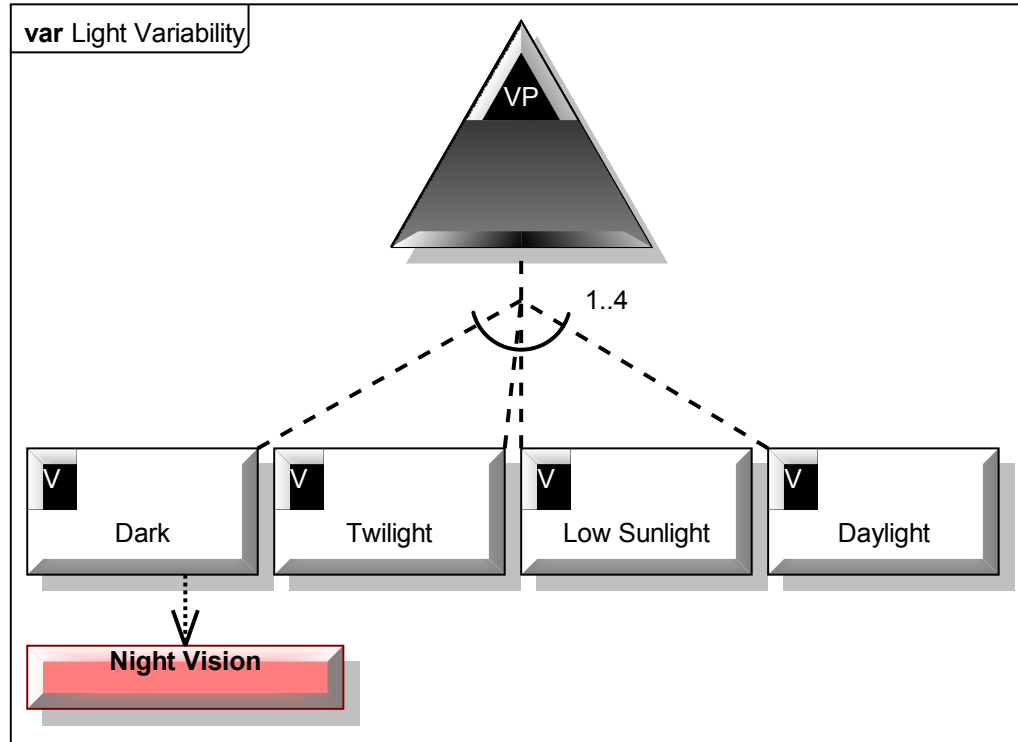
Terrain Variability



Environment Variability



Light Variability

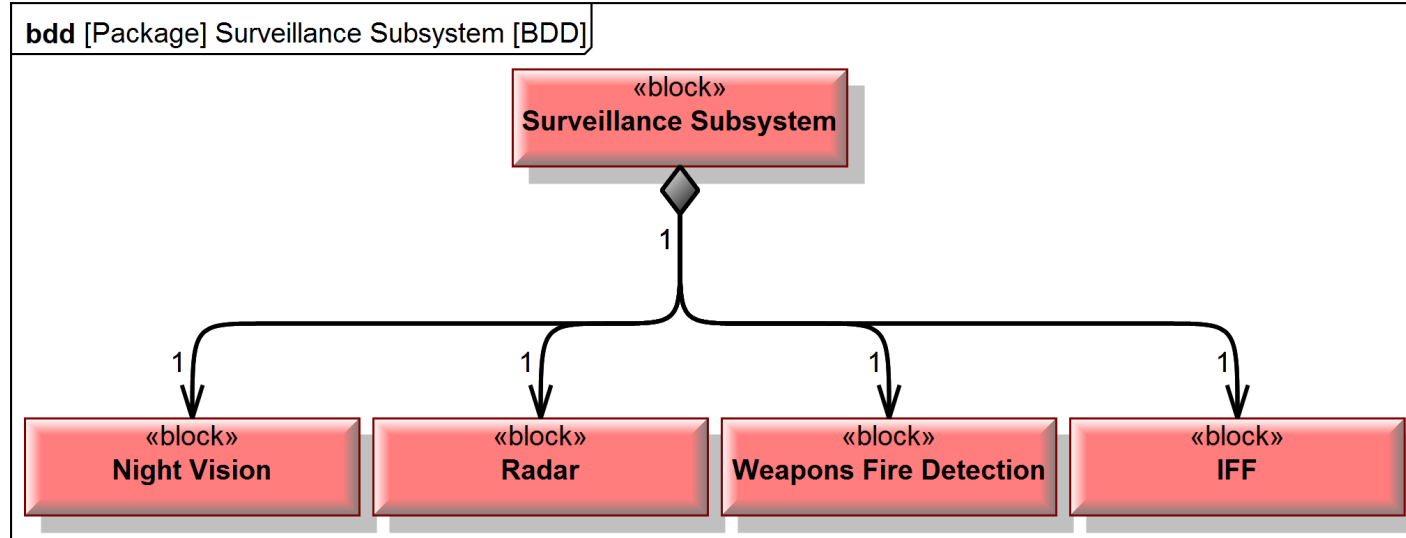


Surveillance Systems

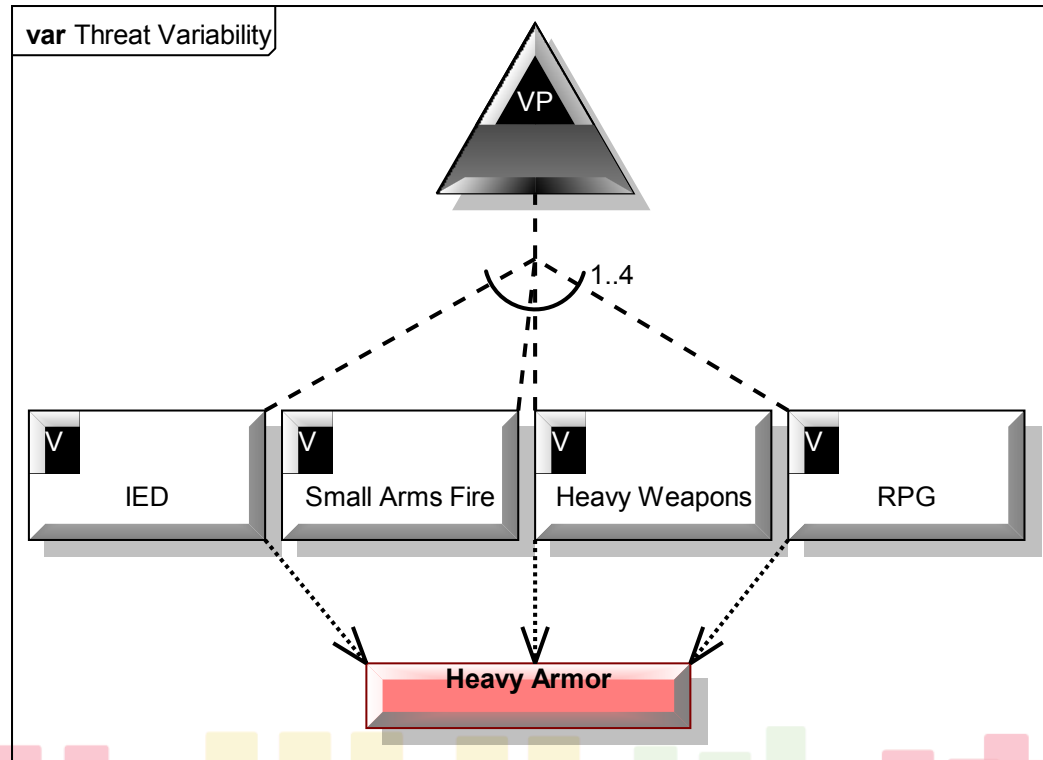


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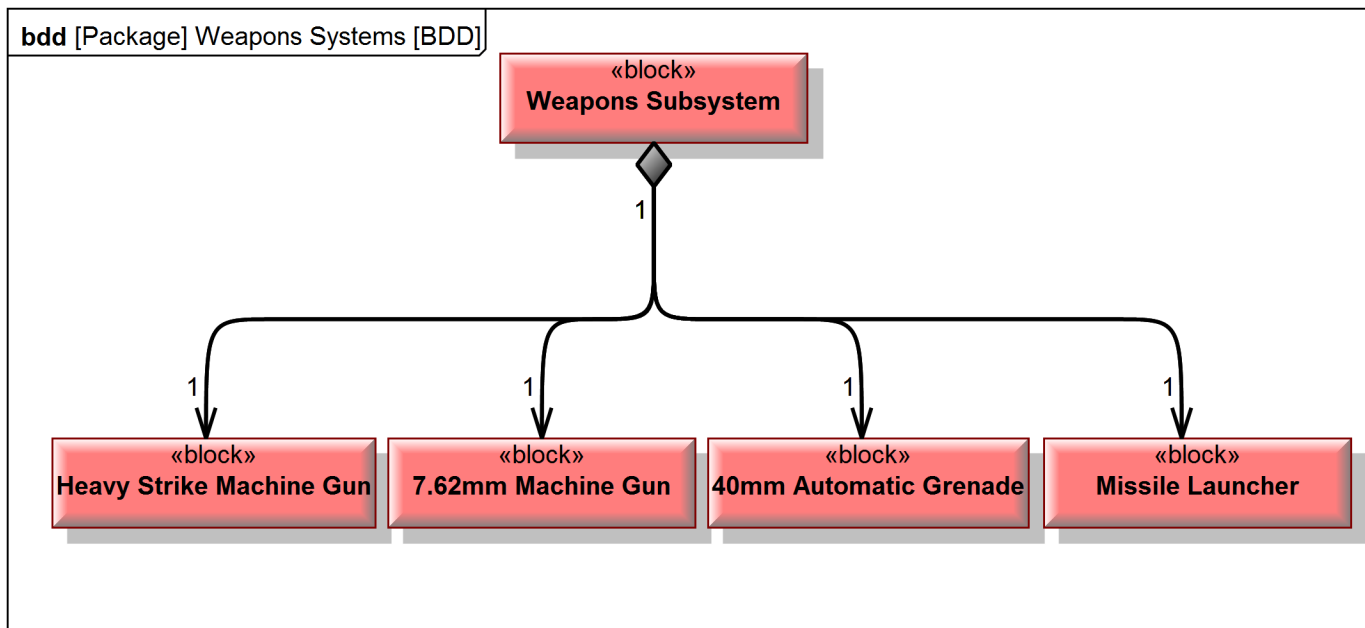
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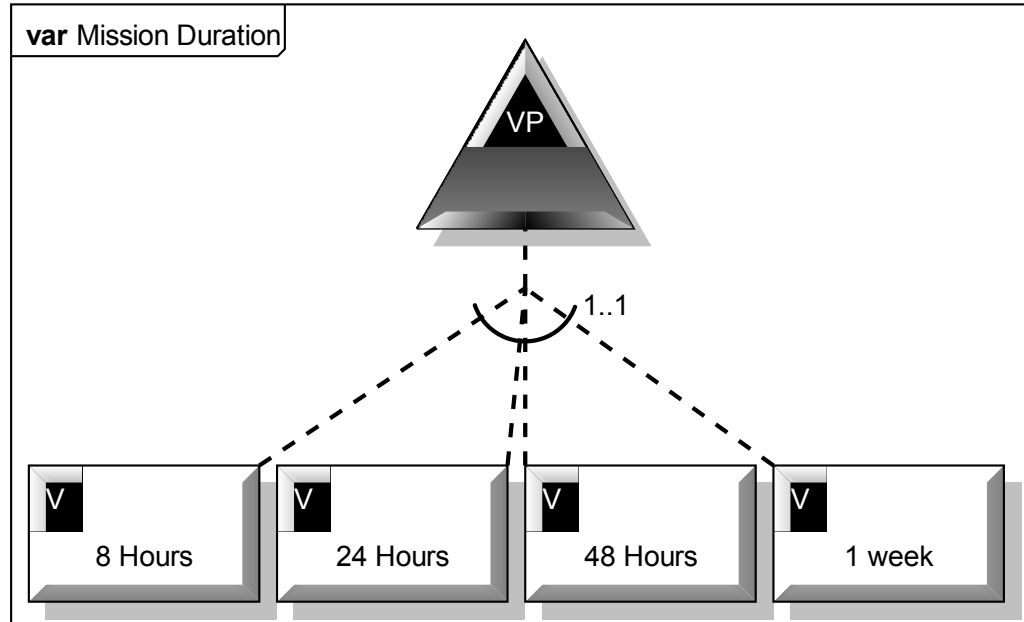
Threat Variability



Weapons Systems



Trade-Off Analysis

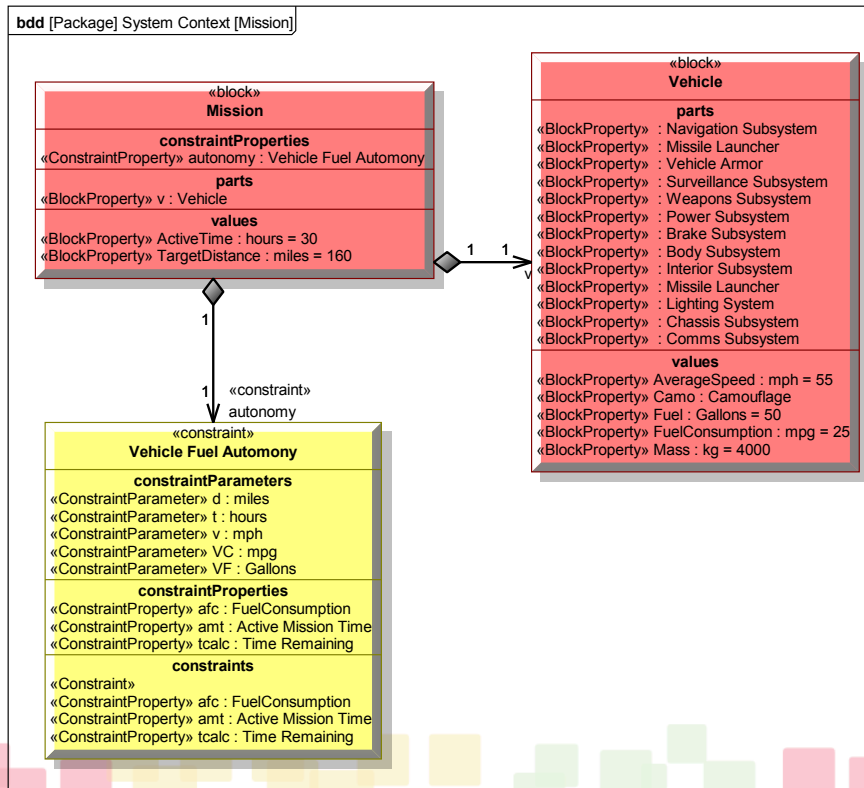


Mission Analysis



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Mission Constraints

bdd [Package] Parametrics [Constraint Types]

«constraint»

FuelConsumption

constraintParameters

«ConstraintParameter» cons : mpg
«ConstraintParameter» remf : Gallons
«ConstraintParameter» t : hours

constraints

«Constraint»

«constraint»

Active Mission Time

constraintParameters

«ConstraintParameter» d : miles
«ConstraintParameter» t : hours
«ConstraintParameter» v : mph

constraints

«Constraint» $t=d/v$

«constraint»

Time Remaining

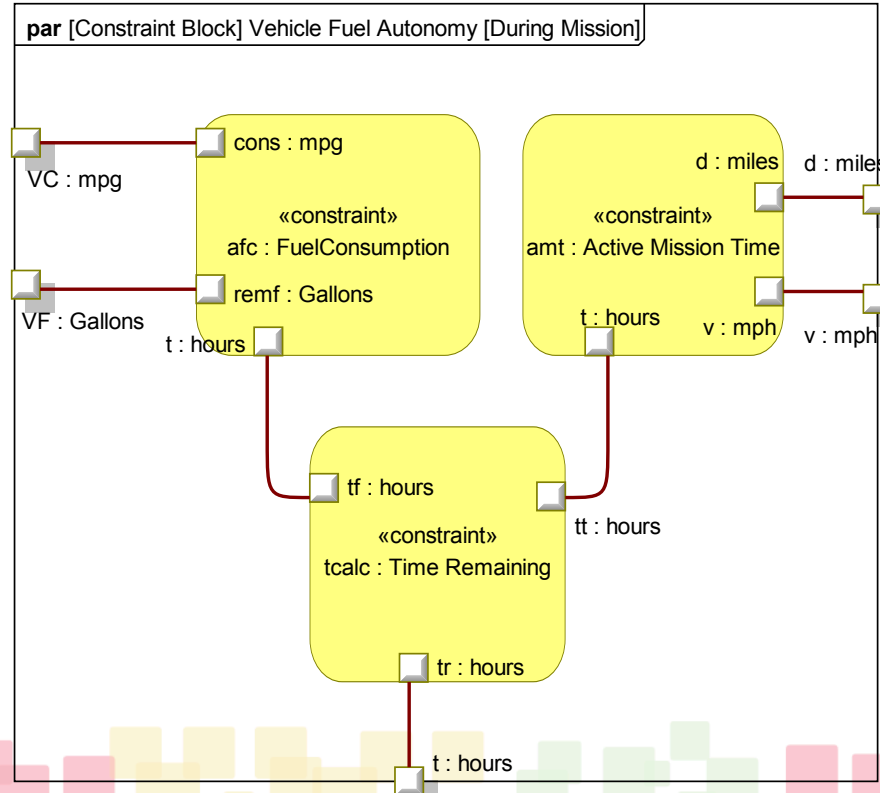
constraintParameters

«ConstraintParameter» tf : hours
«ConstraintParameter» tr : hours
«ConstraintParameter» tt : hours

constraints

«Constraint» $tr=tf-tt$

Fuel vs. Time vs. Weight

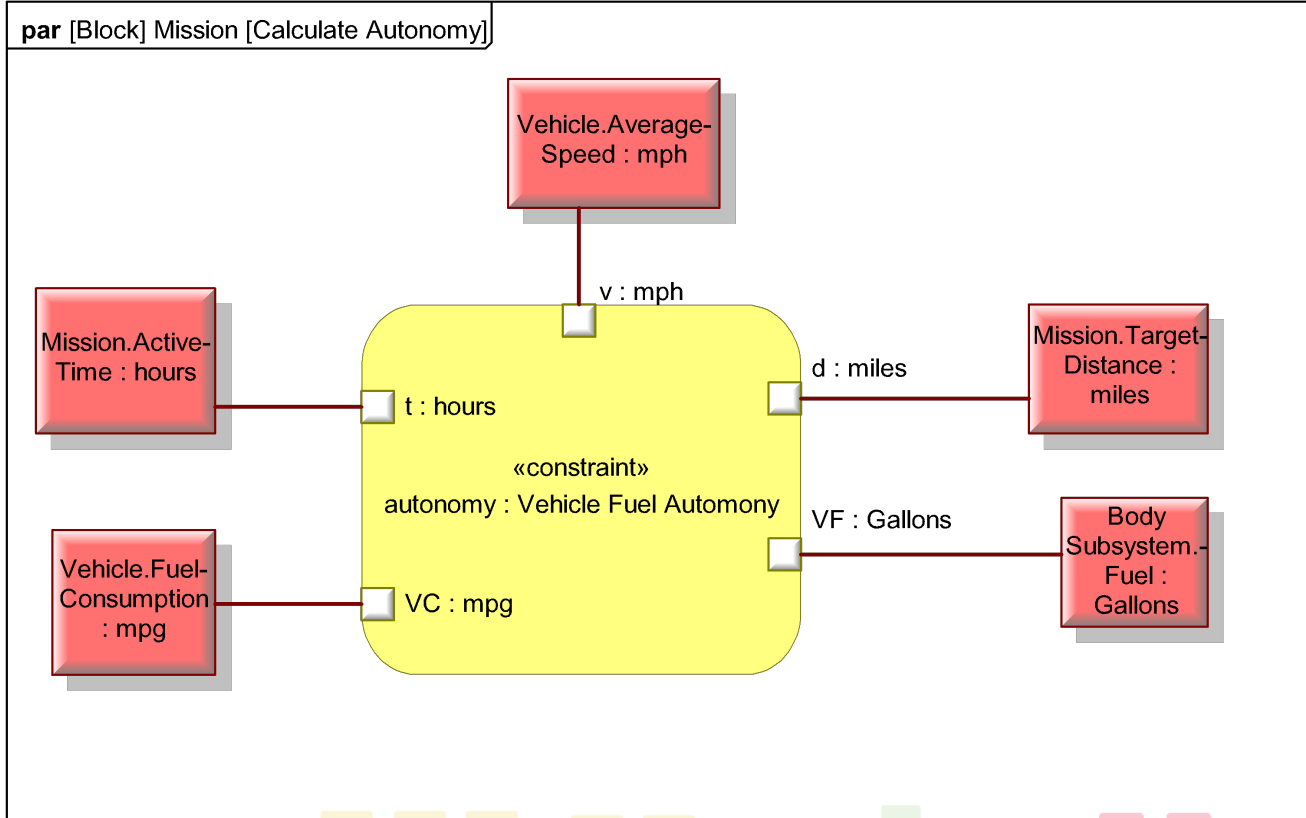


Linking Mission Parameters

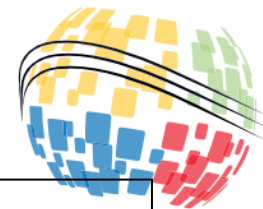


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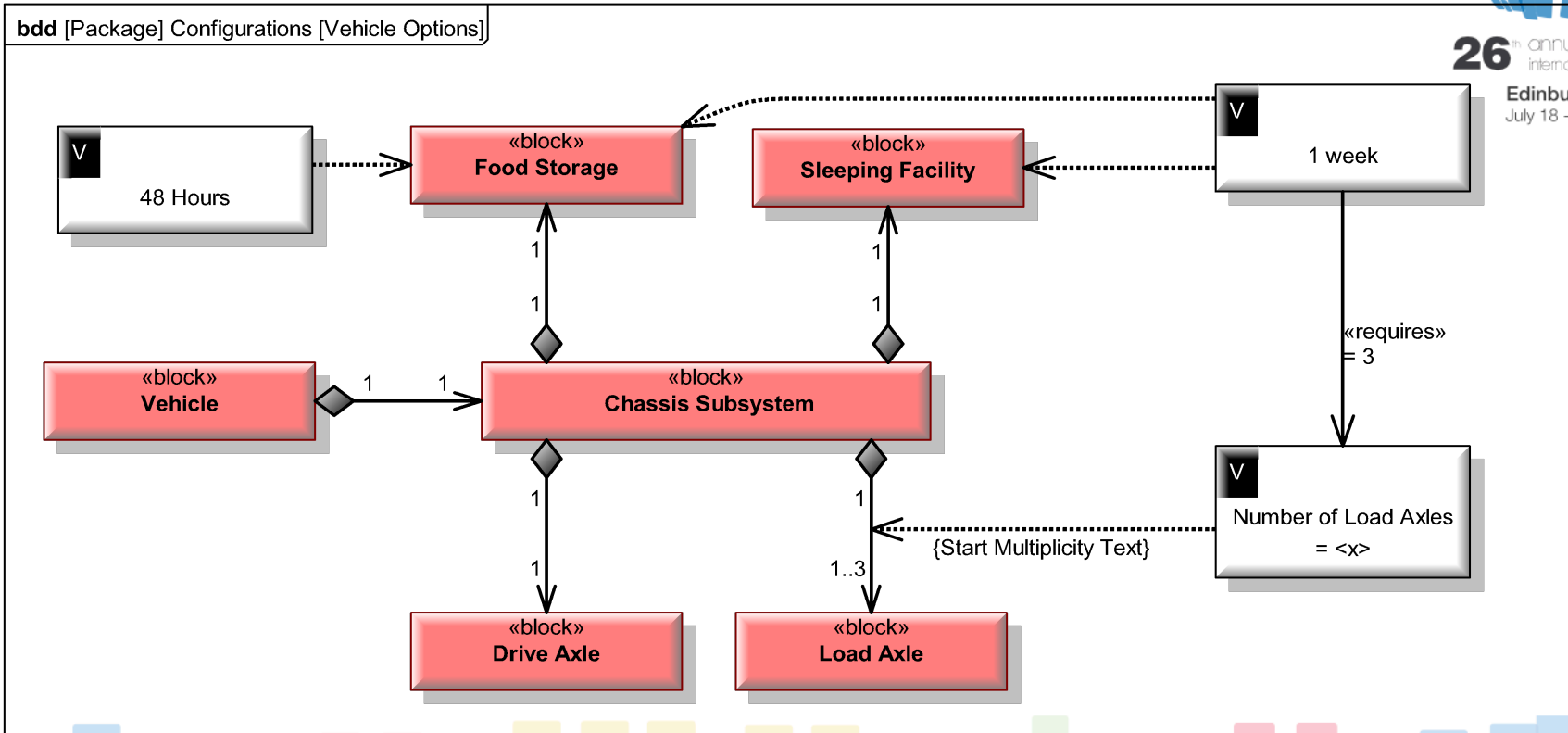
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Vehicle Options: Time vs. Weight



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Additional Rules



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- There are additional rules you can add.
- Variant can have a parameter that can have some values.
- Based on the value you will be able to select it during the Decision or not.
- Other additions are the use of Derivation Scripts that allow the users to have full control over when a variant is allowed or not allowed to be selected.
- Based on other modeling values and or rules the user defines.

The screenshot shows the 'Properties of Number of Load Axes' dialog box with the 'Parameter' tab selected. The 'Has Parameter' checkbox is checked, and the 'Type' is set to 'short'. The 'Has Default' checkbox is unchecked, and the 'Default' value is '1'. The 'Has Maximum Length' checkbox is unchecked, and the 'Max' value is '100'. The 'Multiline Text' checkbox is unchecked. The 'Range Min' is '1' and the 'Range Max' is '3'. The 'Derived' checkbox is unchecked, and the 'Editable' checkbox is checked.

The screenshot shows the 'Properties of Number of Load Axes' dialog box with the 'Derivation Script' tab selected. The script content is as follows:

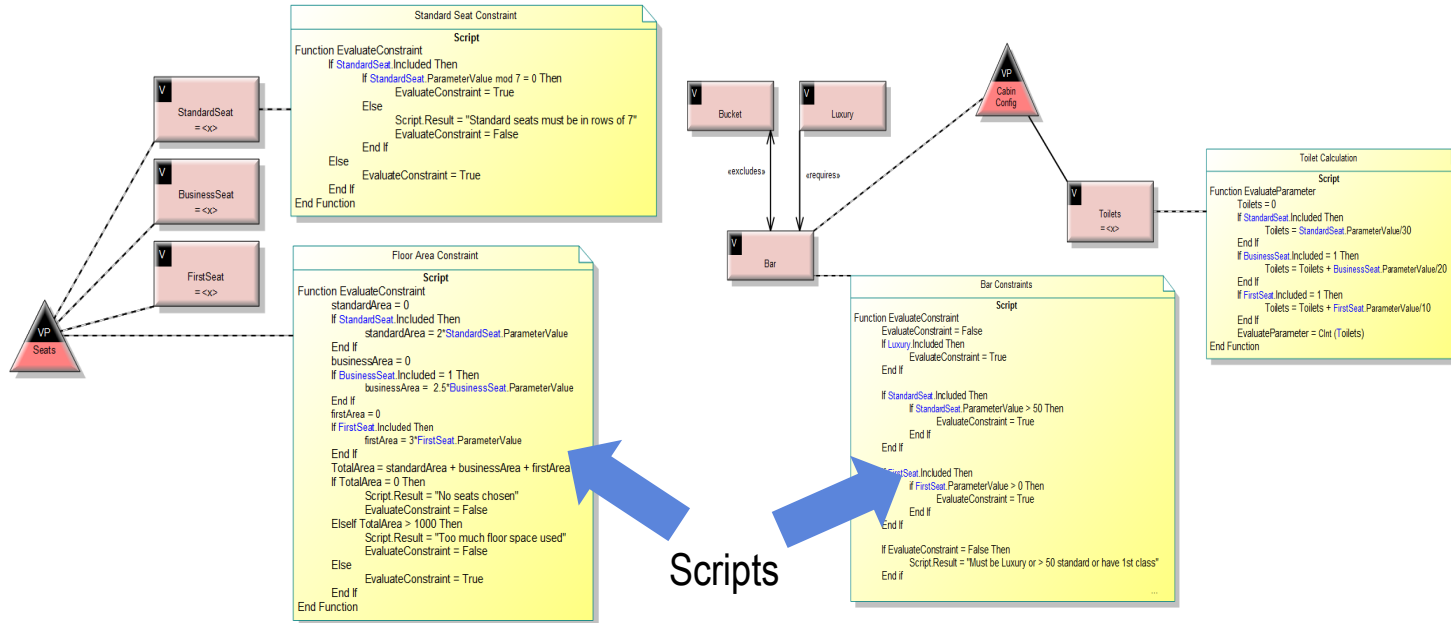
```
Function EvaluateParameter
  if 8 Hours.Included then
    nrOfAxes = 1
  elseif 24 Hours.Included then
    nrOfAxes = 2
  else
    nrOfAxes = 3
  endif
  EvaluateParameter = nrOfAxes
End Function
```

An 'Editor...' button is visible on the right side of the script area.

Model-based Product Line Engineering

Variable Parameters

- Derivation & Validation Scripts

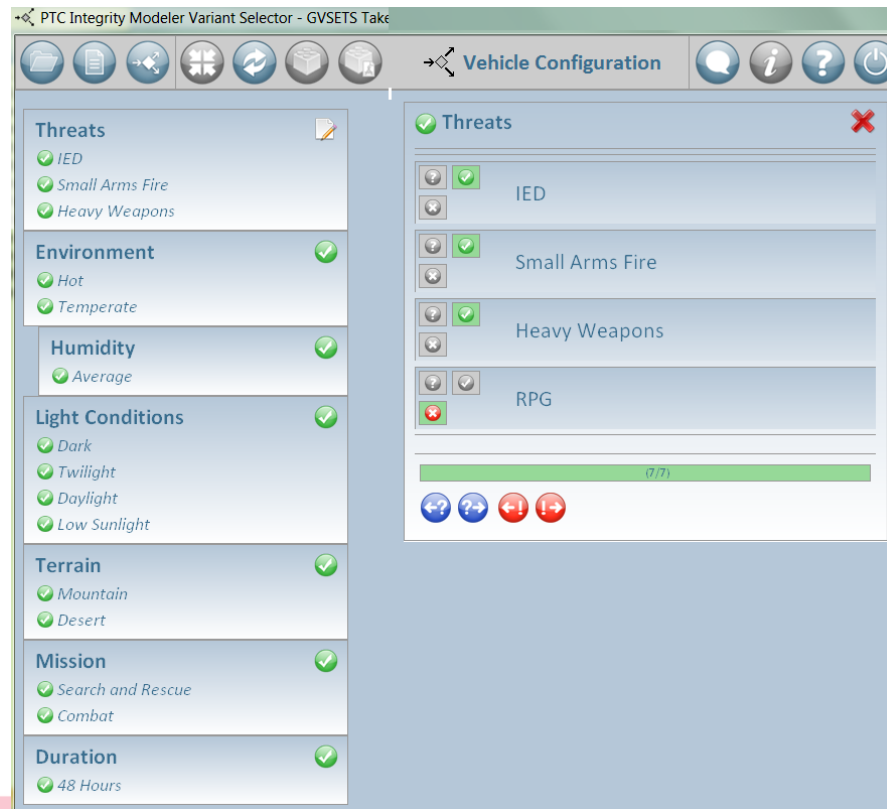


Option Selection



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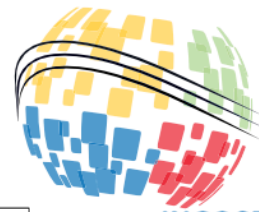
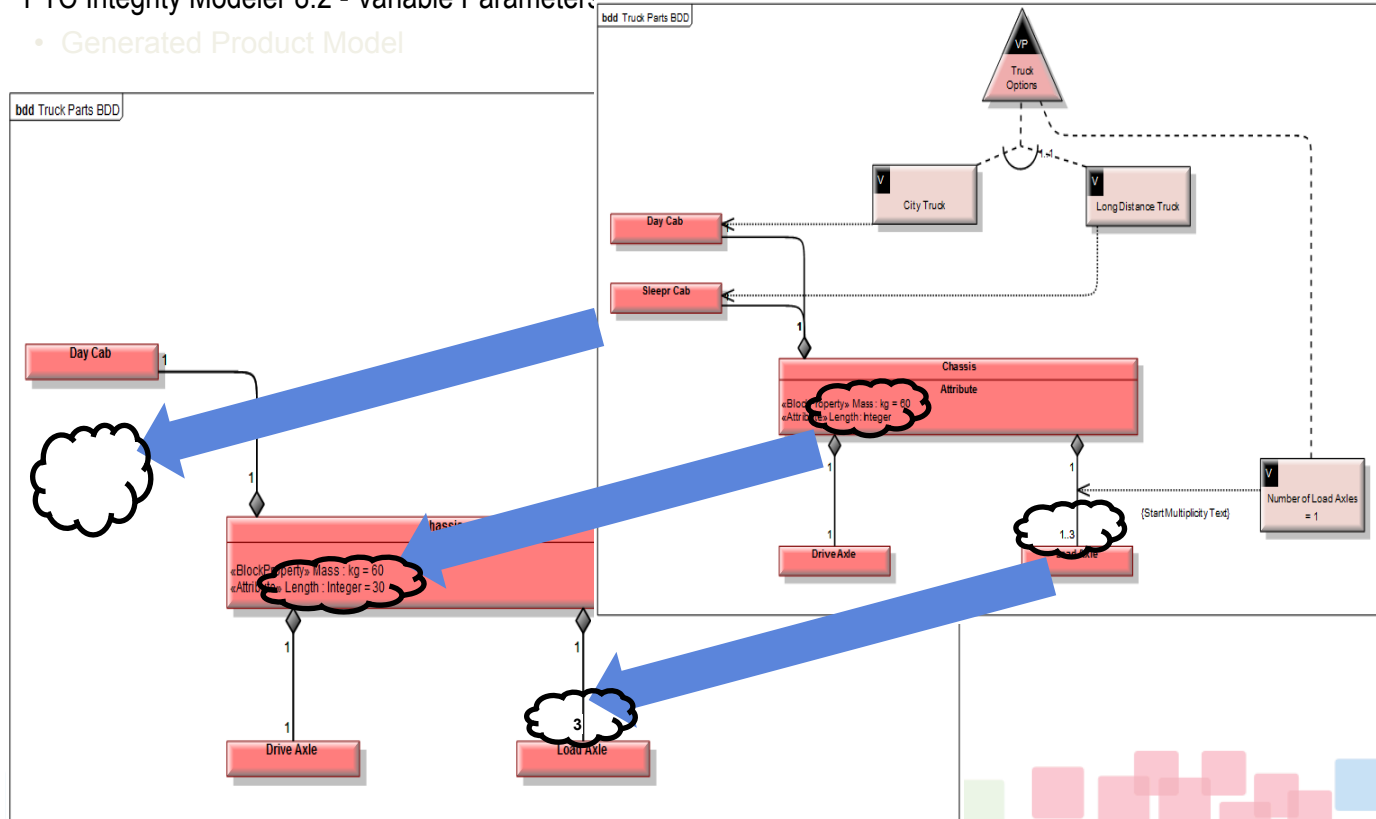
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Model-based Product Line Engineering

PTC Integrity Modeler 8.2 - Variable Parameters

- Generated Product Model



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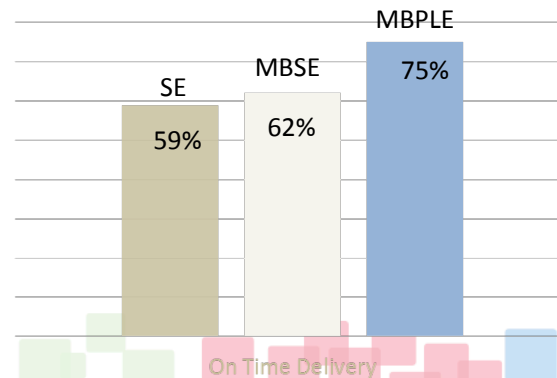
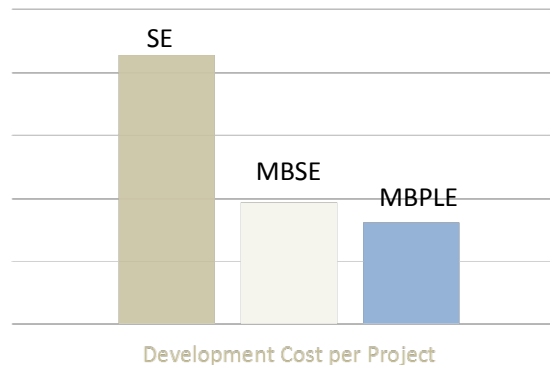
Size, Weight, and Power

	Quantity	Mass (in kg)				
		Estimate	Margin (%)	No Margin	With Margin	Budget
Mission (Vehicle Systems::Struc	n/a	0	0.00%	3800	7980	4000
Vehicle (Vehicle Systems::Stru	1	3800	110.00%	3800	7980	4000
Power Subsystem (Vehicle S	1	0	0.00%	0	0	0
Power Control Unit (Vehicl	1	0	0.00%	0	0	0
Fuel Tank Assembly (Vehicl	1	0	0.00%	0	0	0
Differential (Vehicle Syster	1	0	0.00%	0	0	0
Wheel Assembly (Vehicle S	1	0	0.00%	0	0	0
Battery Pack (Vehicle Syste	1	0	0.00%	0	0	0
Brake Subsystem (Vehicle Sy	1	0	0.00%	0	0	0
Body Subsystem (Vehicle Sys	1	0	0.00%	0	0	0
Interior Subsystem (Vehicle !	1	0	0.00%	0	0	0
Navigation Subsystem (Vehic	1	0	0.00%	0	0	0
Lighting System (Vehicle Syst	1	0	0.00%	0	0	0
Chassis Subsystem (Vehicle S	1	0	0.00%	0	0	0
Comms Subsystem (Vehicle !	1	0	0.00%	0	0	0
Weapons Subsystem (Vehicl	1	0	0.00%	0	0	0

Development Cost Reduction & Delivery Time Improvements

- SE (Non-Modelled Systems Engineering)
 - 59% of Projects Delivered on Time
- MBSE (Model Based Systems Engineering)
 - 62% of Projects Delivered on TimeCompared to SE
 - 55% Reduction in Total Development Cost per Project
- MB-PLE (Model Based Product Line Engineering)
 - 75% of Projects Delivered on TimeCompared to SE
 - 62% Reduction in Total Development Cost per Project

(EMF 2013 Independent Survey Results from 667 Systems engineering respondents)



Summary



- The decision framework guides the product evolution
- Product options are linked to subsystems
- Product commonality can be identified early on
- Single sourcing of equal concepts in Product Family Models
 - Variability as orthogonal or integrated additional information
 - Automated generation of product models based on decision sets
- Asset Reuse of all ISO 26550 Artifacts types possible
 - Top-down, Bottom-Up, IP kept safe
- Model-based Product Line Engineering is the key enabler to develop complex systems in time and in budget

Questions and Answers



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Speaker

Thanks for your attention!