DIGITAL ENGINEERING
/ SYSTEMS ENGINEERING

How Did General Veers Get His AT-AT? Product Line Engineering (PLE), Of Course!

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Agenda

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- Challenges that PLE Solves
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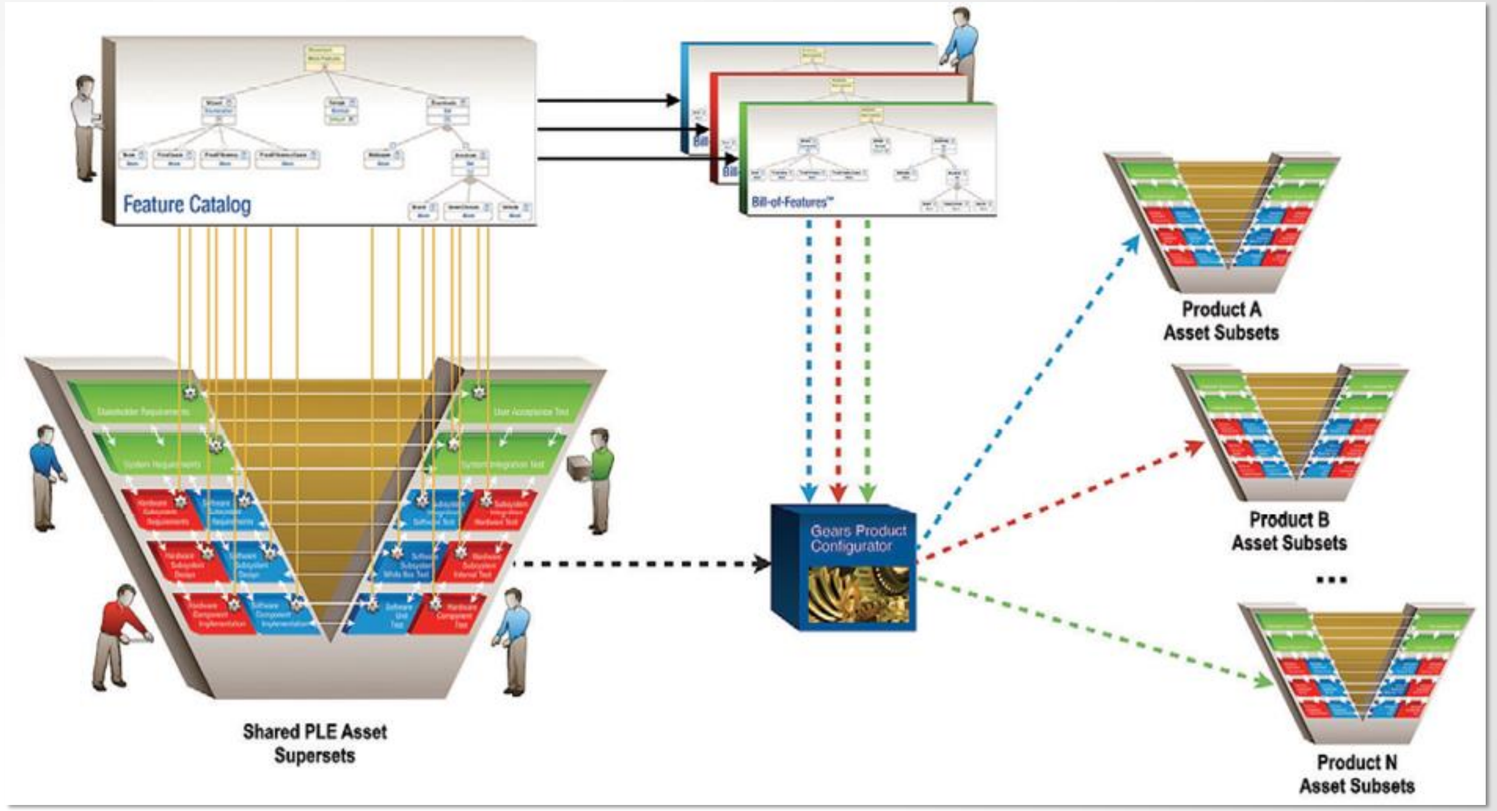
What is PLE?

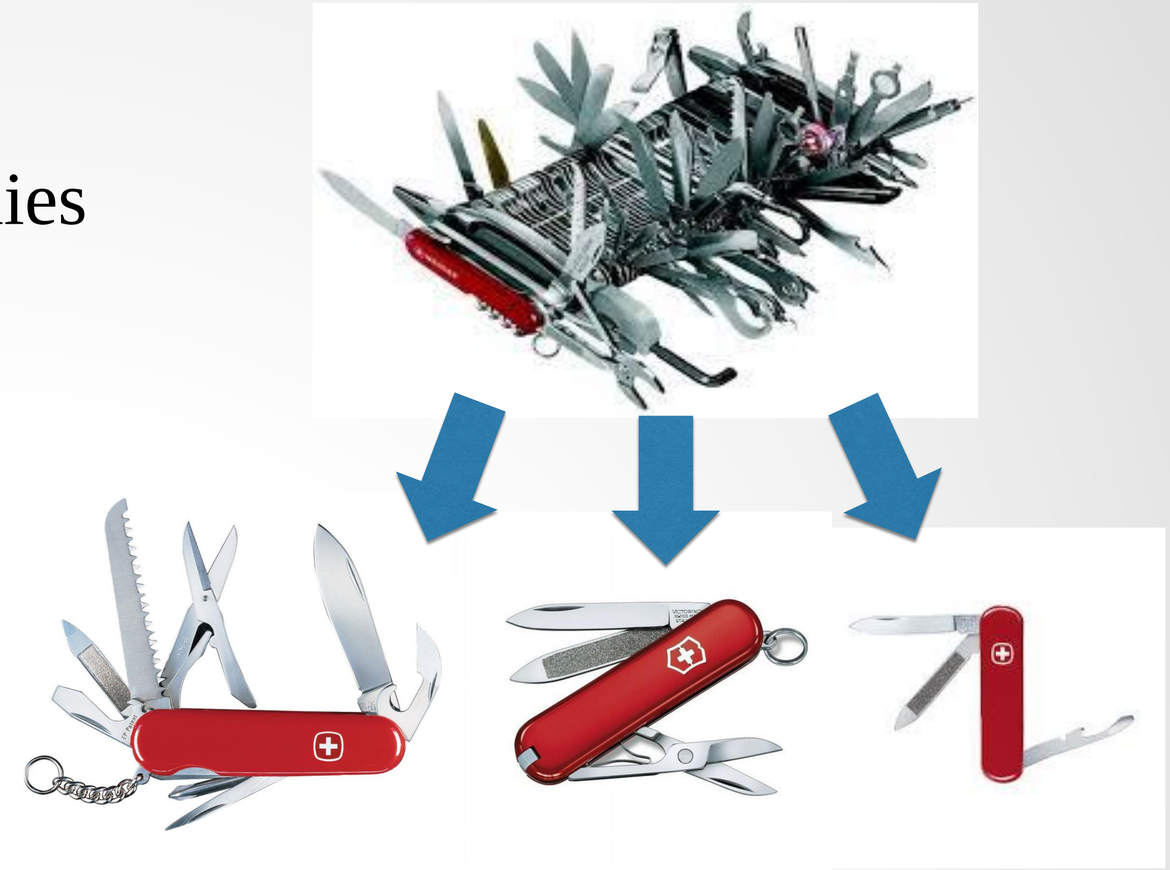
Product Line Engineering (PLE) is the engineering and management of a group of related products using a shared set of assets and a means of design and manufacturing. PLE can include system and software assets and involves all aspects of engineering including electrical, electronic, mechanical, chemical, etc. Model-based Product Line Engineering (MB-PLE)



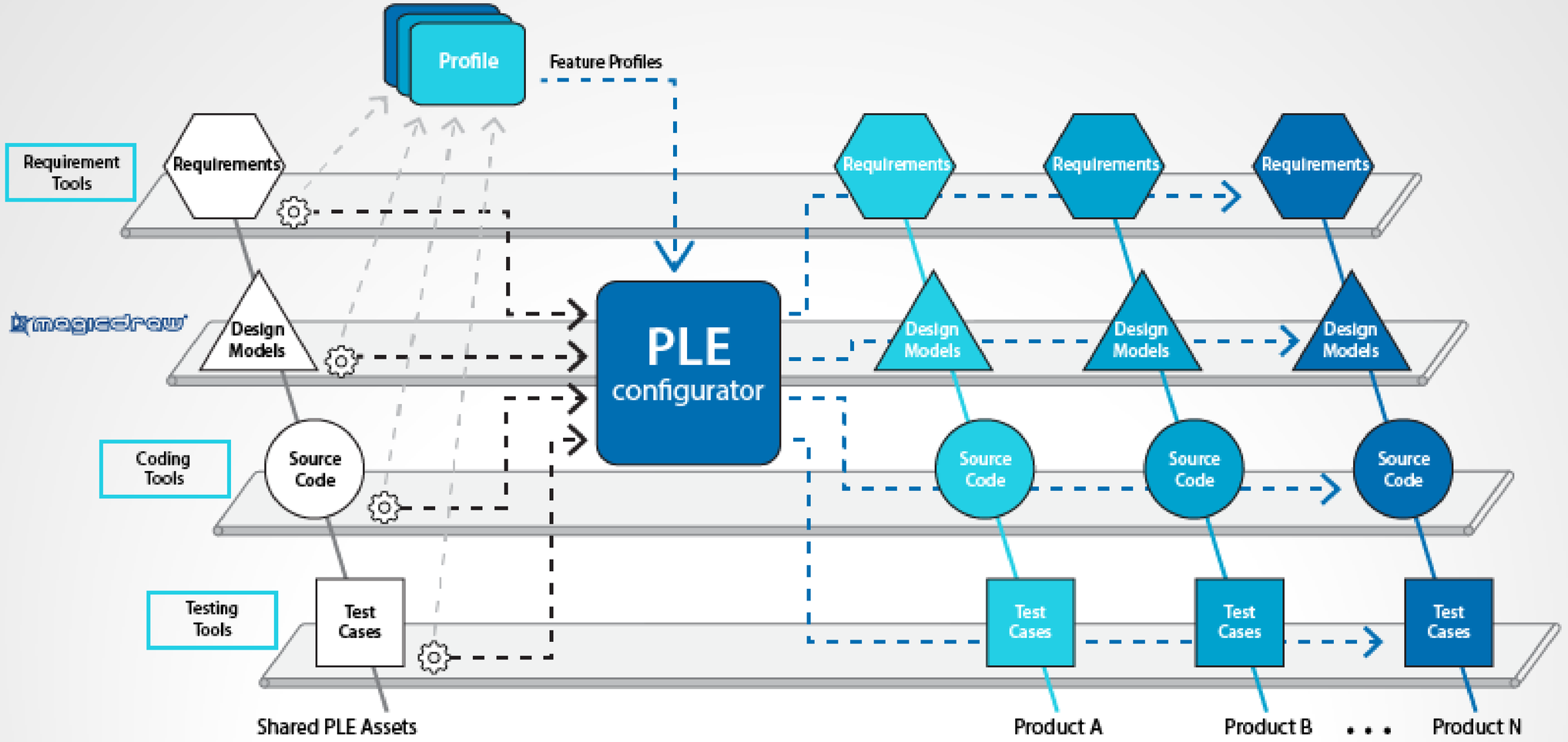
https://www.aerospacemanufacturinganddesign.com/article/what-is-product-line-engineering-ple/

Challenges that PLE Solves

- ❑ 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



MagicDraw PLE Variant Generation



https://docs.nomagic.com/display/PLE190/Product+Line+Engineering

Why the Battle of Hoth?

The example used in this paper is the Battle of Hoth from the second Star Wars movie, “The Empire Strikes Back”

- We are using this as an example because it is well known, contains a rich source of systems, strategies, missions, and behavior as well as illustrates joint operations
- As it is based on a movie, there are no issues of classified materials or problems relating to the release of information
- The actual model created to describe the complete mission would be a large undertaking requiring several diagrams
- For reasons of space and time, we have limited this to a set of example diagrams to express the main concepts covered

Gagliardi M., Hause M., Martin J., Phillips M., 2024, “Darth Vader's Secret Weapon: Implementing Mission Engineering with UAF", presented at the INCOSE International Symposium, Dublin, Ireland July 2-6, 2024

Engineering the Empire's AT-AT

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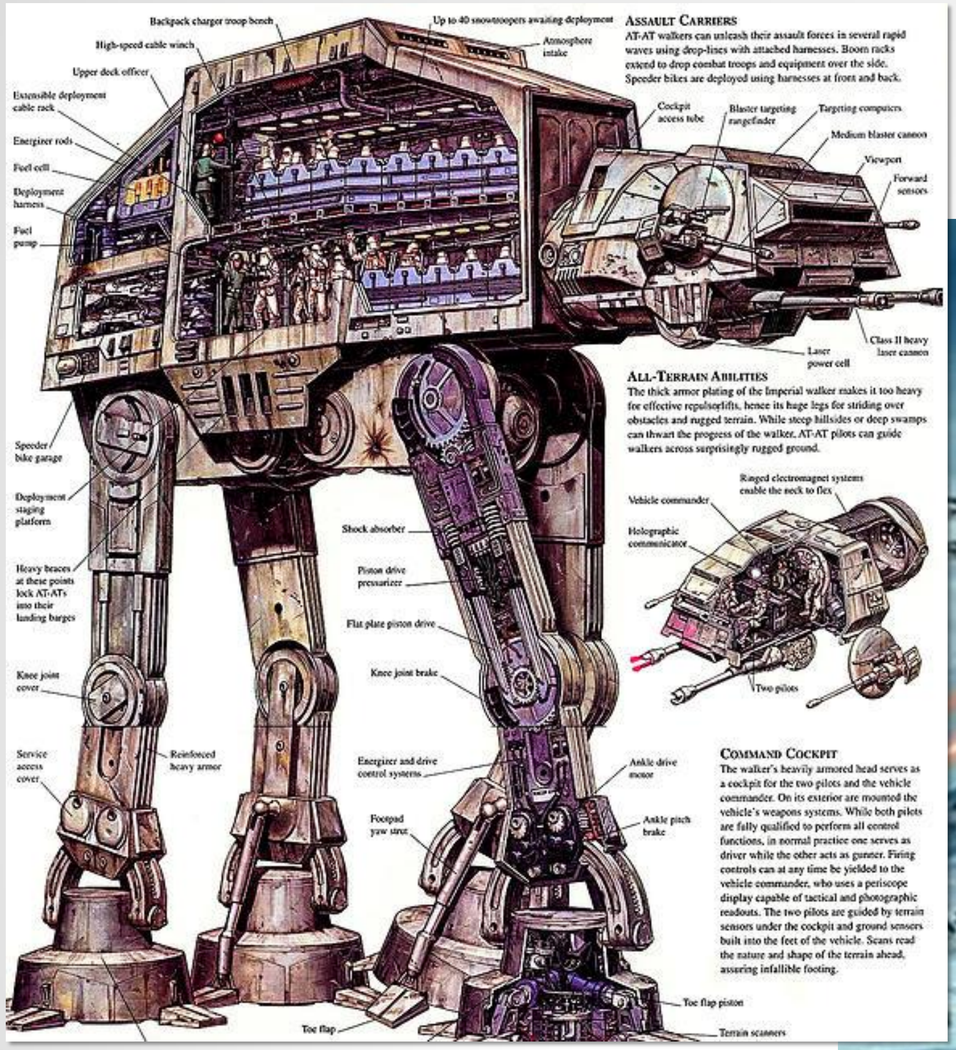
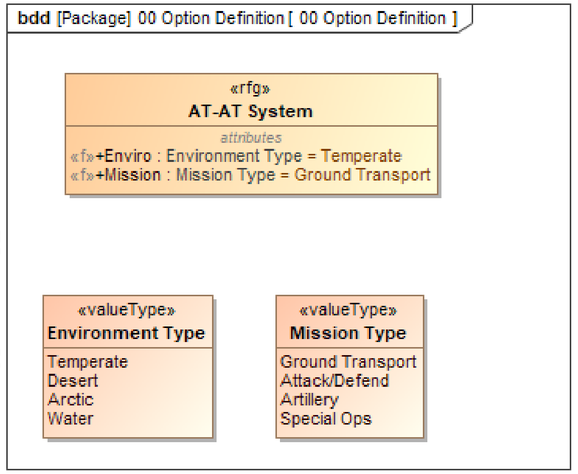


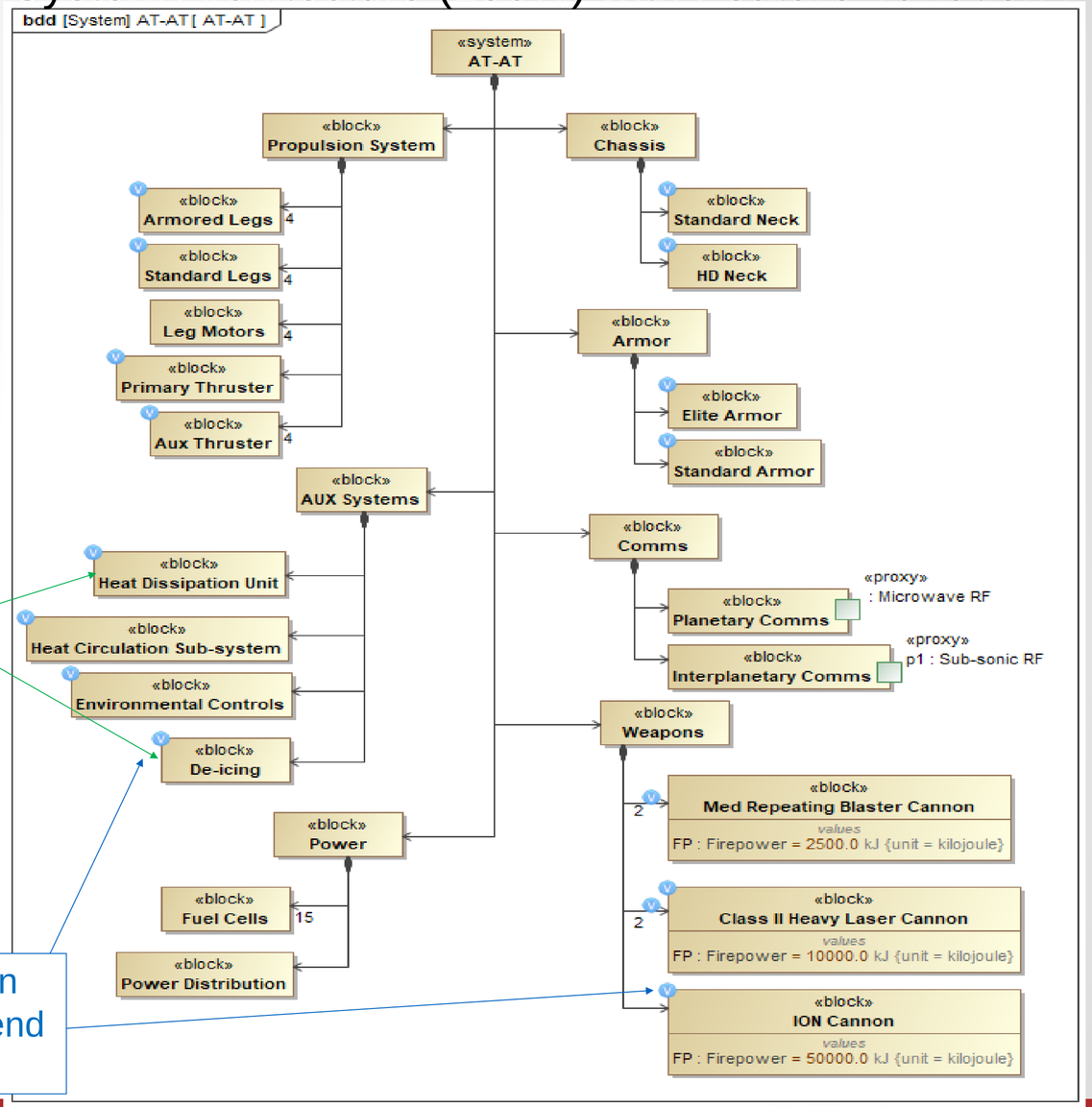
Defining the Product Line Model

- A detailed model Product Line Model (150%) of the AT-AT has been created in SysML with PLE features
- It contains a generic AT-AT and other configuration elements for various missions and climates
- A Root Feature Group defines what options (attributes) will be used to define different system variants
- Note that options can be defined in many ways, but **operationally based attributes** (e.g. environment) allow options to be used across multiple system product lines
- Variation Points (little blue circles) define what system elements, behaviors, or attributes are valid based on option selection(s)

Options Definition



System Architecture (150%) with Feature Variation Po



Note the Heat Dissipation Unit and the De-Icing Blocks for desert and arctic climates respectively

Blue Circles denote variation points of the design that depend on Options selections

Generating the Model Variant

- The figure on the left shows the Product Line model
- Elements with variation points are highlighted
- Red elements are not valid, based on option selections, green elements are
- The right figure shows the resulting generated Arctic AT-AT system with only the valid elements
- Different variants can be generated and integrated with the mission model
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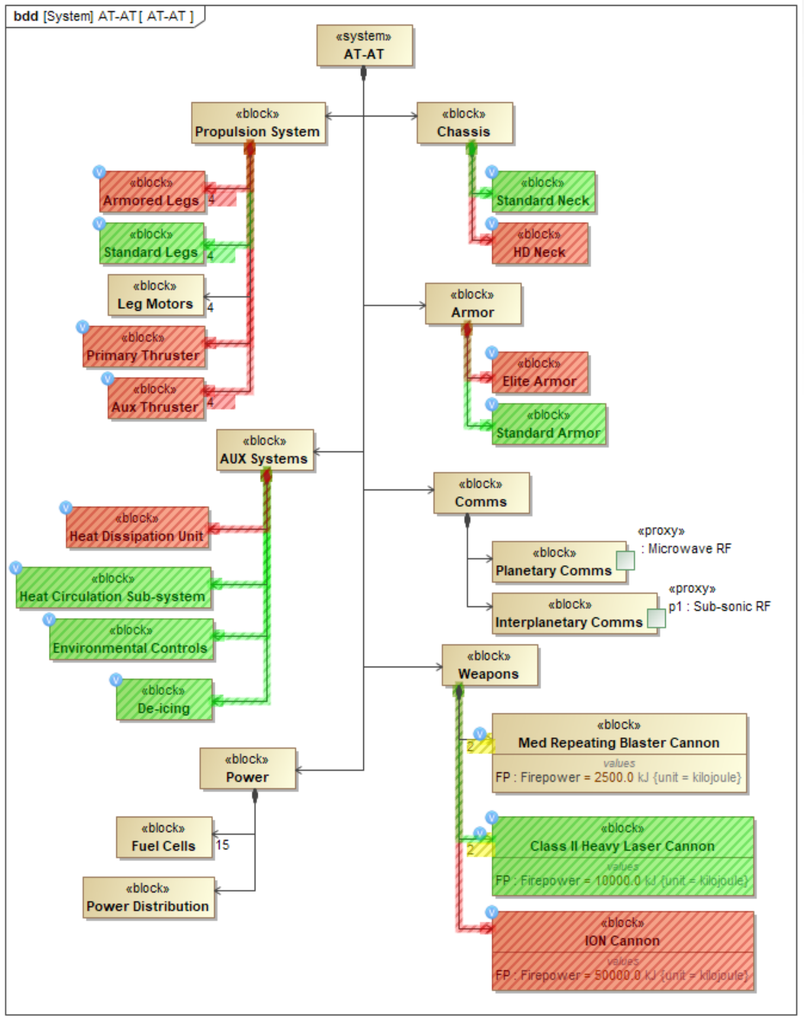
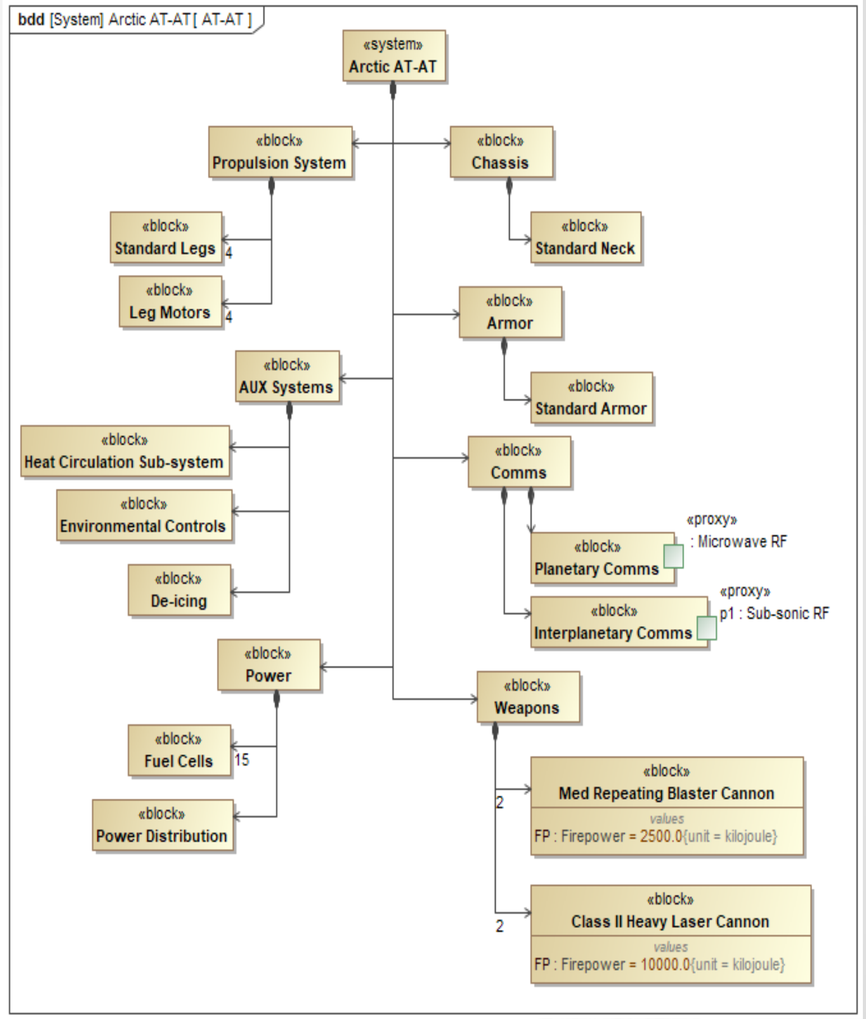
Generic AT-AT Architecture with Arctic Variant Applied

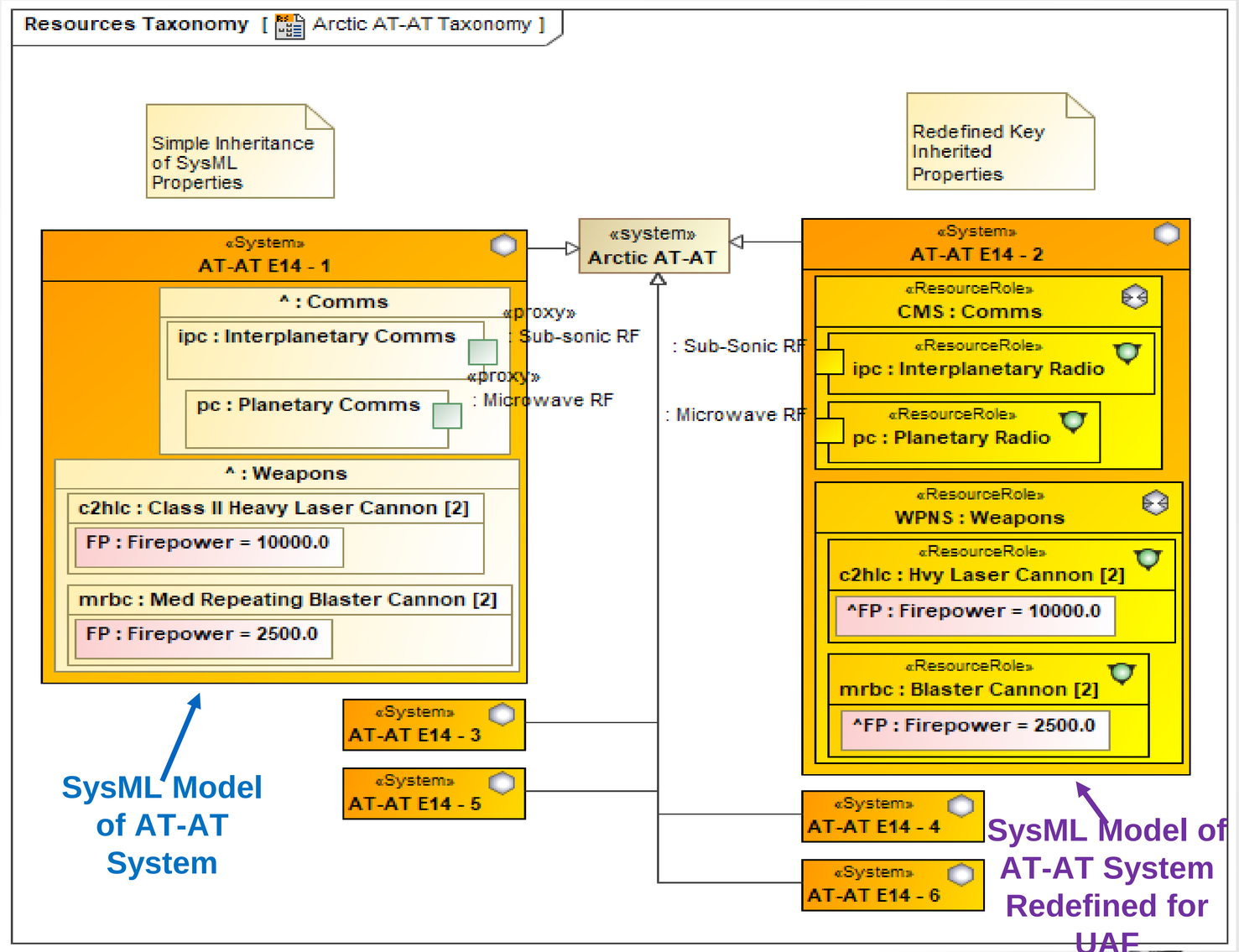


Arctic AT-AT Architecture



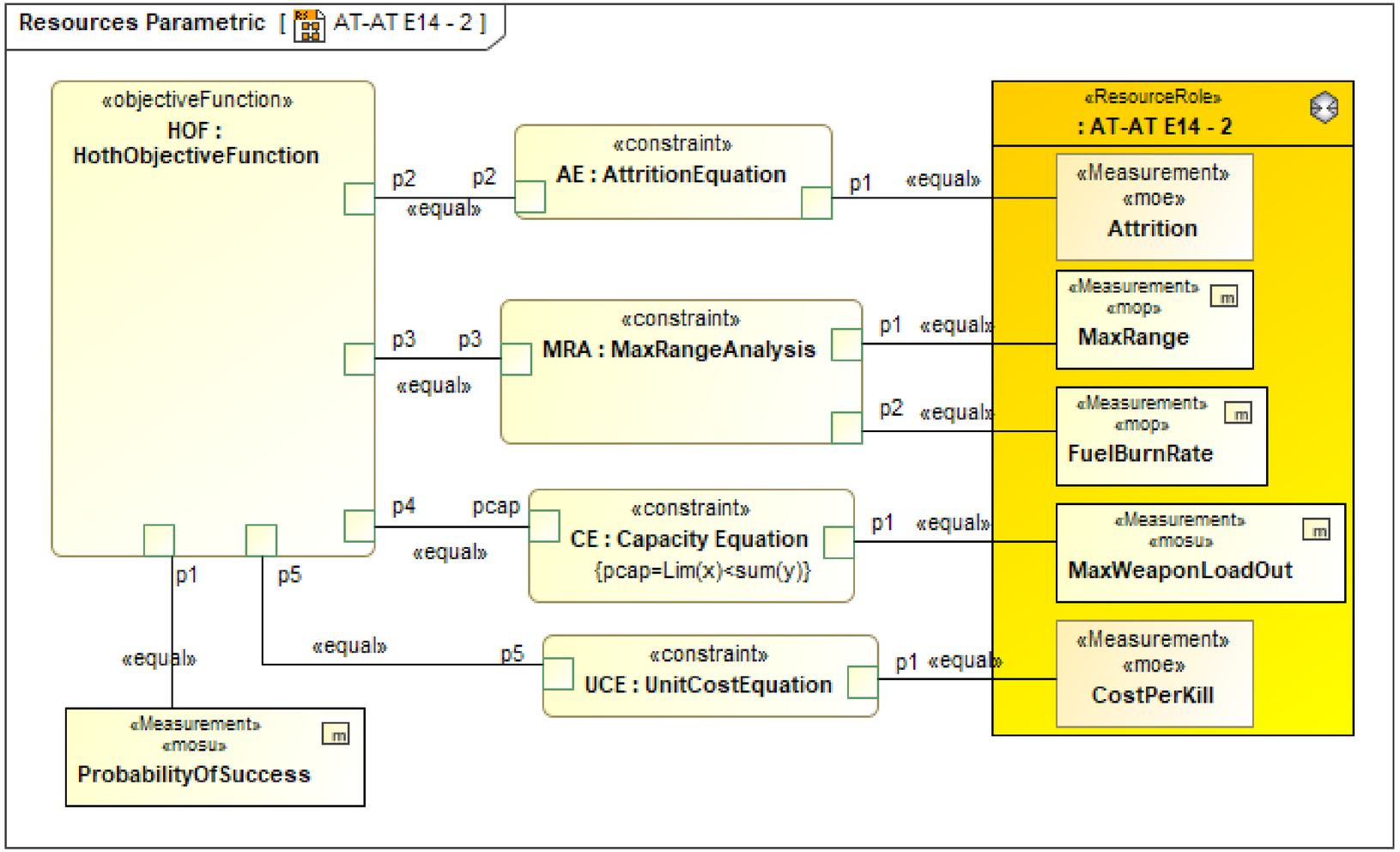
Integrating Into SoS

- The figure shows two variations of the reused model: the left where the SysML parts are maintained, and the right where they are redefined to UAF elements
- Note that for readability not all elements are shown
- Because UAF limits interactions and connection to UAF-UAF elements, ports need to be redefined
- SysML can show both UAF and SysML connections



Analyzing System Suitability Using UAF Parametrics

- The example parametric diagram makes use of both UAF and SysML measurements/ value properties
- These include:
- Measures of Performance (MOP)
- Measures of Success (MOS)
- Measures of Suitability (MOSu)
- Measure of Effectiveness (MOE)
- The measurements are:
- Max Range = MOP
- Fuel Burn Rate = MOP
- Max Weapon Load Out = MOSu
- Cost Per Kill = MOE
- CostE -> Probability of Success = MOS
- Attrition = MOE
- The objective function calculates probability of success
- Note that the diagram simply illustrates the concept and is not a detailed example



Conclusions

- PLE modeling can be a power tool to clarify and simplify modeling of unique systems with common parts/features
- PLE models can aid in analysis of alternatives, in the understanding of product variations and shared sub-systems/components, and variant option selection (among other things).
- If variation points are defined operationally, the feature model itself can be re-used across other systems, as well as help ensure the system is operationally relevant.
- PLE has become more relevant for acquisition as new acquisitions are typically variations on existing systems
- With increase of robotic platforms, PLE is relevant to managing core platforms and modular mission payloads (variants).