



Analyses Made to Order: Using Transformation to Rapidly Configure a Multidisciplinary Environment

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Introducing DARPA “System F6”

- From the website:

System F6 seeks to demonstrate the feasibility and benefits of a satellite architecture wherein the functionality of a traditional “monolithic” spacecraft is delivered by a cluster of wirelessly-interconnected modules capable of sharing their resources and utilizing resources found elsewhere in the cluster. Such architecture enhances the adaptability and survivability of space systems, while shortening development timelines and reducing the barrier-to-entry for participation in the national security space industry.

The program is predicated on the development of open interface standards ...

- Flight demo of interoperability in 2015 with (currently) four spacecraft leveraging F6 infrastructure

Goals of Adaptable Systems Design and Analysis (ASDA) Tool

- “Evaluate the business case for fractionation”
- Our postulate – fractionation valuable when:
 - Needs are dynamic
 - The world is uncertain
- Play out the consequences of postulate and consequences through integrated modeling and analysis

We want to vary ...

- The number and types of spacecraft in the cluster
 - Order of deployment
 - Possible responses to unforeseen circumstances, including various ways to change the cluster
 - The cluster architecture and formation to fly
 - Different operating strategies
 - And so on
-
- Too many combinations to deal with by hand!

Creating a Simple, User-Friendly Tool that is still customizable

F6 Tool: Create user-friendly GUI to setup and run nested experiments: 1) Architecture (Select # of MS, DS, PLs), 2) Stimuli, sizes of elements, run durations, etc.

F6 Design Tool (ASDA)

Why SysML?

- Need a platform for capturing the rules specifying what constitutes a cluster and how it should behave
- Open structure for SysML allows for elaboration as users and modelers get more sophisticated
- Open Modeling Group (OMG) standard that works with many others to help transition to model-based systems engineering (MBSE)
 - Query-View-Transform (QVT)
 - Business Process Modeling Notation (BPMN)
 - Real-time frameworks

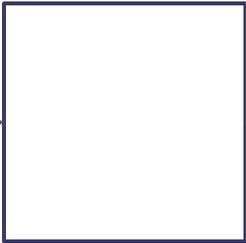
The Trick

- Analysis tools typically have ill-posed data structures, either:
 - Too weak (e.g., Excel, many scripts)
 - Highly specialized (e.g., Finite Element, Modelica, etc.)
- SysML not a strong language for analysis, but excellent standardized data structure
- The trick – use SysML as Source of Truth but instance as analysis inputs via transformation!

Simplified version of Model Transformations

Analysis Needs
Rules to Apply

Done in advance
(human setup)



Produces:
Analysis Specs

Done at build time
(automatic)



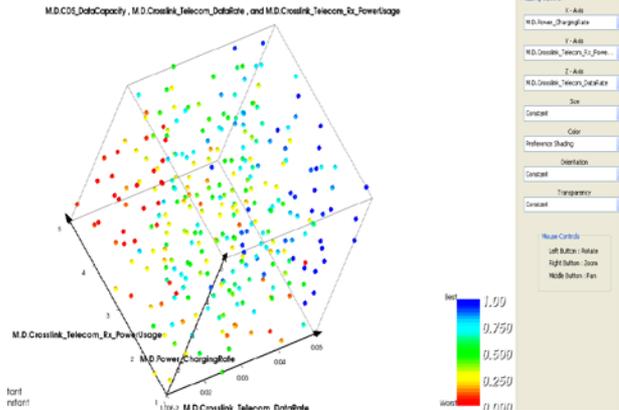
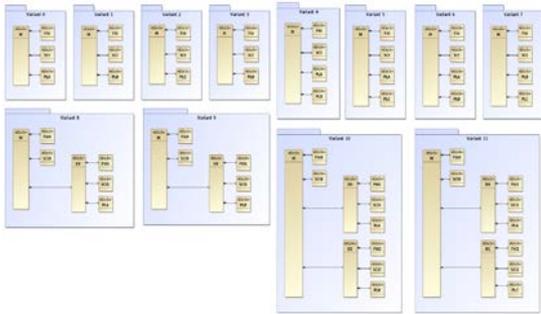
Produces:
Variants

We are here

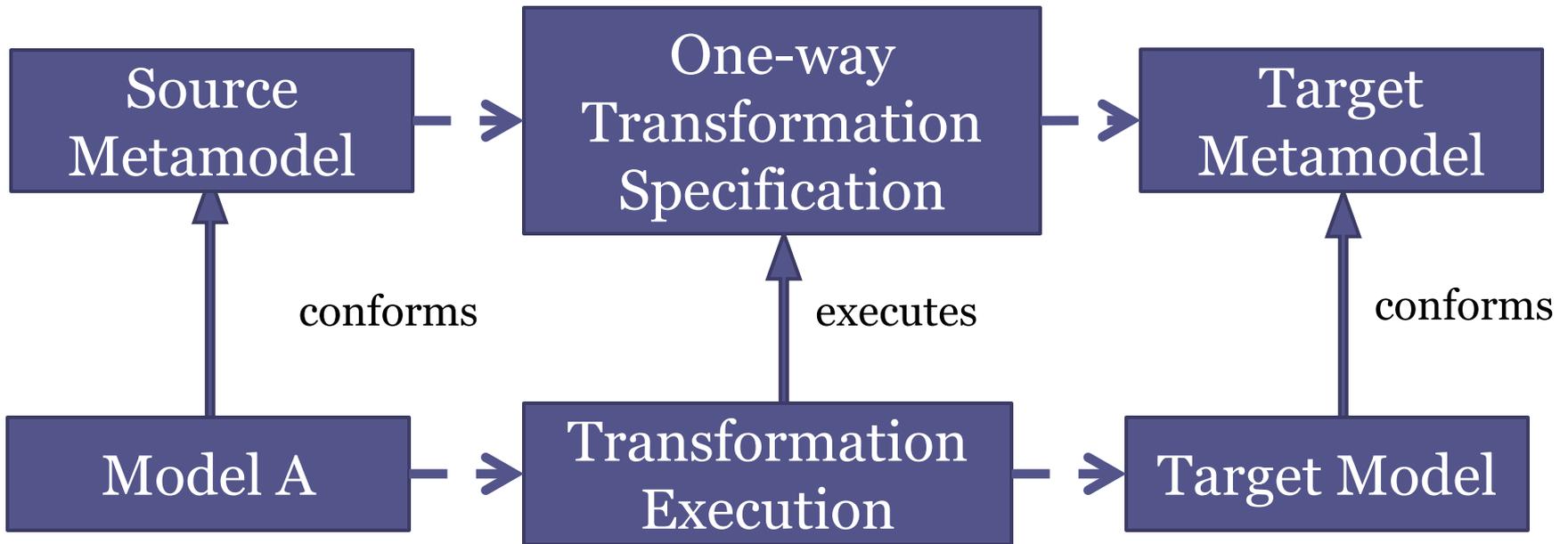
Done at run time
(automatic)



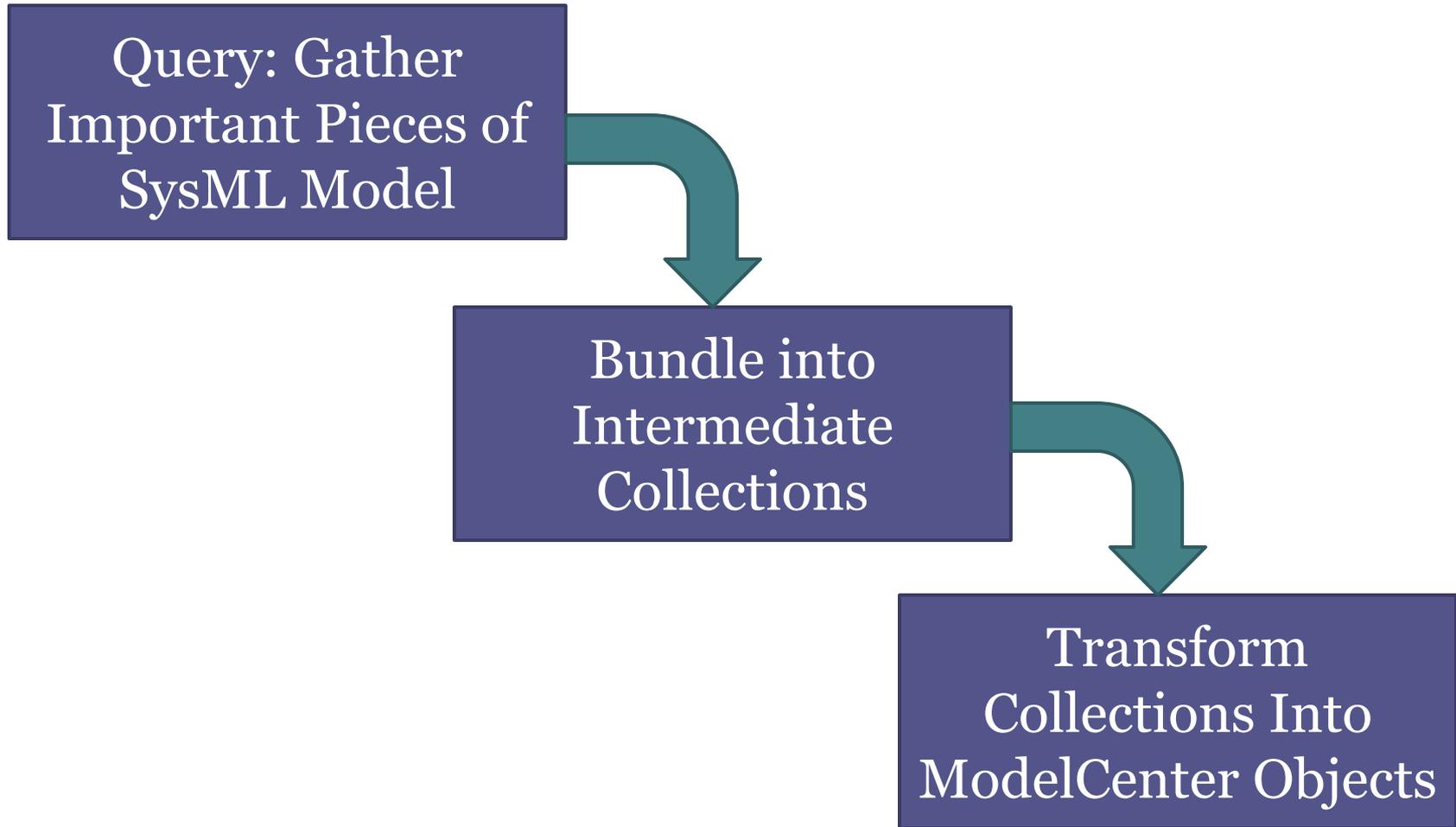
Produces: Populated
Tradespace



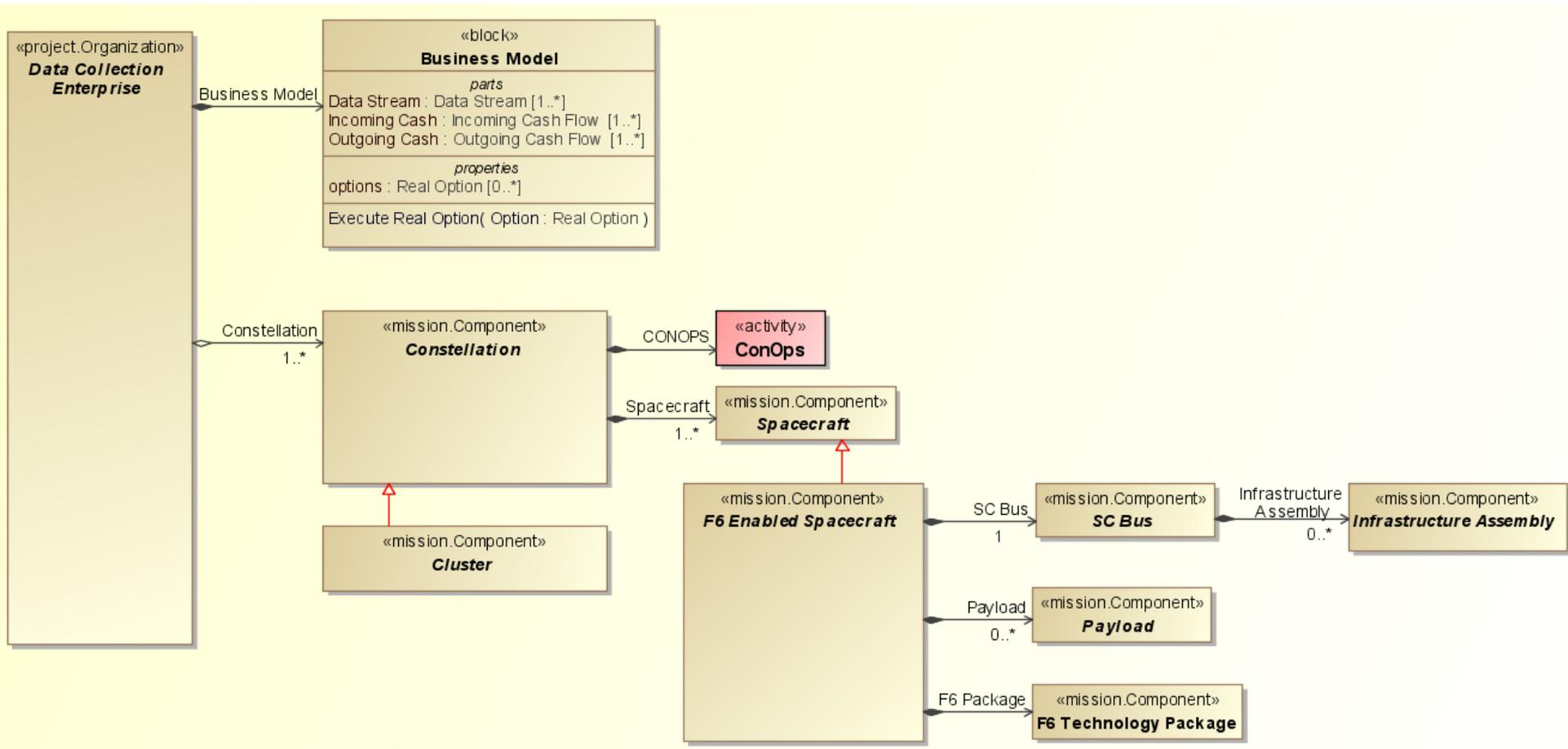
What is Model Transformation?



Transformation Flow: SysML → PHX



DARPA F6 Metamodel



Analysis Idiom from JPL Integrated Model-Centric Engineering (IMCE) Initiative

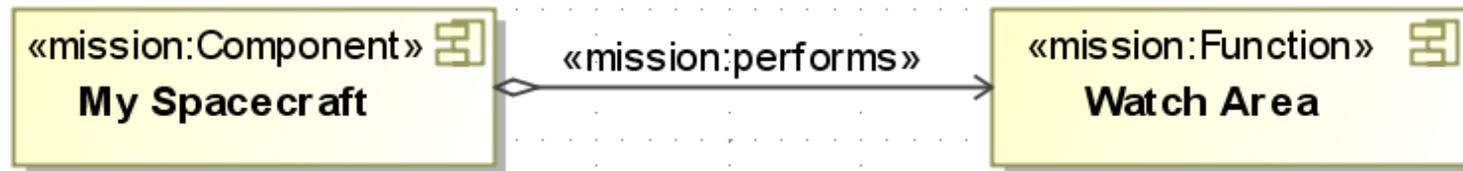
«mission.Component»
Daughtership Bus

«analysis.analyzes»

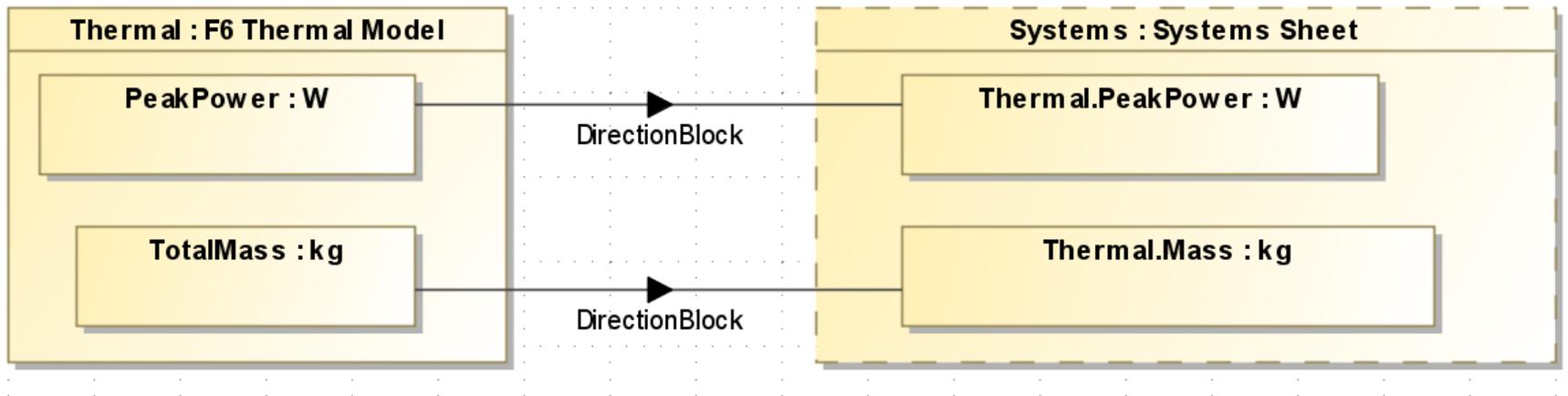
«MC.ExcelWrapper»
F6 Thermal Model



Analysis Context

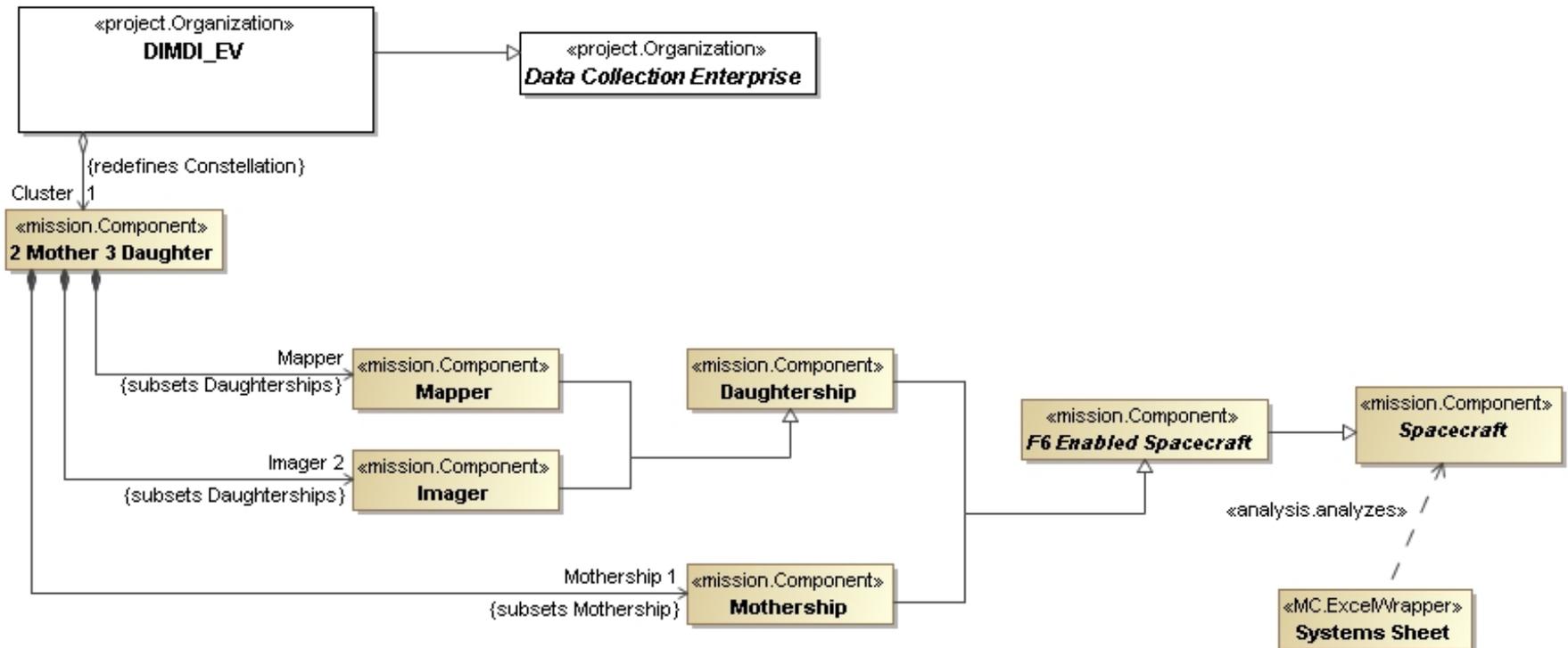


Parameter Cross-Connection

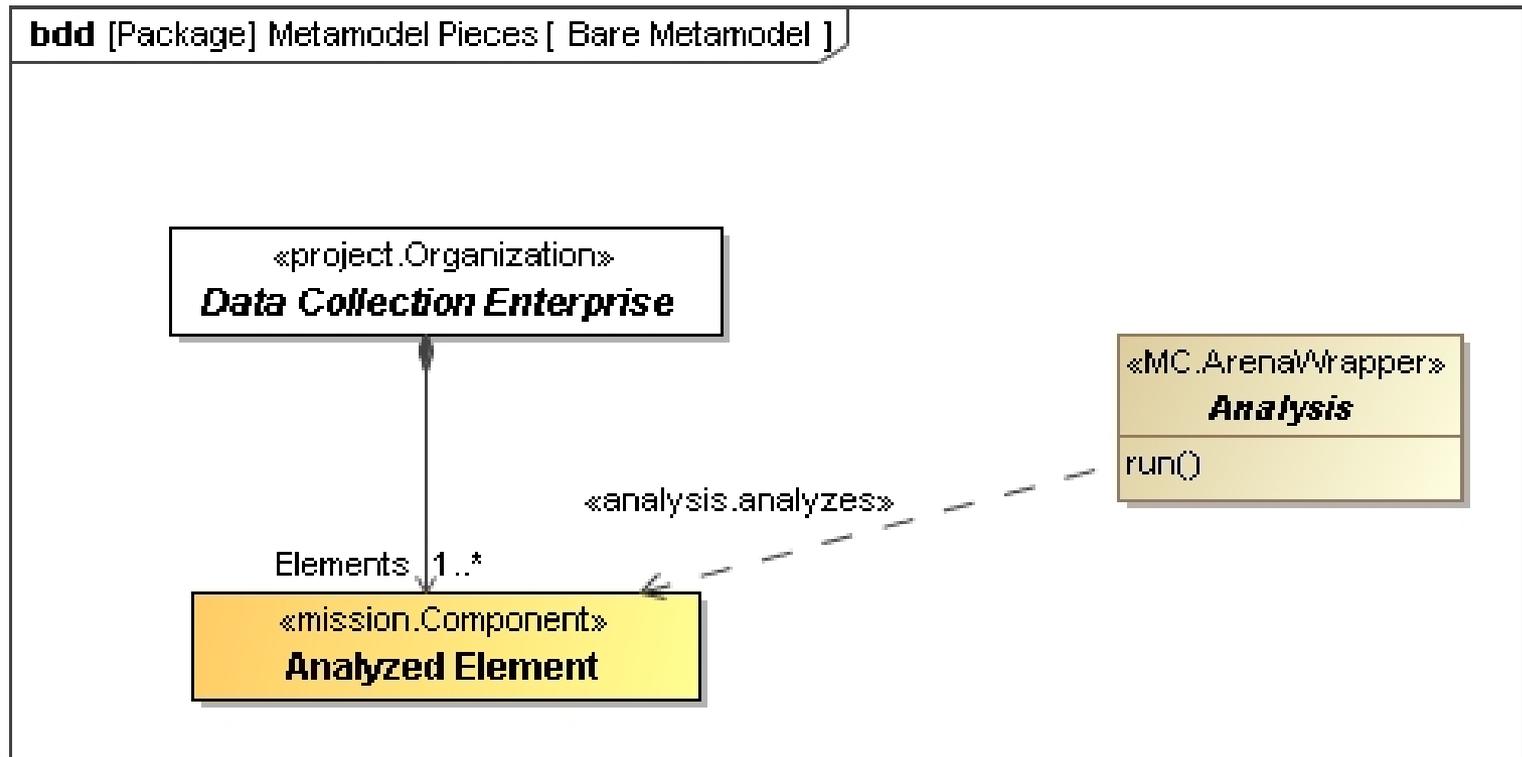


Inheritance of Analysis Connections

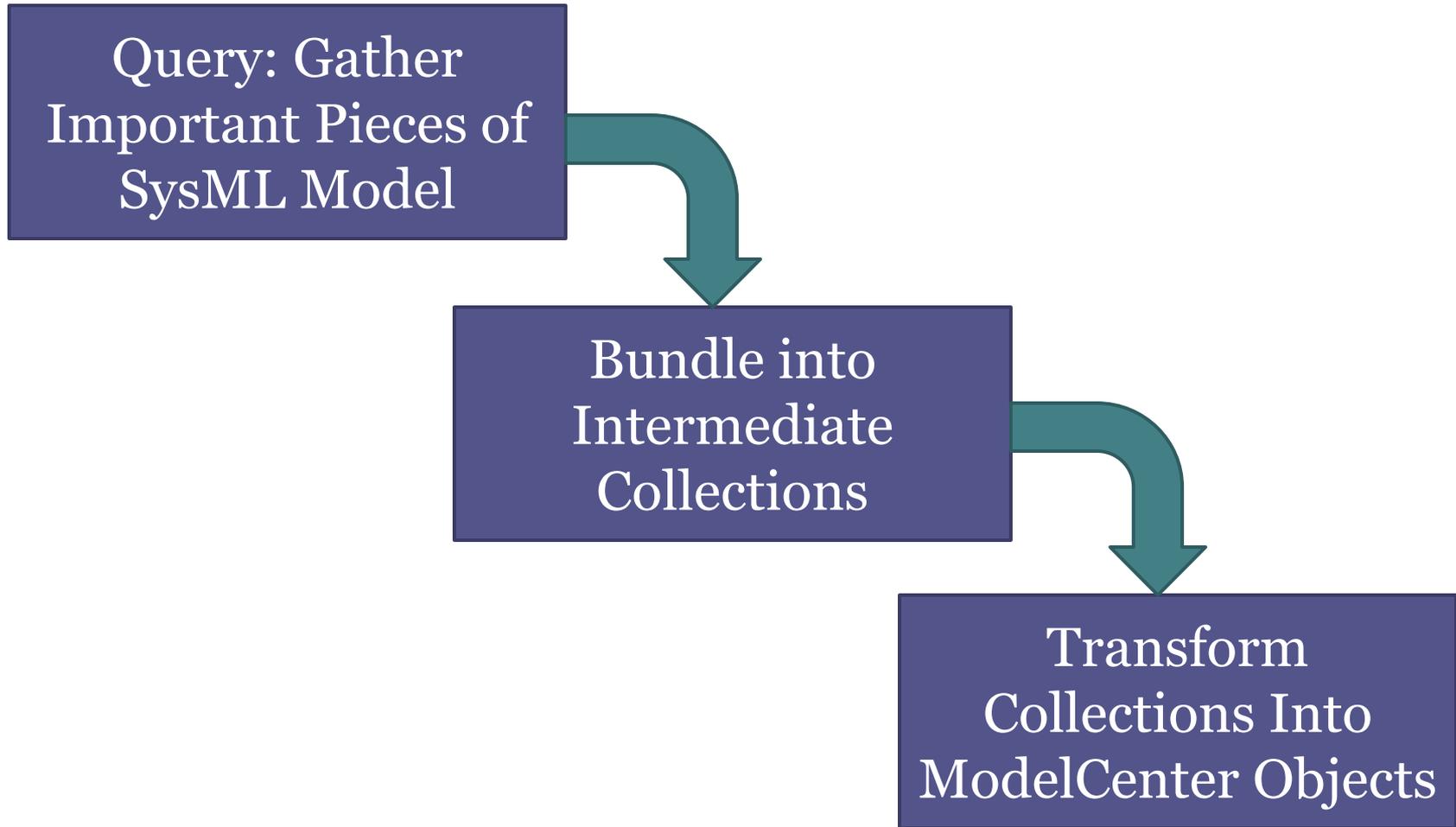
bdd [Package] Analyses [Example Analysis Mapping]



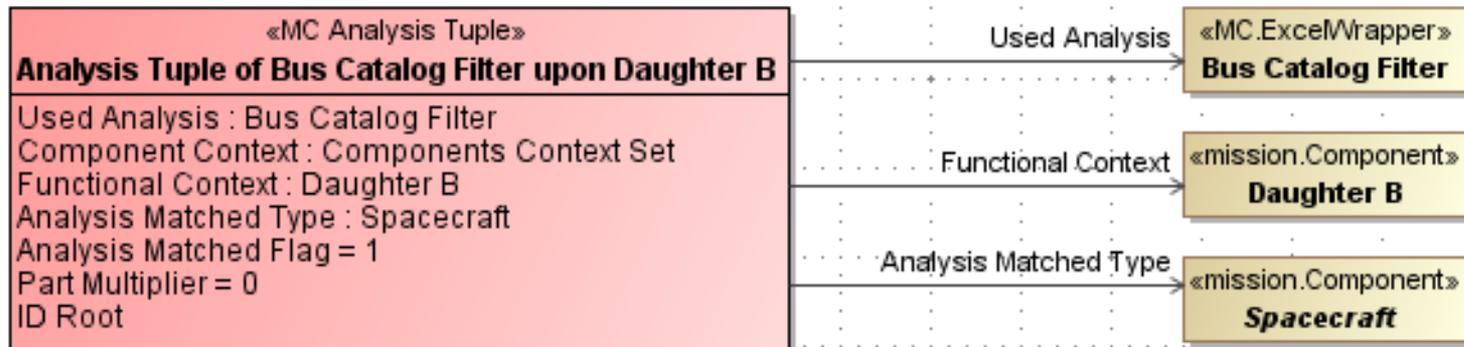
Very Flexible Approach



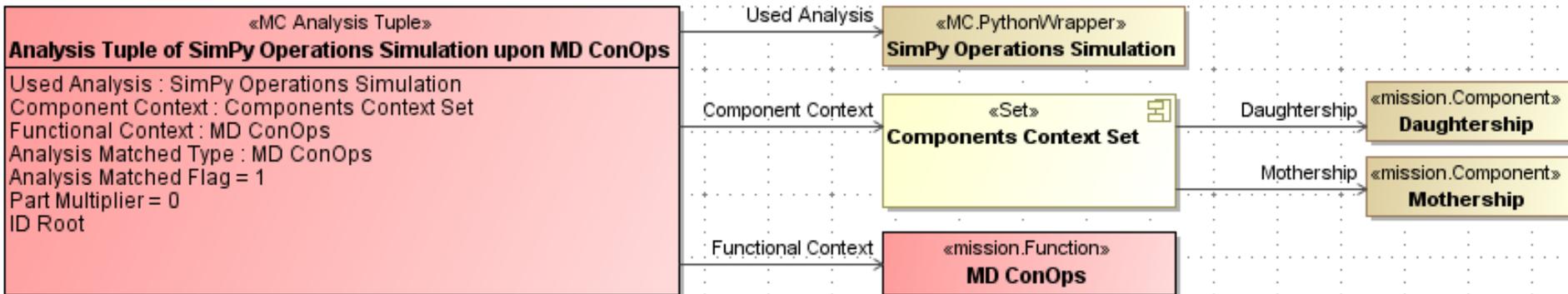
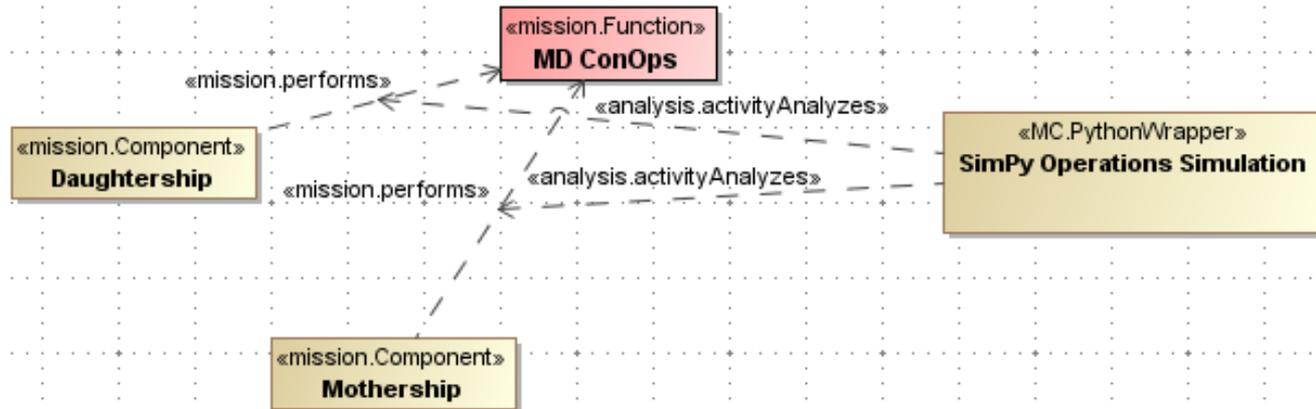
Transformation Flow: SysML \rightarrow PHX



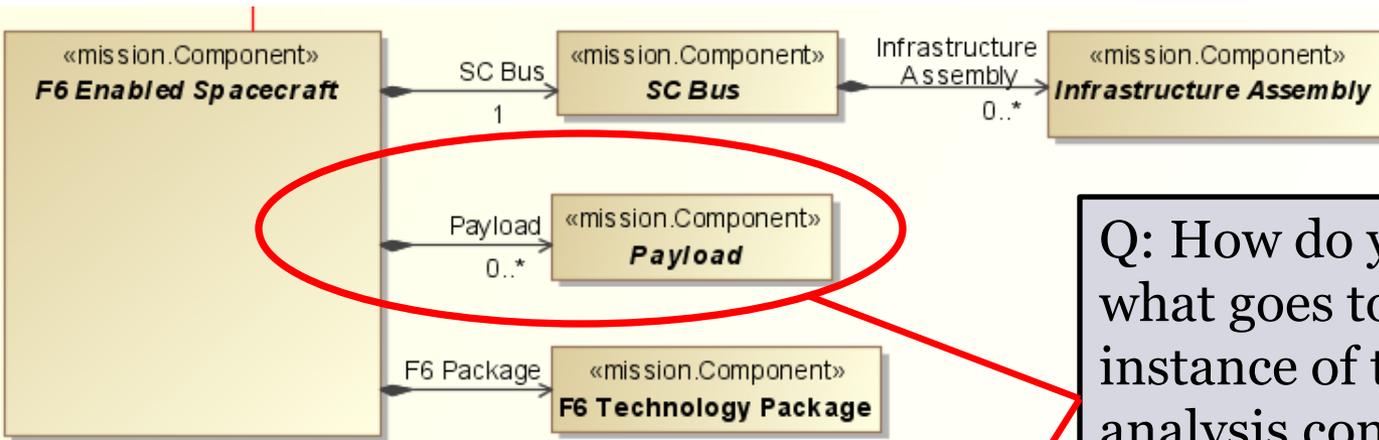
Components with “Default Use”



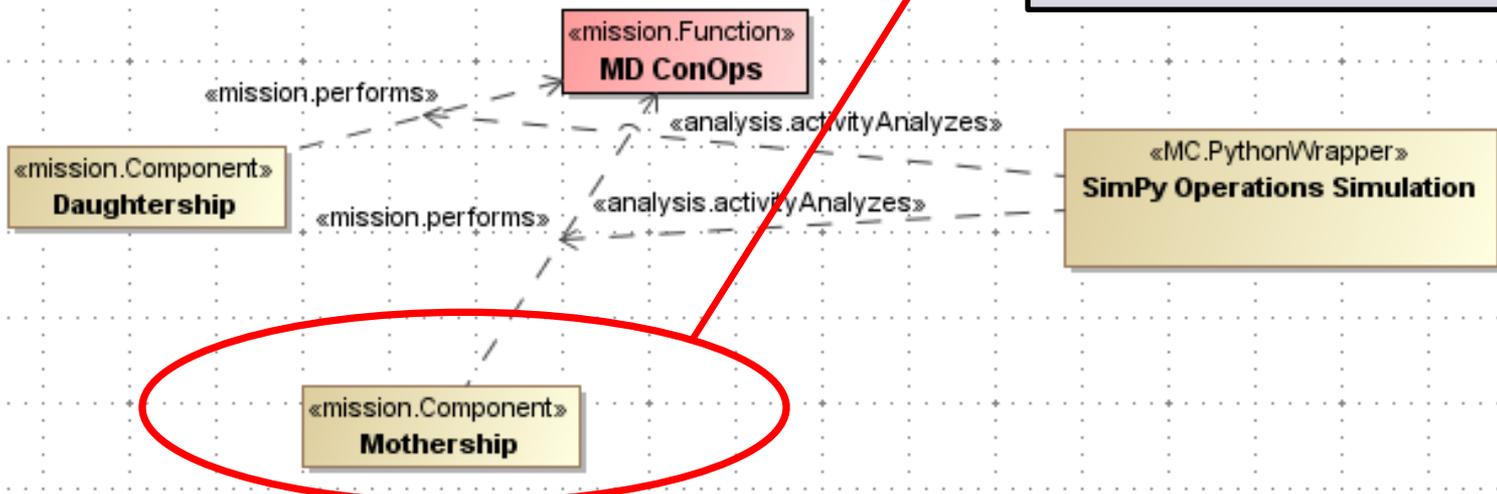
Analyzing Components in Use



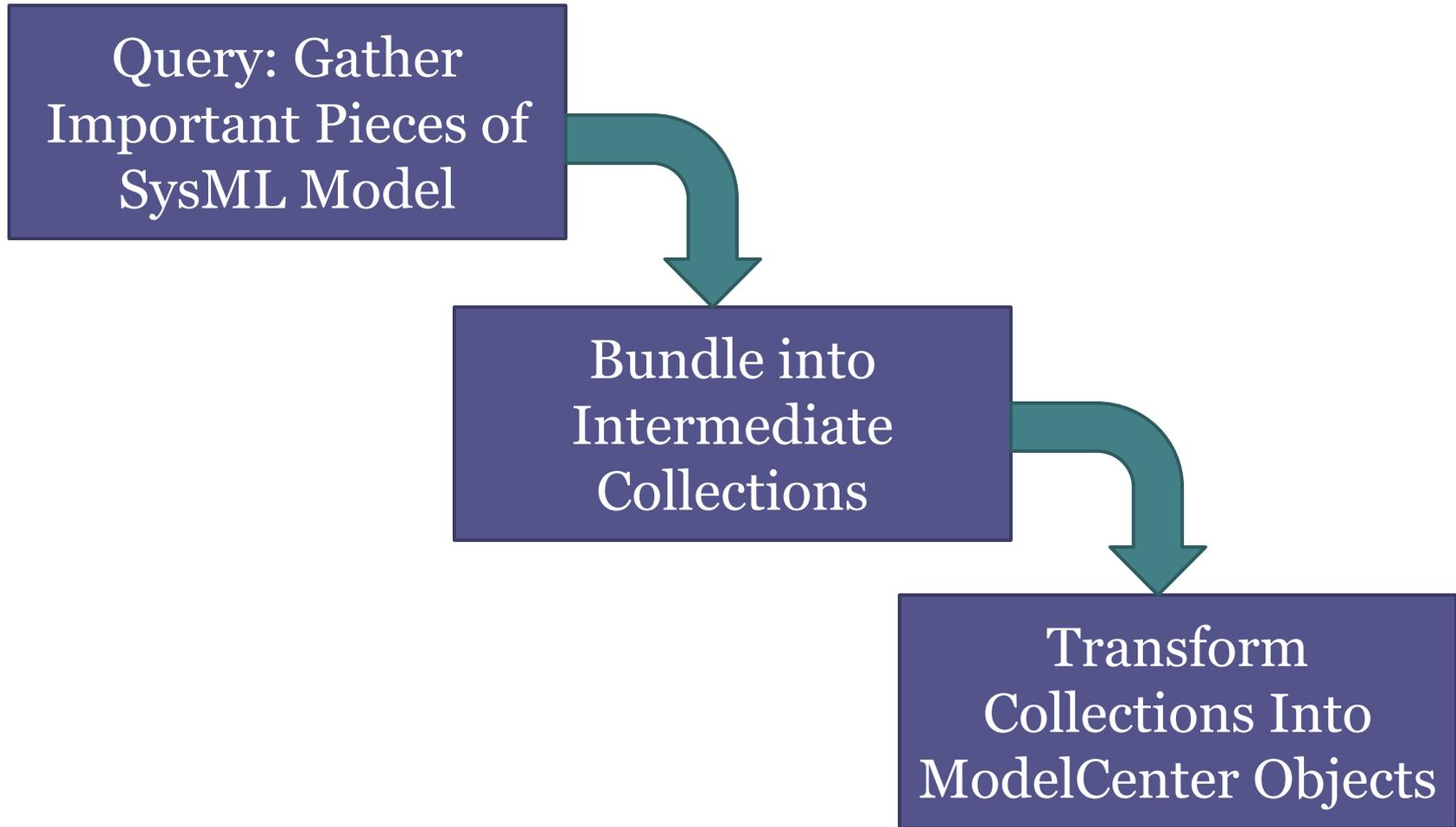
The Hard Part - Composite Objects



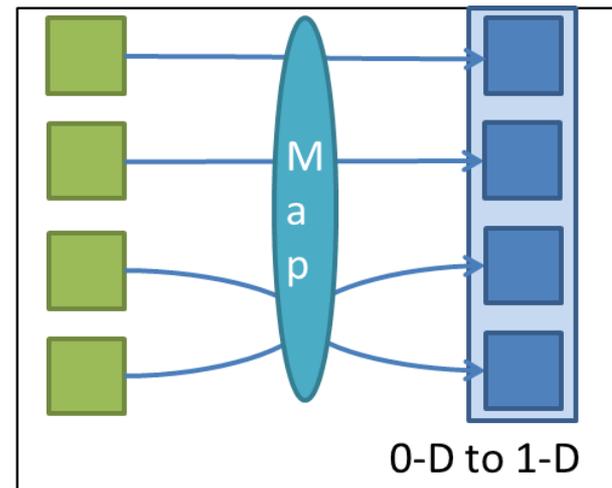
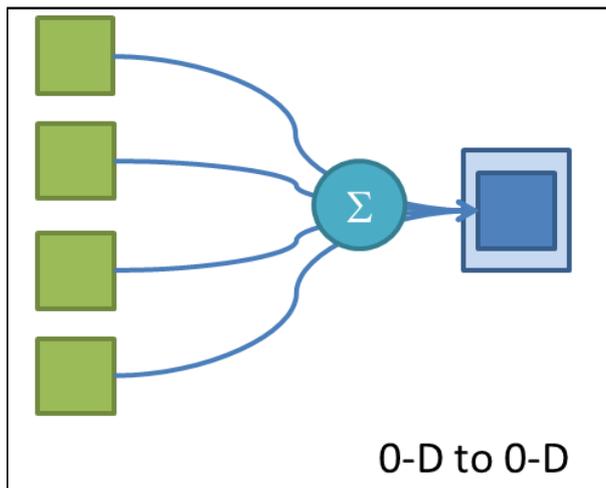
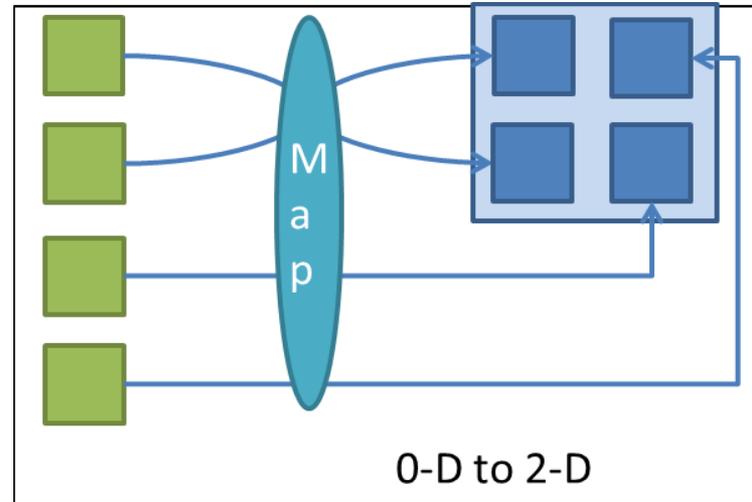
Q: How do you keep track of what goes to which role-based instance of the system in an analysis context?
A: Inheritance (at the cost of some rules)



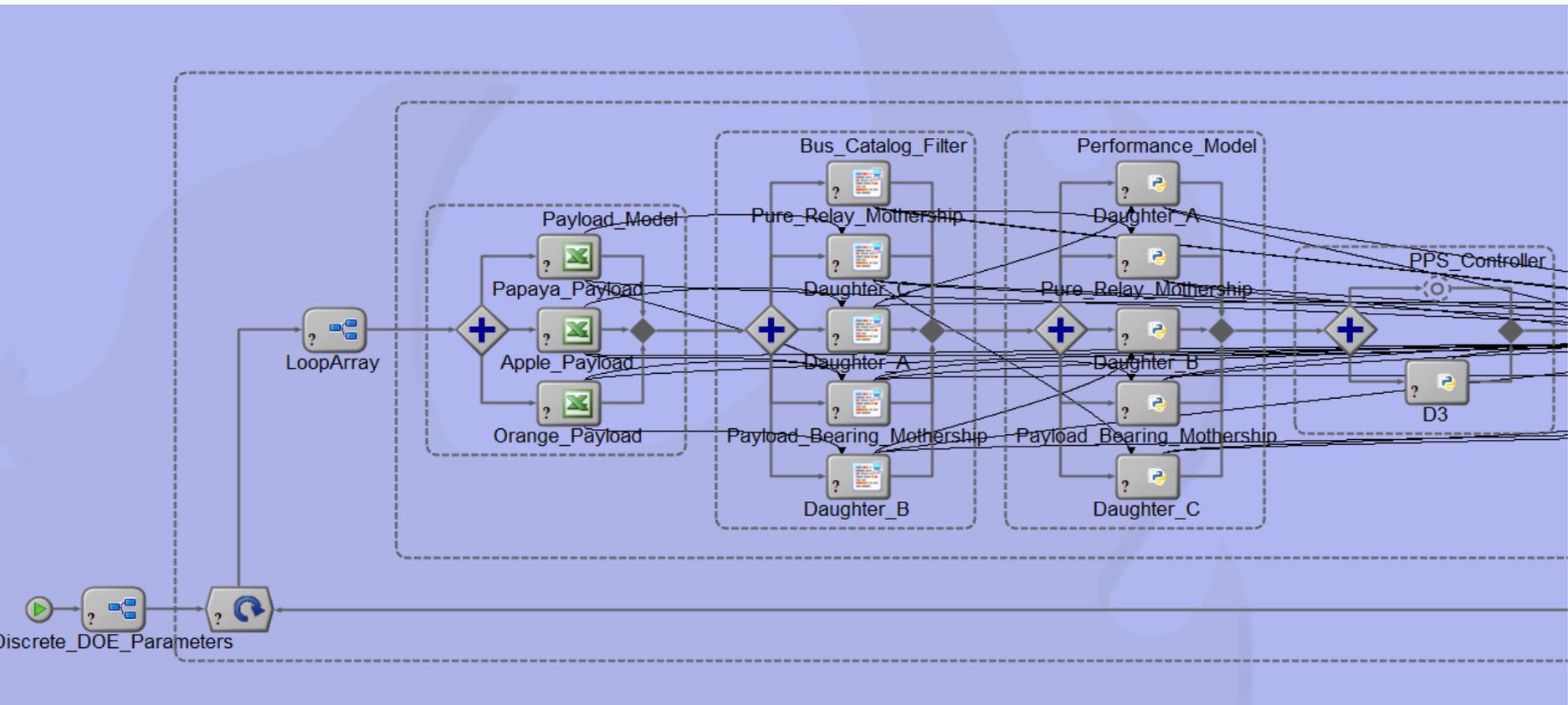
Transformation Flow: SysML \rightarrow PHX



Most Transform Effort Spent on Wiring Parameters on Analysis Instances



A Final Product



What Comes Out In the End

- Instanting of a mothership-daughtership pattern with an arbitrary number of spacecraft
- Proper (and testable) connection between instances of analyses in pre-specified order
 - ASDA model runs typically involve 100-400 links per architectural combination
- (Pending final code module integration)
One-click launch of architecturally distinct configurations from a SysML model