FireSAT: Model vs Documents Alone

Space Systems Working Group

INCOSE MBSE Challenge Team

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Space Systems Working Group Team

- International Group of Engineers
- Commercial and Government
- Students/Academic Team
  - MIT
  - Georgia Tech

Objective

- Can models (with documentation) improve communication, characterization, and specification of the system over documents alone?
- Can such a model achieve enough commonality to be reusable

FireSat Mission

- FireSat Example (*From Space Mission Analysis and Design (SMAD)*, Third Edition, by Wiley J. Larson and James R. Wertz (editors).)
  - Realistic and sharable
  - A mission to detect identify and monitor forest fires from orbit
  - Widely regarded as definitive text on space systems for concept/feasibility studies
  - Examples are sufficiently detailed to create models

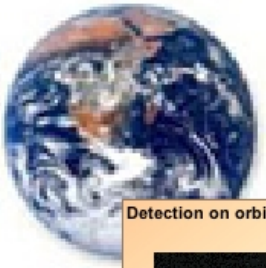
package Concept[Concept Sketch]

Events trigger fires randomly and without warning

Start of Fire

fires grow large before ground based detection can detect

Fire Trigger



Detection on orbit

Earth orbiting detection can detect earlier then conventional means

firefighters arrive in time to contain fire

dispatch foreset service resources

recieve and announce detection

Approach

- Treat book as documented design set
  - Information “siloed” by discipline
  - Various expert authors – conflicting perspectives
  - NOT a critique of the books content, format
    - Special thanks to Wertz and Larson!
- Compare Model to Documents
- Capture reusability
  - Same intent as book
  - Provides compelling demonstration of MBSE
  - Provide as a resource for anyone doing Space Systems engineering

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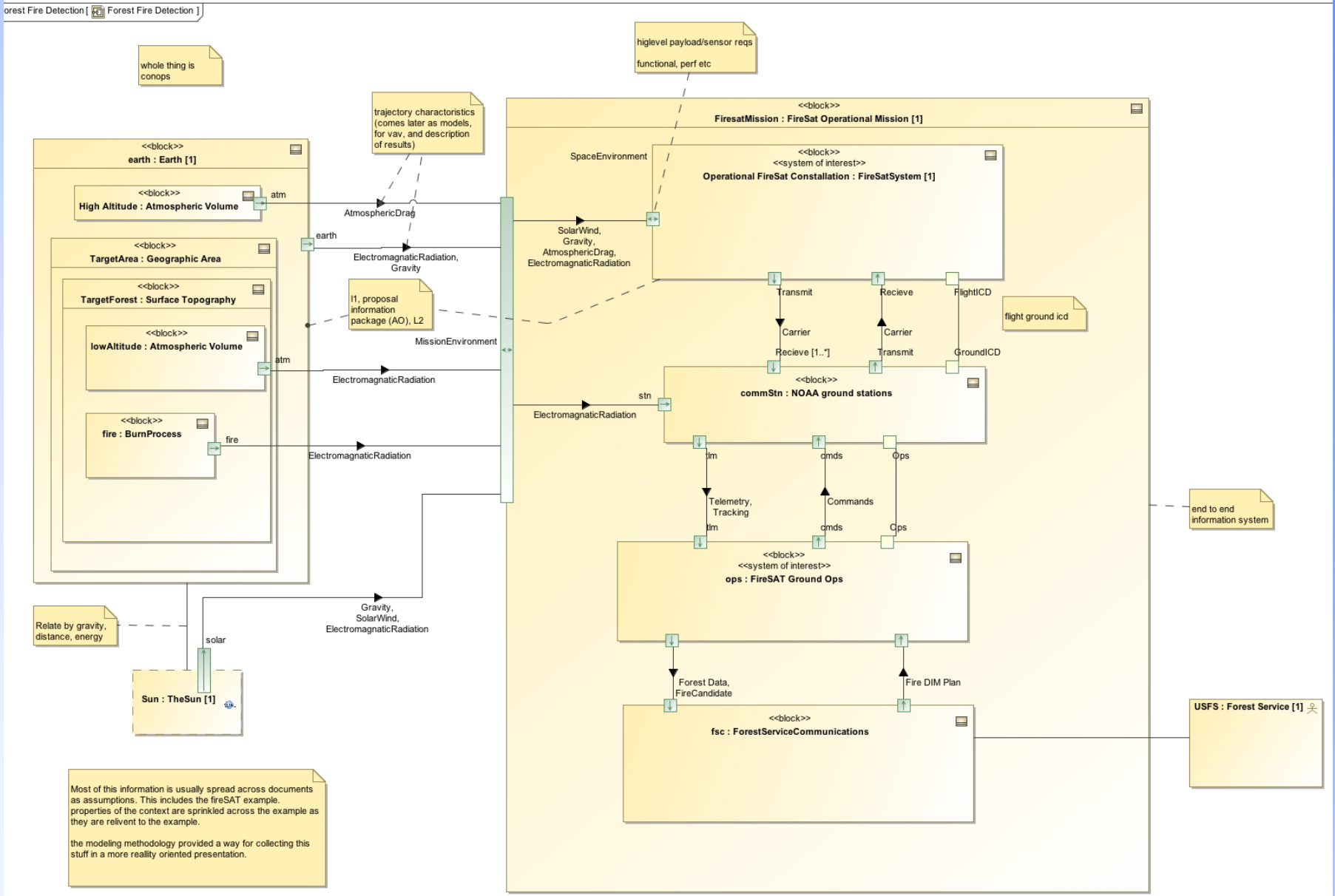
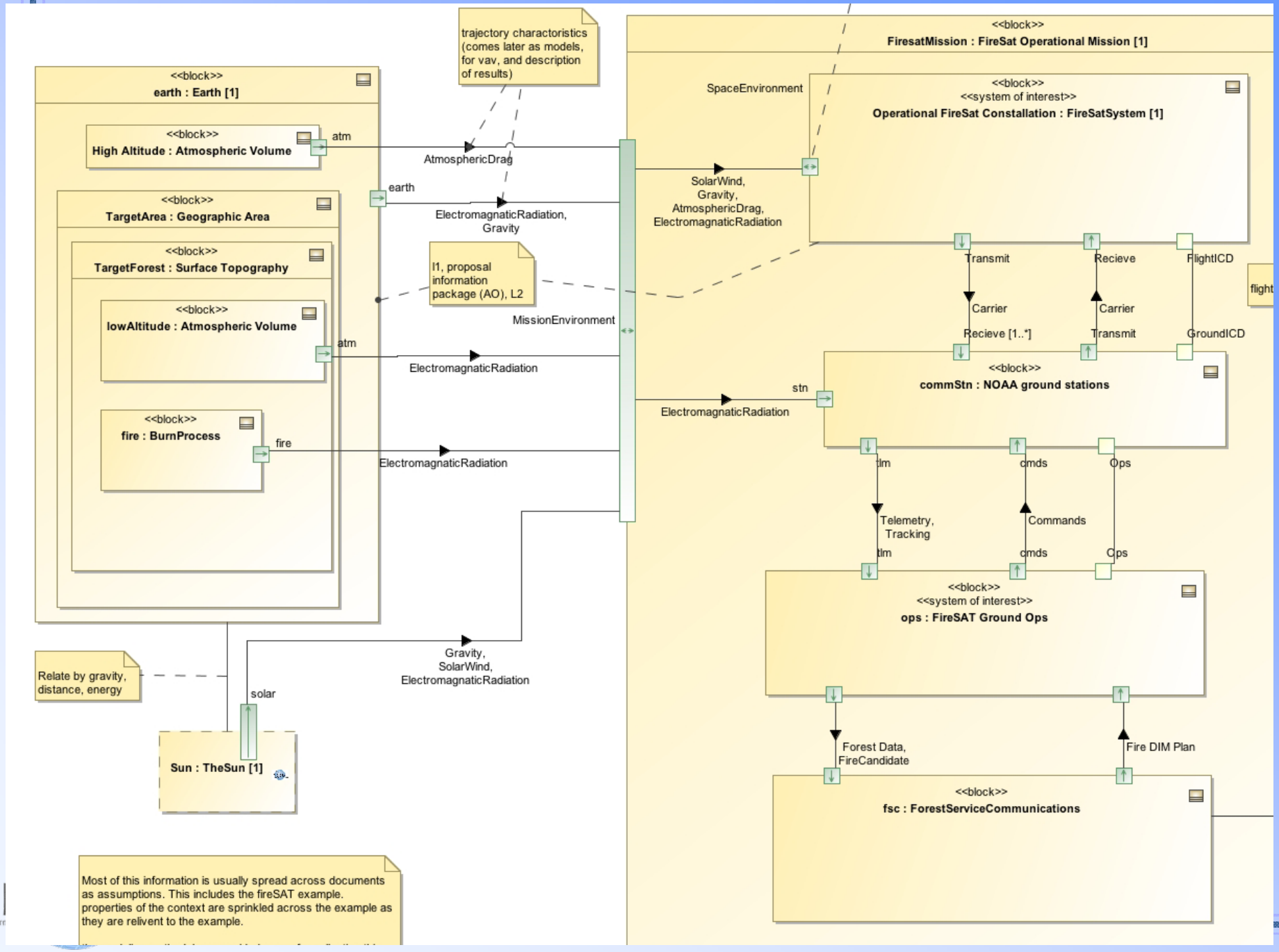
Wymorian MBSE

- Wymore Documents – explicitly tied to system models
  1. Problem Situation
  2. Operational Need
  3. System Requirements
  4. System Requirements Validation
  5. Concept Exploration
  6. System Functional Analysis
  7. System Physical Synthesis
- Commutative property does not apply
  - Systems engineers make these documents DOES NOT imply that making these documents means you are doing Systems Engineering.

Types of Document-based Information in FireSAT

System Documents	FireSAT Example
Concept of Operations	Mission Objective, system requirements
Requirements (SRDs, FRDs etc)	system requirements
Interfaces (ICDs etc)	Data flow diagram, system requirements
Functional Designs	Power functional decomposition
Analysis-specific engineering reports (trades, reliability etc)	Solar Array selection
End-to-end Information systems spec	Data flow diagram


orest Fire Detection [Forest Fire Detection]
whole thing is conops
higlevel payload/sensor reqs
functional, perf etc
trajectory charactoristics (comes later as models, for vav, and description of results)
<<block>>
earth : Earth [1]
<<block>>
High Altitude : Atmospheric Volume
atm
AtmosphericDrag
<<block>>
TargetArea : Geographic Area
earth
ElectromagnaticRadiation, Gravity
<<block>>
TargetForest : Surface Topography
<<block>>
lowAltitude : Atmospheric Volume
atm
ElectromagnaticRadiation
<<block>>
fire : BurnProcess
fire
ElectromagnaticRadiation
I1, proposal information package (AO), L2
MissionEnvironment
<<block>>
FiresatMission : FireSat Operational Mission [1]
SpaceEnvironment
<<block>>
<<system of interest>>
Operational FireSat Constallation : FireSatSystem [1]
SolarWind, Gravity, AtmosphericDrag, ElectromagnaticRadiation
Transmit
Recieve
FlightICD
flight ground icd
Carrier
Recieve [1..*]
Carrier
Transmit
GroundICD
<<block>>
commStn : NOAA ground stations
stn
ElectromagnaticRadiation
tlm
cmds
Ops
Telemetry, Tracking
Commands
tlm
cmds
Ops
<<block>>
<<system of interest>>
ops : FireSAT Ground Ops
Forest Data, FireCandidate
Fire DIM Plan
<<block>>
fsc : ForestServiceCommunications
end to end information system
USFS : Forest Service [1]
Relate by gravity, distance, energy
solar
Sun : TheSun [1]
Gravity, SolarWind, ElectromagnaticRadiation
Most of this information is usually spread across documents as assumptions. This includes the fireSAT example. properties of the context are sprinkled across the example as they are relivent to the example.
the modeling methodology provided a way for collecting this stuff in a more reallity oriented presentation.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fsc : ForestServiceCommunications
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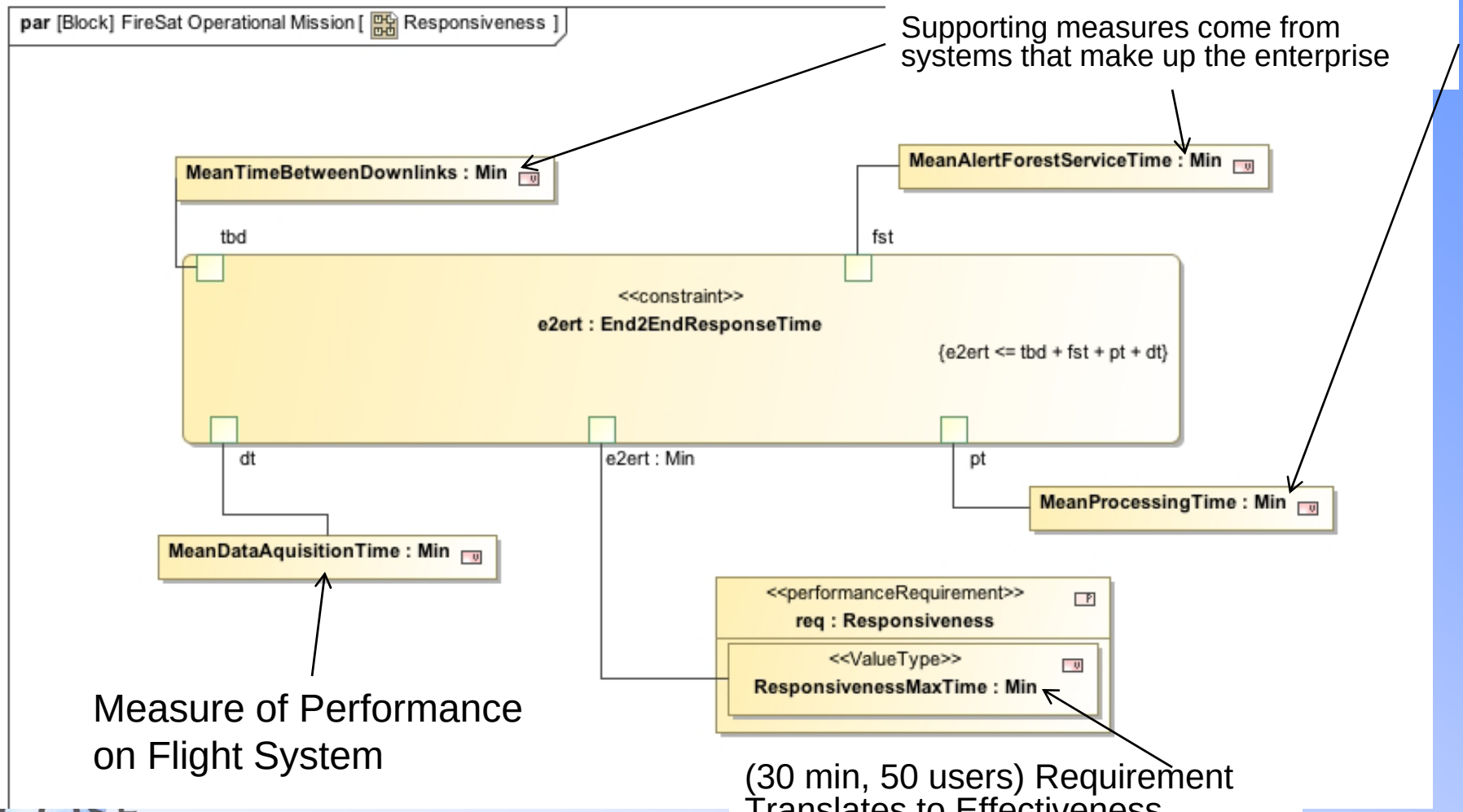
Mission Requirements and Measures Of Effectiveness



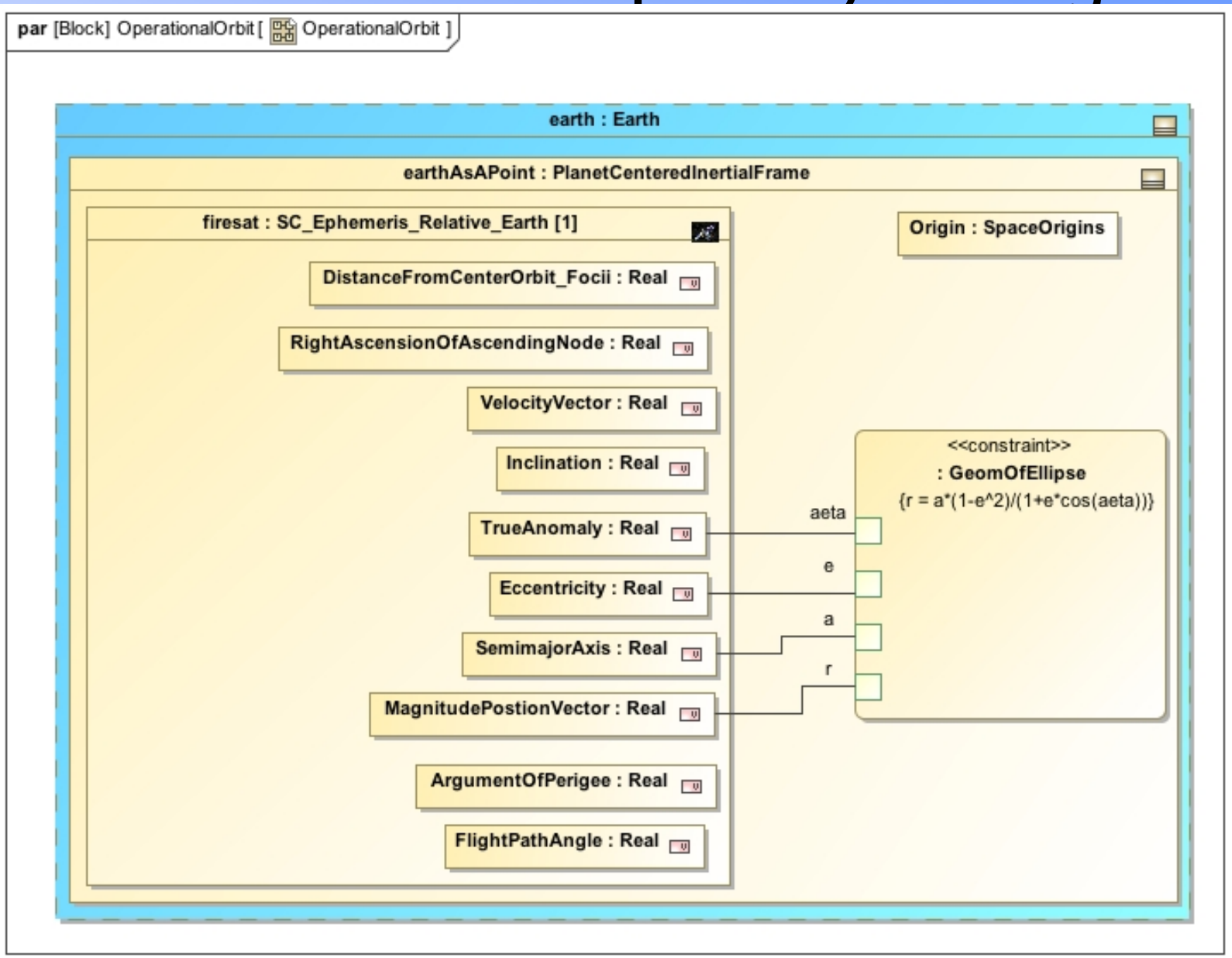
Parametrics Issues

- Would like to be be able to see instance values on these
- Stronger connection between requirements and model properties

Affects

- Responsiveness <-> Coverage
- Coverage <-> Orbit Design
- Orbit Design <-> Power Design

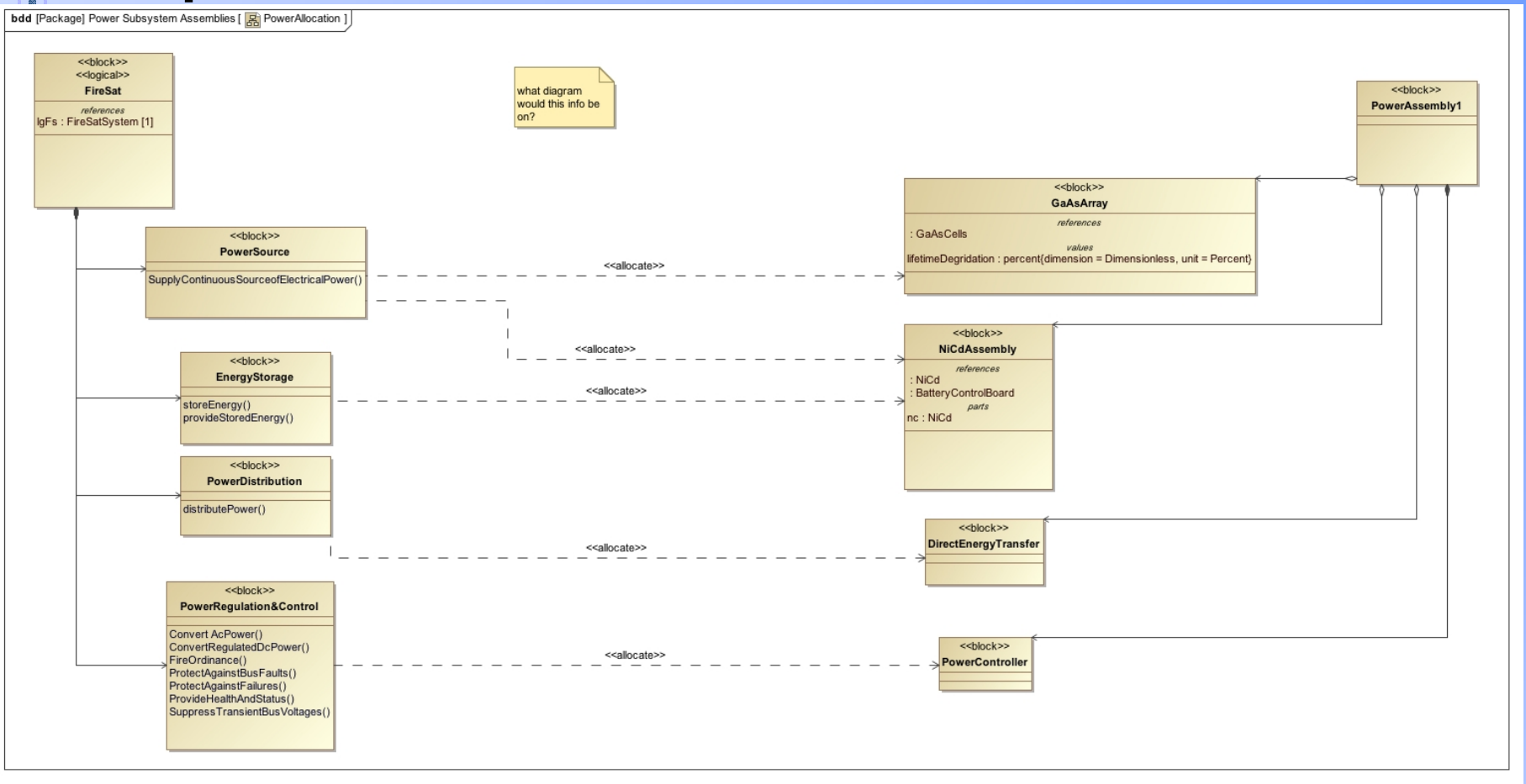
Mission Orbit/Trajectory Design



Parametrics and Activities

- Want to show how a function or goal (delta-v) causes a change in the orbit
- Cant show this
  - putting activity on IBD creates separate usage (meaning is unclear)
  - No way to bridge properties onto activity diagram at all
- It is often desirable to show constraints on functions
- Constraints and activity blocks live in harmony on BDDs why not IBDs and Activity diagrams?
- At the end of the day you have a tree of parts and the leaves are all functions, properties and constraint properties
  - SysML should be consistent in combining these depictions

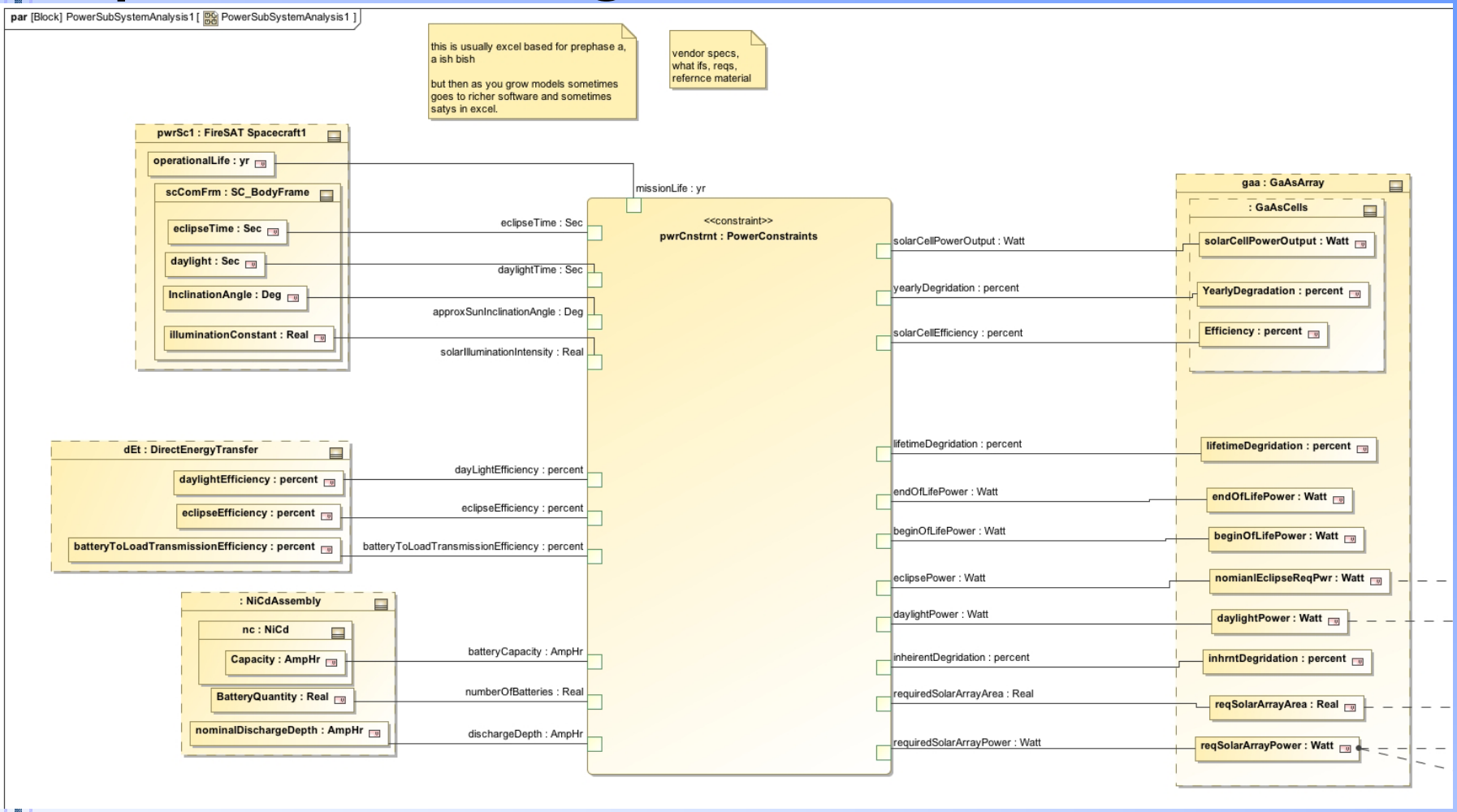
Functional descriptions and requirements

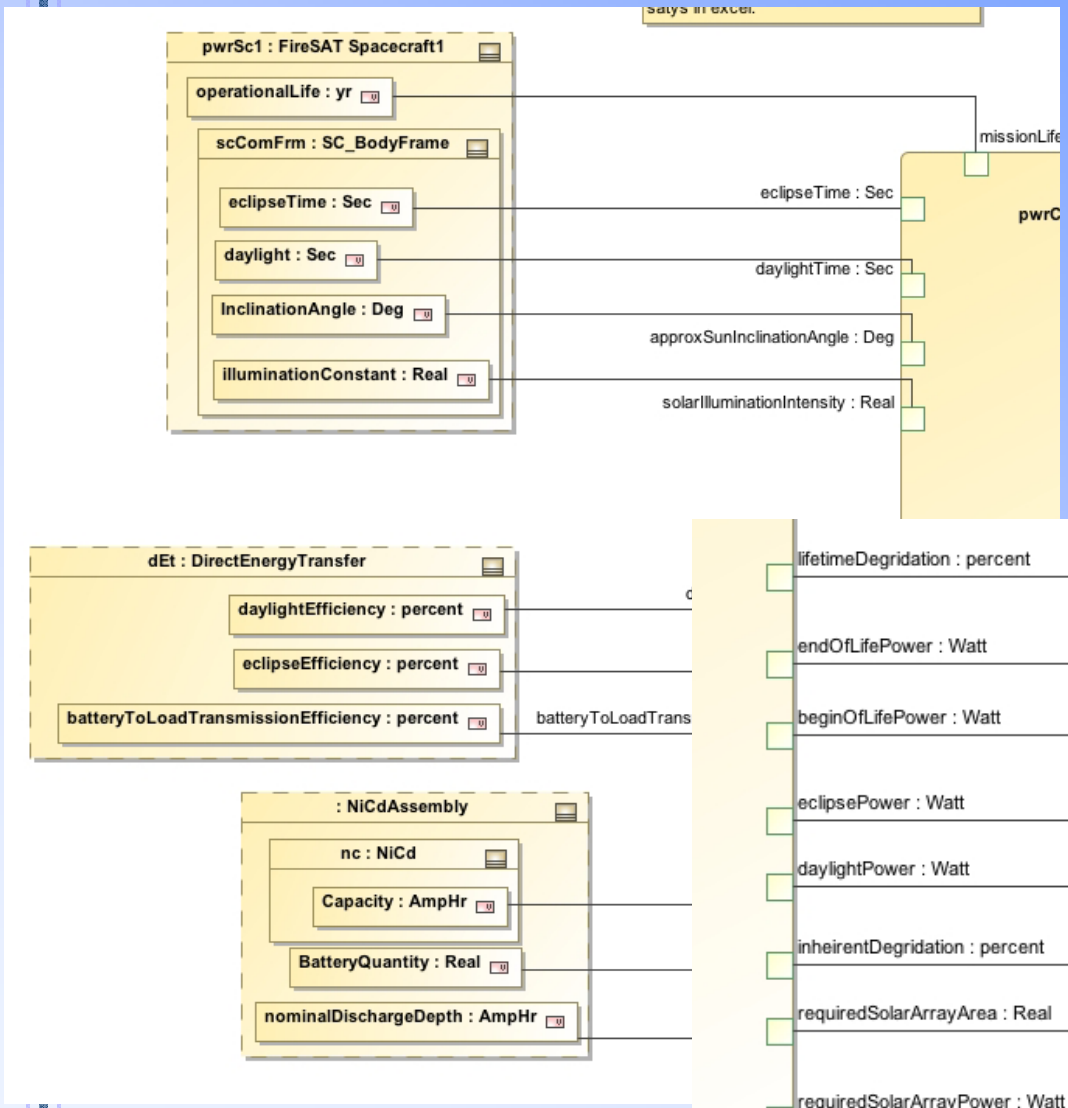


Activities Issues

- Not clear why activities allocated or composed into a blocks are different then operations.
  - Inconsistent
  - leads to lots of extra linking and mapping or just disconnects in model
- Would prefer actions to be like parts
  - Use same on activity or IBD

Specific Configuration





Activities or state models would be useful to show change say from different modes of spacecraft

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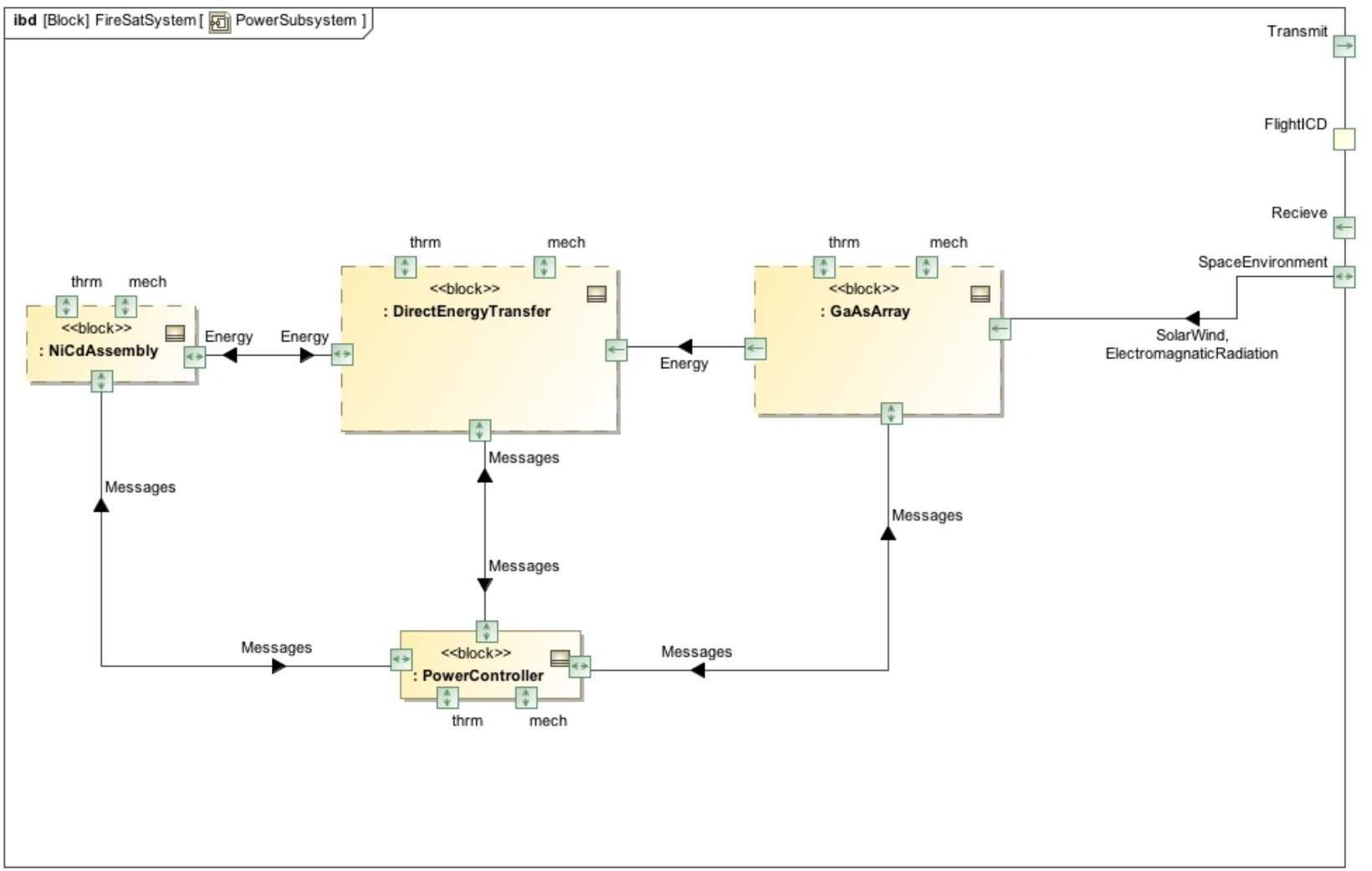
Physical Synthesis



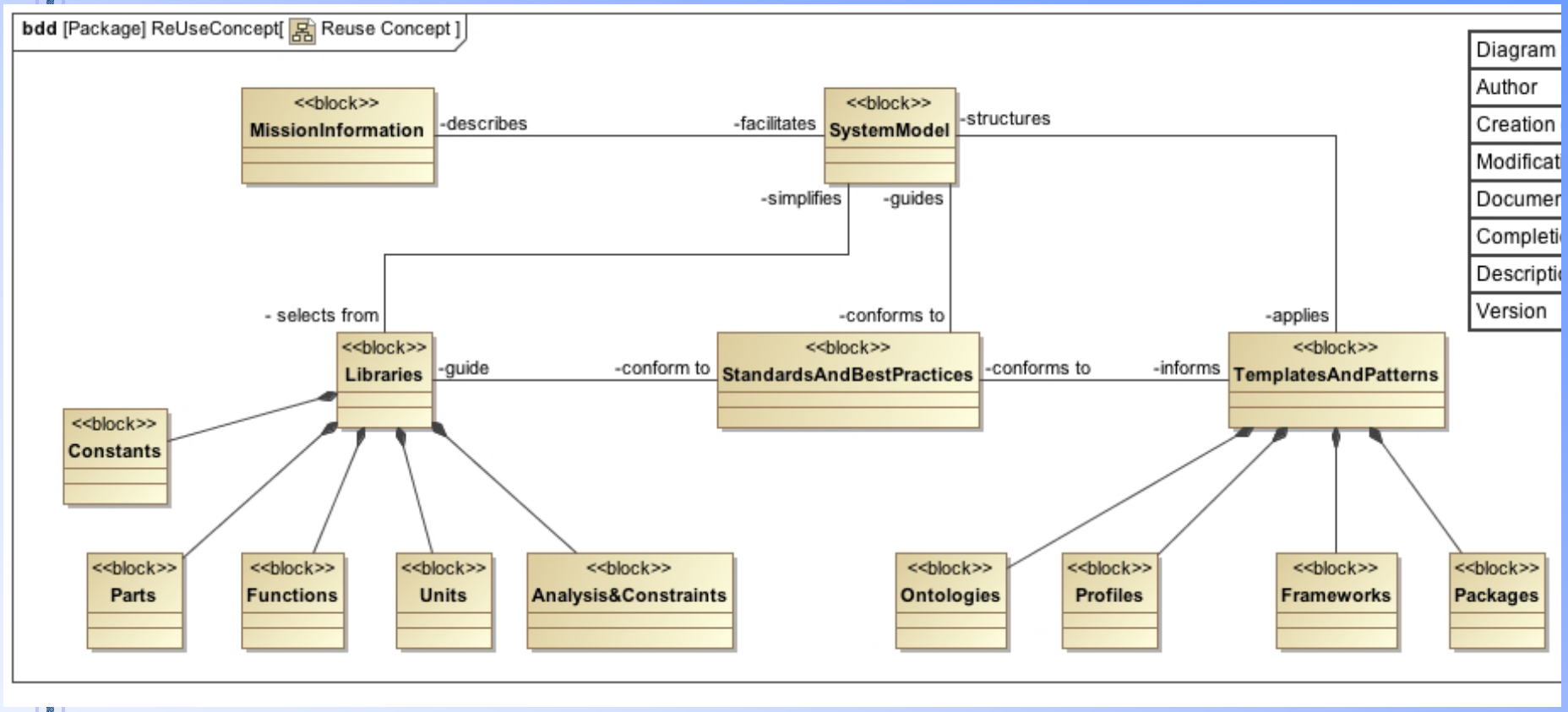
Model Reuse Benefits

- Understanding model reuse at an early stage
  - Becomes a proven set of common modeling tools
  - Extends value of effort
  - Simplifies overall modeling effort
  - Library is testable

Space Systems Model Library

- A collection of reusable artifacts expressed in SysML and various numerical implementations (e.g. Matlab scripts)
  - Thermal, Mechanical, Power etc
  - Functions, Parts etc
- Resource for facilitating MBSE in Space Systems
- Envision a “tool kit“ and “building blocks”

Model Reuse



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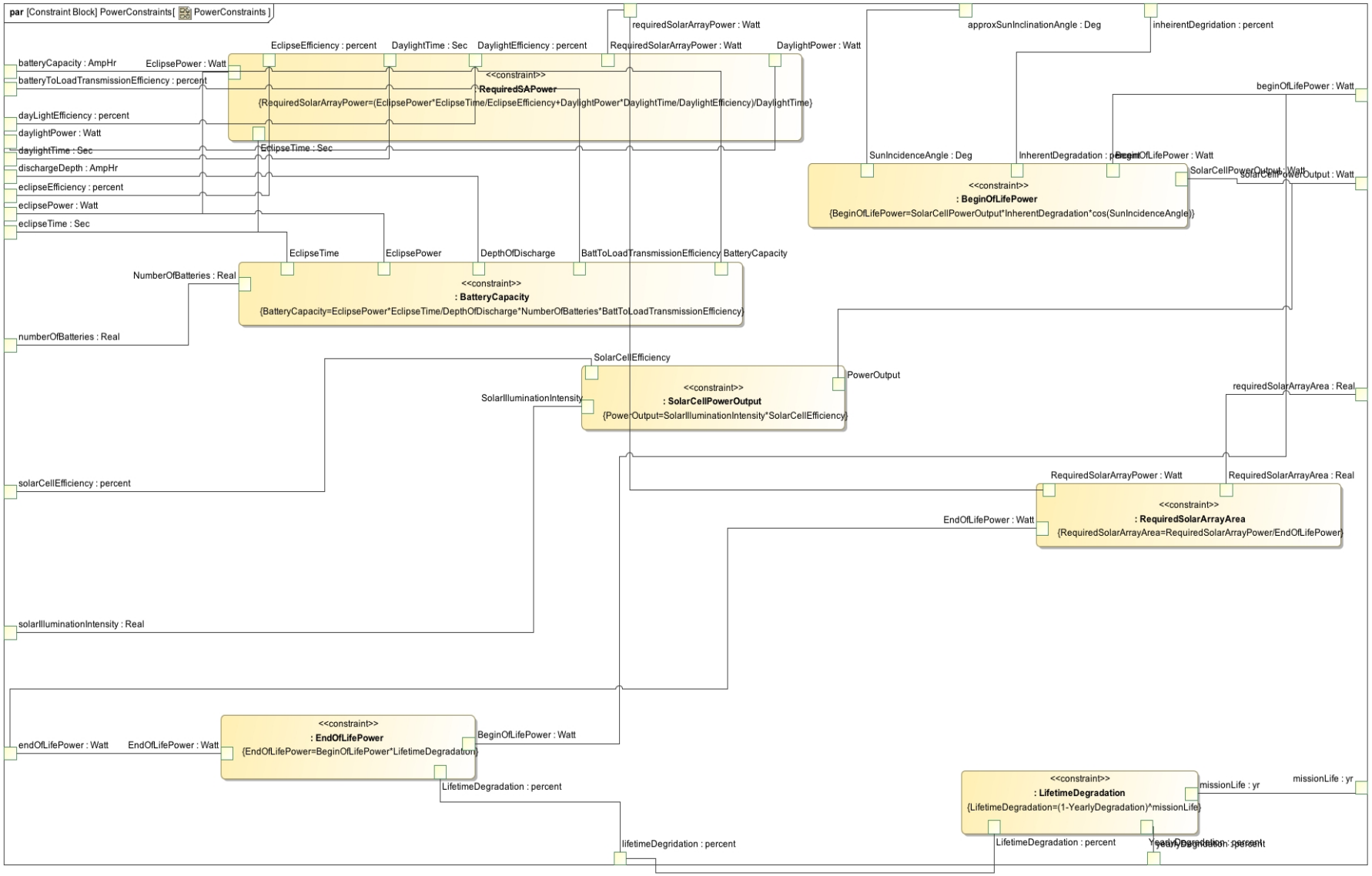
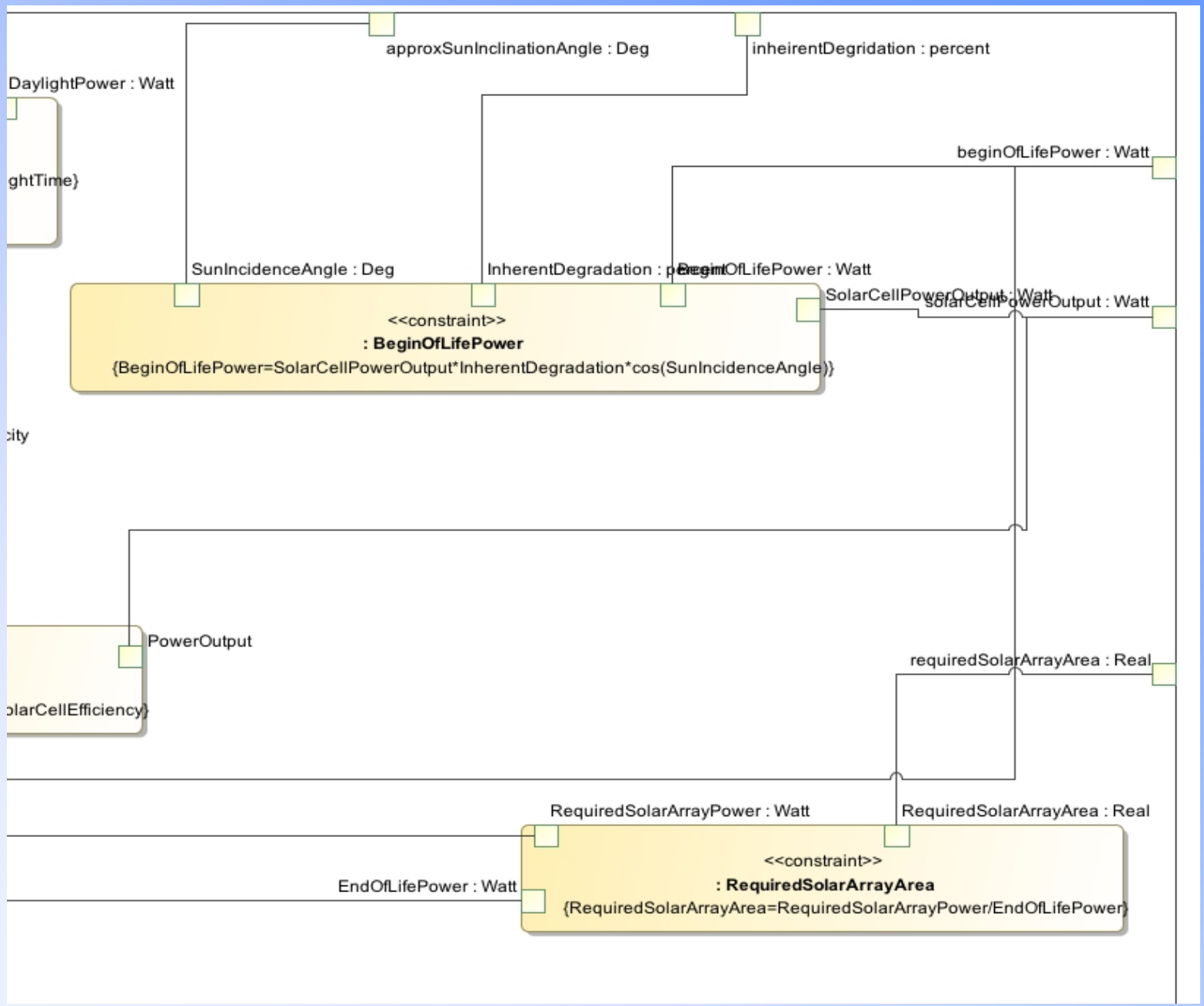
Power Analysis from Reusable Library





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Lack of Robust Model Interchange

- Library is stuck in tool of implementation
- Tools for testing are limited
- Need rules (pre-processing) to ensure built as intended
- No way to tell what fidelity will be provided
- No way to know when it is appropriate to use library elements
- Is ontology the Solution?

Parametrics Equation expression

- Desired to show “mathematical symbols”
- Have list of appropriate solvers within constraint
- TABLES
  - Toggling between diagrams and tables of values and equations is HIGHLY desirable
- Sets of alternatives are pain-staking to represent

Timing, Timelines and Time

- Desire to express states, functions, events etc on a timeline
- No way in SysML to account for time as a first-class element of the model
- Would be very useful to have time related info at least on activities (duration, etc – like a PERT chart)
- Suggestion: Parametrics are part of structure and behavior, make time the 4th pillar

Useability

- Many Systems Engineers don’t have a lot of software/language background
- SysML tools are built on Software tools
  - Many assumptions
  - Software versioning tools
  - Lots of manual stuff
  - Poor support for making Systems Engineering work products – Documents
  - Where are my tables?

What next

- Look at profiling time based examples
- Explore some more state analysis examples
- Rich future for SysML execution

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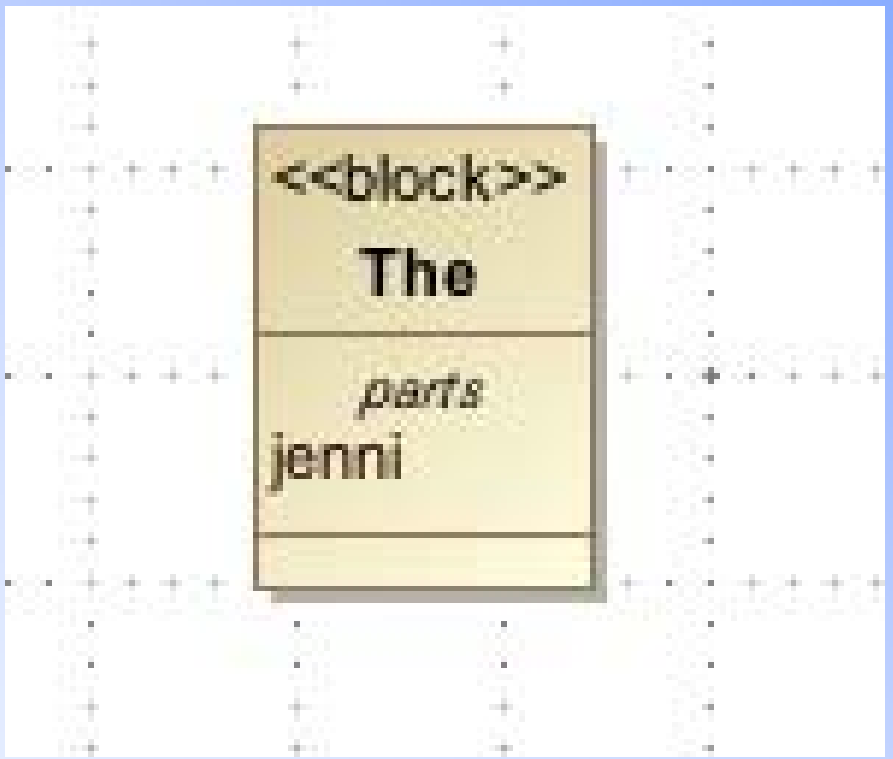
Back Up Slides



What is State Analysis?

- A model-based systems engineering methodology
  - Based on familiar principles from control theory
  - Complementary to the functional decomposition approach
  - Intended to help address the complexity challenge
- It provides a methodical and rigorous approach for: