intercax

# System Analysis

## Requirements for SysML 2.0

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# Contents

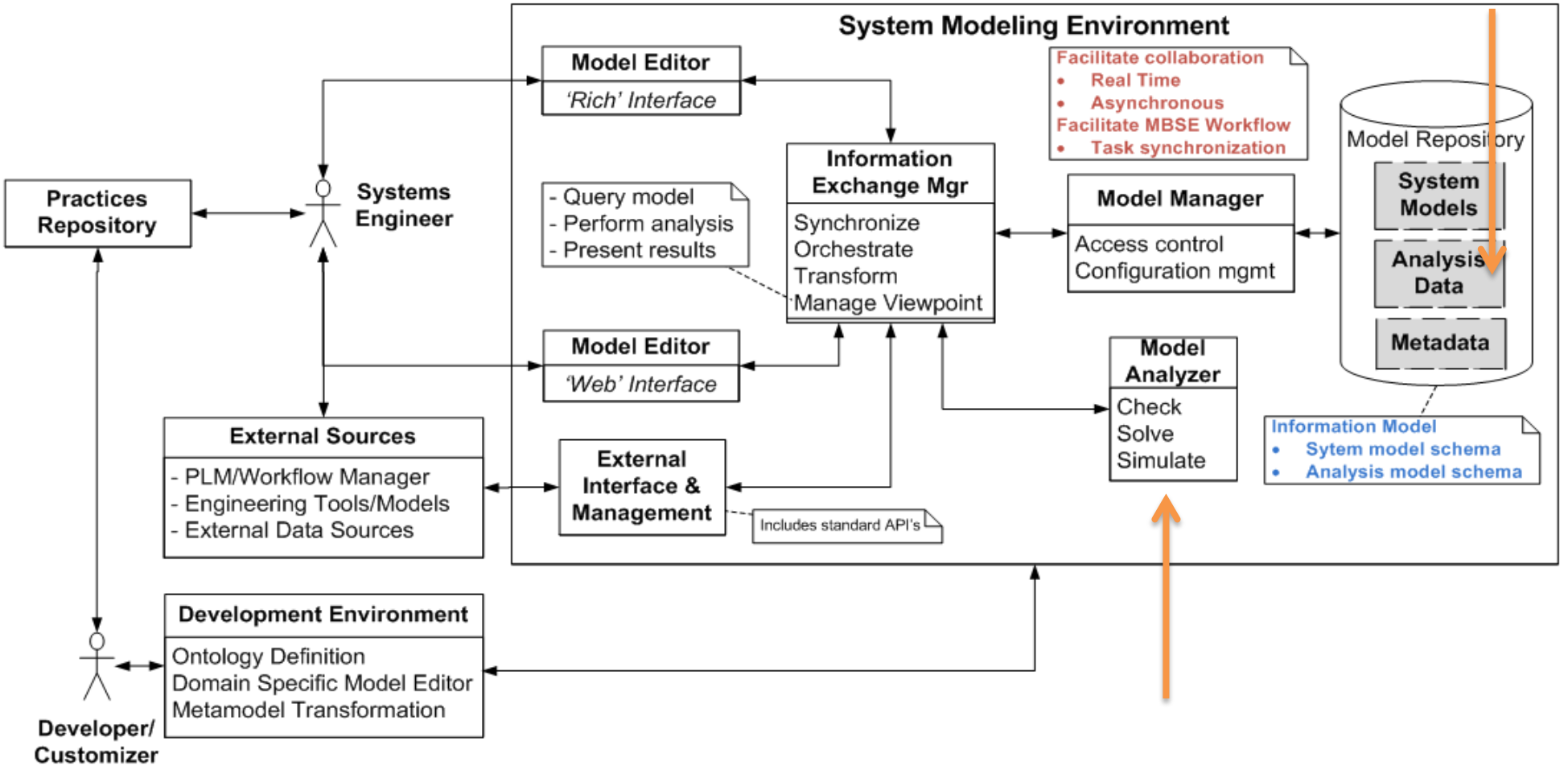
- Goal 
- Analysis
  - Concept
  - Issues in SysML 1.4
  - Effectiveness Measures
  - SME Services to Support Analysis
  - Hybrid SUV Change Scenario
- How can you get involved?

# Starting Point

*Evolving SysML and the System Modeling Environment to Support MBSE*
*Draft (February 1, 2015)*
*S. Friedenthal/R. Burkhart*

The **next-generation modeling language** must include **precise semantics** that avoid ambiguity and enable a concise representation of the concepts. SysML currently leverages the UML metamodel for much of its semantic foundations. The language must be based on a well-specified logical formalism that can leverage the model for a broad range of analysis and model checking. This includes the **ability to validate that the model is correct and consistent, and the ability to answer questions such as the impact of a requirement or design change, or the assessment of how a failure could propagate through a system**. The language and tools must also **integrate with a diverse range of equation solvers and execution environments. The language must also be able to represent, relate, and present quantitative data sets that can vary with time and space, and have probability distributions**.

# System Modeling Environment



# Goals

- Analysis must be seamless integrated with system development and operation
- Support various types of analyses and execution tools
- Manage analysis models and relate results to decisions
- Improved user interaction to define/generate, execute, archive analysis models (analysis lifecycle)

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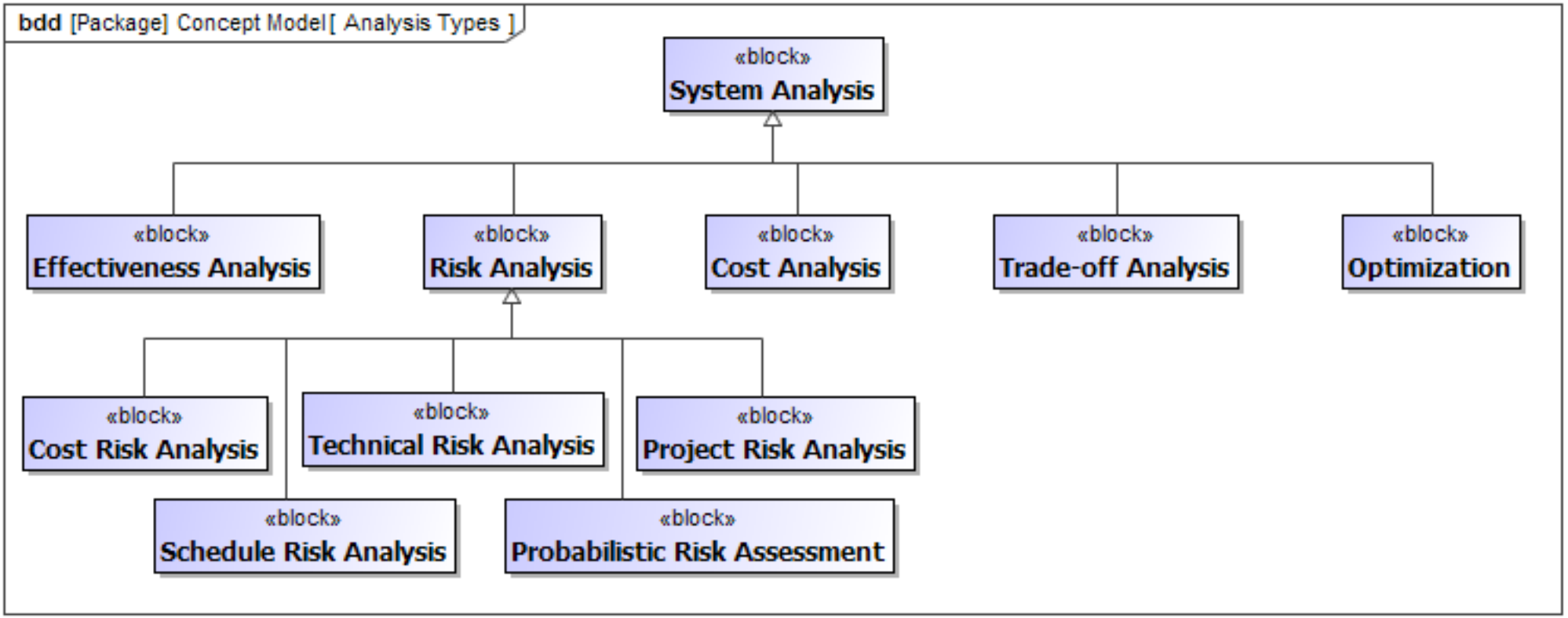
# What is Analysis?

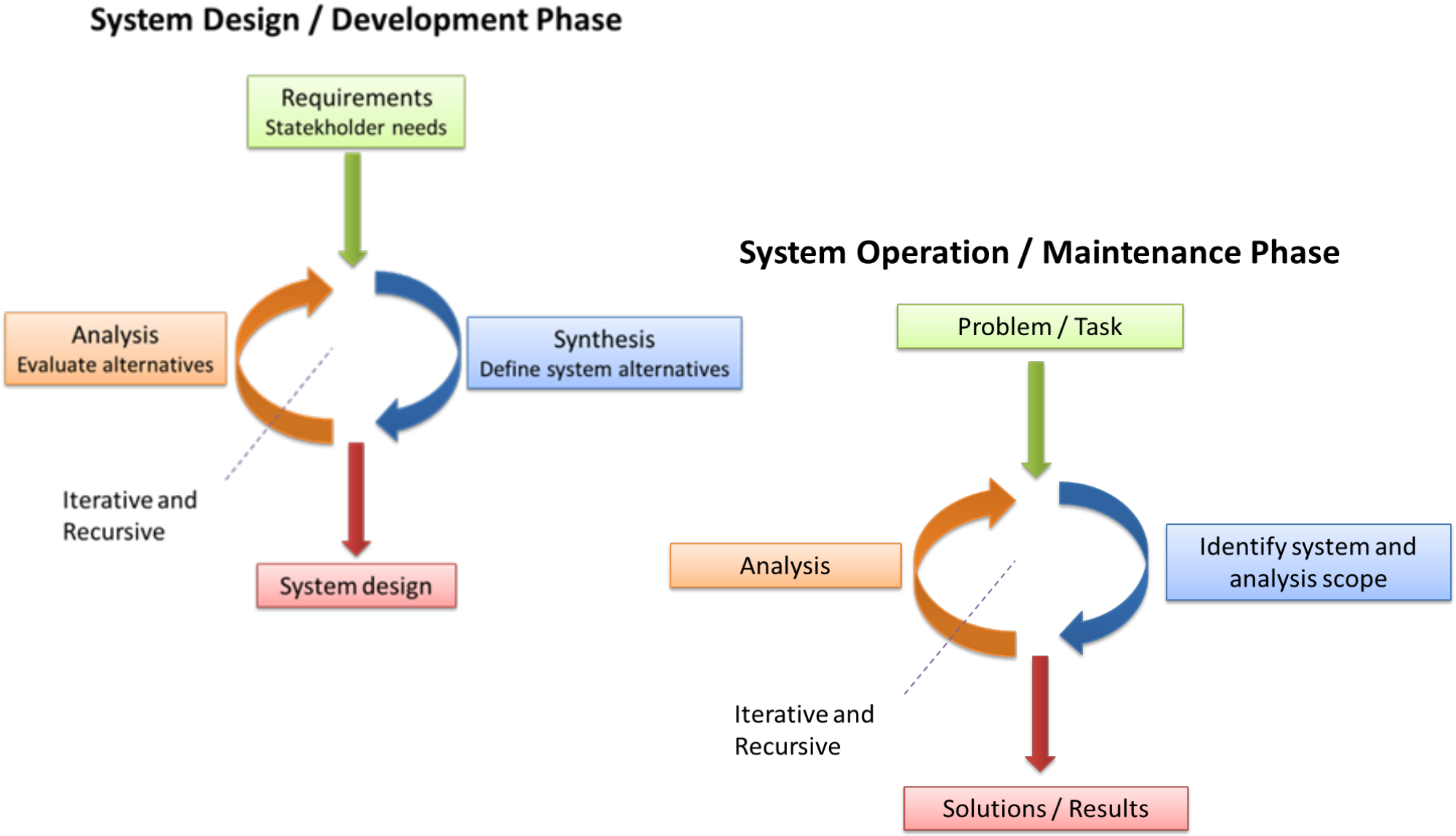
- Systematic investigation of a real or planned system to (a) compare and select candidate system architectures, or (b) determine causes & resolutions of failures / exceptions
  - SEBoK - http://goo.gl/RCtAKt
  - NASA SE Handbook (2007) - http://goo.gl/iVBVES
- Examples (design, manufacturing, operation)
  - Compare the mileage/cost for a set of car designs
  - What is the design impact of a requirement change?
  - Optimize manufacturing process to max yield/cost
  - What parts may have caused a function to fail?

# Types of Analyses

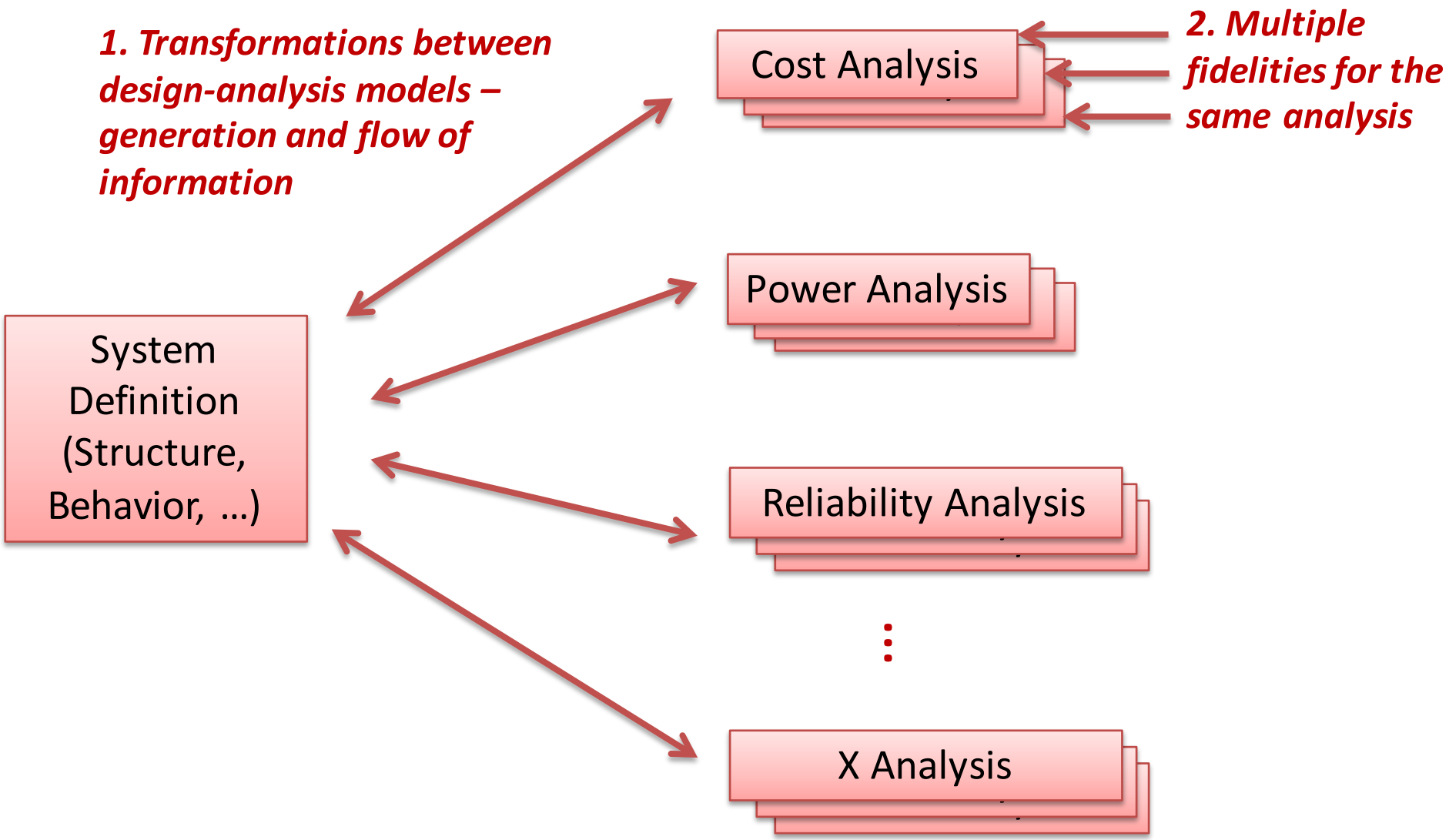



- **Quantitative Analyses**, e.g. computing MoEs
- **Qualitative Analyses**, e.g. If I change (increase) X, will Y change (increase/decrease)?

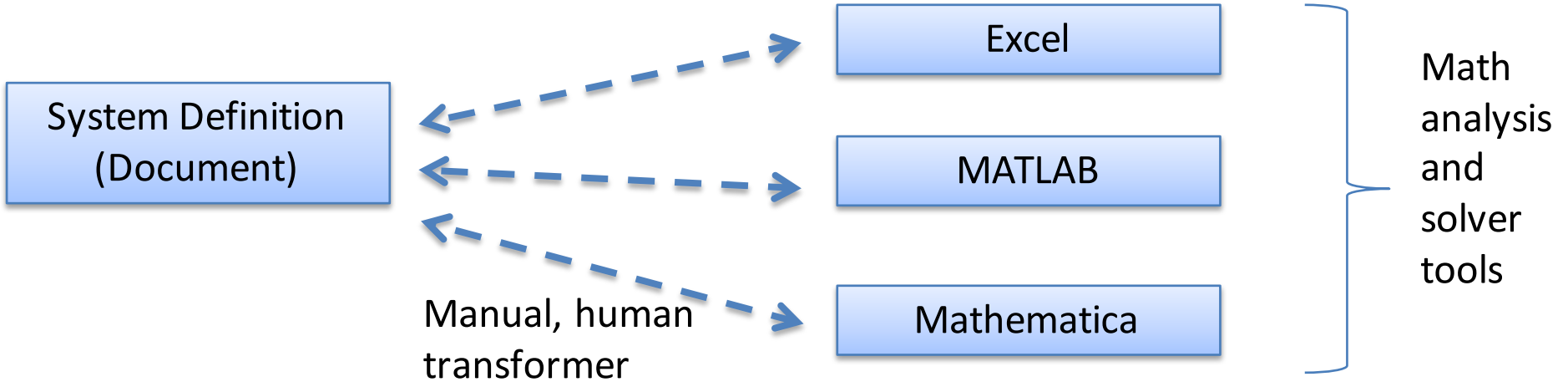
# Analysis during system development and operations



# Design and Analysis are separate models

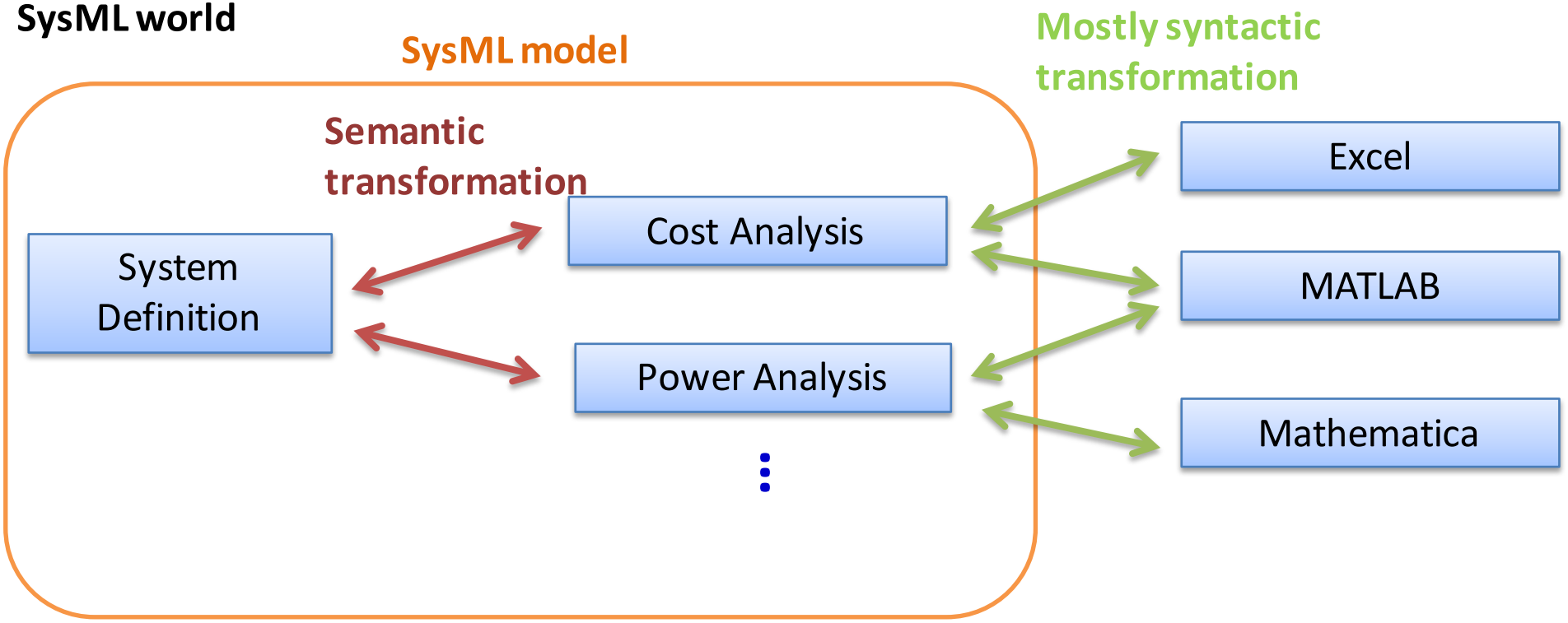


# Where does the system analysis model live?




**Pre-SysML world**

**SysML world**



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# Issue #1 – Analysis is a missing concept, Where do I start?

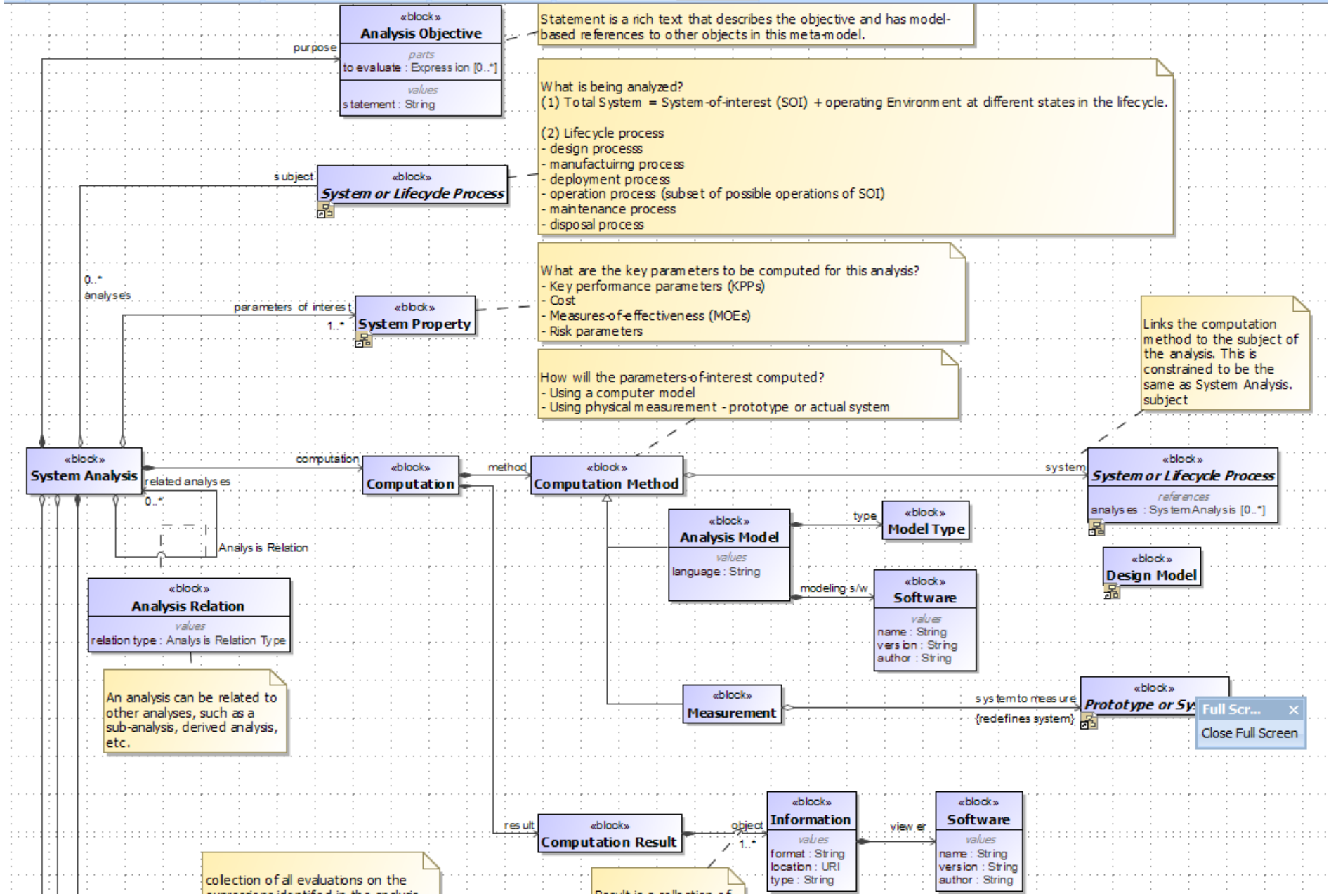
- Analysis is a missing concept in SysML
  - SysML provides low-level modeling constructs (e.g. blocks, constraint blocks, activities) that can be used for representing various SE artifacts. But,
  - Missing high-level SE concepts such as “System”, “Analysis”, “Decision”, “Trade Study”
- Given a system definition/design, can’t easily query
  - What *analyses* will be or have been performed on the system?
  - What are the *results* of the analyses?
  - What issues did the analysis reveal?
  - What architecture decisions were taken from the analyses?
  - Where is the revised version of the architecture?

# Issue #2 – No clear way to represent and query artifacts related to analyses

- No direct and clear way to represent:
  - Objective of the analysis
  - System MOEs being analyzed
  - Analysis models (multiple fidelities) for computing MOEs
  - Execution of analysis models (tools, versions, …)
  - Results of executing analysis models
  - Decisions taken from analysis models
  - Analysis relations
    - Decompose a complex analysis into sub-analyses
    - Upstream and downstream analyses

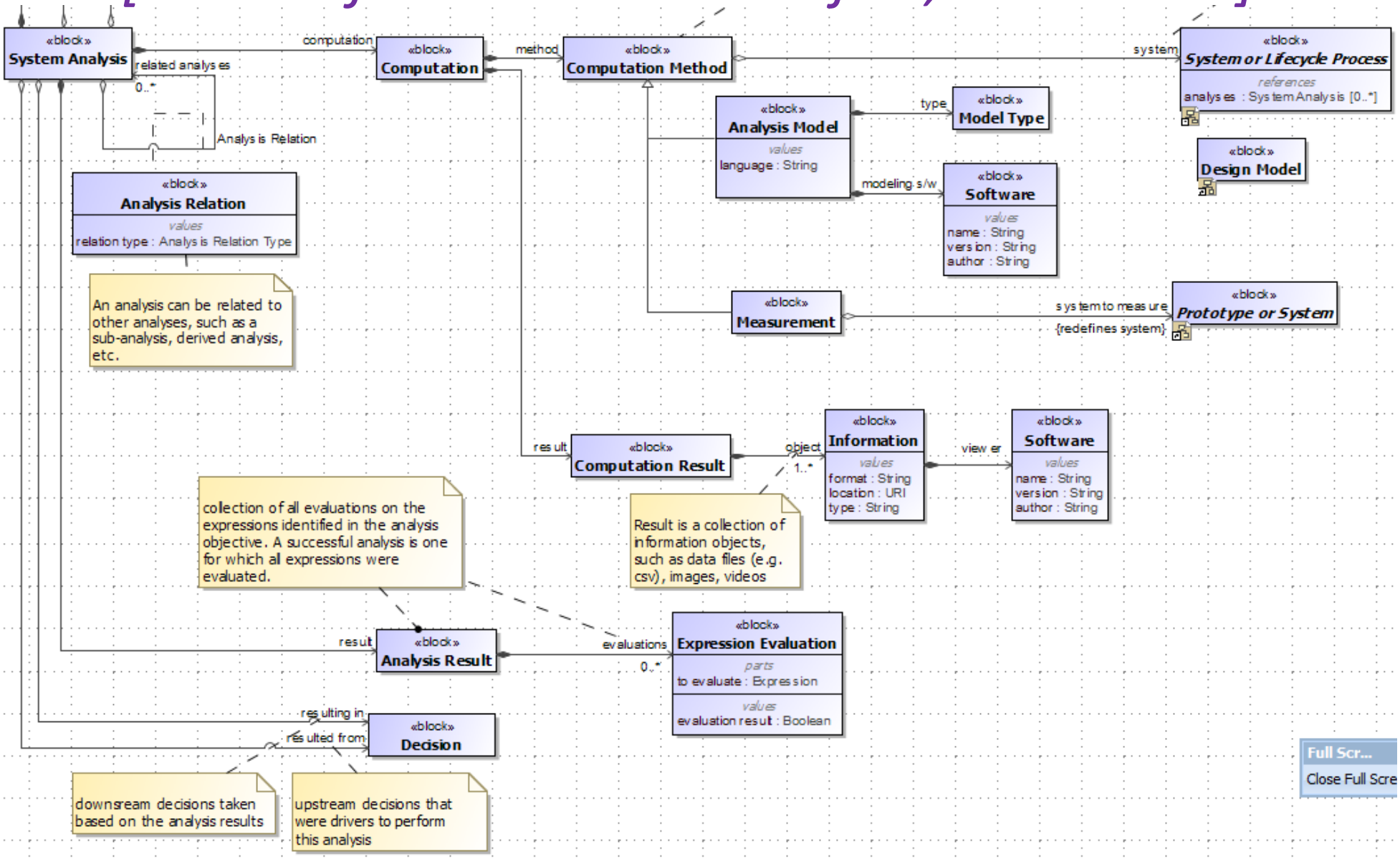
# System Analysis Meta-Model (1/2)

*[Result of NIST-Intercax Project, 2014-2015]*



# System Analysis Meta-Model (2/2)

*[Result of NIST-Intercax Project, 2014-2015]*



# Issue #3 – Design <-> Analysis Model Transformations for Simulation-Based Design

- Where do I express model transformations between design and analysis models?
- Design -> Analysis Model Transformations
  - Knowledge capture -- What assumptions does an analyst take?
  - Executable transforms -- Change the design model, update the analysis model automatically
- Analysis -> Design Model Transformations
  - Relate analysis results of the system design
  - Reconstruct design models from analysis models
- Reference
  - *Knowledge Composition Methodology for Efficient Analysis Problem Formulation in Simulation-based Design (Bajaj, PhD Dissertation, 2008, Georgia Tech)*
    - https://smartech.gatech.edu/handle/1853/26639

# Issue #3 (cont.)

- Express mathematical transformations between constructs in SysML, or SysML and non-SysML constructs, e.g.
  - SysML parametrics <-> equation-based models,
  - SysML state machines <-> state-based models,
  - SysML IBD/Activity <-> flow-based models,
  - SysML <-> graph-based models
- Currently this is no way to express these transformations except for some “tagging” using custom stereotypes
- Potentially extend the viewpoint concept with math formalisms to generate non-SysML models (views beyond static documents)

# Issue #4 – Missing Types and Confusing Units

- System definition and analysis needs a rich representation of types
  - Arrays, Lists (ordered/unordered), Sets, …
  - Matrices (mxn)
  - Map (key-value pairs)
  - Tensors and Vectors
  - Mutable and Immutable objects (constants)
  - Date and Time
  - Geographic map
  - Probability Distributions

# Issue #4 – Missing Types and Confusing Units (cont.)

- Yes, we have a QUDV profile and a library of units but it hasn't been useful
  - Units and quantity definitions are fundamental, shouldn't be non-normative extensions. Not all SysML tool implement this.
  - Library of units only SI, missing FPS system
  - Confusing and difficult to create complex, derived units -- given value types *kg*, *m*, *s*, and *kg.m/s^2*, how do I create the value type *g.cm/s^2* leveraging the existing quantity kinds and dimensions?
- Verify if units are same and automated conversion

# Issue #5 – Operators and Functions

- Operators, such as these, should be a core integral part of the language
  - Differentials $\partial/\partial t$ (of space, time, and other variables)
  - Integrals $\int$ (over space, time, and other variables)
  - Time (temporal properties)
  - Probabilities (property distributions)
  - Math functions
    - Trigonometric, Logarithmic, Hyperbolic, …

# Issue #6 – Geometry

- Lack of geometric concepts needed for design, analysis, and requirements, e.g.:
  - *Distance between CG of comp A and comp B shall be no more than 4.5 cm*
  - *Shape of part A is a Sphere with radius 5 cm*
- Example concepts
  - Co-ordinate systems (Rectangular, Polar, etc.)
  - Primitive 2D shapes (point, line, triangle, rectangle/square, pentagon,…,circle)
  - Primitive 3D shapes (3D point, plane, cuboid/cube, sphere, cylinder, cone,…)
  - Mass properties (mass, volume, density, bounding boxes, moments-of-inertia, …)

# Issue #7 – Visualization of analysis results

- Various forms of visualization of analysis results should be available
  - Tables
  - Plots (2D and 3D)
  - Custom charts (extensibility)

# Issue #8 – Universal Unique ID (UUID)

- Universal Unique ID (UUID) to identify all system elements. We must first identify the system / view being analyzed, analysis model, results, and decisions related to that
- UUID concept needs to be a part of the spec and implemented by each SysML tool. Currently each tool defines its own ID system and some have multiple
- Necessary for SysML elements to interoperate and traceable with elements from non-SysML modeling tools and repositories (e.g. PLM, ALM, Databases, Resource on the web)

# Issue #9 – Version and Configuration Management

- Version chain
  - What version of the system architecture was analyzed?
  - What version of the analysis model was used?
  - What version of the solver tool used for executing the analysis model?
- Configuration control
  - Who created the analysis and who can modify?
  - Who can run the analysis?
  - Who can view the results of the analysis?
  - Who can affect the system architecture based on the analysis?

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# Effectiveness Measures

- Can I unambiguously represent analysis and related artifacts for a system, as listed in Issue #2?
- Can I perform analysis-related queries on the system architecture model, as listed in Issue #1?
- Can I keep track of the analysis and related artifacts for future lookup and queries, as listed in Issues #1,2,9?
- Can I seamless generate analysis models in various tools/languages from the SysML architecture model, and can I update/sync the analysis model if the system architecture changes? (Issue #3)

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    - *See latest version of the spreadsheet*
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# Scenario #1

## *Gov regulation to improve fuel efficiency*

- Analysis needs:
  - HSUV design: Size, Weight, Power,…
  - Environment: Road, Drag (Air), Traffic, Conditions (city/hwy)
  - Driver: Driving profile
- Analysis model
  - Acausal parametric model + trades and optimization
    - Given the design, environment, driver variables, compute fuel efficiency
    - Given the target fuel efficiency and avg values of environment and driver variables, compute max size/weight and min power
  - Fidelities
    - Simple analytical model (static equations)
    - Complex analytical model (dynamic, time-based integrals)
    - CFD model using 2D / 3D CAD of the HSUV
  - Analysis/Simulation Tool
    - Mathematica / MATLAB for equation-based analytical models
    - ABAQUS / ANSYS for CFD models

# Scenario #2

## *Vehicle fails to meet fuel efficiency requirement*

- Search model repository for fuel efficiency analysis models used, and result sets (HSUV design, environment, and drive profile used)
- Compare result set with the actual prototyped / built vehicle.
- Setup and perform new analyses
- Provide recommendations to the design team

# Scenario #3
## *Recall catalytic converter*

- TBD

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# Next Steps

- Review this deck and email feedback to:

  manas.bajaj@intercax.com
- Participate
  - Send me an email
  - Following have expressed interest
    - Michael Chonoles (Independent, Astah)
    - Bjorn Cole (JPL)
    - George Walley (Ford)
    - Hans-Peter (ESA)
  - Setup a simple process to review and expand concepts
  - Bring issues/examples for SysML 2.0