Supporting the Reuse of Algorithmic Simulation Models

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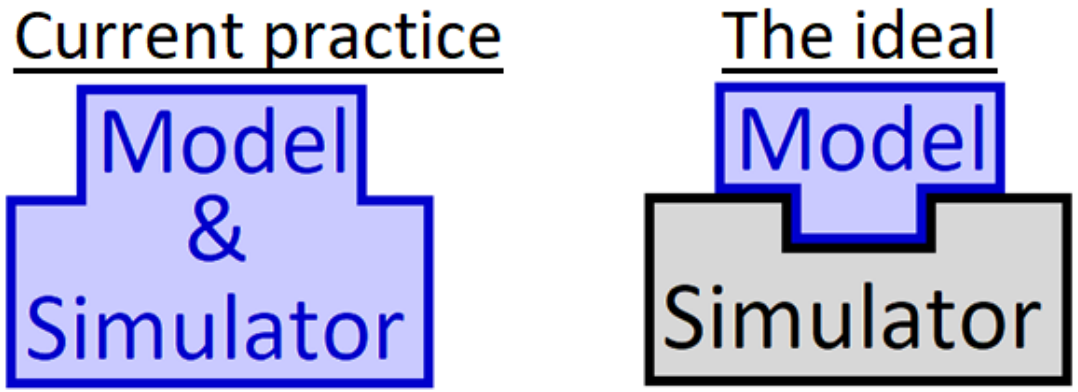
Research problem: simulation model reuse remains elusive

- **Custom monolithic simulation models are the norm in government and industry**
- **Model and simulator not kept separate**
- **Simulation models can't be shared**
  - Modeling teams are constantly 'reinventing the wheel'
- **DEVS modeling formalism allows for model reuse, but has a steep learning curve that discourages use outside of academia**
- **Algorithmic models are specialized DEVS atomic models that return an output in the same (simulation) time instant their inputs are received**
  - They can be thought of as memoryless functions
- **<u>Our solution</u>: reduce the steep learning curve of DEVS through a custom DEVS M&S IDE; start with algorithmic models then generalize so that non-experts can reap the rewards of model reuse.**

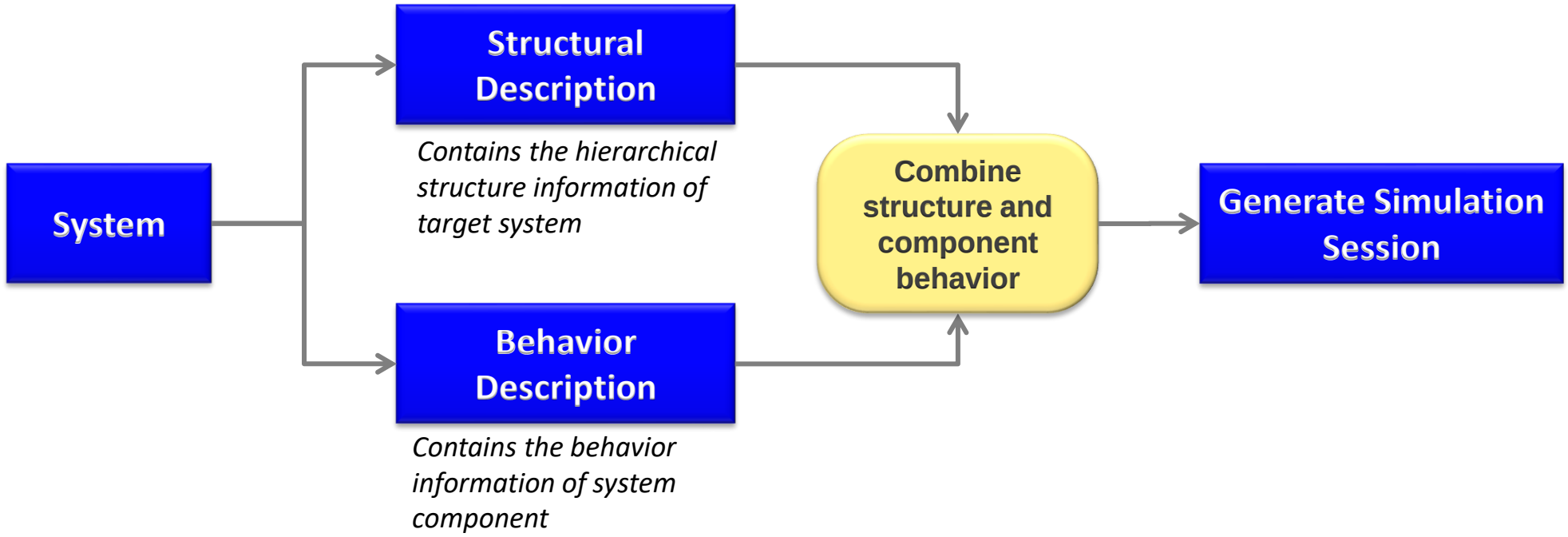


Outline

- DEVS (Discrete Event System Specification)
- MS4 Me
- Algorithmic model reuse case study
- Future work

DEVS Modeling & Simulation Approach

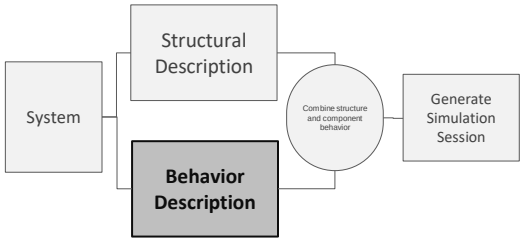
- **DEVS (Discrete Event System Specification) formalism provides an engine for advanced Modeling & Simulation (M&S) technology to support "build and test"**
  - DEVS evaluates different design alternatives of a system, where information of system structure as well as component behavior can be implemented in an integrated simulation environment.

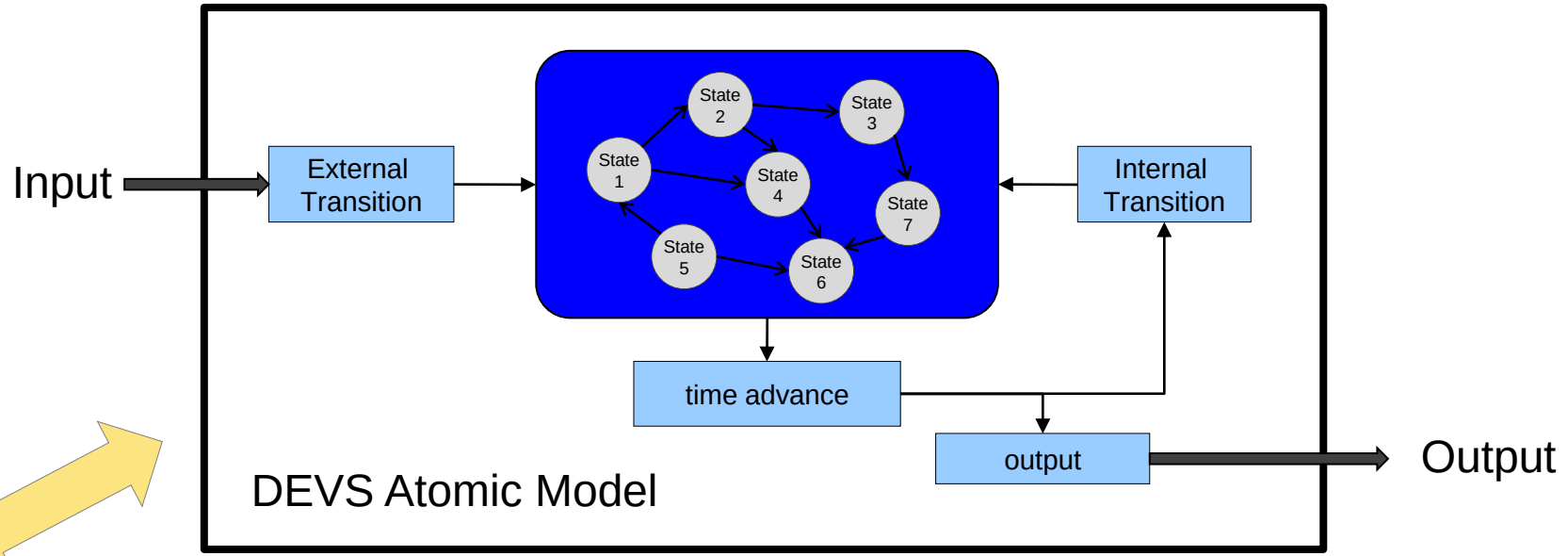


4

Behavior Description : DEVS Model

- **DEVS model describes the behavior of a component based on state transition that displays discrete event activity of system.**





The atomic DEVS Model for Ping-Pong Players

The atomic DEVS model for player A of Fig. 1 is given Player=$< X, Y, S, s_0, ta, \delta_{ext}, \delta_{int}, \lambda >$ such that

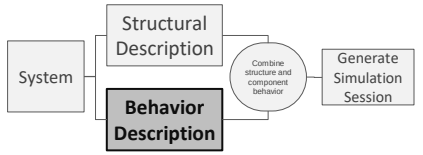
$$
\begin{aligned}
X &= \{?receive\} \\
Y &= \{!send\} \\
S &= \{(d, \sigma) | d \in \{Wait, Send\}, \sigma \in \mathrm{T}^{\infty}\} \\
s_0 &= (Send, 0.1) \\
t_a(s) &= \sigma \text{ for all } s \in S \\
\delta_{ext}(((Wait, \sigma), t_e), ?receive) &= (Send, 0.1) \\
\delta_{int}(Send, \sigma) &= (Wait, \infty) \\
\delta_{int}(Wait, \sigma) &= (Send, 0.1) \\
\lambda(Send, \sigma) &= !send \\
\lambda(Wait, \sigma) &= \phi
\end{aligned}
$$

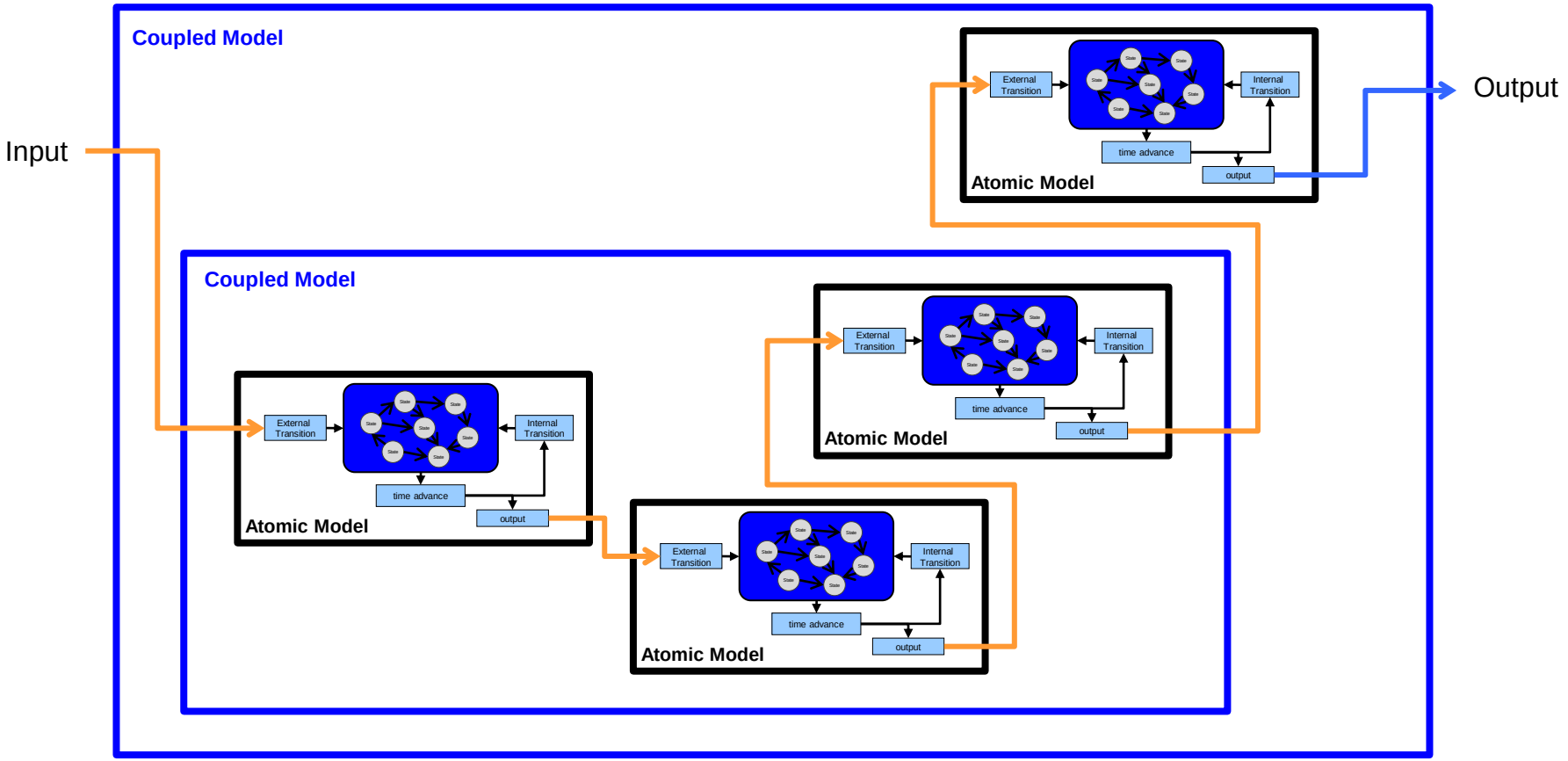
Both Player A and Player B are atomic DEVS models.

5

Behavior Description : DEVS Model

- **Multiple model constructs a bigger coupled model, where each model interfaced via input and output port.**



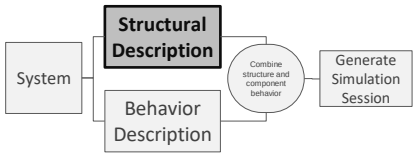


6

Structural Description : System Entity Structure (SES)

The coupled DEVS model

The ping-pong game of Fig. 1 can be modeled as a coupled DEVS model $N =< X, Y, D, \{M_i\}, C_{xx}, C_{yx}, C_{yy}, Select >$ where $X = \{\}; Y = \{\}; D = \{A, B\}$; M_A and M_B is described as above; $C_{xx} = \{\}$; $C_{yx} = \{(A.!send, B.?receive), (B.!send, A.?receive)\}$; and $C_{yy}(A.!send) = \phi, C_{yy}(B.!send) = \phi$.



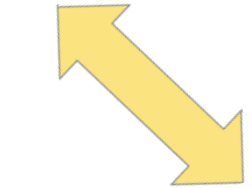
- **The System Entity Structure (SES) is a formal framework to represent the elements of a system (or world) and their relationships in hierarchical manner.**

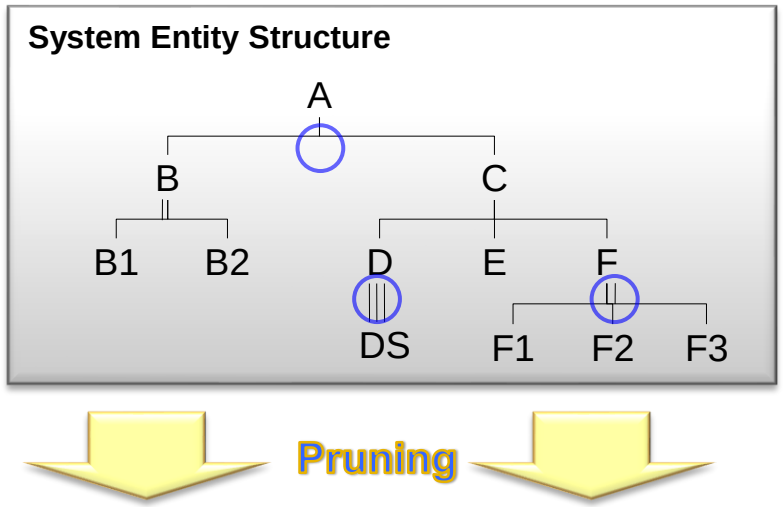
Aspects represent ways of taking things apart into more detailed ones and labeled decomposition relation between the parent and the children

Specialization categorizes things in specific forms and is a labeled relation that expresses alternative choices.

Multi-aspects are aspects for which the components are all of the same kind.

Pruning:
An operation to cut off structure in a SES that is not needed to meet particular problem specifications.





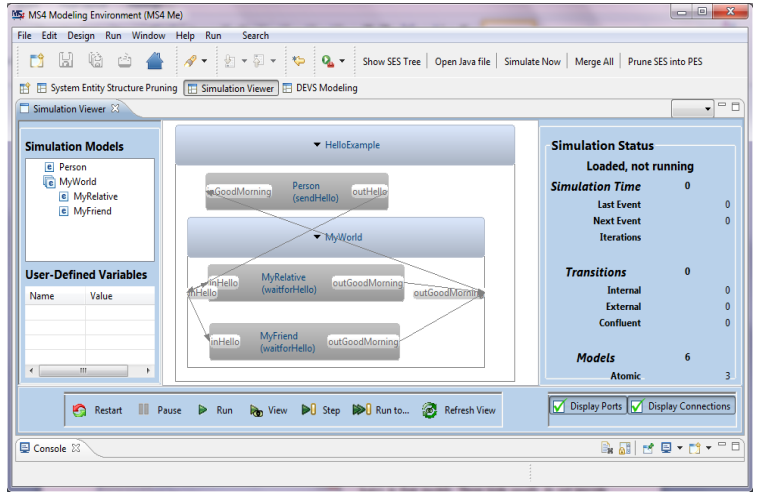
Why was MS4 Me* developed for DEVS based modeling and simulation?

- **DEVS representation formalism needs to be easier for non-experts to understand**
- **Users do not have to learn formal representation of DEVS models and simulation at the beginning**
- **Mapping DEVS to DEVS Natural Language (DNL) provides abstraction layer and makes communication easier**
- **Graphic User Interface can be built on top of the abstraction layers**
- **Flow of information from Top-Down to Bottom-up, High Level and Low Level (codes and GUI)**

* MS4 Me is a commercial M&S Integrated Development Environment (IDE) maintained by MS4 Systems since 2011.

MS4 Modeling Environment

- **Software Tool for DEVS Modeling and Simulation**
  - Based on Java and Eclipse RCP environment
- **Top down modeling methodology**
  - Sequence Diagram Designer generates a SES file and DNL files
- **Bottom up modeling methodology**
  - State Diagram Designer generates DNL files



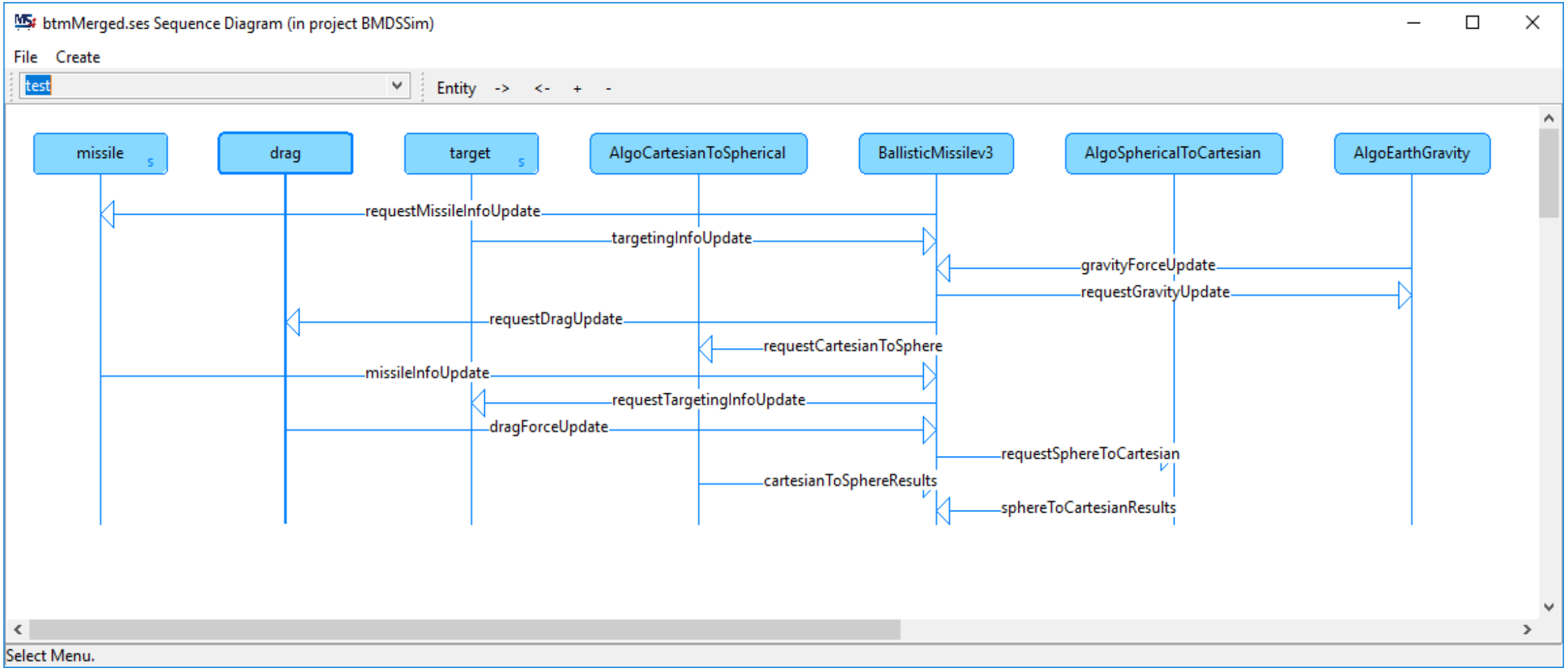
Features

- **Highlight keywords capability when editing SES and DNL files**
- **Automatic converting DNL files to Atomic Java Models**
- **Tree Viewer for a SES file**
- **Pruning process from Pruning SES document to generate coupled Java models**
- **Launch page to help directly access to the SES and PES files**
- **Support dynamic structure model**
- **Graphing capability**
- **1 year free trial license: ms4systems.com/pages/downloads.php**

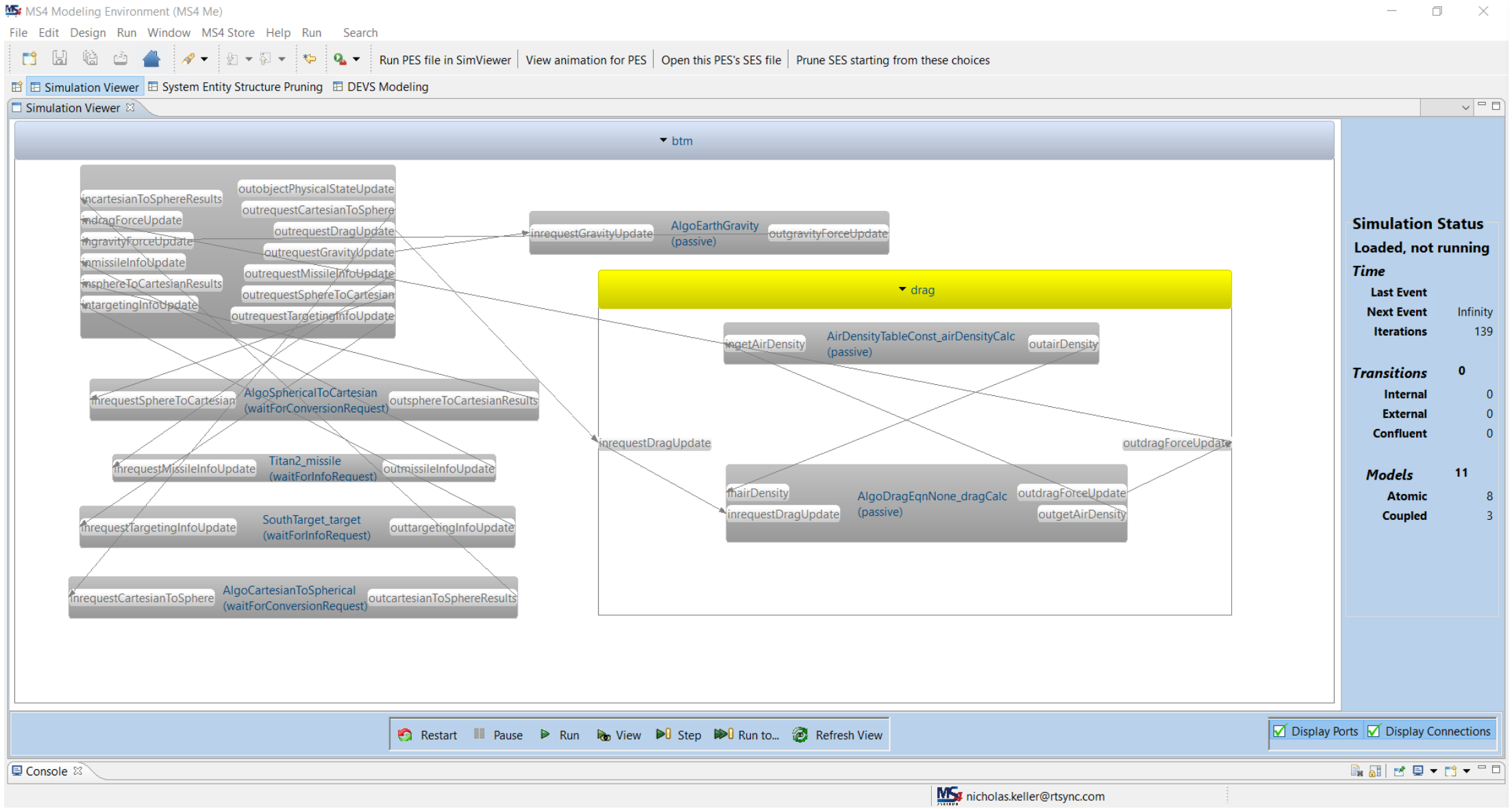
Algorithmic model reuse case study

- **Ballistic missile trajectory simulation built by a programmer (Chase Anderson) with no prior experience in DEVS or MS4 Me**
  - A key goal is to make DEVS more accessible
- **24 (3*2*2*2) possible trajectory simulation variations corresponding to different algorithmic model combinations**
  - Algorithmic models
    - 3 drag algorithmic models
    - 2 air density algorithmic models
    - 2 ballistic missile options
    - 2 possible targeting options
- **MS4 Me makes it easy to define the models and compose and simulate different model combinations**

Interaction diagram for a missile trajectory simulation

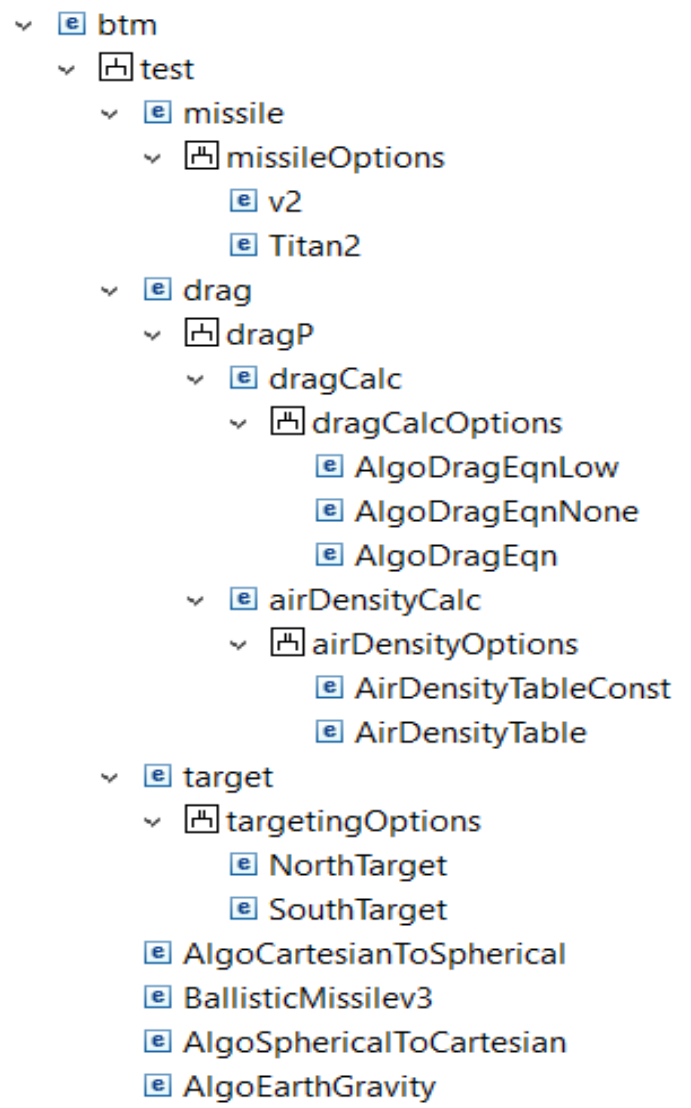


Complete model in MS4 Me



SES outline of a ballistic trajectory missile model

- **24 (3*2*2*2) possible trajectory simulation variations corresponding to different algorithmic model combinations**
  - Algorithmic models
    - 3 drag algorithmic models
    - 2 air density algorithmic models
    - 2 ballistic missile options
    - 2 possible targeting options
- **MS4 Me provides a graphic pruning interface**
- **Users can also manually specify the pruning using a text file**



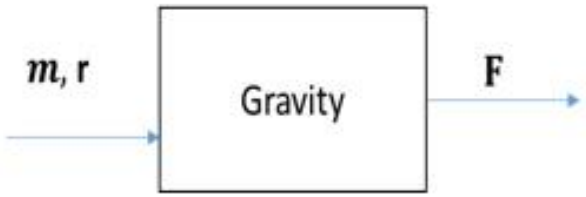
Gravity Algorithmic model

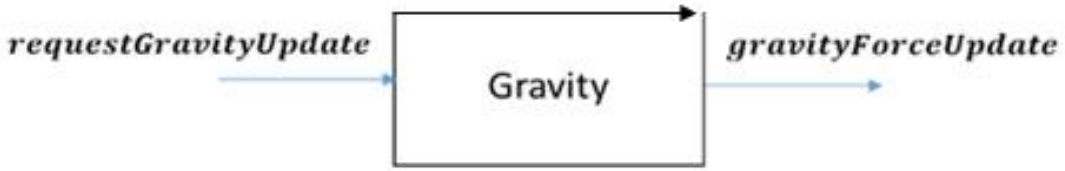
Input: Altitude and mass of object

Output: Force in direction to Earth's center

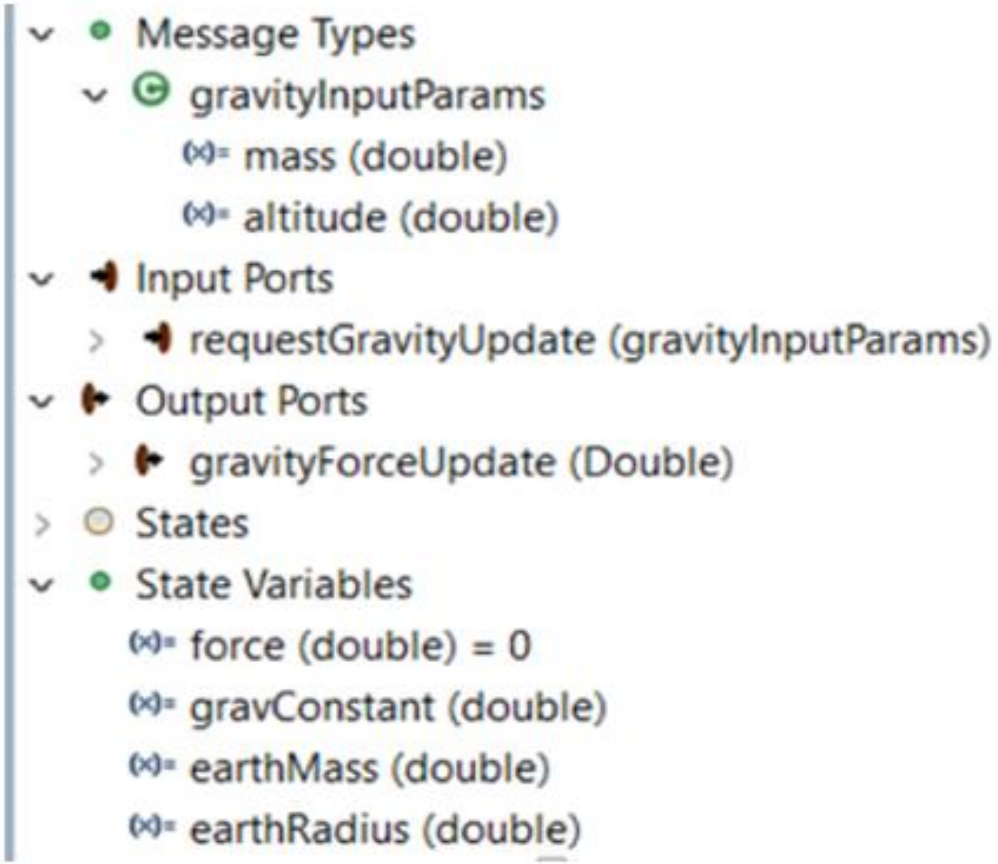
Parameters: Gravitational constant, earth mass an

$$F = G \cdot m_e * m_o / r^2$$

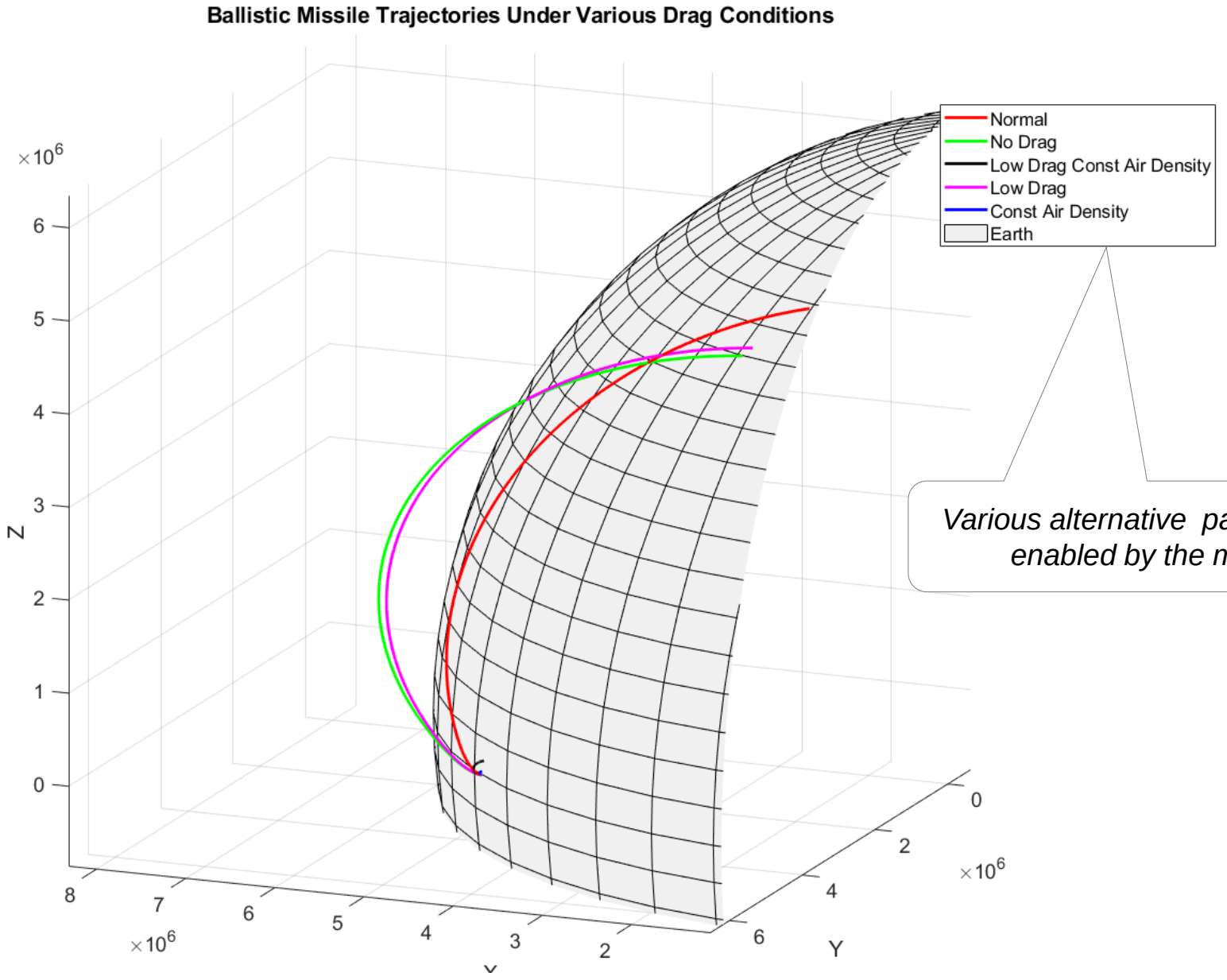




$$m, r \rightarrow G \cdot m_e * m_o / r^2 \rightarrow F$$

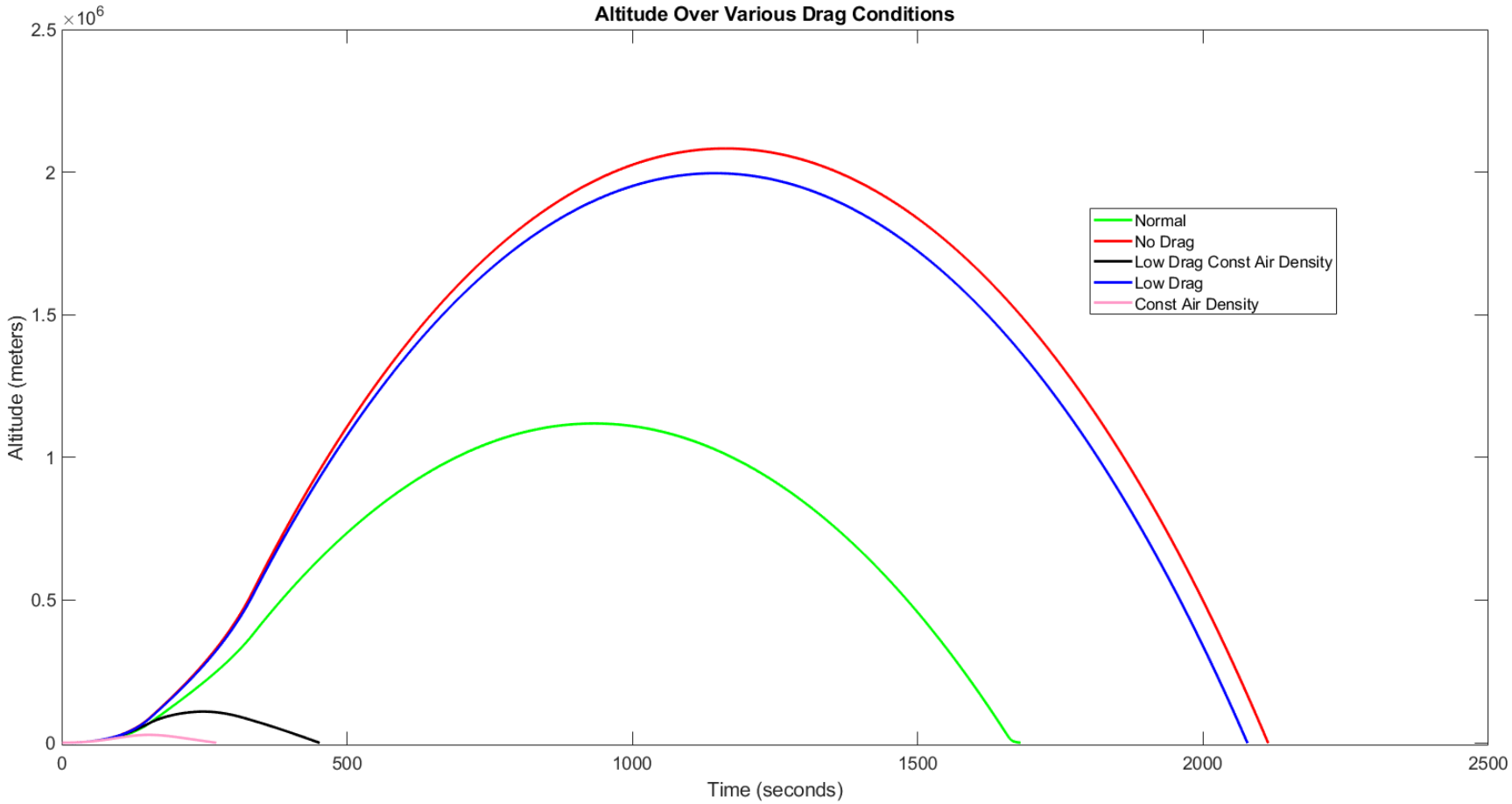


Example Trajectories generated by the model

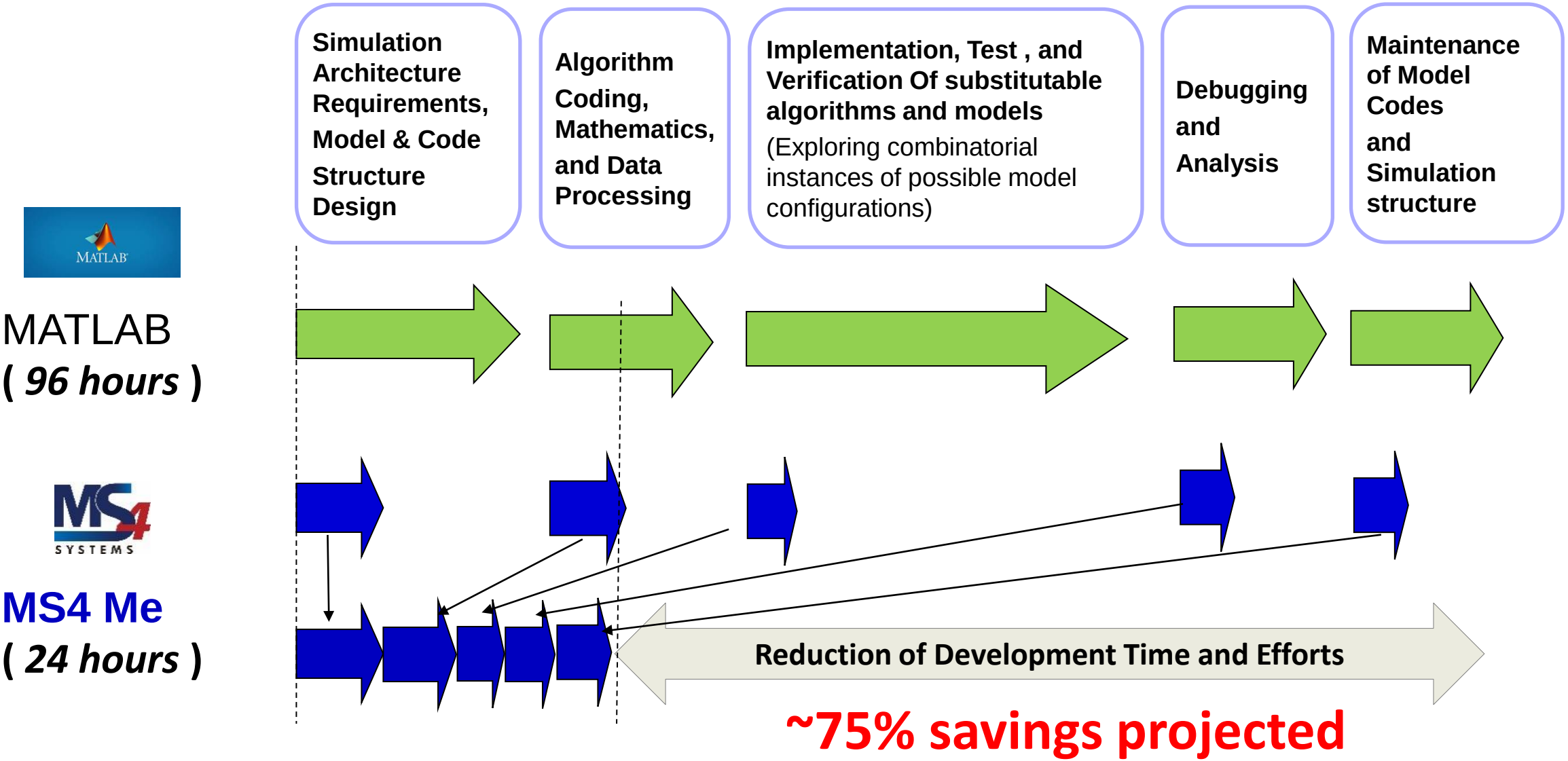


Various alternative parameter settings enabled by the model family

Altitude Over Time



Comparison of Development Time and Efforts



Continuing and Future work

- **Expand MS4 Me to better support collaborative model development and reuse: generalize from algorithmic to all DEVS**
- **Currently input/output ports are Java primitive types or classes, which forces the modeler to document their model to enforce port semantics**
  - We are adding input/output port types, which users can use to semantically define ports
- **Model reuse requires the ability to effectively search for models**
  - We are adding a model browser which users can use to search for models based on keywords and their input/output port types
- **Model reuse requires the management of model libraries to ensure trust**
  - We are adding model libraries, which will facilitate the distribution of models and control who can modify existing models

Questions