DES-based F6 Cluster Analysis Tool:

Optimizing the User Experience

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Agenda

- Introduction
- Approach
- Aspects of improved user experience
- Results
- Obtaining the F6 tool

ASDA

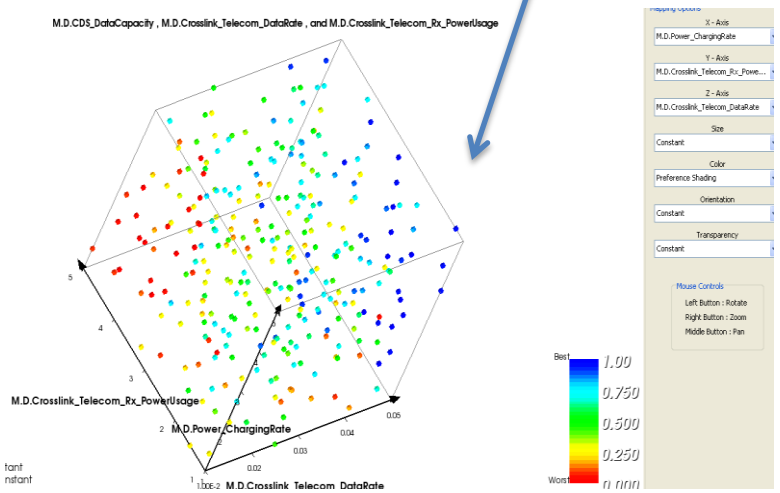
- ASDA=Adaptable Systems Design and Analysis
- The response to the DARPA System F6 BAA (1) proposed to build a tool to not only analyze a fractionated system, but also to design and architect such a system
- The team was a partnership between JPL and Phoenix Integration
  - We proposed to use computers to automatically generate and evaluate many designs
  - We proposed to provide a GUI/tool to allow users to design:
    - **1) futures, missions, architectures, systems, and**
    - **2) their associated parameters**
    - **3) Based on robustness to variety of possible "futures"**
  - We have now completed the final phase

(1) http://www.darpa.mil/our_work/tto/programs/system_f6.aspx

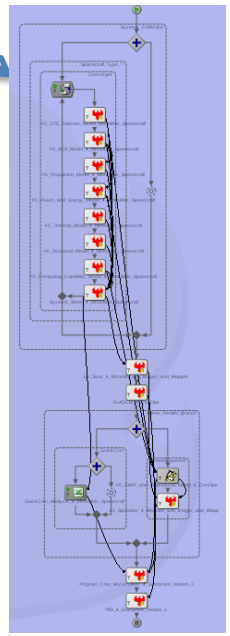
ASDA Results : Brief Summary

- Produced realistic model
  - Included stimuli and responses to measure adaptability and survivability
  - Automatically generated, populated and executed cluster candidates
  - Can Generate populated tradespace with Present Strategic Value as overall metric or other metrics as desired

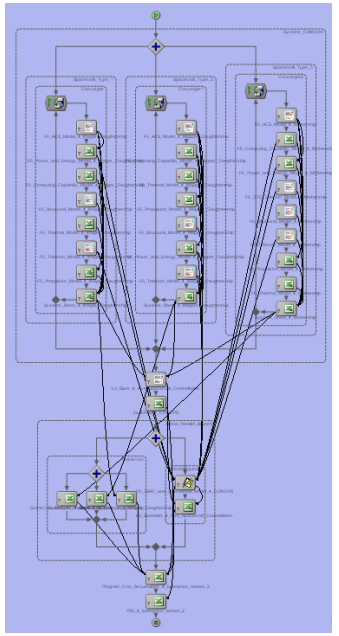
Scenario Parameter Name	Units	Value
Scenario ID		1
Option Penalty	$FY11M	$ 10.00
Ops Cost Multiplier		1.25
Derived Parameter Name	**Units**	**Value**
ATP Date		10/1/2012
Payload launch occured here		7/6/2015
Mothership launch occured here		1/4/2016
Payload launch occured here		7/4/2016
Option Purchase Date		6/2/2014
Option Strike Date		7/6/2015
Simulation End Date		9/6/2032
Operating Breakeven Week		619
Discount (Purchase-ATP)		0.948008528
PV_Option (Operating Profit)	$FY11M	$ (110.79)
PV_Payload_Delta (DBATI)	$FY11M	$ (25.00)
Option Breakeven Draw	$FY11M	$ (164.24)
ERO Name	**Units**	**Value**
Option to Switch Payloads	$FY11M	$ 62.37
"In-the-Money" Probability		0.16



Multi-dimensional plot of tradespace for N=3 configuration

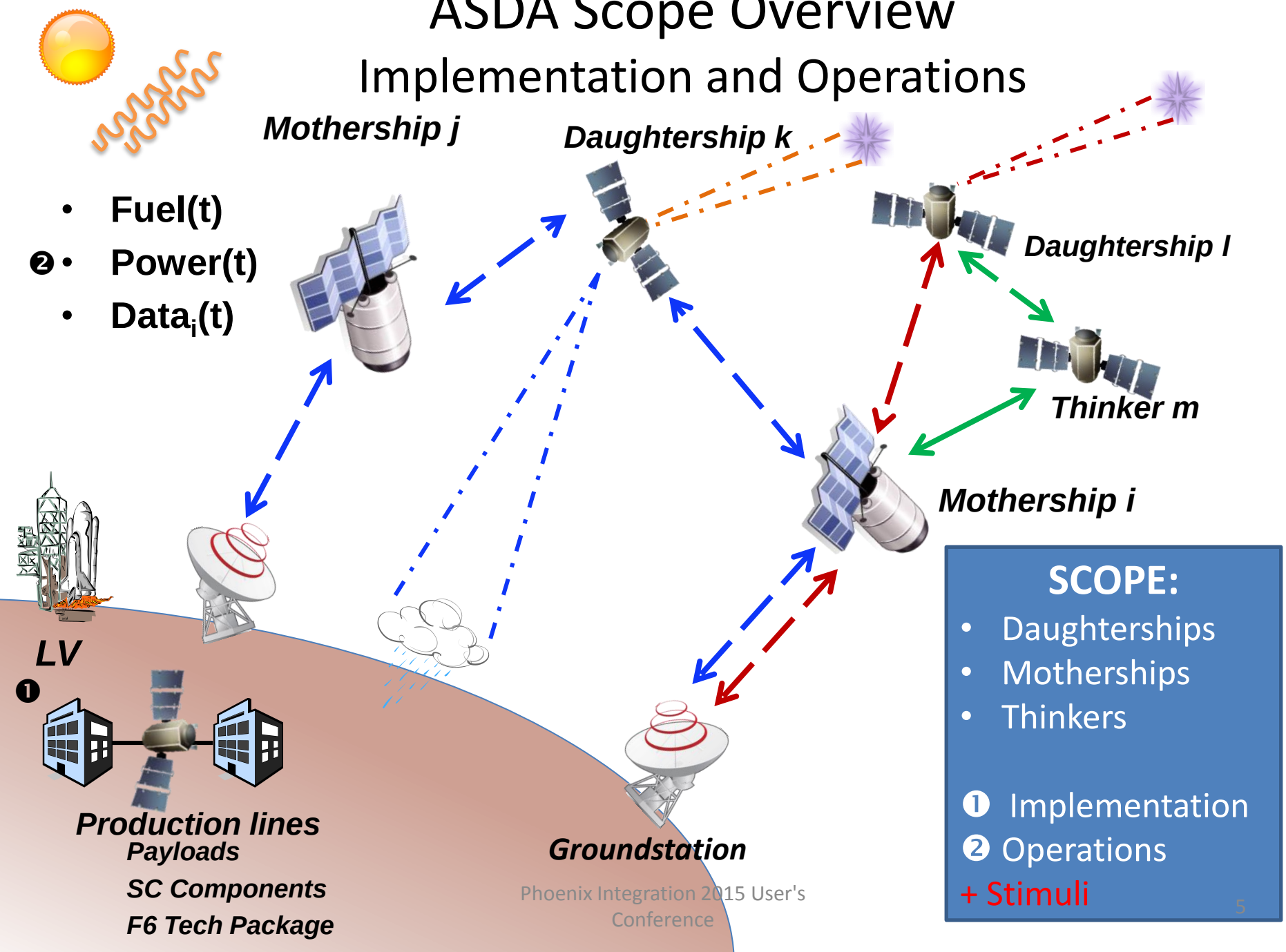


N=1



N=3

ASDA Scope Overview
Implementation and Operations



- Fuel(t)
- ❷ Power(t)
- Data$_i$(t)

SCOPE:
- Daughterships
- Motherships
- Thinkers

❶ Implementation
❷ Operations
+ Stimuli

Uncertainties with Candidate Embedded Adaptability and Survivability Real Options

Adaptability

Uncertainty Type	Embedded Real Options
Technology Development Risk	Option to Switch Technologies Option to Suspend/Slow Ancillary Developments
Supply Chain Delays	Option to Switch Payloads Option to Switch Technologies Option to Suspend/Slow Ancillary Developments
Changes in User Needs	Option to Switch Payloads Option to Discontinue Option to Abandon Option to Expand Option to Accelerate Development Option to Switch Technologies
Program Funding Fluctuations	Option to Defer Development Option to Accelerate Development Option to Expand Option to Delay Launch Option to Suspend Ancillary Development Option to Switch Technologies Option to Switch Payloads Option to Discontinue Option to Abandon
Technology Obsolescence	Option to Abandon Option to Switch Technologies Option to Discontinue Option to Accelerate Development Option to Switch Payloads

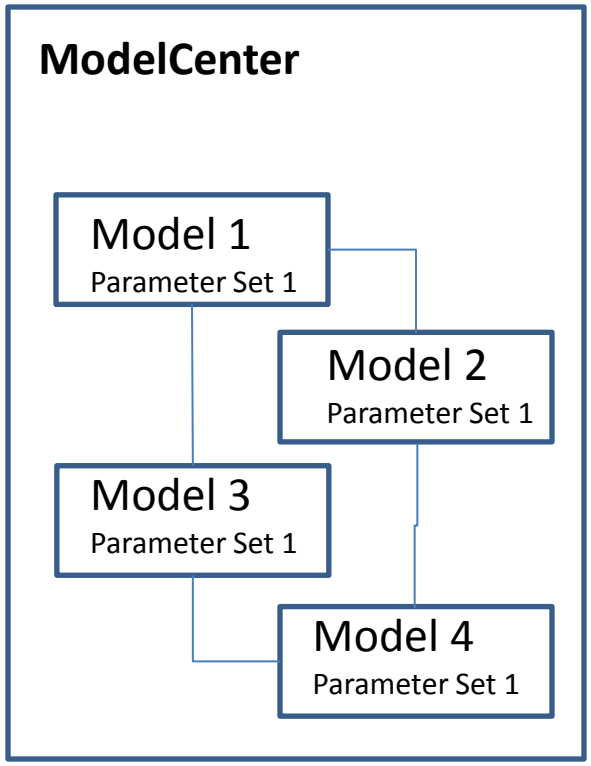
Survivability

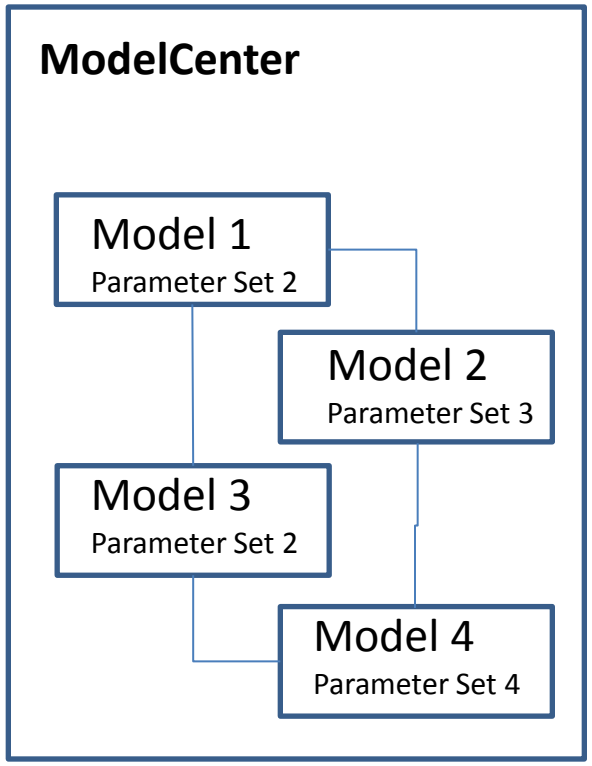
Uncertainty Type	Embedded Real Options
Launch Failure	Option to Accelerate Development
Operator Failure	Option to Accelerate Development Option to Not Replace
Component Failure	Option to Accelerate Development Option to Not Replace
Orbital Debris	Option to Accelerate Development Option to Not Replace
Space Weather	Option to Accelerate Development Option to Not Replace
Collision	Option to Accelerate Development Option to Not Replace
Cyber Security	Option to Discontinue Option to Abandon Option to Not Replace Option to Switch Technologies Option to Accelerate Development

Currently in ASDA model

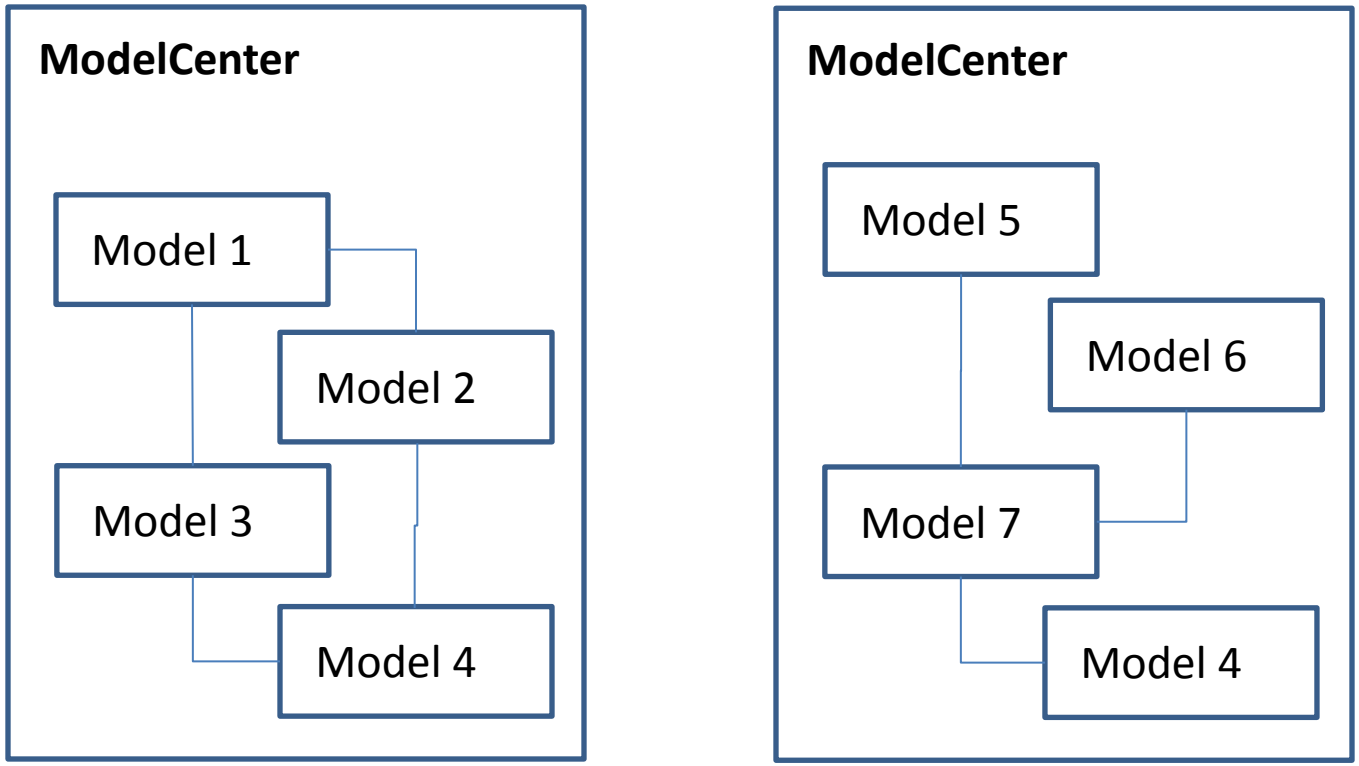
Reconfiguring the Model

Always a ModelCenter strength



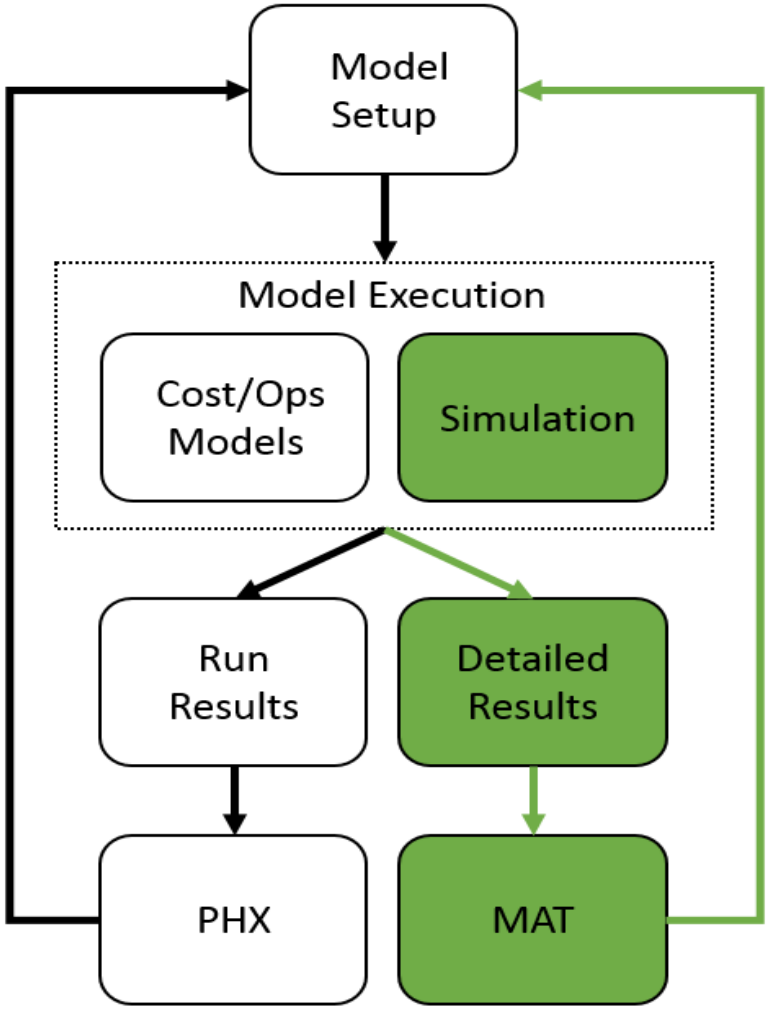


Reconfiguring the topology
Demonstrated with ModelCenter



User Process – Closing the Loop

- Generic User Process
  - Setup case(s)
  - Execute model
  - View model results
    - In Phoenix ModelCenter
    - Deeper insight: MAT
  - Identify next case set
    - Include (or not) with previous runs
  - Rinse and repeat
- User process improvements
  - Simulation:
    - **Revised Discrete Event Simulation (DES) runs over 100X faster than previous version**
    - **Fast, Flexible & Extensible**
  - Detailed Results:
    - Various *.csv files for different kinds of detailed data (Events, Resources and Data Totals)
  - **Mission Analysis Tool (MAT):**
    - **View/modify underlying data**
    - **Compare across runs**
    - **Modify price values**



Timesteps vs. Discrete Events

- We have leveraged advantages of each approach in our simulation
- Speed
  - Discrete event simulations require fewer events
  - Calculating big jumps is faster than executing many small jumps
- Accuracy
  - Timesteps overshoot stopping condition
  - Error compounds when resources are filling and emptying between events

Critical Events are key

- Pre-populate timeline with known critical events
  - Architecture Events
    - Add & remove spacecraft on orbit
  - Network Events
    - Topology changes (i.e. downlink capability)
  - Stimulus Events
    - Disruptions (i.e. failures, delays, etc.)
  - Window Events
    - Open & close downlink & sun windows
- Include resource critical events as they are anticipated
  - Resource Events
    - Resources become full or empty

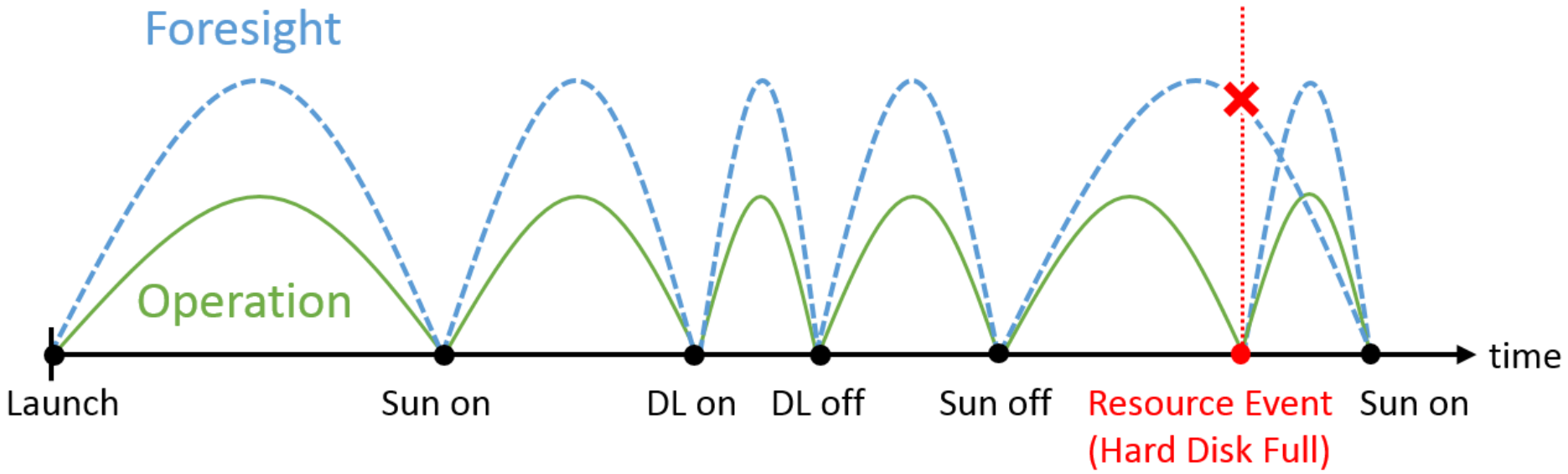
Foresight: determine whether the cluster can operate until the next critical event based on current state

Yes

Operate until next event

No

Schedule resource event and operate until then

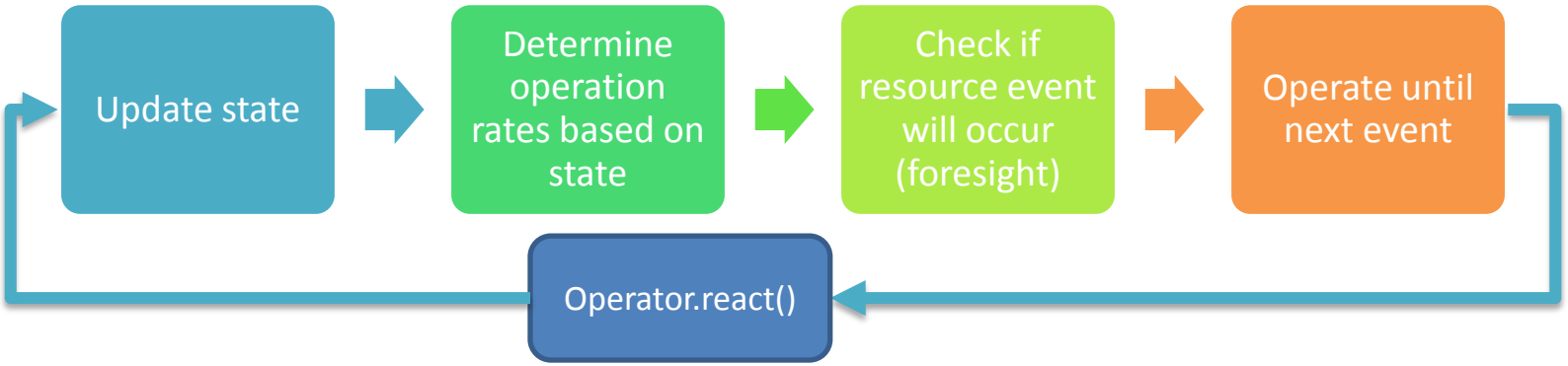


Operator: simulation controller that keeps track of the state of the system and manages operations

Operator State:

- *Cluster architecture* – number of spacecraft on orbit
- *Network topology* – how data flows through the cluster; which spacecraft can talk to groundstations
- *Functions available* – which spacecraft functions can be performed based on orbit location and battery/hard disk constraints
- *Bottlenecks* – factors by which to scale operation rates due to power or data rate limitations

Each event "pushes" information to Operator, which reacts by updating its state



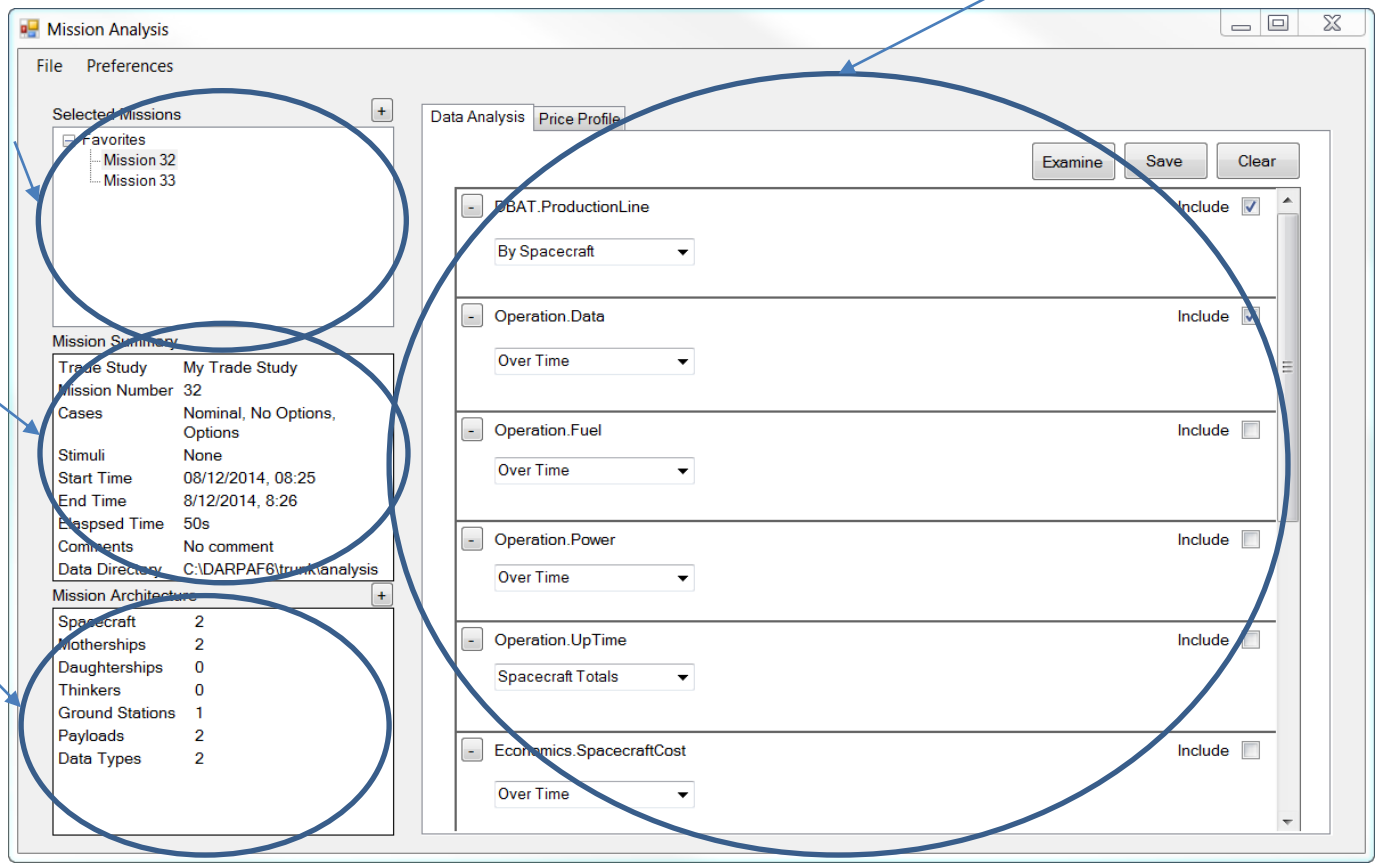
Mission Analysis Tool: Data Analysis

Resource and Results Data

Available Mission (Runs)

MetaData

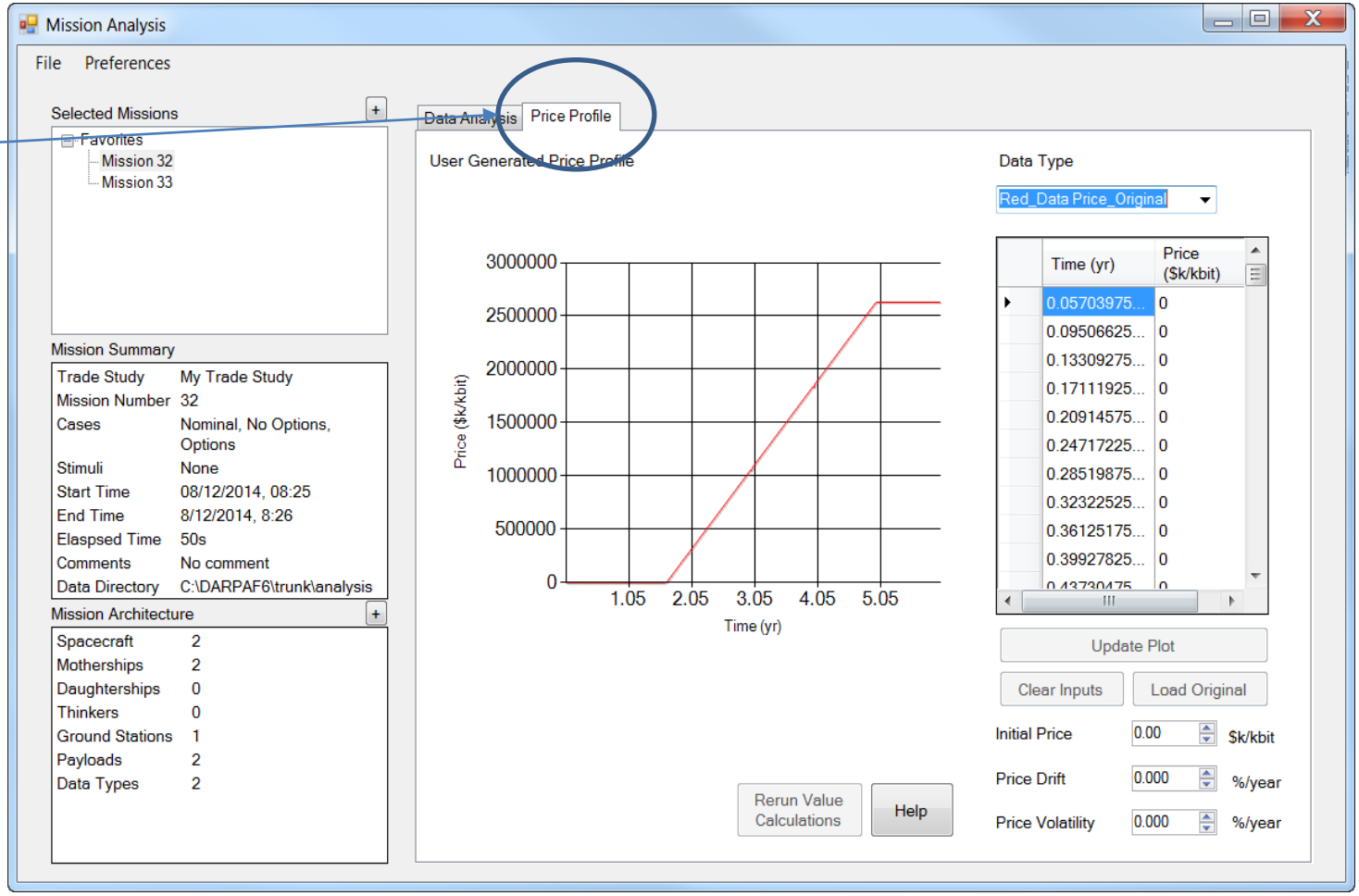
Architectural Summary



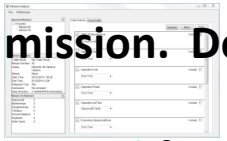
Enables users to explore data sets previously created and select various plots and view to examine, and/or save.

Mission Analysis Tool: Price Profile (original)

Price Profile Tab



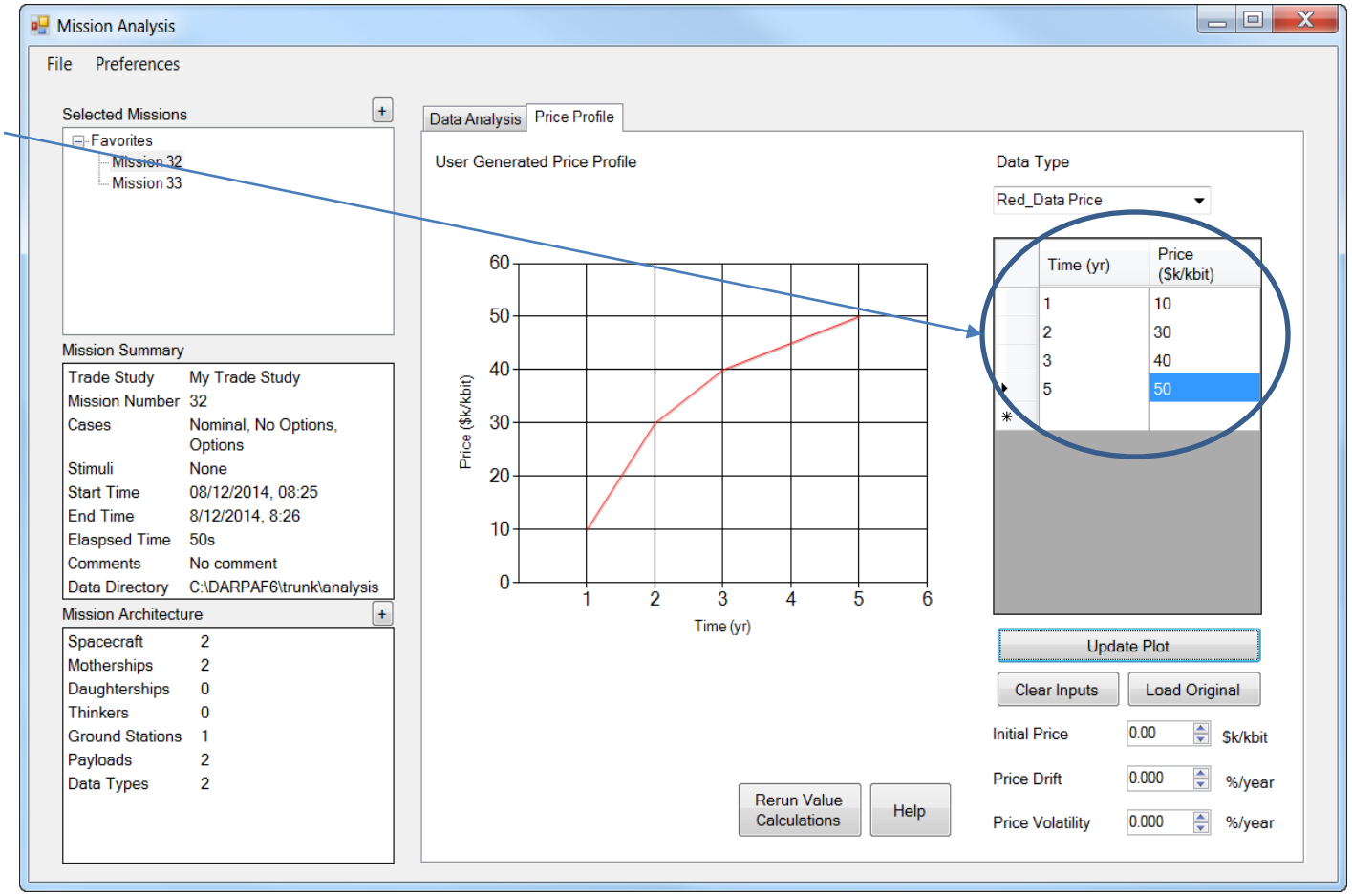
Utilize Data(t), Costs(t) from a given mission. Do the integral vs Price(t) outside the model.



Enables users to examine price profiles used for previously generated runs.

Mission Analysis Tool: Price Profile (user defined)

User-modified Price information



Utilize Data(t), Costs(t) from a given mission. User-modified price profile allows exploration of various pricing cases without re-running the model.

Results

- DARPA System F6 Design tool has been completed and is available
- Features have been previously described in various publications
- Focus of recent effort was improving the user experience
  - Simulation
    - Speed – 100x speed improvement
      - Runtime of several minutes for 10 year missions, and under a minute for simpler cases
    - Accuracy – eliminated error due to timestep sampling
  - Customization
    - User-defined catalogs
      - Spacecraft buses
      - Instruments
      - Launch vehicles
      - Computers
      - F6 Tech Package
  - Documentation
    - Full site containing our philosophy, simulation architecture, terminology, and code documentation
  - Extensibility
    - Add new types of events to the simulation
    - Any individual module can be internally modified for specific needs and applications

Obtaining the F6 Design Tool

- 1) Interested party is sent a link to the F6 Design Tool submission form; http://www.phoenix-int.com/f6dk_request.php.
- 2) After submitting, F6 ASDA team leadership will receive the request via an automated email.
- 3) The requester is sent a reply, either a rejection, or a request for the necessary information to Phoenix Integration to respond with appropriate licenses and download account information.
- 4) When the requested information is received, Phoenix Integration will create the needed ModelCenter and Analysis Server license files, and provide a download link with a download account that has all necessary files, including a word document.
  - Downloads link: https://analysislibrary.phoenix-int.com/content/files/Groups/F6DK/Downloads/
  - Instructions file: F6DK Installation Instructions.docx
- 5) Support is provided as needed.