

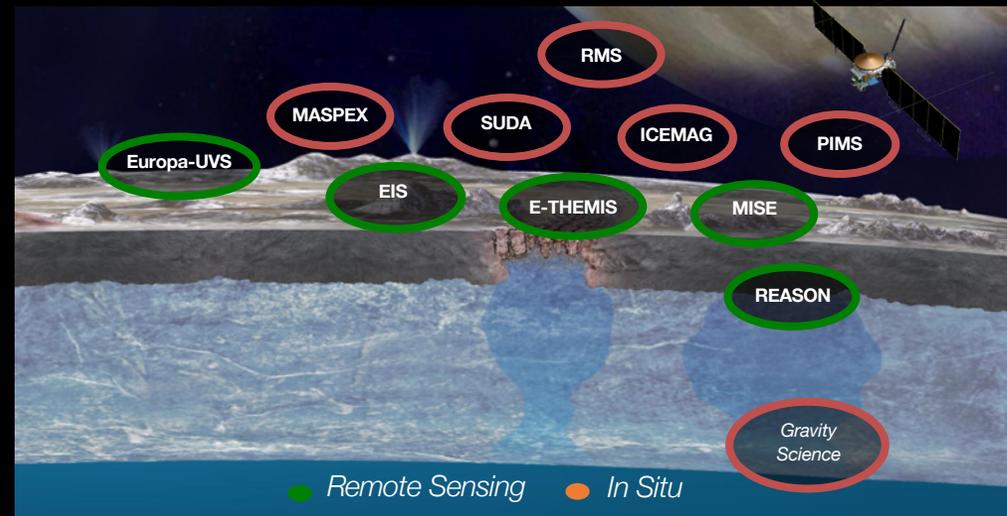
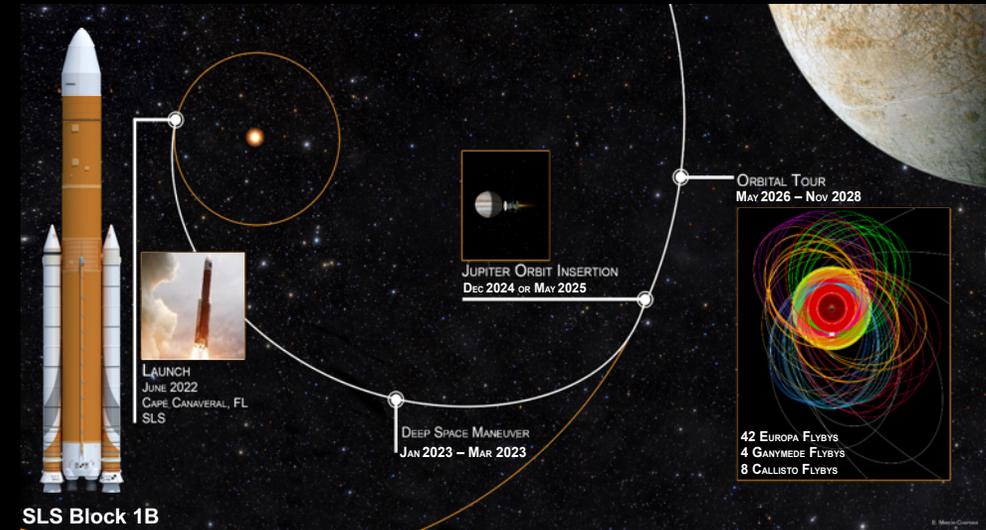
End-to-End Integrated Resource Analysis on Europa Clipper

Erich Lee, *Europa Clipper Resource Systems Engineer Lead*
Jet Propulsion Laboratory, California Institute of Technology



Europa Clipper Overview

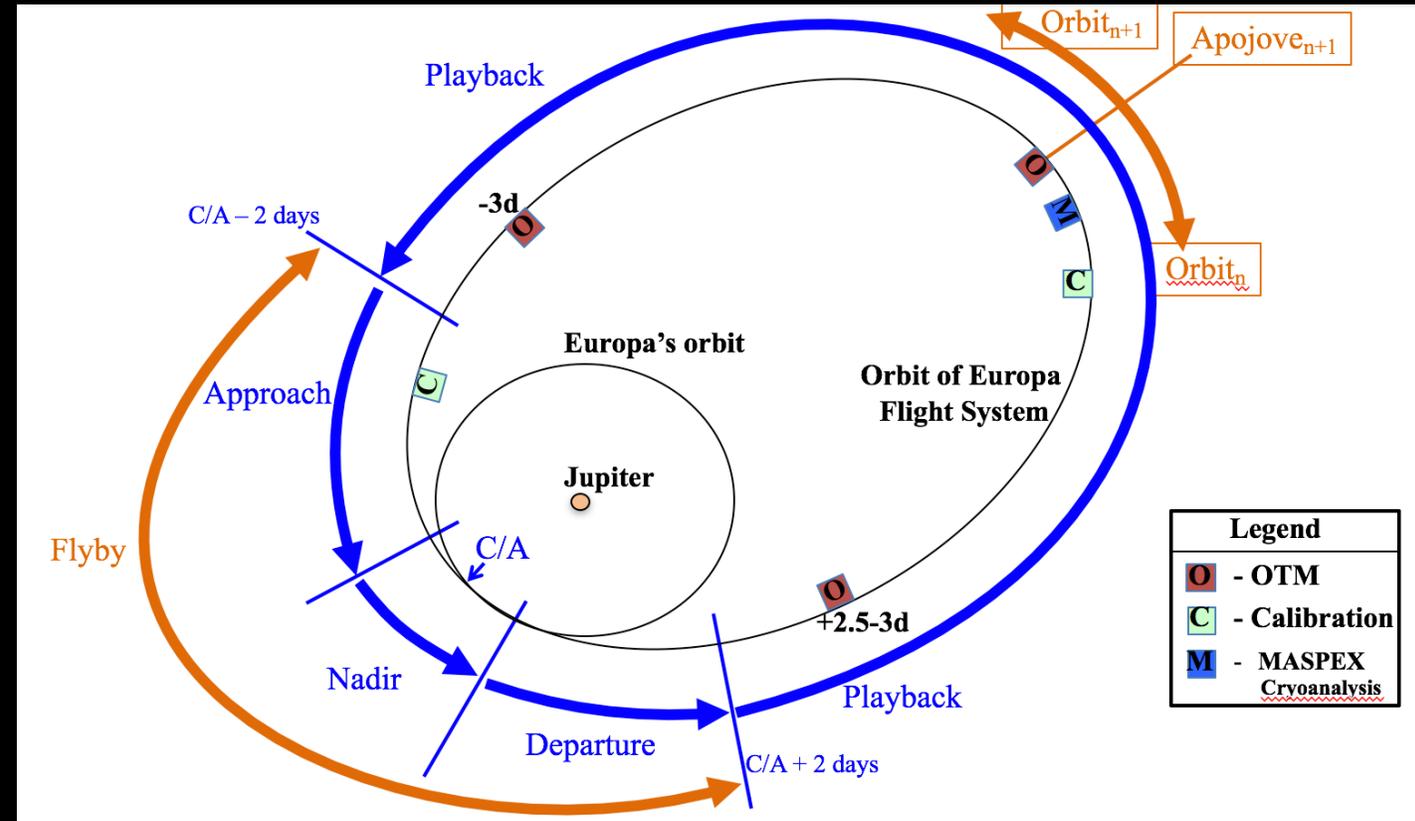
- SLS Block 1B launch in 2022
- 6001kg lift off mass
- 2.5 - 2.7 year cruise
- 1 year pump down
- 2.5 year science tour
- 10 science instruments + gravity science





Resource Challenges

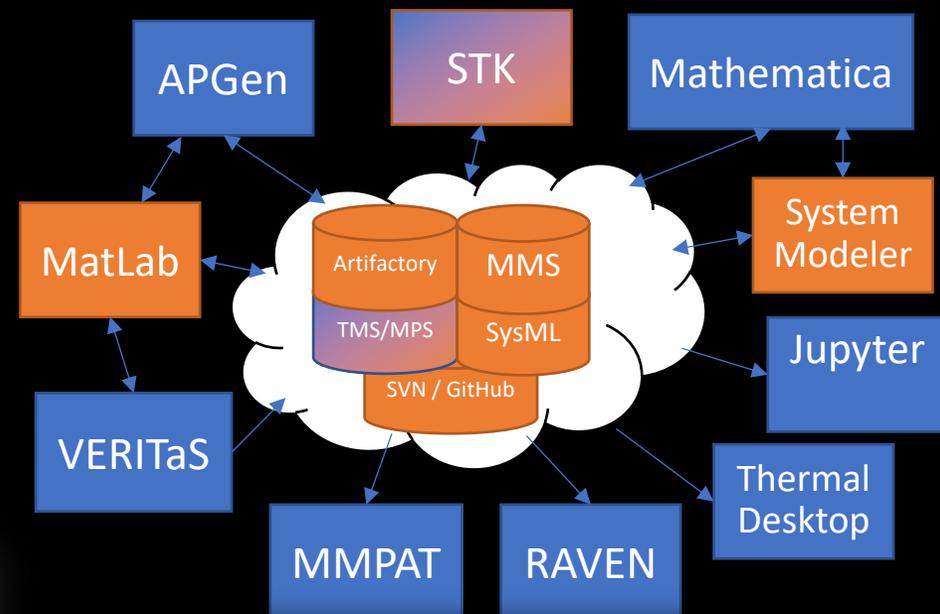
- Mission divided into "Encounters"
 - Minimum of ~10 days
- High energy usage and data generation during "Nadir" portion
- Limited time to downlink data and recharge during "Playback" prior to next encounter





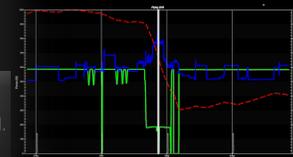
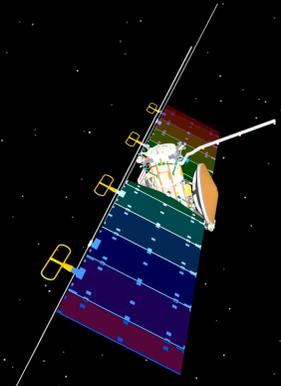
Technical Resource Analysis Overview

- Comprehensive analysis suite that leverages new development and existing tools
 - **MMPAT, Thermal Desktop, System Modeler, Mathematica, System Tool Kit, APMGen, MagicDraw, Model Management System (MMS), MPS Server, Timeline Management Service (TMS), RAVEN, Excel, SVN, GitHub, Tableau, etc.**
- SysML model serving as single-source-of-truth for mass, power, allocations, etc.



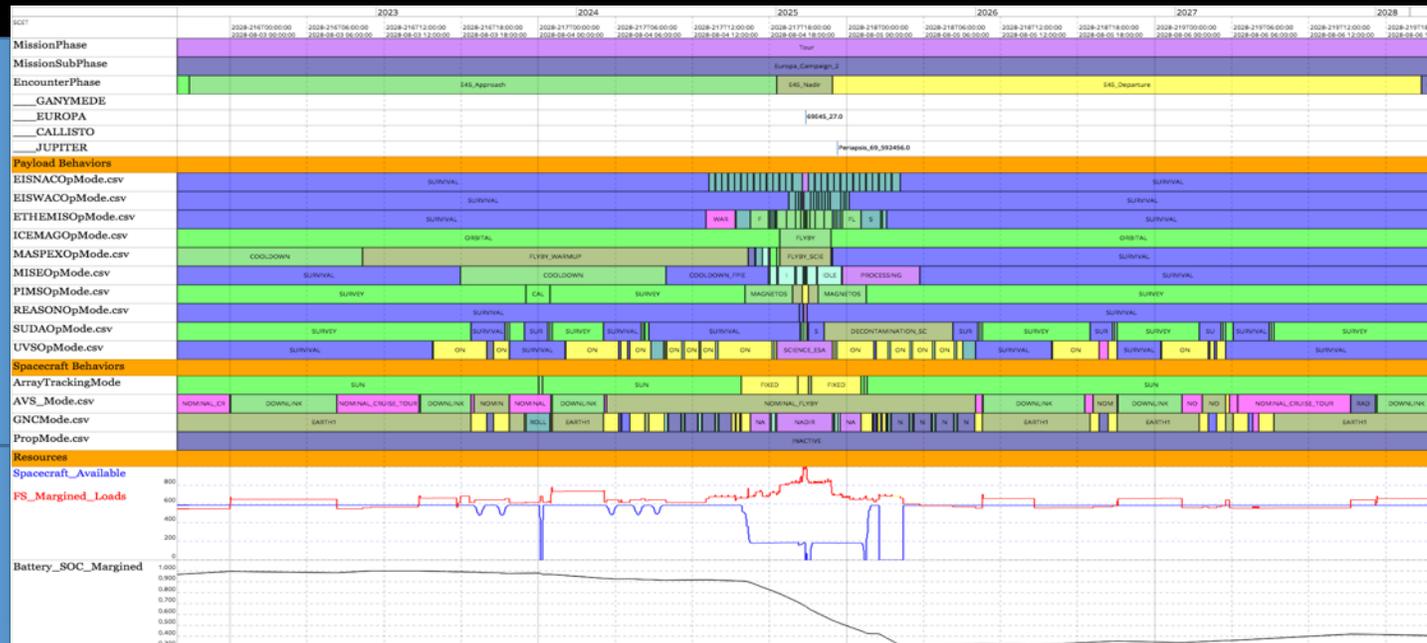
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    Time (UTC): 4 Aug 2028 19:53:17
    Available Power (W): 185.4
    PS Loads (W): 766.0
    Battery SOC (%): 73.06
  
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Mission Phases, events, and behaviors

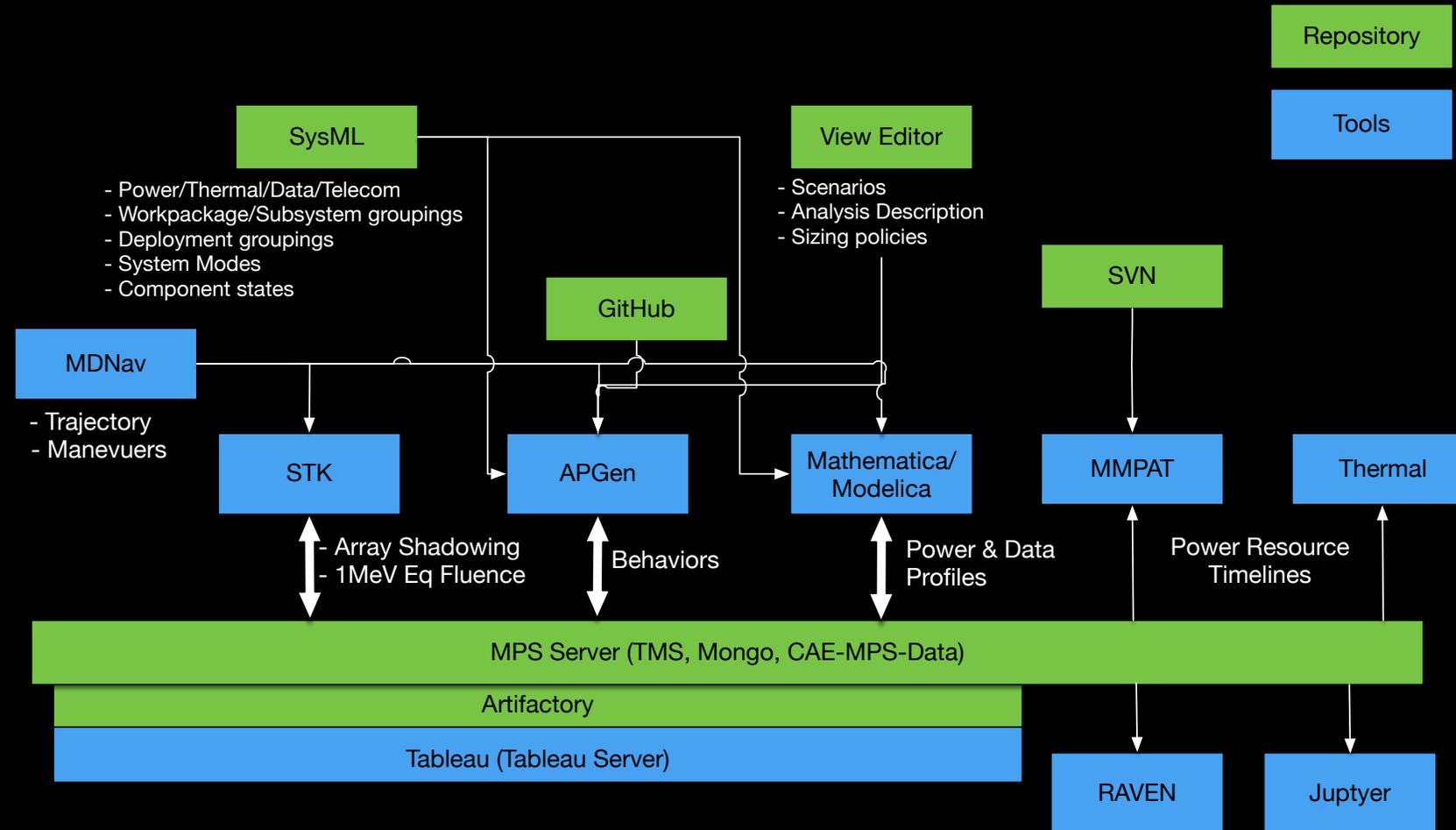
Resource timelines





Architecture Overview

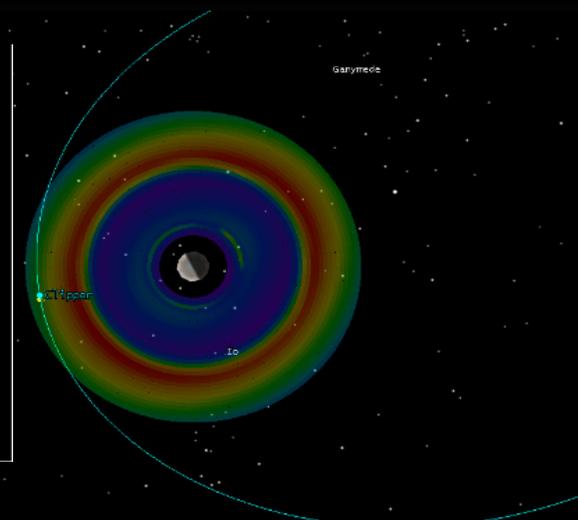
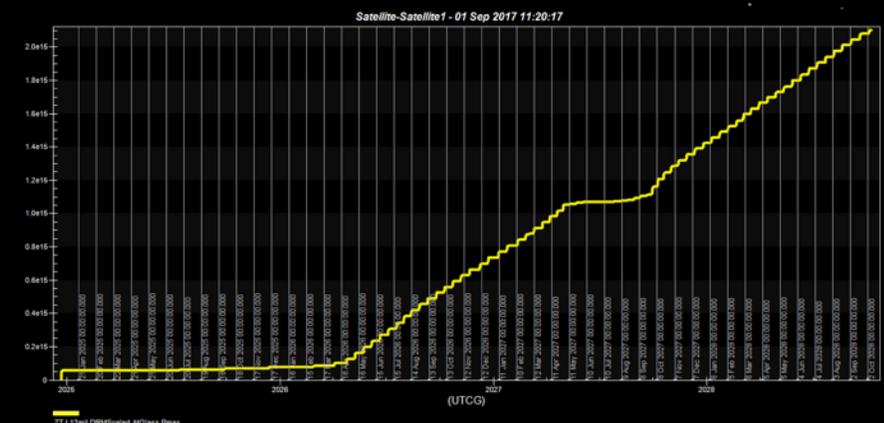
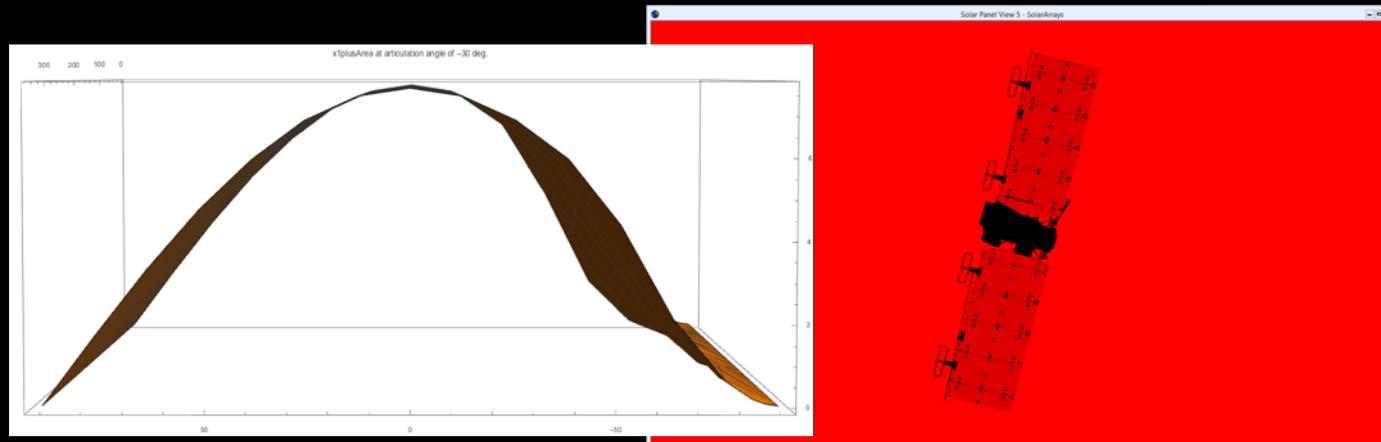
- Strong integration with diverse tool set
 - REST API for web services
 - Standardized outputs from tools/repositories
 - Timeline database key part of analysis workflow
- All systems tied or being tied back to Single-Source-Of-Truth data source
- Metadata handed off between tools and repositories
- Cross-check of analysis results





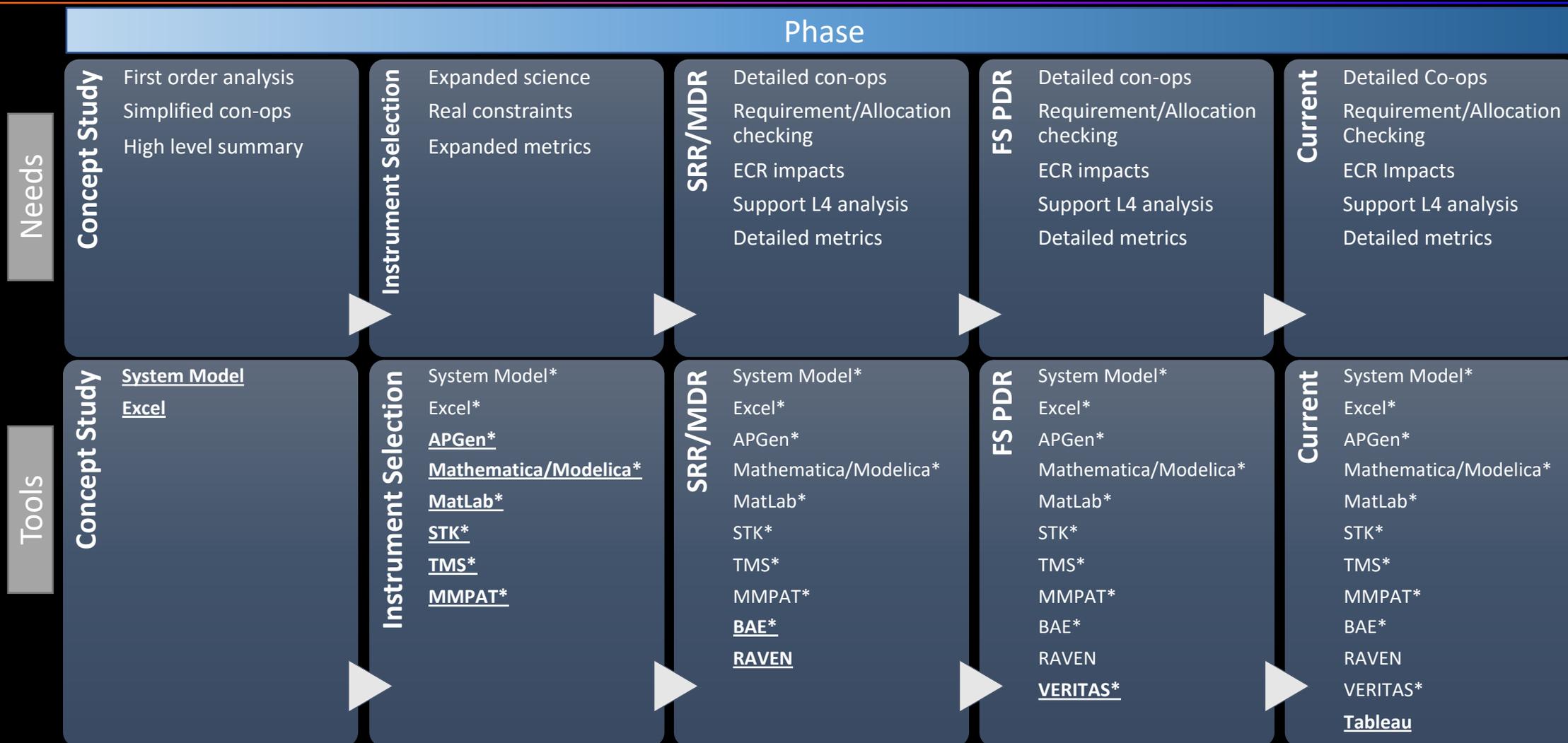
Capability Summary

- Performant End-to-End resource assessment for power and data
 - ~2-3 hours to simulate >5 years of mission
- Behavior modeling based on Ops grade tools
 - Separation of “Design Reference Mission” to size system & Mission Plan
 - Cross-check of behaviors against science requirements
- Power source model
 - Radiation degradation as a function of time
 - Self-shadowing on solar panels
- Data model
 - Data generated based on behavior models
 - Rate stepped DSN downlink
 - Detailed overhead factors from generation to downlink





Resource Analysis Evolution

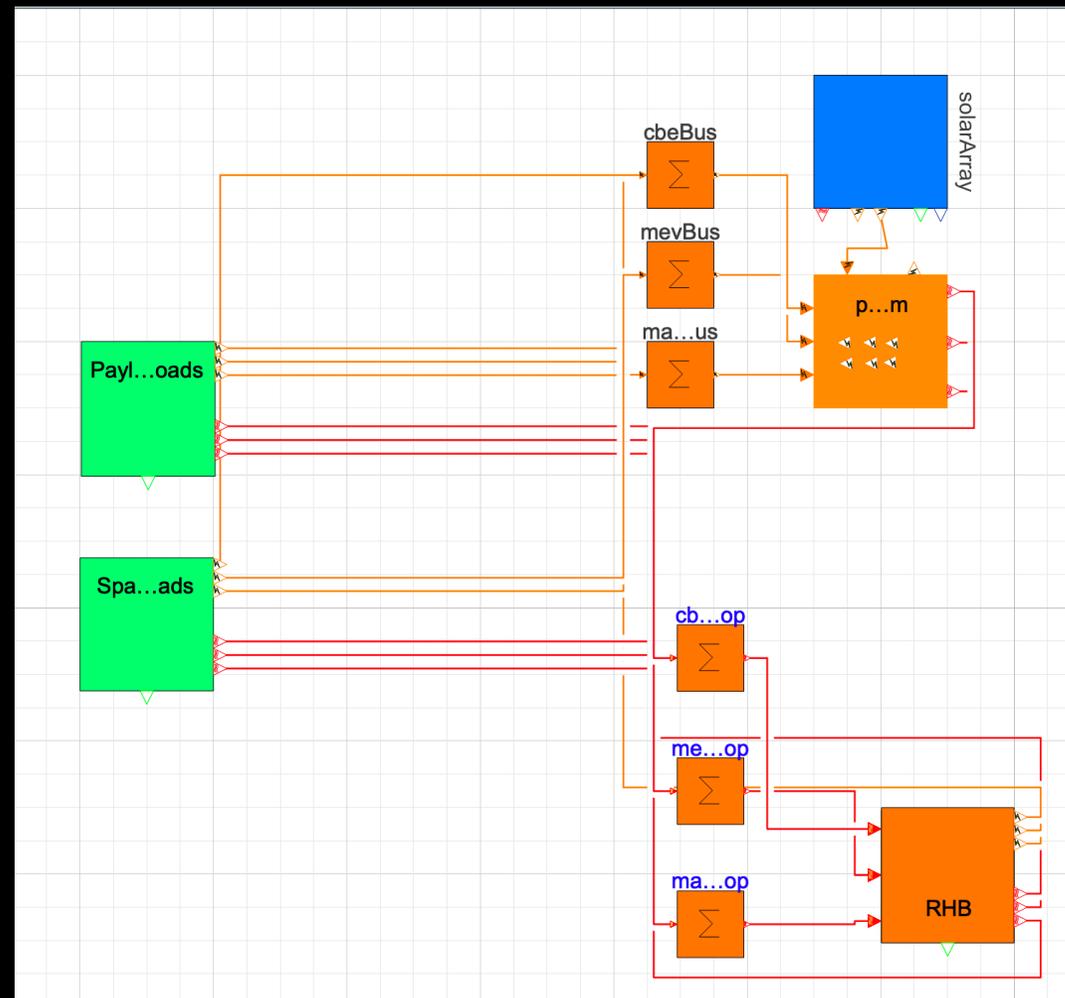


* Peer review and/or cross check of tools throughout development



Flight System Power/Data Model

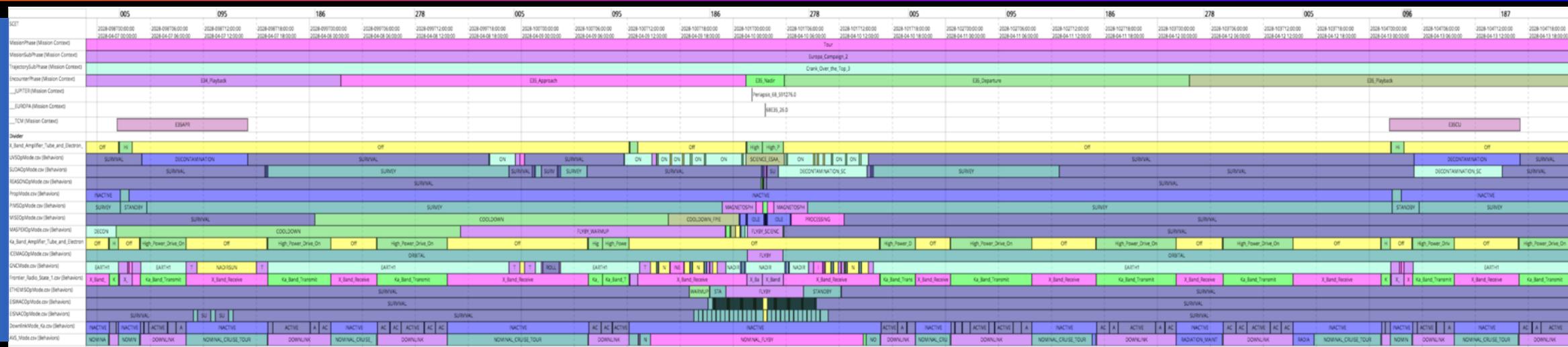
- Built using Modelica language
- Key parameters and state machines exported from MagicDraw directly to Modelica classes
- Web based tool allows user to select top-down or bottoms-up behaviors
 - Unique timelines for each engine
 - Single timeline for AVS hardware





Products (Visualizations)

Mission Phases, events, and behaviors



ECR and Trade study impacts

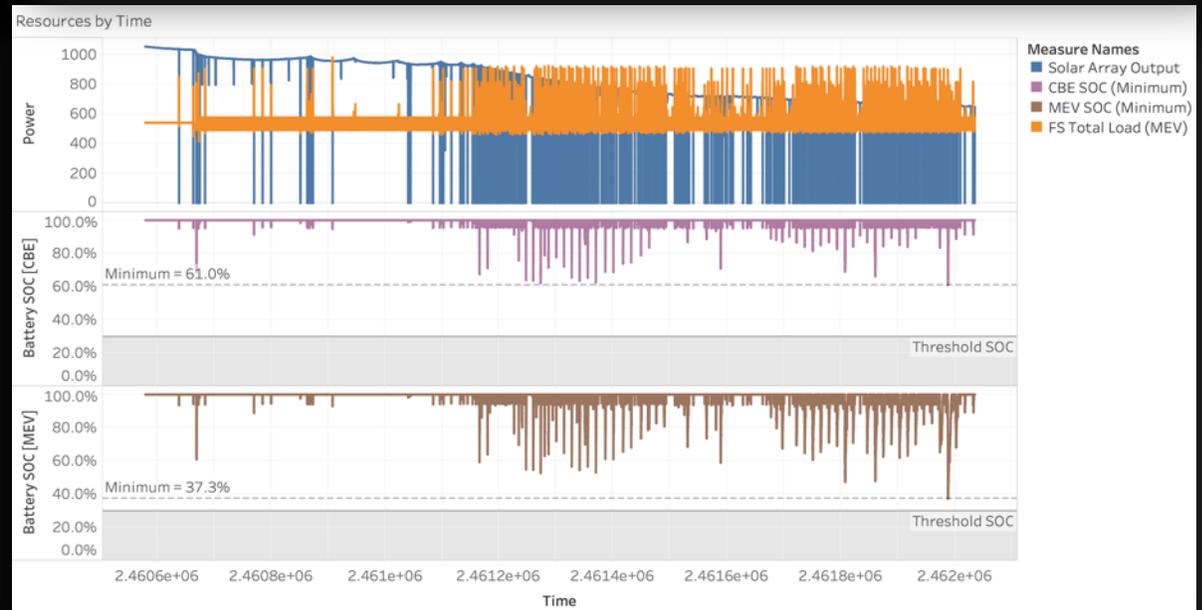
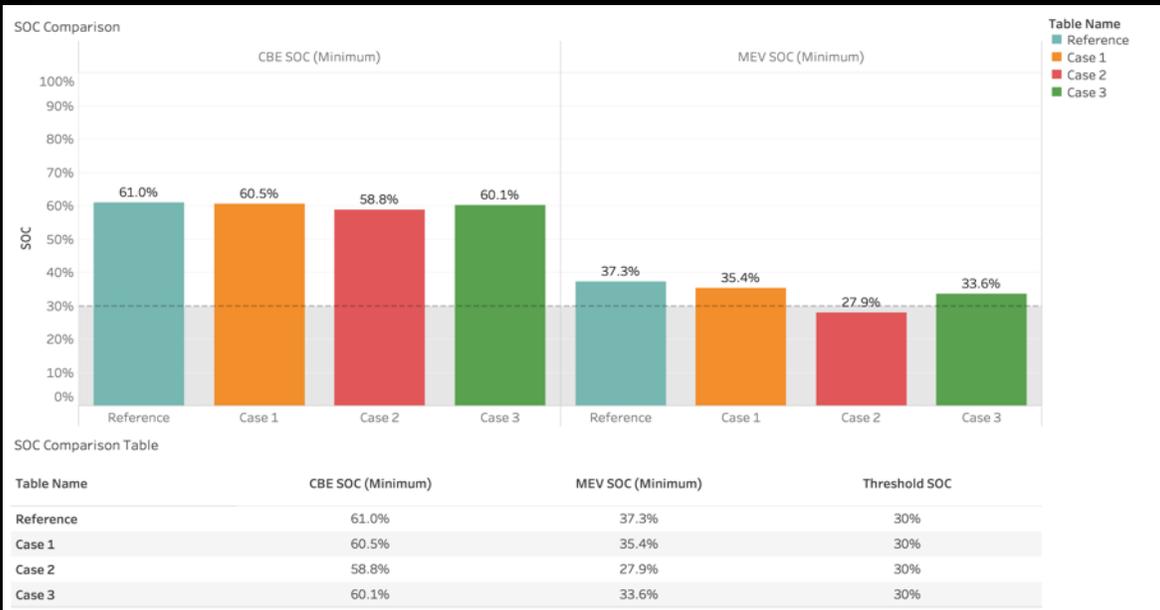
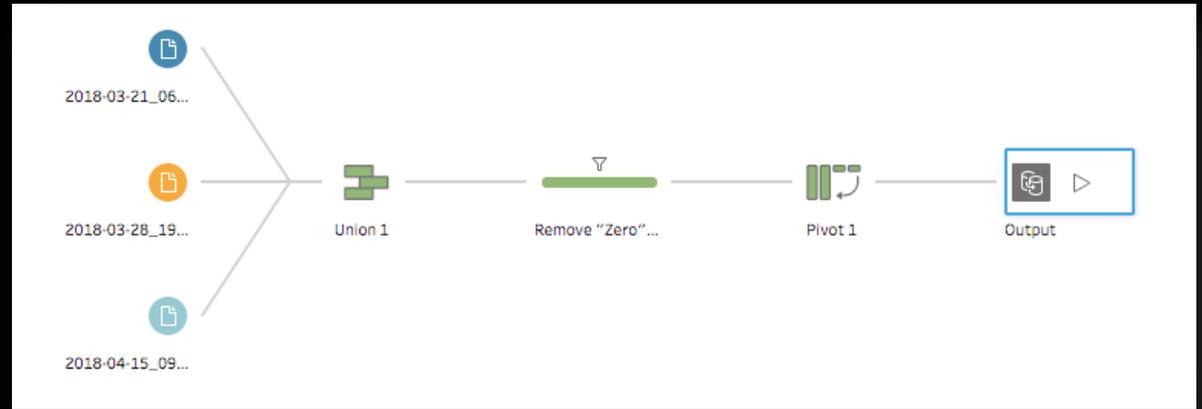


- Analysis results exposed as part of interactive web visualization
- Supports "Was/Is" comparison in addition to baseline interrogation



Data Interrogation

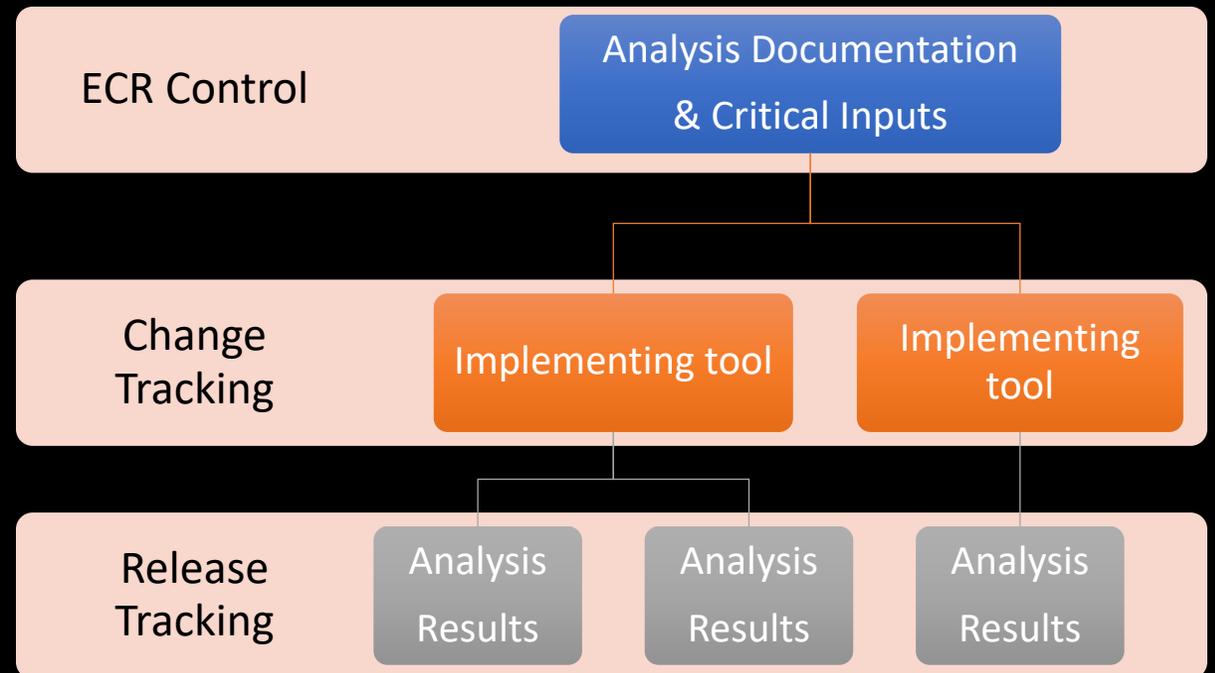
- Analysis tool produce standard data products
 - E.g., CSV, JSON
- Defined workflows post-process data products
- Robust and consistent mechanism for comparisons





Configuration & Release Management

- Full CM and ECR control placed on analysis models and critical inputs
 - Documents under ECR control after initial release
- Tools implementing analysis use some form of change tracking
 - SVN, GitHub, local change log, etc.
- Results are reviewed by tool operator and Europa personnel
 - Tools cross-checked on a regular basis





Documentation

Models

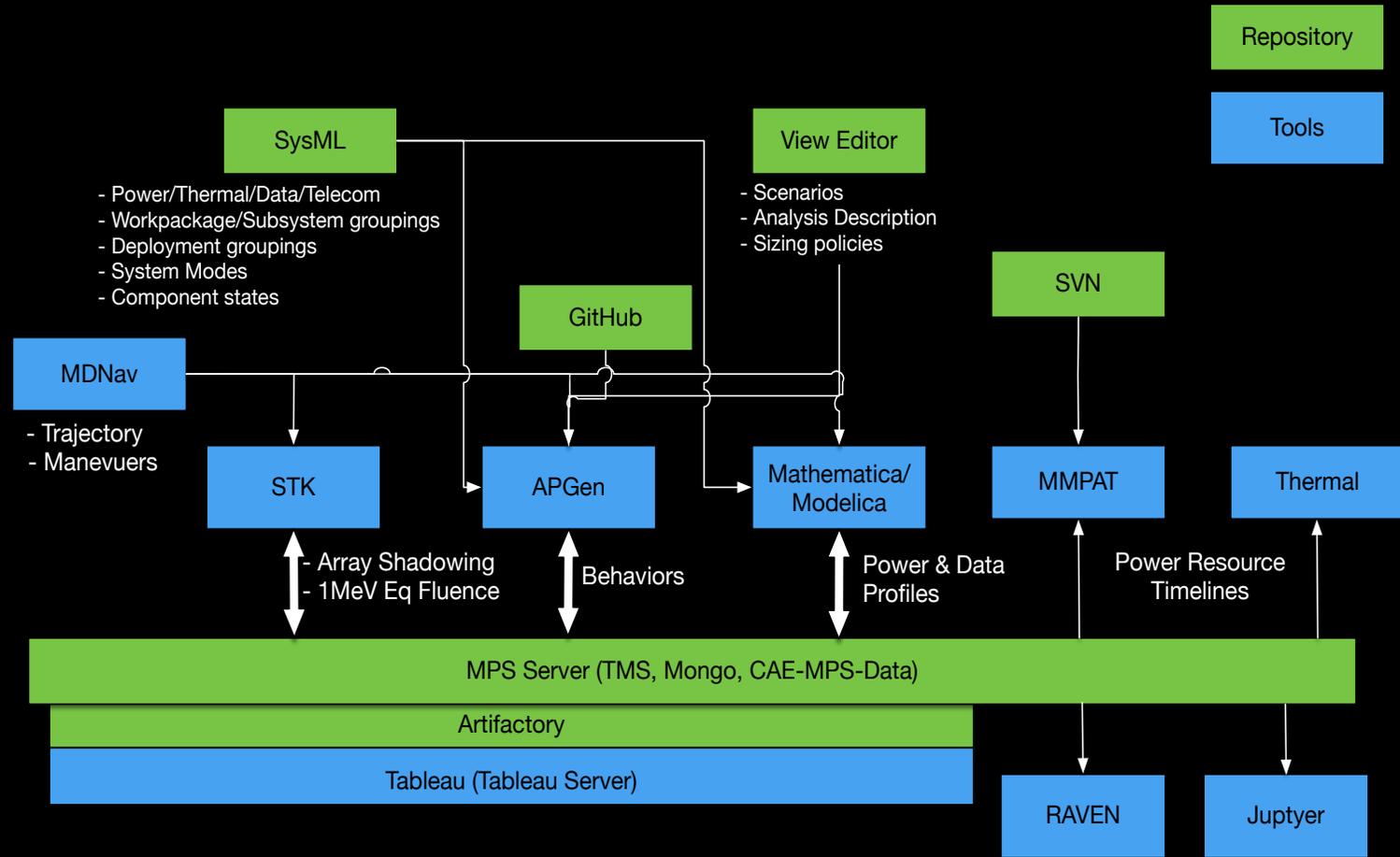
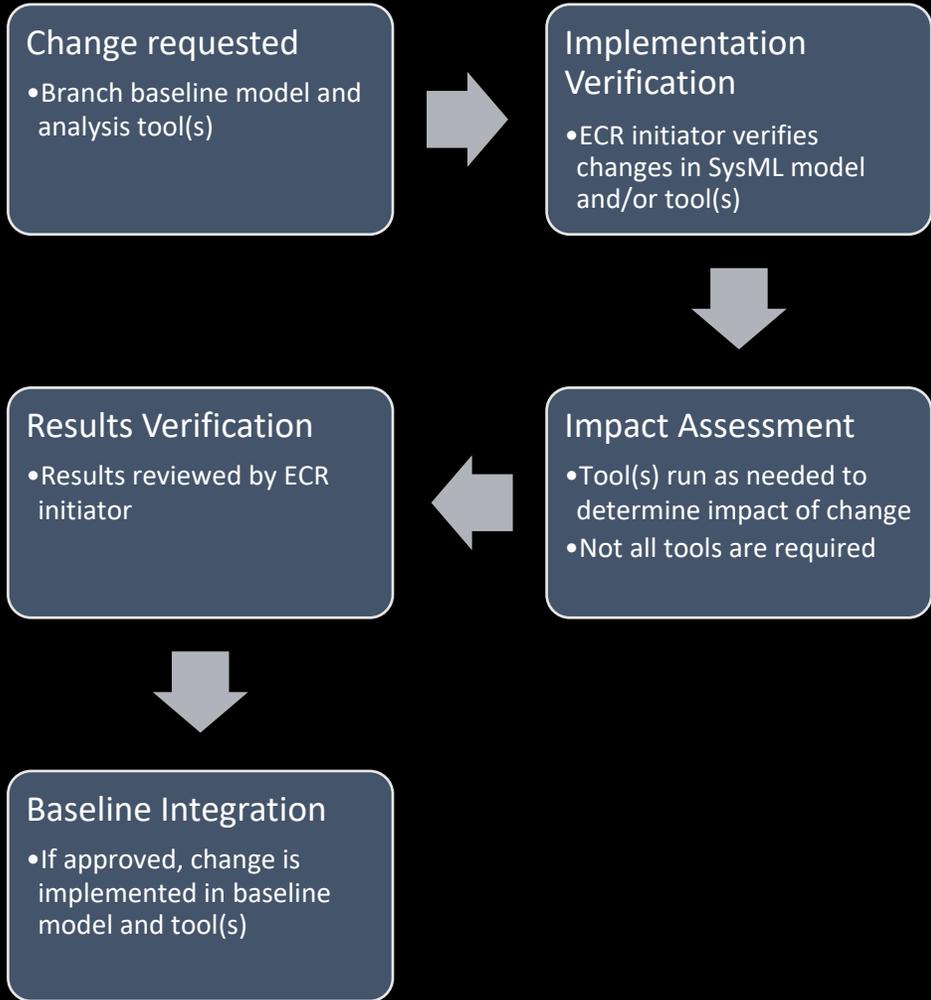
- Description of analysis models
- Single-Source-Of-Authority (SSOA) for calculation method
 - Includes equations, assumptions, examples where applicable, valid use
- Documents developed with Payload and subsystems
 - Approved at Flight System or Project System level

Tools & Analysis

- Description of tools and workflows
- Sizing policies (e.g., use RDF=2) for radiation
- Required metadata
- Namespace organization



Workflow: Engineering Change Request





Benefits

- Strong integration of high fidelity tools
- Check of “Design Reference Cases” using baseline design protect against overdesign
- Repeatable analysis runs allow for clear “was/is” impact assessments
- Runs can be “recreated” to answer new questions



Challenges

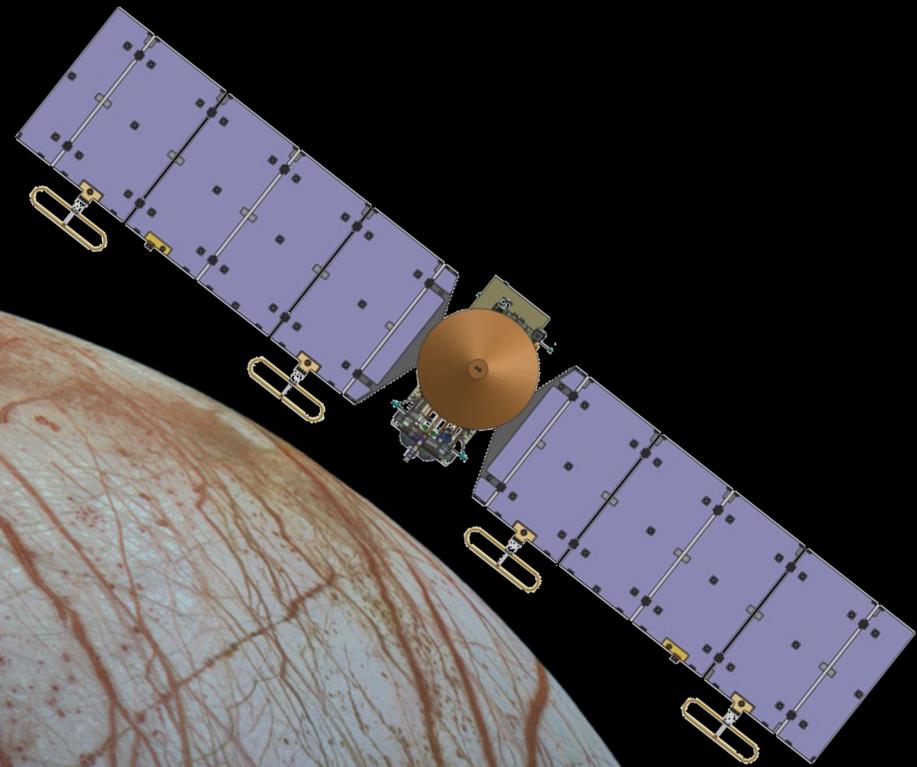
“The better you get,
the better you’d better get.”

- Large upfront investment
 - Strong configuration management early in project life cycle
 - Resistance to new methods and processes
 - Heritage tools can limit flexibility
- Traceability across multiple tools and project levels
 - Ensuring full traceability from L2 through L4/L5
- Continuous integration
 - Presenting the latest knowledge while still have a “clean” baseline
- Validation efforts
 - How do you prevent unintended changes?
- Big Data
 - Managing data at TB scale
 - Traditional tools breakdown quickly (e.g., Excel)
- User Engagement
 - How do you keep model owners involved?



What's next?

- Architecture and process capture
 - Knowledge transfer
 - Workflow automation
- Automation & optimization
 - Lien, Threat, Opportunity assessments
 - Code optimization
 - Infrastructure improvements
 - Tool interface robustness
- Sensitivity analysis
- Requirements verification
- Migration to Operations



Thank you