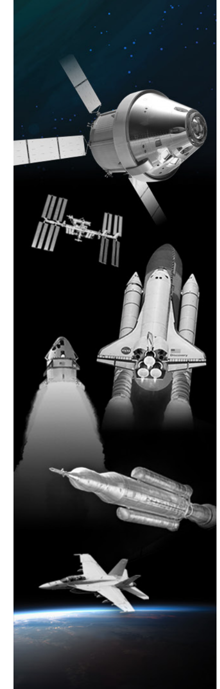
National Aeronautics and Space Administration

NASA Engineering and Safety Center Technical Bulletin No. 23-05



NESC tech bulletin

Flight Mechanics Analysis Tools Interoperability and Component Sharing

As multiple flight mechanics (FM) analysis tools are developed to meet the unique scientific and operational requirements of NASA missions, sharing data, transferring models and trajectory information between tools can be complicated. The NESC recently explored ways that increase interoperability of three mission analysis tools: Copernicus, General Mission Analysis Tool (GMAT), and Mission-Analysis Operations Navigation Toolkit Environment (Monte). These tools are used to generate a variety of products throughout all phases of a mission including: maneuver planning, trajectory optimization and design, orbit determination, performance and error analysis, trade studies and sizing. Establishing a framework to share models, component data and trajectory information is an efficient way to leverage the benefits of an analysis tool without expending development costs to duplicate functionality.

Tool Integration Approach

This work focused on three popular tools primarily used for navigation and mission design. An enterprise system of systems with application programming interfaces (API) and plugins was developed to enable interoperability between tools as shown in Figure 1. GMAT-Monte interoperability uses an API to access GMAT functionality and expand its uses to include real-time tracking data, higher fidelity dynamics modeling, and access to Jupyter notebooks to execute GMAT. GMAT-Copernicus interoperability focused on utilizing a common 3D graphics engine where both tools benefited from improvements in common graphics components. Having access to newly shared capabilities in the graphics library enables multi-core support, cross-platform functionality and showcases new features such as day/night lighting cycles of planets and eclipse shadowing. Monte-Copernicus interoperability included new python interface development, tool updates and use case definitions. Both tools benefited where Monte can now leverage the 3D Graphics capabilities handled in Copernicus and Copernicus can access higher fidelity dynamics modeling found in Monte.

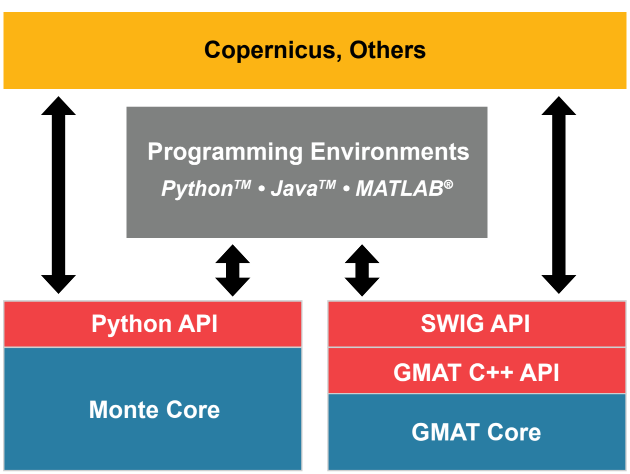


Figure 1. System-of-systems approach to interfacing Copernicus, Monte and GMAT functionality. (Note: Simplified Wrapper and Interface Generator (SWIG))

Trajectory Reverse Engineering

One innovative technique that resulted from this effort is termed "Trajectory Reverse Engineering", which allows for the transfer of a generated trajectory to another platform without carrying all the associated data. This novel method, illustrated in Figure 2, is applicable to any flight mechanics tool by utilizing the spacecraft and planet kernel (SPK) format developed by the Jet Propulsion Laboratory Navigation and Ancillary Information Facility. Details behind this innovative technique can be found in (Ref. 2).

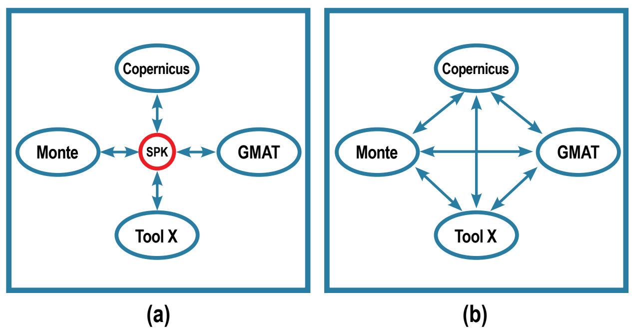


Figure 2. Interoperability between flight mechanics tools, (a) using a standardized trajectory structure and (b) specific tool-to-tool interface design. (Note: Tool X is any commercial tool)

Benefits for the FM Community

Newly developed functionality between these commonly used tools enables solutions to more complex trajectory design problems than can be accommodated with each individual tool by itself. Use cases developed under this effort are available and demonstrate the new interfaces, plug-ins, graphics updates and trajectory transfer features.

References

1. Flight Mechanics Analysis Tools Interoperability and Component Sharing, April 2023, NASA/TM-20230006507 https://ntrs.nasa.gov/citations/20230006507
2. Trajectory Reverse Engineering: A General Strategy for Transferring Trajectories Between Flight Mechanics Tools, Ricardo Restrepo, AAS 23-312.
3. Copernicus Trajectory Design and Optimization System https://software.nasa.gov/software/MSC-26673-1
4. General Mission Analysis Tool (GMAT) https://software.nasa.gov/software/GSC-19097-1
5. Mission-Analysis Operations Navigation Toolkit Environment (Monte) https://montepy.jpl.nasa.gov/
6. Flight Mechanics Analysis Tools Interoperability and Component Sharing Website. https://nescacademy.nasa.gov/FMAnalysisTool