Paper ID: 83370
student

IAF SPACE SYSTEMS SYMPOSIUM (D1)
Interactive Presentations - IAF SPACE SYSTEMS SYMPOSIUM (IPB)

Author: Mr. Rodrigo Schmitt
Purdue University, United States

Mr. Kshitij Mall
Purdue University, United States
Dr. Daniel Delaurentis
Purdue University, United States

# X-SMART: EXPLAINABLE SPACE MISSION ARCHITECTURES FOR RESEARCH ON TRADE-OFFS

**Abstract**

Space mission architectures often feature complex interdependencies and shared operations, making them difficult to analyze using traditional techniques such as sensitivity analysis, optimization, or trade-off analysis. We address these challenges by treating space missions as System-of-Systems (SoS) and introducing an innovative method that unifies surrogate models, Explainable Artificial Intelligence (XAI), and simulated data for evaluating architectures in space. Given AI's role in enhancing space mission efficiency through rapid data analysis, we leverage XAI, a toolset designed to make AI decisions transparent and interpretable, to illuminate intricate relationships among design variables in mission architectures. XAI typically clarifies black-box AI models; however, our work extends its utility to surrogate models, emphasizing the high-dimensionality and interdependencies within the mission design, which are often difficult to interpret conventionally. This combination presents distinct advantages: by revealing the interconnections among design variables, our method provides comprehensive insight, enhancing decision-makers' ability to control and understand mission design choices. The framework also provides efficient explanations by combining XAI with surrogates, which are faster to compute than large data sets - often unavailable for space missions - to efficiently explain mission design. Using SHapley Additive Explanation (SHAP), a model-agnostic interpretability technique, this speeds up model verification and reduces computational resources. Lastly, communication is improved by generating intuitive, visually accessible results, where XAI facilitates seamless understanding and collaboration among stakeholders and promotes consensus on complex mission architectures. Based on our framework's preliminary findings in a case study focused on on-orbit refueling for cislunar missions, we have found that the mass of a lunar descent element is a significant design variable influencing the economic feasibility of a refueling station. With such insights, decision-makers can assess the feasibility of deploying reusable systems and justify their costs. In a nutshell, our proposed method, which refrains from heavily relying on large data sets, contributes to a more manageable, time-efficient model without compromising accuracy and insight. As a result, our approach facilitates informed decision-making and course corrections for cost-effective, sustainable space missions. We also set the stage for a dedicated XAI framework for future space mission designs, advancing the explainability of models in this domain.