 POC: Daniel DeLaurentis (ddelaure@purdue.edu)

Purdue Capabilities Relevant to DARPA Phoenix Program

The Phoenix Program targets reusing expensive components of dysfunctional satellites in GEO to create new space systems at reduced cost. It proposes the development of nano-satellites called as "Satlets", which will be used to facilitate the satellite rejuvenation. Success of the program requires developments in the field of rendezvous, radiation tolerant microelectronics, microminiature guidance and control measurement units, additive manufacturing on structural materials etc. We believe that achievement of these technical developments could be better enabled by innovation in architecture analysis and design tools. Our System of Systems Lab at Purdue has significant experience in delivering tools for design and architectural analysis. Some of these are described below.

The development of aerospace systems involves creating interdependencies between individual components which results in creation of complex networks. While this empowers these systems with high levels of performance, it also makes them prone to disruptions. When systems are interdependent, disruptions in the development or operation of one system can easily propagate to systems directly (or indirectly) dependent on them. Characteristics of component systems, interdependencies, and risk can lead to disruptions that propagate differently in different networks. We have proposed a network-level metric that enables the comparison of different network topologies that provide the same capability but have different risk properties. This will help indentifying the risk-prone systems and eliminate them from further study (and expense) in the design phase.

We have also developed a framework to capture different aspects of system complexity. A system is decomposed into different levels of abstraction and within each level the system is represented using structural (network of components and interactions) and functional graphs (network of functions). These networks are then analyzed with a suite of complexity metrics that address aspects such as size, coupling and modularity. The framework has been demonstrated on different spacecraft architectures. We have also proposed an approach for complexity-enabled design space exploration which helps in identification of network features common in good and bad designs and then use it to facilitate efficient design space exploration.

Apart from developments in design tools, we have also developed tools for architectural analysis. An architectural analysis model has been created to enable the design of Command, Control, Communications, and Information (C3I) services for a campaign of crewed and robotic lunar surface missions. Agent models represent constituent systems and generate interactions at multiple levels of fidelity and in multi-layered networks. The analysis capabilities of the object-oriented tool allow users to evaluate performance metrics and solution structure at multiple levels and including multiple attributes simultaneously.

Finally, we have developed analysis tools for fractionated spacecraft architectures. These support initial sizing of the spacecraft designs and enable analysis of alternatives. We have also conceptualized modular and dichotomous architectures and developed tools for their conceptual design. Some of these tools can play a crucial role in fueling the innovations required for the Phoenix program.