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Petascale Design and Management of Earth Science Satellite Constellations: Bridging Earth Science and Astrodynamics

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Global scale issues such as population growth, changing land-use, and climate change place our natural resources at the center of focus for a broad range of interdependent science, engineering, and policy problems. Our ability to mitigate and adapt to the accelerating rate of environmental change is critically dependent on our ability to observe and predict the natural, built, and social systems that define sustainability at the global scale. Despite the risks and challenges posed by global change, we are faced with critical risks to our ability to maintain and improve long term space-based observations of these changes. Despite consensus agreement on the critical importance of space-based Earth science, the fundamental challenge remains: How should we manage the severe tradeoffs and design challenges posed by maximizing the value of existing and proposed spaced-based Earth observation systems? Addressing this question, requires transformative innovations in the design and management of spaced-based Earth observation systems that effectively take advantage of Petascale computing architectures (i.e. 100,000-300,000 compute cores) to discover and exploit critical mission tradeoffs using high-resolution space-based observation system simulation events (OSSEs). OSSEs provide an ideal framework for simulating the type and quality of observations that could be expected for alternative satellite constellation designs. A key challenge is to ensure they effectively balance astrodynamics concerns and the utility of proposed satellite designs for advancing specific Earth science applications.

Within the high resolution OSSEs, explicitly bridging astrodynamics focused design objectives and end use applications' objectives in the overall design and management of satellite constellations will require a new generation of planning tools. These tools should exploit state-of-the-art astrodynamics simulation, massively parallel implementations of many-objective optimization, global sensitivity analysis and interactive scientific visualization. Petascale computing will be critical for discovering missions' complex cost—performance—risk tradeoffs and their associated sensitivities because rigorous exploration of the space-based OSSEs' highly nonlinear decision spaces will require potentially millions of high resolution astrodynamic and Earth system simulations. High resolution astrodynamics models are necessary for satellite OSSEs to capture the potential perturbations of satellite orbits which include: geopotential, solar gravity, lunar gravity, atmospheric drag, solar radiation pressure, and precession / nutation of the Earth. At present computational barriers cause system's analysts to make limiting assumptions about the astrodynamics that can lead to results that do not provide enough accuracy to realistically model their mission life performance over decade time scales. Likewise, our evaluations of a mission's value to Earth science must also carefully maximize the use and fidelity of Earth systems models and ground observations. In the long term, our research is attempting to overcome computational barriers to transform the optimization of future satellite constellations for delivering high fidelity data to a broad array of Earth science applications.