National Aeronautics and Space Administration

NASA facts

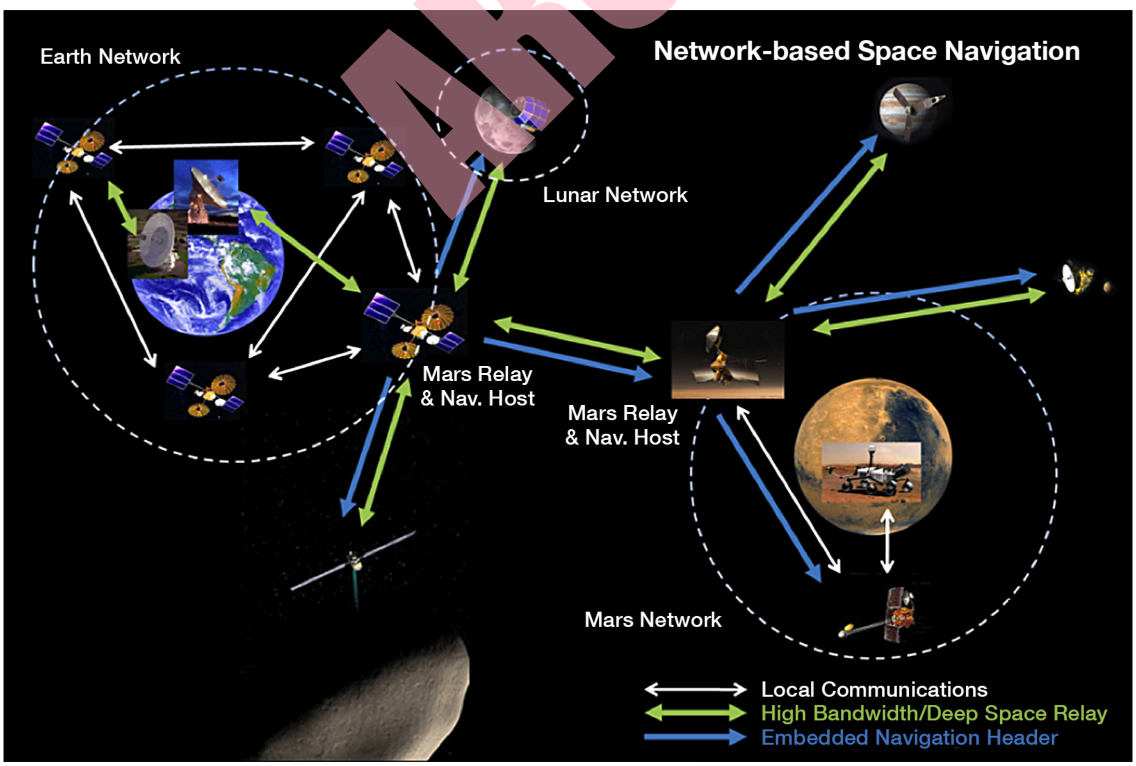
Space Technology

Game Changing Development

Multi-spacecraft Autonomous Positioning System (MAPS)

As the number of spacecraft in simultaneous operation continues to grow, there is an increased dependency on ground-based navigation support. The current baseline system for deep space navigation utilizes Earth-based radiometric tracking, requiring long duration observations to perform orbit determination and generate a state update. The age, complexity, and high utilization of the ground assets pose a risk to spacecraft navigation performance. In order to perform complex operations at large distances from Earth, such as extraterrestrial landing and proximity operations, autonomous systems are required. With increasingly complex mission operations, the need for frequent and Earth-independent navigation capabilities is further reinforced.

The Martian communication network, along with DSN support, provides an initial architecture for simulation and analysis of MAPS, providing a notional deep space implementation. This scenario is used for initial trade studies to determine capability assessments and sensitivity analysis. This architecture also serves as the mission scenario capturing the ideal initial deep space implementation of MAPS.



MAPS architecture.

To support initial flight validation, a low-Earth orbit demonstration mission concept is also being developed and analyzed. This mission scenario focuses on capturing the in-flight accuracy of spacecraft clocks as well as in-flight packet transmission, and state estimation among a limited number of assets. To support this mission, both software and hardware simulation tools have been developed. The simulation architecture allows for analysis of link budgets and estimated performance as a function of individual asset orbits and simulated errors (such as external perturbations and timing uncertainty). To capture the effects of real hardware, a hardware-in-the-loop system is being utilized to integrate flight quality radio and clock hardware to capture receiver delays and clock uncertainty to directly model spacecraft behavior. This framework is described in the illustration below.

The capability for high-accuracy timing measurements and delay modeling is enabled through the use of a truth simulation coordinator and a timing coordinator. These are both synced to high accuracy network clocks, with the timing coordinator running minimal processing to reduce any timing errors in modeling and controlling communication delays. This architecture will allow for verification and performance analysis of MAPS across a variety of mission scenarios, and provides a starting point for a full architecture simulation.

Anticipated Benefits

This technology is well suited to providing navigation capability to spacecraft participating in the communication network. By utilizing this technology, it is possible to turn every communication pass between assets into a real-time autonomous navigation pass as well, supplementing and enhancing traditional state determination methods. This reduces the reliance and load on ground-based assets while also increasing onboard state estimation capability.

Potential Applications

This architecture is designed to support in-space navigation for robotic and human missions. It can also serve as a backup navigation method for cases with limited ground support availability. As onboard clocks improve in capability and multiple spacecraft implement these algorithms, MAPS can be used as a primary navigation source. Additionally, this architecture can be used to develop high-accuracy navigation references throughout our solar system, integrating with interplanetary communication relays.

The Game Changing Development (GCD) Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

For more information about GCD, please visit http://gameon.nasa.gov/

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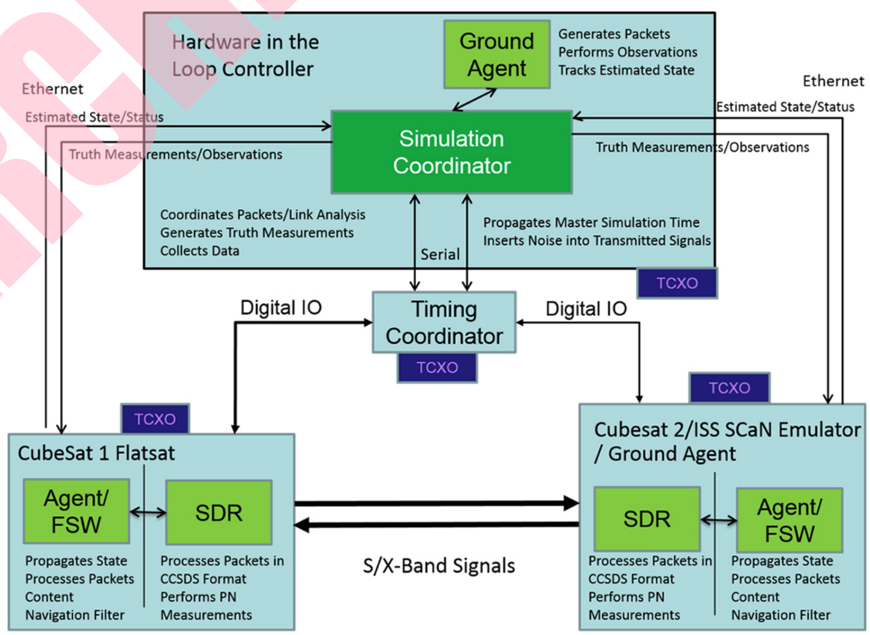

Simulation architecture.

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