NASA SBIR 2019 Phase I Solicitation

H9.03 Flight Dynamics and Navigation Technology

Lead Center: GSFC

Participating Center(s): JSC, MSFC

Technology Area: TA5 Communication and Navigation

Advanced Techniques for Trajectory Optimization

NASA is planning and proposing increasingly ambitious missions such as crewed and robotic missions in cislunar space, multiple small body (comet/asteroid) rendezvous/flyby missions, outer planet moon tours, Lagrange point missions, and small body sample return using low thrust propulsion (including solar sails). Trajectory design for these complex missions can take weeks or months to generate a single reference trajectory. This subtopic seeks new techniques and tools to speed up and improve the trajectory design and optimization process to allow mission designers to more fully explore trade spaces and more quickly respond to changes in the mission. See Reference 1 for NASA Technology Area (TA) roadmaps:

(https://www.nasa.gov/sites/default/files/atoms/files/2015_nasa_technology_roadmaps_ta_5_communication_and_navigation_final.pdf):

- Low-thrust trajectory optimization in a multi-body dynamical environment (TA 5.4.2.1)
- Advanced deep-space trajectory design techniques. (TA 5.4.2.7) and rapid trajectory design near small bodies (TA 5.4.5.1)
- Tools and techniques for orbit/trajectory design for distributed space missions including constellations and formations (TA 11.2.6)
- Tools and techniques for orbit/trajectory design using dynamical systems theory for Earth-Moon and cislunar missions.

Autonomous Onboard Navigation, Guidance and Control

Future NASA missions require precision landing, rendezvous, formation flying, cooperative robotics, proximity operations (e.g., servicing and assembly), non-cooperative object capture, and coordinated platform operations in Earth orbit, cislunar space, libration orbits, and deep space. These missions require a high degree of autonomy. The subtopic seeks advancements in autonomous navigation and maneuvering technologies for applications in Earth orbit, lunar, cislunar, libration, and deep space to reduce dependence on ground-based tracking, orbit determination, and maneuver planning. See Reference 1 for NASA Technical Area (TA) roadmaps:

- Advanced autonomous navigation techniques including devices and systems that support significant advances in independence from Earth supervision while minimizing spacecraft burden by requiring low power and minimal mass and volume (TA 5.4.2.4, TA 5.4.2.6, TA 5.4.2.8).

- Onboard trajectory planning and optimization algorithms, for real-time mission re-sequencing, on-board computation of large divert maneuvers (TA 5.4.2.3, TA 5.4.2.5, TA 5.4.2.6, TA 9.2.6) primitive body/lunar proximity operations and pinpoint landing (TA 5.4.6.1), including the concept of robust onboard trajectory planning and optimization algorithms that account for system uncertainty (i.e., navigation errors, maneuver execution errors, etc.).
- Onboard relative and proximity navigation (TA 5.4.4) multi-platform relative navigation (relative position, velocity and attitude or pose) which support cooperative and collaborative space operations including satellite servicing and in-space assembly.
- Rendezvous targeting (TA 4.6.2.1) Proximity Operations/Capture/ Docking Guidance (TA 4.6.2.2)
- Advanced filtering techniques (TA 5.4.2.4) that address rendezvous and proximity operations as a multi-sensor, multi-target tracking problem; handle non-Gaussian uncertainty; or incorporate multiple-model estimation.
- Vision processing algorithms (TA 5.4.3.2) to extract the maximum amount of information from images used for optical navigation.

Conjunction Assessment Risk Analysis (CARA)

The U.S. Space Surveillance Network currently tracks more than 22,000 objects larger than 10 centimeters and the number of object in orbit is steadily increasing which causes an increasing threat to human spaceflight and robotic missions in the near-Earth environment. The NASA Conjunction Assessment Risk Analysis (CARA) team identifies close approaches (conjunctions) between NASA satellites and other space objects, determines the risk posed by those events, and plans and executes risk mitigation strategies, including collision avoidance maneuvers to protect space assets and humans in Earth orbit. The ability to perform CARA more accurately and rapidly will improve space safety for all near-Earth operations, improve operational support by providing more accurate and longer-term collision predictions and reduce propellant usage for collision avoidance maneuvers. This subtopic seeks innovative technologies to improve the CARA process including (see Reference 1 for NASA Technical Area (TA) roadmaps).:

- Faster and more accurate methods of detecting close approaches and conjunctions (TA 5.7.1) and computing probability of collision (TA 11.3.6).
- Techniques for improving state and covariance characterization and propagation (TA 5.7.2.1, TA 11.3.6), including improved modeling of non-gravitational force effects, Gaussian mixture models, differential algebra, polynomial chaos expansions, etc.
- Techniques for estimation of object characteristics (TA 5.7.2) relevant to accurate orbit propagation such as ballistic coefficient, attitude or attitude profile, mass, configuration, and maneuvers from available radiometric, photometric and/or astrometric data.
- Event evolution prediction methods, models and algorithms with improved ability to predict orbit characteristics for single and ensemble risk assessment, especially using artificial intelligence/machine learning (TA 5.5.3).

Proposals that leverage state-of-the-art software already developed by NASA, or that can optionally integrate with those packages, such as the General Mission Analysis Tool (GMAT), Copernicus, Evolutionary Mission Trajectory Generator (EMTG), Mission Analysis Low-Thrust Optimization (MALTO), Mission Analysis, Operations, and Navigation Toolkit Environment (MONTE), Goddard Enhanced Onboard Navigation System (GEONS), and Optimal Trajectories by Implicit Simulation (OTIS), or other available software tools are encouraged. Proposers who contemplate licensing NASA technologies are highly encouraged to coordinate with the appropriate NASA technology transfer offices prior to submission of their proposals.

Phase I research should be conducted to demonstrate technical feasibility, with preliminary software being delivered for NASA testing, as well as show a plan towards Phase II integration. For proposals that include hardware development, delivery of a prototype under the Phase I contract is preferred, but not necessary. Phase II new technology development efforts shall deliver components at the TRL 5-6 level with mature algorithms and software components complete and preliminary integration and testing in an operational environment.

References:

- NASA Space Technology Roadmaps (2015) : https://www.nasa.gov/offices/oct/home/roadmaps/index.html

- General Mission Analysis Tool (GMAT): http://gmatcentral.org/display/GW/GMAT+Wiki+Home
- Evolutionary Mission Trajectory Generator (EMTG): https://software.nasa.gov/software/GSC-16824-1
- Copernicus: https://www.nasa.gov/centers/johnson/copernicus/index.html
- Optimal Trajectories by Implicit Simulation: http://otis.grc.nasa.gov/
- Mission Analysis Low-Thrust Optimization (MALTO): https://spaceflightsystems.grc.nasa.gov/SSPO/ISPTProg/LTTT/
- Mission Analysis, Operations, and Navigation Toolkit Environment (MONTE): https://montepy.jpl.nasa.gov/
- Goddard Enhanced Onboard Navigation System (GEONS), (https://software.nasa.gov/software/GSC-14687-1), (https://goo.gl/TbVZ7G)
- Navigator GPS Receiver (http://itpo.gsfc.nasa.gov/wp-content/uploads/gsc_14793_1_navigator.pdf)
- NavCube (https://goo.gl/bdobb9)
- NASA Conjunction Assessment Risk Analysis (CARA) Office: https://satellitesafety.gsfc.nasa.gov/cara.html
- NASA Orbital Debris Program Office: https://www.orbitaldebris.jsc.nasa.gov/
- Newman, Lauri, K., "The NASA robotic conjunction assessment process: Overview and operational experiences," Acta Astronautica, Vol. 66, Issues 7-8, Apr-May 2010, pp. 1253-1261, https://www.sciencedirect.com/science/article/pii/S0094576509004913.
- Newman, Lauri K., et al. "Evolution and Implementation of the NASA Robotic Conjunction Assessment Risk Analysis Concept of Operations." (2014). https://ntrs.nasa.gov/search.jsp?R=20150000159

Newman, Lauri K., and Matthew D. Hejduk. "NASA Conjunction Assessment Organizational Approach and the Associated Determination of Screening Volume Sizes." (2015). https://ntrs.nasa.gov/search.jsp?R=20150011461