NASA's current Position, Navigation, and Timing (PNT) state-of-the-art relies on both ground-based and space-based radiometric tracking, laser ranging, and optical navigation techniques. Post-processed GPS position determination performance accuracy is at the cm-level at Near-Earth distances and at meter-level at High-Earth Orbit distances; while autonomous real-time GPS performance, such as provided by GPS-Enhanced Onboard Navigation System (GEONS) can achieve accuracy performance of 20 meters. For missions at Mars, Deep Space Network navigation services provide performance accuracy of 1km, while optical navigation methodologies obtain performance accuracy of 10s of km at this distance.

Future NASA missions will require precision landing, rendezvous, formation flying, cooperative robotics, proximity operations, and coordinated platform operations. As such, the need for increased precision in absolute and relative navigation solutions increases. As operations occur further from Earth and more complex navigational maneuvers are performed, it will be necessary to reduce the reliance on Earth-based systems for real-time decisions. Investments in technologies to implement autonomous on-board navigation and maneuvering will permit a reduction in dependence on ground-based tracking, ranging, trajectory/orbit/attitude determination, and maneuver planning and support functions. Therefore, the early focus for NASA will be to improve PNT through increasing real-time PNT accuracy and precision, as well as achieving this performance in autonomously on-board the spacecraft.

Technologies and software should support a broad range of spaceflight customers. Technologies and software specifically focused on a particular mission's or mission set's needs are the subject of other solicitations by the relevant sponsoring organizations and should not be submitted in response to this solicitation. In the context of this solicitation, flight dynamics technologies and software are algorithms and software that may be used in ground support facilities, or onboard a spacecraft, so as to provide PNT services that reduce the need for ground tracking and ground navigation support. Flight dynamics technologies and software also provide critical support to pre-flight mission design, planning, and analysis activities.

This solicitation is primarily focused on NASA's flight dynamics software and technology needs in the following focused areas:

- Next generation of multi-purpose ground-based and on-board autonomous navigation filtering techniques,
such as adaptive filtering where measurements are selectively weighted, or filters that monitor state noise and measurement noise processes.

- Algorithms for real-time multi-platform relative navigation (relative position, velocity, attitude/pose).

- Algorithms which process clock measurements and estimate and/or propagate the timekeeping model (which generates the time and frequency signal output) and timekeeping system architectures in which outputs of an ensemble of clocks are weighed and software filtered to synthesize an optimized time estimate.

- Sensor measurement models and processing algorithms for next generation sensors, including (but not limited to): optical navigation sensors (high resolution flash LIDAR, visible cameras, infrared cameras), radar sensors, radiometrics, fine guidance sensors, laser rangefinders, high volume/high speed FPGA-based electronics for LIDAR.

- Algorithms for real-time vision processing, path planning and optimization, constraint handling, integrated system health management, fault management (FDIR), event sequencing, optimal resource allocations, collaborative sensor fusion, sensor image motion compensation and processing, pattern recognition/matching, hazard search and detection, feature location and mapping, high performance inertial and celestial sensor models, accurate and fast converging vehicle state estimation filters and adaptive flight control systems.

- Applications of advanced dynamical theories to space mission design and analysis for ground-based and on-board autonomous algorithms, especially in the context of unstable orbital trajectories in the vicinity of small bodies, libration points, and Near-Earth objects.

- Autonomous navigational planning, detection, and filter optimization, as well as attitude control systems for autonomous platform orientation, using sensor measurement fault detection & management and/or fault-tolerant filtering algorithms.

- Addition of novel estimation techniques and/or orbit determination capabilities to existing NASA mission design software that is either freely available via NASA Open Source Agreements, or that is licensed by the proposer.

Proposals that leverage state-of-the-art capabilities already developed by NASA are especially encouraged, such as:

- GPS-Enhanced Onboard Navigation Software:
  - (http://techtransfer.gsfc.nasa.gov/ft_tech_gps_navigator.shtm)


- General Mission Analysis Tool (http://sourceforge.net/projects/gmat/)

- GPS-Inferred Positioning System and Orbit Analysis Simulation Software:
  - (http://gipsy.jpl.nasa.gov/orms/goa/)

- Optimal Trajectories by Implicit Simulation (http://otis.grc.nasa.gov/)

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 Deliverables** - Phase I research should be conducted to demonstrate technical feasibility (to reach TRL 3), with preliminary software being delivered for NASA testing at the end of the Phase I contract, as well as show a plan towards Phase II integration. Phase I Deliverables include:

- Preliminary Software at end of Phase I contract.
- Final Phase I Technical Feasibility Report with a Phase II Integration Path.

**Phase II Deliverables** - Phase II efforts should build on Phase I research towards a Phase II software demonstration and delivering a software package for NASA testing at the completion of the Phase II contract (to reach TRL 5). Also, prototype software should be delivered to NASA at the end of the first year of the contract, to be reviewed and iterated upon towards the development of the final software demonstration and delivery. Phase II efforts should also include development of proper documentation, which includes a thorough Algorithm Specification document. Phase II Deliverables include:

- Prototype Software at end of first year of Phase II contract.
- Final Phase II Technical Report.
- Algorithm Specification at end of Phase II contract.
- Delivery of software package at end of Phase II contract.
- Demonstration of software package at end of Phase II contract.

Potential NASA Customers include:

- Space Communications and Navigation (SCaN) Program