Autonomous Navigation, Guidance, and Control Software in a Low SWaP Box

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Onboard autonomy is a necessity for responsive space operations. Autonomous navigation, guidance, and control (NGC) enables space missions to reduce their dependence on high demand ground assets and costly ground personnel. It also allows for in-situ decision making and higher return on mission data. A flight software and hardware system providing this capability, called “autoNGC,” is currently being developed at NASA Goddard Space Flight Center for infusion into multiple future missions.

The autoNGC flight software is built on the plug-and-play architecture of the core Flight System (cFS) consisting of the standard cFS apps and newly developed autoNGC interface apps and libraries. The various apps cooperate through communication over the message-based software bus. With the plug-and-play architecture of autoNGC, cFS apps can easily be added and replaced to meet the needs of different missions, even after launch.

The first flight software release of autoNGC is targeted for Summer 2024 to provide autonomous navigation at the Moon and beyond. It can perform sensor fusion of multiple measurement types including pseudo-range from a Global Navigation Satellite System (GNSS) receiver (including weak signal), 1-way and 2-way range and Doppler from ground stations (i.e., direct to Earth (DTE)), bearing and range from optical camera images, and accelerometer data. Accurate onboard navigation and timing is obtained through the Goddard Enhanced Onboard Navigation System (GEONS) software library which fuses different measurement types through an extended Kalman filter (EKF) framework. Optical measurements that are ingested in GEONS are first extracted from optical images by the cFS Goddard Image Analysis and Navigation Tool (cGIANT) app. If the imaged body is far enough away that it appears as a pixel or cluster of pixels, then bearing angles to the body centroid can be provided. If the body is close enough and the shape is known coarsely, then bearing angles and range to the body centroid can be derived from the limb. Bearing angles to individual surface features can also be extracted (i.e., terrain relative navigation (TRN)).

Onboard guidance and control capabilities are being developed for a future release to perform autonomous station-keeping and trajectory correction maneuvers in multiple orbital regimes. Capabilities to enable distributed systems missions and constellations, such as crosslink measurements, and onboard time management are being developed as well.

The first hardware implementation of autoNGC is a minimal size, weight, and power (SWaP) design allowing for inclusion into CubeSats and SmallSat-size buses. Advancements in miniaturized space processors, such as the SpaceCube 3.0 Mini and the SpaceCube Mini-Z are utilized for low SWaP while maintaining a high level of performance. The current enclosure design is 12 cm x 17 cm x 13.5 cm. The box mass is expected to be less than 2 kg, and the nominal power is 21 W. In order to accommodate a wide range of missions, the hardware interfaces are designed for flexibility with a variety of sensor inputs.

Through comprehensive testing in the software-in-the-loop, processor-in-the-loop, and hardware-in-the-loop test beds that are concurrently being developed, autoNGC is expected to achieve TRL 6 by late 2024.