Crater-Based Navigation and Timing for Small Satellites in Low-Lunar Orbit

Brandon A. Jones, Renato Zanetti, Sofia Catalan, Rachael Gold, Z McLaughlin

Deficiencies, inefficiencies, and inaccuracies in on-board navigation and timing pose a severe risk to future manned and unmanned operations in cislunar and lunar space, thereby increasing the probability of mission failure. NASA's return to the moon requires operating in a GPS-denied environment while minimizing the need for ground support. Planned support systems, such as LunaNet, hope to provide a GPS-like capability for spacecraft operating in cislunar space, but require their own on-board solutions to aid the end-user. No options exist at high Technology Readiness Levels (TRLs) that jointly satisfy on-board navigation and timing requirements in the near-moon environment, let alone are consistent with the size, weight, and power limitations of the Cube Satellite (CubeSat) platform. There is a critical need to develop Position Navigation and Timing (PNT) technologies that satisfy these operating constraints to support NASA's lunar ambitions. The University of Texas at Austin and the NASA Johnson Space Center are developing a Crater-based Navigation and Timing (CNT) approach to PNT in preparation for an on-orbit CubeSat demonstration.

The CNT system leverages lunar craters as known points in a manner similar to GPS for terrestrial and near-Earth applications or lighthouses for pre-GPS ship navigation. The developed technology integrates crater detection, identification, and state estimation into a unified and unique system for PNT using flight-proven optical cameras. The crater detection algorithm leverages a new approach based on Convolutional Neural Networks (CNNs) to reduce computation load for on-orbit image processing. A novel element of this approach is to leverage a ground-based trajectory for timing. GPS satellites accurately keep time onboard using atomic clocks with their trajectories estimated from the ground. Our proposed methodology flips this approach. The trajectory estimation is done autonomously and onboard, while timing is obtained with support of the ground and periodically steered by comparing the onboard navigation solution with the ground tracking solution. Occasional DSN passes are necessary for the satellite to communicate with ground control. These passes are leveraged to form a precise position solution and to estimate onboard clock errors. The solution is then uploaded to the satellite. The onboard CNT system keeps the navigation and timing errors from growing too large in-between ground contacts. This presentation will discuss the current status (development, testing, and performance) of the CNT system and efforts currently underweight for on-orbit demonstration.