Vision Navigation System Flight Experiment Development

Problem: The NESC, responding to the need to develop and mature guidance, navigation, and control (GNC) component technology, initiated a technical assessment in November 2010 to perform a risk-reducing technology demonstration of an advanced version of the Orion crew module vision navigation system (VNS). The VNS is a flash light detection and ranging (LIDAR) relative navigation sensor used during spacecraft rendezvous. Mounted on a "chaser" spacecraft, the VNS pulses its laser to determine range and bearing relative to optical reflectors mounted on a vehicle that is the rendezvous "target." This is accomplished by measuring the time of flight of a laser pulse to the target and reflected back to a detector.

In a flash LIDAR system, the laser beam is diverged so that the illuminated spot on the target surface closely matches the field of view of the two-dimensional detector array. Each pixel in the detector array is individually triggered, allowing for a measurement of both intensity and time of flight (i.e., range) of the returned laser pulse. Thus, for a single laser pulse, all pixels in the scene are illuminated, with each pixel providing range and intensity information. This results in the generation of a full topographic and intensity map of the entire scene with each VNS laser pulse.

A notional representation of the VNS flash LIDAR illuminating the ISS to determine range and bearing relative navigation information.

This GNC technology demonstration, called the vision navigation sensor autonomous rendezvous and docking (AR&D) relative navigation experiment (VADRE), was a collaborative risk mitigation effort between the NESC, the Orion Multi-Purpose Crew Vehicle Program, and the NASA AR&D Community of Practice (CoP). The VADRE unit is a follow-on and more capable sensor than the sensor test for Orion relative navigation risk mitigation (STORRM) VNS unit. STORRM was demonstrated on-orbit during shuttle mission STS-134 in May 2011. The VADRE unit includes new high-performance microprocessors which host flight software executing sophisticated image processing algorithms. These new embedded algorithms, first developed for VADRE, perform pixel processing (e.g., centroiding), target processing, sensor configuration and control, and limit monitoring functionalities.

NESC Contribution: The VNS was baselined as the primary rendezvous, proximity operations, and docking sensor for the Orion spacecraft. As part of the NESC GNC technical assessment, the VADRE unit has been assembled at Ball Aerospace and Technologies Corp. (the sensor technology provider) from “as-built” engineering development unit electronic boards and optical/laser subassemblies developed for the Orion spacecraft and subsequently transferred to the NESC. Once assembly was completed, the VADRE unit was functionally tested and then system-level calibrated. The VADRE unit has a wide operational range, from 5 kilometers to 2 meters. Optical performance was tested and verified against multiple known and well-characterized targets spanning this operational range.

Result: Following the completion of its testing in September 2011, the VADRE unit has become an asset for the NASA AR&D CoP. The NESC delivered VADRE to the Satellite Serving Capabilities Office at GSFC for integration into their Argon AR&D ground test bed. There the unit was thoroughly exercised in a series of AR&D ground-technology demonstrations.

The data collected from VADRE has been made available to the Agency-wide AR&D CoP, where it is being carefully analyzed and evaluated. Also, in parallel with the VADRE ground demonstrations, plans are being formulated by the AR&D CoP to fly this unit to the International Space Station (ISS). Collaborative demonstrations of the VADRE on ISS over a period well beyond that of the relatively short STORRM VNS flight test, will serve to validate relative navigation and vehicle position estimation algorithms in a realistic operational environment over a broad range of dynamic and lighting conditions.