NASA SPLICE Project: Development and Testing of Precision Landing GN&C Technologies

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Introduction

NASA's technology advancement needs for entry, descent and landing call for high-precision, high-rate sensors that can improve navigation accuracy and vehicle control performance. Higher landing accuracy is required for any future human lander missions, and likely, for most robotic missions [1,2]. Sensors and algorithms that significantly reduce navigation errors and can image the local terrain will enable landing at locations of high scientific interest that would otherwise pose significant risk to the vehicle.

The Safe and Precise Landing—Integrated Capabilities Evolution project, or SPLICE, is developing precision landing and hazard avoidance (PL&HA) technologies for NASA and for potential commercial space flight missions. SPLICE technologies include sensors, algorithms, advanced space flight computing capabilities, and simulation tools used to integrate and study guidance, navigation, and control (GN&C) system performance. SPLICE efforts include hardware-in-the-loop (HWIL) simulation testing, ground testing, and flight testing, including reuse of hardware from the CoOperative Blending of Autonomous Landing Technologies (COBALT) suborbital flight-test payload[3,4].

Two of the precise navigation sensors that are being developed and matured within SPLICE are LiDARs. Since 2006, NASA Langley has been developing a Navigation Doppler LiDAR (NDL) for precise velocity measurements, and SPLICE is building an NDL engineering test unit (ETU) that will be brought up to TRL 6 following environmental and high-speed[1,2] testing. NASA Goddard is developing a Hazard Detection LiDAR (HD LiDAR) engineering development unit (EDU) for SPLICE that has relevance to future human and robotic lander missions. The HD LiDAR will be flight test and matured to TRL 5.

Navigation Doppler Lidar

The SPLICE project will implement the NDL ETU with space flight qualifiable parts and evolve the third-generation NDL design from the former COBALT project[5]. The NDL provides both velocity and range measurements. The sensor hardware consists of a custom optical head and electronics box, as shown in Figure 1. The electronics include a seed laser, fiber amplifier, synthesizer, wideband receiver and a NASA-developed command and data handling (C&DH) board. The NDL ETU is targeting infusion into near-term space flight missions including prospective public-private lunar lander partnerships in the early 2020's and future New Frontiers, Discovery or other robotic-science or technology demonstration missions for the moon, Mars and elsewhere.



Generation-3 navigation Doppler lidar.

Figure 1 Navigation Doppler LiDAR

Hazard Detection Lidar

The SPLICE project HD LiDAR EDU will be designed, implemented and tested to performance specifications relevant to robotic lunar lander concepts and other relevant NASA robotic missions. The HD LiDAR EDU will be capable of generating a real-time, three-dimensional terrain map within seconds and from a slant range of at least 500 meters, similar to what is shown in Figure 2. Figure 2 shows the DEM from a square hazard field at the Kennedy Space Center that was designed to test the ALHAT Hazard Detection System[6]. The HD LiDAR will generate a circular DEM instead. The map resolution will be sufficient to identify lander-sized hazards and safe landing sites. The HD LiDAR map generation will be tested on an airborne vehicle, and hazard detection algorithm performance will be analyzed within the SPLICE HWIL simulation.

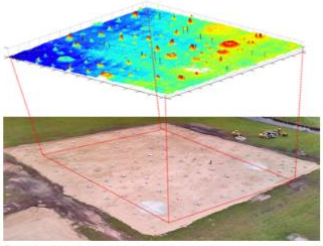


Figure 2 Hazard Field Map

Descent and Landing Computer

The SPLICE descent and landing computer (DLC) EDU leverages a commercial surrogate processor for the in-development, NASA High Performance Spaceflight Computing (HPSC) processor. The HPSC is a joint investment between NASA and the Department of Defense. The HPSC surrogate within the DLC is a commercially available board with an ARM (Advanced RISC Machine) A53-processor and other components in common with the NASA HPSC architecture. The DLC EDU will be ground tested within the SPLICE HWIL simulation and flight tested onboard a revised COBALT payload. The DLC EDU jointly benefits the PL&HA and HPSC communities and can provide use cases for the accelerated development and spaceflight infusion of SPLICE and HPSC technologies.

Simulation and HWIL Testing

SPLICE is developing a HWIL simulation test bed for implementing, maturing and validating PL&HA and GN&C algorithms, avionics, sensors, and flight software. The flight software is being implemented within NASA's core Flight System (cFS) framework to ensure a path to spaceflight infusion. The HWIL test bed leverages the NASA "Trick Simulation Toolkit" framework and the "iPAS" (integrated Power, Avionics and Software) environment, which allows assessment of GN&C technologies within a space mission context. This combined infrastructure provides capabilities for dynamic simulations integrated with the DLC EDU and GN&C/PL&HA hardware. The HWIL test bed also provides a low-cost method for GN&C subsystem development and validation prior to higher-cost suborbital flight testing and follow-on integration and flight onboard space flight missions.

Flight Testing

Flight tests of SPLICE technologies will be planned and conducted on multiple terrestrial test platforms to obtain data to validate SPLICE sensor (NDL ETU and HD LiDAR EDU) and flight software performance. A high-speed test (aircraft, rocket sled, or other platform) of the NDL ETU is planned to validate NDL velocity performance. An airborne vehicle test of the HD LiDAR EDU is planned to collect data from a terrestrial, lunar-like terrain field for evaluation of HD LiDAR map generation. A closed-loop flight test of the revised COBALT payload, incorporating the DLC and NDL, is planned to validate integrated PL&HA sensors and flight software. Figure 3 shows a photo of the first generation COBALT[3,4] payload onboard the Masten Space Systems Xodiac rocket during a flight test in the spring of 2017.



Figure 3 COBALT Flight Test

Infusion of Technologies and Future Work

The NASA PL&HA domain includes a diverse suite of GN&C technologies for precise and safe landing. These technologies will enable new mission concepts by enlarging the trade space of feasible landing sites for surface exploration both for humans and robots. Many of these technologies are approaching readiness for infusion into near-term robotic science missions in the early 2020's. The SPLICE project aims to maintain a knowledge base of all relevant technologies that will aid in any future lander missions and actively work towards making these technologies adaptable and available to future lander missions.

References

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