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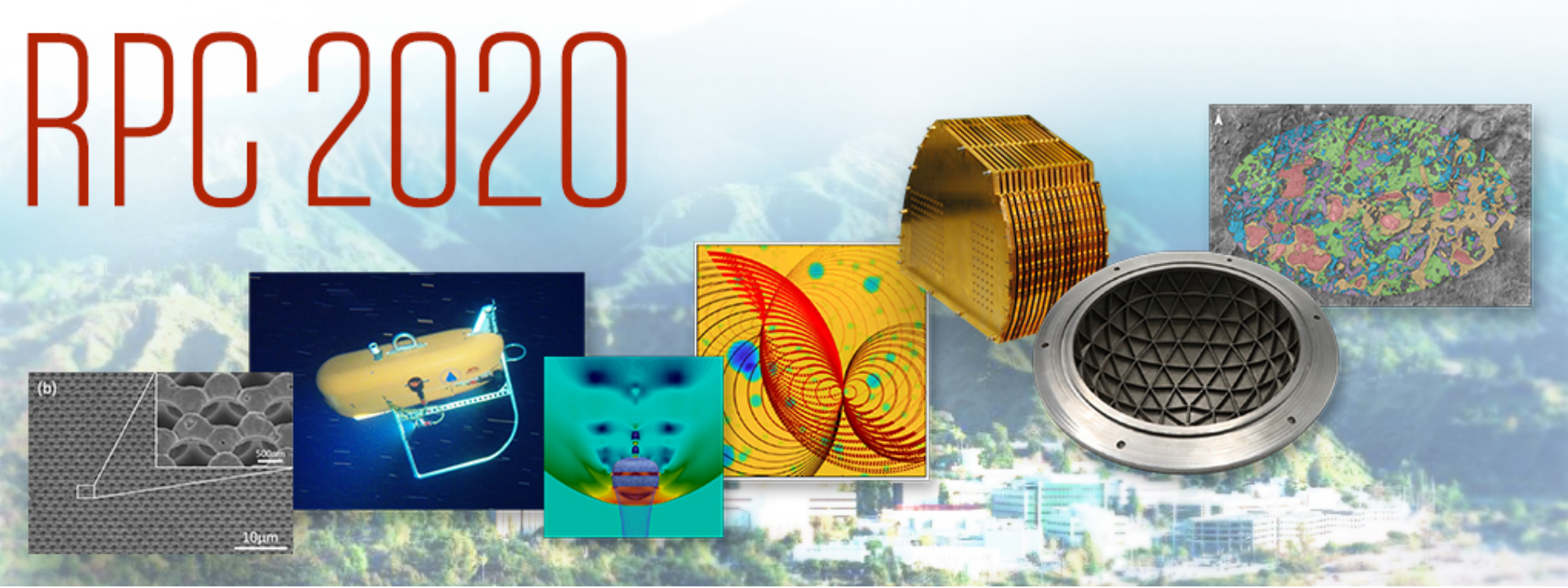

Virtual Research Presentation Conference

Hardware-in-the-Loop Testbeds for Robust Landing Navigation Systems

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Program: SURP
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Jet Propulsion Laboratory
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Tutorial Introduction

Abstract

This research is aimed at developing hardware-in-the-loop testbeds specialized to JPL mission needs to facilitate sensor modality selection for effective guidance and control of reentry vehicles. Hazardous and poorly-mapped environments also demand that we leverage recent technological advances in sensor systems and integrate them for improved navigation. This SURP project is aimed at developing analytical tools to develop functional models of velocimeter sensors for guidance, navigation and control applications. By leveraging Texas A&M's Land, Air and Space Robotics (LASR) laboratory's world-class robotics testbeds and the innovative Aeva systems velocimeter LIDAR, a functional model will be developed that can be deployed in JPL simulation testbeds. Evaluation of the velocimeter LIDAR being aggressively sought after by the autonomous vehicle industry is a unique opportunity afforded by JPL as a part of this SURP study. In particular, this work showcases the functional model capabilities and also showcases capabilities of the new class of LIDAR at the LASR lab.

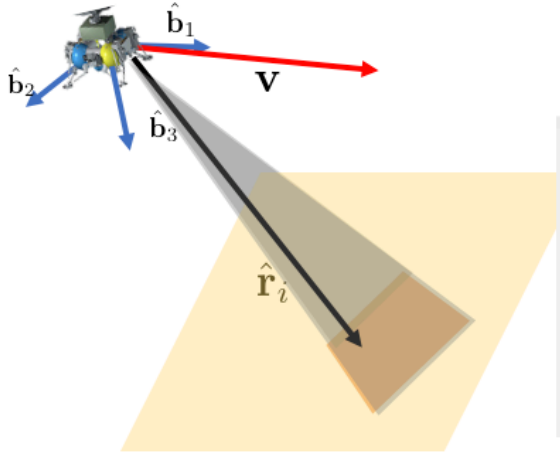
Problem Description

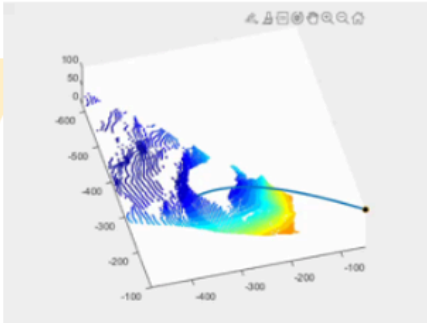
a) Robust safe landing on hazardous and poorly mapped remote planetary environments requires effective fusion of information from a suite of complementary sensors for terrain-relative navigation and hazard detection and avoidance. Hardware in the loop testbeds play a critical role in verification and validation of improved landing systems. This project aims at establishing such a testbed, while evaluating innovative sensing modalities for their utility in entry, descent and landing operations.

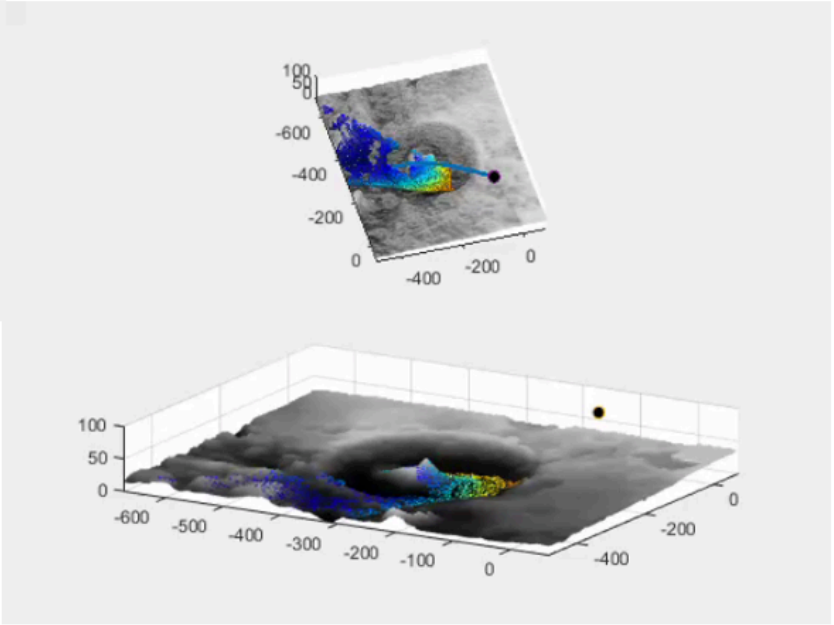
b) The use of Frequency Modulated Continuous Wave (FMCW) technologies with hardware in the loop testing of reentry guidance and control is the state of the art in the world and quite innovative.

c) Proposed work fundamentally advances System Level Autonomy by furthering approaches for Autonomous GNC, planning, scheduling and execution. It also favorably impacts next generation Entry, Descent, and Landing Systems to achieve robust precision landing.

Velocimeter LIDAR: Functional Modeling







$\hat{\mathbf{r}}_i$ Sensor "pixel" direction

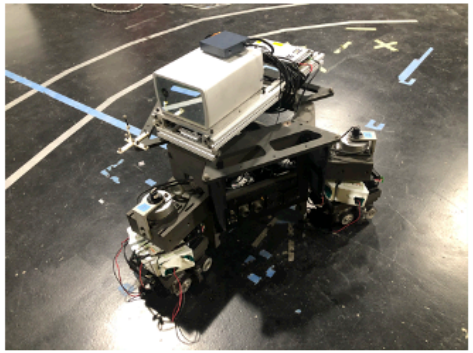
$\mathbf{v}$ Body velocity vector

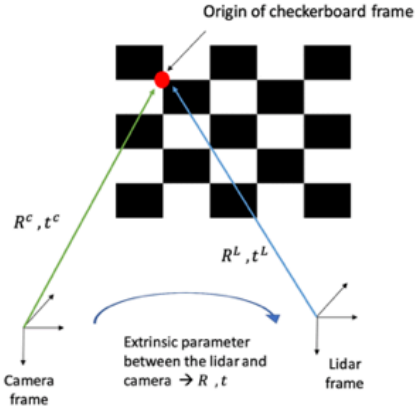
$R_i = \mathbf{v}^T \hat{\mathbf{r}}_i$ Doppler velocity

$$\delta f_i = \frac{2R_i}{c} f = \frac{2R_i}{\lambda}$$

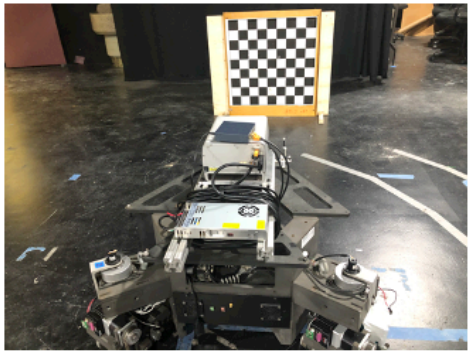
The doppler shift in frequency resulting from the component of target's velocity (range-rate) R_i along the sensor's line-of-sight, is computed in terms of source parameters such as pulse frequency f or wavelength λ as

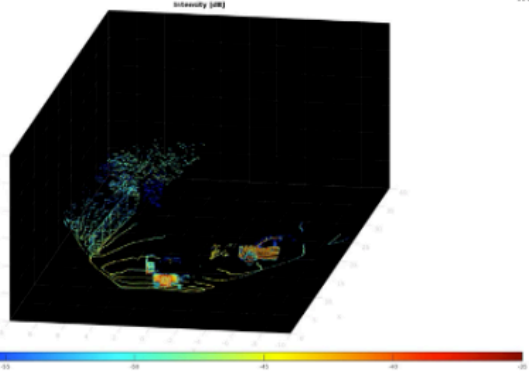
AEVA Systems Velocimeter LIDAR

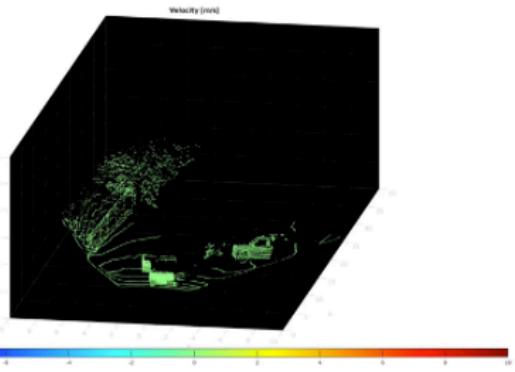




$$x_i^L = R_{L/C} x_i^C + t^L$$







Results

a) Developed a functional model for the novel Frequency Modulated Continuous Wave (FMCW) LIDAR system for simultaneous acquisition of point clouds and rates of the relative motion of the sensor with respect to the terrain. Acquired, tested and calibrated a state of the art FMCW LIDAR instrument to further the functional model development. Test campaign to compare the performance of the lightweight functional model with the true Aeva systems hardware was carried out.

b) Significance

   a) The results thus far make strides towards studying new sensor modalities for improved entry, descent and landing operations.

   b) Functional and physics based modeling will further illuminate the value of information of the measurements made by similar sensors for advanced GNC applications.

   c) Educational and workforce development (PhD students)

c) Next steps

   a) Functional model will be further developed to add higher fidelity and features of the sensor system

   b) Texas A&M will execute various test scenarios to evaluate the instrument capabilities further.

Publications and References

1. Davis, A., Majji, M., “Velocimeter LIDAR Systems for Automated Rendezvous, Proximity Operation and Debris Removal Applications,” submitted for possible presentation at the AAS GN&C Conference, Breckenridge, CO, 2021.