Ocean World Lander Autonomy Testbed

Lander missions to various ocean worlds in the solar system are high on the list of space exploration objectives for NASA and various ocean world lander mission concepts are currently under investigation. Due to the intensity of the radiation environment, adverse thermal conditions and low availability of solar energy, many of these missions are anticipated to have short durations, on the order of tens of days. Given the hour-long communication delay between these ocean worlds and the Earth, autonomy is bound to be a critical component for the success of these time critical missions. In light of this, NASA has enabled the development of an ocean world lander testbed to test and evaluate the performance of various autonomy algorithms and architectures. This testbed has two complementary components:

1) Software testbed
2) Hardware testbed

The hardware testbed at JPL, shown in Fig. 1, comprises the following components

1) A 6-DOF Stewart Platform representing the lander
2) A 7-DOF Barrett WAM7 robotic arm representing the manipulator
3) An Intel Realsense D415 stereo camera for 3D perception mounted on a pan-tilt unit
4) Three force-torque sensors located at the interface between the arm and the platform and force torque sensor located at the end of the wrist of the arm
5) A host of interchangeable tools that can be attached at the end of the arm
6) A simulant area

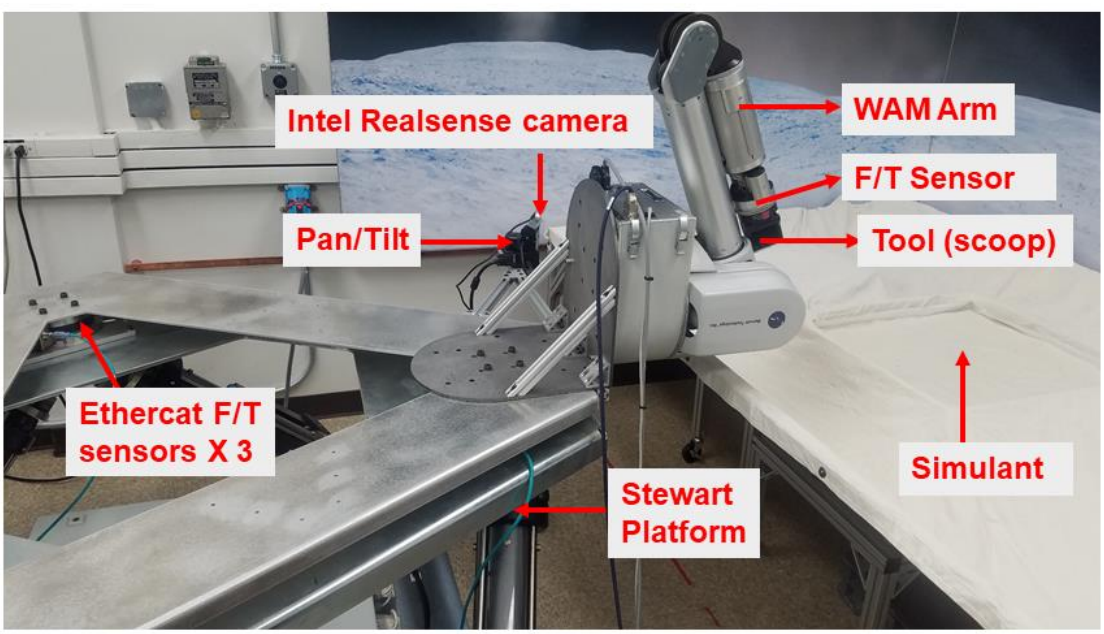

Fig 1. Different components of the Ocean World Lander Autonomy Testbed

An autonomy software can be interfaced to command the manipulator for carrying out surface operations in the simulant testbed such as scooping, drilling and probing. The force-torque sensors located at the end of the wrist, and at the interface between the arm and the Stewart platform, play a critical role in replicating the dynamical environment such landers are likely to experience on the low-gravity icy moons of Jupiter and Saturn. As the tool interacts with the simulant in the testbed, the reaction forces measured are fed into a dynamics model of the system. The computed motion is imposed on the Stewart platform in realtime. The use of high bandwidth Ethercat force-torque sensors allows us to close the loop at 1 kHz and study test cases demonstrating how interaction with the surface on objects with gravity as low an Enceladus ($g = 0.13\ m/s^2$) can cause the legs of the lander to lift off the ground, thereby achieving Earth gravity compensation without the use of suspension cables and gantry mechanisms.

Proposals have been solicited by NASA through ARROW and COLDTech programs for using the testbed and multiple teams are using it to evaluate the performance of their autonomy algorithms for future ocean world lander missions. Due to the wide range of capabilities incorporated in the system, we believe that this testbed could provide multi-mission capability and serve as a state-of-the-arm platform for simulating various planetary missions in the future over a wide range of dynamic environments, including surface operations on small bodies where recreating the dynamics in low gravity is critical.