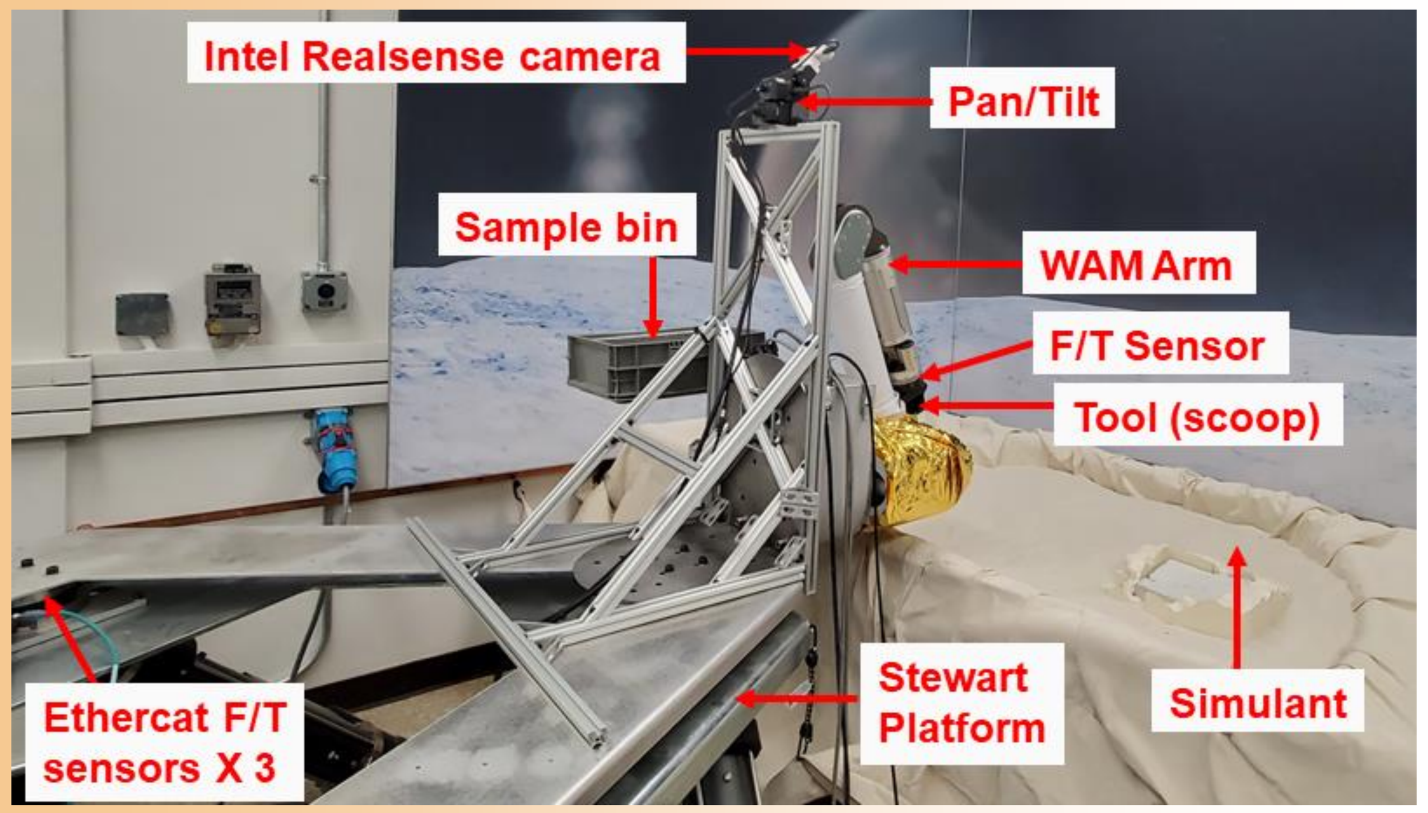
Ocean World Lander Autonomy Testbed

A. Goel[1], A. Boettcher[1], E. L. Tevere[1], E. H. Kramer[2], S. Higa[1], M. Hans[1], J. Sawoniewicz[1], A. Gaut[1], A. Jain[1], C. Lim[1], M. Thomsen[3], M. Goldstein[4], I. Nesnas[1], H. D. Nayar[1]

[1]Jet Propulsion Laboratory, California Institute of Technology; [2]Mechanical Engineering and Aerospace Department, University of California, Los Angeles;
[3]Mechanical Engineering, Massachusetts Institute of Technology; [4]Computer Engineering, University of Maryland

Introduction

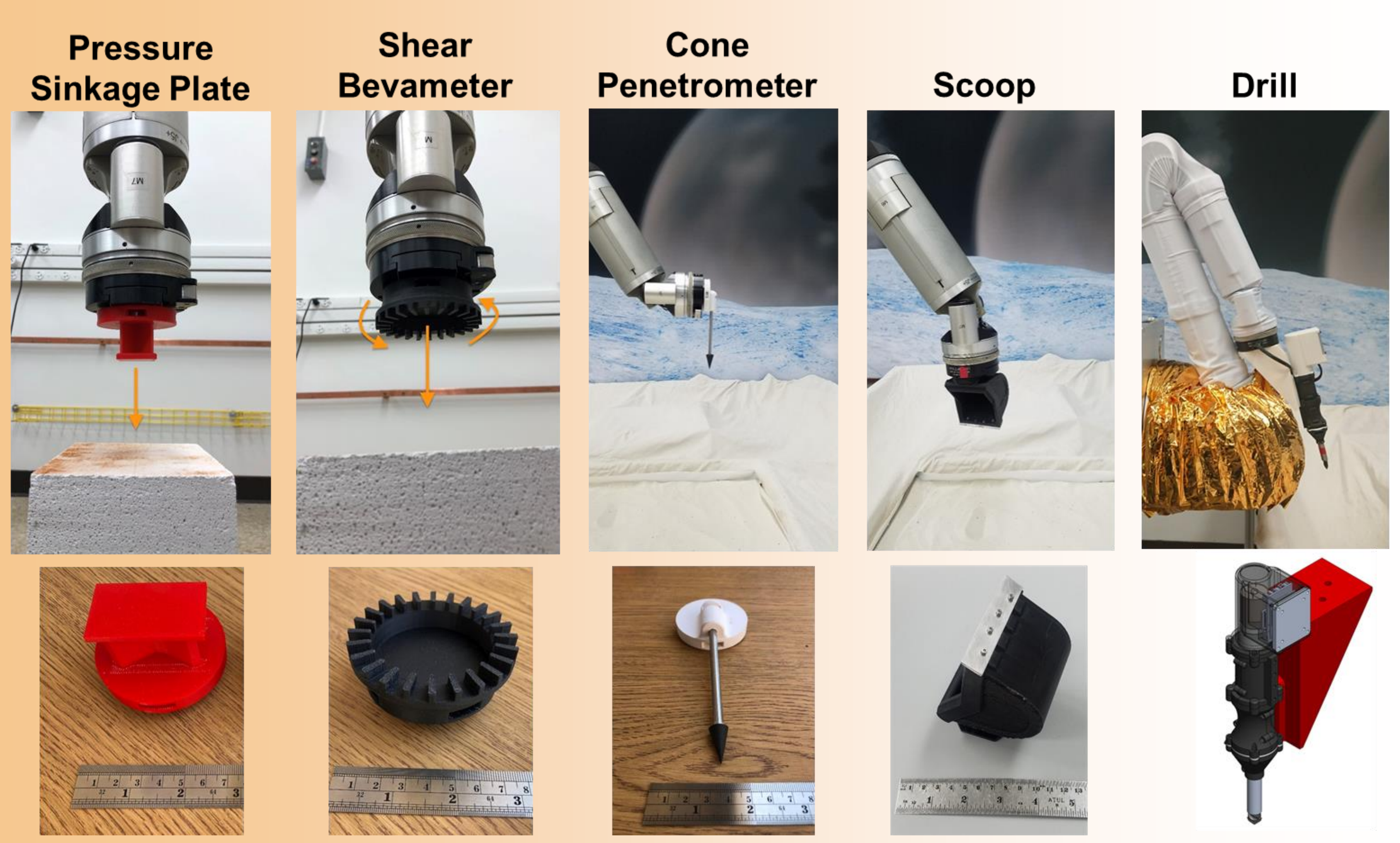
- NASA SMD sponsored physical testbed at JPL for demonstration and evaluation of autonomy algorithms for future ocean world lander missions
- Complementary virtual-only testbed developed by NASA Ames Research Center
- Currently being used by winners of ARROW and COLDTech solicitations



- The testbed comprises a 7-DOF **robotic arm** mounted on a 6-DOF Stewart platform representing the lander.
- A **3D camera** is mounted on a **pan-tilt** unit.
- The **simulant** comprises some textured surfaces with a variety of hard and soft surfaces that can be easily modified.

End Effector Tools

The tool at the end effector can be easily replaced through a quick release adapter. We currently support five different geotechnical surface investigation and sample collection tools



Autonomy Interface

The arm can be commanded in Joint mode or Cartesian in lander frame or tool frame. The inverse kinematics and inverse dynamics engines convert user inputs into appropriate joint and torque commands to the arm respectively.

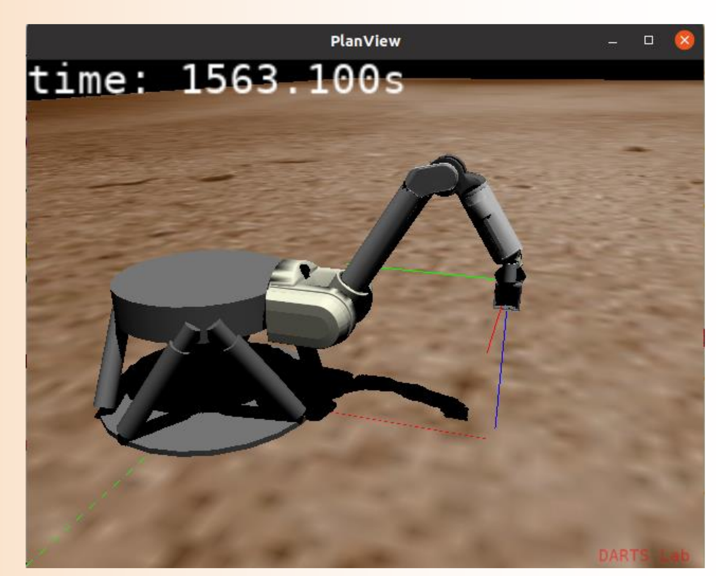
Users interact with the testbed using a standardized **ROS-based interface**
Commands → ROS Actions
Telemetry → ROS Messages

Messages	Actions
arm_joint_angles	ArmMoveCartesian
arm_joint_velocities	ArmMoveCartesianGuarded
arm_joint_accelerations	ArmMoveJoint
arm_joint_torque	ArmMoveJoints
arm_pose	ArmMoveJointsGuarded
arm_end_effector_force_torque	CameraCapture
pan_tilt_position	PanTiltMoveJoints
camera_color_frame	ArmSetTool
camera_depth_frame	TaskDrill
camera_point_cloud	TaskScoopLinear
arm_tool	TaskScoopCircular
arm_fault	FaultClear

A subset of commands and telemetry available to the users

The fault detection and handling system detects basic faults in various systems, categorizes them and reports them to the autonomy software

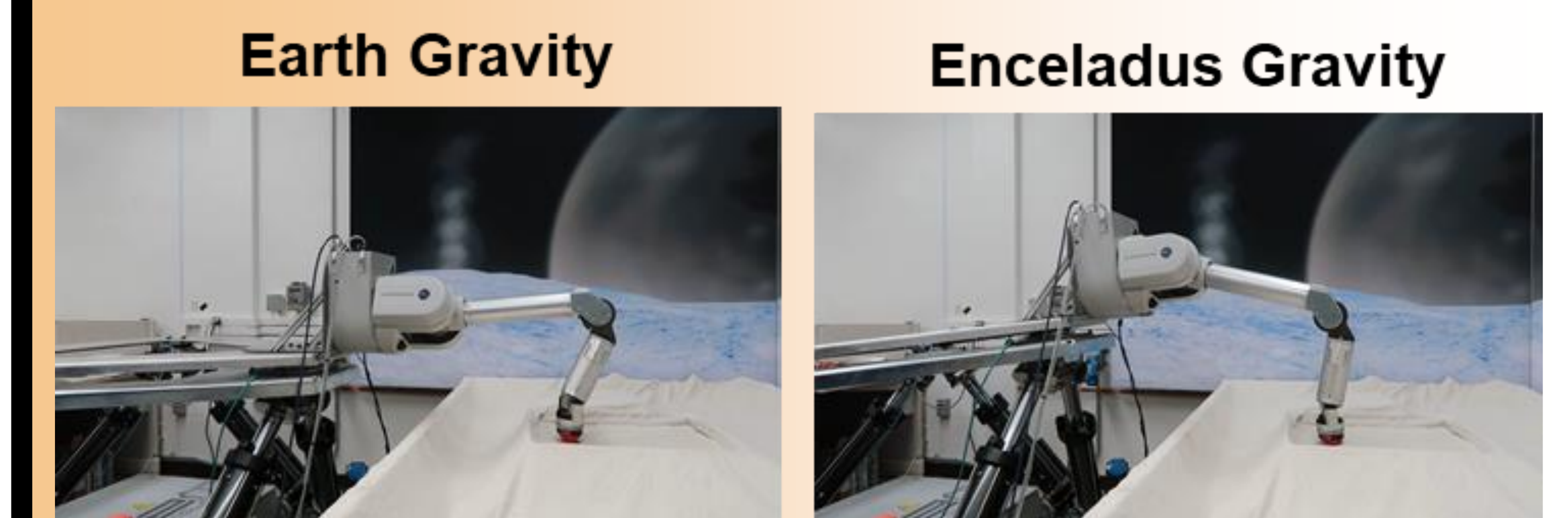
Users also get access to a dynamical testbed simulator developed by the Dynamics and Realtime Simulation (DARTS) lab at JPL to test out their interfaces before using the physical testbed.



DARTS based testbed simulator

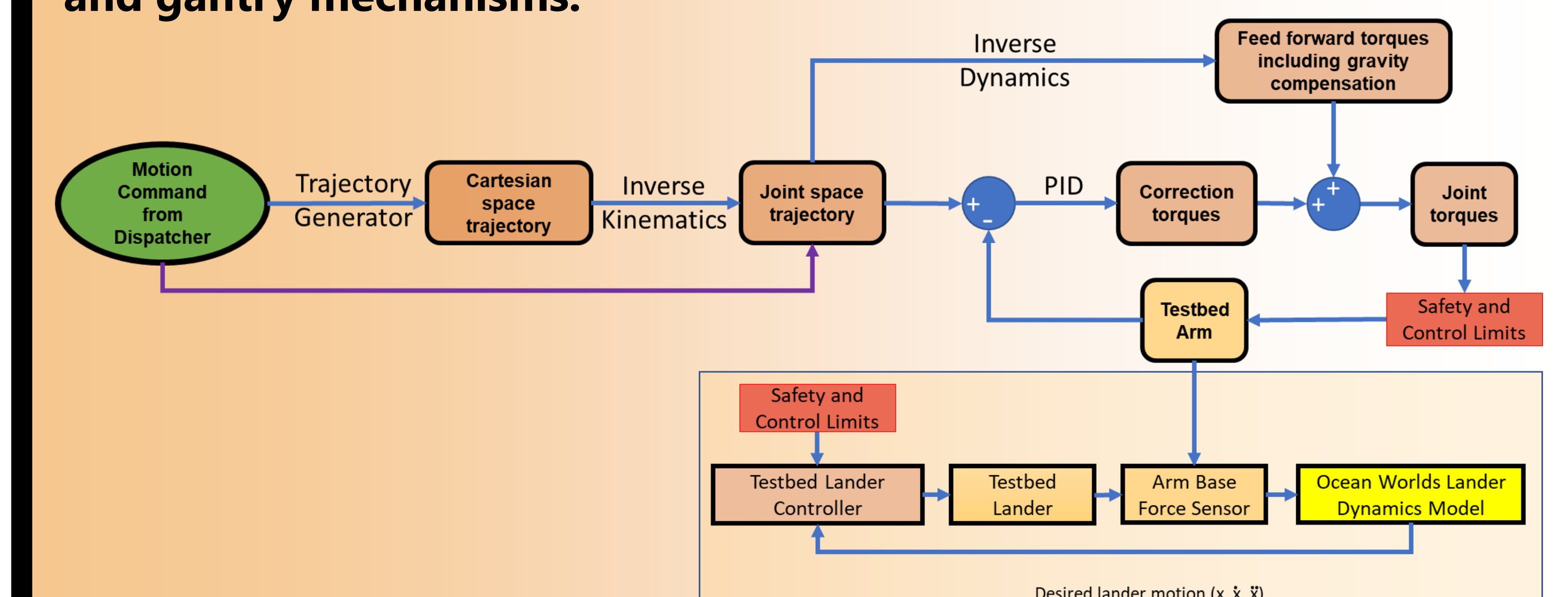
Low Gravity Dynamics

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 and other small bodies in the solar system.**



A demonstration showing how the lander's legs can get lifted off the surface when carrying out a pressure sinkage test in the low gravity of Enceladus

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. This allows us to study for instance, 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.



Future Capabilities

- Power model (based on NASA Ames' testbed)
- Battery thermal model (based on NASA Ames' testbed)
- Faulty telemetry injection
- Fault injection such as frozen joint, bent tool etc.

Contact Information

Hari Nayar: hdnayar@jpl.nasa.gov
Ashish Goel: ashish.goel@jpl.nasa.gov
https://www-robotics.jpl.nasa.gov/how-we-do-it/systems/ocean-world-lander-autonomy-testbed-owlat/

 The research described in this poster was funded by the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.