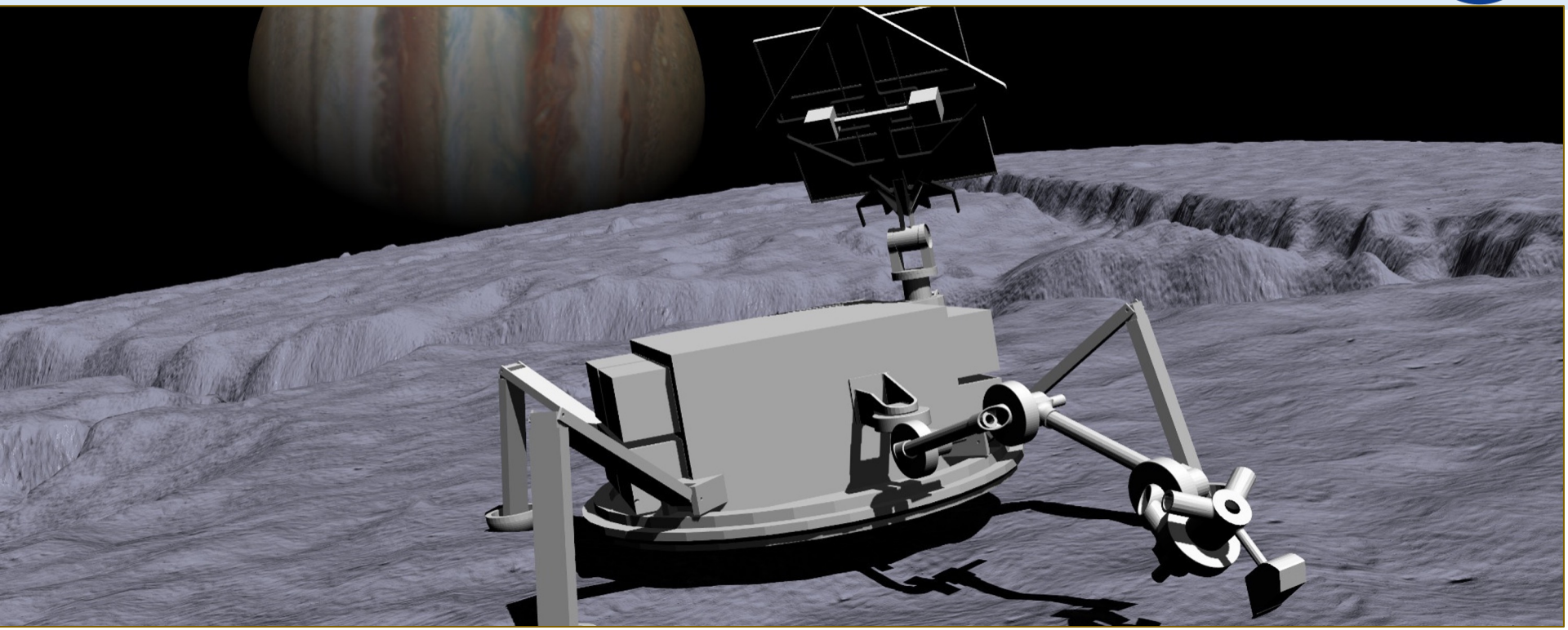
Autonomous Ocean World Exploration: Advancement of a Software Testbed

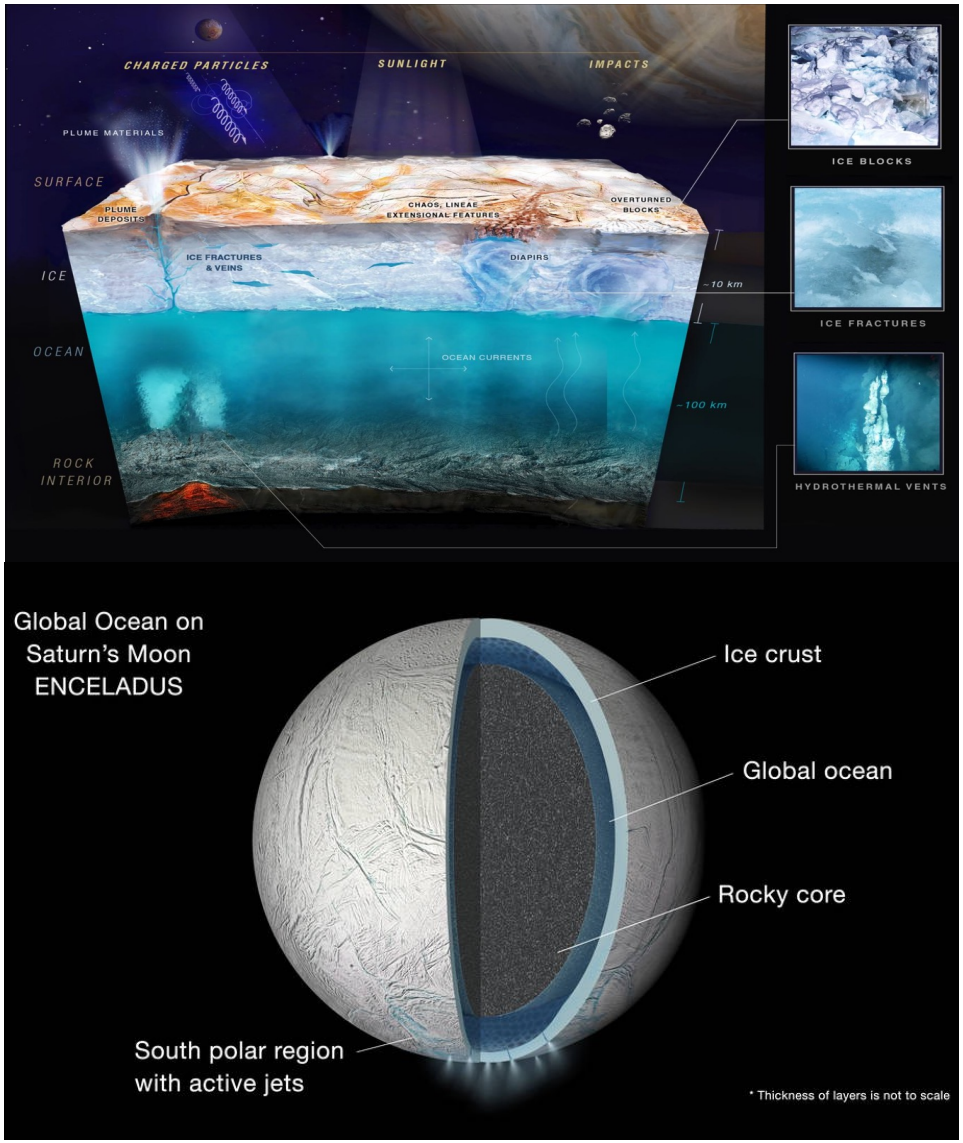


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Motivation: develop autonomy for surface missions to Ocean Worlds



- The search for life (extinct or extant) is one of NASA's top priorities.
- Bodies containing liquid water are prime destinations for such exploration.
- Several Solar System moons are known or suspected to harbor large subsurface "oceans". These include:
  - Europa (above)
  - Enceladus (below)
- Missions to such distant worlds need a high degree of autonomy.
  - Long communication lag with Earth
  - Harsh environments
  - Limited battery life

OceanWATERS is a testbed for lander autonomy software

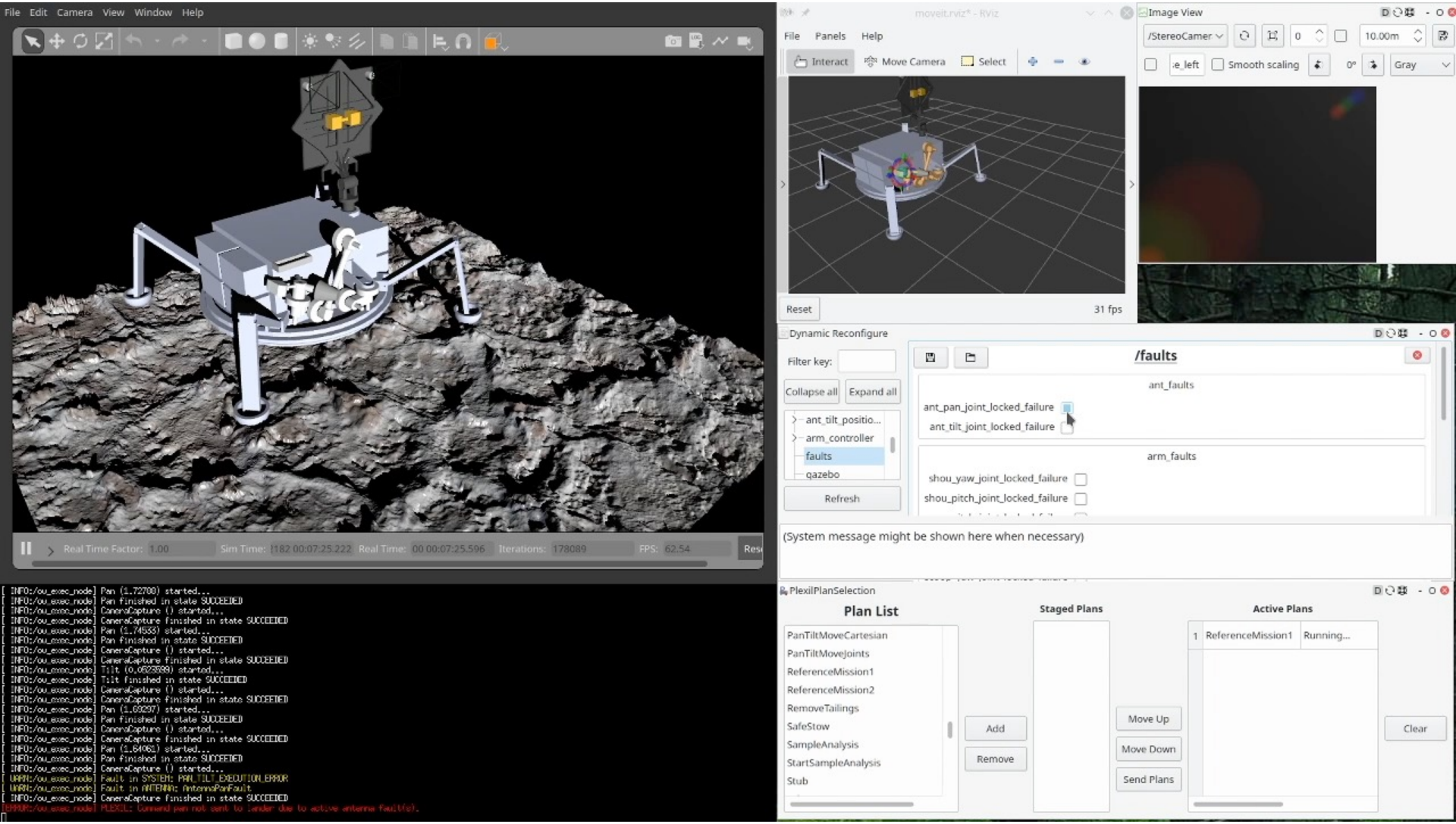
- Provides visual and physical simulation of a lander on Europa
- Provides interface for autonomy to interact with simulation
  - Includes plan execution framework and sample plans
- Built using ROS (Robot Operating System) and Gazebo simulator
- Runs on Ubuntu Linux computers
- Entirely open source at github.com/nasa/ow_simulator
- Uses two other open-source packages from Ames:
  - PLEXIL autonomy plan language and executive
  - GSAP prognostics engine for the power system model

OceanWATERS history: 2018 - 2024

- Developed at NASA Ames, starting in late 2018
  - Funded by NASA's Science Mission Directorate (SMD)
  - Initial development based on JPL's Europa Lander Study (2016)
- Released as open source on GitHub in 2020
- Used by two SMD-funded research programs
  - ARROW : Autonomous Robotics Research for Ocean Worlds (2020-2023)
  - COLDTech : Concepts for Ocean Worlds Life Detection Technology (2021-2024)

OceanWATERS Demo

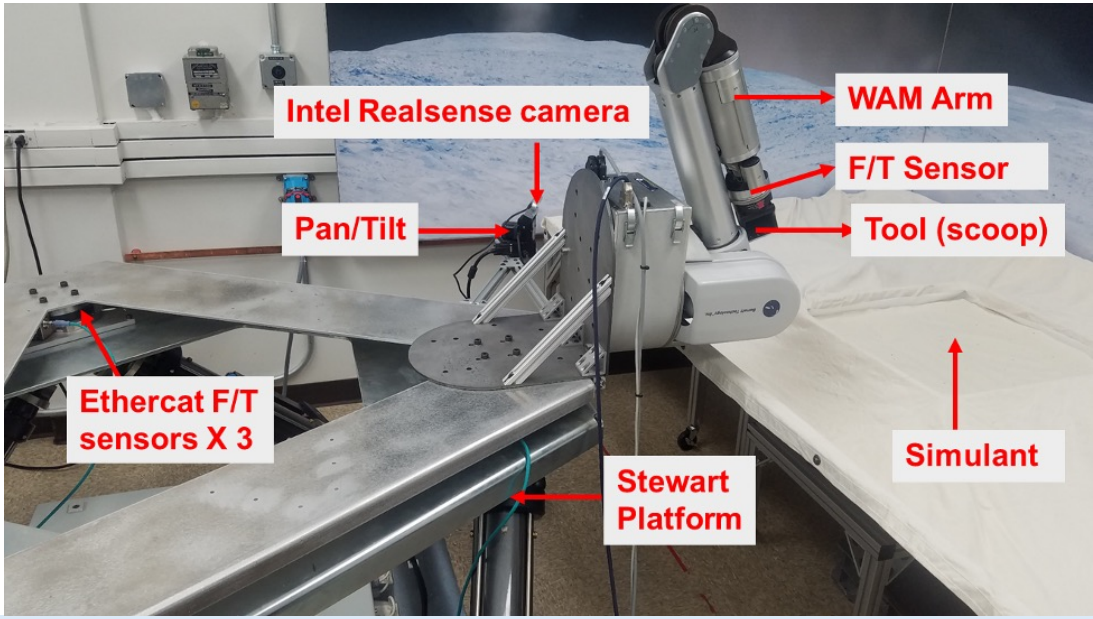
Survey landing site, dig a trench, collect regolith sample



Unification with Physical Testbed at JPL

Ocean Worlds Autonomy Lander Testbed (OWLAT)

- Developed at JPL concurrently with OceanWATERS
  - Also funded by NASA's Science Mission Directorate
- OceanWATERS and OWLAT teams collaborated to have both testbeds:
  - Have a similar set of supported lander operations
  - Share an autonomy interface so that solutions could be more easily used on either testbed
- Unification results:
  - Large overlap in lander functions
  - Highly unified ROS interface
    - Commands
    - Telemetry
  - Shared PLEXIL autonomy plans



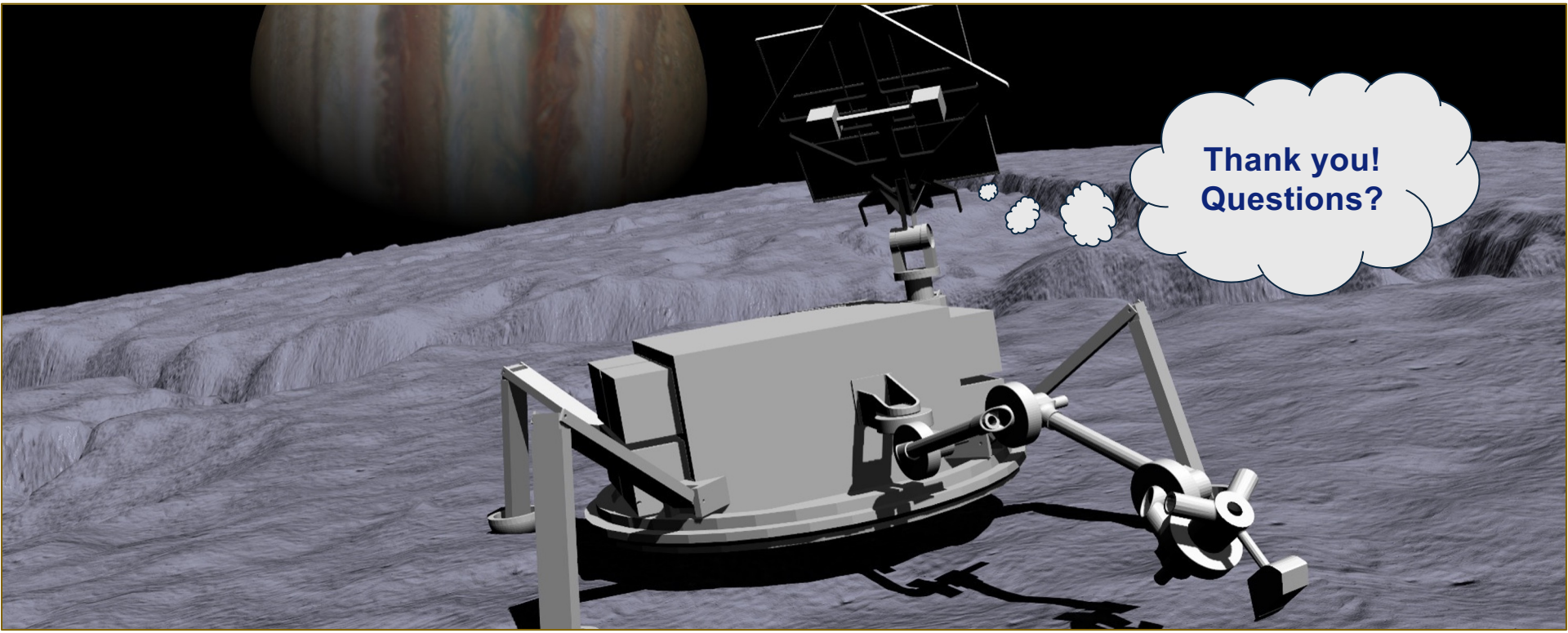
Research and Development using OceanWATERS and OWLAT

- Two ARROW teams (2020 – 2023)
  - Honeybee Robotics
  - University of South Carolina + others
- Four COLDTech teams (2021 – 2024)
  - University of Illinois + others
  - Caltech/JPL/Okean Solutions
  - Lockheed Martin/JPL
  - University of Colorado + others

- Mission challenges addressed include:
  - Sample target selection
  - Fault detection and mitigation
  - Science return prioritization
- Technologies used include:
  - Many forms of machine learning
  - Automated planning
  - Causal reasoning
  - Image analysis
  - Formal methods

Publications are described and referenced in paper.

End of Presentation



Ocean Worlds Autonomy Testbed for Exploration Research and Simulation
... OceanWATERS

github.com/nasa/ow_simulator