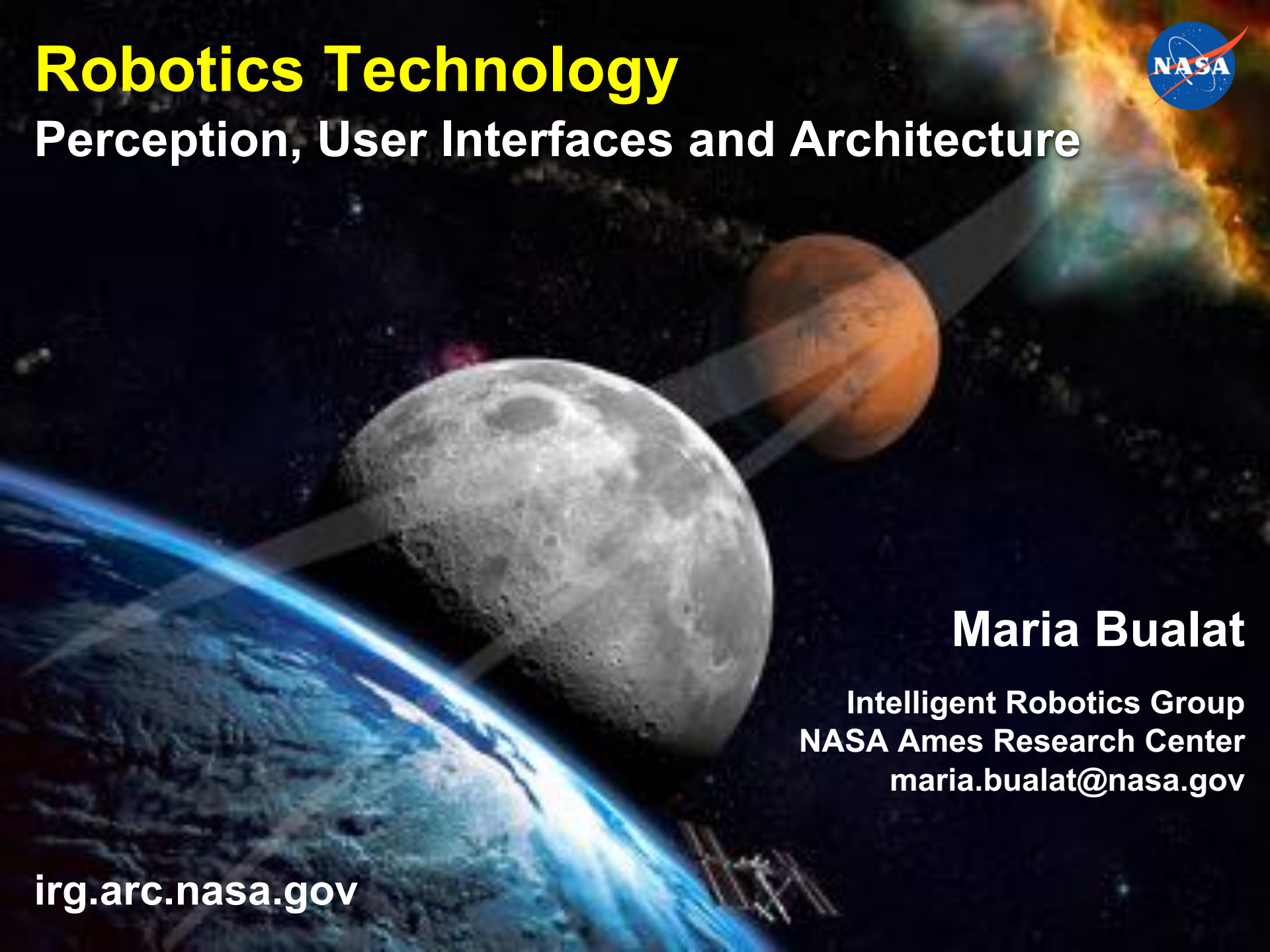
Robotics Technology

Perception, User Interfaces and Architecture



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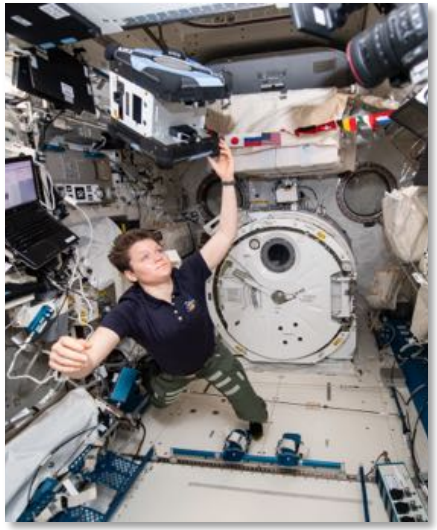
NASA Ames Intelligent Robotics Group

Overview

- 40 researchers (>1/3 PhDs)
- 20+ student interns yearly
- 90+% NASA work
- TRL 1 to 9

Research themes

- **Automated planetary mapping**
  - Base maps & terrain models
  - Geospatial data systems
- **Exploration user interfaces**
  - Robot & science operations
  - Accessible science data
- **Robots for human explorers**
  - Improve efficiency & productivity
  - Free-flyers, lake lander, & rovers



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IRG Collaborations (2015-2019)

Academic

Commercial

Government

Robotics for Human Exploration

Purpose

- Increase human productivity
- Improve mission planning & execution
- Transfer **some** tasks to robots (tedious, repetitive, long-duration)

Before Crew

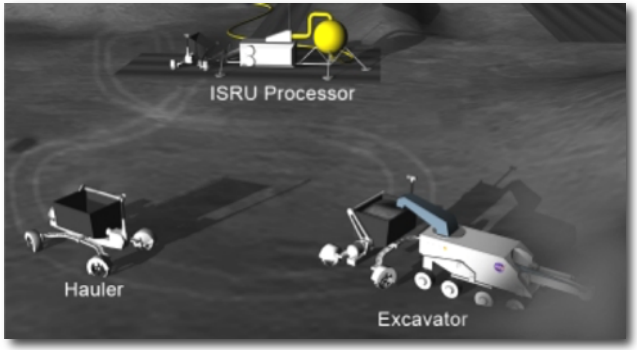
- Recon (scouting) & prospecting
- Site prep, deploy equipment, etc.

Supporting Crew

- Inspection, mobile camera, etc.
- Heavy transport & mobility

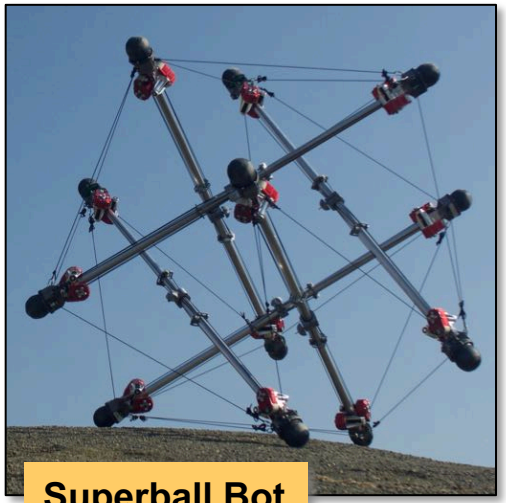
After Crew

- Follow-up & close-out work
- Site survey, supplementary tasks, etc.



Robots

K10



Superball Bot

KREX

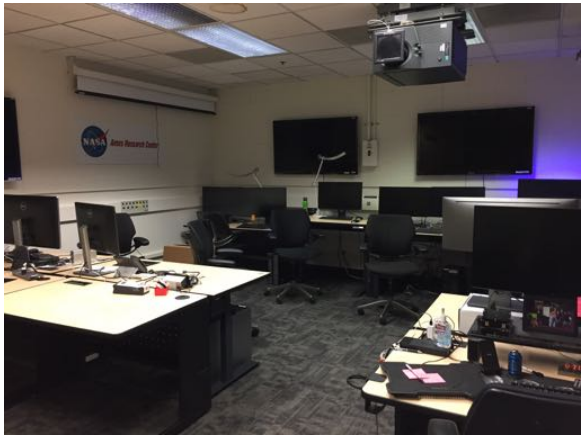
Astrobee

K10 mini

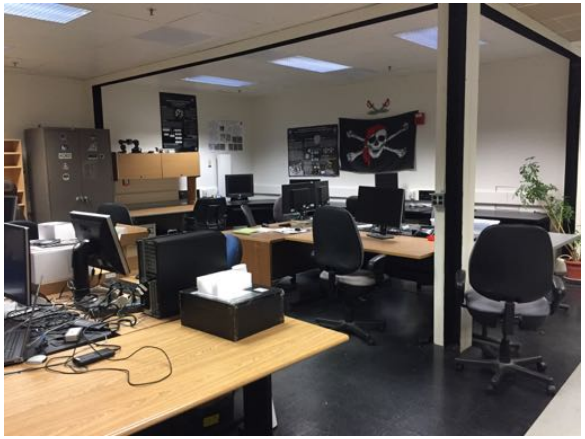
IRG Labs

Rover Lab

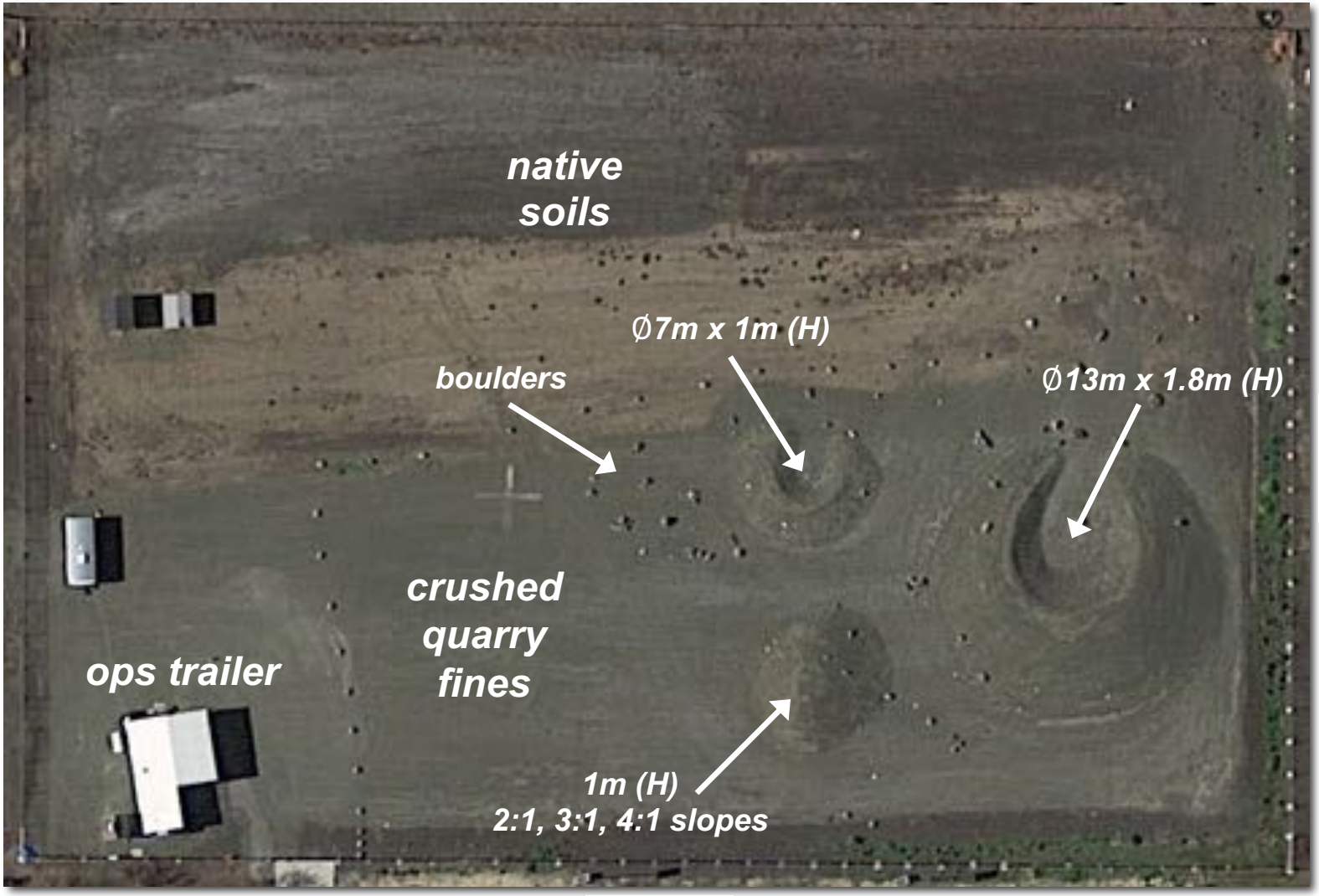
VIPER Lab



Pirate Lab



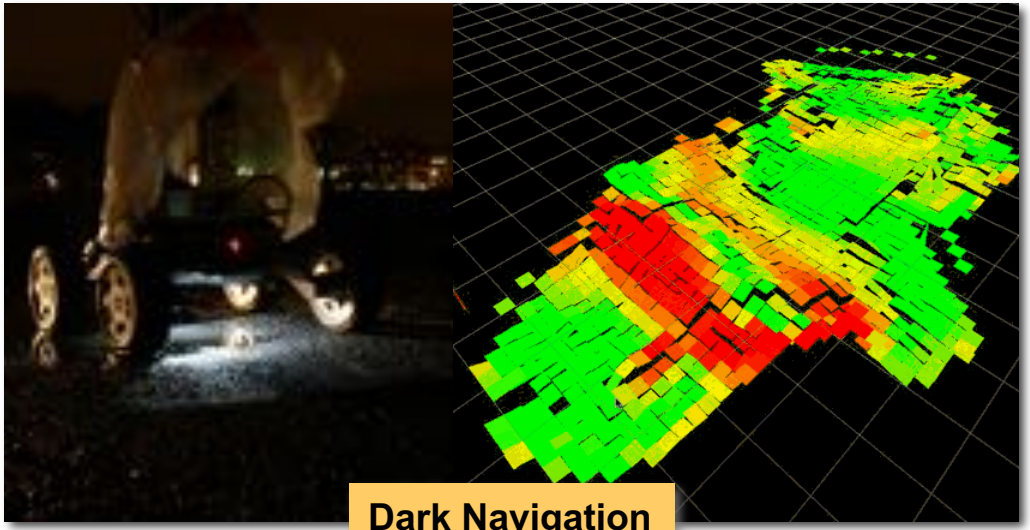
Roverscape Test Facility



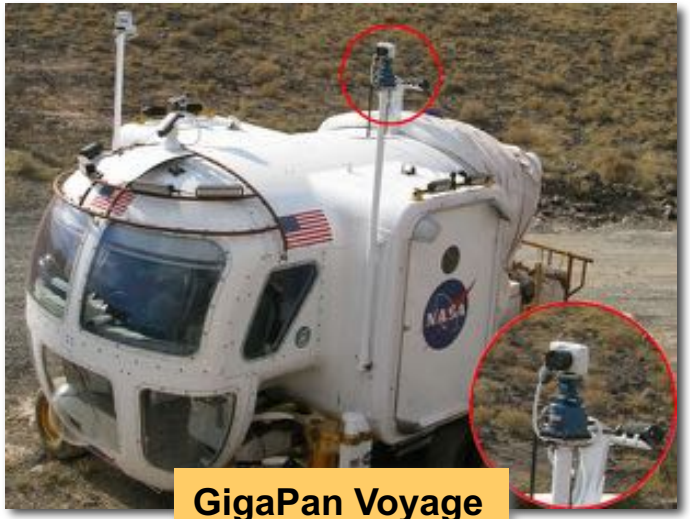
Perception

High Dynamic Range Inspection Imaging

DEM Localization

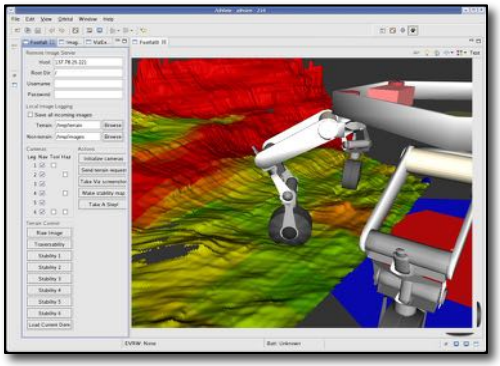


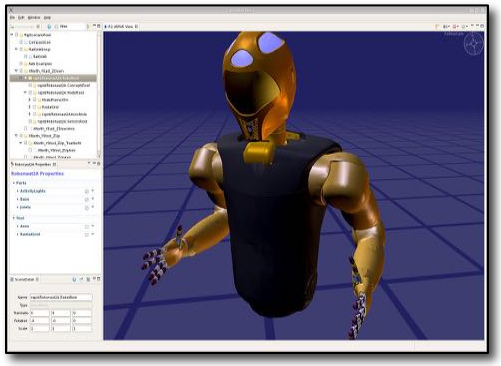
Dark Navigation

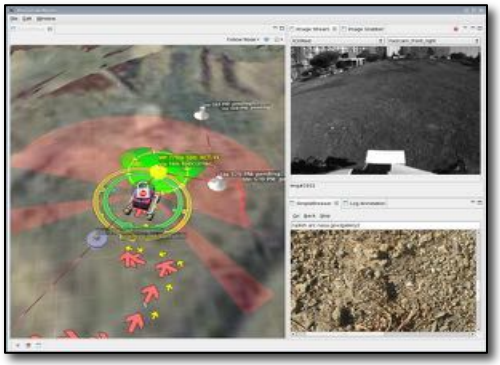


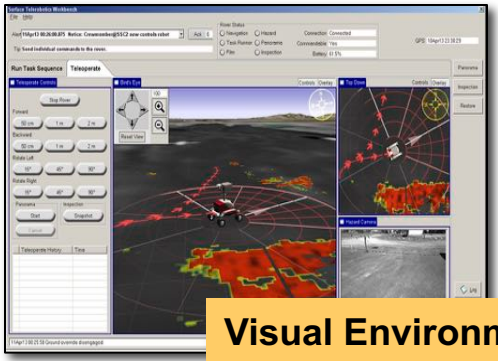
GigaPan Voyage

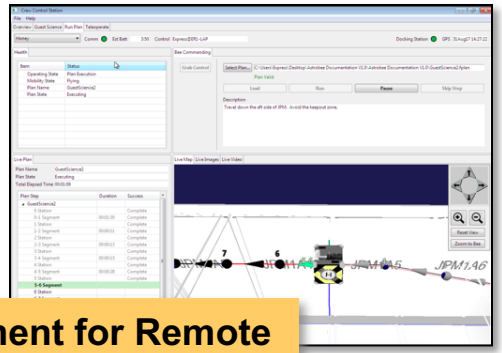
User Interfaces



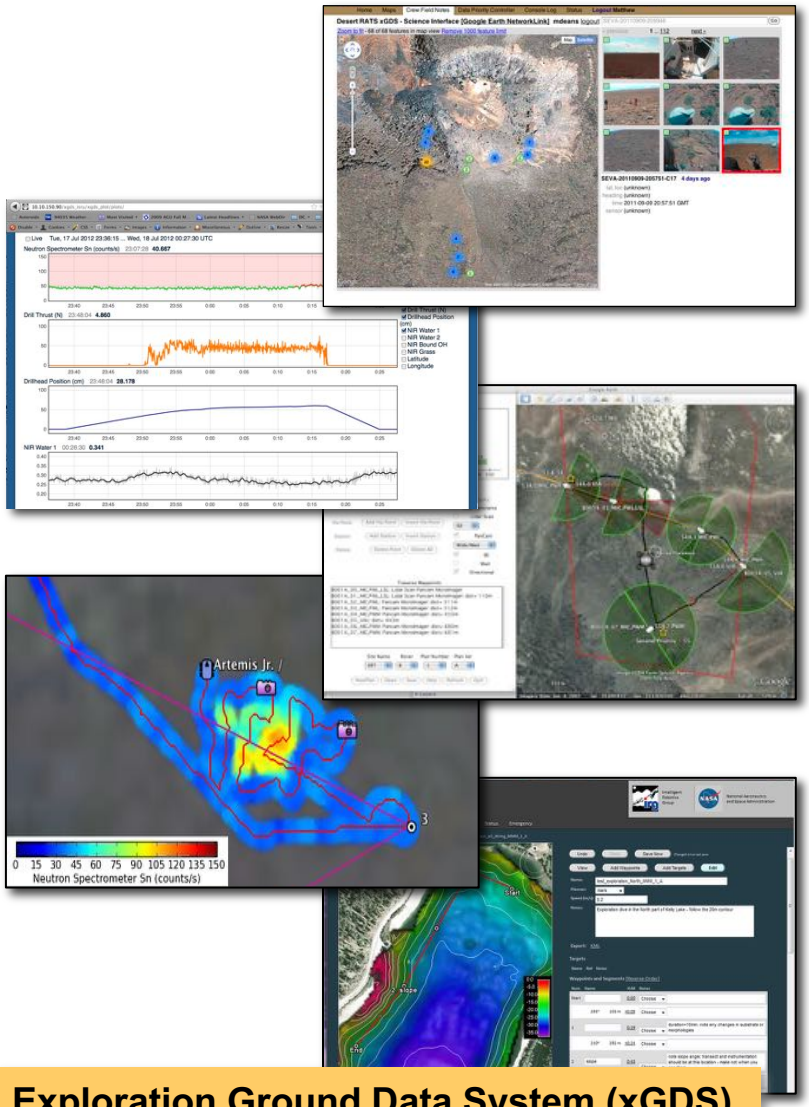






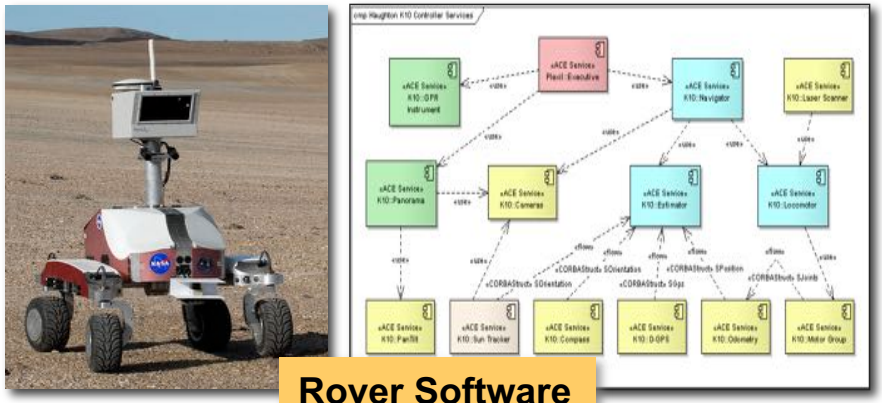


Visual Environment for Remote Virtual Exploration (VERVE)

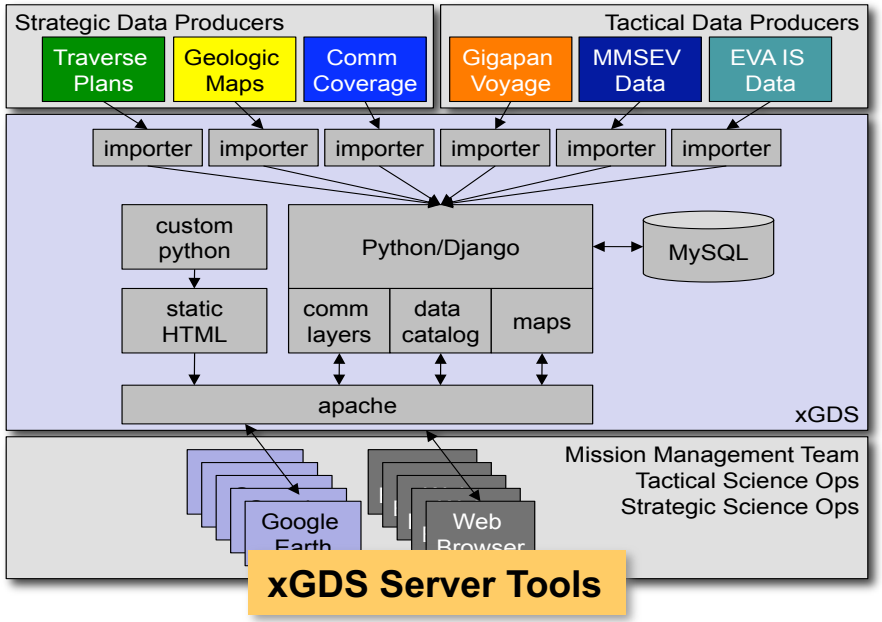


Exploration Ground Data System (xGDS)

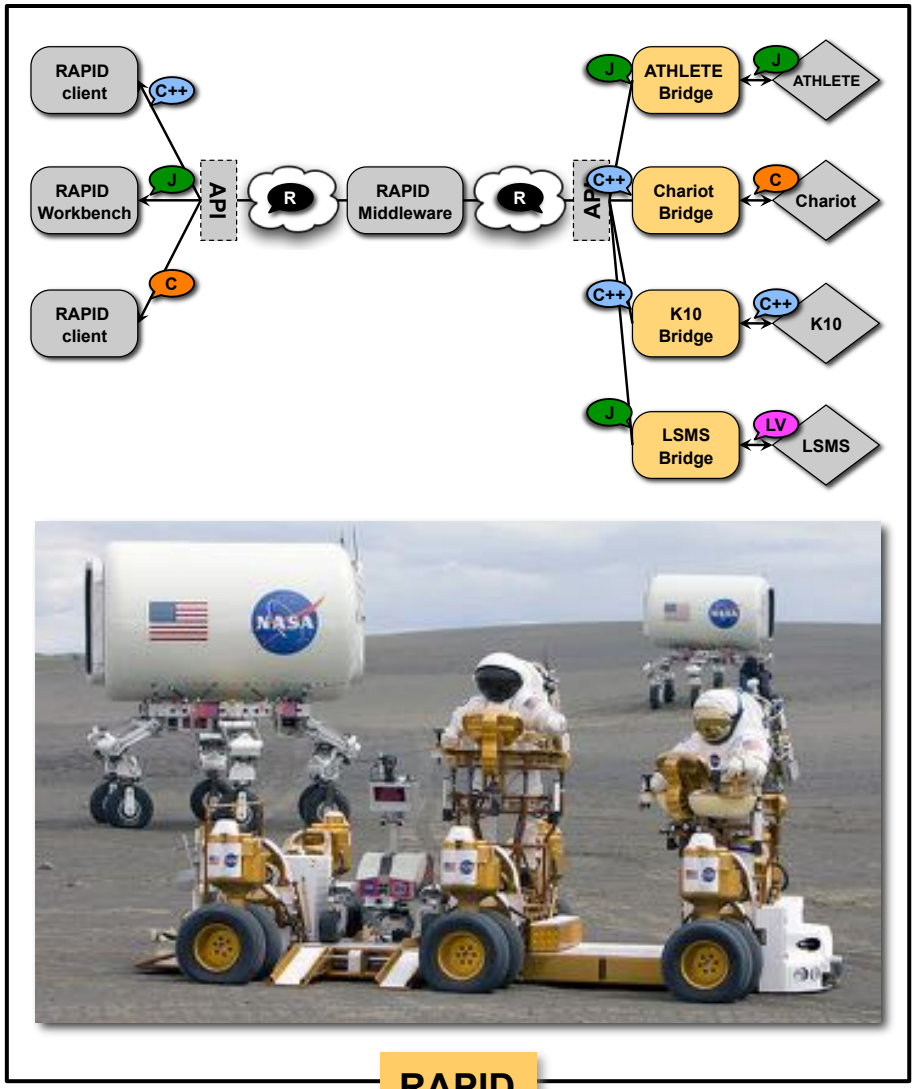
Software Architecture



Rover Software



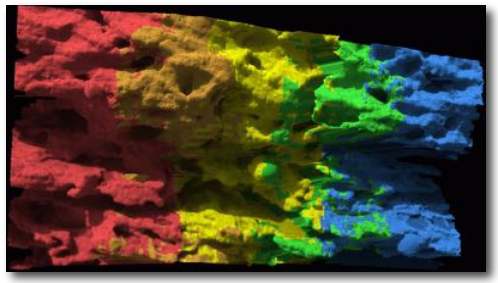
xGDS Server Tools



RAPID

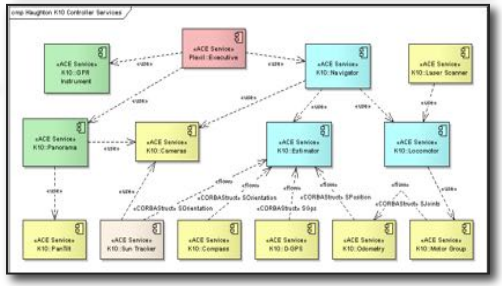
Open Source Software

Vision Workbench



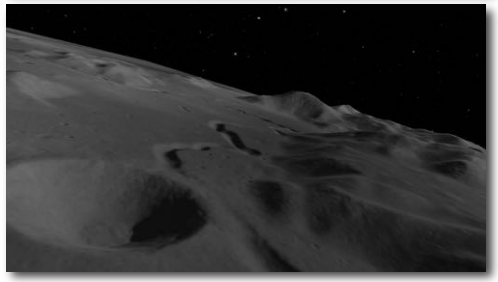
Apache 2

RoverSW



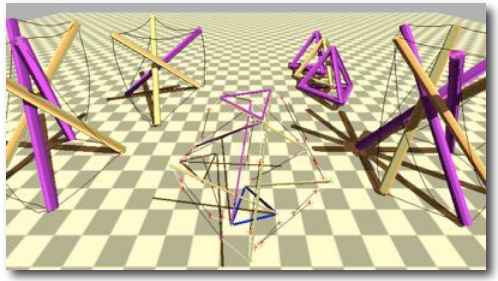
NOSA 1.3

Neo Geography Toolkit
(Ames Stereo Pipeline)



Apache 2

NASA Tensegrity Robotics Toolkit



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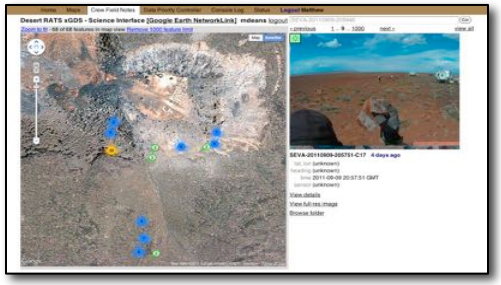
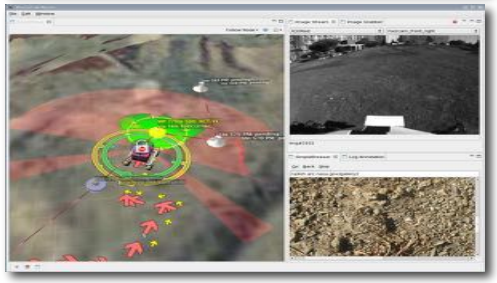


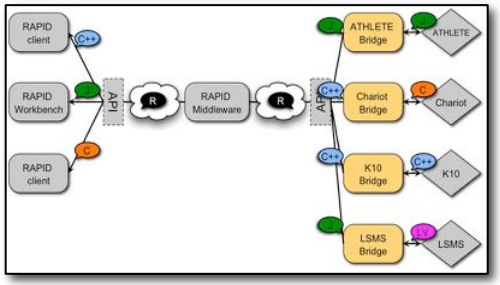
Exploration Ground Data Systems (xGDS)

Apache 2



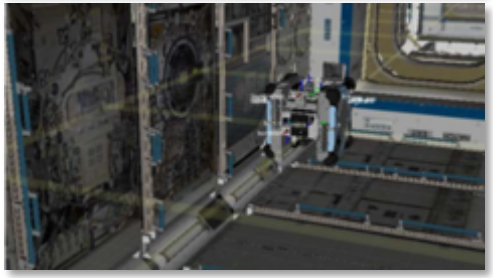
Visual Environment for Remote Virtual Exploration (VERVE)

Apache 2



RAPID
(NASA robot middleware)

Apache 2



Astrobee Robot Software (ARS), Astrobee Simulator, Astrobee Control Station

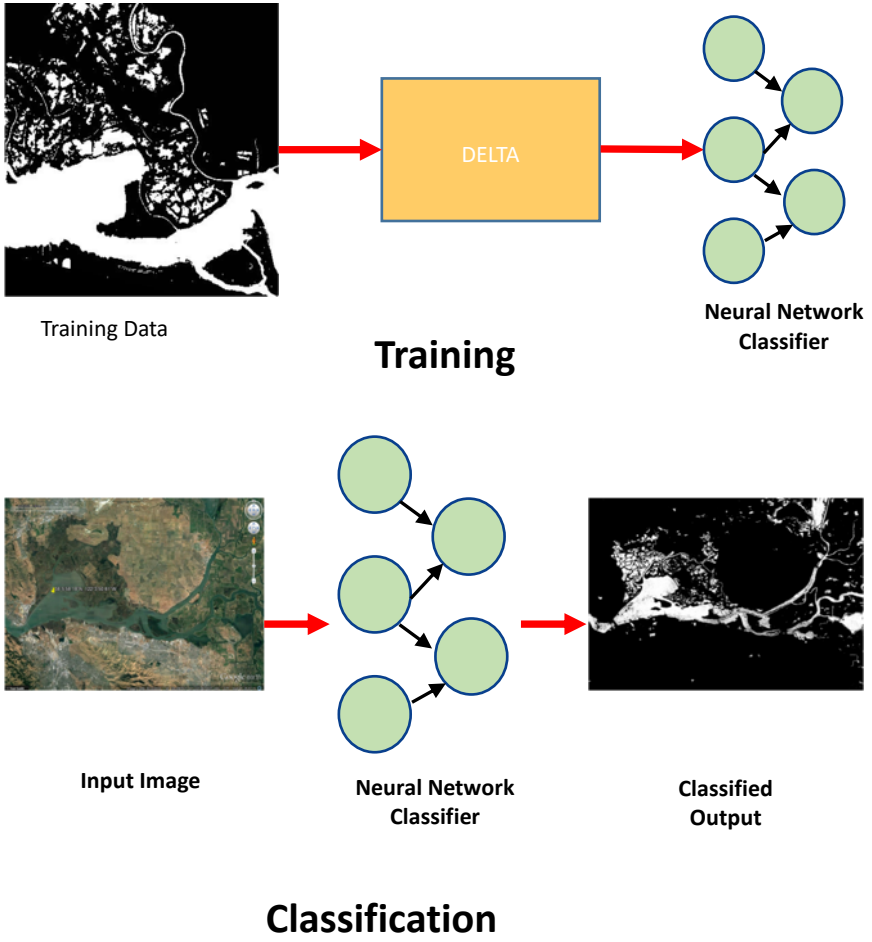
Apache 2

Astrobee on ISS

https://www.nasa.gov/astrobee

Deep Learning for Flood Mapping (DELTA)

- **Developing open-source toolkit for deep learning on satellite imagery**
- **Initial application: flood mapping for disaster response**
- **Achieve state of the art classification for Earth scientists with little knowledge of machine learning and limited computing resources**
- **Provides pre-trained compressed representations for various satellites (starting with Worldview, Sentinel-1, and Landsat)**
- **Collaboration between NASA Ames, USGS, NGA, and University of Alabama**



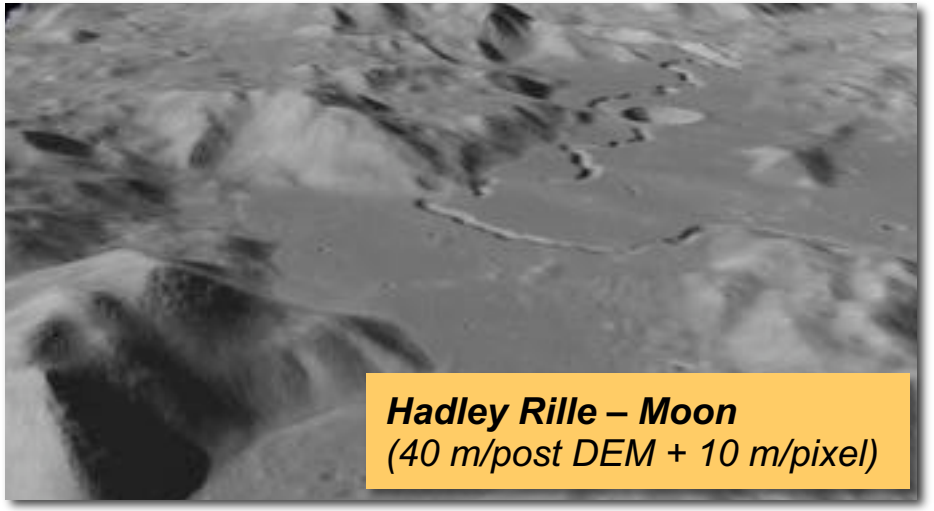
Digital Terrain Models – Ames Stereo Pipeline (ASP)

Automated stereogrammetry

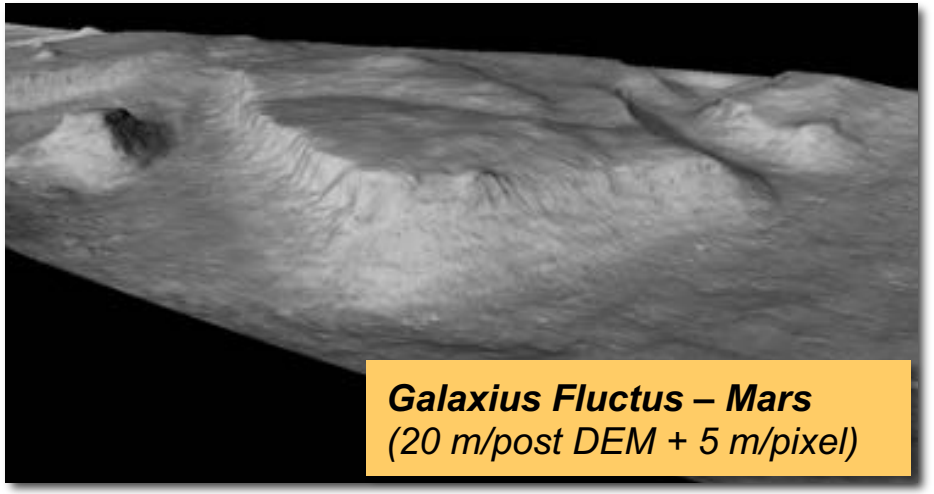
- Command-line processing tools (including bundle adjustment, albedo reconstruction, etc.)
- C++ code hosted on GitHub (Apache 2 license)
- Linux and OS-X binaries

Planetary data (to date)

- Apollo Metric Camera
- Lunar Reconnaissance Orbital Camera (LROC-NA)
- Mars High Resolution Imaging Science Experiment (HiRISE)
- Mars Orbiter Camera (MOC)
- MRO Context Camera (CTX)



Hadley Rille – Moon
(40 m/post DEM + 10 m/pixel)



Galaxius Fluctus – Mars
(20 m/post DEM + 5 m/pixel)

https://github.com/NeoGeographyToolkit/StereoPipeline

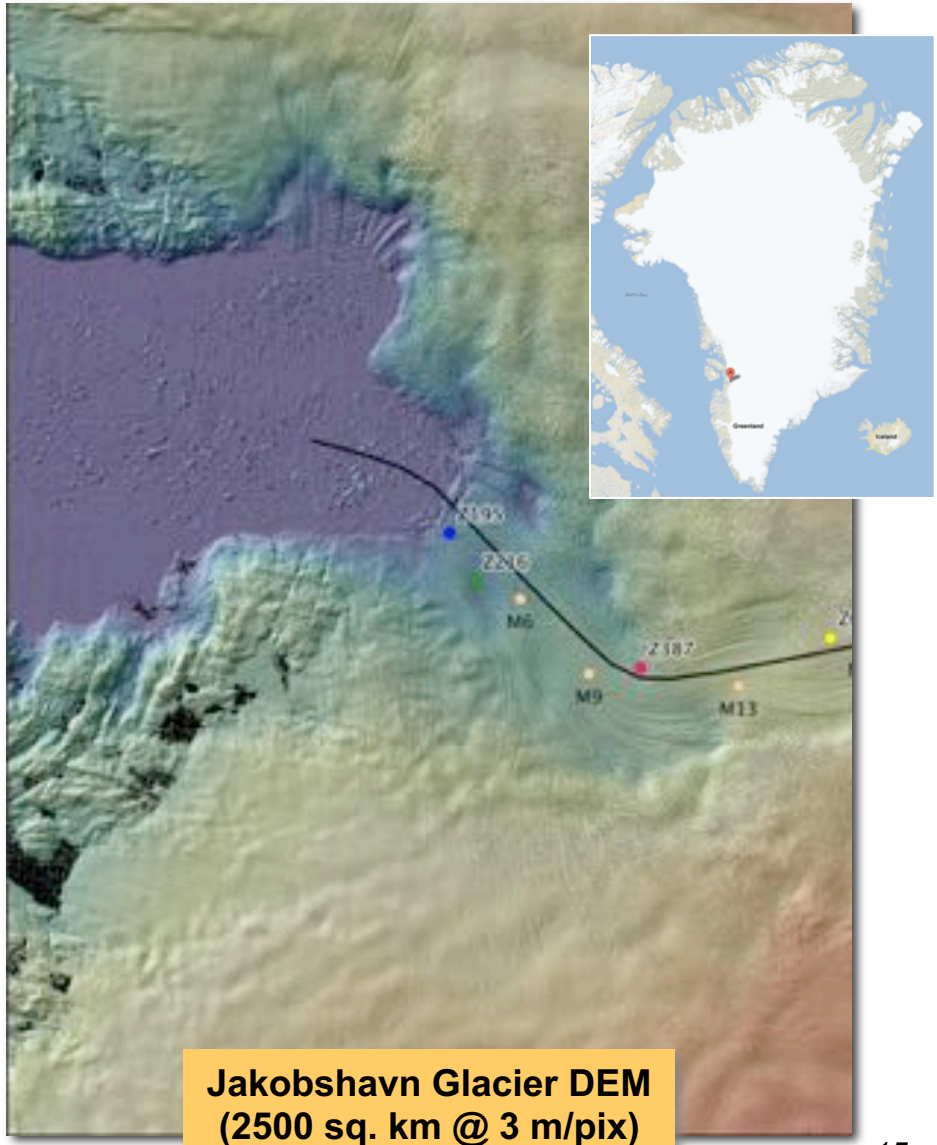
ASP for Earth

3D terrain modeling

- Digital Elevation Models (DEM) produced from commercial satellite images
- 60% success rate processing Digital Globe stereo pairs without human input

Earth science studies

- Glacier volume changes and movement
- Evolution of subglacial lakes
- Sea ice movements
- Climate change measurements



Jakobshavn Glacier DEM (2500 sq. km @ 3 m/pix)

Exploration Ground Data System (xGDS)

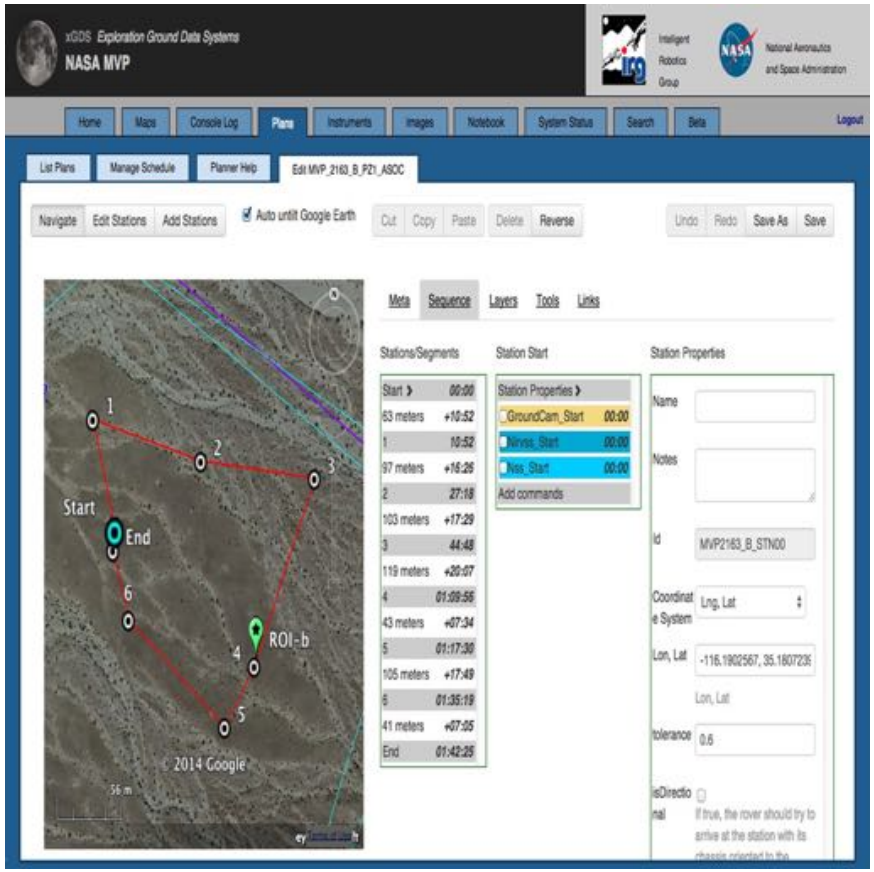
Web-based software system for managing science and operations data for human and robotic missions

Tools for

- Mission planning
- Data management
- Visualization
- Analysis

Modular, uses open source software and open standards

Can be rapidly adapted to different missions



Supported a wide range of field studies and simulated exploration missions.

ExCALiBR: Extractor for Chemical Analysis of Lipid Biomarkers in Regolith

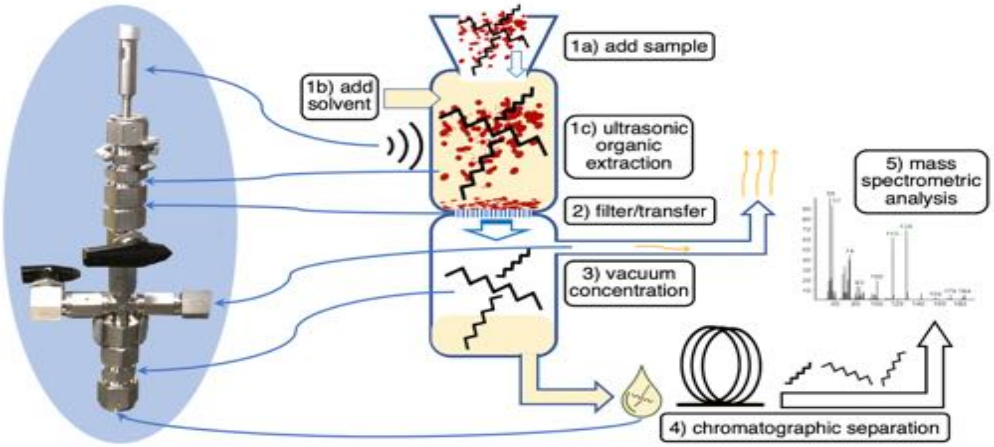
Mary Beth Wilhelm, P. Michael Furlong (Intelligent Robotics Group, NASA Ames), Denise Buckner, Morgan Anderson, Antony Ricco, Trey Smith (IRG), Linda Jahnke

Building Gas Chromatograph-Mass Spectrometer for autonomous astrobiology

Machine learning for classifying samples as biotic or abiotic origin

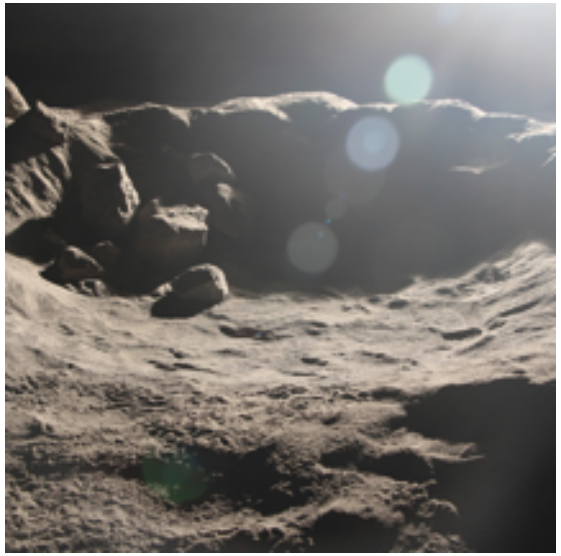
Automatically selecting instrument parameter settings for follow-on sample processing

ECI collaboration between NASA Ames, NASA Goddard, and Shell



Extreme Perception

Novel sensors and perception to enable robots to see in extreme environments



Approach blends

- Computer vision
- Optics
- Physics-based simulation

Advanced decision making and in-situ processing techniques optimize information collection

Innovations:

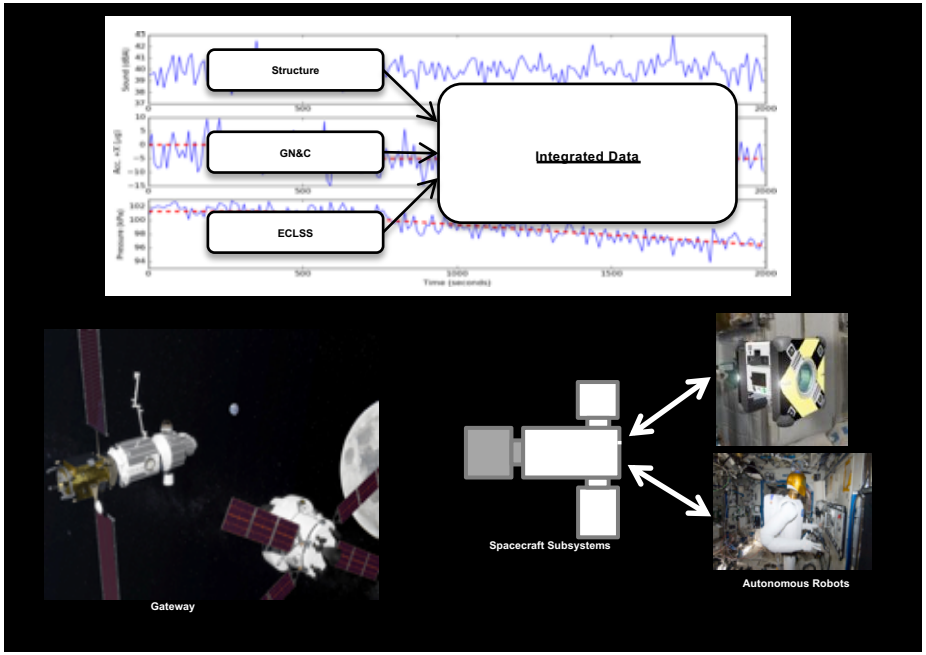
- Thermal vision-based navigation for landing on icy surfaces
- Cold-gas projectiles that map in ballistic flight and form monitoring networks once emplaced
- Programmable microscopes that model individual grains of soil in 3D

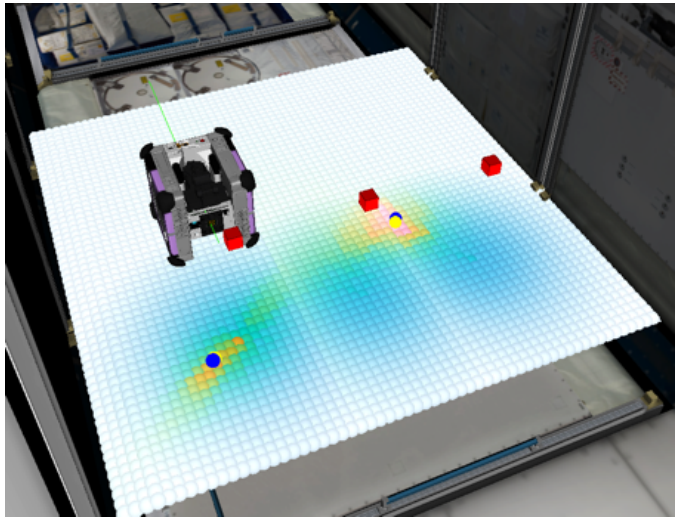
GeoCam Space

- Camera hardware accessory and Web-based software to improve cataloging and geolocation of Earth images taken by astronauts on the ISS
- Attaches to handheld digital cameras and records pointing information
- Web-based software performs semi-automated photo-to-map alignment and facilitates creating digital map overlays

Integrated System for Autonomous and Adaptive Caretaking (ISAAC)

- **ISAAC is building software for caretaking of exploration vehicles, focusing on uncrewed phases**
- **ISAAC technology enables autonomous operation of the integrated system consisting of intra-vehicular robots (IVR) and other vehicle subsystems**
- **Technology infusion primarily targets Gateway (phase 2), but also applicable to other missions**
- **Technology is tested using existing IVR on ISS (Astrobee, Robonaut) as an analog to future IVR on Gateway**





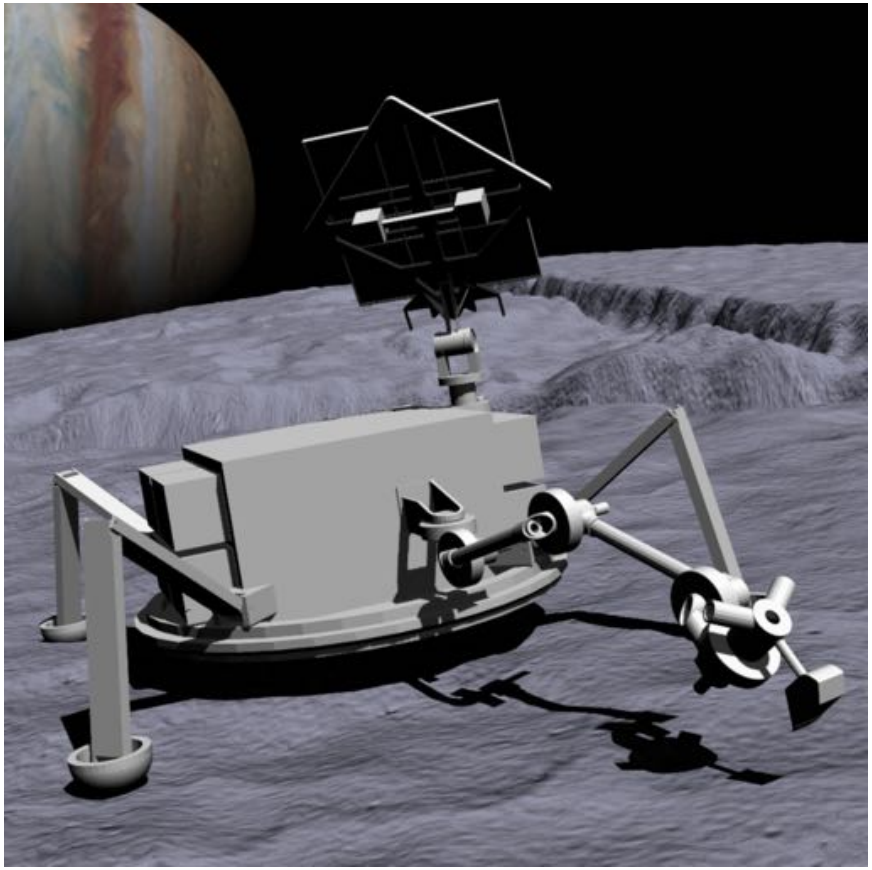
Ocean Worlds Autonomy Testbed for Exploration Research and Simulation (OceanWATERS)

Open-source simulator for developing onboard autonomy software for the robotic exploration of ocean worlds, such as Europa, Enceladus, and Titan

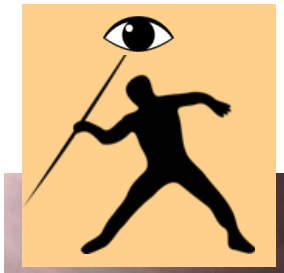
Emulates:

- surface conditions
- robotic manipulator operation
- lander systems

Simulator modeled on the Europa Lander mission, but could be configured for other lander missions and planetary bodies



Projectile Hordes for Advanced Long-term & Networked eXploration (PHALANX)



PI: Dr. Terry Fong
Co-Is: Dr. Michael Dille, Dr. Uland Wong

- **Projectile sensors expanding the reach of landers & rovers**
- **Extend previous CIF-funded SPEARS project work to multiple launches and cooperative behavior**
- **Develop sensor network prototypes leveraging new IoT chipsets**
- **Apply mature mesh network algorithms for robust comms relay**
- **Implement coordinated mapping and long-duration in-situ science measurements of environments**
- **Provide GNSS-denied localization**
- **Pursue Earth science analog field deployments for demonstration**

Skylights and Caves

Skylights = sinkholes that might lead to intact caves

Exploration crucial for

- Science
- Resource development
- Future habitation throughout the solar system

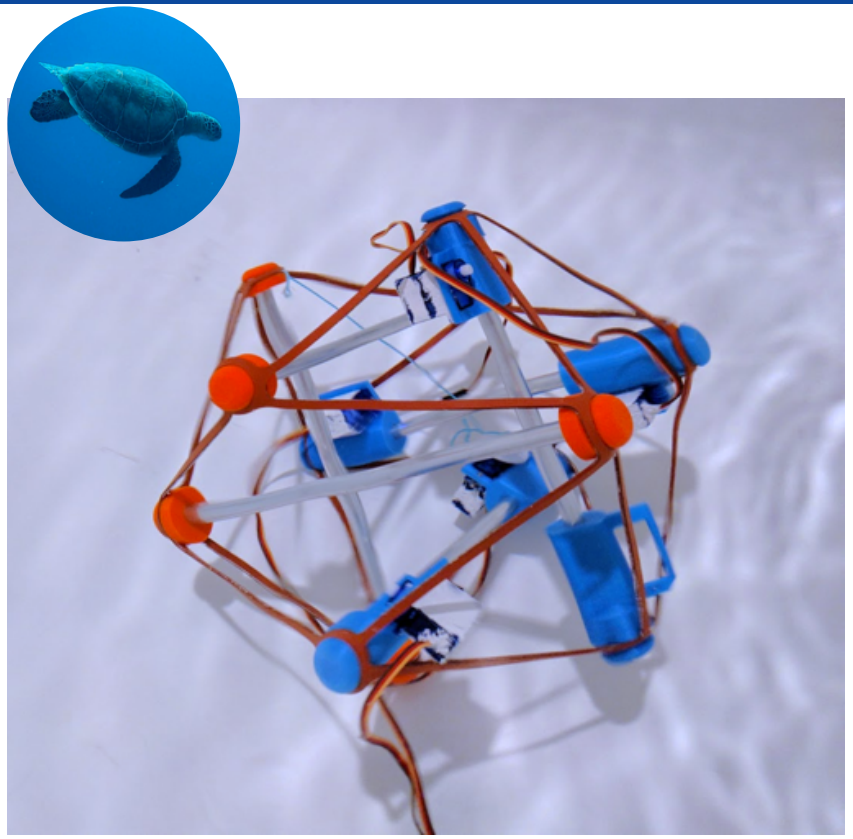
Robotic technologies for exploring subterranean environments

- Life-detection payloads
- Automated mapping software

Tested at terrestrial analog sites

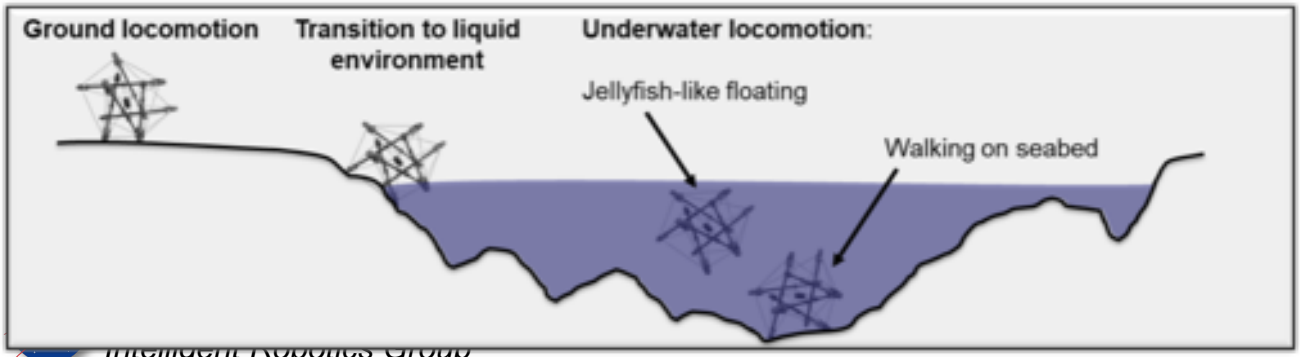
Technology demonstration: first commercially-led micro-rover mission to visit and circumnavigate one of the major Lunar skylights

Tensegrity Underwater Robot for Traversing Liquid Environments (TURTLE)

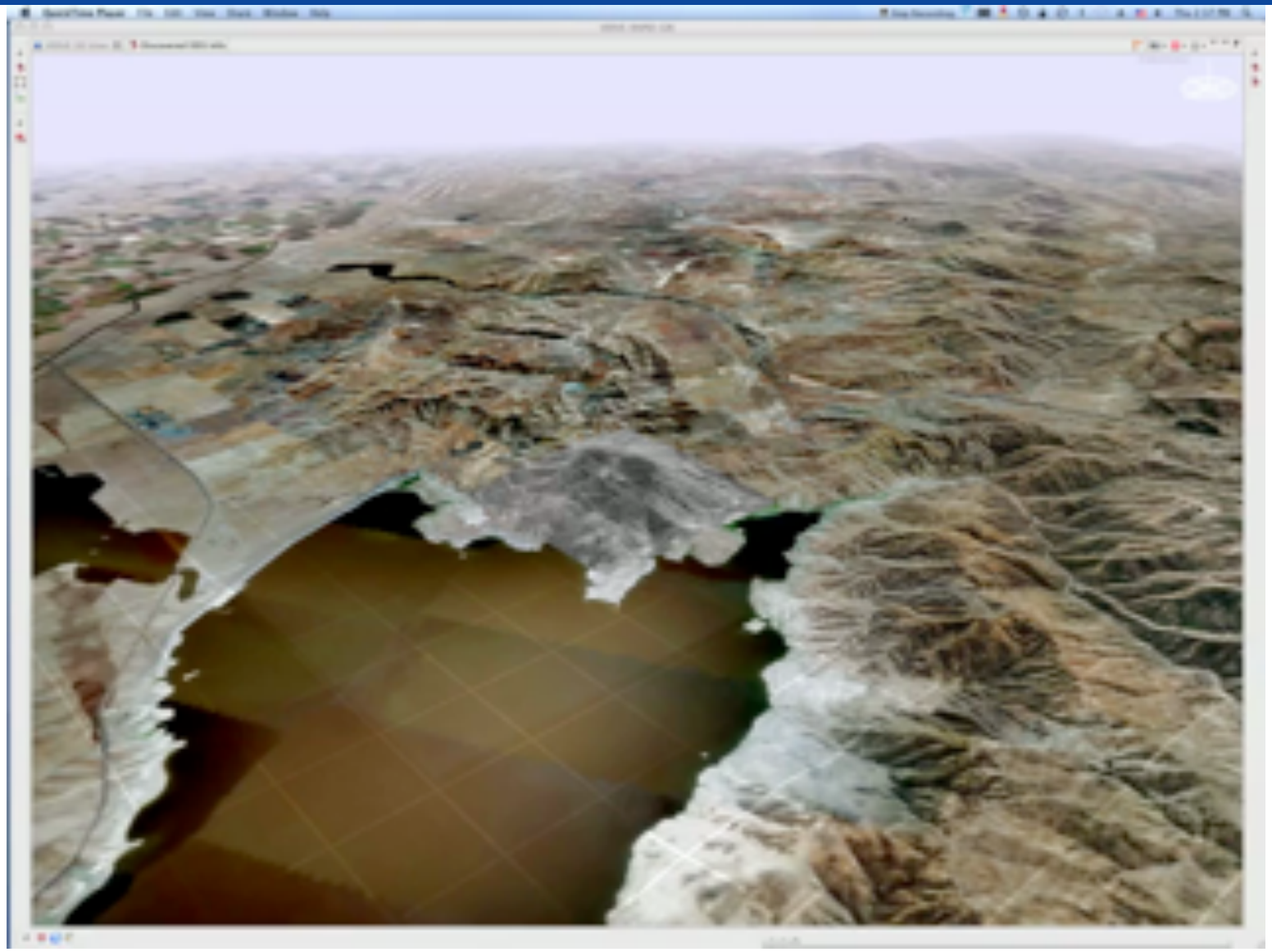


A novel amphibious robot for efficient locomotion through dense fluids

- **FY20 Ames Center Innovation Fund – New start**
- **Hardware development of waterproof tensegrity system for amphibious operation**
- **Implementation of buoyancy control**
- **Demonstration of locomotion control algorithms for navigation on ground and through water**
- **Potential customers and applications: NASA STMD - *Exploration of Titan's lakes, navigation in Venus' upper atmosphere*; USGS - *Stream gauging, ocean ecosystem monitoring*; NASA SMD – *Sensor placement in heavily crevassed glaciers***



VERVE at Basalt Hills



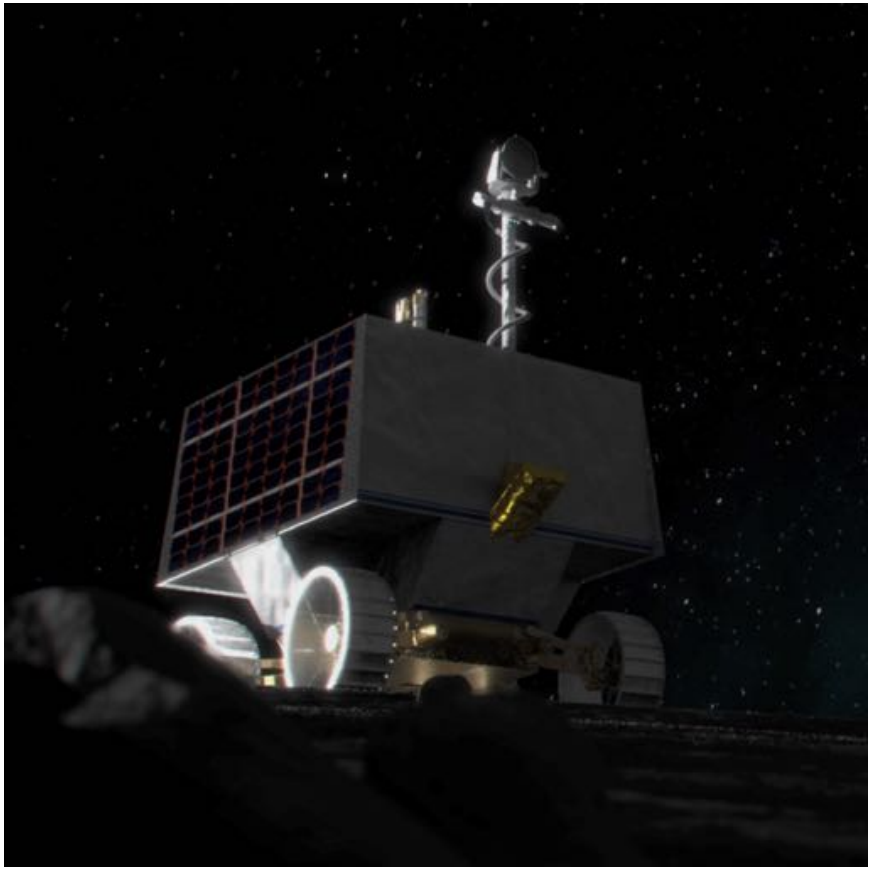
Volatiles Investigating Polar Exploration Rover (VIPER)

2023 rover mission

Search for subsurface volatiles (e.g. water ice) in the polar regions of the Moon

IRG Role:

- Onboard software
- Navigation systems
- Robot driving tools
- 3D Lunar terrain maps from satellite images for mission planning
- Software to support high-tempo science operations



Questions?

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