Robotics for Human Exploration

Future human missions to the Moon, Mars, and other destinations offer many new opportunities for exploration. But, astronaut time will always be limited and some work will not be feasible for humans to do manually. Robots, however, can complement human explorers, performing work autonomously and under remote supervision from Earth.

Robots can do a variety of work to increase the productivity of human explorers. Robots can perform tasks (systematic survey, inspection, etc.) that are tedious, highly-repetitive or long-duration. Robots can perform tasks, such as advance scouting, that help prepare for future crew activity. Robots can also perform "follow-up" work, completing tasks designated or started by humans.

Since 2004, the Intelligent Robotics Group has been working to make human-robot interaction efficient and effective for space exploration. A central focus of our research has been to develop and field test robots that benefit human exploration. Our approach is inspired by lessons learned from the Mars Exploration Rovers, as well as human spaceflight programs, including Apollo, the Space Shuttle, and the International Space Station.

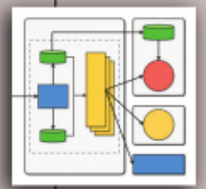
Space Robots

IRG develops planetary rovers and assistive free-flyers to advance robot technologies needed for future exploration missions. K10 is a versatile robot designed to perform field work, including site surveys, scouting, and inspection. K-REX is a high-performance rover that can carry a 200 kg payload over rough terrain. Astrobees are free-flying robots that can perform a variety of astronaut support tasks inside spacecraft.

Research Facilities

IRG's research and development facilities include an electronics lab, two collaboration workspaces, two free-flying robot labs, and the Roverscape outdoor test area. The Roverscape is an 85m x 135m facility for mobile robot research, development, and testing, as well as for conducting medium-fidelity mission simulations. IRG also makes extensive use of the supercomputing and cloud computing facilities at NASA Ames, in addition to its own large cluster of workstations.

Open Source Software



IRG is committed to developing and releasing open source software. Open sourcing increases software quality, accelerates software development, and improves technology transfer to/from NASA. IRG's open source software includes: the Ames Stereo Pipeline, Astrobee Robot Software & Astrobee Control Station, Crisis Mapping Toolkit, Exploration Ground Data Systems (xGDS), GeoCam, NASA Vision Workbench, the Neo-Geography Toolkit, the Robot Application Programming Interface Delegate (RAPID), Rover Software (RoverSW), and the Visual Environment for Remote & Virtual Exploration (VERVE). Visit: **irg.arc.nasa.gov**.

The NASA Ames Intelligent Robotics Group (IRG) enables humans and robots to explore and learn about extreme environments, remote locations, and uncharted worlds. IRG conducts applied research in a wide range of areas including computer vision, geospatial data systems, human-robot interaction, interactive 3D visualization, and robot software architecture.

We firmly believe that collaboration is essential to high-quality research. Thus, we actively encourage joint projects with academia, government, and industry. If you are interested in collaborating or have an application that can benefit from our technology, please contact us today.

For more information about the Intelligent Robotics Group:

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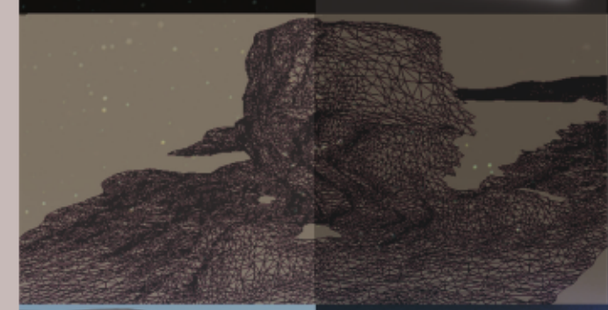
Intelligent Robotics Group



Intelligent Systems Division
NASA Ames Research Center

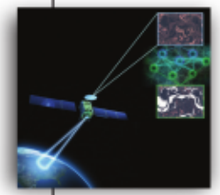
Intelligent Robotics

Perception, Interaction, and Architecture for Planetary Exploration

Astrobee

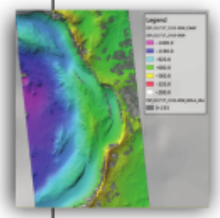
Launched in 2019, the Astrobee free-flying robots operate inside the International Space Station (ISS) alongside astronauts. Astrobee's primary purpose is to host innovative guest science; it can also provide mobile camera views of crew activities and perform environmental surveys. Visit: https://www.nasa.gov/astrobee.

Deep Earth Learning, Tools, and Analysis (DELTA) toolkit



NASA Ames is partnering with the United States Geological Survery (USGS) and National Geospatial-Intelligence Agency (NGA) to develop DELTA, an open source toolkit for deep learning on satellite imagery. DELTA will empower Earth scientists to achieve state-of-the-art classification results with little to no knowledge of machine learning or computer programming. Initially, DELTA will be trained and evaluated for mapping floods for disaster response and recovery. Potential later uses include studying other natural disasters, changing land-use patterns, climate change, and more.

Digital Terrain Models and the NASA Ames Stereo Pipeline (ASP)



Digital terrain models are essential for cartography, science analysis, and mission planning and operations. We have developed software to automatically generate high-quality topographic and albedo models from satellite images. Our software uses multi-view geometry and photoclinometric techniques to produce 3D models with very high accuracy and resolution. ASP is an open source C++ framework for deriving, manipulating, and synthesizing terrain and shape data products. ASP has been used to create 3D terrain models for landing sites on Mars, topography on icy satellites and Kuiper Belt Objects (KBOs) in the outer solar system, as well as glaciers, mountains, and volcanoes here on Earth. Visit: https://github.com/NeoGeographyToolkit/StereoPipeline

Exploration Ground Data System (xGDS)

xGDS is a web-based software system for managing science and operations data for human and robotic missions. xGDS includes tools for mission planning, data management, visualization, and analysis. xGDS is modular, uses open source software and open standards, and can be rapidly adapted to different missions. xGDS has supported a wide range of field studies and simulated exploration missions.

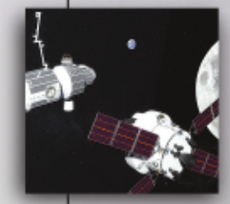
Extreme Perception

NASA's future robotic exploration targets include spike-covered icy surfaces on Europa, liquid methane lakes on Titan, and other environments that exist at the limits of imagination. IRG is developing novel sensors and a perception capability to enable robots to see in these extreme environments. Our approach blends elements of computer vision, optics, and physics-based simulation to understand planetary environments and target effective sensing modalities. We are also developing advanced decision-making and in-situ processing techniques to optimize information collected from our approaches. Technologies innovated by IRG include thermal vision-based navigation for landing on icy surfaces, cold-gas projectiles that map in ballistic flight and form monitoring networks once emplaced, and programmable microscopes that model individual grains of soil in 3D.

GeoCam Space

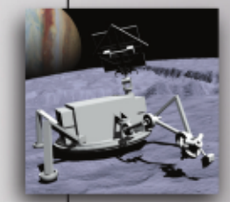
The GeoCam Space project is developing a camera hardware accessory and Web-based software to improve cataloging and geolocation of Earth images taken by astronauts on the ISS. The accessory will attach to handheld digital cameras and record pointing information. The Web-based software performs semi-automated photo-to-map alignment and facilitates creating digital map overlays.

Integrated System for Autonomous and Adaptive Caretaking (ISAAC)



The ISAAC project uses both the Astrobee free-flyers and the Robonaut 2 humanoid robot on the ISS to develop autonomous caretaking capabilities that will enable safe and reliable operation of future human spacecraft, such as the planned lunar orbiting Gateway, especially during extended periods when astronauts are not present.

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

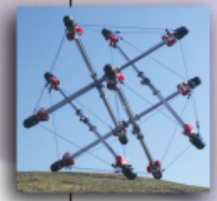


OceanWATERS is an open source simulator for developing on-board autonomy software for the robotic exploration of ocean worlds, such as Europa, Enceladus, and Titan. The simulator emulates surface conditions, robotic manipulator operation, and lander systems. The simulator is modeled on the Europa Lander mission, but could be configured for other lander missions and planetary bodies.

Skylights and Caves robotic technologies

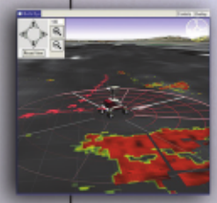
Skylights are gigantic sinkholes that might lead to intact caves on other planets. Exploration of these features is crucial for science, resource development, and future habitation throughout the solar system. We are developing robotic technologies for exploring subterranean environments — from life-detection payloads to automated mapping software — and testing them in field experimentation at terrestrial analog sites. IRG plans a technology demonstration by participating in the first commercially-led micro-rover mission to visit and circumnavigate one of the major Lunar skylights.

Tensegrity Robotics



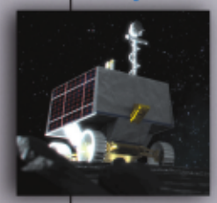
Robots based on tensegrity structures have significant potential to reduce the size, mass, and energy required for manipulation and mobility in space. Tensegrity structures are extremely lightweight, can be compactly stored for launch, are inherently compliant, and are highly robust. Our work focuses on developing these highly non-linear structures to enable new science missions for extreme terrain locations.

Visual Environment for Remote & Virtual Exploration (VERVE)



VERVE is a high-performance, 3D, user interface for visualizing robot data in real-time. VERVE uses a component-based software architecture to flexibly support different applications and users. VERVE has been used to remotely operate many NASA mobile robots in a wide variety of planetary analog field tests.

Volatiles Investigating Polar Exploration Rover (VIPER)



VIPER is a 2023 rover mission that will search for subsurface volatiles, such as water ice, in the polar regions of the Moon. We are developing the on-board software, navigation systems, and robot driving tools for the rover. We are also creating 3D lunar terrain maps from satellite images for mission planning and providing software to support high-tempo science operations.