National Aeronautics and Space Administration

FY26 Strategic Initiatives Research and Technology Development (SRTD)

Low-Cost High-Performance Surface Operations for Mars, Moon, and Beyond

Principal Investigator: Steven Myint (358)**; Co-Investigators:** Andrei Tumbar (358), Jeremy Nash (358), Daniel Zayas (325), Vandana Verma (510), Guy Pyrzak (343), Rebecca Castano (341)

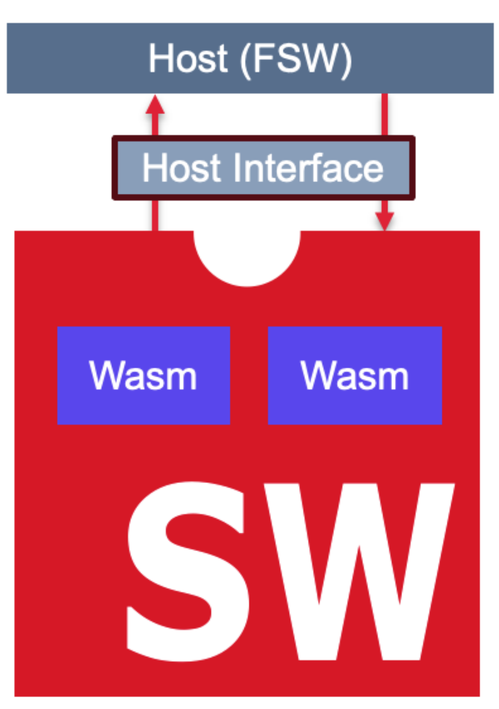
Strategic Focus Area: Exploration Systems Development Office (ESDO) **| Strategic Initiative Leader:** Jennifer H Trosper

Objectives: The objective was to make Mars and lunar surface operations cheaper by moving work that today requires ground-in-the-loop onto the vehicle, and by automating the ground steps that remain, in a form reusable across missions instead of rebuilt for each one. The task pursued three objectives: onboard autonomy that reduces ground-in-the-loop for driving and localization and is portable across heterogeneous vehicles; downlink automation that distills telemetry into actionable summaries; and uplink automation that generates, simulates, and validates commands.

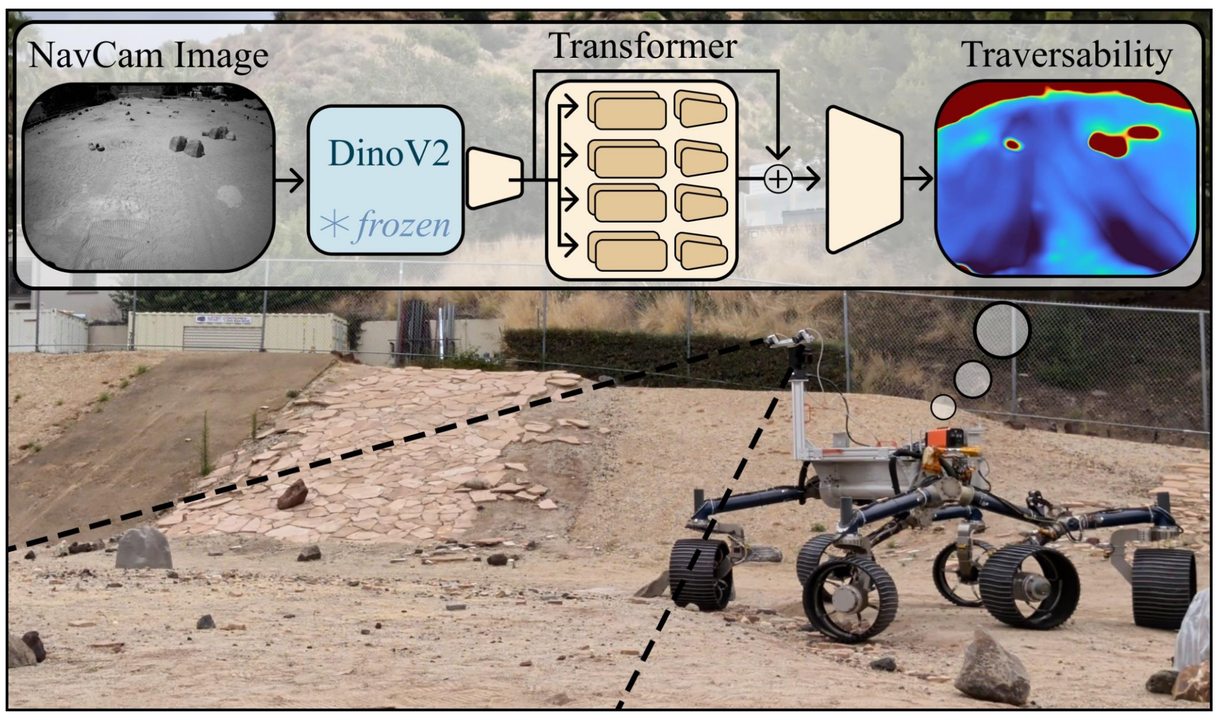
Background: Surface missions are costly because a large set of decision passes through a ground-in-the-loop tactical cycle, and because each mission rebuilds its own onboard autonomy for its own vehicle and flight software. This task builds the reusable building blocks a lunar base needs to operate a fleet of heterogeneous vehicles from multiple vendors: a portable sandboxed execution environment, GPS-free global localization, learned navigation, and automated downlink/uplink tools, engineered for infusion into JPL and commercial missions rather than as a demonstration.

Approach and Results: We build and evaluate each capability against real Mars 2020 mission data on flight or flight-like targets. SpaceWasm, an open-sourced flight-compliant WebAssembly VM (github.com/nasa/spacewasm), is integrated into F Prime; Firefly is integrating it. Moonfall and Skyfall are evaluating it. Global localization runs without GPS across vehicles and environments; all LTV vendors have expressed intent to use it. A learning-based navigation model, pretrained on ~10,000 Mars 2020 image/waypoint pairs, produces traversability maps feeding the EnhancedNav planner and runs on the Scarecrow test rover. DownlinkDigest auto-generates telemetry summaries rivaling operator reports, saving potentially two hours per planning cycle. SequenceAgent, an AI agent for command generation, simulation, and validation, was demonstrated on Mars 2020 abrasion planning.

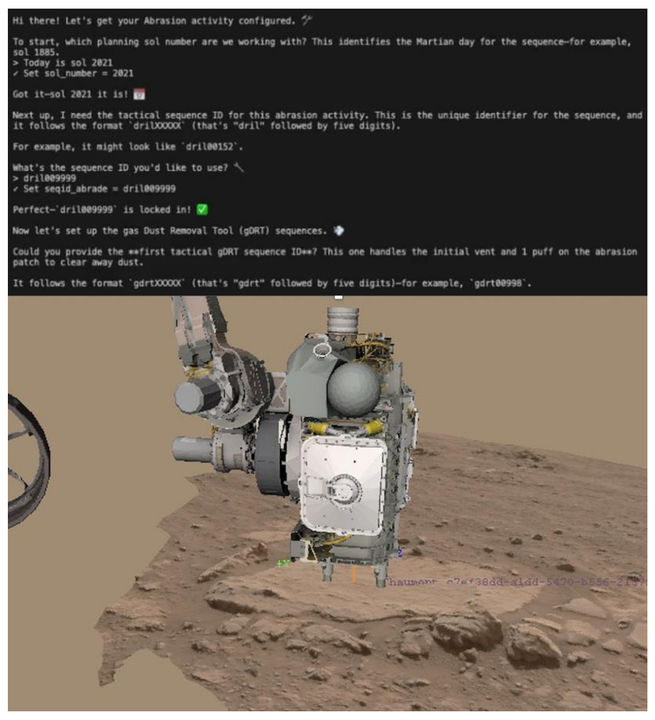
Significance/Benefits to JPL and NASA: These results move the cost drivers of surface operations off the ground team and onto reusable, portable software. SpaceWasm lets one autonomy implementation run across the heterogeneous fleets a lunar base will require. Global localization now works on both Moon and Mars, for rovers and helicopters/drones alike. DownlinkDigest and SequenceAgent reduce the tactical staffing that dominates the cost of extended surface missions, lowering operations cost and speeding tactical turnaround now, while building the portable, supervisable autonomy stack Moon-to-Mars campaigns can reuse across vendors and vehicles instead of funding a new one per mission.



SpaceWasm: a flight-compliant, sandboxed WebAssembly VM that lets one autonomy implementation run across heterogeneous vehicles.



Learning-based navigation: a traversability model trained on Mars 2020 driving data, deployed on the Scarecrow test rover.



SequenceAgent: an AI agent that generates, simulates, and validates command sequences; shown here automating abrasion planning.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

CL#26-3540

Poster Number: RPD-042

Publications (under development):

- Darren Chiu, Cole Wilson, Andrei Tumbar, Gaurav S. Sukhatme, Steven Myint, “Learning to Drive on Mars: Visual Multimodal Traversability Estimation for Off-World Navigation” submitted to IEEE ICRA 2027

PI/Task Mgr. Contact Information:
Steven.Myint@jpl.nasa.gov, (626) 314-4090