NASA Spacesuit User Interface Technologies for Students:
Project Proposal

GAIN-AI

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1. Technical Section

1.1 Abstract

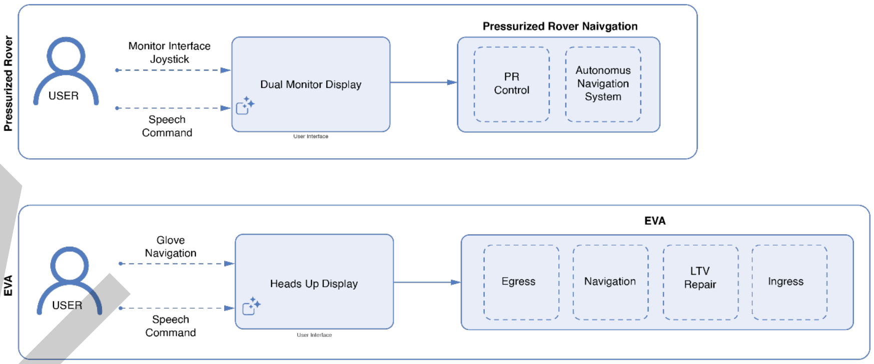


Figure 1 Interface Overview

The MIT SUITS team proposes **GAIN AI (Guided Assistant for Intelligent Navigation)**, an integrated interface system designed to enhance astronaut interaction with mission data during lunar surface operations. GAIN AI combines a heads-up display, a gesture-based glove, and an intelligent assistant to support key phases of extravehicular activity (EVA), including navigation, egress, repair, and ingress. Through feedback and data visualization, the system aims to be a mission multiplier, reduce cognitive load while maintaining clarity in low-light and high-stress environments. The prototype demonstrates how intuitive, multimodal interaction can improve efficiency, safety, and situational awareness during lunar exploration *(refer to appendix Figure 1).*

1.2 Hardware and Software Design

The GAIN AI (Guided Assistant for Intelligent Navigation) system integrates a gesture-based glove, a heads-up display (HUD), and an AI-driven mission assistant to create a unified interface for lunar EVA operations. The soft-textile glove translates natural hand gestures into precise digital inputs through embedded motion and tactile sensors, while maintaining full dexterity via a skin-contact inner layer[1]. The HUD provides clear, real-time visual feedback for navigation and task monitoring in low-light or high-stress conditions. Complementing both, the AI assistant acts as a voice-based mission multiplier, confirming actions, guiding procedures, and enabling hands-free control during critical tasks. Together, these components form an adaptive, multimodal system that enhances efficiency, safety, and situational awareness throughout the EVA process.

1.3 Concept of Operations (CONOPS)
(Pressurized Rover Navigation, Egress, EV Navigation, LTV Repair, Ingress)

The Pressurized Rover (PR) operates in NASA's Digital Lunar Exploration Sites (DUST) simulation to locate the lost Lunar Terrain Vehicle (LTV). To begin the mission, the rover uses a tap-based dual-screen interface similar to NASA's current rover UIs, combining a Gaussian-splatted terrain view and a 2D telemetry map. The GAIN AI Assistant monitors power, heading, and terrain hazards, providing short visual and verbal alerts. Once the LTV beacon is detected, the rover refines its search radius and transmits location and telemetry data to prepare egress.

Egress marks the start of the EVA. The astronaut uses an AR interface paired with a gesture-enabled glove to complete all Umbilical Interface Assembly (UIA) steps. AR visuals highlight the correct switches and indicators, while the glove allows hands-free navigation through four key commands: *EV Telemetry, Procedure List, Navigation Path, AIA*

After egress, the astronaut follows AR navigation cues projected in the helmet display. A breadcrumb trail marks safe return paths while real-time overlays show hazards and route updates. Gestures cycle through map views, place waypoints, or request range updates. The GAIN AI Assistant announces warnings and adjusts navigation based on suit telemetry and terrain conditions.

At the repair site, the AR interface transitions to a task-guided mode. Each procedure, Exit Recovery, Diagnosis, Restart, and Physical Repair, is shown step by step with visual overlays on the LTV model. Gestures allow quick switching between tasks, and GAIN AI provides voice prompts and confirmations. The interface prioritizes essential repairs if time or oxygen is limited.

Ingress guides the astronaut safely back to the PR. AR breadcrumbs display the return route, and the glove interface confirms suit status and system checks. Once at the rover, the AR interface guides umbilical reconnection and pressurization procedures, completing the EVA. GAIN AI verifies all parameters and closes the mission loop.

1.3.1. Artificial Intelligence Assistant (AIA)

The Artificial Intelligence Assistant (AIA) serves as an onboard co-pilot throughout all EVA phases, Pressurized Rover Navigation, Egress, Extravehicular (EV) Navigation, LTV Repair, and Ingress. It functions as a redundant verification layer to reduce cognitive load, confirm procedural accuracy, and ensure safety through real-time decision support. Across phases, the

Core Capabilities

- **Procedural Copilot:** Monitors checklists and verifies step completion.
- **Navigation Advisor:** Validates route and hazard data.
- **Diagnostic Agent:** Supports repair operations with context-aware prompts.
- **Safety Monitor:** Detects inconsistencies between telemetry, visual data, and user actions.

1.3.2. Vision Language Model (VLM) Framework

The AIA leverages a vision–language model (VLM), specifically OpenAI's GPT-5, to interpret visual scenes and link them to procedural steps. Unlike conventional computer vision systems that only classify or detect objects, a VLM jointly understands visual and linguistic cues, allowing it to reason about what is happening in the astronaut's environment and align it with task instructions.

By continuously analyzing visual input from the suit camera, the VLM identifies relevant tools, components, and actions to determine the astronaut's current step and provide real-time feedback. Grounded in both sight and language, the model supports intuitive voice interactions such as "What's next?" or "Did I complete this step?", enabling conversational, hands-free task verification.

1.3.3. Step Verification via Glove Feedback and Vision Language Model

This multimodal framework fuses visual, linguistic, and tactile inputs, allowing the AI to interpret both what the astronaut sees and says with contextual precision. By combining multiple sensing modes, the system remains flexible and resilient in novel or unpredictable environments. To prevent false confirmations, such as misreading a partial gesture or occluded motion, the VLM's visual inferences are cross-validated with glove sensor and voice confirmation data before advancing procedures. During critical phases such as egress, the AIA also requests brief verbal acknowledgments (e.g., "Confirm depressurization?") to meet NASA SUITS redundancy aand safety requirements. This grounding across modalities ensures reliability, mitigates hallucination risk, and maintains trust in high-stakes EVA operations.

1.3.4. Gesture Sensing Glove Restraint Layer

Real-time glove input allows direct menu navigation procedural, with four gestures mapped to a unique set of digital commands. Integration with the HUD provides immediate visual feedback and synchronizes task progress across the physical glove movement, allowing digital confirmation, and opening a communication function for emergency protocols. The glove's gesture mapping is further reinforced by interaction with the onboard AI voice assistant, supporting task verification, voice command redundancy, and adaptive help in critical phases such as egress, navigation, and system diagnostics *(refer to appendix Figure 2)*.

The four gesture mapping includes:

- Navigation Path: Opens the lunar or rover navigation interface.
- AI Voice Assistant: Activates the onboard AI for voice commands and assistance.
- Protocol Procedures: Reveals step-by-step mission checklists and operating protocols.
- Communications Panel: Accesses comms controls for interacting with the crew, mission control, or system notifications.

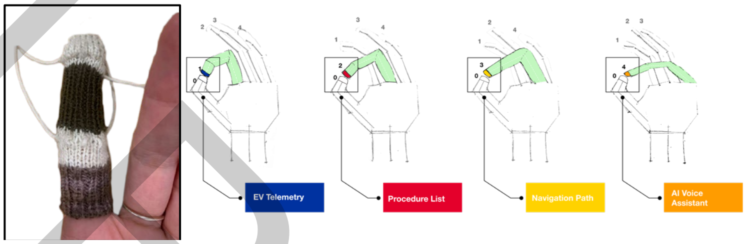


Figure 2 Prototyped Glove Module with Accelerometers and Gesture Mapping to Commands

The software environment integrates the glove data with a heads-up display (HUD) and a simplified rover simulation. The rover interface, developed in Unreal Engine, uses Gaussian splatting to render lunar terrain efficiently and provide spatial feedback without high processing demands. The HUD consolidates information into four main categories, navigation, procedures, telemetry, and communication, and updates dynamically as the user performs tasks. When activated in navigation mode, the glove can enable intuitive gesture-led visual navigation in AR [2]. Communication between the glove, the HUD, and the rover simulation follows a shared data structure, allowing sensor input and telemetry updates to stay synchronized throughout mission operations *(refer to appendix Figure 3)*.

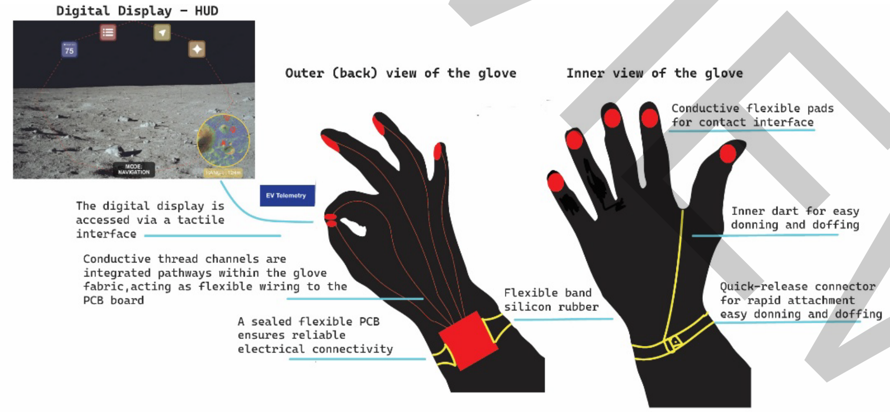
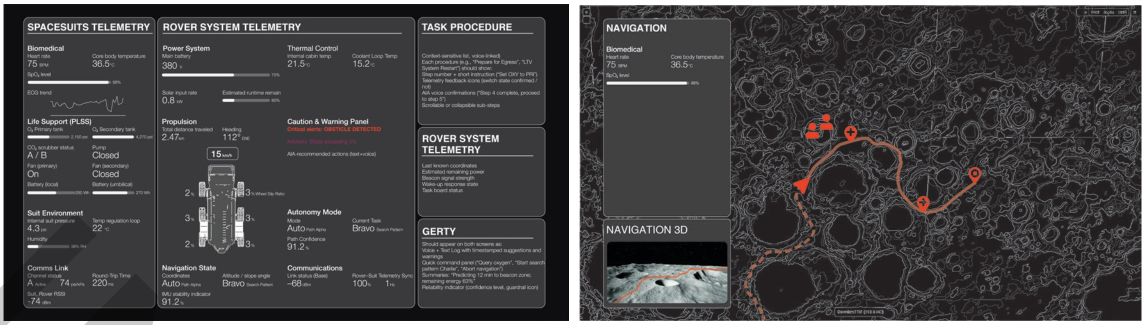


Figure 3 Glove Schematic & System Design

1.4 Pressurized Rover Navigation



SPACESUITS TELEMETRY

Biomedical
Heart rate 75 BPM
Core body temperature 36.5 °C
SpO$_2$ level 98%
ECG trend

Life Support (PLSS)
O$_2$ Primary tank 2,150 psi
O$_2$ Secondary tank 4,270 psi
CO$_2$ scrubber status A / B
Pump Closed
Fan (primary) On
Fan (secondary) Closed
Battery (local) 260 Wh
Battery (umbilical) 270 Wh

Suit Environment
Internal suit pressure 4.3 psi
Temp regulation loop 22 °C
Humidity 38% RH

Comms Link
Channel status A Active 74 psi/kPa
Round-Trip Time 220 ms
Suit, Rover RSSI -74 dBm

ROVER SYSTEM TELEMETRY

Power System
Main battery 380 V 75%
Solar input rate 0.8 kW
Estimated runtime remain 80%

Thermal Control
Internal cabin temp 21.5 °C
Coolant Loop Temp 15.2 °C

Propulsion
Total distance traveled 2.47 km
Heading 112° ENE
15 km/h
2 % 3 % Wheel Slip Ratio
3 % 3 %
2 % 3 %

Caution & Warning Panel
Critical alerts: OBSTICLE DETECTED
Advisory: Slope exceeding 5%
AIA-recommended actions (text+voice)

Autonomy Mode
Mode Auto Path Alpha
Current Task Bravo Search Pattern
Path Confidence 91.2 %

Navigation State
Coordinates Auto Path Alpha
Altitude / slope angle Bravo Search Pattern
IMU stability indicator 91.2 %

Communications
Link status (Base) −68 dBm
Rover–Suit Telemetry Sync 100 % 1 Hz

TASK PROCEDURE

Context-sensitive list, voice-linked)
Each procedure (e.g., "Prepare for Egress", "LTV System Restart") should show:
Step number + short instruction ("Set OXY to PRI")
Telemetry feedback icons (switch state confirmed / not)
AIA voice confirmations ("Step 4 complete, proceed to step 5")
Scrollable or collapsible sub-steps

ROVER SYSTEM TELEMETRY

Last known coordinates
Estimated remaining power
Beacon signal strength
Wake-up response state
Task board status

GERTY

Should appear on both screens as:
Voice + Text Log with timestamped suggestions and warnings
Quick command panel ("Query oxygen", "Start search pattern Charlie", "Abort navigation")
Summaries: "Predicting 12 min to beacon zone; remaining energy 63%"
Reliability indicator (confidence level, guardrail icon)

NAVIGATION

Biomedical
Heart rate 75 BPM
Core body temperature 36.5 °C
SpO$_2$ level 98%

NAVIGATION 3D

Figure 4. PR Dual Monitor UI Design

1.4.1 Navigation Overview:

The Pressurized Rover (PR) Navigation System operates within NASA's Digital Lunar Exploration Sites (DUST) simulation, combining adaptive autonomy and astronaut oversight to locate the missing Lunar Terrain Vehicle (LTV). The architecture integrates four coordinated components[3]: (A) a search module defining the operational area and pattern using orbital and terrain data; (B) a navigation protocol uniting global and local planners with beacon-guided biasing and real-time return logic; (C) a supervisory loop where the GAIN-AI Assistant arbitrates and confirms autonomous decisions; and (D) a visualization layer integrating terrain rendering, telemetry mapping, and multimodal input through a dual-monitor interface (Figure 4). Together, these components establish a resilient human-in-the-loop navigation framework aligned with NASA SUITS objectives for safety, cognitive efficiency, and adaptability in extreme lunar environments.

1.4.2 Feature A: Search Area & Search Pattern

Before initiating movement, the navigation system computes a search boundary derived from the LTV's last known coordinates, last recorded direction of travel, operational mode, remaining energy, and known terrain constraints. Instead of assuming a perfect circle, the rover constructs a search region representing the estimated reachable area of the LTV, shaped by slope, rock fields, and line-of-sight limitations. Within this zone, the rover applies industry-standard search patterns adapted for lunar operations: Expanding Square for close uncertainty, Sector Search for confined areas, and Parallel Track for elongated or irregular terrains *(refer to appendix Figure 5)* [4].

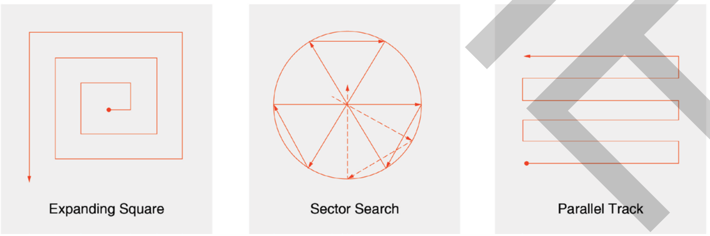


Figure 5. Search Pattern Options

1.4.3 Feature B: Navigation Protocol

The Pressurized Rover (PR) navigation protocol integrates four coordinated layers that balance algorithmic planning with astronaut oversight, enabling adaptive, low-latency navigation across uncertain and resource-*limited* environments.

1) Global Planner, D Lite (Continuous Replanning)*

Maintains a dynamic global cost map combining Gaussian-splat terrain elevation, slope, and surface roughness data. The planner continuously recalculates routes as terrain data changes, ensuring efficient coverage of the evolving search region. Built upon Field D* algorithms used on Mars rovers, this layer provides long-range path coherence [5,6].

2) Local Controller: RAPF (Fast Obstacle Avoidance)
Implements the Robust Artificial Potential Field (RAPF) method for responsive, near-optimal steering around local obstacles detected via LIDAR and stereo vision. Designed for onboard computation limits, this controller produces smooth, stable trajectories while maintaining alignment with the global route[7].

3) Evidence-Guided Bias: Beacon and Coverage Fusion
Integrates LTV beacon signal strength and coverage efficiency directly into the D* Lite heuristic, forming an adaptive "heat field" that biases navigation toward the most probable LTV location while respecting energy and slope constraints. This ensures search efficiency without compromising safety or terrain feasibility[8,9].

4) Awareness and Return-to-Base
To ensure mission safety, the PR continually monitors power, time, and communication status to calculate safe turn-around points. When reserves drop below a defined threshold, the GAIN-AI Assistant issues an alert (e.g., "Power at 25% return-to-base recommended") and highlights the safest RTB route, updating it in real time as terrain and resource conditions change.

1.4.4 Feature C: Supervisor Loop — GAIN-AI Arbitration and Human Oversight

The GAIN-AI Assistant arbitrates between the global and local planners, monitoring confidence levels and risk thresholds. When uncertainty increases or conflicting inputs occur, it surfaces these conditions to the operator for confirmation via voice or manual input before executing major navigational changes. This redundancy loop keeps all autonomous actions auditable, reversible, and traceable, aligning with NASA SUITS' human-in-the-loop autonomy principles.

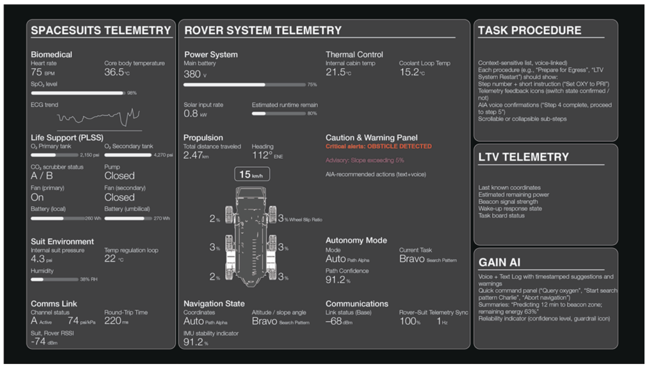
1.4.5 Feature D: Visualization and Interface Layer

The Pressurized Rover interface integrates a Gaussian-splat terrain renderer, 2D telemetry map, and GAIN-AI Assistant for routing, hazard detection, and system management. This phase focuses on a screen-based, tap- and button-driven interface that builds upon NASA's existing rover control architecture to maintain consistency and reliability. The system operates on a dual-monitor configuration mirroring the Johnson Space Center VR Lab, displaying terrain visualization and telemetry data side by side. Designed for low-light lunar operations, the interface emphasizes clarity, efficiency, and reduced cognitive load[10].

Control input is multimodal and redundant. Operators can issue high-level commands through GAIN's voice interface for navigation, status, or data queries, while maintaining manual control for precise maneuvers. This dual-channel redundancy strengthens reliability and allows seamless transition between autonomous and manual operations.

The dual-screen layout divides mission operations into two complementary domains:
(1) the *Main Systems Display*, focused on telemetry and mission control, and
(2) the *Navigation Display*, focused on spatial awareness and path-planning visualization.

Main Systems Display (Screen 1):
The main interface presents critical telemetry from the rover and the EVA suit, including life-support consumables (O_2, battery), environmental conditions (pressure, temperature, humidity), biomedical data (heart rate, SpO_2, body T°), and communication (RSSI, latency, channel) *(refer to appendix Figure 6).* Each variable is paired with an intuitive horizontal bar gauge and numeric value.



SPACESUITS TELEMETRY

Biomedical
Heart rate 75 BPM
Core body temperature 36.5 °C
SpO₂ level 98%
ECG trend

Life Support (PLSS)
O₂ Primary tank 2,150 psi
O₂ Secondary tank 4,270 psi
CO₂ scrubber status A / B
Pump Closed
Fan (primary) On
Fan (secondary) Closed
Battery (local) 260 Wh
Battery (umbilical) 270 Wh

Suit Environment
Internal suit pressure 4.3 psi
Temp regulation loop 22 °C
Humidity 38% RH

Comms Link
Channel status A Active 74 psi/kPa
Round-Trip Time 220 ms
Suit, Rover RSSI -74 dBm

ROVER SYSTEM TELEMETRY

Power System
Main battery 380 V 75%
Solar input rate 0.8 kW
Estimated runtime remain 80%

Thermal Control
Internal cabin temp 21.5 °C
Coolant Loop Temp 15.2 °C

Propulsion
Total distance traveled 2.47 km
Heading 112° ENE
15 km/h
2% 3% Wheel Slip Ratio
3% 3%
2% 3%

Caution & Warning Panel
Critical alerts: OBSTICLE DETECTED
Advisory: Slope exceeding 5%
AIA-recommended actions (text+voice)

Autonomy Mode
Mode Auto Path Alpha
Current Task Bravo Search Pattern
Path Confidence 91.2 %

Navigation State
Coordinates Auto Path Alpha
Altitude / slope angle Bravo Search Pattern
IMU stability indicator 91.2 %

Communications
Link status (Base) –68 dBm
Rover–Suit Telemetry Sync 100% 1 Hz

TASK PROCEDURE

Context-sensitive list, voice-linked)
Each procedure (e.g., "Prepare for Egress", "LTV System Restart") should show:
Step number + short instruction ("Set OXY to PRI")
Telemetry feedback icons (switch state confirmed / not)
AIA voice confirmations ("Step 4 complete, proceed to step 5")
Scrollable or collapsible sub-steps

LTV TELEMETRY

Last known coordinates
Estimated remaining power
Beacon signal strength
Wake-up response state
Task board status

GAIN AI

Voice + Text Log with timestamped suggestions and warnings
Quick command panel ("Query oxygen", "Start search pattern Charlie", "Abort navigation")
Summaries: "Predicting 12 min to beacon zone; remaining energy 63%"
Reliability indicator (confidence level, guardrail icon)

Figure 6. Screen 1 - Main System Display

Bar indicators, selected per NASA human-systems guidance, prioritize fast, at-a-glance magnitude reading, while numerics provide precision; this pairing improves accuracy under load [11]. Color coding (blue/red) with textual redundancy communicates status clearly and accessibly. Icons are kept simple and literal (e.g., Points of Interest, LTV Last Known Coordinates) to minimize interpretation time and align with NASA's guidance on clear symbology and consistent grouping for displays.

Navigation Display (Screen 2):
The second screen manages mission planning and mobility (*refer to appendix Figure 7)*. A 2D topographic map integrates path overlays, hazard zones, and resource radii. Two visualization modes can be toggled:

- Terrain Mode — full-color DEM heatmap for slope and terrain assessment.
- Route Mode — simplified view prioritizing routes, astronaut locations, and search areas.

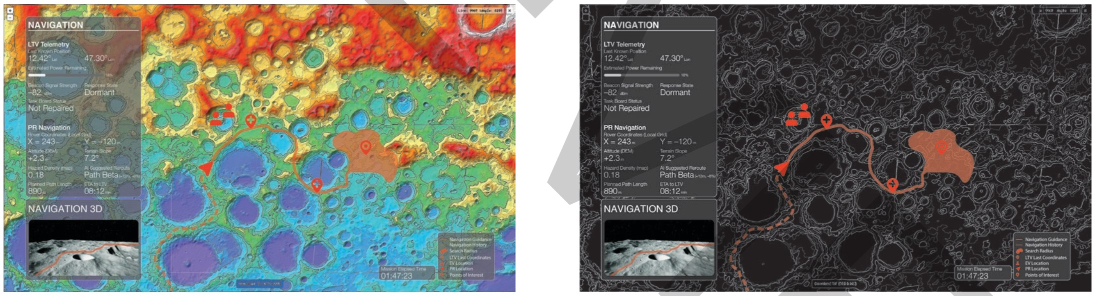


Figure 7. Screen 2 - Navigation Display Terrain Mode vs Route Planning Mode

A compact 3D Terrain Map in the lower-left corner fuses LiDAR point-cloud depth with Gaussian Splat radiance fields, generating a photorealistic, geometrically accurate local model [12,13]. LiDAR ensures reliable structure capture, while Gaussian Splatting enhances visual continuity and color fidelity. GPU-accelerated neural reconstruction maintains 1–2 s latency, providing real-time situational awareness for both autonomous and human navigation.

Modular data organization ensures mission-critical telemetry (power, oxygen, comms) remains visible across both screens, while contextual panels expand for secondary data. The resulting interface supports perceptual immediacy, consistent visual grammar, and reduced cognitive strain under lunar conditions (*refer to appendix Figure 8)*.

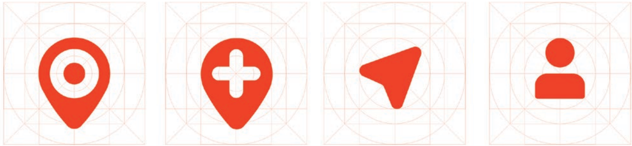


Figure 8. Icon Design for Navigation Display

1.5. Egress

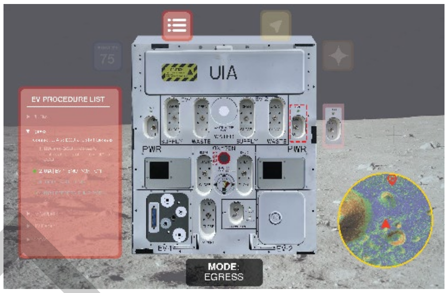


Figure 9 HUD UI Egress Panel

Egress marks the start of the extravehicular activity (EVA), as astronauts move from the Pressurized Rover (PR) to the lunar surface. Our system combines augmented reality (AR) guidance with a gesture-enabled glove interface, allowing astronauts to interact intuitively while focusing on safety-critical tasks. Within the AR display, procedural checklists and UIA states are overlaid directly onto physical components, ensuring depressurization, umbilical disconnection, and suit verification are performed accurately and in order. The glove links human motion to digital procedural visualization, forming a closed feedback loop where physical inputs and visual confirmations reinforce each other.

Procedure List:

The HUD interface is organized around four primary gestures, each mapped to a distinct menu. Within each main menu, users can access contextual submenus that expand relevant information or actions (Figure 9). This structure maintains a clean hierarchy, minimizing cognitive load while ensuring quick, intuitive navigation between tasks.

1.6 LTV Repair

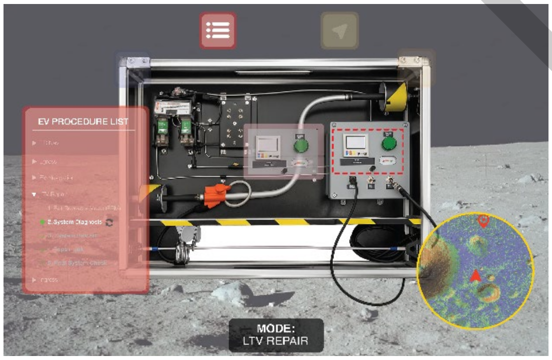


Figure 10 HUD UI for LTV repair

The LTV repair phase begins once the crew arrives at the malfunctioning rover requiring on-site recovery. This operation integrates AR-guided diagnostics, AI-assisted decision support, to ensure safe and efficient restoration of system functionality, similar to the egress system.

Exit Recovery Mode (ERM)
Upon reaching the LTV, astronauts retrieve ERM procedures through the AI Assistant (AIA). These procedures appear as AR overlays, providing step-by-step visual cues for reinitializing the rover recovery sequence. At each stage, the AIA issues a spoken confirmation prompt (e.g., “Ready to proceed?”), requiring a verbal acknowledgment before advancing. This confirmation loop acts as a sanity check, ensuring that every procedural transition is deliberate and verified.

System Diagnosis
Once ERM is complete, the astronaut commands the AIA to initiate a system-wide diagnosis. The AR interface highlights relevant rover components for visual inspection, while the AIA cross-references sensory and telemetry data to identify potential faults. The system then generates procedures, prioritizing tasks based on safety and mission-criticality.

System Restart (Navigation Correction)
If diagnostics indicate navigation errors, the AIA guides the astronaut through a physical restart of the rover navigation subsystem. The AR display visualizes connection points and switch sequences, while the AIA provides spoken progress confirmations. After restarting, the AIA validates position data and confirms system stability before proceeding.

Physical Repair Tasks
For component-level issues, such as a loose bus connector or damaged dust sensor, the AIA provides context-aware procedural guidance. The AR overlay localizes the fault, and the AI issues voice prompts to confirm each critical step. When time or power constraints arise, the AIA dynamically reprioritizes noncritical repairs (e.g., dust sensor replacement) to ensure mission continuity.

Final Verification
Following all repair actions, the AIA conducts a full system verification sequence, integrating diagnostic telemetry and operator confirmations. Once the rover’s stability is confirmed, the AIA announces recovery success and authorizes the transition to the next EVA phase.

1.7 Ingress

Ingress marks the completion of EVA, as astronauts transition from the lunar surface back into the PR. This phase ensures environmental containment, equipment verification, and safe re-pressurization. Our system mirrors the logic of egress, using the same AR-guided and gesture-enabled glove interface. Within the AR display, navigation cues and “breadcrumb” markers guide astronauts along the safest and most efficient return path. Once at the PR, the interface overlays ingress procedures such as suit inspection, umbilical reconnection, and airlock pressurization directly onto physical components. This process ensures that astronauts can complete ingress efficiently, maintain system stability, and prepare the rover for subsequent operations.

1.8 Human in the Loop Testing

The human-in-the-loop evaluation aims to assess the effectiveness, efficiency, and cognitive demands of the GAIN AI system during simulated EVA tasks. Two user studies will be conducted to compare interaction modalities and task performance. In the first, participants will complete navigation tasks using either speech-only input or combined speech-and-gesture control to determine the impact of multimodal interaction on precision and workload. In the second, participants will perform procedural task sequences to evaluate system usability and task completion efficiency. Quantitative metrics will include completion time, while subjective workload will be measured using the NASA-TLX questionnaire to assess fatigue, mental demand, and user satisfaction.

Subject Pools

The study will recruit a diverse participant group which will include a total of 10–15 individuals experienced in simulation or control interfaces (e.g., engineering or robotics students) and those without prior exposure, to capture a broad range of user behaviors and learning curves. This mixed-experience sampling will help evaluate how intuitively the GAIN AI system can be adopted by novice users while still supporting expert-level efficiency.

Study	Objective	Interaction Conditions	Tasks	Metrics
Study 1 Navigation	Compare between speech-only and speech+gesture control during navigation	(1) Speech-only input (2) Speech + glove input	Navigate under simulated EVA conditions	Task completion time, path accuracy, NASA-TLX workload score
Study 2 Task	Evaluate usability and efficiency during procedural task execution	Speech + glove interface	Perform predefined repair or inspection sequence	Completion time, number of errors, NASA-TLX, user satisfaction survey

1.9. Project Management

Weeks	Key Dates	Design	Development	Outreach	Research + Testing
11/3/2025 – 12/13/2025	**Oct 30 -** Proposal submitted	Refine system architecture diagrams. Develop detailed UI wireframes (glove + AR HUD)	Code repo setup and environment testing. Build early UI mock interactions	Post-submission updates. Identify potential testers	Review proposal feedback, refine scope, finalize user study protocol and metrics (NASA-TLX, accuracy)
12/14/2025 – 1/10/2026	*Winter Break* **Dec 15 -** SUITS selection announcement	–	–	Update team social media account	Review related research on multimodal control
1/13/2026 – 1/26/2026	**Jan 25 –** First Functional Prototype	UI refinement	Implement gesture recognition + voice input	Share early progress with SUITS mentors	Internal pilot test (input detection only)
1/27/2026 – 2/16/2026	–	Integrate AIA interface visuals	Link glove + speech + telemetry	Prepare outreach deck,	Pilot test 1 — gesture vs. voice baseline

				apply for tabling	
2/17/2026 – 3/1/2026	**Feb 28 –** Integrated Prototype Ready	Finalize interface layout	Combine VLM + AIA pipeline	Outreach to JSC, MIT XR groups	HITL test #1 (task completion)
3/2/2026 – 3/22/2026	**Mar 21 –** Refined Prototype / Iteration 1 Complete	UI iteration based on results	Debug interaction delays, improve glove tracking	K-12 educational workshops in electronics and VR	HITL test #2 (navigation assistance)
3/23/2026 – 4/11/2026	–	Visual polish, simplify UI hierarchy	Optimize code and data logging	Outreach updates	Analyze NASA-TLX and user feedback
4/12/2026 – 4/25/2026	**Apr 25 –** Final Iteration Implemented	Design tutorial overlay	Final integration & validation	Outreach prep for testing	Final HITL verification
4/26/2026 – 5/9/2026	–	Prep training + documentation	System freeze for field testing	Press + internal presentations	Summary report & readiness review
5/12/2026 – 5/24/2026	**May 18 – 23 –** Onsite Testing at JSC	Field notes and adjustments	Live testing & support	NASA coordination	Data collection and observation
5/25/2026 – 5/31/2026	–	Post-demo visuals & reflection	Code archiving	Outreach wrap-up	Analysis + team debrief

1.10. Technical Reference

Glove

[1] Y. Luo, C. Liu, Y. J. Lee *et al.*, “Adaptive tactile interaction transfer via digitally embroidered smart gloves,” *Nat. Commun.*, vol. 15, Art. no. 868, 2024, doi: 10.1038/s41467-024-45059-8.

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Navigation

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2. Outreach Section

2.1. Community Engagement

Our team is committed to extending the educational mission of NASA SUITS beyond the MIT campus by engaging with community libraries (Cambridge Public Library, Boston Public Library) and local K-12 programs through creative STEM workshops. The community engagement plan aims to educate the public on space technology, wearable systems, and AR/VR that ties back to the core concepts of our GAIN-AI prototype.

Event	**Target Audience**	**Objective & Description**	**Timeline**
Tabling: VR Exploration (2 hours)	MIT students & staff	Tabling event in the MIT Dome to provide immersive VR experience that allows participants to interact with simplified GAIN-AI interfaces. This provides an opportunity to collect user feedback in early-stage testing.	Early-Spring 2026
Electronics Workshop: Wearable Circuits (2 hours)	Grades 8-12	In alignment to our proposal to include haptics to provide tactile feedback through spacesuit gloves, we propose a workshop for teens to create their own electronic embedded items. A sample exercise would be sewing conductive threads on a piece of fabric with a coin cell battery and LilyPad LED, inspired by Sparkfun	Early Spring 2026
Interface Testing (1-2 hours)	Adult Participants	This private event will be limited to a room with adequate cleared walking space for the SUITS demo session. The goal is to collect near final feedback from users on the VR/AR and haptic glove workflow	Mid-Spring 2026
Space & VR Workshop (1-2 hours)	Grades K-12	To raise awareness and gauge interest in space design, VR headsets will be present for students to test out walkthroughs of hypothetical navigation space.	Mid- Spring 2026
Project Exhibition	General Public	Exhibit GAIN-AI protoype and interface through set of posters and recorded demonstrations. The event will likely be an end-of-the semester department/university-wide showcase following a newsletter.	End of Spring 2026

2.1.1. Press & Social Media

To raise awareness about our participation in the NASA suits challenge, our team will implement the following communications strategy to increase participation in outreach events and showcase project milestones.

- Set up a designated team Instagram account (@mit_gainai) that is dedicated to behind-the scenes progress, team milestones, and workshop announcements. At least two posts per month leading up to May 2026 with more frequent, informal story updates.

- Submit information on project participation to MIT's instagram (@mit, @mitarchitecture) for additional outreach for user testing or workshops. Expected one post per account by mid-spring 2026.
- MIT and department news channels will feature articles highlighting the program participation and project achievements. To be expected at the end of the semester.
- LinkedIn updates can be done individually for professional milestones and acknowledgement of project collaborators and mentors. Expected closer to completion of the project.

2.2 Industry Engagement

To strengthen the technical and design viability of GAIN-AI, our team will engage with leading experts in AR/VR, artificial intelligence, wearable technologies, and aerospace design to enhance both the educational and professional development of the MIT student team.

Professor Skylar Tibbits, Director of the Self-Assembly Lab, serves as the team's faculty advisor for the NASA SUITS program. Professor Tibbits co-teaches the Spring Space Architecture Design Studio, which runs in parallel with the Architecture and Aero/Astro Space Systems Engineering courses and the MIT Media Lab Space Exploration Initiative. Professor Jeffrey Hoffman, a former NASA astronaut, from the Department of Aeronautics and Astronautics, co-leads this studio and may provide some insights and expertise during the development of our prototype. In the spring 2026 semester, a couple of team members plan to enroll in this course to gain hands-on experience in identifying and exploring challenges posed by operating in the lunar environment.

We also plan to engage with Dr. Cody Paige, Director of the MIT Media Lab Space Exploration Initiative, whose experience in translating space-related research into zero-gravity flight experiments will provide critical feedback on the feasibility and testing potential of our ongoing research.

The GAIN-AI team brings together a diverse portfolio of industry partners and expertise, including textile and wearable design, robotics, augmented and virtual reality, and computational fabrication, allowing for interdisciplinary approach to human-computer interaction and space interface design. These collaborative efforts will collectively support the development of a safe, intuitive, and adaptive system aligned with NASA SUITS' mission to advance next-generation EVA technologies. The following is a summary of additional industry connections and mentorships opportunities lined up for this project:

- ***Rodrigo Gallardo,*** a researcher specializing in virtual and augmented reality and haptics, is currently collaborating on a project with MIT's AeroAstro department. His work focuses on developing mixed-reality training simulations to enhance task performance, spatial awareness, and human–system interaction.
- ***Ganit Goldstein***, a PhD candidate and senior lead on the glove team, is a computational textile and fashion designer who collaborates with Prof. Skylar Tibbits and Dr. Cody Paige on the design and fabrication of spacesuit garments and responsive textile systems to bridge material innovation with human-space interaction. She also works closely with Prof. Dava Newman, former NASA Deputy Administrator and current faculty member in the MIT Department of Aeronautics and Astronautics, who will provide guidance and expertise in advancing the project's human-centered design and aerospace applications.
- ***Sergio Mutis*** is a researcher, roboticist, and computational designer on the navigation team, developing distributed robotic assembly systems and multi-agent intelligence at MIT. He collaborates with Prof. Danielle Wood of the MIT Space Enabled Group on NASA's Zero Robotics initiative, and with Dr. Pablo Ortiz, a PhD research scientist at Amazon Robotics specializing in computer vision for distributed robotics, who will serve as a mentor on navigation architecture, pathfinding strategy, and Gaussian splatting.
- ***Berfin Ataman***, a senior member of team AIA, previously wrote a paper on folding structures used for space emergency vehicles currently submitted to IEEE. She will also seek advice from Manan Arya, a

researcher from a Stanford Lab, who specializes in deployable space vehicles to better understand the user conditions.

- **Alexander Htet Kyaw** is a researcher at MIT on the AIA team, currently working on Vision-Language Models for robotic assembly in collaboration with researchers at Google. He has also previously worked with Microsoft Research and Autodesk Research on various projects in human–computer interaction and robotics.

3.Administrative Section

3.1 Statement of Supervising Faculty

(Attached below)

3.2 Institutional Letter of Endorsement

(Attached below)

MIT Architecture

AD

Architectural Design
Department of Architecture
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 10–491M
Cambridge, MA 02139–4307
Tel: 617–253–7494 / Fax: 617–253–9407

3.2 Statement of Supervising Faculty

To whom it may concern,

As the faculty advisor for the experiment entitled “GAIN AI: Guided Assistant for Intelligent Navigation” proposed by a team of students from the Massachusetts Institute of Technology, I confirm my full support for the concepts and methodologies outlined in this proposal. I will provide oversight to ensure that the student team adheres to all project requirements and deadlines throughout the duration of the NASA SUITS program.

I understand that any failure by the team to meet submission requirements or deliverables—including the final report—may adversely impact the eligibility of future MIT student teams for participation in this program.

Skylar Tibbits

Sincerely,

Skylar Tibbits
Associate Professor – Department of Architecture, MIT
Founder & Co-Director – Self-Assembly Lab, MIT

MIT Architecture

October 22, 2025

NASA SUITS Program
Extravehicular Activity and Human Surface Mobility Program
NASA Johnson Space Center
Houston, TX

Subject: Institutional Letter of Endorsement – MIT SUITS 2025 Team

To the NASA SUITS Review Committee,

On behalf of the Massachusetts Institute of Technology Department of Architecture, I am pleased to endorse the participation of the MIT SUITS Team in the 2025–2026 NASA Spacesuit User Interface Technologies for Students Challenge.

Our students' proposal, titled GAIN AI: Guided Assistant for Intelligent Navigation represents a rigorous and collaborative effort that bridges design computation, human–computer interaction, and augmented reality interfaces for extravehicular activity (EVA) support. This initiative embodies MIT's commitment to interdisciplinary research and to advancing technologies that enable future space exploration.

The team has the full support of the Department of Architecture in this NASA program. We will ensure that the team receives institutional backing throughout the development and testing phases and has access to the necessary facilities and faculty guidance to complete the project successfully.

Yours sincerely,

Nicholas de Monchaux

Weber-Shaughness Professor and Head of Architecture
Professor of Urban Studies and Planning
Associated Faculty, Program in Science, Technology and Society
External Professor, The Santa Fe Institute

Nicholas de Monchaux
Professor and Department Head
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Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 7-337
Cambridge, MA 02139-4307
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3.3 Statement of Rights of Use

As team members for a proposal entitled “NASA Spacesuit User Interface Technologies for Students: Project Proposal,” proposed by a team of higher education students from the Massachusetts Institute of Technology (MIT), we hereby grant the U.S. Government a royalty-free, nonexclusive, and irrevocable license to use, reproduce, distribute (including distribution by transmission) to the public, perform publicly, prepare derivative works, and display publicly any technical data contained in this proposal, in whole or in part, and in any manner for federal purposes, and to have or permit others to do so for federal purposes only.

Furthermore, with respect to all computer software designated by NASA to be released as open source, which is first produced or delivered under this proposal and any subsequent collaboration, if selected, such software shall be delivered with unlimited and unrestricted rights to permit further distribution as open source. For purposes of defining the rights in such computer software, “computer software” includes source code, object code, executables, ancillary files, and all documentation related to any computer program or similar set of instructions delivered in association with this collaboration.

As team members for the proposal entitled “NASA Spacesuit User Interface Technologies for Students: Project Proposal,” proposed by students from the Massachusetts Institute of Technology (MIT), we further grant the U.S. Government a nonexclusive, non-transferable, irrevocable, paid-up license to practice or have practiced for or on behalf of the United States Government any invention described or made part of this proposal throughout the world.

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3.4 Funding and Budget

Our budget breakdown currently accounts for eight students and one faculty advisor traveling to NASA's Johnson Space Center in Houston (May 2026). Travel estimates are subject to change based on individual schedules and circumstances and will be coordinated with NASA representatives once acceptance into the program is confirmed. The finances will also cover community workshops, prototyping materials, software membership fees, and overhead costs. This is a student-organized team, and there are no additional sources of funding to date as of this writing. We plan to host fundraising events and seek additional research funding opportunities at MIT to supplement the work in the meantime.

Items	**Costs**
Flights	$3,000
Hotel	$6,800
Ground Transportation	$800
Glove Prototyping Materials	$1000
Software	$200
User Study Cost	$600
Misc, Overhead	$300
Total	$12,700

3.5 Hololens2 Loan Program

The team currently has access only to a Meta Quest 3 for initial prototyping and requires a loaned device to continue development. A demonstration on the HoloLens is preferred to fully showcase the system's intended capabilities.

4. Appendix

Figure 1: Interface Overview

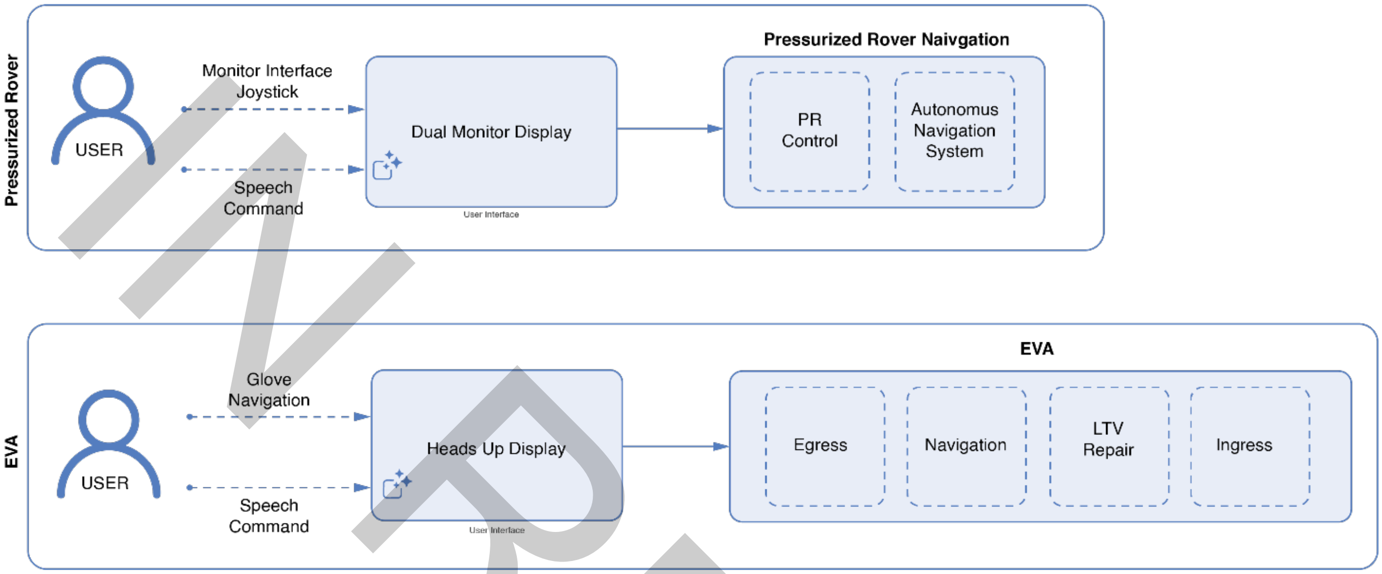


Figure 2: Prototyped Glove Module with Accelerometers and Gesture Mapping to Commands

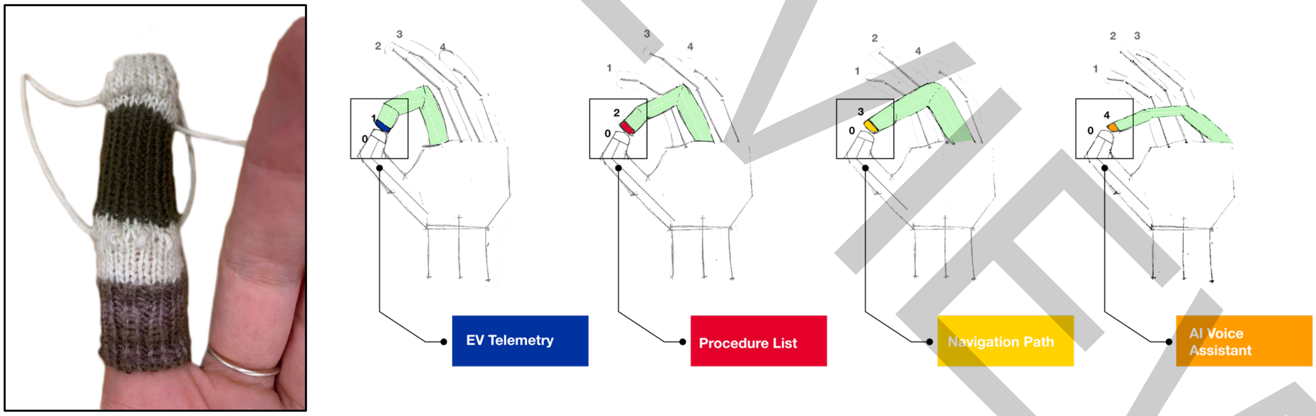
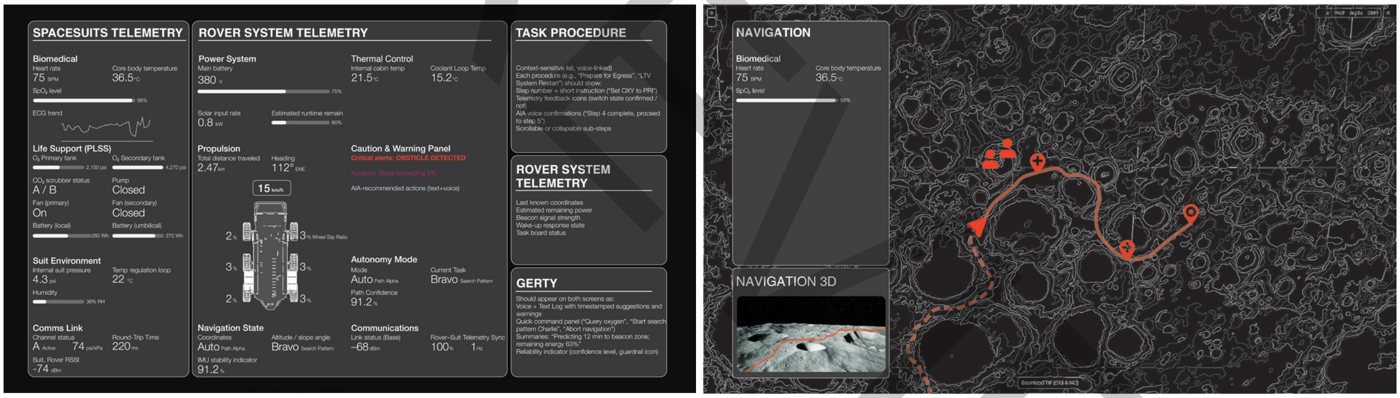


Figure 3: Glove Schematic & System Design

Figure 4: PR Dual Monitor UI Design



SPACESUITS TELEMETRY

Biomedical
Heart rate 75 BPM
Core body temperature 36.5 °C
SpO$_2$ level 98%
ECG trend

Life Support (PLSS)
O$_2$ Primary tank 2,150 psi
O$_2$ Secondary tank 4,270 psi
CO$_2$ scrubber status A / B
Pump Closed
Fan (primary) On
Fan (secondary) Closed
Battery (local) 260 Wh
Battery (umbilical) 270 Wh

Suit Environment
Internal suit pressure 4.3 psi
Temp regulation loop 22 °C
Humidity 38% RH

Comms Link
Channel status A Active 74 psi/kPa
Round-Trip Time 220 ms
Suit, Rover RSSI -74 dBm

ROVER SYSTEM TELEMETRY

Power System
Main battery 380 V 75%
Solar input rate 0.8 kW
Estimated runtime remain 80%

Thermal Control
Internal cabin temp 21.5 °C
Coolant Loop Temp 15.2 °C

Propulsion
Total distance traveled 2.47 km
Heading 112° ENE
15 km/h
2% 3% Wheel Slip Ratio
3% 3%
2% 3%

Caution & Warning Panel
Critical alerts: OBSTICLE DETECTED
Advisory: Slope exceeding 5%
AIA-recommended actions (text+voice)

Autonomy Mode
Mode Auto Path Alpha
Current Task Bravo Search Pattern
Path Confidence 91.2 %

Navigation State
Coordinates Auto Path Alpha
Altitude / slope angle Bravo Search Pattern
IMU stability indicator 91.2 %

Communications
Link status (Base) –68 dBm
Rover–Suit Telemetry Sync 100% 1 Hz

TASK PROCEDURE

Context-sensitive list, voice-linked)
Each procedure (e.g., "Prepare for Egress", "LTV System Restart") should show:
Step number + short instruction ("Set OXY to PRI")
Telemetry feedback icons (switch state confirmed / not)
AIA voice confirmations ("Step 4 complete, proceed to step 5")
Scrollable or collapsible sub-steps

ROVER SYSTEM TELEMETRY

Last known coordinates
Estimated remaining power
Beacon signal strength
Wake-up response state
Task board status

GERTY

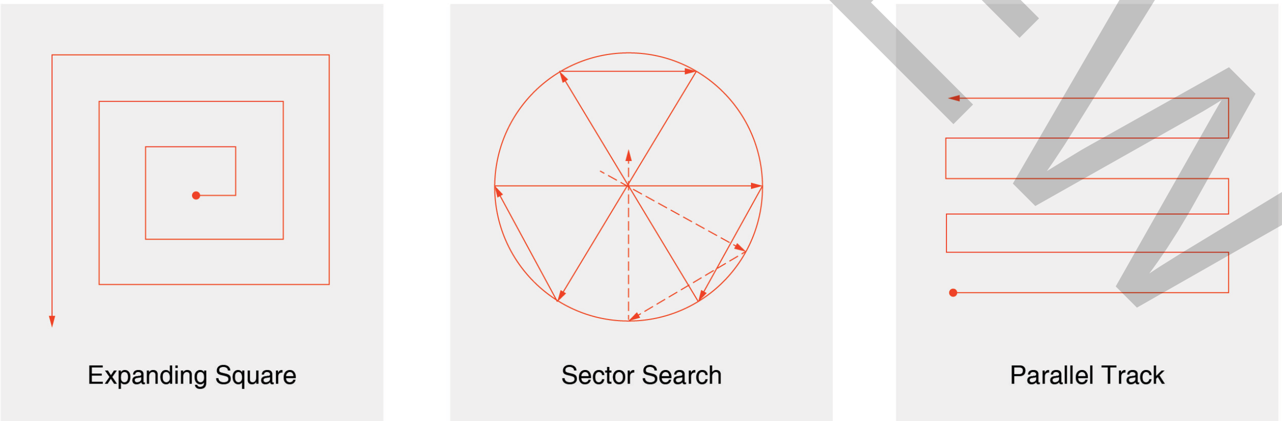
Should appear on both screens as:
Voice + Text Log with timestamped suggestions and warnings
Quick command panel ("Query oxygen", "Start search pattern Charlie", "Abort navigation")
Summaries: "Predicting 12 min to beacon zone; remaining energy 63%"
Reliability indicator (confidence level, guardrail icon)

NAVIGATION

Biomedical
Heart rate 75 BPM
Core body temperature 36.5 °C
SpO$_2$ level 98%

NAVIGATION 3D

Figure 5: Search Pattern Options

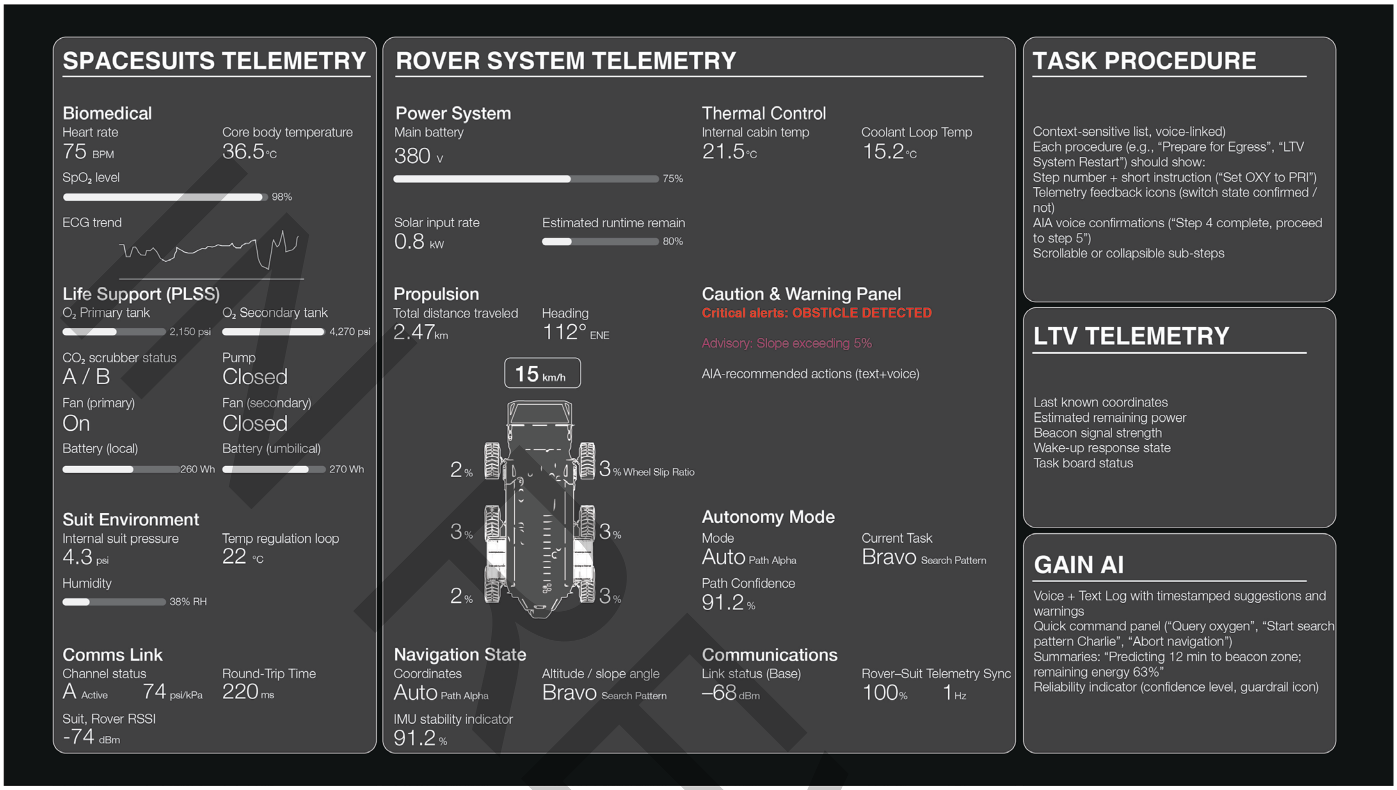


Expanding Square

Sector Search

Parallel Track

Figure 6: Screen 1 – Main System Display



SPACESUITS TELEMETRY

Biomedical
Heart rate: 75 BPM
Core body temperature: 36.5 °C
SpO₂ level: 98%
ECG trend

Life Support (PLSS)
O_2 Primary tank: 2,150 psi
O_2 Secondary tank: 4,270 psi
CO_2 scrubber status: A / B
Pump: Closed
Fan (primary): On
Fan (secondary): Closed
Battery (local): 260 Wh
Battery (umbilical): 270 Wh

Suit Environment
Internal suit pressure: 4.3 psi
Temp regulation loop: 22 °C
Humidity: 38% RH

Comms Link
Channel status: A Active 74 psi/kPa
Round-Trip Time: 220 ms
Suit, Rover RSSI: -74 dBm

ROVER SYSTEM TELEMETRY

Power System
Main battery: 380 V, 75%
Solar input rate: 0.8 kW
Estimated runtime remain: 80%

Thermal Control
Internal cabin temp: 21.5 °C
Coolant Loop Temp: 15.2 °C

Propulsion
Total distance traveled: 2.47 km
Heading: 112° ENE
15 km/h
2 % 3 % Wheel Slip Ratio
3 % 3 %
2 % 3 %

Caution & Warning Panel
Critical alerts: OBSTICLE DETECTED
Advisory: Slope exceeding 5%
AIA-recommended actions (text+voice)

Autonomy Mode
Mode: Auto Path Alpha
Current Task: Bravo Search Pattern
Path Confidence: 91.2 %

Navigation State
Coordinates: Auto Path Alpha
Altitude / slope angle: Bravo Search Pattern
IMU stability indicator: 91.2 %

Communications
Link status (Base): –68 dBm
Rover–Suit Telemetry Sync: 100% 1 Hz

TASK PROCEDURE

Context-sensitive list, voice-linked)
Each procedure (e.g., "Prepare for Egress", "LTV System Restart") should show:
Step number + short instruction ("Set OXY to PRI")
Telemetry feedback icons (switch state confirmed / not)
AIA voice confirmations ("Step 4 complete, proceed to step 5")
Scrollable or collapsible sub-steps

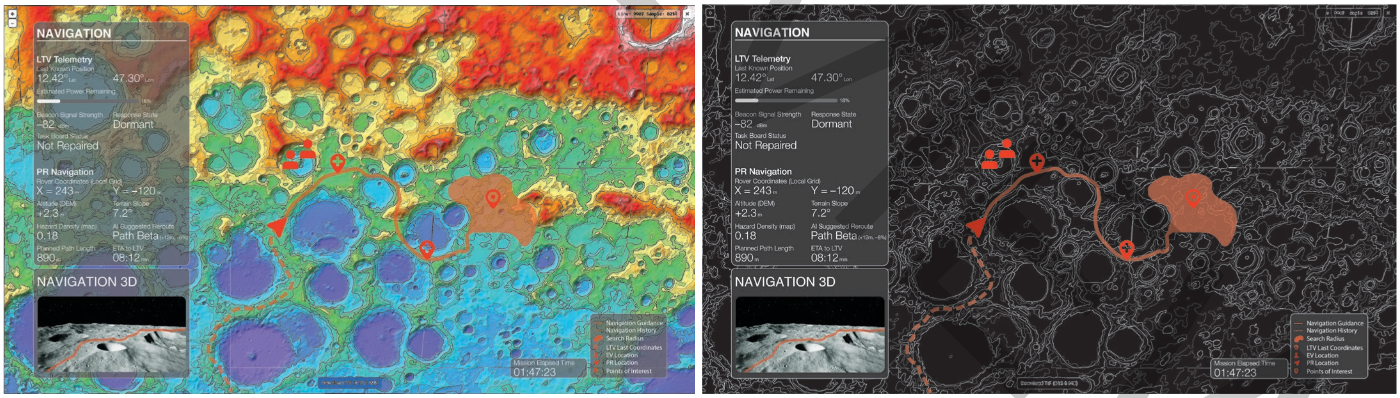
LTV TELEMETRY

Last known coordinates
Estimated remaining power
Beacon signal strength
Wake-up response state
Task board status

GAIN AI

Voice + Text Log with timestamped suggestions and warnings
Quick command panel ("Query oxygen", "Start search pattern Charlie", "Abort navigation")
Summaries: "Predicting 12 min to beacon zone; remaining energy 63%"
Reliability indicator (confidence level, guardrail icon)

Figure 7: Screen 2 – Navigation Display Terrain Mode vs Route Planning Mode



NAVIGATION

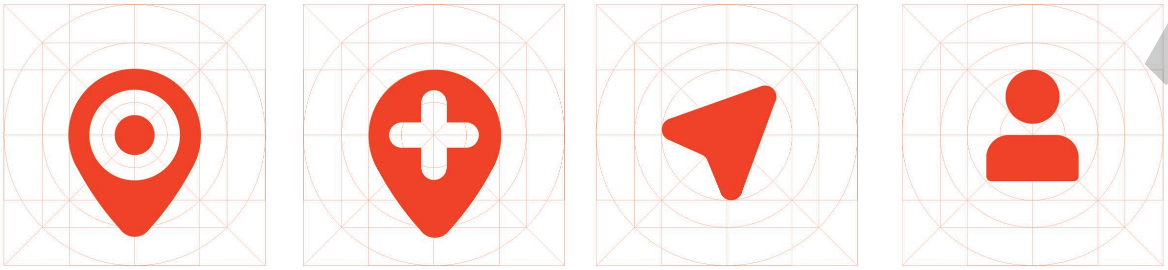
LTV Telemetry
Last Known Position: 12.42° Lat 47.30° Lon
Estimated Power Remaining: 18%
Beacon Signal Strength: –82 dBm
Response State: Dormant
Task Board Status: Not Repaired

PR Navigation
Rover Coordinates (Local Grid): X = 243 m Y = –120 m
Altitude (DEM): +2.3 m
Terrain Slope: 7.2°
Hazard Density (map): 0.18
AI Suggested Reroute: Path Beta (+12m, -8%)
Planned Path Length: 890 m
ETA to LTV: 08:12 min

NAVIGATION 3D

Mission Elapsed Time: 01:47:23

Figure 8: Icon Design for Navigation Display



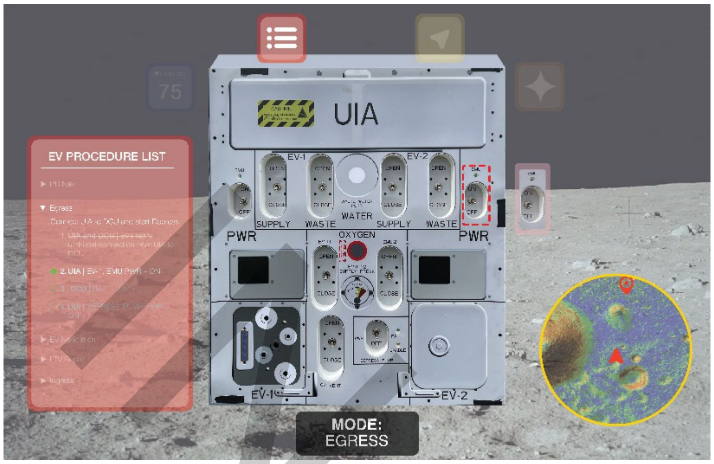


Figure 9: HUD UI for Egress

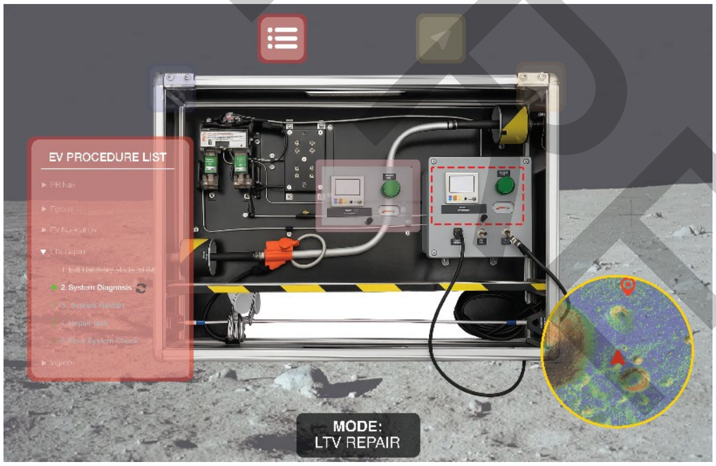
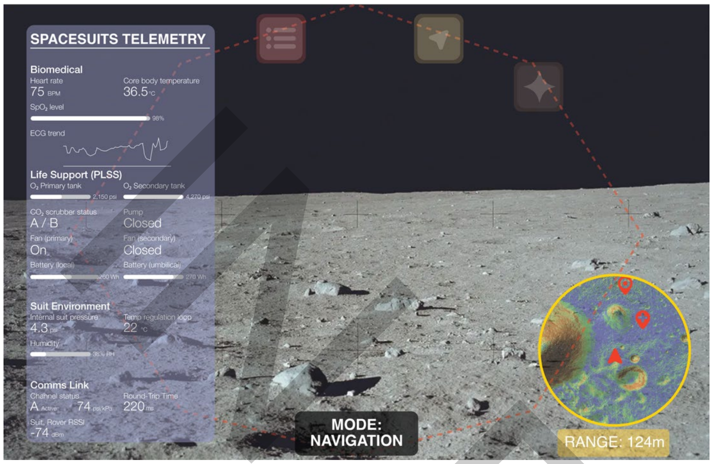


Figure 10: HUD UI for LTV Repair

Heads Up Display UI



SPACESUITS TELEMETRY

Biomedical
Heart rate: 75 BPM
Core body temperature: 36.5 °C
SpO$_2$ level: 98%
ECG trend

Life Support (PLSS)
O$_2$ Primary tank: 2,150 psi
O$_2$ Secondary tank: 4,270 psi
CO$_2$ scrubber status: A / B
Pump: Closed
Fan (primary): On
Fan (secondary): Closed
Battery (local): 260 Wh
Battery (umbilical): 270 Wh

Suit Environment
Internal suit pressure: 4.3 psi
Temp regulation loop: 22 °C
Humidity: 38% RH

Comms Link
Channel status: A Active 74 psi/kPa
Round-Trip Time: 220 ms
Suit, Rover RSSI: -74 dBm

Figure 10: EV Telemetry Full panel

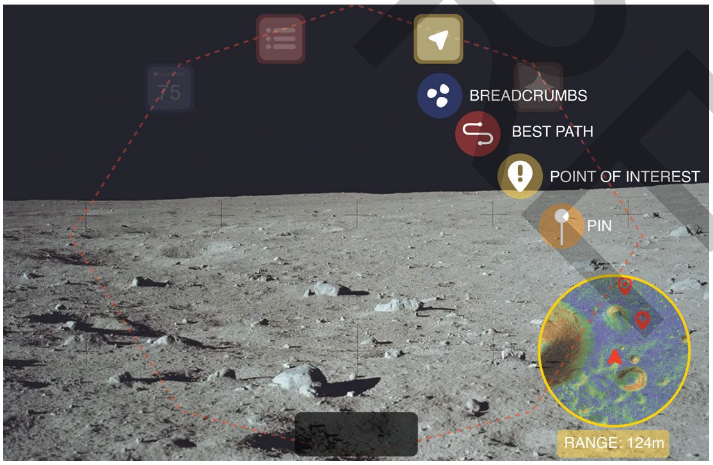
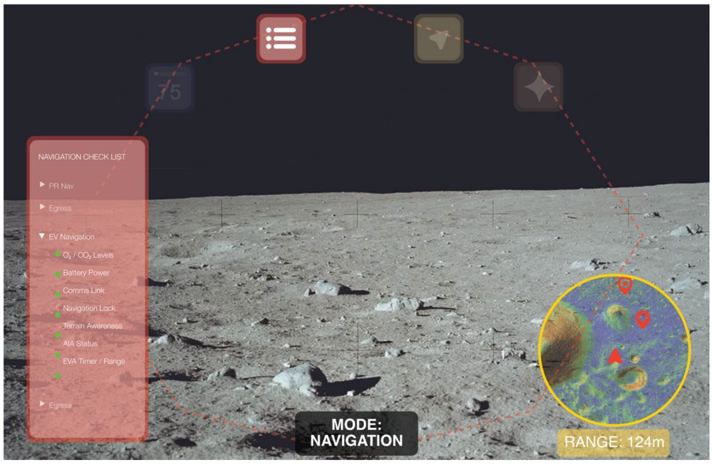


Figure 11: Navigation Sub Menu



NAVIGATION CHECK LIST
- PR Nav
- Egress
- EV Navigation
  - O$_2$ / CO$_2$ Levels
  - Battery Power
  - Comms Link
  - Navigation Lock
  - Terrain Awareness
  - AIA Status
  - EVA Timer / Range
- Egress

Figure 12: EVA Procedure List

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