University of Colorado
Department of Aerospace Engineering Sciences
ASEN 4018 Project Definition Document
S.A.I.L.R

Semi Autonomous Imaging Land Rover

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Approvals

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Problem Statement

On and off earth, there exist a variety of hazardous environments which are unsuitable for humans to explore. Recent developments in rover technology have allowed us to create more dynamic vehicles with the ability to handle a wider variety of environments at a reduced cost compared to previous rovers. The proposed benefit of this project is to create a small and capable rover that can remotely explore a variety of types of hazardous areas while transmitting video of its surroundings. This proposed rover shall be able to navigate semi-autonomously through difficult terrain and underbrush towards a location of interest with the capability of manual control (overriding the autonomous control). This rover provides a benchmark for the capability of small, multi-use, low cost rovers, which can be expanded upon for future use cases. Potential use cases include: a method for law enforcement to investigate dangerous situations; a means to explore places inhospitable to humans; and general terrestrial surveillance.

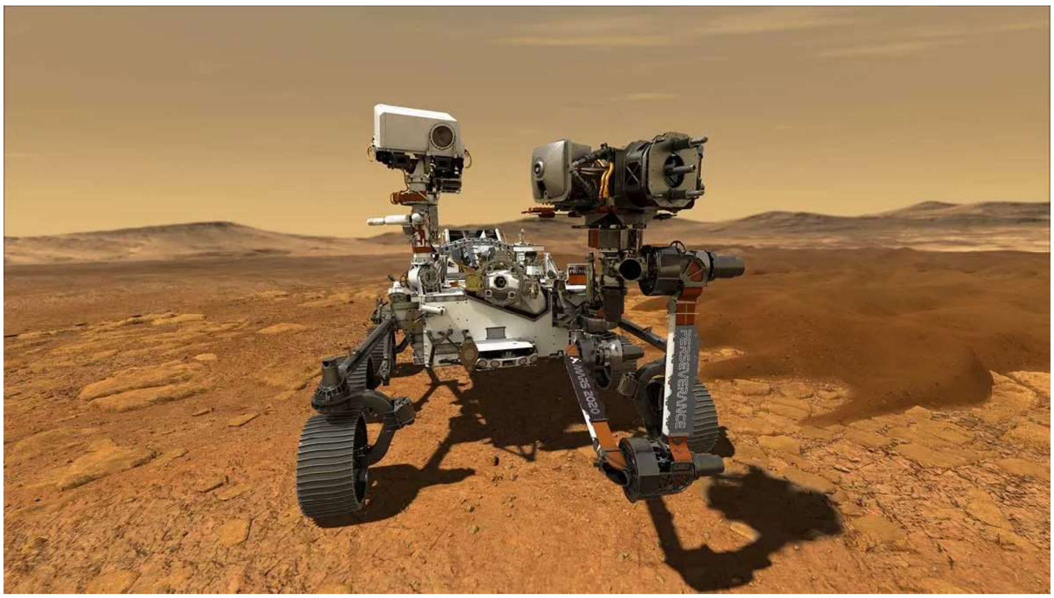

Figure 1: Perseverance Rover[3]

1. Previous Work

NASA's JPL has significant heritage regarding exploratory rovers such as Sojourner, Spirit, Opportunity, Curiosity and most recently Perseverance[1]. Rovers like these have been used for many years in space, and in other applications to explore areas where it may be unsafe or impractical for humans to explore. SAILR's small autonomous rover carries inspiration from the mission of these rovers, developing a small autonomous mobile rover to explore environments that are not suitable for humans to explore. Where our team focus differs from traditional rovers is developing a rover which can autonomously explore its environment and navigate to a location with no operator input. This level of autonomy has been experimented with on Earth through the MAARS program (Machine learning-based Analytics for Autonomous Rover Systems) at JPL, but has yet to be implemented in a Mars rover.

Another previous piece of work that we plan to leverage in the design of SAILR's rover is the JPL Open Source Rover Project[2]. This resource was developed by JPL to allow for individuals to design and build a low cost replica of the mars rover. The JPL Open Source Rover Project will provide a benchmark for the typical components, and design choices made on low cost small scale rovers. We also plan to reference previous senior projects teams' work on similar rover projects. While SAILR's footprint will be smaller than that of previous CU rovers sponsored by JPL, the team can draw inspiration from the electronics, communications, and software that was developed by these teams. Drawing upon all of these resources will be essential to the construction of team SAILR's rover.

2. Specific Objectives

Table 1: Specific Objectives

	Locomotion
Level 1	-Rover shall be able to move 100 meters in any direction from the starting location using autonomous control, manual control, and a combination of both -Rover shall be able to turn 360 degrees and move forward and backward using autonomous control, manual control, and a combination of both -Rover shall be able to move across flat, grassy terrain with no obstructions -Rover shall be able to move in line of sight of communications tower using autonomous control, manual control, and a combination of both
Level 2	-Rover shall be able to move across rolling terrain with underbrush such as sticks and rocks less than 3 inches in height -Rover shall be able to move with limited to no line of sight to communications tower using autonomous control, manual control, and a combination of both -Rover shall be able to navigate around obstructions using autonomous control, manual control, and a combination of both
	Communication
Level 1	-Rover shall be able to receive location coordinates from operator -Rover shall be able to send image and video back to operator -Rover shall be able to receive manual control from operator, and move with operator interaction
Level 2	-Rover shall be able to maintain communications with operator from at least 100m away
	Video Streaming
Level 1	-Rover shall be able to take continuous video while operating -Rover shall be able to stream live video of surroundings to operator
	Imaging
Level 1	-Rover shall be able to take time stamped images and panoramas at regular time intervals
Level 2	-Rover shall be able to take time stamped images and panoromas at the operators instruction
	Autonomy
Level 1	-Rover shall be able to move from current position to instructed location without operator interaction (no obstacles)

Level 2	-Rover shall be able to move from current position to instructed location without operator interaction (with obstacles) -Rover shall be able to survey and explore area without receiving instruction for location of interest
	Endurance
Level 1	-Rover shall be able to operate for TBD hours in typical mission environment
Level 2	-Rover shall be able to operate for TBD*2 hours in typical mission environment
	Footprint
Level 1	-Rover shall retain a footprint equal to or less than 1ft by 1ft (no height constraint)
Level 2	-Rover shall retain a footprint equal to or less than 1ft by 6 in (no height constraint)

Testing

In order to test the functionality of the rover, each subsystem's functionality will be tested in isolation. For example, the camera will be tested for functionality to ensure its resolution is sufficient prior to integration with the communications system. After all systems have been tested individually, they will be integrated and tested in a whole mission profile to include providing reconnaissance for an area, simulating losing GPS connectivity, and autonomously navigating between two locations.

3. High Level Functional Requirements

Table 2: High Level Functional Requirements

Number	Requirement	Rational
1	The method of locomotion shall enable the Rover to move and turn in any direction on various terrain.	Rover mobility allows for increased surveillance capabilities of the environment of interest.
2	The communications system shall be able to send and receive information from the ground station.	Ground station communications allows for user feedback in the event of failure or target location changes.
2.a	The communications system shall be able to send and receive data with the on board computer .	Internal communications allows for the implementation of user segment controls.
3	The communications system shall be able to transmit live video to the ground station.	Video transmission with the ground station provides real-time surveillance of the area of interest.
3.a	The communications system shall be able to transmit images to the ground station.	Image transfer between the rover and ground station allows for specific images of primary points of interest.
4	The automation system shall be able to control movement of the rover.	Rover automation allows for independent surveilling when ground station interaction is not

		possible.
5	The power delivery system shall be able to sustain the Rover last under battery for an extended period of time.	Rover endurance allows for more surveillance and longer operational time resulting in more use cases.
6	Rover shall have a footprint no larger than 1' x 1'.	A rover occupying a small footprint enables the rover to have greater mobility and access to areas of interest for surveillance.

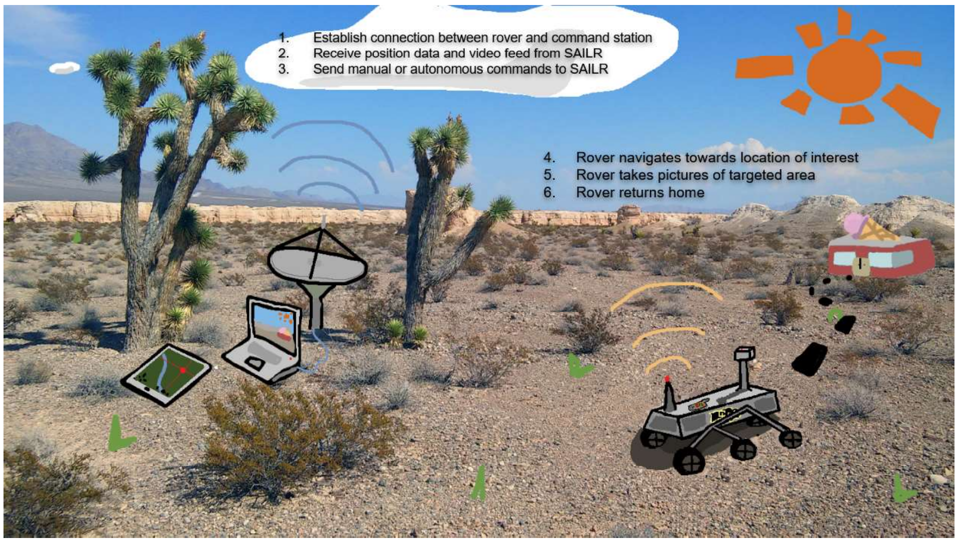

Figure 2: CONOPS

4. Critical Project Elements

Table 3: Critical Project Elements

Number	**Element**	**Description**
1	Locomotion	Locomotion encompasses the systems that receive controls from either the ground station or autonomous navigation system and transforms these signals into physical movement. These processes are vital to the project as a rover that is fixed in place or one that is incapable of turning, has no practical use in surveillance as these constraints severely limit mobility and therefore the information it can gather. The rover must also be able to navigate through underbrush thus it must have adequate traction capabilities to successfully do so.
2	Command and Control - Manual	A backup manual control system will be implemented as a safeguard in the event that the autonomous control of the rover fails. This element of manual control is necessary in the case of automation failure or required operator interaction.
3	Command and Control -	Critical operation systems in the command and control element include all systems that pertain to all guidance, navigation, and control systems. A primary example of these systems is ensuring the rover knows where the

	Automated	target location is relative to its position and determining how to navigate to this location. These systems may incorporate the integrated computer and software that controls the autonomous steering and converts them into movement instructions for the motors. These systems are critical as they ensure proper navigation of the rover through the environment and around obstacles as well as ensuring the return of the rover in the case of ground station connection loss. Remote processing will be used for automation* whereas local processing will be used for contingency operations in which the ground station signal is lost. *Remote processing is used for automation due to processing constraints limited by the rover's size.
4	Video Feed / Transmission	Video feed/transmission includes the camera and the video feed transmission to the ground station. Video can be processed either locally or remotely to the ground station for purposes explained in the *Command and Control - Automated* project element. Potential consequence of having an video failure include the inability to control the rover, and an inability to generate information about the location of interest
5	Ground Station	The ground station will monitor and process the functions of the rover. Manual control can be used at the ground station in the event automation fails. In the event of ground station loss, the rover should be able to return to its original position.
6	Power/Endurance	The battery must be capable of powering all systems for the duration of a typical mission. Endurance and power usage will depend on the weight of the battery, which has implications for other subsystems.
7	Integration into Rover	Integration pertains to integrating all of the previous critical projects elements into a single rover, and the successful interaction of the elements.

5. Sub-System Breakdown and Interdependencies

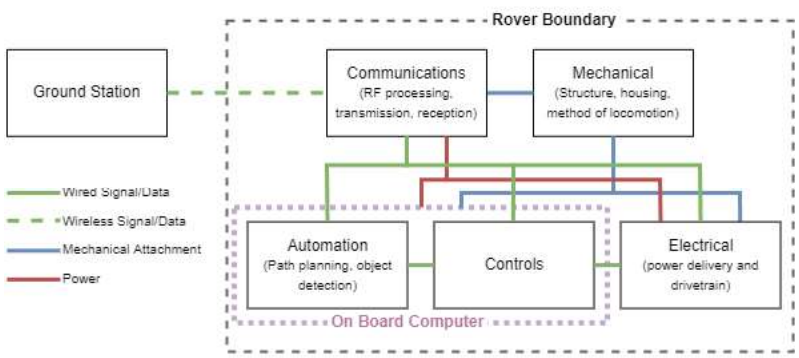

Figure 3: Subsystem Block Diagram

Table 4: Subteams

Subteam	Responsibilities	Members	Resources
Automation	Software development of obstacle detection and path planning algorithms for autonomous travel. Will collaborate with Electrical for relevant sensor and OBC selection.	**Trevor**, Suphakan, Luke, Noah	Rafi, Sunburg, Lahijanian
Communications	Component selection and software for RF transmission of commands, telemetry, imagery, and video between rover and ground station.	**Noah**, Sky, Caleb, Aidan	Schwarts, Akos
Controls	Software and hardware development for translating commands from the ground station controller into movements by the locomotion system of the rover.	**Sam**, Luke, Aidan, Caleb, Chris	Schwarts, Rafi
Electrical	Design of power delivery system, wiring, and drive train. Work with all subteams to select and verify electrical component selection such as sensors, computing units, and motors.	**Sky**, Noah, Caleb, Aidan	Schwarts, Akos
Mechanical	Design of the structure of the rover, component support and housing, and method of locomotion.	**Luca**, Chris, Robert	Rhodes, Lopez-Jimenez

*Team leads are **Bolded**

Team Skills and Interests

Table 5: Team Skill Table

Team Member	Skills & Interests	Critical Project Element Involvement (Fig.4)
Luca Barton	**Skills:** Manufacturing, woodworking, MATLAB, Solidworks, Ansys, Python, soldering **Interests:** Controls, 3-D Modeling, getting to use new equipment	*1,7*
Robert Beddome	**Skills:** Fabrication, MATLAB, management, CAD, Automation **Interests:** Mechanical, Controls	*Project Manager- will be supporting all CPEs*
Caleb Bristol	**Skills:** MATLAB, Python, C/C++/C#, SolidWorks, Raspberry Pi, Arduino, Soldering **Interests:** Electronics, Controls	*2,4,5,6*
Noah Freeland	**Skills:** MATLAB, Python, C++, Java, Git, SQL, Bash, Splunk **Interests:** Automation, Communications	*2,3,4,5*
Krystal Horton	**Skills:** Solidworks, Creo, Fusion 360, STK, Arduino, Raspberry Pi, soldering, welding, MATLAB, Python **Interests:** Manufacturing, Automation, & Controls	*Systems Engineer- will be supporting all CPEs*
Aidan Jones	**Skills:** MATLAB, Python, C, C++, Git, soldering **Interests:** Controls, Communications	*3,5,6*

Chris Nylund	**Skills:** MATLAB, Solidworks, Siemens NX, Fusion 360 **Interests:** Modeling and Simulation, Manufacturing Controls	*1,2,7*
Trevor Reed	**Skills:** IDL, CSTOL, STK, C++, Python3, MATLAB, Git, AI **Interests:** Automation, AI	*4,6*
Luke Roberson	**Skills:** Arduino, C++, Python3, MATLAB, Git, Altium, soldering **Interests:** Robotics, Controls	*3,4*
Skyler Schull	**Skills:** Arduino, Fabrication, git, MATLAB, Python3, Soldering, SOLIDWORKS **Interests:** Circuits/ circuit modeling program, Robotics	*2,3,7,8*
Sam Stewart	**Skills:** MATLAB, C++, Java, Solidworks, Soldering, Fabrication, Arduino **Interests:** Controls, Manufacturing	*2, 3, 7*
Suphakan Sukwong	**Skills:** MATLAB, C++, Python, Data Analysis, Algorithm Design **Interests:** Automation, Controls, AI	*4, 6*

Resources

At this point in the production of SAILR, the additional resources required to reach the defined critical project elements include outside expertise on rover design and controls, a wireless camera to send video to our ground station, and a controlled environment to test in.

References

[1] *"History." NASA, NASA, Available: https://www.jpl.nasa.gov/who-we-are/history.*

[2] *Nasa-Jpl. "NASA-JPL/Open-Source-Rover: A Build-It-Yourself, 6-Wheel Rover Based on the Rovers on Mars!" GitHub, NASA, https://github.com/nasa-jpl/open-source-rover.*

[3] *Ackerman, E., "Everything you need to know about NASA's Perseverance Rover Landing on Mars," IEEE Spectrum Available: https://spectrum.ieee.org/nasa-mars-rover-perseverance-landing.*

[4] *NASA. JPL Robotics: Machine learning-based analytics for Autonomous Rover Systems (MAARS), NASA, https://www-robotics.jpl.nasa.gov/what-we-do/research-tasks/machine-learning-based-analytics-for-autonomous-rover-systems-maars/*