SILAR

2024-2028

SILAR (Space Ice & Lunar Recon) Team

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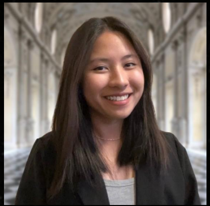

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Agenda

PDR

1 — 2 — 3 — 4

Mission Overview
- Mission Location
- Science Objectives
- Con-Ops

System Details
- System Integration
- Instrumentation & Data Collection
  - Architecture
    - Mechanical
    - Power
    - CDH
    - Thermal

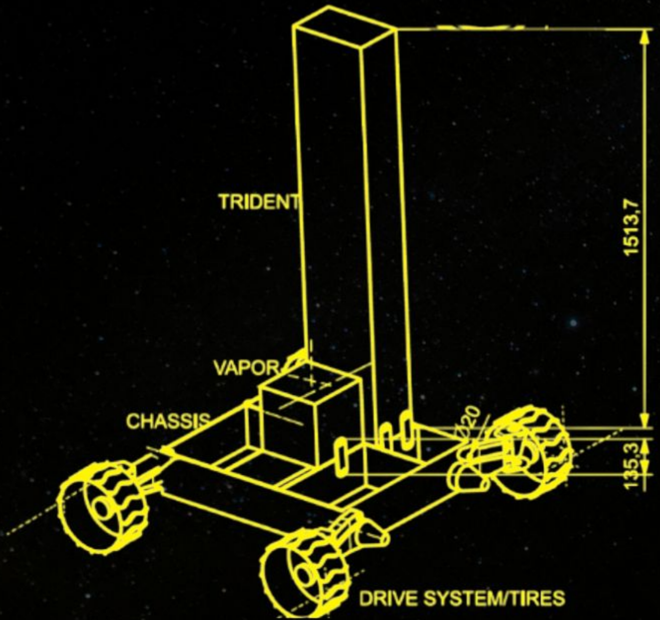
Programmatics
- Risk Management
- Failure Mode and Effect Analysis
- Budget
- Major Milestones

Conclusion

Appendix

SILAR Mission Overview

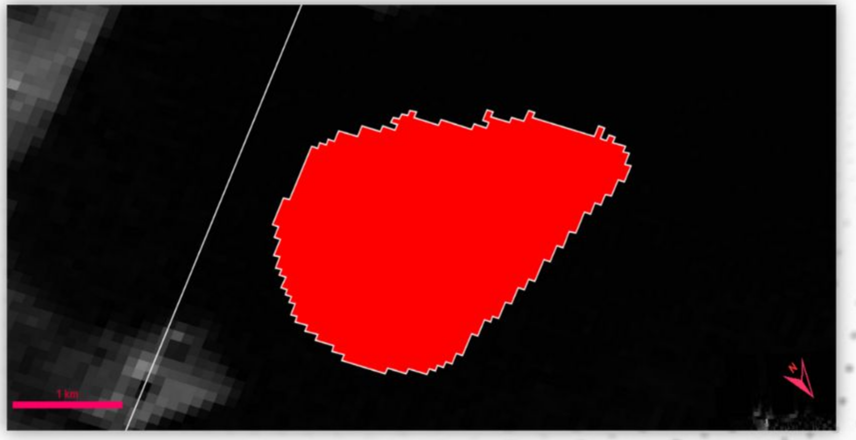
(Space Ice & Lunar Analysis Reconnaissance)



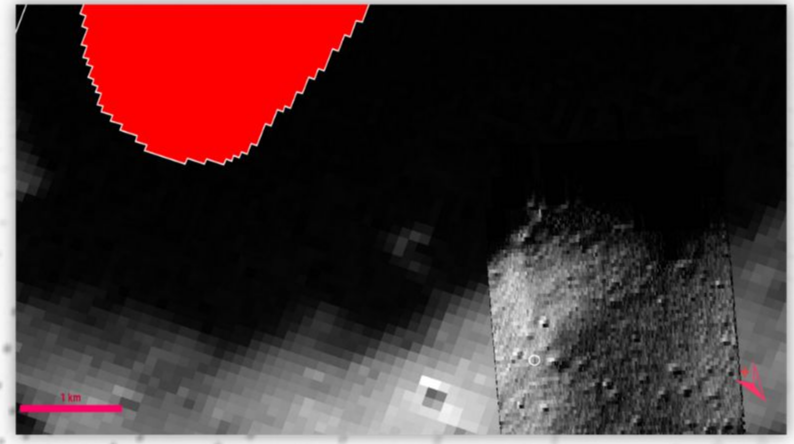
Mission Goals • Data Gathered • Mission Contribution to Future Missions

Mission Location

Peak near Shackleton Crater



Permanently Shadowed Regions



Landing Zone

Science Objectives

*Determine the **water ice abundance** in lunar regolith within and around Permanently Shadowed Regions (PSRs).*

- Determine **concentration of water ice** present in the lunar regolith.
- Determine the **depth of water ice** present in the lunar regolith to determine feasibility of use of water ice.

*Investigate **isotopic variations** in lunar regolith to understand ancient solar and cosmic ray activity.*

- Determine if solar activity has affected **isotope variation** in the lunar regolith.
- Determine the extent of **helium deposits** in the lunar regolith.

Big Idea How do water ice, helium, and isotopic variations in lunar regolith reveal the Moon's geological history and resource potential?

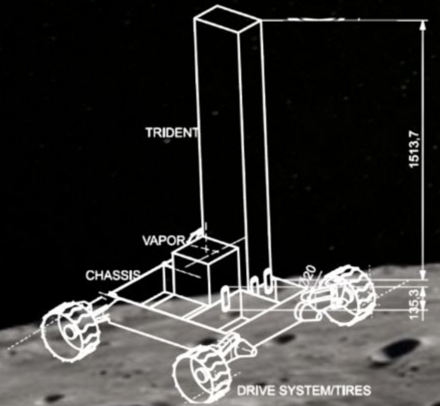
SILAR Team 17

Concept of Operations

T+1-2 days

Surface Deployment

·Arrives at landing site
·Instrument check
·Comms and telemetry check
·Awaits initial commands from ops
·Initial charging(9 hours)



T+2-6 days

Traverse Mode

·Rover stops outside PSR to fully charge batteries before entering
·Autonomous travel to site
·Average speed of 3km/day for 17km
·Telemetry sent every 2 hours
·About 6 days traverse mode

T+7-8 days

Science Mode

·Rover stops at science site
·TRIDENT Drill and COLDArm collect samples of regolith
·Samples are analyzed
·Takes about 10 hours for a sample collection

Data Uplink Mode

Collected data is sent to orbiting satellite

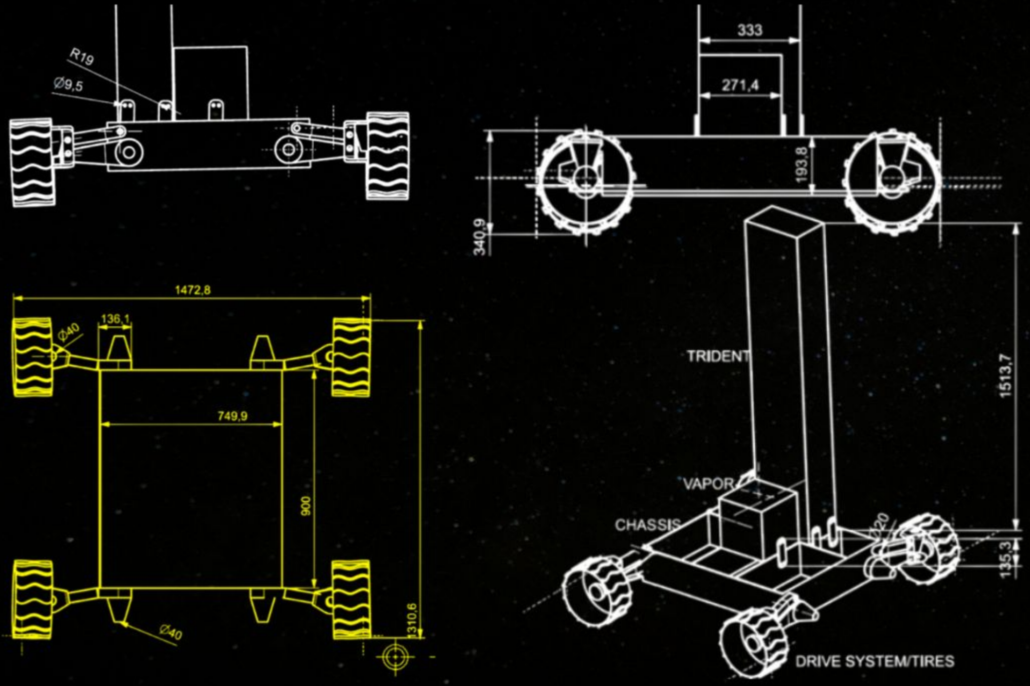
T+9-24 days

Rerun Operation

·Repeat traverse, science, and data uplink modes for mission duration.
·Will repeat for site 2 and site 3.

System Details

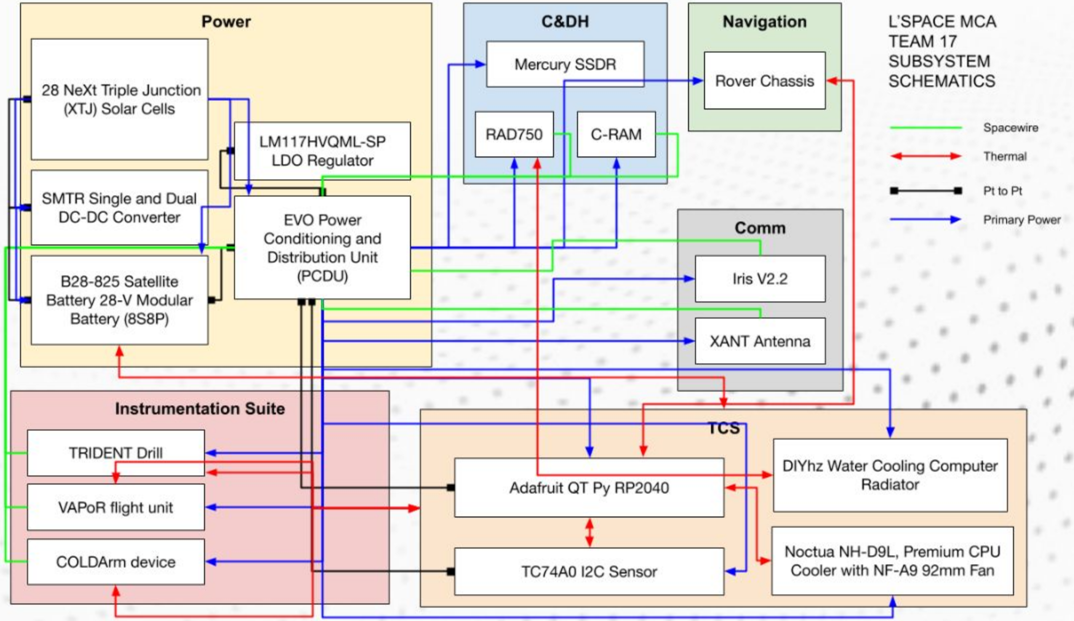
SILAR Rover Architecture



Subsystem	Mass	Volume	Max Power Draw
Mechanical Subsystem	38.928 kg	1.472 x 1.310 x 0.341 m	50W
Power Subsystem	151.16 kg	0.0254 m^3	2383.78W
CDH Subsystem	1,860.5 g	0.12m^2	230W
Thermal Subsystem	1,703.6 g	1443 in^3	11.3W
Payload Subsystem	35 kg	VAPoR: 200 cm^3 TRIDENT: 20.6cm x 33.3cm x 168cm	160W

System Integration

SILAR Block Diagram & N^2 Chart



Payload Instrument Suite: TRIDENT Drill VAPoR flight unit COLDArm device		Collected data Experiment & instrument status			
Sample collection data	**Data Handling** Mercury SSDR RAD750 C-RAM	Collected data uplink	Navigation and hazard data status	System thermal status	Power level & storage
Memory storage status	Sample collection commands	**Comms** Iris V2.2 XANT Antenna			
Terrain Data	Terrain Data Hazard detection Mobility Status		**Navigation** Rover Chassis		
Thermal Control	Thermal Control	Thermal Control	Thermal Control	**Thermal Management** DIYhz Radiator QT Py RP2040 Noctua NH-D9L TC74A0 I2C Sensor	Thermal Control
Power	Power	Power	Power	Power	**Power** XTJ Solar Cells EVO PCDU B28-825 Battery

Instrumentation & Data Collection

TRIDENT Drill

The Regolith Ice Drill for Exploring New Terrain

Function

Rotary percussive drill for sampling lunar regolith and ice in PSRs

Specifications

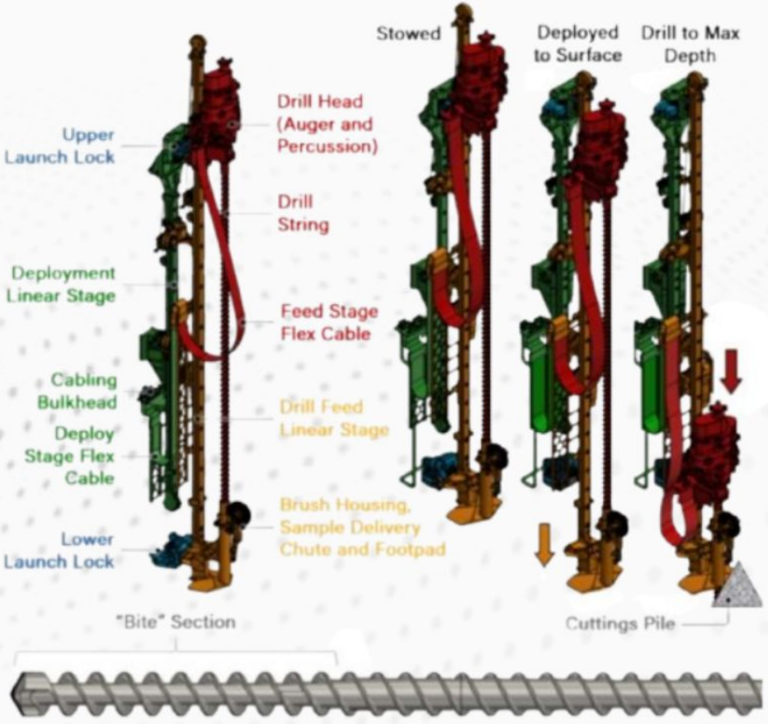
- Depth Capability: Up to 1 meter
- Weight: 20 kg
- Dimensions: 20.6 cm x 33.3 cm x 168 cm
- Maximum Power Draw: 100 Watts

Features

- Drills 10 cm at a time to avoid getting stuck.
- Deposits samples on the surface with a passive brush.
- Proven in previous missions with a TRL of 7.

Sample Handling

Samples are collected in a pile and transferred to the Solid Sample Intake Tube (SSIT) using the COLD arm.



Instrumentation & Data Collection

COLDArm

The Cold Operable Lunar Deployable Arm

Function

Robotic arm for handling samples and navigating extreme cold temperatures in PSRs

Specifications

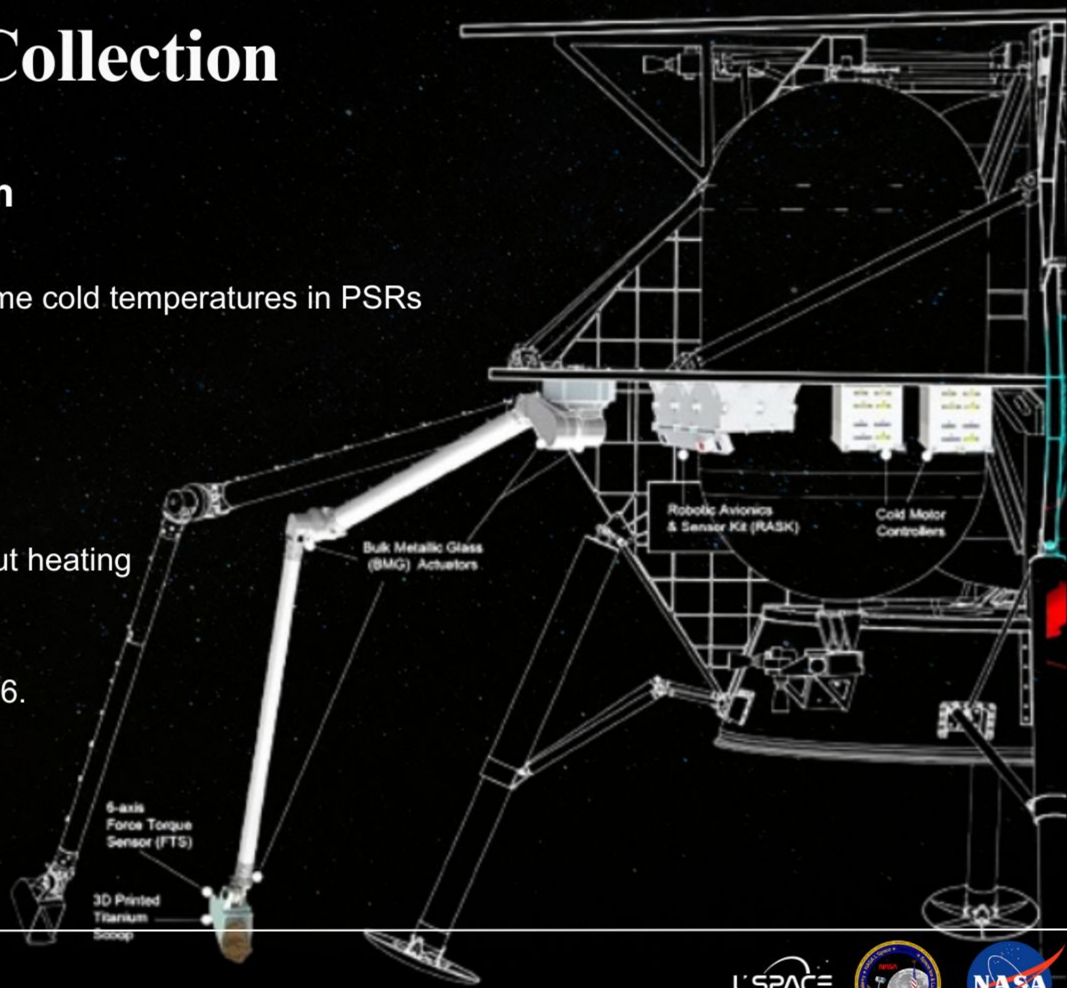
- Length: 6.5 feet
- Scoop Movement: Four directions

Features

- Designed with gears and motors that operate without heating components.
- Saves power for effective sample collection.
- Tested in extreme cold environments with a TRL of 6.

Development

Created by NASA's Jet Propulsion Laboratory (JPL).



Instrumentation & Data Collection

VAPoR System

Volatile Analysis by Pyrolysis of Regolith

Purpose

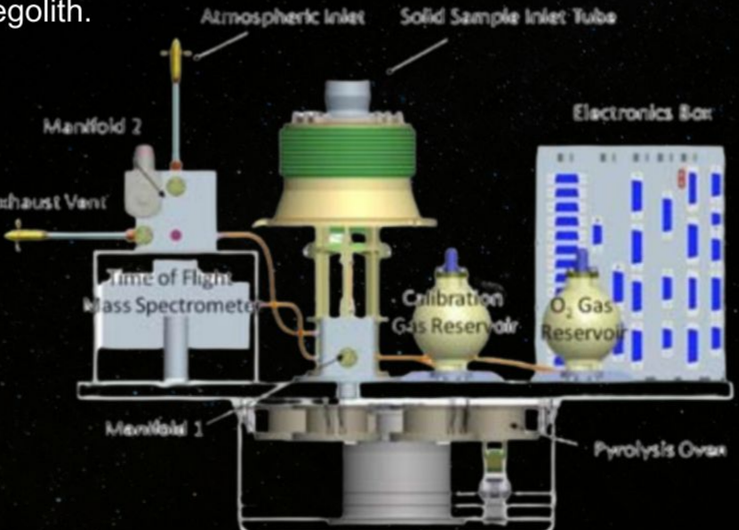
Detects water and noble gases in lunar regolith.

Specifications

- Weight: 10-15 kg
- Dimensions: Approximately 20 dm^3
- Power Consumption: 50-60 Watts
- Temperature Range: Up to 1400°C

Sample Processing

- Solid Sample Intake Tube (SSIT): Receives crushed lunar regolith from the COLD arm.
- Analysis: Quadrupole mass spectrometer identifies isotopes like He-3, He-4, and H_2O.



TRL: 16

Components

- Pyrolysis Crucibles: Six ovens to heat samples and release noble gases.
- Mass Spectrometer: Miniature TOF-MS with sensitivity of 10^-4 (counts/second)/(particle/cc), mass resolution range of ~500 m/Δm.
- Residual Gas Analyzer: Sensitivity of 2 x 10^-4 A/torr.
- Atmospheric Inlet: Directly collects samples from around the spacecraft.
- Getter and Atmospheric Outlet: Enrich noble gases before analysis.

Data Collection

VAPoR Spectrometer

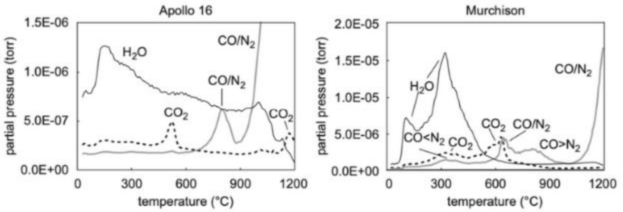


Fig. 5. Water, CO/N_2, and CO_2 evolved gas profiles as function of temperature for Apollo 16 and Murchison. Please note different scales on *y*-axis.

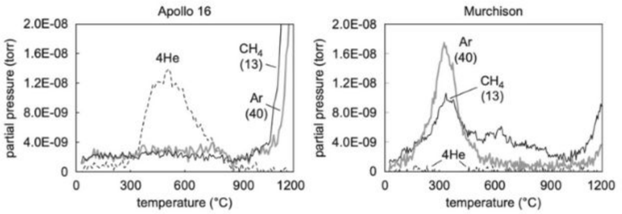


Fig. 6. Noble gases helium and argon, and methane (represented by m/z 13) evolved gas profiles as function of temperature for Apollo 16 and Murchison. The CH-fragment, m/z 13, of methane is shown because the methane contribution in its other fragments (12, 14, 15, 16, and 17) is too small to be distinguishable from other fragments at these m/zs. Please note different scales on *y*-axis.

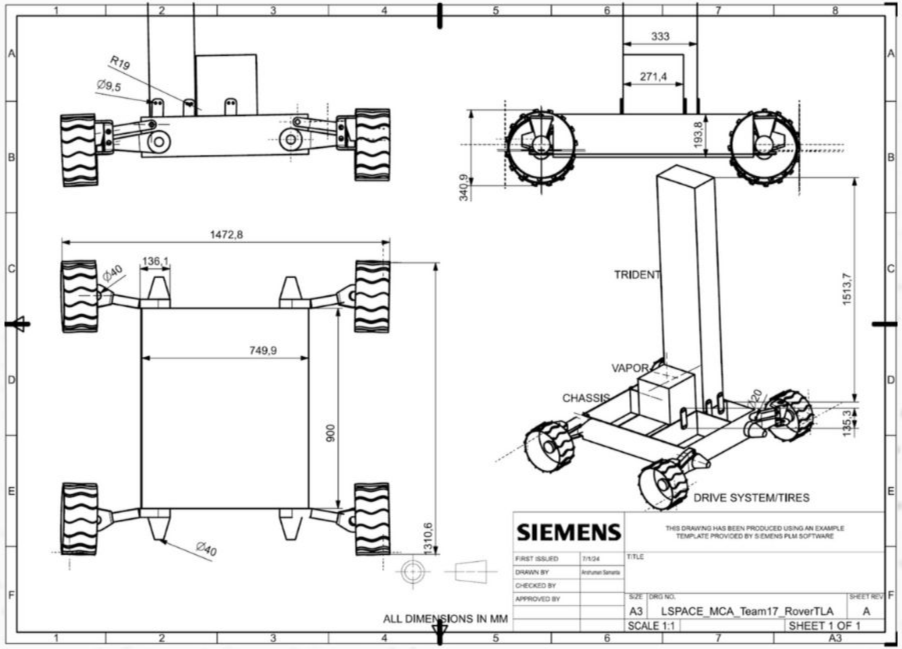
Table 1. Release temperatures of gases targeted by the VAPoR pyrolysis mass spectrometer instrument for compound identification and isotopic analyses.[17]

	VAPoR target gases	Temperature range (°C)
CHONS-Inorganics	Atmospheric volatiles	Not applicable
	H_2O, H_2, CO_2, CO, N_2, SO_2	0-1400[6, 7, 18]
	$^{13}C/^{12}C$ ratio of CO_2	100-1400[18]
	$^{15}N/^{14}N$ ratio in N_2	600-1400[18]
	HDO/H_2O ratio	0-1400
Noble Gases	He, Ne, Ar	300-1400[18, 19]
	Isotope ratios ($^3He/^4He$, $^{36}Ar/^{40}Ar$)	He: 200-500[5] Ar: 300-1400[18, 20]
Organics	$^{13}C/^{12}C$ ratio in CO_2 from organics combustion	400-500[19]
	Volatile hydrocarbons: methane, ethane, benzene, amines, alcohols, formaldehyde	300-1000[18]
Other Resources	Water-ice in regolith	0-100
	O_2	1100-1400[5]
	Reduced inorganic gases such as HCN, NH_3, and H_2S	HCN/NH_3: 100-900[18] H_2S: 700-1300[6]
	^3He relative abundance	He: 200-500[5]
	^3He relative abundance	He: 200-500[5]

Release temperatures of different compounds, and 2010 VAPoR analysis of the temperature vs partial pressure of compounds from an Apollo 16 sample.

Mechanical Subsystem

Overview



SILAR's Hereditary Design

NASA's VIPER(Volatiles Investigating Polar Exploration) Rover

Mechanical Subsystem

Requirements

MEC-1	The system shall be confined to a volume of 0.139 cubic meters before deployment.
MEC-2	The system shall not exceed a total mass of 85kg.
MEC-3	The system shall not contain more than 5g of radioactive material.
MEC-4	The subsystem shall maintain, protect, and effectively integrate all components and motion-related requirements.
MEC-4.1	The subsystem shall protect components from abrasive wear from lunar regolith.
MEC-4.2	The subsystem shall maintain stability while traversing crater slopes.
MEC-4.3	The subsystem shall protect core components from motion-related damage during operation.
MEC-4.3.1	The subsystem shall keep instrumentation within +-0.05 inches of motion relative to the chassis during motion.

General

The subsystem requirements ensure the proper support and operation of all mission requirements and instrumentation, based on lunar surface research and possible risks to mitigate for when designing.

Mechanical Subsystem

Design

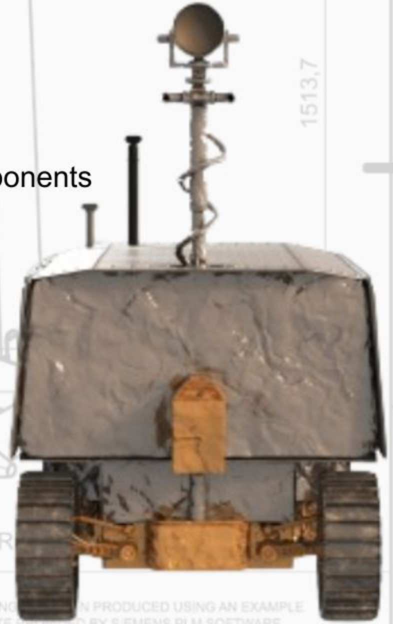
SILAR Design Features

Sub-assembly Integration

Suspension System
Active suspension for lifting wheels and enhancing mobility

Payload Integration
Custom panels and fasteners for secure payload mounting

Protection
Multi-layer insulation and shell structure to protect critical components



Chassis

- Mass: 38.928 kg
- Volume: 1.472 x 1.310 x 0.341 m
- Max Power Draw: 50W
- TRL: 3 (based on VIPER rover design)

- Ribs for added support
- Aluminum for lightweight and thermal management
- Mounts for power, thermal devices, communication, & instrumentation

Tires

- Mass: 3.1488 kg
- Volume: 0.0004021 m³
- Max Power Draw: 0W
- TRL: 6 (improved design from ORNL)

- Additive manufacturing with curved tread profiles
- Improved grip and regolith displacement

Power Subsystem

Requirements

EPS-1	The system shall not contain a Radioisotope Thermoelectric Generator (RTG) or derivative of such.
EPS-2	The system shall power all necessary components for mission completion.
EPS-2.1	The system shall provide continuous power to the payload instruments.
EPS-2.2	The system shall have a battery capacity sufficient for at least 14 days of continuous operation.
EPS-2.3	The system shall have a solar array capable of recharging the batteries within 10 hours of lunar daylight.
EPS-2.4	The system shall include a power management and distribution unit(PMAD) to regulate power usage.
EPS-3	The power subsystem shall operate within the temperature range of 88-100K.

General

The power subsystem must ensure consistent, reliable power distribution across all rover components, addressing the harsh space environment and varying operational needs.

Power Subsystem

Power Distribution & Management

System Operation Phases

Surface Deployment → **Traverse Mode** → **Science Mode** → **Charging Periods**

Data Uplink Mode → **Charging Periods**

Surface Deployment

·Period for rover charging while performing checks
·Reduced power needs as rover awaits commands and completes charging

Traverse Mode

·Powers thermal, CDH, and mechanical subsystems while traversing
·Solar cells recharge the battery during the day

Science Mode

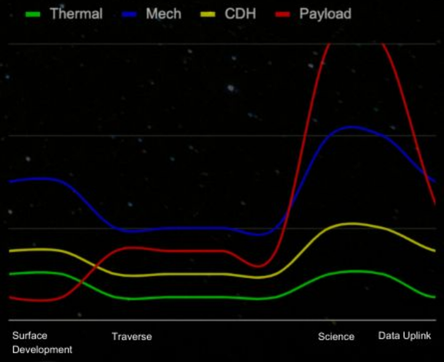
·Increased power needs for payload instruments and CDH during science tasks and data transmission

Data Uplink Mode

·The power subsystem will allocate increased power to the CDH system, communication systems, payload subsystems, and data storage devices

Charging Periods

Additional reduced power usage during stops for charging and before commencing science operations



Power Management

- Solar Cells: Generate power to be stored in the battery.
- DC-DC Converter: Ensures appropriate voltage levels are supplied to rover components.
- PCDU: Distributes power across subsystems efficiently.
- Regulator: Maintains constant DC voltage for system stability.

Power Subsystem

Components

Objective: Ensure reliable and efficient power distribution of SILAR across the various phases of the mission.

NeXt Triple Junction (XTJ) Solar Panel

- High-efficiency **(29.5%)**
- Compact size for rover integration
- Space-proven with **TRL 6**

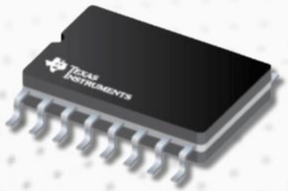
B28-825 Satellite Battery

- Capacity: **825 Watt-hours**
- Radiation and fault tolerant
- **TRL 5**, designed for spacecraft

SMTR DC-DC Converter

- Efficiency: **84%**
- Wide temperature range, radiation tolerant
- **TRL 5**, robust performance

LM117HVQML-SP LDO Regulator



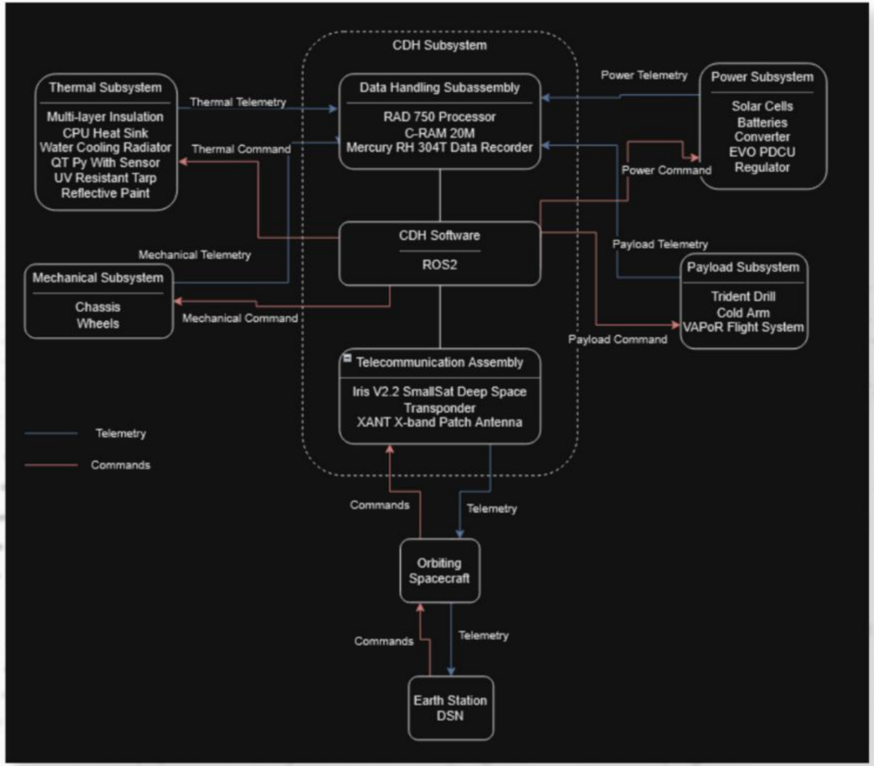
- Designed for interplanetary missions
- Long design lifetime
- **TRL 5**, high reliability

EVO PDCU

- High radiation tolerance
- Adjustable output, thermal protection
- Flight proven with **TRL 6**

Command & Handling Subsystem

Overview



CDH Flow Chart

CDH Subsystem

Requirements

CDH-1	**General** The CDH system will be responsible for interfacing with the orbiting spacecraft to relay communication to Earth.
CDH-1.1	The subsystem communicates directly with the designated orbiting spacecraft.
CDH-2	The subsystem must transmit to the distance of the orbiting spacecraft in a circular polar orbit at 100km.
CDH-2.1	Subsystem functions in environmental hazards present in the lunar environment.
CDH-2.2	Subsystem tolerates radiation levels of up to 1.14 rad
CDH-3	Subsystem is protected from lunar dust containing fine, sharp, sedimentary particles.
CDH-4	Subsystem relays telemetry and commands to other subsystems The subsystem can receive data and telemetry from the other subsystems

CDH Subsystem

Components

OBC: RAD750

<u>TRL</u>: 8
Manufactured by: *BAE Systems*
Tolerates up to **200 krad**
Up to **200 Mhz**
Used in past NASA rover and orbiter missions

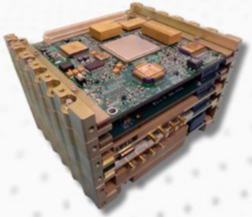
C-RAM 20M

<u>TRL</u>: 6
Manufactured by: *BAE Systems*
256k x 8 bits
Single bit error correction

Mercury RH304T SSDR

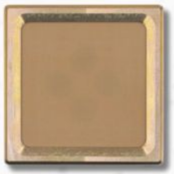
<u>TRL</u>:8
Manufactured by: *Mercury Systems*
4.5 TB of storage
Protection against potential issues

Iris V2.2 SmallSat Deep Space Transponder



<u>TRL</u>: 8
Manufactured by: *NASA Jet Propulsion Laboratory*
Compatible with many networks

XANT X-band Patch Antenna



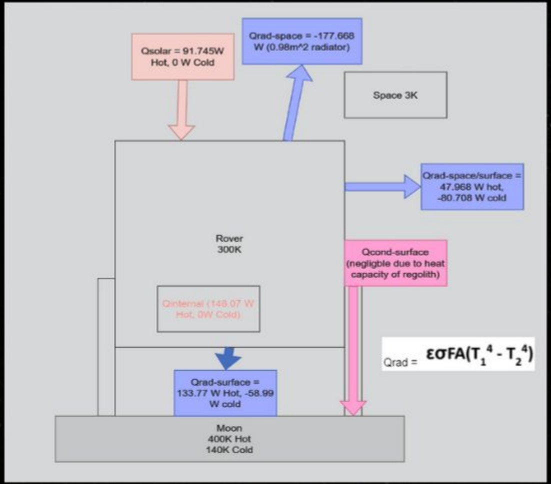
<u>TRL</u>: 6
Manufactured by: *Cubecom*
Integrated radome preventing erosion
8-8.4 GHZ band
Max gain of **8 dbi**

ROS2

<u>TRL</u>: 6
Manufactured by: *ROS*
Open source

Thermal Subsystem

Heat Transfer



Heat Transfer Flow Map

Space is assumed to be 3K with the moon in the sunlit phase at 400K, and in shadow at 130K. Regolith is assumed to have a near infinite heat capacity and thus conduction heat transfer is irrelevant.

Thermal Subsystem

Requirements

TCS-1
TCS-1.1
TCS-1.1.1
TCS-1.2
TCS-1.2.1
TCS-1.2.2
TCS-1.3

General

The thermal subsystem must ensure that all subsystems are within an operable temperature range at about 300K.

- System shall regulate itself to an appropriate temperature range for functionality of all components.
- System shall not go below 138 K and above 358 K to ensure the proper functionality of all components
- System shall generate 50 W of heat to support temperature control
- System shall prevent both overheating and excessive heat loss
- System shall utilize a Multi-Layer Insulation to mitigate temperatures passively
- System shall use a radiator to expel any excess heat passively
- System shall have protective barriers on critical parts

Thermal Subsystem

Components

Multi-Layer Insulation

Manufactured by:
Insulation4Less

- Prevents 97% of radiant heat transfer
- Reflective foil and Polyethylene
- 30 sq ft

UV Tarp

Manufactured by:
Tarps&All

- UV resistant
- Vinyl
- 16 sq ft

PR-W15 Ultra Pure White

Manufactured by:
Behr Paint

- Colors
- High reflectivity
- 1 qt

Noctua NH-D9L

Manufactured by:
Noctua

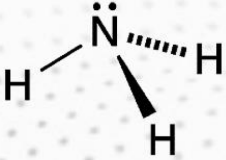
1.2 W
3.74" x 3.74" x 4.33"

Computer Radiator

Manufactured by:
DIYhz

7.2 W
15.5" x 1.18" x 4.72"

Liquid Ammonium



Provided by:
Airgas

Liquid from
196-240K

Qt Py RP2040

Manufactured by:
Adafruit

2 W
0.9" x 0.7" x 0.2"

Programmatics

Overview

Project Management Approach

All sub-teams have their own hierarchy for smooth deliveries of tasks

Additional 5 scientists, 20 engineers, 10 technicians, 4 administrators, 5 managers (YEAR 1)

Change Control Management

Changes are approved by Project Manager

Change Request Form and Change Control Board

Change Tracking Document

Scope Control Management

Downscoping: Budget and Personnel Assessments

Risk Management

Analyses

LIKELIHOOD	1	2	3	4	5
5	20	17	19		
4		22		8, 15	
3	28		7		
2		29		16	
1		21	30		31
	CONSEQUENCES				

Risk Analysis Graphic

ID	Summary	L	C	Trend	Approach	Risk Statement	Status
1	Mechanical	4	2	➡	Accept	Given that the lunar surface contains abrasive particles and dust, exposure to the lunar environment may cause abrasion to exposed components, creating small wear and damage.	Active
2	Mechanical	1	4	⬇	Mitigate	Due to the vehicle being close to the ground, debris could reach and damage the motor, causing motor failure and preventing function and mobility of the vehicle.	Active
3	Mechanical	2	3	⬇	Accept	Because of the variations in the lunar surface, the wheels of the rover could get stuck, disrupting the vehicle's only method of transportation and causing a loss of vehicle mobility and function.	Active
4	Mechanical	1	3	⬇	Mitigate	Given that chassis balance is required for full mobility of the vehicle, uneven payload distribution may cause the chassis to be unevenly balanced, limiting the mobility of the vehicle.	Active
5	Mechanical	3	2	➡	Accept	Given that the rover will disturb the lunar regolith as it moves, it could develop a build up of regolith in the interacting mechanical parts, causing a loss of function.	Active
6	Mechanical	3	2	➡	Accept	Given that motion sensing devices will be necessary for accurately maneuvering the spacecraft, lunar regolith disturbed by vehicle motion may obscure motion sensing devices, creating difficulty in maneuvering the spacecraft.	Active
7	Mechanical	3	3	⬇	Research	Given that extreme cold can impair the function of mechanical components, The extreme cold could have an impact on the mechanical subsystem, causing a loss of function to the rover.	Active
8	Mechanical	4	4	⬇	Research	Given that traveling can cause vibrations, the vibrations from traveling could cause the mechanical subsystem to break during transit, causing a loss of movement and measurement capabilities.	Active
9	Power				Mitigate	Given that exposure to the sun is necessary to keep power flowing through the rover, all electronics apart from the power supply must be shielded by insulation in order to prevent disablement by solar electromagnetic pulses.	Active
10	Power				Accept	Due to the fact that the power subsystem cannot self repair in the event that even one section shorts or overheats, the rover may gain even more power-related issues which will affect every other subsystem.	Active
11	CDH	2	5	⬇	Mitigate	Given that there is a large amount of solar radiation in the lunar environment, there is a possibility of critical components becoming damaged by radiation, causing failure of hardware components, resulting in data received from science instruments not being sent to the orbiting spacecraft.	Active
12	CDH	1	5	➡	Accept	Due to the fact that the CDH subsystem only includes one data recorder, if the data recorder becomes damaged, there is no redundancy for that component, and the system will not have a method of storing data.	Active
13	CDH	2	4	⬇	Mitigate	Due to the extreme cold of the lunar environment, there is a possibility that critical components could be exposed to temperatures outside of their functioning range, causing the CDH subsystem to malfunction.	Active
14	CDH	2	5	➡	Accept	Due to the fact that the CDH subsystem only contains one transponder, if the transponder is damaged, there is no redundancy for that component, preventing communication.	Active
15	Thermal	4	4	➡	Mitigate	Given that the lunar regolith is an abrasive and infiltrating substance, there is a high chance that dust covers exposed thermal units like radiators, reducing their thermal management capacity and stopping the proper regulation of internal temperatures.	Active
16	Thermal	4	2	➡	Accept	Given that many thermal cycles can affect the integrity of materials, there is likelihood that thermal materials like radiators or blankets will suffer some structural integrity compromises, which may affect thermal regulation performance by small amounts.	Active
17	Instrumentation	2	5	➡	Accept	Given that there is only one copy of each instrumentation payload and scientific instrument, there is a possibility one may spontaneously fail, resulting in an inability to collect, transmit, or analyze samples, ultimately leading to a lack of data.	Active

Risk Analysis Table

18	Instrumentation	2	3	➡	Research	As the VAPoR system favors smaller particle size when sampling, it is possible that some samples of lunar regolith drilled by TRIDENT are slightly larger than preferred, leading to potentially inaccurate measurements about volatiles in lunar regolith, resulting in skewed data.	Active
19	Instrumentation	3	5	⬇	Mitigate	Given that connection to the CDH subsystem is necessary for science instruments to function, hazards such as vibrations from vehicle movement could disconnect the science instruments, reducing articulation abilities and sample collection efficacy.	Active
20	Instrumentation	1	5	➡	Research	Given that the vacuum seal in the oven is necessary for sample analysis, vibrations from motion could damage the vacuum seal, disrupting the collection and accuracy of data.	Active
21	Instrumentation	2	1	➡	Accept	Considering that the mission aims to create an understanding of the volatiles and water ice present on the moon, the rover could land in a location with a lower than average quantity of water ice and volatiles, causing the instrumentation to not be able to create an accurate data collection.	Active
22	Instrumentation	2	4	➡	Mitigate	Given that the drill is susceptible to damage when collecting samples, sample collection could cause the drill to get stuck, resulting in a loss of viable sample collection.	Active
23	Instrumentation	4	4	➡	Research	Given that traveling will create vibrations in the rover, traveling on the lunar surface could cause vibrations that could dislodge, break, disrupt, or impair the function of science instruments, preventing accurate sample collection.	Active
24	Programmatics	3	5	➡	Accept	Given that there is a limited budget for the mission control, there is a possibility of overestimating the costs of development, resulting in the need to make unexpected budget cuts to compensate, thus failing to mitigate financial risks associated with the project.	Active
25	Programmatics			➡	Accept	Given the reliance on cutting-edge technology for key mission components, there is a possibility of unforeseen technical challenges or delays, affecting the development and integration of critical systems, potentially leading to significant schedule slippage, cost overruns, or compromised mission capabilities .	Active
26	Planetary Protection	2	2	➡	Accept	Given that future missions may be conducted to confirm or elaborate on the findings of this mission, the sample collection done on the moon during this mission may disrupt the available samples, causing future missions to collect inaccurate data.	Active
27	Planetary Protection	3	2	⬇	Mitigate	Given that the samples could become damaged during collection, removing samples from the regolith could cause the samples to become contaminated.	Active
28	Planetary Protection	1	3	⬇	Mitigate	Given that there are materials on the rover that could be harmful to the lunar environment, chemicals and materials could leak onto the moon, changing the makeup and safety of the lunar surface.	Active
29	Environmental	2	2	⬇	Accept	Given that the rover will be conducting sample collection, The removal of samples could cause a disruption to the lunar environment, possibly releasing new volatiles into the environment.	Active
30	Environmental	3	1	⬇	Accept	Given that sample collection removes substances from the environment, the collection of samples could cause a change of composition to the lunar regolith.	Active
31	Environmental	5	1	⬇	Accept	Given that the rover is not from the lunar environment, if the rover is not returned to earth, the rover will become environmental debris on the moon's surface.	Active

Risk Analysis Table(Continued)

Risk Management

Failure Mode and Effect Analysis (FMEA)

Function	Failure Mode	Effects	Sev	Cause	Occ	Prevention	Det	RPN	Actions
Mechanical Subsystem - Motor	Debris could get into the motor from the lunar surface.	Motor gets clogged and fails to run properly.	9	Risk was accepted rather than mitigated.	5	Build protections or coverings around motor.	4	180	Reenforce coverings around motor.
	Motor is close to the ground and could scrape lunar surface.	Motor is scraped and damaged, or is entirely broken.	8	Testing was skipped to determine proper motor placement.	7	Determine a motor height that gives it appropritate clearance.	2	112	Redesign motor to be in a different location on the spacecraft.
	Electrical issues could stop the motor from recieving power.	Motor loses power and stops functioning.	10	Components could be manufactured or connected improperly.	6	Test to make sure electrcal and motor systems are wired properly and are responding promptly.	2	120	Add redundancies for power connections to the motor.
Mechanical Subsystem - Vibrations	Vibrations could cause different components of the spacecraft to break during the mission.	Spacecraft could have a limited range of motion due to damage.	7	Strength testing of mechanical subsystem was not completed.	6	Complete vibrational tests of the spacecraft to see how it responds to	2	84	Modify spacecraft design to become more resistant to vibration damage.
		Instrumentation subsystem could fail to measure and record scientific	10	Instrumentation subsystem was not tested for vibrations.	8	Secure and test components of instrumentation subsystem.	3	240	Further reenforce instrumentation components.
		Thermal protections could break or malfunction, exposing the spacecraft to extreme cold.	8	Vibrational tests were not completed and breaking points were not discovered.	7	Test temperatures to see how components function when exposed to extreme cold.	4	224	Add extra thermal protections or reenforce existing thermal proections.

Function	Failure Mode	Effects	Sev	Cause	Occ	Prevention	Det	RPN	Actions
CDH Subsystem- Error Codes	There is a possibility that there will be one or more errors in the version of Robot Operating System 2 installed on the rover	Freezes system for rover	8	Broken Code	5	Code Break Down	4	160	Review code several times
		Can't process ground commands	8	Contengincies in the code have come to a halt	7	Peer Review Code	4	224	Test code
		Can't transmit data to orbiter	9						Simulate code in said enviroment
				Malfunction, Reboot	2	Shut rover off accidently	5		
Thermal Subsystem	There is a possibility that critical components could be exposed to temperatures outside of their functioning range.	The CDH subsystem to malfunction	9	Improper installation	5	Inspection of unit	1	45	Descope to insulation alternatives
		Mechanical Systems over work	8	Insulation is broken	6				
		Electrical Systems condensate	9			Simulated Enviroment Testing			Longer Verification process

FMEA Table

Function	Failure Mode	Effects	Sev	Cause	Occ	Prevention	Det	RPN	Actions
Thermal Sub-System	There is a high chance that dust covers exposed thermal units.	Reduces their thermal management capacity	9	Given that the lunar regolith is an abrasive and infiltrating substance	4	Model simulation	3	108	Further Testing
		Stops the proper regulation of internal temperatures.	8			Simulated Enviroment testing			Inspection of all seals
Power Sub-System- Solar	Solar Power heats up other components	Heats up internal components	9	Lack of solar ray deterants	8	Conduct proper research for components used	4	288	Simulation Testing
	Inefficient battery charge	Mission behind schedule	8	Improper electrical components	7		3	168	Material Science Specialist Involvement
	Solar panels are dusty, scratched	Can't absorb the suns rays to charge batteries	10	Incorrect material for solar panels	5		1	50	FEA model simulation

Function	Failure Mode	Effects	Sev	Cause	Occ	Prevention	Det	RPN	Actions
Programmatic subsystem	Going over budget	Budget cuts for other departments	10	Unexpected errors, fines, penalties	6	Follow regulations and policies	1	60	Training for all Personnel
	Going over schedule	Less time to do other admin tasks	8	Short Staff due to illness, personal reasons	8	Have a back up plan and personnel	3	192	Reward system for coming to work
	Poor Scope Management	Budget and Timelines spents on the wrong objectives	8	Poor priority setting	6	Hire Management with similar company interests and experience	8	384	Training and meeting on the objectives of the company

FMEA Table (Continued)

Budget

Cost Breakdown Analysis

Overall Budget: $175 million

Personnel: $31,190,701

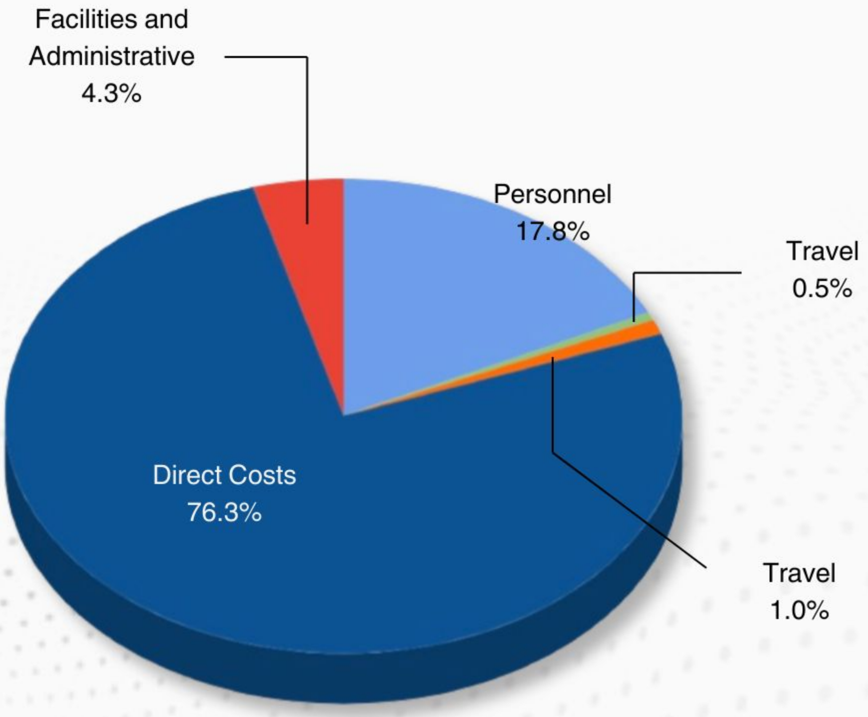
Travel: $931,330

Outreach: $1,774,370

Direct Costs: $133,443,478

Facilities and Administrative: $7,547,548

Overall Mission Total Margin: $39,849,400



Mission Schedule

Major Milestones

High Level View of Mission Schedule (Phase C-F)

Task	Start Date	End Date	Days
System Integration Review (SIR)	8/29/2024	5/30/2026	640
Post-Launch Assessment Review (PLAR)	5/17/2026	09/23/2028	861
Decommissioning Review (DR)	9/24/2028	10/25/2028	32
Final Archival of Data	9/25/2028	12/10/2028	77


SILAR
2024-2028
Conclusion
Preliminary Design Review Summary • Future Plans