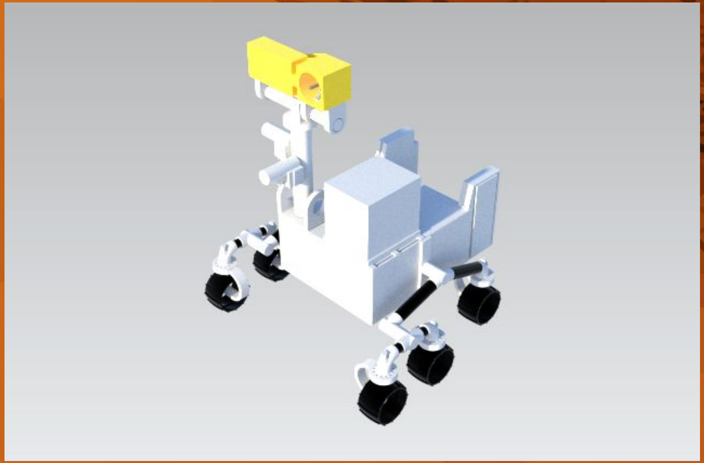
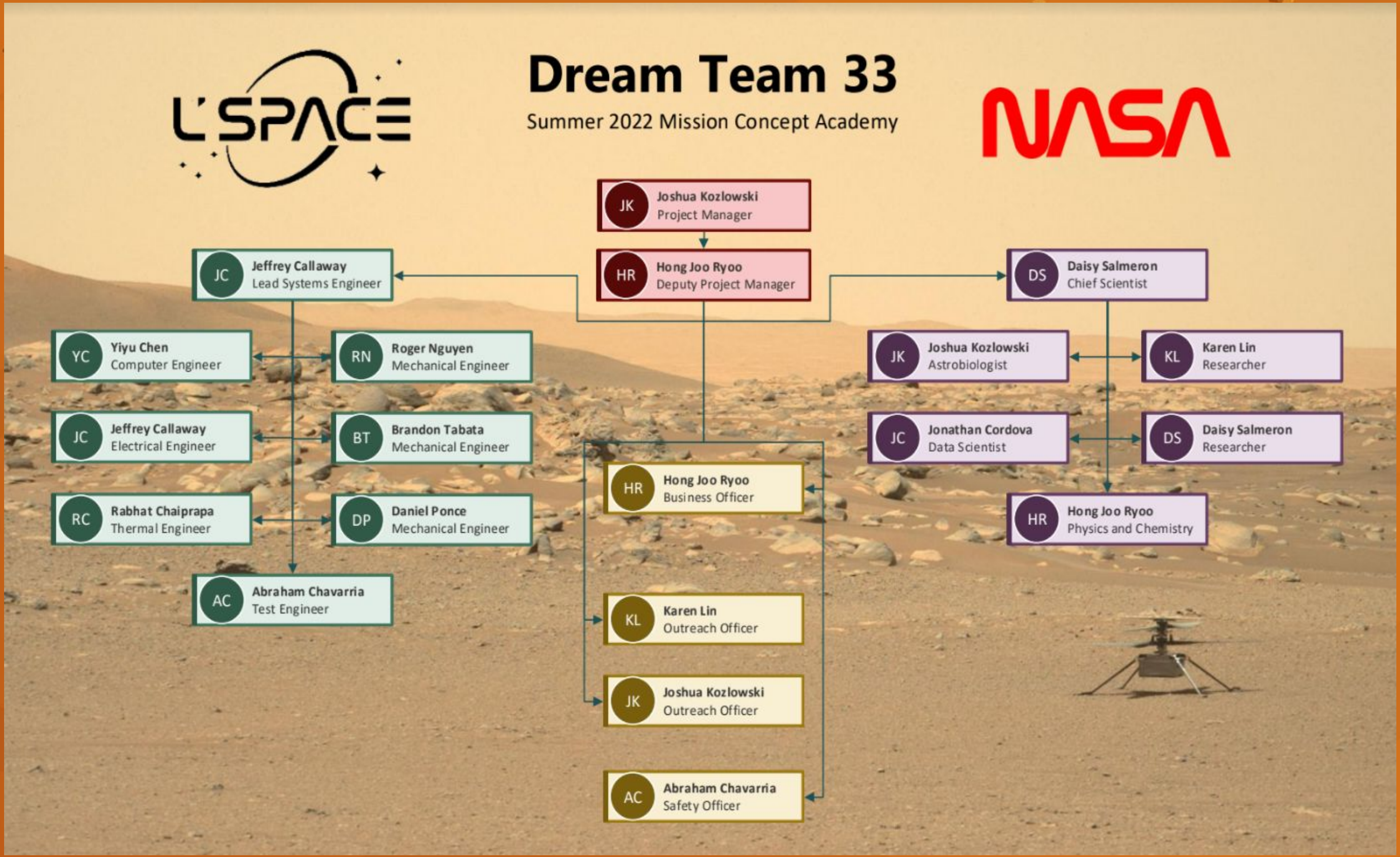
Dream Team 33

Astrobiological Spelunking Martian Robot (A.S.M.R.)



Team 33: Jeffrey Callaway, Rabhat Chaiprapa, Abraham Chavarria, Jonathan Cordova, Roger Nguyen, Hong Joo Ryoo, Brandon Tabata
Daniel Ponce, Daisy Salmeron, Yiyu Chen, Qianyi Lin, Joshua Kozlowski


L'SPACE
Dream Team 33
Summer 2022 Mission Concept Academy
NASA
JK Joshua Kozlowski Project Manager
HR Hong Joo Ryoo Deputy Project Manager
JC Jeffrey Callaway Lead Systems Engineer
YC Yiyu Chen Computer Engineer
RN Roger Nguyen Mechanical Engineer
JC Jeffrey Callaway Electrical Engineer
BT Brandon Tabata Mechanical Engineer
RC Rabhat Chaiprapa Thermal Engineer
DP Daniel Ponce Mechanical Engineer
AC Abraham Chavarria Test Engineer
HR Hong Joo Ryoo Business Officer
KL Karen Lin Outreach Officer
JK Joshua Kozlowski Outreach Officer
AC Abraham Chavarria Safety Officer
DS Daisy Salmeron Chief Scientist
JK Joshua Kozlowski Astrobiologist
KL Karen Lin Researcher
JC Jonathan Cordova Data Scientist
DS Daisy Salmeron Researcher
HR Hong Joo Ryoo Physics and Chemistry

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Mission Objectives, Requirements, & Constraints

The purpose of this mission is to further human understanding of the Martian cave environment by gathering information pertaining to the topics of astrobiology, especially whether life could have existed in the past and if life can exist in the future.

Weight of System: 48.62 kg

Volume of System: 0.98 x 1.00 x 1.19 meter cube

Budget: $259 million/$300 million

Req #	Requirement	Rationale	Parent Req	Child Req	Verification method	Relevant Subsystem
SYS.01	Determine the percent abundance of water ice within the Martian cave.	Science goal 1 for the mission.	STM		Science Review	All
SYS.02	System shall collect data on atmospheric samples within the cave.	Science goal 2 for the mission.	STM	FUN.01	Science Review	All
SYS.03	Determine the viability of human habititation in the radiation environment within the Martian caves.	Science goal 3 for the mission.	STM		Science Review	All
SYS.04	System shall send and receive data to Earth ground station.	Necessary for both remote operations, and for sending instrument data.	Customer		Demonstration	Communications
FUN.01	System shall be capable of recording and storing data.	It is necessary to store data before radio transmission to Earth.	SYS.02		Analysis and Modeling	Instruments
FUN.02	System shall have sufficient power to operate for 2 weeks duration.	System needs power for operations, communication, and instruments.	None		Demonstration	Electrical
PER.01	System shall be able to withstand thermal environment of a Martian cave for 2 weeks duration.	The mission needs to be able to survive the extreme environments on the surface and within the Martian caves.	None		Demonstration	Thermal, Electrical
PER.02	System shall have the ability to manuever into, and around the cave.	Probe must enter cave, and manuever to points of scientific interest.	None		Demonstration	Mechanical, Software
CON.01	System will not exceed a mass of 50kg.	Defined by primary payload's targeted mass.	None		Inspection	Mechanical
CON.01	System will not exceed a volume of 1.5 cubic meters.	This requirement was given by the customer	None		Inspection	Mehcanical

Science Objectives

- Science Objective #1: Measure and map water evidence within the Martian caves
  -ChemCam
- Science Objective #2: Determine biological molecules existence within water-ice within the Martian caves
  -ChemCam and PIXL
- Science Objective #3: Determine atmospheric patterns and methane concentration with Martian caves
  -TLS and REMS

- The STM provides the science objectives to be seen more in depth, in a visual and analytical manner as shown

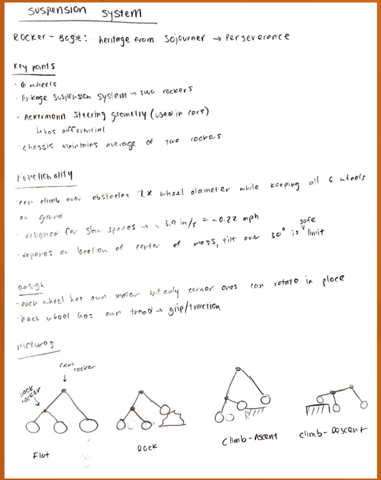
Science Goals	Science Objectives	Science Measurement Requirements		Instrument Performance Requirements		Instrument	Mission Requirements
		Physical Parameters	Observables				
Do Martian caves present past or present evidence of life or demonstrate habitibility for any life?	Measure and map water evidence within the Martian caves	Identify ice and minerals with water molecules in their crystal structures	Detect Hoarfroast formation	Distance from subject	<7 meters	ChemCam	Determine the percent abundance of water ice within the Martian cave
			Detects fallen ice crystals	Size of laser	1 mm		
	Determine the existence of biological molecules within water-ice within the Martian Caves.	Identify key elemnts for life in particular, Hydrogen (H), Nitrogen (N), Carbon (C), Oxygen (O), Phosphorous (P), and Sulfur (S).	Detect materials within the 2 - 535 Dalton range	Pixel Resolution	1024 x 1024 CCD		viability of human habitation in the radiation environment within the
				Wavelength Range:	240 - 850 nm		
			Collect elemental composition of regolith up to 10's ppm level	Beam Diameter	0.12 mm	Planetary Instrument for X-ray Lithochemstry (PIXL)	
				Measurement of elements	0.5 wt%		
	Determine the atmospheric patterns and methane concentration within the Martian caves.	Identify the methane gas concentration at various depths	Detect concentrations of methane gas in ppbv	Spatial Resolution	~ 2 - 10 um	Tunable Laser Spectrometer (TLS)	System shall collect data on atmospheric samples within the cave.
				Instrument Performance Req. Parameter 10	Instrument Performance Req. Value 10		
		Measure atmoshperic properties within the cave	Collect atmospheric pressure and temperature data	Temperature detection Range	-130 C - 70 C	Rover Environmental Monitoring Station (REMS)	
				Humidity Range	200 - 323 K		

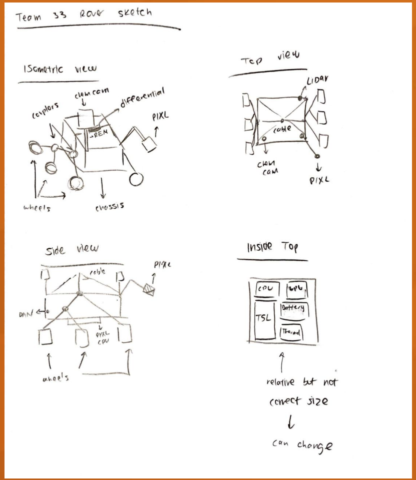
Early Mechanical System of Rover

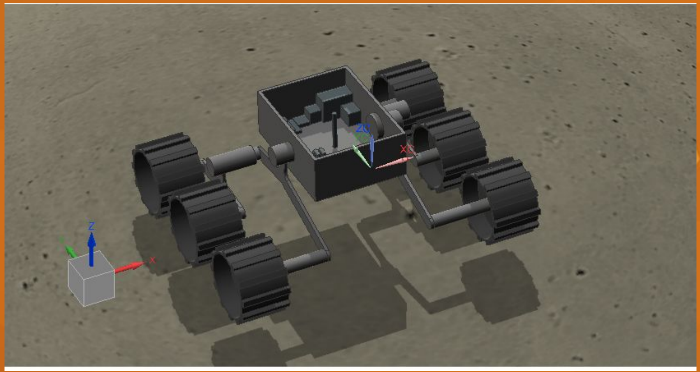
- Based on Perseverance and Curiosity Rover
- Wheels were chosen to be the best option for the mission based on Trade Study
- Rocker-bogie suspension to traverse the cave terrain
- Warm electronics box chassis (WEB) to protect and hold electronics will be used.

Drive Train Trade Study

Criteria	Explanation	Grade	Weight	Lemur 3	Spot	Tread Tank	Wheels
Relative Mechanical Complexity	More complexity requires more research, testing, and analysis	1: New concept 4: Easy to make	10.00%	2	2.5	4	4
Relative Software Complexity	More complexity requires more research, testing, and is prone to errors	1: New concept 4: Existing tested software	10.00%	2	2	4	4
Relative Cost	Budget constraints	1: Expensive 4: Economic	15.00%	2	2	3	4
Relative Mass	Mass constraints	1: Heavy 4: Light	15.00%	3	2	1	2
Power Efficiency	Life of mission depends on power	1: Not very efficient 4: Very efficient	10.00%	1	2	4	4
Mobility in Cave	Necessary to explore cave structure and gather data/take measurements	1: Can only travel on flat terrain 4: Can travel on all types of cave environments	20.00%	4	3	2	2
Relative Speed (assuming Ideal Conditions)	Slower speed means longer mission	1: Slow 4: Fast	5.00%	1	2.5	4	4
Heritage	More heritage means higher confidence since a previous design is being used	1: In Development 4: Tested in Martian Mission	15.00%	1	2	3	3.5
		TOTAL	100.00%	28.13%	28.44%	35.63%	40.31%

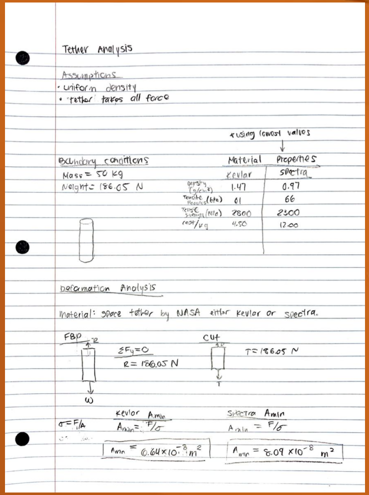


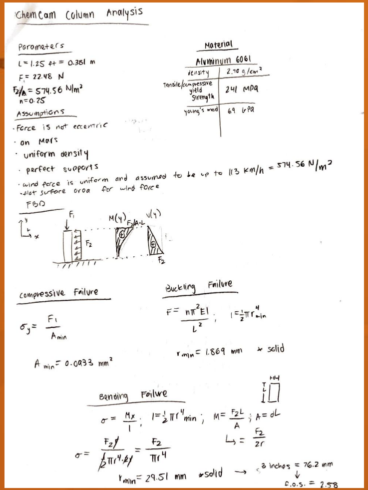


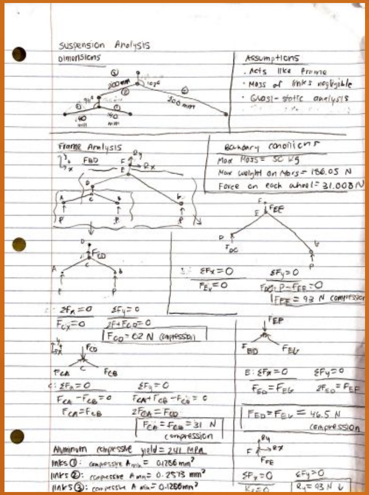


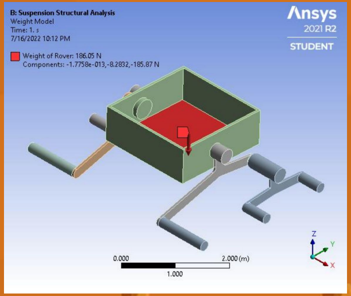
Calculations for Mechanical System

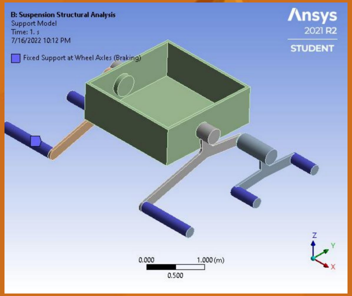
- Interested in tether system, suspension system, and chemCAM mast

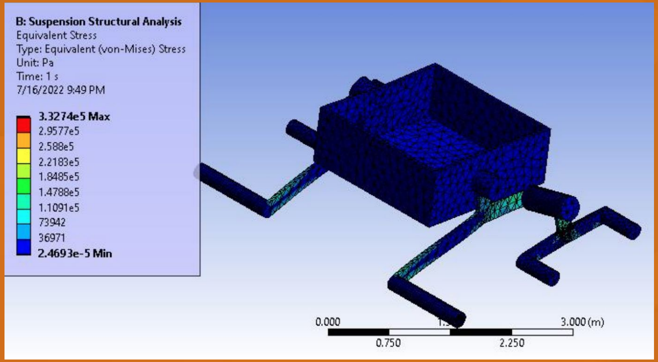






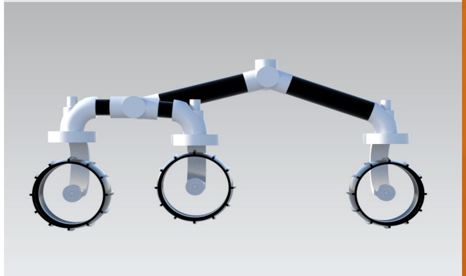






Late Mechanical System of Rover

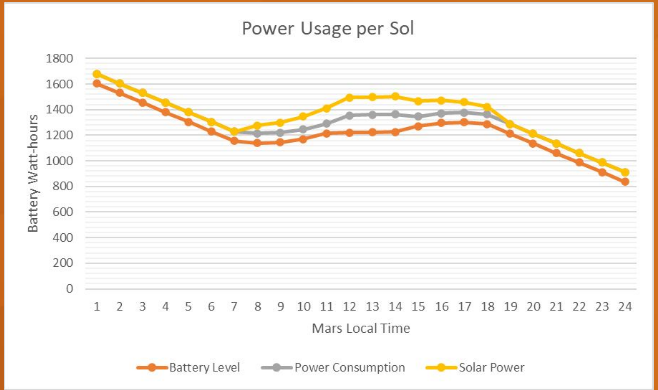
- Changes made to adapt the rover to a cave environment and the new instrumentation.
- Utilized pipes instead of linkages for suspension system
- Chassis is made using T-slot extruded aluminum
- More treading to increase contact area of wheels
- Materials: Aluminum 6061 & Titanium



Power System of Rover

The electrical subsystem utilizes a 60ah lithium battery pack for storage; the estimated mass of the lithium battery pack is 3 kilograms, including the radioisotope heater unit (RHU) and insulation. A dedicated 1m2 surface solar panel, attached to the primary payload tether attachment on the surface, will collect power to recharge the battery pack. At this size, the surface solar panel can provide up to 140 watts over a 4-hour period surrounding local noontime. In order to transfer power to the rover itself, the tether is able to conduct electricity through a pair of copper wires.

The approach to designing the power system is chosen due to the prohibitively high mass(45kg) and cost of a Multi-Mission Radioisotope Thermal Generator (MMRTG). Alternatively, batteries alone would have severely restricted the mission duration, and therefore the ability to achieve the state mission success criteria. Solar panels mounted directly on the rover would not be a viable power source, as there is limited to no solar irradiance within the cave.



Comms & Data Handling System of Rover

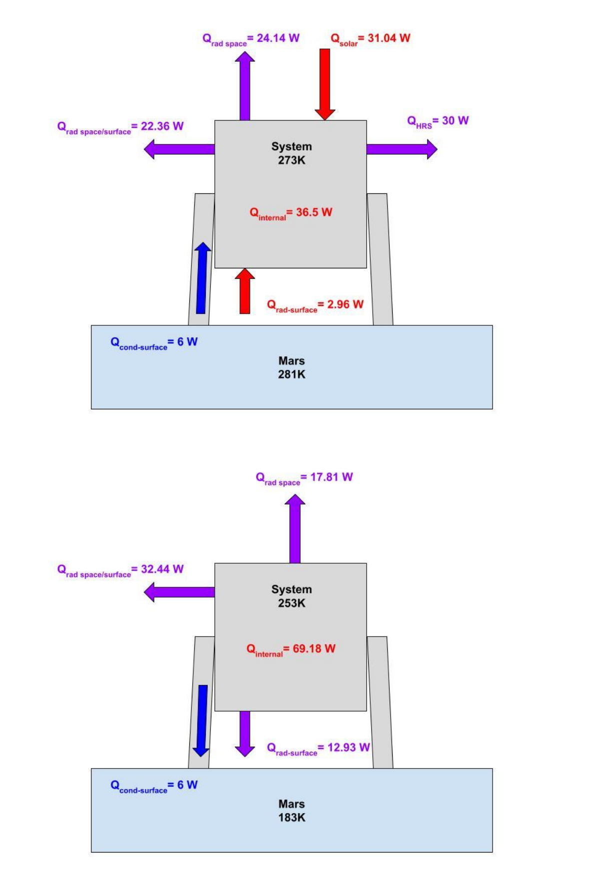
Communications between the cave rover and the primary payload will be achieved utilizing a cable connection on the tether. The tether's communications connection is 100 meters of shielded twisted pair copper cable, utilizing the 10BaseT communications standard- also known as Ethernet. This will provide plenty of bandwidth for transmission of science data from the cave, and IP-based networking with the primary payload will allow error checking and redundancy. There is no radio communication system on the rover.

The computer system selected for this mission is the BAE Systems 5515 System-on-a-Chip (SoC), which is a radiation-hardened system ideal for space environments. The 5515 is a 64-bit single processor architecture, and allows communication with peripheral devices such as the instrument suite and battery charger controller over the SpaceWire bus and I2C. 256mb of dynamic, random-access memory (DRAM) will be utilized for each computer, along with 2 gigabytes of solid-state flash memory. All memory systems shall be error-checking code (ECC) type, allowing for error detection and correction (EDAC) functionality. Two redundant computer systems will ensure that the communication and data handling systems are always accessible by mission controllers on Earth. The power consumption for both computer systems shall be no more than 30 watts.

Thermal System of Rover

Mars Temperature range at CC0068 : -90° C and +8° C

- The instruments that are crucial in achieving the scientific objective could usually withstand a temperature range from -20° Celsius to +30° Celsius [253 K to 303 K]
- ChemCam have an operating temperature between -10° Celsius to 0° Celsius [263 K to 273 K].
- The integral electronics must be kept in the required stable thermal condition in a Warm Electronics Box (WEB) to ensure an instrument's survivability



Heat Generation

- Heat generation mainly come from byproduct of electronics, electrical heaters, and Radioisotope Heater Units (RHUs).

- Byproduct of electronics, electrical heaters require electricity to produce heat. However, electric power is a precious commodity on Mars, and even more so during Martian night, when the rover relies solely on the batteries for power.

- RHU helps provide additional heat through radioactive decay. With a similar concept to radioisotope thermoelectric generators (RTG), RHU provides a constant 1 Watt of power per unit through Plutonium-238 with a half-life of 87 years. (1 x 1.3 in and 34 grams)

Composition of RHU Unit

Heat loss prevention

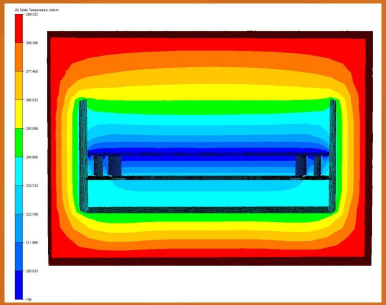
- AZ-3700-LSW Paint / Coating from AZ Technology was selected for its absorbance and emittance profile that satisfies the need of this mission.

- AZ-3700-LSW could be sprayed onto a surface with minimal difficulty without the need to use a primer so that it could be integrated early in the project.

- To keep the electronics warm during the night time CO2 insulation gaps could reduce parasitic heat loss. Due to weight efficiency, space between 5 cm is left, so, at mars, the mainly composed CO2 atmosphere would fill this gap, offering a conductivity constant of only 0.01 at that low pressure which is superior to aerogel.

*Nominal Surface Resistivity	10^6 to 10^9 Ω/sq
*Thermal Emittance (ε_t)	Typically: 0.25 to 0.33
*Solar Absorptance (α_s)	Typically: 0.22 to 0.25 at ≥ 1.25 mils thickness
Use Temperature Range	-180C to 600C (no long duration test data available)
Appearance/Color	Nonspecular metallic gray
*Nominal Dry Thickness	1.0 to 2.0 mils
ASTM D3359A Adhesion Grade	Not less than 3A (Al Substrate)
Full Cure	48-72 hours

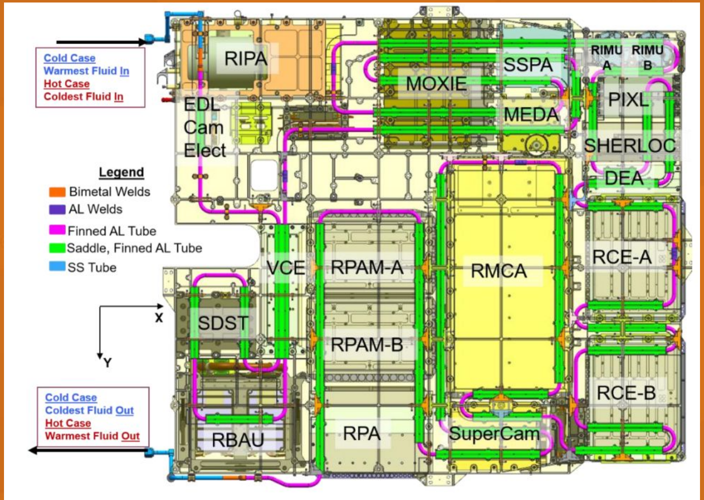
AZ-3700-LSW Performance Parameters



CO2 Insulation Gap Simulation

Heat Rejection

- Similar to Perseverance and MSL, the rover would employ a Heat Rejection System (HRS)
- The HRS would regulate heat energy produced from RHU in cold conditions and a bypass in hot conditions.
- Heat rejection system is a vital system since the rover would overheat from the internal RHU and power used to operate the rover.
- In contrast to those present in Perseverance and MSL, the system would not be able to double as a primary heater due to a lack of RTG to supply sufficient power. HRS would power accordingly when the temperature began to cool or heat up.



Mars 2020 Rover Fluid Loop Routing

Chemistry and Camera Tool (ChemCam)

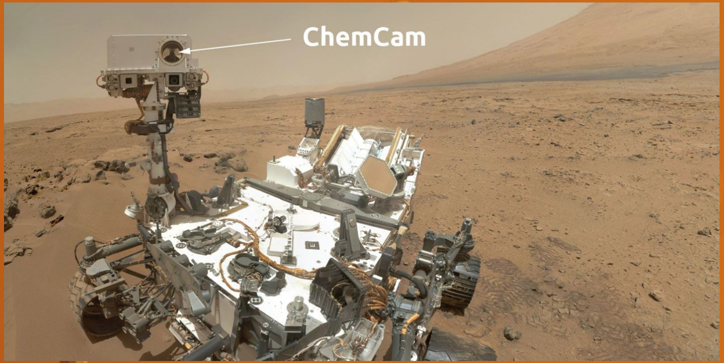


Image of NASA's Curiosity rover with ChemCam as the focus

- Uses laser to analyze vaporize substances
- Takes detailed photos from a distance
- Provides visual assistance

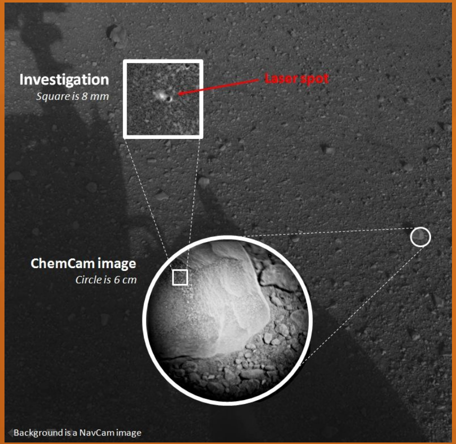


Image from NASA's Curiosity

Image via AppliedSpectra

Tunable Laser Spectrometer (TLS)

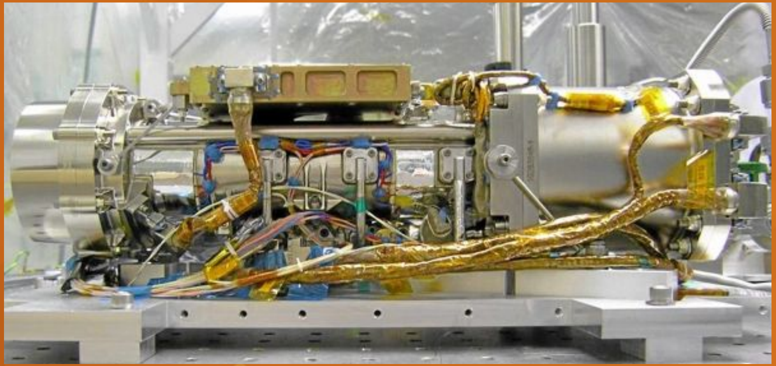
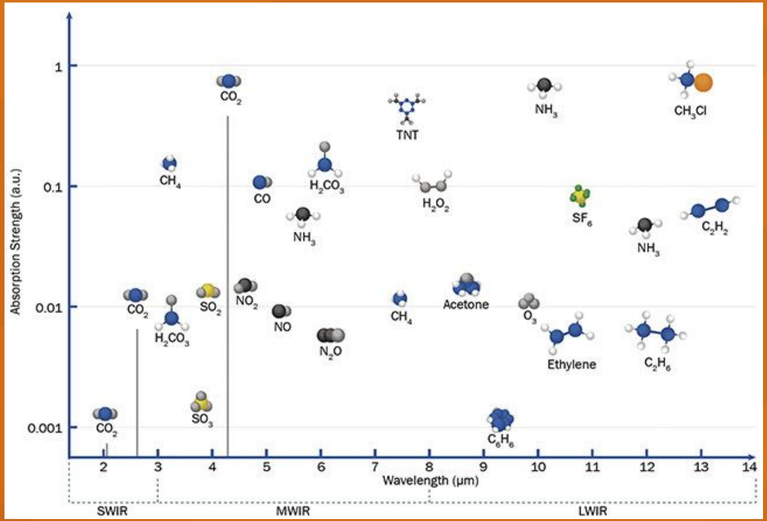


Image of TLS on the Curiosity Rover

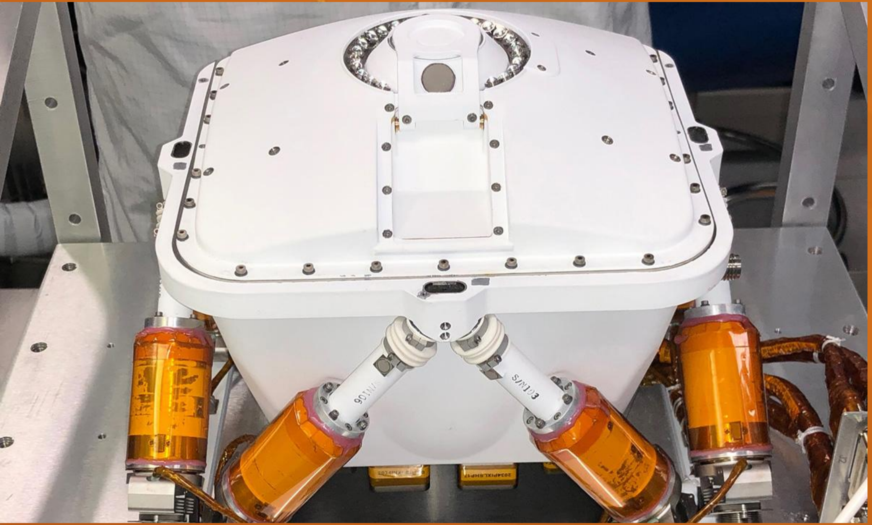
- How?
  - Uses wavelengths of light to identify isotopes
  - Pressure in the environment
- Where?
  - Saturating the atmosphere within a sealed box/room and then remotely activating TLS

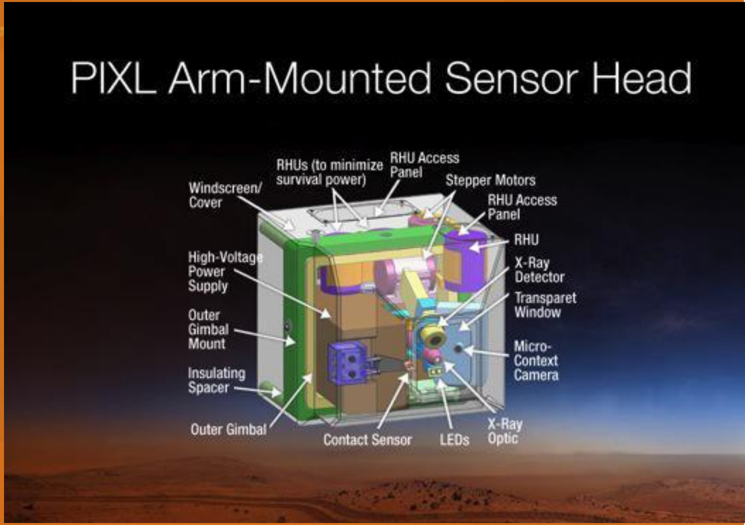
- Why?
  - Search for methane, carbon dioxide and water vapor
  - Is there life on Mars?



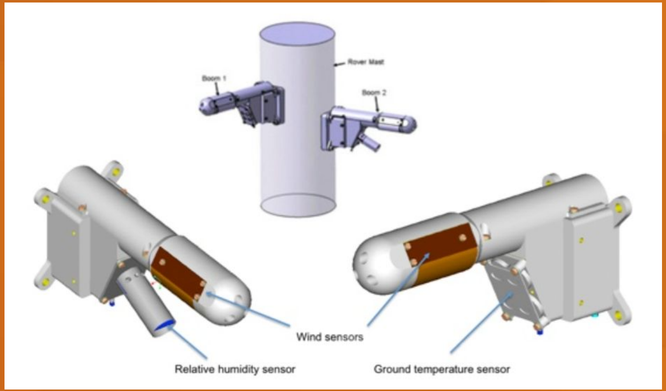
TLS Structure Graph with wavelengths of compounds

Instrumentation Slide (PIXL)





The Rover Environmental Monitoring Station (REMS)



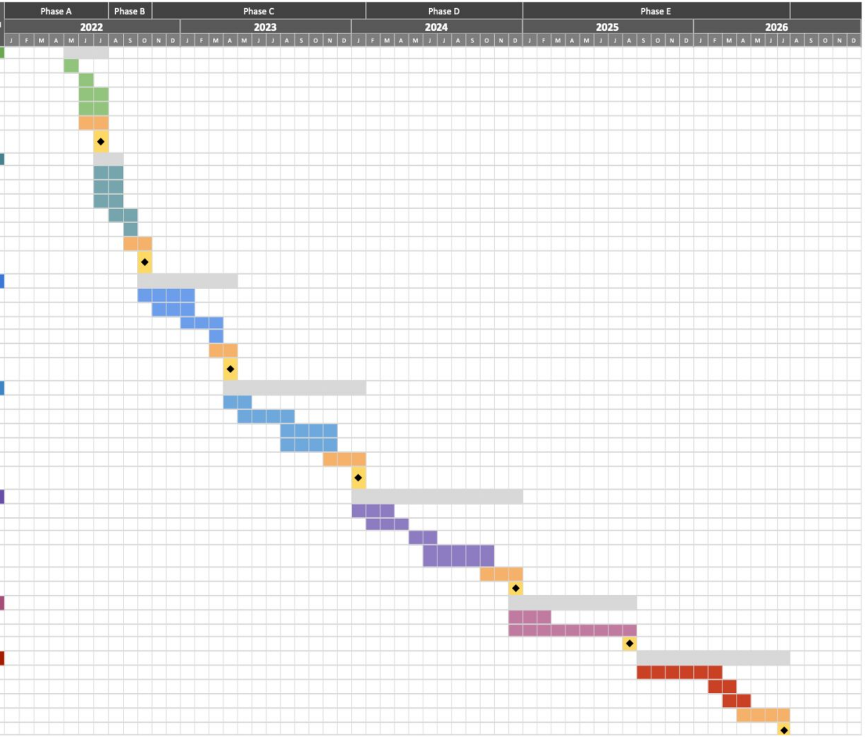
Mission Schedule

Astrobiology in Martian Caves

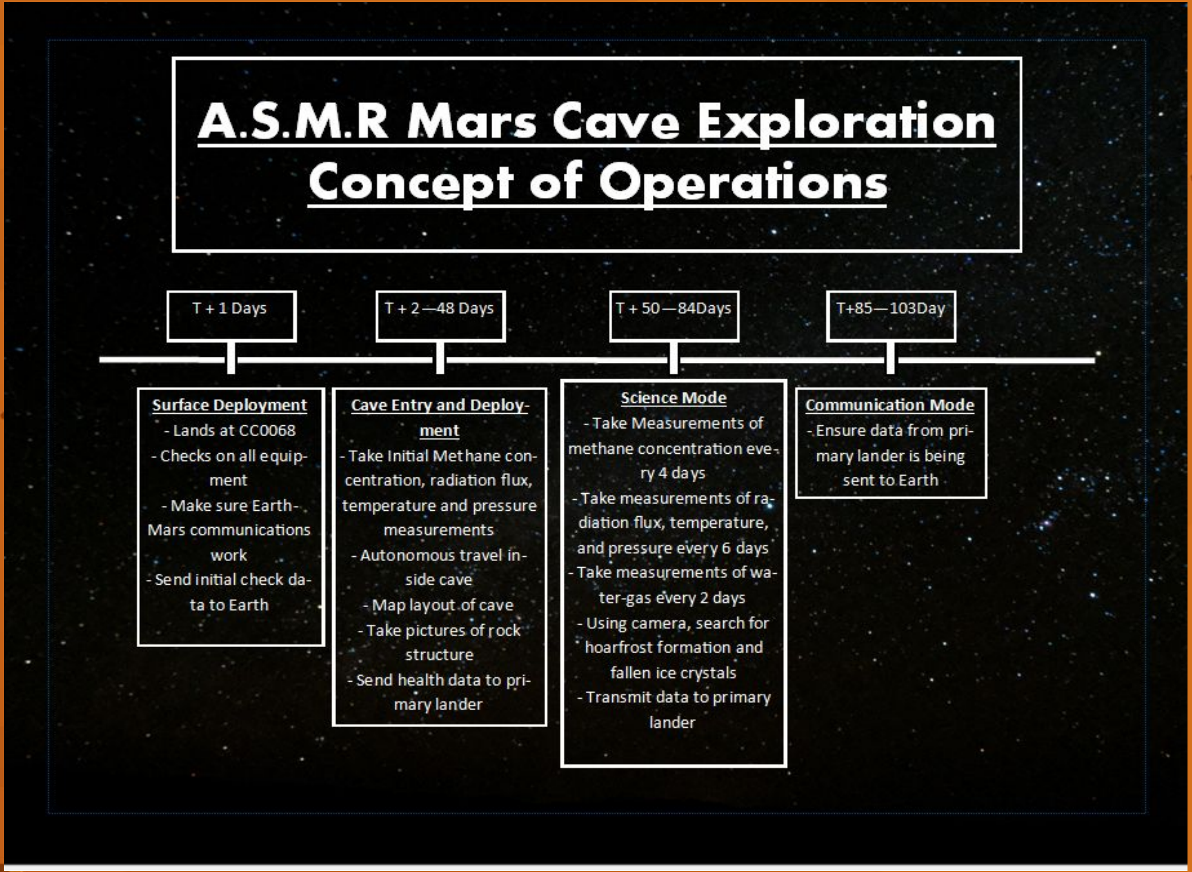
Team Number: #33

Project Team Members: Jeffrey Callaway, Rabhat Chaiprapa, Abraham Chavarria, Jonathan Cordova, Roger Nguyen, Hong Joo Ryoo, Brandon Tabata, Daniel Ponce, Daisy Salmeron, Yiyu Chen, Karen Lin, and Joshua Kozlowski

ID#	TASK	ASSIGNED TO	PROGRESS	START	END	DAYS	MARGIN
1	**Conceptual Development**		100%	5/24/22	7/4/22	42	28
1.1	Concept Studies	All	Complete	5/24/22	5/31/22	8	
1.2	Instrument Identification	Engineering	Complete	6/1/22	6/20/22	20	
1.3	Define Scientific Objectives	Science	Complete	6/22/22	7/4/22	13	
1.4	Preliminary Budget	Admin	Complete	6/1/22	7/4/22	34	
1.5	Schedule Margin			6/7/22	7/4/22	28	
1.6	◆ SRR: System Requirements Review Completion		Complete	7/4/22	7/4/22	1	
2	**Preliminary Design and Analysis**		0%	7/12/22	8/15/22	35	12
2.1	Finalize science objectives	Science	Not complete	7/12/22	7/22/22	11	
2.2	Begin CAD Design	Engineering	Not complete	7/11/22	7/18/22	8	
2.2	Create Concept of operations	Admin	Not complete	7/11/22	7/18/22	8	
2.3	Establish Budget	Admin	Not complete	8/26/22	9/5/22	11	
2.4	System Review (KDP B)	Engineering	Not complete	9/5/22	9/30/22	26	
2.5	Schedule Margin			9/30/22	10/11/22	12	
2.6	◆PDR: Preliminary Design Review Completed		Not complete	8/1/22	8/15/22	15	
3	**Verification and Validation**		0%	10/12/22	4/10/23	181	32
3.1	Finalize CAD design	Engineering	Not complete	10/12/22	1/1/23	82	
3.2	Instrument analysis	Science	Not complete	11/24/22	1/11/23	49	
3.3	Subcomponent analysis	Engineering	Not complete	1/11/23	3/10/23	59	
3.4	Begin supplier requests for quotes	Admin	Not complete	3/10/23	3/10/23	1	
3.5	Schedule Margin			3/10/23	4/10/23	32	
3.6	◆ CDR: Critical Design Review Completion		Not complete	4/10/23	4/10/23	1	
4	**Begin Manufacturing**		0%	4/10/23	1/5/24	271	66
4.1	Submit purchase orders	Admin	Not complete	4/10/23	5/4/23	25	
4.2	Begin manufacturing	Engineering	Not complete	5/24/23	8/10/23	79	
4.3	Subcomponent V&V	Engineering	Not complete	8/10/23	11/1/23	84	
4.4	Instrument V&V	Science	Not complete	8/10/23	11/1/23	84	
4.5	Schedule Margin			11/1/23	1/5/24	66	
4.6	◆ ORR: Operational Readiness Review Completion		Not complete	1/5/24	1/5/24	1	
5	**System Assembly and Testing**		0%	1/8/24	12/2/24	330	64
5.1	System Assembly/Manufacturing	Engineering	Not complete	1/8/24	3/1/24	54	
5.2	System Testing	Engineering	Not complete	2/8/24	4/16/24	69	
5.3	Readiness Review	Engineering	Not complete	5/15/24	6/19/24	36	
5.4	Integration with primary payload, launch vehicle	Engineering	Not complete	6/19/24	10/17/24	121	
5.5	Schedule Margin			10/17/24	12/19/24	64	
5.6	◆ Launch Date	Primary Payload	Not complete	12/2/24	12/2/24	1	
6	**Cruise Stage**		0%	12/5/24	8/13/25	252	N/A
6.1	Launch vehicle performance analysis	Primary Payload team	Not complete	12/5/24	2/12/25	70	
6.2	Monitor vehicle health	Engineering	Not complete	12/6/24	8/13/25	251	
6.6	◆ Landing Date		Not complete	8/13/25	8/13/25	1	
7	**Science Mission**		0%	9/18/25	7/3/26	289	90
7.1	Cave movement and entry	Primary payload/Engineering	Not complete	9/18/25	2/19/26	155	
7.2	Obtain scientific data	Science	Not complete	2/19/26	3/18/26	28	
7.3	Ensure data transmission	Engineering	Not complete	3/18/26	4/5/26	19	
7.5	Schedule Margin			4/5/26	7/3/26	90	
7.6	◆ Robot Completes Science Mission		Not complete	7/3/26	7/3/26	1	



Concept of Operations



Cost

Additional Information

	# People on Team	FTE Year 1	FTE Year 2	FTE Year 3	FTE Year 4	FTE Year 5	FTE Year 6
Science Team:	5	1	1	1	1	1	1
Engineering Team:	7	1	1	1	1	1	1
Administrative Team:	6	1	1	1	1	1	1

NASA L'SPACE Mission Concept Academy Budget - *Astrobiology in Martian Caves*

Year	Yr 1 Total	Yr 2 Total	Yr 3 Total	Yr 4 Total	Yr 5 Total	Yr 6 Total	Cumulative Total
PERSONNEL							
Science Team	$ 400,000.00	$ 400,000.00	$ 400,000.00	$ 400,000.00	$ 400,000.00	$ 400,000.00	$ 2,400,000.00
Engineering Team	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 560,000.00	$ 3,360,000.00
Administrative Team	$ 480,000.00	$ 480,000.00	$ 480,000.00	$ 480,000.00	$ 480,000.00	$ 480,000.00	$ 2,880,000.00
Total Salaries	$ 1,440,000.00	$ 1,440,000.00	$ 1,440,000.00	$ 1,440,000.00	$ 1,440,000.00	$ 1,440,000.00	$ 8,640,000.00
Total ERE	$ 401,904.00	$ 401,904.00	$ 401,904.00	$ 401,904.00	$ 401,904.00	$ 401,904.00	$ 2,411,424.00
TOTAL PERSONNEL	$ 1,841,904.00	$ 1,841,904.00	$ 1,841,904.00	$ 1,841,904.00	$ 1,841,904.00	$ 1,841,904.00	$ 11,051,424.00
TRAVEL							
Total Flights Cost	$ -	$ 6,600.00	$ -	$ -	$ -	$ -	$ 6,600.00
Total Hotel Cost	$ -	$ 21,000.00	$ -	$ -	$ -	$ -	$ 21,000.00
Total Transportation Cost	$ -	$ 3,000.00	$ -	$ -	$ -	$ -	$ 3,000.00
Total Per Diem Cost	$ -	$ 8,460.00	$ -	$ -	$ -	$ -	$ 8,460.00
Total Travel Costs	$ -	$ 39,060.00	$ -	$ -	$ -	$ -	$ 39,060.00
OUTREACH							
Total Outreach Materials	$ 600.00	$ 600.00	$ 6,600.00	$ 6,600.00	$ 6,600.00	$ 6,600.00	$ 27,600.00
Total Outreach Venue Costs	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 1,800.00
Total Outreach Costs	$ 900.00	$ 900.00	$ 6,900.00	$ 6,900.00	$ 6,900.00	$ 6,900.00	$ 29,400.00
OTHER DIRECT COSTS							
Total Outsourced Manufacturing Cost	$ 50,500,000.00	$ 290,000.00	$ 68,000,000.00	$ -	$ 10,000.00	$ -	$118,800,000.00
|> Science Instrumentation	$ 50,500,000.00	$ -	$ -	$ -	$ -	$ -	$ 50,500,000.00
|> Other COTS Components	$ -	$ 290,000.00	$ 68,000,000.00	$ -	$ 10,000.00	$ -	$ 68,300,000.00
Total In-House Manufacturing Cost	$ 106,250.00	$ -	$ -	$ -	$ -	$ -	$ 106,250.00
|> Materials and Supplies	$ 106,250.00	$ -	$ -	$ -	$ -	$ -	$ 106,250.00
Total Equipment Cost	$ -	$ 4,000,000.00	$ 4,000,000.00	$ 11,000,000.00	$ 11,000,000.00	$ 7,000,000.00	$ 37,000,000.00
|> Manufacturing Facility Cost	$ -	$ 4,000,000.00	$ 4,000,000.00	$ 4,000,000.00	$ 4,000,000.00	$ -	$ 16,000,000.00
|> Test Facility Cost	$ -	$ -	$ -	$ 7,000,000.00	$ 7,000,000.00	$ 7,000,000.00	$ 21,000,000.00
In-House Manufacturing Margin	$ 53,125.00	$ 2,000,000.00	$ 2,000,000.00	$ 5,500,000.00	$ 5,500,000.00	$ 3,500,000.00	$ 18,553,125.00
Total Direct Costs	$ 52,502,179.00	$ 8,171,864.00	$ 75,848,804.00	$ 18,348,804.00	$ 18,358,804.00	$ 12,348,804.00	$185,579,259.00
Total MTDC	$ 52,502,179.00	$ 2,171,864.00	$ 69,848,804.00	$ 1,848,804.00	$ 1,858,804.00	$ 1,848,804.00	$148,579,259.00
FINAL COST CALCULATIONS							
Total F&A	$ 5,250,217.90	$ 217,186.40	$ 6,984,880.40	$ 184,880.40	$ 185,880.40	$ 184,880.40	$ 13,007,925.90
Total Projected Cost	$ 57,752,396.90	$ 8,389,050.40	$ 82,833,684.40	$ 18,533,684.40	$ 18,544,684.40	$ 12,533,684.40	$198,587,184.90
Total Cost Margin	$ 17,325,719.07	$ 2,516,715.12	$ 24,850,105.32	$ 5,560,105.32	$ 5,563,405.32	$ 3,760,105.32	$ 59,576,155.47
Total Project Cost	$ 75,078,115.97	$ 10,905,765.52	$ 107,683,789.72	$ 24,093,789.72	$ 24,108,089.72	$ 16,293,789.72	$258,163,340.37

Conclusion

What is our task?

–Robot
-Small (50kg, 1.5 x1.5 x1.5 meters)
-Low-Cost
-Cave Exploration
-Astrobiology

What we deliver:
-Rover
-Fits Constraints (48.6 kg, 976 x 1.002 x 1.189 meters)
-Underbudget
-Science Driven Design

RESOURCES

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PHOTOS:

- Galaxy night view
- View of an undiscovered planet in the universe

VECTORS:

- Mars colonization isometric background with equipment for scientific research
- Mars exploration isometric poster with two astronauts near space ship Mars exploration concept with two astronauts walking on surface of red planet II
- Mars colonization concept set of space flight
- Mars colonization isometric set of astronauts

ICONS:

- Space Icon Pack