Preliminary Design Review

Ernutet Crater - Millenium 7

TEAM MEMBERS:

Sebastian Garcia   Chelsea Nation   Kathrine Owens   Matthew Wharton
Kevin Alegre   Hannie Pham   Toluwani Ogunyemi
Cameron Goodreau   Akhil Abraham   Viganesh Ramachandran

Team Introduction

Agenda of Topics

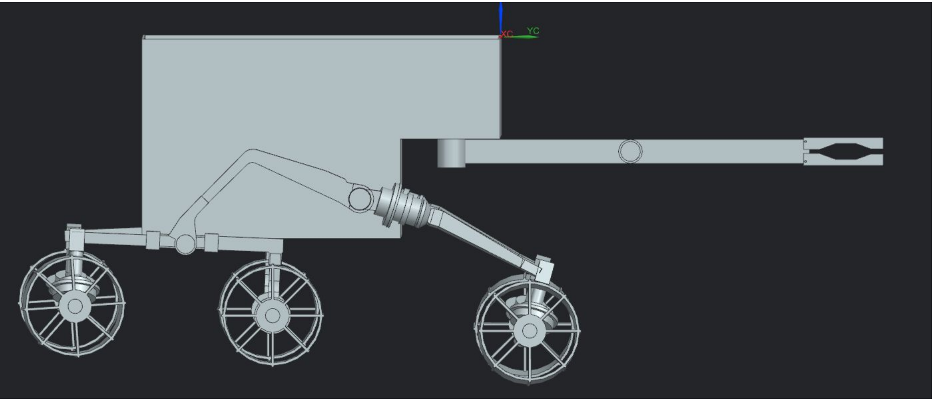
Mission Statement

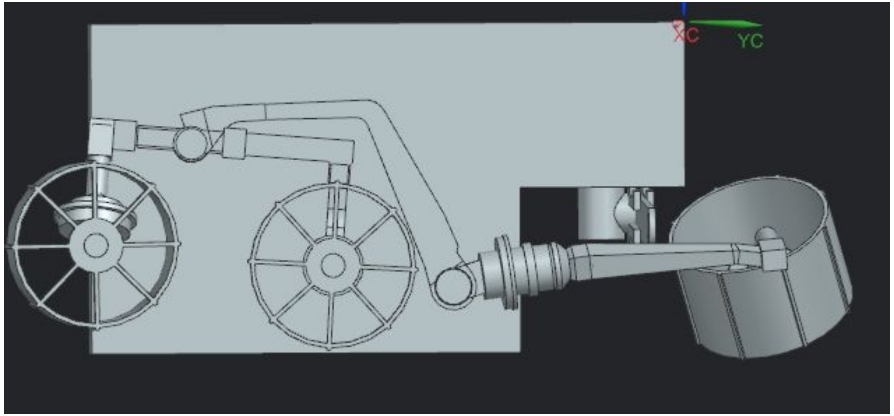
The objective of the Ceres Ernutet Exploration Rover (CAESAR) mission is to deploy a rover on Ceres, tasked with analyzing organic compounds and exploring geological and hydrothermal processes within the Erntutet crater. The mission seeks to understand whether these compounds are indigenous to Ceres or imported from beyond, and to determine if these geological activities could foster microbial life. The data from this mission will contribute to priceless insights into the nature of organic materials on foreign celestial bodies and the mechanisms of geological processes in extraterrestrial environments, thereby enriching our understanding of the diverse processes within our solar system. The team will employ two instruments, namely the mass spectrometer and vis/IR spectroscopy, to discern the origin of organic compounds. They will focus on volatile compounds, excluding certain acids and other compounds due to their interactions with the surface matrix. By utilizing the mass spectrometer, the team can identify complex silicon compounds and large chains that would not be volatile under ordinary conditions. This analysis will help determine whether the organic compounds are indigenous to the celestial body or not. Understanding the organic components on different celestial bodies can help determine if they resulted from chemical reactions or have extraterrestrial origins. It offers insights into the formation of our solar system and the potential emergence of life. NASA's investment in this research is crucial as it deepens our understanding of the cosmos and our place in the universe, benefiting humanity's knowledge.

Mission Requirements

Req #	Requirement	Rationale	Parent Req	Child Req	Verification method	Relevant Subsystem	Req met?
	The system mass shall not exceed 120 kg.	Mission document.	Customer		Inspection	All	
MIS-1	The stored configuration volume must not exceed length 125 x width 125 x height 125 cm	Mission task requirement	Customer	TBD	Demonstration		TBD
MIS-2	The system shall determine evolution of organic matter in Emutet crater			TBD	Demonstration		TBD
MIS-3	The system shall not exceed more than two science instruments	Mission task requirement.	Customer	TBD	Inspection		TBD
Mechanical Reqs.							
MEC-1	The mass of the system must not exceed 120 kilograms	Mission task requirement	Customer	TBD	Inspection		TBD
MEC-2	The cost should not exceed $300 million	Mission task requirement	Customer	TBD	Inspection		TBD
Electric Power							
System Reqs.							
PS-1	The system shall generate enough power to last the duration of mission	Mission success is dependant on the system having power	Customer	300-400 watts	Demonstration		TBD
PS-2	The power generation system shall be designed to withstand the expected environmental conditions.	Mission success dependent on system having power			Demonstration		
Payload Reqs.							
PAY-1	The system should incorporate a sample collection system	Mission task requirement	Customer	TBD			TBD
PAY-2	The payload shall include a spectrometer for analyzing the composition of the surface materials.						
Thermal System Reqs.							
TS-1	The system should be able to operate in temperatures ranging from -120°C to -60°C						TBD
TS-2	The thermal system shall have active heating elements to prevent components from freezing.						
Communication & Data Handling Reqs.							
CDH-1	The system must use X-band frequencies	Mission task requirement	Customer	TBD			TBD
CDH-2	The system should be able to communicate twice per week during 6 hour windows	Mission task requirement	Customer	TBD			TBD

Mechanical Engineering - Vehicle System Overview





Thermal System

- Top:
  - White thermal coating from MAP Space Coatings
- Sides & bottom:
  - Aluminum-coated PET blanket from Sheldahl
- Kapton heaters from Thermo Heating Elements, LLC
  - Extra heaters for redundancy
- All testing done in Ames Research Center

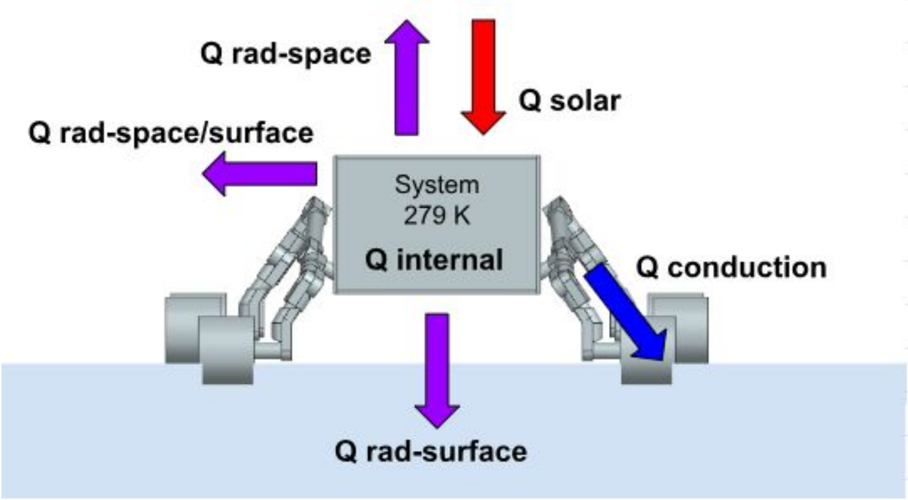


Diagram illustrating the heat flow processes occurring on the rover

Thermal System (continued)

Hot Case (no TCS)	
Q solar (W)	25.11
Q internal (W)	120.00
Q rad-space (W)	65.96
Q rad-space/surface (W)	111.78
Q rad-surface (W)	29.84
Q in (W)	145.11
Q out (W)	207.58
Q net (W)	-62.48

Hot Case (w/ TCS)		
Q solar (W)	16.74	Paint white: a = .2
Q internal (W)	120.00	
Q rad-space (W)	125.33	Paint white: e = .9
Q rad-space/surface (W)	9.78	
Q rad-surface (W)	2.61	MLI: e = .035 sides & bottom
Q in (W)	136.74	
Q out (W)	137.72	
Q net (W)	-0.98	~1 of heating required

Cold Case (w/ TCS)		
Q solar (W)	0.00	
Q internal (W)	120.00	
Q rad-space (W)	125.33	
Q rad-space/surface (W)	12.30	
Q rad-surface (W)	4.77	
Q in (W)	120.00	
Q out (W)	142.40	
Q net (W)	-22.40	~25 W of heating required

Electrical Systems

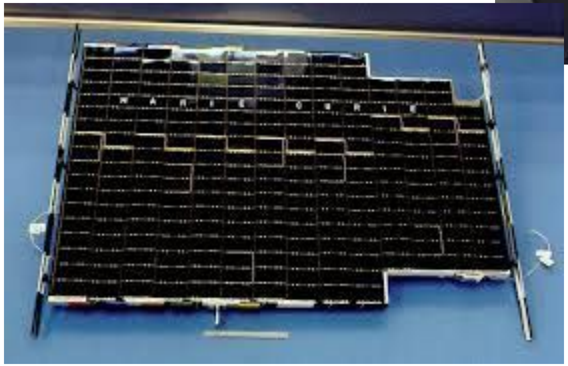
Silicon cells (about 1000W)

Metal frame

Glass casing

- 18.5% efficiency

- Backup battery:
- System must have a voltage range of 20-50V



Command Data & Handling (CDH)

The CDH system of the rover is responsible for handling all intra- and inter-communications within the rover, including communication between various rover systems and instruments, as well as communication between the rover and an orbiter mediary.

Components:

- CPU Subsystem
- Communication Subsystem
- Data Storage and Memory Subsystem
- Power Management Subsystem
- Command Execution and Monitoring Subsystem

Science Instrumentation/ Payload, Data Collection Plan

1. Gas Chromatography-Mass Spectrometry will be used to analyze the aliphatic hydrocarbons present within the surface of Ceres. Surface samples will be collected and crushed in order to achieve maximum sample collection and analyzed using GC-MS. The resulting chromatogram, along with the NIST Mass Spectrometry Data Center Library, to identify compounds present. Sampling will occur in multiple areas to provide more precise and accurate results.

2. Visible and Infrared Spectrometry will be used to identify water on Ceres surface. Using a heritage design of SHERLOC from Mars Perseverance Rover, it will identify wavelengths that undergo interactions with water on the surface. Key wavelengths for water that will be specifically looked for in this mission include the infrared peaks of infrared peaks of 5128 cm^{-1}, 6896 cm^{-1}, 8333 cm^{-1}, and 10300 cm^{-1}

Budget Overview

During budget development and forecasting, a number of assumptions were made. Firstly, budgets are prepared with assumptions about the rate of inflation, assuming that it will remain relatively stable throughout the mission. This assumption helps in projecting future costs accurately. Secondly, the budget assumes that the cost of specific resources, such as fuel, raw materials, or labor, will remain constant throughout the mission period. For example, the personnel budget remains the same for all roles, $80,000 for Science and Engineering, $60,000 for Technicians and Administration, and $120,000 for PM. Thirdly, travel costs are estimated based on certain assumptions, such as flights and destinations being located near the headquarters where the model will be launched to facilitate project implementation. For project timelines, the budget assumes that the mission will be completed within a specific timeframe, and costs will be incurred accordingly. In addition, some external factors like weather conditions, regulatory changes, or geopolitical situations might be assumed to remain stable or within a specific range during the mission. Finally, budgets include contingency funds to account for unforeseen events or changes in project scope, with assumptions made about the likelihood and impact of such occurrences.

Mission Timeline

Major Milestones	Phase	Date
CDR	C	2/7/2023 - 6/12/2023
CDR Approval	C	6/14/203
Manufacturing Complete	C	12/14/2025
SIR	D	2/1/2026 - 4/1/2026
Rover Testing Complete	D	7/19/2026 - 2/10/2027
MRR	D	7/20/2026 - 2/11/2027

Launch	D	12/29/2019
Landing on Ceres	E	2/12/2037
PFAR	E	2/5/2039
Mission Completion	E	4/1/2039
DRR	F	5/1/2039
Lessons Learned	F	7/6/2039 - 1/12/2040

Phase C

- Total Time: 2.5 years
- The Critical Design Review shall be written which shall further detail the information from the PDR.
- Manufacturing of all mechanical, thermal, electrical, and systems engineering, and instrumentation, shall take two years
- The conclusion of Phase C shall be once the System Integration Review (SIR) has been written

Phase D

- Total Time: 3.5 years
- Phase D begins with the assembly of the rover at the Ames Research Center
- Following assembly the Operational Readiness review (ORR) shall be verified to show all validations and required training for rover operations is complete
- Prior to the launch of our rover, a Mission Readiness Review shall be completed. This verifies our vehicles competence for the mission and enables the commencement of the launch.
- The rover shall launch on December 20, 2029 and shall take approximately 7 years to reach Ceres.

Phase C Gantt Chart

4	**Phase C**		0%	10/1/23	4/1/26	914	2
4.1	PDR Revisions	Everyone	Not complete	10/1/23	2/3/23		
4.2	CDR Draft	Everyone	Not complete	2/7/23	6/12/23		
4.3	CDR Approval	Everyone	Not complete	6/14/23	6/14/23		
4.4	Mechanical Manufacturing	Mechanical Engineers					
*	Jet Propulsion Laberatory	Mechanical Engineers					
	Body	Mechanical Engineers	Not complete	6/20/23	11/1/24		
	Rocker-Bogie	Mechanical Engineers	Not complete	6/21/23	11/2/24		
	Collection System	Mechanical Engineers	Not complete	6/22/23	11/3/24		
4.5	Thermal Manufacturing	Thermal Engineers					
*	MAP Space Coatings	Thermal Engineers	Not complete	6/25/23	3/10/24		
*	Multi-Layer Insulation	Thermal Engineers	Not complete	6/26/23	3/11/24		
*	Limited Liability Company	Thermal Engineers					
	Kapton Heater	Thermal Engineers	Not complete	6/27/23	3/12/24		
	Thermostat	Thermal Engineers	Not complete	6/28/23	3/13/24		
4.6	Electrical System Manufacturing	Electrical Engineers		6/29/23	3/14/24		
*	Lockheed Matin	Electrical Engineers					
	Metal Frame	Electrical Engineers	Not complete	7/1/23	1/10/24		
	Glass Casing	Electrical Engineers	Not complete	7/2/23	1/11/24		
*	Human Research Laboratories	Electrical Engineers					
	Batteries	Electrical Engineers	Not complete	2/2/24	12/20/24		
	Solar Panels	Electrical Engineers	Not complete	2/3/24	4/11/25		
	Distribution System	Electrical Engineers	Not complete	2/4/24	2/1/25		
4.7	Instrumentations	Science Team					
	Mass Spectrometer	Science Team	Not complete	2/5/25	12/10/25		
	Infrared Spectrometer	Science Team	Not complete	2/6/25	12/11/25		
	Camera	Science Team	Not complete	2/7/25	12/12/25		
4.8	CDH	Systems Engineers					
	Communications	Systems Engineers	Not complete	1/5/25	12/10/25		
	Data Storage	Systems Engineers	Not complete	1/6/25	12/11/25		
	Software	Systems Engineers	Not complete	1/7/25	12/12/25		
4.9	Evaluation for Manufactored Parts	Science, Engineering Team	Not complete	12/14/25	1/25/26		
	Plan for Assembly - SIR	Everyone	Not complete	2/1/26	4/1/26		
4.1	Schedule Margin					2	
4.11	◆ Milestone - SIR		Not complete	10/1/23	4/1/26	914	

Phase D - Gantt Chart

5	Phase D		0%	7/1/26	12/29/29	1278	2
5.1	Verify and Evaluate materials	Everyone	Not complete	7/1/2026	7/8/2026	8	
5.2	Assemble the Rover	Engineering, Science Team				1	
	Ames Research Center	Engineering, Science Team	Not complete	7/19/2026	2/10/2027		
5.3	ORR	Engineering, Science Team	Not complete	7/20/2026	2/11/2027		
5.4	Instrumentation Testing	Science Team					
*	Ambient Testing	Science Team	Not complete	2/13/2027	7/7/2027		
*	Analysis Testing	Science Team	Not complete	2/14/2027	7/8/2027		
*	Laboratory Hazards Testing	Science Team	Not complete	2/15/2027	7/9/2027		
5.5	Engineering Performance Testing	Engineering Team					
*	Space Enviornment Simulator	Engineering Team	Not complete	7/11/2027	11/20/2027		
*	Vacuum Camber A	Engineering Team	Not complete	11/22/2027	11/24/2028		
*	15 Ft Chamber	Engineering Team	Not complete	11/26/2028	5/18/2029		
5.6	Qualiity Test Assurance	Everyone	Not complete	5/22/2029	10/19/2029	151	
	MRR	Everyone	Not complete	5/23/2029	10/20/2029		
5.7	Launch	Everyone	Not complete	12/29/2029	12/29/2029	1	
5.8	Schedule Margin					2	
5.9	◆ Milestone - Launch		Not complete	7/1/2026	12/29/2029	1278	

Phase E

- Total Time: 9 years
- The rover shall traverse the Ernutet Crater, which is 52 kilometers, for approximately two years. Rovers top speed is approximately 0.152 kilometers per hour based on Mars exploration, so to get through the crater non-stop 342 hours. However, since data and testing shall take place, the team shall allocate two years on the crater
- During this period, the science team shall collect data in the team's points of interest and evaluate whether the current hypotheses are proven correct or need to be revised.
- Following the landing of the rover, a Post Flight Assessment Review (PFAR) shall be conducted to determine whether the payload and operations are adequate for the missions' duration.
- Assuming the mission lasts nine years, and the rover is continuing to collect data, a Decommissioning Review (DR) shall be conducted and the plan for closeout shall be made. Following this, the closeout of the mission in Phase F shall commence.

Phase F

- Total Time: 8 months
- The team shall write up the DRR, the disposal readiness review. This document shall detail the requirements established by NASA, detail the systems and engineering of our rover, and evaluate the performance of our rover post launch
- Following the completion of all Nasa Life-Cycle documentations, the team shall additionally write a "Lessons learned" document. This shall detail all milestones, points of weakness, points of strength, and, most of all, points of improvement.
- Lastly, a wrap up meeting to verbally reflect on the experience shall take place, and the mission shall be officially closed out

Phase E - Gantt Chart

6	**Phase E**		**0%**	**2/1/2030**	**4/1/2039**	**3347**	**1**
6.1	Vehicle Assurance - Throughout	Engineering Team	Not complete	12/29/29	3/1/2039		
6.2	Trouble Shooting - Throughout	Systems Engineers	Not complete	12/31/29	3/3/2039		
6.3	Recharging Time	Electrical + Systems Engineers	Not complete				
6.4	Data Collection - On Ceres	Science Team				1	
	Infrared Spectrometer:	Science Team					
*	Water Testing	Science Team	Not complete	2/12/37	3/17/2039		
	Mass Spectrometer:	Science Team					
*	Volatile Alliphatic Hydrocarbons	Science Team	Not complete	2/12/37	3/17/2039		
6.5	PFAR	Programmatic Team	Not complete	2/5/39	4/1/2039		
6.6	Schedule Margin					1	
6.7	◆ Milestone - Mission Completion		Not complete	2/1/2030	4/1/2039	3347	

Phase F

7	**Phase F**		**0%**	**5/1/39**	**1/13/2040**	**258**	**1**
7.1	DRR	Everyone	Not complete	5/1/39	7/3/39		
7.2	Lessons Learned Document	Everyone	Not complete	7/6/39	1/12/40	191	
7.3	Meeting to wrap up	Everyone	Not complete	1/13/40	1/13/40	1	
7.4	Schedule Margin					1	
7.5	◆ Milestone - Lessoms Learned		Not complete	5/1/39	1/13/40	258	

Budget

The total estimated cost of the mission would be around $300 million. This includes personnel budgets, travel budgets, outreach budgets, and direct costs.

Additional Information

	Phase B	Phase C	Phase D	Phase E	Phase F
# People on Team	FY 1	FY 2	FY 3	FY 4	FY 5
Science Personnel:	8	10	12	12	10
Engineering Personnel:	8	10	12	12	10
Technicians:	7	8	10	10	8
Administration Personnel:	8	8	6	5	6
Management Personnel:	5	5	4	4	4

Here is a table of the number of people our team needs for each position through each phase. In general, the number of people in the Management position is the smallest and most of the human resources are focused on technology positions, especially during project development. Administration and management positions are often emphasized in the early stages of conceptualization and planning because they are the ones who will have to cover the overall project.

Budget (Continued)

NASA L'SPACE Mission Concept Academy Budget - *Ernutet Crater*

Mission Phase	Phase B	Phase C	Phase D	Phase E	Phase F	
Year	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Cumulative Total**
PERSONNEL						
Science Personnel	$ 80	$ 80	$ 80	$ 80	$ 80	$ 400
Engineering Personnel	$ 80	$ 80	$ 80	$ 80	$ 80	$ 400
Technicians	$ 60	$ 60	$ 60	$ 60	$ 60	$ 300
Administration Personnel	$ 60	$ 60	$ 60	$ 60	$ 60	$ 300
Project Management	$ 120	$ 120	$ 120	$ 120	$ 120	$ 600
Total Salaries	$ 400	$ 400	$ 400	$ 400	$ 400	**$ 2,000**
Total ERE	$ 112	$ 112	$ 112	$ 112	$ 112	**$ 558**
TOTAL PERSONNEL	$ 512	$ 512	$ 512	$ 512	$ 512	**$ 2,558**

This section includes 5 key roles in the project: Science Personnel, Engineering Personnel, Technicians, Administration Personnel, and Project Management. For the initial phase, personnel will mainly be focused on Administration and Project Management because the initial steps require a lot of work in creating ideas, plans, and specific timelines to work throughout the project. These are the main professional tasks that the Administration and PM will be in charge of, so for the position of administration, there will be 8 people in charge and the PM will have 5 people. The remaining 3 positions related to scientific and technical expertise will require at least 6 members in each role. All play a role in building a project idea of what the model will look like and how long it will take to complete, as well as the cost required. Through the development phase and moving to model building, more human resources will be added to more specialized scientific and technical teams. At this point, the leadership team will be reduced to about 4 people for PM and 5 people for administration. In the technology and engineering team, there will be at least 8 people for each role. The reason for this change in human resources is that in the process of building a model when there is a specific outline, the steps need a lot of people with expertise to be able to draw as well as understand the parts of the model related to the technical aspects so that the model when presented in reality does not make unnecessary mistakes.

Budget (Continued)

As for the budget for each position, the PM will have the highest level of $ 120k because they are the ones who have to work the most to cover the entire project and take the longest time to connect and organize between teams. Then comes to Science and Engineering Personnels, positions that require highly specialized skills and are active during project construction but only need to be coordinated mainly within a certain team, so will have the second highest budget at $80K. Finally, there are the Technicians and Administration, teams that I think will be a useful source of support for the mainstream teams mentioned above, so it should take up a budget as low as $60k. Assume budget levels are stable so they will stay at those prices throughout the phases.

- **Scientists** for the design of your experiment and analysis of data - $80,000 salary/year
- **Engineers** for designing, building, and testing your mission concept and for mission operations - $80,000 salary/year
- **Technicians** for assisting engineers and scientists with manufacturing, assembly, and testing of instruments and systems of the mission concept - $60,000 salary/year
- **Administration** for tracking schedule and mission costing - $60,000 salary/year
- **Managers** for organizing mission personnel, budgets, and schedules - $120,000 salary/year

These salaries will be assumed to be constant to ensure that the budget does not fluctuate unpredictably.

Budget (Continued)

Expense	**Persons**	**Per Person (USD)**	**Total (USD)**
*Airplane Cost**	5	678	2790
*Shuttle (Uber to LAX if needed)***	5	80	400
Shuttle (Uber to hotel)	5	150***	350
*Hotel****[1]*	5	144/night = 864	4320
Shuttle (Uber to KSC)	5		60
Meals[1]	5	500	2500

*Taking into the assumption that the trip occurs on December 17th 2023 to December 23, 2023, from LAX (Los Angeles) to MCO (Orlando) for important personnel. We have decided to include five people: the program manager, chief scientist, chief engineer, and two others that may be deemed necessary.

** This is assuming personnel cannot find their own rides. This cost may be reduced. This is based on estimated Uber costs.

*** Including tip into all shuttle costs

****Each personnel will receive their own room for the trip.

Budget (Continued)

Expense	**Persons**	**Per Person (USD)**	**Total (USD)**
Airplane Cost to SFO	3	1000	3000
Car Rental	3	N/A	400
Gas	N/A	N/A	50
Hotel	3	110	1980
Meals	3	500	1500

Lead Engineer, lead scientist and astrobiologist will travel to Ames Research Center. This location is where the thermal and payload subsystems are manufactured. This research center was chosen in order for both scientists and engineers to be able to see their aspects of the rover being manufactured.

Budget (Continued)

Expense	**Persons**	**Per Person (USD)**	**Total (USD)**
Avg. Airplane Cost to LAX	2	850	1700
Car Rental	2	N/A	240
Gas	N/A	N/A	50
Hotel	2	100	1800
Meals	2	500	1500

Project Manager and Deputy PM will travel to attend the Standing Review Board (which can take place at any NASA center). For calculations, JPL is used in order to budget for the longest distance travel.

Budget (Continued)

Expense	Persons	Per Person (USD)	Total (USD)
Airplane Cost	15	700	10500
Shuttle (Uber to LAX if needed)	15	100	1500
Shuttle (Uber to hotel)	15	150	2250
Hotel	15	144/night = 864	12960
Shuttle (Uber to KSC)	15	15	225
Meals	15	500	7500

Personnel will be added from the phase C to the end. Other members recruited will move to the NASA center to support the project in the same time.

Budget (Continued)

TRAVEL						
Total Flights Cost	$ 50	$ 50	$ 50	$ 60	$ 60	**$ 270**
Total Hotel Cost	$ 28	$ 38	$ 35	$ 30	$ 30	**$ 161**
Total Transportation Cost	$ 28	$ 38	$ 35	$ 30	$ 30	**$ 161**
Total Per Diem Cost	$ 8	$ 15	$ 15	$ 12	$ 12	**$ 62**
Total Travel Costs	$ 114	$ 145	$ 142	$ 142	$ 146	**$ 689**

The airline that will be prioritized for members to travel is Delta Airlines. And the hotel was chosen as Holiday Inn Express because it is close to Ames Research Center, in Mountain View to facilitate the movement of team members.

At each phase, an amount will be added to each category to make a reserve fund for incurred expenses such as shuttle transportation not available and having to change or add meals, etc.

Budget (Continued)

OUTREACH						
Total Outreach Materials	$ 80	$ 80	$ 70	$ 70	$ 55	**$ 355**
Total Outreach Venue Costs	$ 50	$ 40	$ 40	$ 45	$ 40	**$ 215**
Total Outreach Costs	$ 130	$ 123	$ 116	$ 124	$ 105	**$ 598**

The outreach portion of the CAESAR mission will be allocated $598,000 accounting for inflation of 2.6% per year, or approximately 0.6% of the total budget. Supplies will be purchased and sent to locations such as schools and underrepresented communities as needed. Funds allocated for venues will be used as needed.

During year 1, social media accounts will be set up, email lists will be created, and outreach to K12 schools and higher education institutions will begin. Talks will be given at venues at different universities and conferences such as the American Astronomical Society. Members of the outreach team will reach out to news organizations as well. The CAESAR mission website will be created and public competitions to design products for the mission will start. Promotional videos and images will be taken at various NASA and NASA partner sites where work on the CAESAR mission is being done.

During year 2, work from Year 1 will continue, including operating social media accounts, outreach to K12 schools and higher education institutions, and the creation of promotional videos and images. Design competitions will take place at universities. Talks will be given at universities and conferences throughout the United States.

During year 3, work from Year 2 will continue. Social media accounts will be operated, outreach to schools and universities will be done, and promotional videos and images will continue to be taken at various stages of the development of the rover. The competition to design promotional products will conclude and products will be chosen.

In year 4, social media operations and educational outreach will take place. Videos and images will be produced, including videos of the manufacturing process and associated achievements.

In year 5, outreach operations will conclude. Work from previous fiscal years will be finalized and promotion toward the launch and start of the mission will take place.

The cost of the material also includes online tools such as cameras, laptops and school supplies such as books and minutes to announce the news in that year. Also, the expenditure of marketing agency service and email marketing will be covered. Materials will be priced at the local market price of the project site. Venue costs are determined based on the number of project members and the city's consumption costs. For this term, our team chose schools, colleges, public centers, and online platforms. In addition to, the team will have additional outreach events in industry conferences, space centers, and research institutions in order to gather community. This can take more venue cost than the first event.

Budget (Continued)

DIRECT COSTS						
|> Science Instrumentation	$ 7,000	$ 8,000	$ 10,000	$ 9,000	$ 9,000	**$ 43,000**
|> Other Payload Costs	$ 1,000	$ 1,000	$ 1,000	$ 1,000	$ 1,000	**$ 5,000**
Total Payload Costs	$ 8,000	$ 9,234	$ 11,572	$ 10,780	$ 11,040	**$ 50,626**
|> Mechanical Subsystem	$ 2,000	$ 6,000	$ 6,000	$ 1,000	$ 1,000	**$ 16,000**
|> Power Subsystem	$ 2,500	$ 4,500	$ 4,500	$ 4,500	$ 5,000	**$ 21,000**
|> Thermal Control Subsystem	$ 1,500	$ 3,000	$ 3,000	$ 3,000	$ 3,000	**$ 13,500**
|> Comms/Data Handling Subsystem	$ 1,000	$ 1,500	$ 2,500	$ 3,000	$ 3,000	**$ 11,000**
Total Vehicle Costs	$ 7,000	$ 15,390	$ 16,832	$ 12,397	$ 13,248	**$ 64,867**
|> Manufacturing Facility Cost	$ 4,000	$ 4,000	$ 4,000	$ 2,600	$ 2,600	**$ 17,200**
|> Test Facility Cost	$ 4,000	$ 4,000	$ 4,000	$ 3,000	$ 3,000	**$ 18,000**
Total Facilities Costs	$ 8,000	$ 8,208	$ 8,416	$ 6,037	$ 6,182	**$ 36,843**
Manufacturing Margin	$ 11,500	$ 16,416	$ 18,410	$ 14,607	$ 15,235	**$ 76,168**
Total Direct Costs	$ 34,500	$ 49,248	$ 55,230	$ 43,821	$ 45,706	**$ 228,504**
Total MTDC	$ 7,500	$ 12,312	$ 14,202	$ 11,589	$ 12,144	**$ 57,747**

Combining and using the calculation formulas included in the MCCET form, we have obtained the above estimates with TotalMass = 110 kg and TotalMaxPwr = 100W, MechMass = 11.5 kg. The amounts we estimate are within the MCA task's recommended amount (attached here).

Component	Estimated Cost (in millions)
Chassis and Mobility System	$40 - $60
Power System	$20 - $40
Communication System	$10 - $20
Scientific Instruments	$50 - $80
Avionics and Control System	$30 - $50
Thermal Control System	$10 - $20
Sample Collection System	$20 - $30
Data Storage and Processing	$10 - $20
Navigation System	$10 - $20
Integration and Testing	$30 - $50
Mission Operations	$40 - $60
Contingency	$20 - $30
Total	$280 - $440

Conclusion -Sebastian

The mission at hand is dedicated to the rigorous exploration of Ceres, an opportunity to unravel the intriguing mysteries shrouding this celestial body. Our mission's core purpose is to deepen our comprehension of the solar system's history and contribute vital insights to the realm of space exploration, inspiring current and future generations. The PDR serves as a pillar supporting our purpose-driven endeavor. It ensures that our mission objectives remain steadfastly aligned with the profound significance of Ceres. The PDR connects the future plans to progress in our organic findings which would progress the research on Ceres, as this document moves towards the revised phases, refinements, and etc.

The PDR assesses potential challenges, assuring that every facet of the mission serves our purpose with precision. With our commitment to our mission's purpose, the guiding influence of PDR shows the path ahead. Through thorough analysis and strategic refinement, PDR enables us to optimize resources, mitigate uncertainties, and navigate a well-defined course towards Ceres. The PDR continues to be an instrumental force in shaping our mission. Building upon the foundation set by the PDR, the later stages evaluates the feasibility and technical soundness of our preliminary design. It ensures that our proposed solutions and systems are in perfect harmony with the mission's established purpose and objectives.The PDR’s requirements and information will help us set up for our mission. This document has resulted in a summation of all things that would achieve our science goals of organic compound research. This document shows how all the elements are in alignment. As we embark on our journey to Ceres, our mission speaks volumes about human ingenuity. It's a testament to how far we've come as a species! With the guidance of PDR, we're equipped with the knowledge and professionalism to tackle this cosmic challenge. We're not just here to make history; we want to leave a lasting legacy that'll impact generations to come. We're a bunch of young engineers with a passion for space and a whole lot of determination. Our hearts are set on pushing the boundaries of cosmic understanding. So, with heads held high and unwavering commitment, we're diving headfirst into the wonders of Ceres. Let's show the world what we're made of! Onwards, towards the cosmos!