MROVER

MICHIGAN MARS ROVER TEAM

Astrobiology PDR

10/08/22 | Emeline Hanna

Requirements

Astrobiology Requirements

Astrobiology		Interfaces
GEN.4.C.vi	Science tests used on rover shall provide consistent and conclusive results at ambient temperatures up to 115°F	–
SCI.1.B	Rover shall collect and analyze all soil samples and analyze all rock samples at up to 10 sample sites using in-situ instruments within 20 minutes	SA, ISH, CM
SCI.1.B.i	Rover shall be capable of collecting and analyzing 3 soil samples as well as analyzing 2-9 rock samples within 20 minutes	SA, ISH
SCI.2.A	Rover shall identify a region of high scientific value from which to collect the sample	Teleop, ISH
SCI.3	Rover shall analyze site for presence of extinct or extant life by analyzing several rocks in-situ	ISH, SA
SCI.3.A	Rover shall possess at least one life detection instrument capable of detecting life in-situ from a 15x15x10cm sized rock sitting on ground	ISH, SA
SCI.3.A.i	Instruments shall evaluate rocks for biosignatures of both extinct and extant life local to the Utah desert within 3 minutes of arriving at site	ISH, SA
SCI.3.A.ii	Science shall be able to classify types of rocks and utilize the resulting implications for determining the presence of extinct or extant life	SA
SCI.3.A.iii	Rover shall gather data from rock samples without removing or altering them in any way	ISH, SA
SCI.4	Rover shall analyze site for presence of extinct or extant life by collecting and analyzing a soil sample	SA, ISH, Teleop, ESW, EHW
SCI.4.A	Rover shall possess at least one life detection instrument capable of detecting life in collected soil sample from a partially buried 20x20cm tray of 5cm depth.	SA, ISH, Teleop, ESW, EHW
SCI.4.A.ii	Instruments shall complete all tests that require the rover to remain stationary for each sample within 6 minutes of arriving at site	ISH
SCI.4.A.iii	Instruments shall evaluate the soil sample for biosignatures of both extinct and extant life local to the Utah desert	ISH
SCI.4.A.iv	Tests to determine presence of a target molecule shall be detectable by camera or sensors	ISH, Teleop
SCI.5	Base station operations and Astrobiology test selections shall be presentation focused	Teleop, SA, ISH
SCI.5.A	Results from tests and analyses shall be clear and compelling	Teleop, SA, ISH
SCI.5.A.ii	Science test results shall be produced in an easily extractable format for ease of inclusion in presentation	ISH
SCI.5.A.iii	Results shall be straightforward so as not to require further deliberation during presentation preparation time	ISH

System Overview

System Overview

Tests for rocks

1. Microscope

Tests for soil

1. Chlorophyll Test
2. Amino Acid Test
3. Lipid Test
4. On-Board Raman

Tests & Designs

Microscope

- Digital microscope
- No backlighting required
- “1000x” magnification, actually effective to about 10 microns
- Allow us to view microbial fossils or endoliths (microbes that live in/on rocks), as well as larger signs of life
- Mounted on SA end effector

Chlorophyll

- Of interest since it's a pigment found in organisms to utilize light as a source of energy[1]
- Under UV light, chlorophyll fluoresces at 685 nm[2]
- Acetone disrupts structure of cell walls[3]
- Ethanol extracts chlorophyll a and does not evaporate quickly[4]
- Procedure:
  - Mix dirt with solvent to break down cell walls in 10 mL beaker
  - Excite with 429nm UV LED
  - Use a six channel spectral analysis to analyze if higher red wavelength level
- 100% confirmation of extant life

Acetone, negative (L), positive (R)

Ethanol, negative (L), positive (R)

*pictures are through UV lense

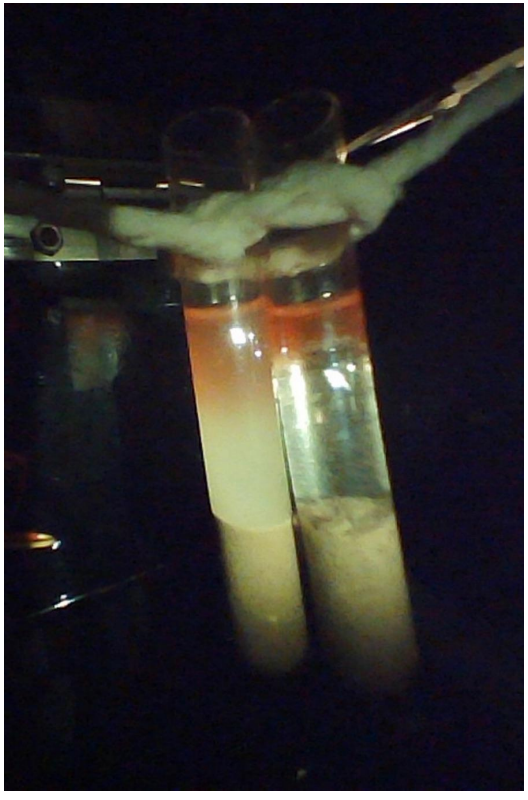
Amino acids (Ninhydrin)

- Amino acids are the building blocks of proteins and enzymes in terrestrial organisms[5]
- Ninhydrin reacts with primary amino groups to form purple dye[6]
- Procedure:
  - Heat water with ninhydrin powder in 10mL beaker and add soil
  - Determine if purple color change with cameras
- Near 100% confirmation of life
  - Does not distinguish between extinct/extant
  - Does not appear enough abiotically for concern[7]

Ninhydrin, negative (L), positive (R)

Lipids (Sudan III)

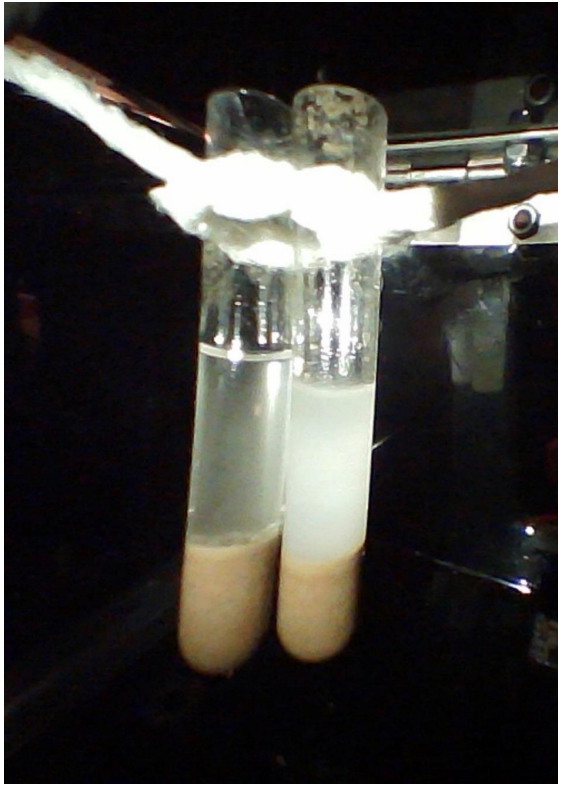
- Lipids are of interest because they form semipermeable membranes that were critical in establishing an orderly system that led to life on Earth[8]
- Studies suggest “lipids from microbial sources can be preserved in the Martian soil” so finding them “could be associated with fossil life”[9]
- Sudan iii is a staining agent soluble in oil[10]
- Procedure:
  - Add soil to test tube with water, add a few drops of Sudan III
  - Determine if layer separation in camera



Sudan III, negative (L), positive (R)

Lipids (Ethanol Emulsion)

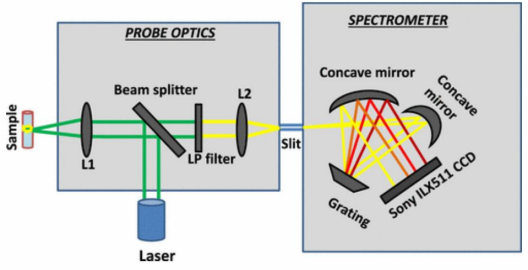
- Lipids soluble in ethanol, solution becomes cloudy due to suspended particles in immiscible solution (created by adding water)[11]
- Procedure:
  - Add soil to test tube with ethanol and stir for a few minutes, then add in water
  - Determine if solution is milky white in camera
  - Improvement the longer solution is left to settle
- Lipids are important biomarker molecules with “structural patterns and physical characteristics that can only result from biological processes, discarding their origin from abiotic sources”[9]
  - Research if confirmation of life or supporting



Ethanol emulsion, negative (L), positive (R)

Raman Spectroscopy

- Raman spectroscopy is “proposed as a valuable analytical technique for planetary exploration”[12]
  - Able to “unambiguously identify key spectral markers in a mixture of biological and geological components”[12]
- Uses a laser to determine molecular composition of sample
- Goal is to detect kerogen and carotenoids’ spectral lines
- Kerogen is fossilized organic matter[13] (extinct)
  - Peaks at 1354 and 1603 cm^{-1} [14]
- Carotenoids are pigments found in photosynthetic organisms[15] (extant)
  - Peaks at 1000, 1150, and 1510 cm^{-1} [16]



Interfaces

Interface Overview

Science mission

- Astro-ISH: Define test protocols, work together to ensure proper on-board procedure
- Astro-SA: Inform on soil sample quantities needed, aid in contamination and soil varieties testing
- Astro-Teleop: Define how control scheme should be laid out to control tests and receive results in a readable form
- Astro-ESW: Inform requirements to perform all of our tests, used to execute order of steps (concept of operations)
- Astro-EHW: Communicate sensor details to facilitate proper integration with electrical

Risk Assessment

Risk Mitigation Table

RISK DESCRIPTION	EVALUATION			MITIGATION PLAN
	LIKELIHOOD	SEVERITY	PRIORITY	
Science team has little working knowledge of geology of region	2	5	10	Have multiple members learn about rocks, each person researches about a specific rock type/ specific aspect of the geology of the region and then does a short presentation, get samples of utah-type rocks, work with Nathan Sheldon
Raman doesn't work	5	2	10	Have new members do more testing based off of Tess's and Abby's recommendations
Contamination	3	4	12	Sealable test chambers, cross contamination testing for all relevant components (i.e. testing procedure for how much contamination is left on the scoop after testing), quantifying how much contamination there is
Low camera visibility	3	4	12	Establishing a threshold for each test, research how to optimize tests in low visibility conditions

Control Scheme

Control Scheme

- Science laptop via teleop
- GUI option to choose site, all test controls are for that site
- Confirmation of tests:
  - Chlorophyll
    - Sensor readings in table, emphasize important channel
  - Amino acids
    - Visual of color change from cameras
  - Lipids
    - Visual of layers forming/color change from cameras
- Capture images for the presentation from screenshots

Budgets

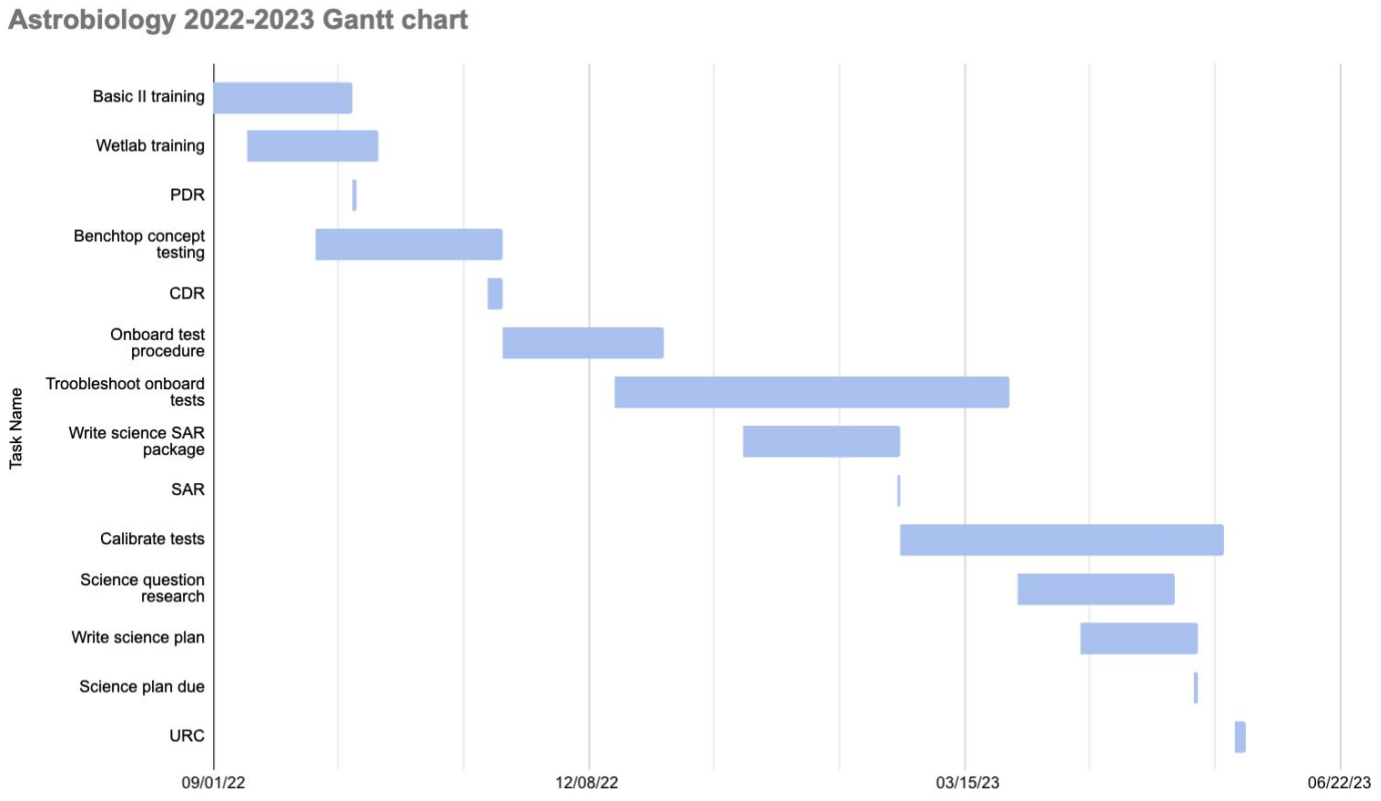
Monetary Budget

	Off-board Cost (USD)
Already spent on testing supplies	$63
Ethanol (16oz)	$32 ($19*2)
Ninhydrin powder (5g)	$14
Sudan III (100mL)	$16
Soil simulants	$50
Other supplies	$175
TOTAL:	$350/$500

*very preliminary

Timeline

Timeline


Astrobiology 2022-2023 Gantt chart
Task Name
Basic II training
Wetlab training
PDR
Benchtop concept testing
CDR
Onboard test procedure
Troobleshoot onboard tests
Write science SAR package
SAR
Calibrate tests
Science question research
Write science plan
Science plan due
URC
09/01/22
12/08/22
03/15/23
06/22/23

Challenges

Challenges

- Wetlab training time
  - Tess offered to help if necessary
- UV glasses
  - Not sure how many more it makes sense to buy
- Might need more electrical help for testing
  - Nichrome wire
  - Chlorophyll sensor
  - LEDs

Members

Member list

Member	Major	Year	New/Ret.	Basic I?	Basic II?	Wet lab?
Emeline Hanna	NERS	Junior	Returning	Complete	Complete	Complete
Yanbo Pan	Astronomy	Sophomore	New	Complete	Complete	Complete
Isaac Chan	Astronomy	Sophomore	New	Complete	Complete	Complete
Shosei Yamane	Business	Sophomore	New	Complete	Complete	Complete
Amin Jazaeri	CMBS/BME	Freshman	New	Complete	Complete	Online done
Arianna Creech	MCDB	Junior	New	Complete	Complete	Not done
Lúthien Liu	Astronomy + FTVM (has BSc in Pharmacology)	Senior	New	Complete	Complete	Not done
Sophia Troshynski	Aerospace Engin	Sophomore	New	Complete	Complete	Online done
Jude Laskey	Engin Undecided	Freshman	New	Complete	Online done	Not done

Appendix

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Astrobiology		Interfaces
GEN.4	Rover shall complete each mission without causing damage to subsystem	Mobility, Teleop, CM, RA, ISH, Power, EHW, Comms, SA
GEN.4.C	Components used on the rover shall provide desirable performance at ambient temperatures up to 115°F	Mobility, Teleop, CM, RA, ISH, Power, EHW, Comms, SA
GEN.4.C.vi	Science tests used on rover shall provide consistent and conclusive results at ambient temperatures up to 115°F	–
ERD.2	Rover shall retrieve designated rock from a rockfield	RA, CM, Mobility, Teleop
ERD.2.B	Rover sensors shall provide operators with clear and complete views of robotic arm to identify and retrieve objects from ground and provide a sense of the arm's movement	Teleop
ERD.2.B.i	On-board cameras shall provide view with sufficient resolution to distinguish a specified type of rock from a distance of 5 m.	Teleop
SCI.1	Rover shall complete all essential objectives of the Science Mission within 20 minutes	Mobility, Power, ESW, Teleop, SA, ISH, CM
SCI.1.B	Rover shall collect and analyze all soil samples and analyze all rock samples at up to 10 sample sites using in-situ instruments within 20 minutes	SA, ISH, CM
SCI.1.B.i	Rover shall be capable of collecting and analyzing 3 soil samples as well as analyzing 2-9 rock samples within 20 minutes	SA, ISH
SCI.2	Rover shall collect a soil sample to be cached and delivered to judges	SA, ISH, Teleop
SCI.2.A	Rover shall identify a region of high scientific value from which to collect the sample	Teleop, ISH
SCI.3	Rover shall analyze site for presence of extinct or extant life by analyzing several rocks in-situ	ISH, SA
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SCI.4.A.iv	Tests to determine presence of a target molecule shall be detectable by camera or sensors	ISH, Teleop
SCI.4.D	Rover shall contain science hardware that is leak-proof and corrosion-resistant	ISH, CM, SA
SCI.4.D.i	Test enclosures shall be spillproof, light-tight, and accessable for sample disposal	ISH, CM
SCI.4.D.ii	Sample Acquisition hardware shall be spill proof and corrosion resistant	SA
SCI.5	Base station operations and Astrobiology test selections shall be presentation focused	Teleop, SA, ISH
SCI.5.A	Results from tests and analyses shall be clear and compelling	Teleop, SA, ISH
SCI.5.A.ii	Science test results shall be produced in an easily extractable format for ease of inclusion in presentation	ISH
SCI.5.A.iii	Results shall be straightforward so as not to require further deliberation during presentation preparation time	ISH

Useful Links

- Testing to do spreadsheet

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  - Wavelengths of 713 nm and 726 nm
- Carotenoids are pigments found in photosynthetic organisms[14] (extant)
  - Wavelengths of 695 nm, 703 nm, and 721 nm