MROVER

MICHIGAN MARS ROVER TEAM

Astrobiology CDR

11/17/22 | Emeline Hanna

Requirements

Summary of Astrobiology Requirements

- 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
  - Rover shall be capable of collecting and analyzing 3 soil samples as well as analyzing 2-9 rock samples within 20 minutes
- Rover shall analyze site for presence of extinct or extant life by analyzing several rocks in-situ
- Rover shall analyze site for presence of extinct and extant life by collecting and analyzing a soil sample
- Results from tests and analyses shall be clear and compelling

System Overview

System Overview

Tests for rocks

1. Microscope
2. Rock camera
3. (Possibly) ThorLabs color CMOS Camera

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

Color CMOS Camera

- USB connection
- 1440 x 1080 Pixel (1.6 MP) Sensor
- Allow us to take images of a 4.968 mm x 3.726 mm view of a rock
- Comes with software to help analyze images after they have been acquired
- 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

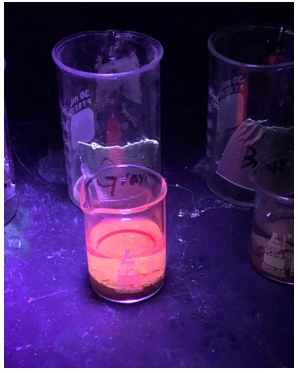
Chlorophyll

- Ethanol at 100% concentration outperformed other ethanol concentrations and all acetone concentrations (both visually and using sensor)
- Lower limit (by chlorella to soil weight percent): 0.5%
  - Corresponds to ~25 on relevant spectral channel when using UV flashlight
- Spectral sensor second channel (680 nm)
  - Stronger positive
    - ~100-900s using UV flashlight
    - ~50-90s using UV LED sensor
  - Negative
    - ~0-15 using UV flashlight
    - ~0 using UV LED sensor

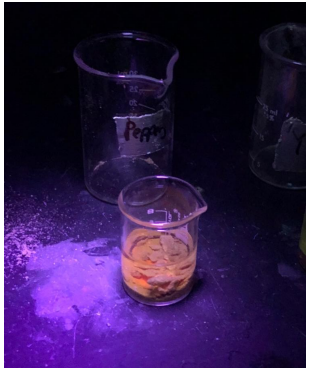
Lower limit testing using ethanol

Chlorophyll

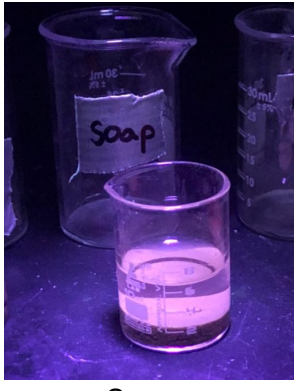
- Soil additives:
  - Very positive for detecting chlorella and grass
    - Spectral sensor ~400-800 using UV flashlight
  - Slightly positive for detecting yellow leaves, a green smoothie, and a pepper
    - Spectral sensor ~25-35 using UV flashlight
  - Negative for lipids and amino acids
    - Spectral sensor ~2-18 using UV flashlight
- Ideal soil amount around 3-6 g



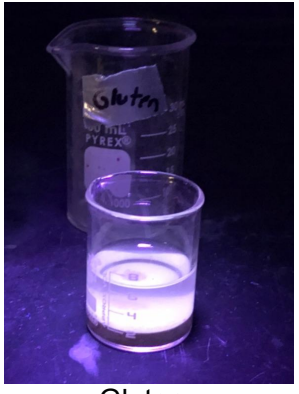
Grass



Pepper



Soap



Gluten

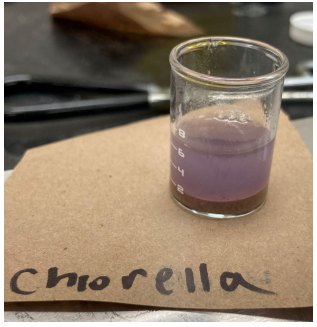
Amino acids (Ninhydrin)

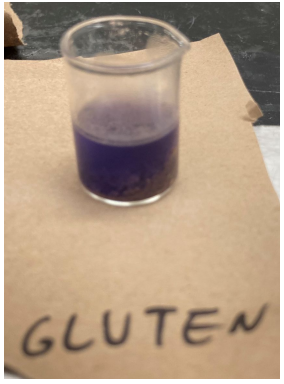
- Amino acids are the building blocks of proteins and enzymes in terrestrial organisms[5]
- Ninhydrin reacts with primary amino groups to form purple dye[6]
- Procedure:
  - Heat water with ninhydrin powder in 10mL beaker and add soil
  - Determine if purple color change with cameras
- Near 100% confirmation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

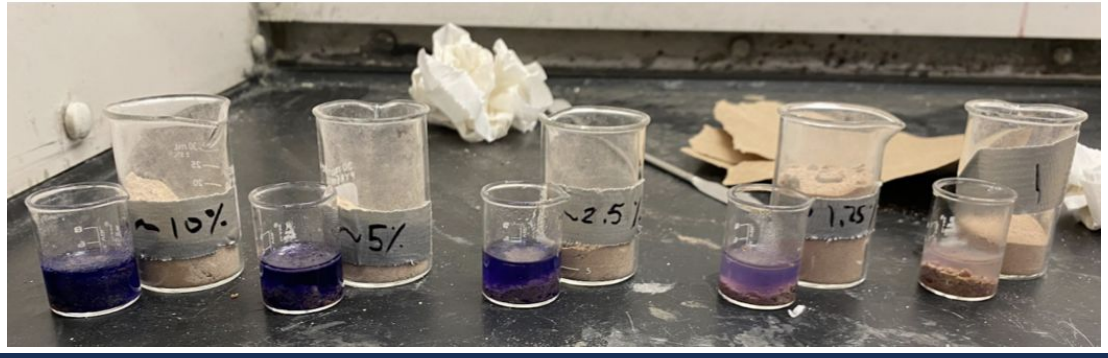
Ninhydrin, negative (L), positive (R)

Amino acids (Ninhydrin)

- Lower limit (by gluten to soil weight percent): 1.25%
- Soil additives:
  - Very positive for detecting gluten and chalk*
  - Slightly positive for detecting chlorella and grass
  - Negative for lipids (butter, canola oil, soap)







*only positive for some chalks

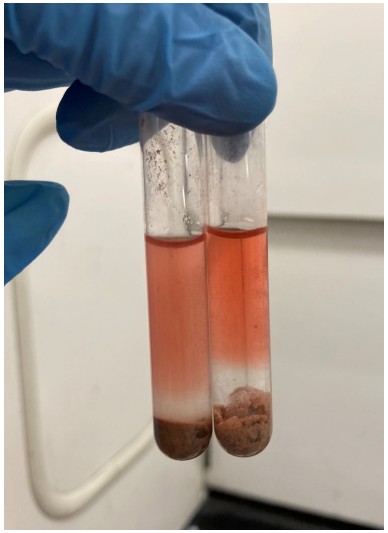
Lipids (Sudan III)

- 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

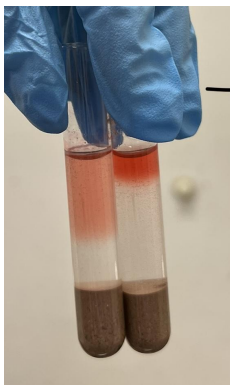
Sudan III, negative (L), positive (R)

Lipids (Sudan III)

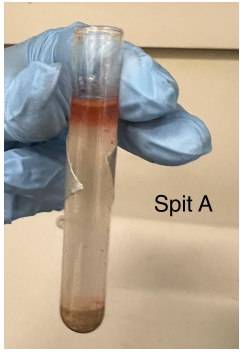
- Lower limit (by canola oil to soil weight percent): ~0.6%
  - Results have not been consistent
- Soil additives:
  - Positive for detecting soap, canola oil, and spit
  - Positive for detecting grass but negative for chlorella
  - Positive for detecting chalk but negative for gluten
- Ideal soil amount around 2 g

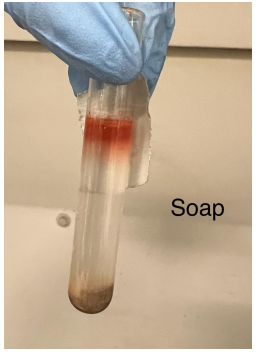


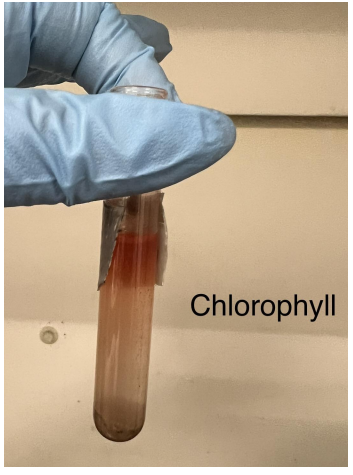
negative (L), positive for butter (R)



negative samples (L), positive samples (R)

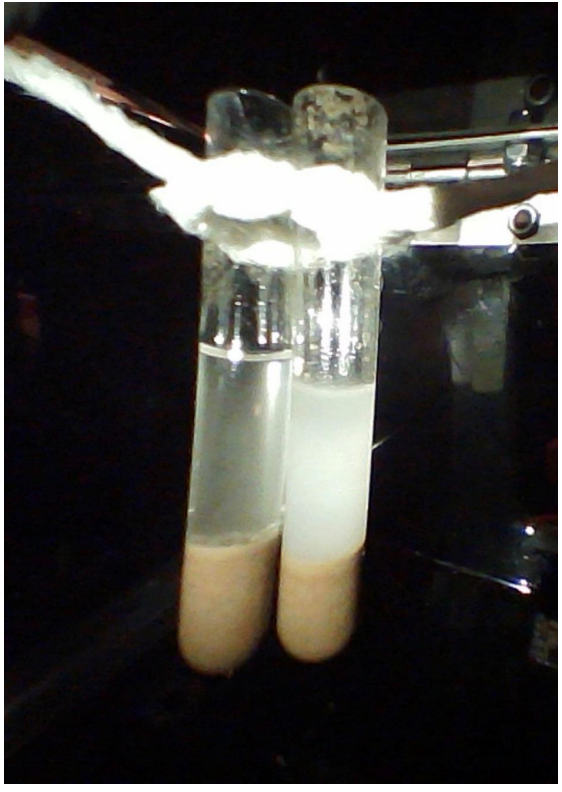






Lipids (Ethanol Emulsion)

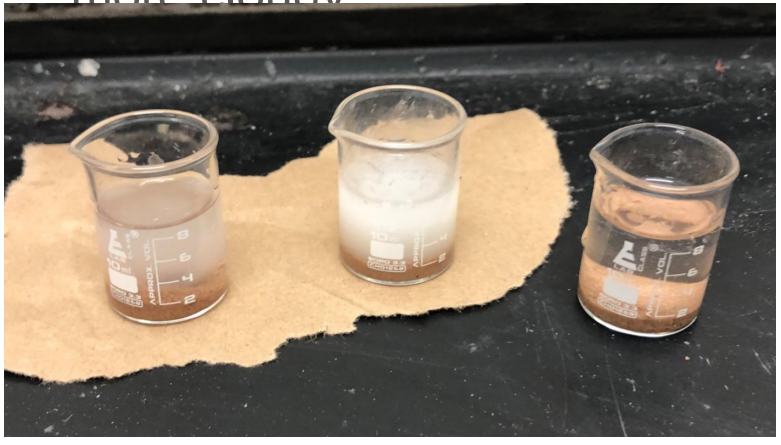
- Lipids soluble in ethanol, solution becomes cloudy due to suspended particles in immiscible solution (created by adding water)[11]
- Procedure:
  - Add soil to test tube with ethanol and stir for a few minutes, then add in water
  - Determine if solution is milky white in camera
  - Improvement the 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]



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

Lipids (Ethanol v. Acetone Emulsion)

- Did testing originally in beakers
- Tested without shaking
- Acetone results were much more cloudy



Positive w/ ethanol (L), positive w/ acetone (middle), negative w/ acetone(R)

0.3% positive with ethanol (L), 0.3% positive with acetone (R)

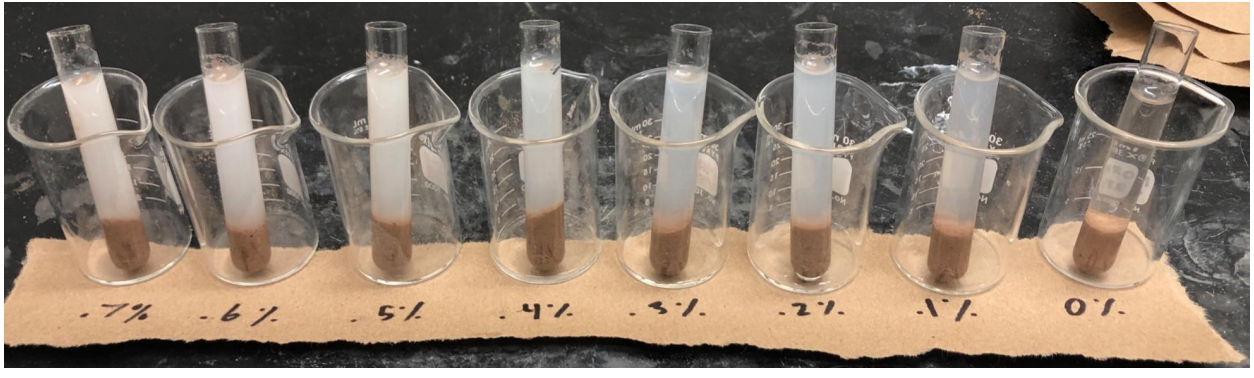
0.7% positive with ethanol (L), 0.7% positive with acetone (R)

Lipids (Acetone Emulsion)

- Lower limit (by canola oil to soil weight percent): 0.05%
- Ideal soil amount around 2 g

0.7% positive (L), 0.1% positive (middle/back), negative (R)

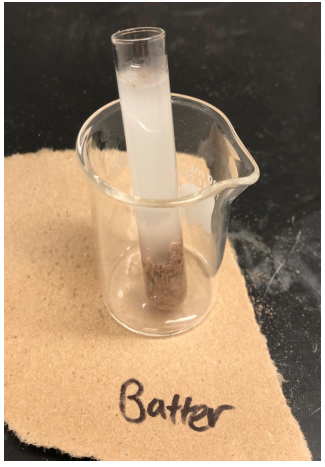
0.1% positive (L), negative (R)

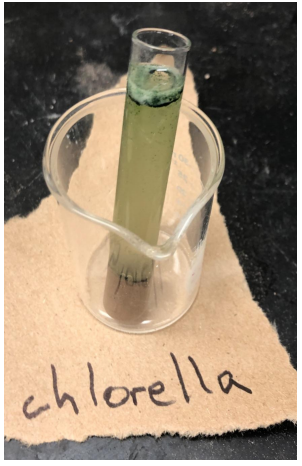


0.05% positive

Lipids (Acetone Emulsion)

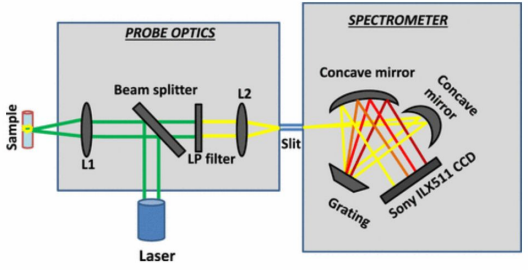
- Soil additives:
  - Positive for detecting canola oil and butter
  - Negative for pepper, yellow leaf, and soap
  - Hard to read results from gluten and chlorella test
- Overall more consistent and likely accurate results but could be hard to read with cloudy or colored soils





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]

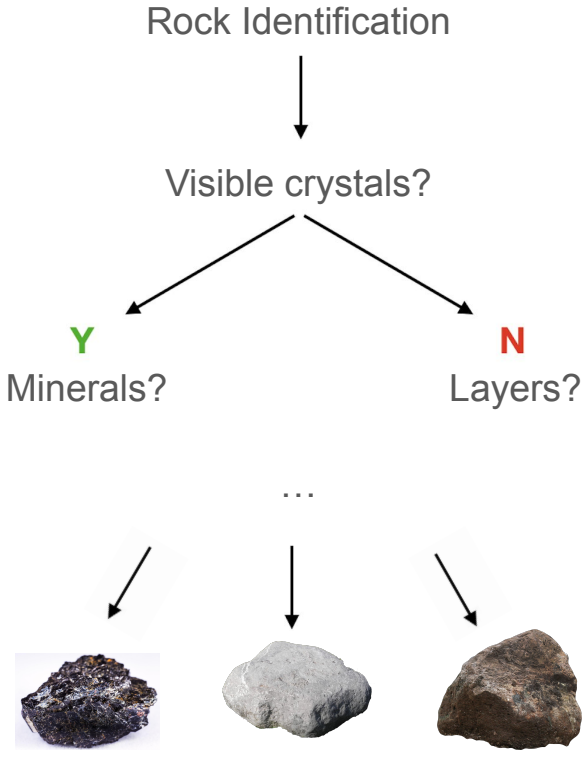


Rock database

Rock parameters:

- Type of rock
- Grain size
- Crystal size
- Color
- Luster
- Layers present

Option of a flowchart:



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	4	8	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	4	1	4	A few members are learning CAD now, have them do more testing based off of Tess's and Abby's recommendations
Contamination	3	3	9	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	2	4	8	Use 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

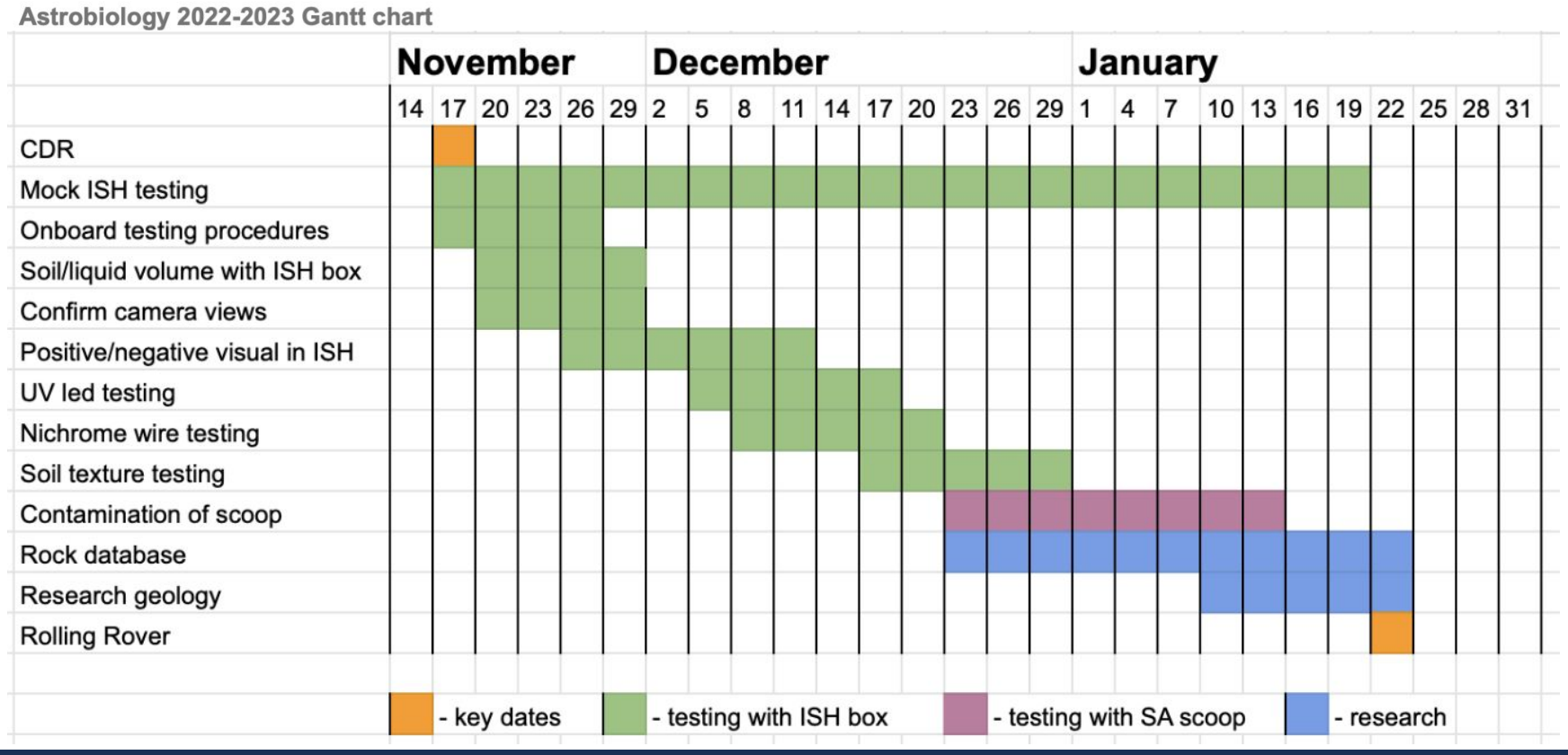
Budgets

Monetary Budget

		Off-board Cost (USD)
Spent		$163.48
Expected future spending		$100
	Ethanol (16oz)	$38 ($19*2)
	Ninhydrin powder (5g)	$14
	Acetone (16oz)	$28 ($14*2)
	Glassware	$20
TOTAL (spent+expected):		$263.48/$500
Worst case future spending		$300
TOTAL (spent+worst case):		$463.48/$500

Timeline

Timeline


Astrobiology 2022-2023 Gantt chart
November
December
January
14 17 20 23 26 29 2 5 8 11 14 17 20 23 26 29 1 4 7 10 13 16 19 22 25 28 31
CDR
Mock ISH testing
Onboard testing procedures
Soil/liquid volume with ISH box
Confirm camera views
Positive/negative visual in ISH
UV led testing
Nichrome wire testing
Soil texture testing
Contamination of scoop
Rock database
Research geology
Rolling Rover
- key dates
- testing with ISH box
- testing with SA scoop
- research

Challenges

Challenges

- Sudan III consistency
- Cleaning glassware
  - Bought ultrasound cleaner
- ThorLabs sensor being expensive and out of stock

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	Complete
Arianna Creech	MCDB	Junior	New	Complete	Complete	Complete
Sophia Troshynski	Aerospace Engin	Sophomore	New	Complete	Complete	Complete
Lúthien Liu	Astronomy + FTVM (has BSc in Pharmacology)	Senior	New	Complete	Complete	Complete

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
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.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

- Soil additives results
- Testing to do spreadsheet