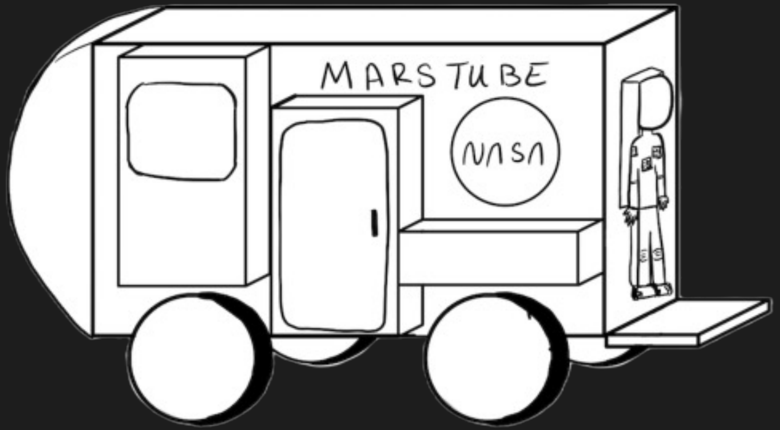
# AERO 455 Final Project: MarsTube

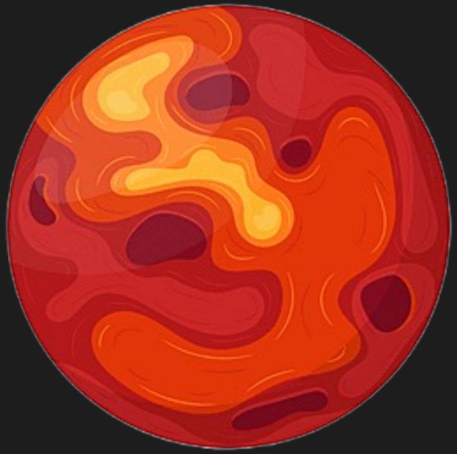



Nathalia De Souza, Johan Govaars, Carlos Lopez, Steven Sharp, Lily Wahleithner

# Table of Contents

# 01

# Project Overview



# Project Overview

- MarsTube is a rover with the capacity to support 14-day long excursions with 2 crewmembers on board.
- MarsTube is equipped with many redundant safety features that ensure the crew’s well-being even if serious issues occur
- MarsTube's purpose is to enable the survey and exploration of locations on Mars that are important to research.

# Concept of Operations

## Phase I

Transit from Earth to Mars

## Phase II

Land on Mars' surface, rover deployment and testing

## Phase III

Traverse to HAB, prepare rover for EVAs

## Phase IV

Initiate 2-week EVA operations,  sample collection

## Phase V

Return to HAB to replenish rover necessities, repeat Phase IV as necessary

## Phase VI

Departure from Mars 6 months later and return to Earth

# 02

# Science Objectives

# Science Objectives

**A1:** Past Life – Search for and characterize past habitability potential in environments with highest preservation potential for ancient biosignatures

**B3:** Characterize the local source and sinks in the dust, water, and CO2 cycles, and the key parameters that determine these sources and sinks across a diversity of surfaces.

**C3:** Constrain the dynamics, structure, composition, and evolution of the Martian interior to answer larger questions about planetary evolution (to be refined based on discoveries during the next decade)

# Landing Site

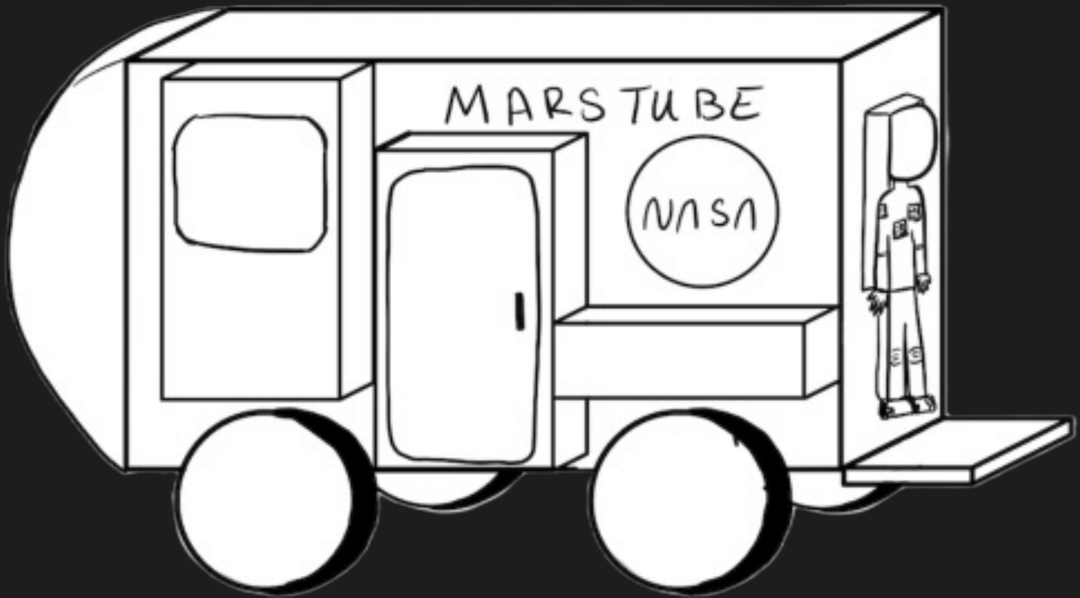
- 20° N, 320° E (40 ° W)
- Immediate surroundings are relatively flat (in the middle of the Chryse Planitia)
- Within range of the extreme canyons to the south and plains to the north
- Pathfinder and Viking 1 can be used as monuments
- Radiation is less intense in the site's lower elevation and higher latitude


Source: Google Earth Pro

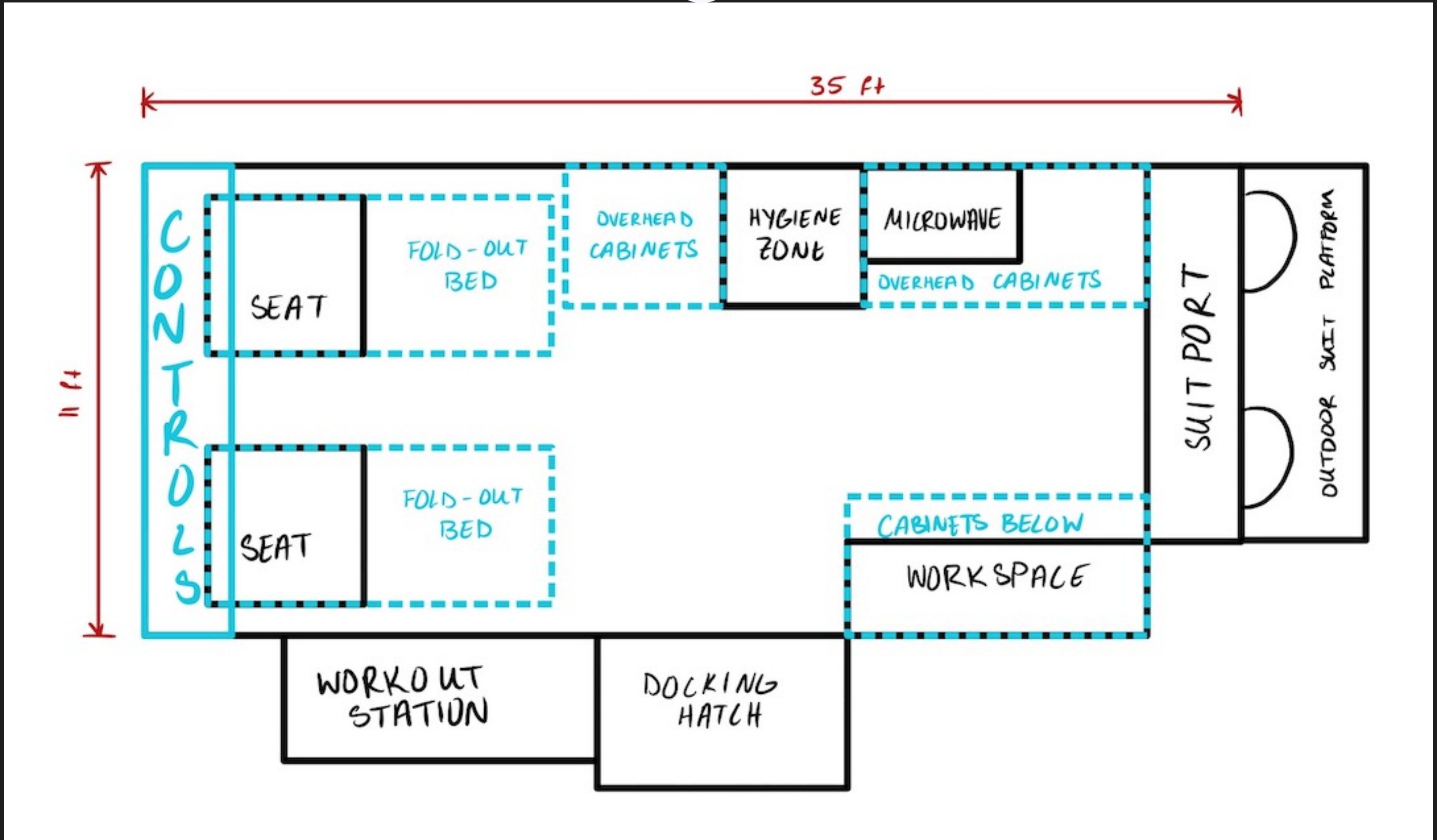
# Meeting the Science Objectives

- ★ Landing site chosen to maximize the chance of past life detection due to its location near ancient river deltas
- ★ Site is also near medium sized impact craters that would allow for analysis of rock samples originally deeper in the crust to help characterize the geological evolution of the Martian interior
- ★ Site has access to a diverse set of terrain types all within rover excursion range that will allow for a characterization of the local sources and sinks of dust, water, and CO2
- ★ Different rover excursions will be focused on one primary science objective, but astronauts will have the option to stop if they feel they may be able to perform some science involving the secondary objectives

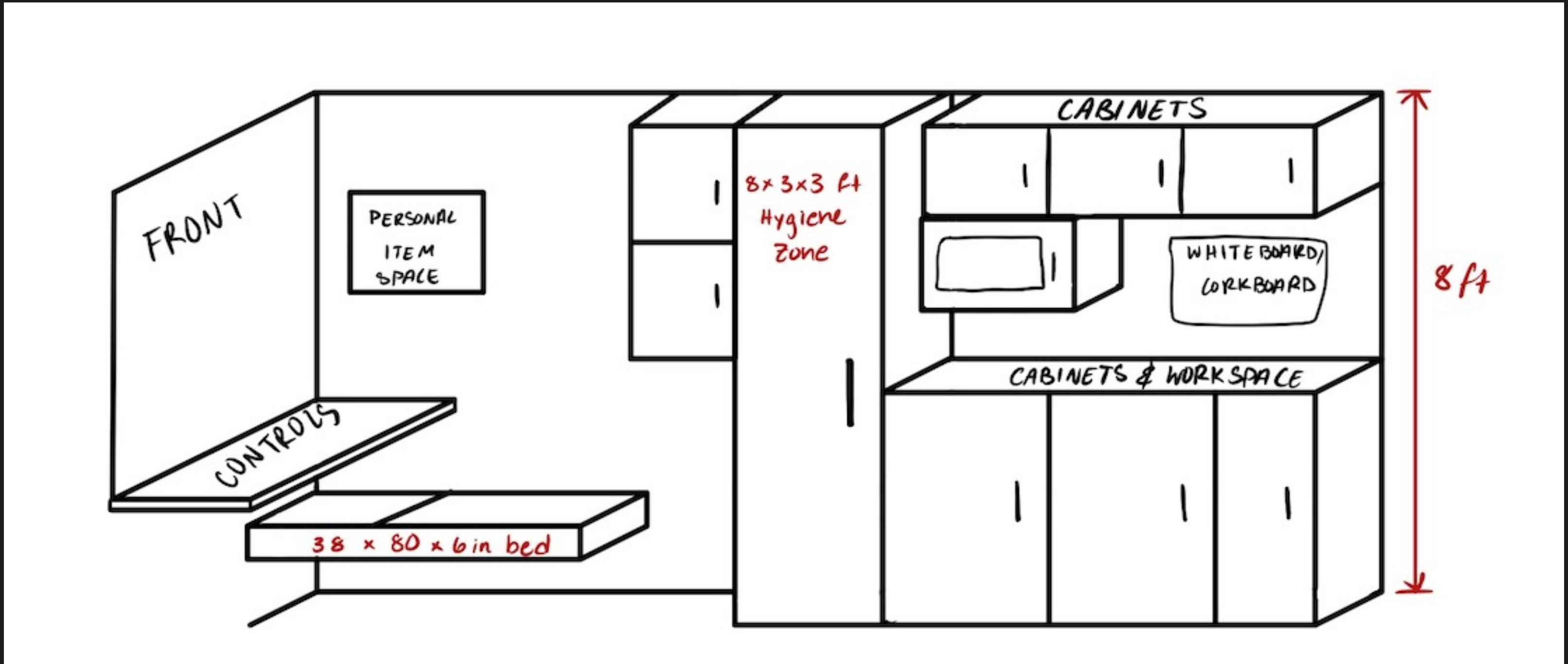
# 03
# Rover Design



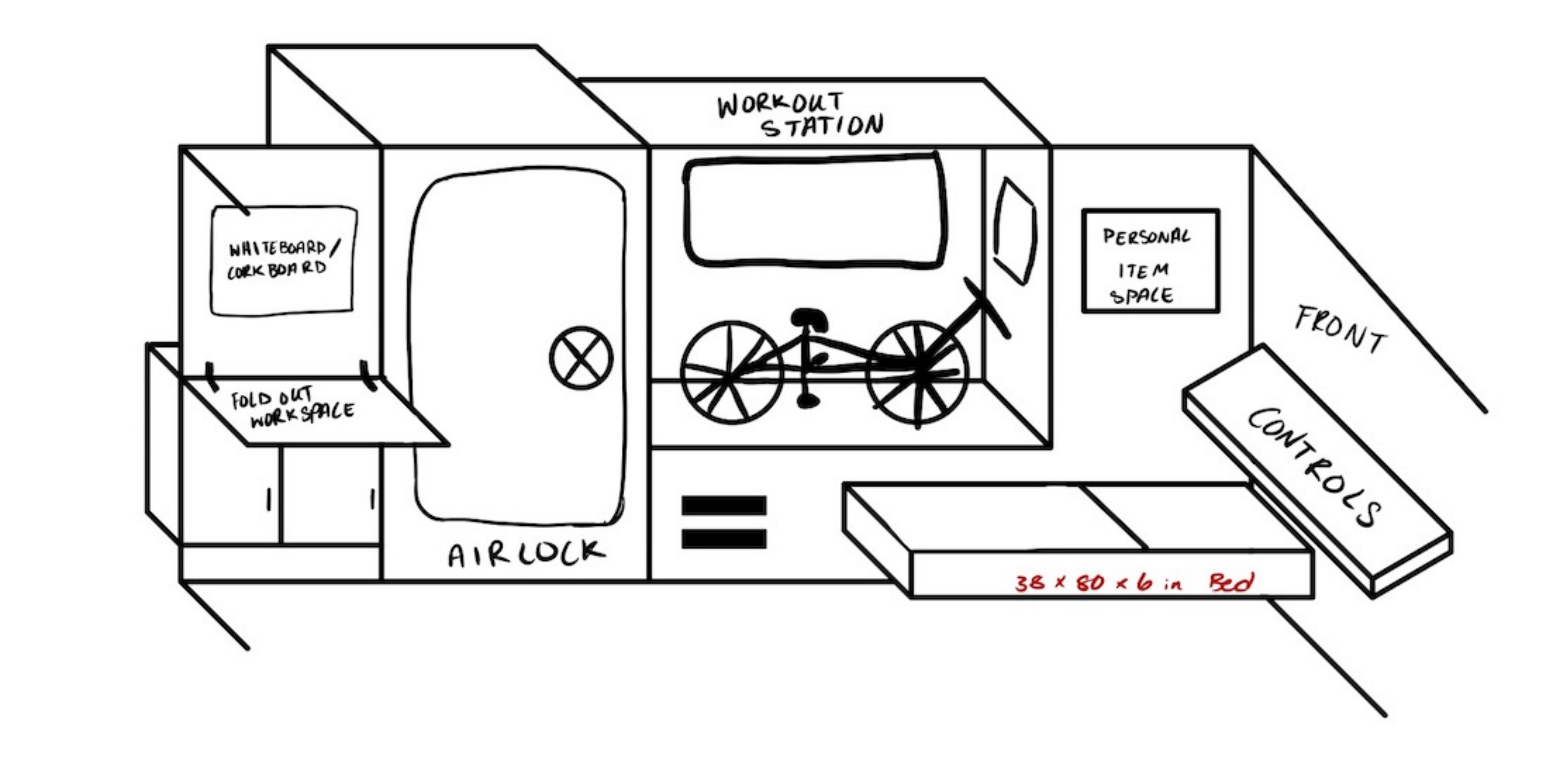
# MarsTube Rover Design



# MarsTube Rover Design



# MarsTube Rover Design



# MarsTube ECLSS

## Oxygen & Water

Storage and
resupply every two weeks

## Atmosphere

Ventilation, CO2 and
contaminant removal,
pressure control

## Temperature

Temperature controlled
and includes humidity
management

## Waste

Waste is dehydrated and
stored until it can be
disposed of at Hab

## Food

Storage in cabinets above
and below microwave

## Radiation

Monitoring and shielding
required to protect from
radiation

# ECLSS Justification

Source: Would Current International Space Station (ISS) Recycling Life Support Systems Save Mass on a Mars Transit? By Harry W. Jones

Table 4. Mass, mass produced, mass breakeven date, and mass payback.

| System | Full name | System mass, kg | One set of spares mass, kg | ORUs mass, kg | Mass of the system and spares, kg | Mass use for 4 crew, kg/day | Mass breakeven date, days | Mass used on 450 day Mars transit, kg | Mass payback ratio |
|---|---|---|---|---|---|---|---|---|---|
| OGS | Oxygen Generation System | 676 | 399 | 1,128 | 1,405 | 3.36 | 418 | 1,512 | 1.08 |
| CDRA | Carbon Dioxide Removal System | 195 | 156 | 389 | 428 | 7.00 | 61 | 3,150 | 7.36 |
| CRS | Carbon Dioxide Reduction System | 329 | 219 | 657 | 986 | 3.27 | 301 | 1,476 | 1.50 |
| OGS + CRS | Carbon dioxide to oxygen | 1,005 | 618 | 1,785 | 2,391 | 3.36 | 712 | 1,512 | 0.63 |
| WRS = UPA + WPA | Water Recovery System | 1,383 | 719 | 2,985 | 3,649 | 18.60 | 196 | 8,370 | 2.29 |
| UPA + 31% WPA | Urine processing | 742 | 366 | 1,660 | 2,036 | 5.76 | 353 | 2,592 | 1.27 |
| 69% WPA | Condensate and hygiene processing | 641 | 353 | 1,325 | 1,613 | 12.84 | 126 | 5,778 | 3.58 |
| ECLSS | Environmental Control and Life Support System | 2,583 | 1,493 | 5,159 | 6,249 | 32.23 | 194 | 14,508 | 2.32 |

# ECLSS Justification

Source: "Total Mass of ECLSS System for Mars Ascent/Descent Lander using Baseline ECLSS Technologies. ESM is equivalent system mass including estimates of mass for power system, cooling and crew time. (30-day duration - crew of six)(Hanford 2005)"

| Subsystem / Interface | M kg | V $m^3$ | P kWe | C kWth | CT CM-hr | ESM kg |
|---|---|---|---|---|---|---|
| Air | 1071 | 2.16 | 4.251 | 2.742 | 1.07 | 2586 |
| Biomass | 0 | 0.00 | 0.000 | 0.000 | 0.00 | 0 |
| Food | 620 | 3.37 | 2.128 | 2.128 | 0.00 | 1638 |
| Thermal | 296 | 0.92 | 0.822 | 0.822 | 0.17 | 665 |
| Waste | 69 | 1.02 | 0.014 | 0.014 | 0.00 | 142 |
| Water | 737 | 2.88 | 0.896 | 0.896 | 0.00 | 1263 |
| Extravehicular Activity Support | 22 | 0.25 | 0.000 | 0.000 | 0.00 | 38 |
| Human Accommodations | 188 | 0.65 | 0.000 | 0.000 | 0.00 | 231 |
| Totals | 3001 | 11.25 | 8.111 | 6.602 | 1.24 | 6560 |

# Mass Breakdown

| | |
|---|---|
| Washer | 100 |
| Clothes | 46 |
| Soap | 0.72 |
| Crew Health Care System | 1500 |
| Treadmill | 106 |
| Bike | 130 |
| Emergency Kits | 400 |
| Microwave | 70 |
| Patchwork Tools & Supplies | 263.2 |
| Food solids | 558 |
| Potable Water | 226.8 |
| Non-potable water | 2286 |
| Oxygen | 756 |

| | |
|---|---|
| EVA Suit | 600 |
| EVA LiOH Canisters | 362.5 |
| EVA Oxygen | 79 |
| EVA Food | 57.5 |
| EVA Water | 362.5 |
| Rover Structural Mass | 3000 |
| Oxygen Candles | 168.7 |
| ECLSS System - air | 861.2 |
| ECLSS System - water | 289.2 |
| RTG System | 4000 |
| Spare Parts | 500 |
| Radiation Shielding | 12993.8 |
| **Total** (kg) | 29717.1 |

# Communications – Data Rates

- UHF communication with orbiters: 2 Mbps
  - Sufficient for voice and video messages
  - Also sufficient to download movies, shows, games, etc. (legally purchased by NASA of course)
  - Can allow for communication even when Earth is at negative elevation but the orbits add an additional delay
- X-band communication with DSN via 0.3 m high gain antenna: 500 – 3000 bps
  - Text communication only
  - Can be used for critical instructions and commands while Earth is at >10° elevation and antenna is pointed at the DSN

# Communications – Time Delay

- Best case: 5 minutes, worst case: 20 minutes
- Direct voice contact will be impossible, but data rate can support recorded video and voice messages
- Instructions will have to be pre-recorded rather than carried out live
- Astronauts may have to pause operations temporarily or for the day if a response is needed from mission control to continue a task
- Text chat will be highly impractical, so complete page-long documents will be preferred (especially for operation instructions)
- Separate channels for non-critical and critical transmissions so the astronauts can't miss a critical warning or change to the operations
  - Especially important for incoming radiation bursts– solar weather will be given twice-daily for low to normal solar activity levels. More times if the sun is quite active

# Power System

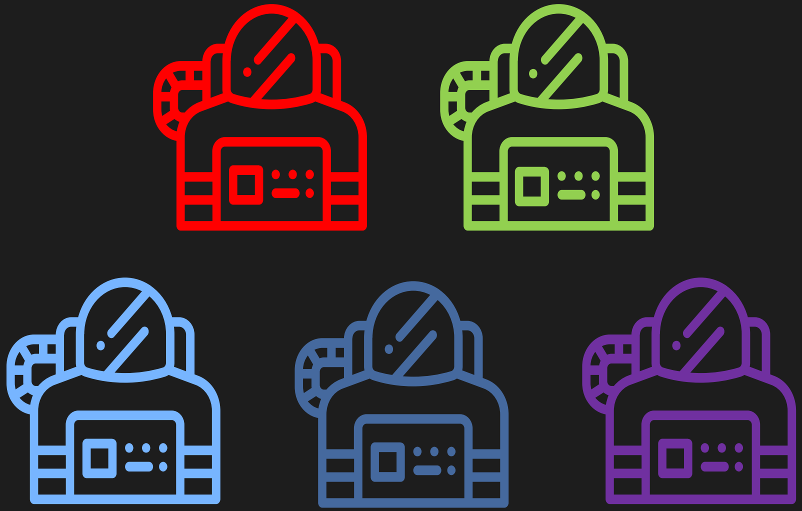
- Rover power will be provided by a Radioisotope Thermoelectric Generator (RTG)
  - While heavy, negates the need for large batteries for the rover and extends its range to the maximum safety range determined before.
  - Smaller and more compact than solar arrays capable of providing kW of power
    - Also does not require intensive labor from regular cleaning of dust
    - Steady, reliable power available at all times including night and dust storms
  - The system also provides heat which can be used to regulate the temperature of the rover
  - Existing radiation shielding on the main rover and on the generator itself ensures radiation exposure is no worse than from the environment

# Radiation Protection

- Assuming rover dimensions are similar to a large RV
- Wall dimensions: 3.5 m x 3.5 m x 12 m
  - Surface area of 192.5 $m^2$
- Shielding thickness – 2.5 cm pure aluminum
  - Resulting shielding density of 6.75 $g/cm^2$
  - Expected mission dose of 390 mGray
    - Less than the 500 mGray 1-year limit for astronauts' organ systems
- Total shielding mass: 12,993.75 kg

# 04

# Crew
# Information



# Crew Hierarchy

## Mission Commander

### Medical Officer

The medical officer has final authority over all matters of crew health and wellbeing

### Geologist

The geologist is the primary planner of science and exploration operations

### Astrobiologist

The astrobiologist will research the possibility of previous life on Mars

### Mission Engineer

The mission engineer will oversee repair of all mechanical issues that arise

# Crew Composition Pt. 1

## Mission Pilot

The pilot will be in charge of driving the rover and commanding the overall mission

## Mission Engineer

The mission engineer will be the technical expert for most mechanical systems and is the main mechanic

## Mars Geologist

Geology is a critical component to multiple science objectives in the mission and as such, a geologist is needed

# Crew Composition Pt. 2

## Astrobiologist

Detection of past life is another critical component of our science objectives and so an expert in life, especially in extreme environments, is needed

## Medical Officer

A medical doctor is critical for maintaining the physical and mental health of the crew for the overall mission as well as responding to any unexpected medical emergencies

# Composition Rationale

Our decisions about crew size and composition were multifaceted. We found this group of people would make the best composition for our mission needs because:

★ A 5-person crew means no possibilities of ties in decision making,
★ This size crew is large enough to boost and maintain morale without compromising on launch mass,
★ And there is a crew member suited to each science objective, as well as crew to manage piloting, engineering, and medical needs.

# Psychological Support

To support our crew's psychological health during the 14-day excursions, MarsTube will be equipped with:

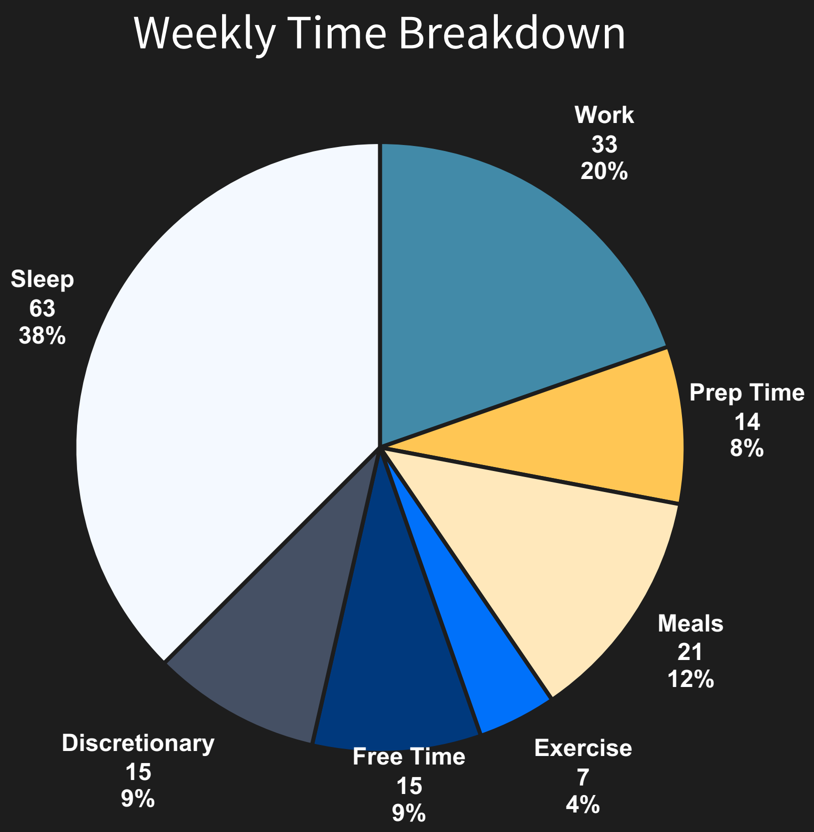
- ★ Biological experiments like growing bean sprouts, peppers, spinach or potatoes for nature exposure and fresh produce
- ★ Closed off areas on the rover for privacy
  - ★ Restroom,
  - ★ Personal hygiene,
  - ★ Private communications with ground
- ★ A panoramic view window for pondering the meaning of life
- ★ Crew-favorite snacks to boost morale
- ★ Crew-selected décor to boost morale

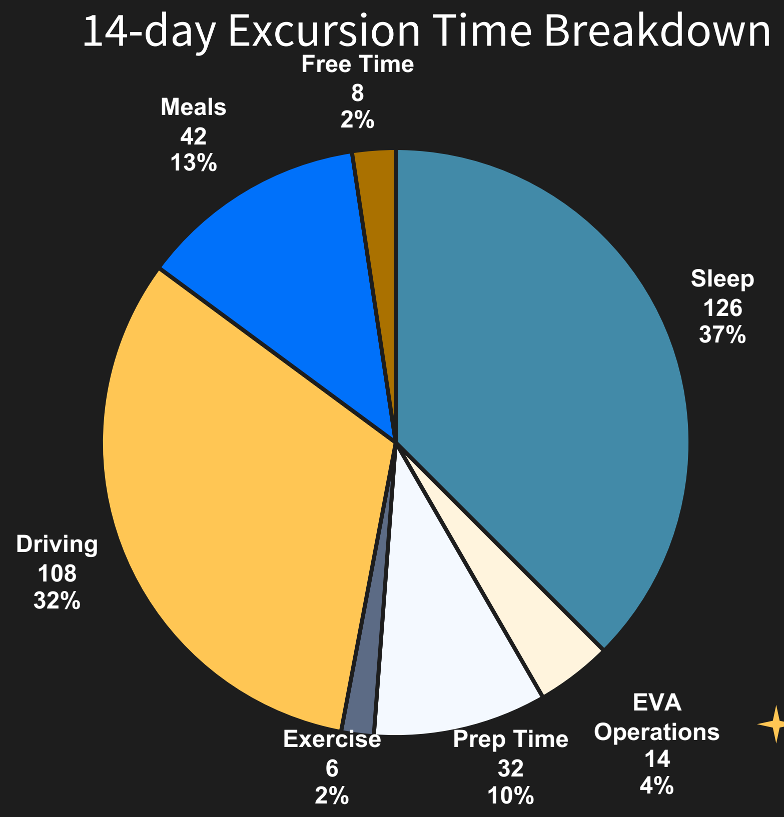
# 05
# Mission Schedule

# EVA Weekly Schedule

<table>
<tr><th>Time</th><th>Nominal Schedule<br>Weekdays</th><th>Nominal Schedule<br>Fridays</th><th>Nominal Schedule<br>Weekends</th><th>Excursion Schedule<br>Driving</th><th>Excursion Schedule<br>EVA Operations</th></tr>
<tr><td>7:00 AM</td><td>Sleep</td><td>Sleep</td><td>Sleep</td><td>Sleep</td><td>Sleep</td></tr>
<tr><td>8:00 AM</td><td>Daily Prep</td><td>Daily Prep</td><td>Daily Prep</td><td>Daily Prep</td><td>Daily Prep</td></tr>
<tr><td>9:00 AM</td><td>Breakfast</td><td>Breakfast</td><td>Breakfast</td><td>Breakfast</td><td>Breakfast</td></tr>
<tr><td>10:00 AM</td><td rowspan="3">Morning Work</td><td rowspan="3">Morning Work</td><td rowspan="3">Discretionary Time</td><td rowspan="4">Driving - Morning</td><td>EVA Prep</td></tr>
<tr><td>11:00 AM</td><td rowspan="7">EVA Operations</td></tr>
<tr><td>12:00 PM</td></tr>
<tr><td>1:00 PM</td><td>Lunch</td><td>Lunch</td><td>Lunch</td></tr>
<tr><td>2:00 PM</td><td rowspan="4">Afternoon Work</td><td rowspan="2">Afternoon Work</td><td rowspan="4">Free Time</td><td>Lunch</td></tr>
<tr><td>3:00 PM</td><td rowspan="5">Driving - Afternoon</td></tr>
<tr><td>4:00 PM</td><td rowspan="2">Discretionary Time</td></tr>
<tr><td>5:00 PM</td></tr>
<tr><td>6:00 PM</td><td>Dinner</td><td>Dinner</td><td>Dinner</td><td>EVA Decompress</td></tr>
<tr><td>7:00 PM</td><td rowspan="2">Exercise/Free Time</td><td rowspan="2">Exercise/Free Time</td><td rowspan="2">Exercise/Free Time</td><td>Dinner</td></tr>
<tr><td>8:00 PM</td><td>Dinner</td><td rowspan="2">Free Time</td></tr>
<tr><td>9:00 PM</td><td>Discretionary Time</td><td>Discretionary Time</td><td>Discretionary Time</td><td>Exercise/Free Time</td></tr>
<tr><td>10:00 PM</td><td>Nighttime Prep</td><td>Nighttime Prep</td><td>Nighttime Prep</td><td>Nighttime Prep</td><td>Nighttime Prep</td></tr>
<tr><td>11:00 PM</td><td>Sleep</td><td>Sleep</td><td>Sleep</td><td>Sleep</td><td>Sleep</td></tr>
</table>

# Breakdown of Crew Time



# EVA Suits and Procedures

★ Suit attached to rear of the rover, always external to mitigate particulates in rover
★ Rover will be at 8.2 psi, acclimatize to 4.3 in suit, 15 minutes between acclimatization and beginning of EVA
★ EVAs are no longer than 7 hours for long missions, short EVAs can occur during transit to destination at astronauts' discretion.
★ Two crew members required on long excursions
★ Short EVAs can be conducted with one or two crew members
★ If EVA consists of only one person, a second crew member must be always on standby
★ At least one crew member must be trained specifically in geology for sample collection specific  EVAs
★ Medical doctor to be on standby during all EVAs

# EVA Supplies Breakdown

| **Component** | **Mass** (kg) *per EVA* | **Mass** (kg) *per crew* | **Mass** (kg) *mission* |
|---|---|---|---|
| EVA suit | | 120 | 600 |
| LiOH Canister | 2.9 | 72.5 | 362.5 |
| Oxygen | 0.63 | 15.8 | 79 |
| Food | 0.46 | 11.5 | 57.5 |
| Water | 3.8 | 72.5 | 362.5 |
| **Total Mass** (kg) | 6.9 | 292.3 | 1461.5 |

# 06

# Contingency Operations

# Failure Modes

- Off-nominal operation
  - Schedule repairs when convenient
- Standard failure
  - Suspend scientific, exercise and leisure operations
  - Schedule repair as soon as feasible
- Critical failure
  - Suspend all non-critical operations
  - Reconvene available crew for repair
- Emergency
  - Suspend all operations
  - Immediately reconvene all crew for repair

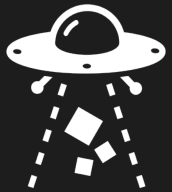
| **Urgency** | **Severity** |
|---|---|
| INCIDENTAL | TRIVIAL |
| PRESSING | MODERATE |
| URGENT | SEVERE |
| CRITICAL | CATASTROPHIC |

# Expected Failures and Mitigation

- Communications system failures
  - Redundant amplifiers, transponders, and antennae
  - Rigorous integration and testing
- Life support system failures
  - Redundant parts
  - Reserve consumables
  - Plenty of spare parts and materials for improvised repairs
    - Temporary habitats for repair work or physical recovery
- Power system failures
  - Redundant, repairable, and easily replaceable solar arrays
  - Tools and materials for electrical system repairs including grounding
  - Reserve power storage for repair work

# Expected Failures and Mitigation

- EVA suit failures
  - Medical training for all crew to reduce chance/severity of injury
  - Emergency and reserve supplies carried on all EVAs
  - Additional materials for EVA suit maintenance and repair
  - Maximum walking distance from the rover maintained at all times
- Contingencies
  - Alternate schedule with only 4, 3, 2 crew available
  - Planned routes to return to the habitat as soon as possible on rover trips
  - Plenty of reserve supplies and spare parts included on the rover
  - Oxygen candles in case of uncorrectable life support system failures



# Figures of Merit

- Excursion capabilities
  - 14-day rover excursions
  - Absolute maximum range: 1,440 km per excursion
    - 10 km/hr maximum speed
    - 2 days reserved for stationary EVA
    - 6 days travel to location, 6 days back
    - Advanced battery and power distribution technology for extended range compared to current rover designs
  - Range with safety margin: 480 km per excursion
    - 6 km/hr average speed
    - 2 x 8-hour shifts per day
    - 2 days reserved for stationary EVA
    - 6 days travel to location, 6 days back
    - 20% margin of safety

# Figures of Merit

- Total mass
  - 16,725 kg brought to Mars
    - 5,840 kg consumables used by the crew
    - 23,880 kg equipment left on the surface
- Exploration time
  - Supplies are sufficient for 25 EVAs, 14 days each, during the mission
    - This covers the entire 6-month mission duration
  - Exploration schedule can be fine-tuned based on demonstrated crew ability and any setbacks, failures, or tangential scientific discoveries
  - Exploration time should probably be less than 50% of the mission to allow for crew rest and recovery

# Summary

- The main objective of the rover is to investigate the possibility of past life on Mars, determining the sources and sinks of various natural cycles, and investigating the interior of the surface to characterize the evolution of the planet.
- A crew complement of 5 will conduct this mission in the custom MarsTube rover
- Missions will last 14 days and rotate crew members
- Total mission mass is well below the total mass budget of 30,000 kg at around 17,000 kg
- Mission schedule designed for crew flexibility and comfort while maximizing time for science and exploration

# Thank you!