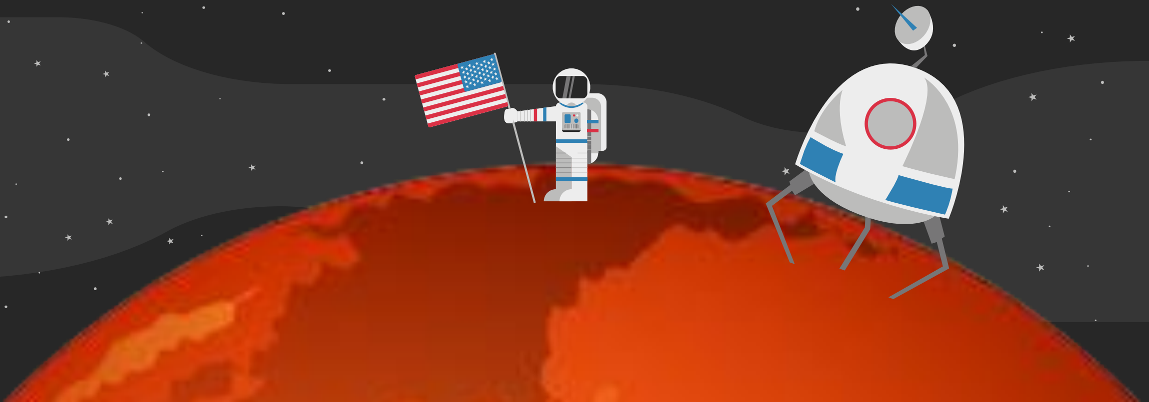
ARES MISSION
PHOBOS AND DEIMOS LANDING

Dylan Carter, Marley Downey, Sean O’Connell, Ethan Hinds, Rody Rodriguez,
Brandon Fallin, Alex Black, Blake Dunn, & Shane Lovello



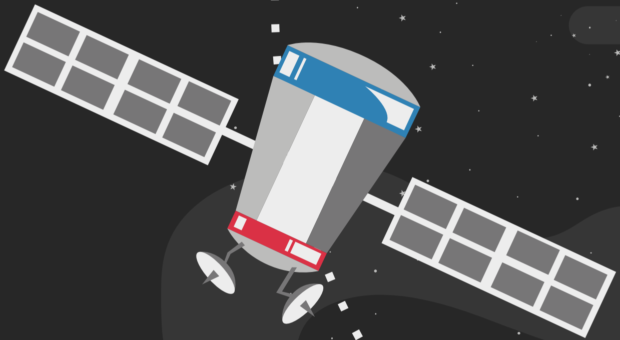
WELCOME TO THE ARES MISSION

Our firm will be partnering with NASA to usher in a new era of Martian exploration and knowledge

TABLE OF CONTENTS

01

BACKGROUND AND MISSION COST



MARTIAN MOONS EXPLORATION EXCURSION VEHICLE

With the recent proliferation of private space exploration, NASA is looking to partner with an entity to explore the Martian moons, Phobos and Deimos

- Bridge the gap between robot mission on Mars surface and crewed landing on Mars
- Low cost, low impact
- No EVA on Phobos and Deimos
- EEV will dock with Deep Space Transport (DST) vehicle to return to Earth

DESIGN OBJECTIVES

Exploration Excursion Vehicle (EEV)

Support 2 crew members on a mission to both Martian moons lasting no longer than 30 days

Scientific Achievement

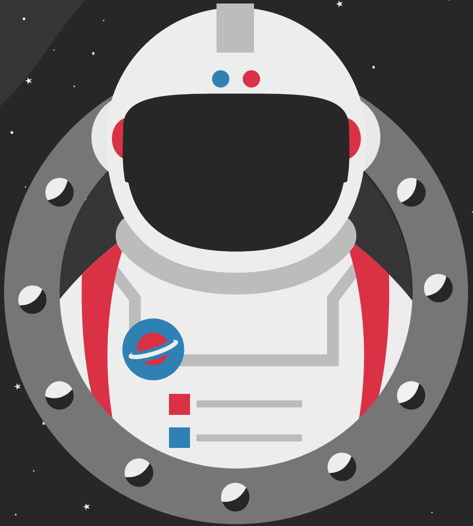
Design scientific experiments and objectives to learn as much as we can about Phobos and Deimos within our budget

Sample Retrieval

Minimum sample quantity of 50kg of material from each moon. Must be brought back to the DST, and then Earth

COST ANALYSIS

Component/Subsystem	Cost Subtotal (USD)
Launch Vehicle + Refuel	$10,000,000
Scientific Objectives and Experimentation	$181,200,000
Exploration Excursion Vehicle	$327,000,000
Rover	$150,000,000
Telecommunications Equipment	$10,000,000
Crew Accommodations	$23,500,000
Total	**$701,700,000**



02

LAUNCH VEHICLE SELECTION

What we will use to accomplish the mission

LAUNCH VEHICLE OPTIONS

Delta IV Heavy

Second-highest capacity launch vehicle in operation

Atlas V-401

Soon to be retired, operated by United Launch Alliance

Falcon Heavy

Old reliable from SpaceX

Space Launch System

NASA's newest launch vehicle designed for interplanetary exploration

Proton-M

Three-stage heavy vehicle from Russia

Starship

On the cutting edge of rocket technology from SpaceX

LAUNCH VEHICLE SELECTION CRITERIA

Payload

Maximum total payload allowed to Mars orbit

Fairing Size

Must be able to fit the EEV in its entirety

Launch Success Rate

Can't afford any failures

Total Cost

Need to make sure we come in under budget

COMPARISON TABLE

Launch Vehicle	Approximate Launch Cost (USD)	Stages	Fairing Height (m)	Fairing Diameter (m)	Max Payload to Mars (kg)
Falcon Heavy	$170 million	2	13.2	5.2	16,800
Atlas V-401	$130 million	2	10	4.2	1,025
SLS	$2 billion	2.5	31	10	20,000
Delta IV Heavy	$350 million	2	11.2	4.5	8,000
Proton-M	$65 million	3 or 4 (optional)	11.8	5.1	6,200
Starship	$2 million	2	18	9	150,000

FINAL SELECTION - SPACEX STARSHIP

$2 Million

Estimated cost per launch

9m Diameter, 18m Height

Fairing dimensions – more than enough for EEV

150,000 kg

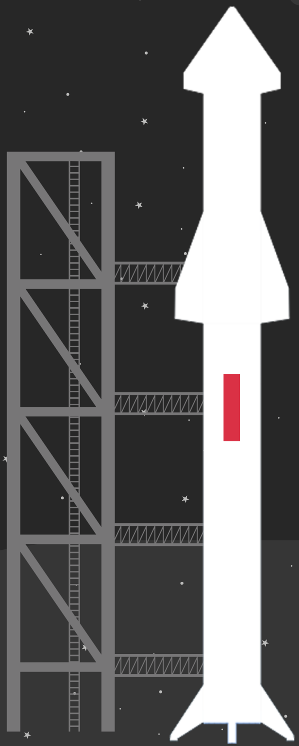
Maximum payload to Mars orbit

2024

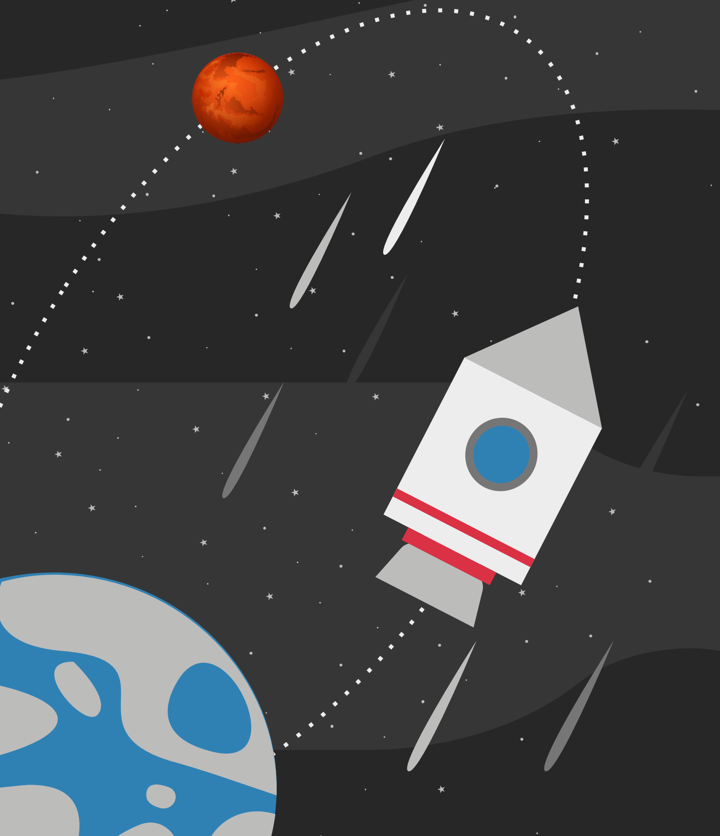
Starship will be ready for commercial flights

16M Pounds

Of thrust generated by Starship engines



LAUNCH VEHICLE FINAL CONSIDERATIONS



Starship arrives to a Low-Earth parking orbit after its initial launch, but needs to be refueled before departing to Mars

- Will be accomplished by a single launch of another “tanker” Starship, loaded with fuel to be transferred to original launch vehicle
- Fuel transferred via docking in orbit
- Will incur an additional $2-4 million cost
- Additional cost ($6 million) added to budget to account for future changes to Starship program

STARSHIP FAIRING AND MOUNTING

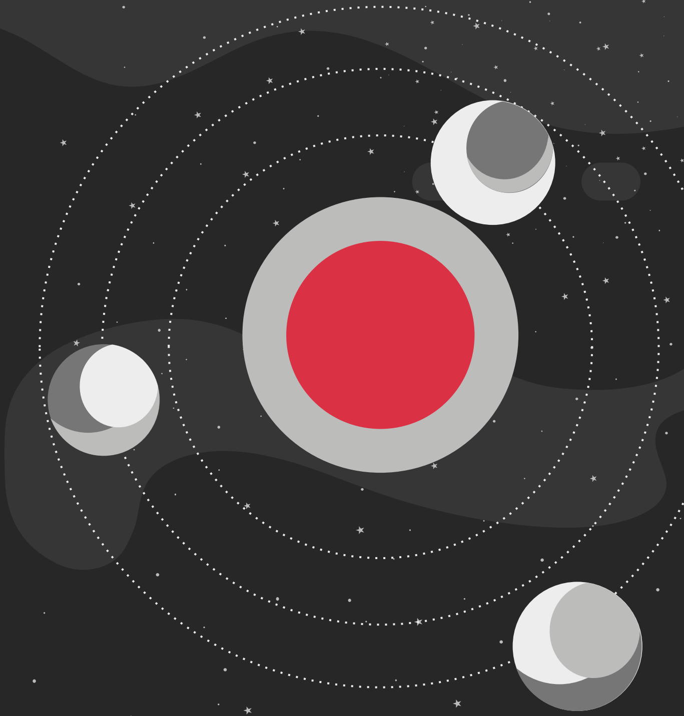
STARSHIP FAIRING SPECIFICATIONS

- Starship's fairing is 18 m in height and 9 m in diameter
- Fairing deploys craft in a clamshell sequence
- EEV is 8 m at its widest point and 12 m tall
- Starship comes equipped with single-manifest payload adapters, with which the EEV will be mounted 0.5m off-center to account for the off-axis center of gravity

03

ORBITAL TRAJECTORIES

How we will get to the mission site



HOHMANN TRANSFER CALCULATIONS

- Assuming circular orbits, the departure impulse can be calculated as:

$$\Delta v_1 = \sqrt{\frac{\mu_s}{R_E}}\left(\sqrt{\frac{2R_M}{(R_E + R_M)}} - 1\right)$$

Where R_E and R_M are the distances of the Earth and Mars to the Sun, respectively, and μ_s is the gravitational parameter of the Sun.

The arrival impulse can be calculated similarly using the equation:

$$\Delta v_2 = \sqrt{\frac{\mu_s}{R_M}}\left(\sqrt{\frac{2R_M}{(R_E + R_M)}} - 1\right)$$

The total time of the transfer is calculated as:

$$t = \pi\sqrt{\frac{(R_E + R_M)^3}{8\mu_s}}$$

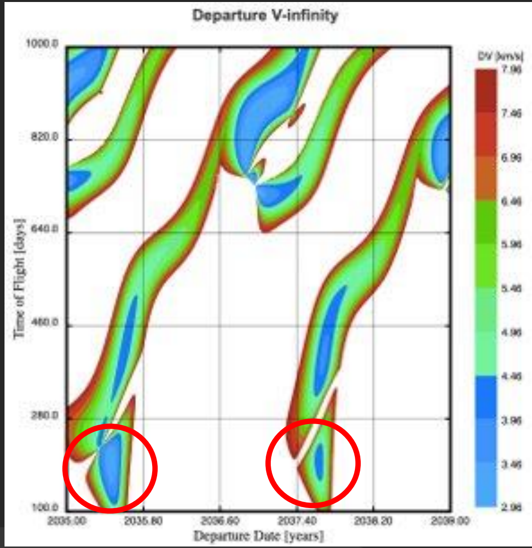
These same equations are used to move in-between the moons and the DST.

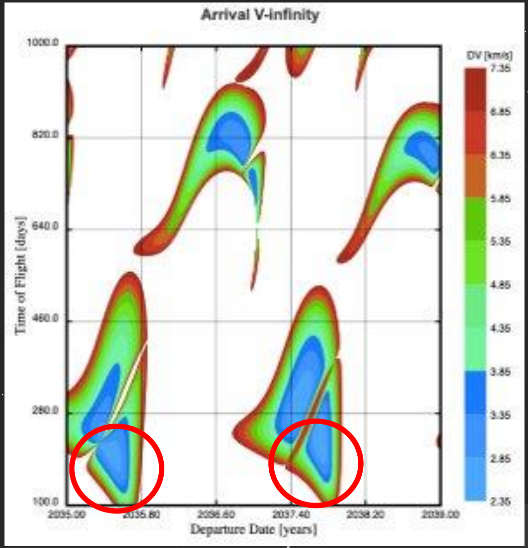
EARTH TO MARS HOHMANN TRANSFER

2035 Departure		
Initial Δv	Final Δv	Total Δv
2.493	1.878	4.371

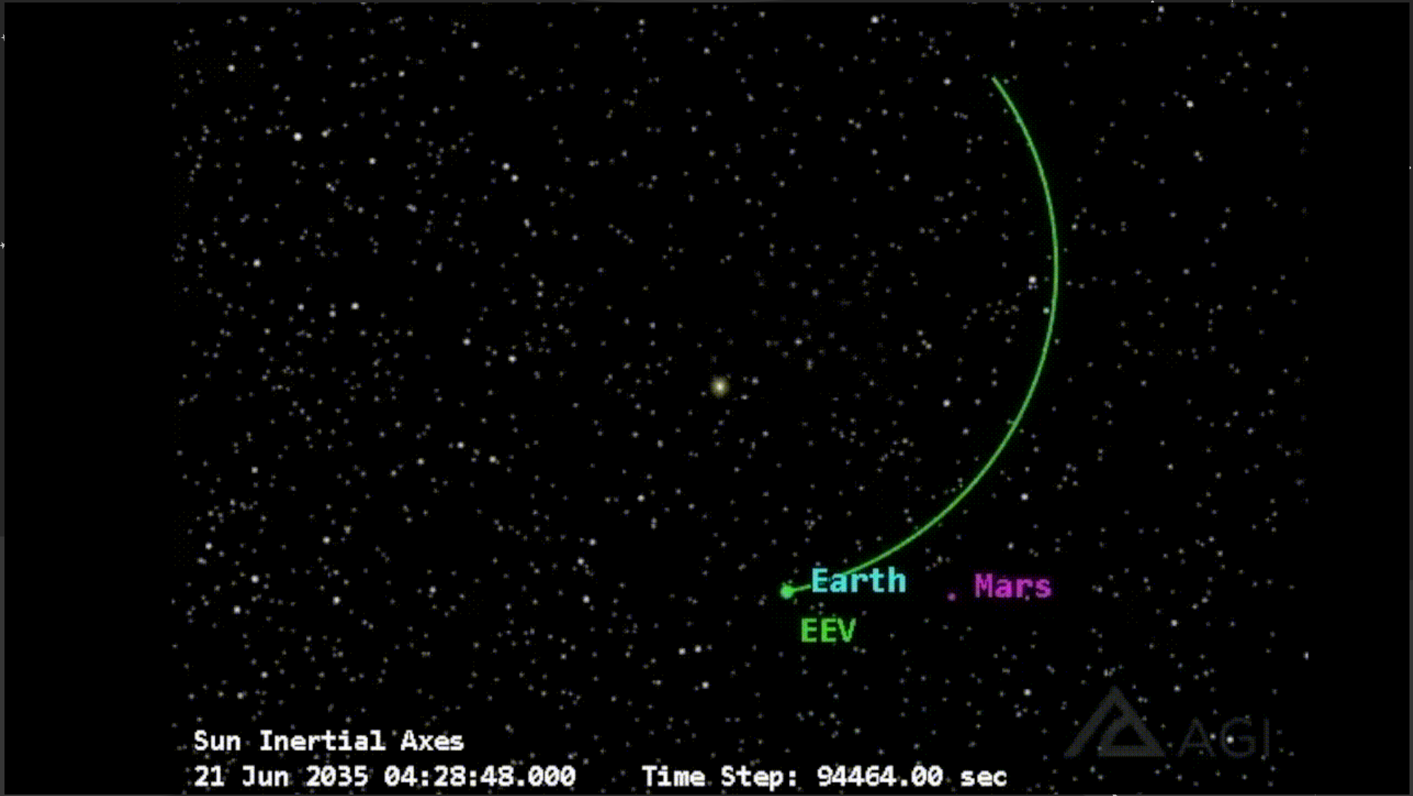
2037 Departure		
Initial Δv	Final Δv	Total Δv
3.126	1.904	5.030

* units in km/s





EARTH TO MARS VISUALIZATION



POTENTIAL VISITING SEQUENCES

	Sequence 1	Sequence 2	Sequence 3	Sequence 4
Total Δv (km/s)	4.284	4.746	6.510	6.363

Sequence 1: DST → Phobos → Deimos → DST

Sequence 2: DST → Deimos → Phobos → DST

Sequence 3: DST → Phobos → DST → Deimos → DST

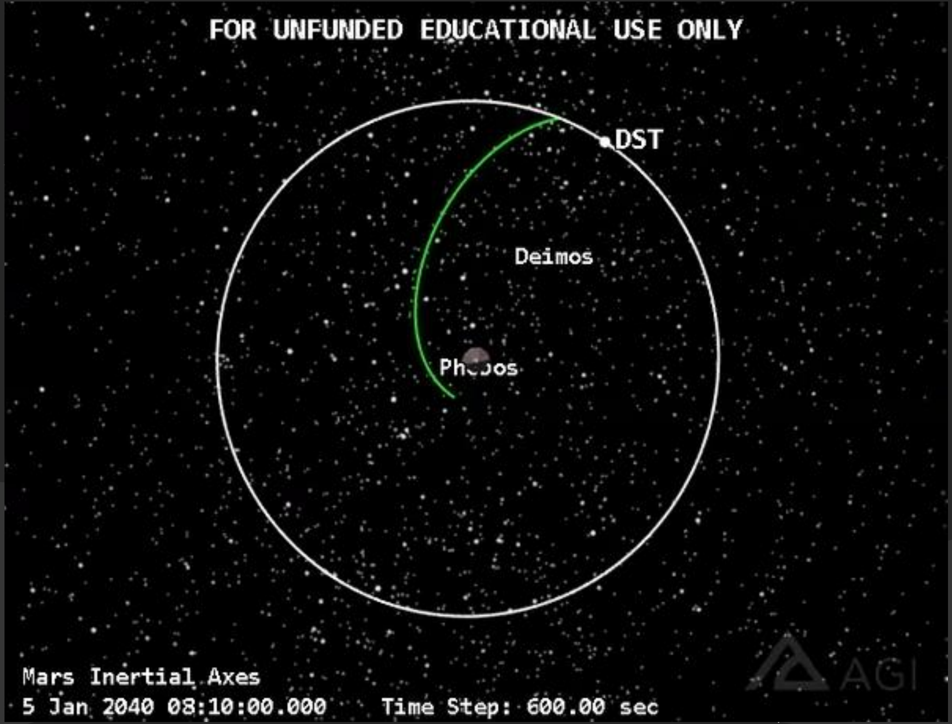
Sequence 4: DST → Deimos → DST → Phobos → DST

VISITING SEQUENCE DETAILS

DST to Phobos			Phobos to Deimos			Deimos to DST			Total
Initial Δv	Final Δv	Total Δv	Initial Δv	Final Δv	Total Δv	Initial Δv	Final Δv	Total Δv	Total Δv
0.362	2.147	2.509	0.679	0.390	1.069	0.387	0.319	0.706	4.284

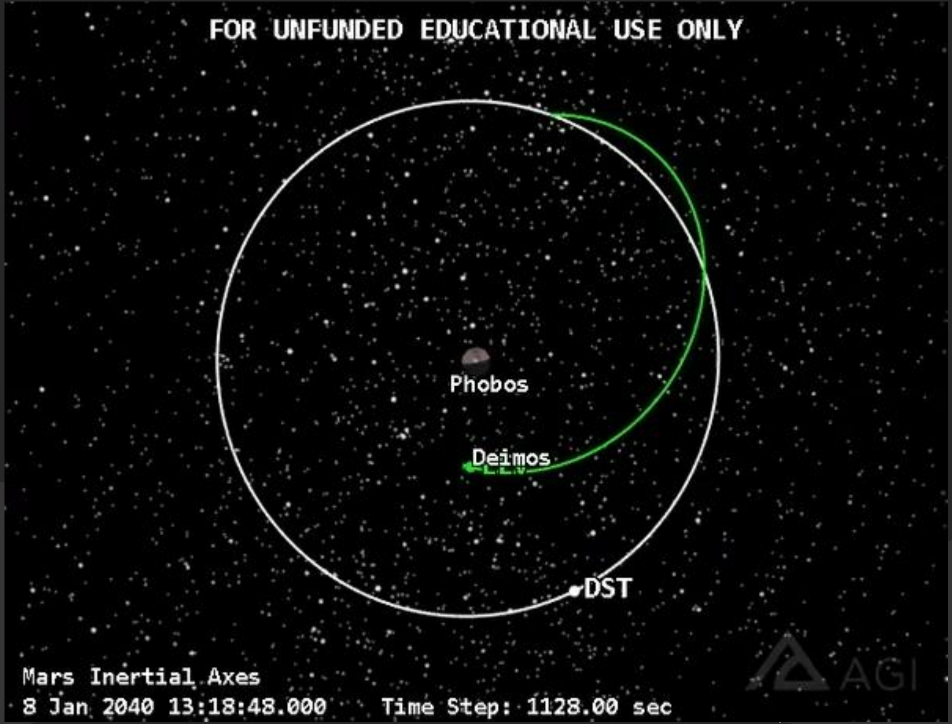
* units in km/s

DST TO PHOBOS VISUALIZATION



PHOBOS TO DEIMOS VISUALIZATION

DEIMOS TO DST VISUALIZATION



MISSION TIMELINE

Notable Times

Earth to Mars Transfer:	196 days (~6.5 months)
Time spent on Phobos:	12 hours
Time spent on Deimos:	32 hours
Visiting Sequence Duration:	5 days

Complete Timeline

Earth Departure: June 20th, 2035	12:00:00 UTCG
Arrival to 5-sol Orbit: January 2nd, 2036	12:00:00 UTCG
Departure to Phobos: January 5th, 2040	12:00:00 UTCG
Arrival at Phobos: January 6th, 2040	08:00:00 UTCG
Departure to Deimos: January 6th, 2040	20:20:00 UTCG
Arrival at Deimos: January 7th, 2040	05:00:00 UTCG
Departure to DST: January 8th, 2040	13:00:00 UTCG
Arrival at DST: January 10th, 2040	11:00:00 UTCG

LANDING SITE SELECTION

LANDING SITE OVERVIEW

Concerns

- Energy – Maximize sunlight to charge batteries
- Terrain – Find smooth terrain to minimize tipping/damage risk to EEV

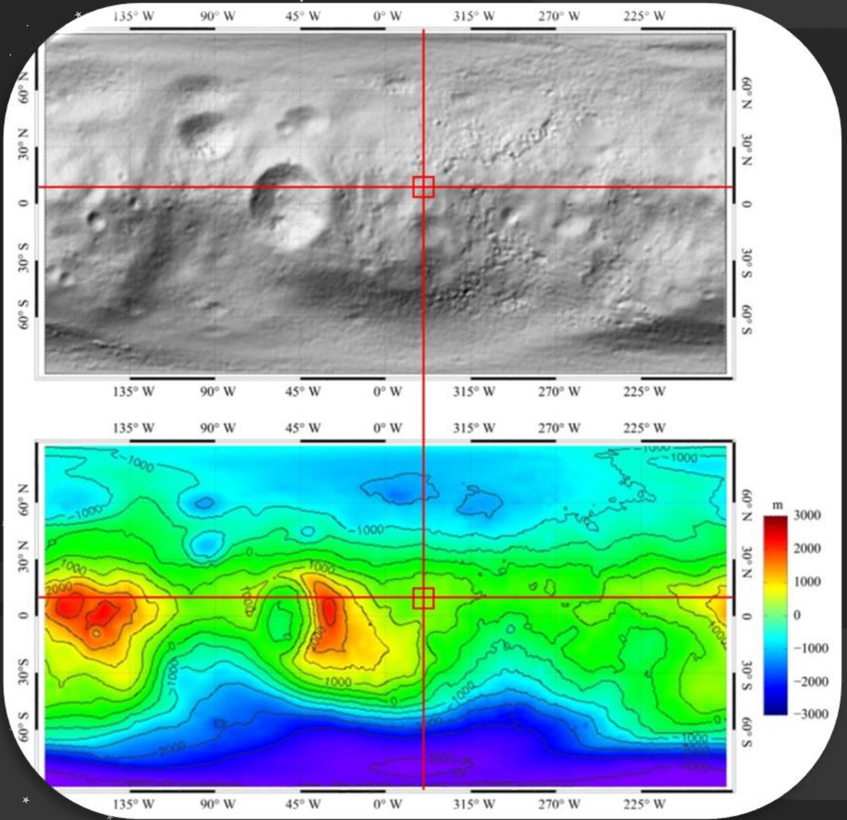
Environment

- Mars Orientation – Mars' axis tilted 25° to orbital plane
- Martian Moon Orientations – Martian moons orbit approximately flat about Mar's equator, minimal axial tilt.
- Martian Moon Orbits – Both tidally locked

Season

- January 2040 – Late Martian spring
- More sunlight in Northern Hemispheres

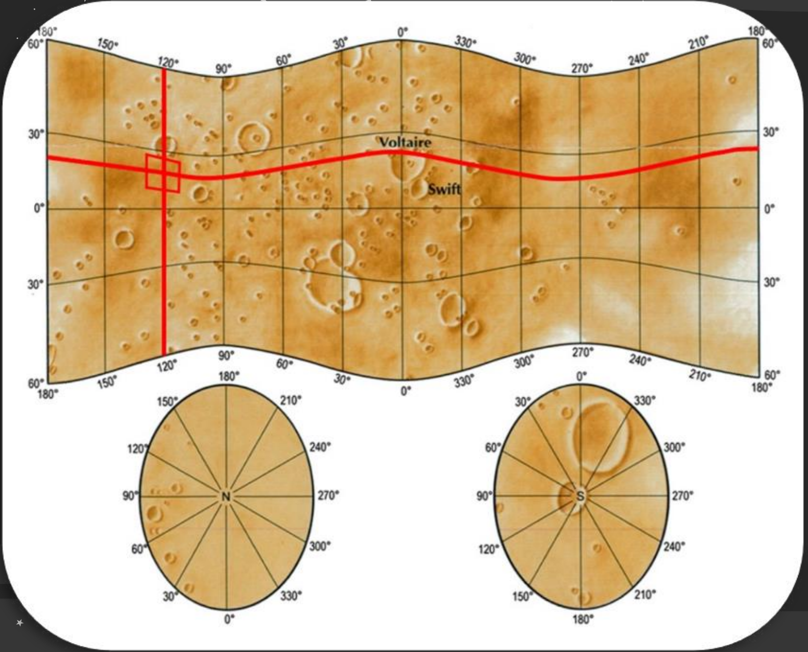
PHOBOS



Location:

- Approx. 10° N, 335° W.
- Slight Northern position yields greatest sun exposure
- Flat terrain expected based on latest surface analyses

DEIMOS



Location:

- Approx. 20° N, 120° W.
- Slight Northern position yields greatest sun exposure
- Flat terrain expected based on latest surface analyses

04

SCIENTIFIC OBJECTIVES

What we will learn on-site

OBJECTIVES

A principal goal for this mission is to investigate the realm of physical science that would characterize both environments found on the moons of Mars; Phobos and Deimos. Subjects on the matter include but are not limited to physics, chemistry, and astronomy.

- Address 7 main objectives
- Conduct various surface experiments swiftly to ensure mission completion within the 30-day envelope
- 12 hours on Phobos & 32 hours on Deimos

4.1 SURFACE MATERIAL CLASSIFICATION

Objective

- Survey and classify the composition of Mars's two moons

Carbonaceous (C-Type) Rock

Procedure

- Various dust and rock samples are to be collected in tubes and bins utilizing the rover and its robotic arms.

Material & Cost

- Mission Designed Rover
- RAT- Rock Abrasion Tool
- **Cost: $100,000**
- (Does not include rover material and production)

4.2 ADVANCED IMAGING

Objective

- View both bodies across different portions of the electro magnetic spectrum

Material/ Cost

- Gamma-Ray and Neutron Spectrometer
- Laser Altimeter
- Atmospheric and Surface Composition Spectrometer (IR-UV)
- **Cost: $12M**

Procedure

- Allow imaging instruments to capture the likeness of each moon during orbit and/or ascent/descent.

Hopkins Ultraviolet Telescope

4.3 MAGNETIC FIELD MEASUREMENTS

Objective

- Measure and confirm the lack of a significant magnetosphere surrounding each moon

Magnetometer with Particles and Fields package

Procedure

- Measure the flux and spectra of energetic protons and electrons surrounding the moons. Also, surveying rocks allow us to draw inferences about past magnetic fields.

Material & Cost

- Magnetometer
- Energetic Particle and Plasma Spectrometer
- **Cost: $50M**

4.4 EXAMINE WEATHERING CONDITIONS

Objective

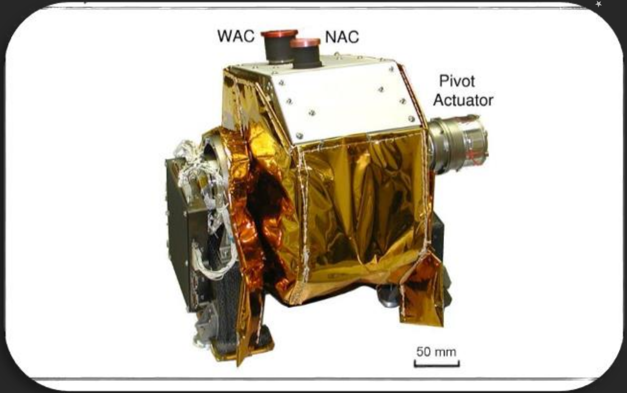
- Seek to mark the differences in weathering conditions present. Solar energy, solar wind, and temperature variation will be some metrics for measure.

Material & Cost

- Dual Imaging System- consists of wide and narrow angle imagers
- Mössbauer Spectrometer
- **Cost: $10.1 M**

Procedure

- Map landforms, track variations in surface spectra and gather topographic information

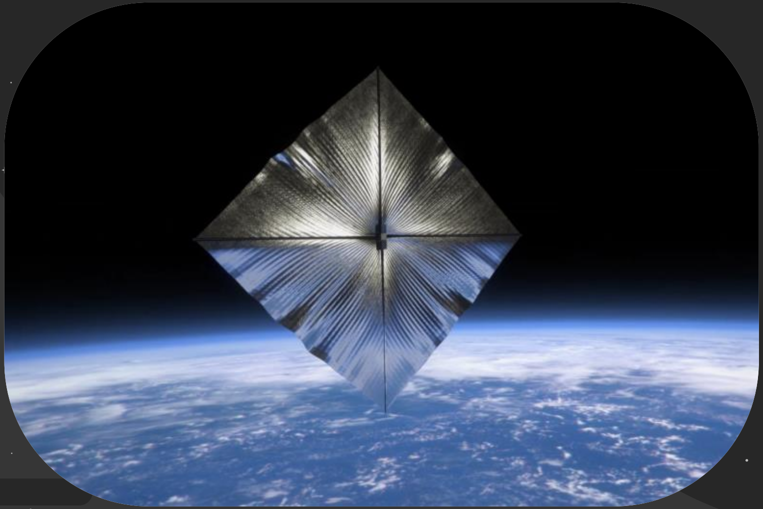


NASA Messenger's Mercury Dual Imaging System

4.5 COLLECT SOLAR WIND SAMPLES

Objective

- Deploy instruments with the intention to capture a significant amount of solar energy



Procedure

- Deploy solar sail once in orbit of each moon, at a point of zero acceleration. Use pressure sensors to evaluate the force exerted by the samples collected.

Material & Cost

- Solar sail (9 m x 9 m)
- Solar panel
- Pressure sensors
- **Cost: $4M**
- (No additional cost incurred by solar panels)

4.6 STUDY INTERNAL STRUCTURE

Objective

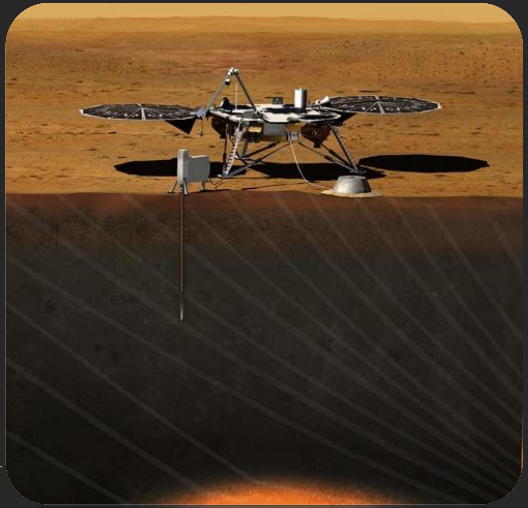
- Determine if the internal structure is uniform or layered

Procedure

- Examine seismic waves and detect temperature variations below surface.

Material/ Cost

- Seismometer
- RIMFAX
- **Cost: $105 M**



Seismometer and Heat Flow Probe from Mars' Insight Mission

4.7 TEST TELECOM EQUIPMENT

Objective

- The crew will use radio receivers as radio telescopes to verify their utilization on both moons.

Procedure

- Take advantage of low noise Martian environment to use receivers as networked deep space radio telescope.

Material & Cost

- Radio Receivers
- Networking Software
- **Cost: $10M**
- (Cost reflects cost of telecomm equipment; no additional cost incurred by science objective)

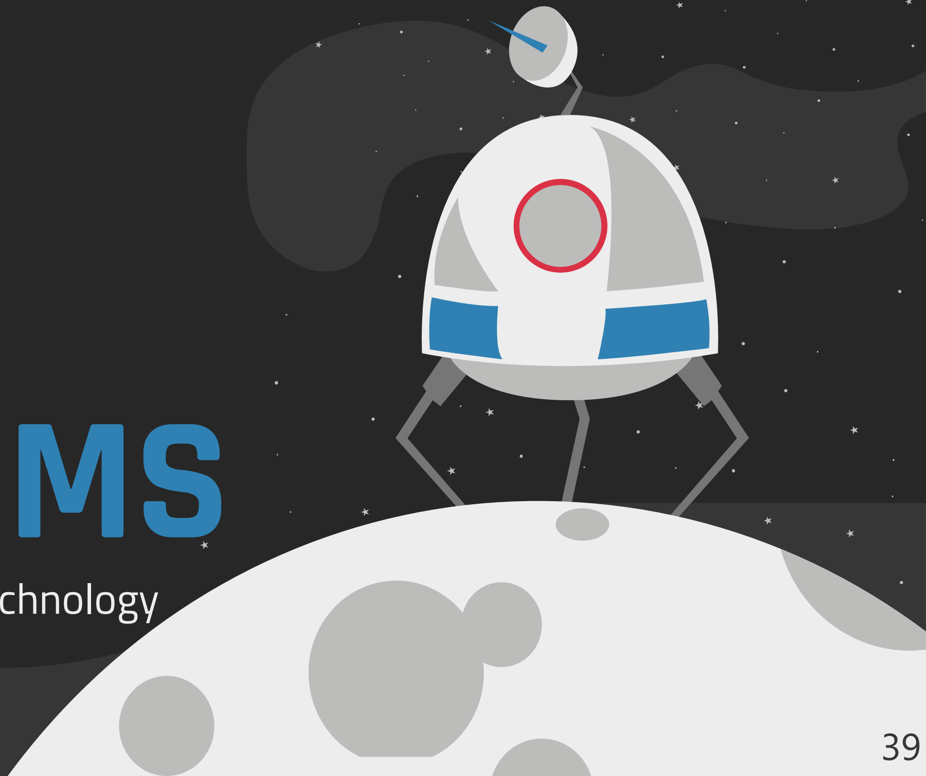
EQUIPMENT AND COST

Objective	Experimentation	Cost (US $ FY2021)
Surface Material	Mission Designed Rover	Included in Production
Surface Material	Rock Abrasion Tool (RAT)	100,000
Imaging	Gamma-ray/Neutron Spectrometer	4,000,000
Imaging	Laser Altimeter	4,000,000
Imaging	Atmospheric and Composition Spectrometer	4,000,000
Magnetic Fields	Magnetometer (MAVEN)	25,000,000
Magnetic Fields	Energetc Particle and Plasma Spectrometer	25,000,000
Weather	Dual Imaging System	10,000,000
Weather	Mossbauer Spectrometer	10,0000
Solar Readings	Solar Panel	Included In Production
Solar Readings	Solar Sail (9mx9m)	3,000,000
Solar Readings	Pressure Sensor	1,000,000
Internal structure	Seismometer	100,000,000
Internal structures	RIMFAX: geological structure of subsurface	5,000,000
Telecommunication		Included in Production
TOTAL	**$181.2 M**	

05

EEV SUBSYSTEMS

Spacecraft subsystem design and technology



PROPULSION SUBSYSTEM

MAIN ENGINE SELECTION CRITERIA

Storability

The mission will take place across 5 years so the fuel must be storable for long periods

Thrust

The engine configuration must produce enough thrust to satisfy the mass of the spacecraft

High Specific Impulse

The specific impulse of the engine must be high to lower fuel requirements

Low Dry Mass

The engine should be light to reduce additional weight to the spacecraft

POTENTIAL ENGINES

Engine	Thrust (kN)	Mass (kg)	I_{sp} (s)	Burn Time (s)
ATE	20.0	58	347	1200
Aestus	29.0	111	324	1100
Aestus 2	55.2	139	336	600
R-40B	4.0	7.23	293	23000

MAIN ENGINE SELECTION- ASTRIUS AESTUS ENGINE

Non-Cryogenic Propellent

The engine uses long term storable propellants MMH/N_2O_4 requiring no insulation in the fuel tanks

Final Mass : Dry Mass ratio

Using the Tsiolkovsky equation the final mass of the rocket will be 4.12 times the dry mass of the spacecraft

Thrust

The thrust of the engine configuration will produce a capable thrust to weight ratio of 0.2

Restartable

The engine is restartable up to 6 times which is necessary to complete the mission

POTENTIAL RCS ENGINES

Engine	Thrust (N)	Mass (kg)	I_{sp} (s)
KEW-1	29.0	0.53	266
R-6C	33.0	0.66	290
RM-1-2	4.41	0.32	238

RCS ENGINE SELECTION- MARQUARDT R-6C

Sufficient Thrust

The engine produces enough thrust to maneuver the EEV

High Specific Impulse

The specific impulse of the engine is high allowing for minimum fuel consumption

FUEL TANK SIZING

Final Fuel Mass of the EEV

The final dry mass of the EEV is 11725 kg and given a 3.12 fuel to dry mass ratio 36582 kg of propellent are required.

Required Propellant Volume

The propellent volume is found using the densities of the propellent of 1450 kg/m^3 for N_2O_4 and 880 kg/m^3 for MMH.

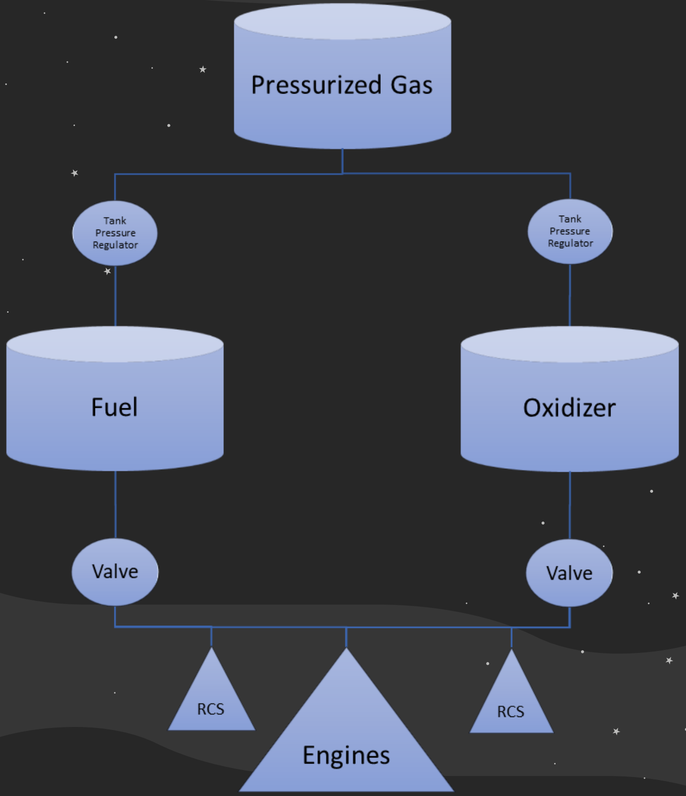
Required Fuel Mass

The oxidizer to fuel ratio of the Aestus engine is 2.05 requiring 24583 kg of N_2O_4 and 11999 kg of MMH.

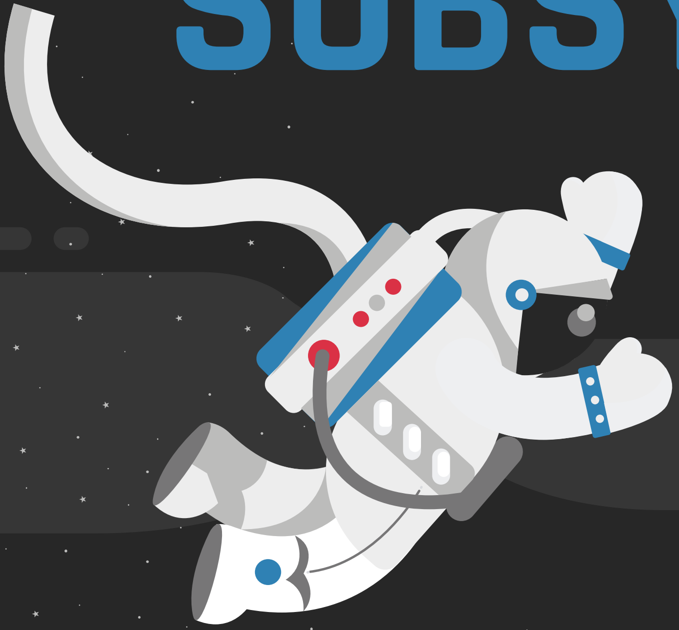
Fuel Tank Diameter

The diameter of the fuel tanks are found using the volume of propellent required at 3.19 m for N_2O_4 and 2.96 m for MMH.

PROPELLANT FEED SYSTEM



POWER SUBSYSTEM



POWER REQUIREMENTS

- Power requirements taken at peak expectation for each sub-system
- Largest source of continuous power will be produced using solar panels

Sub-System	Power Requirements (W)
Propulsion	220
Telecommunication	300
Scientific Objectives	526
Thermal System	384
Life Support	1773
Power	120
Rover	100

SOLAR PANEL SELECTION– ORBITAL ATK MEGAFLEX ARRAY

Scalable size

Options up to 10m diameter with energy from 0.5 kW to 20 kW

High Power

High power up to 200 W/kg

Strong and Lightweight

The MegaFlex array is strong and lightweight with a history of successful flights

BATTERY TRADE STUDY

High energy density

The highest energy density will reduce the mass and cost of the power system

Cost

The cost of the batteries for the overall power system is prioritized

Battery	Power-Weight Ratio (Wh-kg)	Safety
Ni-Cad	30	High
Li-Ion	150	Med
Ni-H_2	60	Med

BATTERY SELECTION – SAFT LITHIUM-ION VL51ES BATTERY

High Power to Weight Ratio

The VL51ES batteries have a power to weight ratio of 130 Wh/kg

Stackable Configuration

The VL51ES batteries are easily stackable allowing a configuration to store all required energy.

POWER CONFIGURATION

Battery Configuration

The EEV will require battery power when solar isn't available. Needing 3.323 kWh the EEV will carry 26 VL51ES batteries.

Solar Panel Production

The MegaFlex solar panel will produce the required peak power at a diameter of 5.33 m.

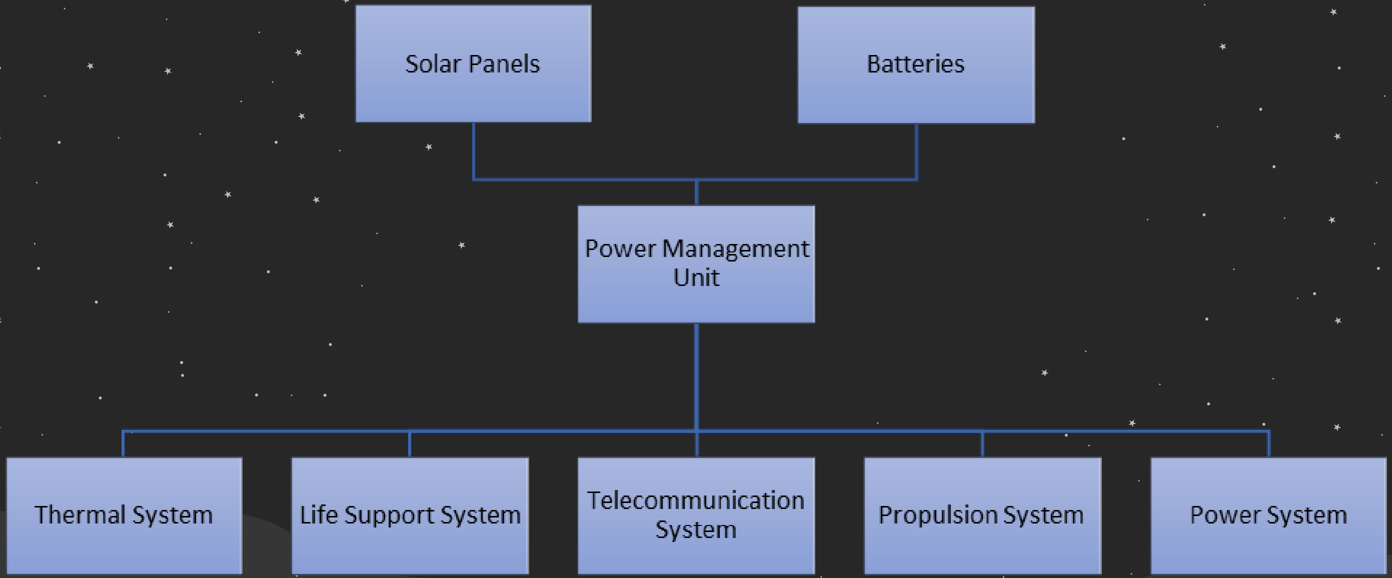
Total Peak Power

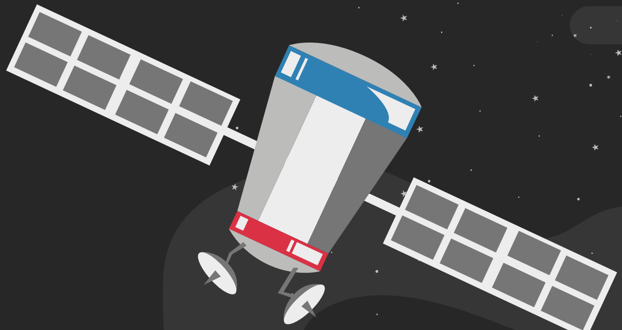
The total power consumption at peak times of the EEV is 3.323 kW

Rover Power

The rover requires 100 W of power at peak and will need a solar panel of 0.22 m diameter and two VL51ES batteries.

POWER DISTRIBUTION





THERMAL CONTROL SUBSYSTEM

THERMAL CONTROL

Temperature Requirements

- < 40°C for electronics
- 18°C - 24°C for crew members

Thermal Control Outputs

- Mass: 2907 kg
- Volume: 4.63 m^3
- Power: 384 W

Thermal Control Systems

Component	Mass (kg)	Volume (m^3)
MLI	2240	2.80
Radiators	350	1.32
Heat exchangers	20	0.03
Cold plates	84	0.20
Pumps	80	0.28
Fluids	26.7	-
Redundant valves and fittings	80.1	-
Controls	26.7	-

RADIATION MANAGEMENT

RADIATION SHIELDING OPTIONS

Kevlar

- ρ=1,400 kg/m^3
- Radiation shielding capabilities in space observed through ISS experimentation

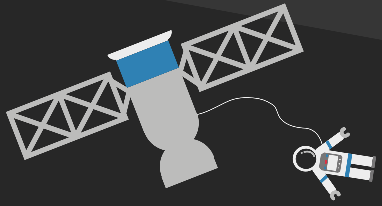
Water

- ρ=1,000 kg/m^3
- Traditionally used in nuclear reactors to slow down neutrons
- Has not been flight tested

Gadolinium Oxide Polymer

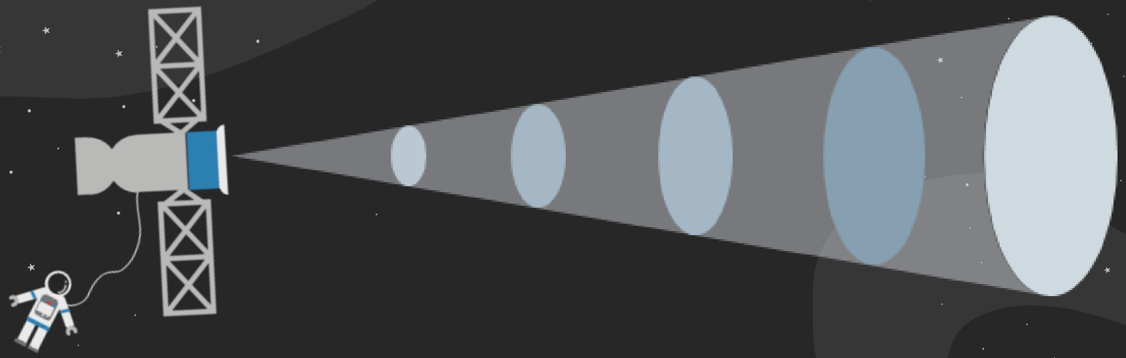
- ρ=741 kg/m^3
- Experimental material developed by researchers at NC State, not flight tested

RADIATION SHIELDING SELECTION



Gadolinium Oxide Polymer

- Mass needs to be conserved as much as possible on this mission – mass budget already dominated by other important needs of the crew
- Short duration of mission on EEV (5 days) means insignificant amount of radiation will be absorbed by each person
- Gadolinium Oxide polymer is 30% more effective than Kevlar and Water at radiation absorption, and is nearly 50% less dense than Kevlar
- Will include a radiation protection layer of 3 cm (derived from half-value thickness of Kevlar)



TELECOMMUNICATIONS SUBSYSTEM

COMMUNICATIONS: BACKGROUND

Historical Systems

- Mariner – S band
- Viking – Adds X band
- 1990's – Adds Ka band
- Mars Landers/Rovers – Utilize UHF to communicate to orbiters
- **Ares:** Primary UHF for local comms, emergency X/Ka band for direct-to-Earth comms

Lag Times

- 4 to 24 minutes

Data Rates

- Mars 2020 Perseverance Rover – 2 Mbps local, up to 3 kbps direct-to-Earth
- **Ares:** 1 Gbps local, 100 kbps direct-to-Earth

COMMUNICATIONS: LINK BUDGET

EEV-Earth Downlink	
T_x Antenna	3-meter High Gain
Frequency	31 GHz (Ka Band)
Max Distance	401,000,000 km
R_x Antenna	70-meter DSN
Data Rate	100 Kbps
Bandwidth	100,000 Hz
System Noise Temperature Model	50 K
Modulation	QPSK
BER	1.0E-06
Required E_b/N_o	11 dB

Link Budget		
Value	Magnitude	Unit
Transmit Power	100	Watts
Efficiency	0.7	
Transmit Power in dBW	18.45	dBW
Transmitter Gain	58.23	dB
EIRP	76.68	dBW
Free Space Losses	-294.34	dB
Misc Losses	-10	dB
Receiver Gain	85.59	dB
Received Power	-142.07	dBW
E_b Received	-192.07	dBW/Hz
N_o	-211.61	dBW/Hz
Received E_b/N_o	19.54	dB
Link Margin	8.54	dB

COMMUNICATIONS: DESIGN SPECIFICATIONS

Overview of Hardware Specifications

- Antenna: 3-meter High Gain
  - 20 kg
- Transceivers:
  - UHF + X/Ka bands
  - 10 kg
  - 70 W
- Amplifiers
  - X, Ka band Travelling Wave Tube Amplifiers (TWTA)
  - 10 kg
  - 100 W each
- Misc. Hardware
  - +100% weight (40kg)
  - +10% power (30 W)

Weight Allowance: 80 Kg

Power Allowance: 300 W

COMMUNICATIONS: SAMPLE BLOCK DIAGRAM

- UHF/X/Ka system demonstrated on NASA Mars Reconnaissance Orbiter:

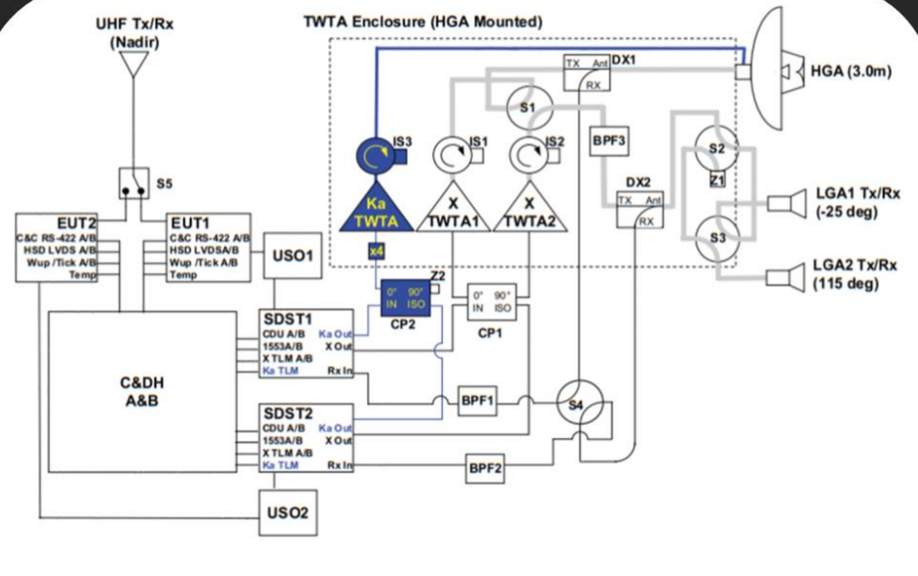


Figure 2-1. MRO Telecom Subsystem block diagram.

Figure: Taylor, Jim, et al. "Article 12; Mars Reconnaissance Orbiter; Telecommunications." *DECANSO Design and Performance Summary Series.* National Aeronautics and Space Administration Jet Propulsion Laboratory California Institute of Technology Pasadena, California. September 2006.

THE EXPLORATION EXCURSION VEHICLE

EEV AT A GLANCE

-Accommodates lack of EVA

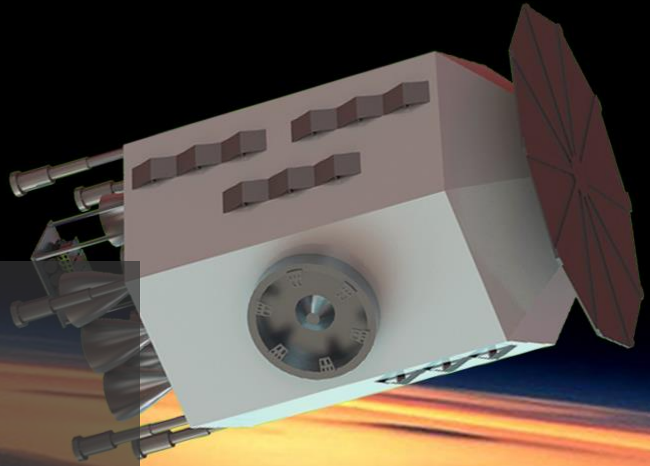
-Crew Space: 222* cubic m

-Deployable Solar Panels

-Home to 2 crewmates

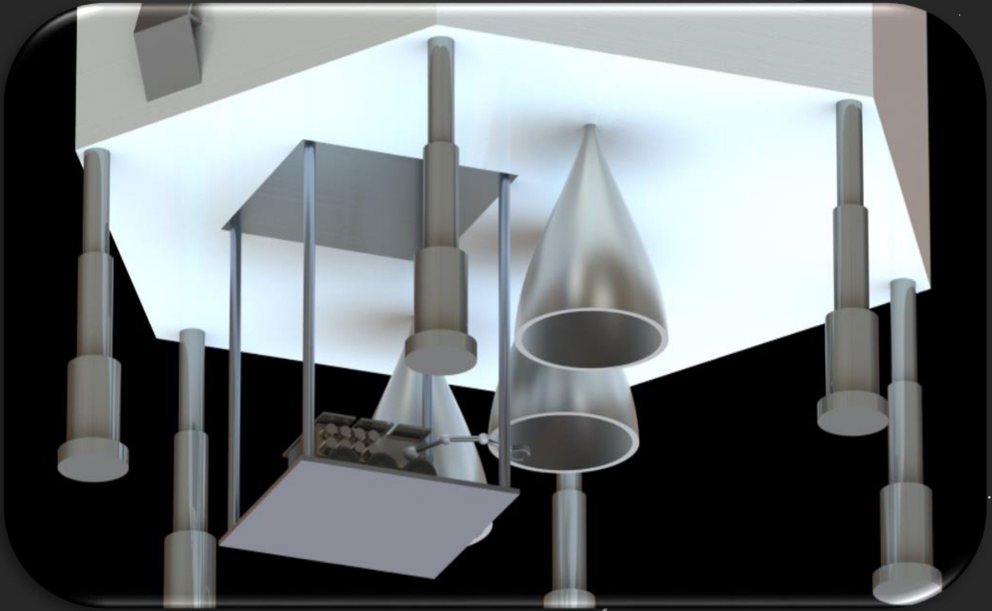
-Primarily composed of 2219-T6 Al and MLI

- Dry mass of 11,725.6 kg



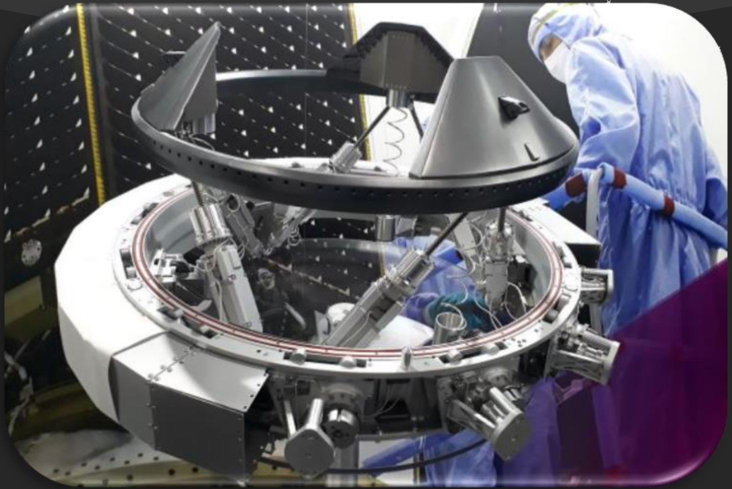
THE ROVER LIFT

- Hydraulic Lift
- Sealed Rover Storage Area
- Variable height for ease of access



DOCKING ENTRANCE

- Enlarged ISS standard docking system
- 2.5m diameter entrance
- Allows for larger science equipment to enter
- DST will have matching system



Moments of Inertia (kg * m^2)					
Ixx	49410475	Ixy	6769154	Ixz	10762826
Iyz	6769154	Iyy	40014354	Iyz	20662712
Izx	10762826	Izy	20662712	Izz	18757429

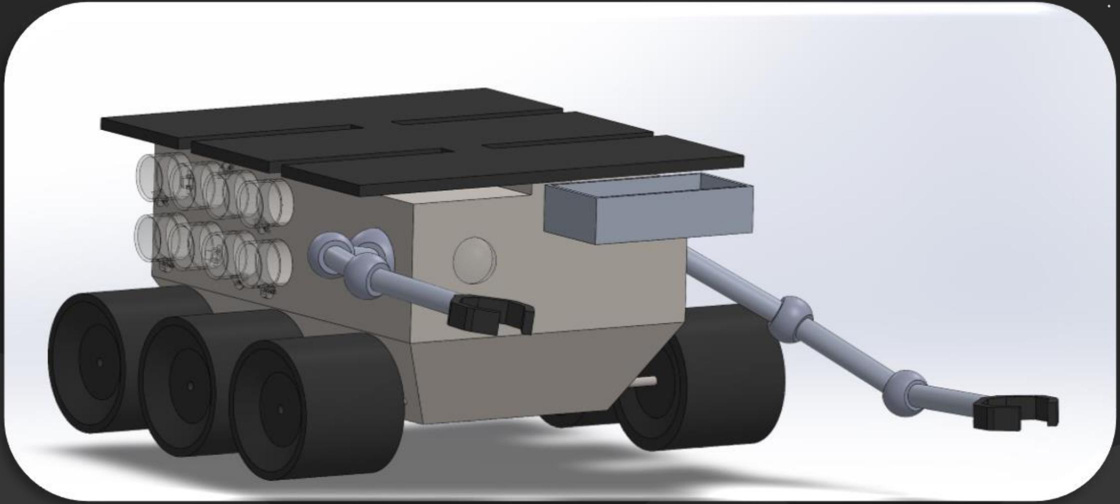
DESCENT AND LANDING

- The EEV will descend with a downward acceleration of 0.5 m/s^2.
- The six landing legs will take on a 3 MPa force during this landing.
- Landing legs will be made from 6061 Aluminum Alloy to minimize mass as determined by the following trade study:

Material	Compressive Strength (MPa)	Density (kg/m^3)
Stainless Steel	152	8050
6061 Aluminum Alloy	276	2700
Titanium Ti-6Al-4V	130	4420
Cast Iron	400	7200
Nickel-Chromium	25	7768

THE ROVER

- Small and Maneuverable
- Sample Collection Method
- Sample Storage
- Multiple Scientific Equipment
- Power Supply
- Total Mass~700kg



MANUVERABILITY

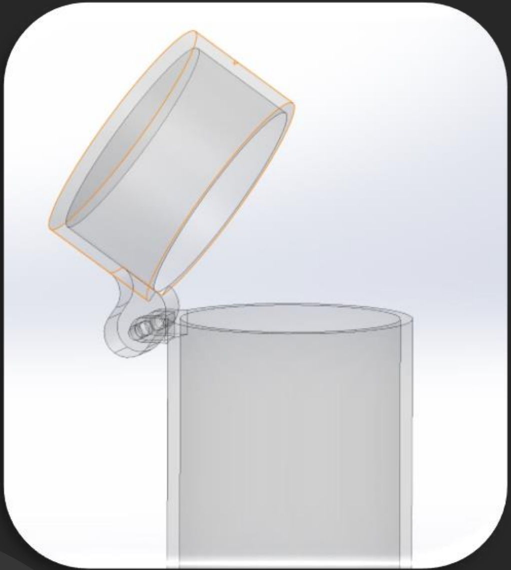
- Designed to allow sample collection at multiple regions
- Tracks multiple areas for the possibility of variations in regolith and other aspects of data
- Rover is equipped with imaging and sensors to allow autonomous control when crew is performing tasks as well as a safety measure

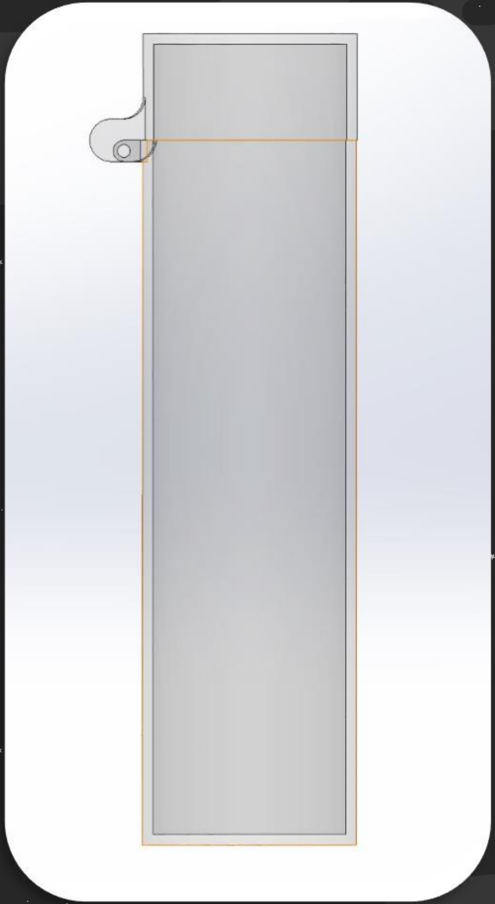
SAMPLE COLLECTION

- Rover arms will grab test tubes and scoop up regolith
- Samples will be collected at numerous depths using RAT to grind away surface material

SAMPLE CONTAINERS

- Volume: 3.506E-3 cubic m
- 5.157 kg per sample
- 10 samples per moon
- 51.57 kg of samples





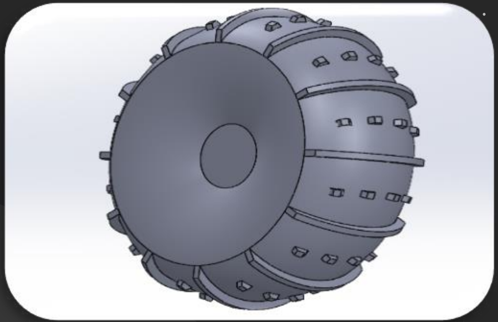
GROUNDING AND WHEELS

Support Rod

- Due to the very low gravity on both moons, grounding when collecting samples allows for stability

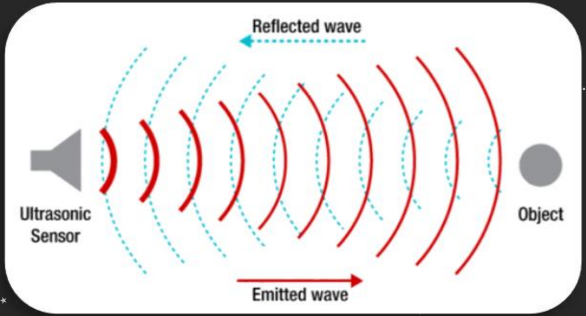
Traction

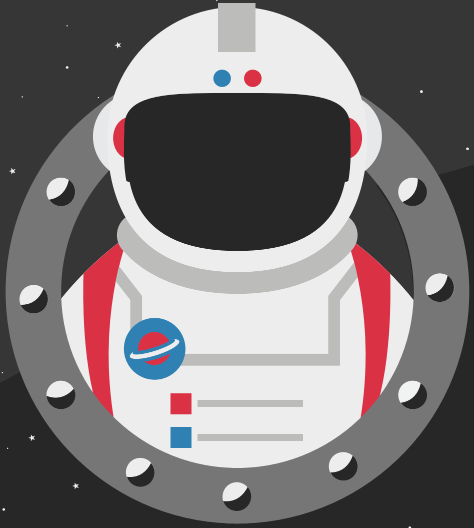
- The rover will be equipped with wheels capable of gripping the regolith so no slipping occurs when collecting samples



ROVER COMPONENTS

- 6 18V Brushed Planetary Gear Motors 76RPM
- Batteries: 2 16Ah 22.2V Lithium Ion Batteries
- Battery Box: Composite Honeycomb with Aerogel to preserve temps
- CCD Image Sensor
- Ultrasonic Transducer
- Intel NUC Processor
- Solar Panel To Help Batteries
- RIMFAX
- Mossbauer
- Total Weight: 810 kg





06

CREW ACCOMMODATIONS

Keeping the crew happy and healthy.

KEY CONSIDERATIONS

Food and Water Allocation

Support 2 crew members on the EEV with proper nutrition to carry out the mission

Waste Management

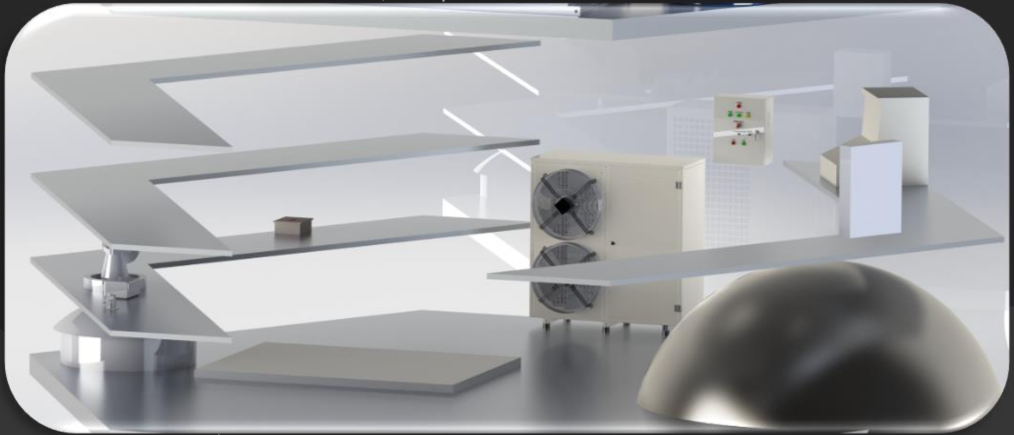
Dispose of any waste generated on the EEV over the course of the 5-day mission

Housekeeping and Miscellaneous

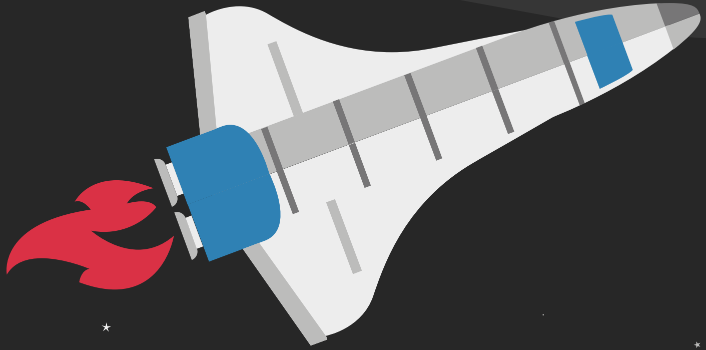
Keep crew members happy, productive, and healthy

EEV INTERIOR

- Two "floors" with access through center
- Science Equipment Storage
- Medical Supplies
- Restroom/Bathroom
- Heaters
- Sleeping Arrangements
- Rover Access Hatch
- Fitness Accommodations
- Rehydrator & Conduction Oven
- 60 Gallon Water Tank



FOOD AND WATER ALLOCATION



Food Requirements

- 2,500 calories per day, per person (minimum)
- 600 calorie breakfast
- 900 calorie lunch and dinner

Water Requirements

- 1 gallon per person, per day
- Used for drinking, bathing, and rehydrating meals

FOOD AND WATER ALLOCATION CONT'D

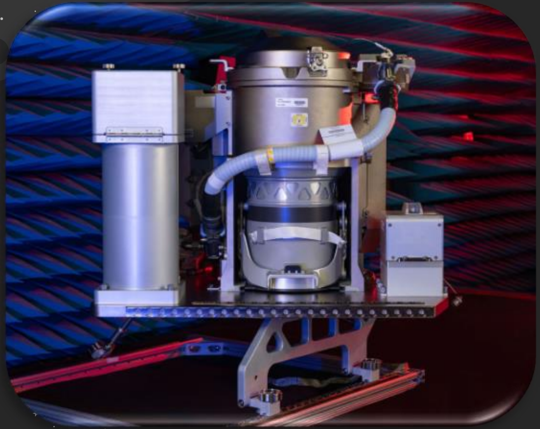
Food Quantities

- 3 meal containers per person, per day (breakfast, lunch, and dinner)
- Additional 10 days of food included for each crew member in event of mission extension
- Water added to dehydrated meals before consumption
- ~0.6 kg per meal
- 54 kg of food on EEV

Water Quantities

- 1 gallon per person, per day
- Surplus of 50 gallons supplied in case of emergency
- 227 kg of water on EEV

UNIVERSAL WASTE MANAGEMENT SYSTEM



UWMS Fact Sheet

- $23 million USD cost
- Weighs 50 kg
- Pulls 274 W passively, 380 W when in use
- Adapted for both male and female use
- Manual waste compression using lever (200 N of force)

- More efficient to store waste on-board than to develop system to vent waste into space
- Approximately 20 kg of urine and 2.5 kg of feces will be produced during mission
- Waste storage equipped with activated charcoal filters to minimize bacterial spread and smell aboard EEV
- Will be used aboard Orion capsule and ISS in the near future

HOUSEKEEPING AND MISCELLANEOUS NEEDS

Hygiene Maintenance (Per Crew Member)

- 2 toothbrushes, 2 tubes of toothpaste
- 2 containers of dry shampoo
- 15 washcloths
- 2 towels
- 5 razors

Additional Everyday Items (Per Crew Member)

- Sleeping bag and restraints
- Set of resistance bands for exercise
- 2 one-gallon canvas zipper bags
- First-aid kit
- Photography equipment
    - Canon 5D MKIV
    - Canon 100-400mm telephoto lens
    - Canon 24-70 wide angle lens

Interior Atmospheric Regulation

Gases Present in Cabin

- Carbon Dioxide
- Oxygen
- Ammonia
- Methane
- Acetone
- Methyl Alcohol
- Nitrogen

Gases Desired in Cabin

- Oxygen
- Nitrogen

Atmospheric Systems

Waste Gas Elimination

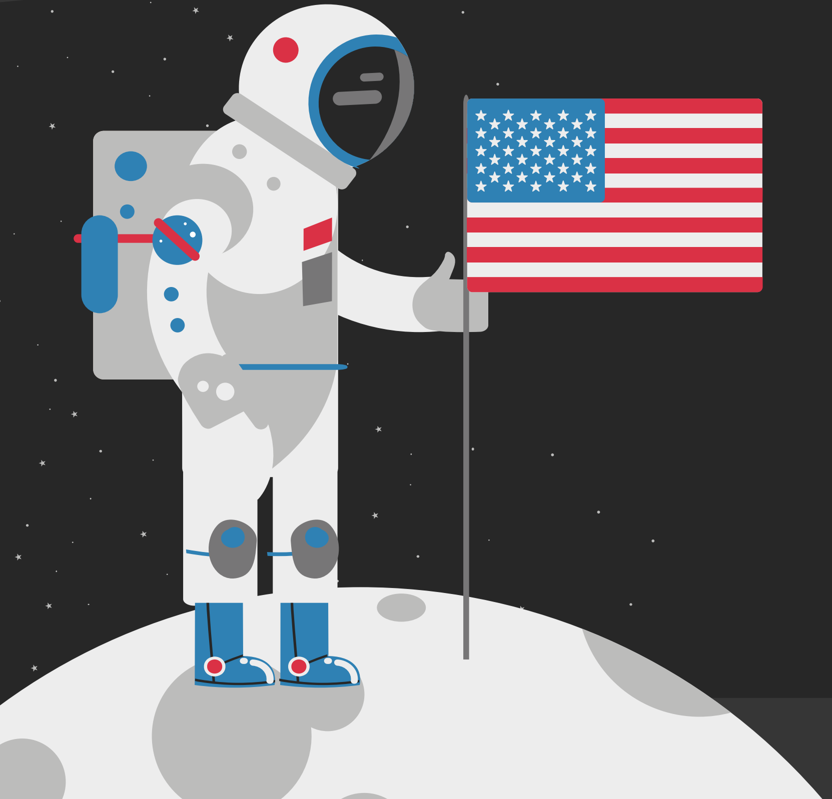
- Bosch Carbon Dioxide Reduction System
- Silica gel for humidity control (60%)
- Activated carbon filters for ammonia, methane, acetone, methyl alc
    - Removes 3.6 pounds of carbon per day
    - Produces 10.8 pounds of water per day
- Pressure relief valves to maintain appropriate pressure (about 1 atm)

Gases Desired in Cabin

- Solid Polymer Electrolyte Electrolysis System to provide oxygen
    - Produces 2 pounds of oxygen per day
- Compressed Nitrogen to be released as needed

CREW ACCOMMODATIONS MASS BUDGET

Crew Accommodation	Mass Subtotal (kg)
Waste Collection	50
Generated Feces and Urine	22.5
Personal Hygiene	17.5
Housekeeping	7
First-Aid	3
Food and Water	280
Photography	10
Total	**390**



CONOPS

Mission overview and summary

CONOPS OVERVIEW

Depart from Earth

→ Refuel Starship in Earth's orbit

→ Transit to Mars 5 sol orbit

→ DST vehicle arrives

↓ EEV and astronauts depart the DST and seal the airlock

← Transit out to Phobos. When close to orbit start measuring magnetic field, imaging experiments, and solar wind capture.

← Land on Phobos, deploy RC rover, collect samples, return samples to EEV, perform surface experiments.

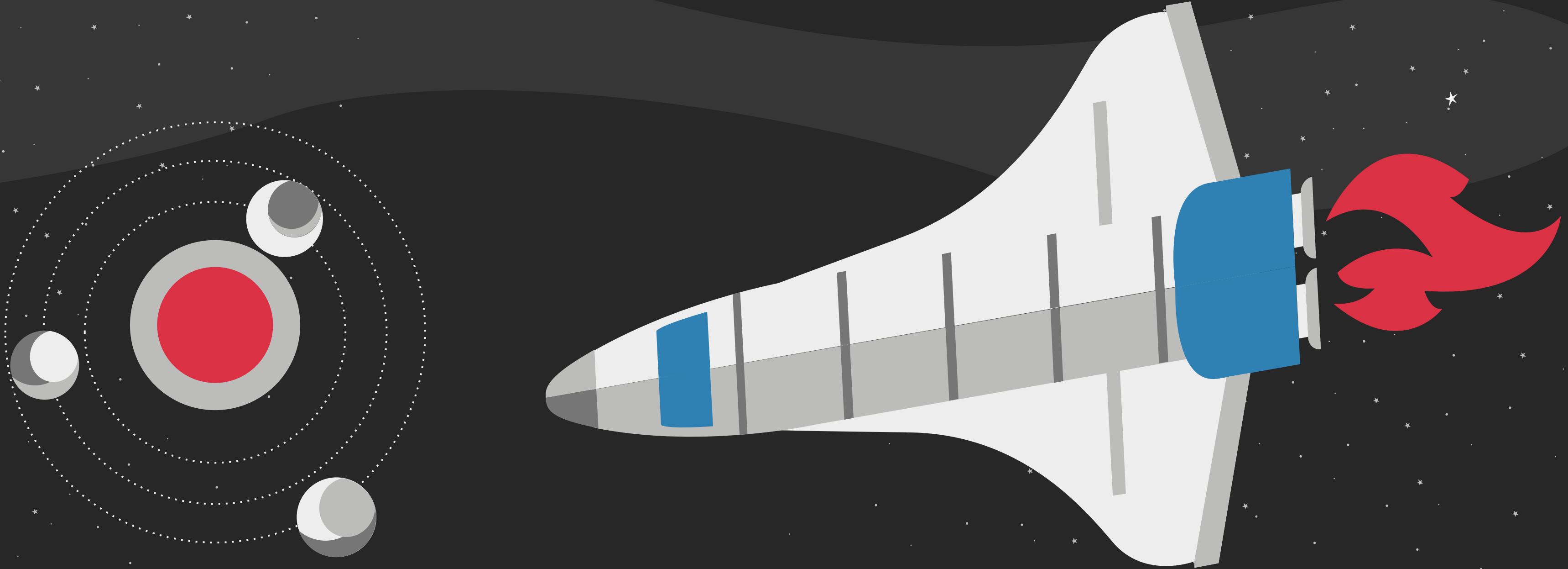
← Ascend from Phobos, transit to Deimos. When close to orbit start measuring magnetic field, imaging experiments, and solar wind capture.

↓ Land on Deimos, deploy RC rover, collect samples, return samples to EEV, perform surface experiments.

→ Ascend from Deimos, transit to DST

→ Dock with DST, transfer materials and astronauts to DST

→ Depart Back to Earth



PROGRAMMATICS

Program Lifecycle Management

RISK ANALYSIS -

A risk analysis of various mission stages was conducted to identify unacceptably high risks and develop risk mitigation strategies.

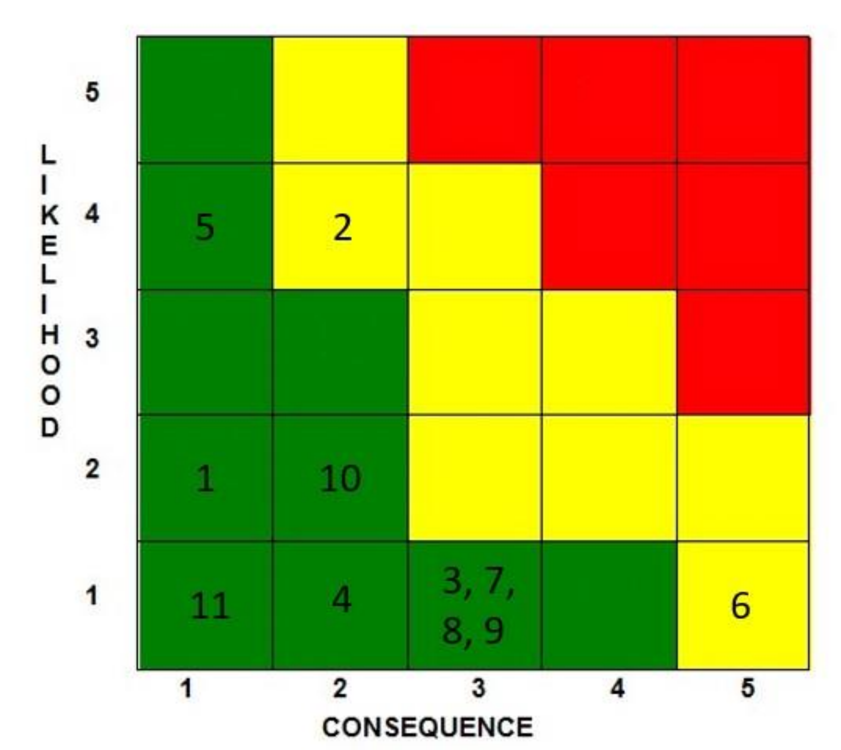
Risk Statements

Number	Risk	Consequence	Likelihood Score	Consequence Score
1	EEV delivery delayed.	Potential to miss launch window and miss rendezvous with DST.	3	3
2	Selected launch vehicle does not meet requirements.	Selected launch vehicle becomes unusable; alternative may be required with delays and increased costs.	4	4
3	Solar panels fail to deploy.	EEV is unable to charge batteries; potential total mission failure.	2	5
4	EEV is struck and damaged by orbital debris.	Potential risk to astronauts and mission completion	1	3
5	EEV Flight/thrust is imperfect.	EEV may require more delta-v and fuel than modeled.	4	3
6	DST fails to capture EEV.	Astronauts unable to enter EEV. Total mission failure.	2	5
7	On-orbit EEV systems failures (non-payload).	Potential risk to astronauts and mission completion.	2	4
8	On-orbit EEV systems failures (science payload).	Potential risk to mission completion.	3	4
9	Landing/Launching maneuvers cause damage to the EEV from debris or terrain.	Potential risk to astronauts and mission completion.	3	4
10	Rover fails to function or retrieve samples	Failure of primary mission objective.	3	2
11	Rover fails to deploy or be recovered due to deployment mechanism mechanical failure.	Failure of primary mission objective; potential risk to astronauts.	2	2

Mitigation Strategies

Number	Mitigation Strategy	New Likelihood Score	New Consequence Score
1	Front-load delivery timeline to allow for slippage. Use flight-proven suppliers.	2	1
2	Pre-select alternative launch vehicle to confirm launch capability	4	2
3	Robust testing. Use of flight-proven hardware. Astronauts may perform EVA to manually fix arrays.	1	3
4	Hardening of exterior surfaces where practicable.	1	2
5	Incorporate extra fuel for additional maneuvering.	4	1
6	Robust testing and modeling. Use of standardized, flight-proven hardware.	1	5
7	Robust testing. Use flight-proven systems where practicable.	1	3
8	Robust testing. Use flight-proven systems where practicable.	1	3
9	Impact-resistant outer layer of EEV. Careful selection of landing sites.	1	3
10	Robust testing. Use flight-proven systems where practicable	2	2
11	Robust testing of deployment mechanisms; designed failure modes to mitigate debris risk.	1	1

MITIGATED RISK MATRIX



THANKS!

Do you have any questions?