Phobos Observation and Composition Understanding System

OrbitLink

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Spacecraft Preliminary Design
Daytona Beach, FL
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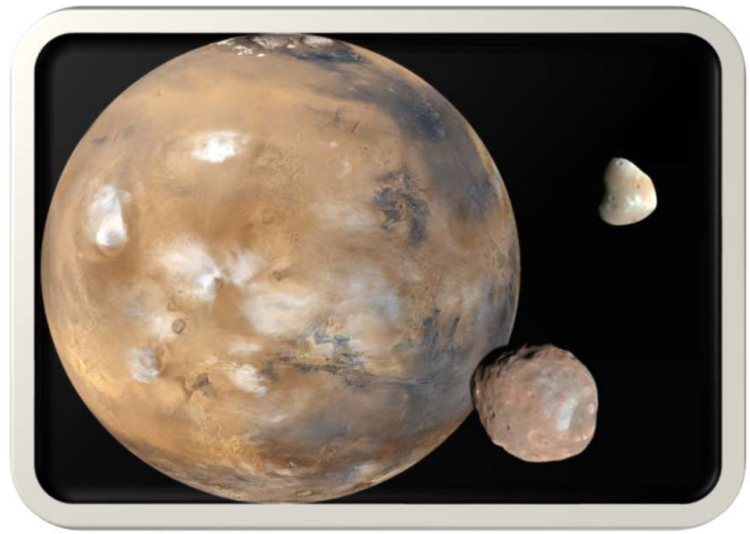
OrbitLink Team Members

OUR
TEAM

EL2

Mission Objective

- Traverse, orbit, and land on Phobos
- Gather images and data of Phobos's and Mars's surface while in orbit
- Locate landing location on Phobos
- Obtain and analyze material samples from Phobos's surface
- Take images of Mars from the perspective of Phobos

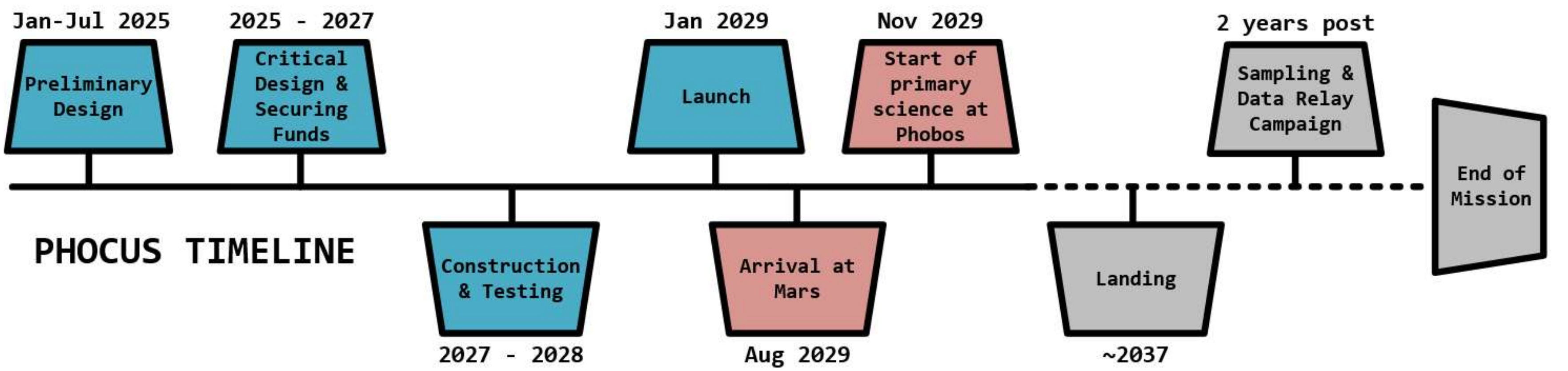


Slide 3

EL1 Discussing what we are doing and why. We are gathering images of Phobos's surface to find a landing location and to start mapping the topography of Phobos for evidence of minerals and potential water sources.
We are analyzing material samples to see it's composition and if there are materials that would be beneficial for future Martian missions.
Then after main operations are complete, we would be taking photos of Mars's surface from Phobos's perspective to further map out its topography, find future sites for missions, and look for areas with potential minerals/water deposits.
Elan, Liya D., 2025-04-20T02:37:54.670

EL2 Add taking photos of mars during mars orbit and phobos orbit
Elan, Liya D., 2025-04-21T14:58:46.906

Schedule



Concept Development and Funding:

- Preliminary Design: 6 months
- Critical Design: 14 months
- Funding: Overlapped significantly

Construction and Testing:

- Construction: 18 months
- Testing: 8 months

Launch and Arrival:

- Shipping and processing: 1 month
- Transfer time: ~8 months
- Commissioning Time: ~2 months
- Orbiting Phobos: 7 years

Landing:

- Sample Collection: Immediately upon landing
- Surface Operations: 3 years

Budget

Category	Cost (in million USD)	Percent of Budget
Preliminary Design	1	0.16%
Critical Design	5	0.8%
Labor (Manufacturing and management)	80	12.8%
Facility Costs (3-year build time)	9	1.44%
Spacecraft Bus + Instruments	220	35.2%
Testing Costs (~30 % of material cost)	60	9.6%
Launch Services (Mainly launch cost)	80	12.8%
Overrun Provisions (Supplier delays)	40	6.4%
Operations/Insurance (~30 people and DSN costs across 10 years *not including extension)	130	20.8%
Total Cost:	625	100%

Category	Cost (in million USD)	Percent of Category
ADCS	36.4	16.55%
Landing System (Gear/ Laser Altimeter)	4.7	2.14%
GNC	22.0	10.00%
Scientific Instrumentation	53.2	24.18%
Structure	33.6	15.27%
Thermal Control	12.7	5.77%
External Communications	19.4	8.82%
Power Generation & Regulation	21.3	9.68%
Propulsion (Monopropellant)	16.7	7.59%
Total Subsystem Cost:	220	100%

Launch Schedule

Departing Location	Departing Date	Departing Time	Flight Duration	Arriving Location	Arriving Date	Arriving Time
Earth	January 5^{th}, 2029	1:00 am	233 days	Mars	August 26^{th}, 2029	1:00 am
Mars	August 28^{th}, 2029	1:00 am	10 days	Phobos	September 7^{th}, 2029	1:00 am

Attitude Determination and Control System- Components

Component Name	Specific Instrument Used
Star Camera	ST400 Star Tracker
Gyroscopes	CRS43 Gyroscope
Sun Sensors	SSOC-A60 Sun Sensor on a Chip
Reaction Wheels	Nano Avionics
Attitude Processors	Intel® Xeon® Gold 6544Y Processor
Solar Array Drive Actuator	High Power Type 5-TC Solar Array Drive Assembly
Computer Pointing System Actuator	C14 Bi-Axis Gimbal

Attitude Determination and Control System- Components

Star Tracker

Gyroscope

Sun Sensor

Reaction Wheels in a Tetrahedral Configuration

Attitude Processor

Solar Array Drive Actuator

Computer Pointing System Actuator

Attitude Determination and Control System - Mass

The mass for each component was found for the Inertia Calculations.

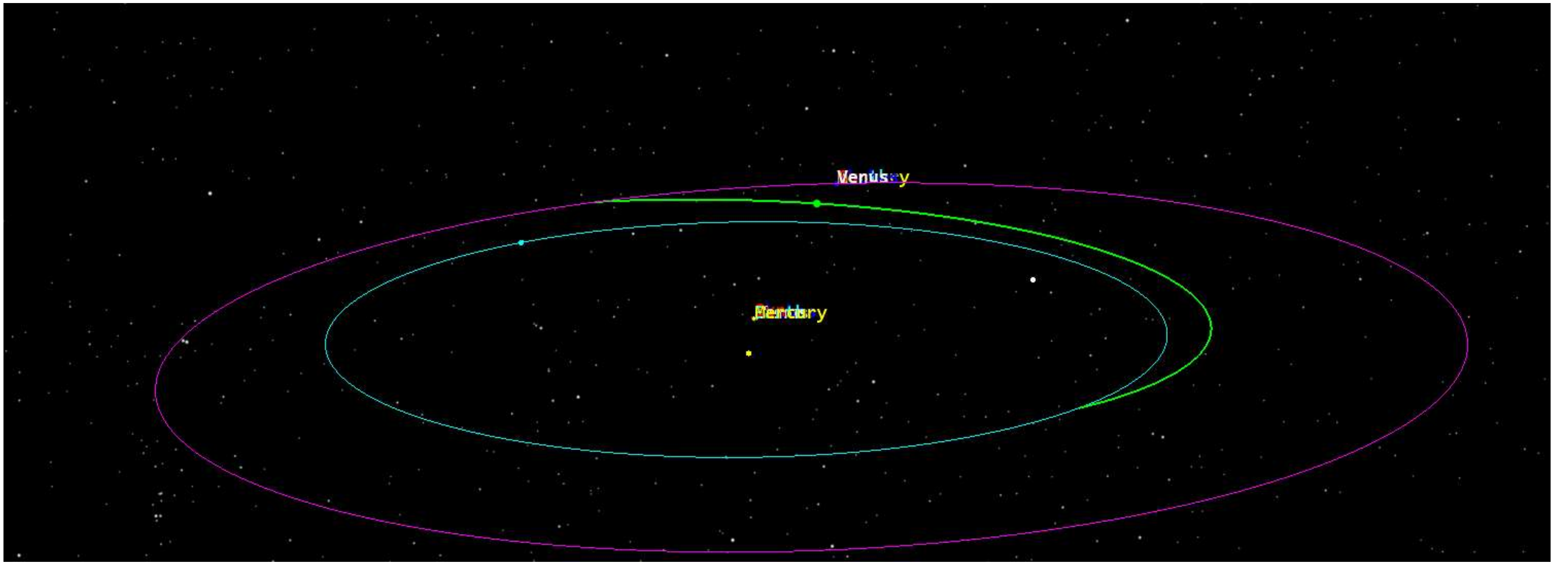
Passive	Mass (kg)
Star Camera	0.085
Gyroscopes	0.000050
Sun Sensors	0.025
Reaction Wheels (4RWO)	0.76
Attitude Processors	~0

Component	Mass
Main Bus (Al honeycomb, 25 mm thickness)	38.5 kg
2 Roll Out Solar Arrays	110.68 kg
Hydrazine Tank (Al, 6 mm thickness)	135.83 kg
Hydrazine Fuel	2780 kg

Attitude Determination and Control System - Inertia

Inertial Axis	Inertia ($kg \cdot m^3$)
Ixx	8430.23
Iyy	1016.88
Izz	8338.05
Ixy	0
Iyz	0
Ixz	0

Attitude Determination and Control System – STK Model

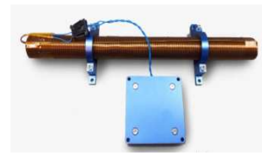


Guidance, Navigation, and Control System (GNC)

Component Name	Specific Instrument Used
High Heritage Miniature Reaction Wheels	Blue Canyon Technologies, RW8
High Heritage Magnetic Torquers	AAC Clyde Space, MTQ800
Magnetometers	MEISEI
Horizon Sensors	Servo Corporate of America Dual Array Single-Headed Earth Sensor
Deep Space Navigation	General Dynamics, Small Deep Space Transponder
Inertial Sensing	L3 Harris, ARIES-25
Atomic Clocks	MR0-50 Safran
LIDAR	Advanced Scientific Concepts, GSFL-16K
Solar Arrays Drive Actuator	High Power Type 5-TC Solar Array Drive Assembly
Communication Pointing System Actuator	C14 Bi-Axis Gimbal

Guidance, Navigation, and Control System - Components

High Heritage Miniature Reaction Wheel



High Heritage Magnetic Torquer

Magnetometer

Horizon Sensor

Deep Space Navigation

Inertial Sensing

Atomic Clock

LIDAR

Solar Arrays Drive Actuator

Communication Pointing System Actuator

Pointing Requirements

The pointing requirements were determined for all passive and active equipment.

Passive	Pointing Requirements
Star Camera	Star cameras cover entirety of the spacecraft
Sun Sensors	Sun sensors cover entirety of the spacecraft

Active	Pointing Requirements	Radian Requirements
Magnetometers	In the direction of the magnetic field being measured	17.5 mrad
Horizon Sensors	Towards the edge of the planet's atmosphere	0.143 rad
Optical Communication	Towards the communication antenna located on Earth	4 mrad
Solar Panel Actuators	Towards the sun	0.35 rad to minimize actuator use

Scientific Instrumentation

Our mission encompasses 3 main objectives to be carried out with specific scientific instrumentation:

The imaging of the topography of the surface of Mars and Phobos

- 8k Super Hi-Vision Cameras
- 4k Super Hi-Vision Cameras
- Laser Altimeter

Determination of the material composition of Phobos through measurements from surface

- Gamma Ray Spectrometer
- Infrared Spectrometer
- Ultraviolet Spectrometer
- *Mass Spectrometer*

Determination of the material composition of Phobos through non-surface measurements

- Neutron Spectrometer
- *Mass Spectrometer*

Scientific Instrumentation

Component Name	Specific Instrument Used
8k Super Hi-Vision Cameras	Hi-Vision 8K Developed Cube Camera, NHK
4k Super Hi-Vision Cameras	Panasonic DMC FZ-2500
Gamma Ray Spectrometer	Ortec Gamma Ray Spectroscopy System
Neutron Spectrometer	SP2 Single-Sphere Neutron Spectrometer
Mass Spectrometer	Neutral Gas and Ion Mass Spectrometer of the Mars Atmosphere and Volatile Evolution Mission
Laser Altimeter	Advanced Scientific Concepts, GSFL-16K
Infrared Spectrometer	HR-X Hi-Res Spectrometer
Ultraviolet Spectrometer	BLUE-Wave Miniature Spectrometer

Scientific Instrumentation

8k Super Hi-Vision Camera

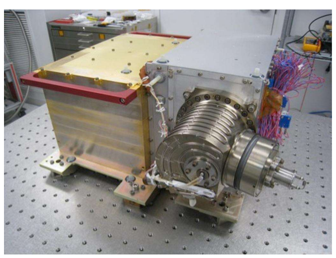
Gamma Ray Spectrometer

Neutron Spectrometer

4k Super Hi-Vision Camera

Laser Altimeter

Infrared Spectrometer



Mass Spectrometer

Ultraviolet Spectrometer

Structure

Main Structure

The main bus will be comprised of aluminum honeycomb panels. The top will be an octagon with an extent of 2.8 m by 2.8 m. The sides will drop down 2.8 m and each panel will have a thickness of 27 mm.

Internal Supports

The internal supports will also consist of honeycomb paneling and other mass optimized aluminum parts where needed. The main components that need support are the sample collection system, main fuel tank, reaction wheels, and batteries.

External Supports

The external supports serve as mounting points for the external components which is mainly the scientific instruments and communication hardware. The mounting hardware will also be made of mass optimized aluminum.

Landing Legs

The landing legs will be made of aluminum tubing that is sized to prevent buckling.

Landing

Sample Collection:
- Passive sample collection
- Introduces combustion products to the sample which will be accounted for

Preparations:
- Spacecraft will have a landing operations mode that covers all subsystems
- Desaturating the reaction wheels and aligning the solar panels

Landing:
- Spacecraft weighs ~20 N under Phobos's 0.0057 m/s^2 of gravity
- Large lightweight landing pads distribute the weight

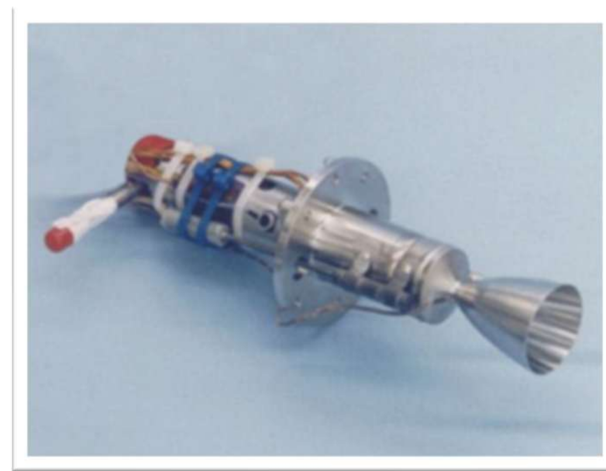
Propulsion

Main Reaction Control Thruster (MR-107B):

- Number of thrusters: 6
- Manufactured by Aerojet
- Produces 257 N thrust each
- Uses hydrazine propellant

Secondary Reaction Control Thruster (MR-106E):

- Number of thrusters: 16
- Manufactured by Aerojet
- Produces 27 N thrust each
- Uses hydrazine propellant



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EL1 Main thrusters are all on the back of the spacecraft
Elan, Liya D., 2025-04-21T15:19:33.235

EL2 These are in places to provide control authority to the spacecraft so that it can turn in all 6 directions and stay on course.
Elan, Liya D., 2025-04-21T15:20:04.189

EL3 Mention type of fuel for both eniges
Elan, Liya D., 2025-04-21T15:20:36.690

EL2

Passive Thermal Control

Passive Thermal Component	Solar Absorptivity (a_s)	Emissivity Value (ε_{IR})
Epoxy Aluminum Paint	0.77	0.31
Solar Cell Coating	0.88	0.80

Slide 21

EL1 explain why we chose more solar absorbent paint
Elan, Liya D., 2025-04-21T15:23:06.805

EL2 Add temperatures around earth, transit, mars, and phobos for reference
Elan, Liya D., 2025-04-22T22:12:13.036

EL1

Active Thermal Control

Omega KHLBA PLM-Series Electrical Heater:

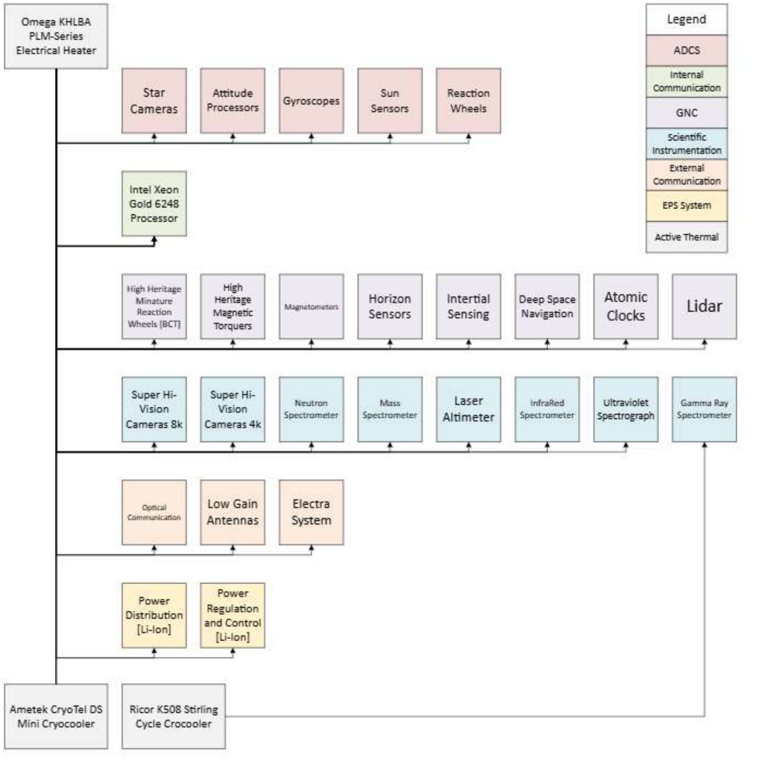
- Regulates from 233.15 K to 422.15 K
- Power draws 10 W

Ameteck CryoTel DS Mini Cryocooler:

- Regulates from 40.00 K to current temperature of spacecraft
- Power draws 80 W

Ricor K508 Stirling Cycle Cryocooler:

- Regulates from 65.00 K to 110.00 K
- Power draws 12 W
- Specific cooling for the gamma ray spectrometer



EL1 explain why we chose more solar absorbent paint

Elan, Liya D., 2025-04-21T15:23:06.805

Communication

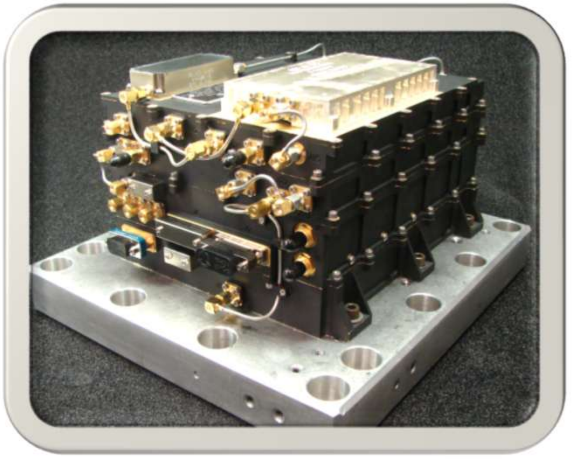
Deep Space Optical Communications:

- High Bandwidth
- Data Downlink
- Flown on the Psyche mission

Frontier-X:

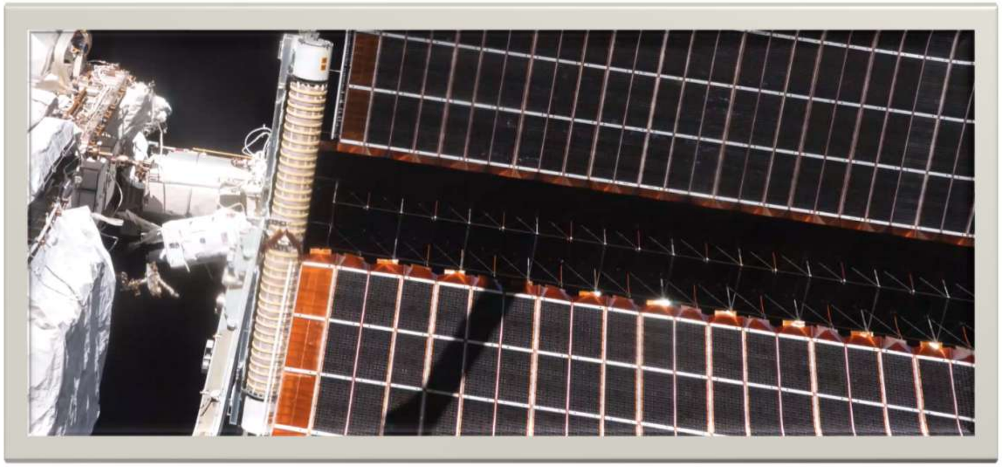
- Low Gain Antenna
- Spacecraft Operations
- Emergency Contact
- Flown on the Europa Clipper mission and Varda W1, W2, & W3.

Electra Proximity Link:



- UHF Transceiver
- Mars Relay Network
- Flown on every US Mars orbiter and lander since 2005

Electrical Power System



Roll Out Solar Arrays:

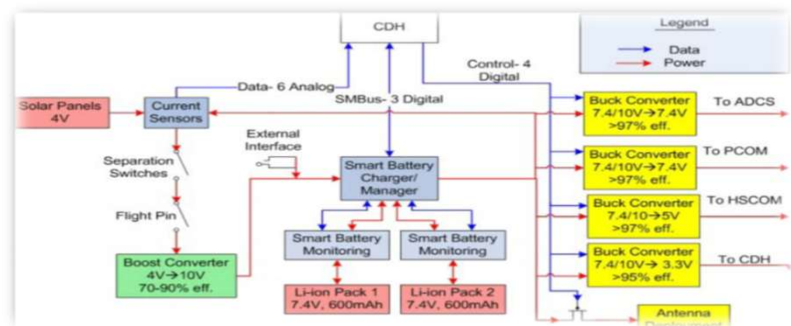
- Power Production
- Flown on DART and the International Space Station

Power Regulation:

- Series of converter and circuits to control the flow of energy
- Tailored to the spacecraft, reference example below

55 Ah Batteries:

- Energy Storage
- Flown on Juno, MAVEN, and OSIRIS-APEX



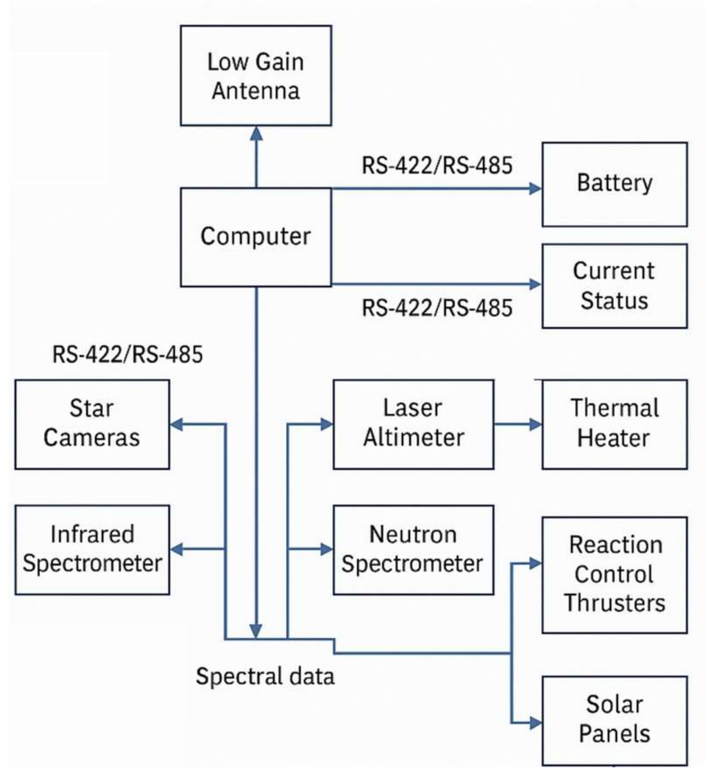
Flight Software & Data Interface Management

Communication Standards:

- RS-422 & RS-485 serial communication protocols
- Bidirectional data flow with low latency and noise immunity
- Modeled from previous Mars heritage flight software

Data Interface Overview:

- Interface Control Documents will be utilized to define how each component and subsystem communicate
- Will update with new data requirements as mission progresses
- ICDs ensure command integrity, science data delivery, attitude control synchronization



Launch Vehicle

Falcon 9 (Space X):

- Payload Mass: 4010 kg
- Approximate Payload Volume: 257.22 m^3
- Delta-V Capability:
  - First Stage: 3210 m/s
  - Second Stage: 4758 m/s
- Rocket Mass:
  - First Stage: 421300 kg (25600 kg empty)
  - Second Stage: 96570 kg (92670 kg empty)
- Cost Per Launch: $62 million
- Expected Availability: Jan 5th, 2029

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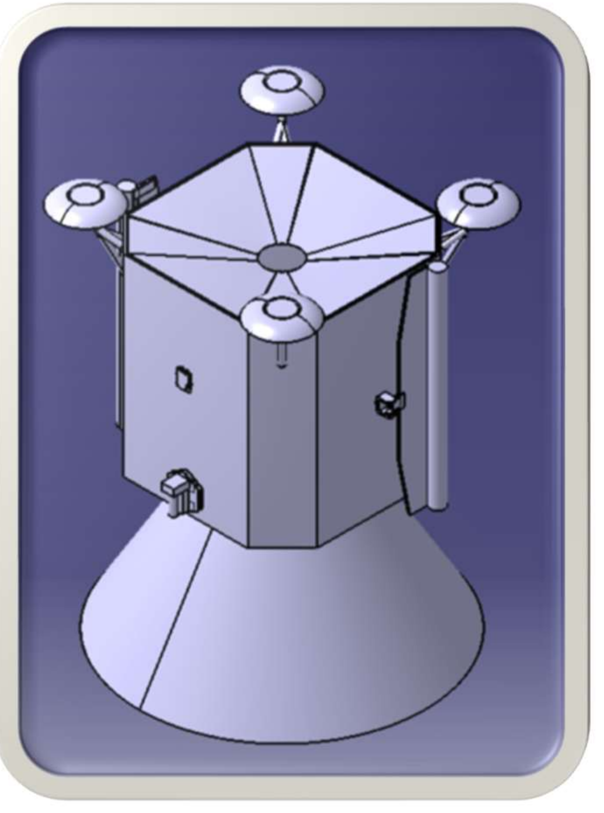
EL1 Dimensions (Diameter, Height): 5.2m and 13.1m

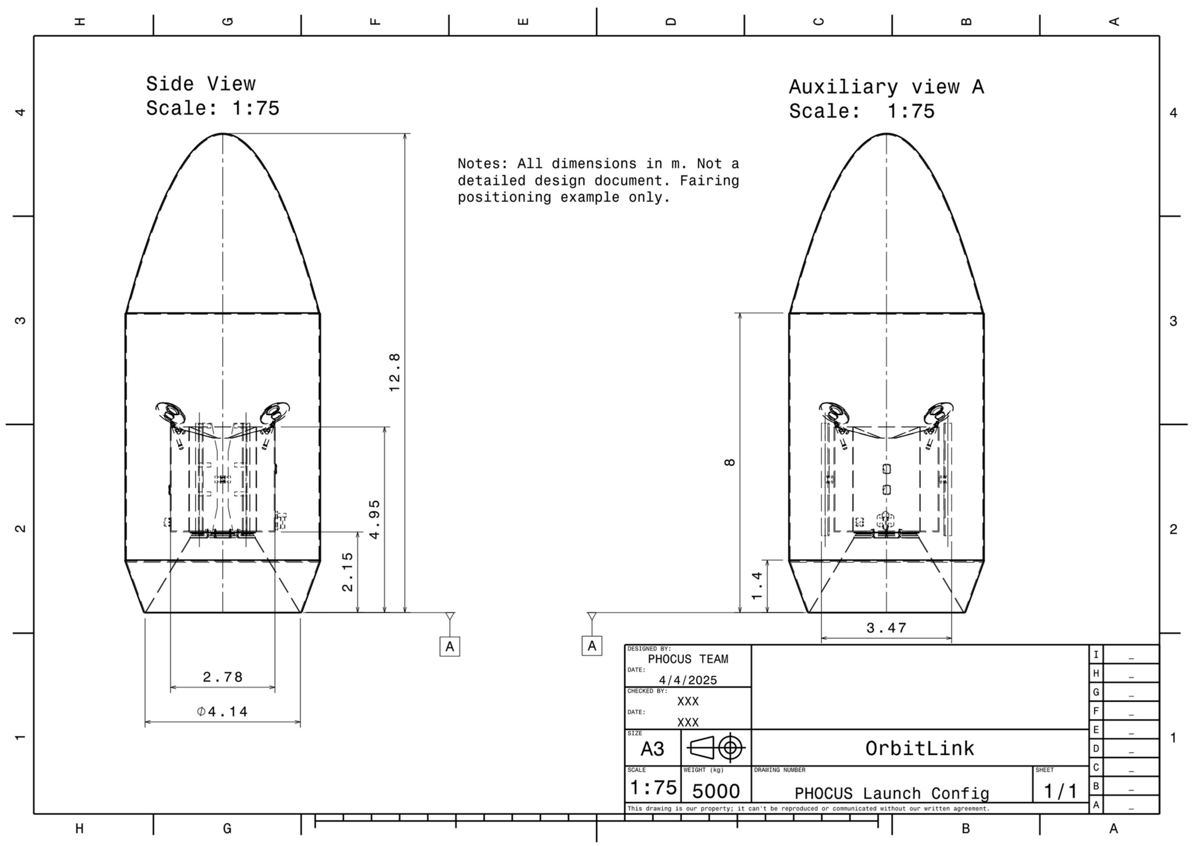
Elan, Liya D., 2025-04-21T15:24:35.731

Models of Spacecraft: Launch Vehicle



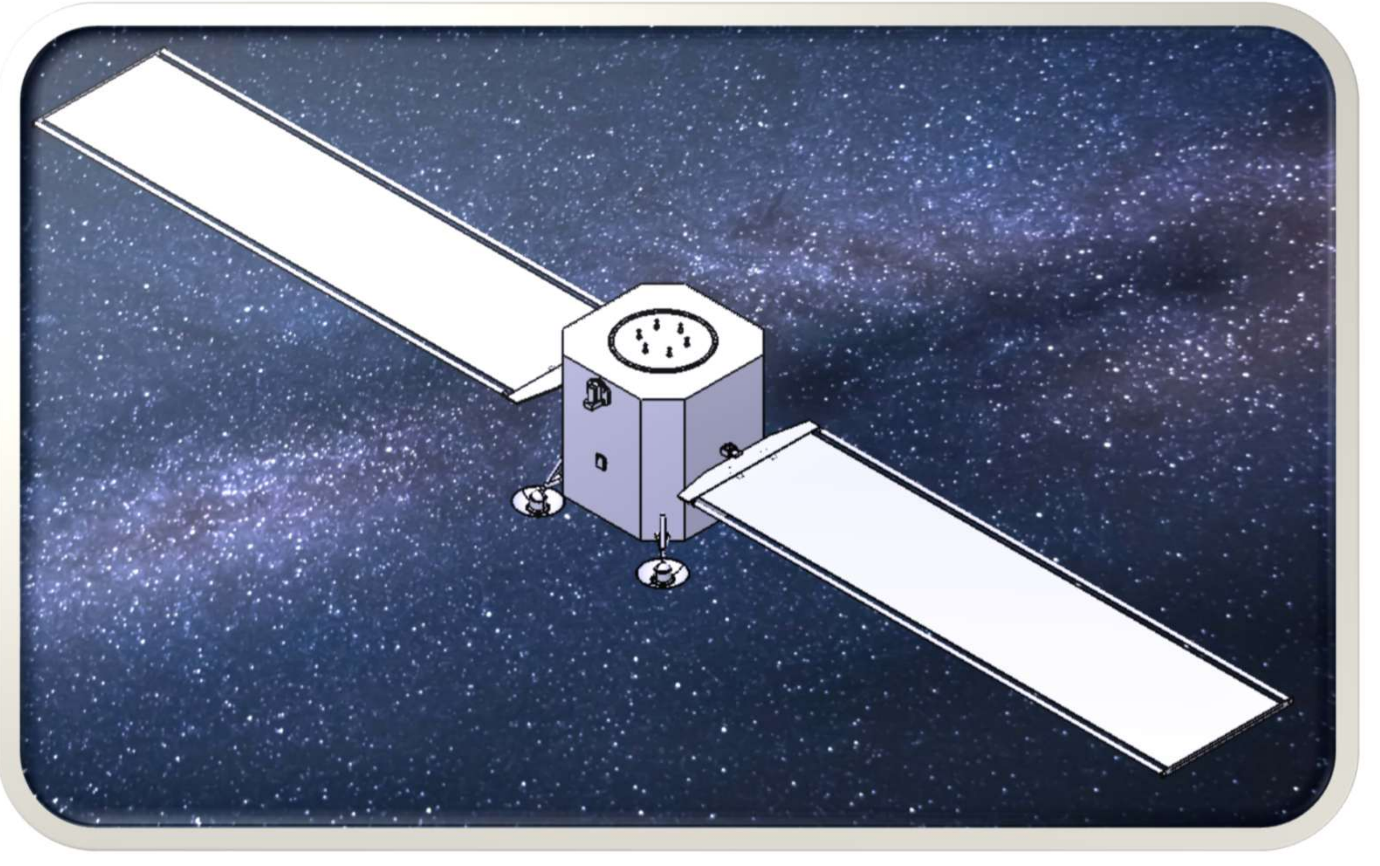
PHOCUS on the payload mount

Models of Spacecraft: Launch Vehicle



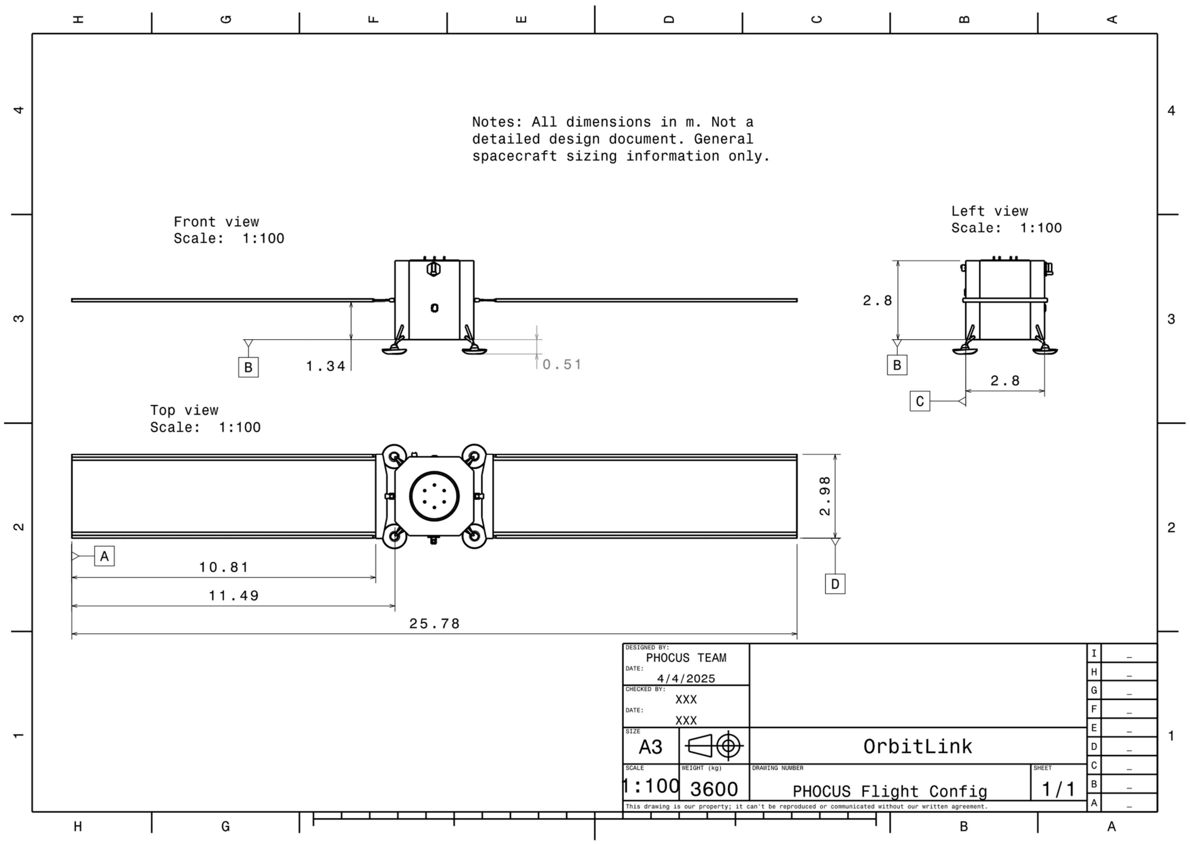
Drawing of the launch configuration

Models of Spacecraft



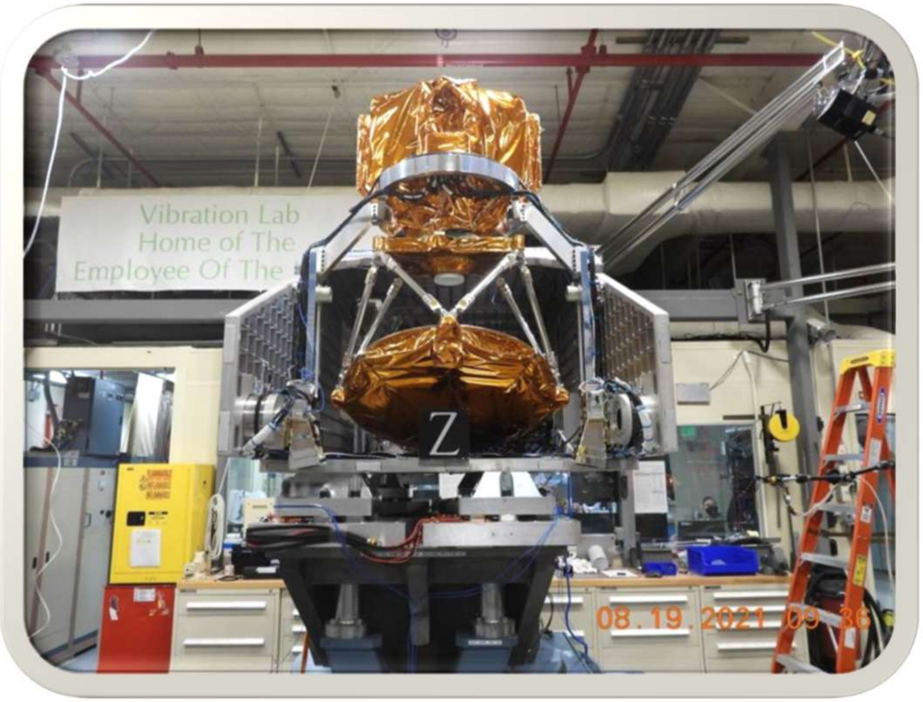
In space deployed configuration of spacecraft

Models of Spacecraft



Drawing of deployed configuration

Environmental & Structural Testing



Thermal Vacuum Testing:

- Max Test Temperature: 426 K
- Min Test Temperature: 216 K

Vibration & Shock Testing:

- Structural Resonance Testing:
  - 8 Hz Lateral
  - 20 Hz Axial
- Shock Loads:
  - 30 g at 100 Hz
  - 1000 g at 1000 - 10000 Hz

Acoustic Testing:

- Max Levels:
  - 122 dB at 160 Hz
  - 126.1 dB at 125 Hz
- Focus: High surface area components

Systems, Software, & Integrity Testing

Electrical Testing:
- Signal Continuity
- Software Operation
- Navigation & Pointing Systems

Post Environmental Checks:
- Repeat Thermal Test Cycle
- Check All Operating Nodes

Sinusoidal Vibration Testing:
- Simulates Low Frequency Launch Stress
- Verifies System Integrity Across Frequency Spectrum

Kennedy Space Center Launch Equipment Test Facility (LETF)

Location:

- Merrit Island, FL

Advantages:

- Minimizes transport risk & cost
- Supports comprehensive testing on-site
- Keeps mission timeline on track

Capabilities:

- Thermal vacuum testing, vibration, shock, & acoustic
- Cryogenic compatibility
- Payload fairing and structural integrity testing

Insurance

- AXA XL will be used to provide insurance for pre-launch, launch, in-orbit, and liability coverage for spacecraft and launch vehicles.
- AXA XL is commonly used for small launch satellites and launch vehicles, unique mission designs, and new technology and applications.

Acknowledgements

The OrbitLink team would like to thank the following people for their contributions to this project and mission report:

- Colin Berg, Craig Dedrick III, Liya Elan, Serena Elijah, and Stephanie Ramsey
- Our professor, Dr. Jennifer Smith, and our teaching assistant, Matthew Willoughby
- Our classmates
- Dr. Thomas Lovell

Without the dedication and expertise expressed by these individuals, this mission would not be possible!