The 8th Mission Idea Contest for Multiple Nano-satellites

# CUBESAT CONSTELLATION TO ANALYZE THE EFFECTS OF EARTH'S MAGNETIC TAIL ON THE MOON

## MAGNETA-CUBE

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3. Orbit/constellation description
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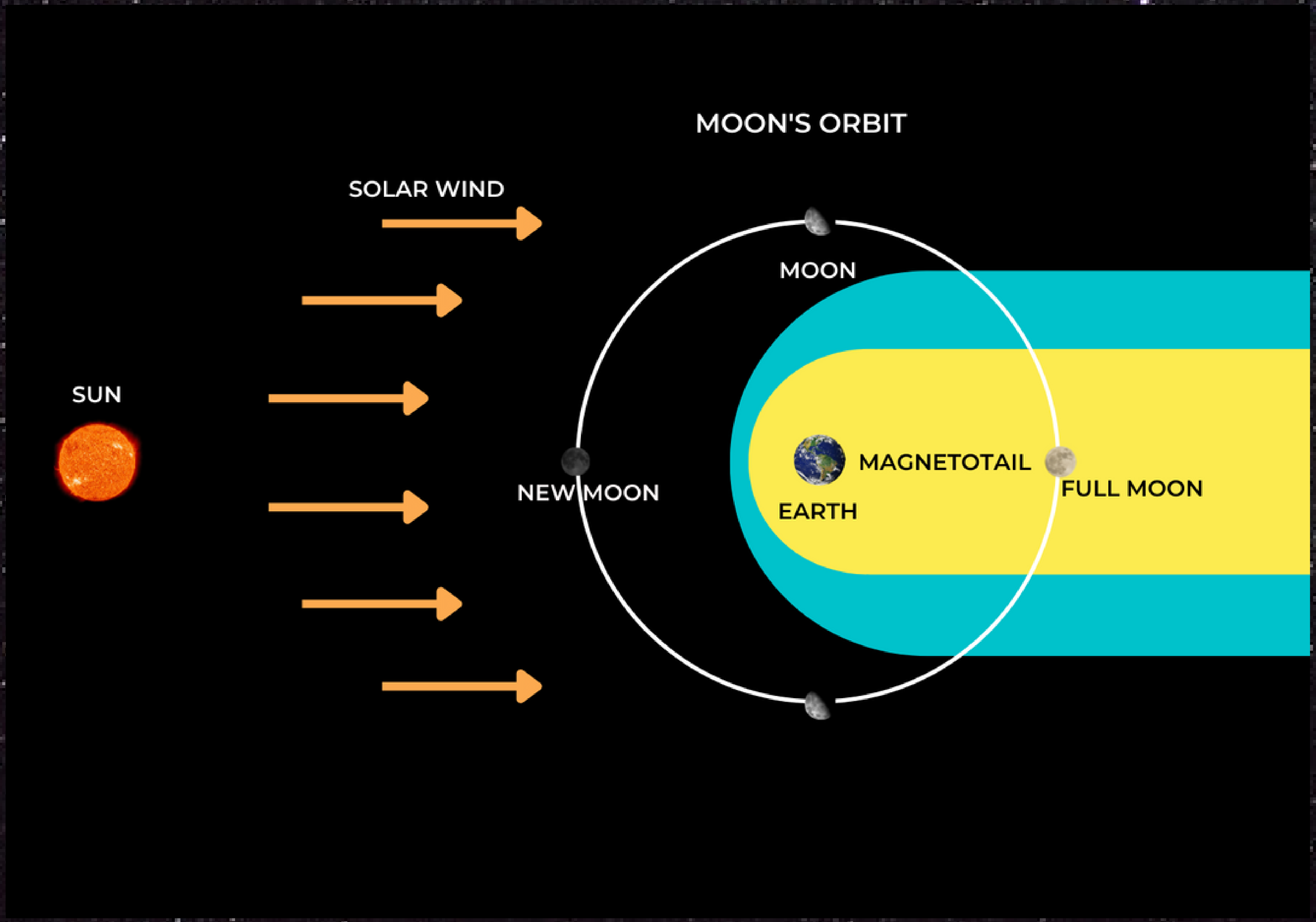
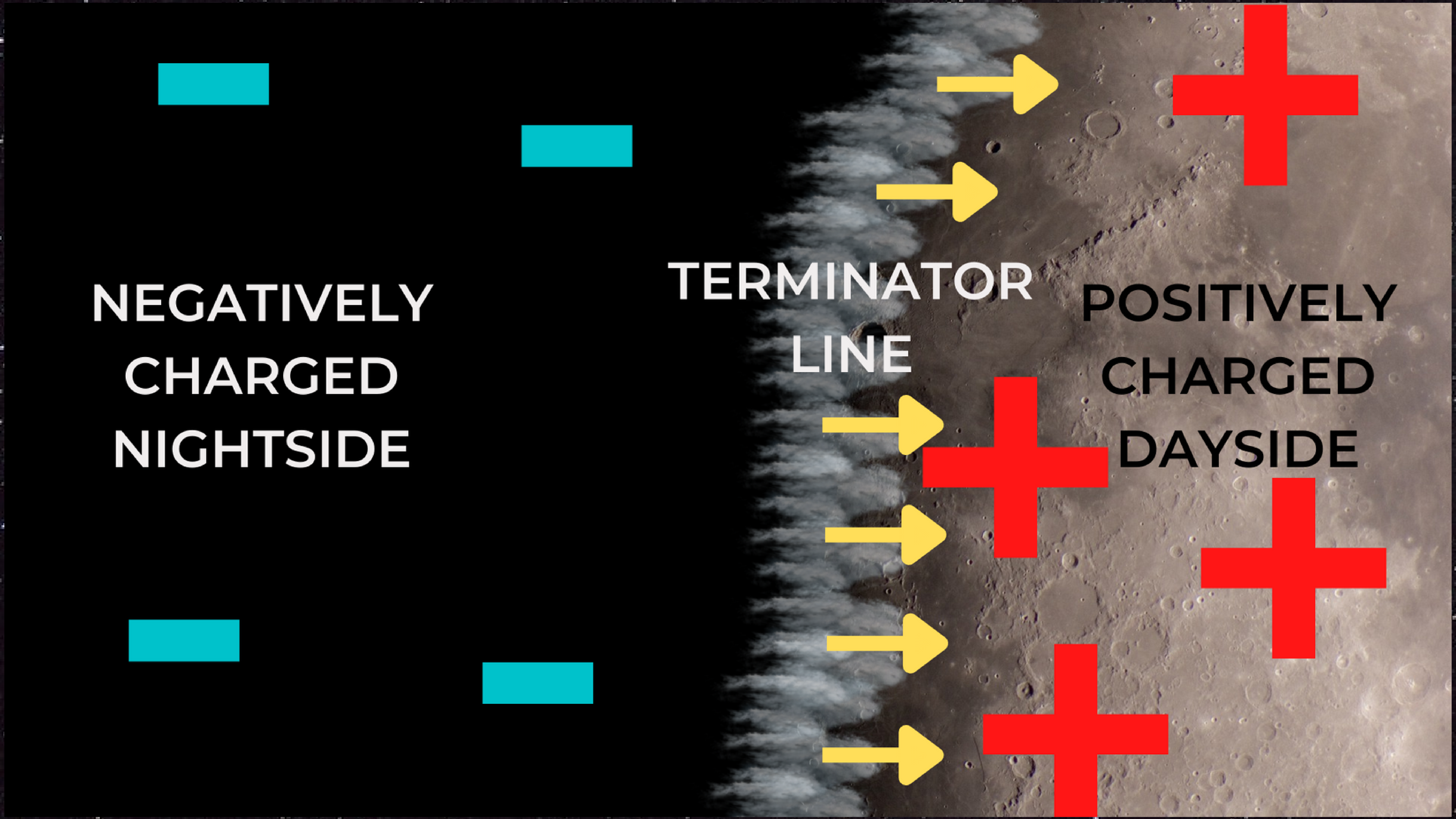
# NEED

NEED

There are still some problems that could occur that have not been well studied regarding to moon exploration, such as those related to Earth's magnetic tail. This issues can have consequences ranging from lunar ‘dust storms’ to electrostatic discharges.

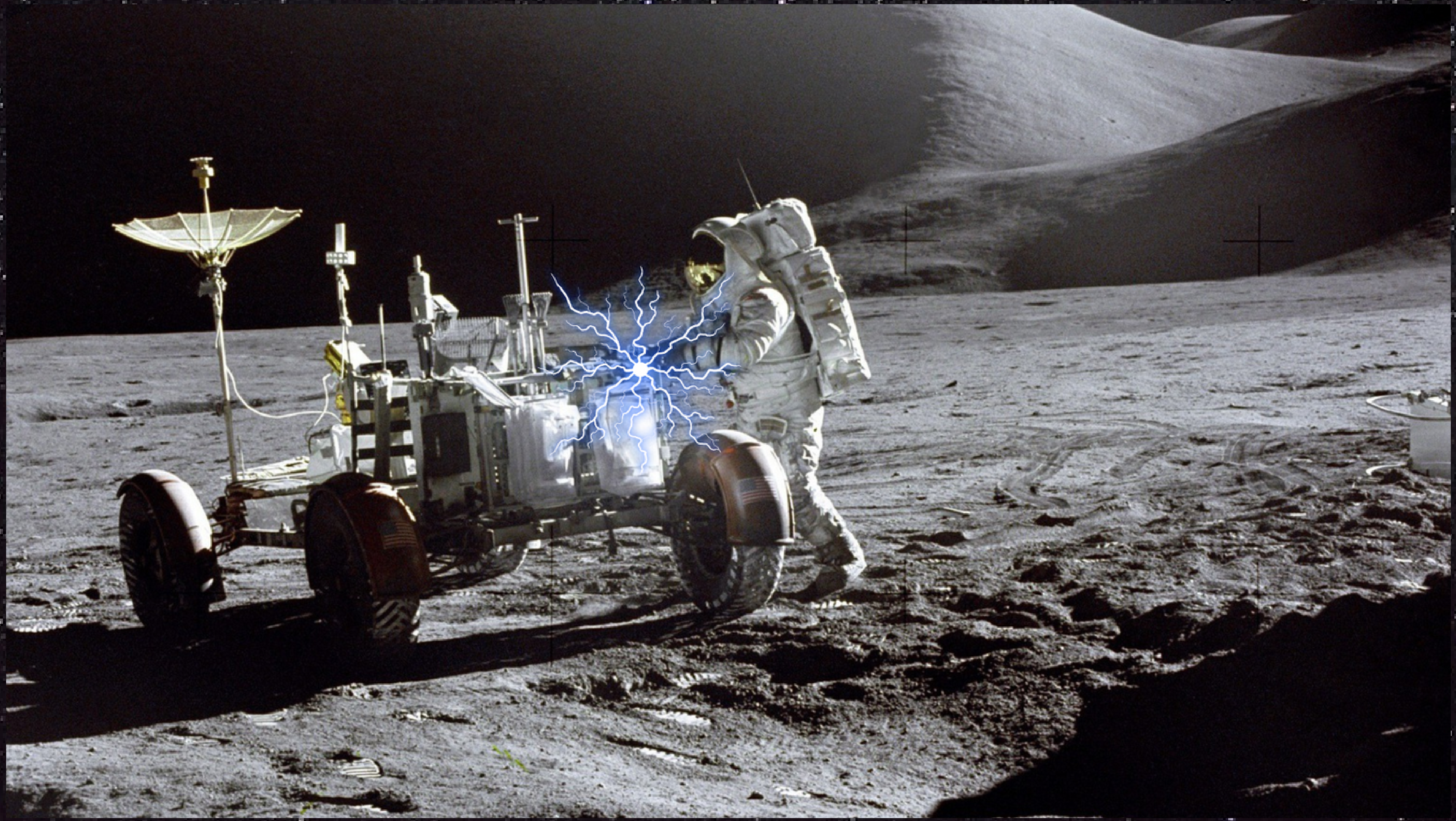


The study of this phenomenon is important, since the moving clouds of lunar dust (or regolith), could affect the machinery, instruments, or habitats installed on the moon.



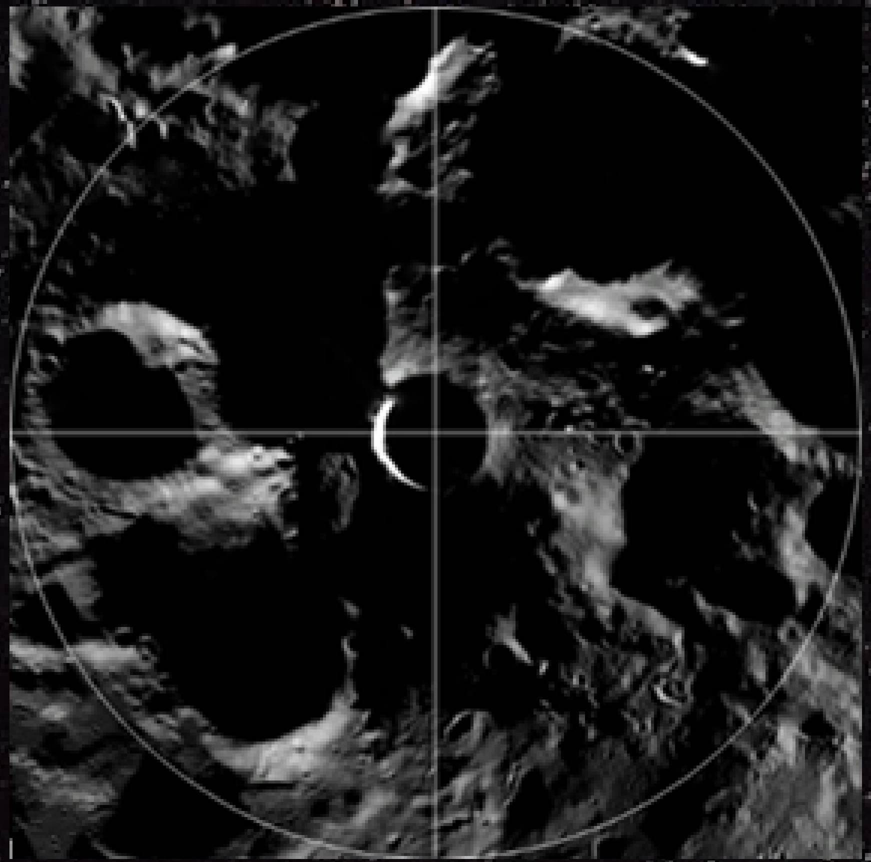
# LUNAR DUST STORM

Also, electrons accumulate and surface voltages can be hundreds or thousands of volts. So astronauts walking on the surface and accumulating a load of excess charge by touching another astronaute, instrument, etc. Could produce an unwelcome discharge.



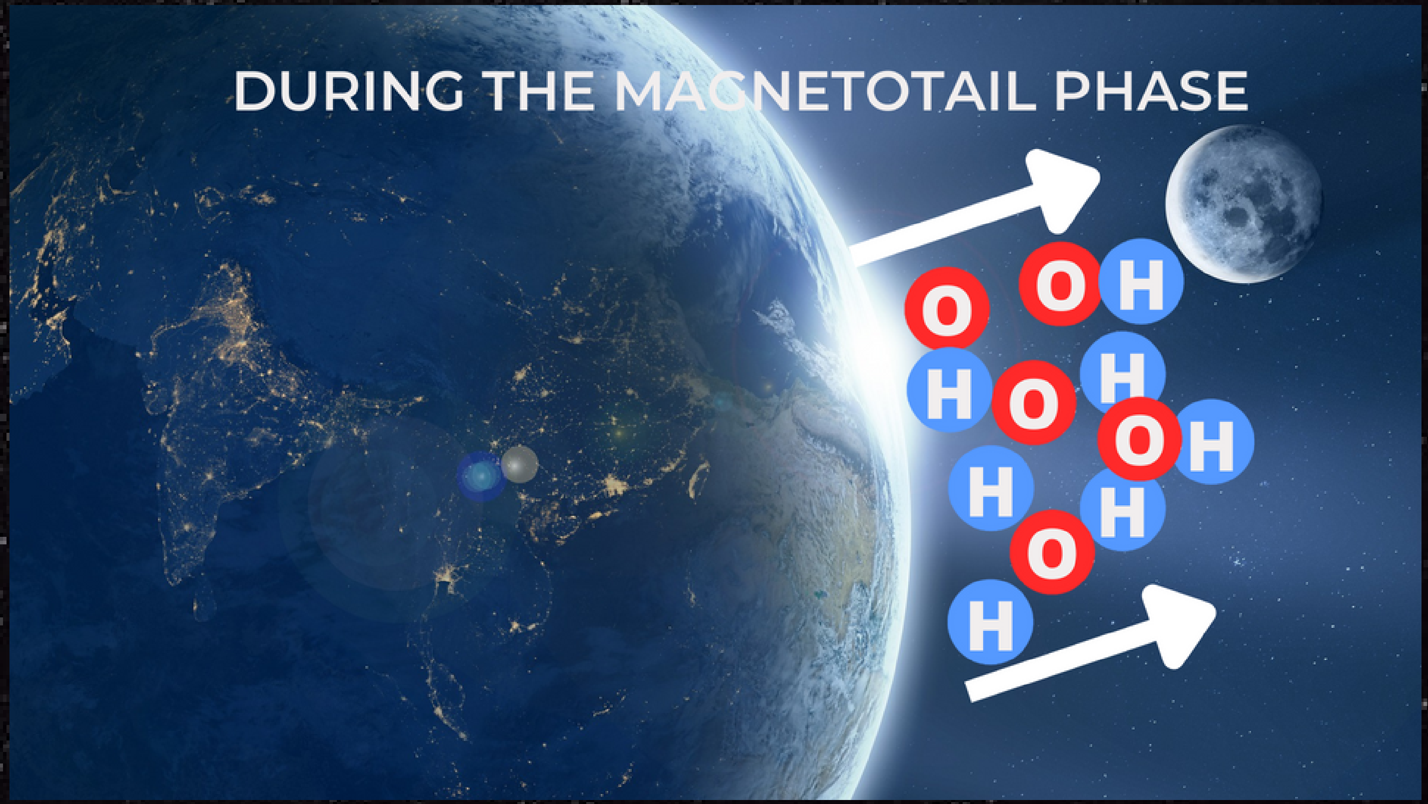
# OBJECTIVES

***Requirement:*** Study the variation of the remanent electromagnetic field in a range from from 6 nT to 313 nT. And the movement of lunar dust clouds of at least 14 meters in size.
***Where?*** at the south pole of the Moon in an area of about 25,000 km2
***When?*** when the moon encounters the "magnetic tail" of the Earth.



Credit: NASA/GSFC/Arizona State University

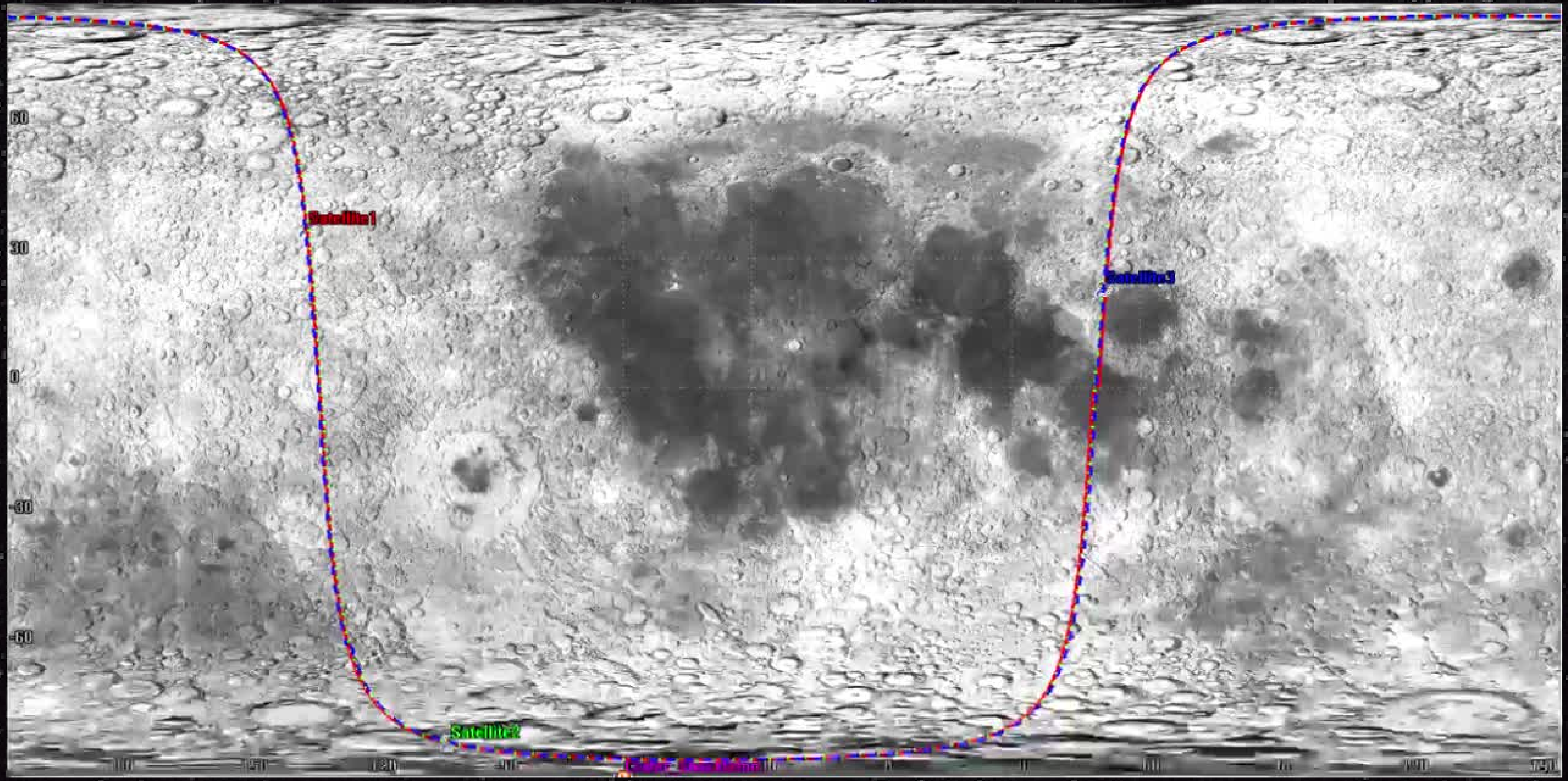
***Requirement:*** Take measurements of both hydrogen and oxygen ions during each day of the magnetotail phase to see if there are variations in the intensity of ion transfer with respect to the course of days within the magnetotail.
***Where?*** In the selected orbit
***When?*** when the moon encounters the "magnetic tail" of the Earth.



# ORBIT/CONSTELLATION DESCRIPTION



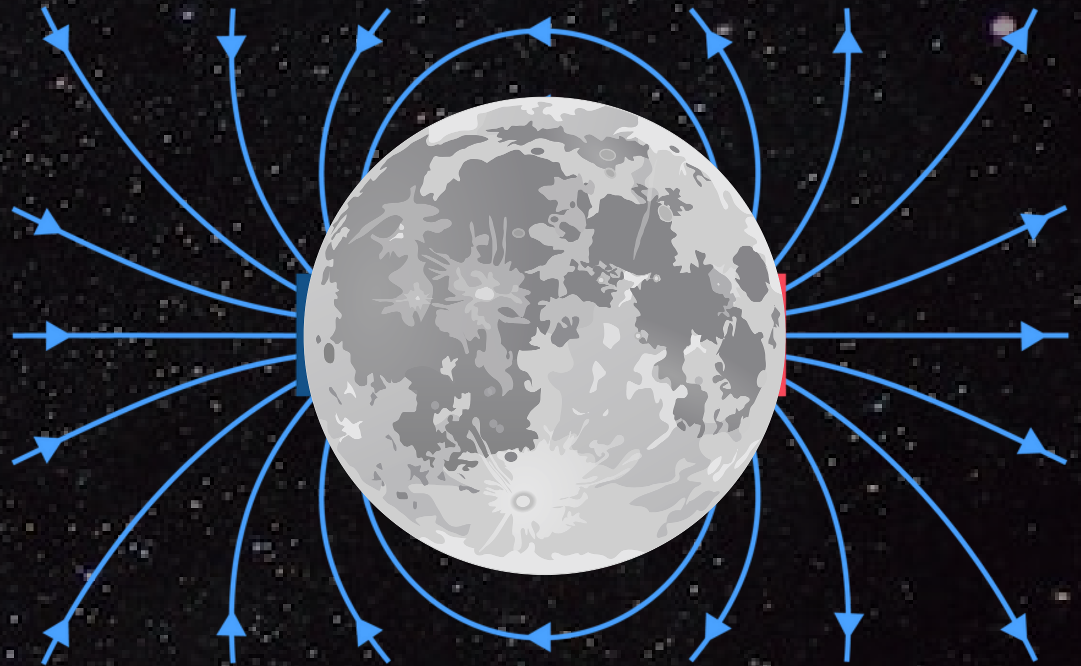
- Type: Circular low lunar orbit
- Altitude: 100 km
- Three CubeSats of 6U placed every 120°
- Orbital period: 2 hours
- Inclination: 86°
- Alex S. Konopliv, planetary scientist at NASA's Jet Propulsion Laboratory



Orbit description of the constellation (elaborated in STK)

# KEY PERFORMANCE PARAMETERS





To take imagery (8-bit or 16-bit) from an altitude of 100 km with a 10 m GSD

Make measurements in orbit looking for H and O ions, every 10 minutes, making it for 12 measurements every 120 minutes (orbital period)

To make measurements in a range from 6 nT to 313 nT with a resolution of at least 8 nT.

# CONCEPT OF OPERATION

## SPACE SEGMENT

LUNAR PATHFINDER will be used as data relay satellite

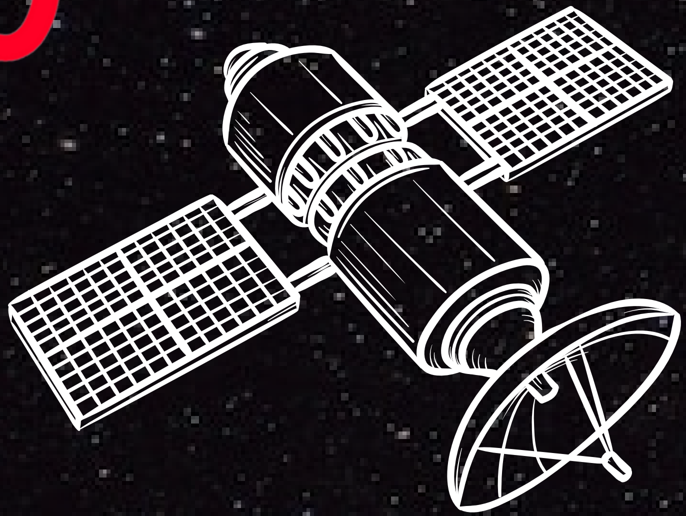


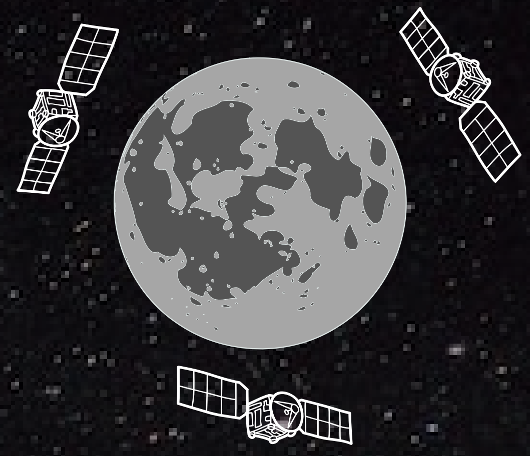
Image and data transmission

Band-S

UHF frecuency

Transmission and reception of telemetry

CubeSat constellation located in a ~100km polar orbit



Satellites scan moon's south pole during magnetic tail phase

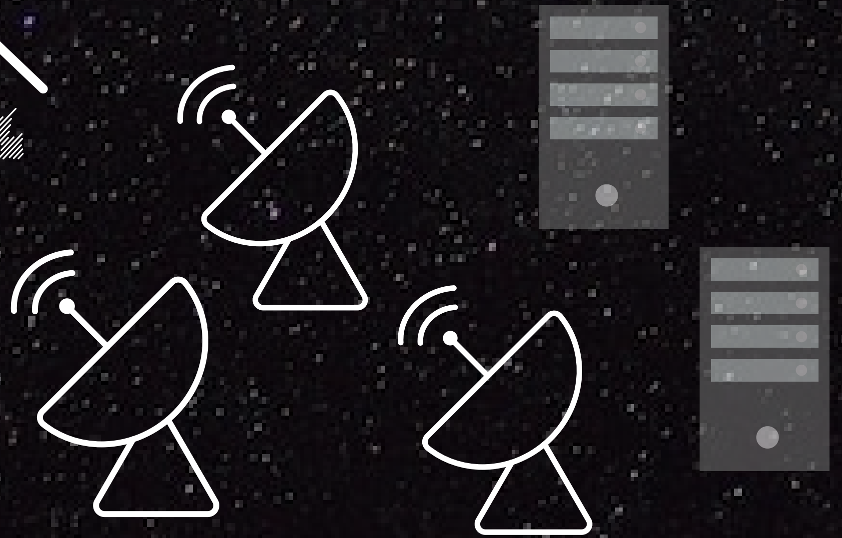
Band-X

Satellite receives data and commands from the ground station

The ground station receives data and images from the satellite

Information sent to the research centers for analysis

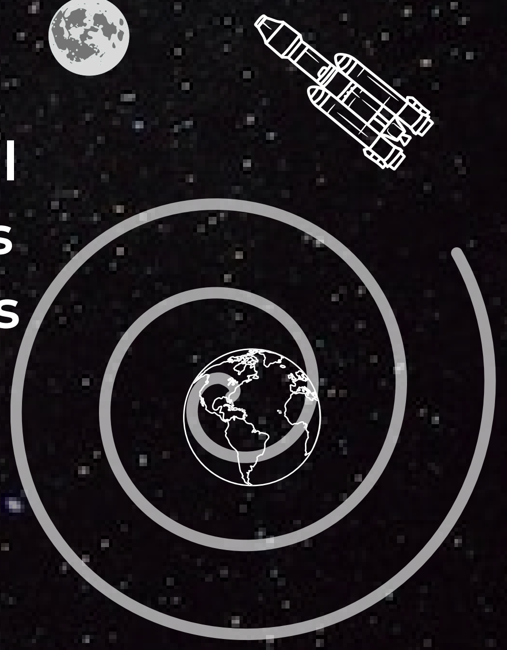
Data processing



## GROUND SEGMENT

ESA ground station located around the earth

The spacecraft will take several orbits before reaching its destination



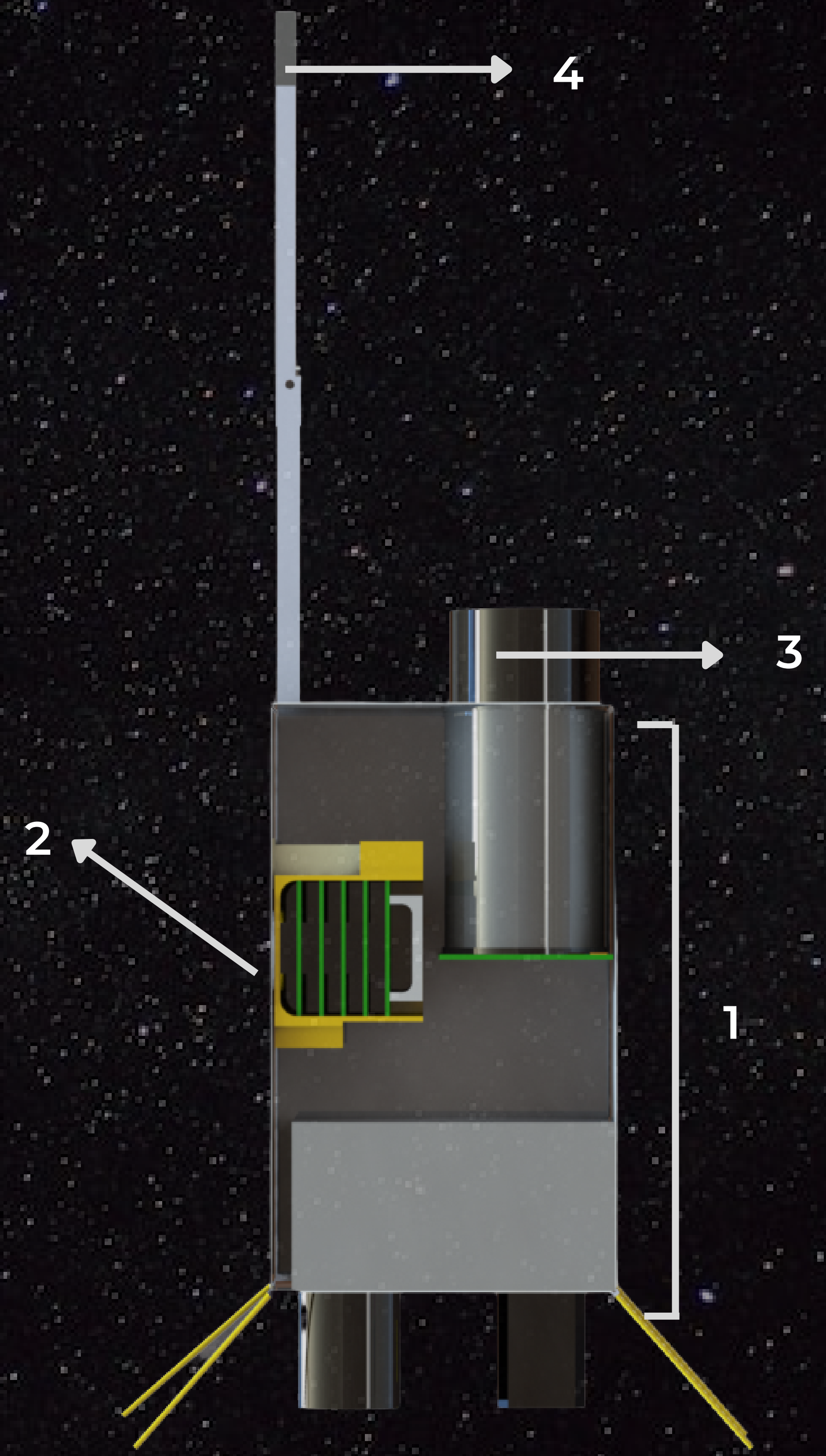
## LAUNCH

Launch by Astrobotic Company

# SPACE SEGMENT DESCRIPTION

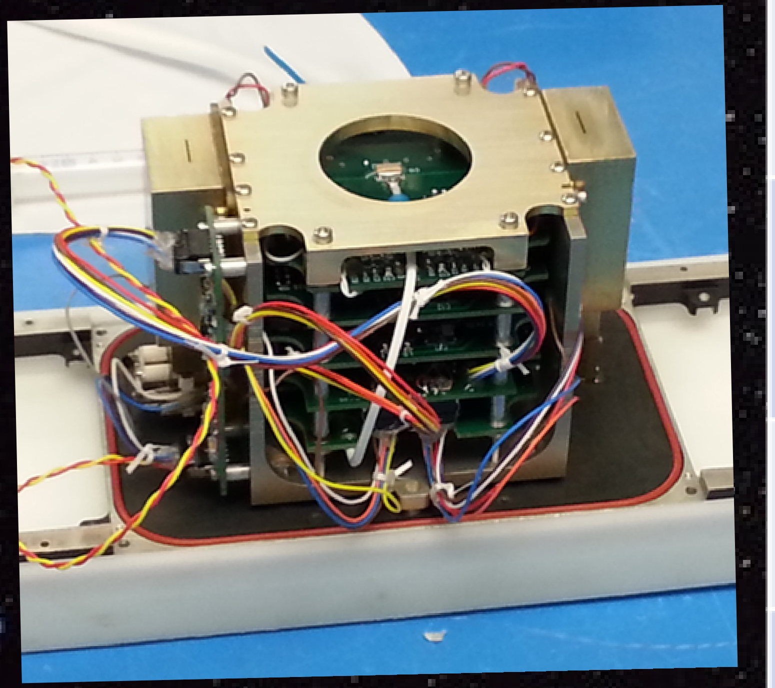


| Component | Notes | CUSTOM/COTS | Mass | Physical Size |
|---|---|---|---|---|
| CubeSat 6U Platform (ADCS, EPS, Solar Panels, Computer, Reaction Wheels, C&DH, Propulsion System) | M6P NanoAvionics | COTS | Empty Bus: 4 500 g / 5 500 g | Payload volumen: Up to 4U |
| Mass spectrometer | Mini-INMS | COTS | 600 g | 1.6U |
| Optical sensor | Chameleon Imager Dragonfly Aerospace | COTS | 1.6 Kg | 2U |
| FG Magnetometer | - | CUSTOM | - | - |




1. CubeSat Platform
2. Mass Spectrometer
3. Optical Sensor
4. Magnetometer FG

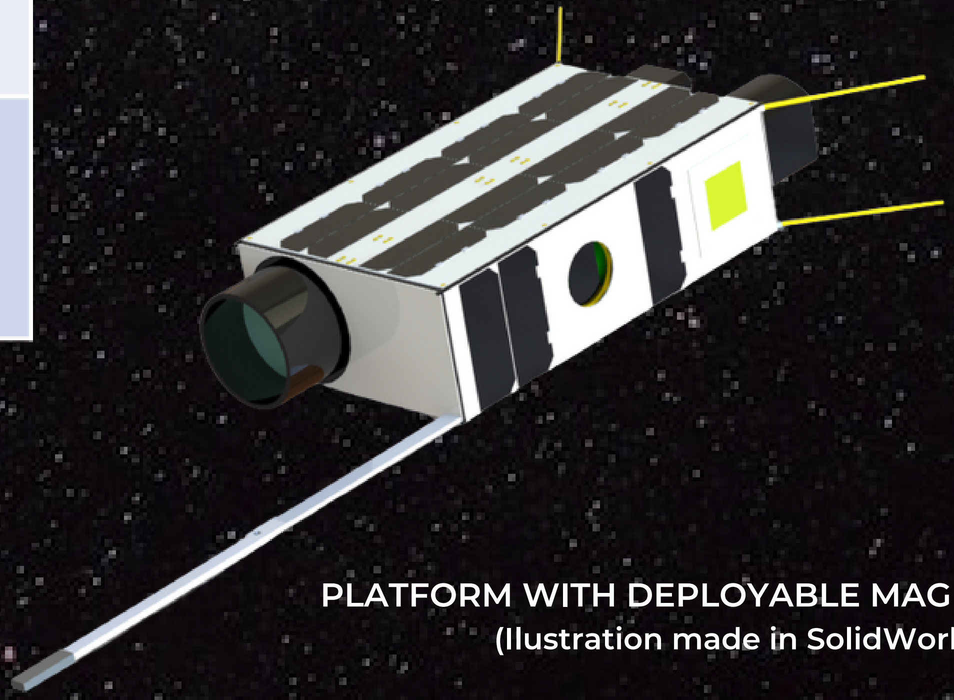
# Payload Subsystem



| | INMS | Requirements |
|---|---|---|
| Volume | 13.5cm x 9cm x 9cm | Within available payload space |
| Power | 1.8W (Ions+Neutrals), 1.3W (ions only) | - |
| Mass | 600 gr | Within CubeSat standards for 6U |
| Data (Raw data, no compression) | 1.3kbps (1s sampling) | - |
| Electrical Interface | ±5V, +3.3V, +12v, LVDS and SPI serial communication | - |

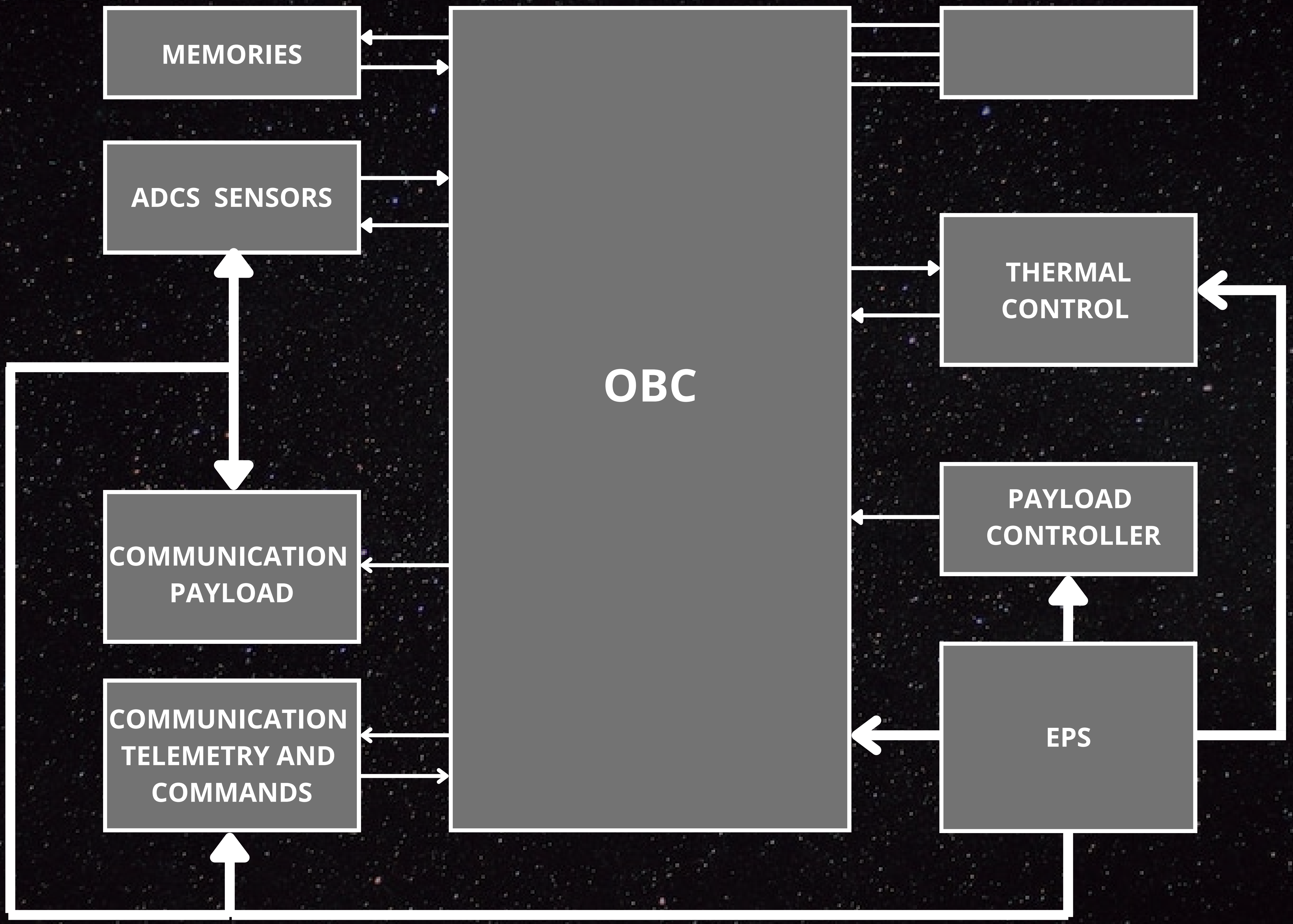
CHAMELEON IMAGER
(by Dragonfly aerospace)

| | Optical Sensor | Requirements |
|---|---|---|
| Spatial Resolution | 10 m | 10 m |
| Swath at 500 km | 40 km | 40 km |
| Mass | 1.6 Kg | Within CubeSat standards for 6U |
| Physical size | 2U | Within available payload space |

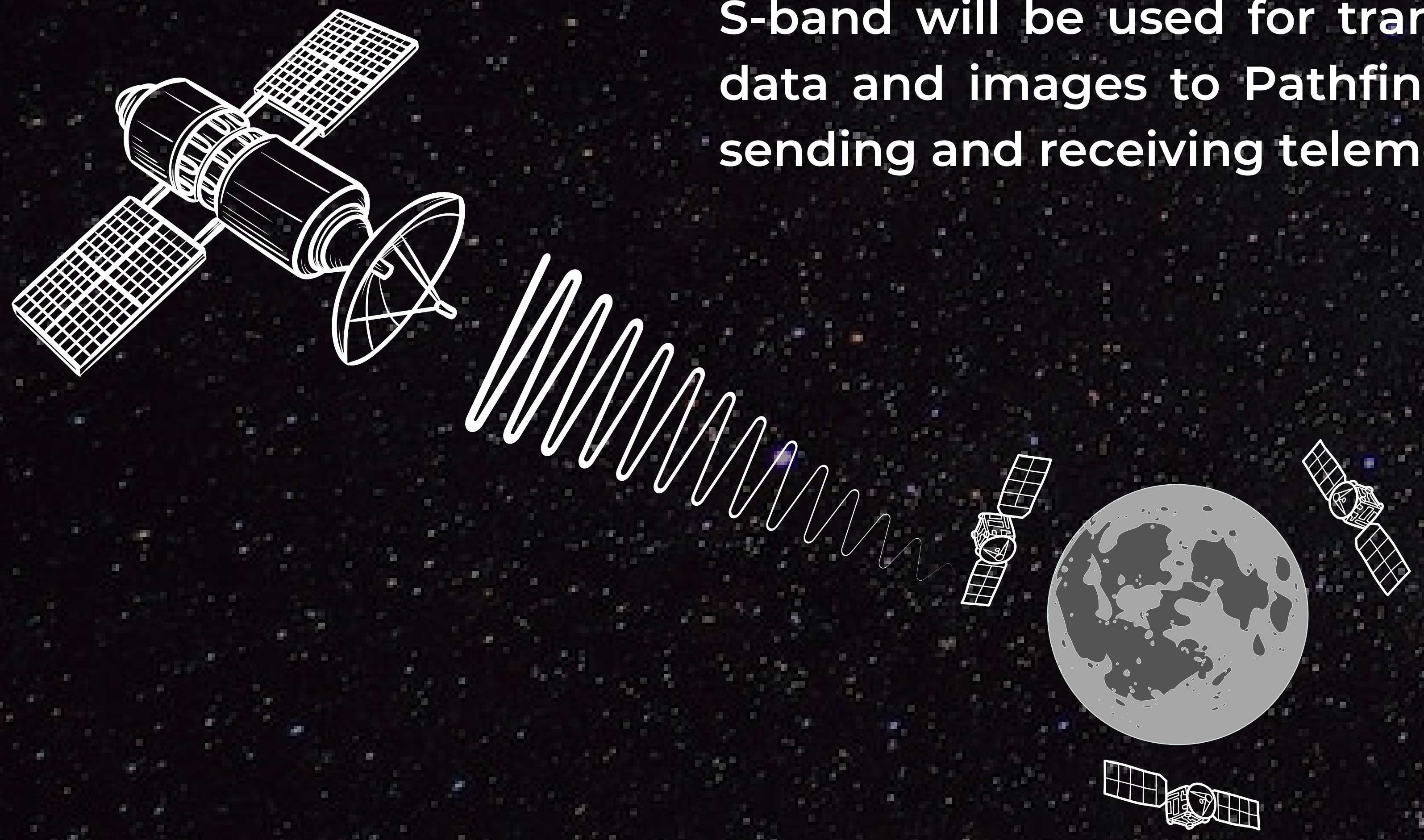


PLATFORM WITH DEPLOYABLE MAGNETOMETER
(Ilustration made in SolidWorks)

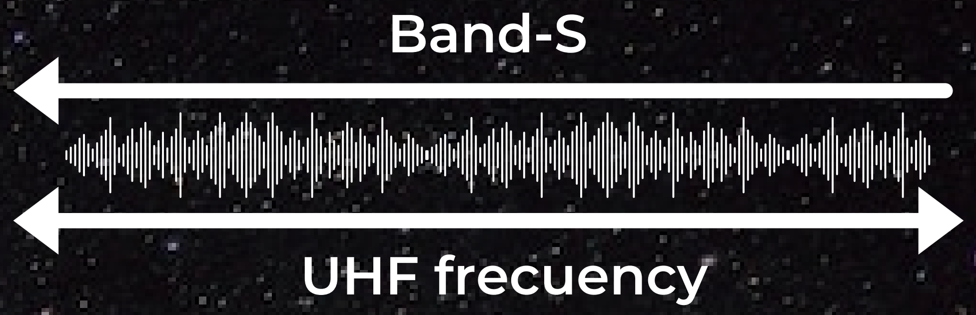
With a range sensitivity of 6nT to 313 nT and resolution of at least 8 nT we will be able to measure the magnitude and variations of the remaining magnetic field


MEMORIES
ADCS SENSORS
OBC
THERMAL CONTROL
COMMUNICATION PAYLOAD
PAYLOAD CONTROLLER
COMMUNICATION TELEMETRY AND COMMANDS
EPS

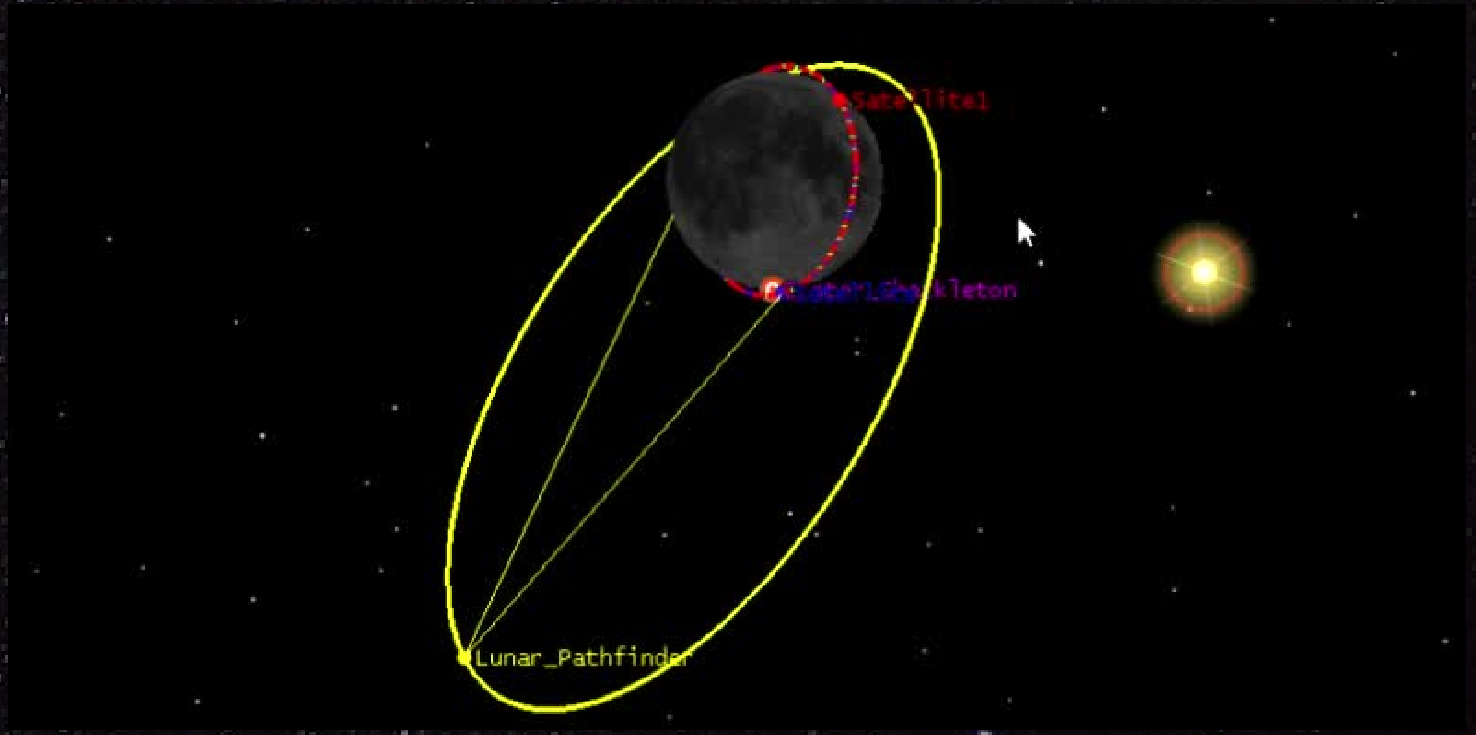
# Communication Subsystem



S-band will be used for transmitting constellation data and images to Pathfinder and UHF band for sending and receiving telemetry

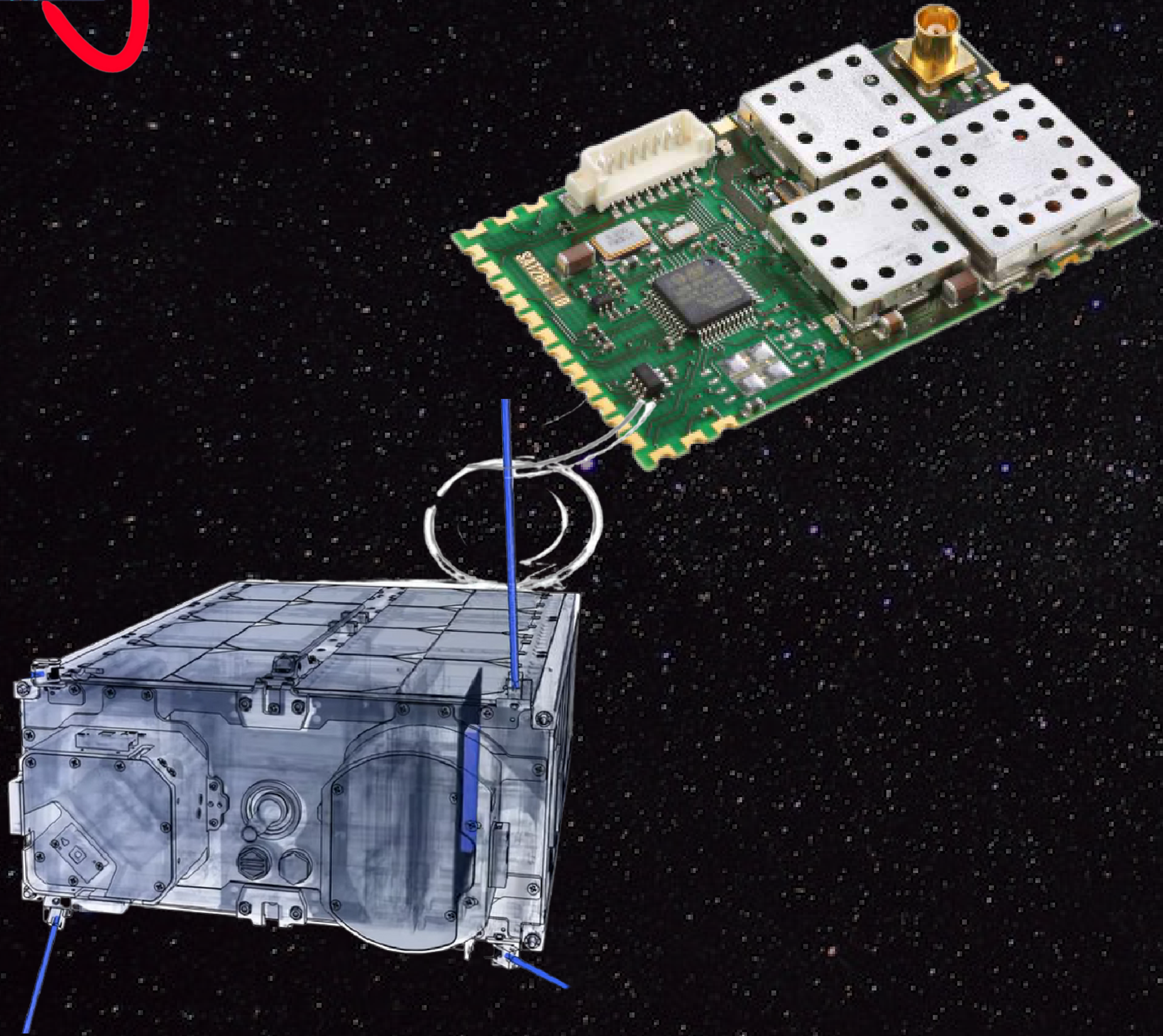



The visibility window with Pathfinder for the Downlink/Uplink connection is about 90-150 minutes per day.




Data transmission is achieved in less than 1 minute (according to the number of data to be sent).

# Command, Control and Telemetry



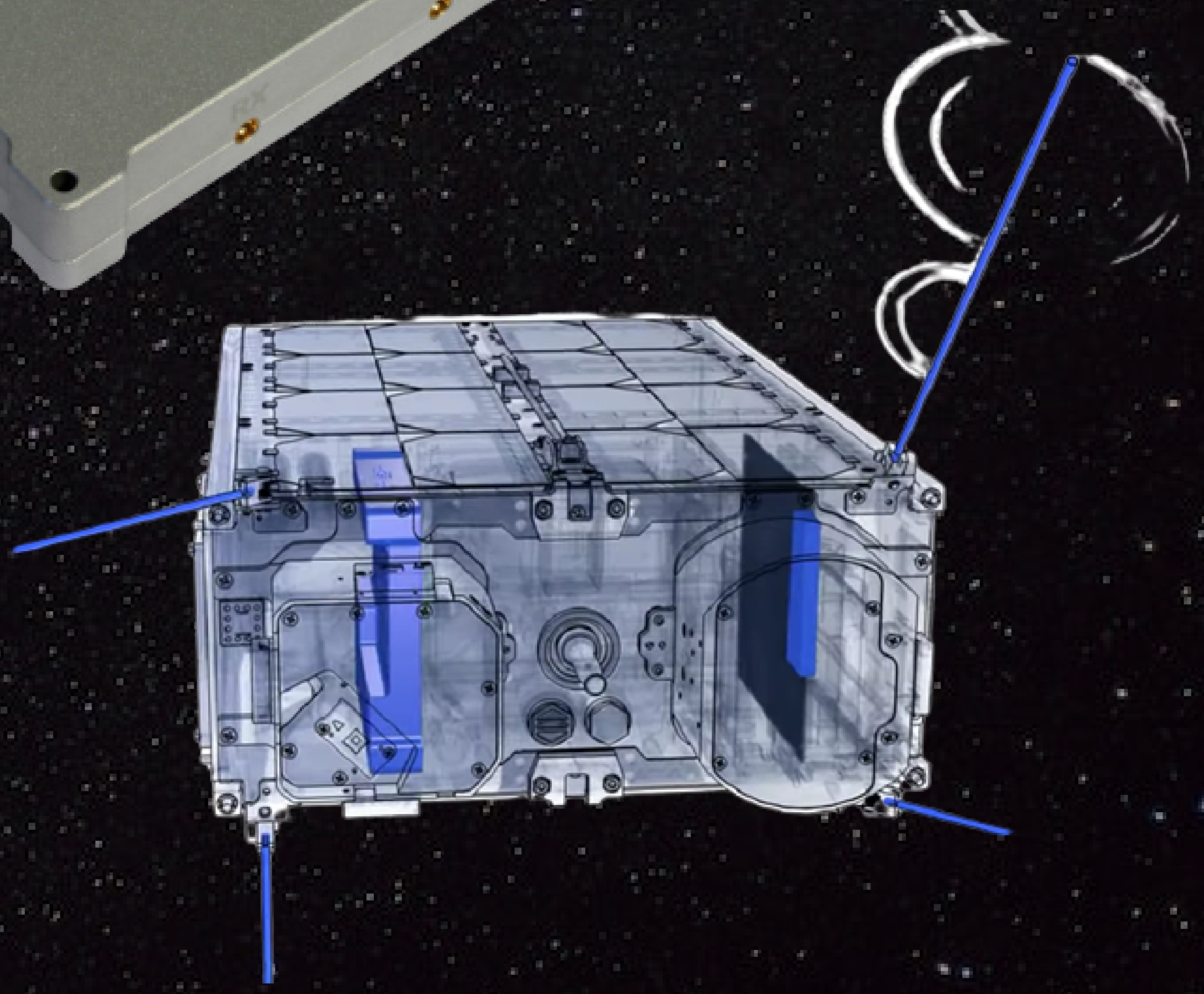
## KEY PARAMETERS

- RF Architecture: half duplex
- Frequency range: 395-440 MHz
- RF output power: up to 3 W
- Modulation: GFSK2 (MSK)
- Symbol rate: 2400 / 4800 / 9600
- Bit rate: 2400 / 4800 / 9600
- Typical sensitivity: -122 dBm (GFSK2, 2400 bps)
- Bit encoding: data whitening PN9 sequence
- CAN electrical interface (Satellite module)
- UART interface (Ground module)
- Power amplifier and oscillator temperature telemetry
- 3 V single power supply

# Payload communication

## KEY PARAMETERS

| | |
|---|---|
| Transmitter frequency | 2200 to 2290 MHz |
| Transmitter modulation | BPSK/QPSK/8PSK, 100 kBd to 5 MBd |
| Transmitter power | 20 to 33 dBm |
| Receiver frequency | 2025 to 2110 MHz |
| Receiver modulation | BPSK/QPSK, 100 kBd to 5 MBd |
| Receiver sensitivity | -122 dBm(<1% PER, 100 kBd BPSK) |
| Input voltage | 5.1 to 28.8 V |
| Typical power consumption (6 V input, 20℃) | RX: 1.5 W (5 MBd)<br>RX+TX: 10.8 W (5 MBd, 33 dBm output) |
| Operating temperature | RX: -40℃ to +85℃<br>TX: -40℃ to +70℃ |
| Dimensions | 93.0 mm × 87.2 mm × 17.5 mm |
| Mass | 253 g |

# Electrical power subsystem

| Subsystem | ADCS | Payload | Communication | Thermal | C&DH |
|---|---|---|---|---|---|
| Power (W) | 5 | 14 | 12 | 20 | 10 |

Based on 8 rechargeable lithium-ion batteries (7.4 V, 13600 mAh, 92 Wh)

Triple-junction solar panels with epitaxial structure (30% efficiency).

According to the benefits offered by the M6P platform with respect to batteries and with the analysis of the energy consumption of the components with the help of its data sheet provided by the manufacturer, it was deduced that the power system would supply the satellite in its operating time. life.

According to the analysis of the orbit and with the help of the System Tool Kit software, the times in which the constellation will have light times for energy collection were known.

## Sunlight Times

| | Start Time (UTCG) | Stop Time (UTCG) | Duration (min) |
|---|---|---|---|
| Min Duration | 25 Mar 2024 06:29:28.533 | 25 Mar 2024 06:58:16.582 | 28.801 |
| Max Duration | 2 Apr 2024 13:38:34.219 | 7 May 2024 07:03:56.369 | 50005.369 |
| Mean Duration | | | 99.317 |
| Total Duration | | | 214127.640 |

## Penumbra Times

| | Start Time (UTCG) | Stop Time (UTCG) | Duration (min) |
|---|---|---|---|
| Min Duration | 16 Jul 2024 02:33:45.942 | 16 Jul 2024 02:33:56.224 | 0.171 |
| Max Duration | 25 Mar 2024 05:33:29.927 | 25 Mar 2024 06:29:28.533 | 55.977 |
| Mean Duration | | | 0.324 |
| Total Duration | | | 1395.881 |

## Umbra Times

| | Start Time (UTCG) | Stop Time (UTCG) | Duration (min) |
|---|---|---|---|
| Min Duration | 2 Apr 2024 01:49:12.695 | 2 Apr 2024 01:51:17.399 | 2.078 |
| Max Duration | 14 Jul 2024 14:26:38.736 | 14 Jul 2024 15:12:57.344 | 46.310 |
| Mean Duration | | | 41.212 |
| Total Duration | | | 88316.479 |

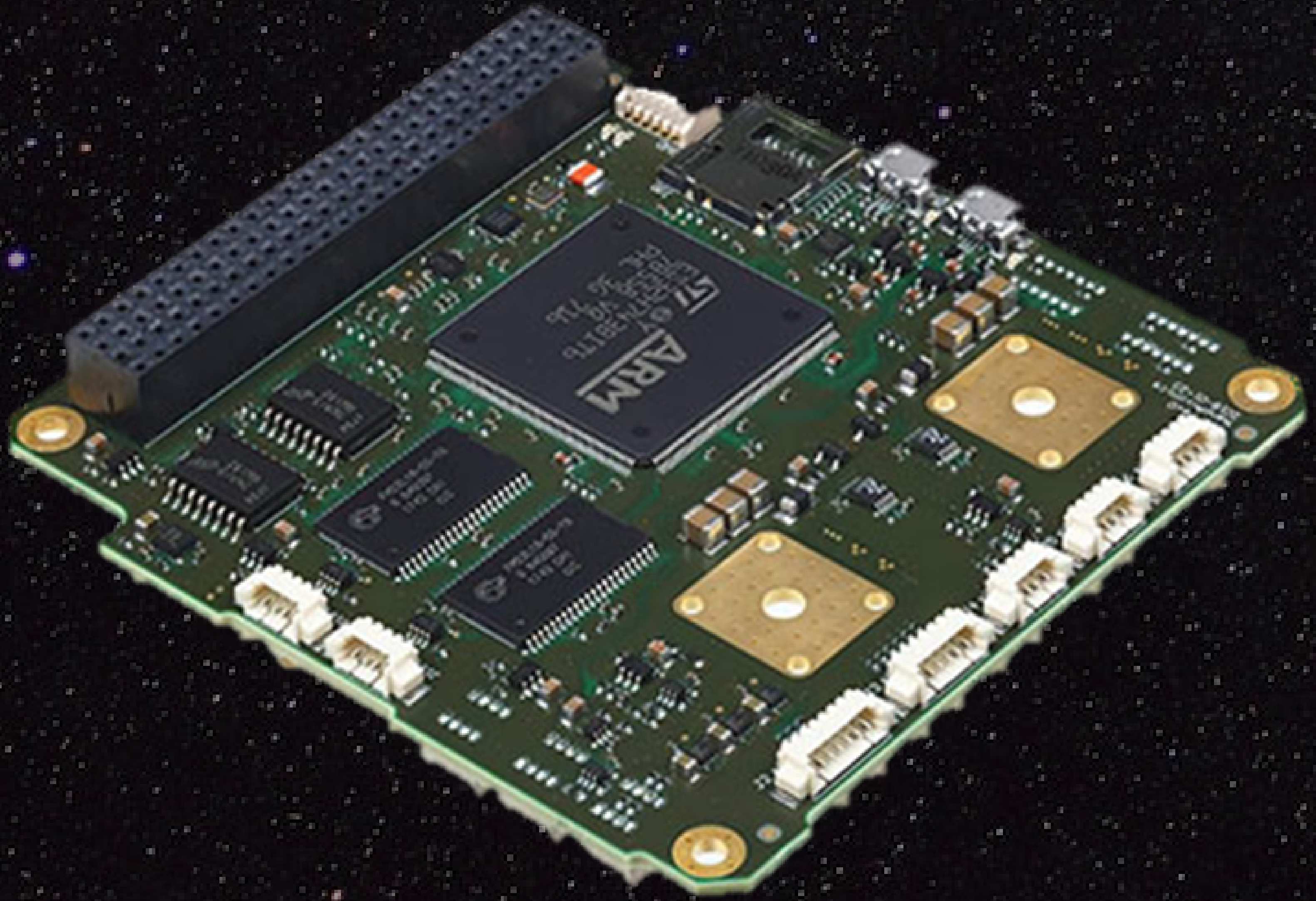
# THERMAL CONTROL SUBSYTEM

Based on the payload data sheet, the minimum operational temperature is approximately - 30 ° C and the maximum of 400 ° C.

The platform manufacturer will guarantee the payload required operational temperature despite the space environment temperature, which ranges from -213.15 ° C to 16.85 ° C depending on the characteristic of the orbit at 100 km

# Command and Data Handling (C&DH)

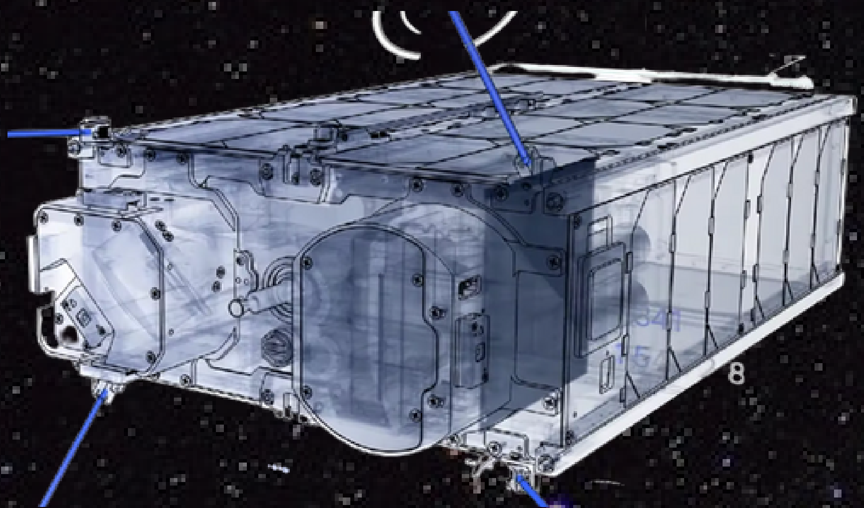
Consists of a SatBus 3C2 single board computer, the architecture of this board is based on a STM32 H7 series microcontroller with high performance and low power consumption ARM Cortex™ M7 core MCU, operating at a frequency of up to 400 MHz



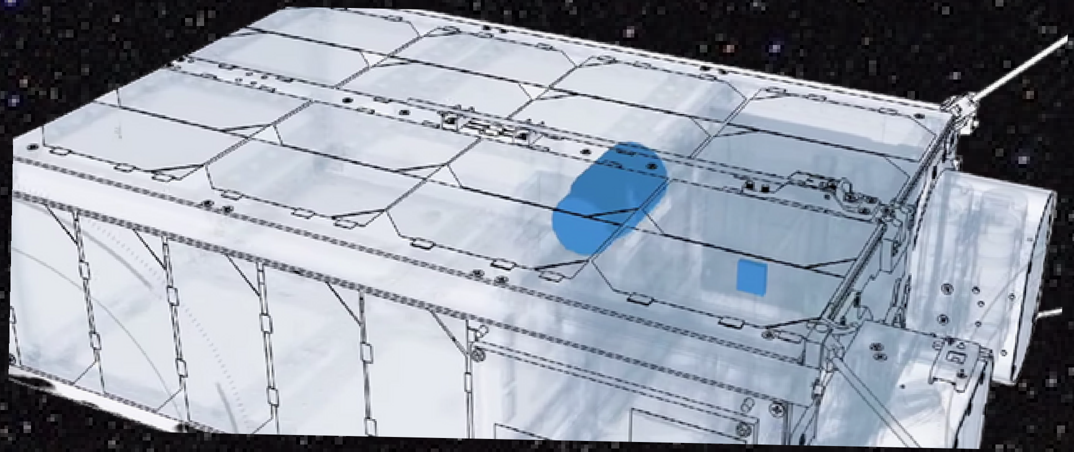

SatBus 3C2

# Attitude Determination and Control Subystem (ADCS)

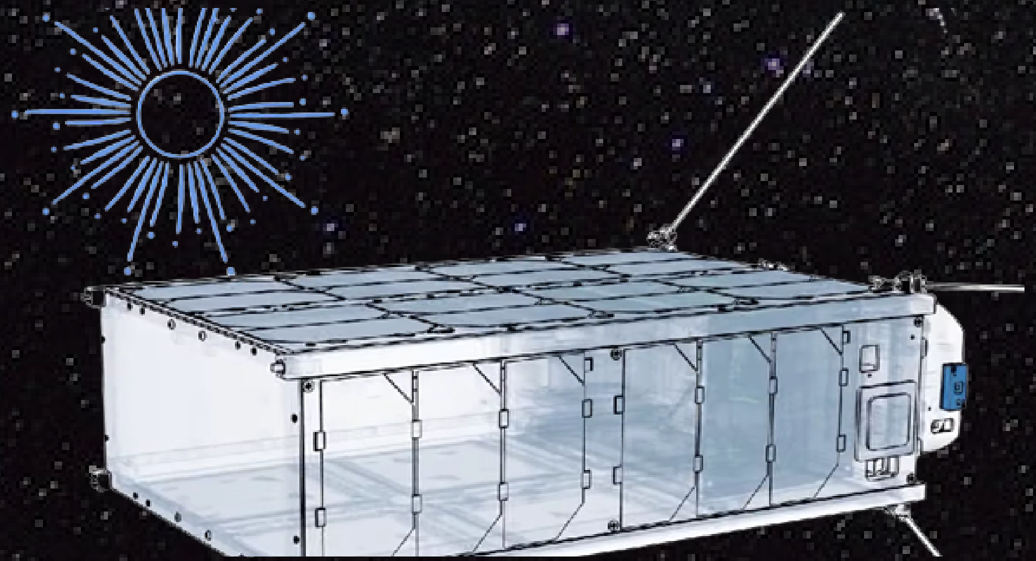
ADCS sensors and actuators:



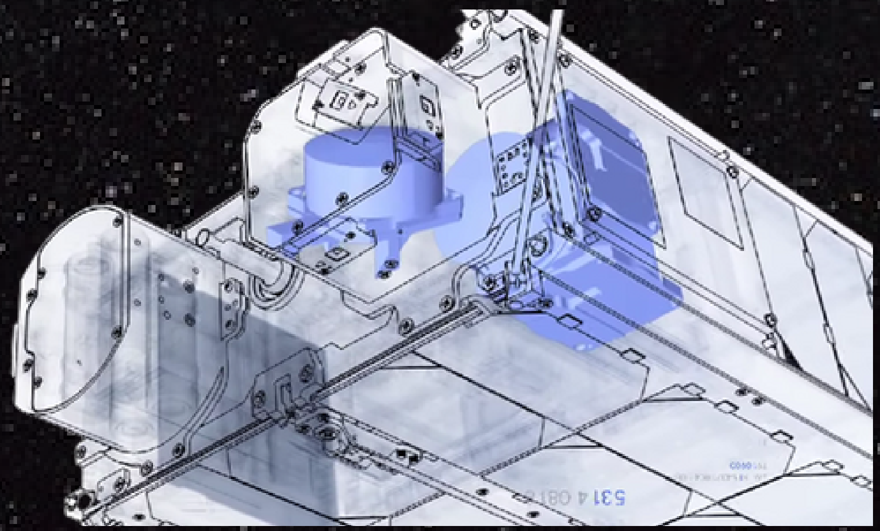
Propulsion system



Start tracker

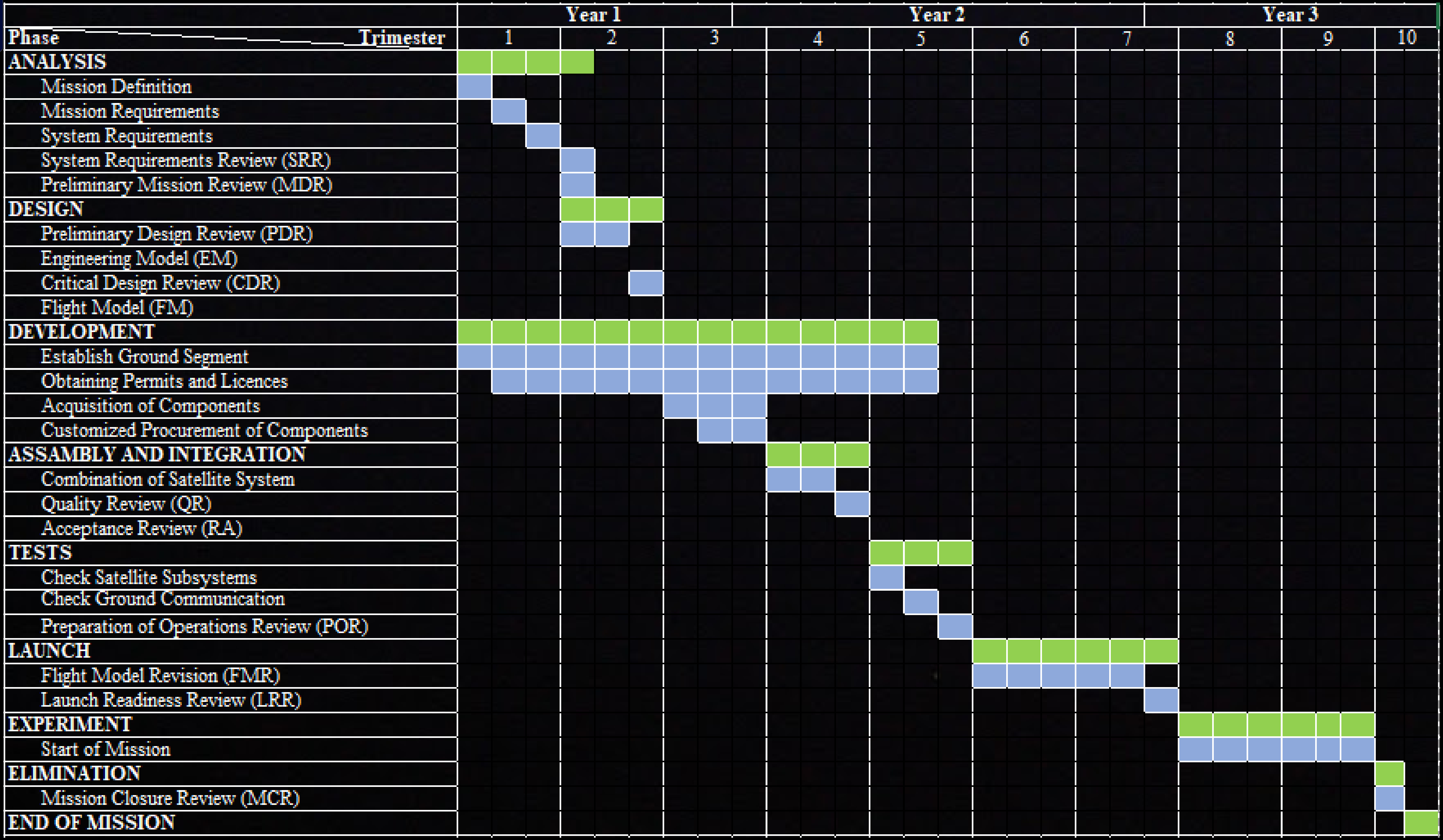


Sun sensor



Reaction wheels

# IMPLEMENTATION PLAN



# Risks that may affect the mission

1. Launch delay of the Lunar Pathfinder, since being the one who would provide us with the communications service.

2. Failure of the deploy of the solar arrays

3. Communication failure between the Lunar Pathfinder and the constellation of CubeSats or ground segment.

4. Delay of licenses for launch

5. Failure of the deploy of the magnetometer

| | | IMPACT | | | | |
|---|---|---|---|---|---|---|
| | | Negligible 1 | Minor 2 | Moderate 3 | Significant 4 | Severe 5 |
| LIKELIHOOD | Very likely 5 | Medium 5 | High 10 | Very high 15 | Extreme 20 | Extreme 25 |
| | Likely 4 | Medium 4 | Medium 8 | High 12 | Very high 16 2 | Extreme 20 1 |
| | Possible 3 | Low 3 | Medium 6 | Medium 9 5 | High 12 | Very high 15 3 |
| | Unlikely 2 | Very low 2 | Low 4 | Medium 6 | Medium 8 4 | High 10 |
| | Very unlikely 1 | Very low 1 | Very low 2 | Low 3 | Medium 4 | Medium 5 |

# THANK YOU!!