Mars Aerosol Tracker (MAT): An areostationary CubeSat to monitor Martian dust and water ice dynamics

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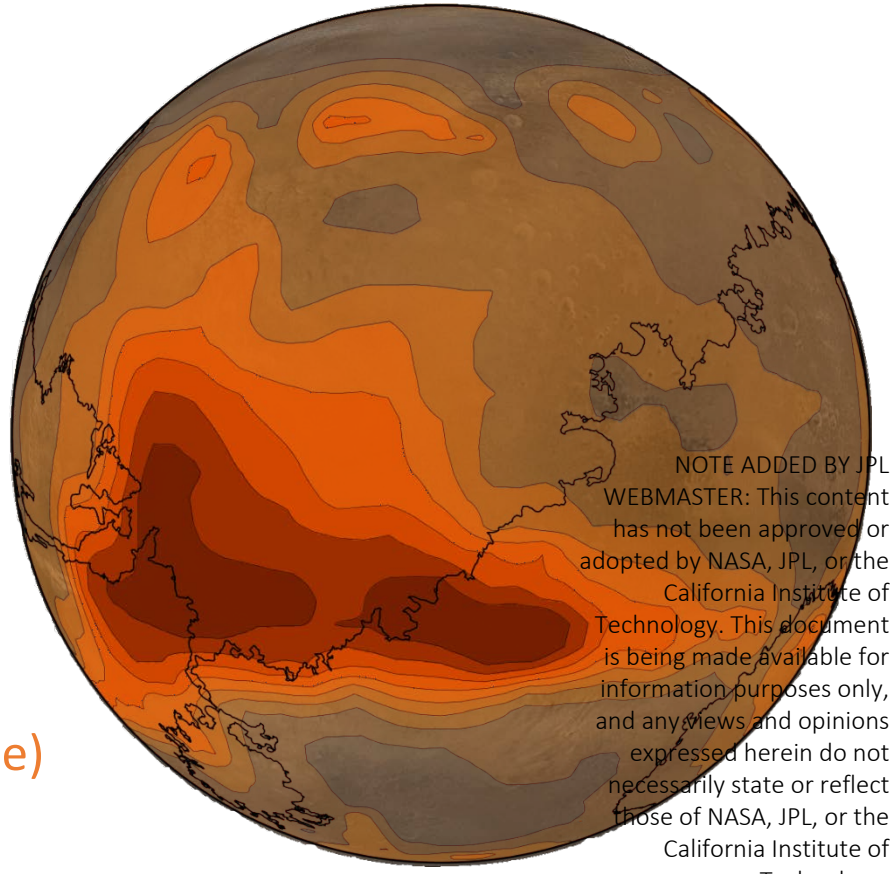

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Preliminary Mission Concept – For Discussion Only

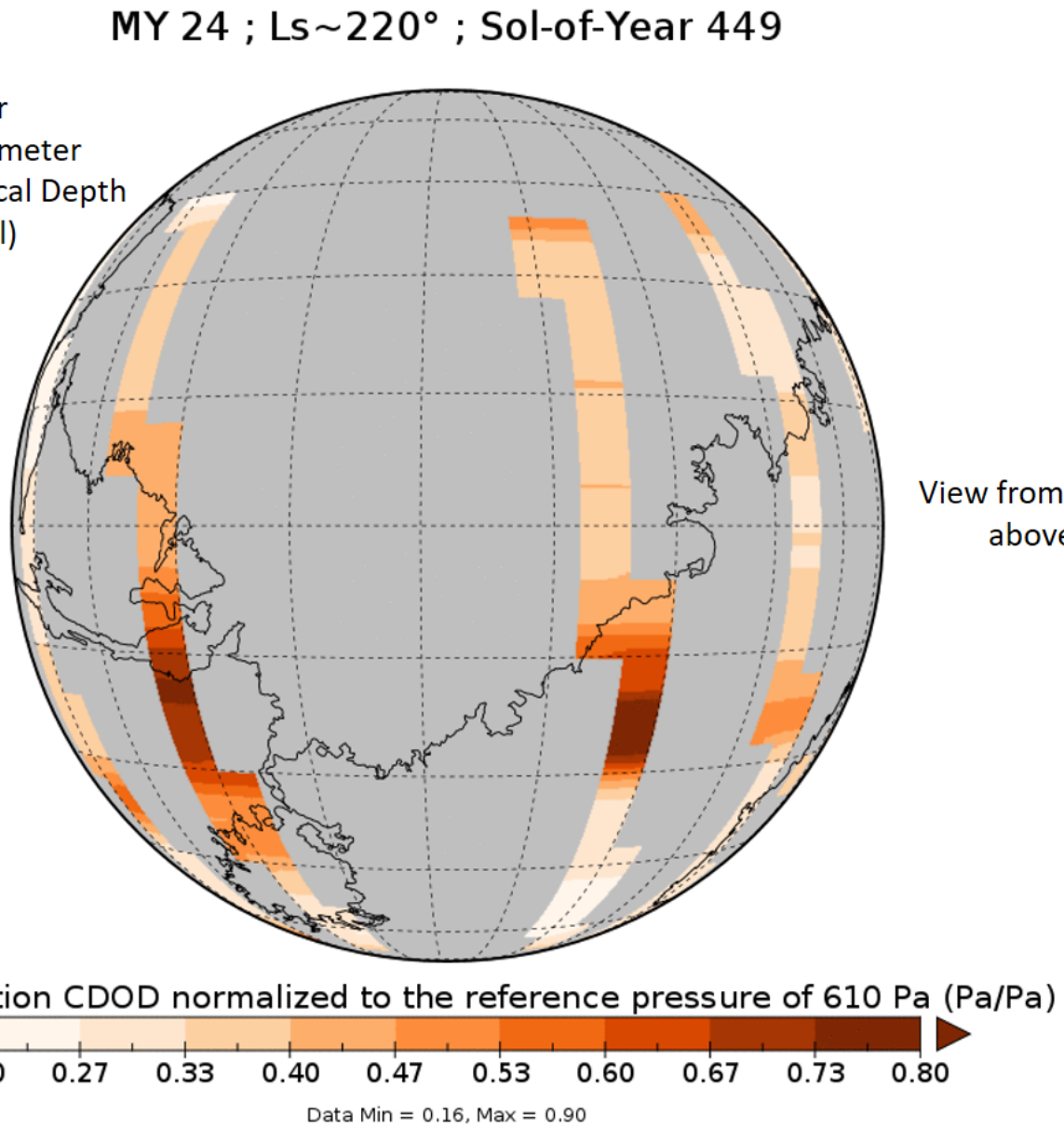
The case for MAT

- Dust and water ice aerosols affect the "weather":
  - → They are both radiatively active.
- There is need for continuous and synoptic aerosol monitoring:
  - → To understand the interaction between aerosols and circulation;
  - → To enable weather forecasting (e.g. evolution of dust storms);
  - → To support robotic AND future human exploration.
- A Mars-stationary (areostationary) orbit is ideal:
  - → To continuously/synoptically monitor the aerosol evolution;
  - → To monitor changes in surface properties (e.g. albedo);
  - → To observe a large, fixed region (~80° away from nadir);
  - → To monitor throughout the daily and seasonal cycles;
  - → To provide high sampling rate (up to ½ hour).

A regional dust storm from polar orbit

Mars Global Surveyor
Thermal Emission Spectrometer
Gridded IR Column Dust Optical Depth
(only data within 1 sol)

Data from:
Montabone et al., Icarus, 2015



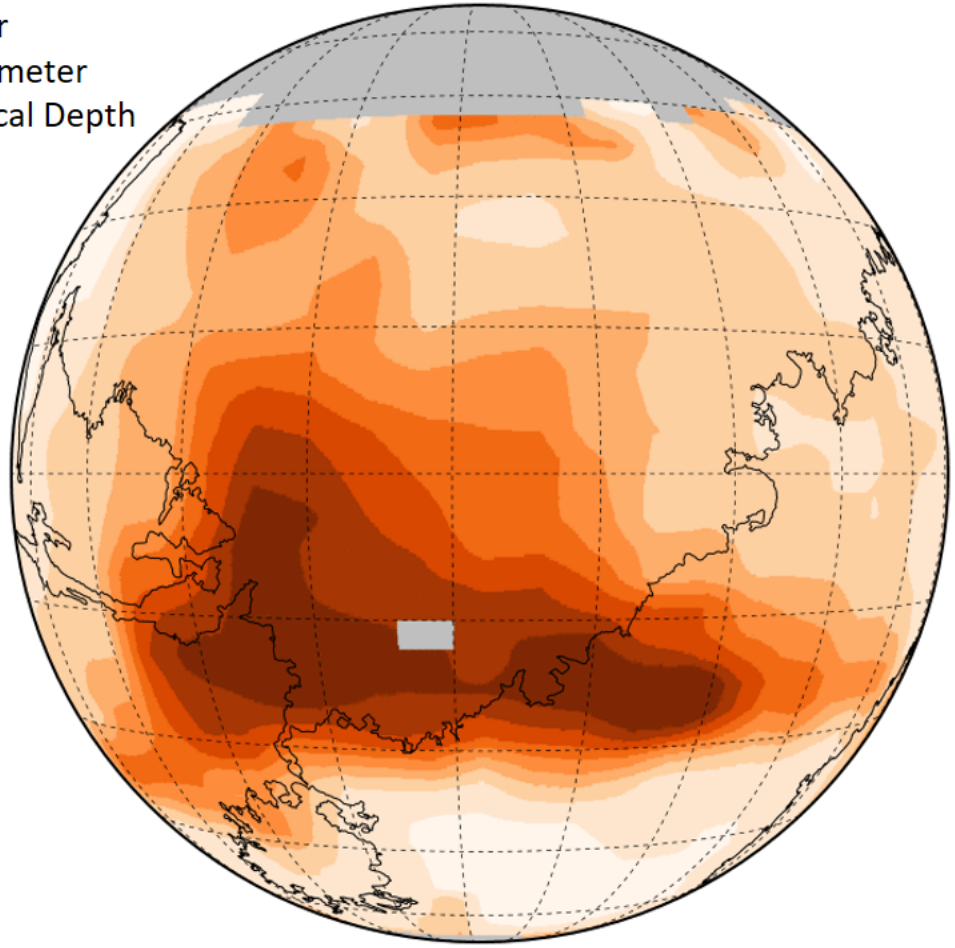
View from about 17,000 km
above the equator

A regional dust storm from areostationary orbit

MY 24 ; Ls~220° ; Sol-of-Year 449

Mars Global Surveyor
Thermal Emission Spectrometer
Gridded IR Column Dust Optical Depth
(data within 7 sol)

Data from:
Montabone et al., Icarus, 2015



View from about 17,000 km
above the equator

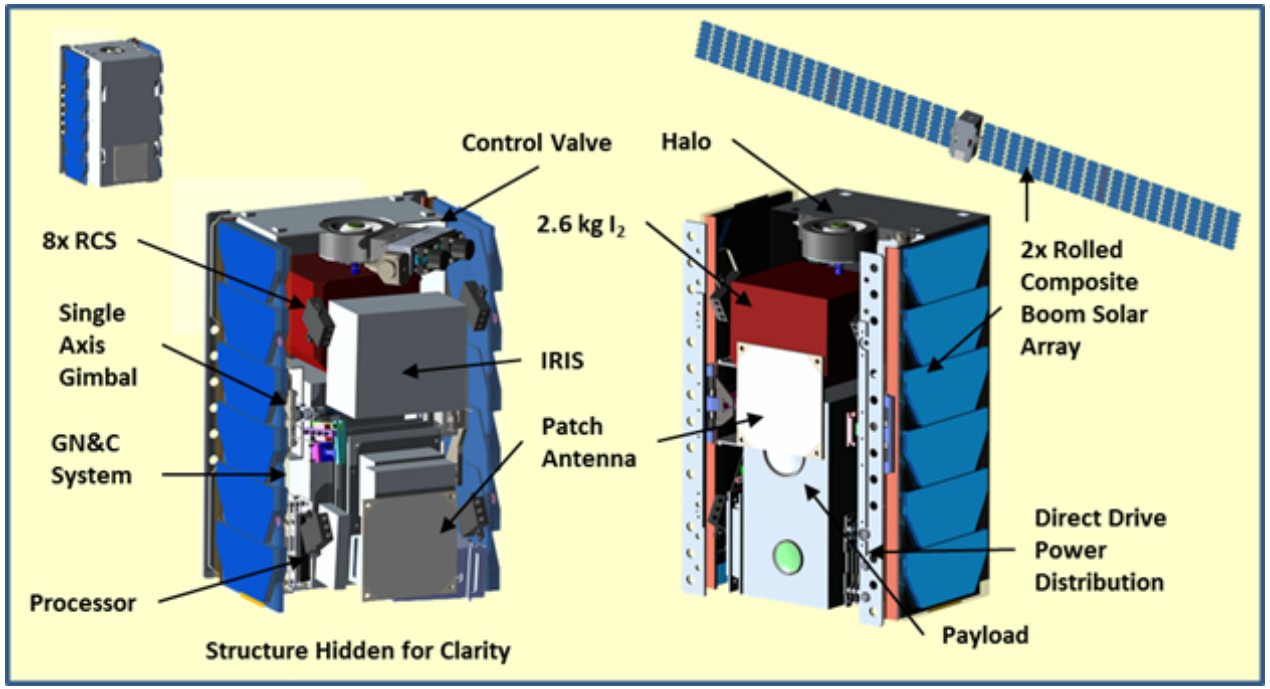
IR absorption CDOD normalized to the reference pressure of 610 Pa (Pa/Pa)

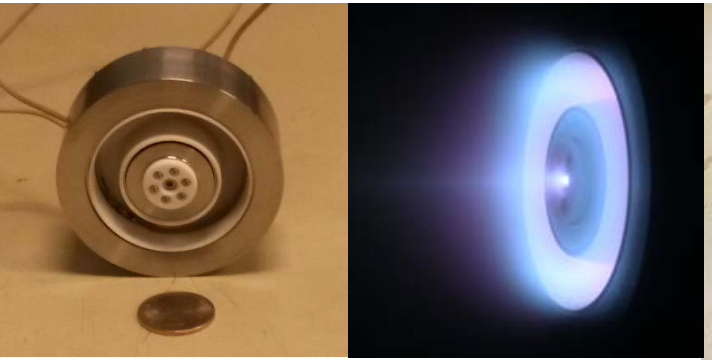
Why flying a CubeSat as an areostationary satellite?

- General reasons:
  - → A CubeSat is reasonably cheap;
  - → It can be built reasonably quickly;
  - → It enables a focused scientific mission;
  - → It allows to take more risks;
  - → There are more opportunities to launch…?
- Specific reasons:
  - → To pave the way for areostationary satellites at Mars;
  - → To possibly enable flying multiple ones for complete coverage;
  - → To demonstrate the potential of synoptic weather monitoring;
  - → To collect specific data to address the scientific questions:

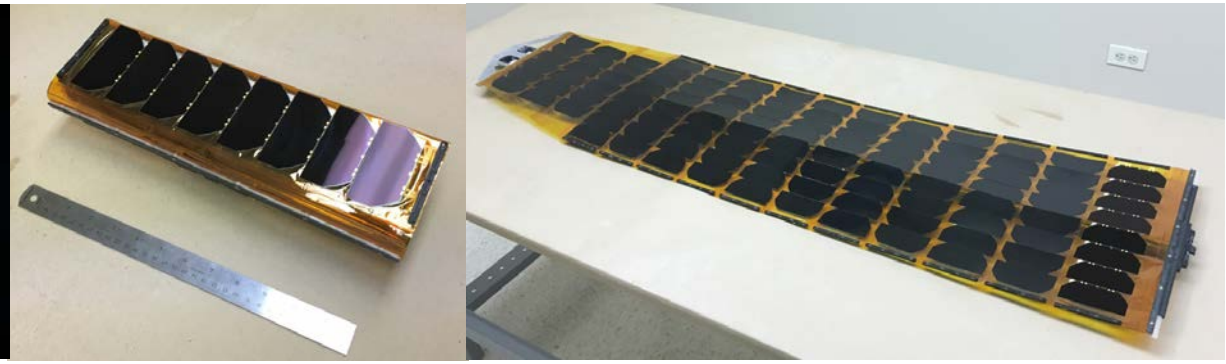
What are the processes controlling the dynamics of dust and water ice clouds, and promoting the evolution of regional dust storms into planet-encircling storms?

The 12U CubeSat (24 kg) with electric propulsion



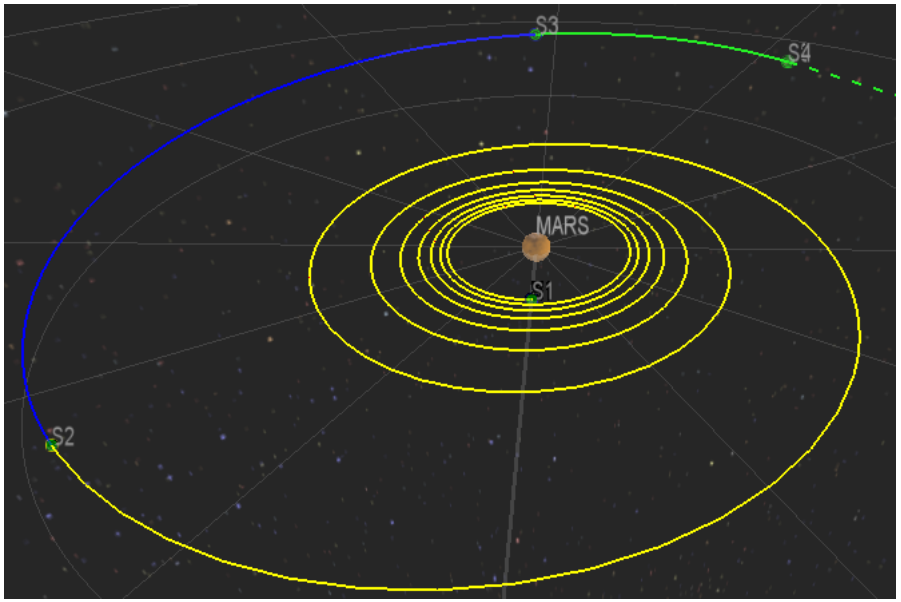


"Halo" 3rd Generation Prototype
150 W, 5-10 mN, Isp 1100-1600 s



Solar Array Deployment (Left: rolled; Right deployed)
160 W/kg, 186 W at Mars at "End of Life"

Baseline Mission Design



- **Journey to Mars**: Rideshare on a primary Mars orbiter mission, deployment at ~310,000 km after initial capture burn.
- **Trajectory**: Thrusters operated for 27 days to spiral down to ~20,000 km
- **Orbit**: Equatorial, circular, planet-synchronous (areostationary) with sub-spacecraft location fixed at one of the two stable longitudes.
- **Total ΔV**: 1.22 km/s (0.2 km/s reserved for orbit maintenance and lifetime operations, 0.3 km/s margin).
- **Duration**: 1 Martian year (primary mission) + possible extension

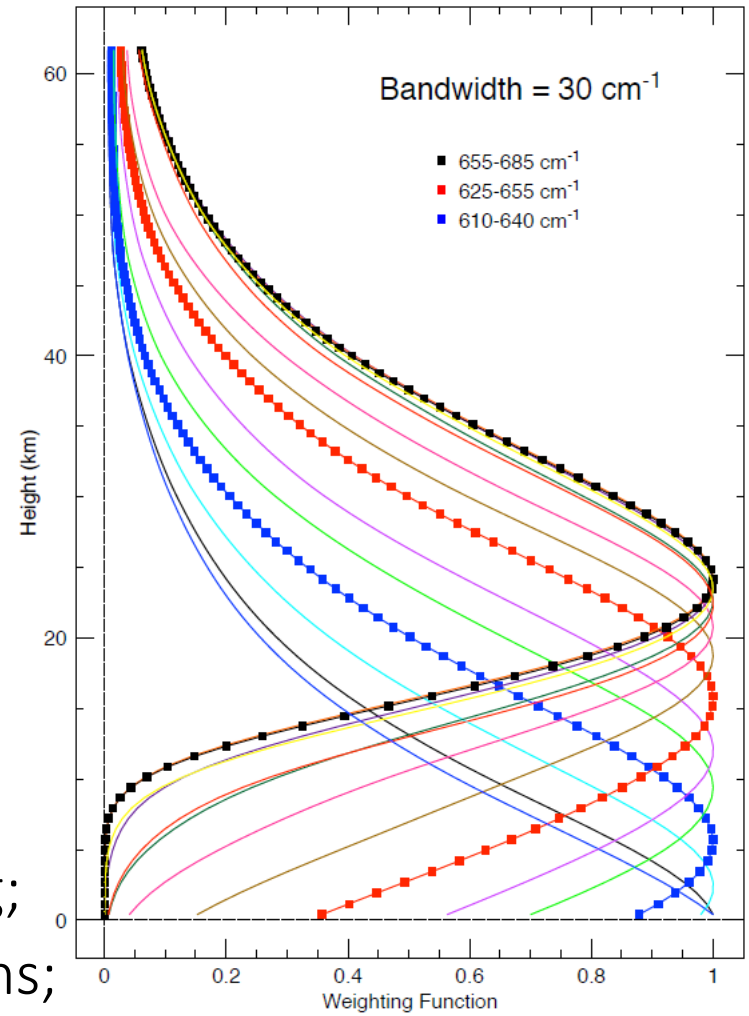
Planned payload

- **Visible camera**: Off-the-shelf camera (ECAM-C30 from MSSS):
  - → Fixed-focus, narrow-angle lens;
  - → 2048 x 1536 pixels;
  - → 29° x 22° FOV (full disk and limb).

- **Thermal infrared camera**: ECAM-IR3A from MSSS:
  - → Fixed-focus, narrow-angle lens;
  - → Filter wheel for selecting multiple spectral ranges;
  - → 640 x 480 pixels;
  - → Same field of view as visible camera;
  - → Detector responsive out to 20 µm.

Planned products

- **Images**: High sampling rate (up to ½h).
- **Retrievals**: Temperature and aerosols (dust, water ice) optical depth up to ~60° from nadir :
  - → 2D maps of τ_{dust} and τ_{ice} ;
  - → 3D maps of T ;
  - → Maps and images are co-located and simultaneous.
- **Note on T retrievals**: 3 independent points, sensitivity up to 45-50 km.
- **Data downlink**: It may require:
  - → On-board storage/pre-processing;
  - → Design of observational campaigns;
  - → Automatic event detection.
- **Data distribution**: Public access.



Weighting functions for several spectral ranges on one side of the CO_2 15 µm absorption band.

Anticipated key challenges for this concept
(minor to major)

- **Data pre-processing**: To develop advanced dust event detection techniques based on neural and/or citizen scientist networks;
- **Pointing accuracy**: To quickly dissipate possible disturbances from moving parts and/or solar array vibrations;
- **Heat dissipation**: To keep all the packed components cool;
- **Radiation**: To have highly radiation-proof components and extend the CubeSat lifetime;
- **Communication**: To develop autonomous high-rate communication, e.g. using JPL KaPDA high gain antenna;
- **Propulsion**: To increase the number of mission opportunities, e.g. to perform orbit capture after release from ballistic trajectory;
- **Opportunity**: To build, test, and fly the first areostationary satellite!

Summary of the mission concept

Science Objectives	
Monitor:	➢ The onset, evolution and decay of large **dust storms;** ➢ The formation, evolution and dissipation of extended **water ice clouds**; ➢ The changes in surface properties (e.g. **albedo**) over the observed area.
Produce:	➢ High-resolution (up to 4.5 km/pixel), **visible images** during daytime; ➢ 2D maps of **column aerosol optical depth**, all local times; ➢ 3D maps of **atmospheric temperature**, all local times; ➢ High sampling rate (up to ½ h) for extended periods over a large, fixed region of the planet.

Mission Overview

- **Spacecraft**: 12U CubeSat orbiter; 24 kg; Electric propulsion (micro Hall thrusters, solid propellant).
- **Payload**: Visible and thermal infrared fixed-focus cameras (several filters for selecting IR spectral ranges).
- **Journey to Mars**: Rideshare on a primary orbiter mission; deployment after initial capture burn.
- **Orbit**: Areostationary (i.e. equatorial, circular, planet-synchronous orbit) at ~17,000 km above the equator.
- **Duration**: 1 Martian year (primary mission).

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Thanks for your feedback !

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