An Areostationary CubeSat Mission to Monitor the Weather on Mars

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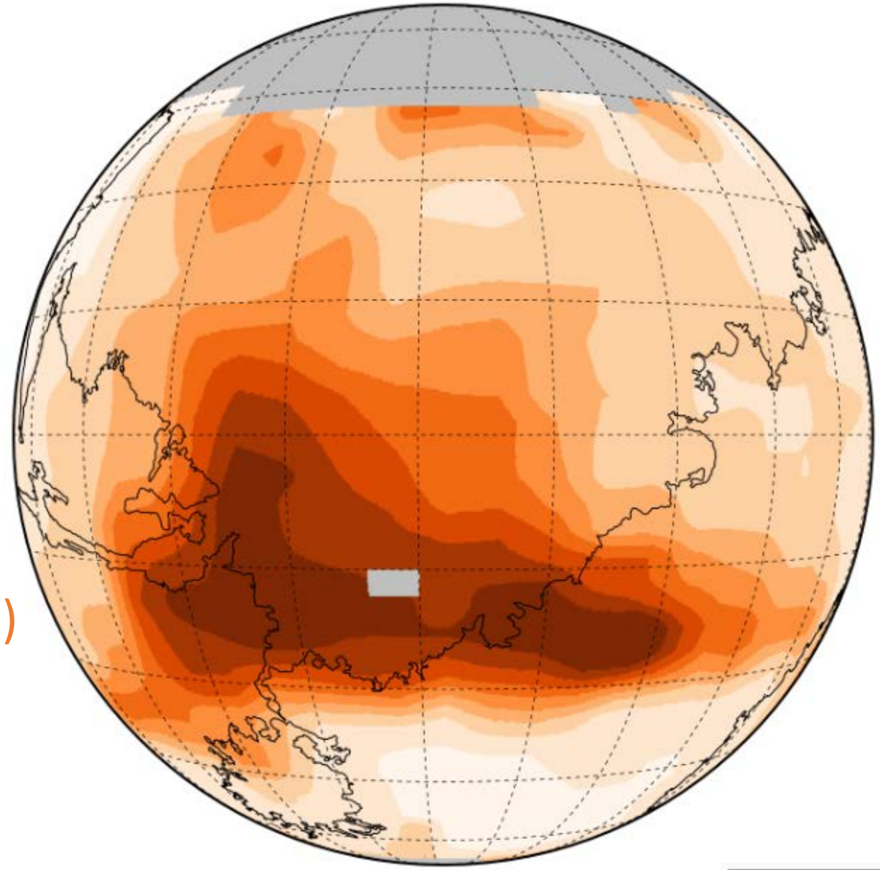

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Preliminary Mission Concept – For Discussion Only

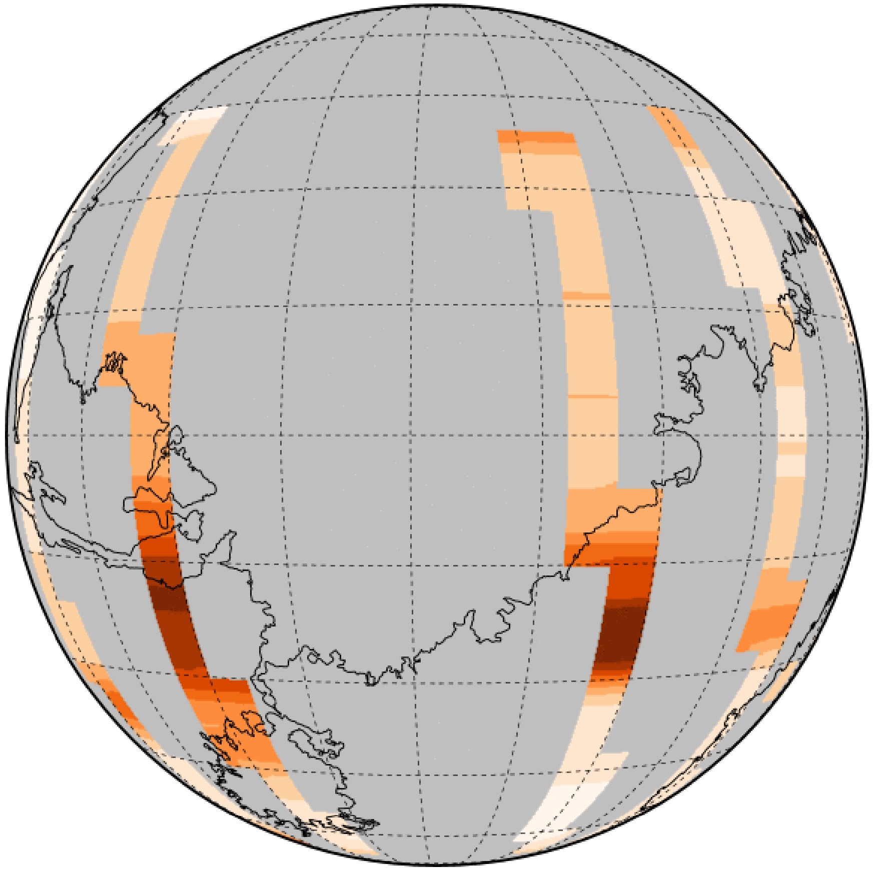
iCubeSat 2017 6th Interplanetary CubeSat Workshop

The case for continuous weather monitoring on Mars

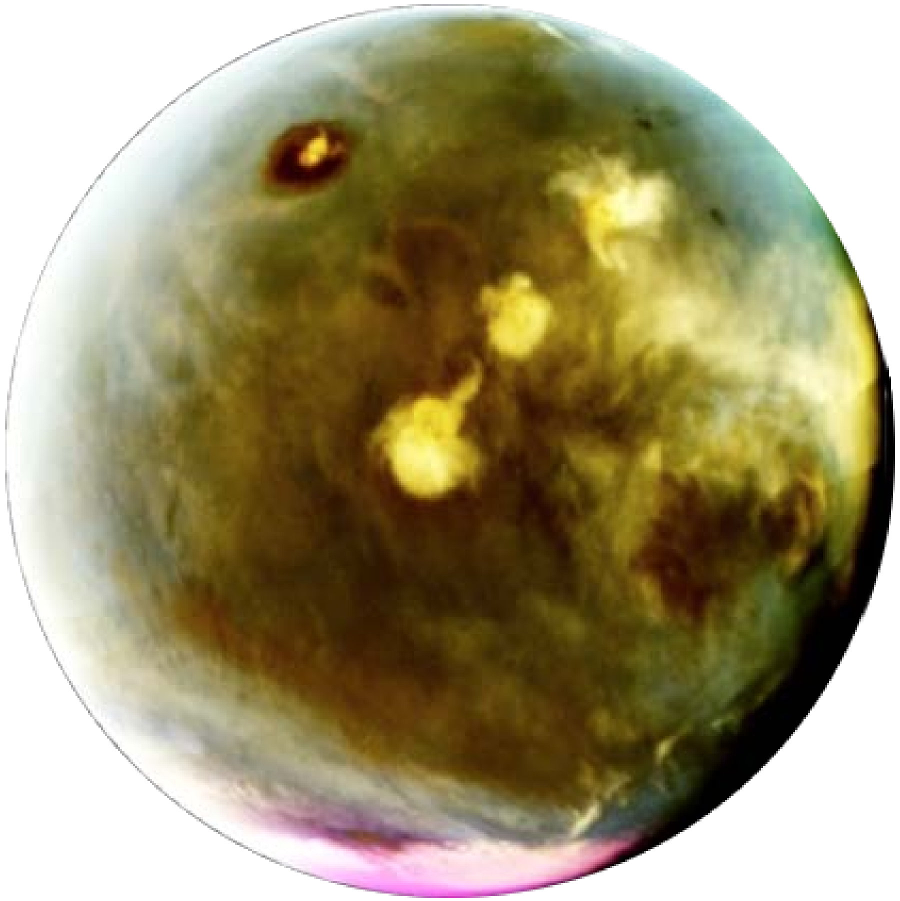
What are the processes controlling the dynamics of the atmospheric circulation and promoting the evolution of regional dust storms into planetary-encircling storms?

- Dust and water ice aerosols affect the "weather".
- Need for continuous and synoptic aerosol monitoring:
  - → To improve weather forecasting (winds, dust storms, etc.);
  - → For robotic AND future human exploration.
- A Mars-stationary (areostationary) orbit is ideal:
  - → To monitor the evolution of the aerosols;
  - → To monitor changes in surface properties (e.g. albedo);
  - → Large fixed region (practically up to 60° away from nadir point);
  - → Daily and seasonal solar cycles;
  - → High sampling rate.

The case for continuous weather monitoring on Mars



NASA Mars Global Surveyor
Thermal Emission Spectrometer
Mars Orbiter Camera
IR Column Dust Optical Depth at 610 Pa
October 16th 1999
October 16th 1999
(Data from Montabone et al., Icarus, 2015)

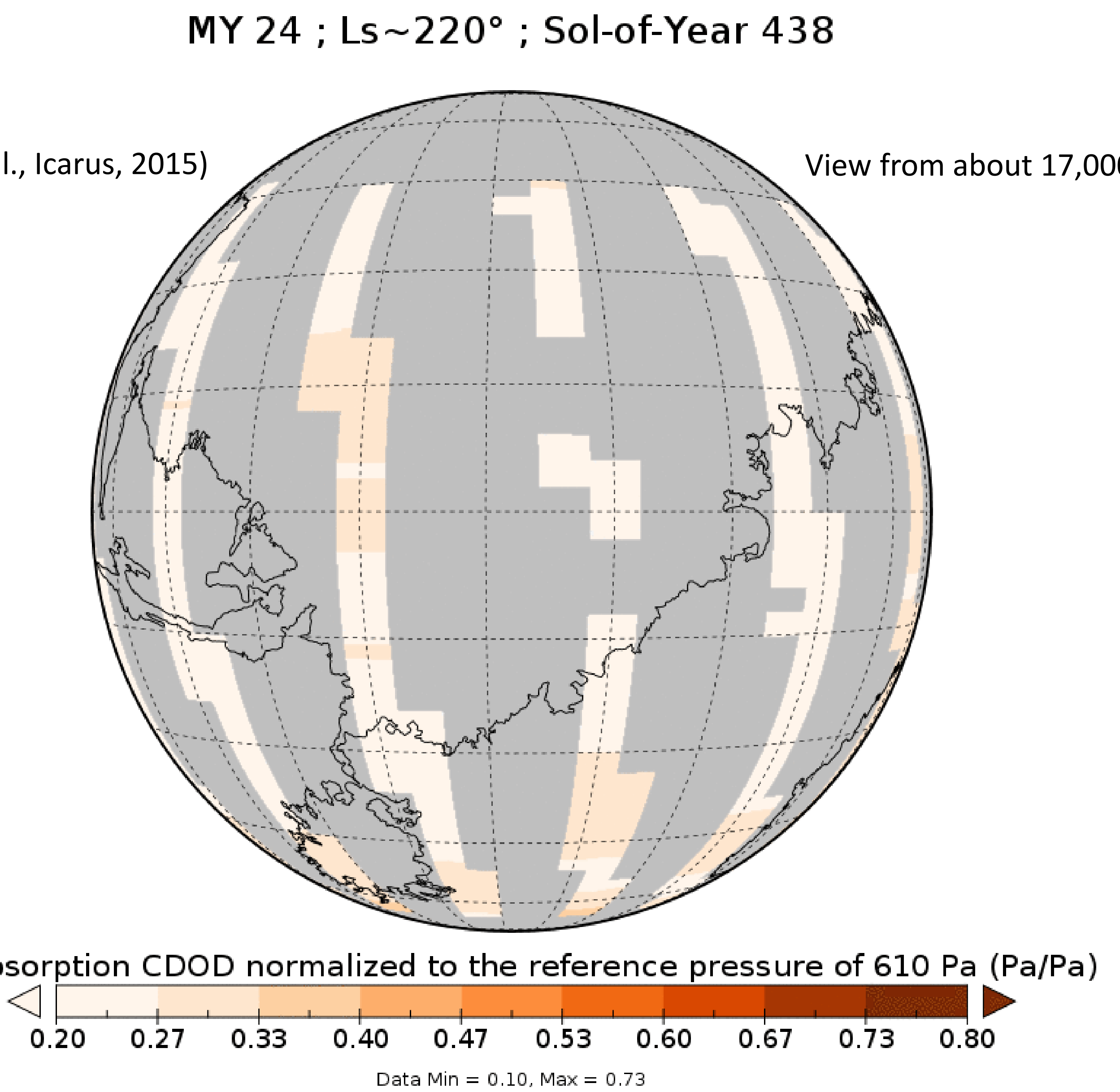


NASA MAVEN
Imaging UltraViolet Spectrograph
July 9th-10th 2016
(Extracted from Schneider et al., 6th MAMO, 2017)

A regional dust storm from polar orbit

(Data from Montabone et al., Icarus, 2015)

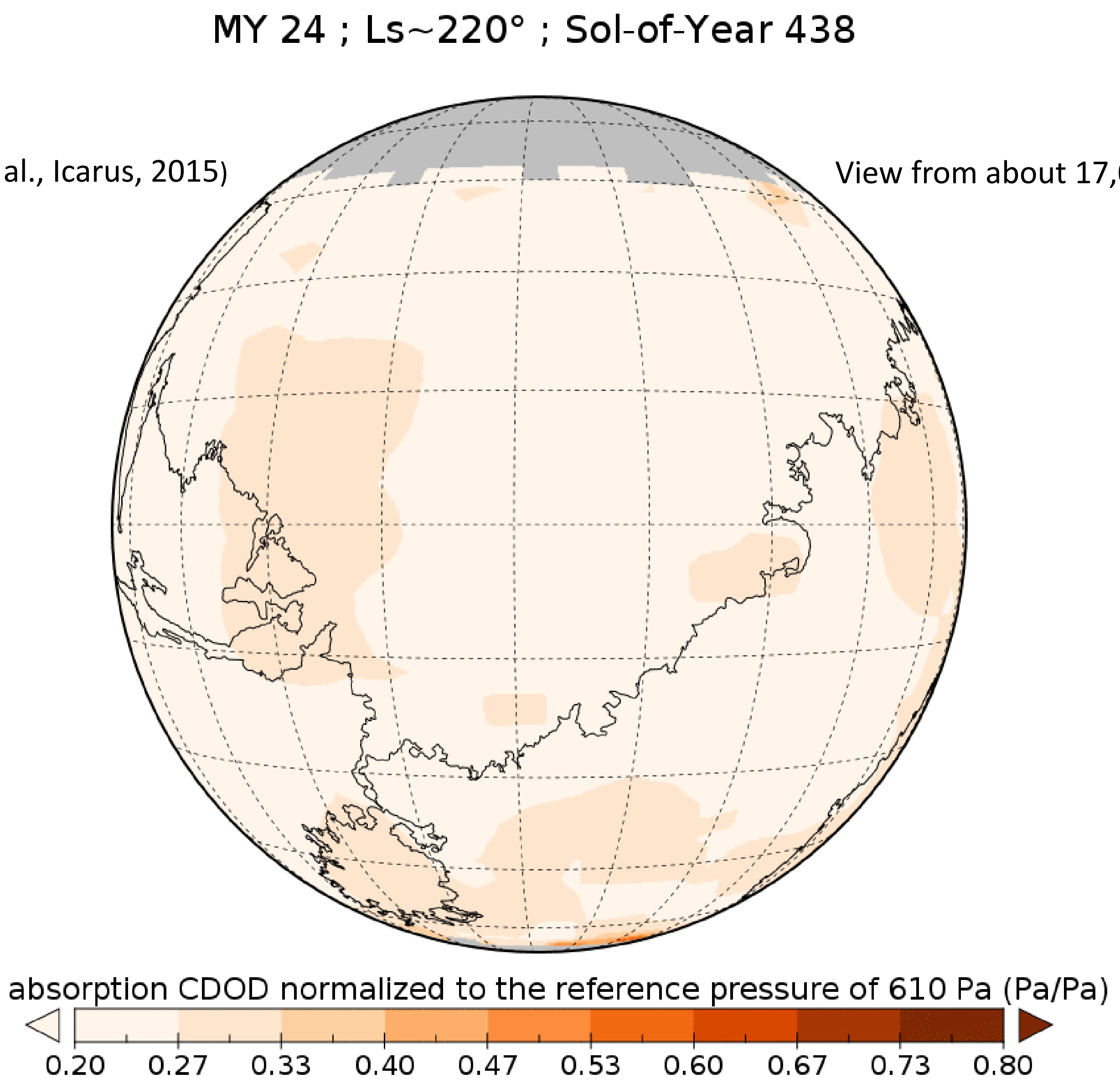
View from about 17,000 km above the equator



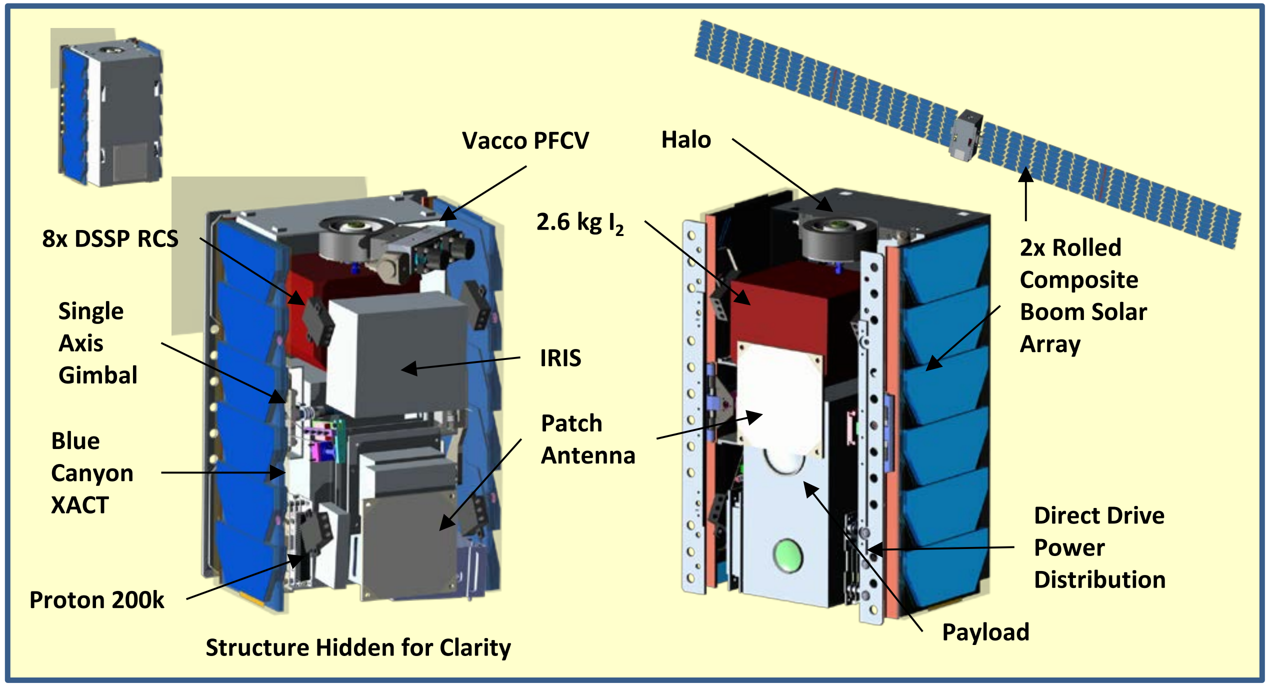
A regional dust storm from areostationary orbit

(Data from Montabone et al., Icarus, 2015)

View from about 17,000 km above the equator



The 12U CubeSat (24 kg)
...or is it a Class A/B nanosatellite ??



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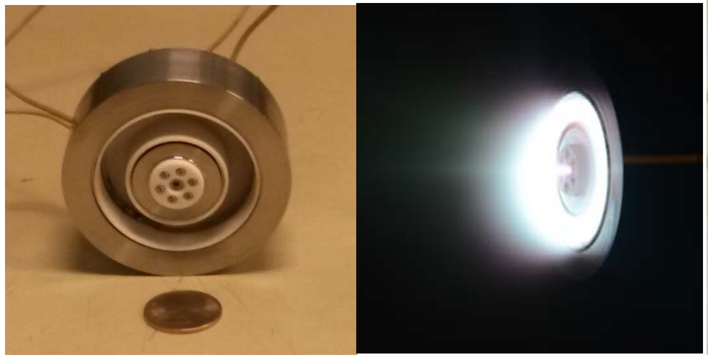
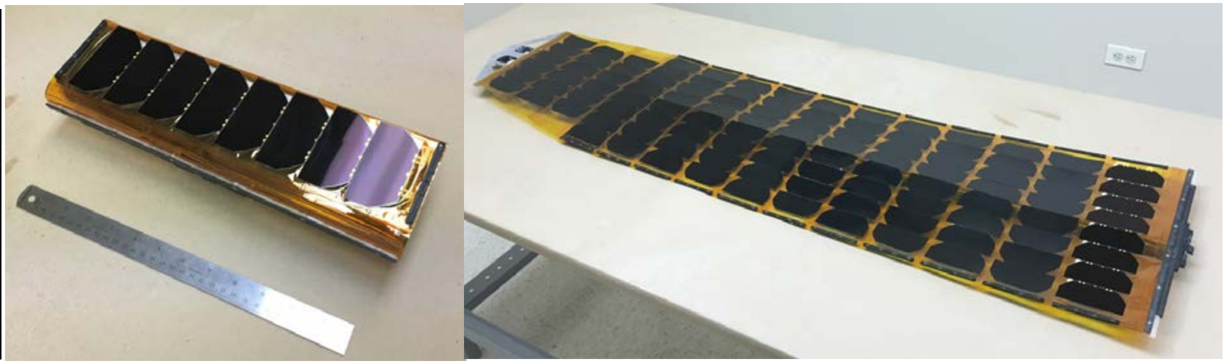
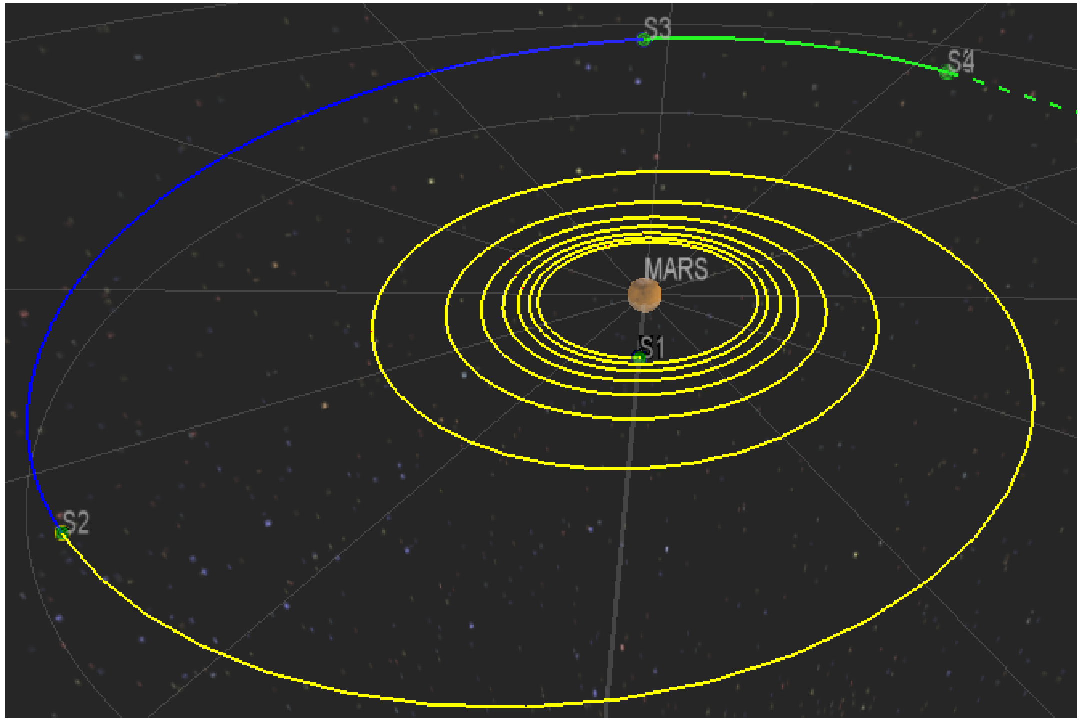


“Halo” 3rd Generation Prototype
150 W, 5-10 mN, Isp 1100-1600 s



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

Baseline Mission Design



- **Journey to Mars**: Ride-sharing to Mars (attached to an orbiter mothership), deployment at ~310,000 km after initial capture burn.
- **Trajectory**: Thrusters operated for 27 days to spiral down to ~20,000 km
- **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

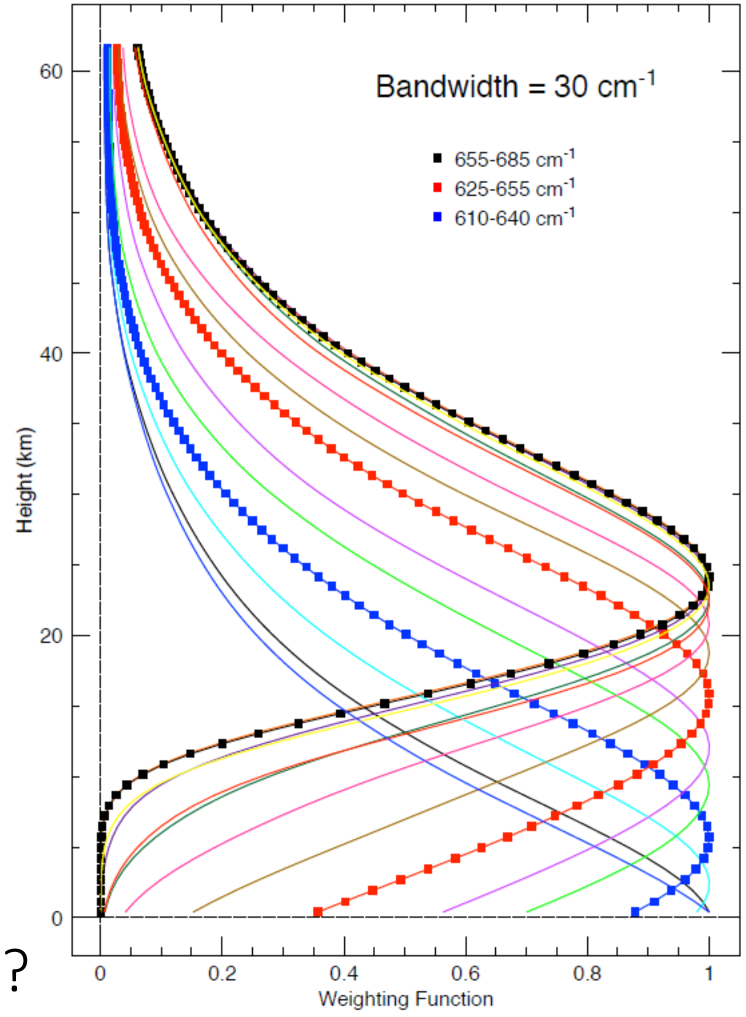
Possible payload

- **Visible camera**: Off-the-shelf camera (e.g. ECAM-C30 from Malin Space Science Systems):
  - → Fixed-focus;
  - → 2048 x 1536 pixels;
  - → 29° x 22° FOV (full disk and limb);
  - → 4.5 km resolution at nadir.

- **Thermal infrared camera**: It would require to provide:
  - → At least a resolution of 15 km at nadir;
  - → Detector responsive over the range 7 to 16 μm;
  - → At least 7 spectral ranges: 3 for CO_2, 1 for T_{surf}, 1 for dust, 1 for water ice, 1 in between dust and ice.
- **Optional UV camera**: Off-the-shelf camera, e.g. from MSSS:
  - → Similar characteristics to visible camera;
  - → 260–340 nm spectral range.

Possible products

- **Images**: High rate sampling (~30 mins).
- **Retrievals**: Temperature and aerosols (dust, water ice) optical depth
  - → 2D maps of τ_{dust} and τ_{ice}
  - → 3D maps of T.
  - → Maps and images are co-located and simultaneous
- **Note on T retrievals**: ~15 km vertical resolution, 3 independent points, sensitivity up to 45-50 km.
- **Data downlink**: Particularly challenging
  - → Trades are required
  - → On-board storage/pre-processing?
- **Data distribution**: Near real-time public access. Flexible data management.



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

Key requisites for the mission

- **Funding**: To develop the mission concept further.
- **Collaborations**: To address key technical challenges:
  - → Payload (specifically the multi-spectral thermal IR camera or equivalent imager);
  - → ΔV (to increase the number of mission opportunities, e.g. to perform orbit capture after release from ballistic trajectory);
  - → Communication (to develop autonomous communication, e.g. using JPL KaPDA high gain antenna);
  - → Data pre-processing (e.g. using techniques based on neural and/or citizen scientist networks);
  - → Pointing (e.g. possible disturbances from solar arrays).
- **Opportunity**: To launch the first areostationary satellite.

Thanks for your feedback !

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