CO_2 Jets and their Influence on the Martian Polar Atmosphere

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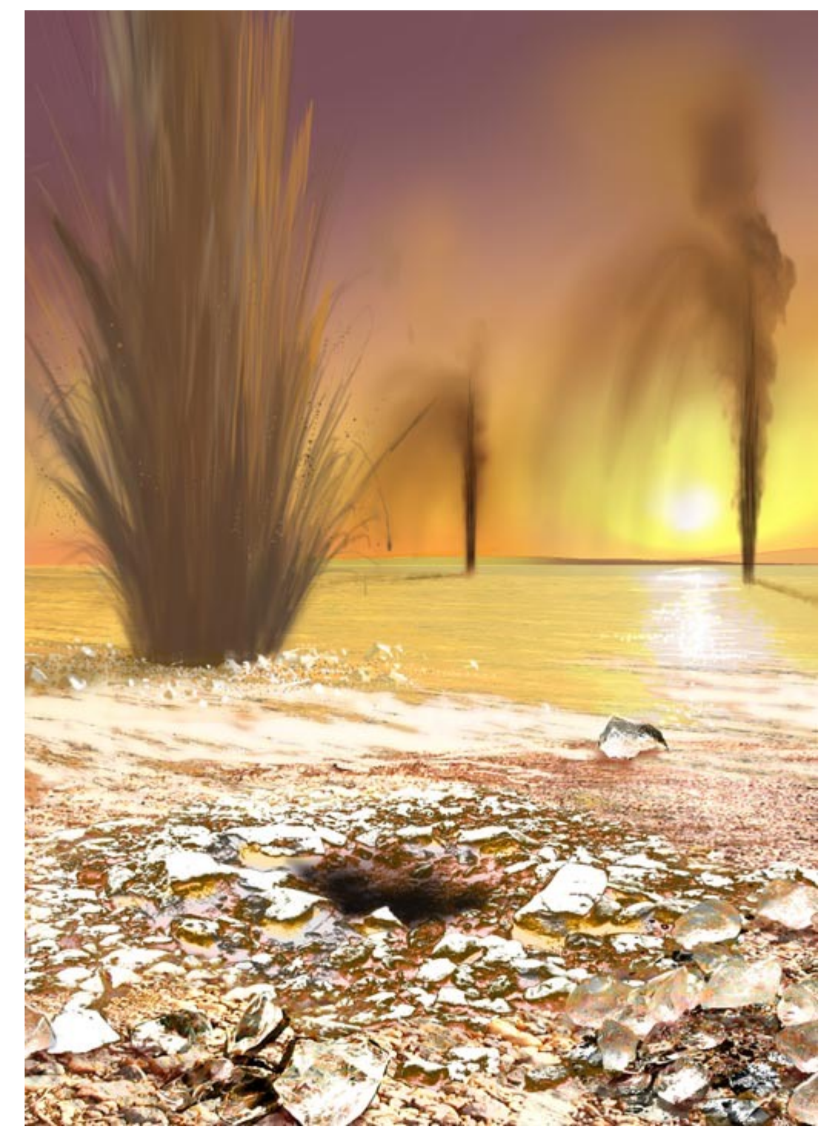

Artist concept by Ron Miller, ASU

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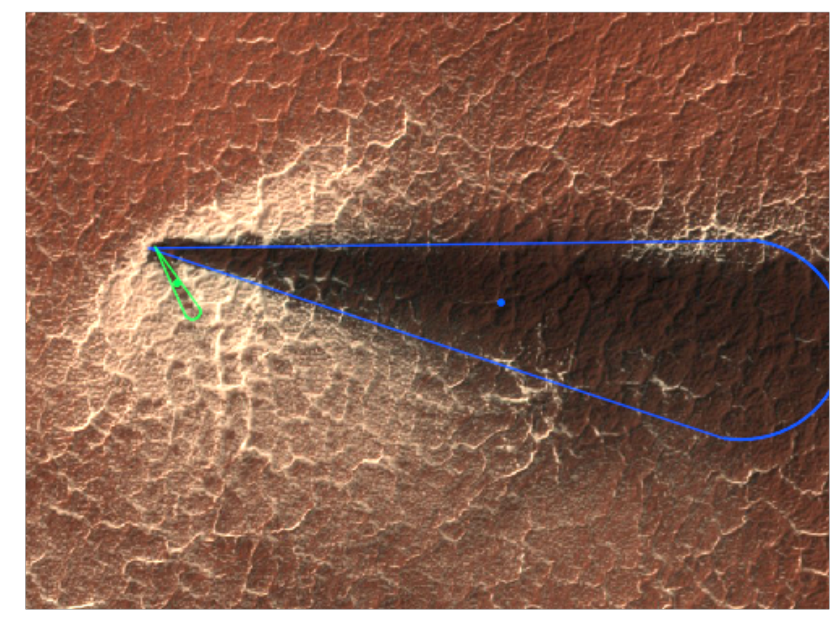
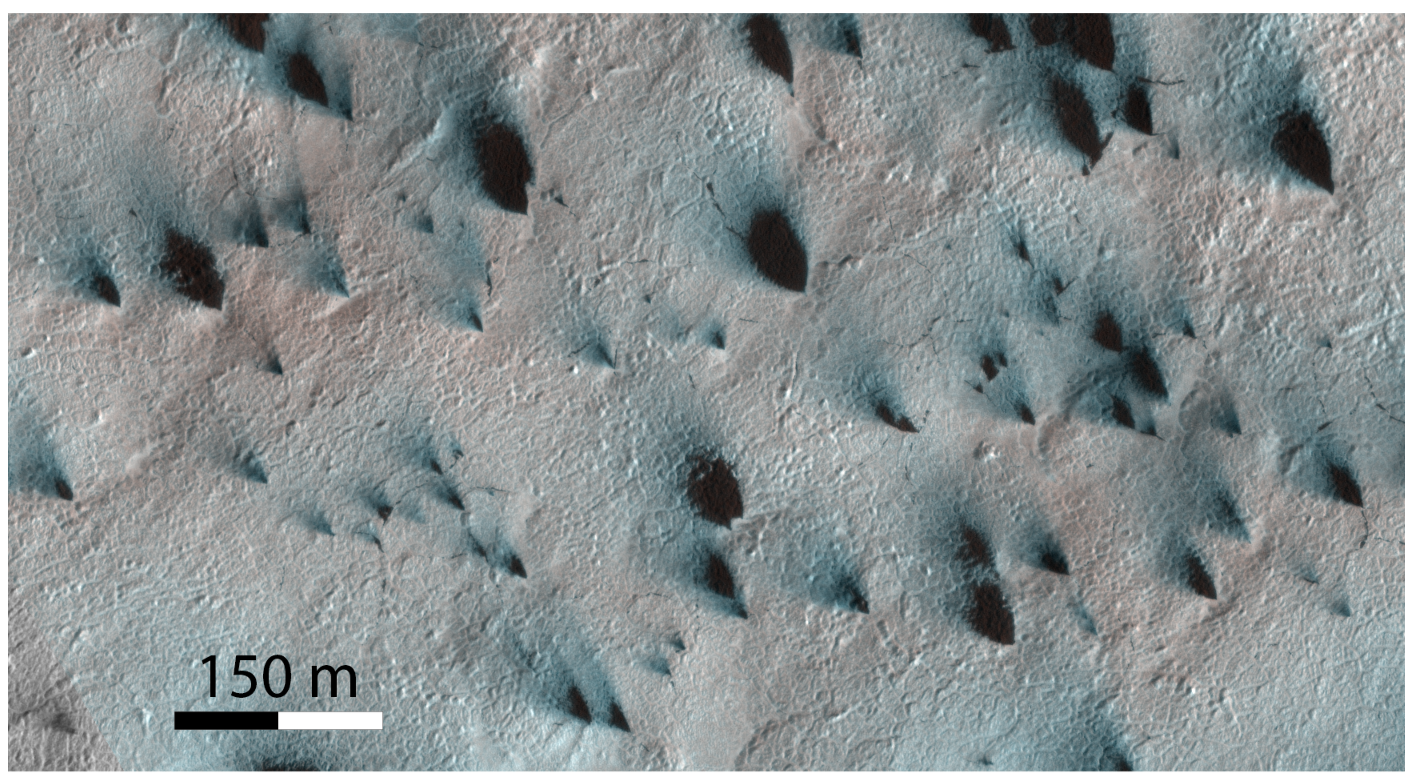


Longest fan deposit identified so far: 370 m (ESP_011961_0935)

Introduction

During local spring, the south polar region of Mars exhibits a host of exotic phenomena associated with sublimation of the seasonal CO_2 polar cap. Images from the Mars Reconnaissance Orbiter (MRO) High Resolution Imaging Science Experiment (HiRISE) document this activity well, best described by the "Kieffer" (2007) model:
In winter, the CO_2 forms a translucent slab of impermeable ice. Penetration of sunlight through the ice, which warms the ground below, results in basal sublimation of the ice. Trapped gas escapes through ruptures in the ice, eroding and entraining material from the surface below. When this dust-laden gas is expelled into the atmosphere the dust settles in fan-shaped deposits on the top of the ice in directions oriented by the ambient wind.



Science objectives explained

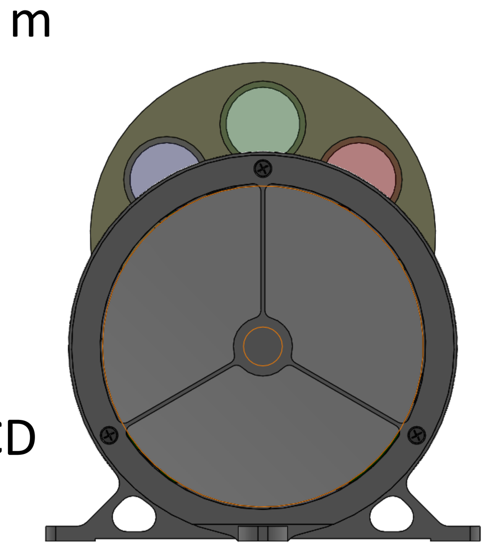
- **Observe active CO_2 jets**
  - Predicted by most widely accepted hypothesis (Kieffer model, see Intro box) **but never been observed in action!**
  - Time of day eruption currently unknown (predicted to be between sunrise and noon, depending on weakly constrained CO_2 ice properties
  - Current jet models do not predict observed fan deposit lengths; those are a convolution between jet height and wind strengths. Observation of jet heights can disentangle this!
- **Constrain amount of dust entering the atmosphere**
  - Piqueux and Christensen (2008) estimated that jets displace 2 orders of magnitude more dust per year than typical global dust storm.
  - Dust contributes to total early spring polar atmospheric aerosol, and thus to its thermal budget and circulation, at latitudes thought to receive minimal dust
- **Monitor diurnal development of albedo of jet deposits and environment**
  - Deposits change their appearance over time, we don't know if this is a state of diurnal subl.-refrosting cycle or a general trend over days.
  - Dust is observed to be removed, we don't know if it sinks in or is blown away (most likely both).
- Observe local weather in form of trough clouds to estimate water flux across spiral troughs

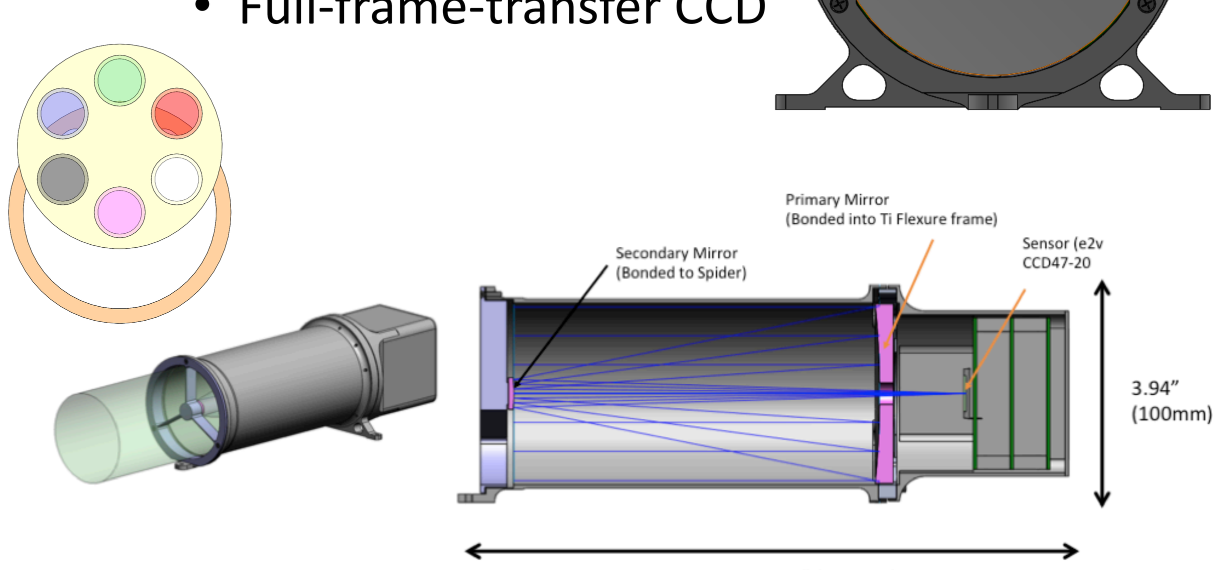
MEPAG Objective	MEPAG Investigation	Mission Science objective	Mission Measurement Requirement	Mission Requirement
Goal II, A4: Constrain the processes by which volatiles and dust exchange between surface and atmospheric reservoirs.	1. Measure the turbulent fluxes of dust and volatiles between surface and atmospheric reservoirs.	•Confirm Kieffer model by observing **active** CO_2 jets	•Determine eruption time of day •Determine jet heights •Measure opacity/contrast changes of field of jets before/after eruption caused by dust in lower atmosphere	•Orbit insertion at local sunrise (=noon at beginning of spring) • Let orbit precess to stay with sunrise •Be able to change local time to determine eruption time (only Cube/Small-Sat can do it fast)
Goal II, A1: Constrain the processes that control the present distributions of dust, water, and carbon dioxide in the lower atmosphere, at daily, seasonal and multi-annual timescales.	3. Measure the forcings that control the dynamics and thermal structure of the lower atmosphere.	•Constrain amount of dust entering atmosphere •Determine surface reflectivity changes over time	•Determine surface reflectivity changes caused by jet deposits (fading time scale and/or assess recycle state)	•Scan one full day of local time to confirm/exclude diurnal subl.-refrosting cycle •measure same location over time-scale that fading has been observed (approx 10-20 days)

MAPSE (MArs Polar Smallsat Explorer)

Instrument Basic Concept

- Requirements and constraints
  - Spatial resolution ~10 m
  - FOV: > ~1 x 1 km
  - Aperture: < ~80 mm
  - Panchromatic
- Design
  - Cassegrain telescope
  - Full-frame-transfer CCD





Specifications and performance

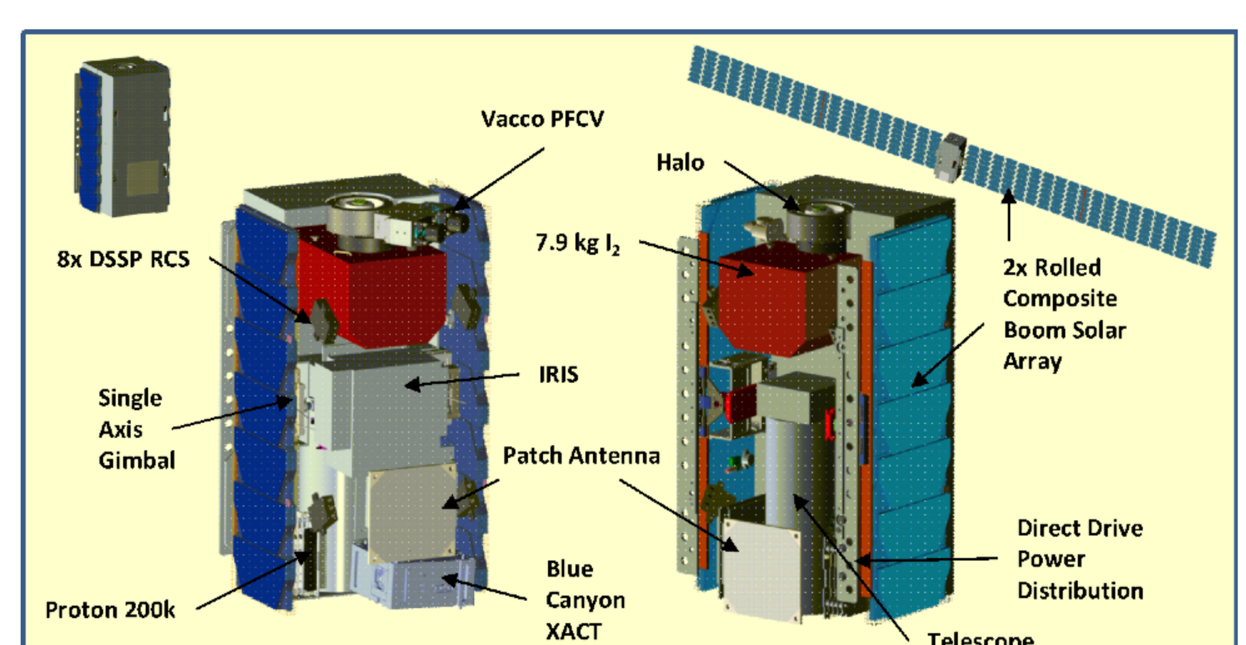
Design	Ritchey-Chretien Cassegrain-style telescope
Focal length	1300 mm
Entrance aperture	80 mm diameter
Pixel scale (sampling)*	4 m/pix
Spatial res. *	10–13 m
FOV*	4096 m (0.59°)
Wavelength range	325–1090 nm (panchromatic)
Mass (CBE)	1.1 kg
Power (CBE)	4 W operating
Volume	28x10x10 cm
Read noise	6 e^- at 1 MHz
Digitization	14 bits
Dark Current	250 e^-/s/pix at 25°C
Image read-out time	1 ms at 1 MHz
Signal	7.3×10^6 e^-/s/pix
SNR	270 in 10 ms

* Projected distances are based on an assumed S/C altitude of 400 km

Mission concept

- Spacecraft bus: Ion-driven SmallSat for continuous orbit adaptation (16 U in last iteration)
- Orbit: Precessing orbit with south-pole perhaps, approx 350 km altitude. Precess from noon-midnight to dusk-dawn orbit within 6 months (local spring)
- Mission duration: 6 months to cover local Martian spring
- Comms
  - 1 image, lossless compression, takes 7 s via 1 MBit/s (IRIS CubeSat relay module from NASA)
  - 5 mins relay could transfer 42 images
- **Challenges**
  - Relay satellites have no experience and no willingness to do relay form moving target
  - Detector needs to cope with ground spot speed of 3.4 km/s
    - Either do TDI, frame let approach, or slew S/C to cancel ground motion

ExoTerra SmallSat Spacecraft



Mass: 32 kg total, 4 kg Science payload 228 W EOL power

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- Kieffer, H.H., 2007. Cold jets in the Martian polar caps. Journal of Geophysical Research 112, 08005. doi:10.1029/2006JE002816
- Piqueux, S., Christensen, P.R., 2008. North and south subice gas flow and venting of the seasonal caps of Mars: A major geomorphological agent. Journal of Geophysical Research 113, 6005. https://doi.org/10.1029/2007JE003009