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**ESCAPADE: A TWIN-SPACECRAFT MAGNETOSPHERIC MARS MISSION LAUNCHING IN 2024**

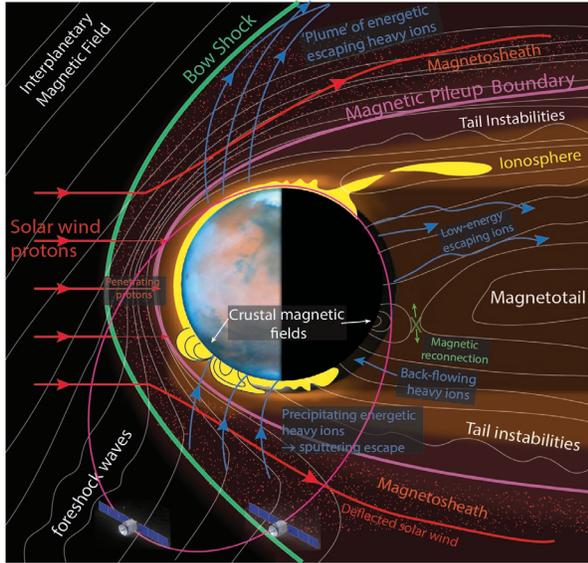
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**Plasma Measurements at Mars: why do we care?**

Plasma measurements of the Mars environment are required to understand:

1. The structure, composition, variability and dynamics of Mars’ unique hybrid magnetosphere (i.e. sharing properties of both intrinsic and induced magnetospheres) [e.g. 1].
2. Atmospheric Escape Processes: ion escape and sputtering escape help drive climate evolution of terrestrial planets [2-5].



**Figure 1: Mars' highly dynamic plasma environment cannot be adequately understood from a single vantage point.**

**A single platform leaves major questions unanswered.** The MAVEN and Mars Express missions have revolutionized our understanding of the Mars near-space environment and atmospheric escape [1]. However, their orbits are not coordinated, nor are there instrument complements similar (crucially Mars express lacks a magnetometer). Thus they are effectively single measurement platforms, suffering from the following drawbacks:

- 1) spatial and temporal variations in escape fluxes cannot be distinguished
- 2) responses of escape fluxes and other magnetospheric dynamics to changing solar wind

conditions (~1 minute) can only be measured with a time-lag of an hour or (much) more

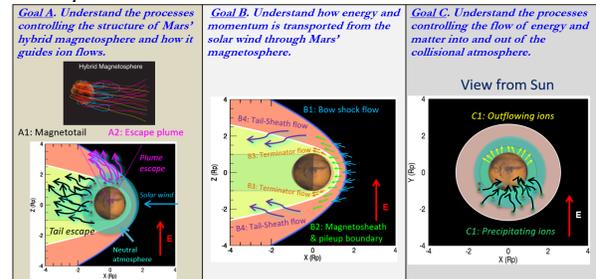
**A Multi-spacecraft revolution.** In the last 20 years, multi-spacecraft missions like Cluster II, THEMIS, Van Allen Probes, and MMS have revolutionized our understanding of the causes, patterns, and variability of a wide array of space plasma phenomena in the Earth’s magnetospheric environment. ESCAPADE is a twin-spacecraft Mars mission that will similarly revolutionize our understanding of how solar wind momentum and energy flows throughout Mars’ magnetosphere to drive ion and sputtering escape, two processes which have helped shape Mars’ climate evolution over solar system history.

**ESCAPADE Goals & Objectives:**

*Goal A: Understand the processes controlling the structure of Mars’ hybrid magnetosphere and how it guides ion flows.*

*Goal B. Understand how energy and momentum is transported from the solar wind through Mars’ magnetosphere.*

*Goal C. Understand the processes controlling the flow of energy and matter into and out of the collisional atmosphere.*



**Figure 2: ESCAPADE’s 3 goals & 7 objectives covering important aspects of magnetic structure and plasma flows in Mars’s unique hybrid magnetosphere.**

**ESCAPADE will measure** magnetic field strength and topology, ion plasma distributions (separated into light and heavy masses), as well as suprathermal electron flows and thermal electron and ion densities from elliptical, 200 km x ~7000 km orbits. These will be measured using four in situ instruments, shown in the figure below with their locations on the ESCAPADE spacecraft.

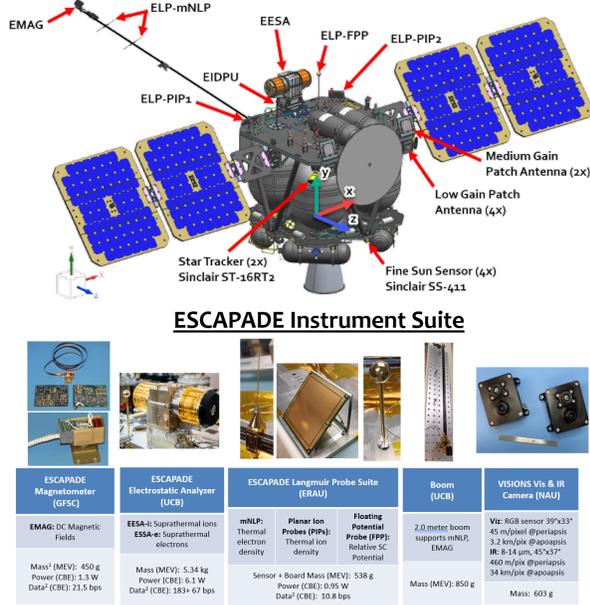


Figure 3: ESCAPEDE in situ instrumentation & accommodation on the ESCAPEDE spacecraft.

**ESCAPADE Spacecraft.** The twin ESCAPEDE spacecraft are provided under a firm fixed-price (FFP) contract between UC Berkeley and Rocket Lab USA (Long Beach, California). At ~180 kg (dry mass) they fall approximately between cubesats and typical interplanetary spacecraft (on a logarithmic scale). And enable >2500 m/s of Delta-V.

**ESCAPADE Mission Design** involves a direct-to-Mars ballistic 11-month Hohmann Type II transfer following a trans Mars injection in October 2024. Following a Mars orbit insertion in September 2025, the spacecraft will spend 7 months adjusting orbits before the 11-month science mission begins in April 2026.

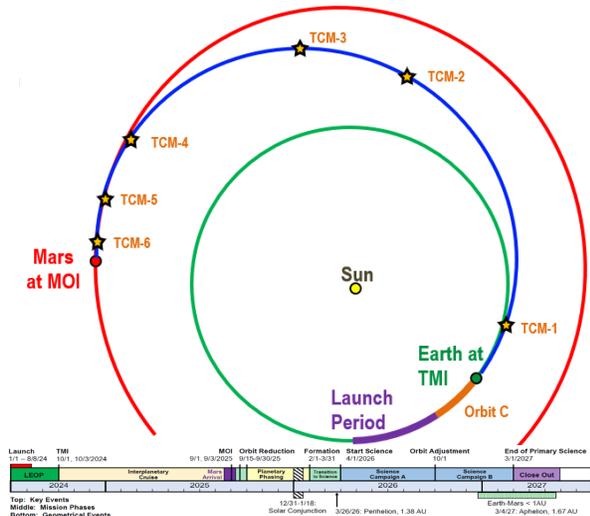


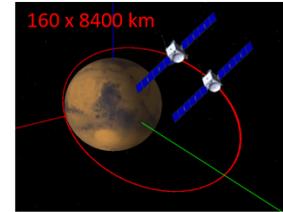
Figure 4: ESCAPEDE Mission design and timeline

ESCAPADE’s strategically-designed, 1-year, 2-part scientific campaign of temporally and spatially-

separated multipoint measurements in different parts of Mars’ diverse plasma environment will for the first time unravel the cause-and-effect of solar wind control of ion and sputtering escape. The figures below illustrate ESCAPEDE’s science operations concept.

**Science Campaign A:**

- String-of-pearls
- Optimized for studies of short-timescale variability
  - Allows limited (shorter-distance) studies of correlation between solar wind and magnetosphere.



**Science Campaign B:**

- Planes precess differentially:
- Optimized for studies of correlations between more distant regions (e.g. solar wind and ion loss in the magnetotail).

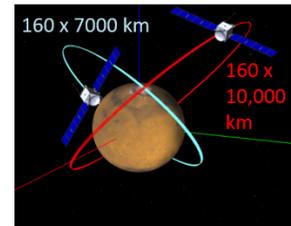


Figure 5: ESCAPEDE's science campaigns A and B.

**ESCAPADE project status.** As of early January 2024, all instruments have been delivered and all subsystems except tanks have been integrated. The Observatories are currently undergoing assembly, integration and test at Rocket Lab’s facilities in Long Beach, California. Launch onboard the first flight of Blue Origin’s New Glenn launch vehicle is scheduled for October 2024 from Launch Complex 36 at Cape Canaveral Space Force Station.

**References:** [1] Brain, D. A. et al. (2015), Mars Book II, [2] Jakosky et al., SSR, 2015, [3] Lillis et al., SSR, 2015, [4] Luhmann et al., JGR, 1992, [5] Brain et al., GRL, 2015



Figure 6: Gold Observatory’s instrument deck. Shown are the Planar Ion Probe (gold square), Floating Potential Probe (gold sphere & stick), Electrostatic Analyzer (gold & black cylindrical instrument), and multi-needle Langmuir probes (4 needles perpendicular to folded boom).