ESCAPADE: A Twin-Spacecraft Simplex Mission to Unveil Mars' Unique Hybrid Magnetosphere

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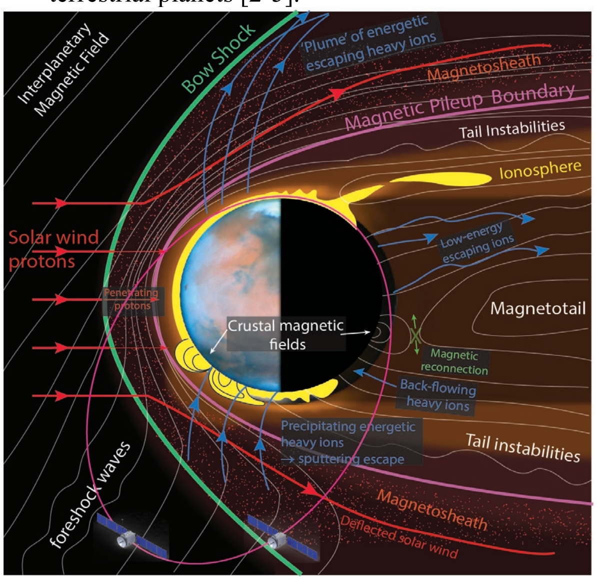
Plasma Measurements at Mars: why do we care? Plasma measurements of the Mars environment are required to understand:

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].



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.*

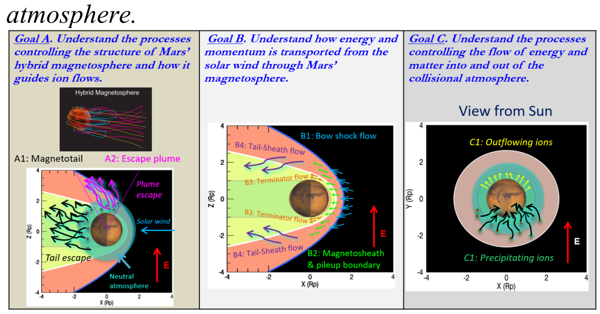


Figure 2: ESCAPADE's 3 goals & 7 objectives covering important aspects of magnetic structure and plasma flows in Mars's unique hybrid magnetosphere.

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.

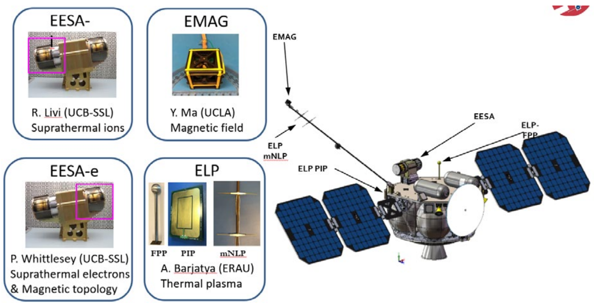


Figure 3: ESCAPADE in situ instrumentation & accommodation on the ESCAPADE spacecraft.

ESCAPADE Spacecraft. The twin ESCAPADE spacecraft will be provided under a firm fixed-price (FFP) contract between UC Berkeley and Rocket Lab USA (Long Beach, California). At ~120 kg (dry mass) they fall approximately between cubesats and typical interplanetary spacecraft (on a logarithmic scale). Powered by deployed solar arrays, propulsion is provided by HyperCurie engines and sufficient fuel to enable >2500 m/s of Delta-V.

ESCAPADE Mission Design involves a 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.

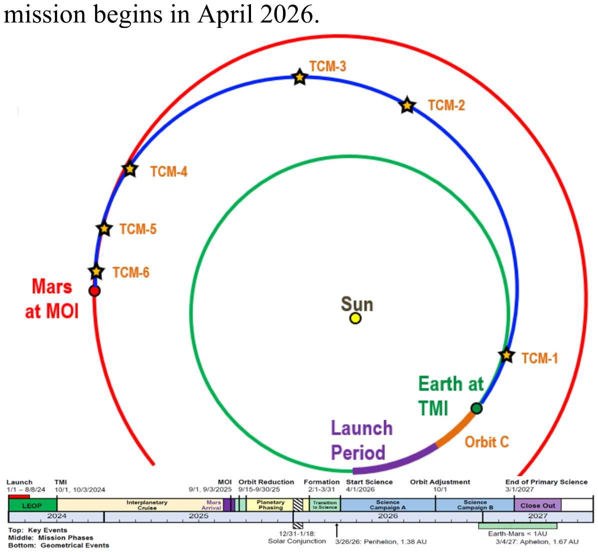


Figure 4: ESCAPADE Mission design and timeline

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 ESCAPADE's science operations concept.

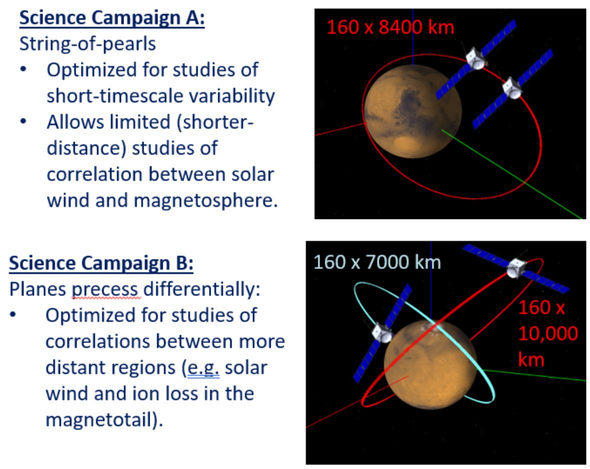


Figure 5: ESCAPADE's science campaigns A and B.

ESCAPADE project status. In August 2021, ESCAPADE passed KDP-C and is currently in Phase C. ESCAPADE is funded by NASA's Heliophysics Division and is managed by the Planetary Mission Program Office (MSFC). Total mission budget is $78.5 million including launch vehicle and all reserves.

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

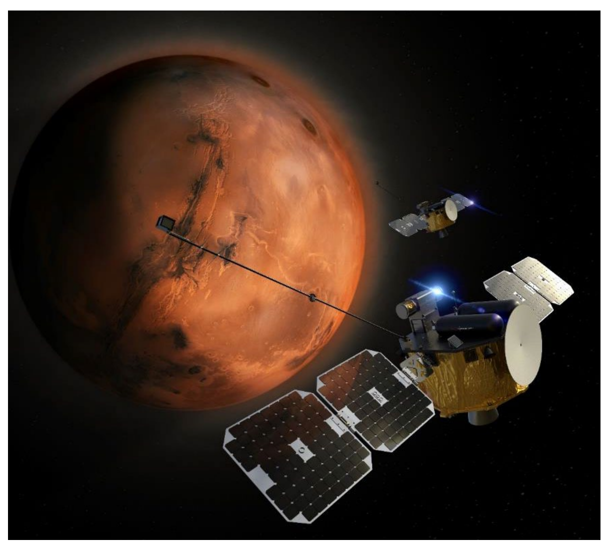


Figure 6: artist's impression of the two ESCAPADE spacecraft ("Blue" and "Gold") in Mars orbit.