ESCAPADE: COORDINATED MULTI-POINT OBSERVATIONS OF ION AND SPUTTERED ESCAPE FROM MARS

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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].

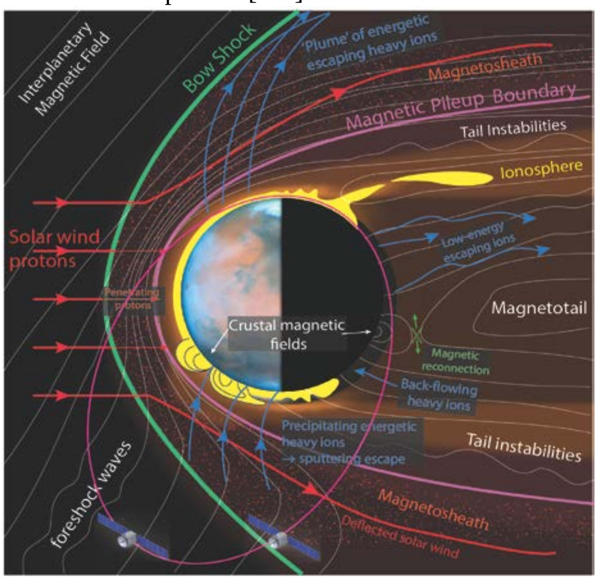


Figure 1: Mars' highly dynamic plasma environment cannot be adequately understood from a single vantage point.

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
3) global escape rate variability in response to space weather "storms" (much more common and intense in the early solar system) must be estimated (poorly) from a single orbit track [6].

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 Science goals:

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.*

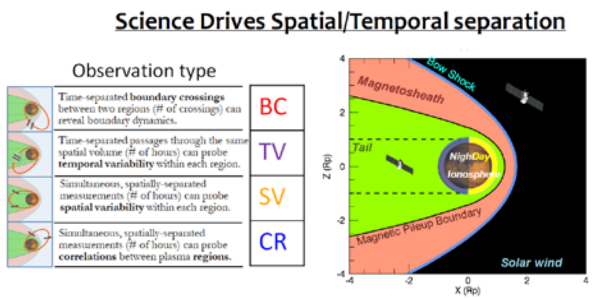
Goal C. *Understand the processes controlling the flow of energy and matter into and out of the collisional atmosphere.*

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. The science payload is described in the table below:

ESCAPADE Science Payload

EMAG (UCLA) Lead: C. Russell	EESA (UCB-SSL) Lead: D. Larson		ELP (ERAU) Lead: A. Barjatya		
	EESA-I: R. Livi	EESA-e: P. Whittlesey	mNLP	PIP	FPP
Magnetic Fields (DC)	Suprathermal Ions	Suprathermal Electrons	Thermal Plasma Density	Solar EUV flux (55-130 nm)	Relative SC Potential
Range: 0 - 1000 nT **Magnitude accuracy**: 0.5 nT **Direction accuracy**: 20° above 1 nT	**Energy**: 2 eV - 20 keV (25% ΔE/E) **Angles**: 2.8π (30° x 30°) **Mass**: M ≤ 4, M ≥ 16 **Eflux**: 10^3-10^{11}±30%	**Energy**: 3 eV - 10 keV (25% ΔE/E) **Pitch angle**: 20 - 160°, 30° resolution **Eflux** 10^4-5x10^9 ±30%	**Range**: 20-3x10^6 cm^{-3} **Accuracy**: 30%	**Flux**: 0.005-0.02 W/m^2 **Relative accuracy**: 10%	**Range**: -5 V to 5 V

ESCAPADE Mission Design. The twin-spacecraft (<90 kg) will travel to Mars via solar electric propulsion as a rideshare with the Psyche metal-asteroid mission in August 2022, matching Mars' heliocentric orbit until capture and spiral-down to science orbits. 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.



Science Campaign A 7/1/24 – 1/1/25		
Periapse altitude:	200	km
Apoapse altitude:	7000	km
Inclination:	60	deg
Period:	4.9	hours

Science Campaign B 2/1/25 – 8/1/25		
Periapse altitudes:	200,	200 km
Apoapse altitudes:	8685,	5660 km
Inclinations:	60,	60 deg
Periods:	4.24,	5.85 hrs

ESCAPADE project status. ESCAPADE has been selected for Phase A/B study by NASA as one of three finalists in the SIMPLEX-II program. We will report on ESCAPADE's science goals, objectives, and requirements, as well as provide a status update.

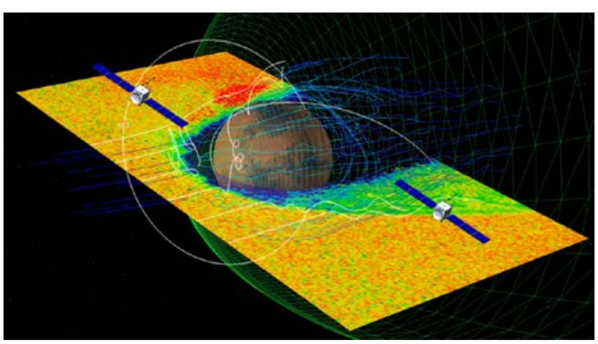


Figure 2: ESCAPADE's orbits within a hybrid simulation of the solar wind interaction with Mars, where the color scale represents ion velocity, blue lines are magnetic field, while white lines are sample proton trajectories and spacecraft orbits.

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, [6] Curry et al., *JGR*, 2018.