URANUS MAGNETOSPHERE AND MOONS INVESTIGATOR (UMaMI). C. M. Elder[1], T. A. Nordheim[1], D. A. Patthoff[2], E. Leonard[1], R. J. Cartwright[3], C. Cochrane[1], C. Paranicas[4], M. S. Tiscareno[3], A. Masters[5], D. Hemingway[6], M. M. Sori[7], H. Cao[8], R. T. Pappalardo[1], B. J. Buratti[1], I. de Pater[9], W. M. Grundy[10], M. Showalter[3], W. Kurth[11], I. Jun[1], J. I. Moses[12], K. L. Aplin[13], J. Casani[1], [1]Jet Propulsion Laboratory, California Institute of Technology, [2]Planetary Science Institute, [3]SETI Institute, [4]Applied Physics Laboratory, [5]Imperial College, [6]Carnegie Institution, [7]Purdue University, [8]Harvard University, [9]University of California, Berkeley, [10]Lowell Observatory, [11]University of Iowa, [12]Space Science Institute, [13]Bristol University.

Introduction: The five largest satellites of Uranus exhibit tantalizing evidence of surfaces that have been active in geologically recent time, including fractures, ridges (Figure 1), relaxed craters [e.g. 2], and evidence for volatiles that should not be stable over geologic timescales [e.g. 3]. These moons could have had subsurface oceans earlier in their histories and could possibly still host them today [2]. The orbits of most of the Uranian moons and rings reside inside the Uranian magnetosphere and their surfaces are therefore continuously exposed to magnetospheric plasma and energetic particles. Uranus is also a prime location to study magnetosphere and solar wind interactions as the combination of Uranus's large obliquity of 97.9° and its highly tilted (59°) and offset (0.35 R_{Uranus}) magnetic field leads to a configuration where the magnetospheric interaction with the solar wind varies considerably over both diurnal and seasonal timescales. Uranus's ring system is also unique in the solar system, comprised of narrow but dense and sharp-edged rings. A mission to investigate the Uranian system should be a high priority in the next decade to advance our knowledge of this unique and intriguing planetary system.

UMaMI: The Uranus Magnetosphere and Moons Investigator (UMaMI) is a mission concept that would aim to study the magnetosphere, moons, and rings of Uranus. These three systems interact with each other in significant and measurable ways making them a natural combination for a mission [4]. Uranus itself would also be observed when possible, but instruments and the orbital tour would be optimized to study the magnetosphere, moons, and rings. UMaMI's main science goals are:

1. Moons: Determine if the Uranian satellites host subsurface oceans, search for signs of ongoing endogenic activity, and determine to what extent the surfaces are modified by exogenic processes (e.g. charged particle bombardment and irregular satellite dust accumulation).
2. Rings: Understand the formation and evolution of the Uranian rings and their interactions with the satellites.
3. Magnetosphere: Characterize the structure and dynamics of the unique Uranian magnetosphere, including its interaction with the solar wind and the Uranian moons.

These focused goals could be achieved within the New Frontiers cost-cap. Such a mission would be complementary to a variety of outer solar system Flagship class missions. For example a Flagship class mission to Neptune could address many outstanding questions related to ice giants and Triton. However, Triton is most likely a captured Kuiper Belt Object whose capture destroyed much of Neptune's native satellite system [e.g. 5], so we must visit Uranus to study a primordial ice giant satellite system. Alternatively, if a Flagship mission

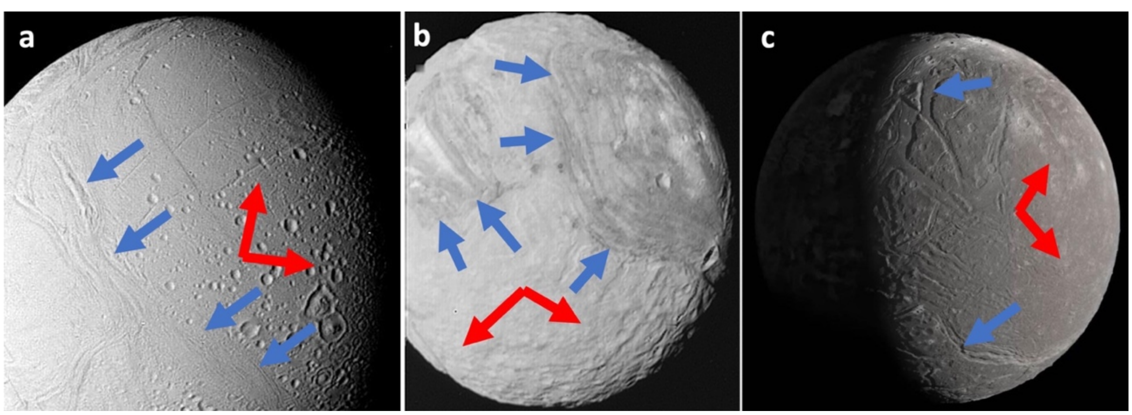

Figure 1: Voyager 2 image mosaics of (a) Enceladus (d=504 km), (b) Miranda (d=472 km), and (c) Ariel (d=1158 km) including night-side illumination by Uranus shine [1]. Cratered regions (red arrows) and boundaries of isolated recent resurfacing (blue arrows) highlighted in each figure. **Miranda and Ariel show evidence of partial resurfacing, similar to Enceladus.** Image credit: NASA/JPL/Caltech/USGS.

to an ice-giant were not recommended for the next decade, UMaMI would provide an opportunity to address a focused subset of the science objectives of a Flagship class mission.

Science Objectives and Measurements: UMaMI would achieve its goals through 12 specific objectives listed in Table 1. The instruments required are a high resolution camera with color filters, a magnetometer, a plasma spectrometer, an energetic particle detector, and a visible and infrared (VIR) spectrometer. In all cases, instruments with significant flight heritage would be sufficient to meet our requirements.

Timing: A mission to the Uranian system should be a high-priority in the next decade due to both launch opportunities and the tilt of Uranus relative to the sun. Over its 85-year orbital period, Uranus' large obliquity (97.9°) results in extreme variations in the insolation conditions of the satellites and the interactions between the magnetosphere and the solar wind. Voyager 2 flew by the Uranian system just after southern solstice, taking the only in situ measurements to date. Arriving within ~10 years of equinox (2049) would enable important comparisons to Voyager 2 measurements and illumination conditions ideal for observing the global geology of the moons. It is also important to consider a mission to Uranus soon, because of limited opportunities for Jupiter gravity assists. Without an available Jupiter gravity assist, the mission must rely on Solar Electric Propulsion (SEP) to reach Uranus, and this greatly increases the cost of the mission [6, 7] potentially putting a New Frontiers class mission out of reach. The next launch window that could capitalize on a Jupiter gravity assist falls from 2030 to 2034 [6]. Using this Jupiter gravity assist would result in arrival at Uranus in the mid-2040s [6, 8], just before Uranus' next equinox.

Conclusion: There are many outstanding questions about the Uranian system and addressing these questions with an orbiter should be a high priority for the next decade. By focusing on the magnetosphere, moons, rings, and their interactions, a subset of the objectives for a Flagship class mission at Uranus could be achieved within the New Frontiers cost-cap. This would be complementary to a more comprehensive Flagship class mission at Neptune or if the decadal committee does not select an ice giant system as a Flagship target, UMaMI would ensure that a focused subset of the outstanding ice giant system questions would be addressed.

Acknowledgements: The information presented about the UMaMI concept is pre-decisional and is provided for planning and discussion purposes only.

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Science Goal	Science Objective	Instrument
Magnetosphere	1. To what extent is the Uranian magnetosphere driven by the solar wind vs internal processes?	mag/plasma/energetic particles
Moons, Magnetosphere	2. Are the major moons sources of magnetospheric plasma?	mag/plasma
Moons, Magnetosphere	3. To what extent are the major moons weathered by magnetospheric particles?	mag/plasma/energetic particles
Moons, Magnetosphere	4. Do any of the major moons have an exosphere? If so, how do they interact with the magnetosphere?	camera/mag/plasma/energetic particle
Moons, Magnetosphere	5. Do the major moons have conducting subsurface oceans? If so, how does this affect moon-magnetosphere interactions?	mag/plasma/energetic particles
Moons	6. Are any of the major moons currently geologically active? What are their geologic histories? What are the relative ages among the moons and among different units on each individual moon?	camera/VIR spectrometer/mag
Moons	7. What are the internal structures of the major moons?	camera/radio science
Moons	8. What are the endogenic and exogenic process that modify the surfaces of the moons? Does material from the irregular satellites mantle the major moons? What is the source of the CO_2 ice detected on the major moons?	camera and VIR spectrometer
Moons, Rings	9. What is the origin and structure of the μ ring?	camera/VIR spectrometer
Moons, Rings	10. Do the rings have the same composition as the nearby moons/moonlets?	VIR spectrometer
Rings	11. What causes the structure of the narrow, dense rings? Are they self-sustaining?	camera

Table 1: Science objectives for the UMaMI mission and the instruments that would be used to achieve them. "Major moons" refers to Miranda, Ariel, Umbriel, Titania, and Oberon; "mag"=magnetometer; "plasma"=plasma spectrometer; "energetic particles"=energetic particle detector.