The ionosphere of Mars: A community white paper for the planetary decadal survey

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The MAVEN Scout mission, scheduled for launch in 2013, will address many, but not all, of the outstanding questions concerning the ionosphere of Mars. This white paper will describe important questions that MAVEN's nominal mission will not answer and identify measurements and instruments that can answer these questions. The areas covered by these questions include solar cycle variations, the state of the bottomside ionosphere, the effects of crustal magnetic fields, and dynamical coupling between the neutral atmosphere and ionosphere. Potential measurements and instruments include a surface package consisting of a magnetometer, airglow imager, ionosonde and riometer, upstream monitoring of the Sun simultaneous with ionospheric measurements, and spacecraft-to-spacecraft radio occultations. One of the distinctive features of the Mars Exploration Program is how later missions build upon the discoveries of earlier missions. We suggest that an aeronomy constellation mission should be studied as a potential response to the anticipated discoveries of MAVEN.

Planetary Science Decadal Survey

NASA and NSF have requested that the Space Studies Board of the National Academy of Sciences deliver advice concerning Planetary Science no later than 31 March 2011

<u>Summary of instructions:</u>
The Space Studies Board has established a decadal survey committee to develop a comprehensive science and mission strategy for planetary science that updates and extends the Board's 2003 solar system exploration decadal survey, "New Frontiers in the Solar System: An Integrated Exploration Strategy." The new decadal survey will broadly canvas the planetary science community to determine the current state of knowledge and then identify the most important scientific questions expected to face the community during the interval 2013-2022. The scope of the survey and report shall encompass the inner planets (Mercury, Venus, and Mars), the Earth's Moon, giant planets (Jupiter, Saturn, Uranus, and Neptune), the moons of the major planets, dwarf planets and small bodies, primitive bodies including comets and Kuiper Belt objects, and astrobiology. The principal components of the report shall include:

1. An overview of planetary science--what it is, why it is a compelling undertaking, and the relationship between space- and ground-based planetary science research;
2. A broad survey of the current state of knowledge of the solar system;
3. An inventory of the top-level scientific questions that should guide flight programs and supporting research programs;
4. Recommendations on the optimum balance among small, medium, and large missions and supporting activities, informed by the Board's study on this topic ("mission-enabling activities") currently in progress;
5. An assessment of NSF-supported infrastructure;
6. A discussion of strategic technology development needs and opportunities;
7. A prioritized list of major flight investigations in the New Frontiers and larger classes recommended for initiation over the decade 2013-2022;
8. Recommendations for supporting research required to maximize the science return from the flight investigations; and,
9. A discussion of the opportunities for conducting science investigations involving humans in situ and the relative value of human-tended investigations to those performed solely robotically.

The decadal survey process depends heavily on white papers provided by the community. White papers on any topic of relevance to the survey are strongly encouraged.

Decadal Survey Structure

- The decadal survey will be conducted by a steering committee supported by topical panels. The chair of the steering committee is Steve Squyres (Cornell)
- Giant Planets - Chair: Heidi Hammel (Space Science Institute)
  - Jupiter, Saturn, Uranus, Neptune, and exoplanets, including rings and magnetic fields, but not their satellites
- Inner Planets - Chair: Ellen Stofan (Proxemy Research)
  - Mercury, Venus, and the Moon
- Mars - Chair: Phil Christensen (ASU)
  - Not Phobos and Deimos
- Primitive Bodies - Chair: Joe Veverka (Cornell)
  - Asteroids, comets, Phobos, Deimos, Pluto/Charon and other Kuiper belt objects, meteorites, and interplanetary dust
- Satellites - Chair: John Spencer (SwRI)
  - Galilean satellites, Titan, and the other satellites of the giant planets

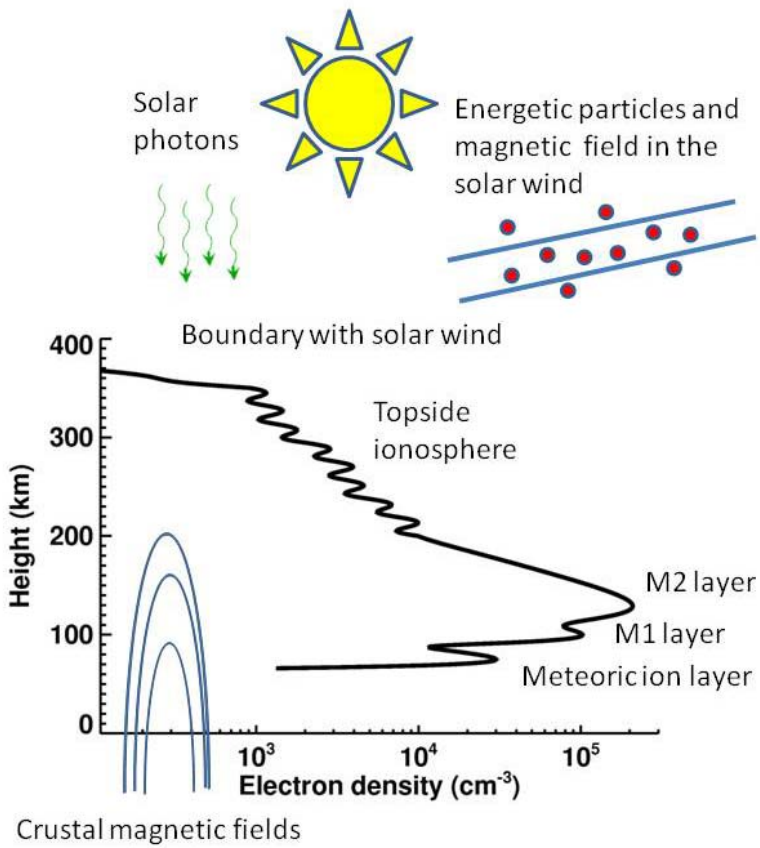
Motivation behind this White Paper

- Desire statement of support in Decadal Survey for the MAVEN mission, which will study the Martian ionosphere in unprecedented detail, and its possible extension

- Advertise that the scientific investigation of the Martian ionosphere should continue beyond MAVEN

- Identify strong candidate instruments for future studies of the Martian ionosphere

What's special about the ionosphere of Mars?



- It affects, and is affected by, the chemistry, dynamics and energetics of the neutral atmosphere
- It is a unique plasma laboratory thanks to Mars' intense, small-scale crustal remanent magnetic fields
- It is an integral part of the boundary between the planet and the solar wind, spanning the homopause and exobase of the atmosphere. It is thus involved in many escape processes and plays an important role in determining the evolution of the climate of Mars

Schematic illustration of the ionosphere of Mars

Outstanding Questions

(Limited to topics that will not have been adequately addressed at the completion of MAVEN’s nominal mission)

- Q1 Solar cycle variations
- Q2 The ionosphere below 125 km
- Q3 Relationships between solar forcings and ionospheric properties
- Q4 Temporal variations on timescales shorter than several hours
- Q5 Global ionospheric coverage accumulated over short timescales
- Q6 Hot atom escape fluxes
- Q7 Coupling between the neutral atmosphere and ionosphere

Required Measurements

<u>Possible with a range of small instrument packages</u>

- M1 Surface measurements of magnetic fields induced by ionospheric currents (Q2, Q4)
- M2 High cadence electron density profiles below the main peak (Q2, Q4)
- M3 High cadence total electron content at one geographic location (Q4)
- M4 All-sky airglow images from the Martian surface (Q4)
- M5 Upstream measurements that are made simultaneously with ionospheric measurements (Q3)
- M6 Orbiter-to-orbiter radio occultation measurements (Q5)
- M7 In situ data on neutral winds and ion velocities (Q7)

<u>Much greater advances possible with a dedicated mission</u>

- M8 Aeronomy constellation mission (At least Q1, Q3, Q4, Q5, Q7)

Recommendations

In priority order, we recommend that the Decadal Survey committee:

- 1) Reiterate support for the scientific objectives of MAVEN
- 2) Affirm that an extension of MAVEN will be scientifically valuable
- 3) Advise NASA to investigate resources required by a spacecraft-to-spacecraft radio occultation experiment at Mars
- 4) Recognize that valuable ionospheric and atmospheric science measurements can be made from surface assets on Mars
- 5) Request that NASA investigate ways to obtain upstream solar wind monitoring during MAVEN’s mission.
- 6) Acknowledge that the electrodynamics of Mars’ atmosphere merit observation.
- 7) Identify direct measurements of hot atom escape fluxes as a priority for MIDP and PIDDP.
- 8) Acknowledge that scientific exploration of the ionosphere of Mars should not end with MAVEN.