Mars Science Orbiter (MSO) Science Definition Team (SDT) *Update Report*

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History of Present MSO Concept:

- **2006**: MEPAG SAG(-1) endorses a strategic mission for 2013 configured for aeronomy and trace gas measurements (Farmer et al., 2006)
- **2007**: NASA narrows selection for the 2011 Scout mission to two aeronomical mission candidates, MAVEN and TGE.
- **2007**: MEPAG SAG-2 considers options for the 2013 mission opportunity with possible emphases on site certification imaging, atmospheric trace gases, orbital geophysics, and landed geophysical packages. SAG-2 defines three desirable mission concepts, but can not prioritize them (Calvin et al., 2007):

  Plan A: Atmospheric Signatures and Near-surface Change
  Plan P: Polar and Climate Processes
  Plan G: Geological and Geophysical Exploration

- **2007**: NASA directs a Science Definition Team (SDT; M. Smith, chair), to analyze *Plan A* for a 2013 mission in the context of controversial (unpublished) reports of methane detection in the atmosphere of Mars
- **2008**: The MSO SDT makes its final report, identifying 5 major objectives for a 2016 orbital mission (see next slide)
- **2008**: The 2011 Scout mission is slipped to the 2013 launch opportunity
- **2008**: MATT-2 places MSO in 2018 mission slot in its preferred Mars architecture scenarios, principally to preserve EDL capability from MSL
- **2008**: New Earth-based observations of Mars methane are published

The SDT originally identified five major objectives for MSO:

- Atmospheric Composition

  Sensitive and comprehensive survey of the abundance and temporal and seasonal distribution of atmospheric species and isotopologues

- Atmospheric State

  Provide new observations that constrain and validate models (winds), and extend the present record of martian climatology to characterize interannual variability and long-term trends

- Surface Change Science

  Investigate surface changes as recorded in surface properties and morphologies due to seasonal cycling, aeolian movement, mass wasting, small impact craters, action of present water

- Site Certification Imaging

  HiRISE-class imaging (~30 cm resolution) for certification of future landing sites

- Telecommunications Support

  Support relay of science data from, and commands to, landed assets

Original MSO SDT History:

- Telecons/meetings October–December 2007
- Final written report January 2008
- Report to MEPAG February 2008

MSO SDT Telecon Update:

- Telecon held February 17, 2009
- Briefing to Michael Meyer
- Briefing to MATT-3

The purpose of the SDT Telecon Update was to consider the previous MSO SDT findings in light of:

- Reported (and now published) detection of methane in the Mars atmosphere and its possible extreme variation in space and time
- The reduced funding available for a 2016 mission opportunity

Questions to the SDT:

- Do the measurement priorities change?
- What is the minimum scientifically credible mission that could be flown to address the measurement priorities?

MSO SDT Telecon Update Participation:

Michael Smith, Chair, NASA Goddard Space Flight Center
Don Banfield (not present, sent email), Cornell University
Jeff Barnes, Oregon State University
Phil Christensen (not present), Arizona State University
Todd Clancy, Space Science Institute
Phil James, University of Toledo (retired)
Jim Kasting, Pennsylvania State University
Paul Wennberg, Caltech
Daniel Winterhalter, JPL
Michael Wolff, Space Science Institute
Rich Zurek, JPL (Mars Program Office)
Jan Chodas (not present, now on JUNO), JPL
Michael Meyer (present at beginning), NASA Headquarters
Tomas Komarek, JPL (MSO Mission Concept Manager)

Given funding limits and the potential importance of the reported methane, the MSO components are prioritized as follows:

1a. Atmospheric Composition

Sensitive and comprehensive survey of the abundance and temporal and seasonal distribution of atmospheric species and isotopologue (not just methane) is the most direct follow-up to the questions raised by the reported methane discovery

1b. Atmospheric Climatology (State)

The first priority is for temperature, dust, and water vapor measurements required to extend long-term climate records for validating transport and photochemical models.

2. Atmospheric State

The second priority is to improve temperature and water vapor measurement accuracy in the presence of dust and to better characterize atmospheric transport by making wind measurements and mapping temporal variations of key transported species (e.g., CO) and methane with good spatial resolution

3. Surface Change Science

This science, important in its own right, does not directly follow up on the reported methane discovery. In a financially constrained environment, it may not fit with instruments required to address (1) and (2) above. Does not necessarily require HiRISE-class resolution.

- **Site Certification Imaging**

  HiRISE-class imaging is not included due to resource constraints and science priority

- **Telecommunications Support**

  Assumed to be a requirement

Minimum mission ("MSO-min"):

- Include instrumentation (next slide) to support priority #1:
  a) Measure concentrations of a *suite of trace gases* of photochemical and radiative importance, including methane and *potential* molecular species related to characterizing its origins and loss (life cycle process); emphasis is on detection (bright source, limb path, spectral survey) and low-spatial resolution mapping
  b) Measure those aspects of atmospheric state needed to constrain photochemical and dynamical (transport) models (T, dust) and to provide context for trace gas detections (dust, H_2O); emphasis is on extending climate record used to validate climate simulations

- Relax constraints for near-polar orbit

  Optimize inclination to support solar occultation (atmospheric composition survey) measurements

Sample “strawman” MSO Payload

- Solar occultation FTIR spectrometer*

  Atmospheric composition: *Addresses Priority #1a and some of #1b*

- Sub-millimeter spectrometer+

  Wind velocity and water vapor, temperatures, etc. without dust effects
  Addresses Priority #2

- Wide-angle camera (MARCI-like)*

  Daily global view of surface and atmospheric dust and clouds
  Addresses Priority #1b

- Thermal-IR spectrometer (TES-like)*

  Daily global observations of temperature, dust, ice, water vapor
  Direct comparison to previous climatology record
  Addresses Priority #1b

- High-resolution camera (HiRISE-class) or 1-m/pixel class

  Surface change science and site certification
  Addresses Priority #3

* *2016 (MSO-min) Constrained Payload* +*included in MSO-lite*

MSO Orbit characteristics:

- Near-circular at low altitude (300 km)
    - Allows best global mapping
    - Allows most solar occultation opportunities
- Near-polar inclination (82.5°)
    - Lower inclination gives faster precession of local time and more uniform latitude distribution of solar occultation points
    - Science requires full diurnal cycle in less than a Martian season
    - Higher inclination favors polar surface imaging
    - Desire to image rotational pole at airmass of two or less
- Orbit altitude increased to 400 km at some point for planetary protection

MSO-min (or MSO-lite) Orbit Characteristics:

- Near-circular at low altitude (300 km) – *unchanged*
- High (but not near-polar) inclination (~74˚)
    - *Optimized* for solar occultation
- Orbit altitude raise an option for relay; consider burn/break-up option for planetary protection

Atmospheric Composition for MSO-min → Same as MSO

Atmospheric evidence for present habitability

Key measurement objectives:

Photochemistry (H_2O_2, O_3, CO, H_2O)
Transport (CO, H_2O)
Isotopic Fractionation (isotopomers of H_2O and CO_2)
Surface exchange (CH_4 and H_2O)
Inventory (H_2O, HO_2, NO_2, N_2O, CH_4, C_2H_2, C_2H_4, C_2H_6, H_2CO, HCN, H_2S, OCS, SO_2, HCl, CO, O_3)

Measurement goals:

Solar occultations to obtain sensitivity of 1–10 parts per trillion
Limb-geometry mapping at sensitivity of 1–10 parts per billion with latitude/longitude/altitude/local time coverage

Intermediate Mission (*preferred if resources available*): MSO becomes "*MSO-lite*"

- Include MSO-min capabilities (previous slides)
- Augment with instrumentation to address priority 2, with the following prioritized (first to last) capabilities:
  a) Map selected trace gases (CO, H_2O, H_2O_2, [TBD]) with greater spatial resolution and unaffected by presence of atmospheric dust to better constrain transport models
  b) Map temperature with greater spatial resolution and unaffected by presence of atmospheric dust
  c) Map winds by direct observation
  ⇒ *Capabilities similar to sub-millimeter "strawman" instrument, but there may be other options*
- Next Augmentation (Priority 3): 1-m/pixel class imager for surface change science
- MSO-min orbit is deemed acceptable for MSO-lite unless surface change science is retained (for polar coverage)

Summary

<u>MSO-min</u>: Minimum mission could follow up on the methane discovery within the harsh constraints outlined for a 2016 U.S. Mars mission

- ⇒ Will significantly improve knowledge of atmospheric composition and chemistry within the context of understanding Mars habitability
- ⇒ Extend climatology record to characterize long-term trends for climate & transport model validation

<u>MSO-lite</u>: Augmented mission can provide significant gain given increased resources or foreign partnering

- ⇒ Detailed mapping more likely to identify localized sources
- ⇒ Validate transport models and improve knowledge of current climate
- ⇒ Some surface change detection (lower priority)

<u>MSO</u>: Full-up mission provides opportunity for all of the above, possibly longer life, global surface change detection, and site certification

Note: Telecom support included in all concepts

MSO SDT: Response to Questions (1 of 2)

1. Do the MSO measurement priorities change in light of the reported detection of methane and its possible extreme variation?

- The new reports give increased emphasis to the atmospheric composition and atmospheric state objectives of the previously defined MSO. The reported methane:
  - — Detection implies that the subsurface is indeed an ***active source*** of trace gases, possibly biochemical as well as geochemical in nature, in the modern epoch (< 1000 years)
  - — Has a spatial and seasonal variability, limited by the range of observations possible from Earth-based instruments, that is ***not consistent with present understandings*** of Martian photochemistry and requires study
- The required measurements needed to understand the four-dimensional chemical nature of the atmosphere and its interaction with the sub-surface are unchanged.
  - — Reported concentrations (~10 ppb) are ***consistent with the measurement capabilities previously advocated for MSO***

MSO SDT: Response to Questions (2 of 2)

2. What is the minimum scientifically credible mission that could be flown to address the measurement priorities?

- The minimum measurements needed to understand the four-dimensional chemical nature of the atmosphere and its interaction with the sub-surface are to:
  - ***Conduct a sensitive and comprehensive survey*** of trace gases, including (but not limited to) methane and their isotopologues
  - ***Conduct basic measurements of atmospheric climatology*** needed to validate models, to provide aerosol information for understanding heterogeneous chemical processes, and to extend the present records.
  - ***Carry telecommunications capability*** needed to support future landed missions

- As resources permit, this minimum capability should be augmented with the following capabilities (in priority order):
  - ***Map selected trace gases*** *at higher resolution to find source regions*
  - ***Map temperature more accurately in the dusty atmosphere***
  - ***Map winds by direct observation or provide surface imaging***

Back-Up

MSO: Atmospheric State

Climate processes responsible for seasonal / interannual change

Key measurement objectives:

Wind velocity
Water vapor and atmospheric temperature without influence of dust
Diurnal coverage of all parameters
Vertical profiles of all parameters
Continue climatology monitoring

Measurement goals:

2-D wind velocity, temperature, aerosol optical depth, water vapor at
- 5 km vertical resolution over broad height range
- diurnal coverage twice per martian season
- 85% or better coverage along orbit

⇒ Extend record of climatology to characterize long-term trends
⇒ Validate and significantly improve models of transport and state

MSO: Surface Change Science

Recent processes of surface-atmosphere interaction

Key measurement objectives:

Polar layered terrain (“Swiss cheese”)
Aeolian features (dust devil tracks, streaks, dust storm changes)
Gullies, avalanches, dune motions
Formation of small impact craters over time

Measurement goals:

1 meter resolution sufficient for these goals
Ability to image all areas (including poles)

⇒ Understanding of active processes and the role of volatiles in this activity
⇒ Exchange of volatiles between the polar surface and atmosphere, and the current evolution of the polar terrains