# MARS SCIENCE PAYLOAD ACCOMMODATION AND OPERATIONS.

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**Introduction:** The sustained robotic exploration of Mars has: (1) enabled profound scientific advances in our understanding of our sibling planet, (2) has captured the excitement of the public, and (3) has developed the groundwork for prolonged robotic and eventual human exploration. The successful exploration is achieved in part by collaboration between the science payloads and the spacecraft on which they reside. Lockheed Martin (LM) has significant experience in accommodating orbiting and landed payloads on Mars exploration missions such as Viking, Mars Global Surveyor (MGS), Mars Odyssey (ODY), Phoenix (PHX), and Mars Reconnaissance Orbiter (MRO). This abstract is in response to Challenge Area 1: Instrumentation and Investigation Approaches.

Payload accommodation falls into a few broad categories, which are as follows: (i) *Resource Allocation*. Mass, power, volume, and electrical interfaces are required for all instruments. (ii) *Environmental requirements*. All planetary spacecraft and their payloads must spend some time in deep space en route to their destination. This requires an ability to manage the instruments within acceptable temperature ranges, and exposes the instruments to some level of radiation. Depending on the duration of the mission and whether the mission involves flyby, orbiting Mars, or landing, the breadth of environmental requirements may include other factors such as residence in the Martian atmosphere, larger temperature excursions, increased radiation exposure, eclipses, materials compatibility with dust, planetary protection considerations, etc. (iii) *Operational considerations*. The nature of an instrument's operation can span an impressive range of plans, with correspondingly different support requirements imposed on the spacecraft. Nadir-pointed remote sensing instruments can be relatively straight-forward, but tight pointing and/or stability control, complexity of commanding, or coordination between instruments can cause significant challenges.

The ability and ease of providing these accommodation requirements is different between orbiters and landers. Here we describe two example scenarios of instrument accommodation for Mars orbiter and a Mars lander. We use past and present LM-designed and built spacecraft as templates upon which to base our analysis, as well as a point trajectory for the 2018 opportunity. For each scenario, we provide an example payload that addresses the science objectives as defined for Design Challenge 1.

**Orbiter Payload:** Challenge Area 1 includes instrumentation with the capability to interrogate the shallow subsurface of Mars from orbit, as well as achieve measurements of surface characteristics such as composition and morphology. Visible and IR instruments have extensively and repeatedly mapped Mars to increasing resolutions, and have provided a wealth of information regarding surface processes. MARSIS and SHARAD probe depths a few tens of meters and deeper, and have provided important constraints on the extent and lower depths of ice deposits in the high latitudes of Mars. However, a missing link between these two regimes is the nature of the Martian surface at depths in between the imagers and orbiting radar sounders. A significant fraction of Mars is covered in a dusty sediment layer, transported from around the planet. This layer can mask the native geology of a region, confounding attempts to understand the extent of volcanic flows, near-surface ice and impact ejecta. Mapping the extent of surficial layers themselves is critical to understanding the types and rates of processes acting over Martian history.

Short-wavelength Synthetic Aperture Radar (SAR) is a remote sensing technology uniquely equipped to address this knowledge gap. Using P- to C-band wavelengths (cm-scale), an orbiting SAR will unveil a wholly new Mars.

**Trajectory Description:** The 21-day launch period opens on May 10, 2018. The direct injection trajectory has a C3 between 8.47 $km^2/s^2$ and 8.75 $km^2/s^2$, with a < 250 day travel time, resulting in a Mars arrival date in January of 2019. MAVEN and MRO have similar Mars Orbit Insertion (MOI) delta-v's; we use MRO's, which is slightly larger and may be more appropriate for a remote sensing mission targeting the Martian surface. With these parameters, Table 1 summarizes the total launch mass for three launch vehicle options.

**Table 1. Launch vehicle capabilities for reference 2018 launch opportunity.**

| Launch Vehicle | Launch Mass |
|---|---|
| Atlas V 401 (NLS2) | 2490 kg |

**Orbiter Scenario:** We use the MAVEN spacecraft (Figure 1), currently under construction for launch in 2013, as a reference spacecraft for an orbiter mission. The CBE dry mass of the spacecraft, minus the instruments and their supporting hardware, is about 623 kg. The monoprop fuel mass required for the maximum launch mass is 1290 kg, which includes 50 m/s of unallocated delta-v. Given the max propellant load, a system-level contingency of 15% and a typical system design practice of 30% mass margin, Table 2 summarizes the CBE, CBE+contingency, and max payload masses available. This mass easily accommodates the mass necessary to fly a capable synthetic aperture radar system, including the antenna feed, the deployable reflector, and boom.

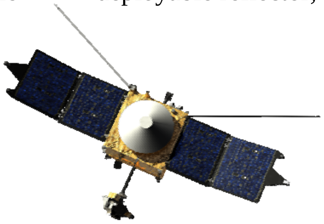

**Figure 1: The MAVEN spacecraft (itself derived from MRO), provides a capable architecture that easily accommodates a deployable SAR system.**

**Table 2. Payload mass values for orbiter.**

| CBE Mass | w/ 15% Cont | w/ 30% Margin |
|---|---|---|
| > 150 kg | > 172.5 kg | > 225 kg |

*Operations*. The orbit insertion burn assumes subsequent aerobraking to reach the science orbit. The successful use of aerobraking for Magellan, MGS, ODY and MRO, as well as continued application on MAVEN, provide a strong baseline of experience to implement this strategy. Aerobraking reduces the propellant needed to reach the final science orbit, thereby increasing the mass available for science payload. During science operations, the general strategy of data acquisition interlaced with data return to Earth, common to many remote sensing platforms around Mars, is directly applicable to this mission. Because the orbital environment around Mars is well characterized from past and current missions, the environmental design requirements are well bounded.

Note that the orientation of the SAR instrument during data acquisition is compatible with other remote sensing instruments. Given the available payload mass exceeds the mass necessary for a SAR system, an orbiter mission with a SAR payload could carry one or more additional remote sensing instruments.

**Lander Payload:** Challenge Area 1 includes instrumentation with the capability to interrogate the shallow subsurface while in-situ. Although lander-based missions do not provide global coverage, their advantage is direct access to the subsurface, providing ground truth and discoveries that an orbital mission cannot make, e.g., soil compositional discoveries by PHX and sulfate-rich subsurface soils by MER. PHX used an arm with an end-effector to access the sub-surface to several cm depth.

LM developed the Apollo Lunar Drill and the Viking sampling system; further, the PHX design has been the spacecraft architecture for numerous near-surface science investigations and their diverse instrument suites (analyzed for mission opportunities spanning the 1998 to 2018 timeframe, see [1]). We consider a design derived from the Apollo drill. The mass of the Apollo drill and supporting equipment was around 14 kg, consumed 430 W during operation, and was designed to penetrate to 3-m depth.

**Lander Scenario:** We use the PHX spacecraft (Figure 2), which successfully reached the surface of Mars on May 25, 2008, as a reference spacecraft for a lander mission. An initial rough estimate for the payload mass available in this opportunity is ~5 kg greater than the PHX payload, or 58.7 kg (PHX) + 5 = 62.7 kg, although the exact number depends on the landing site specifics (e.g., approach trajectory and landing site altitude). (Increased payload capability is possible, requiring modifications to the PHX design.) The available payload mass well envelopes that required for the drill, including allocation for mounting and deployment hardware, and analytical instruments.

**Figure 2: The Mars PHX lander provides an excellent platform for a landed mission utilizing drill technology to reach the subsurface.**

*Operations*. The Apollo 17 drill reached a depth of 305 cm in less than 4 min [2]. Solar-powered landers are inherently driven to achieve energy-balance, and the expected low duty cycle is necessary to reach scientifically valuable subsurface depths indicates this is a viable collaboration between spacecraft architecture and subsurface access technique.

**Connection to Human Exploration:** LM has extensive experience with payload accommodation and has been working low cost mission concepts that address critical science and human exploration requirements for atmosphere and subsurface characterization. We have been working closely with the planetary community to develop low-cost, innovative orbiter mission concepts to measure trace gases in the atmosphere with fourier transform spectrometers and millimeter wave instruments, and to penetrate the surface with synthetic aperture radar instruments. These missions would provide critical measurements for human exploration such as subsurface ice, trace gases, and long duration global dust storms.

**References:** [1] Warwick R.W. et al. (2012), this conference. [2] Han G. et al. (2009) *Principles of Drilling and Excavation*, in Drilling in Extreme Environments, Bar-Cohen and Zacny, eds, Wiley-VCH press.