The 'Long' View with ASO: the Areostationary Science Orbiter. F. J. Calef III[1] and T. McElrath[1], and H. Hemmati[1] [1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109, fcalef@jpl.nasa.gov.

Abstract: An areostationary science orbiter (ASO) (Figure 1) would be a significantly innovative spacecraft configuration at Mars that could increase spectral coverage around the equator, support high data rates for current and future robotic assests, as well as provide a technology demonstration for future human-rated missions. The dwell time over surface targets and/or surface assets in this orbital configuration are minutes or even hours providing an unprecedented signal-to-noise (SNR) return compared to existing polar mapping spacecraft platforms imaging for mere seconds. Long-term observations would be real-time or near-real time versus seasonally for atmospheric and surface properties (e.g. thermal inertia). This orbiter would meet the near-term (2018) requirements and support both robotic and human related missions to Mars in the 2020 and beyond timeframe. This includes potentially adding a plethora of new landing sites for a future Mars Sample Return (MSR) mission by increasing the diversity of sites necessary for a high-value, high-science return goal. Science packages would be upscaled or modified versions of several Mars Reconnaisance Orbiter (MRO) instruments and spacecraft bus, thereby maintaining some heritage with known hardware and operations costs. The main ASO science instrument would have a goal to map large swaths of the equatorial latitudes (±30° latitude) in high spectral (>500 channels) and 'moderate' spatial (~40m/pixel) resolution by pairing the High Resolution Science Experiment (HiRISE) optics with the spectral sensor of the Compact Reconnaissance Imaging Spectrometer (CRISM) sensor. A secondary science instrument would focus on atmospheric and temporal changes over the full Mars disk from sunrise to sunset, exploiting the benefits of the orbit height as do Earth-based geostationary weather satellites (e.g. GOES). An optical (i.e. laser) communication system would allow Gb/s data rates and potentially continuous X or K band contact with surface assets as a technology demonstration necessary for future human missions. Cost savings are expected to be realized by a reduced science instrument payload and heritage with MRO instruments and spacecraft bus, though some savings may be partially offset by increased fuel or engine requirements.

The Current State of Mars Orbiters: All of the current Mars orbiters, Mars Odyssey (11+ years old), MRO (6+ years old), and Mars Express (nearly 9 years old), are aging with instruments showing degradation in returned data (e.g. one CCD sensor on HiRISE is 'dead' and CRISM is having difficulty maintaining cold temperatures for hyperspectral data collection). In all likelihood, there will be limited (if any) performance from these assets in the 2018 timeframe and beyond. These instruments are critical to Mars science and their telecommunication relay functions provide critical uplink/downlink capability for MER Opportunity and the future Mars Science Laboratory (MSL) rover. All future human or robotic missions will rely heavily on orbital capabilities to both attain new science data and high-bandwidth (Gb/s) communication with Earth. While the visible and spectral data returned has been excellent from current and past missions, the ability to provide temporal repeat coverage is hampered by the standard polar mapping orbit and SNR ratios limited by the short dwell time (seconds) of current orbital assets. CRISM hyperspectral data is limited to 10x10 to 10x20 km image footprints at ~20 to ~40 m/pixel at best resolution [1]. Many potential MSR and future human sites require many CRISM full resolution images just to cover the landing ellipse, much less obtain data for regional context.

Areostationary Orbiter Advantages: The largest advantage to an areostationary orbit for science investigations is the long dwell time. Instruments that can 'sit' over an area for long periods (minutes, even hours) to increase the SNR by several orders of magnitude at any one target on Mars. In addition, time-variant processes (e.g. cloud formation, dust-devils, thermal inertia, impact cratering events) could be sampled in real-time for long durations and not sampled over hours (globally) or months (locally). In terms of data relay, the areostationary orbiter could be 'parked' at the longitude of a surface asset and maintain continuous radio contact with it. Studies have already been performed that show optical systems decrease communication equipement mass (60%), have half the energy requirements of an X-band system with a smaller antennas (30 centimeters compared to 1+ meters on spacecraft), yet increased downlink (10 Gb/day) from a Mars mission at 2.7 AU [2].

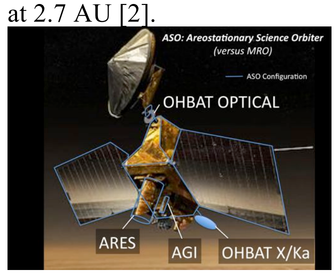

Figure 1: ASO

With a modest amount of propulsion, the spacecraft could transition to an areosynchronous orbit by 'scooting' around Mars to observe new areas of interest and obtain stereo imaging and rotate off-nadir to obtain targets easily within +-30° latitude without significant pixel spatial distortion. Another orbital configuration could be to incline the orbit by 25° to gain nadir imaging over a wider latitude range. Since all current MSR proposed landing sites are within the aforementioned latitude band and human-rated missions are likely going to land near the equator to increase delta-V to return to orbit,an areostationary orbiter could serve future robotic and human missions. This includes the ability to maintain real-time telemetry necessary for a Mars Ascent Vehicle (MAV) launch and recovery during a MSR mission potentially in the 2020's.

Challenges: The altitude for a standard polar mapping orbit is a mere ~400 km, while an areostationary orbiter would be placed at ~17000 km above the equator. While this is still perfect for doing global analysis of weather patterns and some surface science (albedo changes, impact events at night, etc.), ground instantaneous field of view (GIFOV, i.e. pixel size on the ground) would be significantly reduced for all instruments. However, this could be overcome by pairing HiRISE optics (1.14 FOV) with a CRISM-like hyperspectral (557 channels) CCD sensor. The combined instrument would yield hyperspectral coverage at ~40m/pixel without oversampling (assuming a 1 microradian instantaneous FOV like HiRISE) over a ~169 km swath. Oversampling or 'super-resolution' imaging could cut this in half. Extended missions, or even the nominal mission, could trade dwell time for increased resolution by lowering the spacecraft height to gain the resolution afforded standard mapping altitudes (Table 1). However, the decreased orbital period allows revisiting a site up to several times a day versus several times a year compared to high-angle mapping orbits. Orbital maneuvers would require either an increased fuel load, a switch from monopropellent to bipropellent for improved delta-V, or use of solar electric propulsion (SEP) (e.g. Hall thrusters). However, this mission can be accomplished with chemical propulsion (CP) only.

Table 1. Orbit Height, Period, and Pixel Size

Orbit Height (km)	Orbit Period (hours)	Pixel Size (m)
17000	21	41
10000	11	24
5000	5	12
1000	2.1	2.4
500	1.7	1.2

Supporting Human Missions: Human missions will require large and preferably constant contact with Earth. The largest advantage that this orbiter would provide is direct and constant telecommunication relay to the surface. This could be considered a technology demonstation of near-continuous communication experiments with current rover assets and high-bandwith communication (enough to support video!) with Earth [3]. There is also the possibility of using the International Space Station (ISS) as a 'ground station' for the optical communication thereby leveraging existing human space flight assets to avoid atmospheric attenuation and support current human space missions.

Straw-Man Package: I would offer the following instrument types and capabilities for this orbiter:

1. **Areostationary high-REsolution Spectrometer (ARES)**: HiRISE instrument class optics with a hyperspectral CRISM class sensor. Stereo could be obtained by spacecraft reposition or roll. This would directly support science objective of obtaining high spectral resolution of rock outcrops reachable by future robotic (i.e. MSR cache rover) and human landed missions.
2. **Atmospheric Global Imager (AGI)**: A Mars Color Imager (MARCI) class instrument adapted to areostationary orbit. The main focus of this instrument would be for atmospheric science and EPO daily Mars movies. Wavelengths covered would include visible, near-IR and possibly thermal channels for water vapor and cloud mapping. Such real-time observations would allow an unprecedented view of Mars' global climate cycle.
3. **Optical High-BAndwidth Telecommunications (OHBAT)**: One dish (X/Ka band) dedicated to Mars surface asset(s) relay and an optical communication link to Earth as a technology demonstration.

Spacecraft Design and Costs: In many ways, this is an MRO class vehicle in an aerostationary orbit. The total cost for MRO was $845 million USD in 2012 dollars. Savings are possible through heritage with the MRO spacecraft bus, reduced instrument payload (No CTX, SHARAD or Mars Radiometer), and replication of some MRO science instruments. Reductions may be offset by changes from a monopropellent to a bipropellent system or to SEP versus a CP system.

Conclusion: An areostationary orbiter concept combines the necessities of high spectral resolution for analyzing the Mars surface with future technical demonstrations of increased bandwidth with near continous telecommunication with surface assets for future robotic and human missions.

References: [1] Murchie et al., JGR-Planets, doi:10.1029/2006JE002682, 2007. [2] H. Hemmati et al., TDA Progress Report 42-128, 1997. [3] Edwards et al., Concepts and Approaches for Mars Exploration conf. abs.#6080, 2000. **Acknowledgements:** The research described in this article was carried out in part by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.