White paper topic submitted to MEPAG 38
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Observing Mars from Areostationary Orbit: Benefits and Applications

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White paper rationale.

The Martian atmosphere (from the surface up to the exosphere) is a very dynamic system. The lower atmosphere quickly responds to strong radiative forcing due to the absorption of solar radiation by dust particles lofted from the surface by different processes, including dust storms. Radiative forcing due to water ice clouds has a significant impact on the lower atmospheric circulation as well. The effects of dust storms have been observed throughout the atmospheric column, affecting even the ionosphere and the escape of volatiles. These upper layers of the atmosphere, on the other hand, are strongly affected by space weather. So far, such dynamical phenomena spanning a large range of temporal and spatial scales have been observed mainly from spacecraft in polar or quasi-polar orbits, which sample only a narrow range of local times and cannot provide continuous and simultaneous observations over fixed, large regions. Such continuous and simultaneous observations are necessary to understand rapidly evolving atmospheric phenomena, particularly over the diurnal time scale that remains largely unexplored.

This limitation can be overcome by using spacecraft in an equatorial, circular, planet-synchronous (i.e. areostationary) orbit at an altitude of 17,031.5 km above the Martian surface. The unique scientific advantages of satellites in areostationary orbit for weather monitoring are comparable to those provided by geostationary satellites on Earth. These platforms greatly increase the temporal resolution and coverage of single events, allowing observations at multiple local times simultaneously. We expect that these observations also would lead to essential breakthroughs when used for atmospheric data assimilation in global climate models. We are at a turning point in Martian meteorology, shifting from exploring to monitoring and forecasting. As for Earth meteorology, the use of planet-synchronous orbits has the potential to produce a paradigm shift on Mars.

Besides their possible use as Mars weather satellites, however, spacecraft in areostationary orbit can be used for several other important tasks. They can provide space weather monitoring, as they orbit outside Mars' bow shock, and can measure the time-variable forcing that originates in the solar wind at sub-hourly time scale. They can be used for the study of surface properties such as thermal inertia and albedo, as well as their temporal changes (possibly linked to the mobility of surface dust reservoirs). Furthermore, several studies have highlighted the benefits of satellites operating in areostationary orbit for relaying communications from robotic and human missions on the Martian surface. An areostationary orbiter, in fact, is the ideal rover or lander operations relay, allowing continuous streaming of imagery and data, and anytime uplink of command sequences. As such, an areostationary relay would meet the Human Exploration and Operations (HEO) goals of continuous relay from the Martian surface (Breidenthal et al, 2018), and be ideally positioned to serve as a mothership or computational resource for future exploration (March & Casler, 2020, Vander Hook et al., 2020).

This white paper aims to discuss in some detail the overall benefits of the areostationary orbit, while looking at future scientific and operational applications with single satellites as well as networks/constellations.

Desired community involvement.

We would welcome contributions from the Mars community on any of the topics outlined below. Contributions can include collaborative section writing, suggestions, reviewing, etc. We are especially interested in contributions related to science/operation cases for space weather monitoring and surface property studies (including possible aeolian studies) from areostationary orbit. We would also welcome your endorsement of this white paper if you do not want to contribute but think that observing Mars from areostationary orbit is worthy.

Proposed white paper outline.

1. Introduction
2. Elements of areostationary orbit dynamics
3. Benefits of the areostationary orbit
   - 3.1. Continuous coverage
   - 3.2. Simultaneous coverage
   - 3.3. Quasi-global coverage (areostationary constellation)
4. Applications of the areostationary orbit
   - 4.1. Scientific applications
     - 4.1.1. Atmospheric weather monitoring
     - 4.1.2. Space weather monitoring
     - 4.1.3. Study of surface properties
   - 4.2. Operational applications
     - 4.2.1. Weather forecasting
     - 4.2.2. Telecommunication
     - 4.2.3. Computational resource for exploration
5. Conclusions and recommendations

Additional information.

This white paper is currently in the planning phase. Expected schedule is the following: Definition of white paper team of contributors and tasks by end of April, first draft by end of May, final version by mid-June, pre-submission diffusion to the community for seeking endorsement/co-signatories by end of June, submission by July 3rd. It is likely that Microsoft Teams is going to be used for collaborative writing and communication among white paper team members (free download of desktop/mobile version). If you want to contribute to or endorse this white paper, please send an email to the point of contact below specifying your full name, institution(s), expertise, and your intention (contribution/endorsement). Your email address will then be added to MS Teams.

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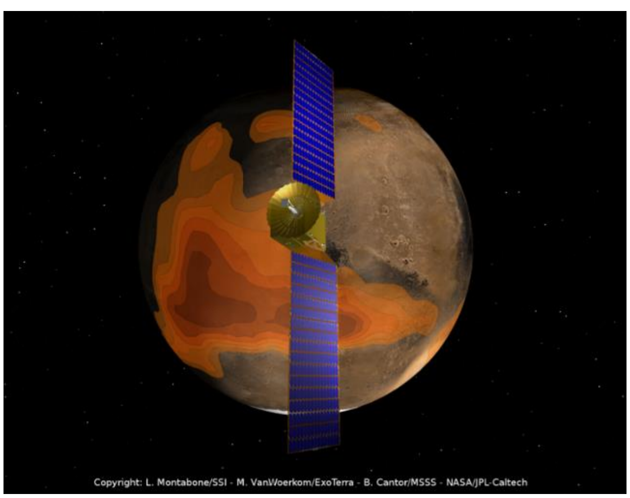

This picture shows a satellite in areostationary orbit observing a regional dust storm on Mars. The storm is highlighted using daytime and nighttime column dust opacity measurements, and is superimposed onto the daytime visible image of the full Martian disk. This graphic was included in the NASA "Planetary Science Deep Space SmallSat Studies" (PSDS3) report on the "Mars Aerosol Tracker" (MAT) mission concept.