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Preliminary results of the search for possible Martian landing sites to be considered for future European exploration missions

P. Martin

European Space Agency, European Space Astronomy Centre (ESAC), Villafranca del Castillo (Madrid), Spain (patrick.martin@sciops.esa.int / Fax: +34 91 813 11 72)

The recently adopted European Space Policy aims at expanding and coordinating the role and activities of Europe's space actors with the purpose of increasing both scientific knowledge in selected space domains and the European presence in the Solar System, as well as optimising the relevant societal benefits. With our Moon and in particular Mars as primary targets of exploration goals for the Solar System, and following a number of very successful orbital missions performing detailed remote sensing and mapping of these planetary bodies, probe landings on the surface of the Moon and Mars represent the next stepping stone of the exploration of our close planetary environment.

Along with developing the hardware capabilities required for Europe to reach such ambitious goals, it therefore becomes increasingly important to pinpoint with precision a number of landing sites well suited for the safety and scientific success of future robotic missions. Focusing on Mars, and although a number of candidate landing sites and associated catalogs with available scientific justification already exist, the results being obtained by orbiters such as Mars Express and Mars Reconnaissance Orbiter are fundamentally transforming our knowledge of the planet's surface, which in turns highlights the need to review, update and revise the candidate sites for future landing missions on Mars.

Detailed investigations of possible future Martian landing sites for European missions are ongoing, based on the wealth of scientific data and high-resolution mapping products available. In order to support the identification of suitable sites, various mapping

products (geological, hyperspectral and compositional) can be consolidated, and various areas of Mars identified in the recent scientific literature as primary targets for landing can be taken into account for further, refined assessment of their suitability for landing. Seasonal and climatic effects potentially influencing landing shall also be considered, as well as lessons learned from past landing experiences. Finally, no-landing zones shall be identified based on a number of available criteria.

A preliminary investigation and classification of potential landing sites for future European Mars exploration missions is summarised here, with the assumed following general requirements:

- Moderate latitudes (e.g., 15ºS to 45ºN). Such a latitude range would be suitable for Exomars.
- Low-to-moderate elevation (e.g., below 2000 m)
- Relatively flat surface in the landing ellipse (e.g., slopes $< 15^{o}$)
- Low-to-moderate rock abundance (e.g., $< 20\%$)
- Moderate thermal inertia (rock/dust abundance)
- Suitability to overriding scientific goals and targets of interest (e.g., niches of extant life, olivine sites, or sites where phyllosilicates or hydrated sulfates were identified)
- Other constraints that shall be taken into account in a more detailed study:
  - Atmospheric and aeolian activity
  - Power and communications systems requirements
  - Illumination and temperature requirements
  - Biological potential and planetary protection

Possible landing regions on Mars resulting from this preliminary investigation can be categorised into two classes, depending on the level of risk assessed for the landing in terms of, e.g., roughness and rock abundance:

- Low-risk regions: Amazonis Planitia, Utopia Planitia, and Elysium Planitia. One of their potential drawbacks is that most areas of these regions exhibit a relatively high dust index [1] which could be detrimental to the scientific interest of the in-situ mission.

- Moderate-risk regions:
  - Syrtis Major / Nili Fossae, where phyllosilicates and hydrated minerals can be found based on recent evidence from orbit (Mars Express/OMEGA [2]).
  - Isidis Planitia, in particular because this region presents a low vertical roughness [3].
  - Chryse/Acidalia Planitia, where phyllosilicates, hydrated minerals and sulfates can be found [2].
  - The region that spans the terrains from Sinus Meridiani to Syrtis Major, between 15ºS and 45ºN. This region exhibits a high dust index, and is represented by rougher, heavily cratered terrains in many areas.

Within these regions, a more detailed identification of landing sites can be performed by refining the study (top-down approach) using higher-resolution geological and compositional maps (e.g., Mars Express/HRSC-OMEGA and/or MRO/HiRISE-CRISM) coupled with other parameters and constraints. Such detail work will be reported and the resulting suitable landing sites will be made available to the science-driven and success-oriented selection process for future Mars missions such as Exomars. This shall then be confronted with bottom-up approaches consisting in the pre-selection of sites purely based on scientific goals prior to the assessment of their suitability for landing.

References: [1] Ruff and Christensen, J. Geophys. Res. 107, 2002. [2] Bibring et al., Science 312, 2006. [3] Kreslavsky and Head, Geophys. Res. Lett. 29, 2002.