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THREE SCENARIOS FOR VALUABLE PLANETARY SCIENCE MISSIONS ON MARS: NEXT GENERATION OF CUBESATS TO SUPPORT SPACE EXPLORATION

Abstract

Planetary science originally tended to make use of “flagship” missions characterized by big satellites and expensive resources. In the near future this traditional satellite paradigm could dramatically change with the introduction of very small satellites. This shift towards smaller, less expensive devices mirrors the paradigm shift that happened in the computer industry with the miniaturization of electronics, as focus has moved from massive machines to personal computer up to smart phones. The ultimate expression of spacecraft miniaturization is today represented by CubeSats, but while over a hundred CubeSats have been launched into Earth orbit, space-based research beyond LEO struggles to find practical application. CubeSat small size poses hard challenges for independent planetary exploration, nevertheless they remain highly attractive due to the reduced development time and cost coming from platform modularity and standardization, availability of COTS parts, reduced launch cost. Constellations of CubeSats, collaborative networks, fractionated or federated systems are becoming popular concepts as they can offer spatially distributed measurements and the opportunity to be used as disposable sensors with a flexibility not achievable by single-satellite platforms. We have worked towards advancing the state of the art in CubeSat missions design and implementation by defining the range of science capabilities for CubeSats beyond LEO, and by enhancing the top technological challenges to support science objectives (e.g. propulsion, communications, radiation environment protection). Planet Mars was chosen as target destination to the purpose of this work, by selecting a set of scientific objectives for CubeSats to serve astrobiology goals and future human exploration. Missions to accomplish orbital and atmospheric measurement, in situ analyses related to biosignatures detection, geological and environmental characterization have been explored. The opportunity to rely on already existing space assets in the proximity of Mars, or on a “mothership” for data relay or orbit insertion, has been considered in this context. A tradespace exploration led to the definition of three classes of mission architectures, respectively based on surface penetrators, atmosphere scouts and orbiting fleet. Each architecture has been assessed in the perspective of science return against a set of leading indicators that draw out cost, utility, complexity, technology readiness among others. For each class a model-based high-level assessment of the system capability has been created, providing

a basis to elicit the definition of top-level requirements and to assess the value of science return in the context of complex mission scenarios.