EXOMARS 2020 SURFACE MISSION: CHOOSING A LANDING SITE.

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Introduction: The ExoMars 2020 rover and surface platform will land on Mars with a suite of instruments to search for the presence of past or present life. A call for landing sites was issued to the science community in 2013, and followed by 5 successive workshops, during which the LSSWG (Landing Site Selection Working Group) reviewed and down-selected the proposed sites. The fifth and last workshop took place in Leicester in November 2018 and aimed at evaluating the two final candidate sites, Mawrth Vallis and Oxia Planum, and come forward with a recommendation for one site.

ExoMars mission: After a launch scheduled in July-August 2020, the ExoMars 2020 mission will land an instrumented platform and a rover on March 19, 2021. The rover has the scientific objectives to search for signs of past and present life on Mars and to investigate the water/geochemical environment as a function of depth in the shallow subsurface. To this purpose, the rover will carry a comprehensive suite of instruments dedicated to geology and exobiology research [1]. The rover will be able to travel several kilometers and analyze surface and subsurface samples down to a 2 meter depth. This depth range has never been probed on Mars before. The powerful combination of mobility with the ability to access shallow sub-surface locations, where organic molecules can be well preserved, is unique to this mission [1].

Landing site constraints: The ExoMars landing site has to comply with the relevant engineering constraints for landing and operation [2]. Requirements are requested to be met for a landing ellipse of 19 km × 104 km, at an altitude < –2 km MOLA, at a latitude between 5°S and 25°N. Terrain should have minimal steep slopes at different scales, and few loose rocks that could damage the platform and rover. The presence of loose soil and sand cover was also evaluated to enhance the rover driving efficiency.

Scientifically interesting sites include locations with evidence of (i) long duration or frequently recurring aqueous activity, (ii) low-energy transport and deposition of fined-grained sediments, (iii) recently exposed sediments, and/or (iv) hydrated minerals such as clays or evaporites. The presence of ancient, Early Hesperian to Noachian sediments is also a requirement. The outcrops of interest must be well distributed over the landing ellipse to ensure their accessibility. Landing sites must also comply with planetary protection requirements [2].

Scientific merit of the two final candidate sites: Oxia Planum [3] and Mawrth Vallis [e.g. 4, 5] both exhibit extensive Noachian clay-bearing layered deposits, evidencing a past, long-lasting aqueous history and potential for biosignature preservation.

Oxia Planum. The proposed site is located in a topographic low exposing a light-toned layered geologic unit where Fe/Mg-phyllosilicates have been detected using OMEGA and CRISM [3]. In some areas, a blueish sub-unit is reported, possibly associated with Al-clay minerals, on top of the Fe/Mg-bearing material [6]. This clay-bearing unit is covered by a discontinuous, resistant dark unit, possibly the remnant of ancient lava flows [3]. Deposits linked to the fluvial activity of the Coogoon Vallis system [7] and other smaller valley systems are also present, including a large fan/delta complex located in the south-east portion of the site [3]. The fan/delta displays layers bearing hydrated silica and/or Al-clay minerals [3]. A few valleys have carved the floor of the basin where the landing ellipse is located [3]. These observations point to a complex hydrologic history with deposition on the floor of the basin, alteration, deposition of the fan/delta in a possible ancient standing body of water (possibly linked to another episode of alteration), and erosion by late fluvial and aeolian activity.

Analysis of impact crater size frequency distributions suggest that the layered clay-bearing unit formed at ~3.9 Ga, and the dark unit at ~2.6 Ga. The Coogoon fluvial activity may have started more than 3.8 Gyr ago. The clay-bearing unit has undergone significant erosion, exposing ancient clay-bearing layers [3].

Mawrth Vallis. The proposed site is located on the plateau south of the Mawrth Vallis outflow channel. The plateau exposes a light-toned layered geologic unit where extensive Al-clay minerals/silica (top) and Fe-phyllosilicates (bottom) are detected in a vertical sequence; a ferrous phase is also detected at the transition between both clay types [e.g. 8]. Outcrops in the region show the most intense clay signature and diversity ever detected on Mars with remote-sensing NIR instruments [9]. Sulfates were also detected in some outcrops of the landing ellipse, as well as allophane [10]. Carbonates have been reported in similar outcrops in the wider region, outside of the proposed ellipse [10]. Throughout the landing site, ridges and veins/halo-bounded fractures are present, likely revealing fluid circulation in fractures after the deposition of the layers [10]. The landing site surface has also been covered by a darker capping unit (probably due to volcaniclastic deposits that once covered the whole region [e.g. 4]) and eroded by fluvial activity [10]. Collectively, these observations evidence a complex and intense hydrologic history with deposition, alteration, erosion, fluid circulation and the presence of local evaporites, pointing to a variety of past aqueous environments.

Analysis of impact crater size frequency distributions suggest the layered clay-bearing unit formed between ~4.0 and ~3.8 Ga, and the emplacement of the capping unit at 3.7-3.6 Ga [11]. Late and ongoing aeolian erosion creates fresh exposures of the clay unit [10].

Possible geological link between the two sites. Quantin and co-workers [6] presented the possibility that the two landing sites are geologically related. A clay sequence similar to the one observed in the Mawrth Vallis region is observed on the plateaus east of Oxia Planum, while at the Mawrth Vallis site, some outcrops show spectral characteristics similar to the Fe/Mg-phyllosilicates mostly present at Oxia Planum. The observations suggest that Oxia Planum-type clay-bearing rocks could belong to the lower part of the Mawrth Vallis clay stratigraphic sequence.

Habitability and the potential for preservation of traces of life. Both sites document past habitability in terms of presence of past wet environments. Opportunistic colonization of the sites by microbes could have occurred, possibly on multiple occasions. If present, microbial biosignatures could have had high chance of long-term preservation in the identified mineral matrix (clays, salts or silica).

Landing and driving hazards at the two final candidate sites: Both candidate sites terrain features were examined by the LSSWG and industry for site characterization. Requirements include the conditions for final landing, the capability to egress from the platform and to drive around the site. This work was enabled using data from remote sensing instruments, in particular MOLA, HRSC and HiRISE.

Oxia Planum. The site shows a few secondary crater fields that may be traps for the rover if the mission were to land there due to steep slopes, float rocks and loose deposits. Also portions of the ellipse are covered with loose deposits forming aeolian ripple fields which might be difficult to navigate.

Mawrth Vallis. The site is located at a higher elevation (~1 km higher) than Oxia Planum, just below the altitude constraint for a safe landing, offering less margin for the descent procedure to respond to various contingencies. Erosion of the terrain has also created roughness at the m-scale that is non-compliant with terrain criteria on a small portion (few percent) of the ellipse (although this could only be tested where HiRISE DEMs were available). Large parts of the ellipse display terrains with a more difficult navigability than Oxia Planum, that could affect the effective distance that the rover could traverse during the nominal mission.

The LSSWG concluded that landing and egressing on Oxia Planum would be less risky than on Mawrth Vallis [12]. Another, lower and flatter landing site at Mawrth Vallis was not proposed due to the presence of large craters and of the Mawrth Vallis channel, given the large size of the landing ellipse.

Recommendation of the LSSWG: Both locations were judged suitable to address the ExoMars 2020 search-for-life objectives. The Oxia Planum site demonstrated an additional margin of safety in term of descent, landing, egress and roving capabilities. The Mawrth Vallis site was acknowledged to be a scientifically rich and unique site, but considered less well matched to the landing and roving capabilities of the mission [12].

The LSSWG therefore recommended Oxia Planum as the landing site for the 2020 rover mission [12]. This recommendation will be reviewed internally by ESA and Roscosmos with an official confirmation expected mid-2019.

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References: [1] Vago et al. (2017) *Astrobiology 17-6/7*, 471-510 [2] http://exploration.esa.int/mars/53462-call-for-exomars-2018-landing-site-selection/ [3] Quantin, C., et al., (2016) *LPSC 2016*, Abstract #2863. [4] Loizeau D et al. (2007) *JGR 112,* E08S08. [5] Michalski et al. (2010) *Astrobiology 10-7*, 687-703. [6] Quantin et al. (2018) *5th ExoMars 2020 landing site workshop*. [7] Molina et al. (2017). *Icarus 293,* 27-44. [8] Bishop et al. (2013) *Planetary & Space Science 86*, 130-149. [9] Poulet et al. (2014) *Icarus 231*, 65-76. [10] Poulet et al. (2018) *5th ExoMars 2020 landing site workshop*. [11] Loizeau et al. (2012) *Planetary & Space Science 72*, 31-43. [12] LSSWG (2018) *Final Report of the 5th landing site selection workshop*.