SPRING DEPOSITS AND LAKESHORE LAYERED SEDIMENTS INSIDE THE VERNAL CRATER (SW ARABIA TERRA): A RESOURCE-RICH AND ENGINEERING SAFE MARS HUMAN LANDING SITE.

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Scientific Rationale: Arabia Terra is a large region of Mars where several signs of past-water occurrence are recorded, both in the form of hydrological, compositional, as well as geomorphological landforms (e.g. [1,2]). Arabia is located between the southern highlands of Mars and the northern plains where the global topographic dichotomy has its minimum slope gradient [3], it is densely cratered and it is considered one of the oldest terrain on the planet [4].

The Vernal crater (Fig. 1) is a 55 km diameter crater centered at 6°N, 355°E in South-Western Arabia: among all craters emplaced in this region it is of particular interest because its southern half likely exhibits both spring and fluvial activity, as well as lacustrine deposits, associated with shoreline-like bedding [5]. From a stratigraphic perspective, the Vernal sediments lie between a minimum of 400 m to a maximum of 900-1200 m below those sediments investigated by the Opportunity rover in Meridiani Planum [6]. Hence, the Vernal in-situ analysis can provide the unique opportunity to study much older deposits, never observed by any other past or present rover located on the surface of the planet, providing insights into the atmospheric and geological conditions that characterized the ancient Mars. From a scientific perspective this makes such a site interesting because its surface dates back to an age (3.7 Ga, +0.05/-0.08, corresponding to the Late Noachian epoch) where past standing bodies of water were still present on the Red Planet possibly associated with habitability conditions.

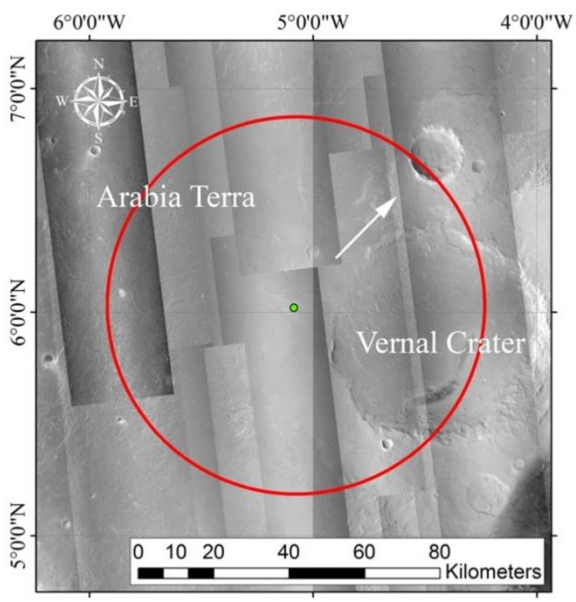

Figure 1: The location of the proposed landing site containing part of SW Arabia Terra and the Vernal crater.

By means of high-resolution CTX images [7] we have prepared a detailed geological map of the landing site. In the western part of the identified landing area the terrain presents ancient dark-toned, rough surfaces that are interpreted as either lava flows or groundwater indurated material. On the north of Vernal crater the Rampart ejecta of a 20 km size crater are well preserved, only partially affected by erosional processes. Inside the Vernal crater a set of different layered units (alternated dark and bright deposits) are in good agreement with a sedimentary origin of such deposits. The spectral analysis of these deposits show that plagioclase, pyroxenes, carbonates, sulphates and minerals typical of hydrothermal environments could be present, according to spectral unmixing modelling (CRISM dataset [8]). The derived mineral classes show spatial distributions consistent with the hypothesis of a confined environment where the circulation of fluids could have been responsible of the alteration of primary phases and precipitation of secondary minerals.

Resource Analysis: A human outpost on Mars can only start and thrive if there are in-situ natural resources that are reachable and exploitable. In order to identify such areas we decided to exploit the Water Equivalent Hydrogen map (WEH map) of Mars of [9], that represents locations characterized by subsurface water ice (at maximum depths of 1-2 m), and/or hydrated subsurface minerals. By analyzing the WEH values of SW Arabia we identified that the Vernal location present the highest WEH values in Arabia Terra as well as among other equatorial regions of Mars, reaching a maximum amount of 16%. This therefore suggests a high potential of in-situ natural resources. Besides the WEH measurements, SW Arabia Terra shows several Rampart craters ranging from 1 to 25 km in diameter [5], with one located 20 km north of Vernal rim (white arrow in Fig. 1). On Mars, such kind of craters commonly imply that in-situ ice or fluids have been in the subsurface for extended periods of time [10], hence supporting the interpretation of a resource-rich Martian area.

Engineering Requirements: Human exploration engineering requirements have not yet been published, nevertheless, the first explorers are expected to be limited to about 100 km of travel from their landing site due to life support and exploration technology requirements (see the NASA Human Landing Sites Study www.nasa.gov/journeytomars/mars-exploration-zones for human missions on Mars). We therefore decided to make use of the strict NASA Mars Science Laboratory 2012 and Mars 2020 rover requirements [11,12] as guidelines for our Vernal proposed site analysis, and quantified their fulfillment over the full proposed landing area, as commonly done on other Mars landing sites [13-15]. As it is possible to see from the resulting analysis presented in Table 1, the elevation of the site is well below the <-0.5 km MOLA datum constraint, hence providing sufficient atmosphere braking during the Entry Descent and Landing phase. This is particularly important if much heavier loads are expected for human exploration than those required for the 2012-2020 rovers. Regarding surface rock abundances, the IRTM dataset [16] shows that 21.02% of the proposed area exceeds the required K value $< 10\%$, in particular inside the south-east area of the Vernal crater (13%). Nevertheless, a higher spatial scale study (7.4 km) made with the TES instrument [17] on the same location indicates that this region has K values below 7%, making it safe from a hazard perspective. Over the proposed landing site we have a partial (54.72%) coverage of a CTX 18 m scale Digital Elevation Model. In order to fully cover the remaining area of the landing site and to provide a complete elevation map with spatial scale ~10 m, we have already planned and started to acquire multiple CaSSIS 4.6 m stereo images [18] of the area. For atmospheric safety assessment as well as to understand the aeolian processes (erosion and deposition of material) that are currently shaping the Vernal crater area we have mapped the aeolian bedform orientations in the proposed landing ellipse (mostly bright-toned megaripples or TARs [19]) and we have performed a statistical analysis of prevailing wind directions and speeds through the use of the NASA AMES Mars General Circulation Model and the Mars Regional Atmospheric Modeling System [20].

Engineering Constraint	Landing Area = 7850 km^2
Center Latitude	6°1′13″N
Center Longitude	5°5′8″W
Elevation MOLA (m)	100% compliant
Min	-2006
Max	-818
Mean	-1419
St. dev.	153
Slopes @ 2 km length scale	99.27% compliant
	0.73% = 57.40 km^2 slope > 5.71°
Slopes @ 463 m length scale	97.14% compliant
	2.86% = 224.31 km^2 slope > 5.71°
Slopes @ 100 m length scale	HRSC DEM partial coverage → 68.66%
	1.67% = 131.42 km^2 slope > 10.0°
Slopes @ 18 m length scale	CTX DEM partial coverage → 54.72%
	1.30% = 101.67 km^2 slope > 20.0°
Rock Abundance (IRTM)	78.92% compliant
	21.02% = 1654.00 km^2 → K = 13%
Min	10
Max	13
Mean	12
St. dev.	1
Rock Abundance (TES)	TES partial coverage → 39.07%
Min	1
Max	10
Mean	4
St. dev.	2
Thermal Inertia	98.51% compliant
	1.49% = 116.97 km^2 40<TIU<100
Min	40
Max	396
Mean	196
St. dev.	50
Albedo	100% compliant
Min	0.22
Max	0.24
Mean	0.23
St. dev.	0.01

Table 1: Summary of the site engineering constraints.

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