CONSIDERATIONS FOR HUMAN EXPLORATION OF AN EXHUMED, INTERCRATER BASIN IN THE MARTIAN CRATERED HIGHLANDS: THE HADRIACUS PALUS AND CAVI EXAMPLE. J. A. Skinner, Jr.[1], T. M. Hare[1], C. M. Fortezzo[1], and D. L. Rickman[2], [1]U.S. Geological Survey, Astrogeology Science Center, 2255 N. Gemini Drive, Flagstaff, AZ 86001 (jskinner@usgs.gov), [1]Jacobs Technologies, Inc., Marshall Space Flight Center, Huntsville, AL 35812.

Introduction: On Earth, exposed sections of geologic strata within structural basins provide critical information about pre-, syn-, and post-basin forming tectonic processes, depositional environments, and interactions with regional to global climate [1]. The widespread occurrence, varied internal architecture, and common aqueous signatures of basin-related (principally non-crater) stratified rocks on Mars are critically important for an improved understanding of broadly-occurring geologic processes and their interaction with climate dynamics through time [1-2]. Though current and past orbital and landed assests have greatly improved our understanding of Mars' evolution [e.g., 2], human exploration is likely to result in a broader observational envelope than currently afforded by recent and upcoming rovers. Here, we describe Hadriacus Palus and Cavi – an exhumed, structural (principally non-crater) basin on Mars – as a highly relevant "type example" exploration zone wherein engineering contraints are satisfied and scientific objectives can not only be reasonably achieved but also broadly extrapolated to enable a more holistic understanding of Mars' evolution.

Regional Setting: Hadriacus Palus (77.30°E, -27.25°N) is a 160-km long by 80-km wide, locally low-lying, nearly horizontal plain located north-northeast of Hellas Planitia and southwest of Terra Tyrrhena in the eastern, mid-latitude region of Mars (**Fig. 1**). The palus surface has a mean elevation of -2640 m and is bounded by gently-sloping cratered terrains, interspersed topographic massifs, and variable diameter impact craters. Two channel systems enter into – and terminate within – Hadriacus Palus from the north (Napo Vallis) and east (Huallaga Vallis). These channels originate in southwestern Tyrrhena Terra and constitute drainage of a diverse section of highland-forming rock sequences, including volcanic and crustal massifs, deeply cratered plateaus, and volcaniclastic plains [2-3]. Hadriacus Palus is defined on its southern margin by the Hadriacus Cavi (78.05°E, -27.25°N), a 50-km long series of east-west-oriented depressions that are locally >800 m deep. These depressions expose diverse stratified rocks with morphologic and textural characteristics suggestive of volcanic (tuff and/or lava), fluvial (channel cross-section), aeolian (dark sand), and impact (breccia and faulting) origin [3].

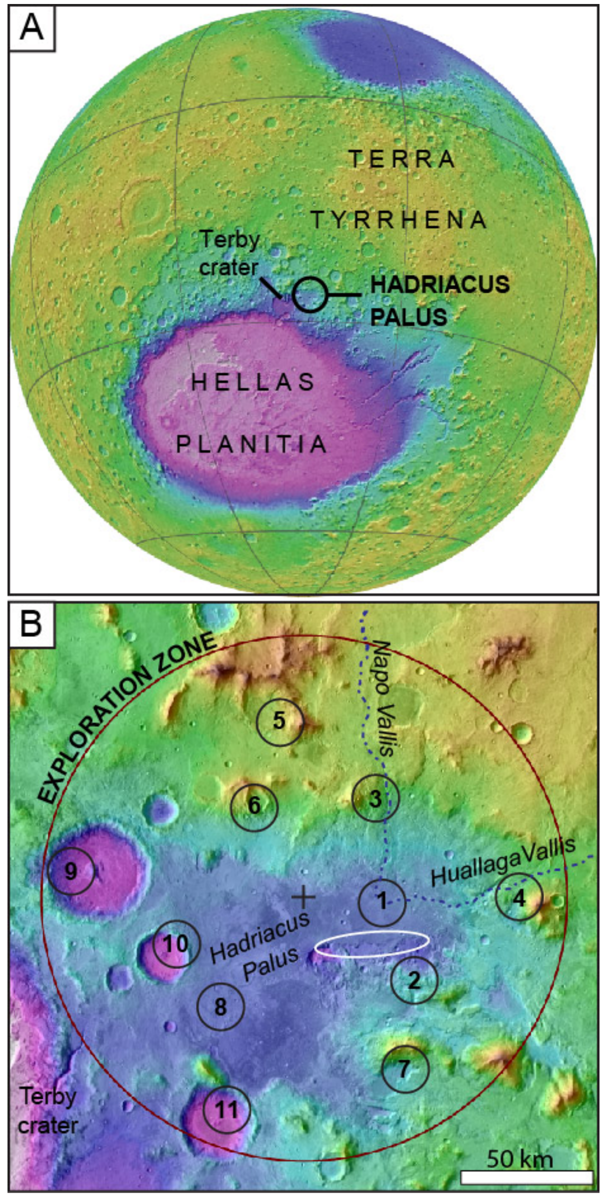

Figure 1. Physiographic characteristics and exploration potential of the Hadriacus Palus and Cavi. (A) Exploration zone (centered at 77.47E, -26.84N) is located NNE of Hellas Planitia, SW of Terra Tyrrrhena, and E of Terby crater. (B) The Hadriacus Cavi – located on SE margin of Hadriacus Palus – expose >800 m of stratified sedimentary and volcanic rocks. The local exposed basin strata, bounding massifs, cratered terrains, and impact craters potentially enable observation of all aspects of the rock cycle from the Early Noachian to Early Amazonian.

Hadriacus Palus is part of the highland plateau unit sequence, as defined by [2]. These include the Early Noachian highland massif (eNhm), Early Noachian highland (eNh), Middle Noachian highland (mNh), and Late Noachian highland (lNh) units [2]. Local crater size-frequency assessments [3] provide model absolute ages for the palus surface of 3.38 ± 0.08 Ga (Late Hesperian), with subsequent resurfacing occurring in parts of the western palus at 1.57 ± 0.55 Ga (Early to Middle Amazonian). The surrounding (subjacent) cratered terrains have an model absolute age of 4.06 ± 0.10 Ga (Early Noachian), with subsequent resurfacing occurring at 3.39 ± 0.15 Ga (Late Hesperian). The model absolute age of resurfacing within the immediately adjacent cratered highland terrains closely correlates with the emplacement age of the palus surface.

Rationale: Though many of the detailed parameters required to establish potential landing, development, and exploration sites have yet to be fully determined, it is essential to ascertain the state of knowledge and the rationale for not only particular sites but also (and perhaps more importantly) for particular <u>types</u> of sites. The identification and evaluation of candidate locations for human exploration of Mars requires a clear understanding of the environmental context wherein that exploration will occur. Hadriacus Palus and Cavi is an excellent "type example" of a structural (principally non-crater) basin containing partly exhumed stratifed rocks that were emplaced through diverse, interacting processes. The rationale for considering Hadriacus Palus and Cavi specifically – and structural basins generally – for human exploration are as follows:

1) The region satisfies known baseline engineering constraints with regard to latitude (<50°), elevation (≤+2 km), landing radius, dust cover, slope, and infrastructure separation.
2) The region provides potential (though indeteremінate) access to subsurface water-ice (< 5m depth) and hydrated mineral phases (phyllosilicates) along the margin of Hadriacus Cavi.
3) The region affords access to multiple outrops of geologically and stratigraphically diverse units within a range of distances from the proposed landing site, including convergence of two discrete channel systems draining contrasting Noachian age terrains (#1 in **Fig. 1B**), uplifted crustal massifs abutted by breccias, lava and/or tuff, and fluvial sediments in stratigraphic section (#2 in **Fig. 1B**), a range of topographic massifs of crustal and/or volcanic origin (#3-7 in **Fig. 1B**), lobate ejecta ramparts (#8 in **Fig. 1B**), impact crater rim, wall, floor, and central peak assemblages (#9-11 in **Fig. 1B**), and intra-crater alluvial fan deposits (#9 in **Fig. 1B**).
4) The region represents a previously un-visited, though widely occurring, geologic setting that affords examination of rocks emplaced through processes that were active during the Early Noachian to Early Amazonian. Moreover, local outcrops are likley to provide details about tectonic processes that have yet to be observed *in situ*.
5) The region is pervasively horizontal and is fed by channel systems that terminate at a common elevation, implicating a potential ancient quiescent environment that potentially supported and preserved evidence of ancient life.

Considerations: Initial selection and evaluation of potential sites on Mars that can reasonably achieve both engineering and science priorities is a challenge on multiple fronts. Engineering constraints, including the identification, extraction, and processing potential of *in situ* resources necessary to sustain human exploration, are likely to be the primary driver for site selection. Scientific constraints, including environments that could have promoted, sustained, and preserved ancient life, are likely to be secondary factors in site selection. The community should ascertain the means by which these constraints can be dynamically integrated using existing and potential future observations to globally identify sites of high relevance for human exploration.

We contend that structural (principally non-crater) basins that have accumulated rocks and sediments from not only various geologic processes but also from various geologic terrains hold the highest potential for achieving both engineering and science objectives. From an engineering perspective, structural basins on Mars (as on Earth) tend to be expansively horizontal, promoting safe development and traversability by human explorers. From a scientific perspective, exhumed structural basins tend to provide access to sequences of rocks and sediments that record long-lived interactions between basin-forming tectonism and regional to global climate oscillations. Records of these processes and their interactions are key pieces of information that are currently missing from our understanding of the evolution of Mars, including the potential ascent and preservation of life on that planet.

References: [1] Busby, C. J. and Ingersoll, R. V., *Tectonics of Sedimentary Basins*, 1995. [2] Tanaka, K. L. et al., (2014), USGS SIM 3292, 1:20M scale. [3] Fortezzo, C. M., and Skinner, J. A., Jr., *LPSC 2013*, #2104.