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MAXIMUM SAMPLE TEMPERATURE FOR MARS SAMPLE RETURN: A HISTORICAL PERSPECTIVE

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Since the first Mars Sample Return (MSR) report published by the Jet Propulsion Laboratory (JPL) in 1974 [1], a series of panels, reports, and white papers have recognized the importance of sample temperature and offered an informed sample maximum temperature (henceforth SMT) limit for returning martian samples to Earth. The Mars Sample Handling and Requirements Panel (MSHARP, 1999) stated that "[t]he main issue in sample preservation is temperature" [2]. More recently, the Mars Exploration Program Analysis Group (MEPAG)'s "Science Priorities for Mars Sample Return" report (2008), declared that "[s]ignificant loss, particularly to biological studies, occurs if samples reach +50°C for three hours", whereby "scientific objectives related to life goals could be seriously compromised" [3]. By contrast, the Mars 2020 mission has adopted a SMT of +60°C as spelled out in Beaty et al., 2016 [4]. Samples will be collected and then deposited on the surface in sealed tubes for possible retrieval and return to Earth. Beaty et al. [4] calculates that the samples will experience maximum temperatures of ∼+30 to +60°C, depending on latitude. At present, there is no mission requirement for the measurement/data logging of sample temperature during this period. We will explore the history of martian SMTs, as they have been recorded since 1974 [1], effectively representing input across multiple generations of Mars scientists. Ten separate publications present SMTs for MSR samples [1-10]. One report [10] is for a mission concept specifically designed to exclude life detection investigations, and recommended an SMT of 50°C. Another did not specify a temperature, recommending "Mars ambient temperature" [5]. Of the remaining eight, SMTs are given as: -30°C [1], -20°C [3], 60°C [4], -73 to 41°C depending on sample type [6], -40°C [7], -43 to 13°C depending on type [2,8], and -33°C [9]. If we restrict the temperatures to samples highlighted in the Mars 2020 mission goals, i.e. organics-bearing and sedimentary rocks, then the average SMT is -28±39°C (n=8). Applying a Dixon's Q Test at P=0.05 (two-tailed), the 60°C SMT [4] fails with Q=0.602 versus Qcrit=0.526. Excluding the outlier produces an average SMT of -40±17°C (n=7). Therefore, the average SMT expressed by the Mars science community over the past 44 years (∼two generations) is a sample temperature no greater than -40°C. The difference in chemical reaction rates between this average SMT and Beaty et al [4] can be estimated using the Arrhenius equation. Assuming a generic chemical reaction with an activation energy of 50 kJ/mol and a pre-exponential factor invariant with temperature, this reaction will proceed 2300x faster at 60°C than at -40°C. To illustrate the effects of the

increased reaction rate, consider 10 ppb of alanine in a Mars 2020 cache, and assume that it becomes unmeasurable if it degrades to 1 ppb, as per the Mars 2020 Organic Contamination Panel contamination limits [11]. If we illustrate the effect with an arbitrary degradation rate such that the alanine will become undetectable in ten years at -40°C, then the same 10 ppb alanine degrades beyond detectability in only 38 days at 60°C. Further research is required to quantify expected analyte losses in the cached samples due to thermal processing.

[1] Jaffe, L.D., et al 1974. JPL Internal Rept., (760-101). [2] Carr, M.H., et al 1999. NASA Tech. Memo, 209145(47), p.1999. [3] Borg L., Des Marais D., Beaty D., 2008. Astrobiology (8,3) 489-535. [4] Beaty, D.W., et al, 2016. 47th LPSC, Abstract 2662. [5] Bogard, et al 1979. NASA Tech Memo 58213 [6] de Vries, J.P., Norton, H.N. and Blanchard, D.P., 1984. JPL D-1845. [7] MRSR, 1989. In 27th Aero. Sci. Mtg. (p. 417). [8] Gooding, J.L., 1990. NASA Tech Memo 4184. [9] Neal, C.R., 2000. JGR: Planets, 105(E9), pp.22487-22506. [10] MacPherson, Glenn J. et al, 2002. http://mepag.jpl.nasa.gov/reports/index.html. [11] 2014 OCP, 2014. Astrobiology 14(12): 969-102