RECOMMENDED MAXIMUM TEMPERATURE FOR MARS RETURNED SAMPLES. D. W. Beaty[1], H. Y. McSween[2], A. D. Czaja[3], Y. S. Goreva[1], E Hausrath[4], C. D. K. Herd[5], M. Humayun[6], F. M. McCubbin[7], S. M. McLennan[8], L. M. Pratt[9], M. A. Sephton[10], A. Steele[11], B. P. Weiss[12], and L. E. Hays[1], [1]Jet Propulsion Laboratory, Pasadena, CA, [2]University of Tennessee, Knoxville, TN, [3]University of Cincinnati, Cincinnati, OH, [4]Universitiy of Nevada, Los Vegas, NV, [5]University of Alberta, Edmonton, Canada, [6]Florida State University, Tallahassi, FL, [7]NASA Johnson Space Center, Houston, [8]Stony Brook University, Stony Brook, NY, [9]Indiana University, Bloomington, IN, [10]Imperial College, London, U.K., [11]Carnegie Institution, Washington, DC, [12]Massachusetts Instittue of Technology, Boston, MA.

Introduction: The Returned Sample Science Board (RSSB) was established by NASA in 2015 to provide expertise from the planetary sample community to the Mars 2020 Project. The RSSB's first task was to address the effect of heating during acquisition and storage of samples on scientific investigations that could be expected to be conducted if the samples are returned to Earth.

Sample heating may cause changes that could adversely affect scientific investigations [1, 2]. Previous studies of temperature requirements for returned martian samples fall within a wide range (-73 to 50 °C) and, for mission concepts that have a life detection component, the recommended threshold was ≤ -20°C [e.g. 2, 3, 4, 5]. The RSSB was asked by the Mars-2020 project to determine whether or not a temperature requirement was needed within the range of 30 to 70°C.

There are eight expected temperature regimes to which the samples could be exposed, from the moment that they are drilled until they are placed into a temperature-controlled environment on Earth. Two of those – heating during sample acquisition (drilling) and heating while cached on the martian surface – potentially subject samples to the highest temperatures. The RSSB focused on the upper temperature limit that Mars samples should be allowed to reach.

We considered 11 scientific investigations where thermal excursions may have an adverse effect on the science outcome. Those are: (T-1) organic geochemistry, (T-2) stable isotope geochemistry, (T-3) prevention of mineral hydration/dehydration and phase transformation, (T-4) retention of water, (T-5) characterization of amorphous materials, (T-6) putative martian organisms, (T-7) oxidation/reduction reactions, (T-8) ^{4}He thermochronometry, (T-9) radiometric dating using fission, cosmic-ray or solar-flare tracks, (T-10) analyses of trapped gasses, and (T-11) magnetic studies. We did not prioritize the various scientific investigations, as those priorities depend on what kinds of rocks are encountered and cached at the various landing sites under consideration, but the temperature constraints on each kind of investigation were considered. We were not able to specify a maximum temperatures for T-6, as we have no credible way of evaluating that; in any case, Mars 2020 is not envisioned as a mission to detect extant life, so refrigeration of samples was not considered. Likewise, we did not determine a maximum temperature for T-10; loss of trapped gas occurs by fracturing during drilling, which is unavoidable.

Findings: The Mars 2020 Project anticipates using duty cycling during drilling to reduce heating. With duty cycling, the temperature regime may be an additional 5 to 30 ^{o}C above ambient temperature, depending on how the drill is operated. We noted, however, that heating during drilling can potentially be more damaging than heating during sample caching, because the former behaves as an open system, and the latter as a closed system. Heating to a temperature of > ~50 ^{o}C during drilling may release volatiles from the samples that would not be recaptured. Although some investigations would benefit from the thermal relaxation of the duty cycling (thermochronometry, radiometric dating), the prolonged open-system heating might be detrimental to others (volatile loss, light element thermometry).

The current mission baseline Returnable Sample Tube Assembly will experience maximum temperatures of ~60 °C (~20 °C above ambient surface temperatures) or lower, depending on the martian landing site. Models of maximum temperatures from time of emplacement of the cached sample on the surface until 10 years later, as a function of latitude, are shown in Fig. 1.

Estimates of the maximum allowed temperatures (or temperature ranges, gray areas) for the 11 scientific investigations we considered are summarized in Fig. 2. Inspection of this figure indicates that 60°C is an acceptable limiting temperature for the preservation of most kinds of geological materials and for planned sample analyses. However, lower maximum temperatures would be desirable for the preservation of some organic compounds, amorphous materials, hydrated sulfates, and some other minerals like zeolites. We requested that the Mars 2020 Project continue efforts to find engineering or operational approaches to keeping the maximum temperature of the samples at or below 40-50 ^{o}C. These lower temperatures can also be satisfied without additional effort for the landing sites in the northern hemisphere, although we did not recommend that sites in the southern hemisphere should no longer be considered.

Some uncertainties in temperature effects can be mitigated if the relative humidity of headspace gas adjacent to the core is low. It would be advisable to minimize humidity within the sample tubes by closing seals at a time of the day when relative humidity is low (preferably < 10), or by including a vapor trap in some of the containers. If it is decided to return the samples to Earth, NASA should adopt a requirement to capture the headspace gas in each sample tube, so that it can be analyzed for volatile species.

The RSSB will continue to represent the planetary materials community in regard to maximizing the scientific integrity of samples cached by Mars 2020 and hopefully returned to Earth in the future.

References: [1] ND-SAG (2008). [2] McLennan S. M., et al. (2011) E2E-iSAG. [3] Carr M., et al. (1999) NASA TM-1999-209145. [4] Neal C., et al. (2000) *J. Geophys. Res.* 105(E9), 22478-22506. [5] MacPherson G., et al. (2002) JPL CL#04-0549.

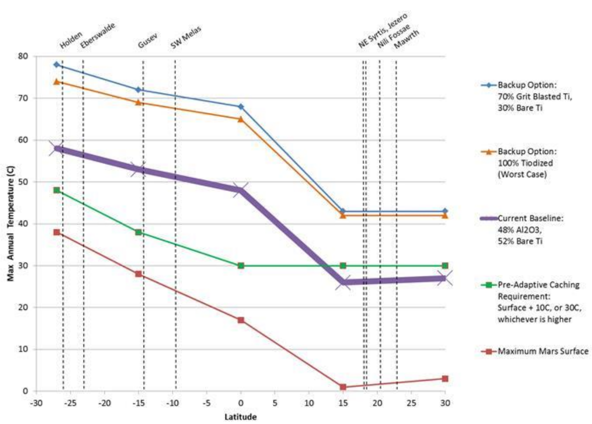

Fig. 1. Relationship between landing site latitude and maximum temperature. Modelling by M. Redmond and P. Bhandari. Current (as of Sept. 2015) mission baseline sample tube is shown as heavy purple line.

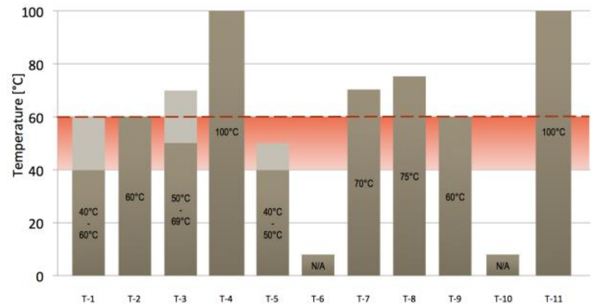

Fig. 2. Graphical representation of the maximum allowed temperatures or ranges for the investigations considered in this study.