SUMMARY OF SAMPLE QUALITY STANDARDS FOR RETURNED MARTIAN SAMPLES. The Returned Sample Science Board (D. W. Beaty[1] and H. Y. McSween[2], co-chairs; B. L. Carrier[1], A. D. Czaja[3], Y. S. Goreva[1], E. M. 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], and B. P. Weiss[12]), [1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, [2]University of Tennessee, Knoxville, TN, [3]University of Cincinnati, Cincinnati, OH, [4]Universitiy of Nevada, Las Vegas, NV, [5]University of Alberta, Edmonton, Canada, [6]Florida State University, Tallahassee, 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 Institute of Technology, Cambridge, MA.

Introduction: The Mars 2020 rover will acquire and cache samples for possible return to Earth at some future date. Over approximately the last 4 years, sample quality standards have been established by several different methods to ensure that the samples would be able to address the planned scientific objectives, within the necessary constraints of mission design and cost [1]. Some of these standards were formulated for the Project by the Returned Sample Science Board (RSSB), a group chartered in mid-2015 by NASA to represent the sample scientific community, and others were formulated by predecessors of the RSSB (and the RSSB never found a reason to modify the specs). Table 1 summarizes the full set of sample quality standards of which we are aware.

Table 1: Campaign-Level Science Requirements for Mars Samples

Organic Contamination	Tier 1 compounds <1 ppb Tier 2 compounds <10 ppb TOC <40 ppb
Inorganic Contamination	Group A <1% (see text) Group B <0.1% (see text) Pb <2 ng/g
Magnetics	Exposure to <0.5 mT Shock pressure <0.1 GPa Orientation to half-cone uncertainty of <5°
Fracturing	Size distribution in a single core of <20% by mass in pieces ≤2 mm, and >70% by mass in pieces with largest dimension >10 mm
Internal Movement	Minimize by preloading tubes compatible with X-ray CT imagine of core
Temperature	<60 °C (<40 °C desired)
Cross-Contamination	<150 mg per sample tube
Sealing	<1% water, translated to He leak rate for 20 y
Radiation	<100 krad over 20y

Earth-sourced contamination: Minimizing Earth-sourced contamination is critically important for geochemistry, isotope geochronology, and astrobiology investigations. Mars-sourced contaminants will be monitored by witness blanks.

Organic compounds. The limits for Earth-sourced organic carbon in/on the samples originated from a nearly year-long study by a science/Planetary Protection team (OCP) carried out in 2014 [2]. Their final recommendation was organized into three components: <1 ppb Tier 1 compounds (organic compounds that would be deliberately evaluated in returned samples as input to life-related interpretations), <10 ppb other C-compounds (everything that is not on the Tier 1 list), and <40 ppb total organic carbon (TOC).

Inorganic elements. The key input for this originated at the "Workshop on MSR Sample Quality", Mar. 16, 2014 (a pre-LPSC workshop), in part aided by a pre-RSSB focus group. It was recognized that for most kinds of elemental geochemistry studies, the data do not matter beyond two significant figures. Thus, for most kinds of Earth-sourced inorganic contamination (e.g. Ni, Zn, Mn, and Zr), agreement was reached to set a limit of 1% of the concentration in SNC meteorites (and Tissint was later chosen as the reference). However, this accuracy is not sufficient for the data used in geochronology studies, and for the primary parent-daughter pairs (e.g. Rb, Sr) a constraint of 0.1% was proposed. Several elements required to build the spacecraft (e.g. Ti, Al, Fe) were left unconstrained. Pb contamination was singled out as being of interest at an especially low level, to allow for U-Th-Pb geochronology, although this is a notoriously difficult contaminant to deal with on Earth. Initial element lists developed above were refined in a 2014 GSA poster [3].

Magnetics: A pre-RSSB magnetics focus group, led by Ben Weiss in 2014, conducted a study to assess the requirements for magnetics measurements on one or more returned samples. These include limitations on exposure to a spacecraft magnetic fields (<0.5mT), shock intensity during launch and landing (<0.1 GPa), and accuracy to which orientation should be determined based on a surface features (to within 5°). Furthemore, to ensure that paleodirectional measurements can be oriented with respect to absolute Martian geographic coordinates at the time the magnetization was acquired by the samples, their parent rocks should be in-place bedrock or at least blocks with paleohorizontal indicators (i.e., bedding planes, flow-top features, vesicularity or crystal size gradients, and/or stratified grain size sorting) [4].

Magnetic field measurements around the Mars 2020 testbed drill suggest that drilled cores will not experience fields exceeding the 0.5 mT requirement. Futhermore, amagnetic witness plates will be included with the Mars 2020 sample tubes to record any strong magnetic fields experienced by the samples.

Mechanical Integrity: The fracturing of a rock sample does not directly affect its scientific utility, as long as the pieces stay together (after all, once the samples arrive at Earth, they would be deliberately broken into small pieces for the purpose of sample allocation). Although this was discussed at the 2014 Sample Quality Workshop, a viable approach to structuring a meaningful and achievable requirement was not identified at the time. Through discussions between the Mars-2020 project scientist and a pre-RSSB focus group, agreement was reached on a size-frequency distribution, which would have enough large pieces (>70%) to support the high-priority preparation of polished thin sections, enough medium-sized pieces (>20%) for many kinds of geochemical investigations, and would minimize the quantity of "fines" (<10%), which are far less useful. Note that since different rocks have different strength, it was necessary to define this requirement with respect to a reference rock, which was selected to be a specific variant of the Bishop Tuff.

Internal Movement: The movement of fragments of a rock relative to each other in the core is generally considered to be more damaging to science than fracturing itself. A fractured rock can be reconstructed if the pieces are still together. However, it was found to be impossible to write defensible requirements relating to distances or angles of movement of multiple particles relative to each other. An alternate approach of minimizing the free volume inside the sample tubes was adopted—this would have the indirect effect of minimizing movement. In addition, the material of the tubes was chosen in part to allow X-ray CT scanning before opening, which may assist in understanding fragmentation, internal rotations and displacements.

Temperature: The RSSB conducted an intensive analysis of temperature constraints for 11 investigations where thermal excursions could affect the outcome. A maximum temperature of 60°C (20° above ambient temperature) was determined for samples within core tubes on the martian surface and during recovery on Earth. Lower temperatures of 40-50°C are desirable for investigations of organic matter, amorphous materials, hydrated sulfates and zeolites, and these lower temperatures can be satisfied for landing sites in the northern hemisphere without additional effort [5]. Temperature excursions during drilling can be mitigated by duty cycling. In response to this study, Project engineers modified the core tube design to achieve this temperature constraint at all the putative Mars landing sites.

Mars-sourced contamination: Because the Mars 2020 rover will reuse drill bits, and not have the ability to clean between their sampling uses, cross contamination between Mars samples is inevitable. This was discussed at the 2014 Sample Quality Workshop, and agreement was reached that for most of the kinds of scientific questions of Mars returned sample science, and for a series of samples that come from a single type of geologic terrane, a cross contamination limit of 1% would be compatible with most kinds of geochemistry studies.

Sealing: Volatiles in the sample, either bound in minerals, or adsorbed on mineral surfaces, may be released during storage of core tubes on the martian surface. Sealing of the tubes is critical to retain volatiles, so that the original volatile inventory will be measured and the original states of volatiles can be calculated from thermodynamic considerations and from atmospheric samples that would be obtained as part of any follow-on retrieval mission. The Mars 2020 sample tubes will also contain some headspace atmospheric gas. The limit is based on the leak rate for He for a 20-year residence on Mars.

Radiation: A radiation limit of 100 krad was proposed--this is approximately the natural dose the samples would receive if they spent 20 years in orbit. Additional sample irradiation beyond that is in general considered undesirable, although this is a relatively low dose, and specific adverse effects caused by exceeding it by a small amount have not been identified.

Summary: The selection, acquisition, storage, and return to Earth of Mars samples is expected to be challenging and expensive, and international partners would have to be assured that the scientific quality and integrity of samples can be assured. This report summarizes the standards to be imposed on samples acquired and cached by the Mars 2020 mission, which should make their return to Earth a priority for planetary science.

References: [1] Beaty D.W. et al. (2014) *8th International Mars Conf.*, abs. #1208. [2] Summons R. E. et al. (2014) *Astrobiology, 14(12)*, 969-1027. [3] Liu Y. et al. (2014) *GSA Annual Meeting*, Paper #225-4. [4] RSSB (2016) *AGU Fall Meeting*, abs. #GP23C-1350 [5] RSSB (2016) *LPSC XLVII*, abs. #2662.