SAMPLE RETREIVAL LANDER CONCEPT FOR A POTENTIAL MARS SAMPLE RETURN CAMPAIGN.

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Introduction: NASA and ESA are jointly studying a potential Mars Sample Return (MSR) campaign which would retrieve samples planned to be collected by the Mars 2020 rover mission [1] and return those samples to Earth for subsequent scientific analysis [2]. Key elements of this campaign are a NASA-led Sample Retrieval Lander (SRL), which would be responsible for retrieving the Mars 2020-collected samples, loading them into an Orbiting Sample (OS) container, and launching the OS into a stable Mars orbit on a Mars Ascent Vehicle (MAV), and an ESA-led Earth Return Orbiter (ERO), which would be responsible for rendezvousing with and capturing the on-orbit OS, safely containing it, and returning the samples to Earth. We present here an overview of the notional SRL concept, outline the roles of NASA and ESA in the study to date, and discuss key architectural trades under study.

SRL Mission Concept Description: The SRL mission would deploy a lander in the vicinity of Jezero Crater, where the Mars 2020 rover plans to land and collect and cache samples during its 1.25-Mars-year primary surface mission. Key payloads on SRL would include an ESA-provided Sample Fetch Rover (SFR) and Sample Transfer Arm (STA), and a NASA-provided OS and MAV.

Mission Design: The SRL would notionally launch on a Type III/IV trajectory, timed to arrive near L_S~0, near the start of spring in the northern hemisphere. The longer Earth-Mars transfer time for SRL allows the ERO mission, launched in the same opportunity, to arrive at Mars in time to support relay telecommunication services for SRL. The solar-powered SRL mission would then carry out its surface activities during Martian spring and summer, maximizing available power, and would complete its surface mission and launch the retrieved samples into orbit before L_S~180 (start of northern hemisphere fall), prior to significant decrease in available solar power and in advance of the potential for global dust storms. Launch opportunities as early as 2026 are under study.

Entry, Descent, and Landing: The Entry, Descent, and Landing (EDL) concept for SRL would include heritage concepts from the Mars 2020 mission, including hypersonic guided entry, supersonic parachute deployment, and use of terrain-relative navigation for improved landing safety and reduced landing dispersion. After separating from the backshell, the SRL would utilize propulsive terminal descent to deliver the legged

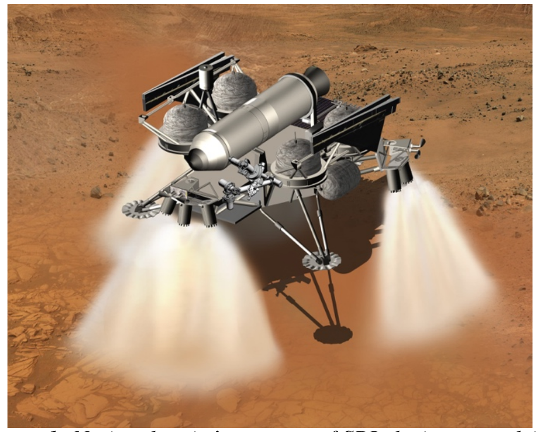

Figure 1: Notional artist's concept of SRL during propulsive descent

lander to the surface. With Mars 2020-heritage capabilities, SRL would achieve a landing ellipse with a semi-major axis of roughly 4 km. Assessment is underway to investigate the possibility of implementing an increased propulsive divert capability during terminal descent; in combination with terrain-relative navigation, this would have the potential to further decrease the SRL landing dispersion, with the important benefit of reducing the required surface drive distances.

Surface Retrieval Mission: Once on the surface, the ~120-kg SFR would egress from SRL and begin its surface mission to retrieve samples previously cached by Mars 2020 at one or more depot locations. The currently

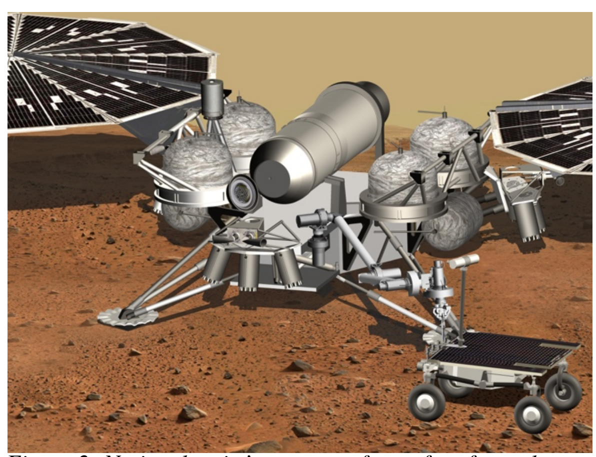

Figure 2: Notional artist's concept of transfer of sample tubes from the Sample Fetch Rover to the Sample Retrieval Lander, using the Sample Transfer Arm on SRL to load the sample tubes into the Orbiting Sample container on the Mars Ascent Vehicle

envisioned surface mission timeline would allocate 150 sols for SFR to complete this retrieval and return to SRL. With a nominal 4-km SRL landing dispersion, this drives the need for high levels of SFR autonomy and mobility, with support for drive distances of up to 500 m/sol, and with efficient operations during tube pickup at the depot site(s) and tube transfer to SRL.

To increase campaign robustness, in addition to SFR retrieval of samples cached by Mars 2020, a subset of collected samples would be retained onboard Mars 2020 itself and, assuming extended Mars 2020 health, would be independently delivered to SRL.

Upon delivery to SRL, the SFR- and Mars 2020-delivered samples would be transferred using the STA, with the retrieved sample tubes loaded into the OS, atop the MAV. The number of sample tubes accommodated remains an open trade, and would balance science motivation – including prior studies of the science strategy associated with return of ~31 sample tubes – with engineering constraints associated with the scaling of the OS, MAV, and payload elements on ERO as a function of the number of returned sample tubes [2,3].

Throughout the SRL surface mission, ERO would provide telecommunication relay services to SRL, SFR, and Mars 2020. Any additional relay assets from the current Mars relay network still operational in the timeframe of SRL would augment these relay capabilities.

Mars Ascent Vehicle: Once the OS loading is complete, the MAV would launch the OS into a stable, low-altitude Mars orbit; current plans target a circular orbit at an altitude of 350 km. SRL MAV launch operations would be carefully coordinated with ERO to ensure that the orbiter is in view of the SRL site to provide critical event communication and tracking during the MAV launch. Accuracy of the MAV orbit delivery drives the complexity of ERO operations to locate, rendezvous with, and capture the on-orbit OS; we are currently targeting delivery accuracies corresponding to better than 10 km in semi-major axis and better than 1 deg in inclination.

Several technology options are under consideration for the 400-kg MAV, including a single-stage-to-orbit hybrid MAV design [4] as well as a two-stage solid propellant option. The hybrid design offers some attractive features associated with delivery accuracy and survivable storage temperature, while the two-stage solid design offers higher technology maturity. Targeted technology development activity over the past several years has advanced the technology readiness level of the hybrid option through a series of full-scale hot-fire tests. A final selection of the MAV propulsion option is expected by the end of 2019.

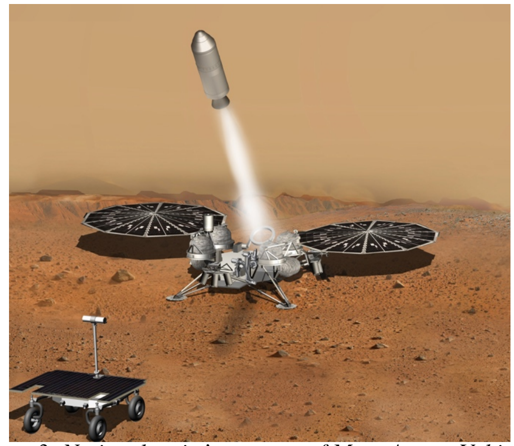

Figure 3: Notional artist's concept of Mars Ascent Vehicle launch, with the Sample Fetch Rover in the foreground.

Summary: A NASA-led SRL mission, with several key payload contributions from ESA, would provide a major flight element of a proposed joint NASA-ESA MSR campaign. The SRL-deployed SFR would retrieve samples previously cached by Mars 2020; additional samples retained on Mars 2020 would independently be delivered to SRL. Retrieved samples would be placed in an OS and launched by a MAV into a stable Mars orbit, for subsequent rendezvous and capture by ERO, for ultimate return to Earth. Key trade studies underway include the final number of sample tubes that can be accommodated, the final landing dispersion for SRL (and the resulting SFR drive distance requirement), and the choice of propulsion technology for the MAV.

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