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MARS SAMPLE RETURN AS A KEY STEP BEFORE MANNED MISSIONS.

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Introduction: In several papers and in a recent review from the International Academy of Astronautics, it is highly recommended to design the Mars Sample Return mission (MSR) in view of the future manned missions to the red planet [1,2]. As complexity is the main cost driver, several MSR studies and plans focused on the simplest and cheapest way to undertake that mission without considering in details how it could best fit in the preparation phase of manned missions [2,3]. It is proposed here to address that problem.

Overview: Many architectural elements or outputs of a MSR mission could be of interest in view of a manned mission (trajectory, Mars orbit rendezvous, in situ resource utilization, etc.). However, the risks, the complexity and the cost of a manned mission are driven by two important elements:

a) The availability and reliability of a heavy rocket to launch and send to Mars each module (habitable module, mars ascent vehicle, propulsion system of the return vehicle, etc.).

b) The availability and reliability of an entry, descent and landing (EDL) system for each heavy module that has to be sent to the surface.

Reliability of complex systems: For any system, there are different ways to determine the risk of failure. In the rocket domain, there are so many subsystems and procedures that the bottom-up approach is generally not considered. In order to be qualified, a system must be flight proven, but even after this step, as environmental conditions, subsystems and context of use always change, some failures may still be observed. The reliability of such complex systems may be estimated by means of a maturity curve. Such curves simply show that the probability of failure is decreasing with the number of consecutive successful uses. Experts will typically use similar curves to estimate the risks for the two complex elements of the manned Mars mission, the launcher and EDL systems.

Launcher: In order to minimize the risks of a manned mission, it is of particular importance to prove the reliability of the heavy launcher that will be used to send all modules to Mars. As can be currently observed with NASA Space Launch System, it is difficult to find relevant missions to test that launcher and improve its reliability. A MSR mission is one of the rare candidate missions that could make use of the heavy launcher. In order to clearly improve the maturity of the launcher, it is of a primary importance to design the MSR mission with a payload of the same mass as one of the module that will be sent to Mars for the manned mission. If another launcher is used, or if the configuration is very different (different mass, different trajectory, etc.), the MSR mission would not be a key preparatory mission and would miss one of its main objectives.

EDL systems: Entry, descent and landing on the surface of Mars has been identified by experts as one of the riskiest phase of the mission. At the moment, it is still not clear what is the best strategy and the best EDL systems to land a heavy payload on Mars. Once again, the reliability will be uncertain. The qualification will require at least one successful landing on Mars with the same exact configuration expected for the habitable module of the manned mission (same mass, same entry velocity, same angle of attack, same EDL systems, etc.). Without humans onboard, it would be a pity not sending several robots, or all the payload required for a MSR mission. Even if a first MSR mission is undertaken with totally different EDL systems, a heavy MSR mission would still be required to qualify EDL systems.

Conclusion: Considering the preparatory phase of a manned mission, it is clear that a specific MSR mission is on the roadmap. A heavy launcher will have to be used and the payload mass will be in the same order as the mass of the habitable module to qualify EDL systems. Such a mission will probably be unavoidable. As the budgets and strategies of space agencies depend on political decisions, a preliminary MSR mission that would not use the heavy launcher of the manned mission and would not test the EDL systems of the manned mission might be preferred, but it would be clearly a loss of time and efforts in view of the manned mission.

References:

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