MARS SAMPLE RETURN VIA ROBOTIC COLLECTION, PHOBOS CACHE AND HUMAN RETRIEVAL.

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Introduction: Mars Sample Return is one of the highest priority goals for deeper understanding of Mars, but its cost and complexity have repeatedly delayed its implementation. Stooke [1] proposed a program of sample return combining elements of robotic and human flight programs, which would spread and share the cost and risks, while allowing ample opportunity for international cooperation. Samples would be collected by robotic missions and delivered to Phobos over a period of about ten years. The first human mission to Mars, an Apollo 10-style rehearsal mission, would land on Phobos instead of Mars to collect the cached samples and return them to Earth. This study updates the concept.

Justification: Mars Sample Return is essential for state of the art analyses of Martian materials in terrestrial laboratories, but mission designs have until now proven to be prohibitively expensive and extremely challenging. Designs vary, but typically require a lander, a mechanism for collecting samples, a launch vehicle capable of placing the sample in Mars orbit, rendezvous with a return vehicle, sample transfer, and a long journey back to Earth. The complexity of orbital operations and the long travel time back to Earth add risk and expense to the mission.

As a separate issue, human flights to Mars will be extremely risky and expensive, making a rehearsal mission like Apollo 10 both necessary for system testing and hard to justify in scientific terms. A few images are not sufficient return. Here I propose combining the two issues into a decade long program of robotic sample collection culminating in a human flight to Phobos to collect and return the samples.

Sample Collection: The sample collection phase would be spread over about a decade and could involve missions from several space agencies. It could combine relatively simple 'ground-breaking' collection using a static lander with a sampling arm, suitable for a uniform geologic target, and sophisticated rover missions collecting samples over large areas.

Each mission would deliver its sample to Mars orbit, rendezvous with Phobos and deposit its sample to the moon's surface using the simplest possible landing system, probably a small braking rocket plus airbags. Tracking or imaging would locate the landing site, and to the extent possible these sites would be reasonably close together.

The advantages of this system are that (1) the long, risky journey back to Earth is eliminated at this stage; (2) international cooperation in building the cache of samples is possible but no single mission is in the critical path for overall mission success; (3) It is assumed that reaching Phobos is easier than a complex orbital rendezvous with a return spacecraft, and (4) a delay in the subsequent human mission can be accommodated by adding more sample return missions.

Nothing precludes additional direct-to-Earth sample return missions. Deimos can substitute for Phobos as a sample cache if it is operationally preferable. If human Mars exploration is eventually deemed impossible, a flagship class robotic mission to Phobos can gather the samples instead.

International cooperation: In its simplest form this would involve parallel Mars sample collection and caching missions. Other options would include Deimos sample collection with delivery to Phobos, Mars trojan asteroid sample return with delivery to Phobos, Mars-crossing or other asteroid sample return missions with delivery to Phobos, plus Phobos rovers to gather samples and group them for easier recovery and Phobos imaging to help locate samples. The flexibility offered by ion propulsion and use of Lagrange Points makes sample transfer even from main belt asteroids feasible today where it may not have been in the past. A range of cooperative missions are available, all valuable if successful, but none critical to overall success if they fail.

Human mission: A human Mars mission will involve great expense and high risk. Long flight times place the crew in danger from solar flares, illness and hardware failures. The Mars entry, descent and landing will be the most challenging human operation ever undertaken in space. A test flight similar to Apollo 10 or a suggested initial Golden Spike landing mission (orbiting the Moon with a crew while testing the lander in automated mode) would be very desirable but may be hard to justify if its science return is minimal.

In this proposal, the first human crew would land on Phobos, not Mars, which should be an easier operation and might use systems closely based on the lunar landing vehicle. Apart from sampling Phobos, itself a major scientific goal, it would collect all the waiting Mars samples and return them to Earth. There they would be distributed to the appropriate space agencies. The high reliability of human-rated return systems should ensure safe return of these valuable samples.

Advantages: The advantages of this system are (1) A rehearsal mission for a human Mars landing is amply justified by its science return; (2) The cost of every sample return mission is shared with the Constellation program; (3) Overall risk in the robotic missions is reduced; (4) substantial sampling takes place before any contamination is introduced to Mars by human surface operations; (5) International cooperation is feasible, but mission success does not depend on it. Disadvantages: The delay in retrieving samples is only an inconvenience. Possible volatile loss should not be much worse than during a normal return flight.

Scenario: One possible scenario is outlined here. The first step might be retrieval of the sample from the NASA 2020 rover in about 2024. Two NASA ‘groundbreaking’ Mars sample return missions (simple sample collection from broad regional target units) could fly in 2026 and 2028. They might be followed by another NASA rover sampling mission at a more complex site in 2030. Further missions could be carried out as funding permitted, perhaps jointly funded by the human and robotic flight budgets.

Meanwhile, international missions can be included in the mix. The post-2020 NASA missions might include international components (e.g. ESA rover, Canadian sample collection systems). ESA might fly one or two sample collection missions of their own between 2020 and 2034. Russia might fly a version of Phobos-Grunt to Deimos and deliver its sample to Phobos, and independently fly a Mars-Grunt sample collection mission with delivery to Phobos.

Japan’s expertise in asteroid sampling could also be exploited. A JAXA mission to a Mars Trojan asteroid could deliver a sample to Phobos using ion propulsion. Since there are several such objects, more than one might be visited during a mission, or more than one mission might be flown over the 14 year period contemplated here. Small Mars-crossing or inner main belt asteroids might also be sampled using systems like these.

Other international contributions could be considered here. India might undertake any of these types of mission independently, or might perform a high resolution imaging survey of Phobos to locate the sample capsules. Another goal of high resolution multispectral remote sensing might be a search for Mars-derived sample blocks for future collection by astronauts. China also could deliver samples from any of these targets, or deploy a Phobos rover to gather the more distant sample capsules and collect them in one convenient location for later collection.

Finally a human mission would fly in about 2037. The astronauts would land on Phobos, sample the little moon’s surface material, search for blocks of Mars ejecta, deploy geophysical instruments, and collect the various cached samples for return to Earth. By 2040 numerous samples of Mars and other targets would be available on Earth for detailed analysis. A sharing protocol would give all contributing nations proportional parts of the cache.

References: [1] Stooke, P. J. (2007) *First International Conference on the Exploration of Phobos and Deimos, 5-7 November 2007, NASA Ames Research Center, Mountain View, CA*. Abstract no. 7001.