

## MARS SAMPLE RETURN AND BIOCONTAINMENT

Margaret S. Race  
SETI Institute, Mountain View, California

### ABSTRACT

In its continuing exploration of the solar system, NASA currently has plans to launch a sample return mission to Mars as early as 2005. The design of such a mission will utilize a variety of contamination control measures, both on the outbound flight to Mars and during the return to Earth of the spacecraft and sample return canister. Biocontainment and quarantine will most certainly be required at a receiving facility where a comprehensive battery of tests will be done to determine if any living, replicating entities are included in the samples and whether the returned materials are harmful in any way to Earth's biota or ecosystems. The task of developing hardware, facilities, laboratory protocols, operations plans and certification standards for extraterrestrial materials will require input from many disciplines, including biosafety and public health experts. By combining basic principles of biocontainment with information about the nature and capabilities of microorganisms, a preliminary protocol has been developed for handling, containing and testing extraterrestrial samples. Plans for biocontainment facilities, quarantine and testing methods for Mars sample return missions will also be important in planning future extraterrestrial sample returns from comets, moons and asteroids which also have the potential for harboring life.

### INTRODUCTION

NASA's ambitious plans for solar system exploration in the coming decade include a series of robotic missions to Mars to explore the planet's geochemical, geophysical and atmospheric features; to seek evidence for water, either past or present; and eventually to return samples of soil and rock to Earth for further study. As planners and engineers design the hardware and software for particular missions, it is also necessary to consider planetary cross contamination. According to the Outer Space

Treaty of 1967 (U.N., 1967), all space exploration must be done in a way that avoids harmful contamination to celestial bodies or adverse changes in the environment of Earth from the introduction of extraterrestrial matter. For Mars exploration, planetary protection controls of various types are used to avoid both forward contamination of Mars by terrestrial microbes on the outbound spacecraft, and back contamination of Earth by the introduction of organisms or contaminants potentially present in returned Martian materials. These same concerns applied to the return of lunar samples during the Apollo program, the only other time that extraterrestrial samples were deliberately returned to Earth.

For a long time, Mars has been a destination of exobiological interest. It is a planet with the necessary ingredients for the origin, evolution and possibly the persistence of primitive life. Although the surface of Mars is cold, dry, and apparently lifeless today, its earlier geological history had a global environment that was warmer and moister. In fact, Mars and Earth both had similar climatic, geological and water conditions about 3.5 billion years ago, when convincing fossil evidence of primitive life on Earth can be found. Planned robotic missions to Mars are designed to look for rocks that might contain similar fossil evidence of primitive life on Mars. If liquid water persists in some rare subsurface refugia or geothermal oases on the planet, it might also be possible that extant primitive life forms could be found, just as they are in thermal springs and subsurface environments on Earth. Ultimately, returning actual Martian materials to Earth will help resolve questions about whether life ever existed on Mars, whether it might persist today, and if so, whether it is the same or different than life on Earth.

Currently, NASA plans a series of one-way robotic exploration missions to Mars with landers and orbiters taking off every 26 months when Earth and Mars are suitably aligned. By the year 2005, NASA hopes to launch the first round-trip mission that will return Martian samples to Earth. In prepara-

tion for these missions, researchers and engineers have begun serious discussion of how to avoid both forward and back contamination. They are guided in their deliberations by the findings of a recent study by the National Academy of Sciences' Space Studies Board, which recommended that sample materials returned from Mars should be considered hazardous until proven otherwise (SSB, 1997). In practical terms the planetary protection controls will include a variety of measures including sterilization of the outbound spacecraft, special design of instrumentation and experiments to avoid taking terrestrial microbes on the outbound trip, strict containment of all returned Martian materials and avoidance of "hitchhiker" contaminants on external surfaces or spacecraft parts, and rigorous analyses of returned materials at a special receiving facility with biocontainment and strict quarantine upon return to Earth.

#### **Containment and Testing of Sample Materials from Mars**

Much can be learned about how to handle extraterrestrial materials by analyzing containment approaches used by the biomedical and genetic engineering sectors. In addition, the conceptual and operational approaches used during the Apollo program are still applicable, albeit with considerable updating in technology, science, and legal requirements. In retrospect, while there were admittedly some problems experienced in handling early samples from the moon, the quarantine facilities and testing protocols that were used ultimately accomplished their objective of safely containing and screening incoming materials to determine whether they could eventually be released (Allton, 1998). Considering that only 500 grams or less of Martian materials will be returned to Earth during the first sample return mission, the sample receiving facilities for Martian materials can be far less elaborate than the first Lunar Receiving Facilities, which provided quarantine and containment of all returning astronauts, spacecraft, and lunar materials during its operation from 1969-72.

As a step towards addressing sample handling needs and planetary protection measures for Mars sample return, a special Protocol Development Workshop was convened in June, 1997 at NASA Ames Research Center (DeVincenzi, 1998). Experts

with diverse backgrounds were invited to participate, including representatives from CDC, USDA, EPA, NASA, university researchers, and the aerospace industry. In their deliberations they addressed how to implement the recommendations of the SSB report (1997) by focusing on three particular areas: biocontainment, life detection, and biohazard testing. Their preliminary findings are summarized briefly below:

**Biocontainment:** Containment of Martian materials must be designed to protect those working with the samples, as well the Earth's biota and ecosystems. In addition, containment must ensure the integrity of the samples themselves and preserve them for scientific investigation. Containment will require addressing two very different aspects of the sample return: 1) containment in transit, both in space during the return flight from Mars and on Earth during transport to the sample receiving facility, and 2) containment and handling of extraterrestrial materials in the sample receiving laboratory itself.

Strict en route containment should be maintained from the time of sample collection on Mars through reentry to Earth and during transfer to the sample receiving lab. A sealable transport container should incorporate a fail-safe passive monitoring system to detect any breaches prior to reentering the Earth's atmosphere. Sterilization en route should be possible in the event of such a breach. In addition, contingency and cleanup plans should be developed for any in-transit accidents that could occur between re-entry and delivery to the sample receiving facility. The sealable transport container should only be opened after it has been securely delivered into the containment laboratory at the receiving facility. At the sample receiving facility, suitably strict containment can be accomplished by a combination of primary and secondary containment. Primary containment should utilize a BSC III cabinet or glovebox line with negative pressure. Secondary containment should be high-end BSL-3, with HEPA filtered air, personal showers and waste water sterilization.

**Life Detection and Biohazard Testing:** The exact protocols for studying and analyzing returned samples have not yet been developed, although a conceptual approach and recommended types of tests have been identified. Analytical and testing

requirements have implications for biosafety and containment because they will effect the size of laboratory and type of equipment required within the quarantine area, as well as the types and numbers of personnel who will work on the samples. Findings from the comprehensive sample analyses will ultimately be used to determine whether materials can be released from containment for distribution to researchers elsewhere, or whether they warrant continued containment. Multiple lines of investigation will be required to determine whether any living entities or parts of putative Martian organisms are contained in returned materials. Test protocols should include a wide variety of chemical analyses, geochemical characterizations, microscopy and bio-hazard challenge tests. Tissue culture and cell lines, rather than whole organisms challenge tests, were recommended as a way of effectively scanning for potential toxic effects, infectivity, and ecological disruptions, while minimizing the need for animal containment space and equipment. Research will also be needed to identify effective sterilization method(s) that can be used on Martian materials with the least impact on the samples or their scientific interpretation.

## CONCLUSION

A Mars sample return mission will no doubt generate considerable public interest because of

excitement about potential extraterrestrial life and questions about possible adverse effects on Earth, however unlikely they may be. Through the environmental impact statement process, the public will be able to scrutinize information about mission plans, risk assessments, biocontainment decisions, laboratory operations, testing procedures, worst case scenarios and contingency plans. Ultimately, the overall success of a Mars sample return mission may depend, in part, on how confident the public is that biosafety concerns have been addressed. Clearly, it will be important to utilize a rational and effective approach to biocontainment as mission plans are developed.

## REFERENCES

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