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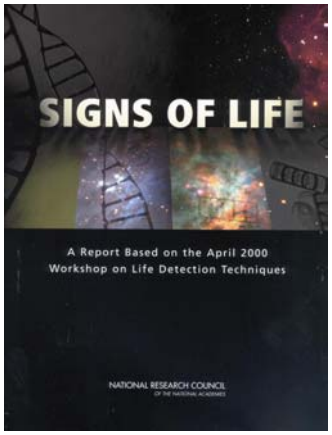
Signs of Life: A Report Based on the April 2000 Workshop on Life Detection Techniques – *Summary*

SPACE STUDIES BOARD

Background



Since the Viking lander made the first inconclusive attempts to detect life on Mars in the mid-1970's, the ability of in-situ instrumentation to detect life on other planetary bodies has been debated. The Viking result led to the belief that the return of samples for analysis in laboratories on Earth was the only way to know for certain that life exists, existed in the past, or has never existed on other planets.

As NASA's Mars Exploration Program moves forward, the scientific community is actively preparing for a Mars sample-return mission in the next 10-15 years. In an effort to assess the state of life-detection technologies that have developed since the Viking mission, the Committee on the Origins and Evolution of Life (COEL) organized a workshop to discuss recent advances in the field.

The workshop's participants addressed a series of four general questions concerning life detection:

- How does one determine if there are living organisms in a returned sample?
- How does one determine if living organisms have been present at some earlier epoch and have left fossil remnants behind in a returned sample?
- How does one determine whether there are living organisms or fossils in samples examined robotically on another solar system body?
- How does one determine if living terrestrial organisms are on a spacecraft before launch?

The responses to these questions provide the basis for a new series of life-detection experiments, responsive to current interest in the search for life in the solar system. As probes begin to search Mars, Europa, and, ultimately, Titan new techniques and experiments could bring us the first evidence that we are not alone.

Life Detection in a Returned Sample. The papers presented at the workshop demonstrated that a multidisciplinary approach must be taken when designing life-detection experiments. Since no one method is currently provides definitive evidence for life in a particular sample, a range of techniques must be used to probe the physical, chemical, and structural characteristics of living organisms and/or their fossil remains.

Not surprisingly, the most sensitive detection techniques currently available are designed to find organisms that are biochemically similar, if not identical, to terrestrial life. Results indicating the presence of extraterrestrial life (even carbon-based) cannot yet be considered definitive. Thus, there is a pressing need not only to refine existing life-detection procedures but, also, to develop more-general methods which do not make restrictive assumptions concerning the nature of the putative organism's metabolic processes, use of specific biopolymers, or other chemical and isotopic signatures.

In its recommendations, COEL emphasizes the need for careful preparatory work and site selection for any sample-return mission. In-situ measurements must be taken to reduce the risk in returning samples to Earth which are uninteresting from a biological perspective. Robotic missions must also be used to identify locales which have the highest probability for finding life, in preparation for the selection of a landing site.

Determining the Past Presence of Life in a Sample. Even the most optimistic astrobiologists do not place high odds of finding living organisms in samples returned from Mars and other planetary bodies. The more-likely scenario involves the discovery of some indication of past life in a returned sample—i.e., the detection of biochemical, molecular, isotopic, or morphological fossils. This possibility led to the most vigorous debate at the workshop. Here, the discussion centered on interpretation of potential signatures of life in samples available today in the laboratory—meteorites—and, in particular the basaltic rock known as ALH 84001. This meteorite was collected in Antarctica in 1984 and is generally accepted to have been a part of the martian crust.

Important disagreements exist within the scientific community over the biological significance of various structures found within ALH 84001. It was, however, clear from the workshop discussions that at least some of the disagreements result of the lack of repeat analysis of a particular sample or phase of this meteorite by multiple groups. As a result, COEL recommends that any plans for analysis of returned extraterrestrial samples include a provision for repeat analyses of a subset of the same material by different teams. The committee also encourages early development and testing of appropriate protocols using existing samples of high astrobiological interest (e.g., ALH 84001)

Apart from discovering actual fossilized remains of extraterrestrial organisms, COEL also recommends refining techniques for discerning the presence of organic molecules on other bodies. This area is perhaps the most advanced of those covered in the workshop, as the existence of such molecules has been remotely sensed everywhere from the atmosphere of Titan to interstellar clouds of gas and dust.

In Situ Detection of Extant or Extinct Life. Life-detection experiments on robotic mission are constrained by the available space and mass of a given craft. Such constraints force scientists to make assumptions about the nature of life at the mission's target, which intrinsically reduces the likelihood of life detection. Because of the continuing rapid improvements in technology, it is not appropriate to recommend a specific set of techniques for in situ life detection at this time, but in situ detection will require commitment to a small set of potential techniques with significant lead time to

ensure that they can be space qualified. COEL encourages continued efforts to develop innovative and miniaturizable techniques for in situ life detection.

The committee also highlights the dominant role of spacecraft safety in the site selection process. The safest areas to land are not necessarily the most interesting from a scientific perspective. For Mars, this means that landing-site selection cannot be based primarily on issues of spacecraft safety. Furthermore, proper site selection will require a series of missions including orbital reconnaissance followed by exploration of selected sites by landed vehicles. An informed and continuing dialogue between scientists engaged in life detection and mission planners is essential if astrobiologically interesting samples from Mars are to be obtained.

Preventing Forward Contamination. The most strikingly definitive result coming from the workshop concerns the dramatic improvement in laboratory techniques designed to detect terrestrial organisms. Such techniques are key to ensuring positive results from life-detection experiments—be they in situ or in a terrestrial laboratory—do not result from the detection of terrestrial contamination. Such concerns and related planetary-protection issues can be allayed by the use of more sensitive assays to certify that spacecraft are biologically clean before they are launched. Since NASA's current planetary-protection protocols mandate the use of bioassays that could miss up to 99 percent of the microorganisms on a spacecraft, new technologies must be incorporated as they are developed.

Complicating the already difficult contamination issue is the fact that some of the most sensitive life-detection methods developed in recent years—e.g., those incorporating biochemical techniques such as the polymerase chain reaction—are not suited to distinguishing between viable and nonviable organisms. This is a key factor in, for example, planetary-protection calculations relating to the inadvertent contamination of extraterrestrial bodies by terrestrial organisms.

COEL recommends that studies of future missions to astrobiologically interesting targets include explicit consideration of the types of cleaning and/or sterilization of spacecraft systems, subsystems, and components and that sterilization costs be included in a realistic fashion. COEL also recommends that special near-term emphasis be given to the issues of sample selection, spacecraft sample-handling, and characterization. Finally, COEL encourages further work to refine sterilization approaches to minimize impacts on mission costs and success.

Follow-on Activities and Further Information. Motivated in part by the findings of this report, COEL held an informal 1-day workshop in April, 2002, to discuss issues relating to the nature of and means to detect life that is not biochemically similar to terrestrial life. As a result of these discussions, the committee is developing a possible study on "The Limits of Organic Life in the Solar System."

For further information.

Copies of the complete report, *Signs of Life: A Report Based on the April 2000 Workshop on Life Detection Techniques*, can be obtained on the National Academy Press Web site <www.nap.edu/>**.**

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