MARS SCIENCE LABORATORY, PRESERVATION POTENTIAL OF BIOSIGNATURES AND ENVIRONMENTAL RECORDS, AND THE ATTRIBUTES OF PROMISING LANDING SITES

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MSL Mission and Payload: Due to launch in 2011, MSL will investigate a site that shows clear evidence for ancient aqueous processes based on orbital data and undertake the search for past and present habitable environments. The MSL payload was specifically assembled for the purpose of environmental (and paleoenvironmental) assessment and includes a gas chromatograph-mass spectrometer and gas analyzer that will search for organic carbon in rocks, soils and in the atmosphere; an x-ray diffractometer that will determine mineralogical diversity in rocks and soils; color cameras that can image landscapes and rock/soil textures in unprecedented resolution; an alpha-particle x-ray spectrometer for *in situ* determination of rock and soil chemistry; a laser-induced breakdown spectrometer to remotely sense the chemical composition of rocks and minerals; an active neutron spectrometer designed to search for water in rocks and soils; a weather station to measure modern-day environmental variables; and a sensor designed for continuous monitoring of background solar and cosmic radiation.

Biosignatures and Preservation: MSL is not a life detection mission and has no capability to detect extant vital processes that would betray present-day microbial metabolism. Nor does it have the ability to image microorganisms or their fossil equivalents. MSL does have, however, the capability to detect complex organic molecules in rocks and soils. If present, these might be of biological origin, but could also reflect the influx of carbonaceous meteorites. More indirectly, MSL will have the analytical capability to probe other less unique biosignatures, specifically, the isotopic composition of inorganic and organic carbon in rocks and soils, particular elemental and mineralogical concentrations and abundances, and the attributes of unusual rock textures. The main challenge in establishment of a biosignature is finding patterns, either chemical or textural, that are not easily explained by physical processes. MSL will also be able to evaluate the concentration and isotopic composition of potentially biogenic atmospheric gases such as methane, which has recently been detected in the modern atmosphere. But compared to the current and past missions that have all been targeted to find evidence for past or present water, the task of searching for habitable environments is significantly more challenging. Mostly, this is because it is unknown to what degree organic carbon would be preserved on the Martian surface – even if it were produced in abundance.

Earth's early geologic record is a useful guide to prediction of biosignature preservation in the ancient Martian rocks to be sampled by MSL. Scientists working on the terrestrial record of early life long ago recognized to focus on rocks whose preservation character maximizes the chances of success. Paleontological exploration is critically sensitive to the diagenetic processes that control preservation and, paradoxically, the very characteristics (water, gradients in heat, chemicals, and light, and also oxidant supply) that make so many environments habitable also cause them to be destructive to biosignature preservation. Nevertheless, though most habitable environments destroy organic materials, there are rare circumstances that facilitate spectacular preservation; these often involve geochemical conditions that favor very early mineralization. Authigenic silica, phosphate, clay, sulfate, and less commonly, carbonate precipitation are all known to promote biosignature preservation when all other factors, such as environmental redox conditions, are equal.

Therefore, if MSL is to succeed in detecting organic compounds this will require a habitable environment that also favors preservation of organic compounds. This search can be optimized by pursuing an exploration strategy that focuses on the search for windows of preservation. We should be guided but not limited by our terrestrial experience, lest we forget that Mars may indeed have its own unique paleoenvironmental conditions favorable to the preservation of organic compounds and other potential biosignatures. It will be MSL's task to identify the characteristics of these environments and where they can be found.

Environmental Records and History: An essential point that Earth also teaches us is that in the search for signs of early life a null result is a not always a disappointment. Whatever may be lost in terms of insight into possible paleobiologic markers may be gained by an equally rich reward into the processes and history of early environmental evolution. Studies of Earth's Precambrian sedimentary record have revealed secular changes in the oxidation state, acid-base chemistry, and precipitation sequence of minerals in the oceans and atmosphere. Knowledge of an equally informative environmental history may also be uncovered on Mars. The evolutionary path of surface environments on an Earth-like planet that lacked a biosphere would make a highly desirable comparison to Earth in order to understand better the unique aspects of our own planet's history. These records of environmental history are also embedded within the same kinds of rocks and minerals that may also preserve the calling cards of biology. Therefore, an MSL mission that focuses on understanding mechanisms of potential biosignature preservation will also insure that we capture the record of early Martian environmental processes and history.

This approach holds both the hope and promise of Mars Science Laboratory. The hope is that we may find some signal of a biologic process. The promise is that MSL will deliver fresh insight into the comparative environmental evolution of the early stages of Mars and Earth. That alone is a valuable prize.

Landing sites: Four very promising landing sites have been identified that will give MSL a good head start on the search for past habitable environments that could preserve paleoenvironmental indicators: Eberswalde crater; Gale crater; Holden crater; and Mawrth vallis. While each site has its own particular strengths, they share in common two very important attributes: definitive evidence for the former presence of water as seen by either mineralogic or morphologic features (or both), and the presence of prominent stratigraphic sequences, hundreds to thousands of meters thick in some cases, suggestive of sedimentary rocks. Historical accounts of planetary surface evolution are largely written in stone, and processes that operate at a planetary surface have the potential to create a record of sedimentary rocks. This is important because our experience on Earth shows that sediments and sedimentary rocks can preserve high-resolution proxies of present and past climatic, tectonic, and biological processes as well as providing the dominant archive of major events in Earth's evolution. Sedimentary rocks precipitated from water are particularly important because they embed signals of elemental and isotopic variability that relate to geochemical and biogeochemical processes, expressed at local to global scales. Although other rock types such as hydrothermal deposits within volcanic terrains also hold potential to be both habitable and favorable for preservation of biosignatures, terrestrial experience shows that sedimentary rocks are the favored medium for preservation of *both* biosignatures and global environmental records.