

Spectroscopy and the Search for Ancient Life on Mars

This article examines a new instrument combining UV, visible, and near-IR spectroscopic sensing with on-board statistical computing that is designed for use on NASA Mars rover missions. The team that developed the system hopes it will be used to successfully settle the question of whether life ever existed on Mars.

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Ever since the Viking Landers first completed their biological testing of the soil on Mars almost 29 years ago, lingering questions have remained as to whether or not life ever evolved or continues to exist there. Since then, actual rock samples from Mars have been found on Earth as meteorites and laboratory analysis has revealed that they contain indigenous organic molecules, further igniting the possibility that life might have left telltale residues behind. Today, a total of five spacecraft, three orbiters, and two rovers currently are studying Mars in detail, and all have found some geological evidence that Mars once was awash with abundant liquid water at some point in its history. There even are indications from NASA's Mars Global Surveyor orbiter that intermittent liquid water from melting ice might be running down hillside gullies within certain craters. Yet, the question of life remains open because none of these spacecraft has the appropriate instrumentation to find the actual residues of life. This is about to change as NASA prepares to begin sending new robotic rovers equipped with instruments designed to look for the habitats of ancient life on Mars.

For Robert A. Lodder, an expert in the field of biomedical spectroscopy from the University of Kentucky, College of Pharmacy (Lexington), the challenge of looking for possible biosignatures on Mars is an achievable goal. Lodder has designed a new experiment capable of revealing the biosignatures of ancient life on Mars, and in doing so hopes he and his science team will get a chance to settle the question once and for all. Lodder calls his new instrument SEARCH, an acronym for Scan for Extinct Astrobiological Residues and Current Habitats. It is now under consideration for a future NASA Mars rover mission.

"The experiment uses lasers and lidar as its analytical technology," Lodder says. SEARCH will use an array of laser diodes combining UV, visible, and near-IR spectroscopic sensing with an on-board statistical classification data analysis algorithm. SEARCH ultimately will look at a series of different wavelengths from rocks and soils to obtain a detailed profile, with the aim of identifying ancient biological processes that might once have existed on Mars. The new instrument

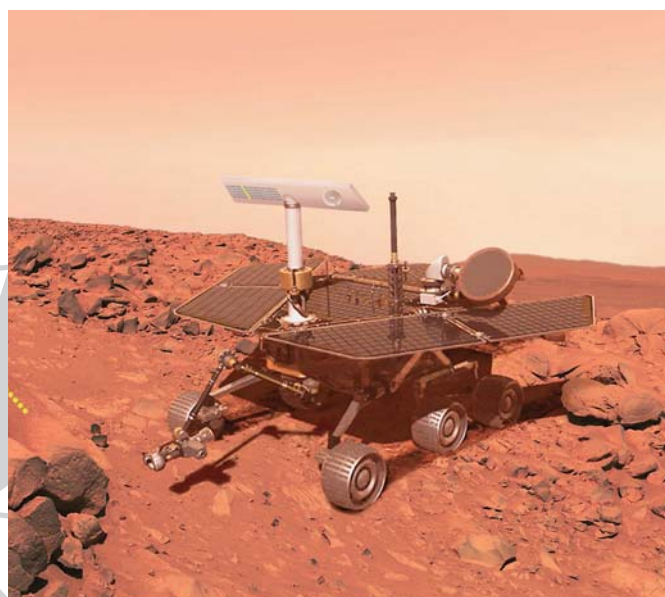


IMAGE COURTESY ROBERT A. LODDER

An artistic conception of how the SEARCH instrument would look on a Mars rover. The SEARCH instrument is painted white, attached to the white mast. Note that the diodes all emit invisible UV or NIR light except for the one column of green DPSS lasers.

also will be able to identify amino acids, carbohydrates, polycyclic aromatic hydrocarbons (PAHs), and complex organic compounds. Lodder's rationale for using some of the laser diodes in the near-IR part of the spectrum is that nearly all organic compounds including paraffins, carboxylic acids, and PAHs show unique spectra in this region that can be measured accurately. Aside from its unique ability to look for these biosignatures of ancient life, SEARCH also can double as a superb geological instrument and will be able to detect a wide variety of minerals including hematite, jarosite, sulfides, sulfates, halites, silicates, limestone, amphiboles, and many others. Add to this the ability to find water in any of its phases — liquid, solid, or as hydrates — and SEARCH becomes an even more versatile tool for this type of research.

With a mass of only 580 g, the SEARCH instrument is



The SEARCH laser head prototype, shown here filled with visible light diodes. The diodes plug in and are easily replaceable with near-IR wavelengths.

designed to be light enough to be mast-mounted on a Mars rover where it then will have a useful target range of up to 10 m. This will allow SEARCH to make a detailed spectral portrait of the landing area and any suspected localized biohabitats could be analyzed from a distance. Once a habitat is detected, the rover vehicle then could drive directly over to the site and conduct further in-situ sampling and imaging. Using only 3.7 W of electricity internally supplied by the Mars rover power source, SEARCH has a laser diode array of 25 radiation-hardened low power laser diodes 5 mm in diameter with frequencies ranging from 300 to 2400 nm. The instrument is designed to work either during the Martian day or night.

How SEARCH Works

After the spectrum of a sample of Martian rock or soil is obtained by SEARCH, it then will be classified and compared to its internal geochemical library to identify what substances are present. This internal library is the heart of SEARCH and uses the Bootstrap Error-adjusted Single-sample Technique

(BEST) pioneered by Lodder in 1993 while conducting near-IR imaging of atheromas in arterial tissues. Because the BEST classification algorithm is onboard, it can be programmed to carry out the classification of large sampled areas while alerting ground controllers on Earth only when a particular interesting substance has been found. Gilbert V. Levin, an astrobiologist who worked on three previous missions to Mars, is a coinvestigator on SEARCH. "The BEST technology relies upon processing the data in to a

profile signal that is then immediately matched with its terrestrial twin residing in a computer bank that we will establish by testing and storing program files from everything we believe might be of interest on Mars," he says. The advantage of SEARCH compared with other spectroscopic techniques such as Raman spectrometry is considerable. Besides its small size and light weight (a prime consideration for any experiment flown on NASA Mars missions) the SEARCH near-IR lasers quickly can detect one in 10 photons scattered by rocks and soils, whereas Raman spectrometry can only detect one in 109 photons.

The BEST software program developed by Lodder compresses data so that its transmission to and from Earth requires very little bandwidth. Because rovers such as NASA's Spirit and Opportunity share the bandwidth time with a number of other instruments including the software to drive the rover, the cameras, and scientific instruments, it is important for those developing planetary science instruments to make sure they use as little bandwidth

as possible. Another advantage is the ability of SEARCH to help guide the Rover to interesting spots for its detailed analysis.

Lodder and his team have been busy gathering spectra for the BEST library of standard target materials and will compare these spectra remotely to those in a master spectral computer library to verify that they match. In a recent test, Lodder's group killed some lichen biofilm on the surface of terrestrial rocks using heat, and then tested them using SEARCH. The tests readily detected the dead biofilm.

Penetrating the Dust Coatings on Mars

Mars is an extremely dusty environment. Fine loose dust covers both rocks and soils and is the reason NASA decided to include a rock abrasion tool on each of its rovers Spirit and Opportunity. Before each of these rovers uses any of its scientific instruments (thermal emission spectrometer, Mossbauer spectrometer, and alpha proton x-ray spectrometer) it needs to drive up to the rock or area to be sampled and grind off the outer layer of adhering dust. At this point an analysis can be performed. While this technique works well, it is very time consuming. Because of low molar absorptivities in the NIR range, SEARCH immediately will be able to penetrate thin dust and rock coatings for an instant analysis from a distance of 10 m. This is because NIR light is known to penetrate layers to reveal subsurface chemistry.

It is interesting to note that Lodder's SEARCH instrument has its origins as a tool for diagnosing pharmaceutical contaminants. Lodder reasoned that if laser light scattering using liquid crystal tunable lasers were able to identify proteins for pharmaceutical cleaning verification, then it would make a powerful tool for looking for biofilms on Mars. ■

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