A Novel Infrared Spectrometer and the Exploration of Mars

University of California, Berkeley

American Chemical Society
“The infrared spectrometer was a groundbreaking design of unprecedented sensitivity, mechanical stability, and environmental robustness, which enabled it to make the first chemical measurements of the makeup of the Mars surface and atmosphere.”

— Richard A. Mathies, chemistry professor, University of California, Berkeley, 2016
Herr won a grant from NASA in 1964 to develop a prototype, and in 1966 it was accepted for the Mars Mariner missions.

Pimentel, Herr, and their team at UC Berkeley designed and built the new IR spectrometer. Pimentel and Herr determined that the best wavelengths to be explored were in the 2–15-micron region, which would capture the reflected sunlight as well as the thermal emission from Mars. As chemists, they understood that fingerprints of several important molecules would be absorbing in these wavelengths. To utilize the most sensitive detectors—lead selenide and mercury-doped germanium (Hg-Ge)—in this region of the spectrum, an innovative and effective cooling system was required, because the Hg-Ge detector needed to be cooled to within 22 degrees of absolute zero. The investigators decided to use a novel refrigeration unit employing a high-pressure gas system that would operate only during the 30-minute flybys of Mars. This decision would later cause anxious moments.

**TENSIONS WITH NASA**

The UC Berkeley group was a different bunch than the buttoned-down NASA bureaucrats were used to working with, and the relationship between them was sometimes rocky. As Jeanne Pimentel (b. 1935), George’s widow, put it in a 2000 article in *The Chemical Intelligencer*, “The starry-eyed recruits embarked on their mission, little realizing the difficulties they would encounter with their monolithic bosses, NASA and its contractor, Jet Propulsion Lab (JPL). ... Personality and mode of operation were partly responsible for the division, but at the heart of the matter was the approach to the scientific endeavor at hand. George and Ken were determined to push the state of the art of instrument design in order to get the best possible scientific results; NASA and JPL wanted a safer, less ambitious approach.”

Nevertheless, Mariner 6 and 7 were launched in February and March 1969 and reached Mars in late July and early August to examine different areas of the planet. Only a few days before Mariner 6 arrived at Mars, JPL lost contact with Mariner 7 and suspected that a rupture in the spectrometer’s high-pressure cooling tank was to blame. JPL regained contact with Mariner 7, but Pimentel and Herr wouldn’t know whether the spectrometer on Mariner 7 would function until the unit was turned on during the flyby. Their anxiety is evident in video recordings made at JPL during the actual mission. Ultimately, the instruments on both spacecraft successfully scanned the atmospheric and surface chemistry of Mars.

**SCIENTIFIC RESULTS**

The novel chemical measurements carried out by the IR spectrometers included:

- The first evidence for solid CO$_2$ in the Martian atmosphere.
- The detection of goethite, which forms in aqueous weathering processes, the first evidence that there was once liquid water on the Martian surface.
- The determination of water vapor concentration in the Martian atmosphere.
- The detection of solid water and water hydrates on the Martian surface.
- The determination of water vapor concentration in the Martian atmosphere.

Both spacecraft transmitted their IR spectral data back to Earth, along with photos and data from the other scientific instruments. Because the actual encounters with Mars were so extraordinarily brief, Pimentel designed equipment for conducting follow-up experiments back on Earth using the data in simulated space conditions, which verified and expanded the findings.

**REDISCOVERY OF THE SPECTROMETER TAPES**

Amazingly, the tapes containing the IR spectral data from Mars wound up socked away in a basement at UC Berkeley, and would have remained there were it not for the efforts of Laurel Kirkland (b. 1962), who in the mid-1990s was working on her Ph.D. in geophysics at Rice University. Kirkland was highly impressed by a spectrum of the Martian surface from one of the Mariner missions, and was stunned to discover that most of the data collected by the IR spectrometers were missing. She contacted Jeanne Pimentel, and the two of them eventually found the tapes. Through Kirkland’s efforts, the tapes were read and the data decoded with the help of Herr and other former members of the spectrometer team, who then went on to finish earlier draft papers and publish some new ones.
Mars Mariner Infrared Spectrometer
A National Historic Chemical Landmark

The American Chemical Society (ACS) designated George Pimentel and Kenneth Herr’s design of a revolutionary infrared spectrometer as a National Historic Chemical Landmark (NHCL) in a ceremony at the University of California, Berkeley, on May 15, 2017. The commemorative plaque reads:

In the 1960s, UC Berkeley’s George Pimentel and his team, including Kenneth Herr, developed a revolutionary infrared spectrometer at the university’s College of Chemistry and Space Sciences Laboratory. Two of these instruments flew past Mars aboard the Mariner 6 and 7 spacecraft in 1969. They sent back new data about the chemistry of Mars, including measurements of carbon dioxide, carbon monoxide, and water vapor in its atmosphere. Solid carbon dioxide and water ice were detected at the south polar cap, while vibrational signatures of iron oxyhydrates showed that liquid water once existed on Mars. The design and performance of these instruments set a new standard for spectroscopic studies of our solar system.

About the National Historic Chemical Landmarks Program

ACS established the NHCL program in 1992 to enhance public appreciation for the contributions of the chemical sciences to modern life in the United States and to encourage a sense of pride in their practitioners. The program recognizes seminal achievements in the chemical sciences, records their histories, and provides information and resources about NHCL achievements. Prospective subjects are nominated by ACS local sections, divisions or committees, reviewed by the ACS NHCL Subcommittee, and approved by the ACS Board Committee on Public Affairs and Public Relations.

ACS is a nonprofit organization chartered by the U.S. Congress. ACS is the world’s largest scientific society and a global leader in providing access to chemistry-related research through its multiple databases, peer-reviewed journals, and scientific conferences. Its main offices are in Washington, D.C., and Columbus, Ohio.

Acknowledgments:

Written by Rudy Baum.

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The UC Berkeley College of Chemistry and ACS California Section sponsored the nomination for this Landmark designation.

Cover photo: Kenneth Herr is shown with a test model of the Mars Mariner infrared spectrometer at UC Berkeley’s Space Sciences Lab, ca. 1967. Cover photo and page three photo courtesy of UC Berkeley.

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