REMOTE SENSING OF PLANETARY SURFACES USING GAMMA-RAY/X- .W.% SPECTROSCOPY; ^*

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The gamma rays and x rays emitted from planetary surfaces can be detected and used to determine the abundances of many elements. Parts of the lunar surface were quantitatively mapped using gamma- ray anti x-ray spectrometers on Apollo 15 and 16. Gamma-ray spectra were obtained from Mars by gamma-ray spectrometers (GRS) on the Soviet Mars- 5 anti Phobos- 2 spacecraft . The Viking landers determined elemental abundances by x-ray fluorescence (XRF). Venus's surface composition has been studied Using Soviet GRS and XRF systems. More recently, improved gamma-ray and x-ray spectrometers have been built for severs] planetary orbiters, including the Mars Observer.

To plan for future planetary missions that will require measurements of elemental abundances, a team was established four years ago under NASA Planetary instrument Definition and Development Program (PIDDP). The leader of this team has been J. 1. Trombka. This team combines resources from various NASA centers, other government, laboratories, some universities, and several companies. The goals of the PIDDP-supported work by this team have been to develop better gamma-ray and x-ray spectrometer systems, to study the performance of such systems under a wide range of environmental conditions, and to plan for future planetary missions. The x- ray spectrometer (XRS) and GRS for the Near Earth Asteroid Rendezvous (NEAR) mission resulted from work done by this team, as did several GRS systems on the Russian Mars-96 mission. Some of the results of this gamma- ray/x- ray PIDDP team are summarized here.

Semi-conductor Gamma-Ray Spectrometers

High-energy resolution is very important to help resolve the many gamma rays produced in planetary surfaces by primary and secondary cosmic- ray particles. Germanium (Ge) has the best energy resolution but must be below about 130 K to operate. Studies have been done on cooling GeGRS systems on **planetary** missions, including mechanical coolers anti passive radiators. New cryotechnologies, such as using lasers, are also being considered for planetary missions.

Semi-conductors that can operate near room temperature, such as cadmium-zinc telluride, are being studied. While the energy resolution is not as good as Ge, the ability co work without large, powerful cooling systems is a big advantage for these detectors. Our experience with such systems is limited, especially as it relates to planetary missions. Several studies are examining the possible use of such detectors on future missions.

Scintillator Gamma-Ray Spectrometers

Some scintillators, such as NaI(Tl), have been around for decades, anti their performance is well known. Scintillators do not need cooling 'but have much poorer energy resolution than most semi-conductors. Some new scintillator materials, such as bismuth germanate (BGO), gadolinium oxyorthosilicate (GSO), and lutetium oxyorthosilicate (LSO) have been studied for use in planetary gamma- ray spectroscopy. Possible problems that have been identified with some of these new scintillators include natural radioactivity in the lutetium of LSO anti capture of neutrons by gadolinium in GSO.

Gamma-Ray Spectrometer Systems

Methods to improve the performance of gamma-ray spectrometers include active anti passive shields and collimators. Such systems reduce unwanted signals. The NEAR GRS uses a BGO collimator so that the main NaI detector only views the asteroid. Besides rejecting charged particles, this collimator also reduces backgrounds by identifying gamma rays that have only partially been absorbed in the primary detector, such as by Compton scattering or pair production. For scintillators, new methods to detect the light emitted as the result of gamma-ray interactions are being investigated.

X-Ray Spectrometers

To date, most planetary x- ray spectrometers have used proportional counters with balanced elemental filters to distinguish among incident x rays at energies below 2 keV. New x-ray detectors being studied include mercuric iodide (Hg I.?.), avalanche photodiodes, and other Si-based systems. A thermo-electrically cooled 1.2 mm^2 si~.icon PIN detector is being used as a solar monitor on the NEAR XRS Many of these systems lack the volume or surface area needed for planetary systems, thus methods to stack or link such detectors are being studied. Some of these detectors are also being considered for detecting photons made by various scintillators.

Environmental Effects

The effects of cold and hot temperatures on various x-ray and gamma-ray spectrometers have been studied. Some detectors, such as BGO, work better at cold temperatures.

The effects of radiation on these detectors often are serious. Nays to reduce or remove radiation damage induced by charged particles in germanium have been studied. The radioactivities made in detector materials are being studied using system studies, accelerator Irradiations, and returning material from space flights. Some systems are being flown in space or on balloons or are being exposed to radiations similar to that in space to study t.heir performance and to better understand their backgrounds and operation.

Active Excitation Sources

Most planetary x--ray and gamma-ray missions use natural exe].LatlcIl sources, such as solar x rays or the high-energy particles in the galactic cosmic rays. The ability to use artificial sources of x rays and neutrons with XRS and GRS systems is being studied for surface missions. Some work has focused on getting sources that require low power and low mass. Excitation sources used for other applications, such as well logging, ar?. being examined for their modification for planetary missions.

System Studies and Mission Profiles

Trade-offs between mission requirements anti the desired science lead to most or' the studied systems being candidates for some planetary missions The combination of systems, such as neutron detectors and gamma-ray spectrometers, has been studied. The ability of various systems to tie*.e,;* certain elements, such as hydrogen, has been examined. Methods to properly calibrate such systems for -planetary applications have been considered,

This x-ray/gamma-ray team has shown that there are many ways to determine elemental abundances on future missions. Many of these systems can be used in situ for identification of possible resources and the determination of their elemental abundances