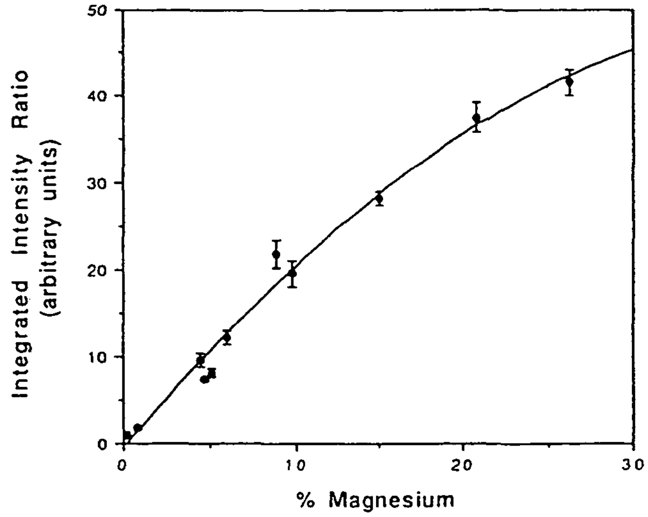

Fig. 2. Calibration curve for magnesium generated by monitoring the Mg I (285.2 nm) emission line.

intensities with negligible background interference indicating the feasibility of extending the analysis distance significantly beyond 18 m. This would require optimization of the focusing optics and an automated alignment capability to optimize light collection.

Experiments to date have proven the qualitative analysis capabilities of this technique. Preliminary calibration curves have been generated using rock powder standards to provide a quantitative measure of the technique. These curves were generated by monitoring the emission intensity of specific elemental lines. The calibration curve for magnesium is shown in Fig. 2. Similar curves have also been obtained for calcium and aluminum. Further experiments are needed to verify the quantitative capabilities of LIBS and to determine a set of optimum operating parameters.

N93-17255 1993008066 48054

ROBOTIC LUNAR ROVER TECHNOLOGIES AND SEI SUPPORTING TECHNOLOGIES AT SANDIA NATIONAL LABORATORIES. Paul R. Klarer, Sandia National Laboratories, Robotic Vehicle Range, Division 9616, P.O. Box 2800, Albuquerque NM 87185, USA.

Robotic Rovers: Existing robotic rover technologies at Sandia National Laboratories (SNL) can be applied toward the realization of a robotic lunar rover mission in the near term. The facilities and robotic vehicle fleet at SNL's Robotic Vehicle Range (SNL-RVR) have been used to support technology base development in the mobile robotics field since 1984. Applications ranging from DOD battlefield and security missions to multiagency nuclear emergency response team exercises have utilized various elements of that technology base. Recent activities at the SNL-RVR have demonstrated the utility of existing rover technologies for performing remote field geology tasks similar to those envisioned on a robotic lunar rover mission. Specific technologies demonstrated include low-data-rate teleoperation, multivehicle control, remote site and sample inspection, standard bandwidth stereo vision, and autonomous path following based on both internal dead reckoning and an external position location update system. These activities serve to support the use of robotic rovers for an early return to the lunar surface by demonstrating capabilities that are attainable with off-the-shelf technology and existing control techniques. Sandia National Laboratories' Advanced Vehicle Technologies Department's extensive experience in designing and producing fieldable robotic rover systems provides a practical, realistic basis for integrating this technology within a multiagency team's scenario for a near-term robotic lunar rover mission.

SEI Supporting Technologies: The breadth of technical activities at SNL provides many supporting technology areas for robotic rover development. These range from core competency areas and microsensor fabrication facilities, to actual space qualification of flight components that are designed and fabricated in-house. These capabilities have been developed over the years to serve SNL's role in missions for a variety of customers, including U.S. industry, the U.S. Department of Defense, the U.S. Department of Energy, and elements of the nation's intelligence community.

N93-17256 1993008067 48055

LUNAR PROSPECTOR: A PRELIMINARY SURFACE REMOTE SENSING RESOURCE ASSESSMENT FOR THE MOON. A. A. Mardon, Department of Space Studies, University of North Dakota, Grand Forks ND 58202, USA.

The potential existence of lunar volatiles is a scientific discovery that could distinctly change the direction of pathways of inner solar system human expansion. With a dedicated germanium gamma ray spectrometer launched in the early 1990s, surface water concentrations of 0.7% could be detected immediately upon full lunar polar orbit operations. The expense of lunar base construction and operation would be dramatically reduced over a scenario with no lunar volatile resources. Global surface mineral distribution could be mapped out and integrated into a GIS database for lunar base site selection. Extensive surface lunar mapping would also result in the utilization of archived Apollo images.

The presence or lack of solid water and other frozen volatiles at or near the surface of the Earth's nearest celestial neighbor, the Moon, will dramatically affect the way in which we will approach the surface exploration of the Moon. For almost three decades, various scholars have debated the existence of water ice at the lunar poles. A variety of remote sensing systems and their parameters have been proposed for use in the detection of these lunar ice masses. The detection or nondetection of subsurface and surface ice masses in lunar polar crater floors could dramatically direct the development pathways that the human race might follow in its radiation from the Earth to habitable locales in the inner terran solar system.

Over time, the lunar surface soil is turned over in a process called gardening, which results in lunar regolith. It has been proposed that this process involves lunar material overlying cometary, asteroidal frozen, and condensed volatiles that would have impacted over the entire lunar surface. The three potential sources of lunar volatiles, especially water, are in lunar polar crater bottoms, transient lunar phenomena (TLP), and a thin layer of ice distributed broadly over the lunar globe at a depth of 200 m. The proposed lunar sensing devices could only detect the first two volatile deposit regimes. The depth of surface penetration of the gamma ray spectrometer is 1 m with a sodium iodine scintillator and up to several meters with a germanium solid-state detector. This will mean that lower deposits cannot be detected until there has been on-site base development. The polar ice would form at the base of small lunar polar craters where the measured ambient temperatures are 120 K. With a thin covering of native lunar material, it would be possible for the cometary source volatiles to remain continuously in the shade for several million to several billion years if the models of planetary stability are correct. The second lunar ice potential, TLP, has been postulated as an outgassing process of near-surface volatiles. If the spectrometer were pointed to a lunar event, which was previously detected by an Earth telescope, it would be possible to determine if this is an outgassing. If an outgassing event occurred, it might indicate recoverable volatile concentrations in liquid form near the surface. The TLP might be an outgassing of existing deep subsurface ice or liquid deposits. However, there have been no distinct references to this potential correlation of source and event of TLP. The third potential volatile source deposit cannot be investigated nor developed at present without direct contact with the planet's surface.

In all remote sensing, a major factor that the field scientist has to face is the logistical tether and how this directly affects the payload capability. The Space Studies Institute (SSI) did a comparative study of various probe designs that showed that many transorbit vehicles already are available to place a remote sensing platform in lunar polar orbit.

The first distinctions that digital remote sensing made was between solid rock and liquid water on Earth. The spectral signatures of various elements are distinct from one another, having distinct signatures when they are combined in various molecular chains. In the neutron spectral mapping mode, the germanium gamma ray spectrometer detector will be able to detect the presence of water in surface material to a ratio of 0.7%. The Apollo spectral mapping around the equator was a gamma ray sodium iodine scintillator detector. The neutron mode mapping of lunar cold sink volatiles will occur at a faster rate with a germanium gamma ray spectrometer detector than with an sodium iodine scintillator detector 30X the rate.

The secondary surface mineral features that are targeted for mapping are iron, titanium, uranium, thorium, and potassium. Out of the 20 mapping experiments proposed for the lunar prospector, the most public mission is the mapping of hydrogen and oxygen distribution. Yet, with the additional 19 experiments, it will be possible to map out surface minerals for a nonlunar ice development scenario. The germanium gamma ray spectrometer has distinct advantages in resolution and spectral definition over the Apollo-era sodium iodine scintillator detector. With a germanium gamma ray spectrometer, detection time for valid distinction of surface composition will decrease by several orders of magnitude. In no reference was any note made of the pixel size from the proposed 100-km orbital altitude.

The lunar surface has been systematically mapped for the last four centuries. The various images have not been integrated into a digitized GIS. The detailed mapping during the selection of the lunar landing sites in the 1960s, along with the satellite flybys that produced a wealth of surface images, have been underutilized and have not been integrated into one digital database. Any new surface digital images should be preserved in an archive that integrates existing images with two-decade-old images. While many of these older images did not contain any spectral information, they were extremely detailed and would be useful to overlay in a GIS context with new gamma ray spectrometer information from the Moon. This would allow a combination of the high-resolution characteristics of the early missions and the spectral information from a lunar polar orbiting imaging platform. The current focus of funded astronomical projects has moved away from the taxonomic cataloging of asteroids and other small bodies within the solar system. These small bodies are not seen as solving some of the basic puzzles of our solar system's genesis. Like the sensing exploration and mapping of the Moon, this kind of detailed cataloging is very boring science. Rather than discovering new vistas, it is filling in ultimately predictable blanks in already outlined scientific structures. The purpose of remote sensing capabilities over the lunar surface is the preliminary step in the mapping of future landing sites. While a lunar remote sensing platform will not solve many, if any, great questions of the solar system, it will lead to a greater understanding of our next home: the Moon's surface.

With the increasing number of countries that can launch small payloads into LEO, options exist beyond the conventionally perceived launch systems such as the U.S. space shuttle or an unmanned rocket system. Different systems have been compared as they directly relate to the science payload with the Shuttle Lunar Getaway Special proving to be the cheapest and most deployable under a wide variety of political and financial considerations. This would only require a 150-kg spacecraft as compared to an unmanned launch system that weighs 570 kg. The Getaway Special spacecraft could be launched on a wide variety of rockets including those of the Chinese. Their agency, the China Great Wall Industry Corporation, is interested in the concept of launching a lunar-bound vehicle, although they wish to concentrate on commercial launches. SSI has not investigated the possibility of a communist Chinese launch of a lunar reconnaissance probe. However, as of late April 1990, the SSI was of the opinion that they would launch with a U.S.S.R. unmanned rocket to LEO for a transorbital flight to a lunar polar orbit.

The initially proposed scenario of deployment was a Shuttle Garbage Can special launch with an ion propulsion engine that would inject the probe into a lunar orbit within two years. While the launch vehicle has still not been decided, the structure and performance characteristics of a prospector have been discussed at some length. Up to the 1990s, ion propulsion systems have not been used in any lunar probes. The trajectory of the slower shuttle launch would follow a similar telemetry as that of a faster chemical propulsion system, except in the LEO-to-transfer-orbit section of the trip. The mass of a launched prospector platform would be approximately 150 kg. The current NASA plan for a lunar remote sensing probe is an observer-class polar orbiter that would be ready for launch tentatively in the late 1990s. The observer platform is quite complex and expensive and would be ready in 8 to 10 years. The observer-class vehicle would not be compromised by a dedicated one-instrument germanium gamma ray spectrometer mission to a lunar orbit, since an observer mission to the Moon would be substantially more comprehensive than a prospector mission. A late 1990s observer mission could build on the images that were received by the prospector and would be substantially more comprehensive than the precursor mission.

The majority of the outer solar system science probes that have been launched are not in any way tied directly to the process of human expansion off the Earth. Scientific data are creating new paradigms but not directly contributing to the radiation of the species into space. The NASA lunar observer class probe has been proposed for launch in the later part of the decade. At the point when the information from this observer class probe is analyzed, a direction will appear. The immediate launch of a lunar orbiting platform carrying a germanium gamma ray spectrometer could expect a data return by late 1992, which could set science on a determined course toward colonization. With on-site surface exploitable volatiles, a lunar base could "live off the land" to a greater extent than expected than under a scenario without any lunar frozen water or other volatiles. With a joint surveying and mapping mission of the Moon with American instrumentation and an immediate Soviet launch to lunar polar orbit, globally redundant projects such as the U.S. space station *Freedom* and the Soviet station *Mir* could be replaced with a more culturally and politically diverse lunar base. With marginal modification, modules built for LEO could be placed on the lunar surface and/or attached to Mir. While much has been written on the utilization of lunar volatiles as a source of propellant fuel for a LEO, inner solar system, transportation node, the potential of the discovery of lunar ice will enable human outposts to "live off the land" on the Moon.

The development of strategies focusing on the utilization of existing, nonterrestrial resources on-site is of primary concern. This would not be a departure from the ideology of exploration of the solar system, but would merely be wisely following the Punjabi proverb "Grasp all, lose all." It does not function in a pattern of evolutionary development and growth. Currently, the Western program is not focused in a specific direction. The assessment of these mineralogical maps of the Moon could lead to an evolution of direct launching to the Moon without an expensive station around the Earth. Previously, the U.S. had an existing operational space station, but abandoned it to the elements and its ultimate fiery fate. A lunar base would involve less ultimate short-term and long-term expenditure than would space station development. The primary justification made for the lunar base is the ultimate export of volatiles to LEO.

With the recent offer by the U.S.S.R. to launch a germanium gamma ray spectrometer instrumented platform to the Moon, the direction of the planet for the next 25 years will become clearer. Comparing the Ride Report and The National Commission on Space Report, Hempsell found that each of these pathways of solar system expansion could be developed in the twenty-first century. His conclusion was that immediate investment in an extensive lunar infrastructure would offset its initial costs.

Current human decisions will have an impact on global development over the next thousand years. These decisions include proposals and data that will reinforce our commitment to expansion off the planet. The previous lunar mission and telescope images that have been compiled over a 30-year period should be digitized in a standardized format and integrated into a GIS computer database. The gamma ray spectrometer data would then be only one level of the overlaid cartographic information. This same technique could then be duplicated on other terrestrial and nonterrestrial site locations. Currently, the only portions of the Moon that have been mapped with spectrographic analysis are those around the lunar equator from the Apollo exploration period. One example of lunar surface features that have not been mapped totally is the lunar lava tubes, which could supply excellent first-stage radiation shield structures.

A dedicated, one-instrument, gamma ray spectrometer that is being developed for the lunar prospector probe could be used in an identical format to map surface resources on other inner solar system bodies. The resulting maps would also give us definite information on those resource nodes that should be targeted for development and human settlement. With limited monies, hard decisions must be made whether to fund projects that, while of immense scientific merit, have little utility to the potential expansion of our species off the planet. Any expansion off the Earth will involve lunar resource development in some manner. The discovery of lunar ice at the poles would influence the immediacy of a lunar polar station.

Spectral surface characteristics of the Moon have been an ignored area of scientific inquiry. The sensing systems and launching platforms are available, and a prospector mission would cost about $30 million in a shuttle launch configuration through to a $75 million cost. While it is not a flashy area of study, it will pave the way for permanent habitation of our nearest celestial body. Politicians should be supplied with maps and information, rather than fantasian utopian images, to base decisions of funding and political directions of scientific research.

When the U.S. President Thomas Jefferson sent Lewis and Clark westward, he expected and received detailed reconnaissance maps. These maps were the basis of all later discussions of how the U.S. should expand. Many expensive interplanetary probes have been launched without any discussion as to whether they will impact on the expansion of the human solar system ecumene.

The germanium gamma ray spectrometer is an inexpensive, already extant instrument that, while not necessarily answering many scientific questions, will tell human beings where and how to direct their expansion of the mineral exploitation of the Moon.

N93-17257 1993008068 488059

UTILIZATION OF GEOGRAPHIC INFORMATION SYSTEM IN LUNAR MAPPING. A. A. Mardon, Department of Space Studies, University of North Dakota, Grand Forks ND 58202, USA.

Substantial digital remote sensing, lunar orbital photography, Earth-based remote sensing, and mapping of a variety of surficial lunar phenomena have occurred since the advent of the Space Age. This has led to a bewildering and quite disparate collection of archival sources insofar as this digital data and its cartographic representation can be found within many countries of the world. The importance of this mapping program in support of human expansion onto our nearest planetary neighbor has been recognized since the advent of the Space Age [1]. This is still as true as when it was stated in 1964 that, "The program for landing men on the lunar surface requires that suitable and safe sites be defined and verified before the actual landings" [2].

In 1991 only the U.S.A. has landed humans on the Moon. If during the preceding decade efforts had been dedicated to developing inexpensive labor-intensive tasks such as the detailed mapping of the Moon [3], we would be further ahead today in lunar exploration. A series of small-scale maps of the Moon at 1 km to 1 cm, done with the support of Geographic Information System (GIS), would serve decision makers well in the process of accessing the development of manned occupance of the Moon. Nothing has been published to this date on the use of GIS in a lunar mapping context [4].

Maps and the data that they are derived from are the primary way in which people explore new environments and use previously discovered data to increase the bounties of any exploration. The inherent advantage of GIS is that it would allow immediate online access on the Moon of topographically represented data [5,6], with analysis either on site or from Earth. This would mean that astronauts in the field would be able to get instantaneous cartographic data representations on any of the suited visual monitors that would be part of an astronaut's extravehicular suit.