MINMAP: A N Imaging Spectrometer for High Resolution Compositional Mapping of the Moon. C. M. Pieters¹, J. W. Head¹,², T. B. McCord² and the MinMap Team. ¹Brown University, Providence, RI, ²SETS Technology Inc. and Univ. of HI, Honolulu, HI; #MinMap PI, *MinMap Deputy-PI.

MinMap has been selected by the Lunar Scout program to characterize and map the mineral composition of the Moon. The instrument will be built as a collaborative effort between Brown University, SETS Technology Inc., and Ball Aerospace Corp. MinMap is a visible to near-infrared imaging spectrometer that contains 192 spectral channels from 0.35 - 2.4 μm with signal to noise >200 and 256 cross-track spatial elements. The spectrometer design has a 6° field of view (FOV) and utilizes grating dispersive elements and two dimensional detectors (no moving parts). An "image cube" of data is produced that contains two dimensions of spatial information and one dimension of spectral information. All spectral channels and cross-track spatial elements are recorded simultaneously with spacecraft motion scanning the second spatial dimension. The high spectral resolution and continuous spectral range of MinMap are designed to measure the diagnostic absorption features of principal lunar minerals and their lithologic mixtures. Since the optical properties of lunar materials change in a regular manner upon exposure to the space environment, this spectral range is also quite sensitive to variations in exposure history (soil maturity). Nominal measurement strategy is to obtain full global data of the Moon at 1800 m/pixel from a 450km polar orbit during the first month or two of operation. A 100 km orbit is anticipated for the remaining part of a 1 year mission allowing higher resolution data (~80 m/pixel) to be obtained for targeted regions. MinMap exceeds LExSWG's measurement recommendations and will provide the highest spatial resolution compositional map of lunar rocks and soils currently planned for orbital missions. Since all spectral channels are co-registered and obtained simultaneously, "image cube" data swaths will be available for analysis almost immediately.

Global MinMap data are to be obtained from a ~450 km circular polar orbit rather than the nominal 100 km orbit traditionally used in LExSWG planning. There are several important reasons for this. First, it is highly desirable to have overlapping sequential data swaths. This minimizes the effort to produce a global mosaic since neighboring swaths have similar geometric properties. At 100 km, orbit spacing is 33 km at the equator requiring a FOV of 22° for orbit-to-orbit overlap. At an orbit of 450 K, orbit spacing at the equator is 42.5 km requiring only about a 6° FOV for data overlap. Except near opposition at the equator, a 6° variation in phase angle across the data swath requires little correction. A second important reason for the global data to be obtained from a high orbit is orbit stability. The variations in orbit altitude due to variations in lunar gravity field are substantially less at the higher orbit (10% vs 50%), a highly desirable attribute for global mapping.

In terms of mineral characterization, the distinguishing feature of MinMap is that it is a spectrometer. That is, it obtains contiguous spectroscopic information at high spectral resolution and high precision. Such spectroscopic data are required to identify key lunar minerals (pyroxenes, olivines, etc.) and to estimate their composition by the wavelength and shape of observed absorption bands (1, 2). Near infrared high spectral resolution measurements obtained with earth-based telescopes for lunar areas 3 - 20 km in diameter have quite successfully identified a
variety of lunar mineralalloys and rock types ranging from anorthosites to dunites (e.g., 3). Equally important, continuous spectroscopic data are required in order to assess the relative abundance of several minerals in a mixture when their absorption properties are superimposed. Several analytical approaches have been developed over the last few years to extract mineralogical information from complex or multicomponent spectra (e.g., 4, 5, 6) and these continue to improve. Subtle variations in absorption shape undetectable by visual inspection, for example, can be very important in compositional assessment (e.g. 7), but such small systematic variations require continuous spectral coverage for evaluation. In contrast, multispectral imaging (with fewer spectral channels) cannot characterize surface mineralogy, but with careful selection of channels can distinguish and map several compositional units.

MinMap operations and data management are designed to be extremely flexible in order to derive the maximum return within mission constraints on mass storage and downlink data rate. Specifically, several options will be programmed that select several cross-track elements to obtain full spectroscopic coverage (192 spectral channels) and a number of selected spectral channels for which full spatial coverage will be obtained. Full spectroscopic and full spatial coverage by MinMap produces data (uncompressed) at a rate of ~4Mbp/s for the high orbit and ~6Mbp/s for the low orbit. MinMap operation at full capacity will thus likely be reserved for selected targets of high interest to the scientific and exploration community. Full "image cube" data acquisition will be the normal operation plan for the low orbit, high resolution targeted data since it allows the most detailed compositional analyses. It is anticipated that the nominal mission plan for global coverage will allow 4 -10 elements of full spectroscopic coverage nested in 20 - 40 spectral channels of full spatial coverage. In other words, the high orbit global data set will consist of global coverage at 180 m/pixel for up to 40 co-registered spectral channels with a N-S grid of full spectral resolution data spaced 4 - 11 km at the equator. This measurement strategy should provide an excellent assessment of lunar lithologies and provide a global basemap of principal compositional and maturity units.

The primary return from MinMap is an assessment of the global and regional mineral composition of the surface (spectroscopic information) in its naturally occurring geologic context (spatial information). This dataset provides key information in evaluating lunar resources, in site selection for robotic and/or human exploration, and for surface operations planning. Without question, the global assessment of lunar mineralogy provides fundamental information to address broad scientific issues such as the formation and evolution of the primordial lunar crust, volcanism and the thermal evolution of the Moon, and the transformation and dispersal of material in a major impact event. The MinMap Team is beginning to develop a list of targets for the high resolution detailed analyses and invite suggestions from the scientific community as the Lunar Scout program proceeds.