DEVELOPMENT OF THE RAMAN/CHAMP INSTRUMENT FOR LUNAR RESOURCE IDENTIFICATION. K.R. Johnson[1], G.S. Mungas[1], C.A. Sepulveda[1], J.L. Lambert[1], and C.C. LaBaw[1]. Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109

Introduction: The Exploration Systems and Mission Division of NASA plans to develop In-Situ Resource Utilization (ISRU) technologies for the exploration of the Moon, Mars and beyond. It has been frequently suggested that in-situ resources might be beneficially used to provide consumables for astronaut survival (esp. oxygen and water), propellant for return vehicles, radiation shielding (using regolith covers and berms), and even to produce metals and ceramics for spare parts and solar photovoltaic cell substrates. These suggestions imply that if we can reduce the need to take all of the necessary supplies for a mission from Earth, there will be a net gain to a mission in terms of reduced Earth-launch mass, enhanced exploration duration, and/or even the possibility of enabling long-term human/robot colonization.

Water is by far the most important in-situ resource. Without water, human (and plant) life can't be sustained. Therefore, finding an available, adequate in-situ source of water is necessary to enable a long-term human stay on the lunar surface. Periodic transport of large masses of water from the Earth will very likely be economically and politically untenable.

The neutron spectrometer on the Lunar Prospector mission (1998) indicated significant concentrations of hydrogen-bearing materials at or near the polar craters. This indiction has led to considerable speculation that water ice could exist in the permanently shadowed polar lunar craters. To verify this speculation, ground-truth measurements are needed to identify the form, quantity and location of any hydrogen bearing materials that are present. Raman spectroscopy is ideally suited to make rapid and unambiguous determinations of the form of hydrogen in lunar regolith (water ice, chemisorbed solar-wind deposited hydrogen, mineral hydrates, organics, ammonia, etc.) while also providing in-situ measurements of the mineral chemistry of the regolith. Optical imagery and microscopy can provide corroborating evidence of the Raman spectroscopy measurements and can help to establish the context of the measurements.

JPL is currently developing a Raman/CHAMP instrument (RCI) that combines Raman spectroscopy with optical imaging and microscopy (CHAMP is Camera, Handlens and Microscope Probe) [1,2]. This presentation will discuss the current design and development status of the RCI.

Raman/CHAMP Instrument design: The RCI will be capable of imaging from infinity (for locating resources - tourist mode) continuously down through close ranges (for obtaining a magnifying glass look at minerals - hand-lens mode), and ultimately down to microscopic range (3 microns/pixel for identifying particle shape, size distribution, color, and mineral type - microscopy mode). An illuminator provides lighting for optical imaging in a variety of selectable LED colors: white, red, green, blue and UV. Four LEDS mounted 90˚ apart are available for each color. Any combination of four LEDS can be lit at any time including one or more of the four turned off to provide side lighting for increased contrast. Lighting two red LEDS and then two blue LEDS can yield an anaglyphic image. The Raman spectrometer will be capable of measuring the chemical composition of regolith constituents within the field of view of the microscope to within ~1 wt% (Raman spectroscopy mode). The RCI will be capable of nearly simultaneous optical and chemical identification of individual regolith particles, condensed volatiles (i.e. ices), and conglomerates visible within the field of view of the microscope.

The RCI design consists of two lens cells, an optical detector, a laser light source, a scannable Raman spectroscopy probehead and a Raman spectrometer. The optical imaging part of the instrument (CHAMP) consists of the two lens cells and the detector along with a means for moving lens cell #2 relative to lens Cell #1. Lens Cell #1 and the illuminator are attached together in a dust-free aswembly and then mounted in a fixed position.. Lens Cell #2 is aligned optically in-line with Lens Cell #1 and is movable axially relative to Lens Cell #1 to provide a continuously variable field of view from infinity to microscopy. A beam splitter mounted as the last element in Lens Cell #2 reflects 30% of the available light to an optical detector and transmits the remaining 70% to the probehead. This is done to ensure that an adequate Raman signal is transmitted when operating in the Raman spectroscopy mode.

The Raman spectroscopy part of the instrument consists of a laser light source, a probehead and a spectrometer.. Laser light at 532 nm is introduced into the probehead which directs the light through the lens cells onto a sample (when in focussed microscope mode) at a spot size of approximately 20 nm. The Raman signal returns back through the lens cells and beamsplitter to the probehead which receives the return Raman signal and directs it to the Raman spectrometer. The eschelle-based Raman spectrometer disperses the signal and directs it onto a detector Output from the detector is used to create spectrographs that are then interpreted to yield qualitative and quantitative measurements of the chemical composition of the sample being scanned. The Raman probehead can be scanned in both the x and y directions to enable measurements at a variety of <10μm spots within the microscope's field of view.

Current status - Design details and criteria: The engineering breadboard conceptual and preliminary designs for CHAMP are complete and the optical elements are being fabricated in preparation for an Apri/May 2007 technology demonstration. During the optical design process, a variety of candidate optical glasses were procured and tested for fluorescence when illuminated by laser light at 532 nm. Lens element Glasses that exhibited low fluorescence were selected for fabricating the lens elements.

Breadboard elements for the Raman probehead and the spectrometer have been specified and procured and an initial assembly of these elements is also planned to take place by April/May 2007 for demonstration.

Table 1 provides a summary of the projected RCI measurement performance. Table 2 provides a synopsis of a typical RCI measurement scenario.

Table 1. Raman/CHAMP Instrument Measurement Performance Summary

Raman/CHAMP Measurement Characteristics	
Working Distance	CHAMP imaging: continuously variable from Infinity to 18mm (infinity to microscopy)
	Raman probing: 18mm (microscopy)
Image resolution	Infinity down to 3 micron/pixel (microscopy)
Image Field of view (FOV)	Infinity down to 2.1x2.1mm
CHAMP Spectral Range	450-650nm (chromatic aberration corrected)
Illumination	RGB,W+UV
Depth of Field	Microscopy Nominal: 45 micron
	Microscopy w/ Z-stack: ~1mm
Raman Laser Probe	<10 micron spot 2D scannable within microscopy FOV
Raman Measurement Sensitivity	<1%wt typical
Optical Bandwidth	200-1700 cm^{-1} and 2500-4000 cm^{-1}
Spectral Resolution	5-7 cm^{-1}
Laser Power on Target	>10 mW

Experiment	Minimum	Maximum
Initial Localization	30 BW images (panoramic)	100 RGB images (panoramic)
Images per 25cm Sample Core	10 RGB images	100 RGB z-stack images
	100 Raman spots	1000 Raman spots
Images per General Site Investigation (includes approach through handlens/ microscope)	5BW+10 RGB z-stack	10BW+100 RGB z-stack
	10 Raman spots	100 Raman spots

Table 2. Typical Measurements for Raman/CHAMP

References: [1] J. Boynton et. al. (2005). IEEEAC #1510. [2] G.S. Mungas et. al.(2007). IEEEAC# 1554