ROVER-BASED INSTRUMENTATION AND SCIENTIFIC INVESTIGATIONS DURING THE 2012 ANALOG FIELD TEST ON MAUNA KEA VOLCANO, HAWAII. L. D. Graham[1], T. G. Graff[2], and the 2012 MMAMA team, [1]ARES NASA Johnson Space Center, Houston, TX 77058 (lee.d.graham@nasa.gov), [2]Jacobs Technology ESCG, Houston, TX 77058.

Introduction: Rover-based 2012 Moon and Mars Analog Mission Activities (MMAMA) were recently completed on Mauna Kea Volcano, Hawaii. Scientific investigations, scientific input, and operational constraints were tested in the context of existing project and protocols for the field activities designed to help NASA achieve the Vision for Space Exploration [1]. Several investigations were conducted by the rover mounted instruments to determine key geophysical and geochemical properties of the site, as well as capture the geological context of the area and the samples investigated.

The rover traverse and associated science investigations were conducted over a three day period on the southeast flank of the Mauna Kea Volcano, Hawaii. The test area was at an elevation of ~11,500 feet and is known as “Apollo Valley” (Fig. 1). Here we report the integration and operation of the rover-mounted instruments, as well as the scientific investigations that were conducted.

Figure 1: SE flank and summit of Mauna Kea Volcano, Hawaii; inserted box indicates the Apollo Valley and analog test region.

Instrumentation: The instruments used in the test were selected based on several considerations, the major criteria included: 1) applicability to the scientific investigation of the valley, 2) mobility, 3) availability, 4) remote control capability, and 5) weatherproofing capability. The selected instruments were configured and mounted on a JUNO II rover chassis (Fig. 2) in partnership with Ontario Drive and Gear (ODG) and the Canadian Space Agency [2]. The instruments selected for rover-based operation included a combined miniaturized-Mössbauer/XRF spectrometer (MIMOS IIA), a ground penetrating radar, a 360 degree panoramic video camera, a magnetic susceptibility sensor, a GPS sensor, and a 3-axis accelerometer.

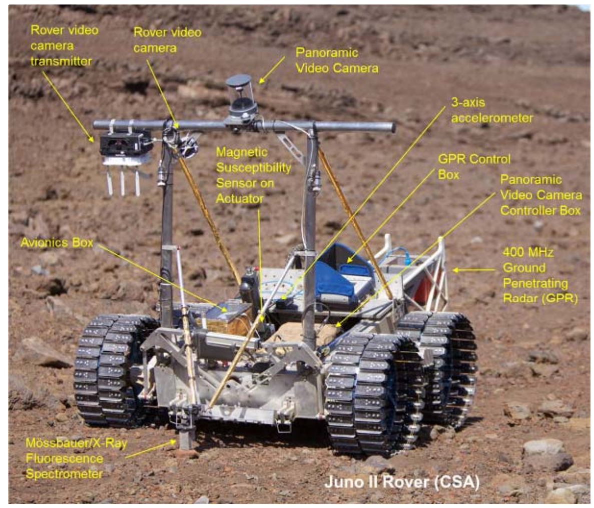

Figure 2: JUNO II rover with integrated instrumentation.

Mössbauer/X-Ray Fluorescence Spectrometer: The MIMOS IIA (MIniaturized MOSsbauer Spectrometer) instrument is a combined Mössbauer and X-Ray Fluorescence spectrometer. The design allows for the instrument to be placed in contact with a rock or soil sample, providing *in-situ* analysis of the sample’s iron mineralogy and chemical composition with no sample preparation. The MIMOS IIA prototype uses new detector technologies and electronic components to significantly increase the sensitivity and performance of the instrument. This instrument was mounted to a bracket extending from the rover chassis, allowing for quick and simplified deployment of the sensor head to the surface utilizing the JUNO II rover’s tilting capability. During the rover-mounted operation the MIMOS IIA measured quantitative Fe-mineralogy and the chemical composition for 1 soil and 8 rock samples in Apollo Valley [3]. Integration times varied from 30 to 90 minutes.

Ground Penetrating Radar (GPR): The GPR system used to investigate the subsurface features during this field test was a commercially available Geophysical Survey Systems, Inc. monostatic radar unit. A 400 MHz and 200 MHz antenna were both deployed in Apollo Valley during this test, however only the 400 MHz was mounted to the rover via a trailing radar-transparent composite support structure. The 400 MHz antenna has a mass of 5 kg and measures 30 cm x 30 cm x 17 cm with a signal penetration up to a max of 4 m. Approximately 2 km of data lines were collected during rover-mounted operations, performing the first known GPR science investigation of Apollo Valley. Results demonstrate that the valley has a complex geologic history. In addition, numerous best practices were developed and tested for the deployment of a GPR system from a robotic platform, particularly in rough terrain.

Panoramic Video Camera: The Lucy-S is a professional-level panoramic capture system for collecting seamless 360° video. The camera head was mounted on the JUNO II cross bar and is approximately 13 cm in diameter, 20 cm tall, with an approximate mass of 2.5 kg. An onboard laptop was used for data capture, storage, and transfer. During the three days of testing this system acquired ~42 panoramic videos for site characterization and planning. The use of the panoramic video demonstrated the usefulness of video for situational awareness and determining rapid geologic context; however improved resolution is required for detailed science-driven imaging and target selection.

Magnetic Susceptibility Meter: A Bartington MS3 magnetic susceptibility meter with a MS2K magnetic contact head was used to obtain magnetic susceptibility readings from a variety of soil surfaces in Apollo Valley. The magnetic contact head was attached to a linear actuator enabling it to be remotely deployed to the surface, and then retracted to a safe position within the JUNO II chassis during movement of the rover. During the rover-mounted operation, 13 separate magnetic susceptibility measurements were conducted revealing the broad diversity of materials found within the valley.

Global Positioning System (GPS): A ruggedized Trimble NOMAD handheld computer was used as the GPS sensor system for logging data collection and sample locations, recording traverse path and altitude, and integrating the remote control of several instruments through a single portal. This unit features 2-4 m GPS accuracy with integrated Bluetooth capability used for remote monitoring and control.

Three-Axis Accelerometer: A Vernier Wireless Dynamics Sensor System was used to record the accelerations seen by the vehicle and instruments while traversing particularly rough terrain. Each of the three accelerometers had a range of ±50 m/s^2, a resolution of 0.04 m/s^2, and a maximum frequency response of 100 Hz.

Scientific Investigation and Operations: Satellite imagery of Apollo Valley was used as an analog to the orbital images available prior to a planetary “landing” in order to create notional traverse paths prior to the mission. Although there were many legs of the planned traverses that were not executable (given the challenging trafficability of the surface), the planned traverses provided a framework to vary from, and maximized the team’s efficiency in the field where rapid re-planning was required. From the available imagery and the previous day’s instrument data, the science backroom conducted a "plan-operate-evaluate-replan" operation. This operational strategy allowed the next day’s plan to be modified, if required, during the evening prior to the following day’s traverse.

Results and Discussion: The combined rover-based MMAMA science activity in Apollo Valley allowed for a small team to perform significant instrument testing, operational strategies, and rover-based *in-situ* science over the three primary days of testing. The JUNO II rover platform performed exceptionally well traversing ~5 km over extremely rough terrain. It’s flexible design and capabilities were integral to rapid integration and instrument deployment.

The entire suite of rover-mounted instruments completed all established test objectives providing key geophysical and geochemical properties of the field site. Given the acquired instrument data, initial evaluation of the geologic context and history of landing site were continually refined during the analog test. In addition, a geologic map created using data acquired during this analog test represents a significant improvement over previous geologic maps for the valley. This mission map better defines and characterizes the geological units, including those not clear on orbital imagery. Interpretations of the units were largely confirmed, though some hypotheses could not be solved on the tactical timeline.

The "plan-operate-evaluate-replan" operational strategy avoided rover down time and allowed for rapid tactical planning to be conducted. With JUNO II’s capability and the successful operation of the instrument suite, the data load the science team had to analyze often greatly exceeded the data acquisition plan.

References: [1] Graham et al. (2013) submitted to the *2013 IEEE Aerospace Conference*. [2] Jones et al. (2010) *15th CASI Astronautics Conference*. [3] Graff et al. (2013) *LPSC44*.

2012 MMAMA team with the JUNO II rover.