**SCIENTIFIC APPLICATION OF VISUAL SYSTEMS INSTRUMENTATION USED DURING LUNAR SAMPLE RETURN ANALOGUE MISSIONS.** E. McCullough[1], A. E. Pickersgill[1], R. Francis[1], A. Bassi[1], B. Shankar[1], M. M. Mader[1], M. Beauchamp[1], G. R. Osinski[1], and the KRASH Operations and Science team[2]. [1]Centre for Planetary Science and Exploration, University of Western Ontario, Canada. [2]KRASH Operations and Science Team (see [1]). (emccull2@uwo.ca).

**Introduction:** Four deployments of a lunar sample return analogue mission campaign were conducted at three sites during 2010-2011 (see [1] for an overview): 1) a purely robotic mission; 2a) a robotic precursor mission; 2b) a human follow-on mission to 2a; and 3) a purely human mission. Throughout, the Mission Control (MC) team at the University of Western Ontario, Canada, included only scientists who had never visited the sites. During surface missions, visual data is critical to geologists for scientific interpretations. The visual instrumentation employed by the rover and astronauts provided the only way for MC to "see" the sites in 2D (photos, panoramas) and 3D (stereo images, models, LiDAR point clouds). Instrument parameters and an astronaut perspective are presented in [2]. Here, we present the use visual systems data for situational awareness and geological interpretations from a MC perspective.

**2D Visual Imagery:** *Gigapan*: The Gigapan instrument is an optical camera on a pan/tilt mount on the rover and/or lander which produces high resolution panoramic images. MC indicated the position of the desired mosaic as azimuthal angles with respect to the rover, a tilt from horizontal and the desired resolution. The greatest difficulty for MC was providing sufficient pointing instructions remotely, without precise knowledge of the rover's orientation. A 360° panorama upon landing was considered absolutely necessary at the beginning of each mission for a survey of terrain and geological context around the landing site, and for localization of the site on maps and orbital images. These images were the primary data product used to identify outcrops of interest and to plan and modify traverses [3]. Precursor panoramas from different vantage points, when available, eased localization and traverse planning. Pairs of MC members examined each panorama to identify and annotate notable features in the image. The annotated images were discussed by the entire science team to a) ensure that everyone was informed about what had been found, b) allow all team members to contribute to the scientific interpretation of each panorama, c) identify any features in common or contrasting between various panoramas. For a 360° panoramic image from 16° below to 16° above horizontal, a total resolution of 100 Megapixels (MP) was sufficient for understanding the local scene at the context level. Referring to individual images at outcrop scale, panoramas taken in good lighting conditions showed colour and some textural variation. To make geological interpretation of nearby features and to select sample points for contact instruments [4], higher resolution was needed. Data use in MC was maximized by a) requesting appropriate resolution for each panorama; b) developing procedures to minimize the amount of wasted image data (e.g., sky); and c) requesting complementary data products (e.g., 3D model or LiDAR scan) which provide a scale for the image.

*Digital cameras:* In missions 2b and 3, each astronaut carried an 8 MP digital camera, and in scenario 3, one astronaut also carried a 15 MP camera. This allowed MC to request specific highly detailed photos with objects for scale included wherever possible. These outcrop-scale images were extremely helpful for interpreting lithologies, geologic contacts, and for selecting appropriate (sub-cm sized) points for contact instruments and sampling. Returns on this activity were maximized when MC discussed the goals of the photos with the astronauts so that the astronauts could use their own judgement for the resolution, focus, and extent of the image to provide the best photos to meet that goal. Ensuring that the astronauts were free to photograph any additional sites of interest that they noticed, particularly those for which MC did not have good imagery, gave MC a better understanding of the descriptions astronauts relayed during the operations for the day. Cataloguing observations through pictures is paramount in connecting visual observations in the field to descriptions that may be reviewed at a later time, and provides contextual views for samples that are collected. Therefore capturing photos should always be part of the documentation protocol.

**3D Visual Imagery:** While 2D images effectively provide MC with large-scale impressions of the rover's or astronaut's surroundings, they do not convey 3D relief or scale and can be somewhat deceiving to the eye. The stereo camera instruments (mSM and C2SM) use image pairs to build 3D visual models of outcrops. See [5] and [6] for more detail about these instruments and their applications. Anaglyphs created from the stereo image pairs were used with success for qualitative interpretations. At MC, the models may be manipulated (rotated) and distances and sizes within them measured. This provides the necessary tool for determining scale, which can be compared with and mapped to 2D images.

*mSM:* The Mobile Scene Modeler (mSM) is carried and operated by an astronaut. Useful 3D models were acquired of single outcrops from a distance of 2-5 m, collecting many images from a variety of angles. The best of these models were helpful for identifying sub-outcrop scale targets for sampling and for contact measurements, and for conveying a general sense of relief and texture to MC.

*C2SM:* The Chemical, Biological, Radiological, and Nuclear Crime Scene Modeler (C2SM) is rover-mounted, and consequently has a more limited range of motion than the msM. It is however equipped with a high-resolution 2D camera and it appends this image to the 3D model. Models taken from less than 2 m away were extremely useful for determining the accessibility of cm-scale targets for sampling. Single-shot images were used to assess distances to obstacles and to document positions in which the rover became stuck or was unable to carry out the planned path. Improvements to the C2SM's articulation to allow imaging of the rover's wheels and to gauge the distance to a very-nearby outcrop are recommended.

*Limitations of mSM and C2SM:* The use of mSM and C2SM in the science processes at MC was limited by a) low resolution image overlay in the models; b) patchy models with "holes" from undersampling during scanning and shadowed areas due to sun angle; c) standalone nature of each software; d) short-range application (for which the instruments were originally designed). Higher-resolution cameras and integration of these instruments with the LiDAR in a single user-interface would greatly help to mitigate these issues.

**Laser Surface Imager:** Two different LiDAR units were used to create 3D point cloud images for use in determining scale, range, and navigability of terrain, both at outcrop and regional scale. Using its own laser light, the LiDAR has no requirement of ambient sunlight to create models. The LiDAR's use would be maximized through its integration in a single user-interface with other data products (e.g. 2D images, mSM and C2SM models).

*Optech ILRIS-3D LiDAR:* In some scenarios, the ILRIS was mounted on the lander, providing only one 360° scan of the landing area. Otherwise, it was mounted on the rover, performing scans at various locations which could then be stitched together into one cumulative map, using software developed by UTIAS. The pan/tilt and adjustable resolution capabilities of ILRIS allow long-range site surveys as well as careful examination of nearby outcrops and the ground near the rover/lander. Even at low resolution, it is an ideal tool to measure general topography, providing distance and scale measurements to a distance of approximately 1 km. Higher resolution helped determine the surface texture of nearby features. Different lithologies sometimes corresponded to different backscatter intensities. Very high resolution scans of distant objects (e.g. mm-resolution hundreds of metres away) were possible, but the time required for such a scan was prohibitive. The limiting factor for LiDAR in MC was the software. MC did not have access to proprietary software. Simpler viewers used in early missions did not have the capability to stitch together individual scans, nor was it possible to import images to drape over the point clouds. A fully integrated user interface for the 3D visualization data is highly desirable for real-time interpretation.

*Autonosys LVC-0702 video LiDAR:* This rover-mounted unit was intended only for navigation. Its scans were occasionally used by MC as “bonus” data in scenarios for which the ILRIS was unavailable.

**Conclusions:** Both 2D and 3D visualization data products were indispensable during these lunar analogue missions. 2D imagery was referred to repeatedly in MC, providing an intuitive "look" at the region and detailed geological information. Distance, scale, and texture measurements provided by 3D data sets maximized the scientific gain and decision making based on all other products. The mSM and C2SM provided the necessary detail at outcrop scale, while the ILRIS was required at regional scales. Visualization data facilitated communication between the astronauts in the field and the scientists in MC. Software integration of all data products, particularly the 3D products, would drastically increase the value of the returns, and would allow quicker real-time processing, decision making, and scientific interpretations.

**References:** [1] Marion et al. (2012) 43$^{rd}$ LPSC (this meeting). [2] Pickersgill et al. (2012) 43$^{rd}$ LPSC. [3] Shankar et al. (2012) 43$^{rd}$ LPSC. [4] Pontefract et al. (2012) 43$^{rd}$ LPSC. [5] Osinski et al. (2010) *Planet. Space Sci. 58*:691-700. [6] Se and Jasiobedzki. (2008) *IJICS. 13*:47-58.

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