

VIPER Visible Imaging System Ross A. Beyer^{1,2}, U. Wong², L. Edwards², A. Colaprete², K. Ennico-Smith², K. Jeppesen², J. Joy³, M. O'Connor², R. Reed³, B. Wright³, P. Becerra⁴, M. Nilsson⁴, G. Vives⁴, S. Benekos⁴, and S. Beauvivre⁴. ¹SETI Institute, (rbeyer@seti.org), Mountain View, CA 94043, USA, ²NASA Ames Research Center, Moffett Field, CA 94035, USA, ³Jacobs, NASA Johnson Space Center, Mail Code ER4, Houston, TX 77058, USA, ⁴Micro-Cameras & Space Exploration, Puits-Godet 10A, CH-2000, Neuchatel, Switzerland

The Volatiles Investigating Polar Exploration Rover (VIPER) will use a suite of instruments to conduct exploration science. It will map volatiles, especially hydrogen bearing volatiles in a lunar polar region [1].

The VIPER rover carries eight visible wavelength cameras which constitute the VIPER Visible Imaging System (VIS). VIS is primarily used for driving and hazard avoidance, but adds additional science capability to the VIPER payload [2] including topography and surface geometry, rock and grain size distribution, crater identification, evaluation of rover-surface interaction (e.g. wheel-track imaging, pre+post drill imaging), regolith photometric behavior, and more.

During roving, rover stereo images are taken every waypoint (4 to 8 m). Every ~50 m, a nominal 6-image stereo panorama is taken for localization. HazCam images are taken as needed. Upon entrance to a science station or drilling activity, additional panoramas are taken.

There are two stereo NavCams mounted on the navigation gimble at the top of the mast. There are two stereo AftCams mounted on the aft body panel. There are four HazCams which are mounted in each of the four wheel wells (Fig. 1).

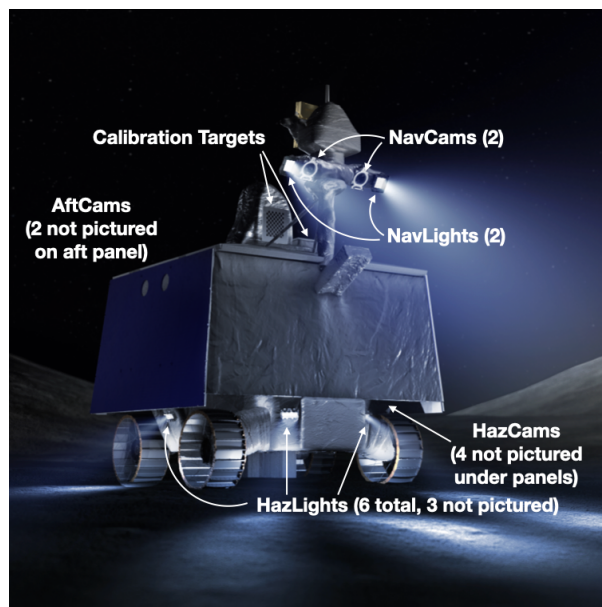


Figure 1: Location of various VIPER VIS components on the rover.

Cameras: Each of the cameras in the VIPER VIS shares the same camera body design, and differ in their lenses or physical arrangement. The camera units and the twin camera control units (CCUs) are provided by Micro-Cameras & Space Exploration SA, Switzerland (Fig. 2) with lenses by StingRay Optics, G & H LLC, USA. The cameras are all grayscale. Of the eight cameras, only the NavCams and AftCams are arranged as stereo pairs.

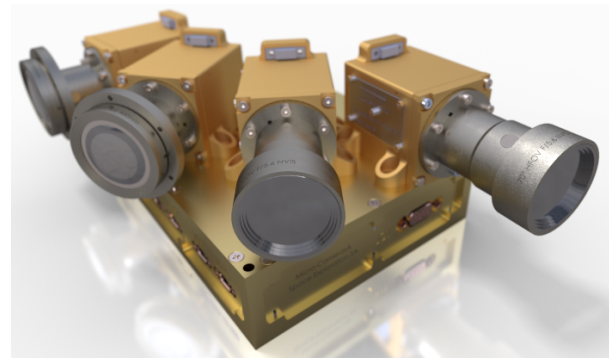


Figure 2: Digital rendering of some of the MCSE VIPER hardware. Pictured on the left are two AftCam/HazCams (identical optics), on the right are two NavCams (with the longer lens assembly), and they are sitting on top of one CCU box.

Each camera is composed of a detector and electronics within a single mechanical housing, specifically: (1) an optical lens assembly, (2) a CMOS image sensor, and (3) electronics that includes FPGAs, a heater, and an electronics interface. The image sensors have 2048×2048 pixels which record 12-bit values.

The CMOS sensor is a CMV4000 which has flown on Mars 2020 (SuperCam), BIOMASS, and BepiColombo. The lens is a native f/5.6, stopped down to f/6.7.

NavCams are a stereo pair of cameras with a 40 cm baseline separation and nominally stand 2 m above the lunar surface. They are primarily used for navigation purposes and site characterization (360° panoramic images and targeted images of interest, including terrain not viewable by the HazCams). They each have a $70^\circ \times 70^\circ$ field of view.

AftCams are a stereo pair mounted on the rear panel of the rover with a 30 cm baseline separation. They are used to aid navigation because the near-field area beyond

the aft panel of the rover is mostly obscured from the NavCam due to the mast being mounted toward the front of the rover and the TRIDENT chimney. They each have a $110^\circ \times 110^\circ$ field of view.

HazCams provide images primarily of the near field of each rover wheel. These cameras are used to determine safe driving directions for the rover. Since the rover wheels can swivel and the rover can advance in almost any direction without altering the heading of the rover body frame, this ability to examine the near field in all directions is important for hazard detection. Each HazCam has a $110^\circ \times 110^\circ$ field of view.

Calibration Targets: There are two checkerboard calibration targets mounted on the rover's top deck (Fig. 1) that are used for verifying pre-mission calibrations and for performing in situ geometric camera calibrations on the NavCams. There is one reflectance calibration target composed of five optical patches, which provide references for scene albedos, camera exposures, and dynamic range. They can help indicate dust accumulation on the NavCam lenses or luminaires. Each optical patch is a distinct grayscale with reflectance values representative of the expected reflectances of lunar regolith and possible surface frosts.

Luminaires: VIPER is exploring the lunar pole and will drive into areas of persistent shadow while also observing with the Sun low on the horizon. It carries two configurations of LED arrays packaged into luminaires (Fig. 3). Two NavLight luminaires mounted just outboard of the NavCams illuminate the scene imaged by the NavCams. Six HazLight luminaires are mounted near the wheel wells and illuminate the scenes imaged by the HazCams and AftCams. Two of these eight luminaires can be operated at any one time to properly illuminate the scenes for imaging (Fig. 1 shows more than two in operation for illustration only). The luminaires emit blue (457 nm) light as this wavelength is very efficient to produce and has good quantum efficiency with the cameras' spectral bandpass. Each NavLight produces up to 190 W of light; each HazLight produces up to 32 W of light. Each luminaire will operate for up to 10 s and a maximum duty cycle of 50%. The NavLight has a parabolic reflector with a $94^\circ \times 100^\circ$ field of view; the HazLights utilize internal reflectors to direct light laterally from the luminaire and have a 100° field of view.

Compression: Images from all of the VIS cameras pass through the same processing chain on the rover. The 12-bit images will be ICER-compressed on board the rover. ICER allows VIPER to obtain losslessly compressed images when needed by science, as well as a variety of lossy compression options. Moderately compressed images are useful for science while recognizing downlink constraints. More aggressive compression is

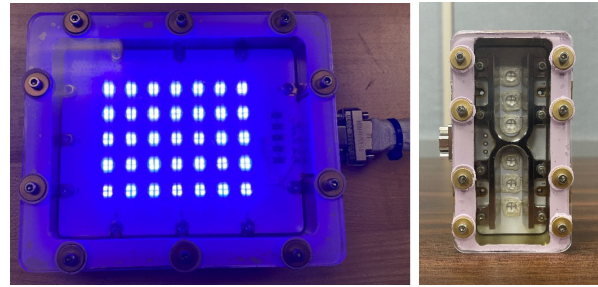


Figure 3: Engineering test units for the NavLight (left, without reflector) and HazLight (right).

needed for the steady stream of images which must be sent to the Earth for visual navigation.

Download, Retention, and Replay: During driving operations, images will be acquired frequently to aid navigation, and these highly compressed images are available to the rover drivers and Science Team approximately a minute after their acquisition on the lunar surface. However, since the rover cannot move while it is downlinking data, larger science images with less compression can either be downlinked immediately (if we are willing to wait), or can be downlinked later when the rover is stopped for other reasons.

The VIS CCU has the ability to retain hundreds of full images taken by the eight cameras before it fills this storage and the earliest images taken would need to be overwritten with new images. The rover is regularly downlinking images to the Earth, but this retention ability allows us delay downlink of a large image, to re-request downlink of an image that had transmission issues, or allows us to re-downlink an image with a different compression ratio.

Expected Products: All VIPER VIS products will be made available via the Planetary Data System's Cartography and Imaging Sciences node, conforming to the PDS4 standard. This consists of Raw and Calibrated versions of all downlinked images, as well as panoramas, mosaics, point clouds, terrain models, and other Derived products.

References: [1] A. Colaprete et al. "The Volatiles Investigating Polar Exploration Rover (VIPER) Mission". In: *52nd LPSC*. 2021, p. 1523. [2] K. Ennico-Smith et al. "The Volatiles Investigating Polar Exploration Rover Payload". In: *51st LPSC*. 2020, p. 2898.