BOPPS Infrared Camera. Z. J. Fletcher[1], R. McMichael[1], A. F. Cheng[1], and C. A. Hibbitts[1]. [1]The Johns Hopkins Applied Physics laborataory (zachary.fletcher@jhuapl.edu).

Introduction: The Balloon Observation Platform for Planetary Science (BOPPS) is a stratospheric balloon mission planned to fly from Fort Sumner, NM in late September, 2014. It is designed to develop and demonstrate gondola and payload systems for balloon-borne planetary astronomy to achieve decadal survey science objectives. The heart of BOPPS is a stabilized pointing platform mounting an 80-cm telescope on a gondola capable of operating at 110,000 to 140,000 feet, above most of the atmosphere's water and carbon dioxide. The BOPPS instrument payload comprises two instruments on separate optical benches: the BOPPS Infrared Camera (BIRC), for photometric imaging from 2.5 to 5.0 um, and a near-ultraviolet and visible imaging system (UVVis) with a fast steering mirror and fine guidance for obtaining sub-arcsec pointing stability. The primary science objectives of the BOPPS mission are to measure CO_2 and H_2O emissions from the Oort Cloud comets Comets C/2013A1 Siding Spring and C/2012K1 PanSTARRS. The BOPPS measurements of Comet Siding Spring occur a few weeks before the comet's extrememly close approach to Mars. This encounter will also be observed from Earth and from both Mars surface and orbiting platforms. BOPPS data will be telemetered immediately to the ground as well as stored in dedicated payload solid state memory; the payload and gondola will be recovered after landing. BOPPS is the re-flight of the BRRISON mission [1,2].

IR Camera: BIRC is a multispectral, cryogenic HgCdTe infrared imager with a 3' x 3' FOV and a 1.16"/pixel plate scale using a Teledyne H2RG focal plane with 18 µm physical pixels. The image PSF FWHM at 3 um is ~2.5". BIRC uses cooled relay optics and a filter wheel with 3% passbands centered at 2.47, 2.70, 2.85, 3.05, 3.20, 4.00, 4.27, 4.60 µm. BIRC also has a target acquisition broadband R filter (0.60 – 0.80 um) setting. BIRC uses 12-bit digitization and returns either full frame (2048x2048 pixel) or windowed (320x200 pixel) images. BIRC's sensitivity is limited by the sky and instrumental thermal background, particularly at the longer wavelengths.

BIRC is designed to measure the water and CO_2 emissions from a comet coma and to determine their ratio as an important diagnostic of cometary origins. BIRC is mounted on an IR optical bench behind the main telescope, one of two benches mounted there; the UVVis instrument is mounted on the proximal bench and BIRC is mounted on the distal bench. A pick-off mirror either diverts light into UVVis or moves aside to let light pass through to BIRC. The arrangement of the two optical benches is shown in Figure 1.

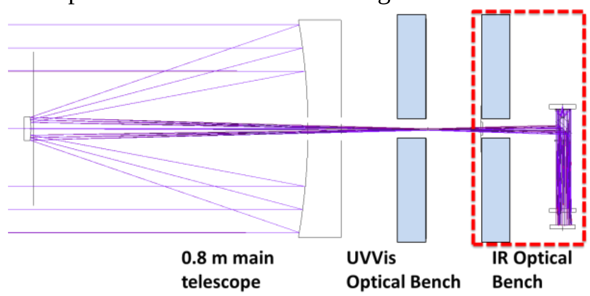

Figure 1. BOPPS optical benches, with ray trace from 0.8 m main telescope. The IR optical bench mounts relay optics, a filter wheel, and the IR camera.

BIRC integrates the infrared camera, with its HgCdTe array detector, SIDECAR readout ASIC, and integrated cryostat, to a cooled, 9-position filter wheel and cooled relay optics that couple the camera to the main 80 cm aperture, f/17.5 BOPPS telescope. Both the filter wheel and relay optics operate near LN2 temperatures to reduce thermal background emission.

The relay optics include a 50.3 mm, f/4 Ritchey-Chretien ("mini-RC") telescope that is mounted within the integrated cryostat and vacuum system of the BIRC camera, immediately in front of the H2RG focal plane array. The light from the main telescope reaches prime focus at the UVVis optical bench, where a field stop is located, and then enters the IR optical bench through a CaF_2 window. On the IR optical bench, the relay optics (with three fold mirrors and an aspheric mirror) collimates the light and provides an exit pupil at the mini-RC, at which a cold shield is placed. The cryogenic filter wheel is also near the exit pupil. Figure 2 shows the layout of the BIRC optical bench.

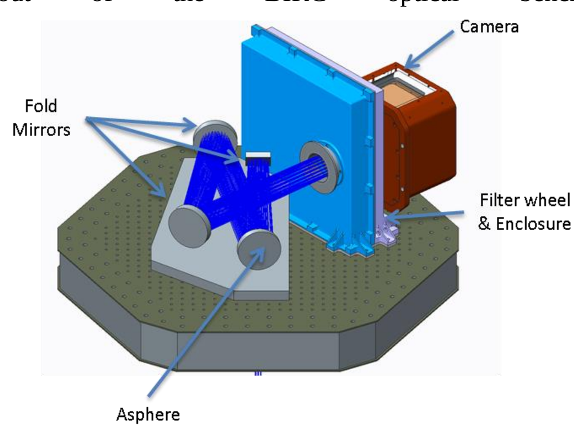

Figure 2. BIRC optical bench

The BIRC thermal design is divided into multiple zones. The camera focal plane is operated at approximately 70K, within a structure ("inner sanctum") to which the mini-RC telescope is mounted, all of which is cooled by the cryocooler; the mini-RC is operated at ~80K. The filter wheel mechanism is within the same vacuum enclosure as the camera inner sanctum, but is separately cooled with liquid nitrogen; the filter wheel is operated at ~125K. A separate enclosure, also cooled by liquid nitrogen, is mounted on the BIRC optical bench and contains the three fold mirrors and the collimating asphere of the relay optics; this cold enclosure is separated from the camera and filter wheel vacuum system by a Ca F2 window. The relay optics in the cold enclosure operate at ~190K. Another Ca F2 window is located at the entrance to the cold enclosure on the IR optical bench, where light from the main telescope is passed into BIRC. The optical bench and the main telescope are operated at or above ambient temperatures. Two 50 liter dewars for LN2 are located on the gondola base structure. A separate liquid cooling loop services both the BIRC camera and the UVVis cameras, to transport excess heat from the cameras to an external radiator on the gondola, maintaining the camera external housings near ambient temperature

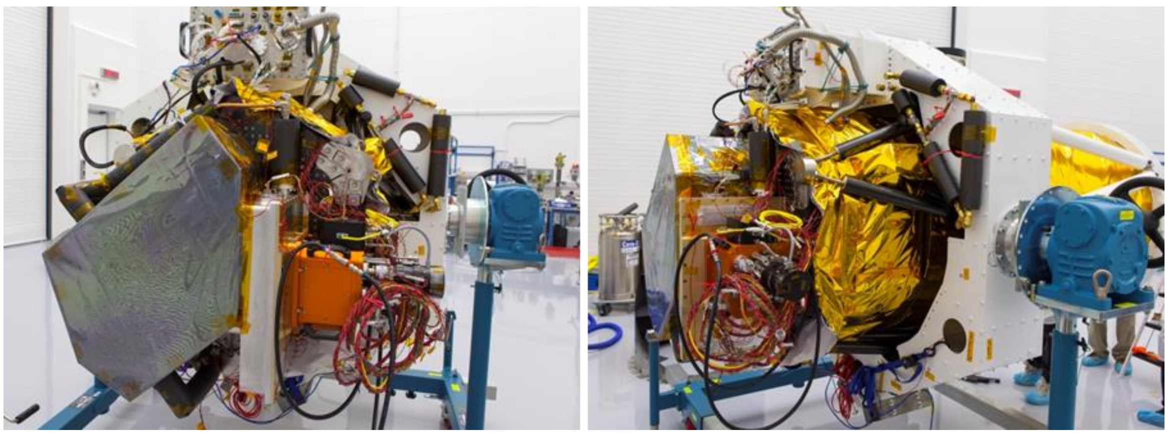

Figure 3 (left panel) The IR bench, with cold enclosure containing relay optics (gray polygonal box), filter wheel (in aluminum housing), IR camera (orange box), and cryocooler (black cylinder). (right panel, left to right) The IR bench (cryocooler pointing out of page), and the UVVis bench (in thermal blanketing), both mounted on the mounting ring (white) of the main telescope at the right side of the image, in thermal blanketing.

Calibration Results: The calibration program for BIRC included ground testing under ambient and under thermal and altitude conditions in an environmental chamber, as well as hang testing integrated to the main telescope and the gondola, with the gondola suspended from a crane and free to swing and rotate.

Tests of image quality were made with wavefront measurements and with full aperture collimated sources. Geometric calibration was also obtained with star fields in hang tests. Radiometric calibration was obtained with measurements of a blackbody target plate in the altitude thermal environmental chamber and with measurements of star fields in hang tests. The H2RG detector characterization was performed with photon transfer testing in the altitude thermal environmental chamber. The read noise measured in the photon transfer test was 1.67 ± 0.06 DN. The gain characteristic was such that 100 DN corresponded to 2620 electrons detected, while 500 DN corresponded to 20,200 electrons.

References: [1] Cheng A. B., Hibbitts K., Young E. F., Heffernan, K. and Bernasconi, P. (2013) *AGU Fall Meeting, P24-A05* [2] Cheng A. F., Hibbitts, C., Bernasconi, P., Young, E., Kremic, T., Arnold, S., Adams, D. (2013) *AGU Fall Meeting, P31A-1791*

.