CALIBRATION OF MULTICOLOR TV IMAGING AND KRFM SPECTROMETER OBSERVATIONS OF PHOBOS. S. Murchie, D. Britt, J. Head, S. Pratt, and P. Fisher, *Dept. of Geological Sciences, Brown University, Providence, RI 02912*; B. Zhukov, A. Kuzmin, L. Ksanfomality, G. Nikitin, and A. Zharkov, *Space Research Institute, Moscow, U.S.S.R.*; F. Fanale, D. Blaney, and M. Robinson, *Hawaii Institute of Geophysics, University of Hawaii, 2525 Correa Rd., Honolulu, HI 96822.*

The multispectral detectors "VSK" and "KRFM" on *Phobos 2* have provided disk-resolved measurements of the spectral reflectance properties of Phobos's surface over a greater geographic area and spectral range than were observed by *Viking*. Wide-angle VSK TV cameras with CCD detectors obtained 12 pairs of images of Phobos covering the wavelength ranges 0.40-0.58 µm (the "visible" channel) and 0.78-1.10 µm (the "NIR" channel). Portions of images from two pairs are saturated, and in a third pair Phobos is observed at only 1 km/pixel resolution. Of the remaining nine pairs, three show Phobos with Mars in the background, and six show different views of the part of Phobos between 30°W and 250°W at resolutions of 0.3-0.5 km [1,2]. In addition, a point spectrometer in the KRFM instrument package obtained 1-km resolution 10-channel reflectance measurements in the wavelength range 0.3-0.6 µm, along two groundtracks in the equatorial region of Phobos's anti-Mars hemisphere [3,4]. 8 of the channels returned useful data with a high signal-to-noise ratio. Each of the groundtracks was acquired simultaneously with a sequence of 3 VSK images, a visible image, a NIR image, and a narrow-angle image with a bandpass of 0.4-1.1 µm.

In an ongoing study we are using VSK and KRFM results to analyze the spectral properties, visible/near-infrared color ratio, and distribution of color units on Phobos's surface. This abstract summarizes how we have calibrated and processed the data. One accompanying abstract [5] describes the systematics and spatial distributions of color units that the VSK data reveal, correlation of these data with spectral reflectance measurements by KRFM, and preliminary interpretations of these results. A second accompanying abstract [6] compares the spectral properties of Phobos's surface with those of meteoritic materials proposed as analogs to Phobos's regolith.

VSK Images

Engineering Calibration. Based on the results of on-ground and in-flight measurements of the instument, the following steps were performed during an engineering calibration of the imagery [2]:

(a) Local median filtering and Fourier filtering were used to remove impulse and periodic noise.

(b) Dark current was subtracted as a channel-dependent constant, determined from exposures at -70°C for times of 1-32 ms.

(c) VSK images were transferred to a memory unit under illumination, using an "electronic shutter" technique. Charge accumulation during the transfer was corrected using a recursive algorithm, and the efficiency of the correction was controlled visually.

(d) A flat-field correction was made for each channel by subtracting a flat-field image. For the visible channel the flat-field image was acquired on-ground; the CCD for the NIR channel was changed shortly before launch of the spacecraft, so the flat-field image for this channel was built up from in-flight images.

(e) A DN to brightness transformation was performed based on results of on-ground sensitivity calibration of the two cameras. However, the on-ground calibration was performed at -10°C, whereas images of Phobos were acquired at -60°C. This difference was accounted for on the basis of on-ground measurement of sensitivity as a function of detector temperature.

Recalibration. In order to provide a more accurate determination of Phobos's color properties, we recalibrated visible-NIR image pairs using a known region of Mars as a standard. From these products, we created color ratio images of Phobos from different viewing geometries. The following procedure was employed [2]:

(a) Relative brightnesses of all image pairs were corrected for camera exposure times, sensitivities, frequency response functions, and the shape of the solar continuum, so that DN levels in each image had the same nominal linear relationship to brightness. Preliminary color ratio images were constructed.

(b) The engineering calibration was tested employing Mars as a standard, using image pair 2300111/2300123. This pair shows both Phobos and a large uniform region of Mars away from the limb and its atmospheric effects on color. The specific region, a southern-hemisphere dark area between the craters Newton, Mariner, and Barnard, was modeled spectrally as an average of seven dark areas measured by McCord *et al.* (7). The visible and NIR reflectances expected for such an area have a ratio of 0.48. The measured ratio (0.41 ± 0.03) is significantly different, so the image pair was recalibrated to the earth-based Mars spectra by multiplying visible DN's by a coefficient of 1.16.

(c) The recalibration of the image pair was then tested using previous whole-disk spectral measurements of Phobos as a standard [8,9,10]. The average recalibrated color ratio of Phobos, 1.0 ± 0.1, is consistent with telescopic, *Mariner 9*, and *Viking* data. The average color ratio that would result from images on which only the initial calibration had been performed (0.87 ± 0.1) is much less consistent with previous observations.

(d) Next, "test areas" on Phobos were selected and identified both in the Mars-Phobos image pair and in pairs obtained at different phase angles that show Phobos alone. The areas' color ratios are largely independent of phase angle, but there is a systematic variation in color between the image pairs.

(e) On the basis of this last result, the six higher-resolution image pairs showing Phobos alone were recalibrated, in each case by multiplying visible DN's by a coefficient in the range of 0.87-1.00 to equalize the color ratios of the "test areas" with their color ratios in the "recalibrated" Mars-Phobos image pair.

Calibrated color ratio images showing Phobos from different perspectives were then constructed. To aid in geologic interpretation of these data, false-color images were also created from the color ratio images and Gaussian-stretched visible images, through a transformation from hue-saturation-intensity space into red-green-blue space.

KRFM Spectra

Groundtrack Locations and Color Properties. Locations of the groundtracks were determined initially on the basis of navigation data and the assumption of a model ellipsoidal figure, and were given nominally as 4.5°S,140°-260°W for track 1 and 2.7°S,196°-229°W for track 2 [3]. These nominal coordinates were revised using data from the VSK narrow-angle camera. Assuming that variations in brightness measured by the KRFM spectrometer result predominantly from differences in surface illumination, brightness profiles measured by KRFM should approximately match profiles of brightness across the corresponding parts of concurrent VSK images. For each of the ground tracks, the nominal location was identified on the appropriate VSK narrow-angle image using controlled U.S.G.S. photomosaics of *Viking* images of Phobos as a guide. The DN levels of the image were measured along seven profiles spanning the spectrometer's field of view. These measurements were then compared to the brightness profile measured by channel 9 of the spectrometer (550 nm), which falls well within the spectral sensitivity range of the VSK camera.

In the case of track 1, the channel 9 brightness profile is a good match to the VSK brightness profile for the imaged portion of the nominal groundtrack, approximately west of 190°W. Further west than 242°W, both Mars and Phobos are in the spectrometer's field of view, so that the actual longitude range of useful measurements is probably 140°-242°W. The VSK brightness profile is largely unaffected by movement of the nominal track north or south by 2-3°, so that a small error in the given latitude of 4.5°S would not be identifiable by this technique. In the case of track 2, the channel 9 brightness profile is a poor match to the VSK brightness profile for the nominal track location. Moving the nominal track location 5° to the north and 2° to the east produces a good match to the VSK brightness profile, which cannot be duplicated if the track were more than a degree or so different in latitude. Thus the actual coordinates of track 2 appear to be approximately 2°N,194°-227°W. Given these coordinates, the 2 along-track bands measured by the spectrometer are adjacent but do not overlap.

In Figure 1 of one of the accompanying abstracts [5], these locations are mapped on color-ratio images of Phobos. Most of the two tracks are located in areas with a redder color ratio than the "average" for Phobos. Only two locations, at 147°W and 165°W along track 1, represent surfaces with globally "average" color properties.

Calibration of Spectra. The KRFM spectrometer measurements were calibrated initially by multiplying raw DN levels by channel-specific calibration constants determined on-ground, and by dividing by the solar spectrum. Comparison of adjacent regions of the two groundtracks reveals systematic differences in their spectra, despite relative along-track homogeneity of spectral properties in these locations, suggesting the possibility of instrumental drift. This possibility led to empirical recalibration being performed, employing the color ratio images and a composite spectrum of Phobos [9] based on *Mariner 9*, *Viking Lander*, and telescopic data [4].

(a) The material along track 1 at 165°W with a globally "average" color ratio of 1.0 was assumed to have a 0.3-0.6 μm spectrum like that of the global composite "standard" spectrum.

(b) Other spectra along track 1 were divided by the measured spectrum at 165°W to produce relative spectra, and were multiplied by the standard to produce recalibrated spectra.

(c) Track 2 does not cross an area with an "average" color ratio, so it was recalibrated to track 1 using a patch at 196°W, crossed by both tracks, with a uniform color ratio. Both tracks were assumed to have identical spectra here.

(d) Track 2 was therefore recalibrated by dividing through by the measured spectrum at 196°W to produce relative spectra, and by multiplying these by the recalibrated spectrum of track 1 at this location.

This recalibration procedure should remove instrumental drift incurred since launch from earth and between acquisition of the two groundtracks.

REFERENCES: [1] Avanesov, A. *et al.*, *Nature*, *341*, 585-587, 1989. [2] Avanesov, A. *et al.*, submitted to *Planetary and Space Science*, 1990. [3] Ksanfomality, L. *et al.*, *Nature*, *341*, 588-591, 1989. [4] Ksanfomality, L. *et al.*, submitted to *Planetary and Space Science*, 1990. [5] Murchie, S. et al., *Lunar Planet. Sci. XXI*, this volume, 1990. [6] Britt, D. *et al.*, *Lunar Planet Sci. XXI*, this volume, 1990. [7] McCord, T., *et al.*, *Icarus*, *31*, 25-39, 1977. [8] Zellner, B. and R. Capen, *Icarus*, *23*, 437-444, 1974. [9] Pang, K., *et al.*, *Science*, *199*, 64-66, 1978. [10] Pollack, J., *et al.*, *Science*, *199*, 66-69, 1978.