SCATTERED LIGHT REMEDIATION AND RECALIBRATION OF NEAR SHOEMAKER'S NIS GLOBAL DATASET AT 433 EROS. N. R. Izenberg, The Johns Hopkins University Applied Physics Laboratory, 11100 Johns Hopkins Road, Laurel, Maryland 20723, USA, noam.izenberg@jhuapl.edu

Introduction: The original calibration of NEAR Shoemaker's Near Infrared Spectrometer (NIS), while complete [1], omitted a critical correction for internal scattered light of the spectrometer grating [2]. This kind of scatter is a natural feature of grating spectrometers, but it was initially discounted as a significant factor in NIS calibration. After a re-analysis of the ground calibrations, [2] determined the scattered light contribution to be significant enough to warrant correction, and generated a correction factor for the instrument's raw data-to-radiance conversion coefficients. The NIS+MSI in [2] used calibrated and photometrically corrected Eros spectra, and a post-processing scattered light correction applied to those spectra directly. Ideally the scattered light, and other post-mission calibration corrections should be applied as part of the calibration pipeline, before any post-processing (including photometric correction). Future analysis using calibrated NIS data is better served by propagating corrections through the complete (over 200,000 spectrum) dataset from the raw original.

Grating Scatter - CRISP and NIS: Ground calibrations of the Comet Nucleus Tour (CONTOUR)'s Combined Remote Imager and Spectrometer (CRISP) revealed an internal scatter within the spectrometer portion of that instrument [3]. Light from wavelengths up to hundreds of nanometers out-of-band was found to contaminate any given CRISP spectrometer channel, including "dark" pixels positioned outside the nominal light path. The effect was attributed to scatter from the spectrometer grating. The individual contamination of light at any one wavelength to the detectors of another was small (*i.e.,* <1% of the in-band signal), but the aggregate effect of all out-of-band wavelengths inflated the apparent signal in all channels. The effect was greatest in the channels that measured the lowest radiances (*i.e.,* the longer wavelength channels) and required correction for proper calibration of the instrument (Fig. 1.).

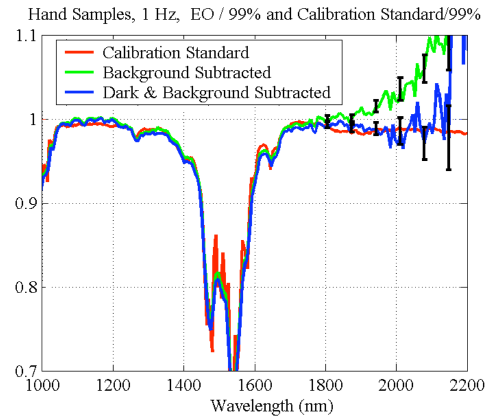

Figure 1. Hand sample comparison from CRISP and RELAB measurements. Ratio of 99% reflectance standard and Erbium Oxide (EO) wavelength standard hand samples as measured by RELAB (red) and CONTOUR CRISP (blue and green) Green line shows ratio including internal scattered light. Blue shows scattered light corrected data.

NIS calibration did not incorporate a scattered light correction from pre-flight tests. Initial analysis of NIS ground calibrations concluded that internal scattering effects were likely to be of the same order as off axis response; 0.1% or less [4]. Upon revisiting ground data, [2] determined that the cumulative effects of this scattered light within the instrument had non-trivial effect on the measured spectrum not accounted for in extant instrument calibrations.

In both Germanium (Ge) and Indium-Gallium-Arsenide (InGaAs) detectors of NIS, most individual channels received small amounts of light from both near- (10's of nm) and far-wavelengths (100's of nm). Incoming light at a given wavelength is scattered off the grating, causing some of it to fall onto detectors out of the intended band. Examples are shown in Fig. 2. The near-wavelength effect was most significant in immediately adjacent channels and stronger in the InGaAs detector. The far-wavelength contamination, most noticeable in the Ge detector, was small on a per-wavelength basis, but summed to an appreciable effect. Far-wavelength effects were amplified when wavelengths with higher radiance scatter into channels that normally receive lower radiance (*e.g.,* longer wavelength channels in InGaAs).

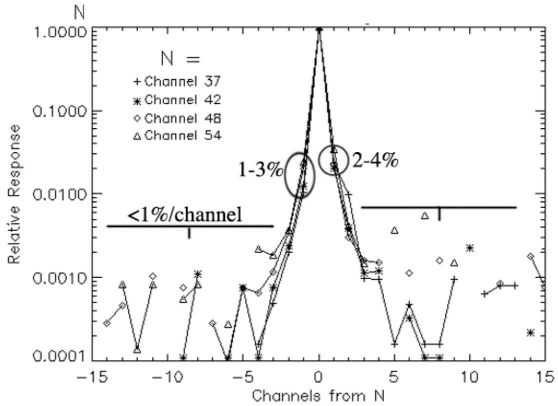

Figure 2. Plot of channel-to-channel relative response in the NIS InGaAs detector (1400-2500 nm) showing near- and far-wavelength scattered light, from [2]. Near-wavelength scattered light is on the order of <1-4%, greater from the N+1 channel wavelength than the N-1 channel. Far-wavelength scattered light is under 1% per channel, but the additive effect is up to 1% or more on a given channel.

As shown in [2], near- and far-wavelength scatter in both detectors, though individually small, summed to out-of-band contributions of up to several percent in any given NIS channel.

NIS Scattered Light Removal: Removal of instrument scattered light is accomplished by generating a "scrubbing" filter from ground calibration data. The near-wavelength component of the filter is generated by taking the set of well matched monochromator and NIS wavelengths (*e.g.,* 1140 nm for channel 16 at 1140.4 nm), determining the near-neighbor scattered light into a given channel N out to channels N±3, and interpolating for NIS channels that do not have well matched monochromator data (*e.g.,* channel 20 at 1226.8 nm). The far-wavelength component is determined by interpolating the dark-subtracted data for channels beyond N±3 across the monochromator scan range to the 32 NIS channel wavelengths of each detector. The results of the interpolation are a 32x32 channel vs. wavelength matrix of relative response for each NIS detector (Fig. 3).

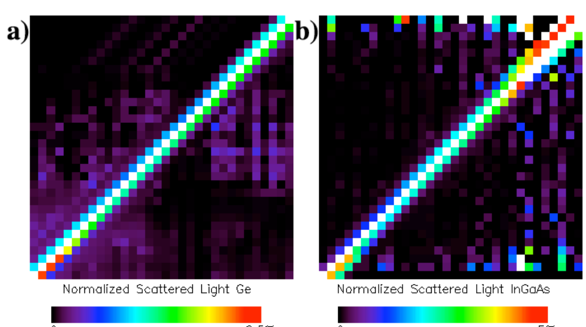

Figure 3. Relative response matrices for the two NIS detectors. The X-direction shows the 32 channels of each detector. The Y-direction (increasing upward) shows relative signal strength incoming to a given channel X from all wavelengths in the detector. At coordinates X=Y, where the incoming light wavelength equals the bandpass of the NIS channel, the relative response is 1.0. Nonzero values where X≠Y denote scattered light.

Summing all out-of-band contributions for a given NIS channel N and subtracting that sum of scattered light from the signal at channel N, the final filter for a given spectrum is derived:

$$R'_{(\lambda=\mathrm{N})} = R_{\lambda=\mathrm{N}} - \sum F_{(\lambda=\mathrm{N},\lambda\neq\mathrm{N})} \bullet R_{\lambda\neq\mathrm{N}} \qquad (1)$$

where $R'_{\lambda=N}$ is the net response at a given NIS channel N, $R_{\lambda=N}$ is the measured response at that channel, $F_{(\lambda=N,\ \lambda\neq N)}$ is the out of band response array for channel N, and $R_{\lambda\neq N}$ is the response of channel N to light from other wavelengths.

First utilization of the scattered light remediation [2] applied a average R' scalar version of this filter to already calibrated, photometrically corrected, and publicly released data using a back-end approach. Ideally, Equation (1) should be incorporated into a revised calibration equation [1], and applied spectrum-by-spectrum during the calibration process itself. The poster will present the results of this incorporation; the complete NIS spectral data set at Eros will be re-calibrated using the scatter-corrected radiance conversion, and possibly other refinements to the calibration pipeline completed since [1]. Old and new calibrations will be compared. Impact of global recalibrated spectra on other NIS science results will also be examined.

Results and Implications: The post-calibration scatter correction used in [2] resulted in a net improvement in calibrated NIS spectra: reduced spectral red slope; increased silicate absorption band center wavelengths; decreased band depths; and decreased band area ratios. Application of the scatter correction during calibration of raw data will improve calibration further, though effects on the resulting spectra may differ somewhat. NIS results to date have shown the spectrum of Eros to appear substantially redder than telescopic spectra [2,5-7]. This work may help determine whether the NIS mismatch with telescope data is due primarily to errors in NIS calibration coefficients derived from on-ground radiometry, or whether other explanations are necessary.

References: [1] Izenberg N. R. *et al.* (2000) *Icarus,* 148, 550-571. [2] Izenberg N. R. *et al.* (2003) *MAPS* [3] Izenberg N. R. *et al.* (submitted) *Optical Eng.* [4] Warren J. R. et al. (1997) *Space. Sci. Rev.* 82, 101-167. [5] Murchie S. L. and Pieters C. M. (1996) *JGR, 101,* 2201-2214. [6] Clark B. E. *et al.* (2001) *Icarus* 155, 189-204. [7] Bell J. F. III *et al.* (2002) *Icarus* 155, 119-154.