RECALIBRATION OF THE NEAR GAMMA-RAY SPECTROMETER: ENABLING NEW SCIENCE FROM THE LANDED AND ORBITAL NEAR GRS DATASETS. Z. W. Yokley[1*], P. N. Peplowski[1], J.O. Goldsten[1], [1]Johns Hopkins University Applied Physics Laboratory 11100 Johns Hopkins Road (*email: zachary.yokley@jhuapl.edu)

Introduction: The Near-Earth Asteroid Rendezvous (NEAR) mission studied the mineralogical and elemental composition of the near-Earth asteroid 433 Eros. To achieve this, NEAR carried several instruments including a scintillator-based gamma-ray spectrometer (GRS; [1]), which has been used to determine the bulk elemental composition of Eros [2–4].

The NEAR GRS consisted of a NaI inner detector surrounded by a bismuth germinate (BGO) anti-coincidence shield (ACS). The ACS surrounded the NaI on all but one side, creating a boresight through which the NaI viewed the asteroid during orbital operations [1]. The opening in the ACS provided a ~50° field of view (FOV) for the NaI. The ACS was included to provide a means to detect and reject backgrounds from galactic cosmic rays and spacecraft-borne gamma-ray backgrounds. However, the larger size and higher efficiency of the ACS, relative to the NaI, provides an alternative means of characterizing surface composition [3].

The GRS was calibrated for orbital operations using radioactive sources that were placed at small incidence angles to the instrument [5]. The angular coverage was sufficient to cover the instrument's orbital FOV. However, after NEAR's landing, the GRS was located on the surface which drastically increased the FOVs (< 108°) for both the NaI and the ACS [2]. Because of the increased signal from surface operations, the gamma-ray data taken after landing surpassed in quality the data taken in orbit; therefore, its use is ideal for determining the composition of NEAR's landing site.

Analysis of the landed measurements, particularly the ACS data, required knowledge of the instrument response at larger angles than was covered during the initial calibration campaign [5]. To that end, we obtained the NEAR GRS engineering model (EM), previously on loan to the Smithsonian Institution, for the purpose of conducting a new calibration. The EM is mechanically identical to the flight instrument, making it suitable for characterizing the response of the NEAR GRS.

Our initial calibration efforts only included the ACS, due to the larger signal it provided for landed data compared to the NaI. The landed data along with the recalibration was used to provide evidence for an L- or LL-chondrite-like surface composition [3]. The GRS response models were then incorporated into the analysis of orbital data presented by [4].

The results from this recalibration of the EM are presented here. We are currently extending our efforts to include all NaI products (raw, anti-coincidence, single- and double-escape spectra) [1], and the results from that measurement campaign will also be presented at the meeting.

Methods: The GRS's detection efficiency is a function of both the energy and incidence angle of the impinging gamma rays. Of particular concern is the NaI photomultiplier tube (PMT), with is located within the boresight and attenuates low-energy gamma rays prior to detection by the GRS. The full detector response, including attenuation losses and the intrinsic detection efficiency of the sensors, must be well understood in order to convert observed spectra into elemental composition. Prior to NEAR's launch, calibrations were done with the GRS flight unit, spares, and EM, but only for the NaI sensor [5]. Our initial ACS calibration used the EM plus MESSENGER GRS flight spare electronics [2]. Full GRS calibration will be carried out using a similar setup.

The ACS calibration was carried out in a similar manner to the calibration measurements on the MESSENGER GRS [6], which well reproduced the observed energy and angular response of that system. Our calibration was done with various standard laboratory sources at incident angles of 0°, 30°, 60° and 90°. The angular range covers the ~2π FOV of the ACS after NEAR landed. Gamma-ray lines from the source had energies of 340, 569, 662, 834, 1067, 1173, 1332, and 1770 keV [3], covering the lower portion of the energy range of interest.

After the spectra were collected, the GRS was modeled in Geant4 [7] following [6]. The model served to extend our detector response knowledge to all angles and higher energies. The experimental data provided a benchmark for the models. The model was then used to recreate the landed geometry of the NEAR GRS and provide the basis for the reanalysis of that dataset [3].

Results: Measurements and the Geant4 model, at the 60° orientation (angle between the boresight vector and the source position) are shown in Figure 1. Efficiency is shown as the probability that a gamma ray will reach the ACS and be detected at full energy (photopeak) as a function of energy. This value includes attenuation losses between the source and the GRS, attributed to GRS components (housing, PMTs, etc.).

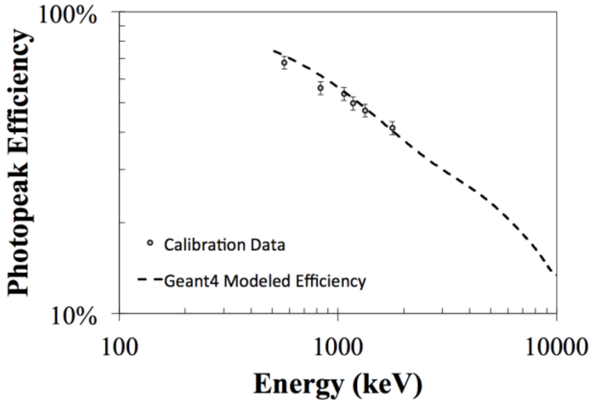

Figure 1. Geant4 model of the ACS photopeak (full energy gamma ray) detection efficiency as a function of energy, compared to measurements made with the GRS EM.

As illustrated, there is good agreement between the model and data, supporting the accuracy of the Geant4 model of the GRS. Some discrepancies were observed at low energies at 0°, suggesting that the Geant4 model of the NaI PMT was imperfect.

A small but statistically significant gamma-ray signal from Eros was recently identified in low-altitude GRS data collected from orbit [4]. This signal, shown in Figure 2, was compared to modeled spectra derived from simulated gamma-ray signals multiplied by the detector response [4]. The agreement between the models and data indicate that the response of the GRS ACS is well characterized by the Geant4 model.

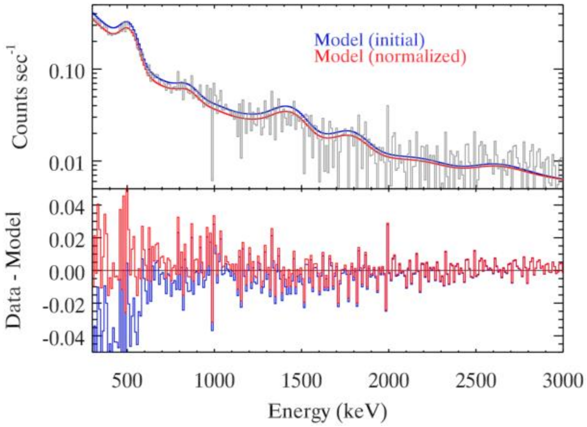

Figure 2. ACS "residual" spectrum (grey), obtained during the low-altitude flyovers, compared to modeled gamma-ray spectra calculated using the ACS response function. The "normalization" (0.86) accounted for uncertainties in the gamma-ray inducing galactic cosmic ray flux. Residual represents the low-altitude spectrum minus a spacecraft background spectrum, derived from high-altitude data (see [5] for details).

Recalibration of the NaI main sensor, including the raw, anti-coincidence, single-, and double-escape peak modes has not yet been conducted. We anticipate completing these tests in time to present the results at the conference.

Discussion: Our results show that our model shows good agreement with our lab-based benchmarking data and that our results are useful for reanalysis for NEAR GRS data. Our data also shows a statistically significant discrepancy at low energies for sources along the boresight axis. A possible cause of the discrepancy is the inexact modeling of the NaI PMT.

The NaI PMT was a rugged metal–ceramic PMT, rather than a more typical glass PMT [1]. While its ruggedness was useful for the rigors of spaceflight, its composition made it more attenuating than a typical glass PMT. The attenuation is non-negligible, and was first noticed during calibration of the flight unit [5]. Calculations presented in [5] that did not account for the NaI's PMT gave efficiencies ~4 times lower than observed. The attenuation from this PMT is particularly significant for the orbital NaI data since all the signal gamma rays needed to first penetrate the PMT before being detected.

Our efforts to recalibrate the NEAR GRS detectors will enable new scientific results to be obtained from the GRS measurements. The usefulness of these efforts has been demonstrated by [3] and [4], who reported new results from the NEAR GRS dataset some 15 years after the original analyses were published [3]. NaI measurements from orbit have not been reported, and NaI measurements from the surface should be revisited in light of results published since 2001 [2]. By providing the recalibration data to the planetary science community, we hope to stimulate new interest in this valuable but underutilized dataset.

References: [1] Goldsten, J.O et al. (1997), *Space Sci. Rev. 82*, 169–212. [2] Evans, L.G. et al. (2001), *Meteorit. Planet. Sci. 36*, 1369–1660. [3] Peplowski P. N. et al. (2015) *Meteor. Planet. Sci. 50*, 353–367. [4] Peplowski P. N. (2016) *Planet. Space Sci. 134*, 36–51. [5] Evans L. G. et al. (2000) *Icarus 148*, 95–117. [6] Peplowski P. N. et al. (2012) *JGR Planets 117*, E00L04. [7] Agostinelli S. et al. (2003) *Nuc. Inst. Meth. A 506*, 250–303.