THE IMAGING AND NIR SPECTROSCOPY EXPERIMENTS ON THE *NEAR* SPACECRAFT
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The main objectives of the Multispectral Imager (MSI) and Near-Infrared Spectrograph (NIS) experiments on the Near-Earth Asteroid Rendezvous (NEAR) spacecraft are to determine the shape, surface morphology, albedo and color properties, and mineralogy and mineralogic heterogeneity of the S asteroid 433 Eros, and to assess the relationship of this asteroid with known meteorite types. Achieving these objectives requires reliable instrumentation, a careful observational strategy, and rigorous data calibration and analytical procedures. This report reviews instrument characteristics and calibration, and inflight observational and calibration strategy prior to launch.

Imager characteristics and on-ground calibration. MSI [1] is a body-fixed imager containing a frame-transfer CCD with an active area of 537x244 pixels. Individual pixels have 161x95 µrad resolution, yielding an instrument field-of-view of 2.9°x2.25°. Data are digitized to 12 bits, and several data compression schemes are selectable by command. Exposure times are commandable manually up to 999 ms, or an automatic exposure control can be used. The telescope is an *f*/3.4, 5-element refractor, with a protective lens cover to be deployed shortly after launch. A filter wheel contains 7 narrow band filters selected to discriminate Fe-containing silicate minerals known to occur on S asteroids, and one broadband filter for low-light imaging and optical navigation (Figure 1).

On-ground calibrations were conducted at the APL Optical Calibration Facility. Tests at the piece-part level included measurements of CCD linearity, responsivity as a function of wavelength and temperature, and dark-current characteristics, as well as spectral transmissivity of the filters (Figure 1). Instrument-level calibrations included measurement of responsivity as a function of temperature and wavelength, focus, point-spread and modulation-transfer functions, dark current characteristics, flat-field characteristics, scattering, and rejection of out-of-field light. Once integrated onto the spacecraft, inter-instrument alignments and contribution of other components of NEAR to MSI noise were measured. Key results of these tests are that: responsivity is sufficient for 3-σ detection of a source as low in magnitude as a solar-type star of magnitude +10.6; noise is sufficiently low for S/N ratios of ~500:1 to be attained at high DN levels; geometric distortion is at the limit of ability to measure on-ground ($\leq$1 pixel); and scattered light is of low magnitude, and compares favorably with the best filters on the Galileo SSI [2].

Spectrometer characteristics and on-ground calibration. NIS is a grating spectrometer, in which light is directed by a dichroic beam-splitter onto a 32-element Ge detector (center wavelengths, 816-1486 nm) and a 32-element InGaAs detector (center wavelengths, 1371-2708 nm). The field-of-view is selectable using slits with dimensions calibrated at 0.37°x0.76° (narrow slit) and 0.74°x0.76° (wide slit). A shutter can be closed for dark current measurements. For the Ge detector, there is an option to command a 10x boost in gain. A scan mirror rotates the field-of-view over a 140° range, and a diffuse gold calibration target is viewable at the sunward edge of the field of regard. Spectra are measured once per second, and up to 16 can be summed onboard.

On-ground calibration at the detector level was similar to that of the MSI CCD. Additional piece-part calibrations included the grating, dichroic beam splitter, mirror rotation, and (most importantly) spectral reflectance of the calibration target as a function of illumination geometry, at the emission angle occurring while mounted on NIS. Instrument-level calibration included measurement of responsivity as a function of temperature and wavelength, center wavelengths and fields-of-view of each detector element, rejection of out-of-field light, dark current characteristics, dependence of responsivity on mirror position and polarization, and reflectance of the mounted calibration target. These calibrations show that for radiances expected at Eros at 0° phase angle, S/N of >3000 is easily attainable with the Ge detectors and S/N of >500 can be attained over the central wavelengths of the InGaAs detector, assuming an average of four exposures. Out-of-field light rejection is such that only 0.2° out of field, the signal from a point source is attenuated by a factor of ~3000 from the center of the field-of-view.

Sample measurements. The goal of both instruments is to produce accurate, interpretable measurements of rocks and minerals. To test this capability, a suite of known and unknown mineral, rock, and meteorite samples was measured with both instruments. Ultimately, these will be calibrated against spectral standards to be used inflight. For NIS, the standard is the calibration target, and this was measured at the same time as the samples. For MSI, the standards inflight will be the moon, Vega, and Canopus; these could not be measured in the calibration facility, so a calibration plaque of known properties was accommodated. Spectra of the known samples will be compared against published and independently measured spectra to validate instrument radiometric calibration. The unknown samples represent a variety of meteorite types; their spectra will be used in a blind test of the compositional interpretability of MSI and NIS spectral data, to be published ~1 year after launch. Even in their raw form (e.g., Figures 2 and 3), both sets of measurements demonstrate excellent internal agreement of data from the two instruments.

Inflight calibrations. Most aspects of MSI and NIS calibration will be remeasured inflight. For example, MSI will use the moon as a primary inflight calibration target. The main lunar observations will be during the earth gravity assist in January 1998, at which time images will be acquired though all filters with the moon in a matrix of locations in and out of the field-of-view, to redetermine radiometric calibration, rejection of out-of-field light, internal scattering of light, and to check the flat-field. To track stability of calibration over time, Vega and Canopus will be observed every few months, and it is planned that the moon will also be observed a second time (2-3 days after launch, in February 1996). Any changes of geometric properties of the imager will be determined using several episodes of imaging of star fields. At Eros, the magnitude of out-of-field light will be measured repeatedly with image scans off the asteroid's limb, as illumination and viewing geometries evolve.

Eros observation strategy. Geologic observations of Eros will begin in earnest 8 days before encounter, when for 2 days several broad-band image mosaics of Eros's sphere of influence will be acquired to search for small asteroid satellites. It is anticipated that a natural satellite with Eros's reflectance properties and a diameter of 12 m could be detected as this time. Approximately two days before closest approach and for the duration of at least one asteroid rotation, MSI will acquire monochrome mosaics every 10° of asteroid rotation and color mosaics every 20°, and NIS will acquire one spectral mosaic every 5° of rotation. At this time the southern hemisphere and equatorial region will be illuminated. (Eros's axis is inclined ~90° to its orbital plane.) Subsequently NEAR will pass between Eros and the sun and be captured into retrograde orbit on 6 February 1999. NIS observations will be carried out continuously every few degrees of asteroid rotation at phase angles of 0°-70°.

MSI and NIS will acquire mosaics of the illuminated portion of Eros at increasing spatial resolution using all MSI filters, as the orbit is lowered stepwise, at 1000-, 400-, 200-, and 100-km altitudes. From March through December, with one exception the orbit with be maintained at 35-50 km radius. In the low orbits both instruments will operate in a "push-broom" mode, in which periodic acquisition of MSI images and scanning of the NIS mirror perpendicular to spacecraft motion will be used to build up overlapping data strips. Priority for coverage will be given to areas of interest identified earlier in the mission. In August 1999 the orbital radius will be increased for several days to 100 km and the orbital plane will be flipped 180° to maintain retrograde revolution. During this maneuver all latitudes will be illuminated, and global imaging and spectral coverage will be acquired at one time.

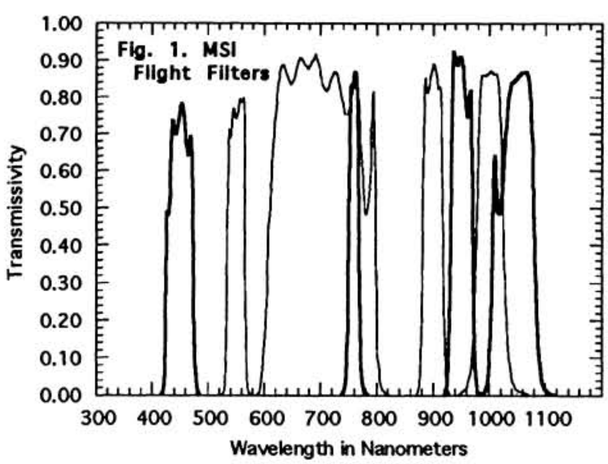

Fig. 1. MSI Flight Filters

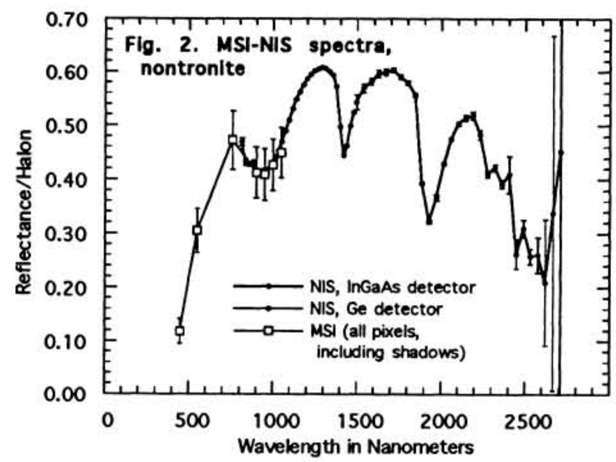

Fig. 2. MSI-NIS spectra, nontronite

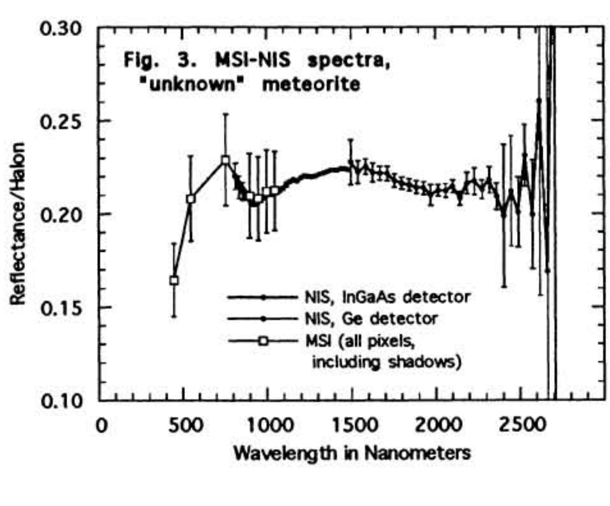

Fig. 3. MSI-NIS spectra, "unknown" meteorite

References. [1] Veverka, J. *et al.*, LPSC XVI, 1447, 1995. [2] Gaddis, L. *et al.*, J. Geophys. Res., in press, 1996.