GAMMA RAY AND NEUTRON SPECTROMETER FOR DAWN. T.H. Prettyman,[1] B.L. Barraclough,[1] W.C. Feldman,[1] J.R. Baldonado,[1] J.D. Bernardin,[1] R.D. Dingler,[1] D.C. Enemark,[1] C.K. Little,[1] E.A. Miller,[2] D.E. Patrick,[1] B. Pavri,[2] C.A. Raymond,[2] C.T. Russell,[3] S.A. Storms,[1] M.R. Sweet,[1] R.L. Williford,[1] B. Wong-Swanson[1] [1]Los Alamos National Laboratory, Los Alamos, NM, [2]Jet Propulsion Laboratory, Pasadena, CA, [3]University of California Los Angeles, CA.

Introduction: Dawn is a NASA Discovery mission that will explore two complementary protoplanets, Ceres and Vesta, which are among the largest main belt asteroids [1]. Vesta is a dry, inner-belt asteroid that was differentiated by igneous processes and whose surface consists of pyroxene-bearing basalts similar in composition to the Howardite, Eucrite, and Diogenite (HED) meteorites [2]. Ceres is a water-rich, mid-belt object that likely underwent aqueous differentiation at low temperature and may contain liquid water [3]. The main belt asteroids are thought to be remnants of the earliest epoch of solar system evolution. By exploring Ceres and Vesta, the Dawn mission will peer into the distant past, providing new information on processes by which the planets formed.

Following launch, which is expected in late 2006 or early 2007, the Dawn spacecraft will embark on its 10-year mission, traveling to and orbiting each of the asteroids and acquiring data on their elemental composition, mineralogy, topography, and gravity fields. The information acquired by Dawn in combination with meteoritic data and telescopic observations will enable us to determine the origin and evolution of Vesta and Ceres. The science payload includes two framing cameras, a visible near-infrared mapping spectrometer, and a gamma-ray and neutron detector (GRaND). GRaND will map the near-surface abundance of major rock-forming elements, long-lived radioactive elements, and volatiles such as H, C, N and O which are the major constituents of ices [4,5].

Instrument Description: In order to meet mission science objectives, GRaND uses heritage technology from Lunar Prospector and 2001 Mars Odyssey, including a bismuth germanate (BGO) scintillator for high efficiency gamma ray spectroscopy and boron loaded plastic scintillators for fast and epithermal neutron detection. GRaND also includes new sensor technologies to improve the accuracy of elemental abundance measurements. These include a 16-element, CdZnTe (CZT) semiconductor detector array for high resolution gamma ray spectroscopy, and boron-loaded plastic/Li-loaded-glass phoswiches ("phosphor sandwiches") to separately measure thermal, epithermal, and fast neutrons originating from the asteroids.

A photograph of the flight instrument is shown in Fig. 1 along with a cutaway view of the instrument, which shows the arrangement of the sensors and electronics. The instrument is compact, containing a total of 21 sensors, analog and digital signal processing

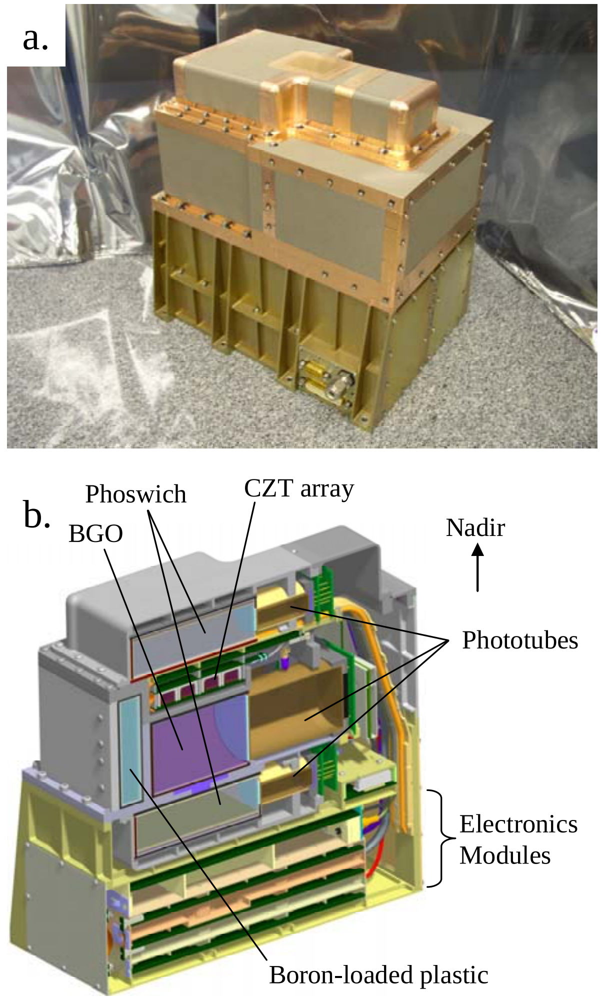

Fig. 1. a) A photograph of the GRaND flight instrument is compared to b) a cutaway drawing of the instrument. GRaND is a deck-mounted instrument that is pointed towards nadir while acquiring science data.

Table 1. Instrument specifications.

Dimensions	26 cm × 19 cm × 26 cm
Mass	9.3 kg
Power consumption	15 W[1]
Telemetry rate	3.1 kbps[2]

[1]During science data acquisition mode.
[2]Nominal rate during science data acquisition.

electronics, and low- and high-voltage power supplies. A field programmable gate array is used to categorize radiation interactions measured by the sensors, including coincidence events, such as the double-pulse signature of fast neutrons interacting with boron-loaded

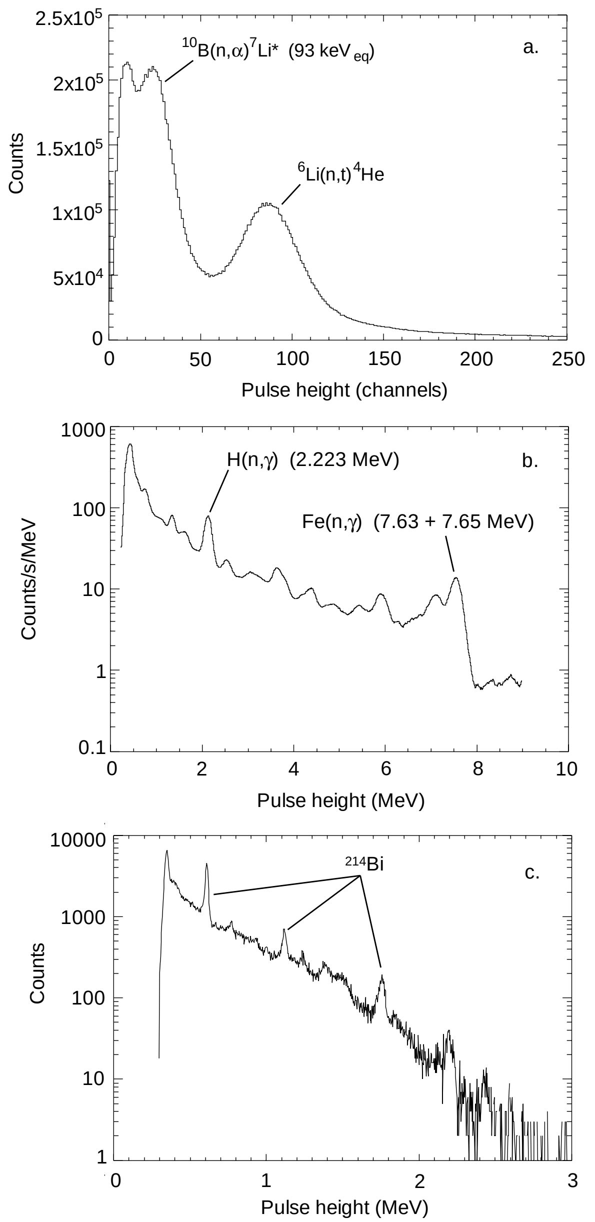

Fig. 2. GRaND data products for a) the nadir-pointing phoswich, b) the BGO sensor, and c) the CZT array (see text).

plastic [6]. Data processing, telemetry, and instrument control are facilitated by a microcontroller. The instrument has no moving parts and is simple to operate. If necessary, the CZT array can be annealed during flight to mitigate the effects of radiation damage caused by long-term exposure to energetic particles and cosmic rays [4].

Performance: Results of extensive calibration and testing show that GRaND functions properly and provides all of the information needed to meet science objectives at Vesta and Ceres. For example, three of the science data products are shown in Fig. 2. The pulse height spectrum shown in Fig. 2a for a phoswich sensor, was acquired using a laboratory neutron source with an energy distribution similar to that of a planetary leakage spectrum. Thermal and epithermal neutrons interacting in the Li-loaded glass produce a distinct peak associated with the recoil energy of the reaction products for the $^{6}Li(n,t)^{4}He$ reaction. Epithermal neutrons that interact with the B-loaded plastic produce a separate peak at 93 keV$_{eq}$. The two peaks are well separated in energy and can be used together to measure the thermal and epithermal components of the neutron spectrum [4,5].

The BGO sensor has high efficiency for gamma ray detection and can measure gamma rays over a wide energy range (see Fig. 2b for a spectrum acquired for neutrons incident on an Fe slab). The CZT array has a more restrictive energy range (0- to 3-MeV), but has somewhat higher energy resolution than the BGO sensor (better than 3% at 662 keV). A spectrum for an ore sample, showing prominent gamma rays from the decay of ^{214}Bi (from the ^{238}U decay chain) is shown, for example, in Fig. 2. The CZT array will enable improved accuracy for the analysis of the low energy region of the spectrum, which is densely populated by gamma rays from radioactive decay and nuclear reactions.

The operational plan for Dawn provides ample integration time and coverage at each asteroid, sufficient to globally map surface elemental composition. The geochemical data provided by GRaND will, for example, provide strong constraints on thermal evolution, including the role of water and other volatiles in planetary development, context for the HED meteorites, and the degree of volatile depletion in the source material from which the asteroids accreted.

Present Status: On November 14, 2005, GRaND was delivered to Orbital Sciences Corporation for integration with the spacecraft; however, NASA has directed the Dawn mission to stop spacecraft integration while the project's schedule and technical viability is evaluated. Work on integration may resume in February of 2006 if NASA decides to provide funding to continue assembly, test, and launch operations. We are looking forward to a successful launch and the science that will be carried out over the next decade as Dawn visits two unexplored planetary bodies.

References: [1] Russell, C. T. et al. (2004), *PSS*, **52**, 465–89. [2] Keil, K. (2002), In Bottke Jr., W.F., Cellino, A., Paolicchi, P., Binzel, R.P. (Eds.), *Asteroids III*, 573–84. [3] McCord, T. B. and C. Sotin (2005), *JGR*, **110**, E05009, doi:10.1029/2004JE002244. [4] Prettyman, T. H. et al. (2003), *IEEE TNS*, **50**(4), 1190-97. [5] Prettyman, T. H. et al. (2004), *Proc. SPIE*, **5660**, 107-16. [6] Feldman, W. C. et al. (1991), *NIM*, **A306**, 350-65.