# Dawn Mission

## Overview

The Dawn spacecraft was successfully launched atop a Delta II rocket on September 27, 2007. Dawn is an ion-propelled spacecraft capable of visiting multiple targets in the main asteroid belt. In the baseline mission, Dawn flies to and orbits the main belt asteroids 1 Ceres and 4 Vesta, orbiting Vesta for a period of not less than seven months and Ceres for not less than five months. The spacecraft flies by Mars in a gravity assist maneuver in 2009 en route to Vesta.

Dawn carries three science instruments whose data is used to characterize the target bodies. The instrument suite consists of redundant Framing Cameras (FC1 and FC2), a Visible and Infrared mapping spectrometer (VIR) and a Gamma Ray and Neutron Detector (GRaND). In addition to these instruments, radiometric and optical navigation data is used to determine the gravity field. The Dawn mission is an international cooperation with instrument teams located in Germany, Italy, and the United States.

## Science Goals

In order to achieve the overall scientific goal of understanding conditions and processes acting at the solar system’s earliest epoch, the Dawn spacecraft images the surfaces of the minor planets Vesta and Ceres to determine their bombardment, thermal, tectonic, and possible volcanic history. It determines the topography and internal structure of these two complementary protoplanets that have remained intact since their formation, by measuring their mass, shape, volume, and spin rate with navigation data and imagery. Dawn determines mineral and elemental composition from infrared, gamma ray, and neutron spectroscopy to constrain the thermal history and compositional evolution of Ceres and Vesta, and in addition provides context for meteorites (asteroid samples already in hand). It also uses the spectral information to search for water-bearing minerals.

## Instruments

### Framing Camera (FC):

The Framing Camera is a multispectral imager that also serves as an optical navigation camera. The detector is a 1024x1024 pixel Atmel/Thomson TH7888A CCD with 14 micron pixels. It has eight filters numbered F1 through F8, including a broadband (clear) filter and narrow band filters ranging from 438 nm to 965 nm. The Framing camera instrument includes two redundant cameras of identical design, referred to as FC1 and FC2. For full information about the FC instrument, see Schroeder and Gutierrez-Marques (2011).

### Visible and Infrared Mapping Spectrometer (VIR):

VIR is an imaging spectrometer with an optical design derived from the visible channel of the Cassini Visible Infrared Mapping Spectrometer (VIMS-V) and from the Rosetta Visible Infrared Thermal Imaging Spectrometer (VIRTIS). It has moderate resolution and combines two data channels in one instrument. The two data channels, Visible (spectral range 0.25-1 micron) and Infrared (spectral range 0.95-5 micron), are committed to spectral mapping and are housed in the same optical subsystem. The spectrometer has the ability to point and scan along the direction perpendicular to the slit. A complete description of the instrument and its performance can be found in De Sanctis et al. (2010) and Coradini et al. (2011).

### Gamma Ray and Neutron Detector (GRaND):

GRaND is a nuclear spectrometer that will collect data needed to map the elemental composition of the surfaces of 4 Vesta and 1 Ceres (Prettyman et al. 2003B). GRaND measures the spectrum of planetary gamma rays and neutrons, which originate from cosmic ray interactions and radioactive decay within the surface, while the spacecraft is in orbit around each body. The instrument, which is mounted on the +Z deck of the spacecraft, consists of 21 sensors designed to separately measure radiation originating from the surface of each asteroid and background sources, including the space energetic particle environment and cosmic ray interactions with the spacecraft. A complete description of GRaND is given in the GRaND instrument paper, Prettyman et al. (2011). Instrument performance during cruise and Mars Flyby is given by Prettyman et al. (2012).

## Mission Phases

(Dates in parentheses are projected at the time of writing.)

Phase Name (Phase ID) Start time End time

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INITIAL CHECKOUT (ICO) 2007-09-27 2008-01-19T00:00

EARTH-MARS CRUISE (EMC) 2008-01-19T00:00 2009-02-16T00:00

MARS GRAVITY ASSIST (MGA) 2009-02-16T00:00 2010-03-23T00:00

MARS-VESTA CRUISE (MVC) 2010-03-23T00:00 2011-05-03T10:49

VESTA ENCOUNTER 2011-05-03T10:49 2012-09-10T21:50

VESTA SCIENCE APPROACH (VSA) 2011-05-03T10:49 2011-08-11T12:00

VESTA SCIENCE SURVEY (VSS) 2011-08-11T12:00 2011-08-31T20:26

VESTA TRANSFER TO HAMO (VTH) 2011-08-31T20:26 2011-09-29T09:59

VESTA SCIENCE HAMO (VSH) 2011-09-29T09:59 2011-11-02T10:40

VESTA TRANSFER TO LAMO (VTL) 2011-11-02T10:40 2011-12-12T22:44

VESTA SCIENCE LAMO (VSL) 2011-12-12T22:44 2012-05-01T11:50

VESTA TRANSFER TO HAMO 2 (VT2) 2012-05-01T11:50 2012-06-15T10:00

VESTA SCIENCE HAMO 2 (VH2) 2012-06-15T10:00 2012-07-25T15:10

VESTA TRANSFER TO CERES (VTC) 2012-07-25T15:10 2012-09-10T21:50

VESTA-CERES CRUISE (VCC) 2012-09-10T21:50 2014-12-26T02:50

CERES ENCOUNTER 2014-12-26T02:50 (2016-07-01)

CERES SCIENCE APPROACH (CSA) 2014-12-26T02:50 2015-04-24T00:00

CERES SCIENCE RC3 (CSR) 2015-04-24T00:00 2015-05-09T10:00

CERES TRANSFER TO SURVEY (CTS) 2015-05-09T10:00 2015-06-04T12:00

CERES SCIENCE SURVEY (CSS) 2015-06-04T12:00 2015-07-01T00:00

CERES TRANSFER TO HAMO (CTH) 2015-07-01T00:00 2015-08-16T23:59

CERES SCIENCE HAMO (CSH) 2015-08-16T23:59 2015-10-23T20:30

CERES TRANSFER TO LAMO (CTL) 2015-10-23:20:30 2015-12-16T01:00

CERES SCIENCE LAMO (CSL) 2015-12-16T01:00 (2016-07-01)

END OF MISSION (2016-04-21) 2018-11-01

The following mission phase activities are summarized from the *Dawn Science Plan* (Raymond 2007).

**Initial Checkout (ICO)** - ICO covers the 60-day period following launch and is used to turn on and perform initial checkout of the instruments. Only a minimal set of instrument checkout activities are performed during ICO to minimize interference with critical spacecraft checkouts.

**Cruise Phases** - Seven days of non-thrusting periods per year are designated for science calibration activities. These periods are used to perform functional, performance, and calibration tests of the instruments using stellar and planetary targets. During cruise, GRaND measures the response to galactic cosmic rays and energetic particles in the space environment, characterizing the background sources.

**Mars Gravity Assist (MGA)** - The purpose of MGA is to add energy to the spacecraft trajectory to ensure adequate mass and power margins for the designated trajectory. In addition, the MGA provides an opportunity for instrument calibration, a readiness exercise for Vesta operations, an absolute calibration of GRaND, and an extended source for calibrating VIR and FC. VIR obtains scientifically valuable spectroscopy. GRaND acquires data for direct comparison with data from 2001 Mars Odyssey, enabling cross calibration during flight. None of the data gathered at Mars are critical to achieving the goals of the mission.

**Approach Phases** - During the Vesta Approach phase the instruments go through complete calibration, repeating some of the activities that were done during the post-launch checkout calibration period, including annealing GRaND if necessary. For both Vesta and Ceres Approach phases, the FC collects rotation characterization (RC) maps and VIR obtains full-disc spectra coincident with the RCs. Data obtained in the Approach phases provide a range of illumination angles to initialize the topographic model, and data to aid in finalizing the plans for HAMO and LAMO. During the approach phases several searches for hazards (dust, moons) are performed in the near-asteroid environment. An additional activity in the Vesta Approach phase is to exercise the processing streams for the instruments’ data, mainly the FC and VIR, to verify that quicklook products can be produced on the required timelines, and to check and improve the calibration parameters.

**Survey Orbits** - The goals for the Vesta and Ceres survey orbits are to obtain global coverage with VIR, and to create overlapping global images with the FC in multiple filters. The VIR map constitutes the primary (and perhaps only) global reference set. The VIR and FC global maps will be used for defining targets to be investigated at lower altitudes, and the FC data will contribute significantly to the topographic model. Cross-calibration of the VIR and FC will be facilitated by concurrent imaging during this phase.

**High Altitude Mapping Orbit (HAMO)** - The HAMO is used primarily to create global FC maps of the lighted surface of the body in multiple filters from a nadir attitude, and two clear-filter maps from two different off-nadir viewing angles. These maps will be used to create a topographic model. VIR will also collect at least 5000 frames to sample the spectral variability at smaller scales than the global survey map, and to build up high-resolution coverage of areas of interest. Additional imaging is planned near the end of the encounter (after LAMO), as the spacecraft is spiraling out from the asteroid, to capture different lighting conditions and fill in gaps in the coverage. These activities will not constitute a separate mission phase, but will supplement the HAMO objectives in order to complete the global FC mosaics in multiple filters, and obtain supplemental VIR coverage of selected targets.

**Low Altitude Mapping Orbit (LAMO)** - The purpose of LAMO is to obtain spatially resolved neutron and gamma ray spectra of the asteroid, and global tracking coverage to determine the gravity field. In addition, as much FC and VIR nadir imaging as can be fit into the data buffers will be obtained. Data lost or not acquired in HAMO that are needed to complete the global mapping may be acquired in LAMO using very short FC exposures or using target motion compensation. Off-nadir targeted acquisition is anticipated for a small fraction of the time, including some very high resolution imaging of selected targets. A dedicated gravity campaign (several days to one week) will be used for resolving the wobble in rotation to measure the moment of inertia of the asteroid.

## References

De Sanctis, M. C., A. Coradini, E. Ammannito, G. Filacchione, M.T. Capria, S. Fonte, G. Magni, A. Barbis, A. Bini, M. Dami, I. Ficai-Veltroni, and G. Preti, VIR Team, The VIR Spectrometer, Space Sci Rev, doi:10.1007/s11214-010-9668-5, 2010.

A. Coradini, D. Turrini, C. Federico, G. Magni, Vesta and Ceres: crossing the history of the Solar system. Space Sci. Rev., 2011.

Prettyman, T.H. and W.C. Feldman, PDS Data Processing: Gamma Ray and Neutron Detector, version 5.0, Feb. 1, 2012. [Archived as a document in the Dawn GRaND Calibrated Mars Flyby data set, DAWN-M-GRAND-2-RDR-MARS-COUNTS-V1.0.]

Prettyman, T.H., W.C. Feldman, F.P. Ameduri, B.L. Barraclough, E.W. Cascio, K.R. Fuller, H.O. Funsten, D.J. Lawrence, G.W. McKinney, C.T. Russell, S.A. Soldner, S.A. Storms, C. Szeles, and R.L. Tokar, Gamma-ray and neutron spectrometer for the Dawn mission to 1 Ceres and 4 Vesta, IEEE Transactions on Nuclear Science Volume: 50, Issue: 4, 1, August 2003B, pp. 1190-1197.

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Schroeder, S.E. and P. Gutierrez-Marques, Calibration Pipeline, MPS report DA-FC-MPAE-RP-272, Issue 2, Rev. a, 20 July 2011. [A copy of this document is included in the /DOCUMENT directory of the Dawn FC1 and FC2 PDS3 archive volumes.]