Dawn Mission Status and Plans

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Dawn will map two new worlds

Dawn carries a scientific payload that will characterize the surfaces of two complementary protoplanets, Vesta and Ceres

- Map the geologic units
- Create detailed shape models
- Determine how and when the bodies formed
- Understand the internal and external forces that shaped them

Dawn will sense the structure of the interior of the bodies by measuring their gravitational pull on the spacecraft

- Accomplished by measuring the perturbations of the spacecraft’s orbit with precise doppler data on the radio frequency link to Earth
Spacecraft configuration, assembly for launch
Dawn spacecraft being lifted to the top of its Delta II launch vehicle
Artist’s view of Dawn spacecraft
Ion propulsion system

Dawn mission is only possible within Discovery cost cap using IPS

Dawn will have $2.5\times \Delta V$ ever obtained by a spacecraft with its propulsion system

Dawn will thrust for $>5$ years in its 8-year mission, $3\times$ the longest powered flight
Flight System Configuration

- Framing Camera
- Gamma Ray and Neutron Detector
- Solar arrays (articulable around y)
- Visible and Infrared mapping spectrometer
- Antennas
- Ion propulsion system thrusters (2 obscured in this view; all 3 in x-z plane)

20 m
Dawn Spacecraft Current Location
Nov. 18, 2009 04:18:55 UTC.

- Dawn trajectory thrust on
- Dawn trajectory thrust off
- Earth’s orbit
- Mars’s orbit
- Vesta’s orbit
- Ceres’ orbit

Distance to Vesta 1.337 AU
Distance to Earth 1.116 AU
Distance to Mars 0.1078 AU
Distance to Sun 1.676 AU

MYSTIC simulator
Both bodies resemble planets
Both are spheroidal except for the large southern polar crater on Vesta

Vestas’s surface is basaltic
Ceres’ shape appears to be fully relaxed and consistent with a 400 km radius rocky core with a 100 km water (ice?) shell

The surface of Ceres is more dusty (clay) than icy.

Ceres and Vesta are much larger than near-Earth asteroid 433 Eros
Dawn’s Payload

- Dawn carries two redundant framing cameras (1024 x 1024 pixels, and 7 color filters plus clear); a visible and infrared mapping spectrometer (UV to 5 microns) and a Gamma Ray and Neutron Detector
- These were provided by Germany (MPS and DLR), Italy (INAF and ASI), and LANL
- Radiometric data provides gravity information; imaging provides topography
Dawn objectives at Vesta

• Resolve the topography of Vesta to 10-m height at 100-m spatial resolution

FC imaging to map surface elevations (laser altimeter was descoped for mission); topography needed to define size and shape, identify tectonic processes, and remove elevation effects from gravity signals
Dawn objectives at Vesta

- Map the gravity field to 90-km half-wavelength resolution, to characterize crust and mantle density variations, and possibly detect a core

Gravity science using spacecraft orbit tracking via radiometric navigation, provided by USA (Orbital Sciences Corporation and JPL)
Dawn flew by Mars on Feb 17th, 2009

Gamma-Ray and Neutron Detector (GRaND) turned on one month before closest approach
Framing Cameras and GRaND collected data around the closest approach

Spacecraft safing just after closest approach terminated the calibration sequences and prevented the Visible and Infrared Spectrometer from obtaining data.
Preparing for Vesta Encounter

All the instruments on Dawn were checked out after launch using calibration routines and by observing stars.

- Dawn flew by Mars on Feb 17
  - Altitude ~550 km at closest approach to Mars
  - Approach was from the dark side over the northern polar region
  - Spacecraft crossed the dawn terminator, and retreated over the southern polar region
- Spacecraft pointed towards Mars at closest approach to get some calibration data
  - GRaND instrument began measuring the background particle fluxes one month before the Mars encounter to establish the background levels
  - Framing camera turned on just before encounter and took calibration images
  - VIR did not take data at Mars
Dawn Framing Camera Views Mars

Mars Elevation Model from Mars Global Surveyor Data

Dawn image frames

High-Resolution Stereo Camera (HRSC) Images from Mars Express (MEX)

Dawn images on top of MEX/HRSC

Image credit: NASA/JPL/MPS/DLR
Gamma Ray and Neutron Detector (GRaND) Senses Mars

- Altitude vs. Time (s)
- Gamma ray spectrum: BGO
- Csi1Up: Li-glass
- Scalers (Events processed: Green; Cosmic ray monitor: Black)
And On to Vesta!

Vesta exhibits an ancient differentiated surface and appears to be the most geologically diverse of the large asteroids.

- Basaltic volcanism (detected with spectroscopy)
- Large impact crater near the south pole - may excavate into the interior (mantle) of the asteroid
- Distinctive light and dark areas observed with the Hubble Space Telescope

**Asteroid Vesta**

Diameter: 519 km  
Density: 3700 kg/m³

HST • WFPC2

PRC97-27 • ST Sci OPO • September 4, 1997
P. Thomas (Cornell University), B. Zellner (Georgia Southern University) and NASA
Vesta Science Orbits

- Dawn will begin taking data in a high *Survey* orbit
- It will then use the ion propulsion system to transfer two times to lower orbits
  - High Altitude Mapping Orbit (HAMO)
  - Low-Altitude Mapping Orbit (LAMO)
- Dawn will then depart from Vesta and repeat the same orbit strategy at Ceres
DAWN instrument footprints

Vesta operations

**orbits - altitudes**

Survey - 2720 km
HAMO - 620 km
LAMO - 170 km

GRaND sensitivity region at LAMO

VIR slit footprints

FC footprints
Operational Sphere Search

- Range of $5 \times 10^4$ km ($4.8$ km/px)
- 10-minute exposures of each image
  - Take multiple images and co-add
- Take two 10-minute images at each position and repeat serially (~3.5 h):
  - 1-1-slew-2-2-slew-3-3-slew-4-4 (achieves the ~10-min repeat pairs),
  - 1-2-3-4 (achieves the ~1-hour repeat pairs),
- Wait: Perform RC2 (~6 h duration)
- Repeat sequence in serial fashion:
  - 1-2-3-4 (~1.0 h) for long-period object search (12 h spacing from 1st obs.)
- Total time ~13 hr + playback
How Dawn will Map Vesta

Camera frames in the HAMO orbit

N. Hemisphere

S. Hemisphere

Spectral Images in Survey Orbit

Individual spectral frames in HAMO orbit
VIR Pushbroom Imaging in Survey Orbit

- Pink = 20 sec repetition, Blue = 15 sec repetition

- Views of the pushbroom mapping with VIR in C1 and C3 is shown at left
- Begins at 5-15N and ends at 45-60S
  - Gaps appear at the edges of the slits near the equator (below)
1x3 Equatorial FC Mosaics in Survey
VIR Scan Cube Coverage

VIR Survey Orbits 2 and 4 Cube Footprints

Pushbroom imaging fills in the equatorial coverage

30-day phase is split into six global mapping cycles (5 days each)
- Two cycles collect nadir image data (10 days) to achieve 90% global mapping (LI req) with significant overlap
  - Two near-complete mappings separated by 9.4 days
  - Each has one extra orbit dedicated to downlink
- Three cycles collect off-nadir views for topo determination
- One cycle (Cycle 6) for further off-nadir data and targeted VIR and FC imaging
- VIR ride-along during Cycles 1 to 5
- GRaND collects low-resolution data

Mean orbit radius: 950 km
Initial Beta Angle: 30.0 deg
Inclination: 92 deg
Orbit period: ~12h 12m
Duration: 30.5 days – 60 orbits

Ground track sweeps out full 360 degrees of coverage in 10 orbits over 4.7 days, deemed one cycle.
Cycle 1 nadir mapping (shown at left in pink) obtains nearly 80% coverage of Vesta with minimal image overlap.

Cycle 4 nadir mapping (2 orbits shown at left in blue) fills the Cycle 1 gaps with generous overlap and achieves 91.7% coverage.

Nadir and off-nadir coverage for stereo-optimized look angles obtained during Cycles 2, 3 and 5 is shown in binned plot below.

**Stereo 10-40°**
**Incidence 20-70°**
Four or more views (blue through purple) is more likely to achieve best height accuracy.

Cycle 6 could fill in SPC coverage north of 25N.

Possible hybrid strategy of Stereo-optimized angles between 20N and 30S, SPC angles at high latitudes?

- HAMO-2 would extend northern coverage, add SPC coverage in subsolar latitudes.
VIR Imaging in HAMO

Cycle 1 = pink; Cycle 2 = green; Cycle 3 = yellow; Cycle 4 = blue; Cycle 5 = red

- **ABOVE**: VIR slit geometry shown for one cycle
- **RIGHT**: Illustration of VIR HAMO imaging strategy, showing coverage during ten orbits from Cycles 1 (in pink) and two orbits from each of Cycles 2-5 (see legend)
- Good coverage of southern hemisphere can be obtained within the allocated data budget
LAMO for Gravity and GRaND

- LAMO orbit propagated for 70 days
- GRaND integrates count rates while looking at Vesta
- Gravity tracking is done while pointing high-gain antenna at the Earth
LAMO Gravity Coverage – All

Plan oversamples relative to the required coverage for gravity. This is a consequence of the tracking needed to return the Cycle 3 data.
LAMO FC (Nadir) Coverage

Includes data compressed at 1:6 for last 20 days

All data assumed losslessly compressed
Vesta operations -
August 2011-July 2012

Then on to Ceres
Density suggests 75% rock / 25% ice

Science objectives are similar to those at Vesta, but Ceres is very different.

Nominal mission Ceres operations commence Feb 2015

Ceres’ layers

Thin, dusty outer crust

Water-ice layer

Rocky inner core
What might DAWN find at Ceres?

• The properties of Ceres are believed to be similar to a diverse class of primitive (unmelted) carbonaceous chondrite meteorites - much different than Vesta

• Tectonic features resulting from thermal expansion and contraction, and density instabilities of the rock-ice crust

• Volcanic features resulting from water and probably CO$_2$ and methane eruption onto the surface

• Chemically-altered organic material on the surface that is of biological interest

• A radially-structured density distribution that will constrain and refine models of Ceres’ evolution

Diameter: 980 km
Density: 2100 kg/m$^3$
Summary

- Dawn will explore two very different protoplanets with the same spacecraft for the very first time.
- Ion Propulsion is an enabling technology for exploration of the Main Asteroid Belt.
- This comparative study of two remnants of the earliest epoch of solar system evolution will significantly advance understanding of our planetary neighborhood.
- The Dawn at Vesta Participating Scientist call is out.