What is MANTIS?

- MANTIS is the Main-belt Asteroid and NEO Tour with Imaging and Spectroscopy

- MANTIS is an asteroid diversity tour mission visiting the planetary building blocks from our solar system's past, exploring the dynamically active asteroid population of the present, and informing our knowledge for mitigation and exploration of asteroids in the future.

- MANTIS firsts include:
  - encountering an NEO binary asteroid
  - exploring a metallic asteroid
  - visiting asteroids that span a factor of 200 in size, including the smallest object ever visited
  - more than doubling the number of asteroids explored by humankind

- MANTIS revolutionizes our understanding of asteroids through its state of the art payload of complementary instruments:
  - A powerful infrared imaging spectrometer and narrow angle camera, both with flight heritage and both being used at small bodies for the first time
  - The first-ever multispectral mid-IR imager brought to a small body
  - A dust instrument to provide important data to the micrometeorite and exploration communities
  - Datasets taken at each target with a common instrument suite that can be readily intercompared with one another
Asteroids are important

- Dominate the inner solar system by number
- Experienced and record a wide range of processes
- Offer hazards and opportunities to civilization

From xkcd, by Randall Munroe
Asteroids have a variety of compositions.

![Graph showing reflectance and calculated emissivity for different asteroid compositions like Orthopyroxene, Olivine, Ordinary Chondrite (L4), Odessa (IAB Iron), Orgueil (CI1), Bells (CM), Ivuna (CI), Rupota (L4 Ordinary Chondrite), and Odessa (IAB Iron).]
Asteroids show geological variety.

Eros’ surface is dominated by craters, lineaments, blocks, and ponds.

Itokawa’s surface is dominated by blocks and smooth terrain.

Eros images: NASA/JHUAPL
Itokawa image: JAXA
Asteroids experience a variety of “unusual” processes.

Model for binary asteroid system formation

- YORP-induced spin-up shortens rotation period
- Mature (orange) material moves toward equator, leaving fresher material (white) poleward
- After sufficient spin up, material lifts from equator, forming a satellite

Main-belt asteroid P/2013 P5 episodically sheds dust (Jewitt et al. 2014)
Investigating the compositional relationship between asteroids, meteorites, and interplanetary dust particles to understand the origin of life and the evolution of solar system objects.

Investigating how the geochemical and physical properties of asteroids affect surface geology and regolith processes to understand the operation, interaction, and evolution of processes in our solar system.

Investigating the interior structure, formation, and evolution of asteroids to understand how our solar system evolves.

Characterizing potentially hazardous asteroids in Earth’s neighborhood to identify and characterize objects that pose threats to Earth or offer resources for human exploration.
What resolution is needed?

“Typical” flyby image and spectral resolution is insufficient for understanding the nature and evolution of small bodies.

“Typical” Flyby Image: 50 m/pxl (Itokawa)

“Typical” Flyby Spectra: 200 m/pxl (Phobos)
What resolution is needed?

MANTIS instruments provide the spatial and spectral resolution necessary to identify water, organics, and mafic mineralogy, and to determine the geological origin and evolution of asteroid surfaces.

Desired Image Resolution: ~m/pix (Itokawa)

Desired Spectral Cube Resolution: ~dam/pxl (Phobos)
Asteroids < 100 km in diameter for which we have:

- Resolved imaging data

- 433 Eros - 33 x 13 km
  NEAR, 2000

- 5535 Annefrank
  6.6 x 5.0 x 3.4 km
  Stardust, 2002

- 2867 Steins
  5.9 x 4.0 km
  Rosetta, 2008

- 951 Gaspra
  18.2 x 10.5 x 8.9 km
  Galileo, 1991

- 25143 Itokawa
  0.5 x 0.3 x 0.2 km
  Hayabusa, 2005

- 19969 Braille
  2.1 x 1 x 1 km
  Deep Space 1, 1999

- 253 Mathilde - 66 x 48 x 44 km
  NEAR, 1997

- Dactyl
  [(243) Ida I]
  1.6 x 1.2 km
  Galileo, 1993

- 4179 Toutatis
  4.5 x 2.4 x 1.9 km
  Chang’ e 2, 2012

- 243 Ida - 58.8 x 25.4 x 18.6 km
  Galileo, 1993
Asteroids < 100 km in diameter for which we have:

- Resolved imaging data
- Resolved NIR spectral data
Asteroids < 100 km in diameter for which we have:
- Resolved imaging data at ~few m scale
- Resolved NIR spectral data
Asteroids < 100 km in diameter for which we have:
- Resolved imaging data at ~few m scale
- Resolved NIR spectral data at ~few dam scale
Asteroids < 100 km in diameter for which we have:
- Resolved thermal IR
MANTIS High-Resolution Observations Enable Rendezvous-Quality Science

- 80 cm/pixel - Itokawa
- 3 m/pixel - Toutatis
- 3.2 m/pixel - Eros
- 17 m/pixel - Vesta
- 24 m/pixel - Ida
- 54 m/pixel - Gaspra
- 68 m/pixel - Lutetia
- 17 m/pixel - Steins
- 68 m/pixel - Mathilde
- 54 m/pixel - Annefrank
- 24 m/pixel - Braille

- Rendezvous Imaging
- Rendezvous Spectra
- Flyby Imaging
- Flyby Spectra
MANTIS High-Resolution Observations Enable Rendezvous-Quality Science

- Best Global Data (m/pxl):
  --Itokawa: 80 cm/pxl
  -Toutatis: 3 m/pxl
  -Eros: 3.2 m/pxl
  -Vesta: 17 m/pxl
  -LdA: 24 m/pxl
  -Gaspra: 54 m/pxl

- Spectral Imaging Resolution Need:

- Rendezvous Imaging

- Flyby Imaging

- Flyby Spectra
MANTIS Explores the Diverse Asteroid Population

What do intermediate-sized asteroids look like at comparable resolution?

Is Itokawa a typical ~300 m asteroid? Is it unique?

Congressional mandate: Discover 90% of PHAs

NEA data from the Harris Report

Cumulative Number of NEAs ≥ D

Mean Diameter

10 m 100 m 1 km 10 km

1 m 10 m 100 m 1 km

10^0 10^1 10^2 10^3 10^4 10^5 10^6 10^8

MANTIS targets

Geophysical transition zone for rotation, strength, and cohesion.
MANTIS has a flexible set of target requirements

- Diverse set of targets required to answer science questions
- Physical properties databases enable identification of many targets to fulfill needs
- Many trajectories exist that provide required diversity
- Can accommodate changes in launch date, specific targets of NASA interest, etc.
MANTIS Explores Asteroid Diversity: Location

MANTIS visits both Main Belt and Near Earth Asteroids
MANTIS is the first mission to visit a known binary asteroid system.
MANTIS Explores Asteroid Diversity: Composition

S Complex

C Complex
(associated with water/organics)

Unknown Complex

X Complex (M-type)
(differentiated parent body)

MANTIS visits all three main spectral complexes, and is the first mission to visit an M-type asteroid
MANTIS Explores Asteroid Diversity: Size

MANTIS visits a diverse size range of asteroids, including objects in four key size ranges:

- < 350 m
- < 2 km
- 2–5 km
- > 5 km

Cumulative Number of NEAs > D

NEA data from the Harris Report

Itokawa

Eros
We have only begun to sample the diversity present in the asteroid population!

MANTIS visits important representatives of unsampled groups!

MANTIS delivers consistent, intercomparable datasets at all of its targets!

MANTIS augments existing asteroid data by a large multiplier!

The MANTIS concept is flexible, supporting a myriad of trajectories as priorities evolve!