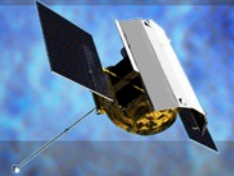




APL

**MESSENGER**

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



# Welcome to the Mercury Dual Imaging System (MDIS) Data Users' Workshop!

We would like to have an informal setting, with questions and discussion being welcome at any time.

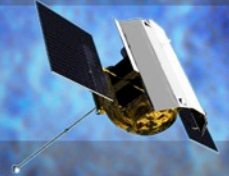
Our goal is for you to leave this workshop with the ability to start using MDIS data in your current and future research projects.



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## Agenda

**1. Overview of the mission, instrument, and imaging campaigns** (~15 min.)

Nancy Chabot, Johns Hopkins University Applied Physics Lab

**2. MDIS calibrations** (~30 min)

Brett Denevi, Johns Hopkins University Applied Physics Lab

**3. Accessing and searching for MDIS data in the PDS** (~20 min)

Lisa Gaddis, United States Geological Survey

**4. MDIS data in QuickMap** (~20 min)

Erick Malaret, Applied Coherent Technology Corporation

----- Break ----- (~15 min)

**5. Using MDIS data in ISIS** (~2 hrs)

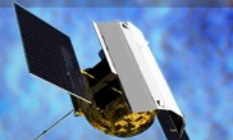
Kris Becker, Tammy Becker, and Trent Hare, United States Geological Survey



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A NASA Discovery mission to conduct the first orbital study of the innermost planet

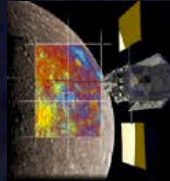


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## Website

This website will have all of the presentation materials from today posted.

There is also a contact email that will stay active.



Why Mercury?

The Mission

Gallery

Education

News Center

Science Operations

Who We Are

FAQs

Related Links

Contacts

Home

Download iPhone/iPad App!

Explore Orbital Data with QuickMap

MESSENGER Q&A

Information about Mercury Orbital Operations

Where is MESSENGER?

## MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging

### MESSENGER Mercury Dual Imaging System (MDIS) Data Users' Workshop 2013

[About the Workshop](#) | [Online Registration](#) | [Agenda and Presentations](#) | [Resources](#) | [Contact Information](#)

#### Agenda and Presentations

Sunday, March 17, 2013, 2 pm CDT  
Montgomery Ballrooms B/C  
The Woodlands Waterway Marriott Hotel and Convention Center  
The Woodlands, TX

#### 1. Overview of the mission, instrument, and imaging campaigns

Nancy Chabot, Johns Hopkins University Applied Physics Lab (~15 min.)

#### 2. Available MDIS data products and calibrations

Brett Denevi, Johns Hopkins University Applied Physics Lab (~30 min.)

#### 3. [Accessing and searching for MDIS data in the PDS](#)

Lisa Gaddis, PDS Imaging Node, United States Geological Survey (~20 min)

#### 4. MDIS data in QuickMap

Erick Malaret, Applied Coherent Technology Corporation (~20 min)

----- Break -----

#### 5. Using MDIS data in ISIS (Integrated Software for Imagers and Spectrometers)

1. ISIS3 Fundamentals
2. Standard Processing Concepts and Tools
3. Cartographic Map Projections

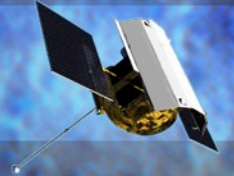
<http://messenger.jhuapl.edu/workshop2013/workshop.html>



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# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## 1. Overview of the mission, instrument, and imaging campaigns

**Nancy Chabot**

*Johns Hopkins University Applied Physics Lab*

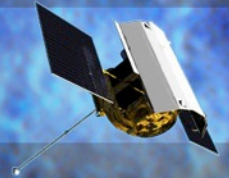
*MDIS Instrument Scientist*



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# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MESSENGER: The Mission

### Team Members

#### Principal Investigator

Sean C. Solomon,  
Carnegie Institution of Washington

Science Team: 47 scientists from  
21 institutions

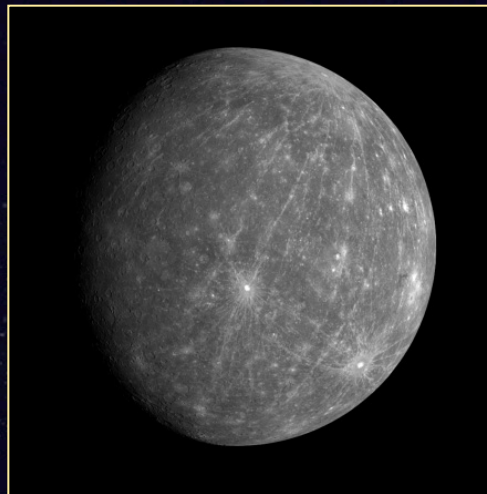
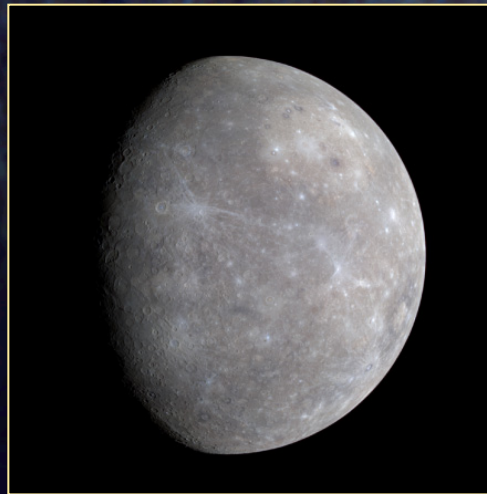
Project Management: APL

Spacecraft Development/  
Operations: APL

Propulsion: Aerojet

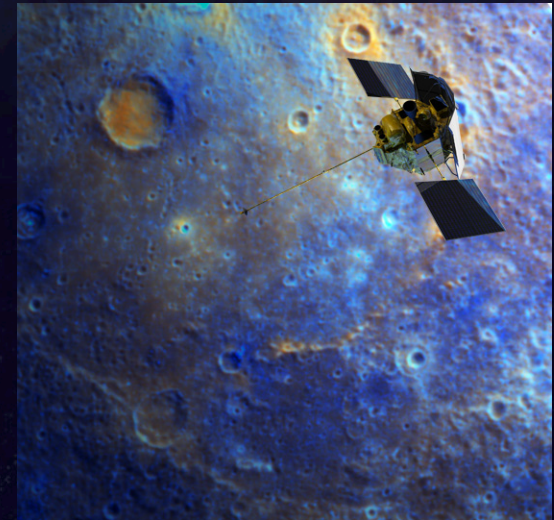
Structure: Composite Optics

Instruments: APL, Goddard Space  
Flight Center, University of  
Colorado Laboratory for  
Atmospheric and Space Physics,  
University of Michigan Space  
Physics Research Laboratory



### Sponsor

NASA Headquarters  
Science Mission Directorate  
Discovery Program Office

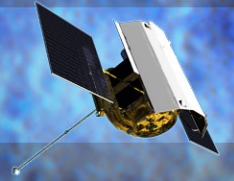




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# MESSENGER

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## MESSENGER: The Mission

### Milestones

- |  |             |
|--|-------------|
| ✓ Launch                                     | 3 Aug 2004  |
| ✓ Earth Flyby                                | 2 Aug 2005  |
| ✓ Venus Flyby 1                              | 24 Oct 2006 |
| ✓ Venus Flyby 2                              | 5 Jun 2007  |
| ✓ Mercury Flyby 1                            | 14 Jan 2008 |
| ✓ Mercury Flyby 2                            | 6 Oct 2008  |
| ✓ Mercury Flyby 3                            | 29 Sep 2009 |
| ✓ Mercury Orbit Insertion                    | 18 Mar 2011 |
| ✓ End of Orbital Operations (primary)        | 17 Mar 2012 |
| ✓ End of Orbital Operations (extended 1)     | 17 Mar 2013 |
| • ??? (proposal for extended 2 under review) |             |
| • Longest Possible Mission Duration          | ~ Mar 2015  |

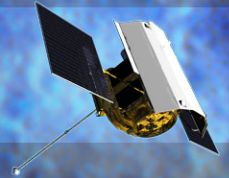




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# MESSENGER

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## MESSENGER: The Spacecraft



Ceramic cloth sunshade

667-N bi-prop thruster

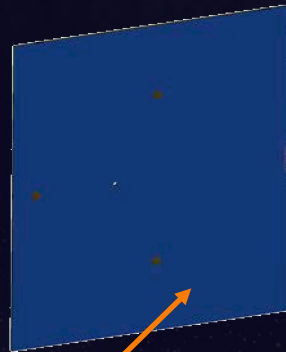
Low-mass, carbon fiber composite structure

Phased-array high-gain antenna

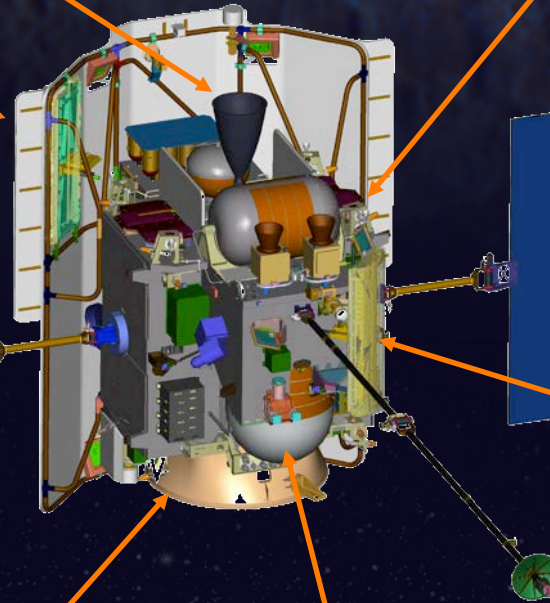


Solar panels are 2/3 mirrors

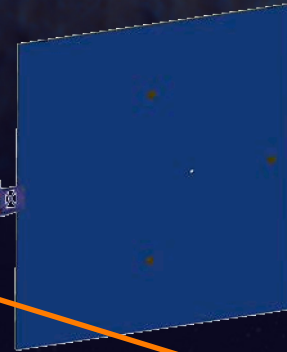
3/17/2013



Custom aluminum launch vehicle adapter



Three large custom propellant tanks



### Key Characteristics:

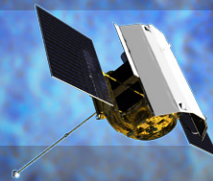
- 1100-kg launch mass
- 2300 m/s  $\Delta V$  capable
- >720-W orbit power



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# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MESSENGER: The Instruments

*7 instruments +  
radio science*

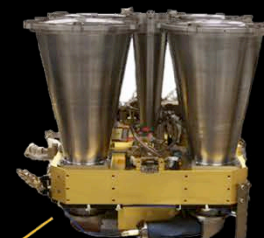
## MDIS: Mercury Dual Imaging System



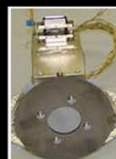
Mercury Atmospheric  
and Surface Composition  
Spectrometer  
(MASCS)



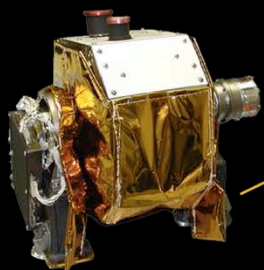
Gamma-Ray  
Spectrometer  
(GRNS/GRS)



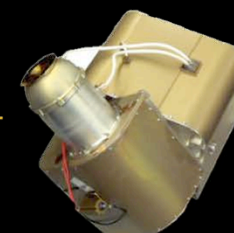
Mercury  
Laser  
Altimeter  
(MLA)



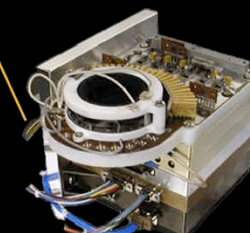
X-ray  
Spectrometer  
Solar Assembly  
(XRS/SAX)



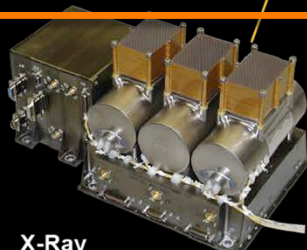
Mercury Dual  
Imaging System  
(MDIS)



Fast Imaging Plasma  
Spectrometer  
(EPPS/FIPS)



Energetic Particle  
Spectrometer  
(EPPS/EPS)



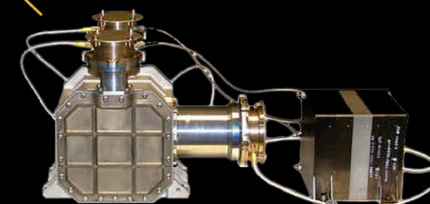
X-Ray  
Spectrometer  
Mercury Unit (XRS/MXU)



Data Processing  
Unit (DPU)



Magnetometer (MAG)  
[at end of boom not shown]



Neutron Spectrometer  
(GRNS/NS)

3/17/2013

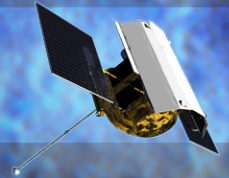




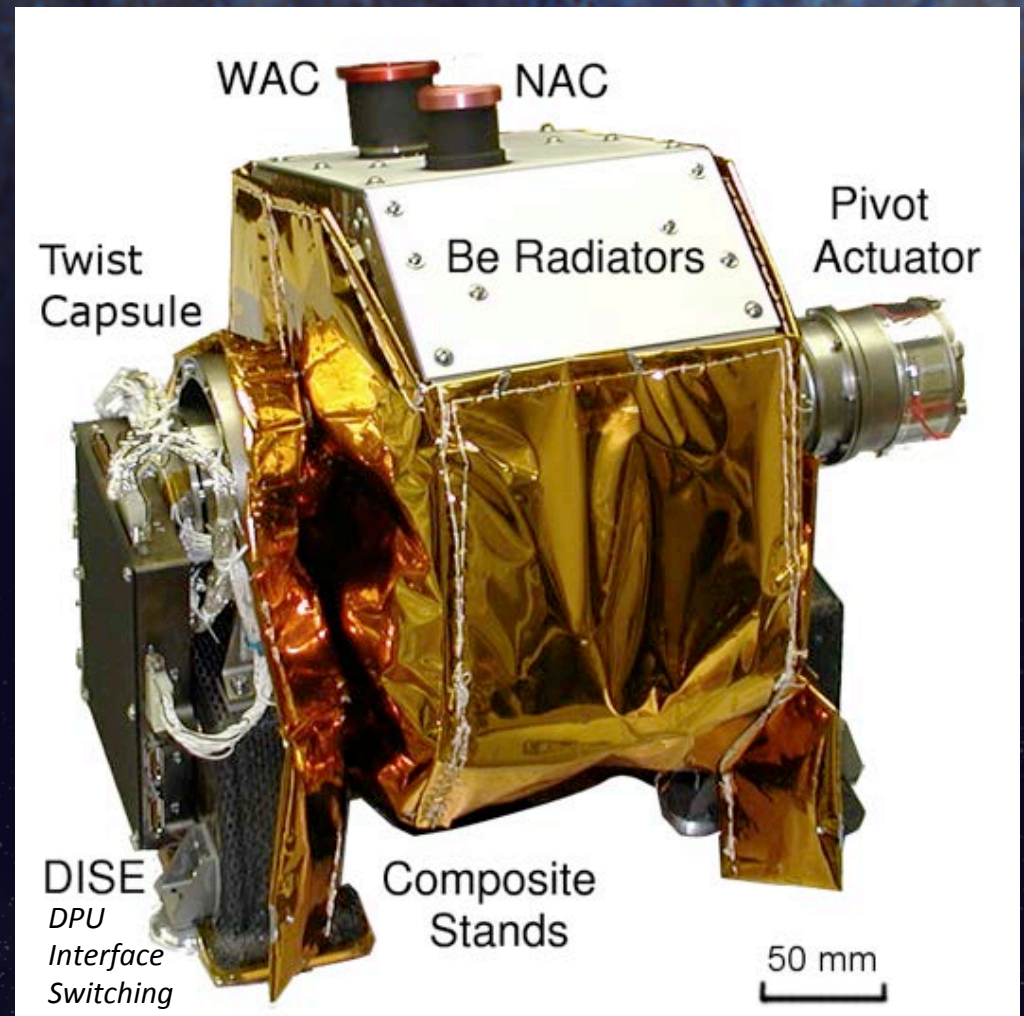
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# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



- MDIS is a dual imaging system with two miniature cameras on a pivot
- Monochrome narrow-angle camera (**NAC**)
- Multispectral wide-angle camera (**WAC**)
- Only one camera operates at a time, allowing them to share a common set of control electronics

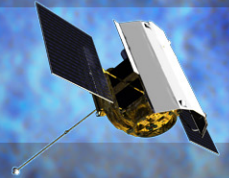




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# MESSENGER

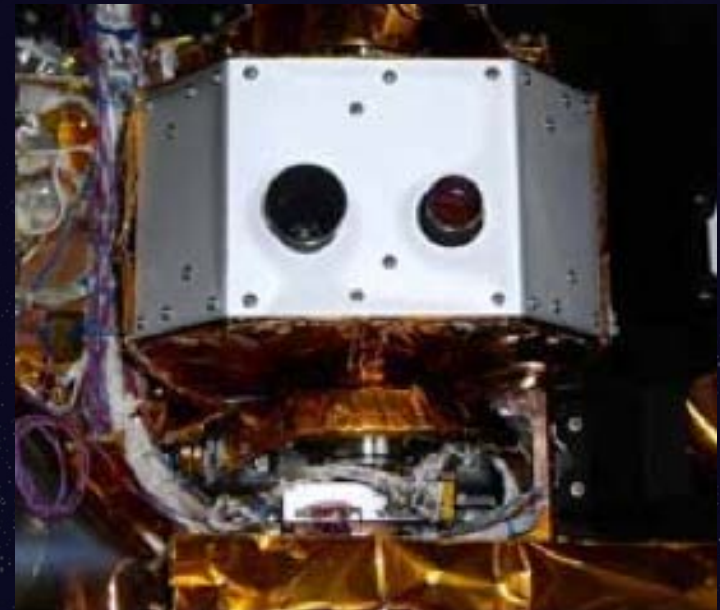
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Narrow-angle Camera (NAC)

MDIS		
	Narrow angle camera	Wide angle camera
Focal length	550 mm	78 mm
Field of view	1.5° x 1.5°	10.5° x 10.5°
Pixel FOV	5 m at 200-km altitude	35 m at 200-km altitude
Spectral range	725 - 775 nm 1 filter	395 - 1,040 nm 11 spectral filters, 1 clear
CCD	1024 x 1024 Atmel (Thomson) TH7888A	
Pivot range	-40° to +50°	

The **NAC** is a 1.5° field-of-view off-axis reflector, with 25  $\mu$ rad/pixel, providing 5 m/pixel from 200 km range

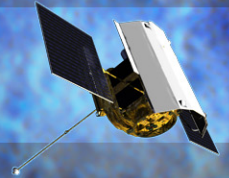




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# MESSENGER

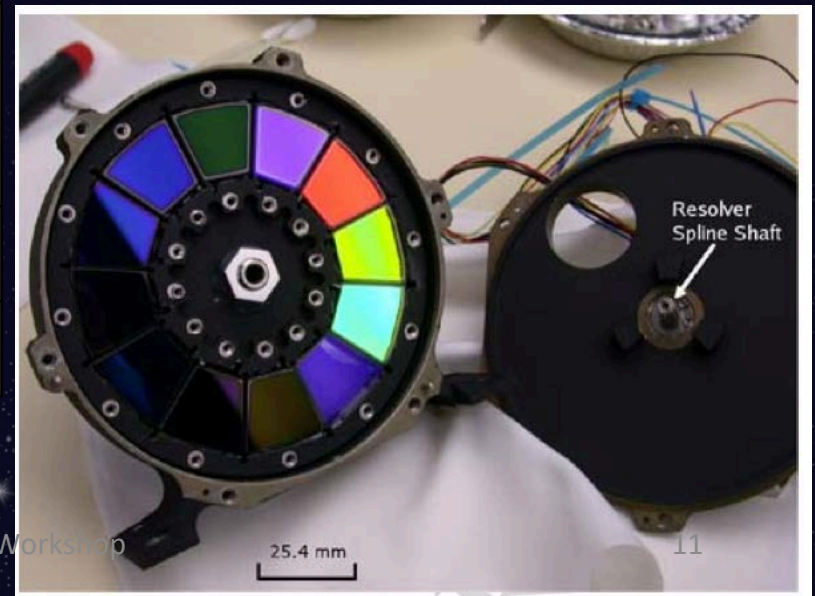
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Wide-angle Camera (WAC)

MDIS		
	Narrow angle camera	Wide angle camera
Focal length	550 mm	78 mm
Field of view	1.5° x 1.5°	10.5° x 10.5°
Pixel FOV	5 m at 200-km altitude	35 m at 200-km altitude
Spectral range	725 - 775 nm 1 filter	395 - 1,040 nm 11 spectral filters, 1 clear
CCD	1024 x 1024 Atmel (Thomson) TH7888A	
Pivot range	-40° to +50°	

The **WAC** is a four-element refractor with a 10.5° field-of-view; a 12-position filter wheel is equipped with 11 narrow-band color filters and 1 clear filter for star imaging

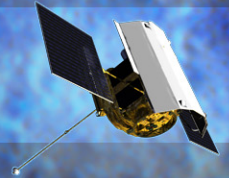




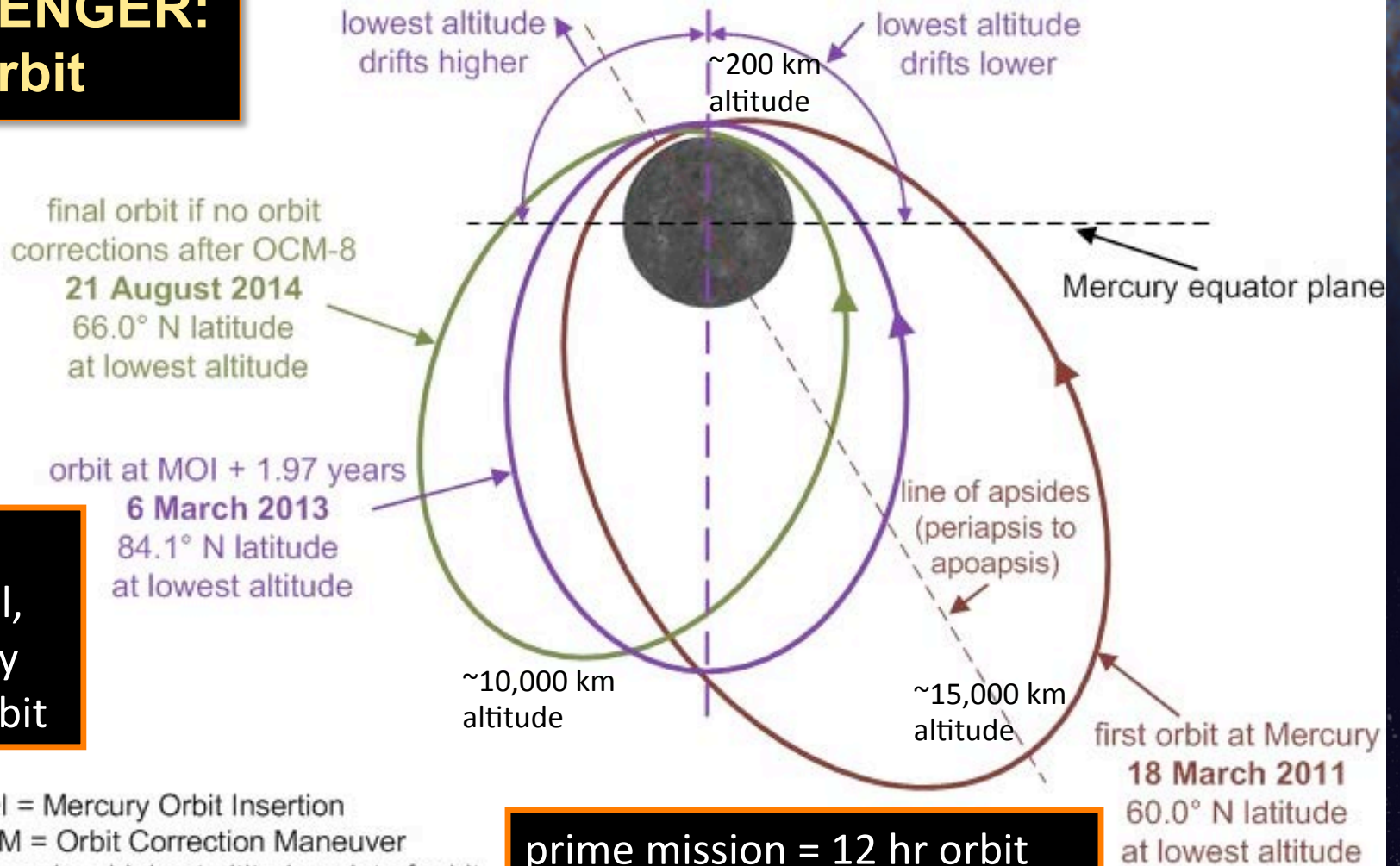
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# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MESSENGER: The Orbit



Highly elliptical, inertially fixed orbit

prime mission = 12 hr orbit  
extended mission = 8 hr orbit

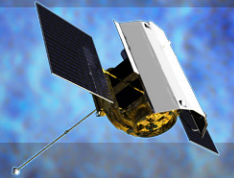
MOI = Mercury Orbit Insertion  
OCM = Orbit Correction Maneuver  
Apoapsis = highest altitude point of orbit  
Periapsis = lowest altitude point of orbit



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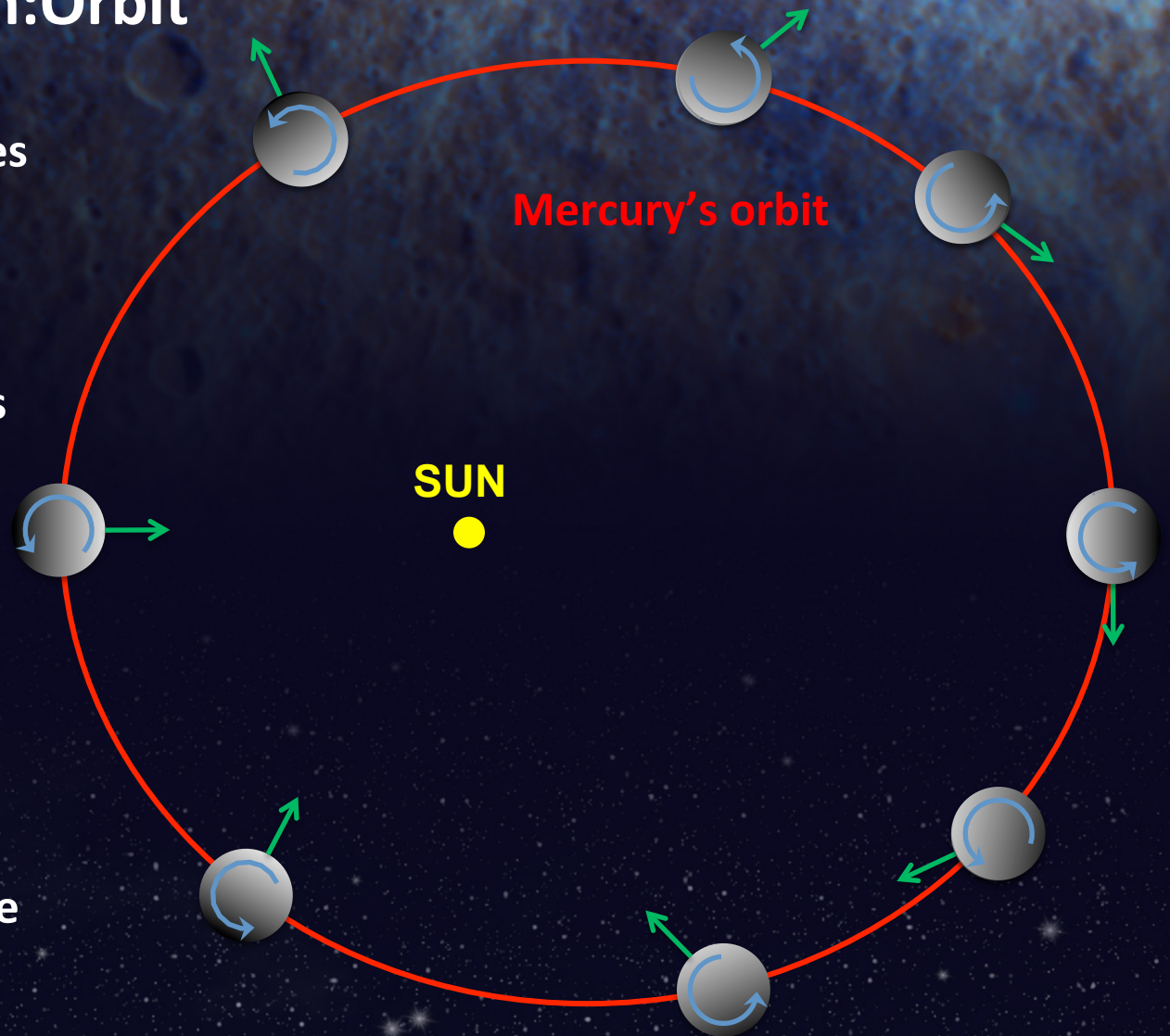
# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## Mercury's 3:2 Spin:Orbit Resonance

- Mercury rotates 1.5 times for each of its orbits around the Sun.
- One **Mercury solar day** (sunrise to sunrise) takes **TWO** orbits around the Sun: 176 Earth days.
- A **one-year mission at Mercury** only has two 'days' to work with for imaging the surface.
- **0° longitude** and **180° longitude** always face the Sun when Mercury is closest to the Sun.

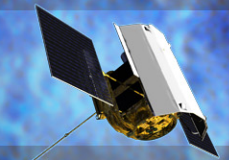




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# MESSENGER

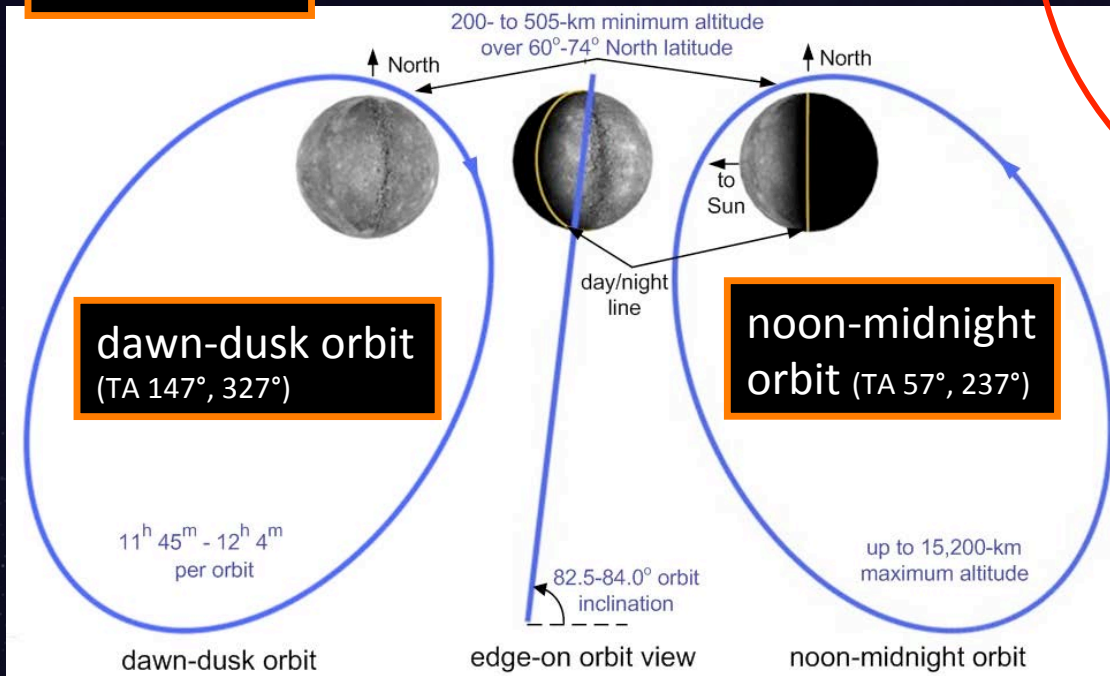
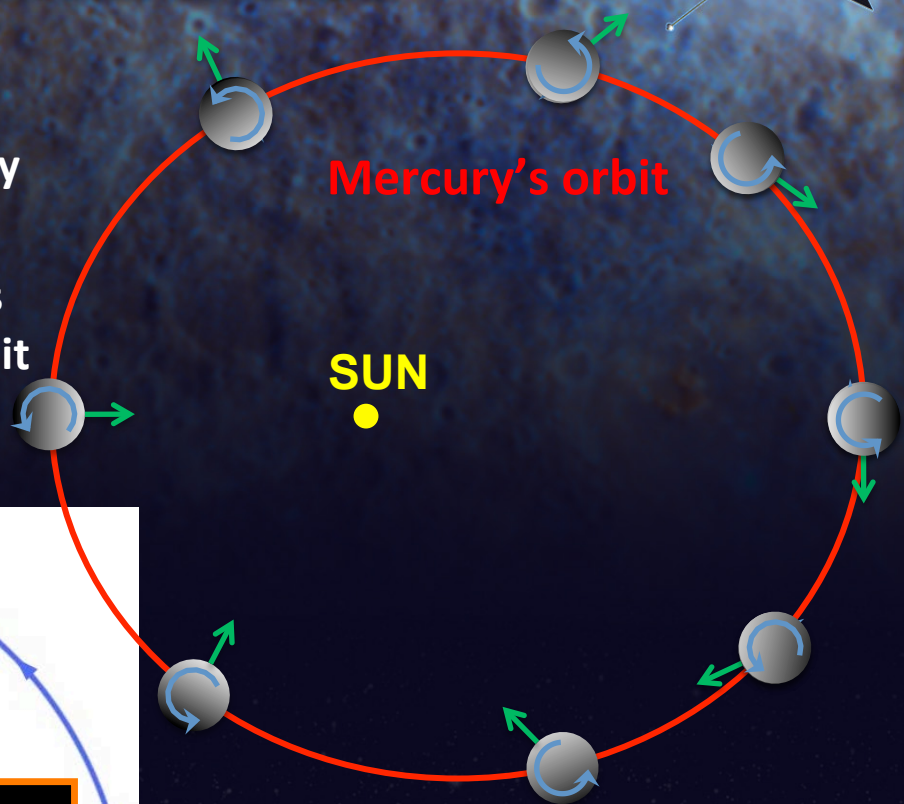
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MESSENGER: The Orbit

Highly elliptical, inertially fixed orbit

- 0° longitude and 180° longitude always face the Sun when Mercury is closest to the Sun.
- MESSENGER is always near a dawn-dusk orbit when closest to the sun.



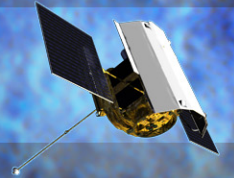
- Different illumination conditions complicate imaging the surface.



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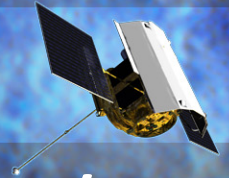
- **MESSENGER's orbit has a large influence on MDIS imaging campaigns because of:**
  - the highly elliptical nature of the spacecraft orbit (close to the north, far from the south)
  - the time of 1 Mercury solar day (176 Earth days)
  - the presence of dawn-dusk vs. noon-midnight orbits



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# MESSENGER

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## MDIS Imaging Campaigns: Primary Mission, 03/11-03/12

- MDIS acquired 88,746 images
- **Three global mapping campaigns**
  - **8-color map**
    - minimizing incidence and emission
    - average ~1 km/pixel
    - majority of images acquired during solar day 1
  - **morphology map**
    - targeting 68° incidence and minimizing emission
    - average ~250 m/pixel
    - acquired with both NAC and WAC
    - majority of images acquired during solar day 1
  - **stereo complement to the morphology map**
    - surface imaged under same illumination conditions on solar day 2
    - targeting a stereo convergent angle of 22°

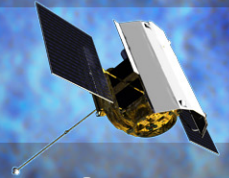




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# MESSENGER

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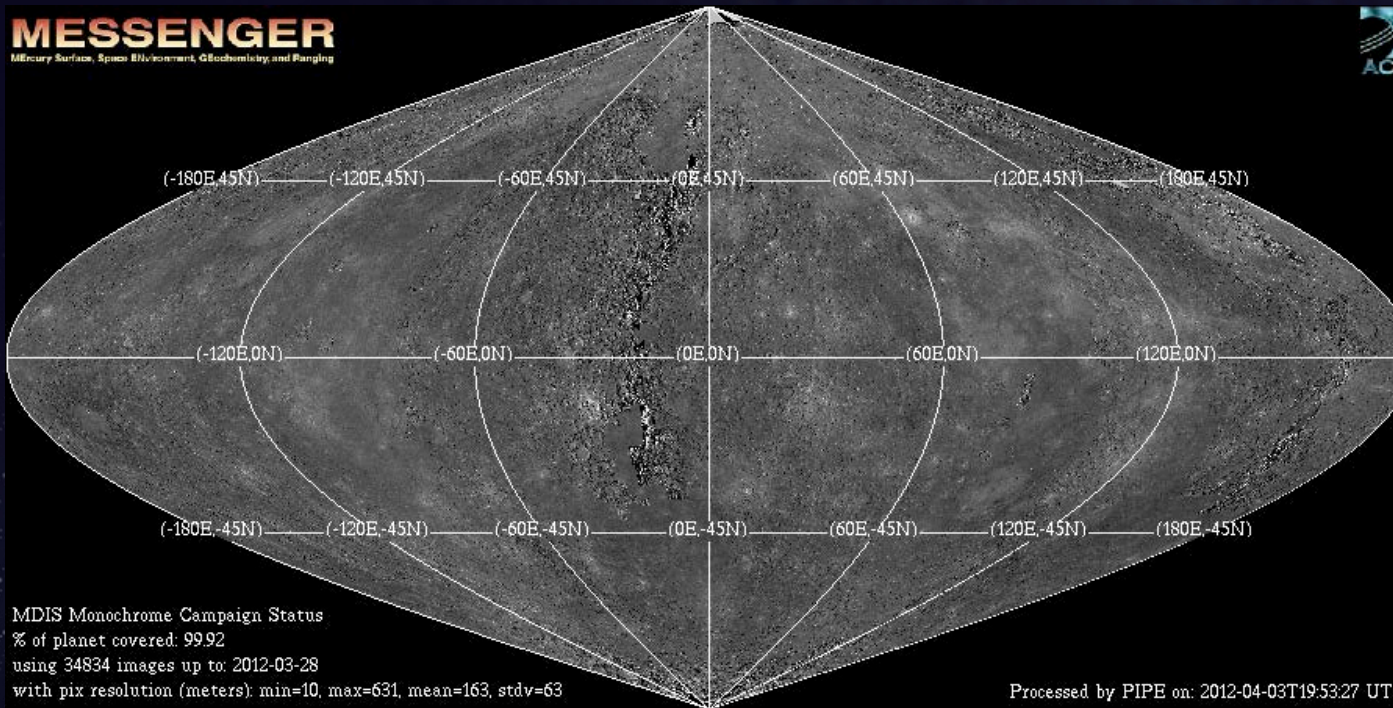
## MDIS Imaging Campaigns: Primary Mission, 03/11-03/12

- morphology map
  - targeting 68° incidence and minimizing emission
  - average ~250 m/pixel
  - acquired with both NAC and WAC
  - majority of images acquired during solar day 1

**MESSENGER**  
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



**>99% coverage**  
**>34,000 images**



MDIS Monochrome Campaign Status  
% of planet covered: 99.92  
using 34834 images up to: 2012-03-28  
with pix resolution (meters): min=10, max=631, mean=163, stdv=63

Processed by PIPE on: 2012-04-03T19:53:27 UTC

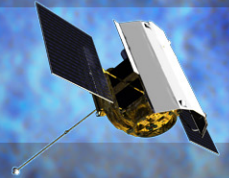
**Advanced product**  
**released by PDS on**  
**March 8, 2013**



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# MESSENGER

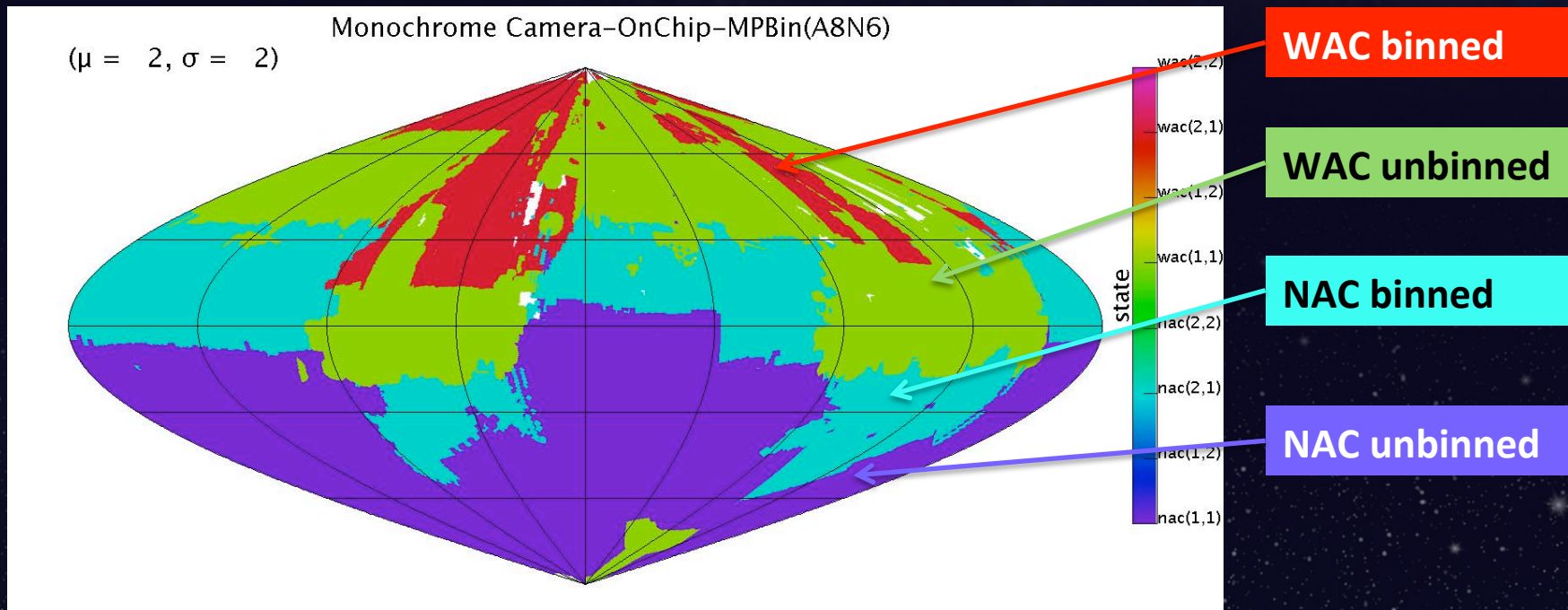
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Imaging Campaigns: Morphology Map

To fit within the data volume limits of the mission while providing global coverage at  $\sim 250$  m/pixel, a number of trade-offs were made:

- Use of NAC in the south and WAC 750-nm filter in the north
- Use of single binning (1024x1024 image  $\rightarrow$  512x512 image)
- Lossy wavelet compression of 4 for most images (some uncompressed, wavelet 0, when possible)

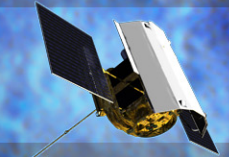




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# MESSENGER

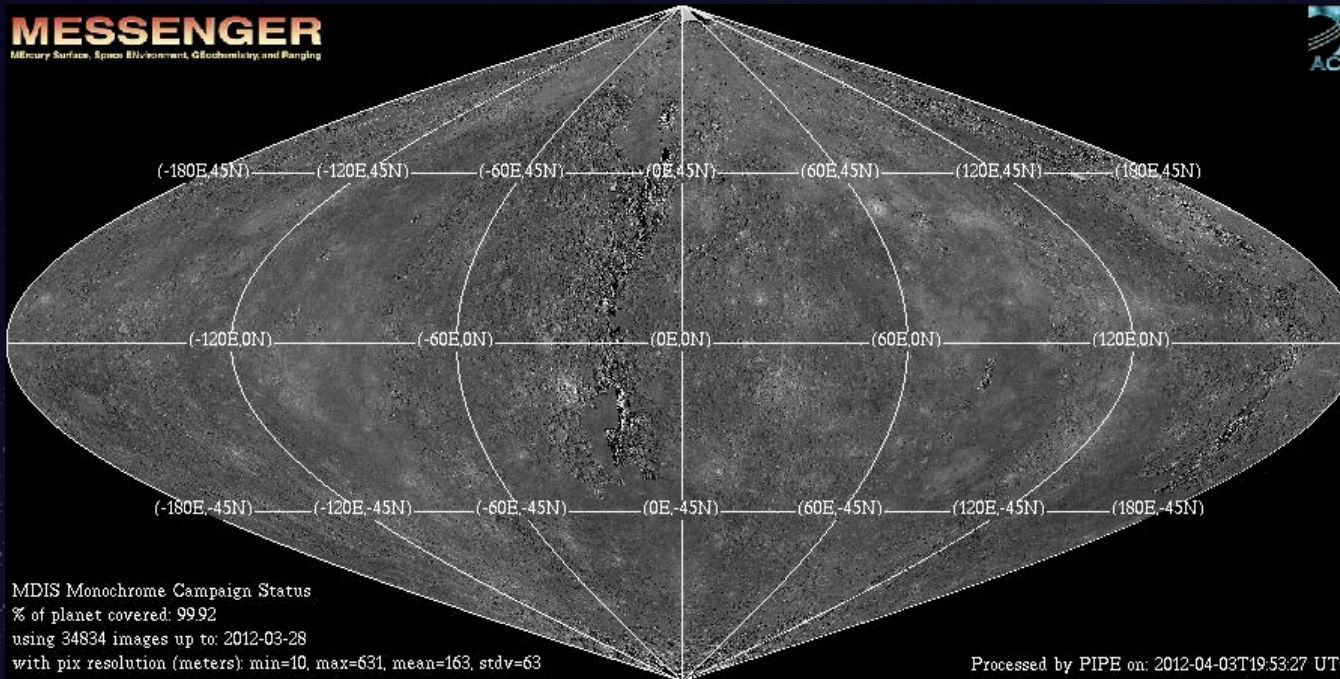
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## MDIS Imaging Campaigns: Morphology Map, PDS product

Images tagged as belonging to the “monochrome” base map campaign used a **stacking order** to favor high spatial resolution, low emission angle, and a solar incidence angle as close as possible to 68°.

- Where  $\text{abs}(lat) \leq 65^\circ$  and  $i \geq 68^\circ$ , the metric is:  $\text{PIXEL\_SCALE} / (\cos e * (\cos(\text{flatten\_factor} * i) / \cos(\text{flatten\_factor} * 68)))$  where  $i$  is solar incidence angle,  $e$  is emission angle,  $lat$  is planetocentric latitude, and  $\text{flatten\_factor}$  is set to 0.85 to de-emphasize low solar incidence angles.
- Where  $\text{abs}(lat) \leq 65^\circ$  and  $i < 68^\circ$ , the metric is:  $\text{PIXEL\_SCALE} / (\cos e * (\cos 68^\circ / \cos i))$
- Where  $\text{abs}(lat) > 65^\circ$ , the metric is:  $\text{PIXEL\_SCALE} / (\cos i * \cos e)$



**>99% coverage  
>34,000 images**

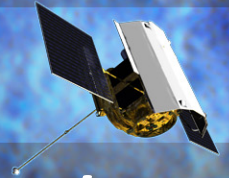
**Advanced product  
released by PDS on  
March 8, 2013**



APL

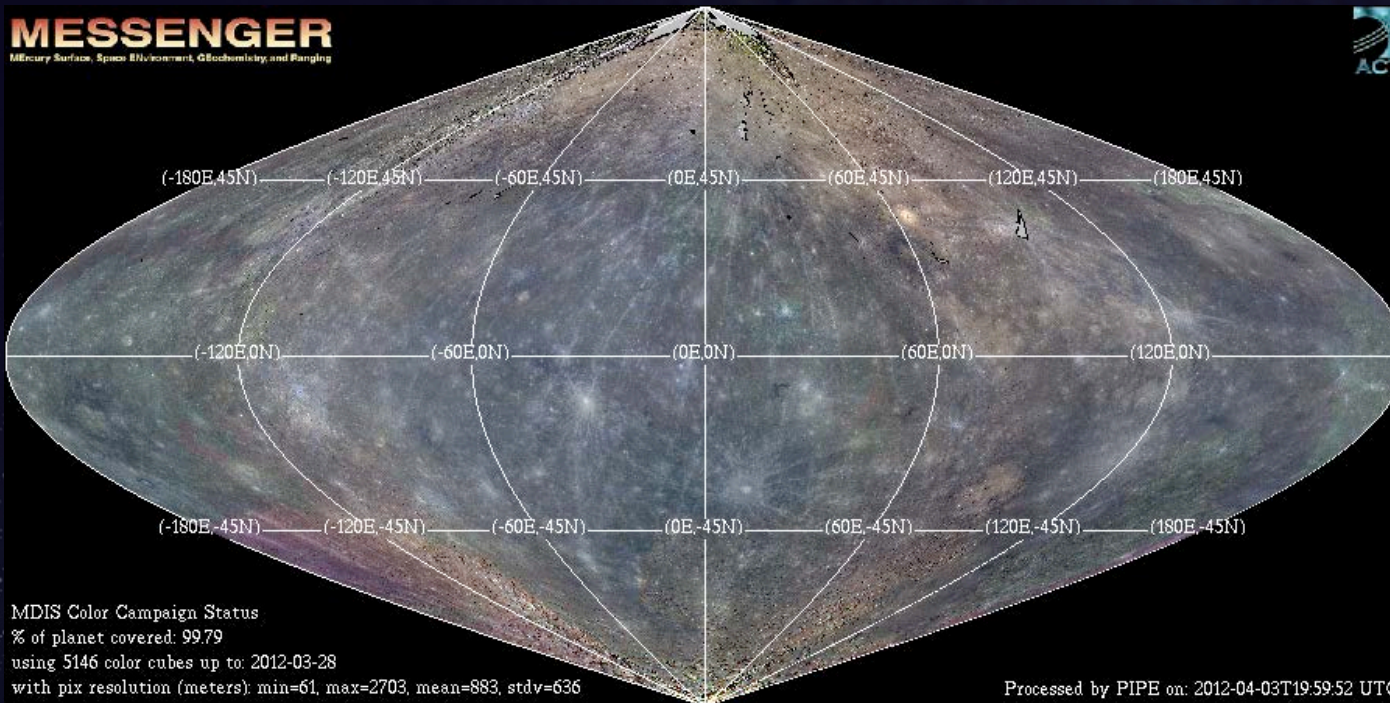
# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Imaging Campaigns: Primary Mission, 03/11-03/12

- 8-color map
  - minimizing incidence and emission
  - average ~1 km/pixel
  - majority of images acquired during solar day 1
  - 430, 480, 560, 630, 750, 830, 900, 1000 nm filters



**>99% coverage**  
**>41,000 images**  
 (>5,000 8-color sets)

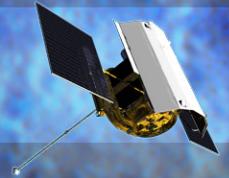
**Advanced product released by PDS on March 8, 2013**



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# MESSENGER

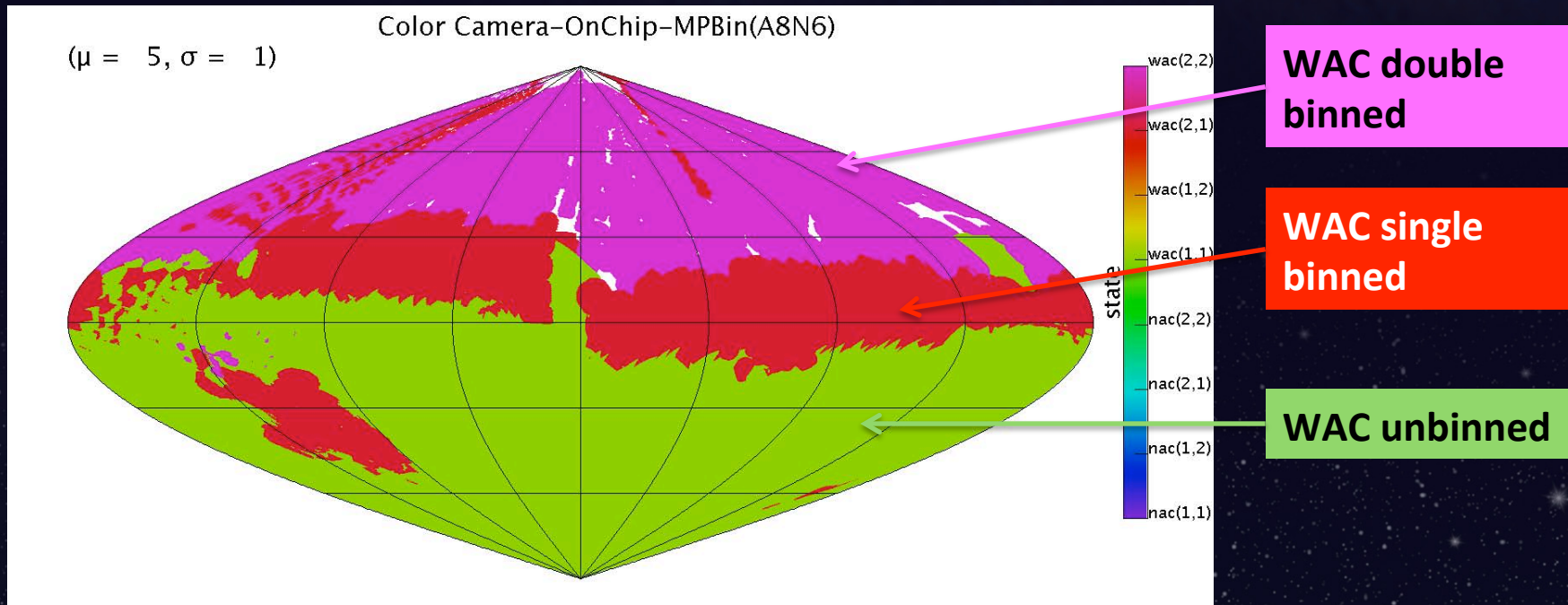
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Imaging Campaigns: 8-Color Map

To fit within the data volume limits of the mission while providing global coverage at  $\sim 1$  km/pixel, a number of trade-offs were made:

- Use of single binning (1024x1024 image  $\rightarrow$  512x512 image)
- Use of double binning (1024x1024  $\rightarrow$  256x256 image)
- Lossy wavelet compression of 3 for most images (some early images at wavelet 4, some uncompressed, wavelet 0, when possible)

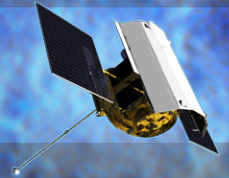




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# MESSENGER

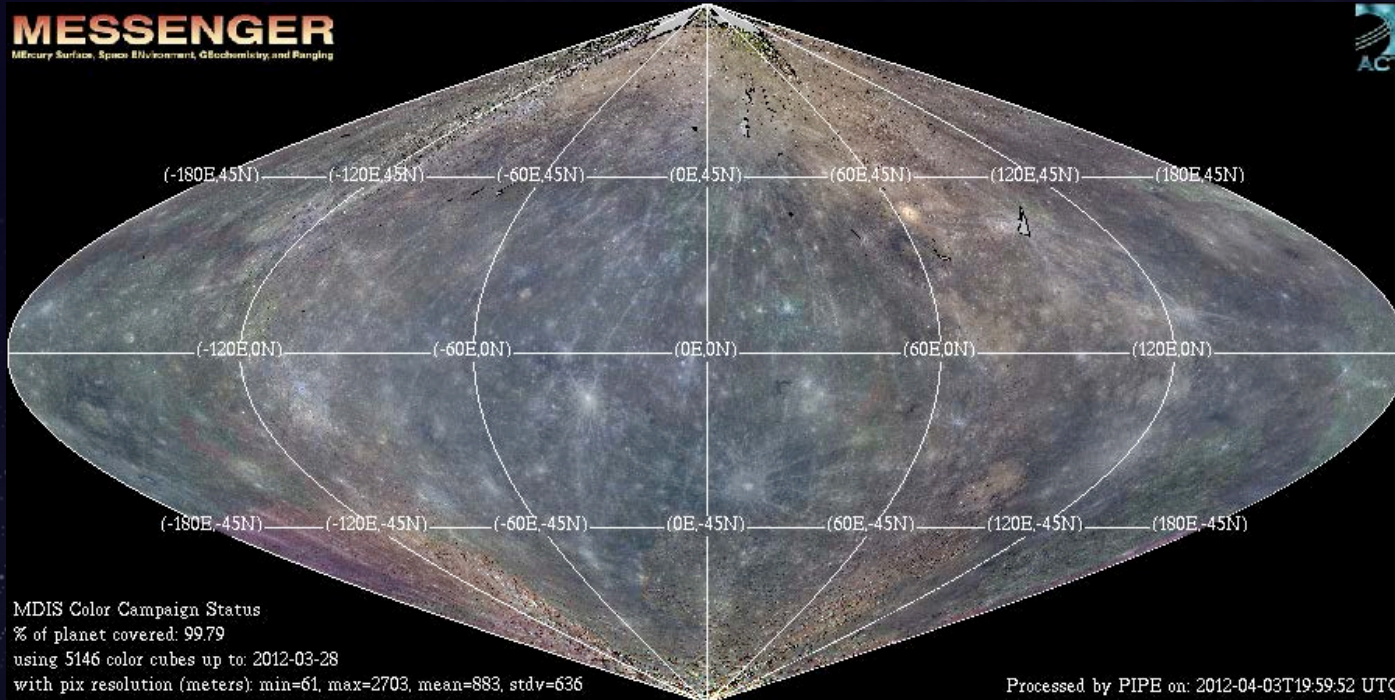
MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Imaging Campaigns: 8-Color Map, PDS product

Images tagged as belonging to the “color” base map campaign used a stacking order to favor high spatial resolution, low emission angle, and low solar incidence angle.

- Stacking order =  $\text{PIXEL\_SCALE} / (\cos i * \cos e)$



**>99% coverage**  
**>41,000 images**  
**(>5,000 8-color sets)**

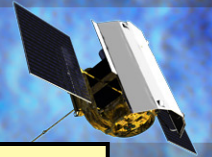
**Advanced product released by PDS on March 8, 2013**



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## MDIS Imaging Campaigns: Primary Mission, 03/11-03/12

- MDIS acquired 88,746 images
- Images in addition to the three global maps:
  - Repeated imaging of the south polar region
  - Images of Mercury's limb
  - Calibrations
    - Regular imaging of star fields
    - Repeated imaging of the same surface for photometric correction effort
  - **High-resolution imaging of targeted areas**

*All primary mission images are in the PDS*

*Floor of Rachmaninoff basin  
100 km across; 150 m/pixel*



*Hollows in Kertesz crater  
15 km across; 30 m/pixel*

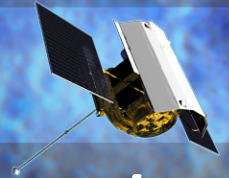




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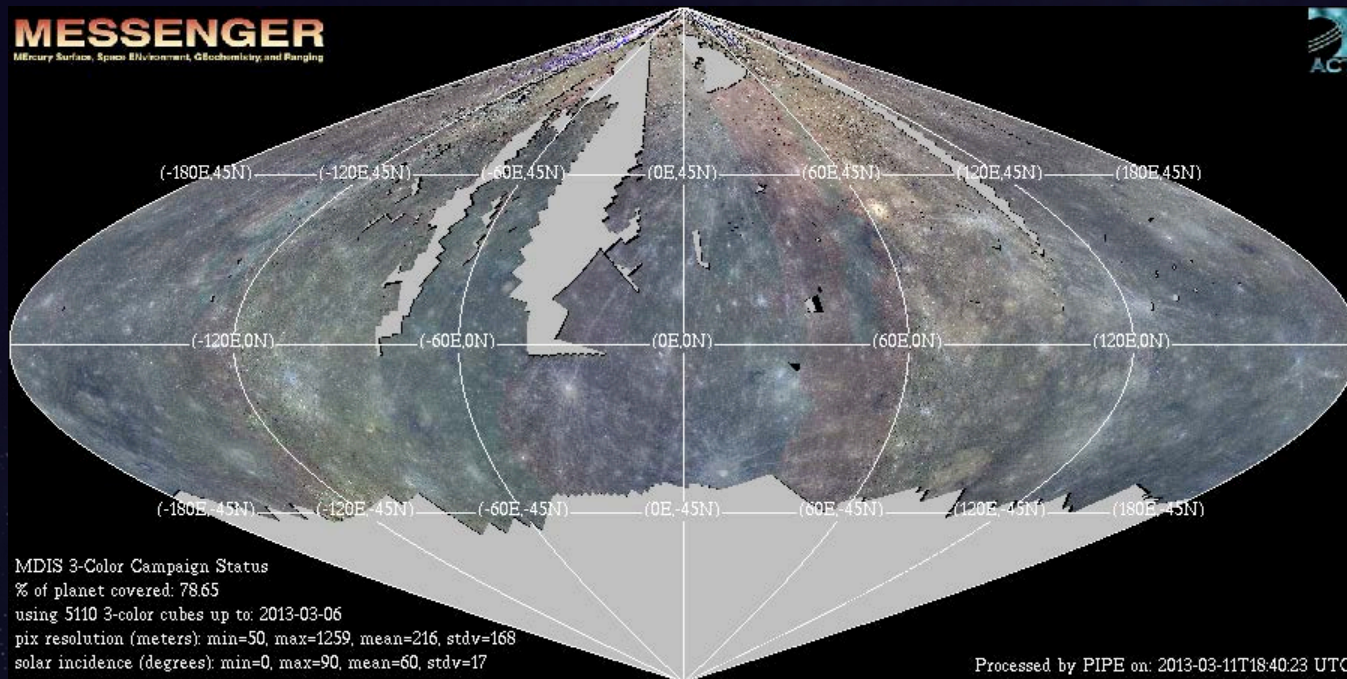
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## MDIS Imaging Campaigns: Extended Mission I, 03/12-03/13

- Four new major mapping campaigns
  - 3-color northern hemisphere map
    - minimizing incidence and emission
    - ~100-400 m/pixel in northern hemisphere
    - 430, 750, 1000 nm filters



Most images in the PDS as of March 8, 2013; advanced product planned for release in March 2014

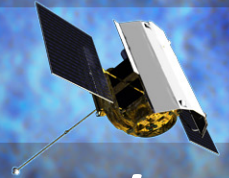




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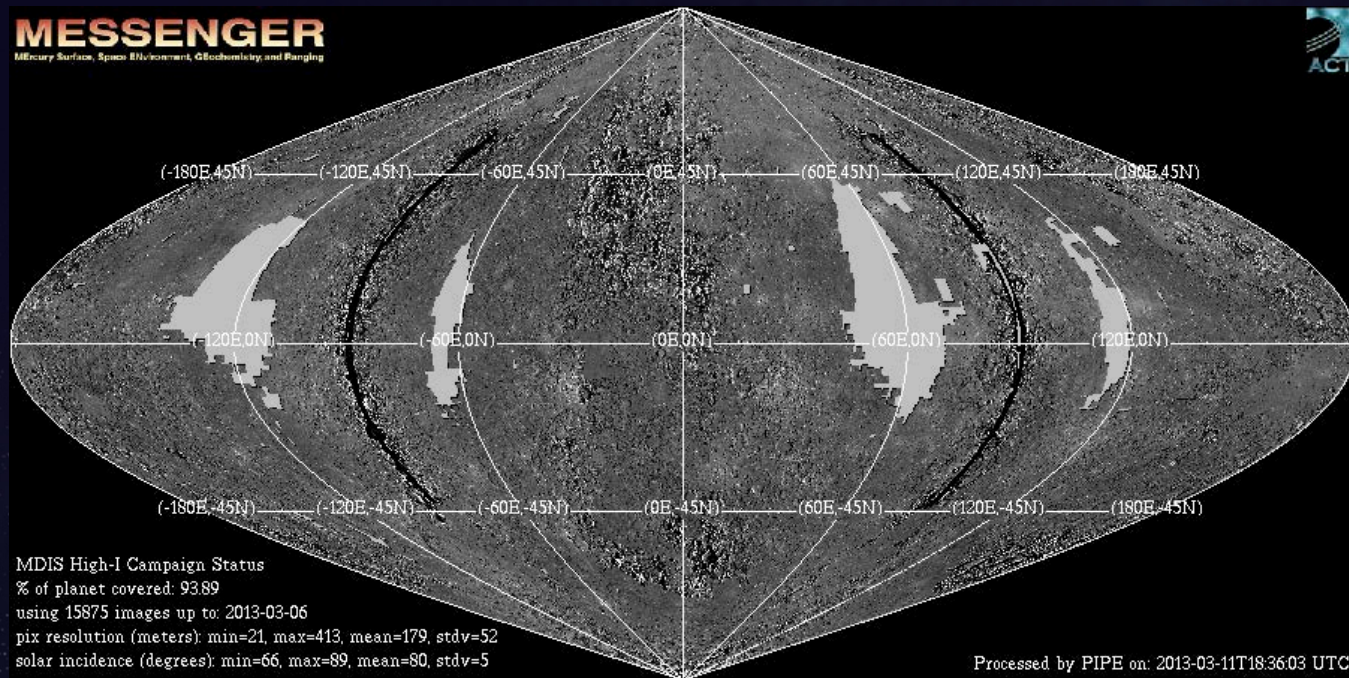
# MESSENGER

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## MDIS Imaging Campaigns: Extended Mission I, 03/12-03/13

- Four new major mapping campaigns
  - High-incidence map
    - incidence targeting  $\sim 80^\circ$  and minimizing emission
    - 250 m/pixel
    - acquired with both NAC and WAC



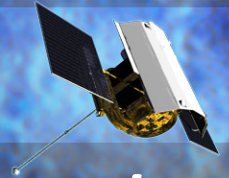
Most images in the PDS as of March 8, 2013; advanced product proposed for release in March 2015, **dependent on Extended Mission II funding decision**



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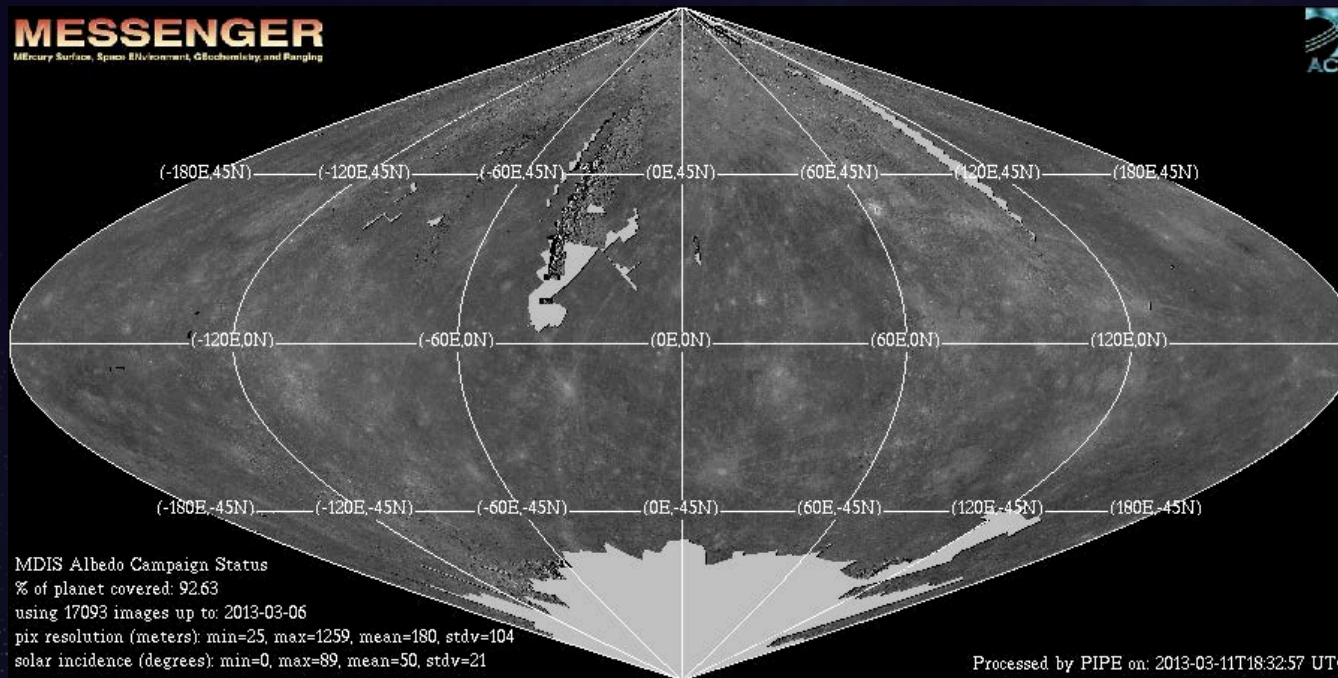
# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Imaging Campaigns: Extended Mission I, 03/12-03/13

- Four new major mapping campaigns
  - Albedo map
    - minimizing incidence and emission
    - 250 m/pixel
    - acquired with both NAC and WAC; also has stereo complement map



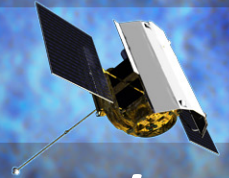
Most images in the PDS as of March 8, 2013; advanced product proposed for release in March 2015, **dependent on Extended Mission II funding decision**



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# MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



## MDIS Imaging Campaigns: Extended Mission I, 03/12-03/13

- In addition to the four new major mapping campaigns:
  - Continuation of high-resolution targets, limb imaging, calibrations
  - Repeated imaging of the north polar region
  - Campaigns to search for vulcanoids or satellites
  - Exploratory imaging of permanently shadowed regions

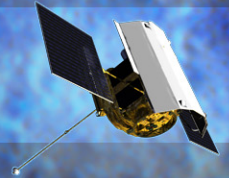
All images through September 17, 2012, are in the PDS as of March 8, 2013.



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## MDIS Imaging Campaigns:

**Extended Mission II, 03/13- end of mission (up to 03/15)**

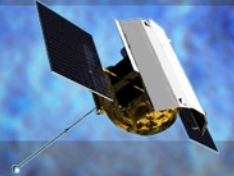
- *Future operations are dependent on the MESSENGER Extended Mission II proposal currently being reviewed by NASA*
- **New proposed MDIS observations include:**
  - Minimum phase 5-color map of the northern region
  - High-resolution stereo and east-west illuminated targets
  - 11-color targets
  - Campaign to image inside permanently shadowed areas
- **Low altitude (<350 km) imaging opportunities are present starting Nov. 2013 through March 2015**
  - Resolutions to  $\sim 2$  m/pixel can potentially be acquired



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## Agenda

**1. Overview of the mission, instrument, and imaging campaigns** (~15 min.)

Nancy Chabot, Johns Hopkins University Applied Physics Lab

**2. MDIS calibrations** (~30 min)

Brett Denevi, Johns Hopkins University Applied Physics Lab

**3. Accessing and searching for MDIS data in the PDS** (~20 min)

Lisa Gaddis, United States Geological Survey

**4. MDIS data in QuickMap** (~20 min)

Erick Malaret, Applied Coherent Technology Corporation

----- Break ----- (~15 min)

**5. Using MDIS data in ISIS** (~2 hrs)

Kris Becker, Tammy Becker, and Trent Hare, United States Geological Survey