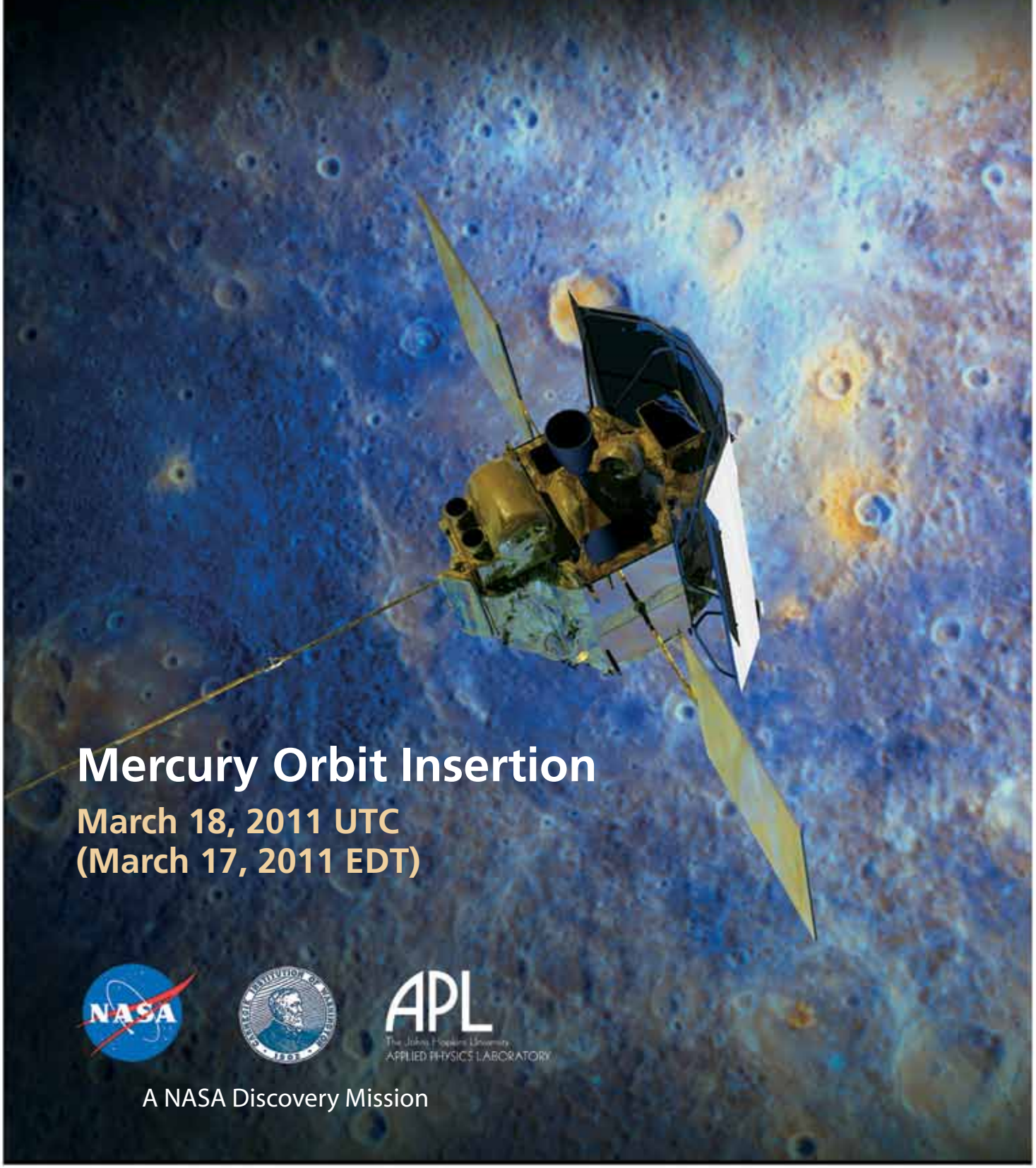
MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging



Mercury Orbit Insertion

March 18, 2011 UTC
(March 17, 2011 EDT)

The Johns Hopkins University
APPLIED PHYSICS LABORATORY

A NASA Discovery Mission

MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging

Mission Overview

MESSENGER is a scientific investigation of the planet Mercury. Understanding Mercury, and the forces that have shaped it, is fundamental to understanding the terrestrial planets and their evolution.

The MESSENGER (MErcury Surface, Space ENvironment, GEochemistry, and Ranging) spacecraft will orbit Mercury following three flybys of that planet. The orbital phase will use the flyby data as an initial guide to perform a focused scientific investigation of this enigmatic world.

MESSENGER will investigate key scientific questions regarding Mercury's characteristics and environment during these two complementary mission phases. Data are provided by an optimized set of miniaturized space instruments and the spacecraft telecommunications system.

MESSENGER will enter orbit about Mercury in March 2011 and carry out comprehensive measurements for one Earth year. Orbital data collection concludes in March 2012.

Key Spacecraft Characteristics

- Redundant major systems provide critical backup.
- Passive thermal design utilizing ceramic-cloth sunshade requires no high-temperature electronics.
- Fixed phased-array antennas replace a deployable high-gain antenna.
- Custom solar arrays produce power at safe operating temperatures near Mercury.

MESSENGER is designed to answer six broad scientific questions:

- Why is Mercury so dense?
- What is the geologic history of Mercury?
- What is the nature of Mercury's magnetic field?
- What is the structure of Mercury's core?
- What are the unusual materials at Mercury's poles?
- What volatiles are important at Mercury?

MESSENGER provides:

- Multiple flybys for global mapping, detailed study of high-priority targets, and probing of the atmosphere and magnetosphere.
- An orbiter for detailed characterization of the surface, interior, atmosphere, and magnetosphere.
- An education and public outreach program to produce exhibits, plain-language books, educational modules, and teacher training through partnerships.

Mission Summary

Launch:	3 August 2004
Launch vehicle:	Delta II 7925H-9.5
Earth flyby:	2 August 2005
Venus flybys (2):	24 October 2006, 5 June 2007
Mercury flybys (3):	14 January 2008, 6 October 2008, 29 September 2009
Mercury orbit insertion:	17 March 2011 (EDT) 18 March 2001 (UTC)

MESSENGER — Mercury, the Last Frontier of the Terrestrial Planets

Understanding Mercury is fundamental to understanding terrestrial planet evolution.

Discoveries from MESSENGER's Mercury Flybys:

In addition to providing key gravity assists that enable orbit insertion as well as opportunities to test scientific operations and command sequences for all payload instruments, MESSENGER's three flybys of Mercury yielded a number of discoveries that have markedly changed our view of Mercury and influenced our preparations for orbital operations. These include:

Geology

- Volcanism was widespread on Mercury and extended from before the end of heavy bombardment to the second half of solar system history.
- Mercury experienced explosive volcanism, indicating that interior volatile contents were at least locally much higher than thought.
- Contraction spanned much of Mercury's geologic history.

Composition and surface-derived exosphere

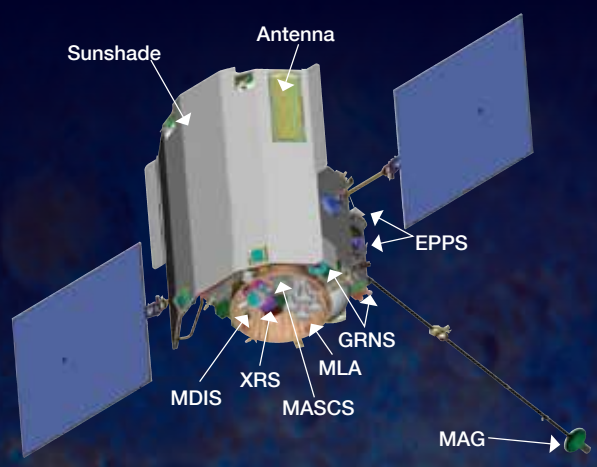
- Mercury's surface silicates, even in fresh crater ejecta, contain little or no ferrous oxide.
- Mercury's thermal neutron flux matches that of several lunar maria, indicating that iron and titanium are present in comparable collective abundances, perhaps as oxides.
- Magnesium and ionized calcium are present in Mercury's exosphere.

Internal structure and dynamics

- The equatorial topographic relief of Mercury, in agreement with earlier radar results, is at least 5.5 km.
- The case for a liquid outer core in Mercury is greatly strengthened.
- Mercury's internal magnetic field is dominantly dipolar with a vector moment closely aligned with the spin axis.

Magnetospheric dynamics

- Mercury's magnetosphere is more responsive to interplanetary magnetic field (IMF) fluctuations than those of other planets.
- Under southward IMF, rates of magnetic reconnection are ~10 times that typical at Earth.
- Loading of magnetic flux in Mercury's magnetic tail can be so intense that much of Mercury's dayside could be exposed to the shocked solar wind of the magnetosheath during such episodes.



Science Payload

Mercury Dual Imaging System (MDIS) takes detailed color and monochrome images of Mercury's surface.

Gamma-Ray and Neutron Spectrometer (GRNS) measures surface elements (including polar materials).

X-Ray Spectrometer (XRS) maps elements in Mercury's crust.

Magnetometer (MAG) maps Mercury's magnetic field.

Mercury Atmospheric and Surface Composition Spectrometer (MASCS) measures atmospheric species and surface minerals.

Energetic Particle and Plasma Spectrometer (EPPS) measures charged particles in Mercury's magnetosphere.

Mercury Laser Altimeter (MLA) measures topography of surface features; determines whether Mercury has a fluid core.

Radio Science uses Doppler tracking to determine Mercury's mass distribution.

Mission Management

Principal Investigator:	Sean C. Solomon, Carnegie Institution of Washington	**Instruments:**	JHU/APL, NASA Goddard Space Flight Center, University of Colorado, University of Michigan
Project Management:	The Johns Hopkins University Applied Physics Laboratory (JHU/APL)	**Structure:**	Composite Optics, Inc.
Spacecraft Integration and Operation:	JHU/APL	**Propulsion:**	GenCorp Aerojet
		Navigation:	KinetX, Inc.

On the Web

MESSENGER mission: http://messenger.jhuapl.edu

NASA Discovery Program: http://discovery.nasa.gov

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MESSENGER Quick Facts

Spacecraft

Size: Main spacecraft body is 1.44 meters (57 inches) tall, 1.28 meters (50 inches) wide, and 1.85 meters (73 inches) deep; a front-mounted ceramic-fabric sunshade is 2.54 meters tall and 1.82 meters across (100 inches by 72 inches); two rotatable solar panel "wings" extend about 6.14 meters (20 feet) from end to end across the spacecraft.

Launch weight: Approximately 1,107 kilograms (2,441 pounds), including 599.4 kilograms (1,321 pounds) of propellant and 507.6 kilograms (1,119 pounds) of "dry" spacecraft and instruments.

Power: Two body-mounted gallium arsenide solar panels and one nickel-hydrogen battery. The power system generated about 490 watts near Earth and will generate its maximum possible output of 720 watts in Mercury orbit.

Propulsion: Dual-mode system with one bipropellant (hydrazine and nitrogen tetroxide) thruster for large maneuvers; 4 medium-sized and 12 small hydrazine monopropellant thrusters for small trajectory adjustments and attitude control.

Science investigations: Mercury Dual Imaging System (MDIS), with wide-angle color and narrow-angle monochrome imagers; the Gamma-Ray and Neutron Spectrometer (GRNS); the X-Ray Spectrometer (XRS); the Magnetometer (MAG); the Mercury Laser Altimeter (MLA); the Mercury Atmospheric and Surface Composition Spectrometer (MASCS); the Energetic Particle and Plasma Spectrometer (EPPS); and the radio science experiment.

Mission

Launch: August 3, 2004, from Pad B of Space Launch Complex 17 at Cape Canaveral Air Force Station, Fla., at 2:15:56 a.m. EDT aboard a three-stage Boeing Delta II rocket (Delta II 7925H-9.5).

Gravity assist flybys: Earth (1) August 2005; Venus (2) October 2006, June 2007; Mercury (3) January 2008, October 2008, September 2009.

Enter Mercury orbit: March 18, 2011 UTC (March 17, 2011 EDT).

Total distance traveled from Earth to Mercury orbit: 7.9 billion kilometers (4.9 billion miles). Spacecraft circles the Sun 15.2 times from launch to Mercury orbit insertion.

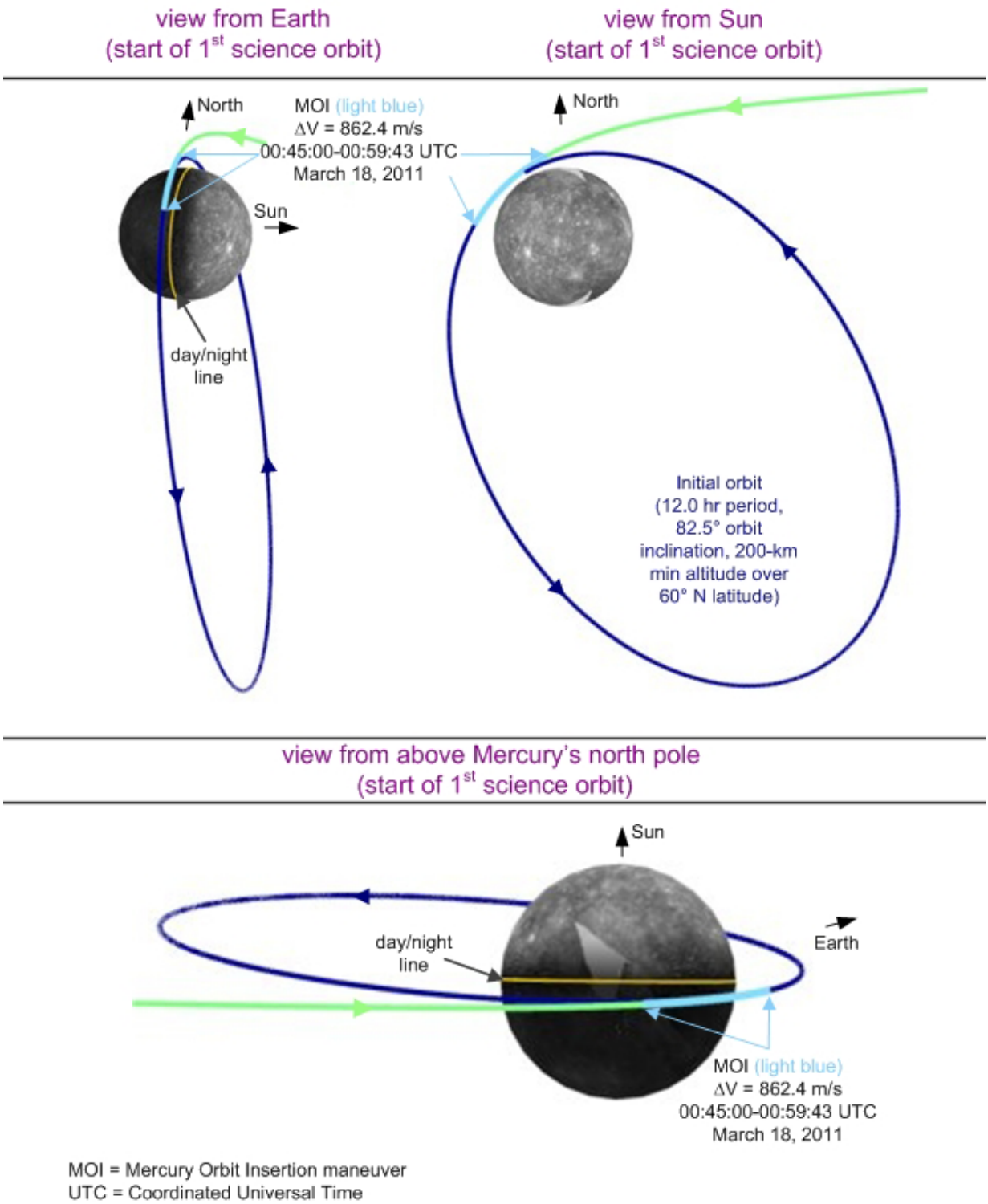
Primary mission at Mercury: Orbit for one Earth year (equivalent to just over four Mercury years, or two Mercury solar days), collecting data on the composition and structure of Mercury's crust, its topography and geologic history, the nature of its thin atmosphere and active magnetosphere, and the makeup of its core and polar materials.

Program

Cost: Approximately $446 million (including spacecraft and instrument development, launch vehicle, mission operations, and data analysis).

Ground Receipt Time*		Spacecraft Time		Event
Eastern Daylight Time (EDT)		Coordinated Universal Time (UTC) {DOY-hh:mm}	Time Relative to Burn Start {hh:mm}	
Tuesday March 15	8:54 p.m.	75-00:45	48:00	Start initial pre-burn propulsion system configuration
Wednesday March 16	11:40 a.m.	75-15:31	33:14	Start critical Deep Space Network coverage (two stations, one primary and one backup)
	8:54 p.m.	76-00:45	24:00	Spacecraft commanded to pre-critical burn configuration
Thursday March 17	5:00 p.m.	76-20:51	03:54	Start configuration for DSN burn coverage (four stations arrayed together)
	6:30 p.m.	76-22:21	02:24	Finish configuration for DSN burn coverage (backup 70-m antenna)
	7:45 p.m.	76-23:37	01:09	Start final pre-burn propulsion system configuration
	8:09 p.m.	77-00:00	00:45	Start RF configuration for burn execution
	8:21 p.m.	77-00:12	00:33	Complete RF configuration for burn execution
	8:24 p.m.	77-00:15	00:30	Turn spacecraft to burn attitude and configure attitude control for burn execution
	8:34 p.m.	77-00:25	00:20	Configure solar arrays for burn execution
	8:49 p.m.	77-00:40	00:05	Configure spacecraft fault protection for burn execution
	8:54 p.m.	**77-00:45**	**00:00**	**Mercury orbit insertion (MOI) engine ignition**
	9:09 p.m.	**77-01:00**	**00:15**	**Engine shutdown**
	9:21 p.m.	77-01:12	00:27	Turn spacecraft to Earth and acquire post-maneuver data
	9:32 p.m.	77-01:23	00:38	Re-configure spacecraft systems for normal post-maneuver operations
	10:25 p.m.	77-02:16	01:31	End DSN burn coverage (back to critical coverage with 2 stations)
Friday March 18	2:56 a.m.	77-06:47	06:02	First orbital apoapse passage (start orbit #1)
	12:40 p.m.	77-16:31	15:46	End DSN critical coverage (back to 1 station continuous coverage)
	2:57 p.m.	77-18:48	18:03	Second orbital apoapse passage (start orbit #2)
Monday March 21	12:56 p.m.	80-16:48		Orbital commissioning period begins (spacecraft checkout)
Tuesday March 22				Start Gamma-Ray Spectrometer (GRS) cooler
Wednesday March 23				Turn on all instruments and configure for operations (except imagers)
Monday March 28	3:51 p.m.	087-19:45		Continue orbital commissioning period (Instrument checkout — imagers turned on)
Monday April 4	4:20 p.m.	094-20:15		Mercury science observations begin

*Ground Receipt Time adjusted for one-way light time, which gradually decreases through the reporting period.
-- Events without specific execution times are initiated by direct commands from the ground.



Three views of MESSENGER's insertion into orbit about Mercury are shown above; they include a view from the direction of Earth, a view from the direction of the Sun, and a view from over Mercury's north pole looking down toward the planet. Time is given in Coordinated Universal Time (UTC). The 15-minute orbital insertion maneuver is shown in light blue in the figures and places the spacecraft into the primary science orbit, which is shown in dark blue. The bright areas near the poles indicate portions of the surface not imaged by either Mariner 10 or MESSENGER during their respective flybys.

Mercury at a Glance

General

- One of five planets known to ancient astronomers; in Roman mythology Mercury was the fleet-footed messenger of the gods, a fitting name for a planet that moves quickly across the sky.
- The closest planet to the Sun, Mercury is also the smallest planet in the Solar System.
- Prior to January 2008, Mercury had been visited by only one spacecraft; NASA's Mariner 10 viewed less than half the surface (~45%) in detail during its three flybys in 1974 and 1975.

Physical characteristics

- Mercury's diameter is 4,880 kilometers (3,032 miles), about one-third the size of Earth and only slightly larger than our Moon.
- The densest planet in the Solar System (when corrected for compression), Mercury's density is 5.3 times greater than that of water.
- The largest known feature on Mercury's pockmarked surface is the Caloris basin (1,550 kilometers or 960 miles in diameter — see http://messenger.jhuapl.edu/gallery/sciencePhotos/image.php?page=&gallery_id=2&image_id=149), likely created by an ancient asteroid impact.
- Mercury's surface is a combination of craters, smooth plains, and long, winding cliffs.
- There is possibly water ice on the permanently shadowed floors of craters in Mercury's polar regions.
- An enormous iron core takes up at least 60% of the planet's total mass — twice as large a fraction as Earth's.

Environment

- Mercury experiences the Solar System's largest swing in surface temperatures, from highs above 700 Kelvin (about 800° Fahrenheit) to lows near 90 Kelvin (about –300° Fahrenheit).
- Mercury's extremely thin atmosphere contains hydrogen, helium, oxygen, sodium, potassium, calcium, and magnesium.
- The only inner planet besides Earth with a global magnetic field, Mercury's field is about 100 times weaker than Earth's (at the surface).

Orbit

- Mercury's average distance from the Sun is 58 million kilometers (36 million miles), about two-thirds closer to the Sun than Earth is.
- The highly elliptical (elongated) orbit ranges from 46 million kilometers (29 million miles) to 70 million kilometers (43 million miles) from the Sun.
- Mercury orbits the Sun once every 88 Earth days, moving at an average speed of 48 kilometers (30 miles) per second and making it the "fastest" planet in the Solar System.
- Because of its slow rotation — Mercury rotates on its axis once every 59 Earth days — and fast speed around the Sun, one solar day on Mercury (from noon to noon at the same place) lasts 176 Earth days, or two Mercury years.
- Mercury's distance from Earth (during MESSENGER's orbit) ranges from about 87 million to 212 million kilometers, about 54 million to 132 million miles.

The Spacecraft

After Mariner 10's visits to Mercury, the space science and engineering communities yearned for a longer and more detailed look at the innermost planet — but that closer look, ideally from orbit, presented formidable technical obstacles. A Mercury orbiter would have to be tough, with enough protection to withstand searing sunlight and roasting heat bouncing back from the planet below. The spacecraft would need to be lightweight, since most of its mass would be fuel to fire its rockets to slow the spacecraft down enough to be captured by Mercury's gravity. And the probe would have to be sufficiently compact to be launched on a conventional and cost-effective rocket.

Designed and built by the Johns Hopkins University Applied Physics Laboratory (APL) — with contributions from research institutions and companies around the world — the MESSENGER spacecraft tackles each of these challenges. A ceramic-fabric sunshade, heat radiators, and a mission design that limits time over the planet's hottest regions protect MESSENGER without expensive and impractical cooling systems. The spacecraft's graphite composite structure — strong, lightweight, and heat tolerant — is integrated with a low-mass propulsion system that efficiently stores and distributes the approximately 600 kg of propellant that accounts for 54% of the total launch weight.

To fit behind the 2.5-m by 2-m sunshade, the wiring, electronics, systems, and instruments are packed into a small frame that could fit inside a large sport utility vehicle. And the entire spacecraft is light enough to launch on a Delta II 7925H-9.5 ("heavy") rocket, the largest launch vehicle allowed under NASA's Discovery Program of lower-cost space science missions.

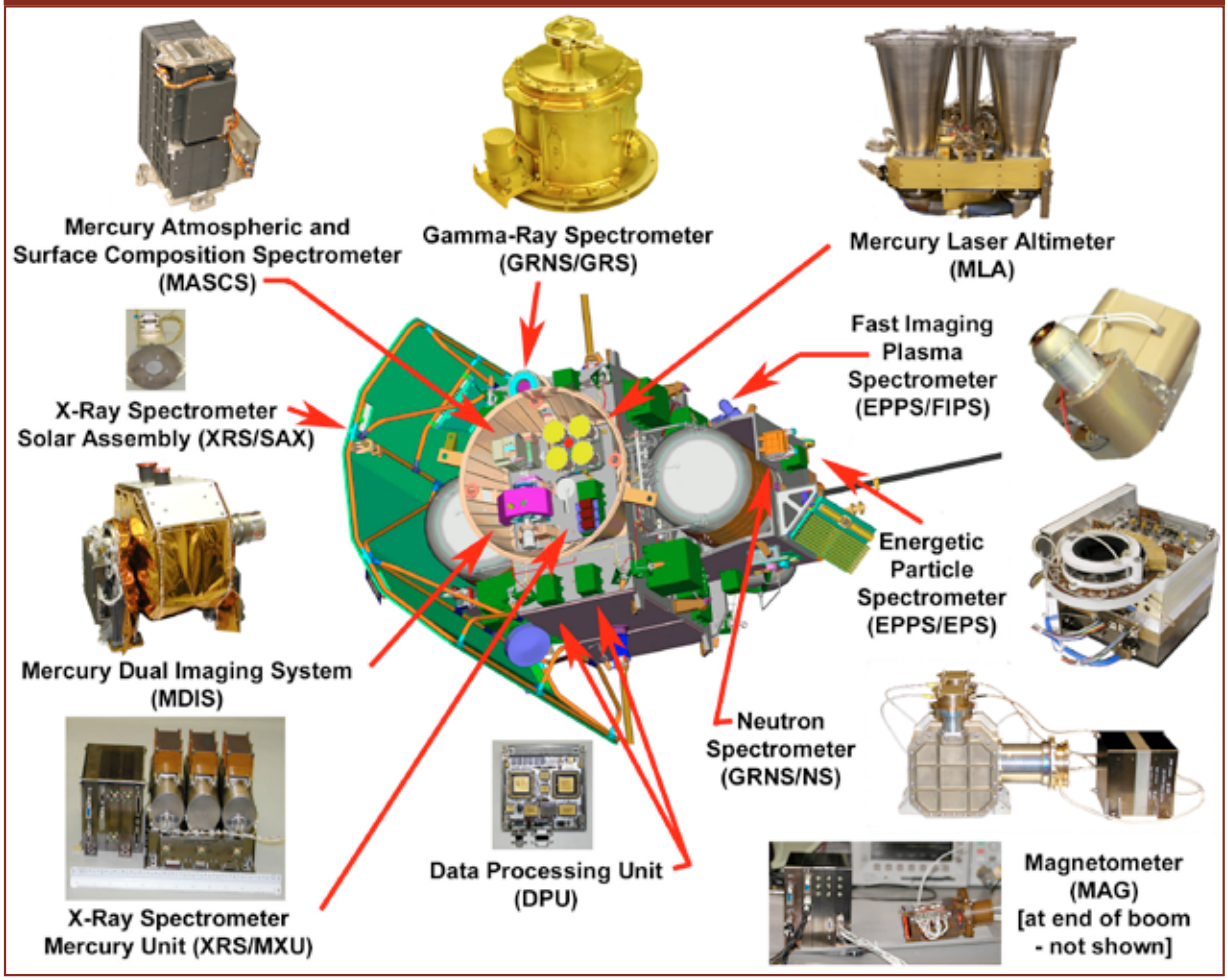
MESSENGER spacecraft during integration and testing. The sunshade is visible on the left with the spacecraft undergoing testing in thermal-vacuum conditions at NASA's Goddard Space Flight Center. On the right, the solar panels and Magnetometer boom are in their position for flight during work at APL.

Science payload

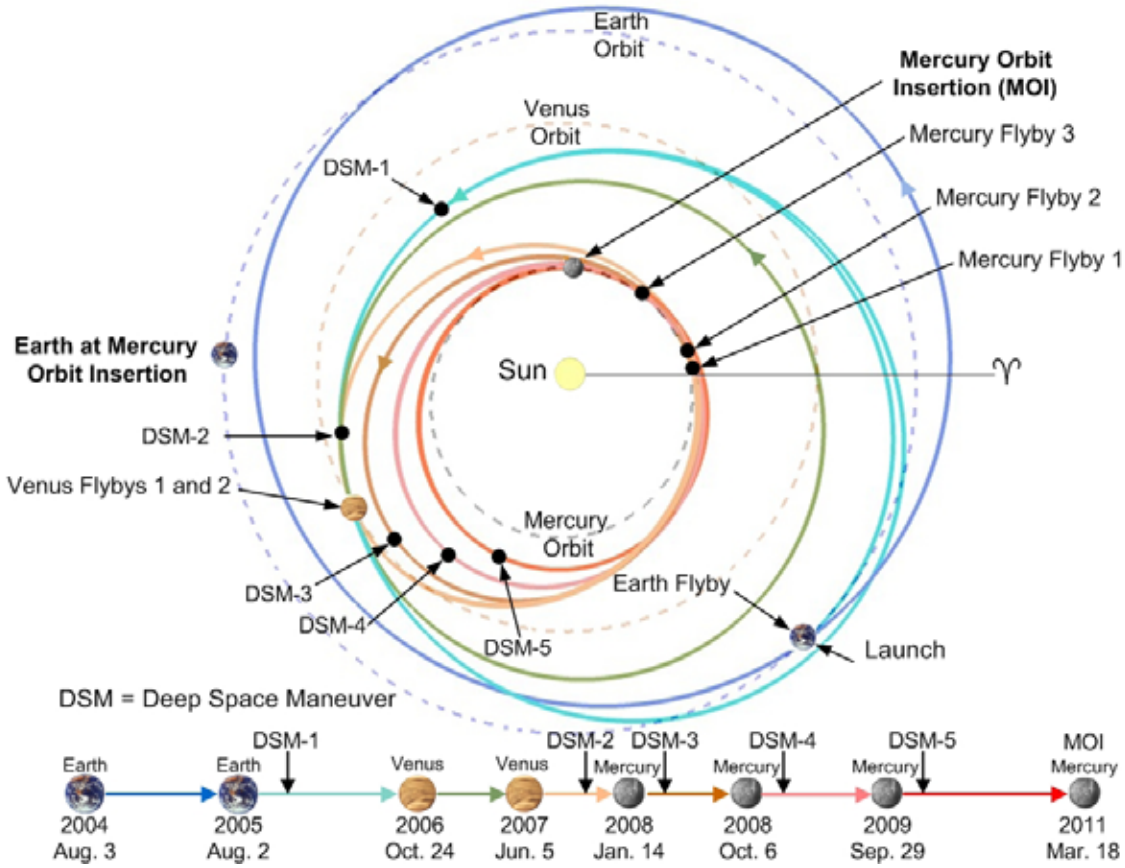
MESSENGER carries seven scientific instruments and a radio science experiment to accomplish an ambitious objective: return the first data from Mercury orbit. The miniaturized payload — designed to work in the extreme environment near the Sun — will image the entire surface of Mercury, as well as gather data on the composition and structure of Mercury's crust, its geologic history, the nature of its active magnetosphere and thin atmosphere, and the makeup of its core and the materials near its poles.

The instruments include the Mercury Dual Imaging System (MDIS), the Gamma-Ray and Neutron Spectrometer (GRNS), the X-Ray Spectrometer (XRS), the Magnetometer (MAG), the Mercury Laser Altimeter (MLA), the Mercury Atmospheric and Surface Composition Spectrometer (MASCS), and the Energetic Particle and Plasma Spectrometer (EPPS). The instruments communicate to the spacecraft through fully redundant Data Processing Units (DPUs).

Spacecraft Instruments



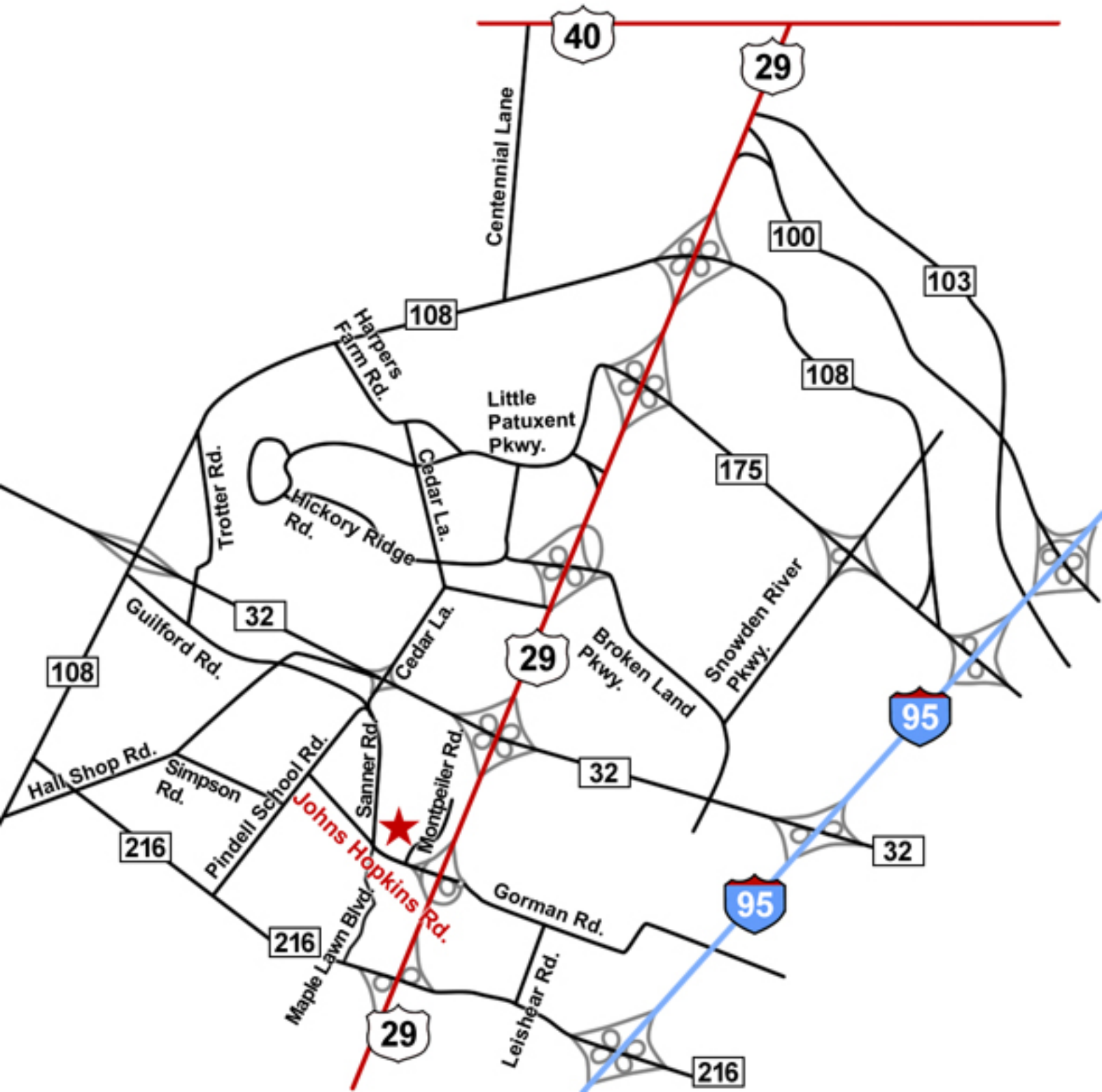
Earth to Mercury



MESSENGER cruise trajectory from the Earth to Mercury with annotation of critical flyby and maneuver events. View looks down from the ecliptic north pole.

Multiple Flybys

Mariner 10 flew past Venus to reach Mercury, but the idea of multiple Venus/Mercury flybys to help a spacecraft "catch" Mercury and begin orbiting the planet came years later, when Chen-wan Yen of NASA's Jet Propulsion Laboratory developed the concept in the mid-1980s. MESSENGER adopted this mission design approach; without these flybys, MESSENGER would move so fast past Mercury that no existing propulsion system could slow it down sufficiently for it to be captured into orbit.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Guilford Rd.
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29
Broken Land Pkwy.
Snowden River Pkwy.
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Hall Shop Rd.
Simpson Rd.
Pindell School Rd.
Sanner Rd.
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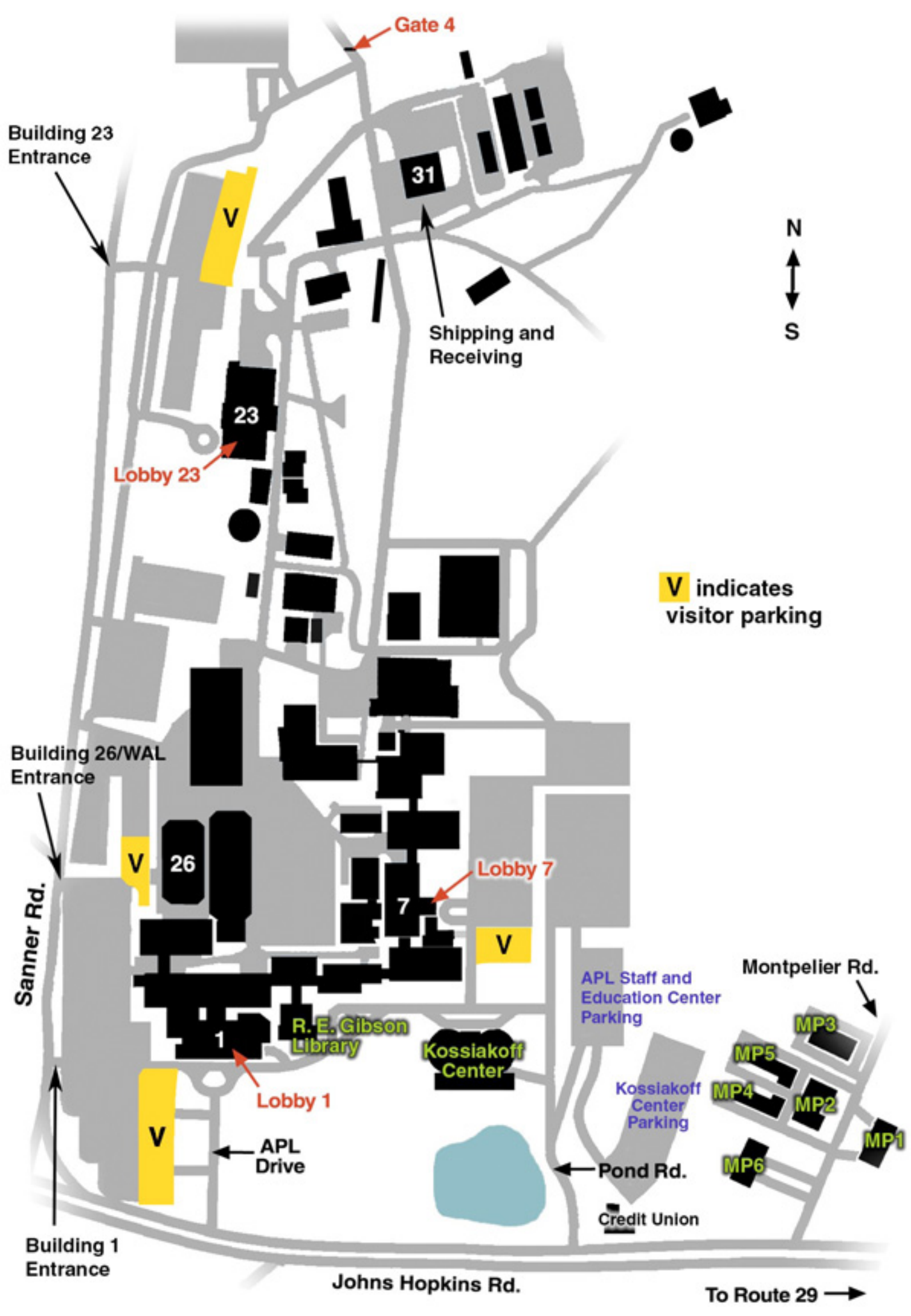
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Lobby 23
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Building 26/WAL Entrance
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26
Lobby 7
7
V
Sanner Rd.
APL Staff and Education Center Parking
Montpelier Rd.
R. E. Gibson Library
1
Kossiakoff Center
MP3
MP5
Kossiakoff Center Parking
MP4
MP2
Lobby 1
V
APL Drive
MP1
MP6
Pond Rd.
Credit Union
Building 1 Entrance
Johns Hopkins Rd.
To Route 29

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