Carnegie Institution for Science

Johns Hopkins Applied Physics Laboratory

MESSENGER

MErcury Surface, Space ENvironment, GEochemistry, and Ranging

MESSENGER:

Overcoming Engineering Challenges To Enable Exploration of Mercury

Design of Discovery Workshop

March 7, 2015

Jim McAdams

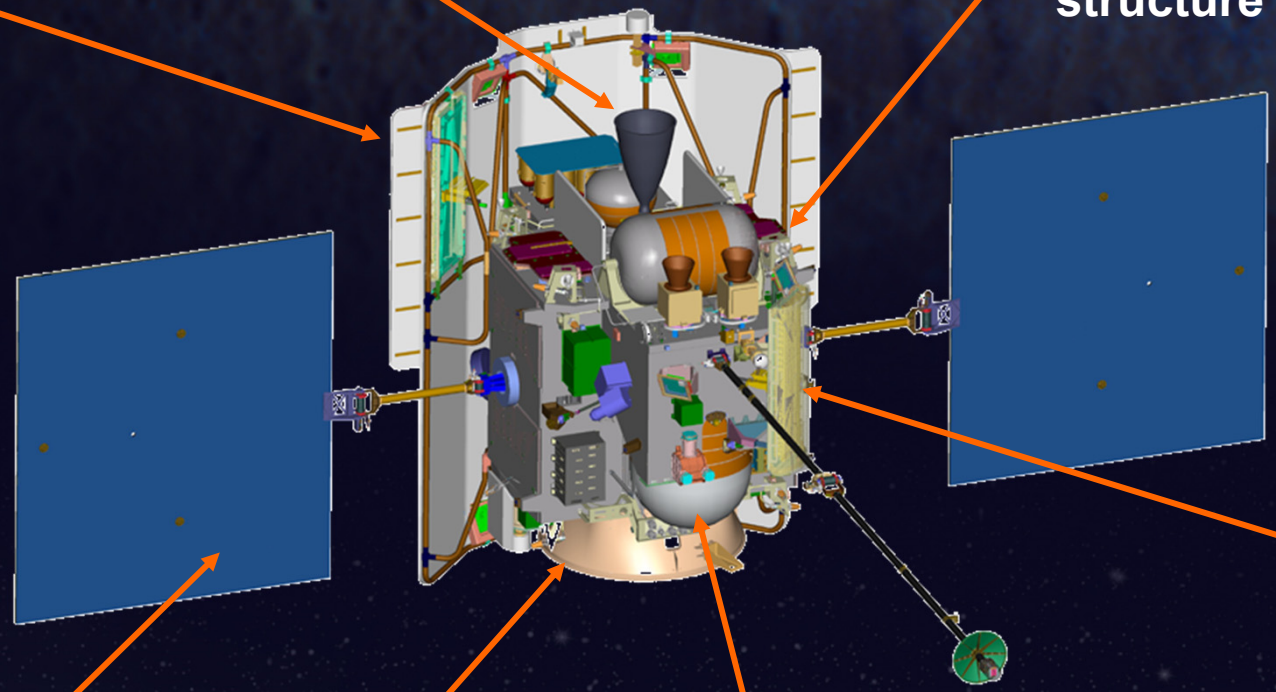
Mission Design Lead Engineer

The Spacecraft

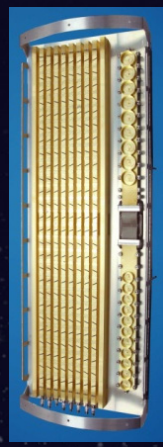
Ceramic cloth sunshade

672-N bi-propellant thruster

Low-mass, carbon fiber composite structure



Phased-array high-gain antenna



Gimbaled solar panels are 2/3 mirrors

Custom aluminum launch vehicle adapter

Three large custom propellant tanks

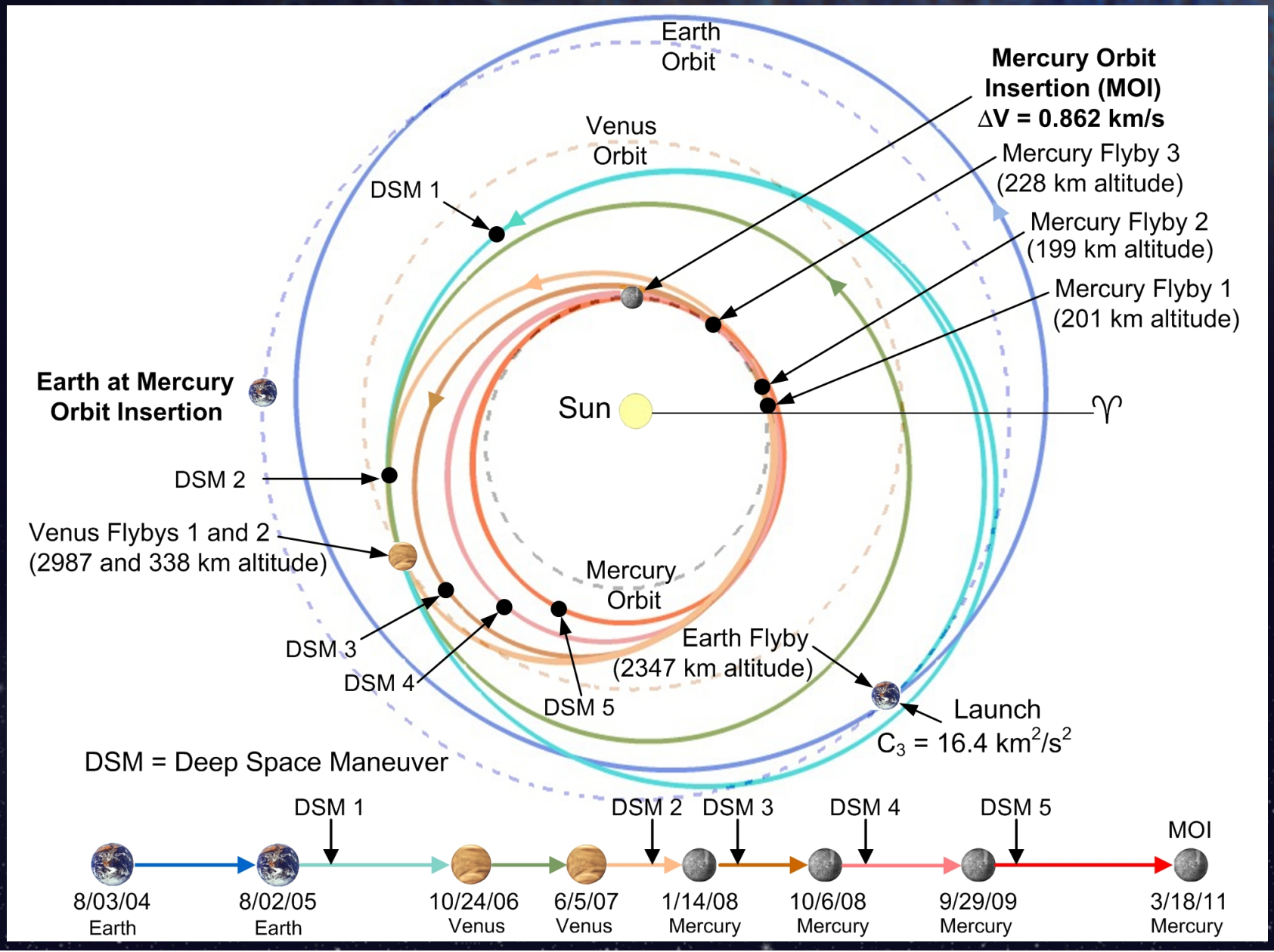
Key Characteristics:

- *1107-kg launch mass*
- *2200 m/s ΔV capable*
- *>720-W orbit power capable*

Design Challenge Before Launch:
Find a Trajectory that Uses Less Propellant

- May 2000 Systems Requirements Review
  - 15-day baseline & 14-day 1st backup launch periods, 16.0 km^2/s^2 max launch energy, 5.4 years to Mercury
  - 2750 m/s velocity change budget using onboard propellant including 2487 m/s + 263 m/s statistical & margin
- March 2015 Final result: 20% propellant savings!
  - Launch on 5th day of 15-day 2nd backup launch period, 16.4 km^2/s^2 launch energy, 6.6 years to Mercury orbit
  - 2210 m/s velocity change achieved including 85 m/s statistical and 154 m/s during extended missions

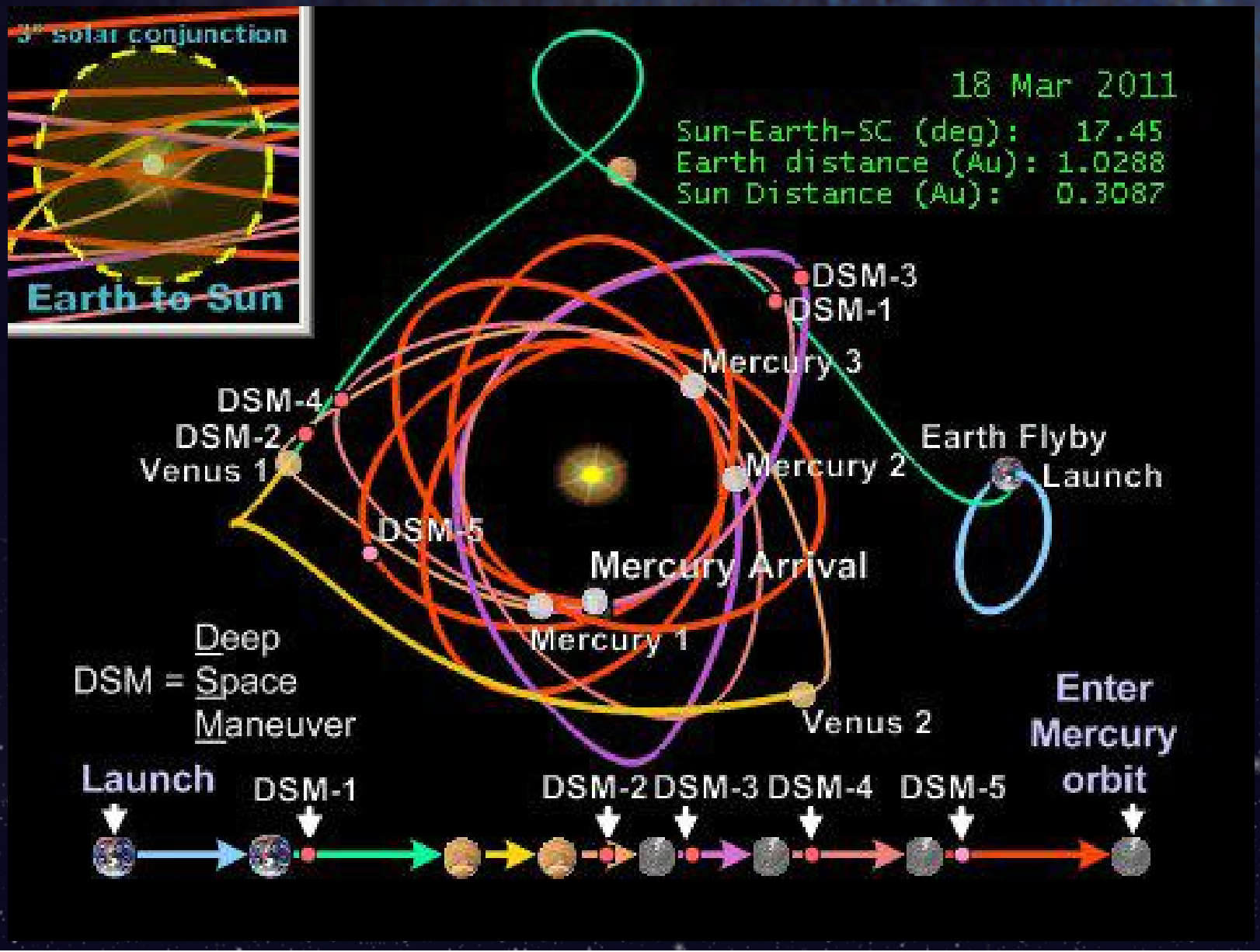
Earth Orbit Plane Projection of Heliocentric Trajectory Profile



All 16 Heliocentric Orbits are Visible in the "Sun-Earth Line Fixed" Frame

Superior Solar Conjunction is when the S/C appears < 3° from the Sun, with the Sun between the Earth and S/C.

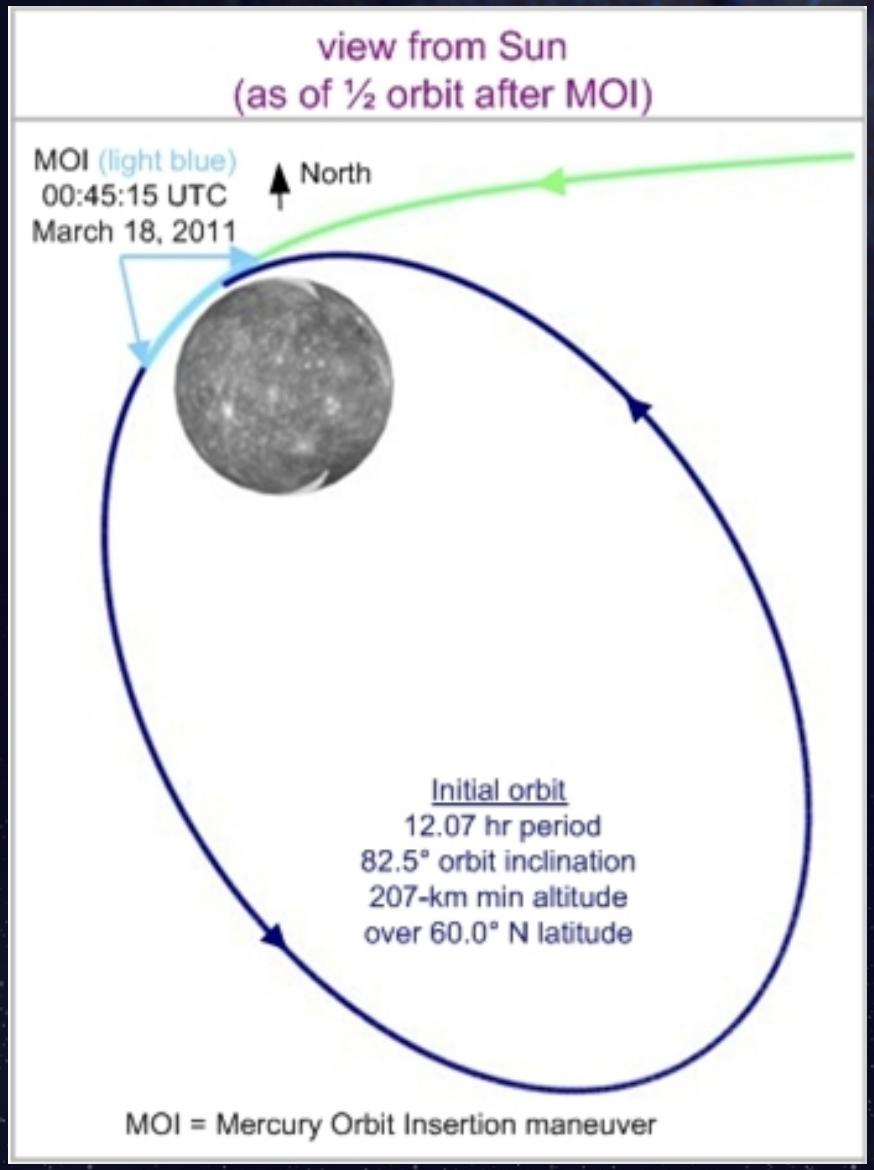
This condition results in loss of data when communicating with tracking stations on Earth, so **TCMs are never executed during solar conjunctions**.

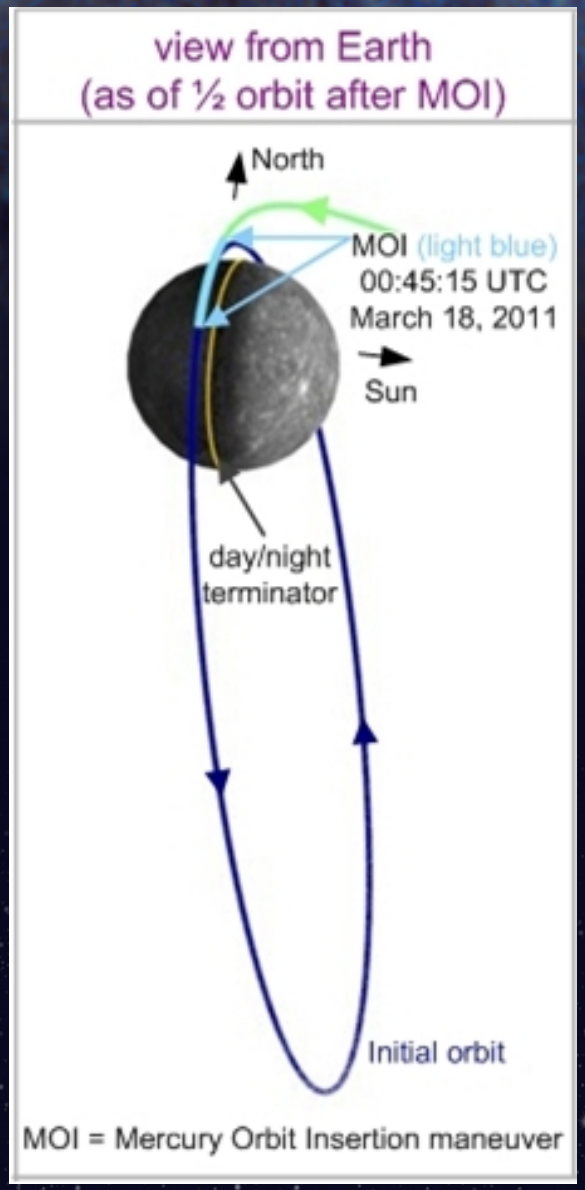


Design Challenge After Launch: Plan & Implement a Successful Mercury Orbit Insertion (MOI)

- Initial MOI design: 2 maneuvers ~1/2 week apart
  - Precise clean-up MOI-2 as 4%-5% of primary MOI-1
- Final MOI design used 31% of total propellant and 1 maneuver to enter 207-km X 12.07-hr orbit
  - If a major anomaly occurred during MOI, contingency planning indicated an excellent recovery outlook for full mission success within 5 years for 81% of all potential MOI shortfalls
  - Key techniques for MOI practiced during cruise TCMs

MOI and the Initial Mercury Orbit



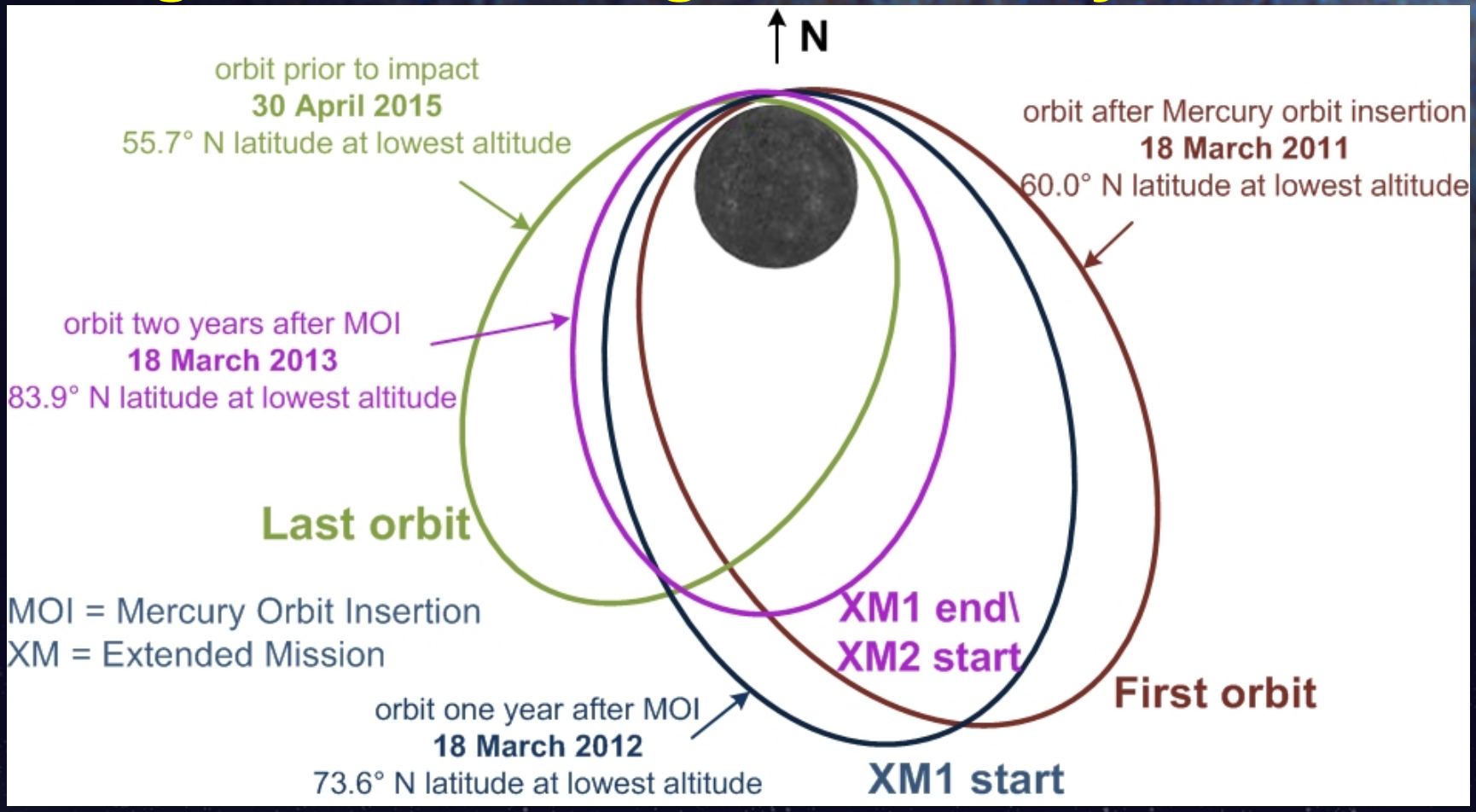


100% of MOI Observable, no Solar Eclipse during Initial Orbits

Design Challenge after Mercury Arrival: Find Amazing New Science Opportunities

- Baseline Mission Prime Science Plan
  - 1 year in 200-500 km X 12-hr, 82.5° -84.1° inclination orbit, 5 orbit adjusts, Mercury & near –Mercury space focus, finished after 7.6 years into 8-year S/C design life
- Enabling Science Plan Enhancements
  - 1.1 yrs in 12-hr orbit +3 yrs in 8-hr orbit - late April 2015 end
  - Answered ?s on potential H_2O ice in perm. shadowed craters
  - Nov. 2013 Comet Observations of Encke and ISON
  - >240,000 images returned from Mercury orbit
  - SciBox Science Planning Software Tool maximized science

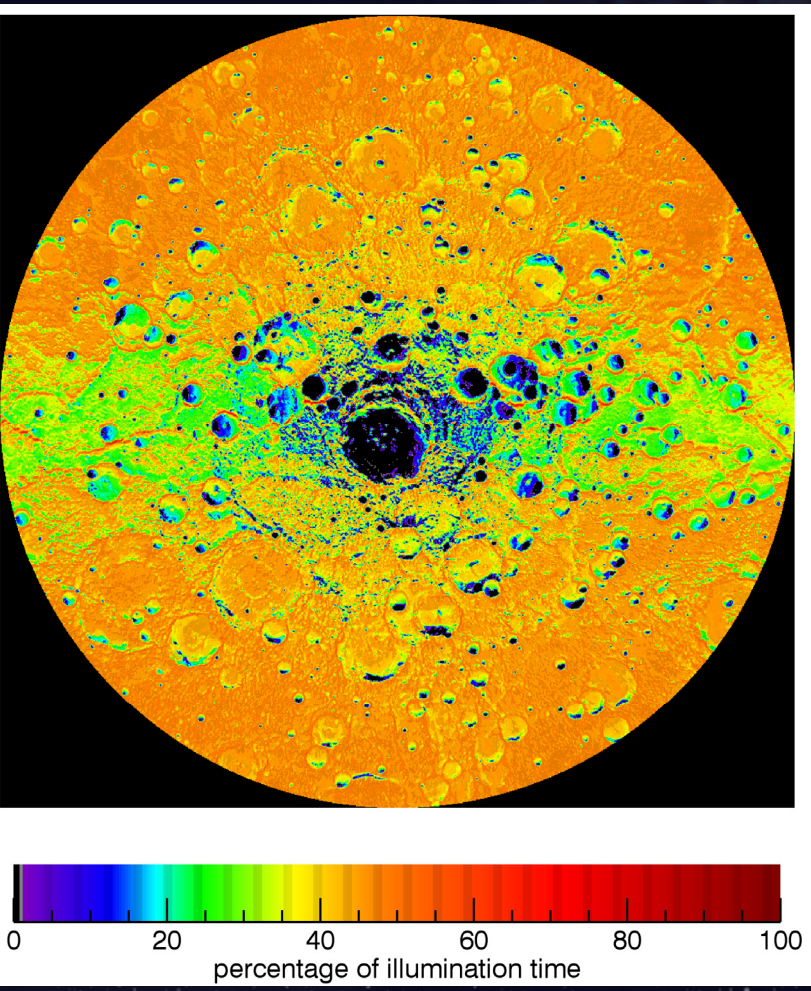
Orbit Progression During the Mercury Orbital Phase



Phase	Duration (yr)	Orbit Period (h)	# OCMs	OCM Purpose	OCM ΔV (m/s)
Primary	1.00	12.07 – 11.60	6	Lower Periapsis, Adjust Orbit Period	102.5
Extended 1	1.00	11.60 – 8.00	2	Lower Orbit Period, Deplete Oxidizer	84.8
Extended 2	2.00	8.00 – 8.27	4	Raise Periapsis, Extend Mission	42.6
Extended 2’	0.12	8.27 – 8.35	5	Raise Periapsis, 5-36 km Low Altitudes	12.2

Water Ice in Polar Deposits

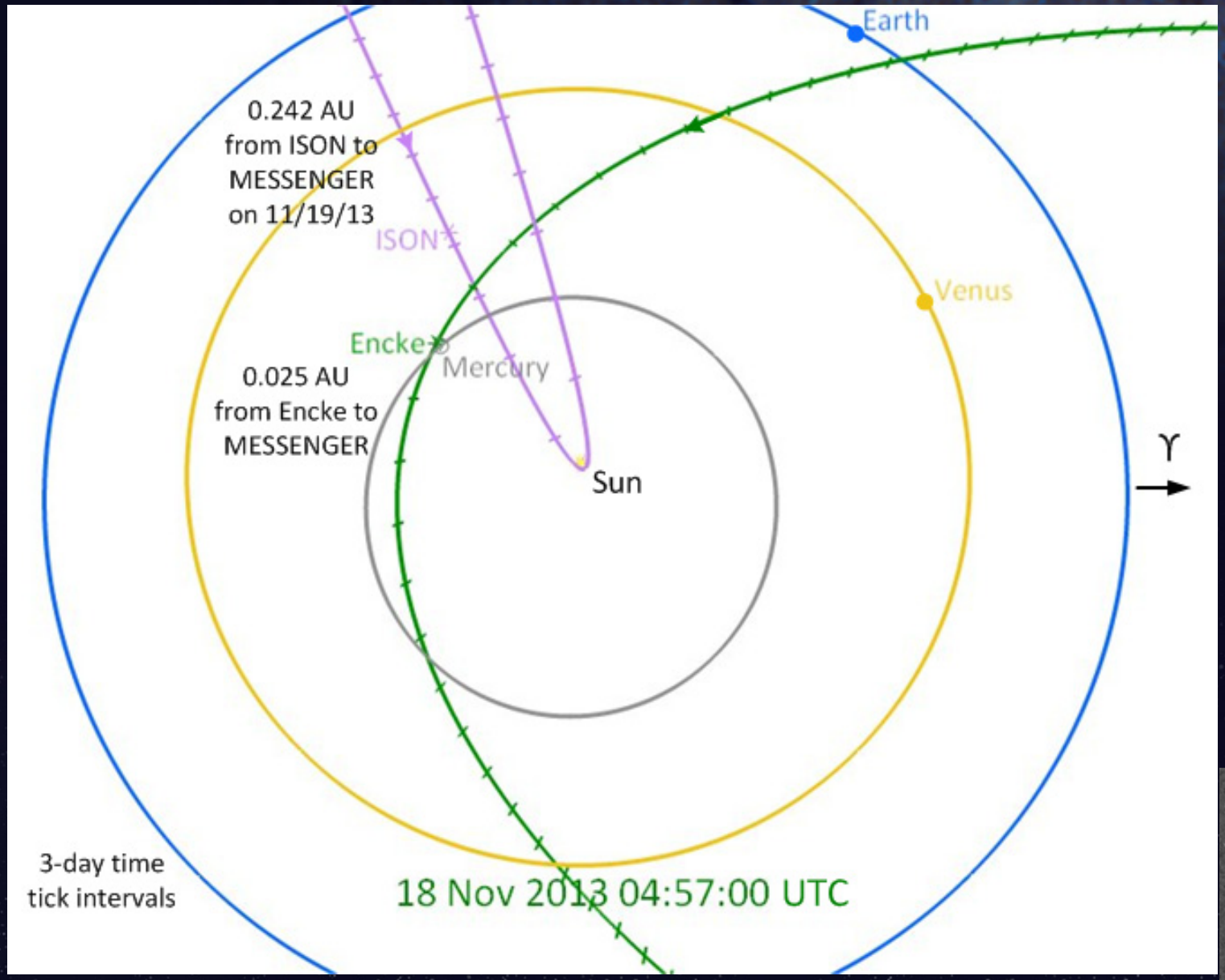
Polar deposit type	Thermal modeling	Interpretation
Radar-bright, MLA-dark	One-to-one correspondence between dark spots and locations where water ice is thermally stable within ~10 cm of the surface	Dark, complex organics (common in asteroids & comets) overlying water ice
Radar-bright, MLA-bright	One-to-one correspondence between bright spots and locations where water ice is thermally stable at the surface	Surficial water ice



Sunlight illumination in the north polar region

Ice mass ranges from 10^{13} – 10^{15} kg.
Assume ice depth of 0.5 m to 20 m.

November 2013 – Observing Two Comets



MESSENGER acquired and returned 431 images of comet 2P/Encke near the comet's perihelion.

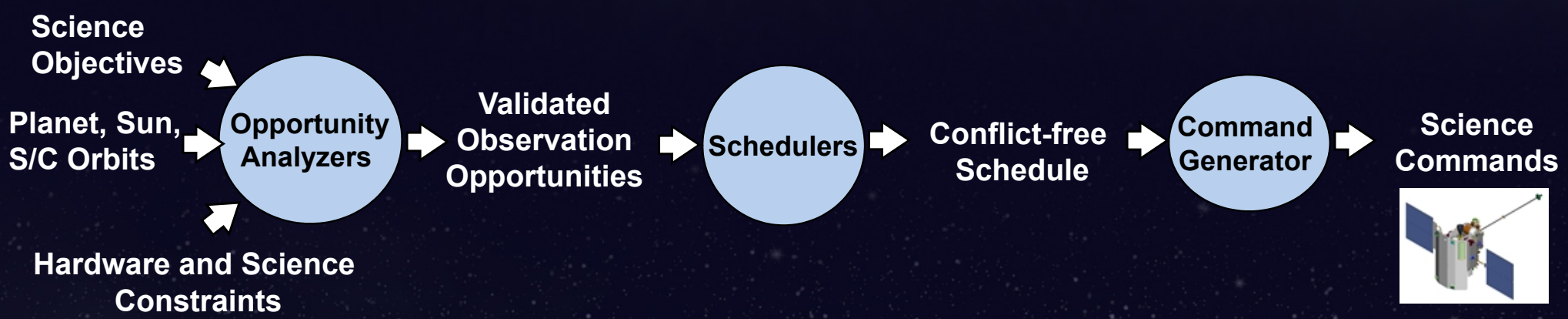
Image from 11/17/13

MESSENGER acquired and returned 280 images of comet 2012 S1 (ISON) before the comet's 0.0124 AU perihelion.

Image from 11/20/13

Planning science observations, spacecraft operation, and communications with SciBox

- SciBox is a unique end-to-end automated science planning and commanding system that maximizes science return



Summary

- 7th Mission in NASA's Discovery Program
- 6.6-year Heliocentric Cruise with 6 Planetary Flybys
- 4.1-year Mercury Orbital Phase >4,000 Orbits of Mercury
- Overcame Engineering Challenges for Mission Success
- MESSENGER First S/C to Orbit the Planet Mercury
- Multiple Global Maps of Mercury's Surface
- Water Ice in Polar Shadowed Craters

U.S. MESSENGER postage stamp was issued in May 2011