

What Goes Up Must Come Down

Cassini Maneuver Experience During the Inclination-Raising Phase Prior to End of Mission

Frank E. Laipert, Sean V. Wagner, Yungsun Hahn,
Sonia Hernandez, Powtawche Valerino, Mar Vaquero, and
Mau C. Wong

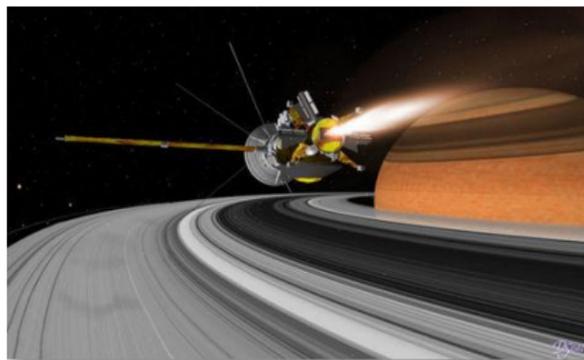


Jet Propulsion Laboratory
California Institute of Technology

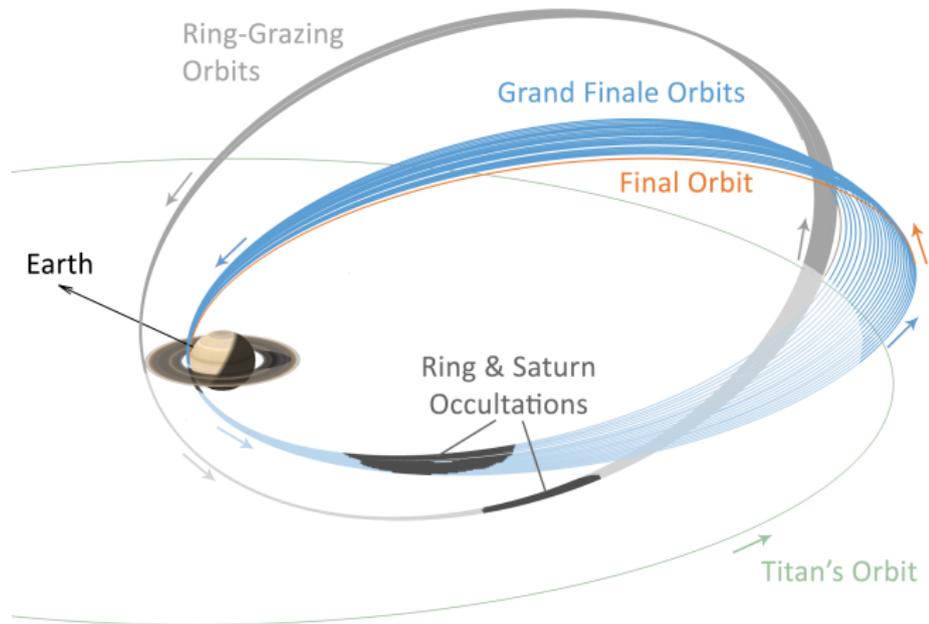
February 7, 2017

Cassini Today

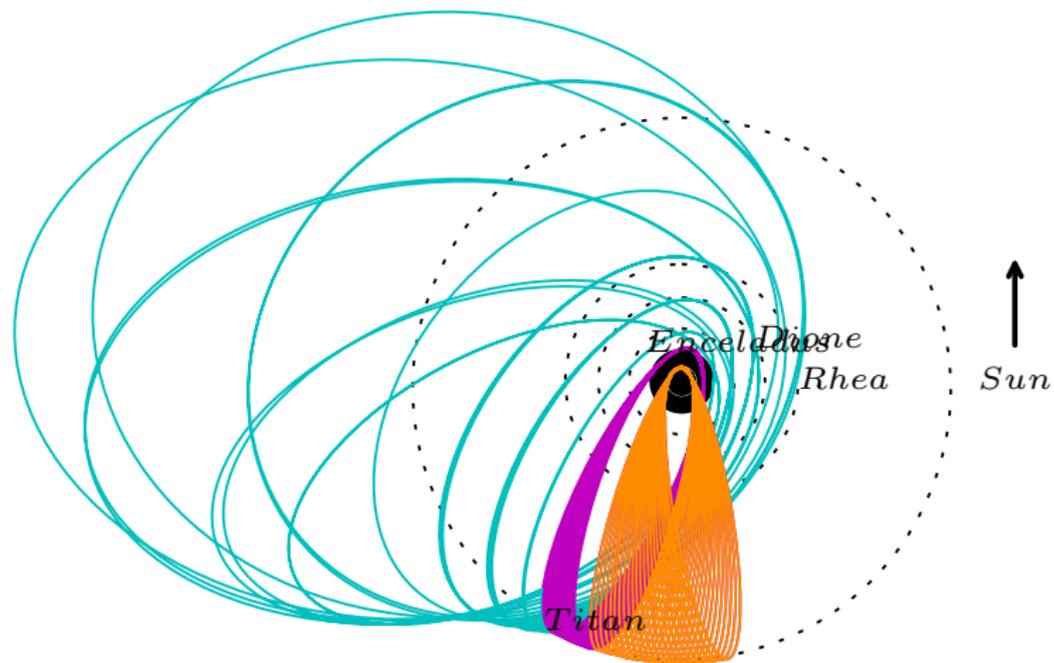
- ▶ Launched in 1997
- ▶ Arrived at Saturn in 2004
- ▶ Entering Saturn's atmosphere September 15, 2017



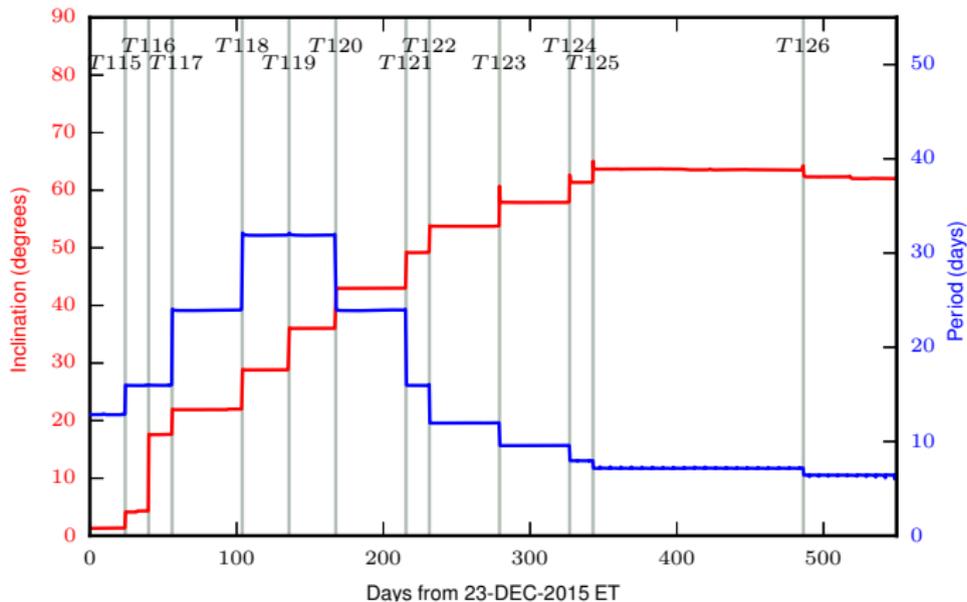
Current Orbit



Third Inclined Phase



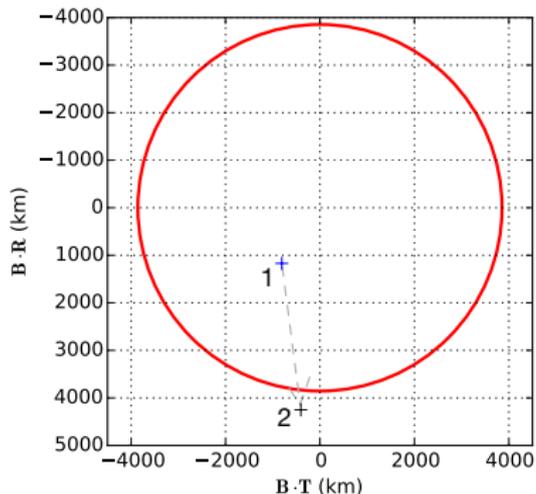
Third Inclined Phase



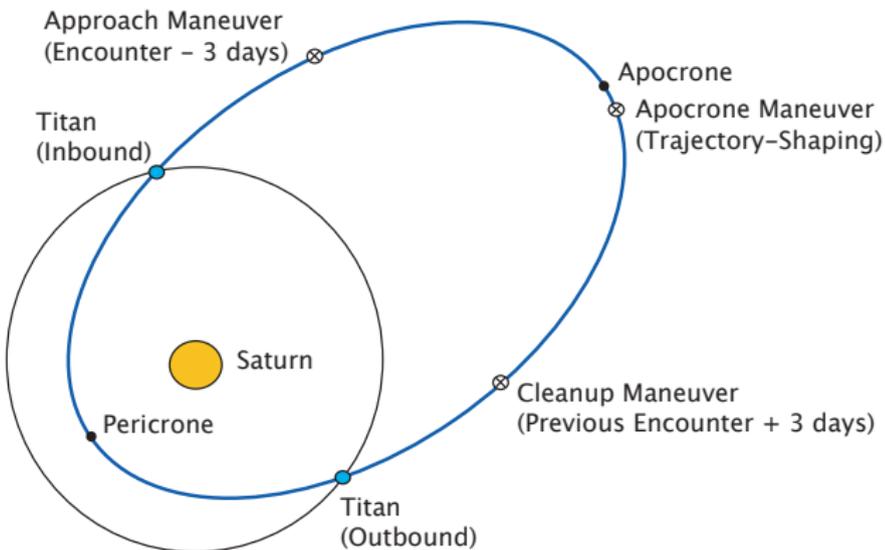
Maneuver Design Process

Trajectory controlled via satellite flybys

- ▶ Match $\mathbf{B} \cdot \mathbf{R}$, $\mathbf{B} \cdot \mathbf{T}$, and flyby time.
- ▶ Drift from reference is allowed between flybys.



Maneuver Design Process



33 planned maneuvers

- ▶ Dec. 19, 2015–Nov. 29, 2016
- ▶ 8 maneuvers canceled
- ▶ 4 performed at backup time

12 satellite encounters

- ▶ 1 Enceladus, 11 Titan
- ▶ Titan flyby altitudes of 971–3548 km

How did we do?

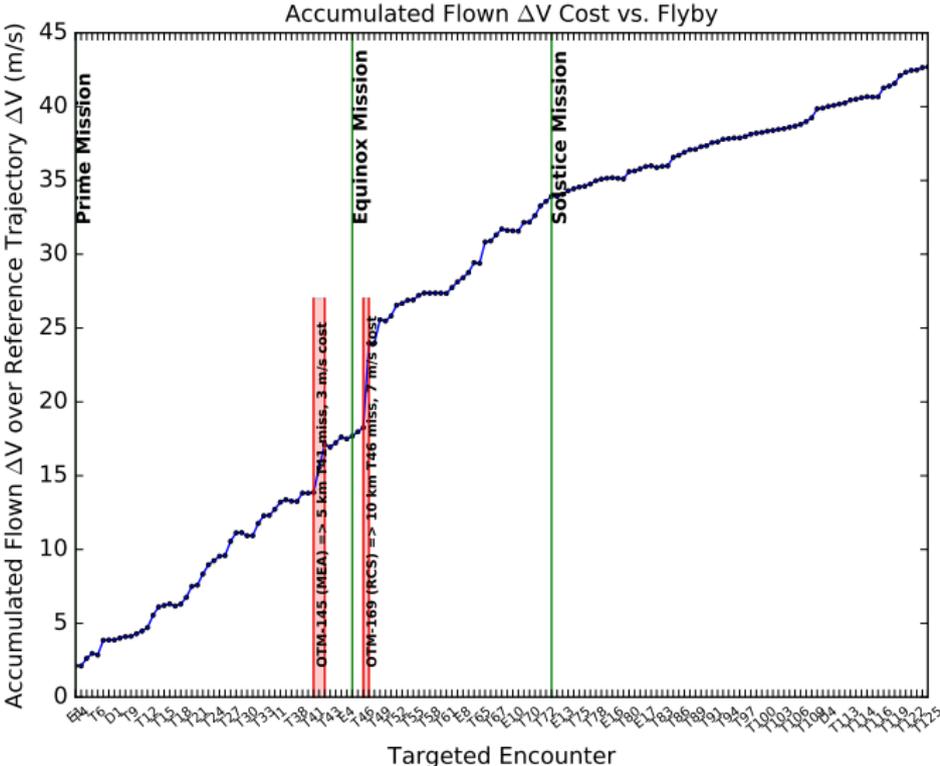
Flyby Misses

- ▶ We miss every time!
- ▶ Average miss for Titan: **929 m**
- ▶ Minimum: **153 m** at T123
- ▶ Maximum: **2.47 km** at T119

Navigation Cost

- ▶ $\Delta V_{actual} - \Delta V_{ref} = \text{Navigation Cost}$
- ▶ Target for Solstice Mission is 0.3 m/s per encounter
- ▶ Achieved 0.182 m/s per encounter during this span.

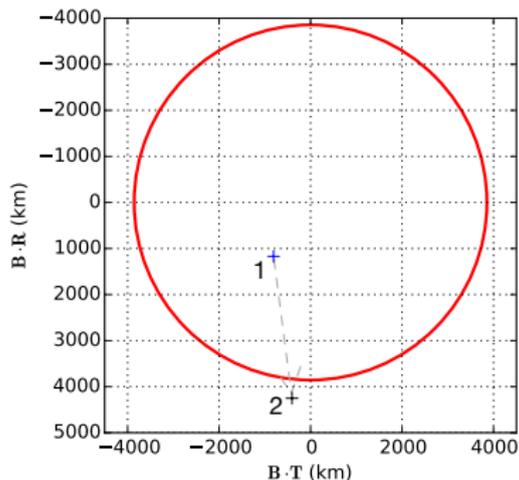
Navigation Cost Per Flyby



Last Big Main Engine Burns

OTM-438

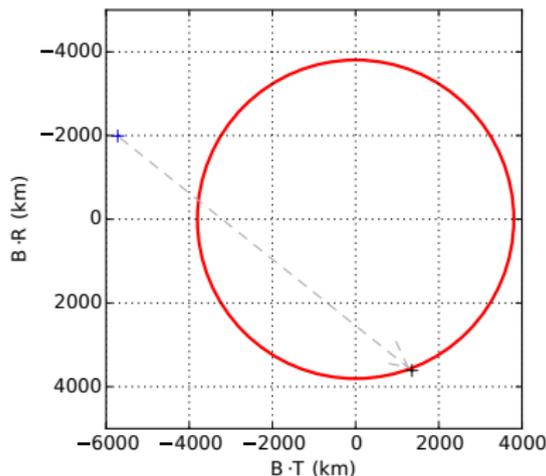
- ▶ January 23, 2016
- ▶ $\Delta V = 6.85$ m/s
- ▶ 1.2% chance of propellant depletion



AAS 17-283

OTM-444

- ▶ March 25, 2016
- ▶ $\Delta V = 7.95$ m/s
- ▶ 6.0% chance of propellant depletion

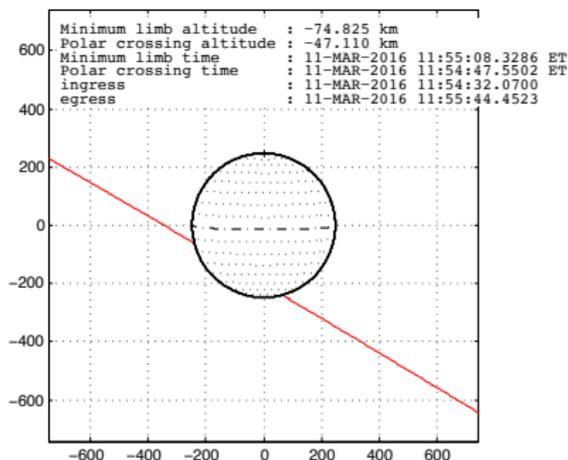


Frank Laipert

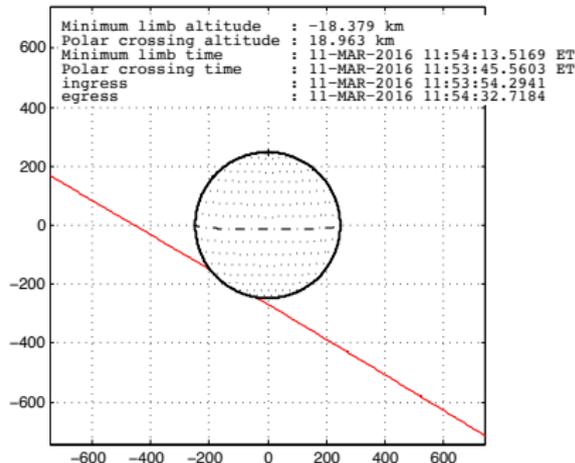
11



Stellar Occultation



Before Maneuver

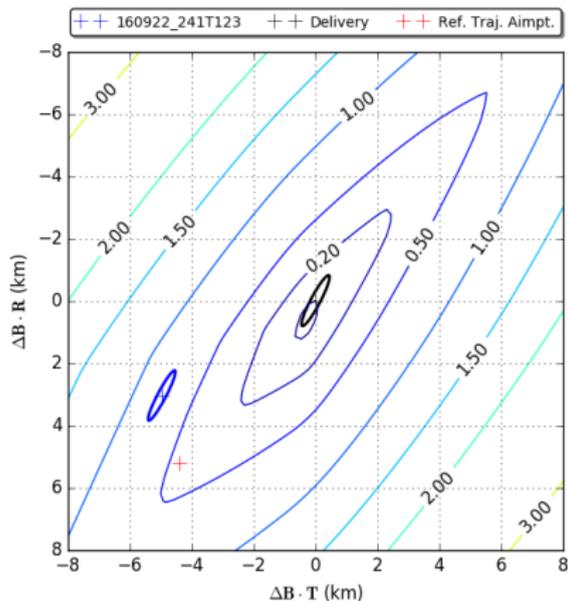


After maneuver

OTM-443 Backup

- ▶ T117 Cleanup maneuver used to target occultation point.
- ▶ Needed to use the backup time to get more tracking data.
- ▶ Maneuver on Feb. 20, occultation on Mar. 11.

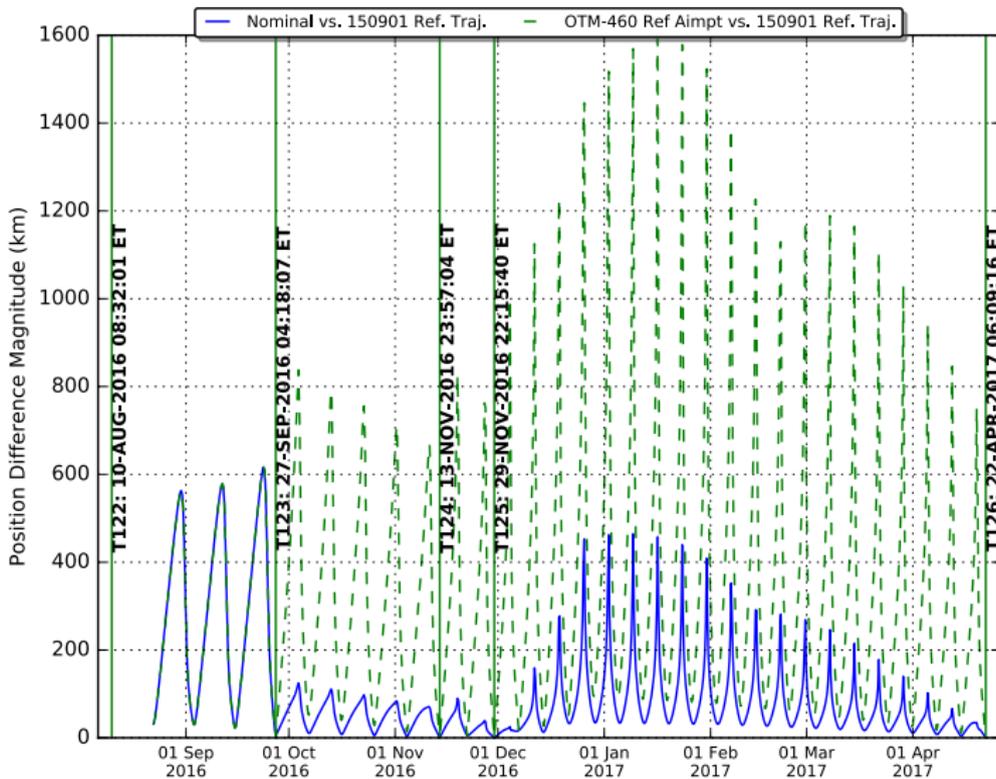
T123 B-plane Shift



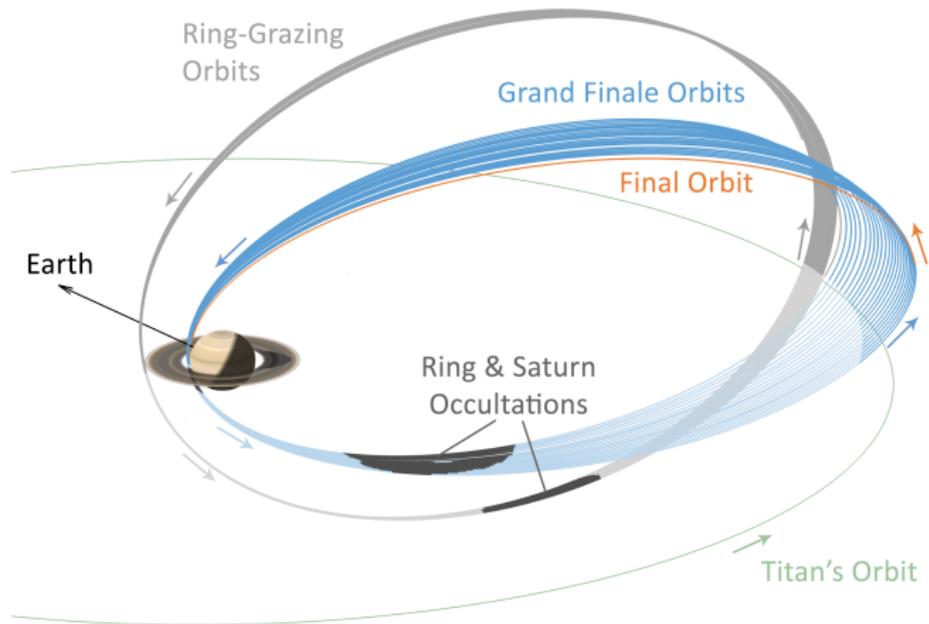
T123 Bplane

- ▶ Shifting aimpoint saved 0.34 m/s.
- ▶ Greatly reduced downstream deviations.

T123 B-plane Shift



Look Ahead to Proximal Mission



Thank you!

Questions?