



**Jet Propulsion Laboratory**  
California Institute of Technology

# A Journey with MOM

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# MARS ORBITER MISSION



# Agenda

*ISRO Mars Orbiter Mission*

- JPL MDNav Support of ISRO Missions – Past & Present
- Spacecraft
- Launch/Trajectory
- IDSN (Indian Deep Space Network) Validation
- ‘Flexible’ Mission Design Plans
- MOI
- Results
- Work to Go

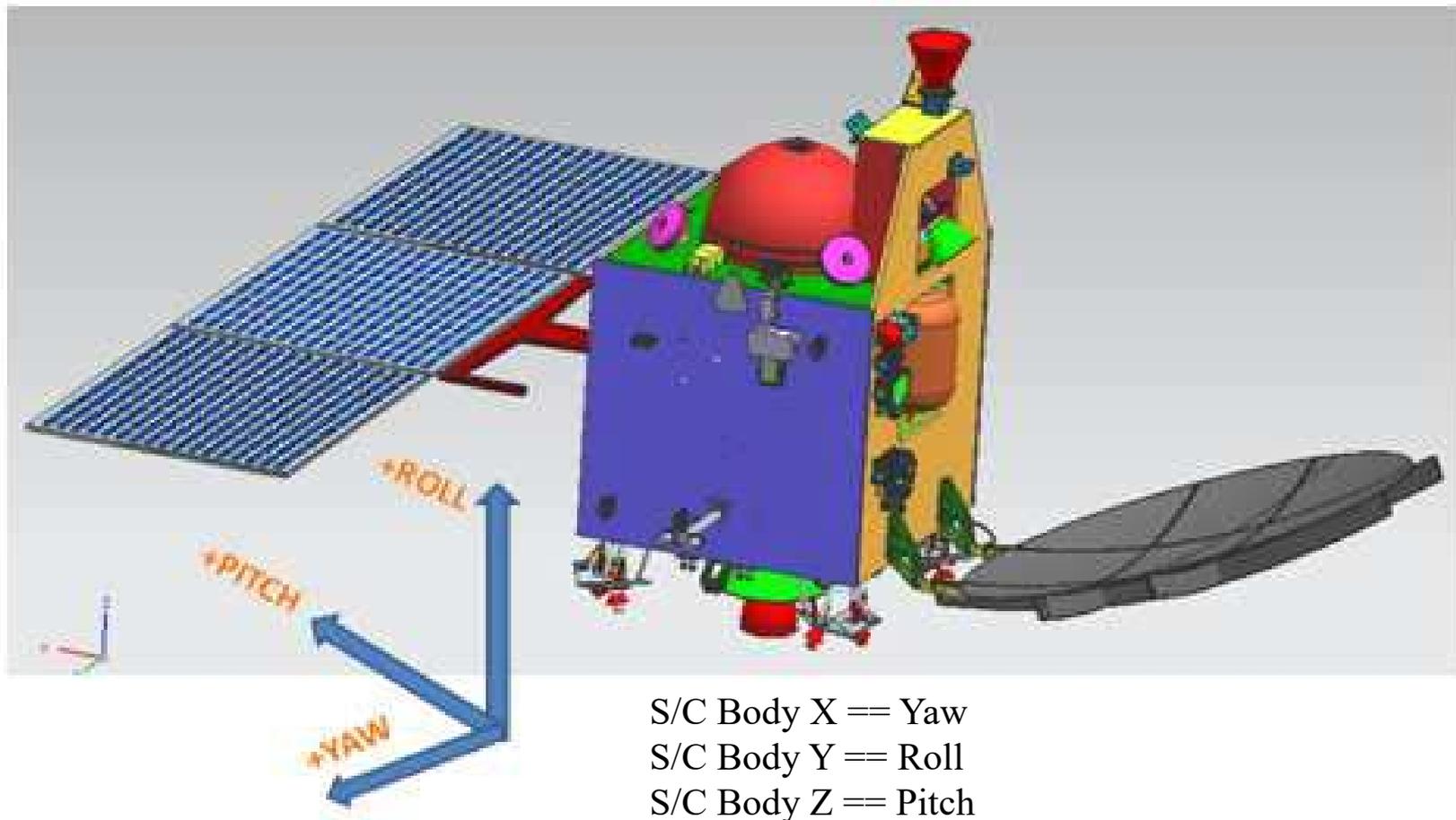
# JPL MDNav Support of ISRO Missions – Past & Present

*ISRO Mars Orbiter Mission*

- JPL Mission Design and Navigation (MDNav) previously helped ISRO with their lunar orbiter launched in 2008, Chandrayaan-1
- JPL MDNav Role: Perform navigation activities in development, design, and operations
- Additional task on MOM: IDSN validation
- Note: DSN provided telecom and tracking data for both Chandrayaan-1 and MOM

# MOM Cruise Configuration

*ISRO Mars Orbiter Mission*



**S/C ON ORBIT CONFIGURATION**

# Two Key Points About MOM Spacecraft That Impacted Navigation

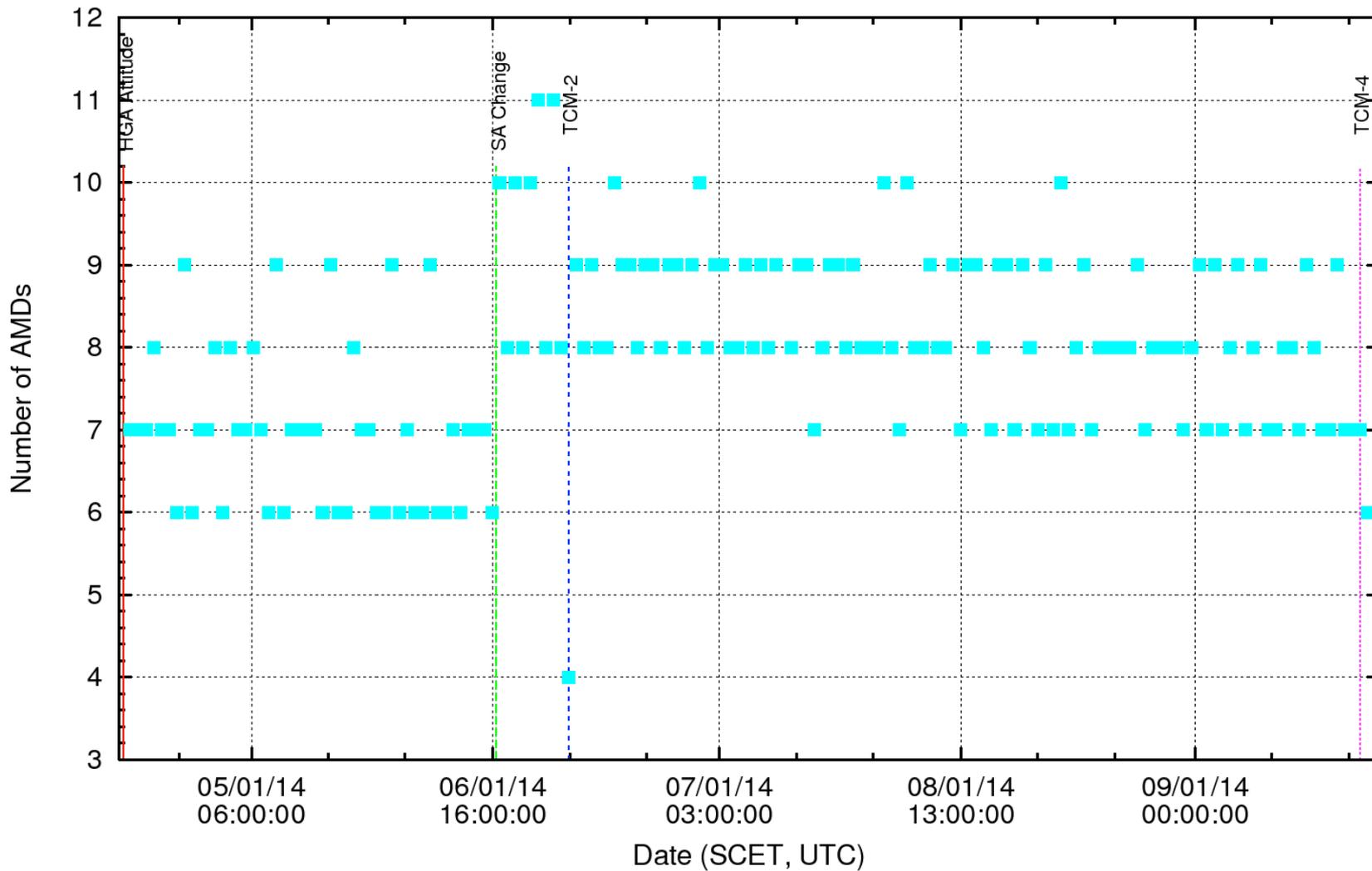
*ISRO Mars Orbiter Mission*

- Unbalanced Thrusters
  - Frequent desats meant frequent dv's
  - Fortunately, largest component was Y, and in line-of-sight
- S-Band
  - Noisier data, both Doppler and  $\Delta$ DORs
  - More sensitive to media

# AMD\* Activity – Events per Day

ISRO Mars Orbiter Mission

ISRO MOM AMDs per Day



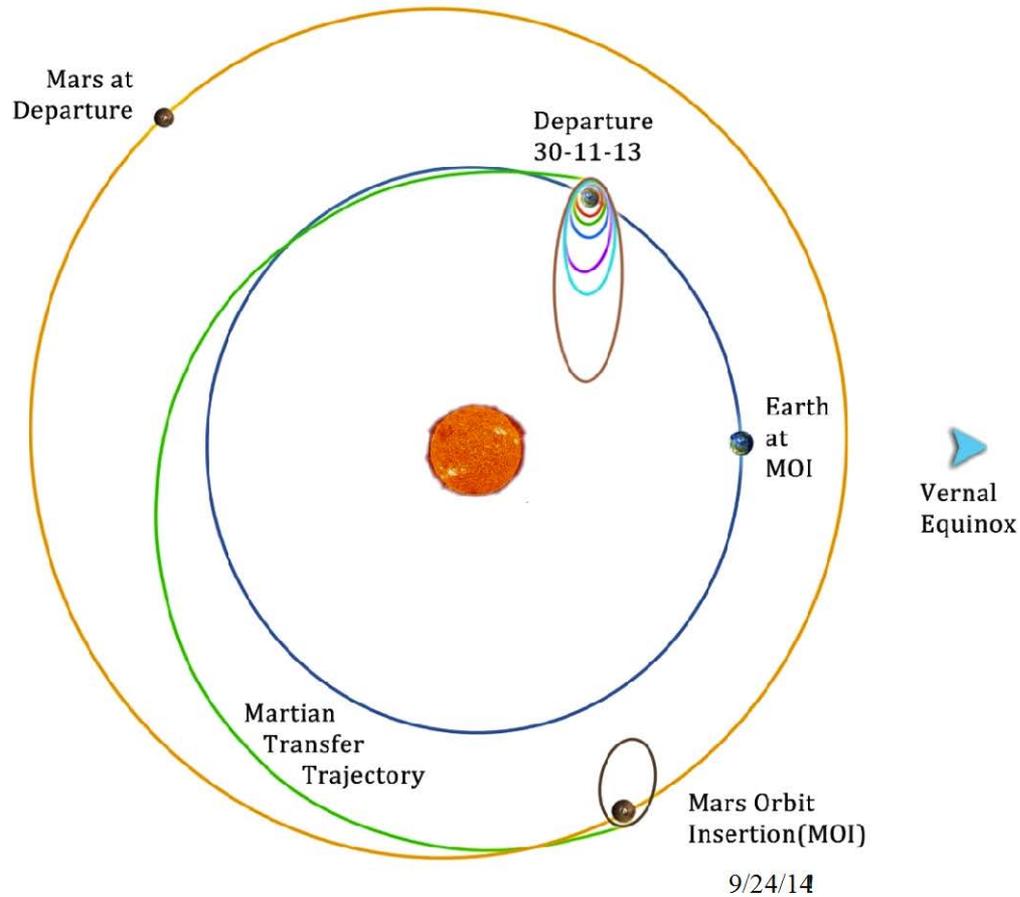
# Launch

*ISRO Mars Orbiter Mission*



# MOM Trajectory

*ISRO Mars Orbiter Mission*



Note: Earth phasing orbits and Mars insertion orbit not to scale

# Geocentric Phase and Trans Mars Injection

*ISRO Mars Orbiter Mission*

Note: Yellow orbit shows result of partial burn, EBN-4

# IDSN Validation

- JPL MDNav also tasked with IDSN validation
- IDSN Doppler:
  - Compatible with DSN to level of limiting factors
  - Limiting factors:
    - Frequent desats limit higher precision trajectory determination
      - Inhibit ability to create higher accuracy solar pressure model
    - Accuracy of media calibrations
      - Increased sensitivity at S-band
      - Proximity of Geomagnetic Equator
    - Possible station location error
- IDSN Range:
  - Most noticeable is higher noise, 3.8 m vs 0.6 m for DSN

# Fit IDSN & DSN Doppler/Range/VLBI

## IDSN & DSN Doppler Residuals

ISRO Mars Orbiter Mission

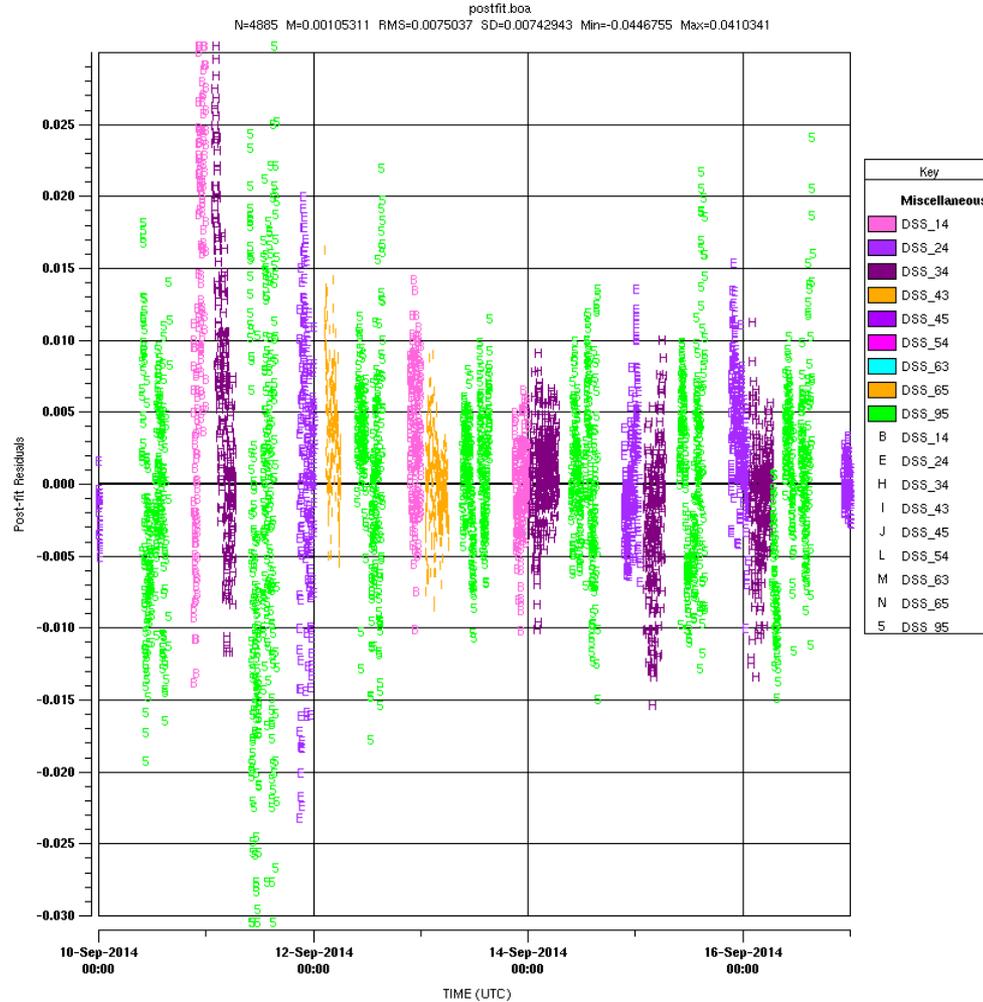
10 to 17 September 2014

Scale +/- 2 mm/s

Bias 0.0011 Hz / 0.07 mm/s  
SD 0.0074 Hz / 0.49 mm/s

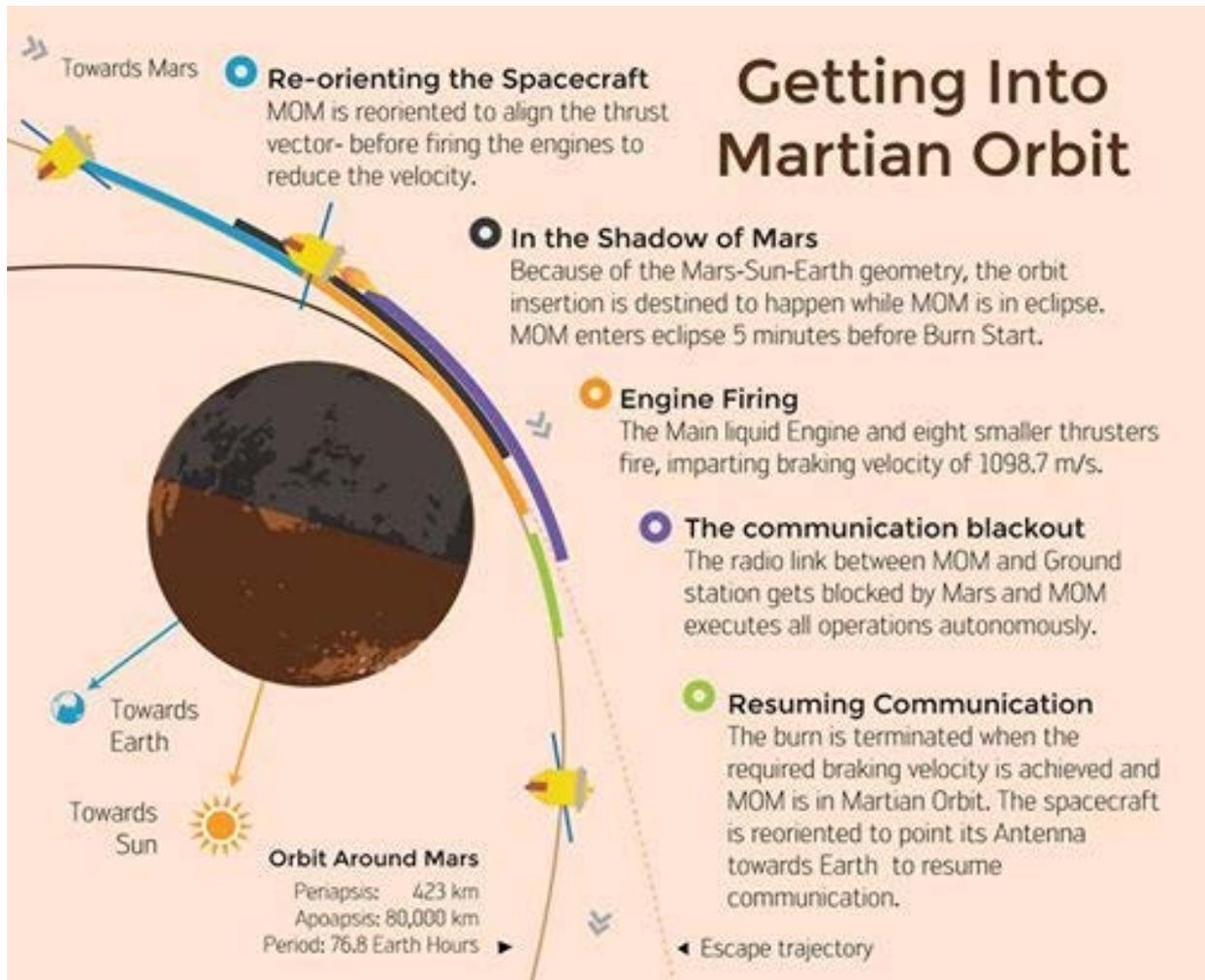
60 second count time

IDSN Data in green

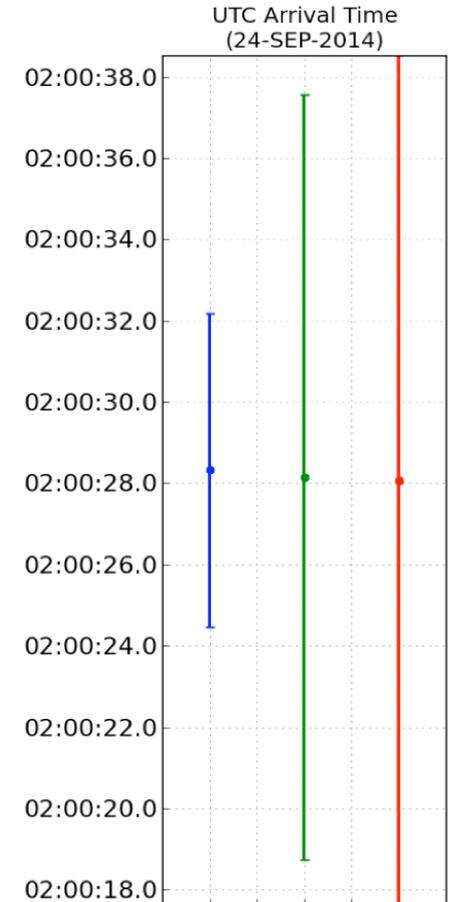
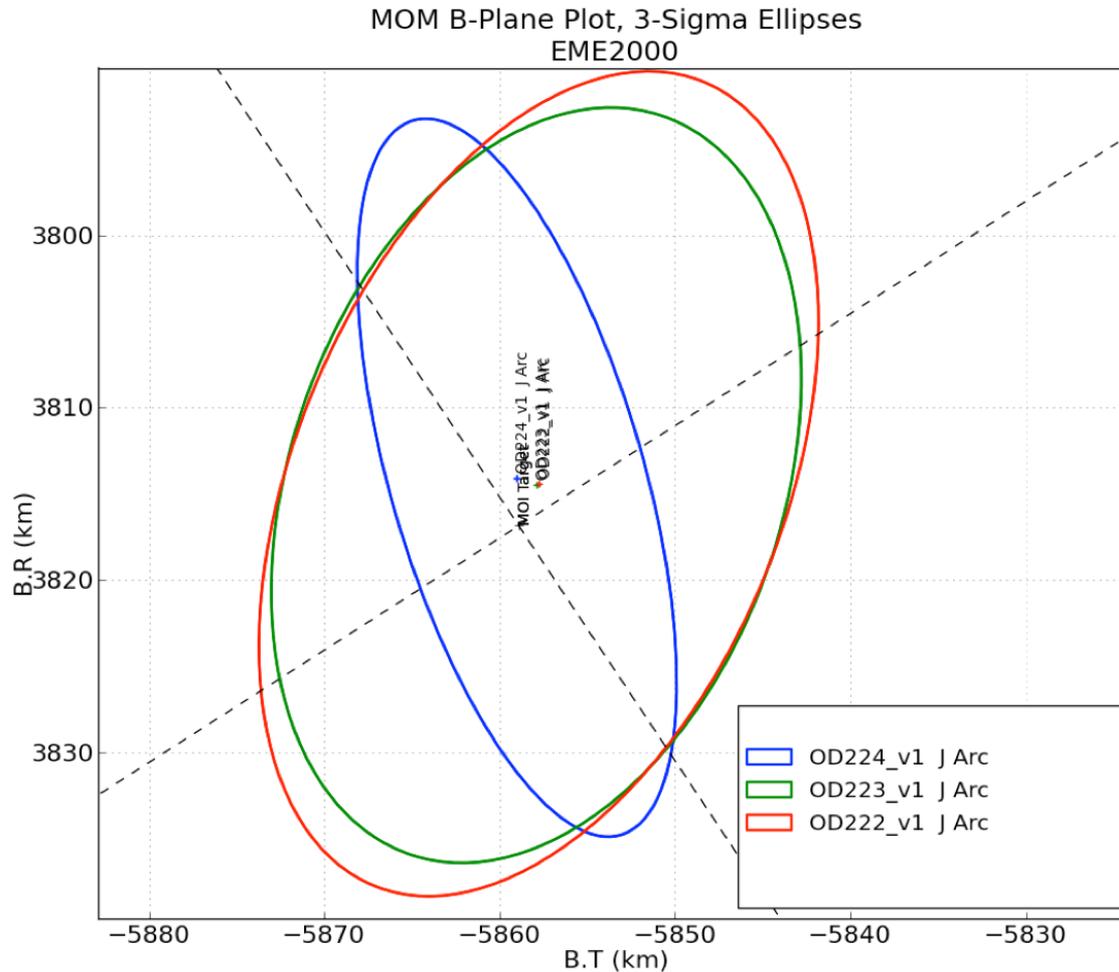


# Challenge: 'Flexible' Mission Design

- Examples include TCM's 3 and 4:
- TCM-3: Aug. 14 -> Aug. 21 -> Aug. 19 -> Aug. 30 -> cancelled!
- TCM-4: Sept. 14 -> MOI-15h -> MOI-41h -> MOI-24h -> MOI-41h (again!)

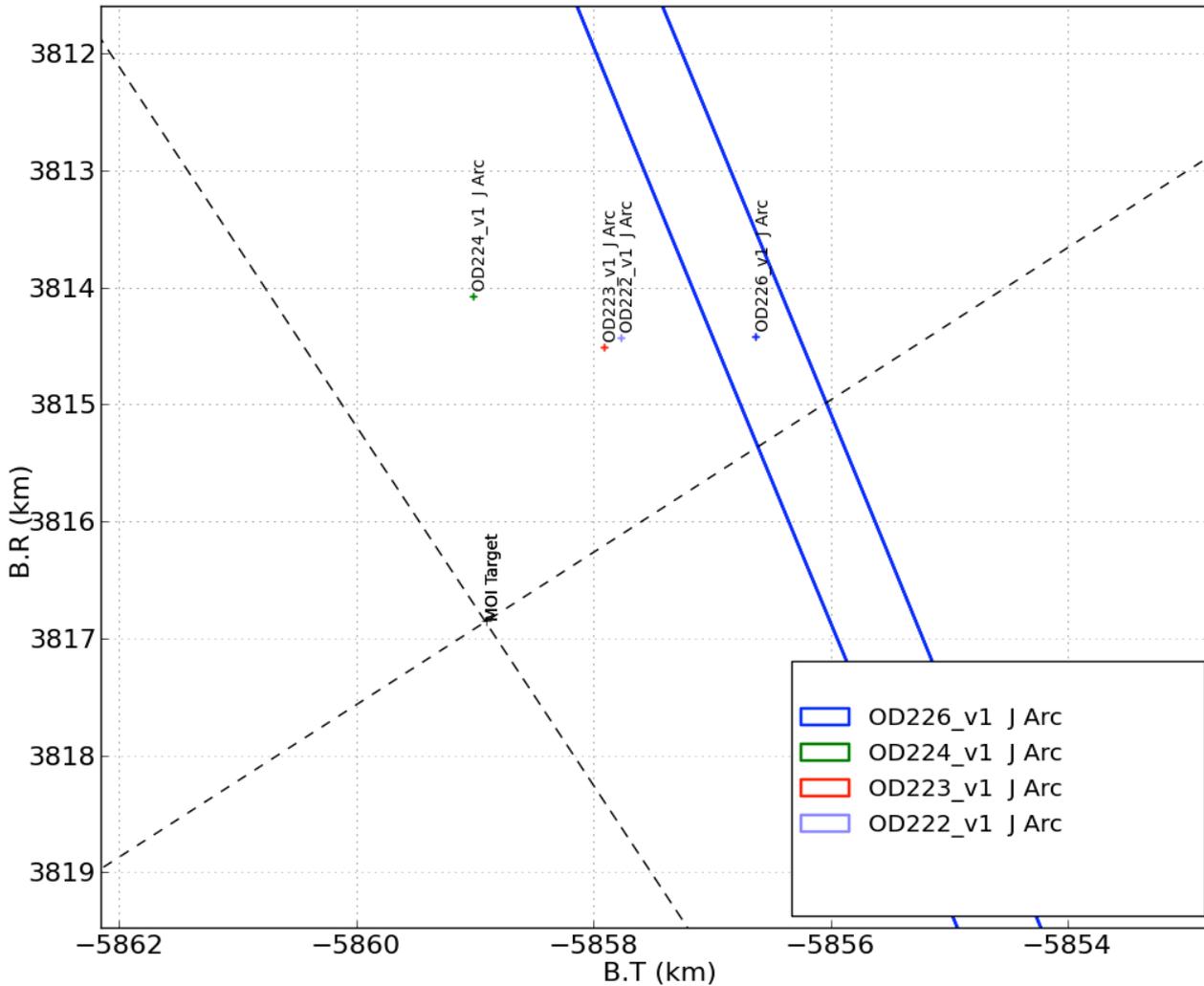


# B-plane 20 Hours Prior to MOI

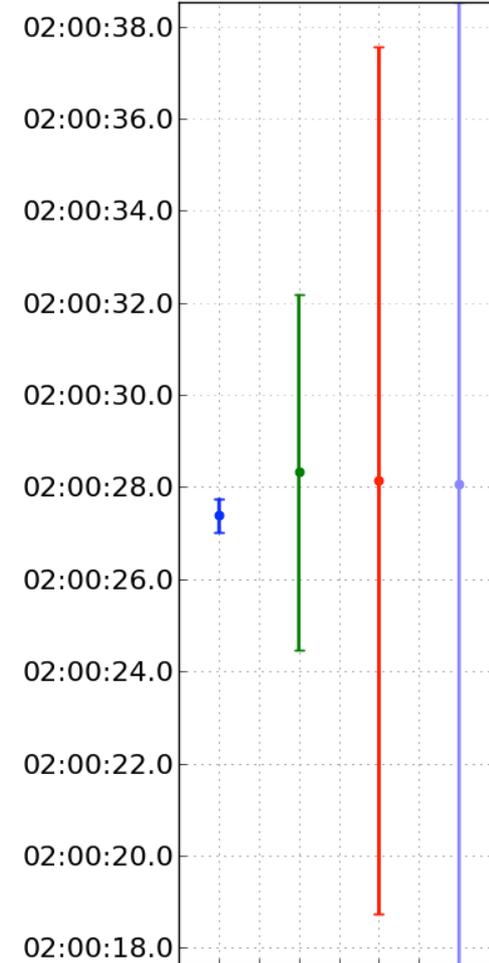


# B-plane Just 2 Hours Prior to MOI

MOM B-Plane Plot, 3-Sigma Ellipses  
EME2000



UTC Arrival Time  
(24-SEP-2014)

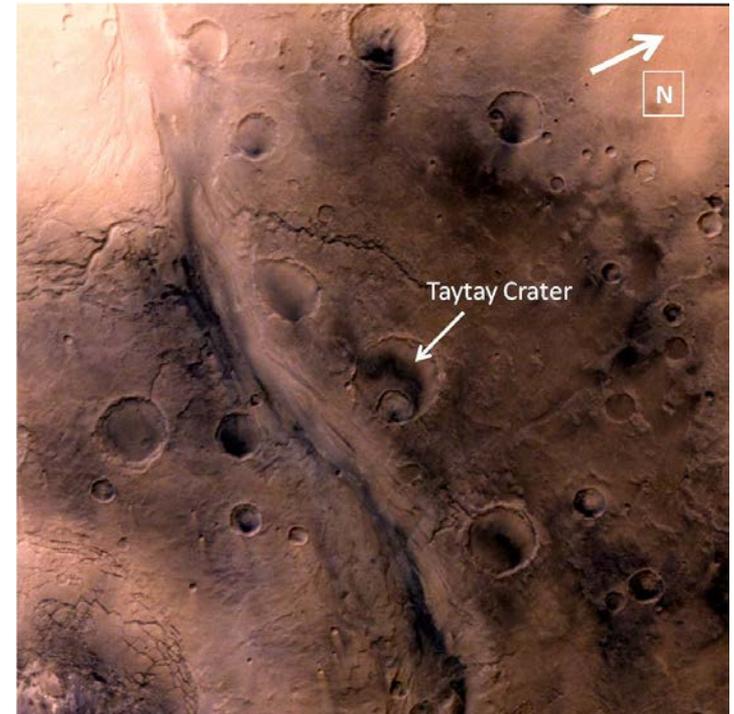
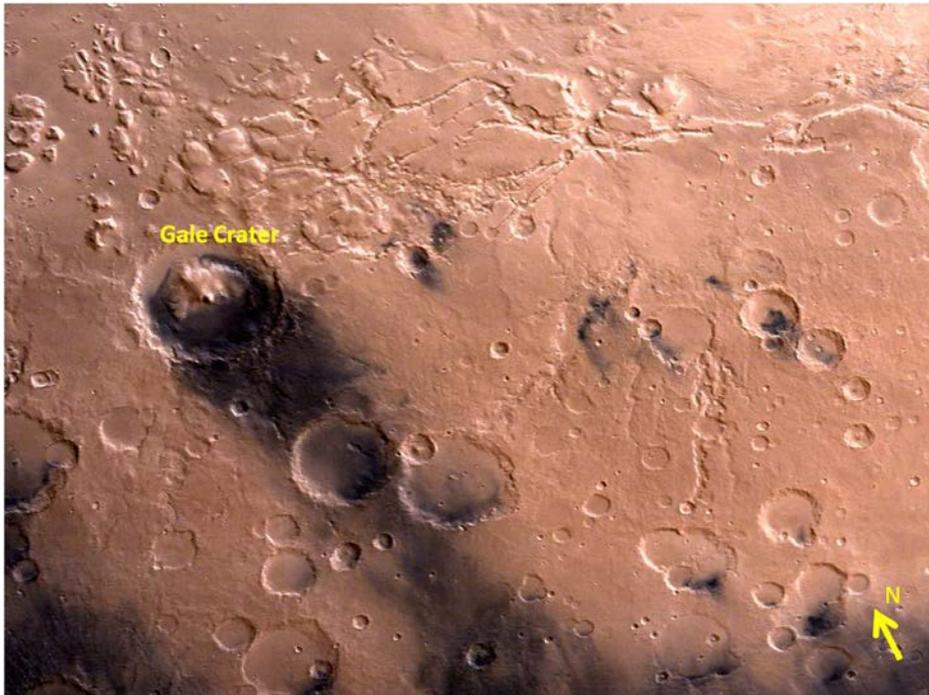


# The Results

*ISRO Mars Orbiter Mission*



# The Results, continued



- Gale Crater and Taytay Crater as seen by Mars Colour Camera
- Pics taken from ISRO MOM website

# Time Magazine – 25 Best Inventions of 2014

*ISRO Mars Orbiter Mission*

THE 25 BEST INVENTIONS OF 2014 FOR THE FUTURE



## THE SUPERSMART SPACECRAFT

MANGALYAN / DEVELOPED BY THE INDIAN SPACE REGIONAL ORGANIZATION

Nobody gets Mars right on the first try. The U.S. didn't, Russia didn't, the Europeans didn't. But on Sept. 24, India did. That's when the Mangalyaan (Mars craft in Hindi) went into orbit around the Red Planet, a technological feat no other Asian nation has yet achieved. **Building the craft cost India just \$74 million, less than the budget for the film Gravity.** At that price, the Mangalyaan is equipped with just five onboard instruments that allow it to do simple tasks like measure Martian methane and surface composition. More important, however, it allows India to flex its interplanetary muscles, which portends great things for the country's space program—and for science in general.

The Mangalyaan is one of just 16 probes to successfully complete a Mars mission since 1960

# Work To Go

- ISRO plans to launch Chandrayaan-2 in 2017
  - Lunar mission with lander and rover
- ISRO plans to launch MOM-2 in 2020
- JPL plans to continue support these missions in a similar capacity



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