Initial Navigation Analysis for the Europa Multiple Flyby Mission Concept

Sumita Nandi (presenter), Brent Buffington, Julie Kangas, Powtawche Valerino, Dylan Boone, Rodica Ionasescu

Jet Propulsion Laboratory, California Institute of Technology

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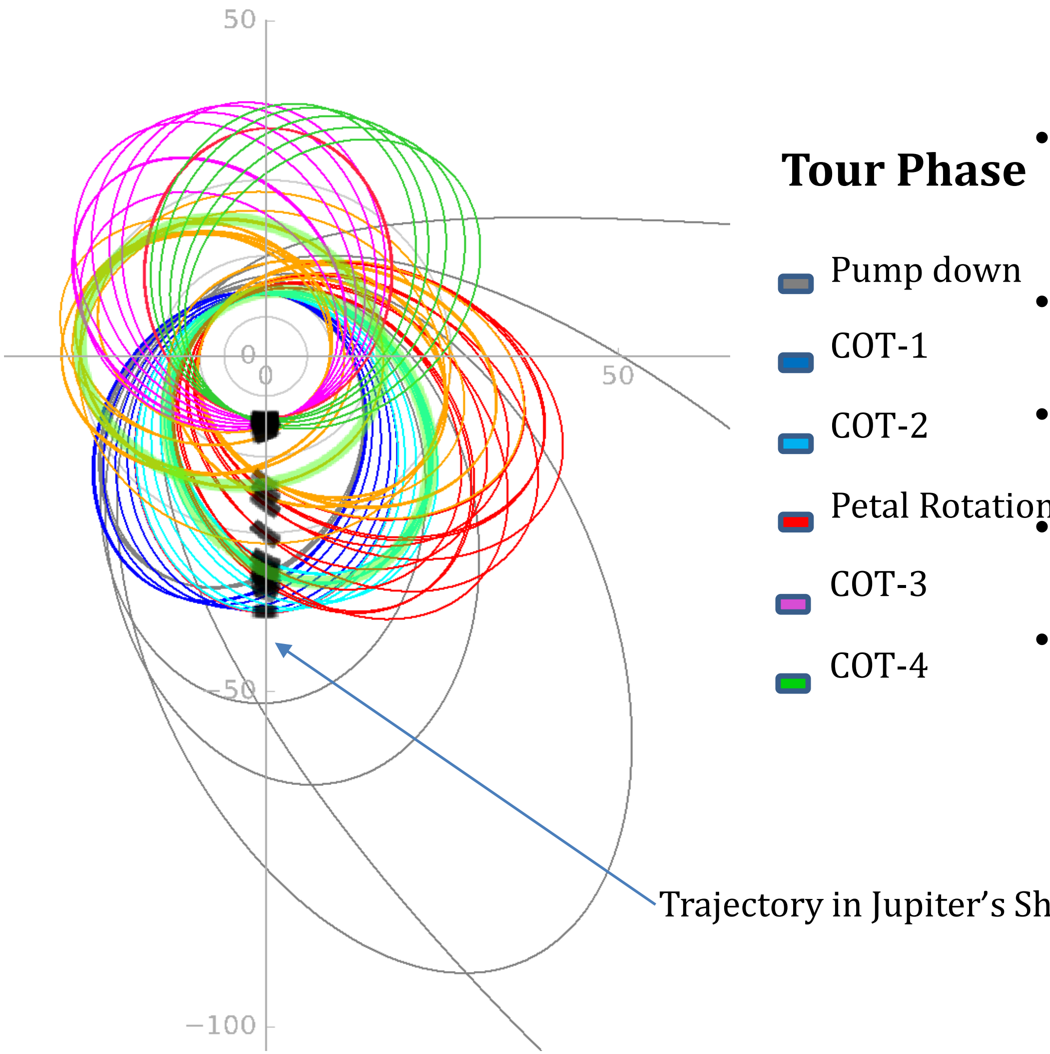
Jet Propulsion Laboratory
California Institute of Technology

Agenda

- Reference trajectory overview
- Navigation concept description
- Navigation analysis process description
- Analysis results for Europa Mission Concept baseline trajectory
  - Expected Encounter Delivery Knowledge
  - Expected ΔV budget

Europa Mission Concept Reference Trajectory



- Use multiple targeted flybys of Europa to create opportunities for science observation
- Reference Tour trajectory shaping using Jovian satellite flybys
- Europa Observation opportunities globally distributed
- Most observation opportunities during 'Crank-over-the-top' sequences
- Equatorial observation opportunities during 'Petal Rotation' phase

Pre-Decisional Information -- For Planning and Discussion Purposes Only

Navigation Concept Description

Notional Success Criteria

What makes a reference trajectory potentially navigationally feasible?

- Trajectory dispersions can be kept small enough to:
  - Meet notional instrument science pointing needs (this is likely to be the most challenging item)
  - Keep expected ΔV budget within baselined mass allocation
  - Locate the spacecraft for communications

Navigation Concept Description

Potential Challenges

What are the navigational challenges for Europa Mission Concept reference trajectory?

- The in-flight behavior of a spacecraft will always diverge from a planned reference due to
  - Uncertainties and simplifications in the physical models used
  - Unexpected events in flight
  - Specific such items include: the uncalibrated portion of non-gravitational forces on a spacecraft, uncertainties in the gravity of natural bodies, and dispersions in the execution of maneuvers required to implement the reference trajectory.

Navigation Concept Description

Baseline Implementation

Key Implementation Features Baselined:

- Plan to return the spacecraft to a reference trajectory at the time of targeted flybys (allow deviation when away from targeted flybys)
- Plan to have a purely statistical maneuver three days prior to targeted flybys
- Support the design of deterministic and statistical maneuvers with ground-based Doppler and range measurements with an every other DSN visibility tracking cadence (synergistic with current baseline data downlink strategy)
- Baseline design of reference tour maneuvers using tracking up to one day prior to planned execution time

Navigation Analysis

Overview

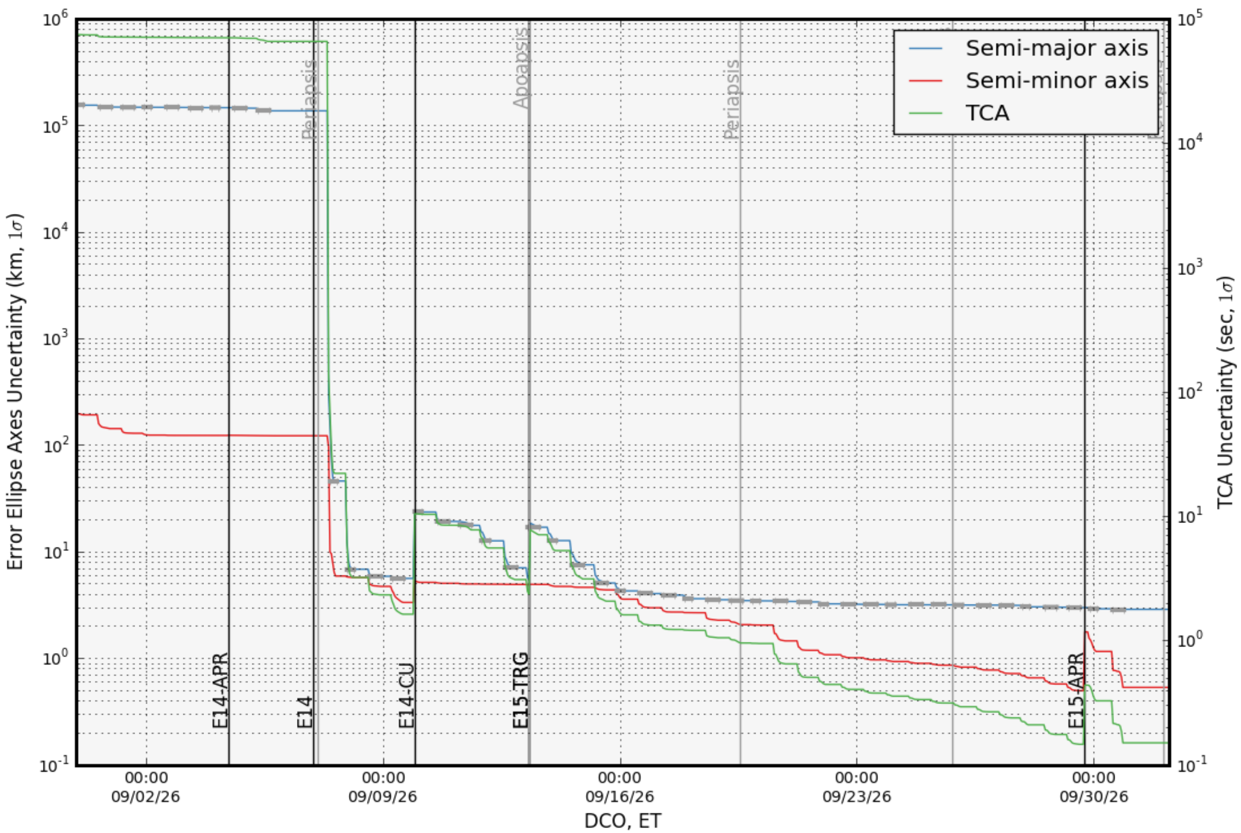
Analysis components:

- **Maneuver Analysis**: Maneuver dispersions determined with Monte Carlo tool
  - Used to calculate baseline mission $\Delta V99$ to be used for predicting potential fuel requirement
  - Used to determine expected covariance for each maneuver
- **Orbit Determination (OD) Analysis**: Covariance Study used to determine expected state errors at times of interest
  - Can be used to assess potential capability against baselined instrument requirements
  - Provides state covariances used in Monte Carlo maneuver dispersion analysis
- **Iteration:** The two components are used in concert, with feedback

Navigation Analysis

Orbit Determination Analysis

Orbit Determination Analysis Framework



Evolution of Error Components During an Arc

- Covariance study broken into 'arcs' for convenience
  - Arcs contain two targeted encounters
  - Typically contain 4 maneuvers (two deterministic)
- Estimated parameters include spacecraft and natural body states, maneuvers, non-gravitational forces
- Consider errors for Earth platform parameters
- Expected improvement in natural body ephemeris is used to initialize subsequent arcs

Navigation Analysis

Orbit Determination Analysis

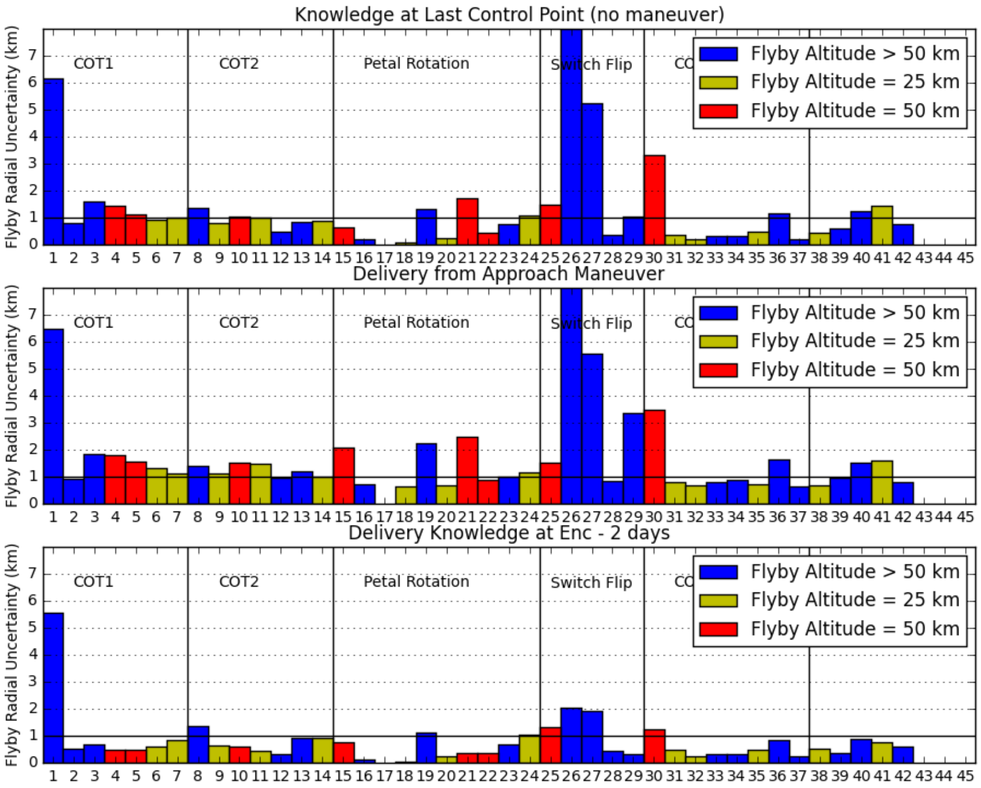
Orbit Determination Analysis Input Assumptions

Tracking Data Schedule	Every other 8 hour pass
Doppler data weight	0.1 mm/s for 60 s sampling for Sun-Earth-Probe (SEP) angles higher than 15°; 1 mm/s between 7.5° and 15°; 5 mm/s below 7.5°; no data used below 3°
Range data weight	3 m for SEP angles higher than 7.5°; no data used below 7.5°.
Tracking exclusion near encounters	No tracking data collected from 12 hours before to 12 hours after the flyby
Un-modeled accelerations	4.5 x 10^{-6} mm/s^2 per axis estimated stochastically as white noise in 8-hour batches
Maneuver design data cutoff	1 days prior to maneuver

Navigation Analysis

Orbit Determination Analysis

Potential Encounter Error Capability



Potential Radial Error Capability (1-sigma) for 15F10-S22 Reference Tour

- Potential capability at three times of interest mapped to targeted encounter
  - Data cutoff for design of approach maneuver at encounter minus 3 days
  - Data cutoff for design of approach maneuver with expected dispersion from maneuver
  - Encounter minus 2 days, including tracking post maneuver

Navigation Analysis

Maneuver Analysis

Analysis flow:

- Statistical maneuvers are inserted using experience-based placement
- For each maneuver (deterministic and statistical):
  - States sampled at maneuver data cutoff times (based on OD covariance study)
  - Maneuvers searched to target encounters (or intermediate states)
  - Dispersions from execution error model added to each sample
- Total maneuver distribution used to calculate $\Delta V99$
- Executed-designed distribution used for OD analysis input

Navigation Analysis

Maneuver Analysis

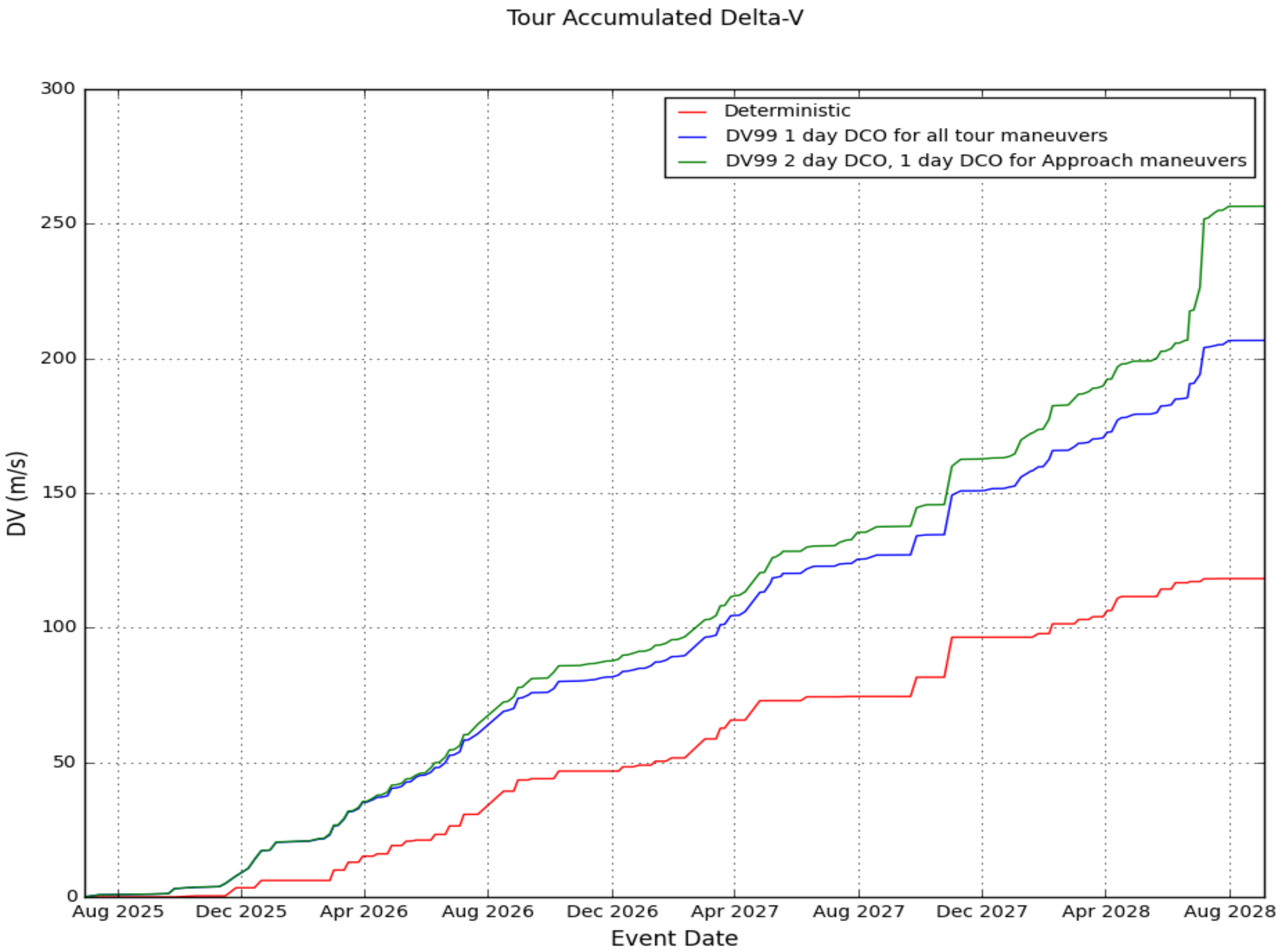
Baseline Maneuver Execution Error Model Gates Parameters(One-sigma)

		8x22N Configuration	4x22N Configuration
Magnitude	Fixed Error (mm/s)	4.67	4.67
	Proportional Error	0.33%	1.00%
Pointing	Fixed Error (mm/s)	3.33	3.33
	Proportional Error (mrad)	6.67	6.67

Navigation Analysis

Maneuver Analysis

∆V99 Expected Baseline for 15F10-S22 reference tour



Conclusions

- Potential capability of a ground-based navigation strategy using radiometric data has been developed
- Encounter delivery knowledge of 1 km would be possible for most encounters in the reference tour analyzed
- The statistical ΔV cost of the reference tour is similar to its deterministic cost (both about 100 m/s)

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