Preliminary Analysis of Ground-Based Orbit Determination Accuracy for the Wide Field Infrared Survey Telescope (WFIRST)

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The Wide Field Infrared Survey Telescope

- **WFIRST**
  - 2.4-meter space telescope, 100x field of view of Hubble
  - Planned launch in 2026 to Sun-Earth L₂
  - Studying dark matter, exo-planets, galaxy structure
  - Requires frequent momentum unloads

- **Ongoing navigational study**
  - Determine appropriate ground station configuration
  - Estimate achievable orbit solution accuracy
  - Quantify navigational impact of momentum unloading
Outline

Preliminary Analysis

– Ground station characterization

Covariance Analysis

– Preliminary tracking schedule study
– Launch to midcourse correction
– Post midcourse correction
– Orbit insertion

Simulated Operations

– Configuration
– Results
Ground Station Characterization

• **Metric Tracking Data Evaluation (MTDE)**
  – Ongoing effort in the Flight Dynamics Facility (FDF)
  – Quantifies quality of incoming tracking data
  – Orbit solutions for 38 spacecraft from 50 tracking sources
  – Reports stats for each pass

• **Studies use aggregate of MTDE data**
  – Mean & standard deviation of residuals over 1 year
  – Focused on “similar” Lagrange point orbits
WFIRST Planned Trajectory
Early Orbit Covariance Analysis

- **Linear covariance analysis in ODEAS**
  - Orbit Determination Error Analysis System
  - Propagates parameter uncertainties through orbit trajectory
  - Quantifies expected batch solution error

- **Intended as a preliminary study**
  - Initial pass at choosing required ground stations & schedule
  - First look at orbit solution accuracy

<table>
<thead>
<tr>
<th>Station Location</th>
<th>Station ID</th>
<th>Organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goldstone, California</td>
<td>DS24</td>
<td>DSN</td>
</tr>
<tr>
<td>Canberra, Australia</td>
<td>DS34</td>
<td>DSN</td>
</tr>
<tr>
<td>Madrid, Spain</td>
<td>DS54</td>
<td>DSN</td>
</tr>
<tr>
<td>Santiago, Chile</td>
<td>AGOS</td>
<td>NEN</td>
</tr>
<tr>
<td>White Sands, New Mexico</td>
<td>WS1S</td>
<td>NEN</td>
</tr>
<tr>
<td>New Norcia Station, Australia</td>
<td>NN1D</td>
<td>ESA</td>
</tr>
</tbody>
</table>
Preliminary Tracking Schedule Study

- Position results from 21 days of mission orbit
  - Quantifies peak position solution error
  - Assume 1 mm/s momentum every 18 hours
  - Best-case error of 4-5 km
Preliminary Tracking Schedule Study

- Velocity results from 21 days of mission orbit
  - Quantifies peak velocity solution error in cm/s
  - Best-case error of 2-3 mm/s
Ground Station Configuration

• **Current planned schedule**
  – Includes Madrid (DS54), White Sands (WS1S), and Dongara, Australia (USPS)
  – Dongara geometrically similar to Canberra
  – Distinct schedules for early orbit and operational
Launch to Midcourse Correction

- **Orbit error at first maneuver (L + 25h)**
  - Quantifies error vs total tracking data span
  - Assumes constant coverage
  - < 10% error due to noise for convergence
  - **Conclusion:** At least 12 hours of data required
Post Midcourse Correction

- **Orbit error after first maneuver (L > 25h)**
  - Quantifies 1-week prediction error vs total tracking data span
  - Assumes constant coverage
  - Assumes no orbit knowledge after maneuver
  - **Conclusion:** At least 24 hours of tracking data required
• **Orbit error at L₂ orbit insertion**
  
  – Quantifies error vs total tracking data span
  – Assumes operational tracking schedule
  – **Conclusion:** At least 21 days of tracking data required
Mission Orbit Simulated Operations

- **Filter-based simulation to mirror operations**
  - Once-daily orbit solutions
  - One year simulation span
  - Accuracy measured through ephemeris compares

- **Filter configuration similar to previous study**
  - Assume mission orbit tracking schedule
  - Momentum unloads not modeled in filter
  - Stationkeeping every 21 days
  - Three momentum unloading configurations: 18, 40, 200 hours
Results

• Results for first year on mission orbit
  – Quantifies error vs orbit prediction span
  – **Conclusion:** Without modeling, more frequent unloads are desirable
  – **Conclusion:** Expected 1-day prediction accuracy of 3-4 km and 1 cm/s
  – Stationkeeping maneuvers dependent on error
Conclusions

• **Studies are ongoing**
  – This work represents current understanding
  – Spacecraft parameters remain in flux
  – Mission requirements in development

• **Covariance study captures early-orbit behavior**
  – Around MCC-1: 12-24 hour span required
  – Prior to orbit insertion: 21 day span required
  – Mission orbit: at least two hours of tracking/day

• **Filter study captures mission-orbit behavior**
  – Expect 3-4 km, 1 cm/s error for 1-day prediction
  – Without modeling, more frequent momentum unloads → lower impact