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

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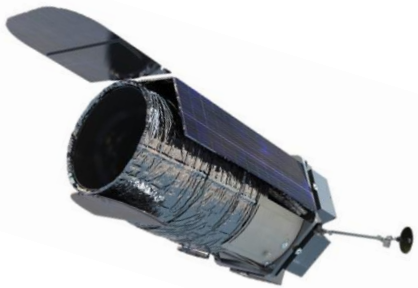
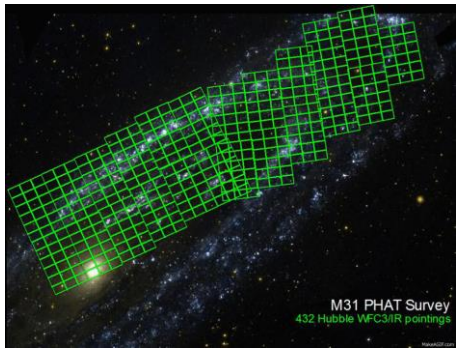
The Wide Field Infrared Survey Telescope

- **WFIRST**
  - 2.4-meter space telescope, 100x field of view of Hubble
  - Planned launch in 2026 to Sun-Earth L_2
  - Studying dark matter, exo-planets, galaxy structure
  - Requires frequent momentum unloads



NASA WFIRST Mission Website, https://wfirst.gsfc.nasa.gov/about.html



- **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

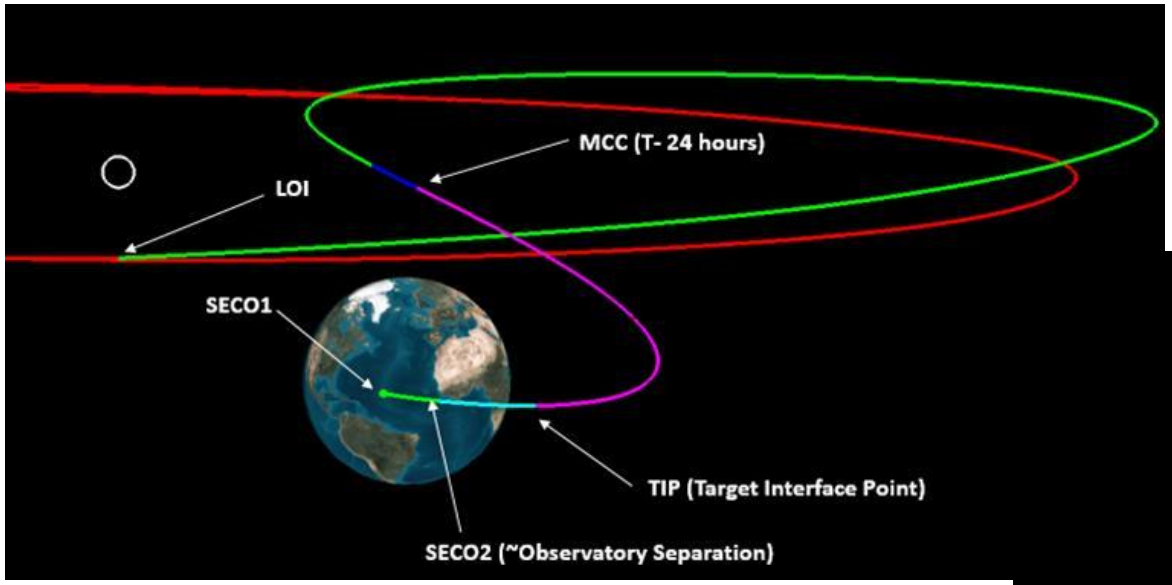
- Configuration
- Results

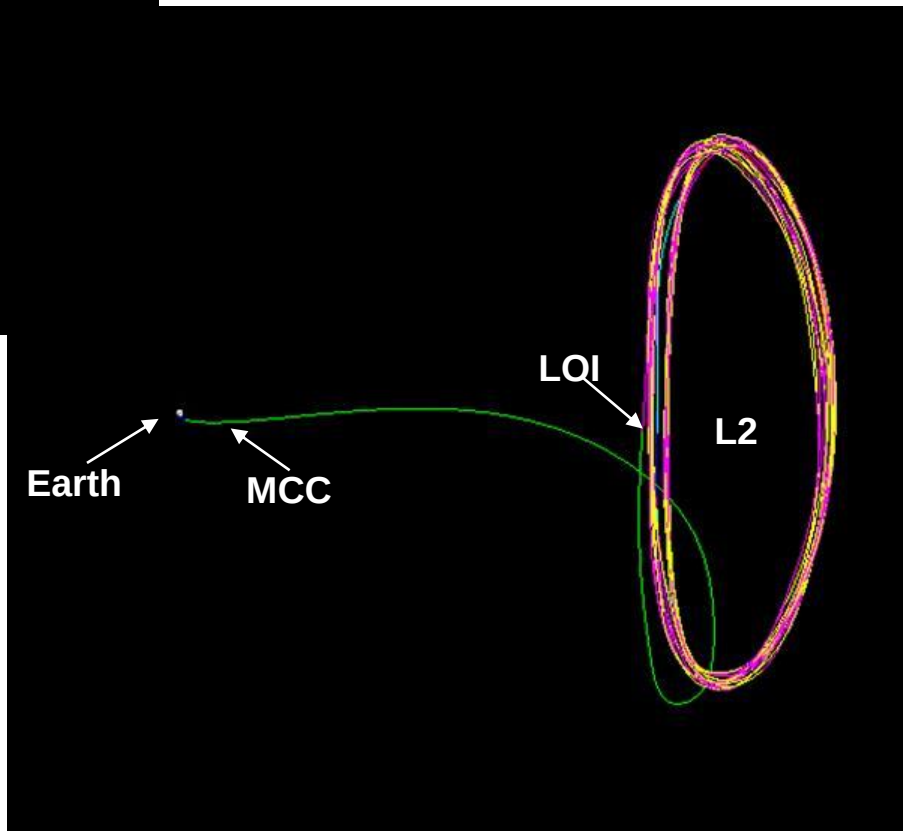
Ground Station Characterization

- **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





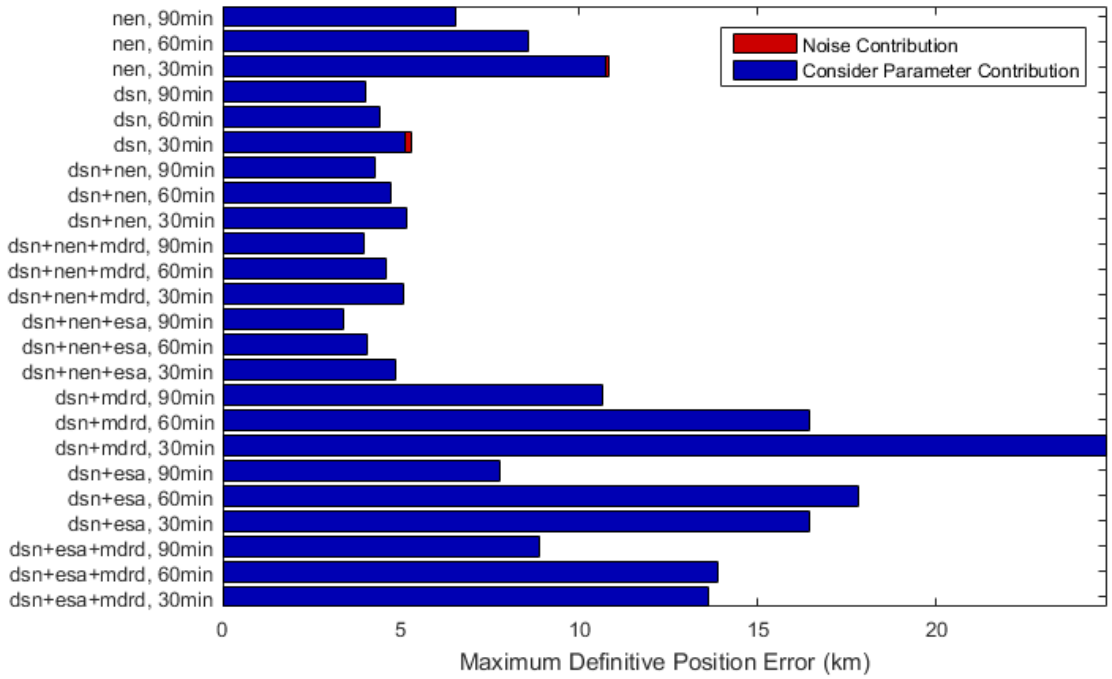
Early Orbit Covariance Analysis

- **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

Station Location	Station ID	Organization
Goldstone, California	DS24	DSN
Canberra, Australia	DS34	DSN
Madrid, Spain	DS54	DSN
Santiago, Chile	AGOS	NEN
White Sands, New Mexico	WS1S	NEN
New Norcia Station, Australia	NN1D	ESA

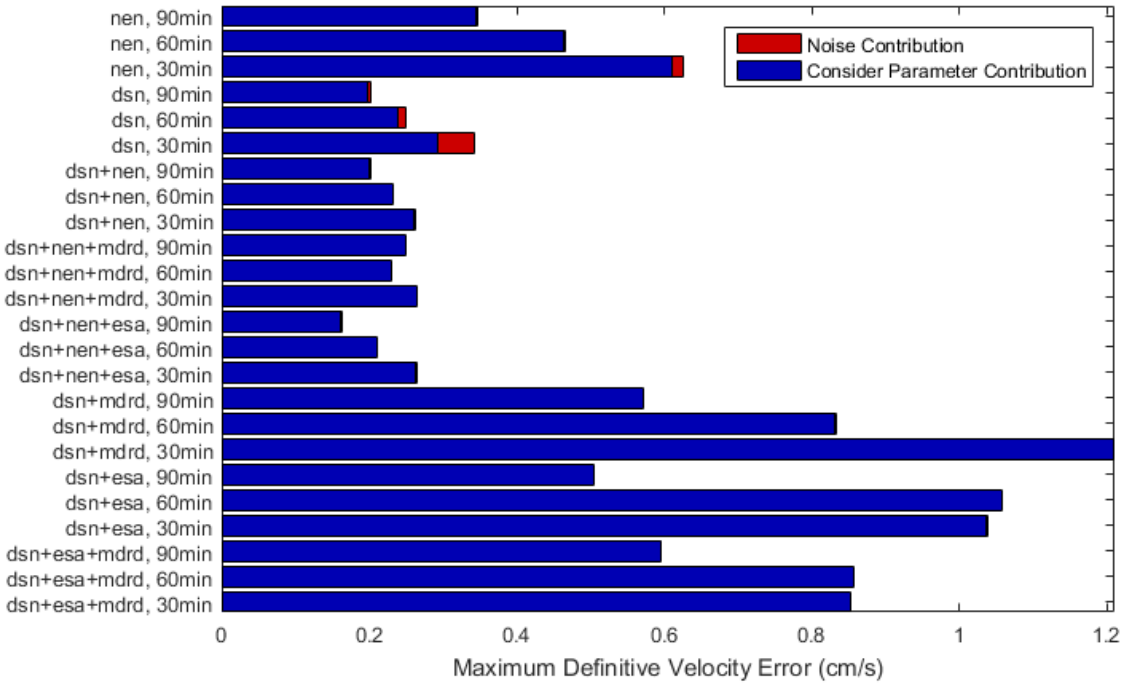
Preliminary Tracking Schedule Study

- **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



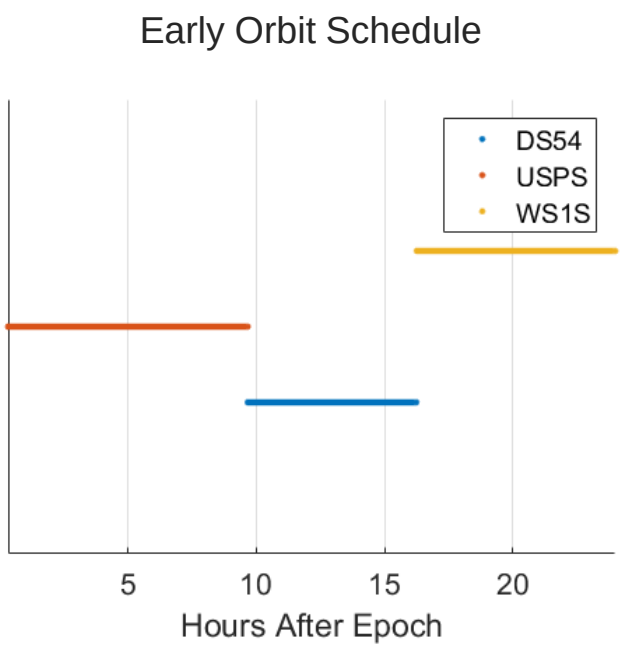
Preliminary Tracking Schedule Study

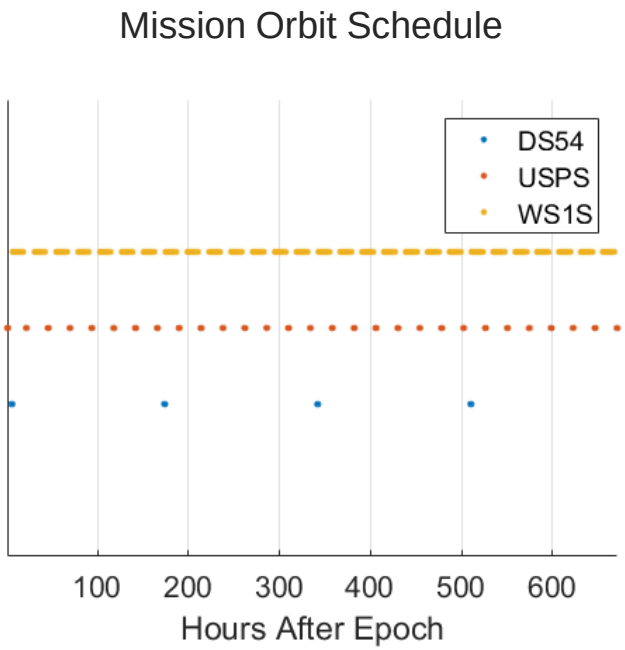
- **Velocity results from 21 days of mission orbit**
  - Quantifies peak velocity solution error in cm/s
  - Best-case error of 2-3 mm/s



Ground Station Configuration

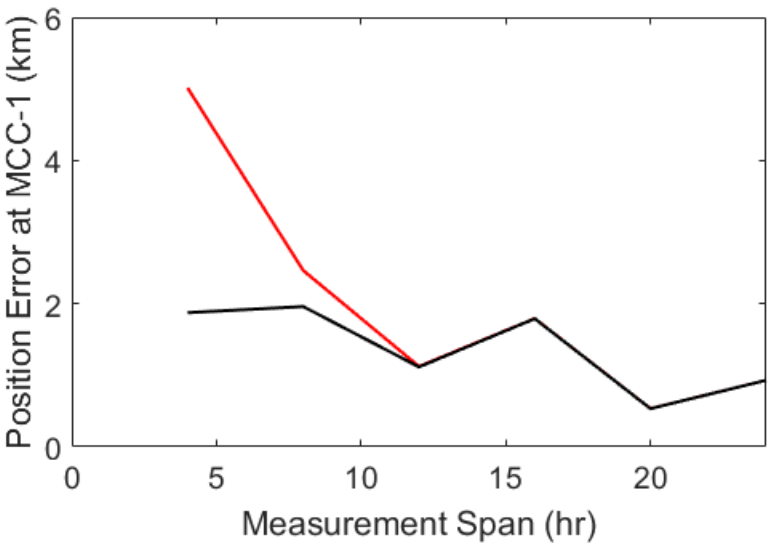
- **Current planned schedule**
  - Includes Madrid (DS54), White Sands (WS1S), and Dongara, Australia (USPS)
  - Dongara geometrically similar to Canberra
  - Distinct schedules for early orbit and operational

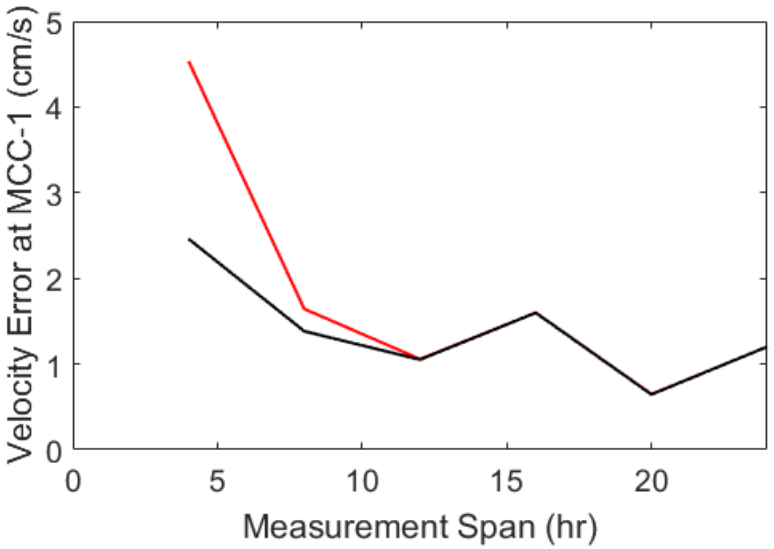




Launch to Midcourse Correction

- **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



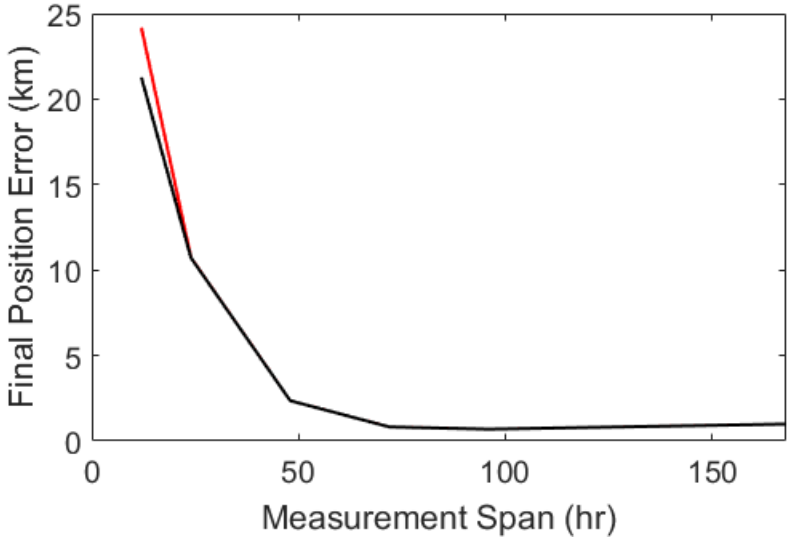


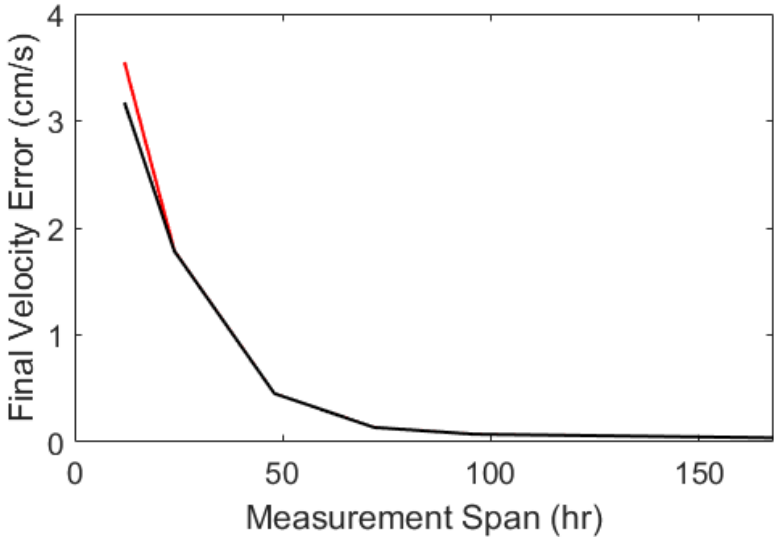
Error with Noise Contribution

Consider Parameter Error Only

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



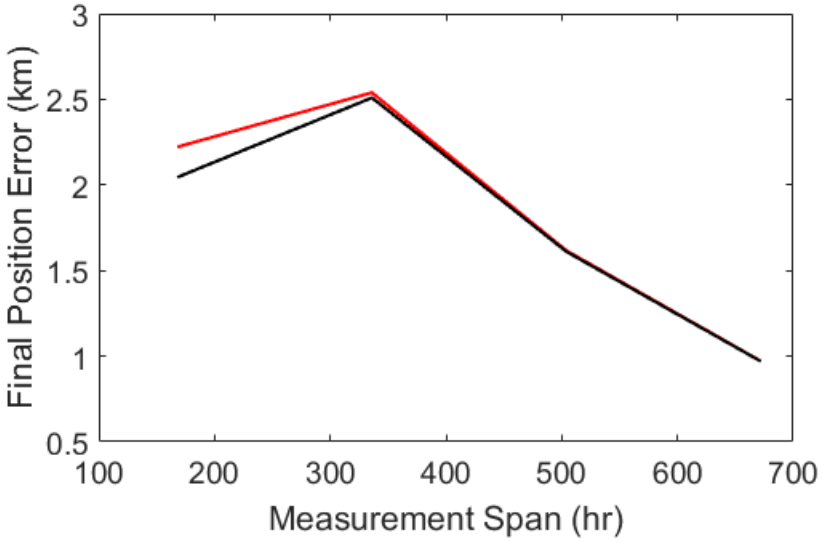


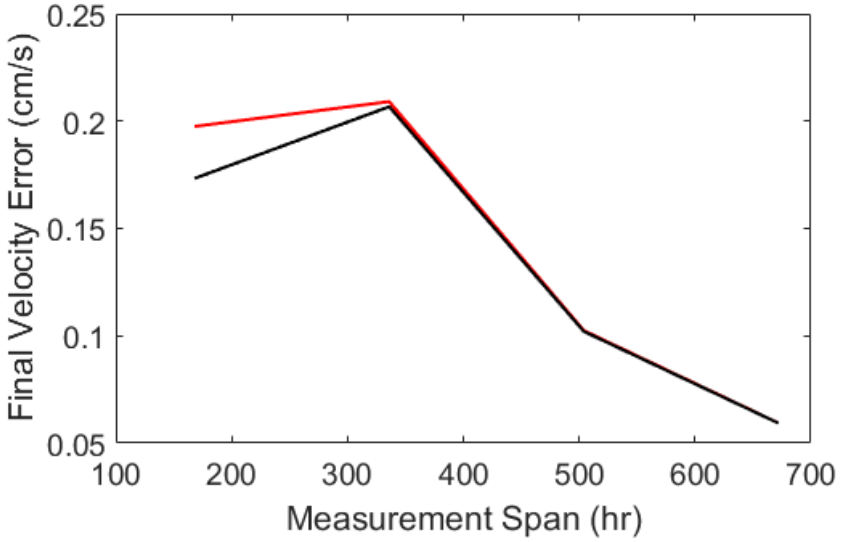
Error with Noise Contribution

Consider Parameter Error Only

Orbit Insertion

- **Orbit error at L_2 orbit insertion**
  - Quantifies error vs total tracking data span
  - Assumes operational tracking schedule
  - **Conclusion:** At least 21 days of tracking data required



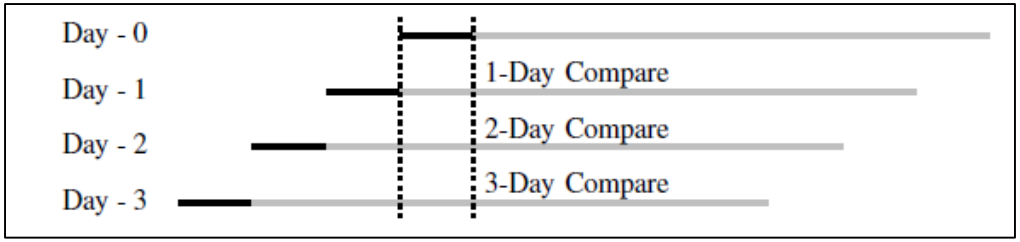


Error with Noise Contribution

Consider Parameter Error Only

Mission Orbit Simulated Operations

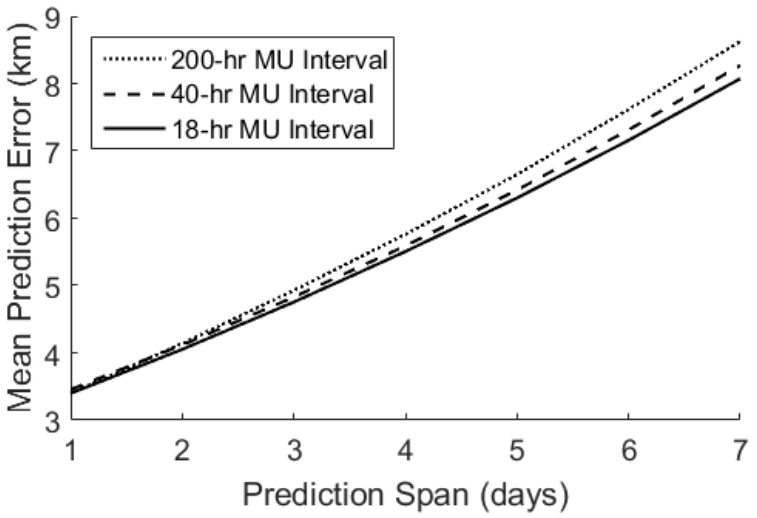
- **Filter-based simulation to mirror operations**
  - Once-daily orbit solutions
  - One year simulation span
  - Accuracy measured through ephemeris compares

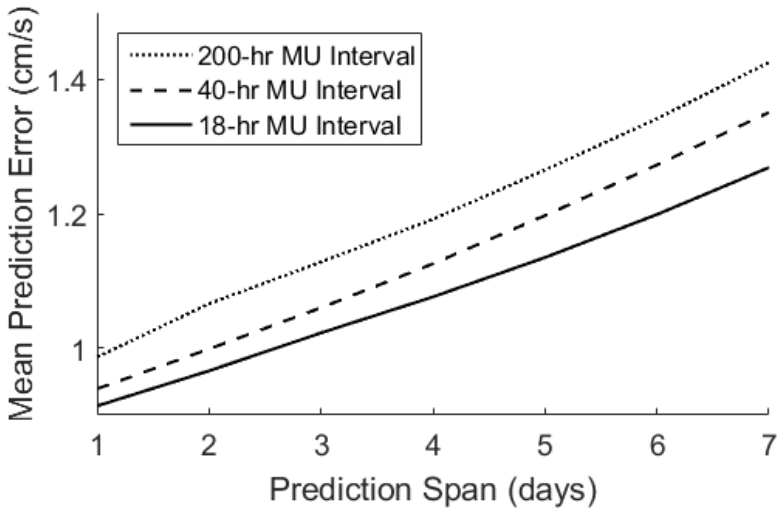


- **Filter configuration similar to previous study**
  - Assume mission orbit tracking schedule
  - Momentum unloads not modeled in filter
  - Stationkeeping every 21 days
  - Three momentum unloading configurations: 18, 40, 200 hours

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