Autonomous Optical Navigation at Jupiter

Nathan B. Stastny
Dr. David K. Geller

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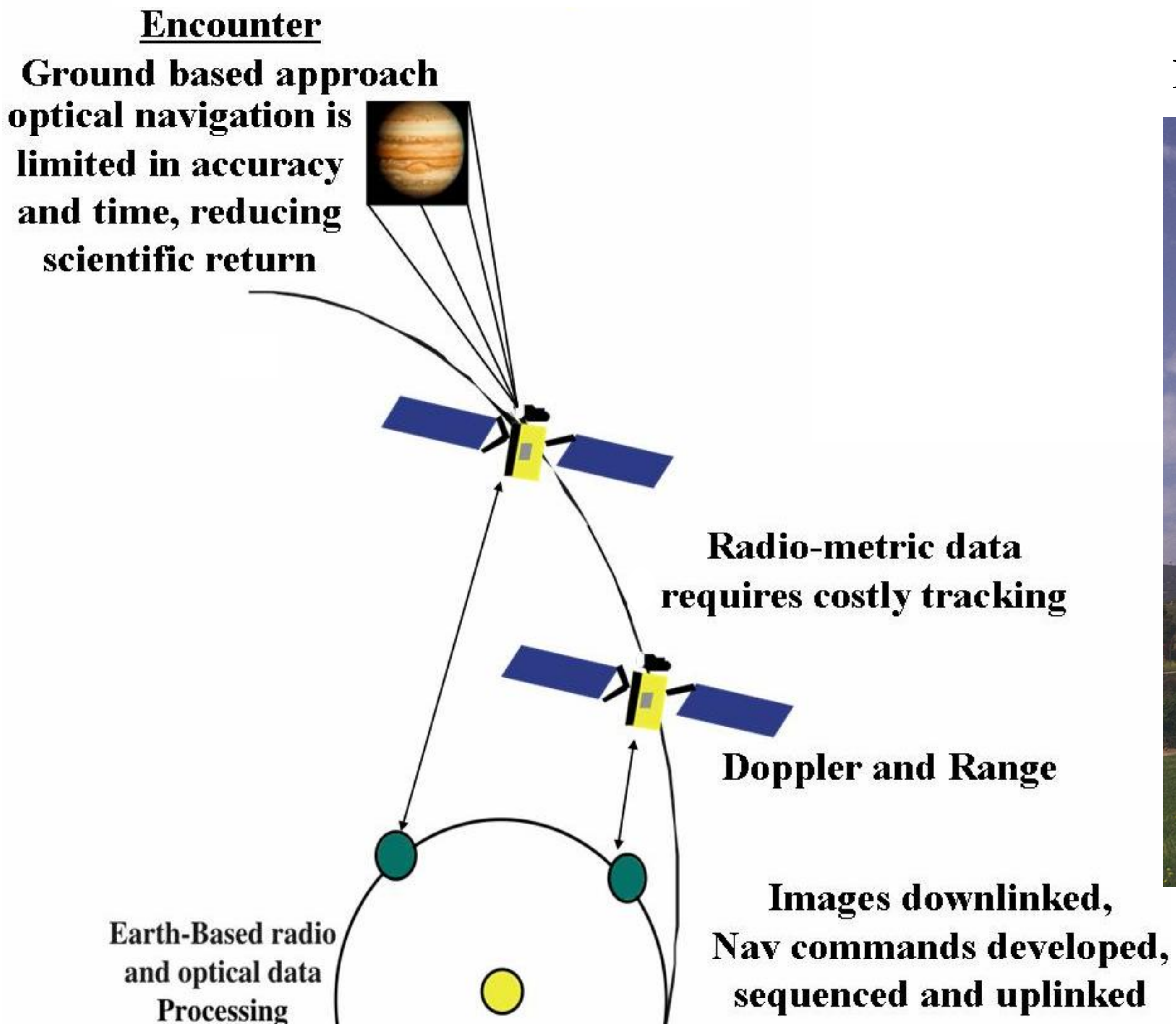
Utah State University
Mechanical & Aerospace Engineering

Outline

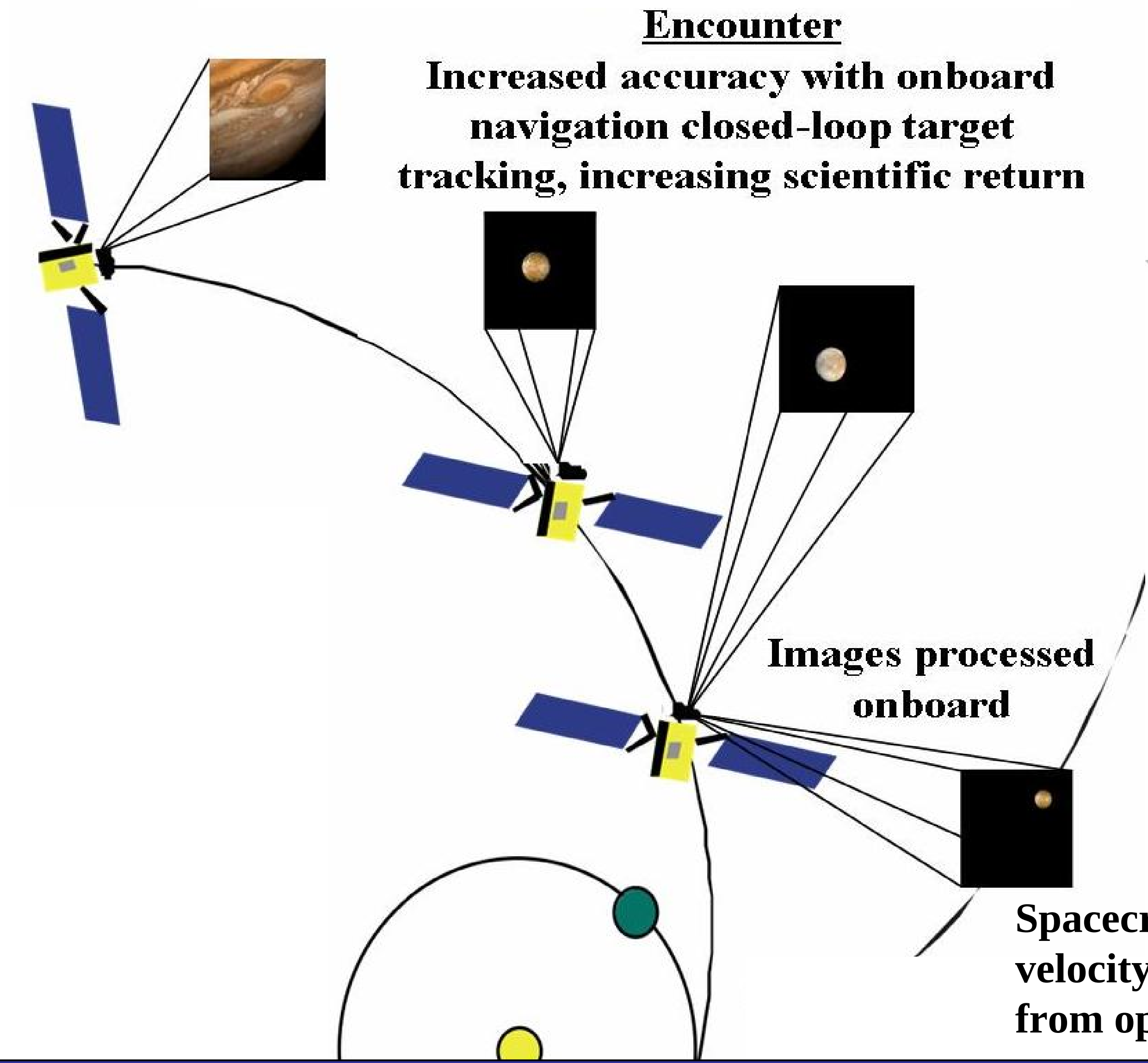
- Conventional vs. Autonomous Optical Interplanetary Navigation
- AutoNav at Jupiter
- Dynamic Models for Simulations
- Position and Velocity Estimation
- Analysis Tools
- Future Research

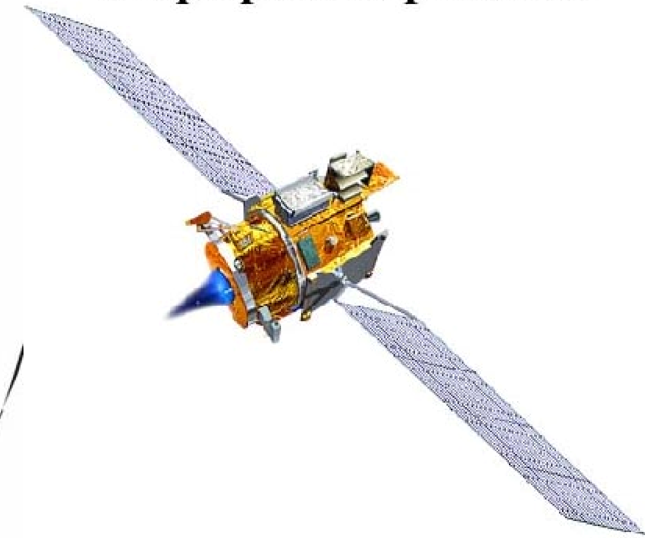
Conventional Interplanetary Navigation



Deep Space Network - DSN

Autonomous Optical Navigation (AutoNav)





- Can an AutoNav system be used for orbit insertion and orbit determination around Jupiter?
- What are the key parameters that affect system accuracy?
- Research:
  - Baseline: NASA's proposed Juno mission
  - Navigation: Line-of-sight optical measurements of Jupiter's moons
  - Performance Analysis: Linear Covariance

Truth Models

- Dynamic models required for simulation and analysis:
  - Spacecraft Trajectory
  - Jovian System Model

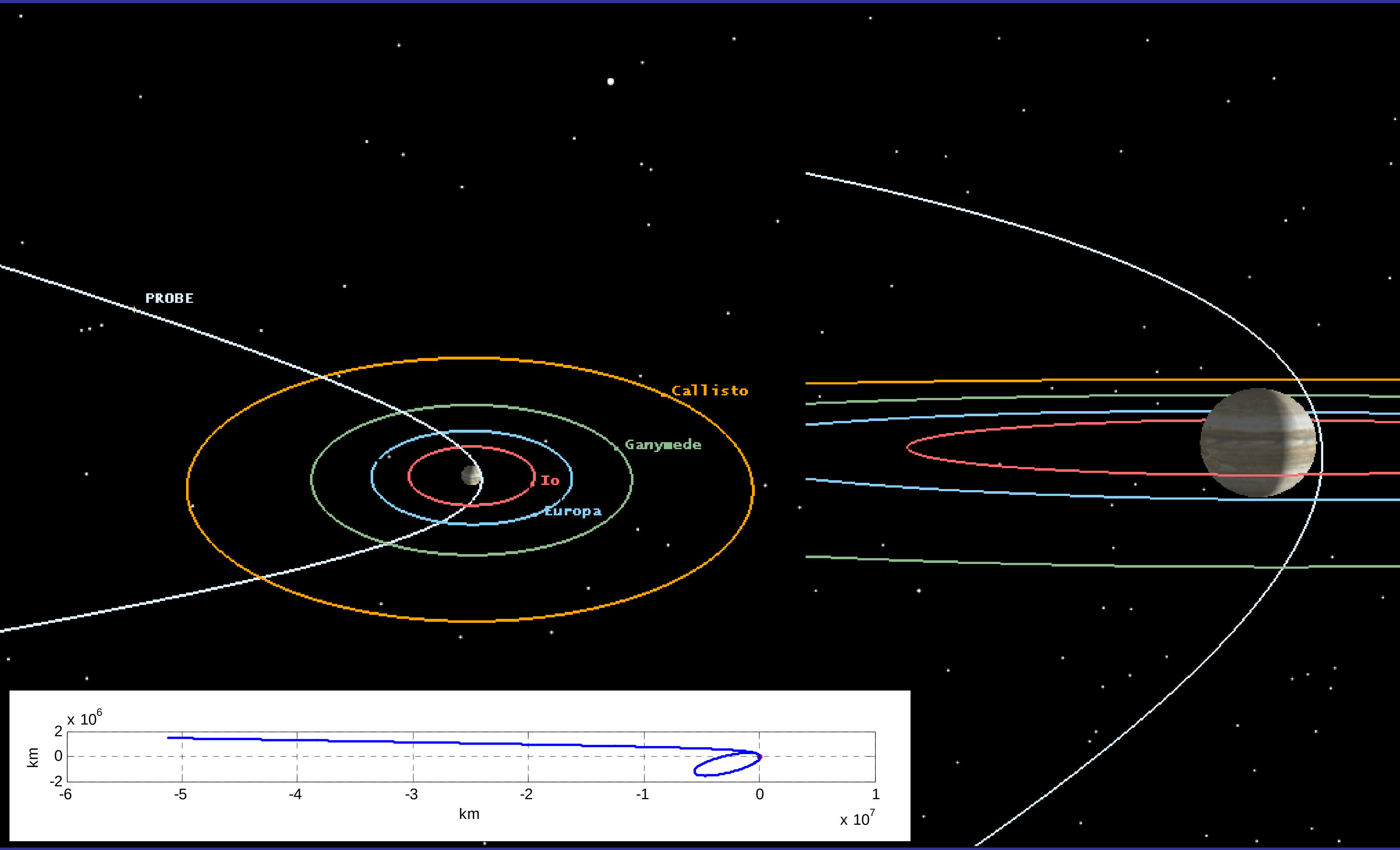
Truth Models – Spacecraft Trajectory Development

- Two general trajectory segments:
  - Hyperbolic approach
  - Polar orbit ($e \approx 0.97$)

- Point-mass plus J2 Gravitational Model

- Additional perturbations (n-body, J3, J4, etc) are not included, but are accounted for as random disturbances

Truth Models – Spacecraft Trajectory



Truth Models – Jovian System

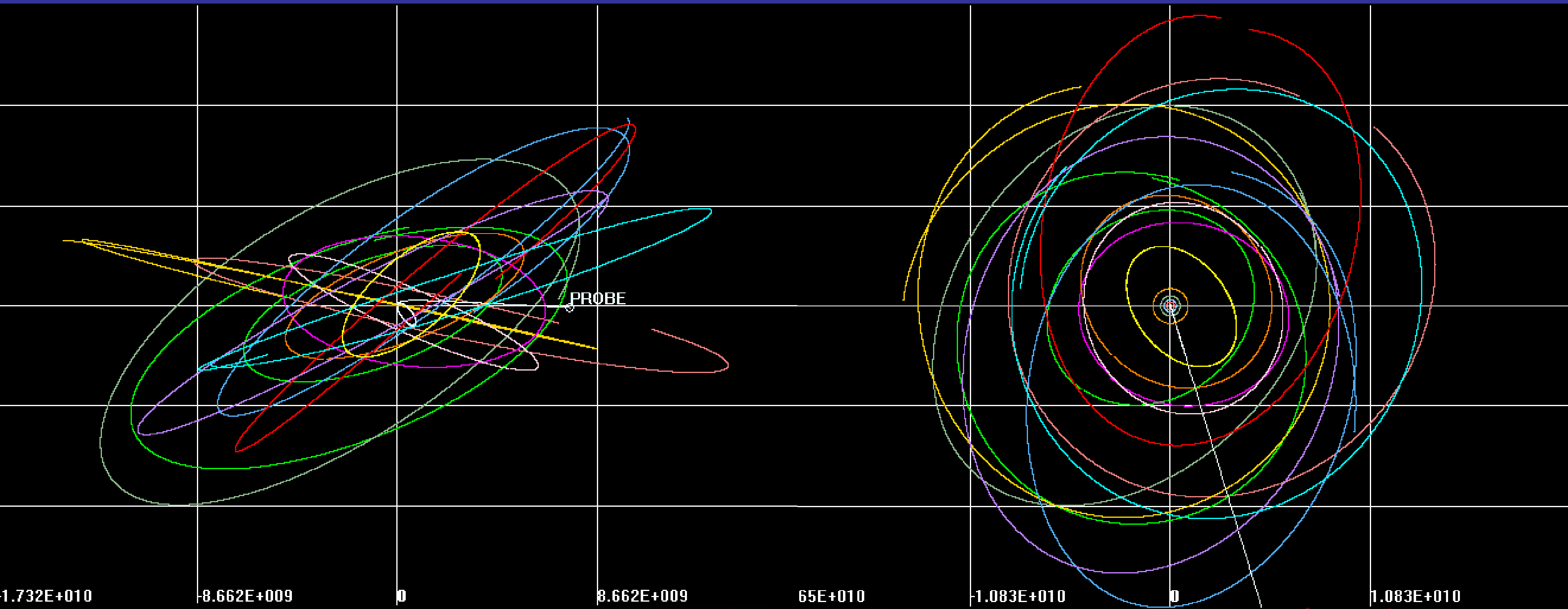
- Jupiter, with 63 known moons, is a very complex system to model
- Utilize "SPICE" to obtain accurate ephemerides
- SPICE is provided by NASA's Navigation and Ancillary Information Facility (NAIF) at JPL
- High-accuracy data similar to that flown on DS1 and Stardust AutoNav systems

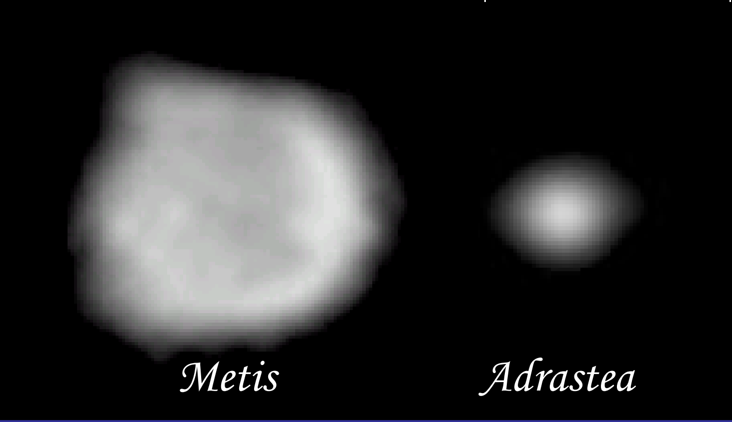
Truth Models – SPICE Ephemeris Data Files

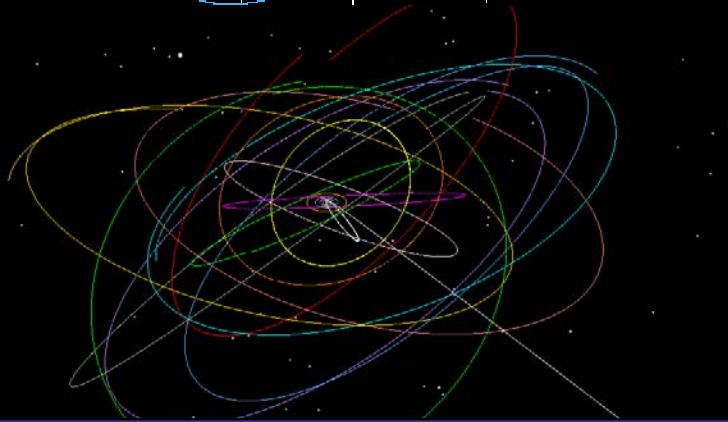
- SPICE
  - Spacecraft, Planet, Instrument, C-Matrix (Attitude), Events

- Used at JPL for
  - Pre-flight evaluations
  - Modeling
  - Analysis
  - Planning
  - Visualization

Jovian Satellite Orbits (17 of 63) from SPICE Data File

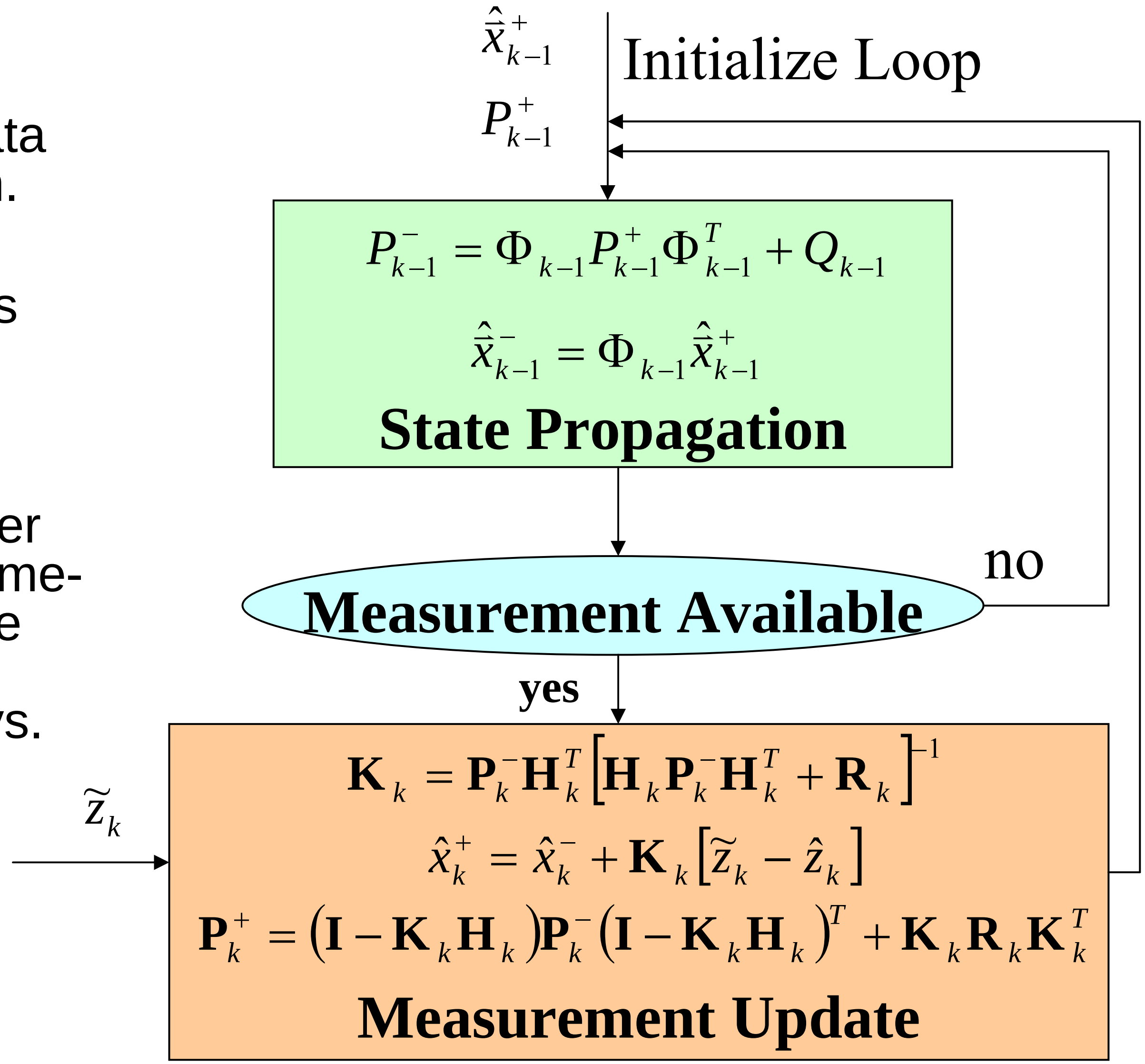






State Estimation – Kalman Filter

- Kalman filter is an optimal, recursive data processing algorithm.
- Estimate spacecraft's position and velocity
- Continuous-discrete extended Kalman filter would allow for the time-critical operations like orbit insertions maneuvers and flybys.



Analysis Tools

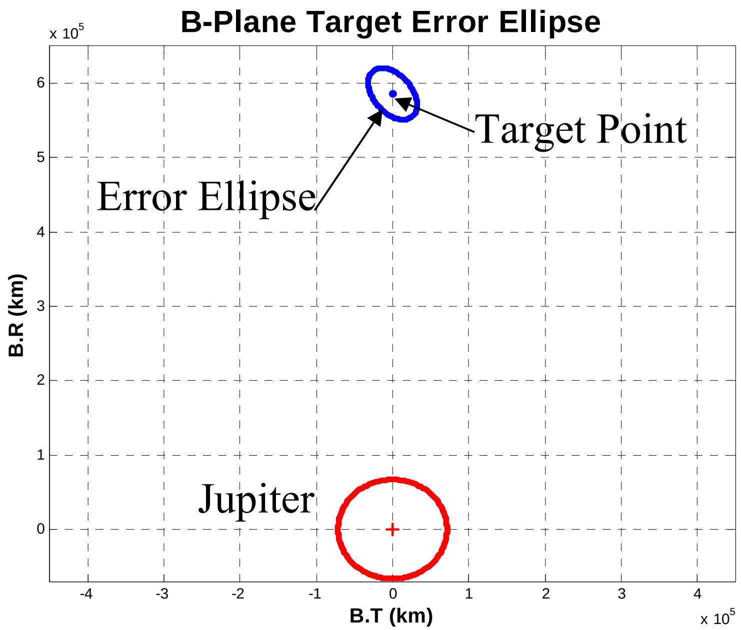
- Monte-Carlo Analysis:
  - Uses model simulation and Kalman filter (with random processes) to obtain results
  - May require hundreds of runs
- Linear Covariance (LinCov) Analysis:
  - Propagates the model using Gaussian distributions rather than random numbers
  - Results can be obtained in a single run
  - Can save lots of time in pre-flight analysis

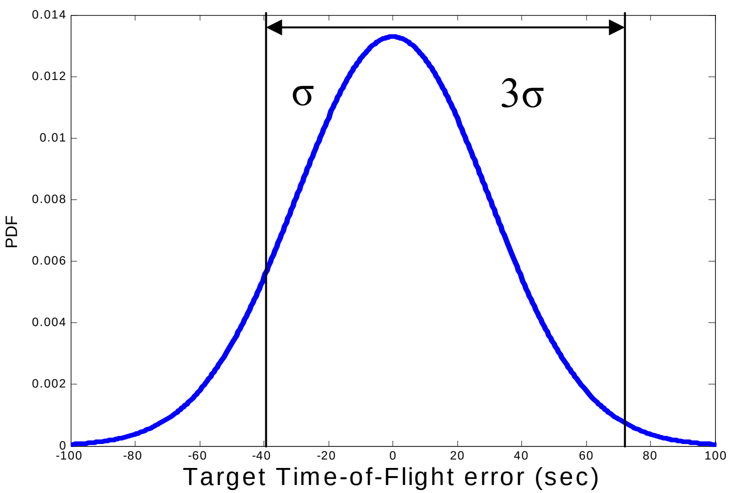
Problem Parameters

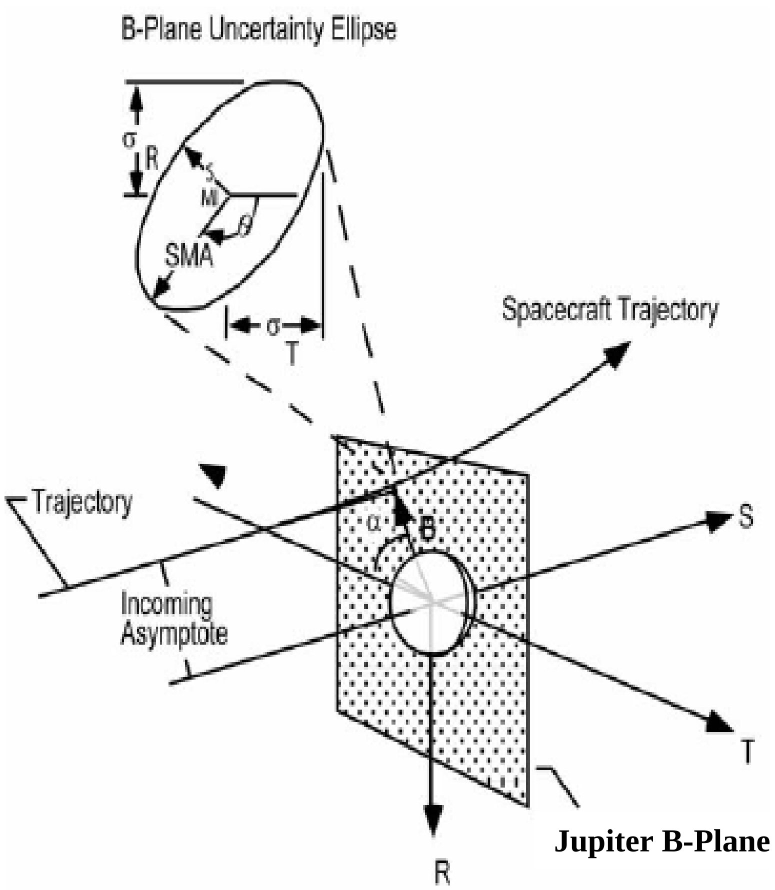
- What are the key parameters affecting the system accuracy?

- Parameters analyzed:
  - *A-Priori* Covariance
  - Accuracy of estimated moon positions
  - Un-modeled accelerations
  - Number of moons imaged & imaging frequency
  - Image Processing Accuracy
  - Noise

Results (Anticipated) – B-Plane Targeting

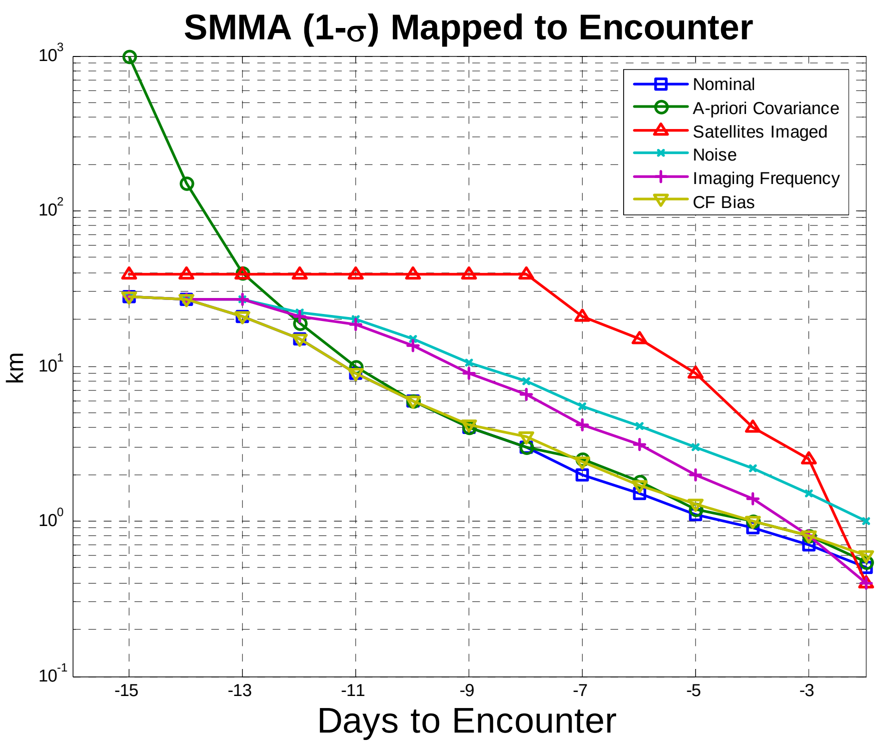


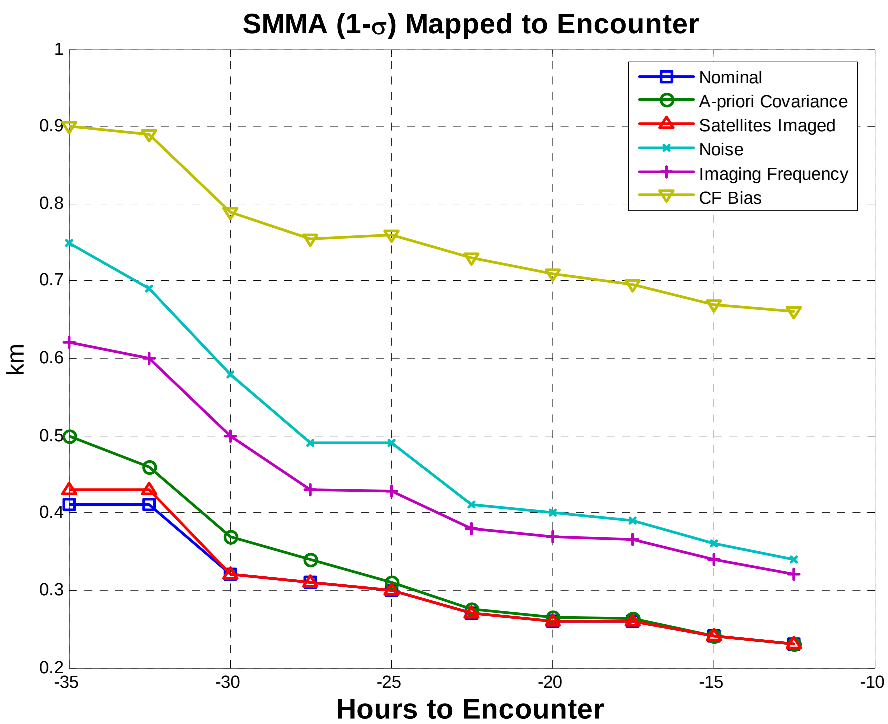




Results (Anticipated) – Problem Parameters

1-σ Semi-Major Axis of B-Plane Error Ellipse Mapped to Encounter





Possible Future Work

- Expand the model from 3-DOF to 6-DOF
- Include correction maneuvers and controls
- Include background stars in optical measurements
- Use simulated images and image processing algorithms

Summary

- AutoNav Systems
- Truth Models
  - Spacecraft Trajectory
  - SPICE
- Kalman Filter
- LinCov Analysis
- Problem Parameters
- Anticipated Results

Questions?