



Quantification of interplanetary laser ranging system requirements through bottom-up link simulations

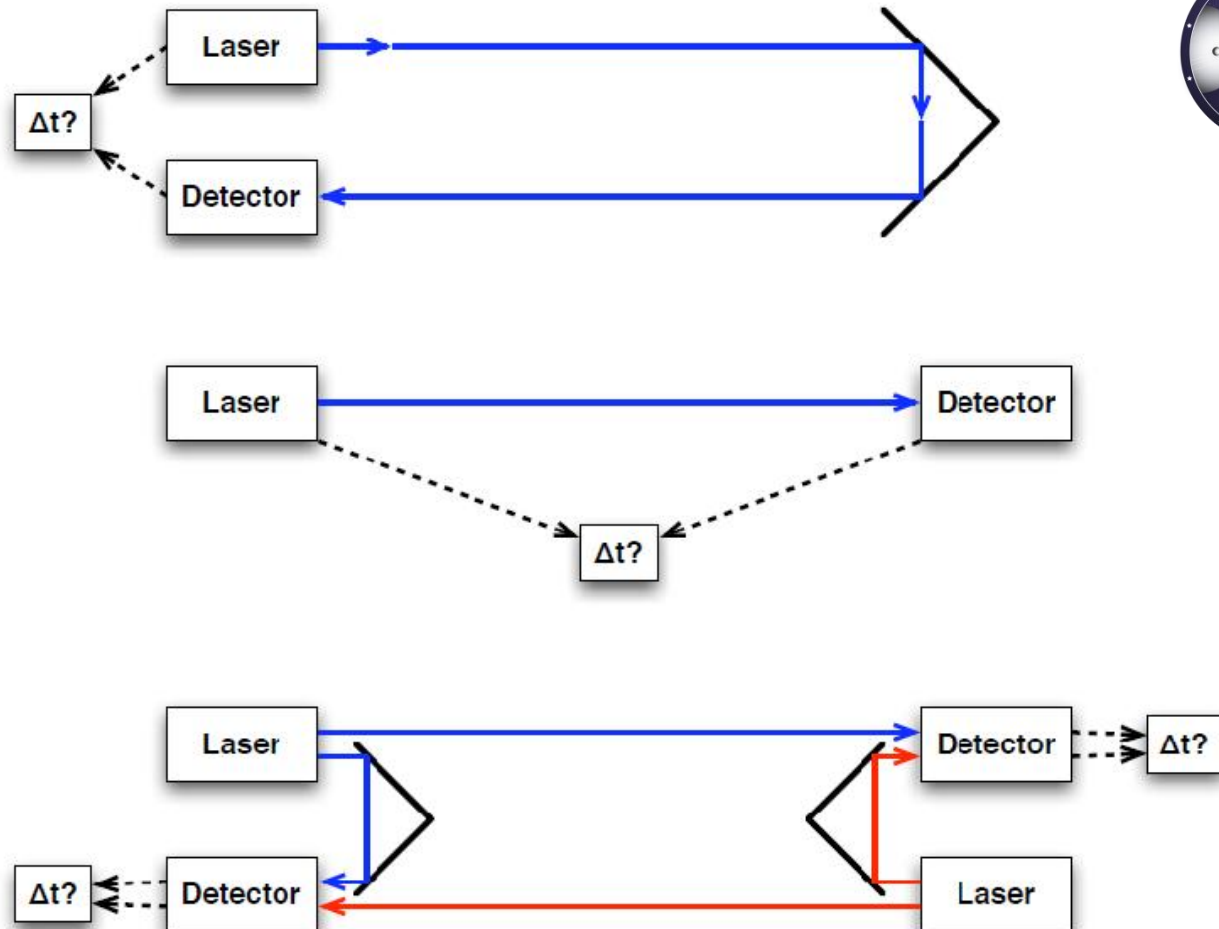
D. Dirks, B. Vermeersen, R. Noomen, P. Visser

Contents



- Interplanetary laser ranging
- Link simulations
 - Hardware
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- Outlook

Interplanetary Laser Ranging



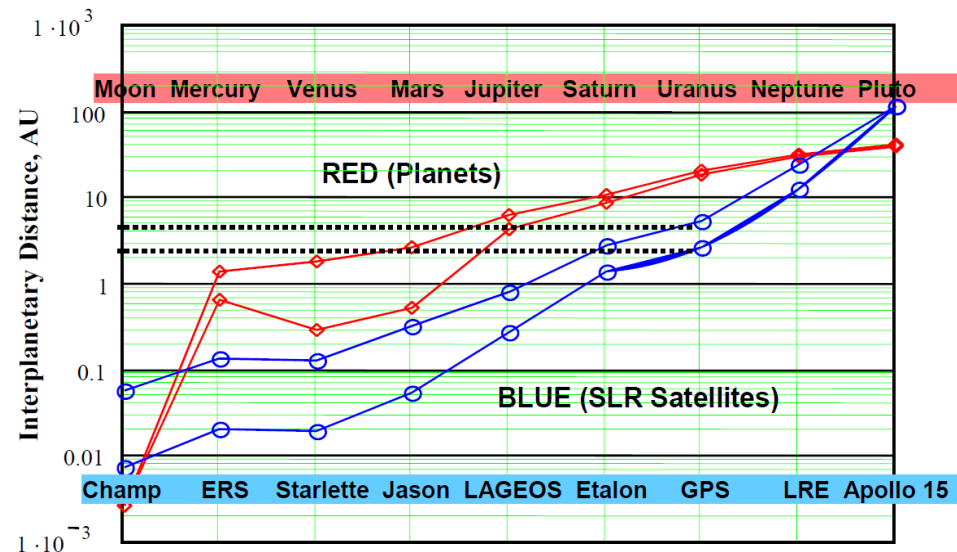
Birnbaum, K.M. et al., SPIE Proc. Vol. 7587, 2010

Interplanetary Laser Ranging



Prospects

- Laser tracking can provide unprecedented accuracy
- Applications in the fields of
 - Planetary science and ephemerides
 - Gravitational physics
 - Deep space navigation
- Possibility of combination
 - Laser communications
 - Laser altimetry system
- Satellite signature effect is eliminated



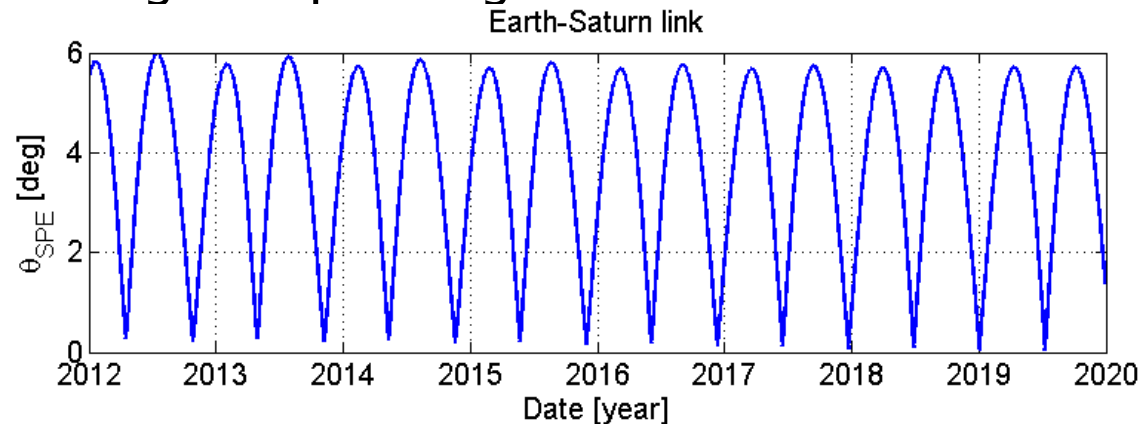
Degnan, J.J., 17th International Workshop on Laser Ranging, 2011

Interplanetary Laser Ranging

Challenges



- Space-based clock stability limits precision
 - Requirement reduced by two-way emulation
- Stray light limits Sun avoidance angle
 - Crucial for relativistic measurements
 - Crucial for outer planet ranging
- Long-distance pointing, acquisition and tracking
- Ground segment planning



Interplanetary Laser Ranging



ESPaCE Project

- FP7 project for improvement of solar system ephemerides
 - Combination of radiometric, astrometric observations
- Investigation of near-term potential of planetary laser tracking
 - Technological challenges
 - Comparative analysis with radiometric tracking
 - Analysis of LRO tracking data



Link simulations

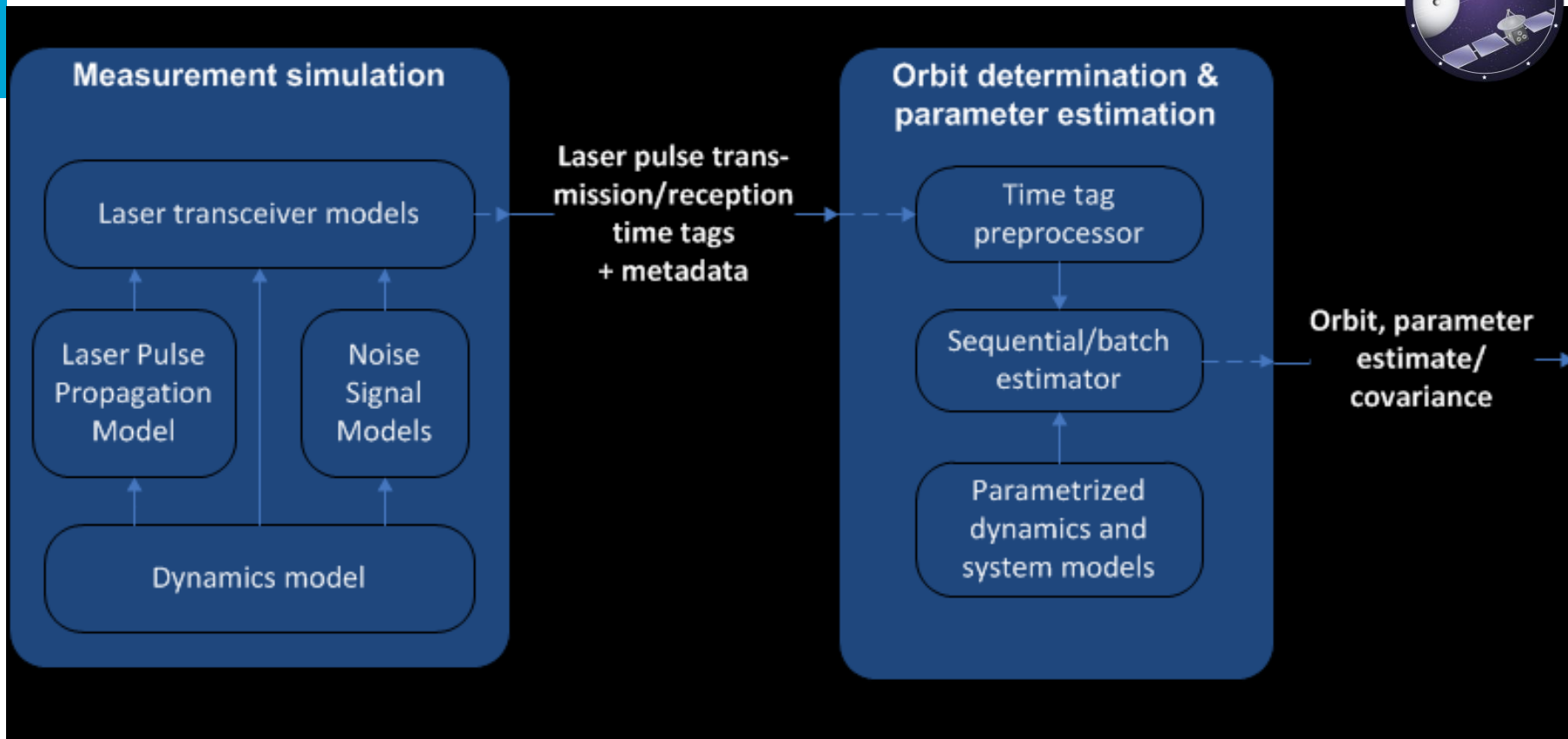
Overview

- No interplanetary laser tracking used operationally
 - Feasibility has been demonstrated
 - Simulations required for detailed performance evaluation
 - To be validated using available data
- Simulations to be performed in framework of Tudat library
 - Bottom up analysis of accuracy and precision
 - To be capable of both simulating and processing measurements
 - Modular setup



Link simulations

Layout



Link Simulations

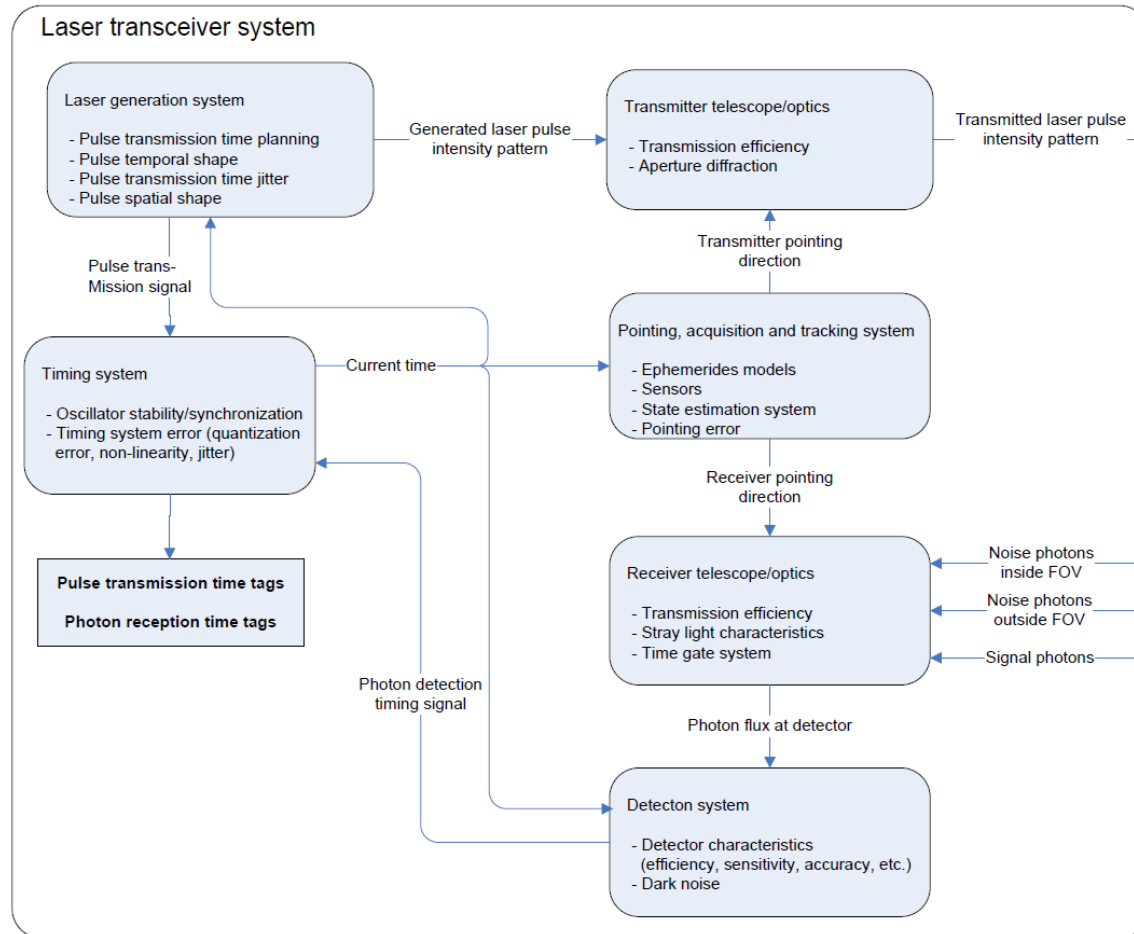
Hardware models

- Parametrized hardware models
- Time tag precision and accuracy from combined characteristics
 - Numerical combination
 - Controllable, transparent relation between system performance and characteristics
- Evaluation of performance of existing systems
 - Identify bottlenecks



Link Simulations

Hardware models



Link Simulations

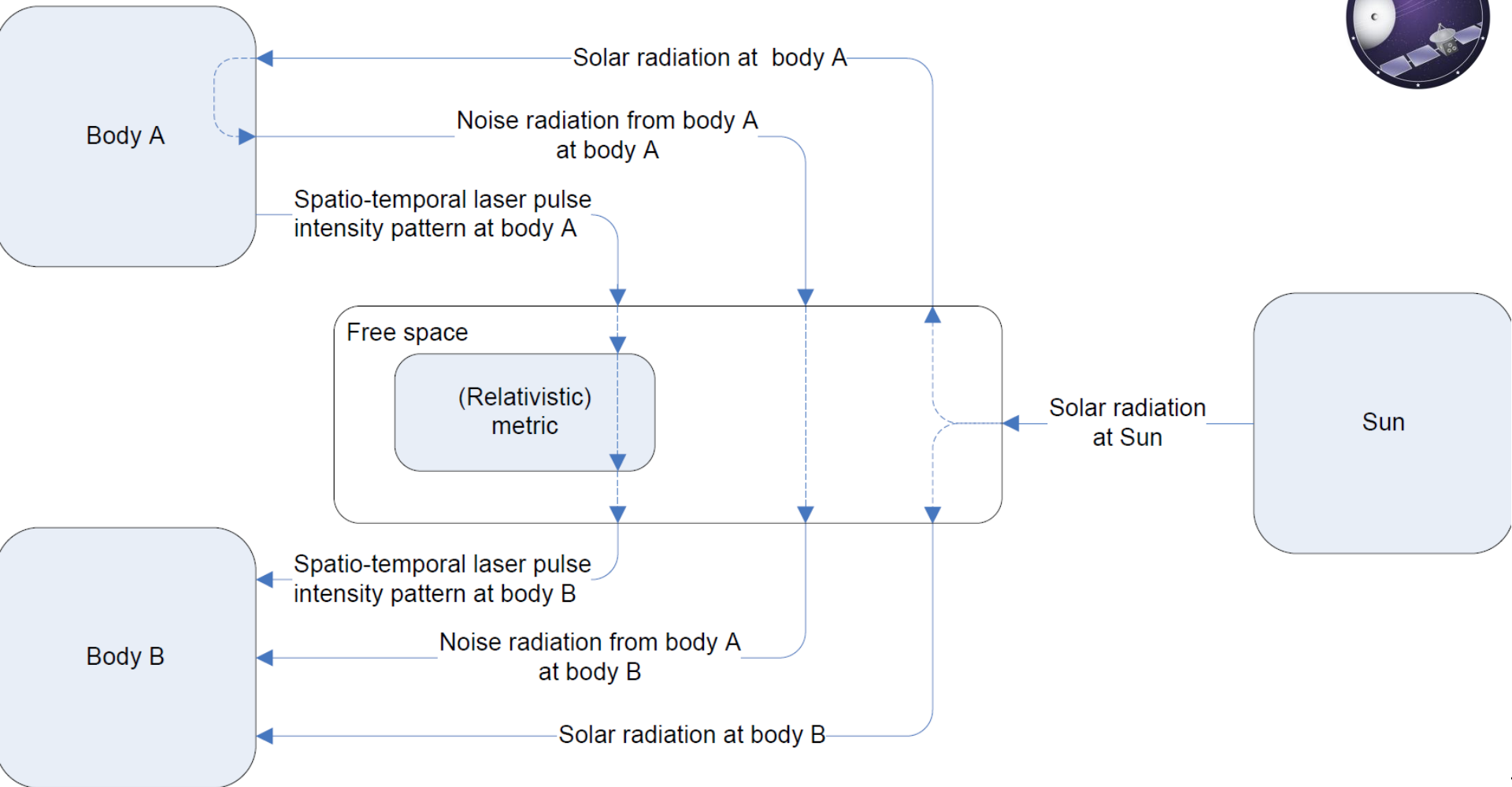
Noise models

- Noise levels can limit system performance
 - Planetary noise levels
 - Atmospheric noise levels
 - Stray light
 - Internal noise
- Software design provides SNR from hardware, environment models
 - Laser pulse strength
 - Pointing accuracy
 - Detector precision
 - Mission geometry



Link Simulations

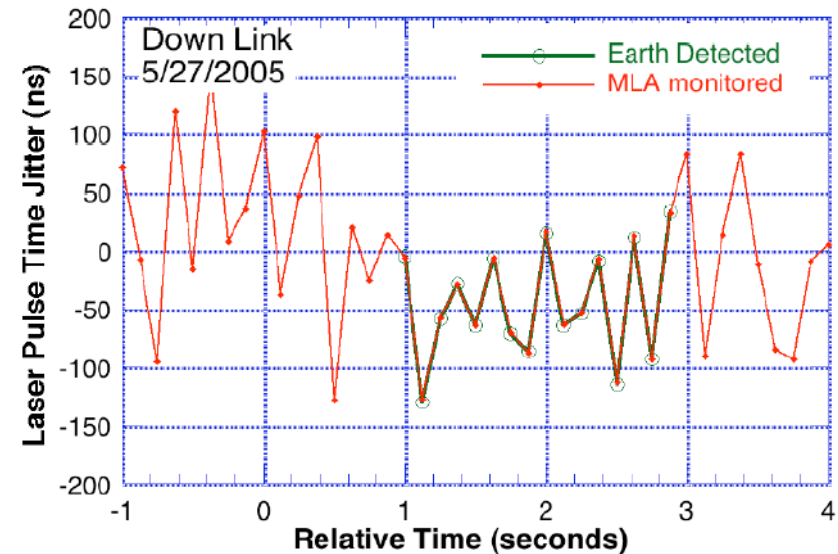
Noise models



Link Simulations

Data analysis methods

- Filtering and matching of laser ranging data
 - Matching of laser pulses
 - Noise filtering at small sun incidence angles
- In collaboration with LRO data reduction



Neumann, G.A. et al., 16th International Workshop on Laser Ranging, 2008

Link Simulations

Verification & validation

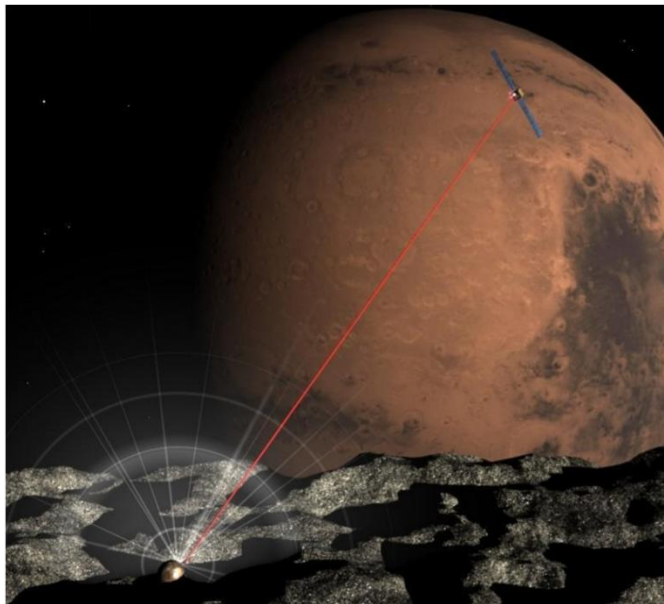
- Unit tests to compare module output to existing code/literature
- Several system-level validation steps are planned
 - LAGEOS orbit determination
 - LRO measurement simulations
 - Simulations of full rate data to representative satellite
 - Simulations of planetary noise levels at SLR station



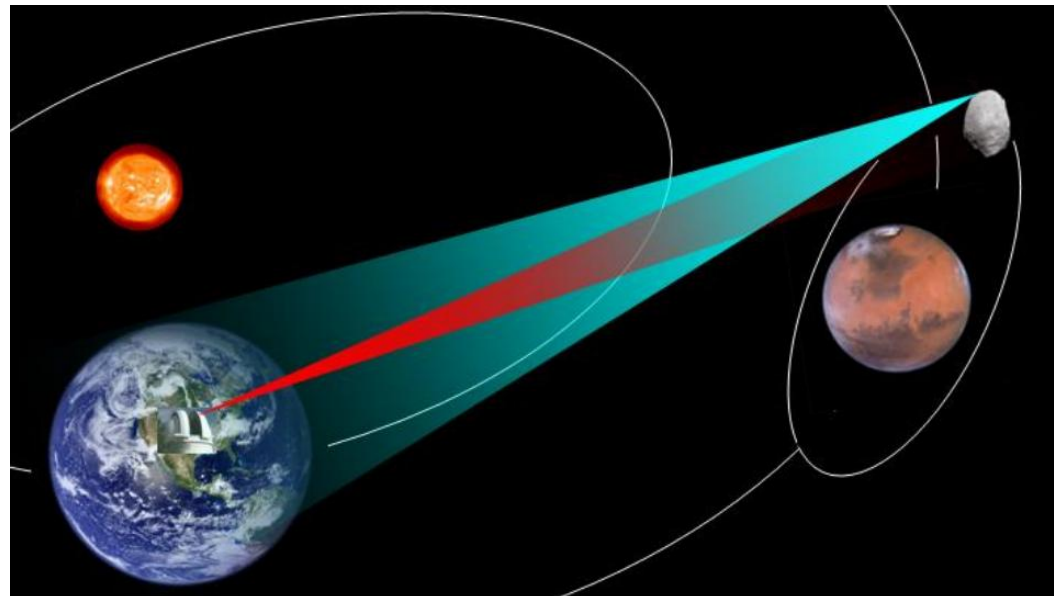
Outlook



- A number of mission proposals incorporate laser tracking
 - Numerous possible mission architectures



Oberst, J. et al., *Experimental Astronomy*, 2012



Turyshev, S.G. et al., *Experimental Astronomy*, 2010

Outlook



- Software to be applied for mission analysis of proposed missions
 - Assess added value of one- or two-way laser tracking
 - Quantify system requirements from science requirements
 - Compare to radiometric-only performance
- Combined analysis with ongoing VLBI sensitivity analysis
- Possible applications
 - Phobos Laser Ranging
 - GETEMME
 - JUICE

