Micro-newton Thruster Modulation and Analysis for the LISA Pathfinder

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Background

- eLISA – space-based gravitational wave observatory
- Free falling bodies and gravitational waves
- Inertial sensor and relative motion
- LISA Pathfinder (LPF) – technology demonstration package
Propulsion system

- Colloid micro-newton thrusters (CMNTs)
- Translation and attitude control
  - Test mass reference
- Configuration and control loop
- Consistency check and error tracking
Thrust modulation

- Thruster modulation frequency assignment
- Frequency-domain signal analysis
- Response amplitudes and directions
- Measurables: thruster calibrations, orientations, time delays
  - Location of space craft’s center of mass?
“Raw” data

Figure 1: Linear accelerations of test mass 1 relative to space craft
“Raw” data (frequency domain)

Figure 2: Frequency-domain linear accelerations of test mass 1 relative to space craft

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“Raw” data (frequency domain)

Figure 3: Frequency-domain linear accelerations of test mass 1 relative to spacecraft (zoomed in)

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Signal filtering

Figure 4: Data streams filtered at modulation frequency of thruster 1

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Figure 5: Data streams filtered at modulation frequency of thruster 4

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Figure 6: Data streams filtered at modulation frequency of thruster 7

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Data analysis

- Principal component analysis (PCA)
  - Time-independent linear and angular acceleration vectors
- Covariance matrix
  - Eigenvectors and eigenvalues

\[ C_{ij} = \langle (x_i - \langle x_i \rangle)(x_j - \langle x_j \rangle) \rangle \]

- Model (in)dependence

Figure 7: PCA sketch
Data analysis

Figure 8: Normalized modulation commanded to thruster 1 and angular acceleration of test mass 1 about x-axis.

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Confidence intervals

- Spacecraft sub-system model
- “Residual” signals
- Variation of thruster parameters
- Noise-weighted inner product

**Figure 9**: Linear acceleration accelerations of test mass 1
Future efforts

- Testing various spacecraft models
- Porting code to LTPDA infrastructure
- Alternate characterization methods
Thank you