The ST7 Interferometric Displacement Sensor
- a progress report -

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ST7 Interferometer people

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Acknowledgement

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Disturbance Reduction System

- Technology validation of sensor and thrust-producing technologies to control a space vehicles flight path so the payload responds only to gravitational forces.

Sensor: Stanford University, Stanford, CA

- Launch 2006 as NASA’s Space Technology 7 project (ST7)
- Piggy-backing on ESA’s SMART-2 Mission
ST7 Technology Objectives

• Validate that a test mass follows a trajectory determined by gravitational forces only within $3 \times 10^{-14} \text{ m/s}^2/\sqrt{\text{Hz}}$
  - Low acceleration noise is needed for study of general relativity, planetary gravity, gravitational waves

• Validate spacecraft position control to an accuracy of $<10 \text{ nm/} \sqrt{\text{Hz}}$
  - Spacecraft position control is required for separated-spacecraft interferometers which do not use internal delay lines
The DRS instrument package consists of
- Two gravitational reference sensors
- Microthrusters for spacecraft position control
- Interferometer to measure the distance between the two test masses.
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<th>Requirement</th>
<th>LISA @ 1 mHz</th>
<th>Proof Mass Sensor Noise</th>
<th>Interferometer Noise Requirement</th>
<th>ST7 Goal @ 1 mHz</th>
<th>LISA @ 10 mHz</th>
<th>Interferometer Noise Requirement</th>
<th>ST7 Goal @ 10 mHz</th>
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<tr>
<td></td>
<td>3*10^{-15} m/s^2/√Hz</td>
<td>1 nm/√Hz</td>
<td>250 pm/√Hz</td>
<td>3*10^{-14} m/s^2/√Hz</td>
<td>1.5*10^{-14} m/s^2/√Hz</td>
<td>25 pm/√Hz</td>
<td>1.5*10^{-13} m/s^2/√Hz</td>
</tr>
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</table>

- \( a = (2\pi f)^2 \times 5 \times 10^{-10} \text{ m/√Hz} \sim 2 \times 10^{-14} \text{ m/s}^2/\sqrt{\text{Hz}} \) @ 1 mHz
- \( a = (2\pi f)^2 \times 1 \times 10^{-9} \text{ m/√Hz} \sim 4 \times 10^{-14} \text{ m/s}^2/\sqrt{\text{Hz}} \) @ 1 mHz
- \( a = (2\pi f)^2 \times 5 \times 10^{-11} \text{ m/√Hz} \sim 2 \times 10^{-13} \text{ m/s}^2/\sqrt{\text{Hz}} \) @ 10 mHz
DRS Performance Limits

Extrapolation from DRS by x10

DRS Capacitor Readout Limit; $10^{-9} \text{ m/} \sqrt{\text{Hz}}$

DRS Homodyne Interferometer Limit; $2 \times 10^{-14} \text{ m/s}^2/\sqrt{\text{Hz}}$

DRS Acceleration Noise Goal = 10 x LISA goal

LISA Acceleration Noise Goal

LISA Sensitivity for SNR=5 and 1 year Integration

Frequency (Hz)
Laser Requirements

- Average unstabilized laser noise seen: \(~5.5 \text{ MHz}/\sqrt{\text{Hz}} @ 10 \text{ mHz}\)
- \(~30 \text{ MHz}/\sqrt{\text{Hz}} @ 1 \text{ mHz}\)
- Interferometer pathlength mismatch: \(\Delta L < 1 \text{ mm}\)
- Laser noise -> path noise: \(\Delta x = \Delta L \cdot \Delta v/v\)
  @ 10 mHz \(< 20 \text{ pm}/\sqrt{\text{Hz}} \text{ (avg.)}\)
  @ 1 mHz \(< 100 \text{ pm}/\sqrt{\text{Hz}} \text{ (avg.)}\)

Compare to:
- Interferometer noise req’d: \(25 \text{ pm}/\sqrt{\text{Hz}} @ 10 \text{ mHz}\)
- Interferometer noise req’d: \(250 \text{ pm}/\sqrt{\text{Hz}} @ 1 \text{ mHz}\)
Results

Optical Isolator Installed -- t112402a; 4 < t < 11 hr; BW = 234 uHz

- Metal Mounts
- ULE
- $f^{-1.3}$ fit
- Electronic + Intensity Noise (Metal)
- Electronic + Intensity Noise (ULE)
- Shaddock: Free-space laser, ULE
- Requirement