ST7-DRS

New Millennium Program Space Technology 7 Disturbance Reduction System

Overview

W. Folkner

JPL

Team Members

JPL

G. Man, C. Dunn, H. Abakians, A. Sirota, A. Kuhnert, G. Man, D. Miller, R. Spero, M. Girard, G. Franklin, D. Hollert, D. Johnson

Stanford University

R. Byer, S. Buchman, D. DeBra, D. Gill, J. Hanson, G. Keiser, D. Klinger, D. Lauben, S. Williams

Busek Co. Inc

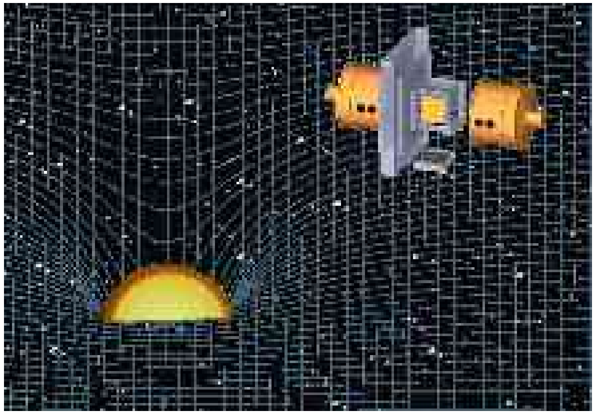
V. Hruby

Goddard Space Flight Center

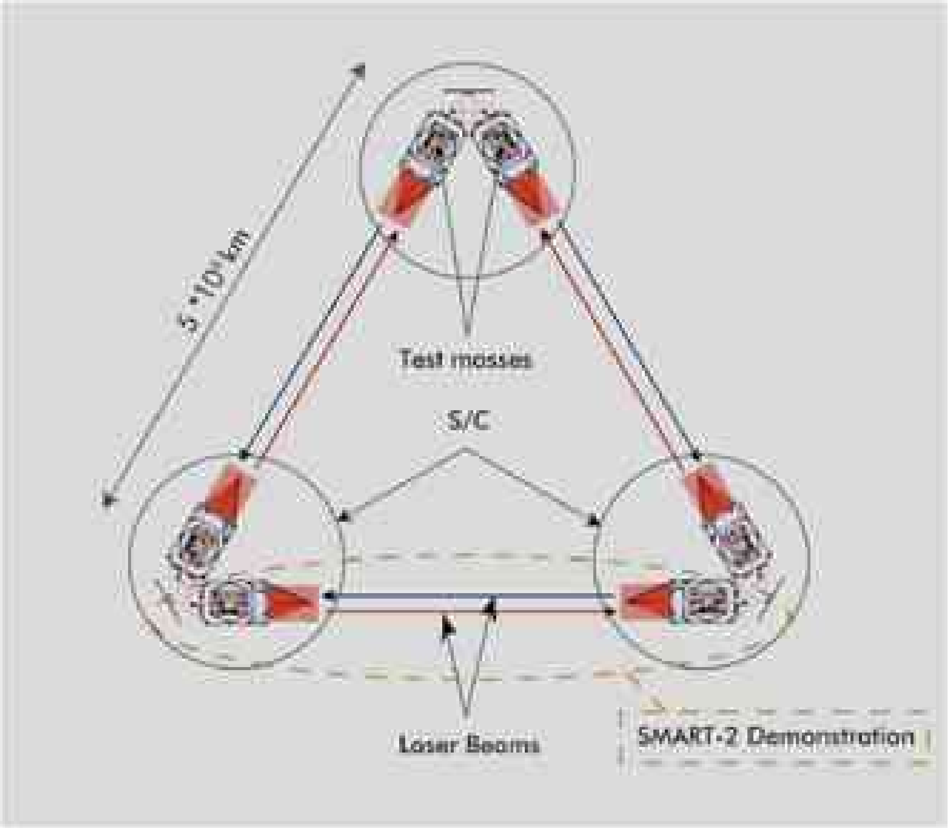
J. O'Donnell, F. L. Markley, P. Maghami, O. Hsu

Mission Objectives

- LISA pathfinder is designed to validate the capability for a test mass to follow a purely gravitational trajectory
- The LPF spacecraft will carry LTP and DRS as payloads
  - Each payload includes two test masses and a laser interferometer for measuring changes in distance between test masses
- Launch mid-2008 to L1 orbit
- Mission duration 1 year
  - 90 days of operation for each payload

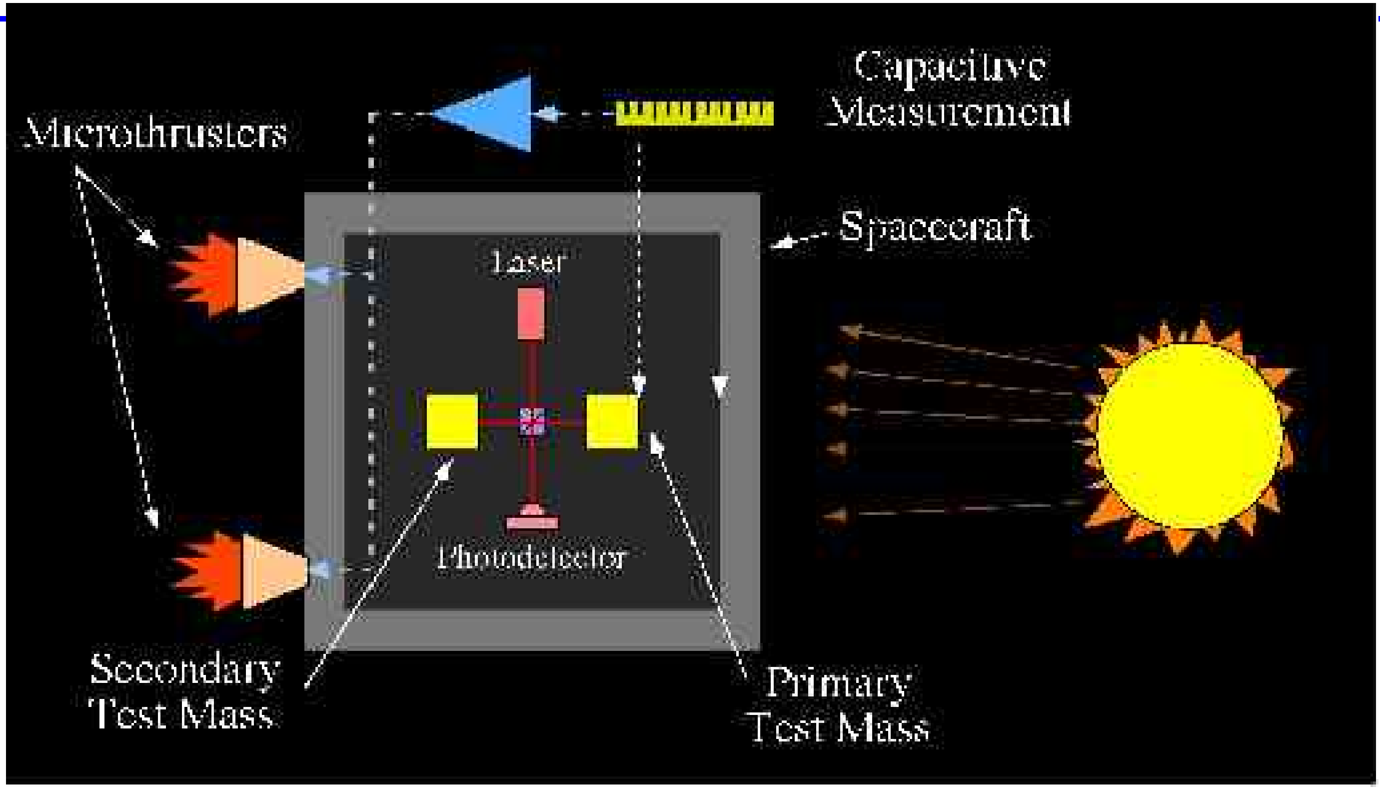


Mission Concept



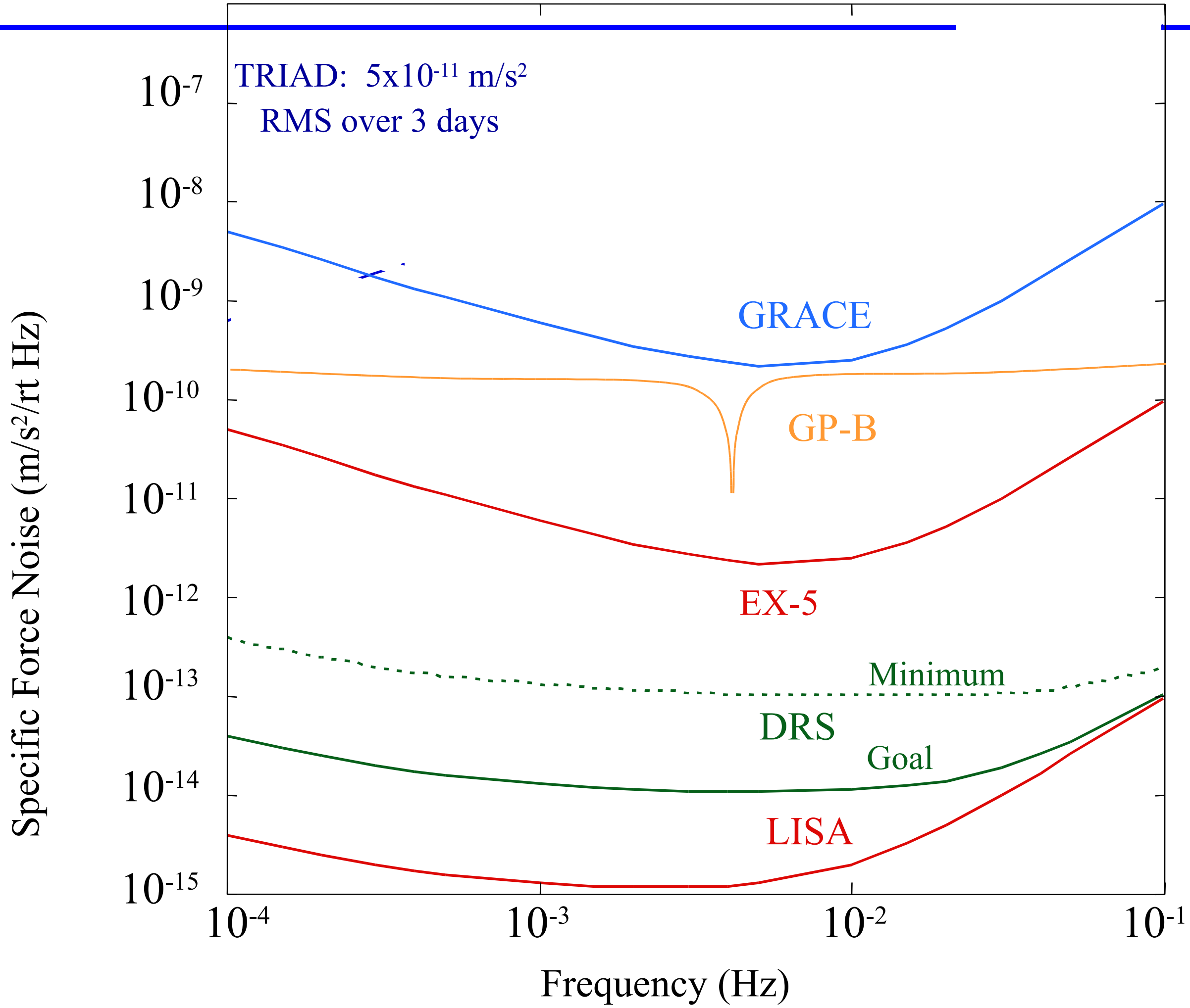
- **A significant part of the LISA technologies cannot be proven on the ground**
- The primary goal of the **DRS** test is to verify that a test mass can be put in pure gravitational free fall within one order of magnitude from the requirement for LISA.
- The basic idea is that of 'squeezing' one **LISA** interferometer arm from 5 $*10^6$ km to a few centimetres (DRS) on-board a small spacecraft.
- A similar system LISA Test Package (**LTP**) will be provided by ESA

DRS Concept



- Each instrument package consists of
  - Two gravitational reference sensors
  - Microthrusters for spacecraft position control
  - Interferometer to measure the distance between the two test masses.

Mission Drag-Free Requirements



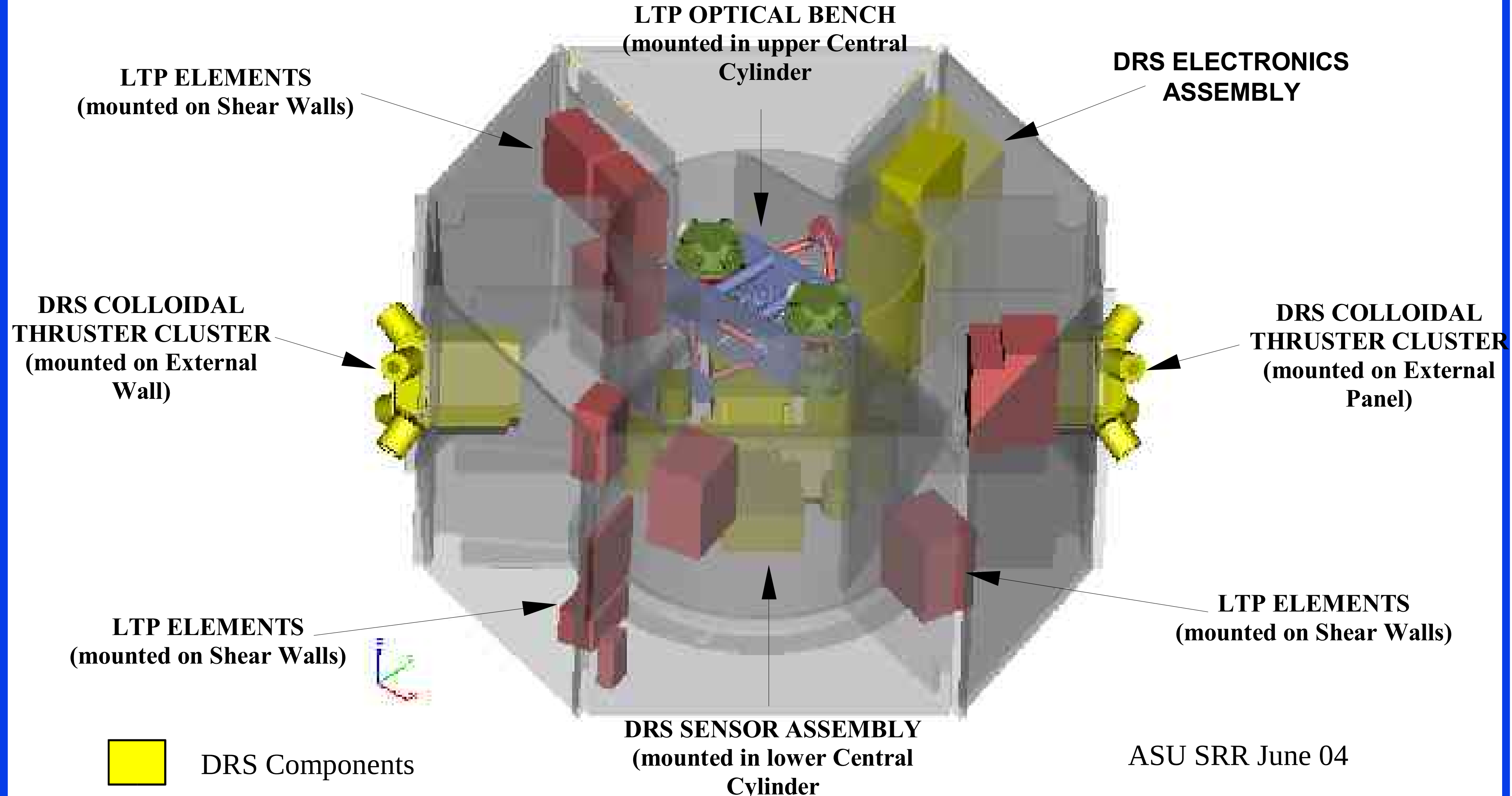
LTP and DRS

- DRS and LTP payloads will achieve similar performance with different approaches
  - Provides redundancy as well as options for LISA implementation
- Simultaneous operation of LTP and DRS has significant advantages
  - Identification of noise sources to spacecraft environment or to specific payload
  - Calibration signal through controlled modulation of test mass position

ESA LISA Pathfinder Spacecraft

Diameter: 2.1 m
Wet mass: 1880 kg
Power: 550 w

LPF Spacecraft Configuration

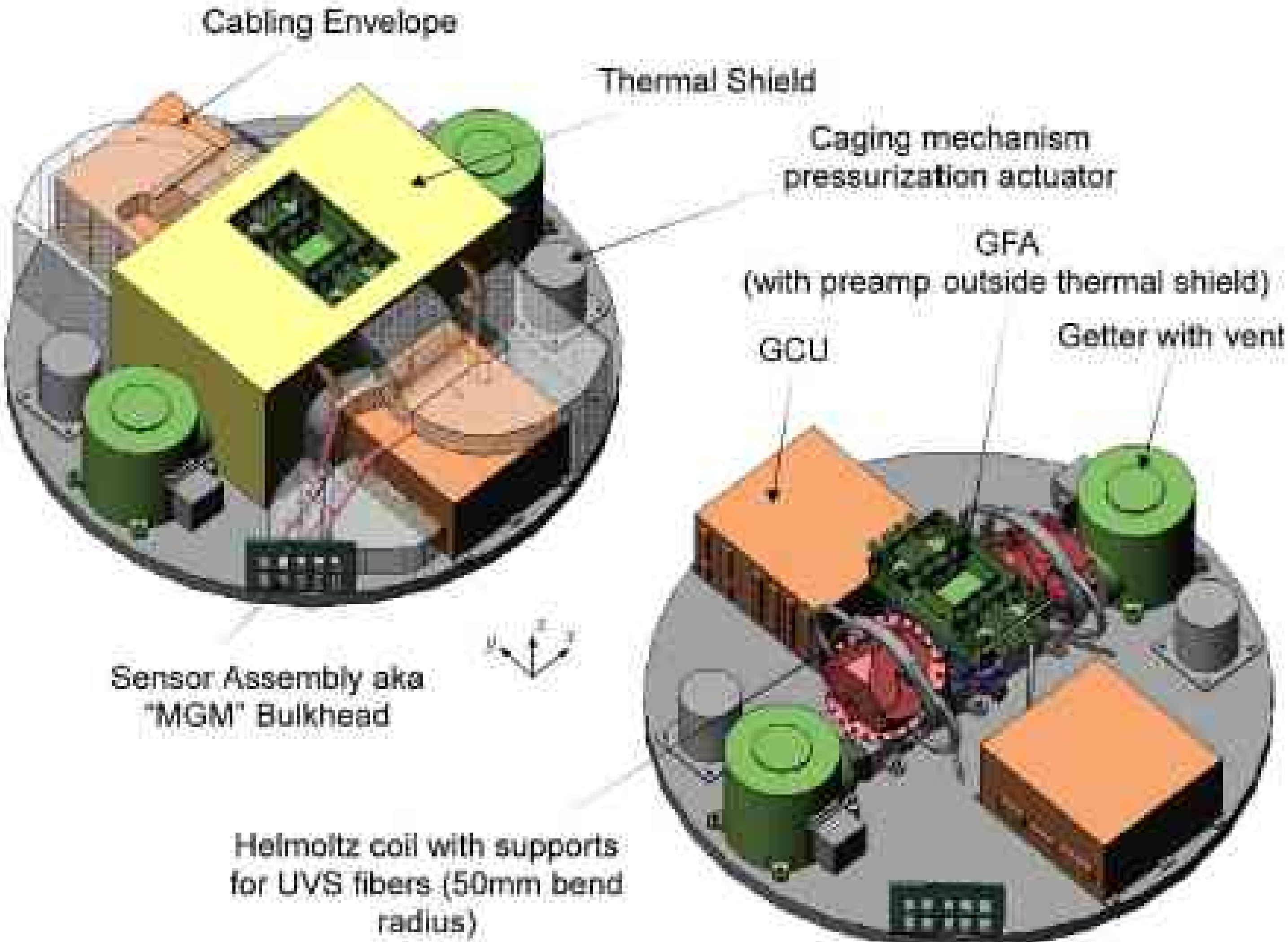


DRS Components

LTP Components

ASU SRR June 04

DRS Sensor Assembly



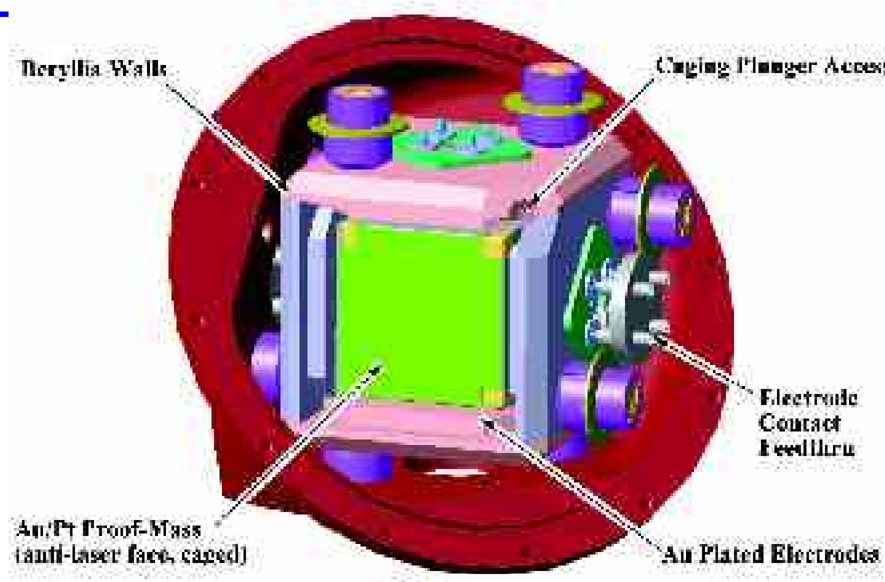
GRS Assembly

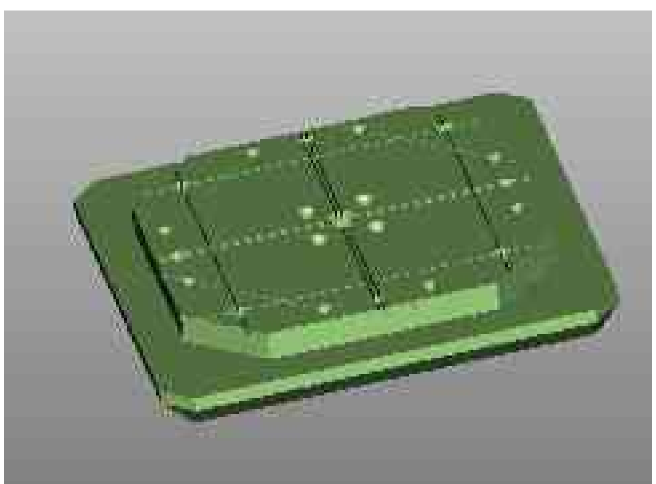
- Monolithic titanium chassis
  - Common base structure for both sensors and interferometer
    - Includes getter-pump chambers
    - Structural support for caging system
  - Reduces mass and number of mechanical interfaces

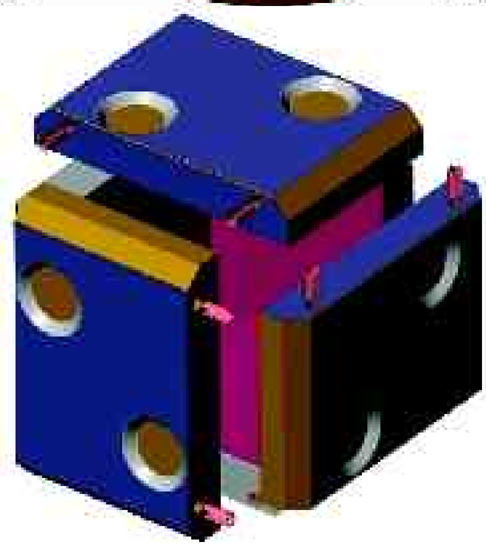
QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

GRS Housing

- Beryllia electrode housings
  - Electrodes evaporated on
  - Six plates interlock to form cube
    - Precision alignment by plates
    - Compressive force applied by titanium vacuum enclosure

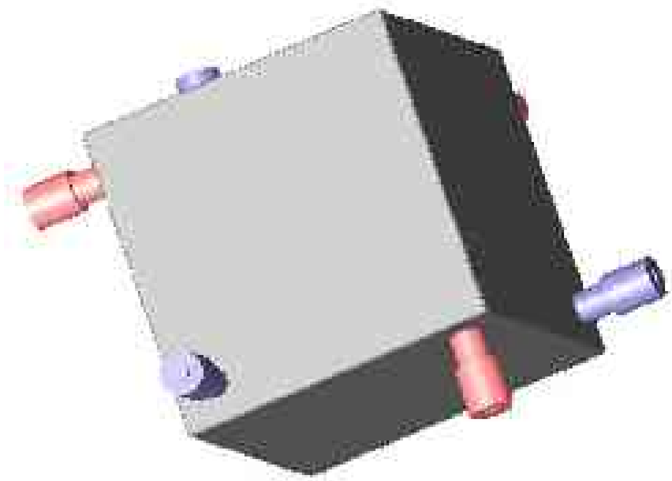


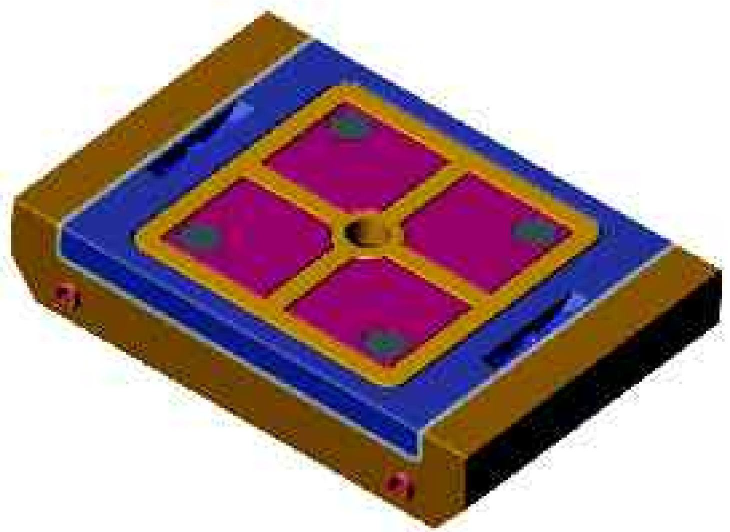


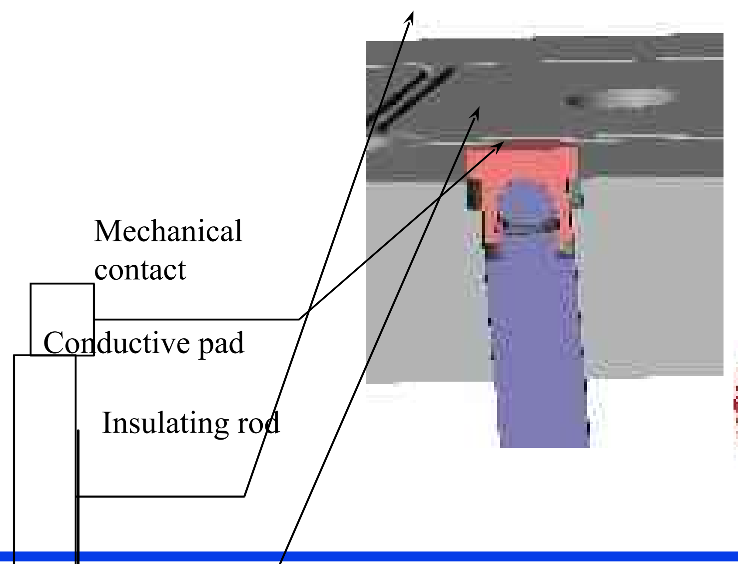


GRS Caging System

- Six active, self aligning, over-retracting caging actuators
  - Contact pads at end of actuators are integral part of active electrode area
- Actuators are gas driven
  - Spring loaded with damping to accommodate high vibration levels at launch

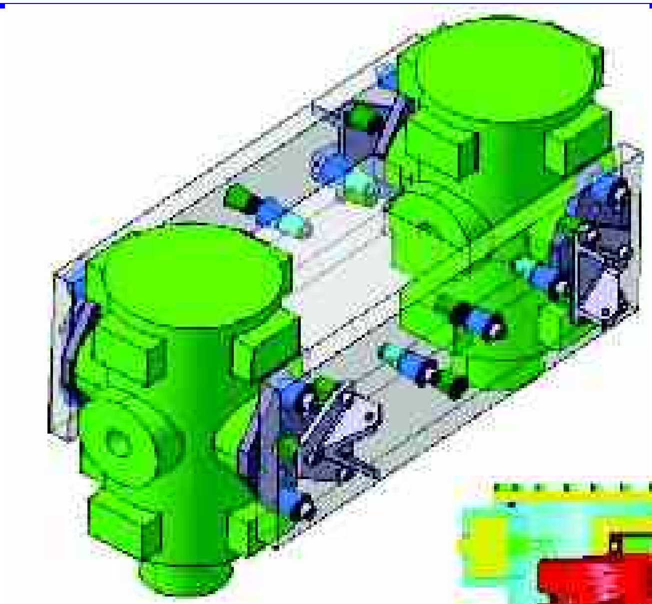


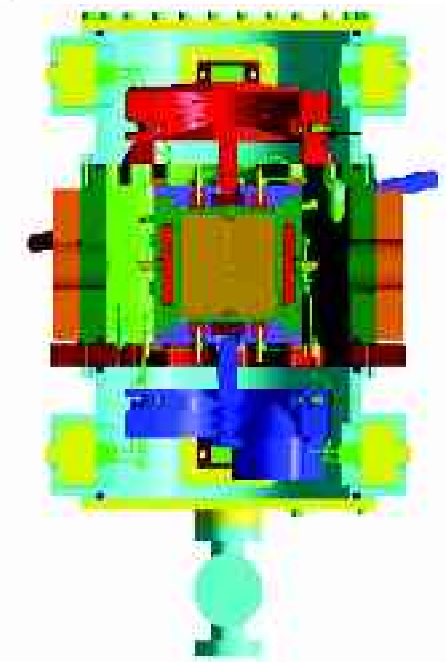




LTP Sensor Configuration

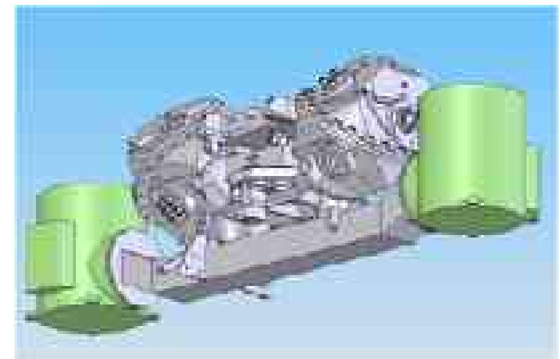
- Two test masses in separate vacuum enclosures joined by metering stricture
  - Molybdinum electrode housings
  - Electrodes on ceramic inserts
  - Constant-voltage position-sensing electronics
  - Motorized caging mechanism
  - Complex heterodyne interferometer

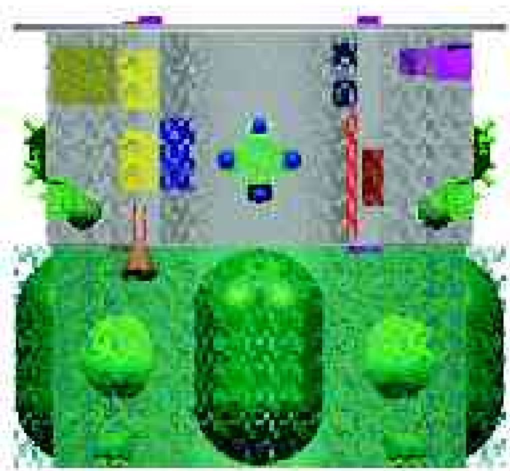


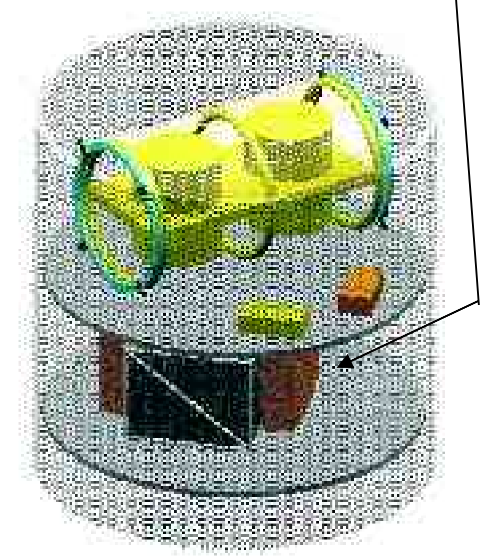


Payload Installation on Spacecraft

- Spacecraft contains payloads in layers
  - Oriented at 45° to allow measurements in 3 degrees of motion and for some cross correlation
  - Spacecraft propulsion jettisoned to avoid propellant motion
- Mass distribution of all components must be known to high accuracy
  - To avoid gravity field and gradients

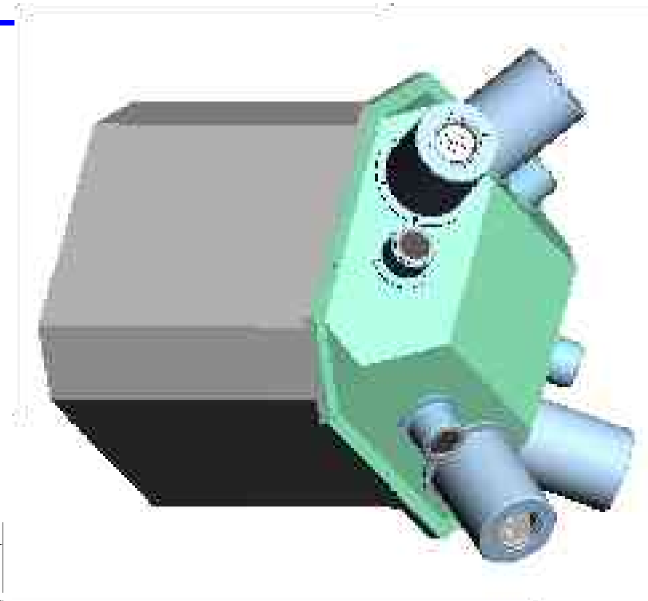


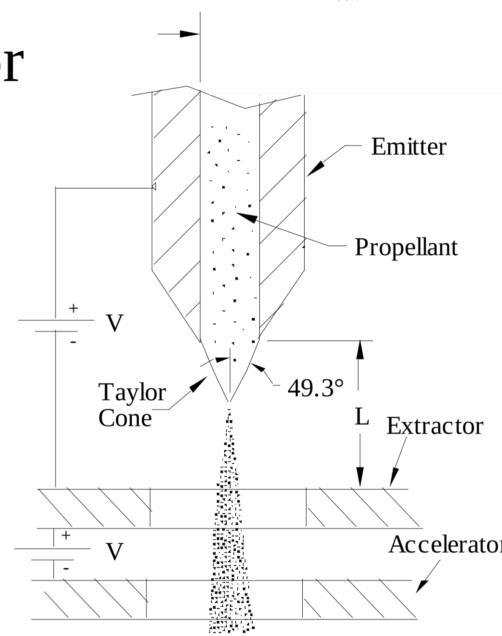




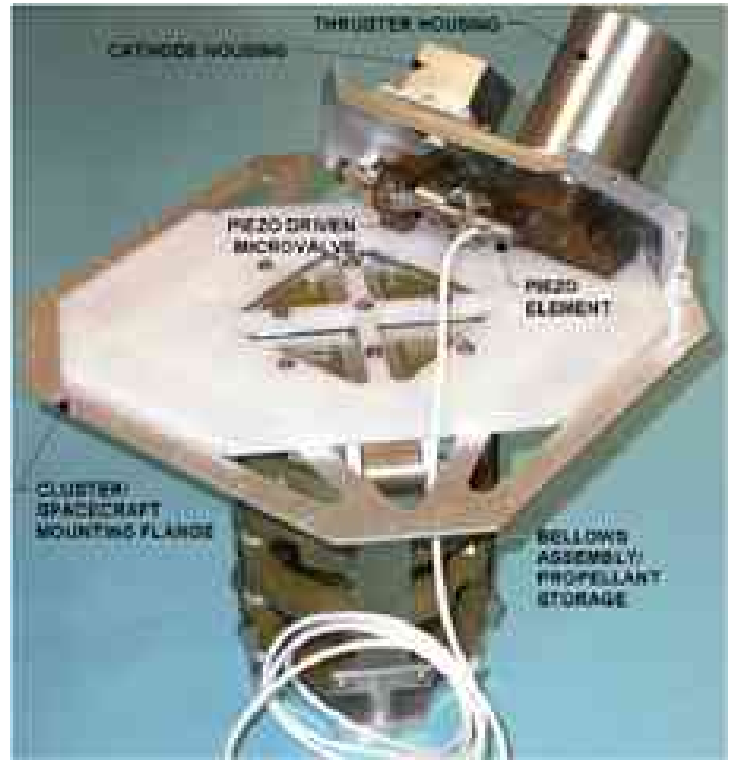
DRS Colloidal Thrusters

- High-conductivity fluid fed through small needles by pressurizer
- High voltage applied to produce stream of charge droplets
- Array of six needles used to achieve 20 μN of thrust
- Clusters of four thrusters used for DRS



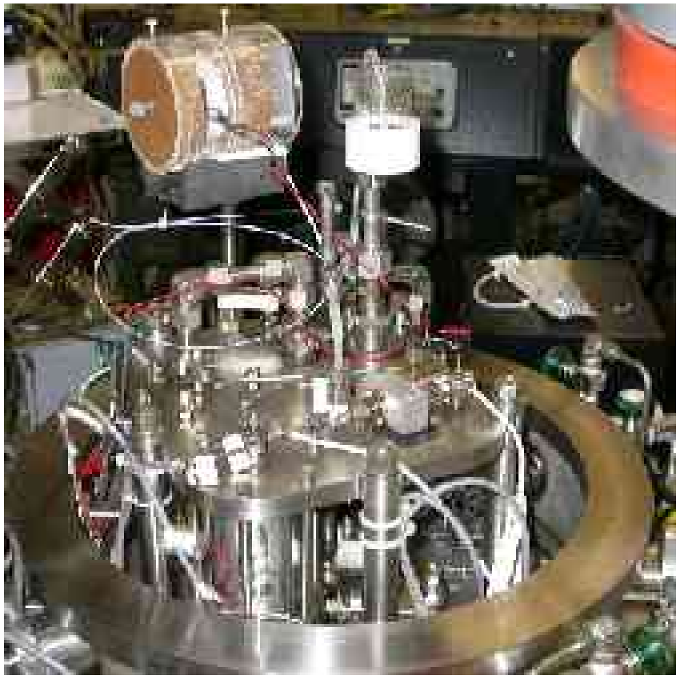


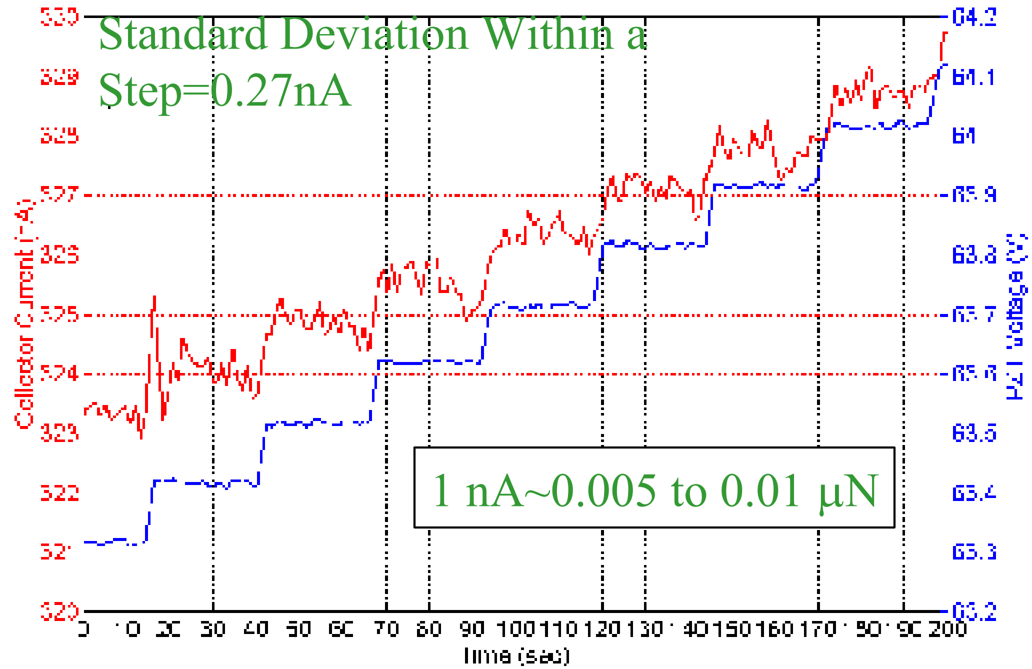
Colloid Cluster Breadboard



Shows 1 of 4 thruster systems

Propellant Flow Measurement

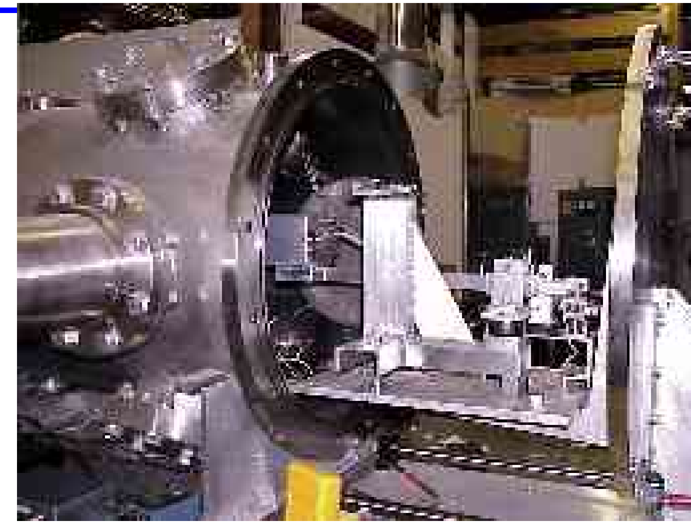


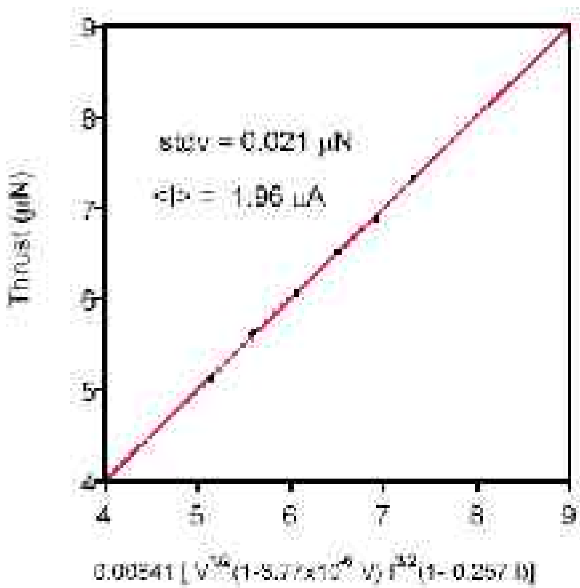


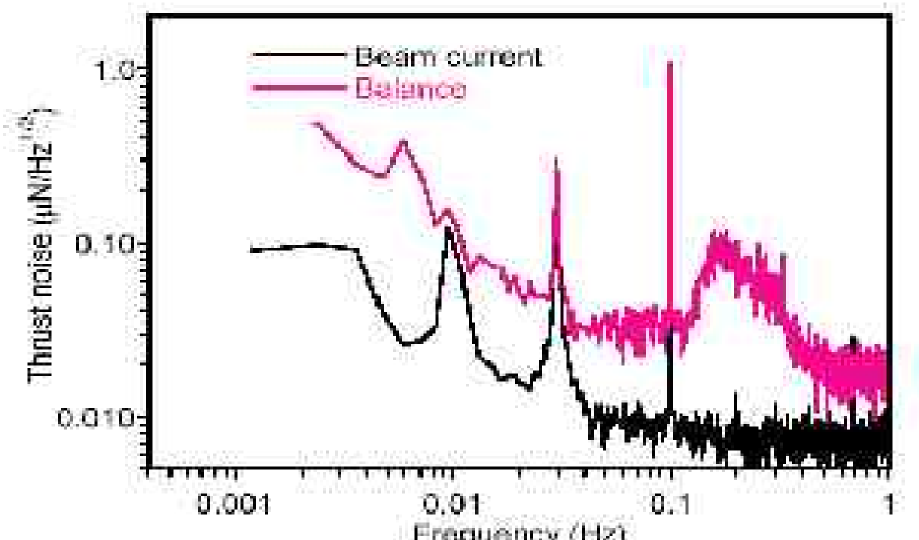
- In vacuum (~10^{-5} Torr), propellant (EMI Im) in bellows at near constant pressure
- Electrospray current averaged over 1 second interval
- Average standard deviation within a step=0.27nA
- 10 nm motion of PZT (0.1 Volt step) gives electrospray current change of <1 nA
- 5 nm steps attempted – cannot resolve steps with present noise levels

Thruster Performance

- Torsion balance developed to measure colloidal thruster output and noise
- Preliminary tests show performance meets noise requirement of < 0.1 µN/√Hz

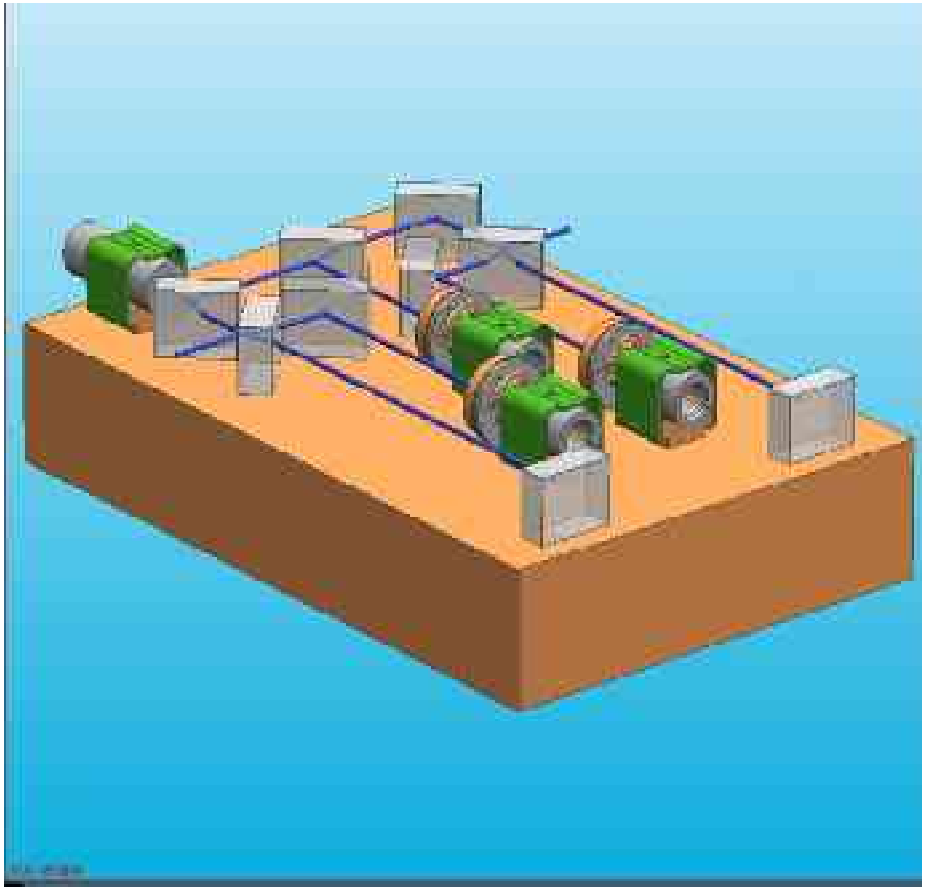






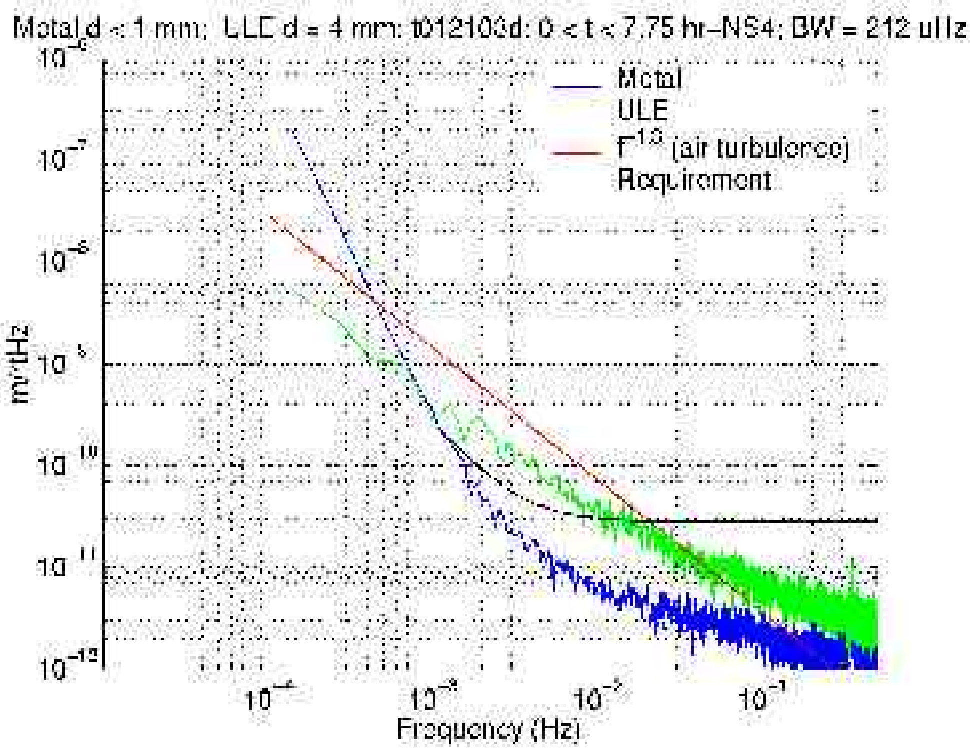
Interferometer

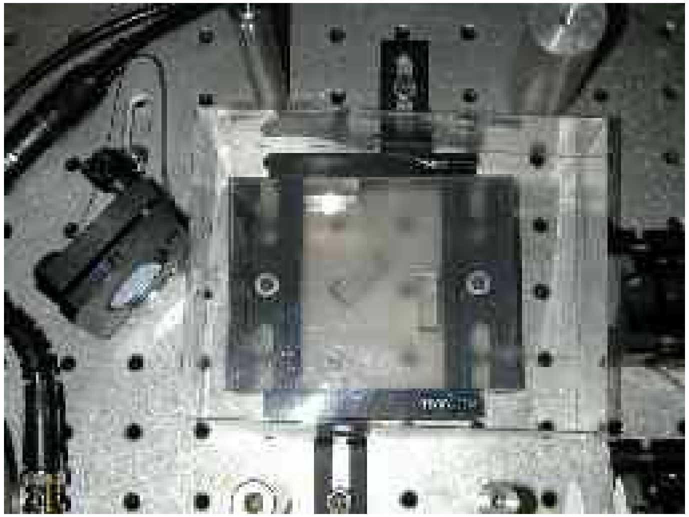
- DRS uses simple homodyne interferometer for GRS validation
  - *Not a new technology*
  - One readout per test mass
  - No electro-optics
    - Lower cost, lower power



Interferometer Performance

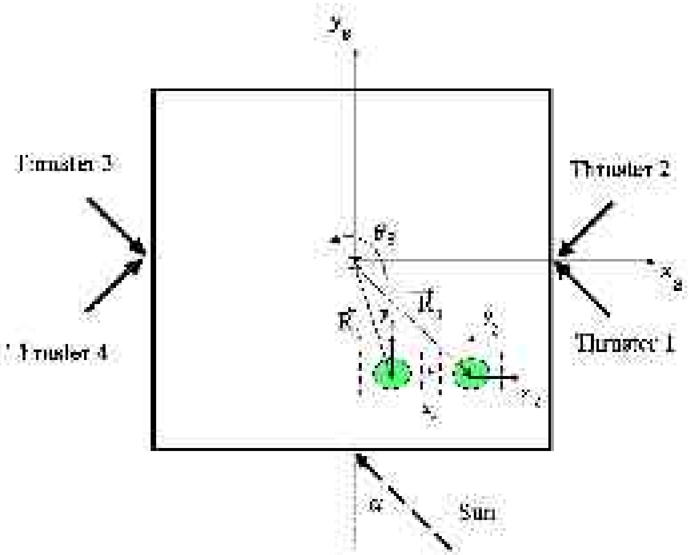
- Homodyne interferometer
  - Intensity modulated by test mass position
  - Test interferometer meets DRS requirements
    - Alignment with test mass still under development

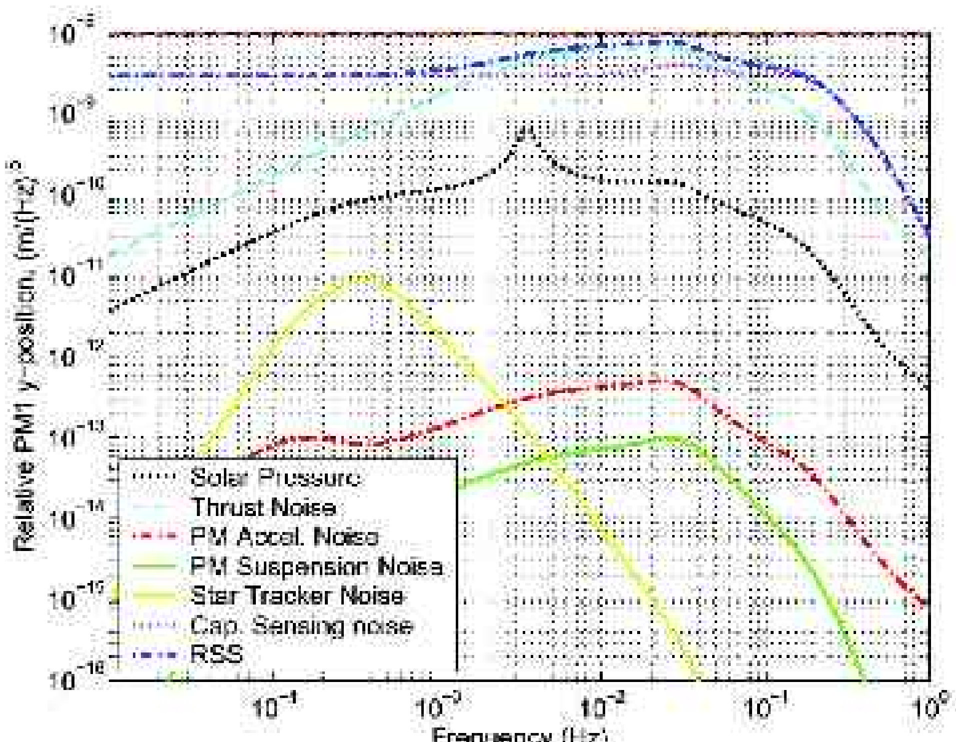




Spacecraft Control Performance

- 2-D models of spacecraft control show compatibility with SMART-2 requirements
  - Coupling of rotation and translation control is challenging for 10^{-4} Hz





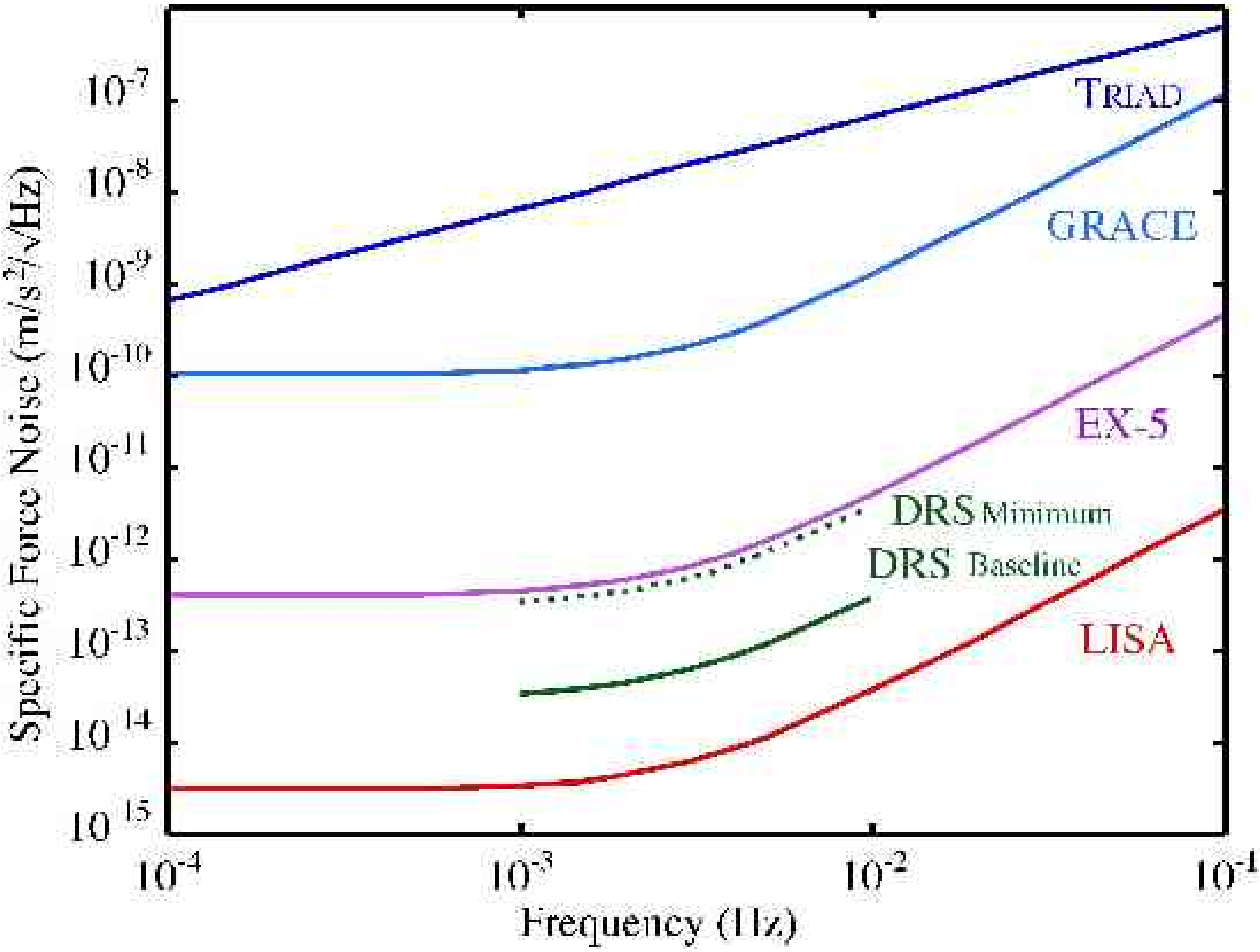
Differences between ST7 and LTP

Item	ST7	LTP
Test mass size	40 mm	bigger
Gap	2 mm	3-4 mm
Housing	beryllia	Mo/Ceramic
Electrodes	1-2-4	2-3-4
Electronics	auto-balance	transformer
Caging	gas/damper	motor
Centering	landing pads	caging
Control rate	10 Hz	1 Hz?
Thruster	colloid	FEEP/LmIS

DRS Path to Flight

August, 2004	**DRS Critical Design Review**
January, 2006	**DRS Delivered to ESA**
May, 2008	**LAUNCH**

DRS Performance Context



DRS Performance and LISA