



SE&I Pre-Proposal Meeting

System Architecture

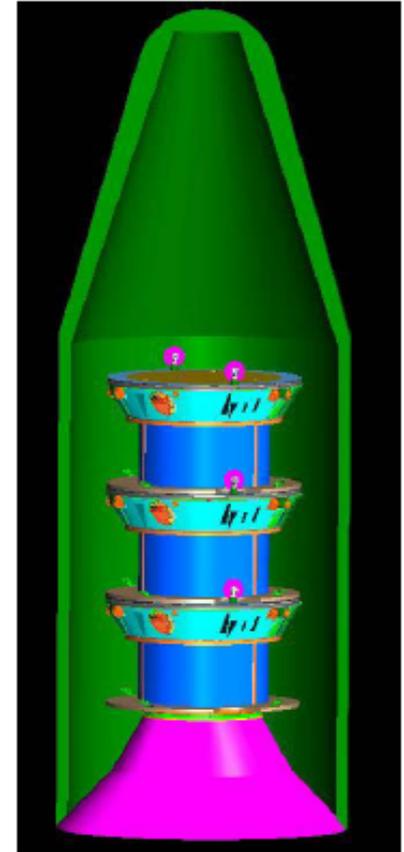
Mark Herring

(Stephen Merkowitz Presenting)

Launch and Cruise

Beyond
Einstein:
From the
Big Bang
to
Black
Holes

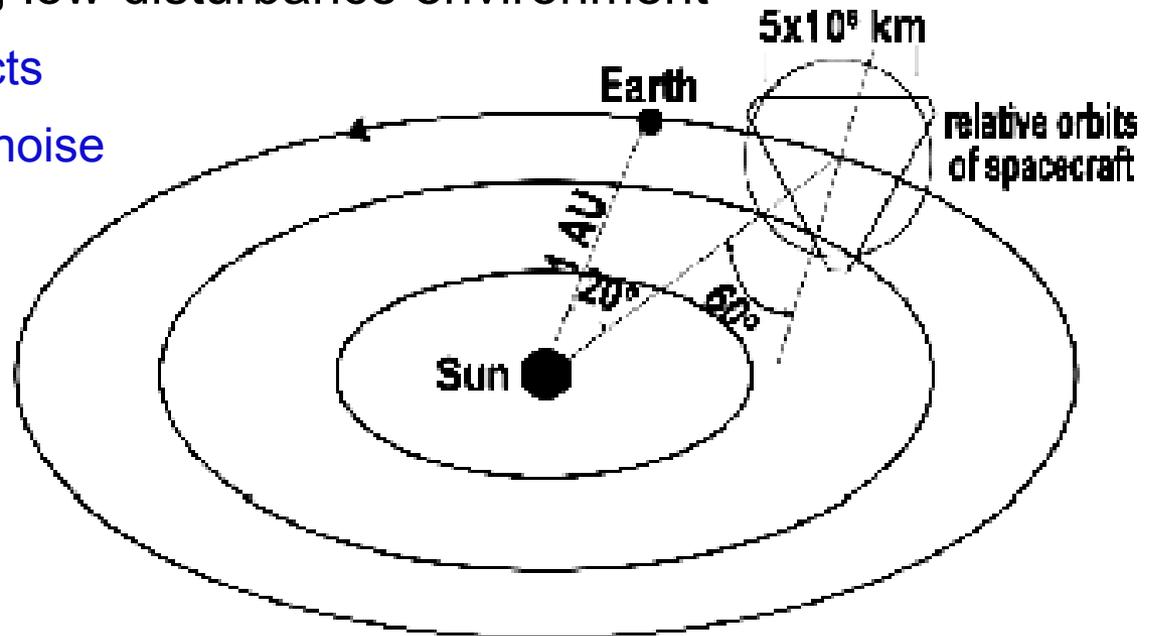
- Delta IV medium launches all 3 spacecraft
- Each Spacecraft coupled to propulsion module
 - Delta-V = 1.22 km/sec
 - Bi-propellant system with RCS for attitude control
 - Prop module is controlled by S/C computer
- 13-month cruise phase
- Prop. Modules jettisoned during setup phase



Orbits

Beyond Einstein:
From the Big Bang
to Black Holes

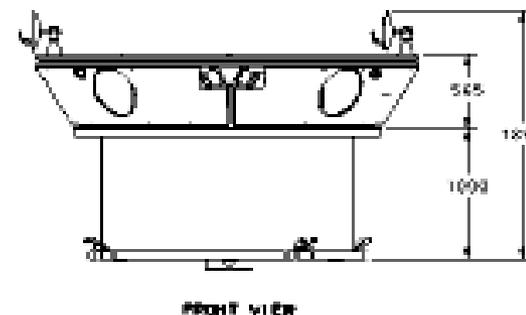
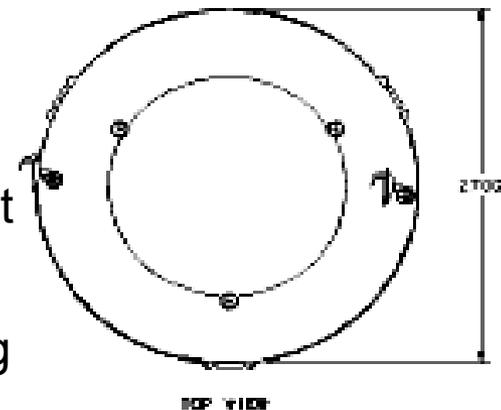
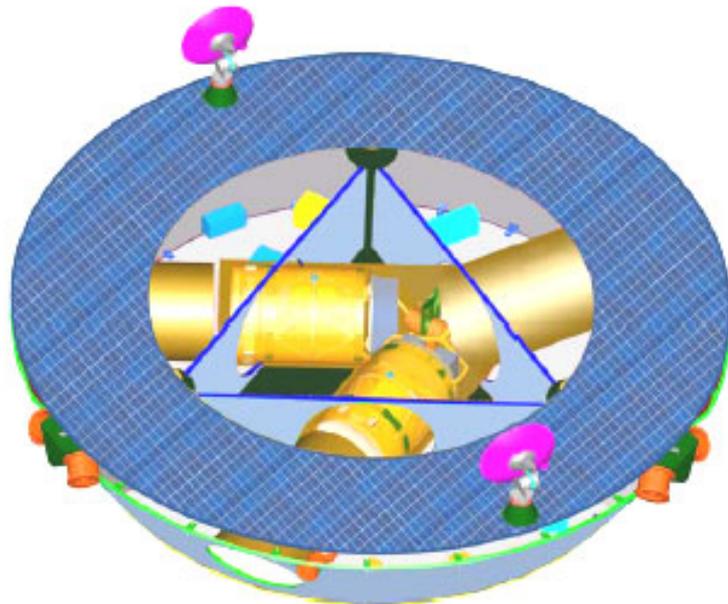
- ☪ Heliocentric orbit, trails Earth orbit by 20 degrees
- ☪ Constellation plane inclined 60 degrees with respect to the ecliptic
- ☪ Triangle rotates 1 degree per day (one complete revolution in one-year circuit)
- ☪ Constellation “breathes” ~ 1 degree per year
- ☪ Provides stable, low-disturbance environment
 - Thermal effects
 - Acceleration noise
 - Radiation



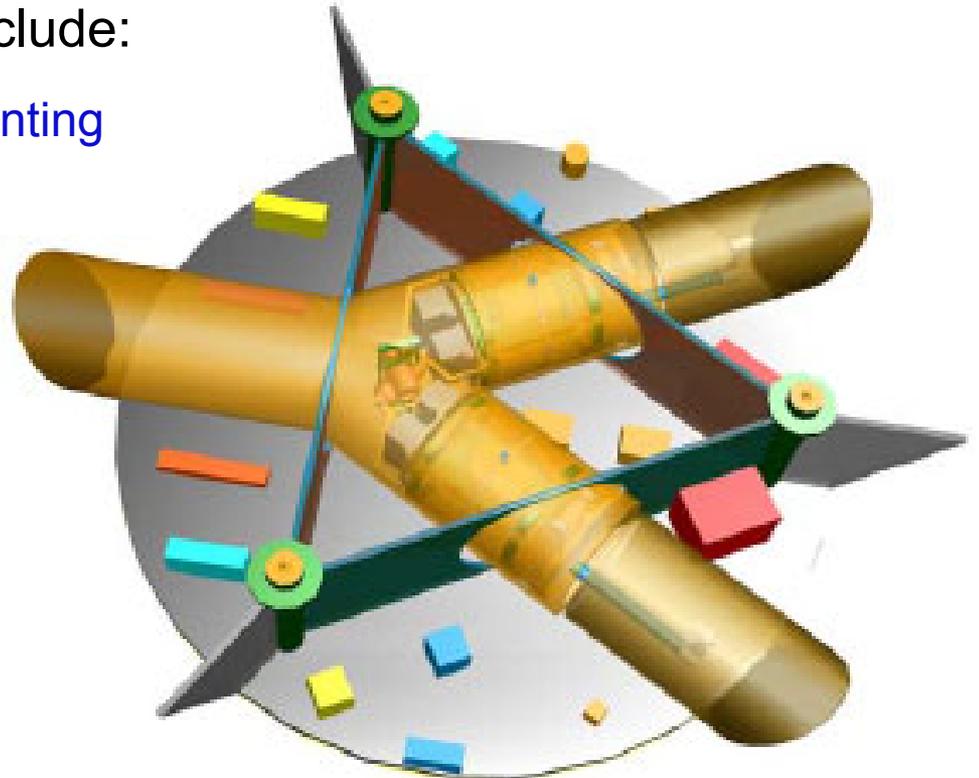
Spacecraft

Beyond Einstein:
From the Big Bang
to Black Holes

- 2.7 meter diameter X 0.57 meter high (not including prop. Module)
- Aluminum honeycomb and CFRP
- Triple-junction GaAs solar array, 3.45 square meters
- Straightforward subsystem designs with extensive flight heritage
- Electronics mount on top and bottom plates, depending on thermal considerations

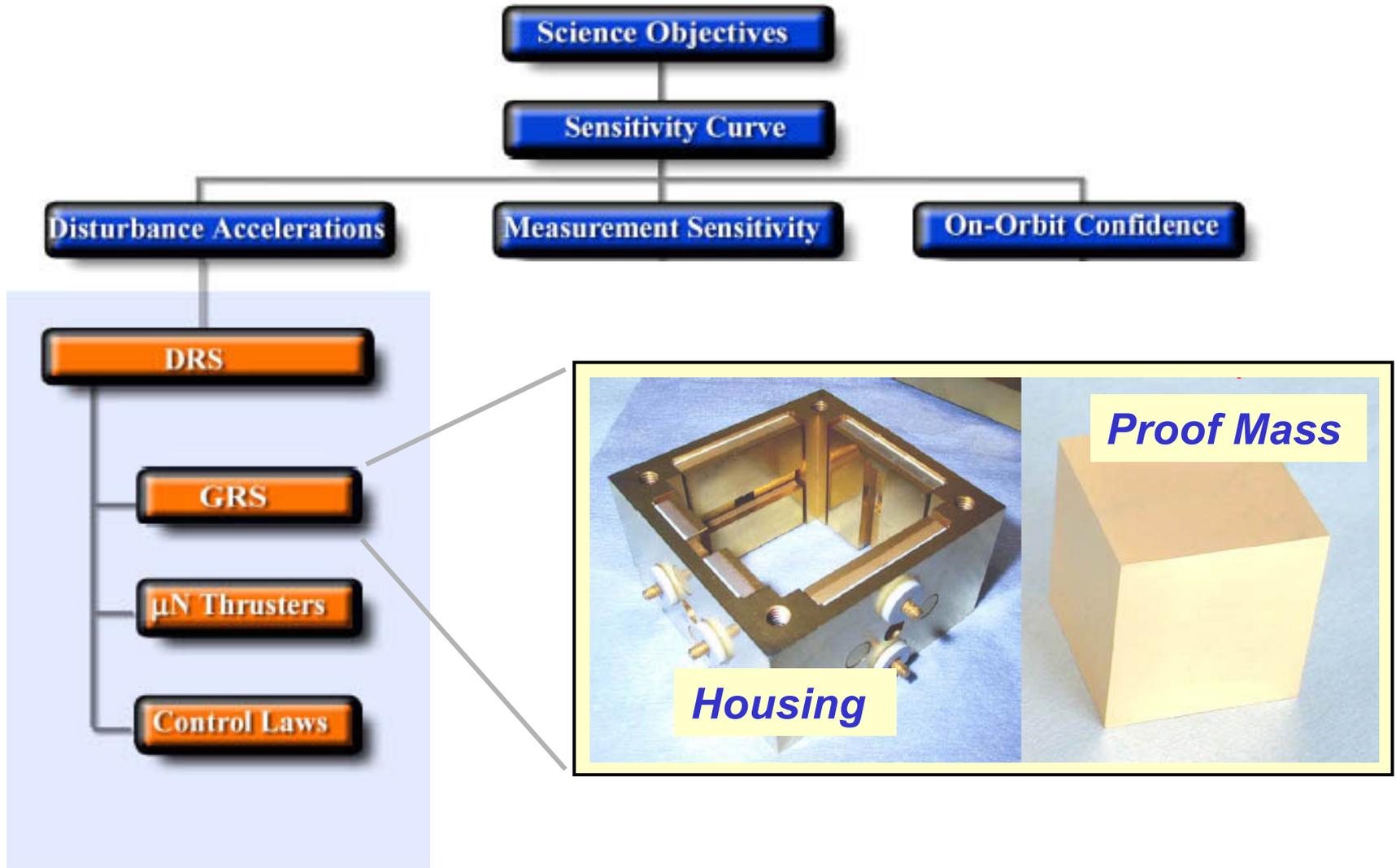


- Two key functions:
 - Proof mass control and disturbance reduction (DRS)
 - Strain measurement (IMS)
- Supporting elements include:
 - Structure (Y-tube), pointing mechanisms, payload computer



Payload ~ DRS/GRS

Beyond Einstein:
From the Big Bang
to Black Holes



Payload ~ IMS

Science Objectives

Sensitivity Curve

Measurement Sensitivity

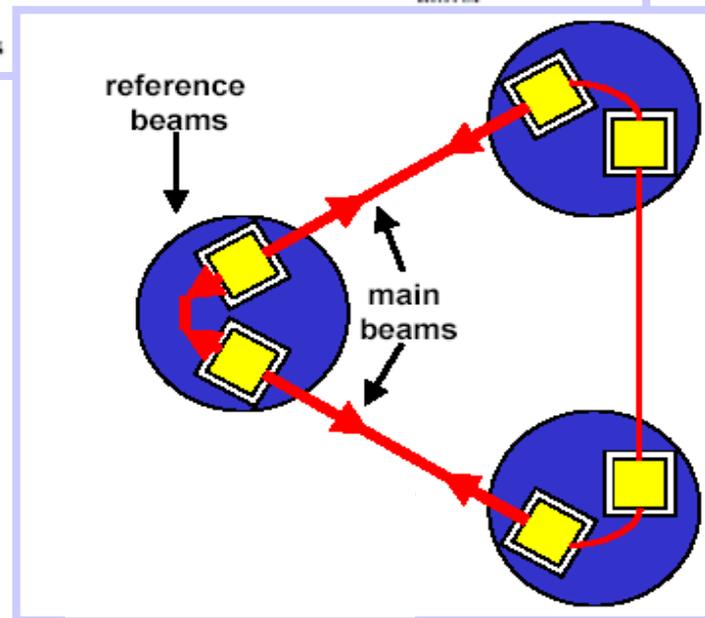
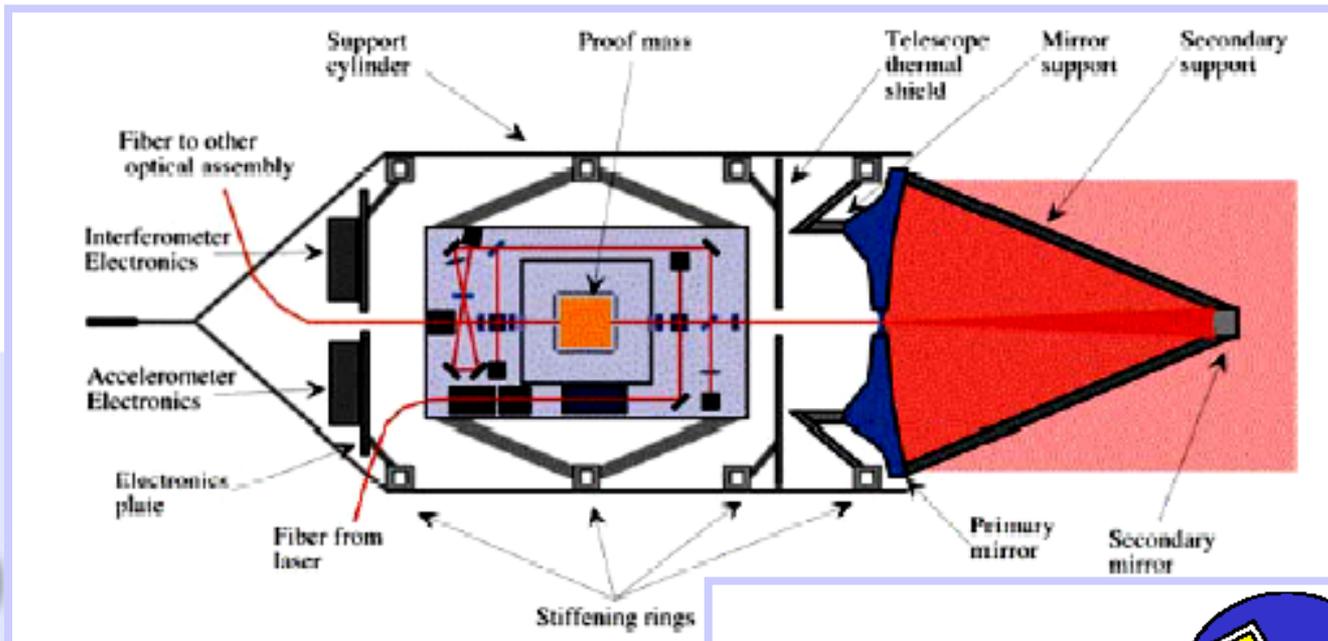
Interferometry Measurement System

Laser System

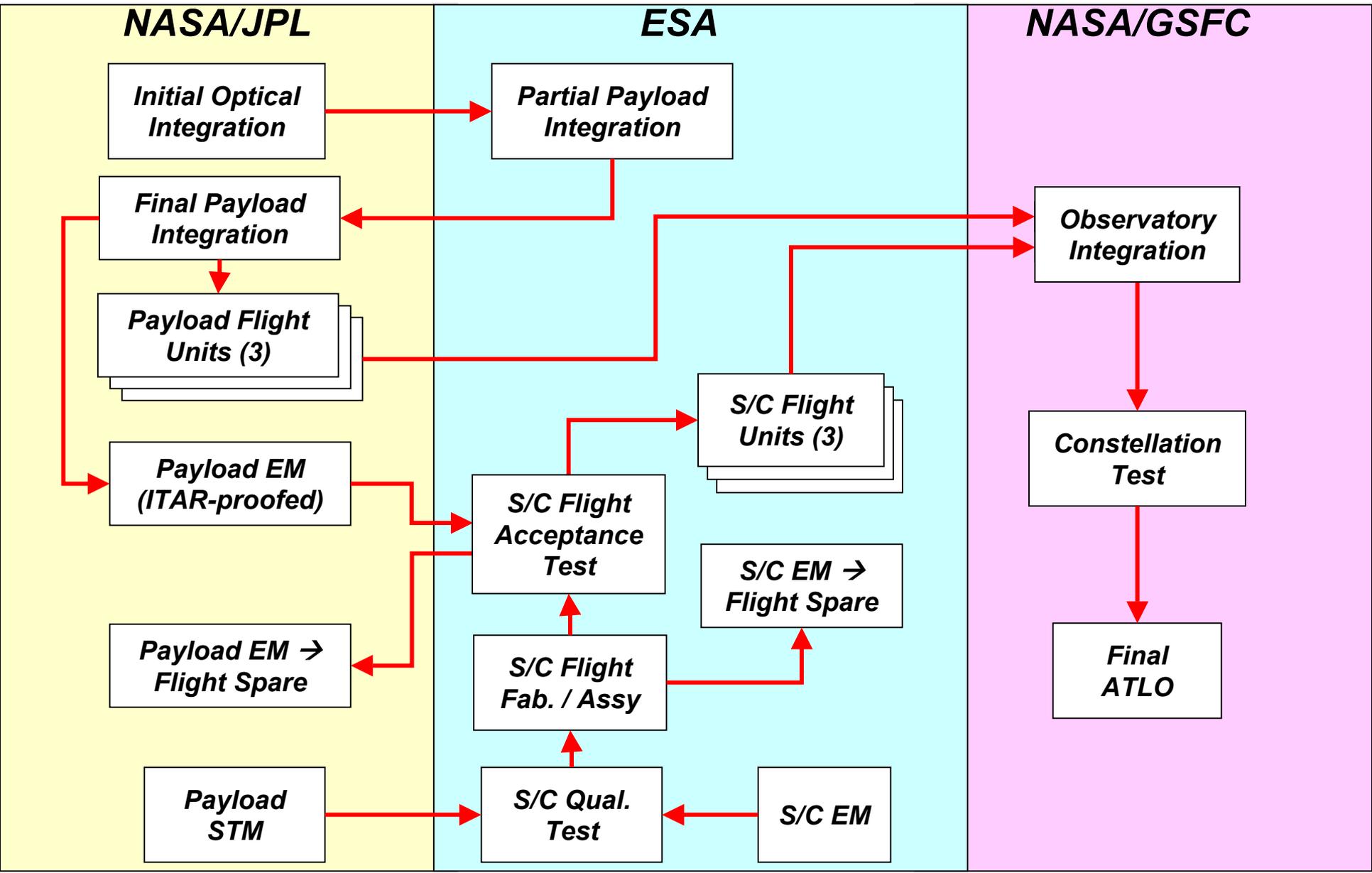
Phase Measurement

Ultra-Stable Structures

Frequency Noise Corrections



Strawman Integration Flow



Verification During I&T

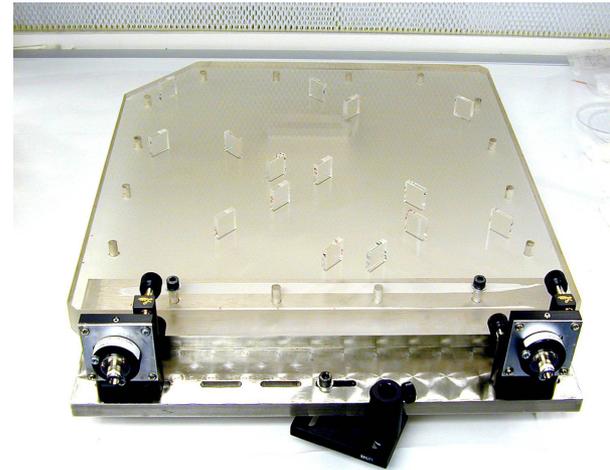
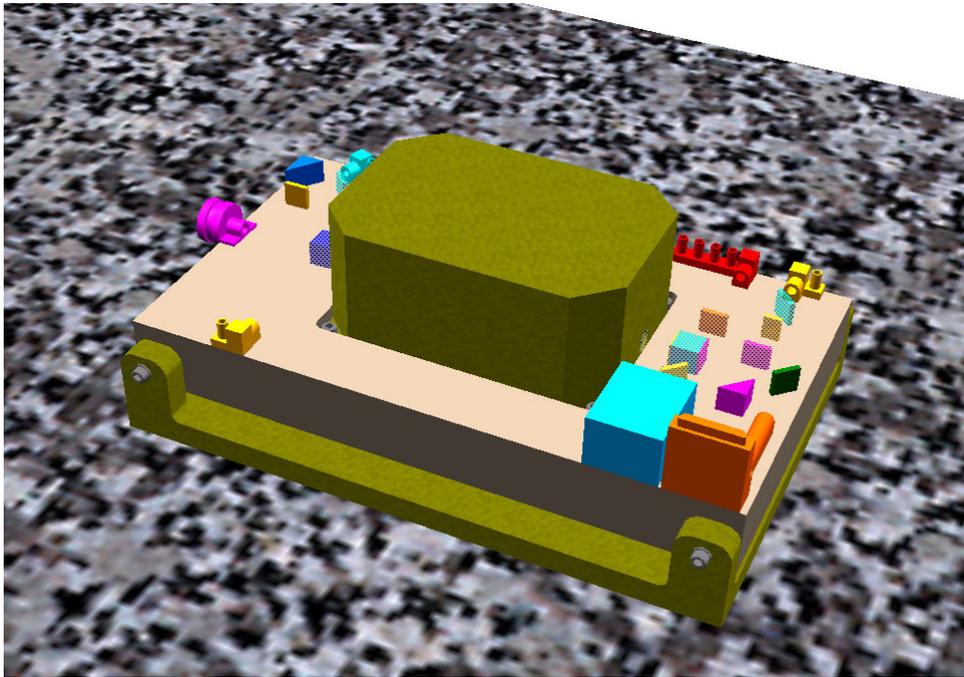
Beyond
Einstein:
From the
Big Bang
to
Black
Holes

Step	Integration Components	Performance Tests	Environmental Test	Modeling
Initial IMS Integration	Dummy proof mass, ULE block, fiber, laser stabilization cavity, optics	Wavefront quality, contrast, scatter, bond stability	Vibration	None
Intermediate IMS Integration	Optical bench, laser, CCD, phase modulator, phase detector, ultra-stable oscillator, electronics	Detector noise, phase noise, laser frequency and amplitude noise, oscillator noise, pointing stability	TV, EMI/EMC	Frequency noise corrections, pointing, STOPG
Final IMS Integration	Electro-optical bench, telescope, star trackers	Wavefront quality, pointing actuation and stability, phase stability; IMS subsystem test	Vibration, Thermal, EMI/EMC, Magnetic	Frequency noise corrections, pointing, WFE at 5×10^6 km, STOPG
GRS Integration	Initial optical assembly, charge management unit, flight proof mass, proof mass housing, caging and vacuum assembly	Charge control, proof mass actuation and control, vacuum level	Vibration, TV, EMI/EMC, Magnetic	GRS performance
Y-Tube Integration	Final optical assembly, Aft Fiber, Payload C&DH FSW, Y-Tube Structure	Pre-ship functional of GRS, Pre-ship functional of optical assembly, Pre-ship testing of thermal isolation, Pre-ship testing of phase readout, Pre-ship testing of laser stabilization	Mass properties, EMI/EMC, Magnetic, Acceptance-level vibration	STOPG, Frequency noise corrections
Observatory Integration	Spacecraft bus and payload	Displacement sensitivity, alignment sensitivity, pointing control, wavefront quality, frequency noise, gravity gradient	TV, EMI/EMC	STOPG, WFE at 5×10^6 km, pointing
Constellation Testing	Three spacecraft	Michelson sensitivity, frequency noise rejection, lock acquisition, spacecraft communication, data processing, constellation testing	Thermal, Vibration, EMI/EMC, TV	DRS Performance, pointing, frequency noise corrections, science data simulator
Final Integration	Three spacecraft, Payload attach fitting, shipping container	Functional tests for launch campaign	None	None

Initial IMS Integration

Beyond Einstein:
From the Big Bang to Black Holes

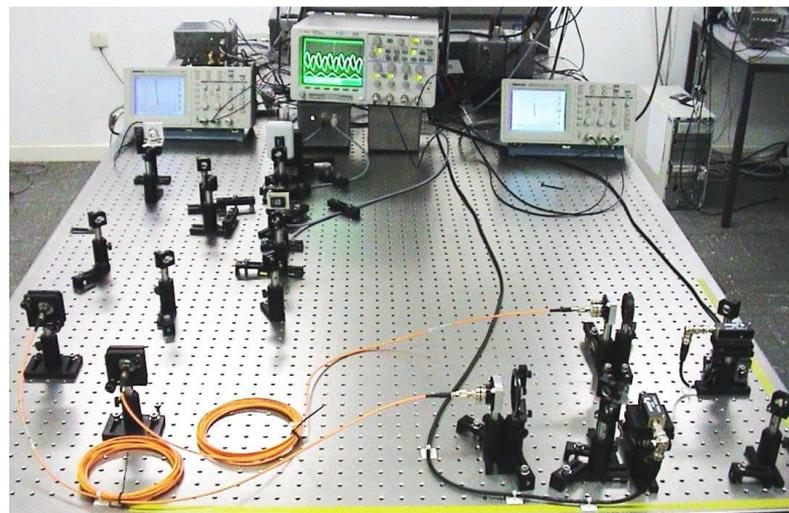
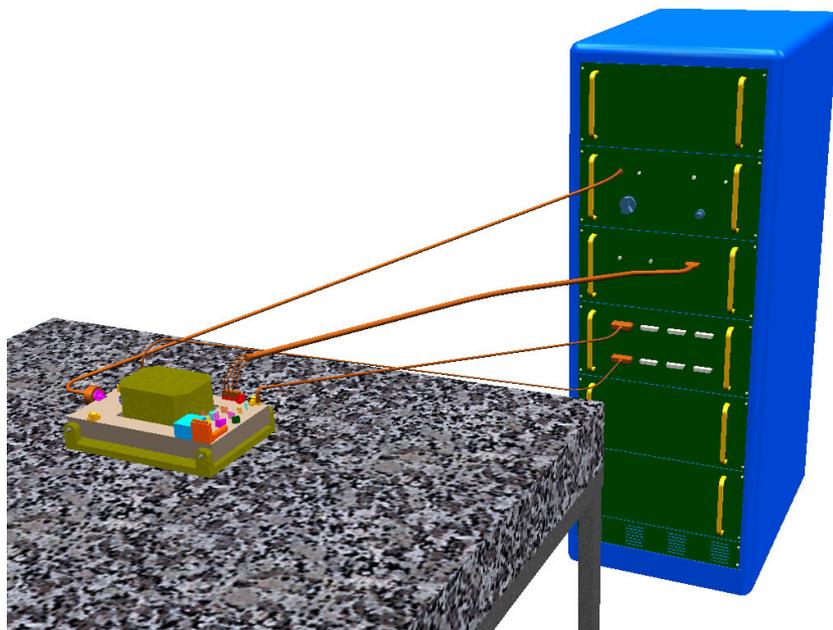
INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Dummy proof mass, ULE block, fiber, laser stabilization cavity, optics	Wavefront quality, contrast, scatter, bond stability	Vibration	None



Intermediate IMS Integration

Beyond Einstein:
From the Big Bang
to Black Holes

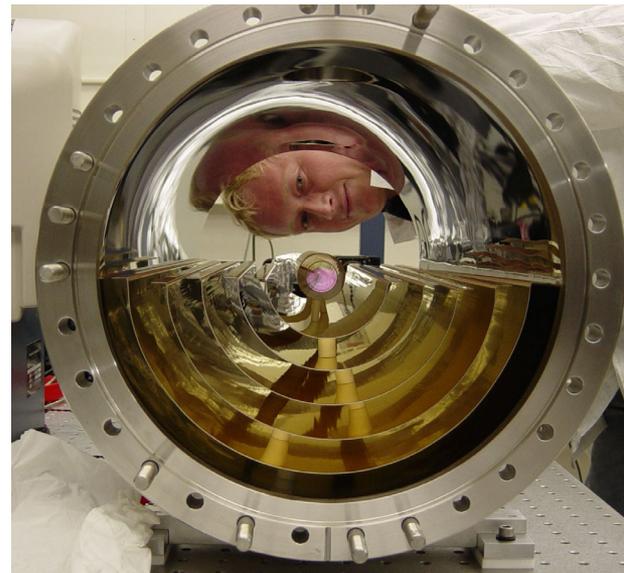
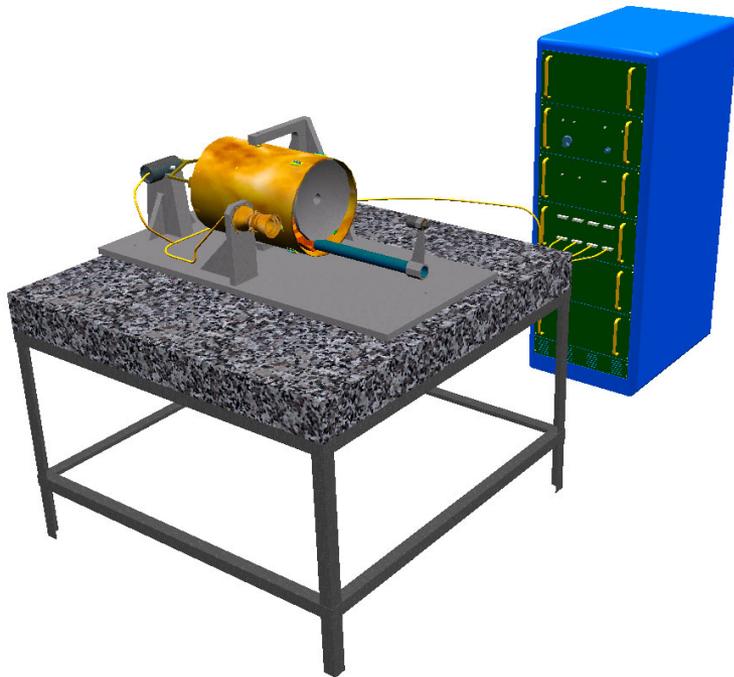
INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Optical bench, laser, CCD, phase modulator, phase detector, ultra-stable oscillator, electronics	Detector noise, phase noise, laser frequency and amplitude noise, oscillator noise, pointing stability	TV, EMI / EMC	Frequency noise corrections, pointing, STOPG



Final IMS Integration

Beyond Einstein:
From the Big Bang
to Black Holes

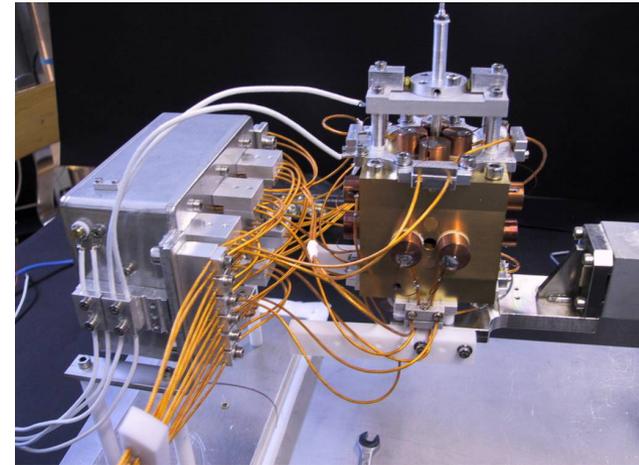
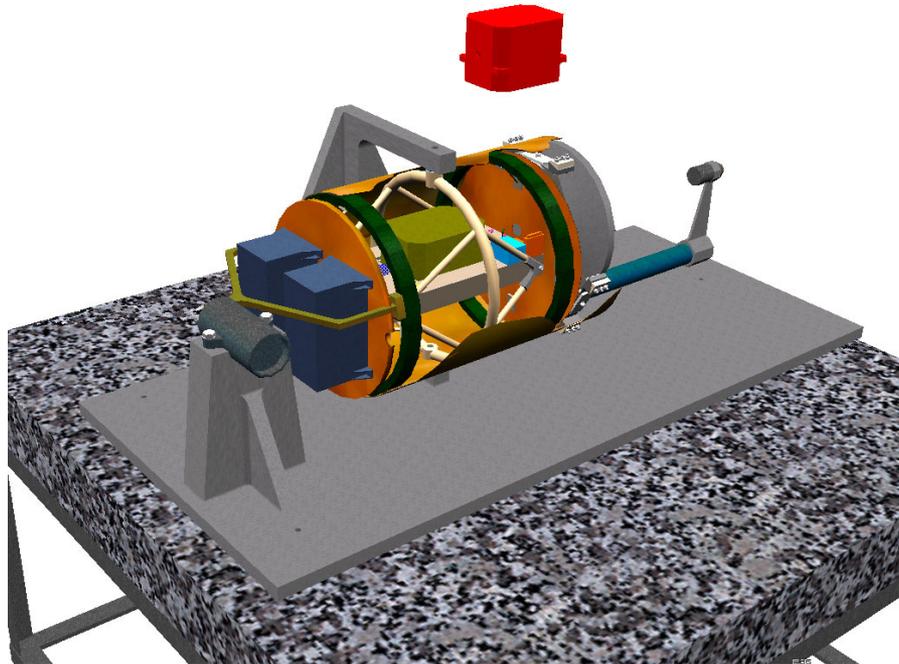
INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Electro-optical bench, telescope, star trackers	Wavefront quality, pointing actuation and stability, phase stability, IMS subsystem test	Vibration, Thermal, EMI / EMC, Magnetic	Frequency noise corrections, pointing, WFE at 5×10^6 km, STOPG



GRS Integration

Beyond Einstein:
From the Big Bang
to Black Holes

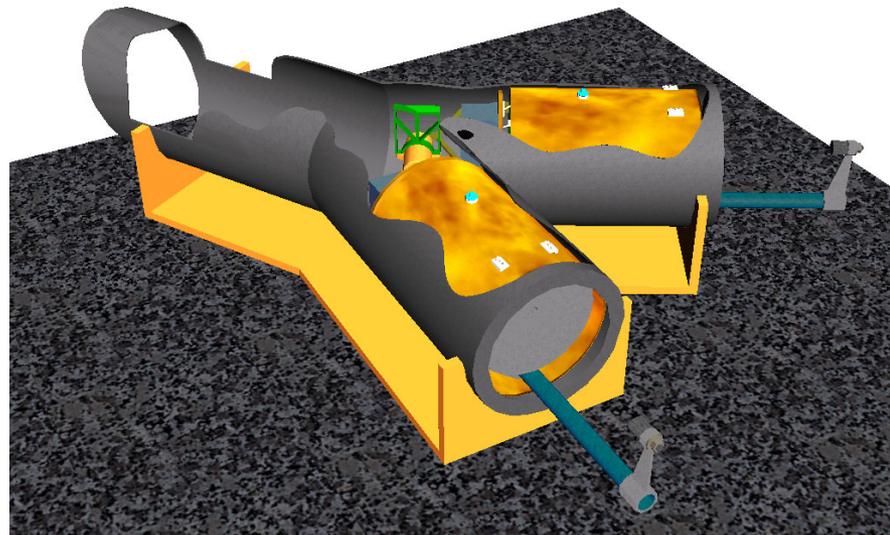
INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Initial optical assembly, charge management unit, flight proof mass, proof mass housing, caging and vacuum assembly	Charge control, proof mass actuation and control, vacuum level	Vibration, TV, EMI / EMC, Magnetic	GRS performance



Y-Tube Integration

Beyond Einstein:
From the Big Bang
to Black Holes

INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Final optical assembly, Aft Fiber, Payload C&DH FSW, Y-Tube Structure	Pre-ship functional of GRS, Pre-ship functional of optical assembly, Pre-ship testing of thermal isolation, Pre-ship testing of phase readout, Pre-ship testing of laser stabilization	Mass properties, EMI / EMC, Magnetic Acceptance level vibration	STOPG, Frequency noise corrections, Pointing



Observatory Integration

Beyond Einstein:
From the Big Bang to Black Holes

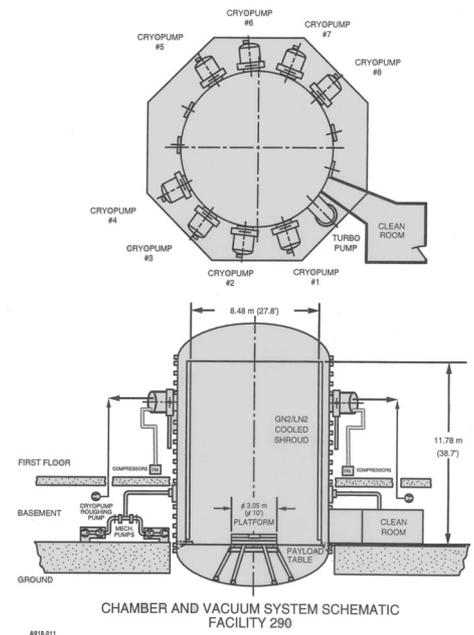
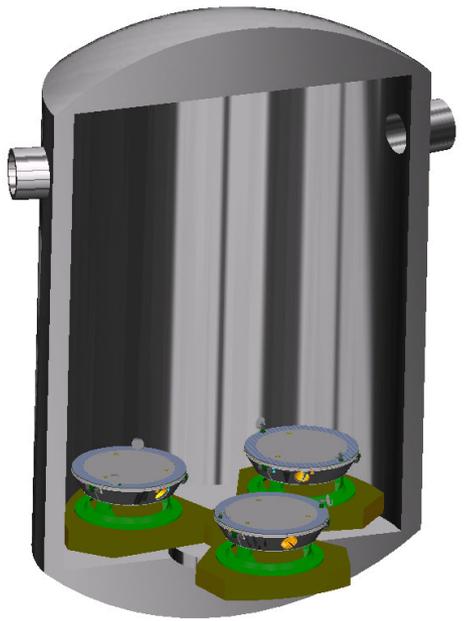
INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Spacecraft bus and payload	Displacement sensitivity, alignment sensitivity, pointing control, wavefront quality, frequency noise, gravity gradient	TV, EMI / EMC	STOPG, WFE at 5×10^6 km



Constellation Testing

Beyond Einstein:
From the Big Bang to Black Holes

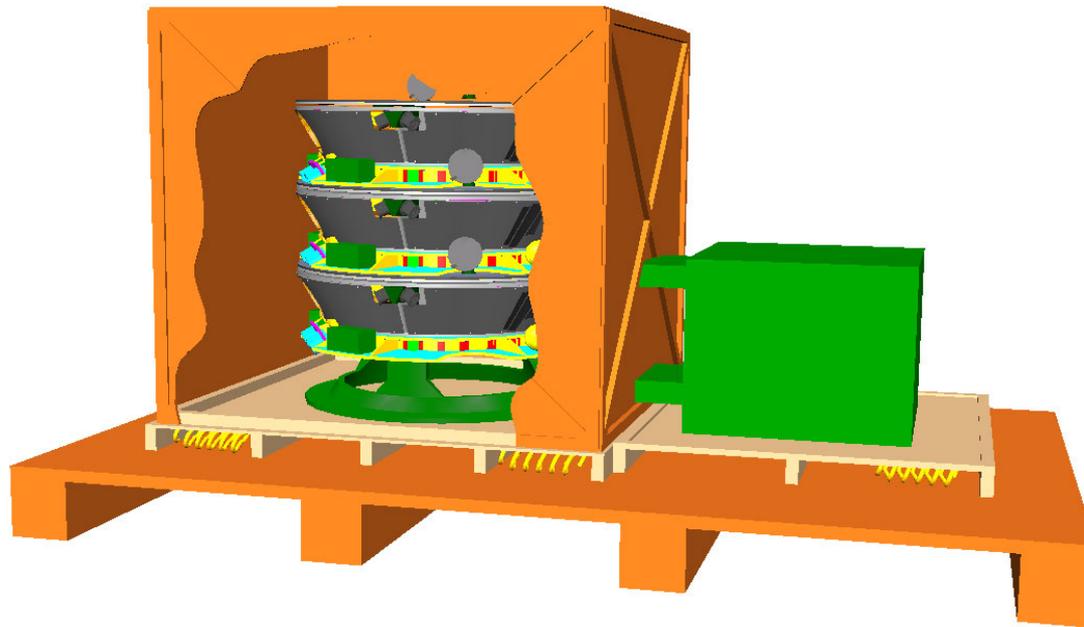
INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Three spacecraft	Michelson sensitivity, frequency noise rejection, lock acquisition, spacecraft communication, data processing, constellation testing	Thermal, Vibration, EMI / EMC, TV	DRS Performance, pointing errors, frequency noise corrections, science data simulator



Final Integration

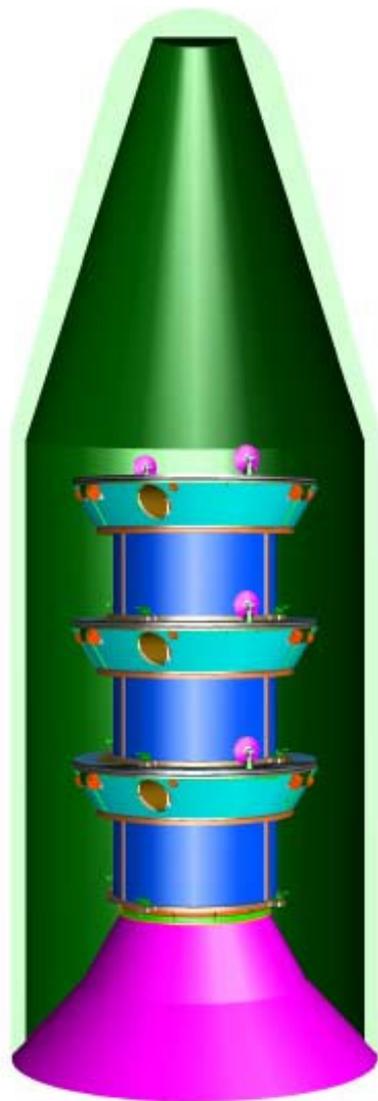
Beyond
Einstein:
From the
Big Bang
to
Black
Holes

STEP	INTEGRATION COMPONENTS	PERFORMANCE TESTS	ENVIRONMENTAL TEST	MODELING
Final Integration	Three spacecraft, Payload attach fitting, shipping container	Functional tests for launch campaign	None	None



Launch

Beyond
Einstein:
From the
Big Bang
to
Black
Holes



- After set-up, operations are straightforward
 - 1 science mode
 - Periodic interruption for “tuneup”
 - IMS pointing
 - HGA pointing
- DSN 34 meter antenna, X-band, 7kbps down / 2 kbps up
- JPL Mission Operations Center
- One or more Science Data Analysis center(s)
- Performance monitoring to determine schedule for tuning