LIGO ADVANCED SYSTEM TEST INTERFEROMETER

Program Status Report

Dave Ottaway, Gregg Harry, Ken Mason, Mike Zucker

LIGO Science Collaboration Meeting

LIGO Hanford Observatory

14 August, 2001

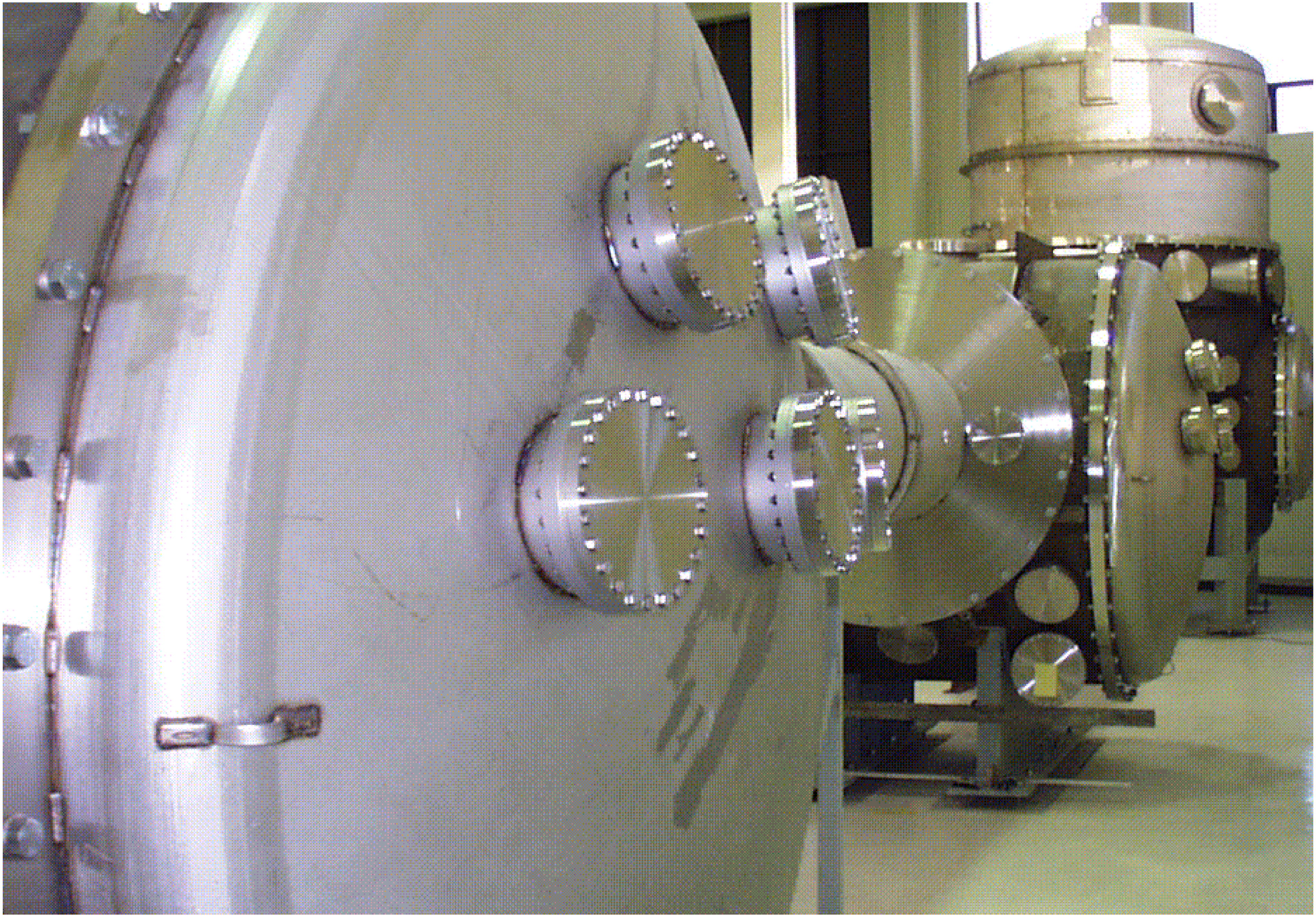
LASTI Mission

- Test LIGO components & systems at full mechanical scale
- Practice installation & commissioning
- Minimize delays & downtime for LIGO observatory upgrades

Specific Advanced LIGO Program Tasks ('01 - '06+):

- Qualify advanced seismic isolation & suspension systems and associated controls at full scale
- Develop detailed SEI/SUS installation & commissioning handbook
- Look for unforeseen interactions & excess displacement noise
- Test LASER and Input Mode Cleaner together at *full power*

Vacuum envelope, left (S) arm



People

•Local Staff

Grads - Jamie Rollins, Josh Phinney

Engineering - Ken Mason, Dan Mason

Tech support - Myron MacInnis, Fred Miller, Bob LaLiberte

Scientists - Rich Mittleman, Gregg Harry, Dave Ottaway

Lunch - David Shoemaker, Mike Zucker

•Visitors (since previous LSC meeting)

Initial SEI - Corey Gray, Hugh Radkins

Advanced SEI - Joe Giaime, Giles Hammond, Brian Lantz, Wensheng Hua, Tuck Stebbins

Advanced SUS - Norna Robertson, Calum Torrie, Janeen Romie, Phil Willems

CDS/DAQ/PSL/Initial SUS - Jay Heefner, Rick Karwoski, Paul Russel

•TODAY'S TOPICS

◊Optical configuration & PSL progress (Dave Ottaway)

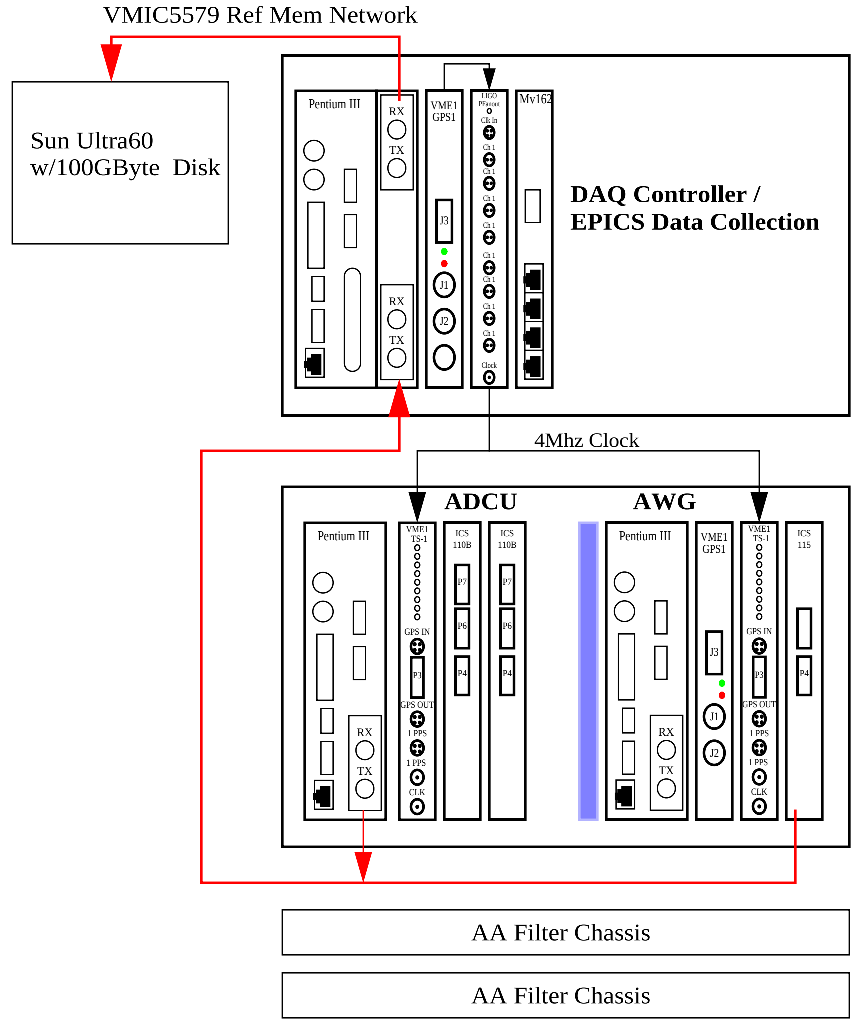
◊Displacement noise model projections (Gregg Harry)

◊Hydraulic SEI pre-isolator design (Ken Mason; *companion talk later by Brian Lantz*)

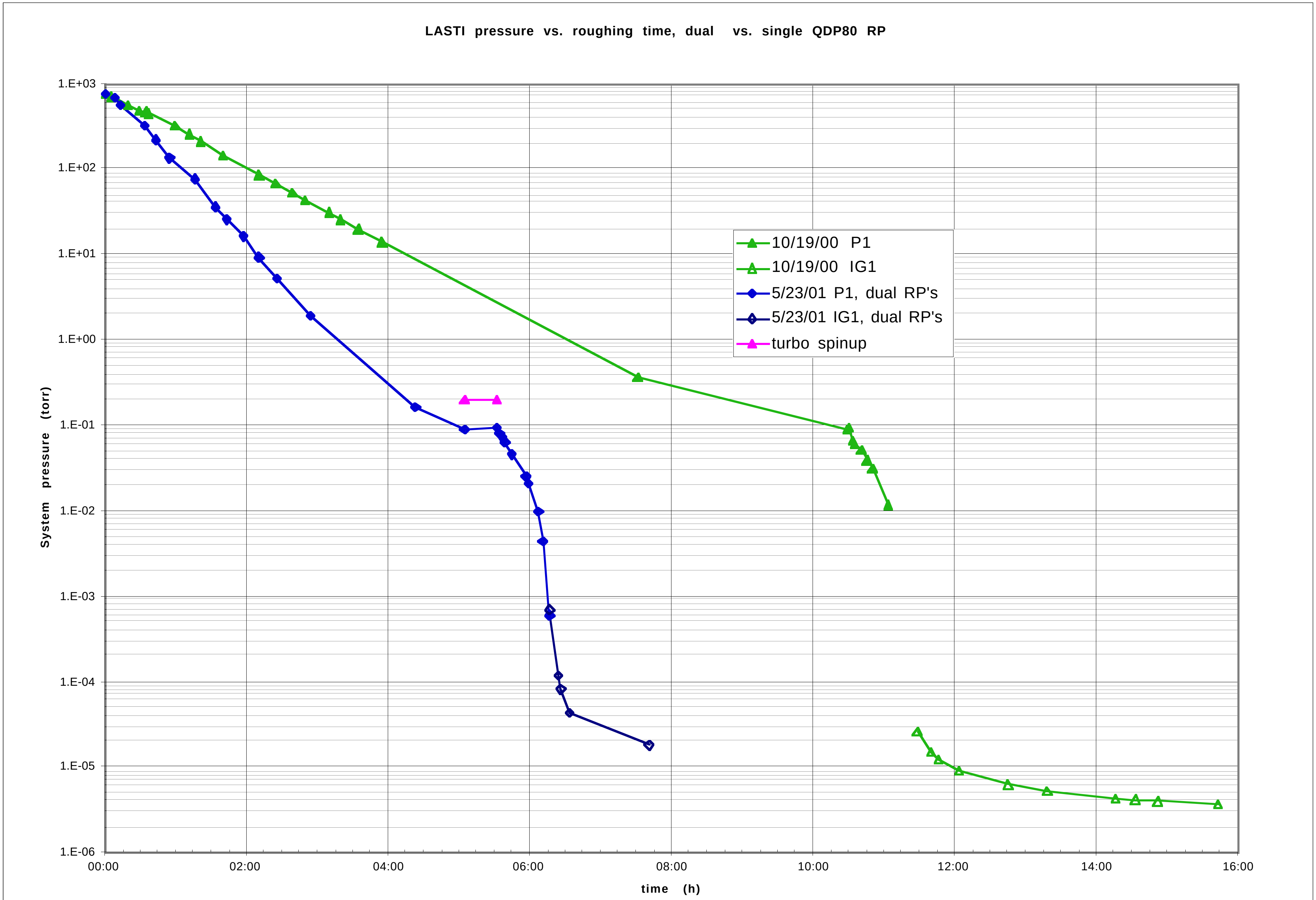
◊Milestones, schedule, etc. (MZ)

◊*Note: advanced quad suspension work @ MIT will be reported next session*

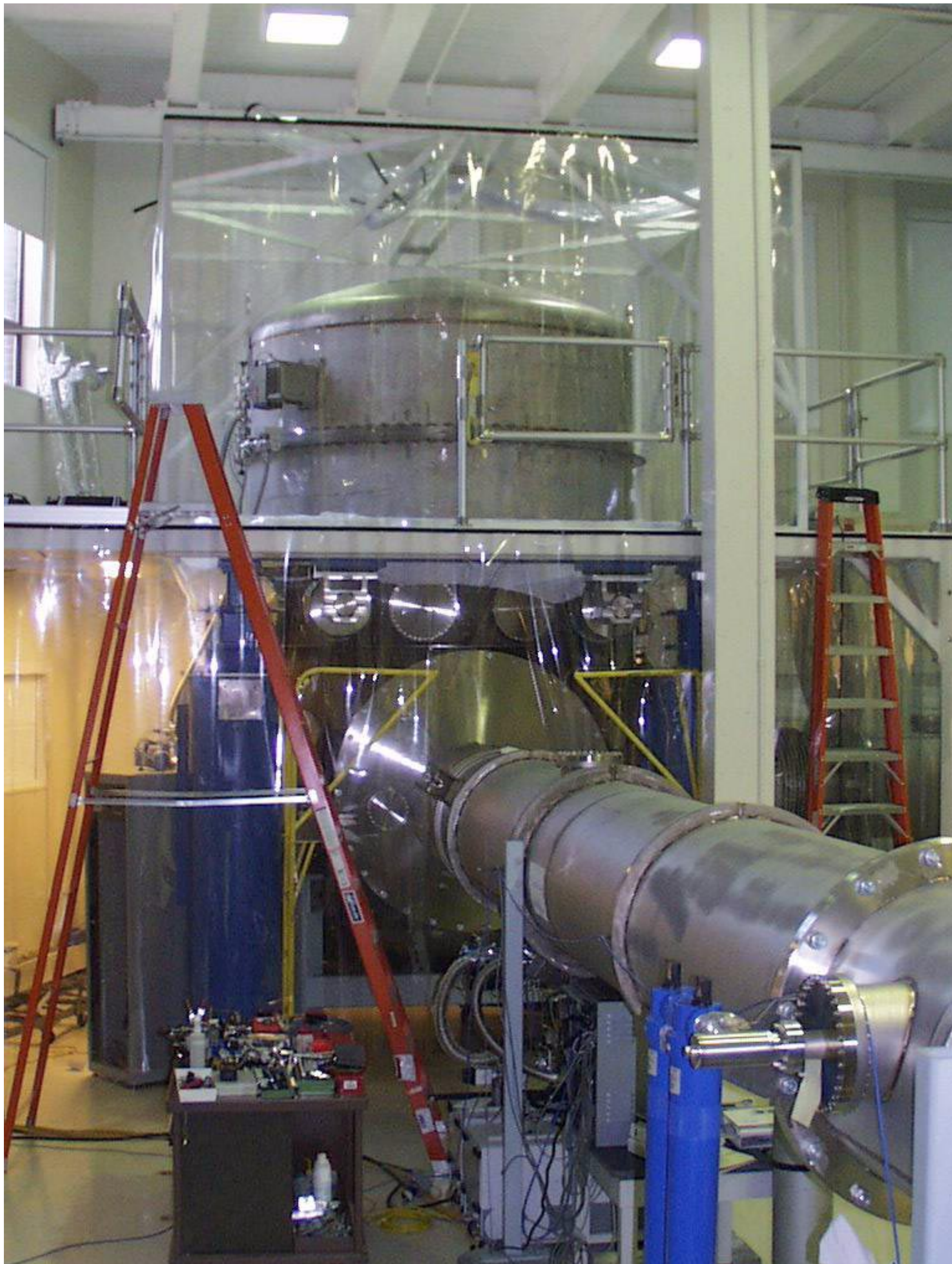
New Infrastructure: DAQ, EPICS, GDS*



NEW! IMPROVED!! *Faster Pumpdowns!*



Special BSC Cleanroom



Quad Pendulum

LASTI PSL

Status & Plan

- Accomplishments this period
  - ◊SEI base installation & leakcheck completed*
  - ◊BSC cleanroom completed, HAM cleanrooms refurbished
  - ◊pumping system augmentation completed
  - ◊CDS backbone, DAQ, EPICS systems installed & tested
  - ◊Initial SOS and PSL controls complete (except live-ammo testing)
- Coming up
  - ◊Initial 2-mirror test cavity suspension & installation: 9/01
  - ◊PSL complete & operating, “first light”: 9/01
  - ◊Test cavity program starts (cavity locking): 10/01
  - ◊Cable tray installation: 11/01
  - ◊SEI/SUS assembly “Mezzanine”: 1/02

Milestones/longer term

◊4Q99 / 4Q99 act: LASTI vacuum envelope commissioned √

◊1Q00sch / 3Q01 act: LASTI external structures installed (site tooling & help) √

◊2Q00sch / 4Q00 act: LASTI infrastructure design review √

◊3Q01: LASTI infrastructure completion (DAQ, CDS, PSL, test cavity, ...)
test cavity program, hydraulics, intensity stabilization, other expt's?

◊1Q02: HAM pathfinder installed for standalone testing *probable slip*

◊2Q02: MC controls SUS installed testing starts *possible slip*

◊3Q02: BSC pathfinder installed for standalone testing *probable slip*

◊4Q02: TM controls SUS installed for standalone testing

◊3Q03: LASTI controls test review

◊2Q04: LASTI noise prototype installed *not allowed to slip!*

◊2Q05: LASTI SUS/SEI test review

◊3Q05: Adv LIGO PSL/MC tests start

Pressing Issues

- Integration test of hydraulic pre-isolators
  - ◊Based on LIGO I pressure, looks best to do HAM13 as soon as working prototypes are ready; can we do this & get useful data in time to influence pathfinder HAM and BSC advanced SEI deliveries? can there/will there be a LLO LIGO I retrofit?
- Short cavity test
  - ◊g-parameter nearly unstable (coincidentally, close to adLIGO baseline)
  - ◊tests to help relieve anxiety about cavity instability, Guoy phase separation, WFS operation with "the big spots"?
  - ◊can we fit in some backlogged PSL-enabled tests (req'd for adLIGO but unassigned)?
    - –super-duper intensity stabilization (like 3e-9/rHz)
    - –high power photodetectors
    - –spatial wavefront sensing
    - –other ideas?

Optical Configuration and Initial Experiments

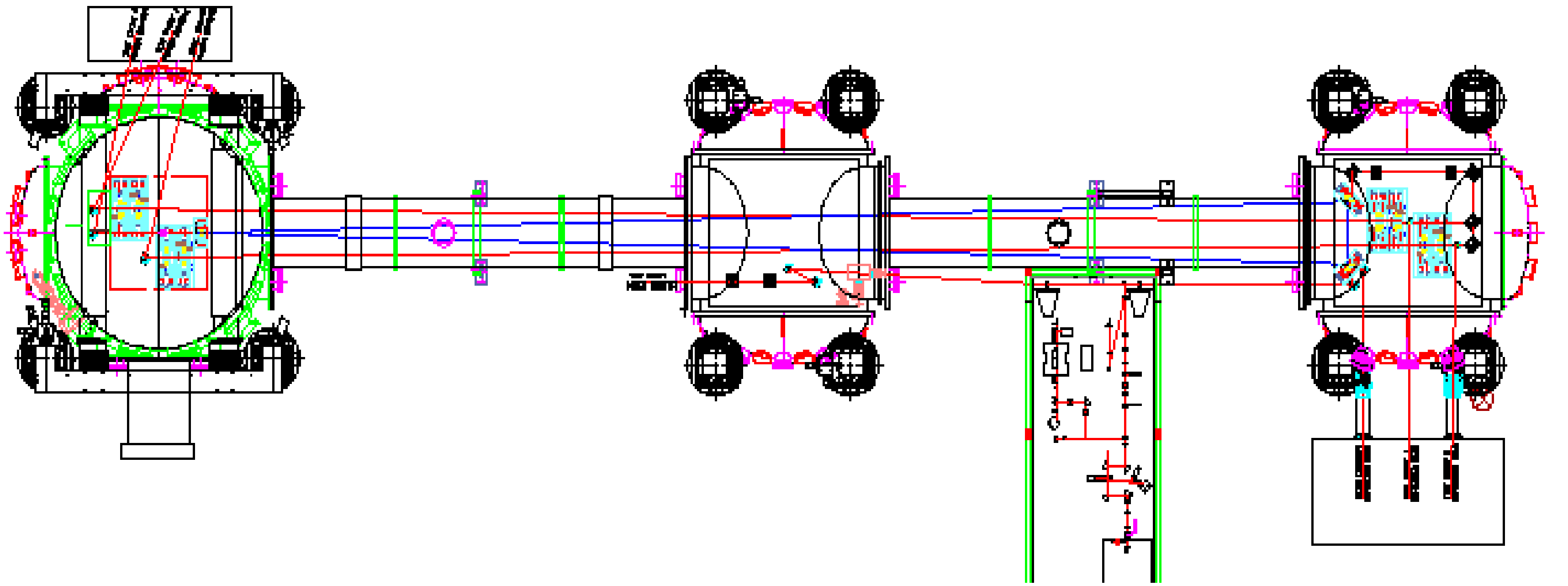
LASTI Review

LSC 9

LIGO Hanford Observatory

August 8th, 2001

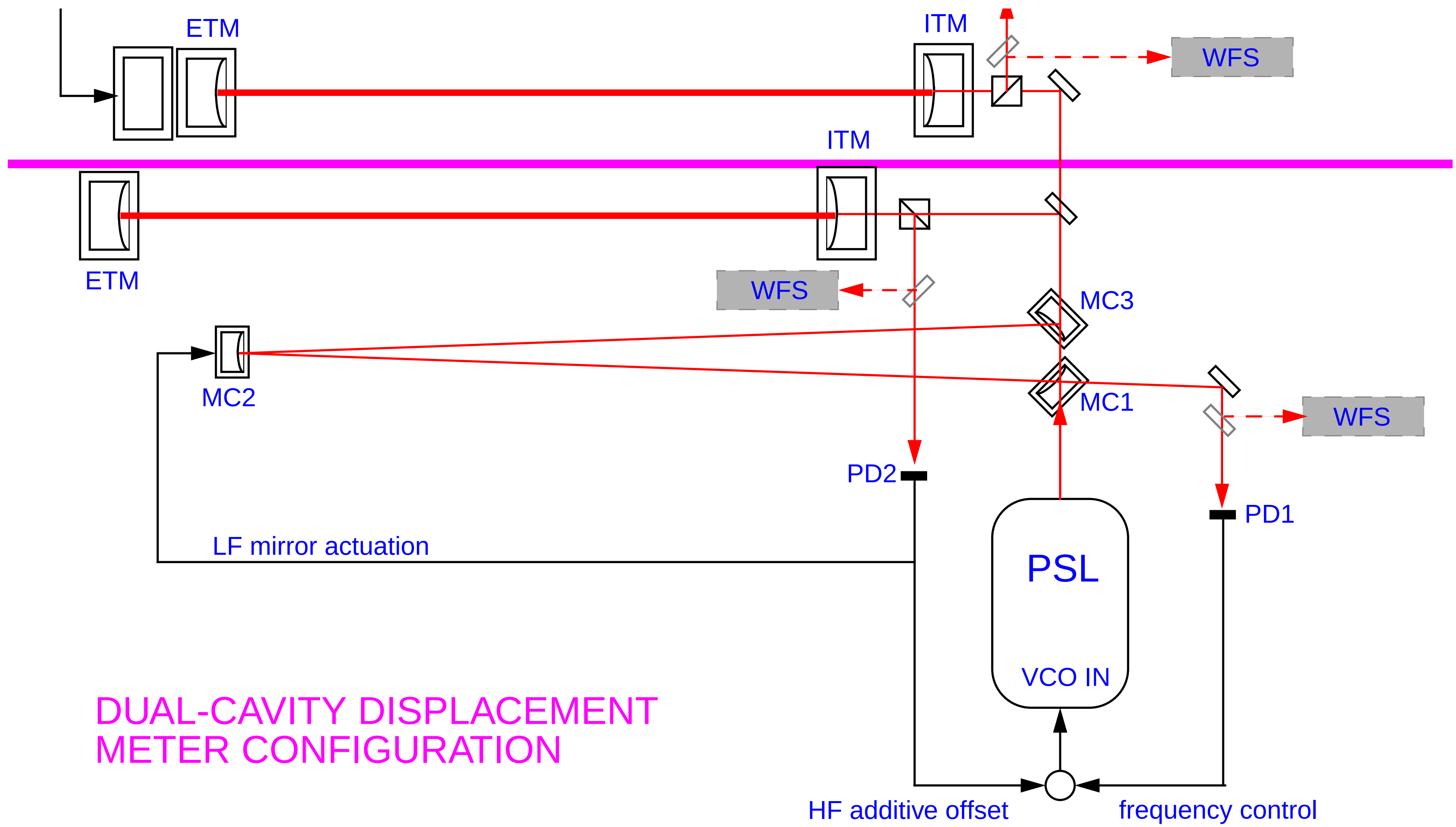
LASTI Configuration



- Initial test cavity included in center HAM
- Full LASTI in end HAM and BSC chamber

LASTI Features

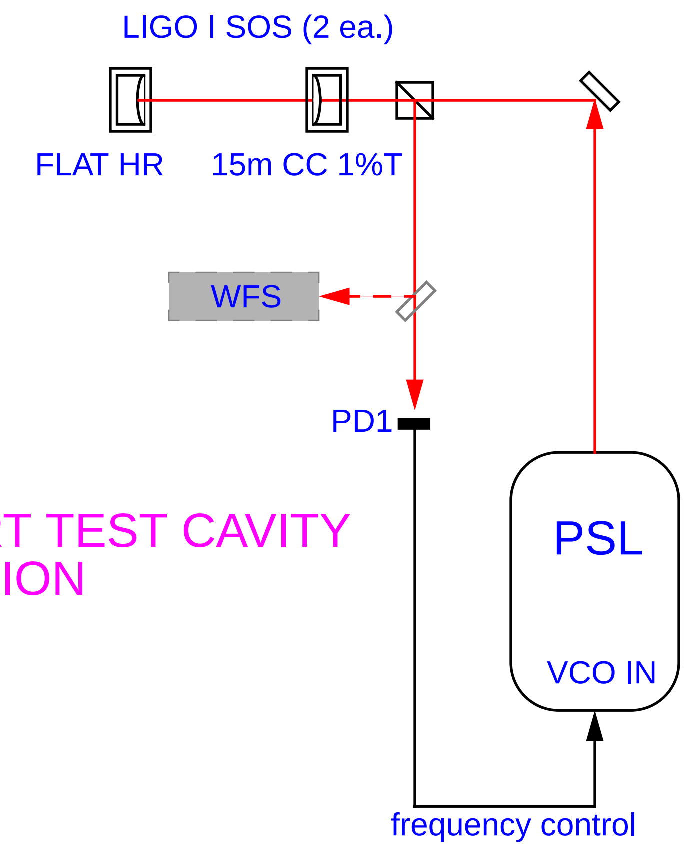
- LIGO I style PSL
- Advance LIGO mode cleaner inc. suspensions
- Two test cavities
  - Limits frequency noise
  - Increases spot size to limit thermoelastic noise for sapphire
- Test cavity properties
  - waist size ~3.5 mm, length 16m
  - g factor ~ 0.9 , finesse ~ 2000
  - Triple suspensions (HAM) , Quad suspensions (BSC)
- Test cavity parameters realized by selecting the properties of the input mirrors



DUAL-CAVITY DISPLACEMENT
METER CONFIGURATION

Initial In-Vacuum Suspended CavityTest

- Aim: To commission the LASTI 10W PSL and to gain expe-rience operating suspended marginally stable cavities inc. wavefront sensing (small Guoy phase separation)
- Initial Cavity Parameters:
  - Length ~1 m
  - Mirrors: Flat HR Mirror, 10m ROC 0.63 % T
  - Derived Cavity Parameters: g ~ 0.9, Finesse ~1000
  - l and finesse similar to full LASTI test cavities
- Suspensions are LIGO I SOS suspension



INITIAL SHORT TEST CAVITY CONFIGURATION

Summary of Current Status

- PSL
  - Table layout design completed
  - Optical assembly commenced
  - Electrical installation completed
  - Full commissioning to commence early Sept. 2001.
  - Enclosure designed and expected delivery late Sept. 2001
- Initial Test Cavity
  - Assembly of suspended mirrors to start early Sept. 2001.
  - In - vacuum installation to be completed by end Sept. 2001‘.
- Seismic Isolation
  - Initial LIGO I HAM installation completed

Displacement noise modeling and trade studies

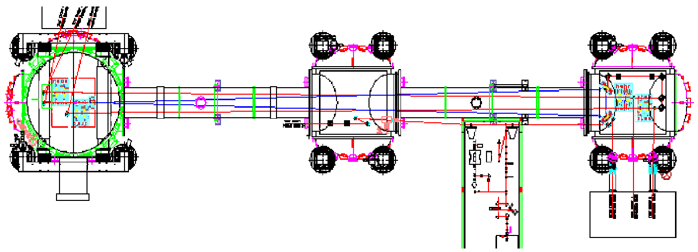
LASTI Progress Report

LSC 9

LIGO Hanford Observatory

August 8, 2001

Baseline Configuration



- 15 meter cavity length
- 2 cavities side-by-side
- Fused silica input couplers in HAM21 suspended from recycling mirror (3 stage) suspensions
- Sapphire ETMs in BSC00 suspended from core optics (4 stage) suspensions
- Pendulum suspensions with fused silica fibers/ribbons

Two Variants

- Different radii of curvature on mirrors
  - Changes in stability of cavity (g factor)
  - Changes in beam radius (thermal noise)
- "Conservative" approach
  - Stable cavity g = 0.33
  - Smaller beam w_0 = 2.25 mm
- "Aggressive" approach
  - Close to marginal stability g = 0.85
  - Larger beam w_0 = 3.6 mm

Parameters

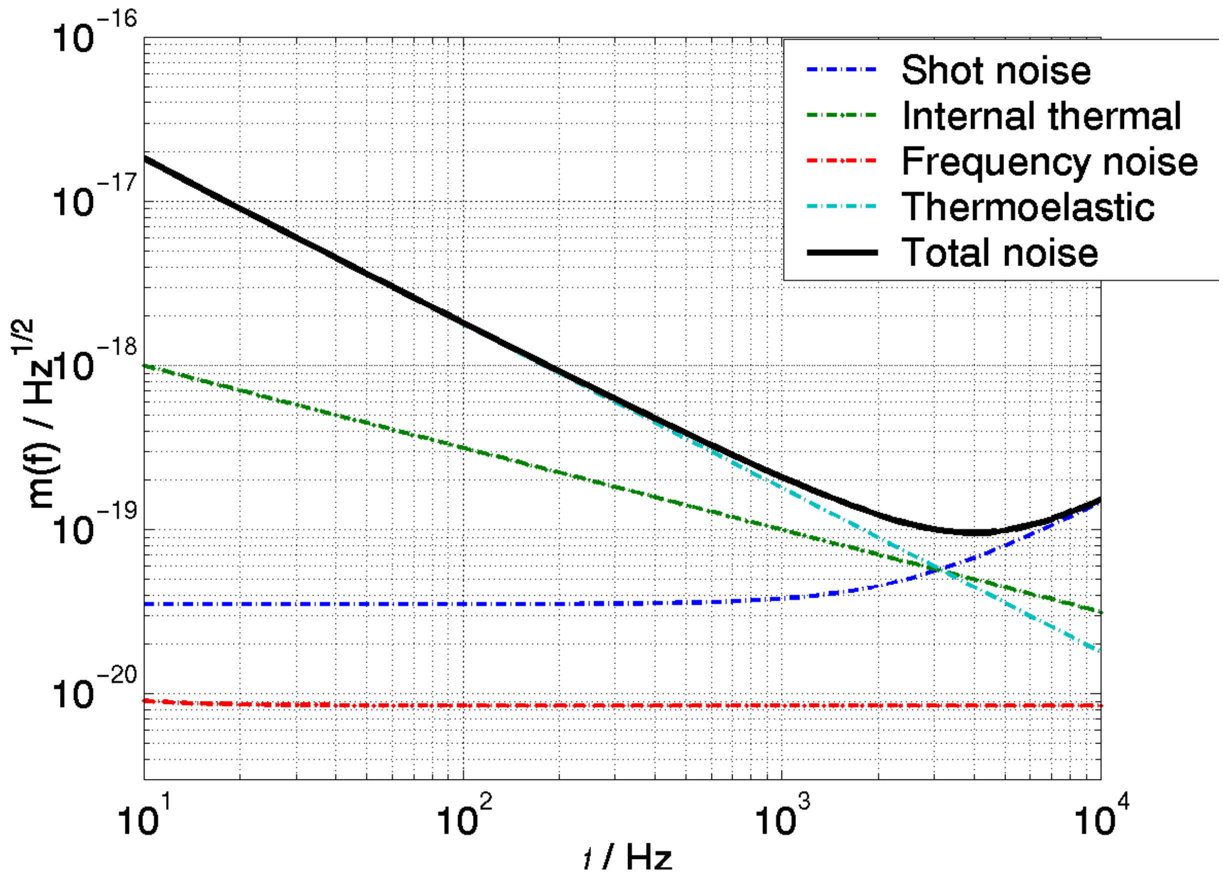
- Cavity length: 15 m
- Residual gas pressure: Water at 10^{-6} torr
- Mode cleaner length: 15 m
- HAM seismic noise: 2×10^{-13} m/Hz$^{1/2}$ @ 10 Hz
- Finesse: 2000
- Laser power: 6 W
- Frequency noise stabilization gain: $10^9 / f^2$
- Ta_2O_5/SiO_2 optical coatings, 3% and 1 ppm
- 40 kg Silica input couplers (RM) / Sapphire ETMs

Noise sources I

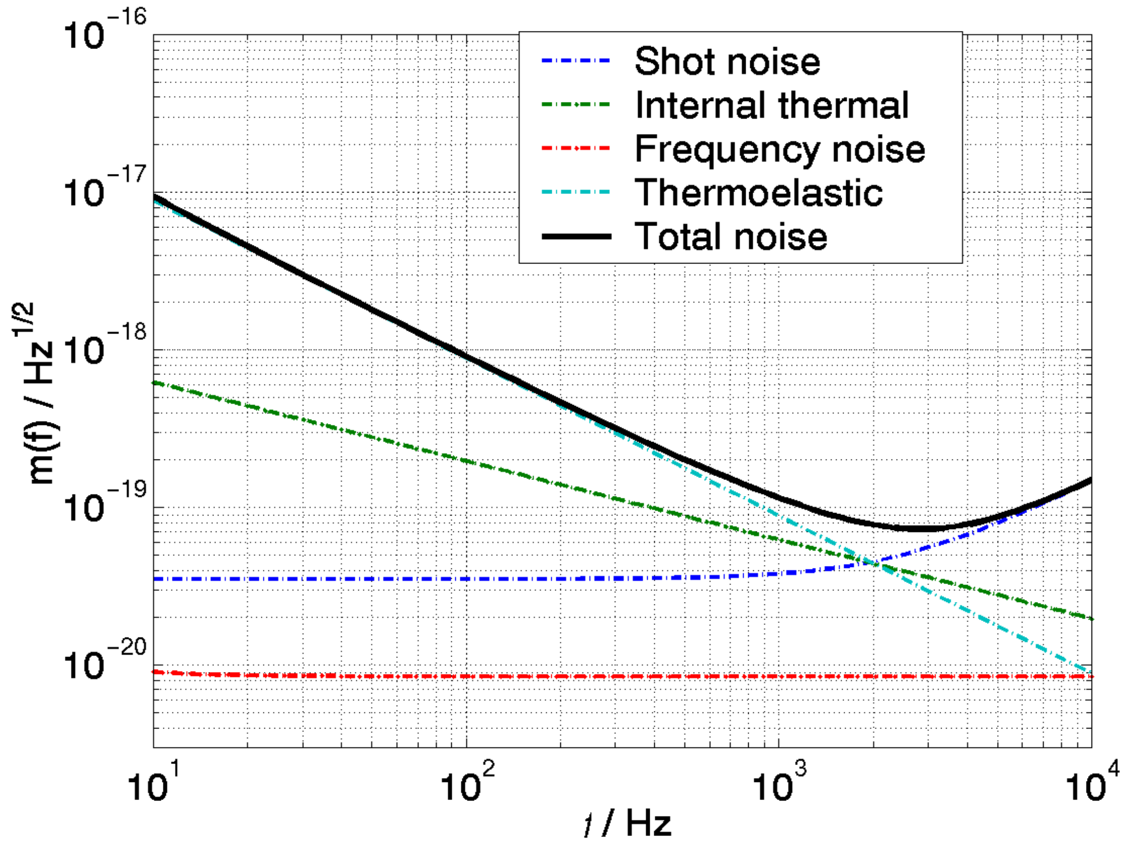
Noise sources that contribute to total noise

- Seismic
  - Advanced LIGO seismic isolation stacks/suspensions
- Thermoelastic thermal noise
  - Only important in sapphire mirrors
- Structural thermal noise (coating thermal noise)
  - Ta_2O_5/SiO_2 coatings-see talks by Rowan & Gretarsson
- Technical frequency noise
  - 5 kg mode cleaner mirrors
  - Reduced by servo from second cavity
- Shot noise

Conservative configuration



Aggressive configuration

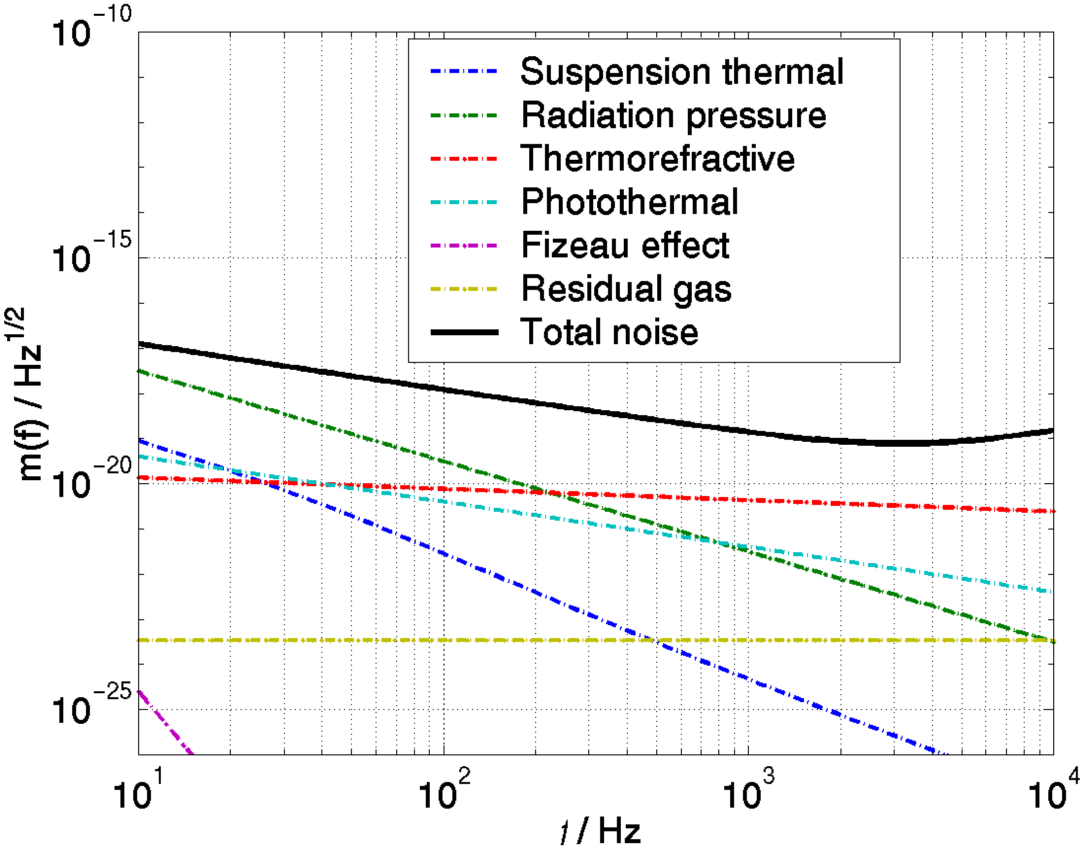


Sources of noise II

Noise sources that do not contribute

- Fizeau noise (Noise from transmission through moving optic)
  - 5 cm Faraday isolator, n = 1.5
- Photothermal noise (Elastic response to photon heating)
  - Coating absorption 0.5×10^{-6}
- Thermorefractive noise (Change in n from thermal fluctuations)
  - Ta_2O_5/SiO_2 coatings
- Suspension thermal noise
- Residual gas noise
- Radiation pressure

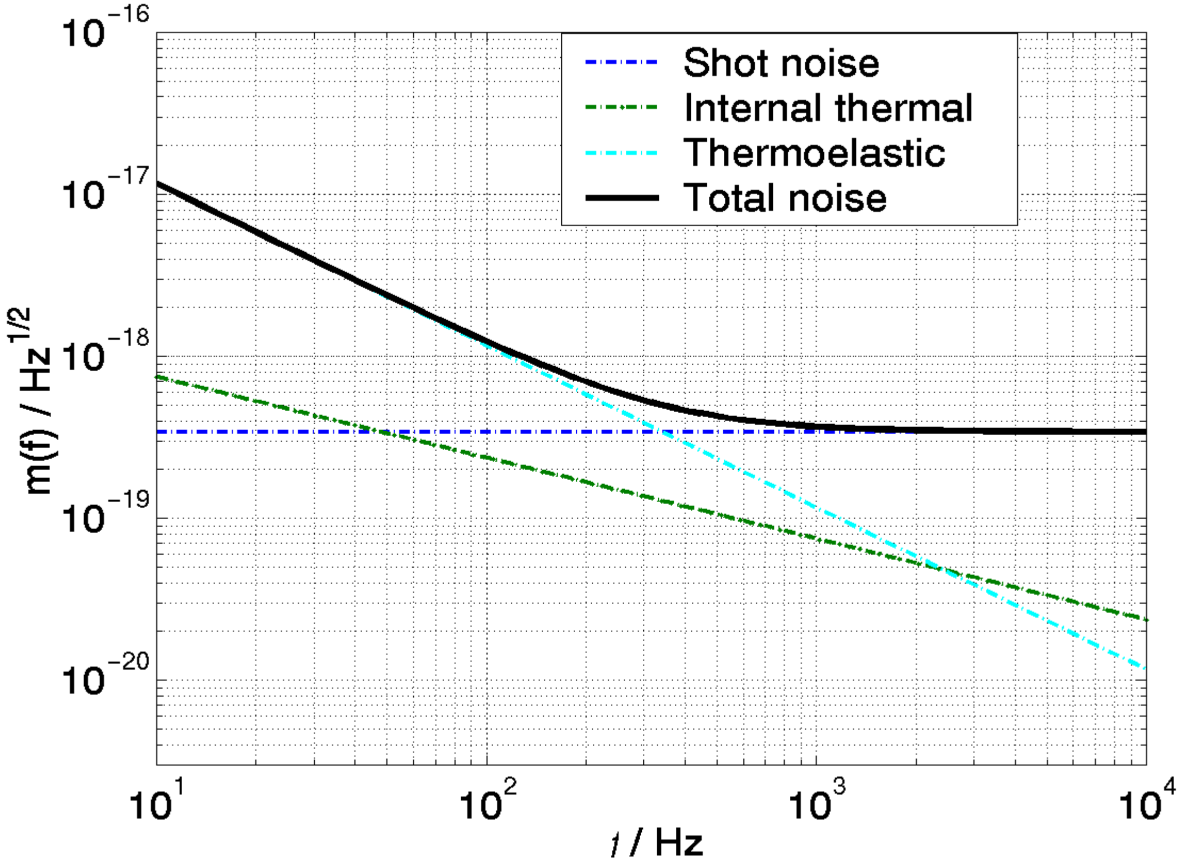
Smaller noise sources



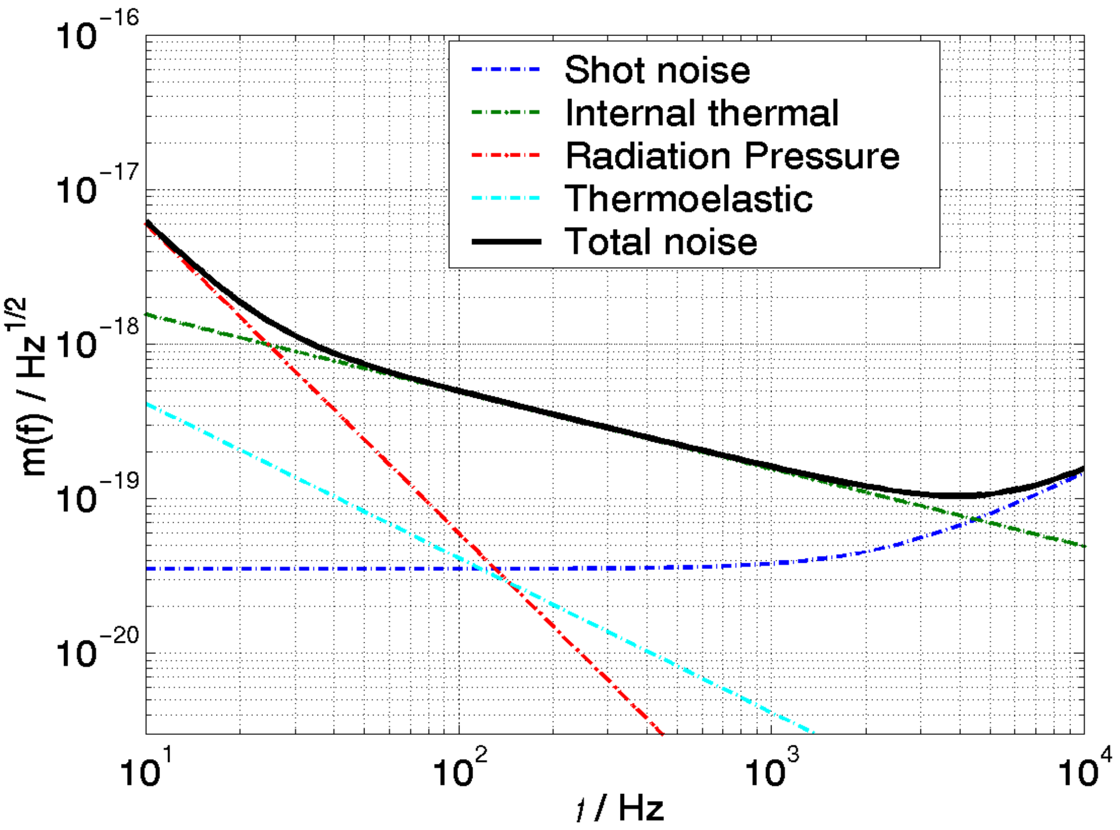
Other configurations
Under possible consideration

- Short (20 cm), nearly flat-flat cavity
  - Larger spot size reduces thermal noise
  - Measure thermoelastic dependance on w_0
  - Cavity very near unstable, hard to get finesse of 200
- Silica end mirrors (if problems develop with sapphire)
  - Reduced thermoelastic noise
  - Coating thermal noise detectable
- Flat-top beams
  - Reduces thermoelastic noise

Short cavity



Silica test mass substrates

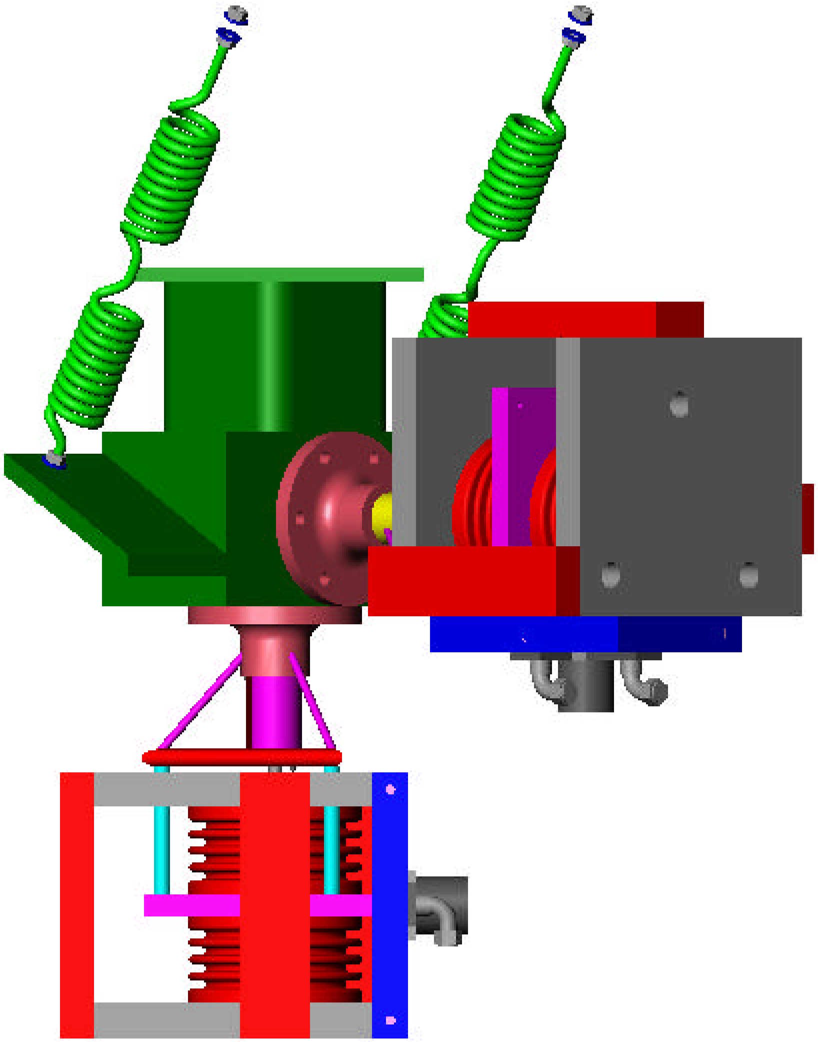


Hydraulic SEI Pre-isolator Design

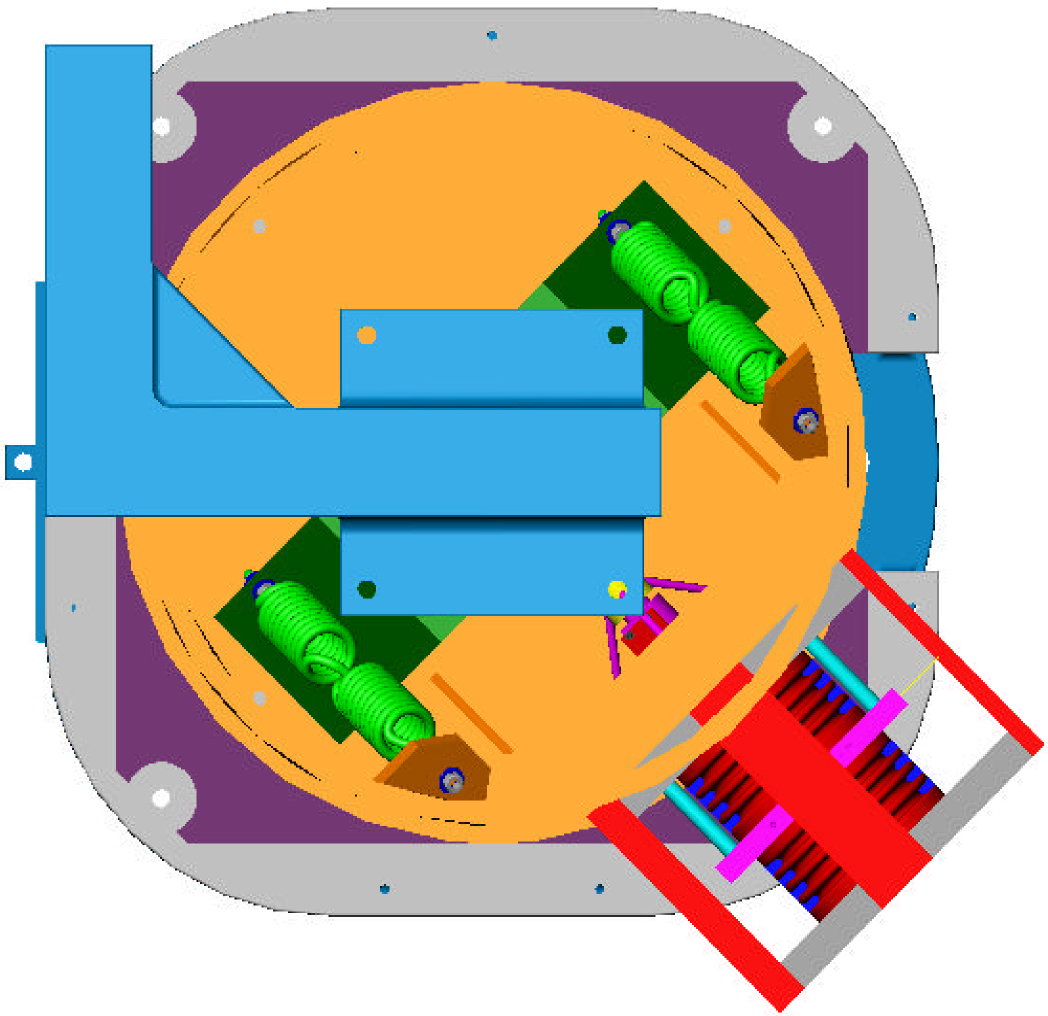
- Hydraulic actuator, pumping, and control system has been developed at Stanford.
- Implementation and testing of a 6 DOF system under a LIGO stack at MIT
- Joshua Phinney (MIT) at Stanford for 3 weeks
- Part of LIGO 2 seismic plan T000024
- Purpose of Quiet Hydraulic actuation system is to:

  - provide factor of 10 sensor correction of low frequency ground noise (.1 to 10 HZ)

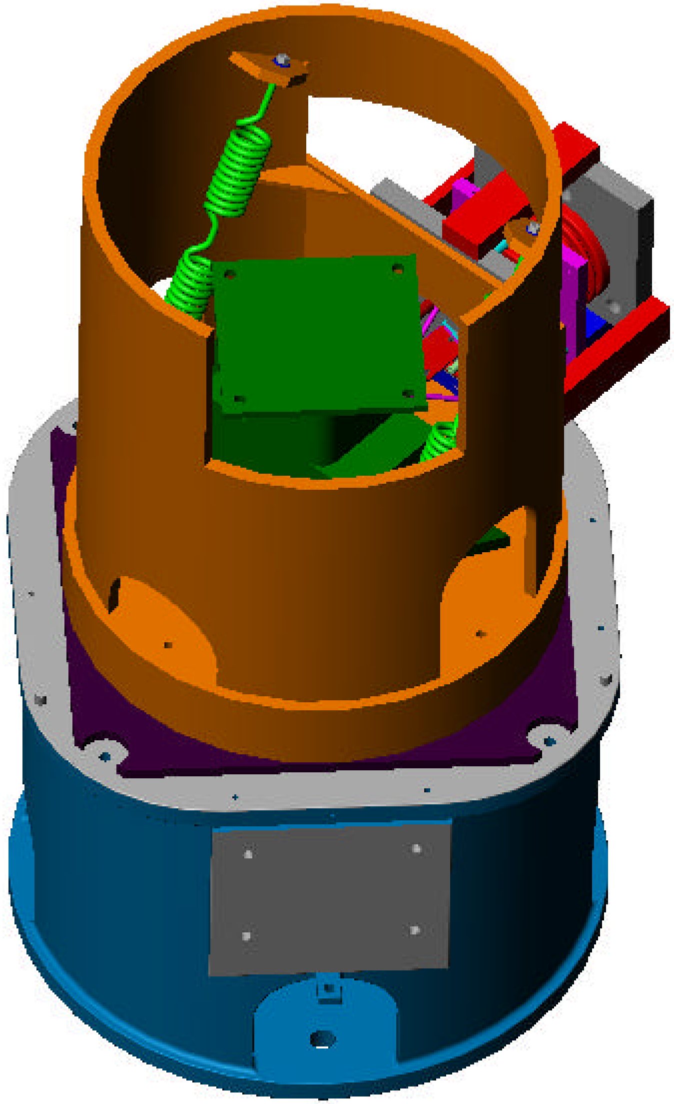
  - provide sufficient dynamic range (+/- 1mm) for earth tide and seasonal drift correction



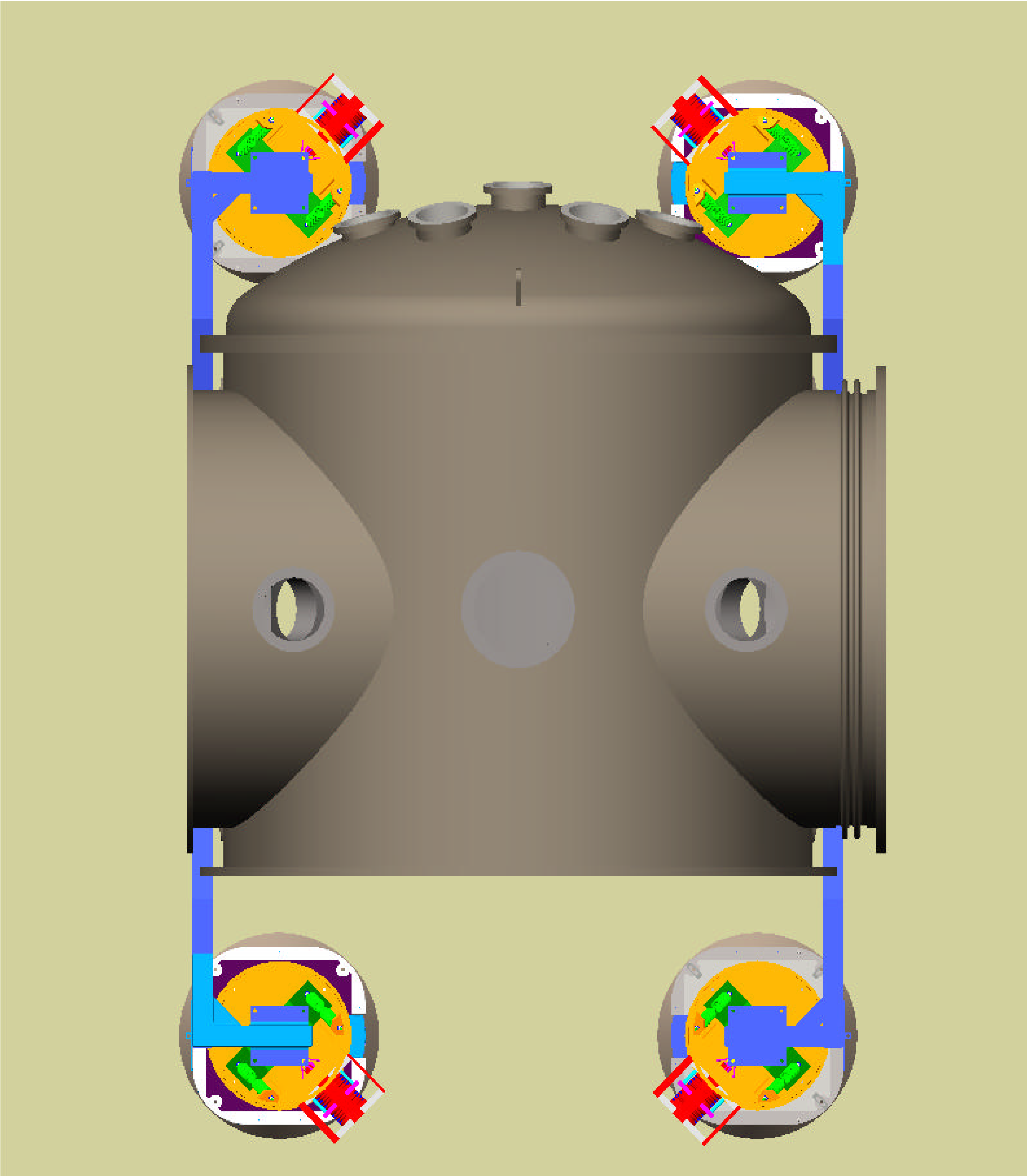
- Counter-wound springs 2 pc
- Hydraulic Actuators
- Flange mount to center element
- Position sensors concentric to actuator axis



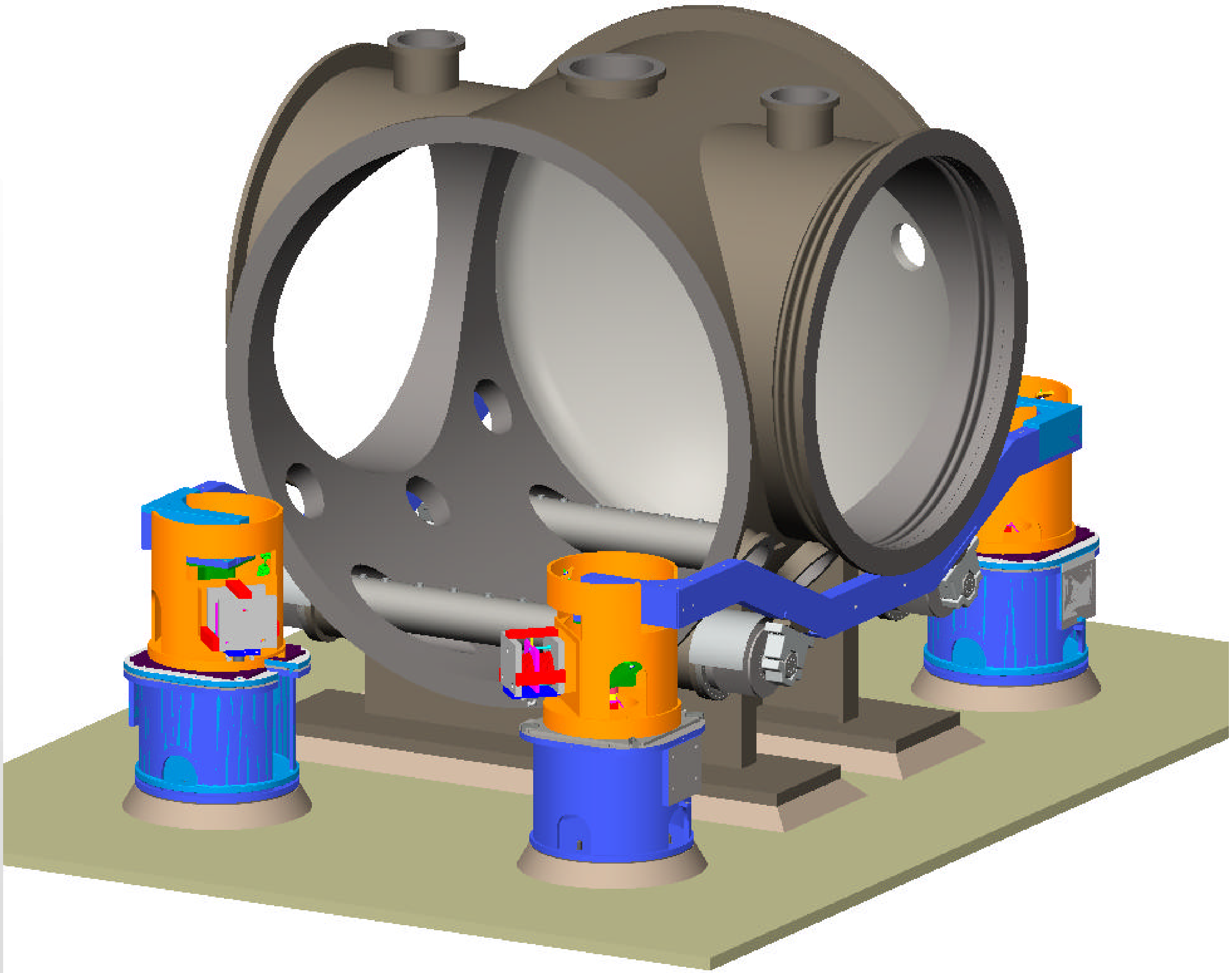
- Springs attach to support structure
- Takes stack weight and provides tension on actuator
- Uses existing piers and adapter plates



- Hard stops and top plate not shown
- Fits in place of existing course actuators
- Course actuators to consist of x and y axis dovetails kinematic z axis



- 6 DOF actuation
- Tangent to table center
- Analysis remaining



8/14/2001

SCHEDULING MILESTONES

Joshua returns from Stanford	9/1/01
Design and analysis complete	11/24/01
Long lead and fabricated parts in house	2/15/02
Mechanical and electronics assembly complete	4/1/02
Programming and troubleshooting complete	5/15/02
6 DOF testing complete	7/30/02

Note:

Schedule could be accelerated to resolve problems with impulsive noise disturbing lock at LLO