LIGO ADVANCED SYSTEM TEST INTERFEROMETER

Description & Status Report

LIGO Science Collaboration Meeting

16 March, 2000

M. E. Zucker, D. Shoemaker

G000027-00-R

Mission

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

LIGO II specialization:

- Test LIGO II seismic isolation & suspension system and associated controls at full scale
- Develop detailed SEI/SUS installation & commissioning handbook
- Look for unforeseen interactions & excess displacement noise
- Goal: complementarity to 40m, other performance demonstrations

Plan

- Set up and test the infrastructure: vacuum system, optical sensing system, and data handling
- test seismic isolation systems 'stand-alone' using seismometers
- to measure relative displacement between the two seismic systems using interferometry
- to test the suspensions as stand-alone elements
- to assemble a Mode Cleaner suspension cavity between the two seismic isolation systems, perform tests of relative motion
- to form a short Test-Mass suspension cavity on the BSC isolation system, illuminated with mode-cleaned light, perform tests of relative motion
- Suspension tests to be done first for 'controls prototypes' of the suspensions; and then for final 'noise performance prototypes' of the suspensions.

Measurement goals and challenges

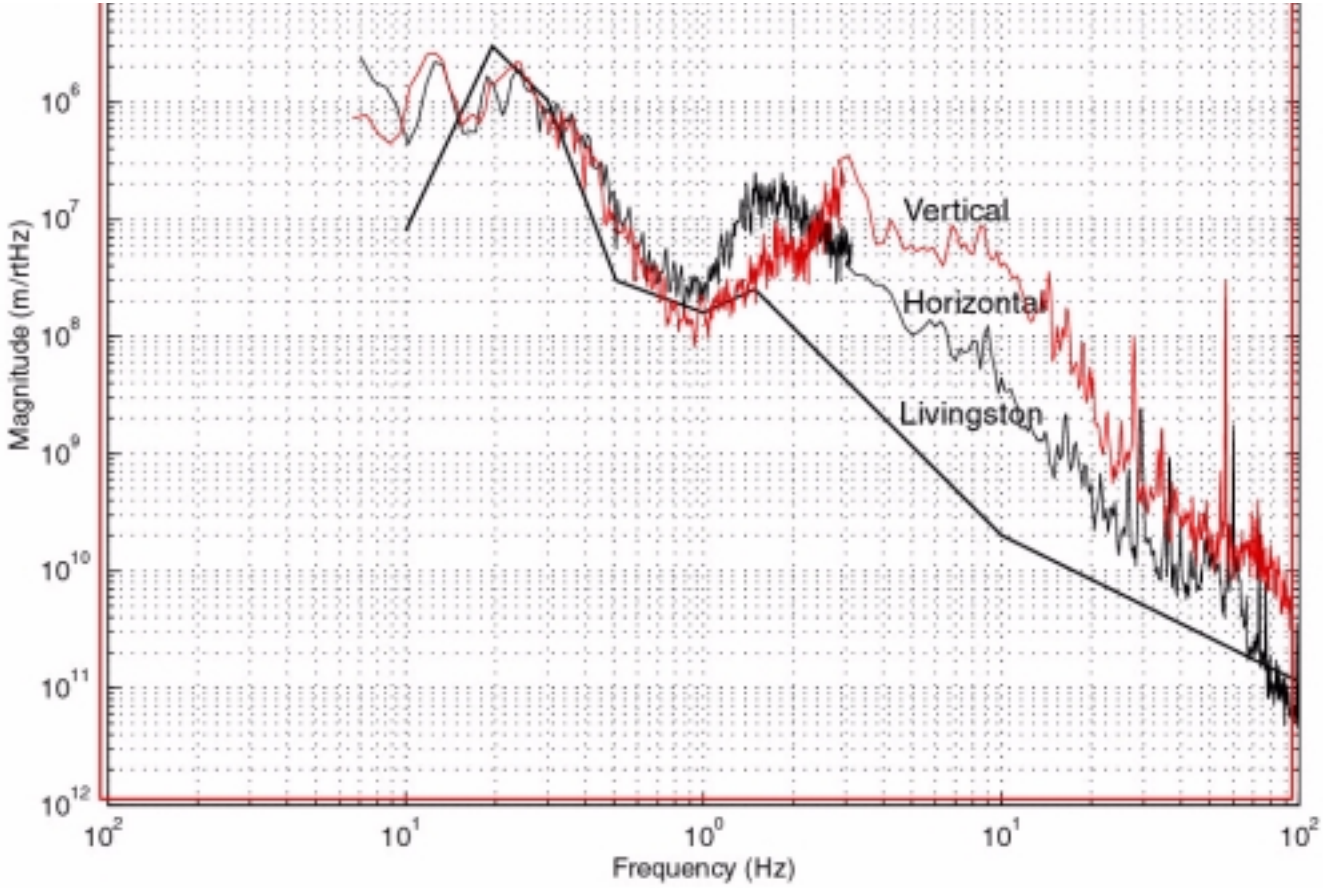
- Complete LIGO II controls test of mechanical actuators
  - length actuation and Suspension/Isolation hierarchy
  - angular controls, fine and coarse test mass positioning
- Ideally, would measure at LIGO II displacement and frequency
  - some clear difficulties, and a point of diminishing returns (TBD)
- Shot noise: looks feasible with LIGO I 10W laser, ~4 W incident on cavity
- Frequency noise: require ~10^{-6} at 10 Hz, 10x better at 100 Hz
  - like LIGO II noise requirement;
    requires LIGO II Mode Cleaner suspensions, MC 'test masses'
- Intensity noise: challenge for frequency noise requirement
  - technical flucuations pushing mirrors around
  - again, LIGO II-like performance should suffice
- Beam jitter (have LIGO II Mode Cleaner, but short cavity sensitivity TBD)

Measurement goals and challenges

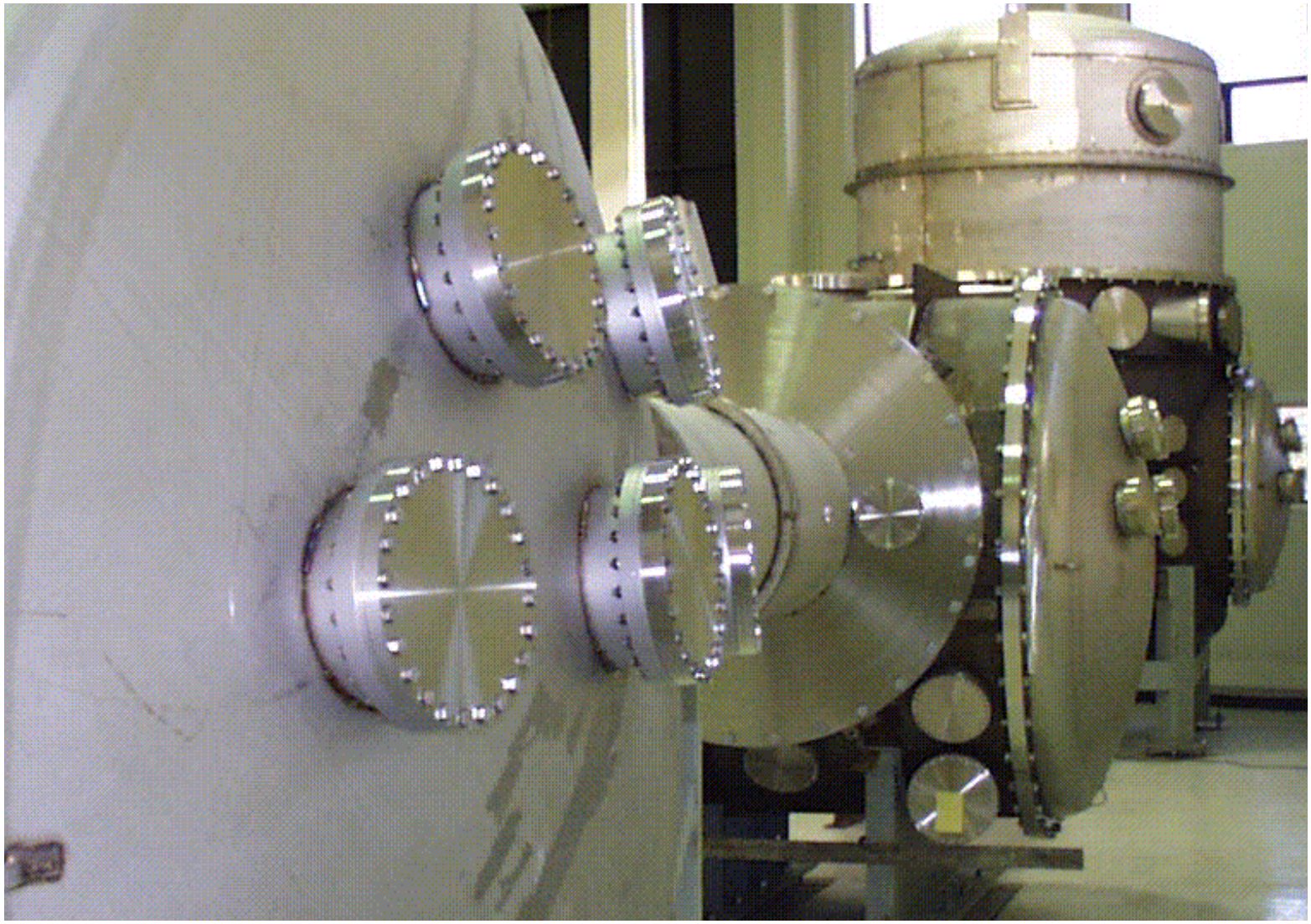
- Thermal noise: thermoelastic to dominate (sapphire masses)
- Beam spots smaller than LIGO
  - sqrt(cavity length) if similar ‘g’ factor;
  - would give thermal noise 1700x greater than LIGO
  - can make larger beam, possibly 1/10 LIGO (7km ROC)
  - leads to thermoelastic noise ~30x that of LIGO II
  - may consider fused silica masses for low-frequency tests
- Technical challenges - high-finesse and well-aligned nearly unstable cavity

Measurement goals and challenges

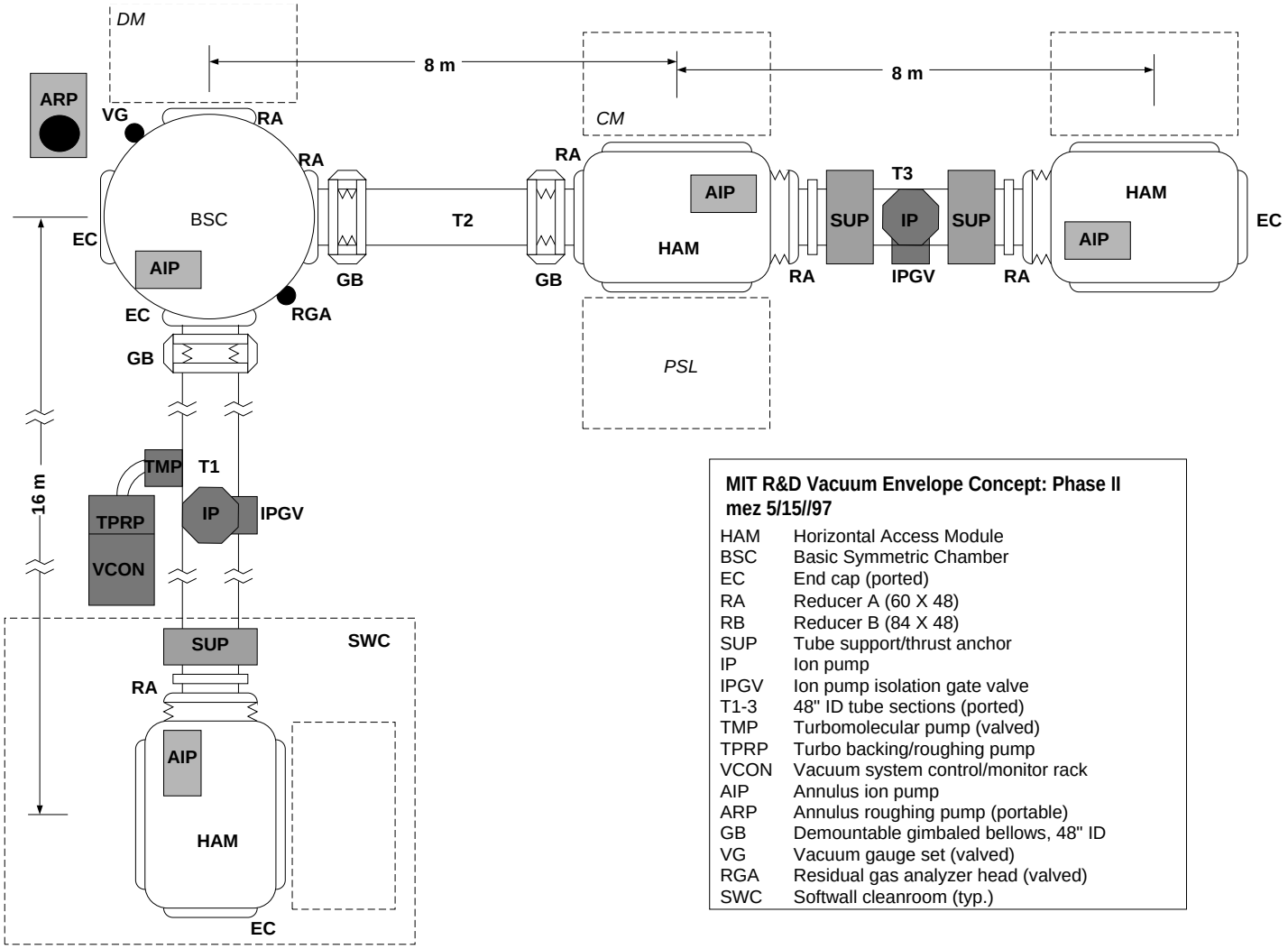
- Seismic noise at MIT Campus site greater
  - similar RMS (dynamic ranges ok, performance test realistic)
  - larger at e.g., 10 Hz by 10x to 100x
  - makes only small change in test start frequency



Vacuum envelope, left (S) arm



General vacuum equipment arrangement plan



MIT R&D Vacuum Envelope Concept: Phase II
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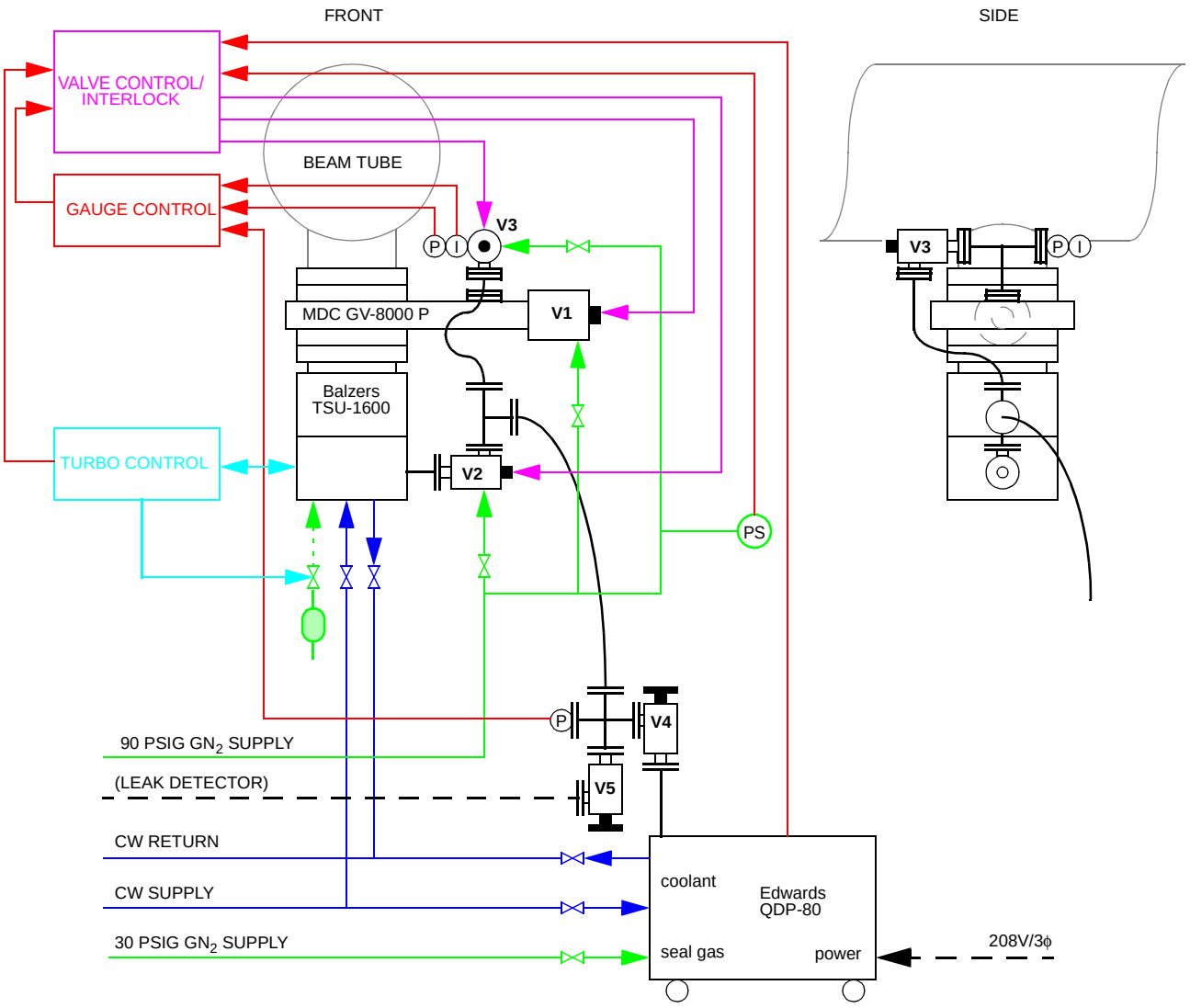
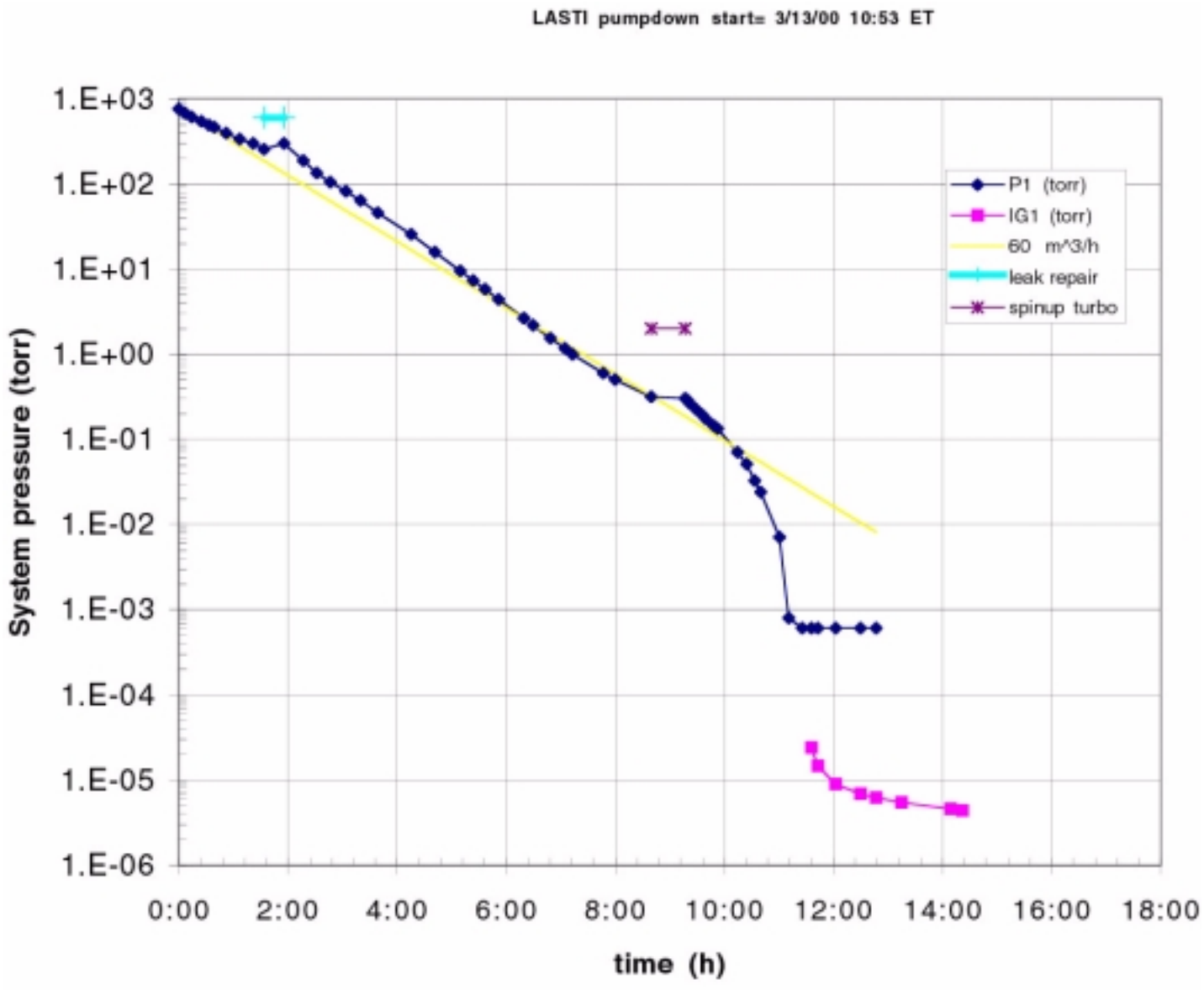
HAM	Horizontal Access Module
BSC	Basic Symmetric Chamber
EC	End cap (ported)
RA	Reducer A (60 X 48)
RB	Reducer B (84 X 48)
SUP	Tube support/thrust anchor
IP	Ion pump
IPGV	Ion pump isolation gate valve
T1-3	48" ID tube sections (ported)
TMP	Turbomolecular pump (valved)
TPRP	Turbo backing/roughing pump
VCON	Vacuum system control/monitor rack
AIP	Annulus ion pump
ARP	Annulus roughing pump (portable)
GB	Demountable gimbaled bellows, 48" ID
VG	Vacuum gauge set (valved)
RGA	Residual gas analyzer head (valved)
SWC	Softwall cleanroom (typ.)

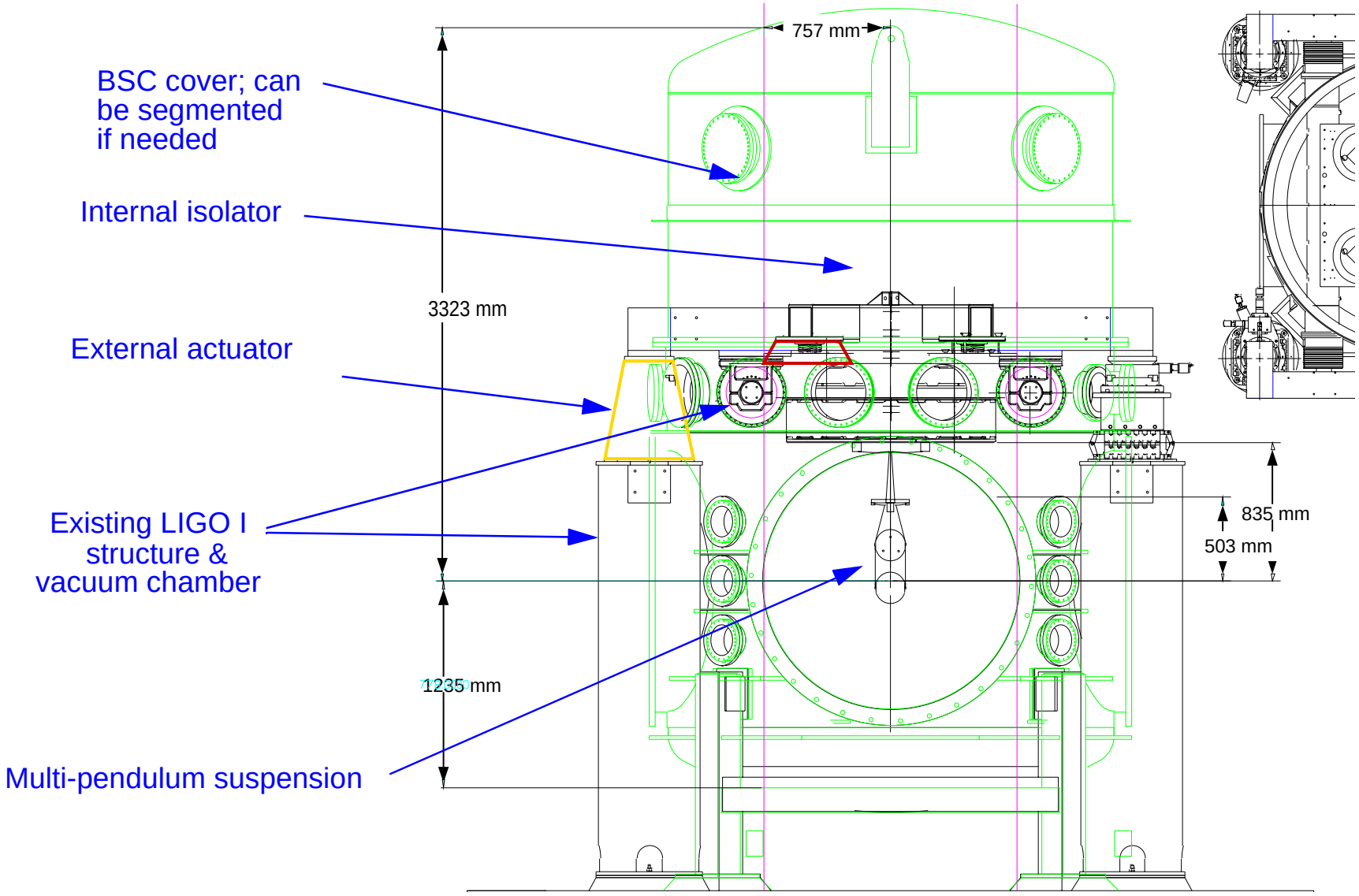
Turbo/roughing pump arrangement & control diagram



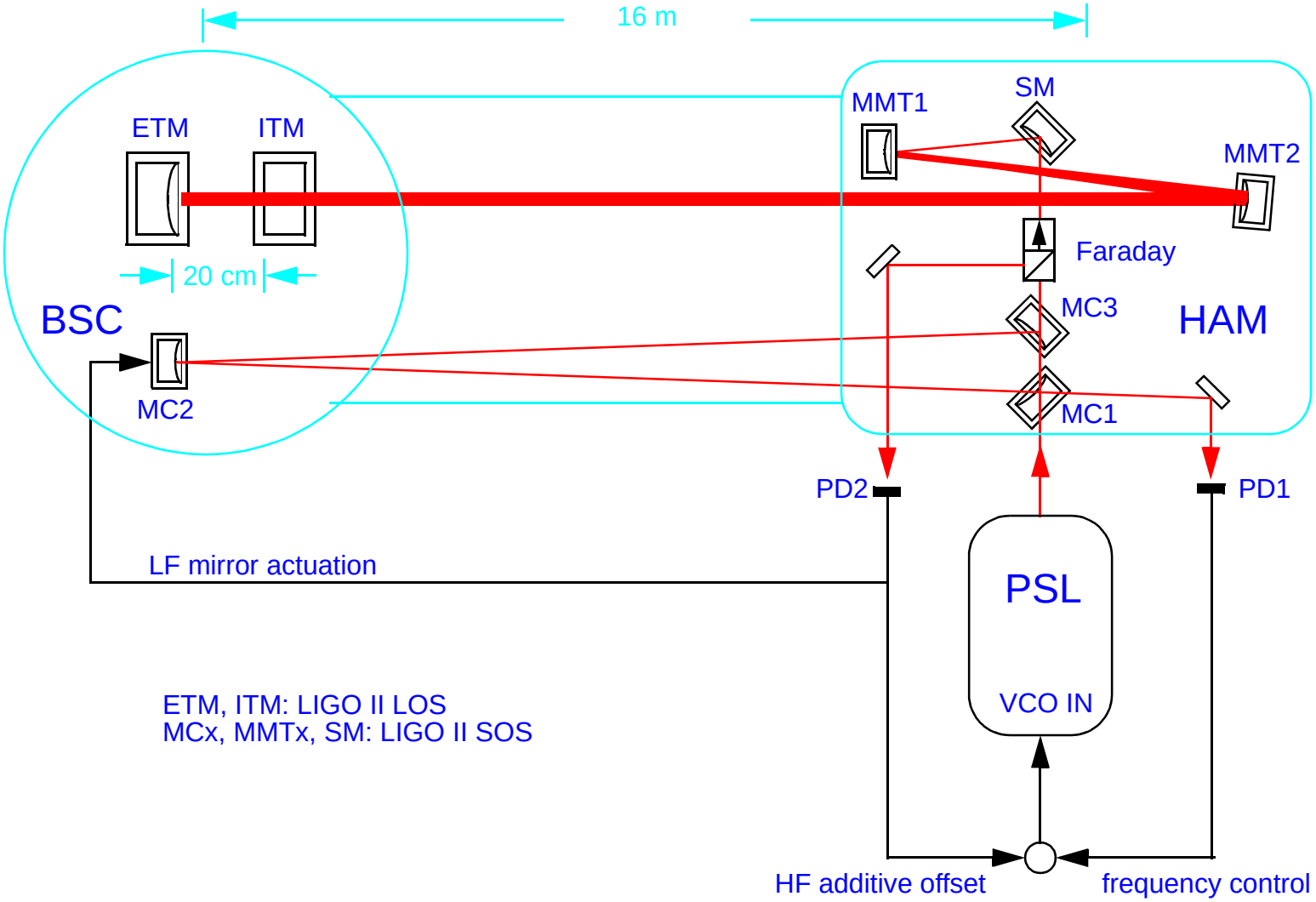
Initial pumpdown curve (fresh data; annuli @ atm)



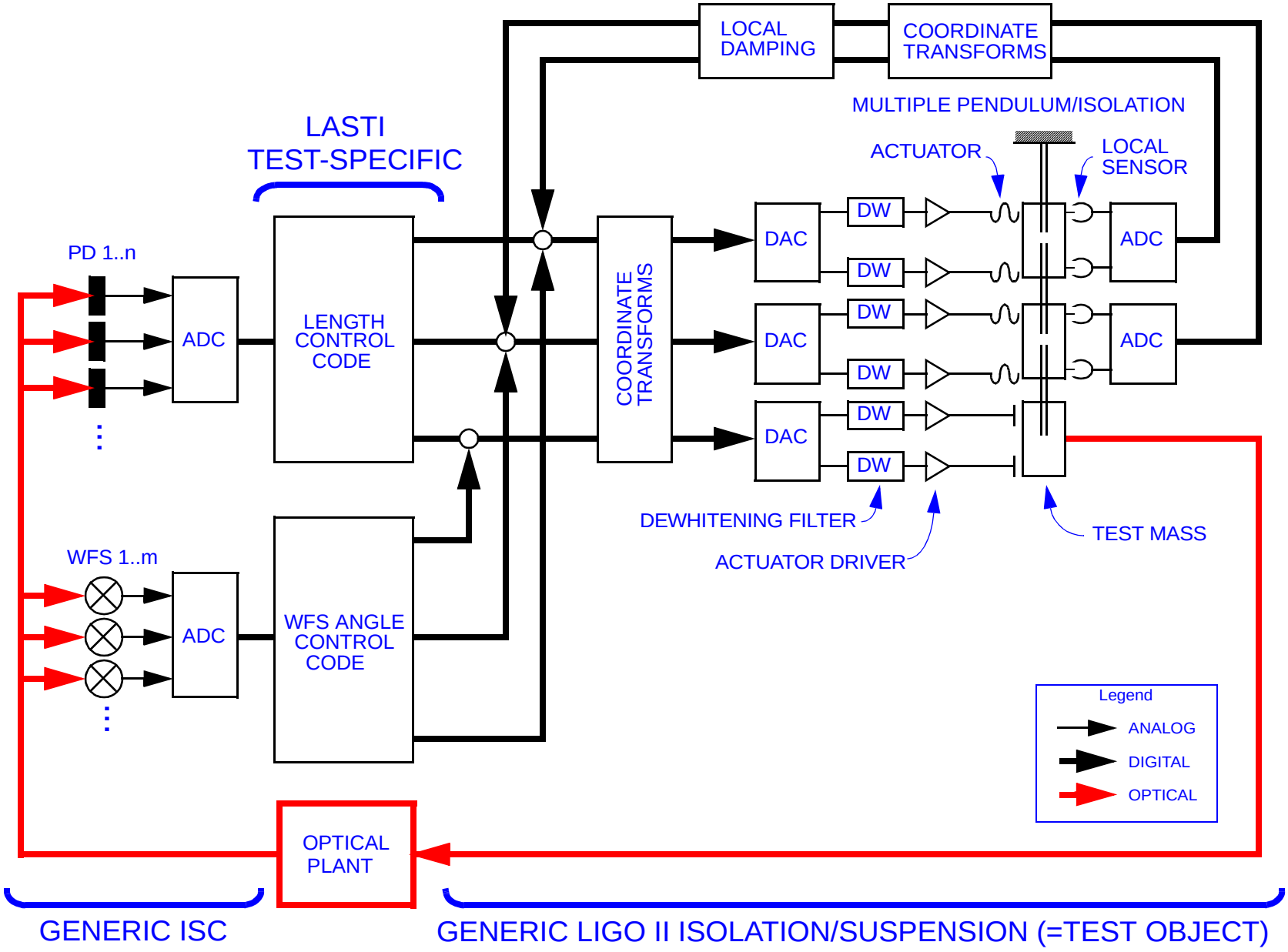
Test target


BSC cover; can be segmented if needed
Internal isolator
External actuator
Existing LIGO I structure & vacuum chamber
Multi-pendulum suspension
757 mm
3323 mm
1235 mm
835 mm
503 mm

Proposed optical configuration



Proposed controls implementation (mostly 'generic LIGO II')



Schedule

- Dates as per White Paper; needs review/revision for near-term
- 4Qq99: LASTI envelope commissioned DONE
  - The vacuum envelope is installed and aligned; the vacuum pumping system is commissioned, and the system is pumped down for the first time.
- 1Q00: LASTI external structures installed
  - The seismic piers are erected around the HAMs and BSC. We wish to delay this milestone until a firmer baseline for the seismic isolation is established to avoid any backtracking.
- 2Q00: LASTI infrastructure design review
  - covers noise sources; models for the performance of the system; complete costing and manpower estimates for the optical sensing system, control and data, mechanical interfaces to LASTI; and the experimental program.

- 3Q01: LASTI infrastructure complete
  - sensing system, control and data, and a trial cavity test of the complete system function
- 1Q02: LASTI prototype installation complete
  - high-quality prototypes of the HAM and BSC isolation systems, and 'controls prototypes' of the suspensions, installed and ready for tests
- 3Q02: LASTI locked
  - The optical sensing system for the Mode Cleaner and the Test Mass Suspensions functioning and the cavities locked. No performance requirement.
- 1Q03: LASTI controls test review
  - An understanding of the controls performance of the seismic isolation systems and of the suspensions
- 2Q03: LASTI noise prototype installed
  - The 'controls prototypes' for suspensions changed out and fused silica fiber, sapphire test mass Test Mass suspensions installed.

- 1Q04: LASTI final test review
  - This milestone should indicate the status of tests to meet the noise performance verification.
  - is only 6 months after start of noise testing phase...
- 1Q04: LASTI first article installation starts
  - using the planned installation jigs and procedures, for seismic isolation and suspensions.
- 3Q04: LASTI first article tests complete
  - may or may not include performance testing.

Personpower

- The success of this endeavor will require significant contributions from LSC members in and out of the Lab for success.
- presently a technician and bits and pieces of Zucker and Shoemaker working on the vacuum system and experimental design.
- will ramp up this year to perform the design, procure and install the infrastructure; principally in-Lab personnel (at both MIT and Caltech, the latter for fabrication of PSL and CDS components).
- roughly 5-6 FTEs in the MIT Lab for the latter stages: 1 technician, 1 net FTE engineer, 2 students, 1-2 postdocs/scientists.
- need roughly again as many LSC Folk in moderate-term visits to MIT or thinking hard about the data and making frequent visits
- These manpower guesses do not include the staff associated with specific subsystems; there will clearly be constructive overlap in manpower.

The Last Slide

- some important design decisions and trades remain
  - optical layout, Test Mass cavity beam parameters
  - target position sensitivity
- clear that a significant test of the LIGO mechanical system can be performed
  - controls
  - performance
- schedule aggressive; ‘reasonable’ up to noise testing
- personpower requires strong collaborative effort, as for all of LIGO II