Consideration of HAM SAS for Advanced LIGO

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30 April 07

G070284-00

History

- Two approaches used in field, pursued in R&D in Laboratory
- Low natural resonant frequencies, low-bandwidth control systems
  - Most attenuation of seismic noise provided by inertia of seismic elements, optics table
  - Virgo, Tama, UWA; initial LIGO
- High natural resonant frequencies, high-bandwidth control systems
  - Most attenuation provided by slaving optics table to inertial masses
- Both approaches pursued over ~10 year baseline in LIGO Lab, longer in the field
- Both show promise in principle

Seismic Isolation in Advanced LIGO

- Active system adopted as design approach in 2000, and presented officially as the AdL Baseline in June 2006
- Prototypes of two-stage internal systems modeled built, tested
  - ‘Rapid’ – Bosch Tinkertoy structure
  - Stanford Engineering Test Facility unit (ETF)
- Met many requirements, missed some others, lessons learned
- BSC/Test Mass isolation system designed, fabricated
  - Assembled, tested for solid body modes, now out for cleaning
- HAM ISI: designed by HPD, recent Final Design Review
  - A simplified single-stage system meeting present HAM requirements
  - Looks good to the Lab review team
  - Cost (bids at present) is a bit less than the CostBook

HAM-SAS

- Group developing low-natural resonant frequency isolators developed design for HAM as alternative
- Lab decided in Feb 2006 to pursue a prototype and test of the ‘soft’ system
  - Potentially less expensive – should not require an external positioner/pre-isolator (HEPI), saving ~250k/unit
  - Potentially simpler once installed to commission, operate
- Schedule tied to AdL: Must have the evaluation completed by the time of the FDR for the baseline ‘stiff’ system (April 2007)
  - HAM Seismic Isolation is the critical path for AdL
  - Also schedule pressure from ELI, which should test AdL SEI
  - More generally the *Lab does not have the resources to continue two developments in parallel*

A lot accomplished, some things left unfinished

- Drawings reviewed, updated, bid; won by Galli and Morelli
- Fabrication, cleaning done well, lessons learned, techniques of general utility for LIGO developed
- Unit delivered to MIT LASTI, installed using elevator/transport system
- Some characterization performed, fundamental principle demonstrated: attenuation above resonant frequencies
- Characterization ncomplete in a number of ways:
  - Resonant frequencies not brought to desired low values
  - Control systems not brought on line/optimized
  - No stability issues studied
  - No suspension interaction explored experimentally

Results reviewed

- Review Committee asked to evaluate HAM-SAS as a solution for AdL HAM isolation
  - Rana Adhikari, Mark Barton, Doug Cook, Peter Fritschel, Joseph, Giaime, Richard Mittleman, Norna Robertson, Fred Raab (chair)
- Charge in simplified form: Installation and commissioning ease; seismic attenuation in the GW and controls bands; pointing and control stability and margin from instabilities; ease of payload installation and dynamic interactions with the payload; controls compatibility; reliability, flexibility; cost/schedule impacts
- Not possible to answer many of the questions – results just not there due to the short characterization time;
- Clear that more progress could be made if more time/energy spent
- But the snapshot ‘now’ must be used

Evaluation

- It fit, it was vacuum-friendly, and it basically functioned – this is significant and not at all trivial, and we all learned from what worked here
- Seismic isolation requirement not demonstrated
  - Did meet requirements in 0.8-8 Hz
  - Excesses at higher frequencies due to spring resonances, probably ‘dampable’, but not demonstrated
  - Significant excesses at lower frequencies, either direct coupling or a tilt-horizontal coupling
- Tuning/commissioning did not appear to be evidently easier or quicker than the process for the baseline
- Models predict interaction of multiple suspensions on a given HAM platform
- Controls models not well enough developed to understand how the controls hierarchy would work

Future path

- Advanced LIGO will use the baseline ‘stiff’ design
  - Some remaining risks and unknowns there, but the combination of modeling and past prototype experience give enough confidence to proceed
  - More expensive than SAS (due to presence of HEPI external pre-isolator), but at or below AdL Cost Book
- Two prototypes to be fabricated for ELI ASAP, followed by one under Project funding for LASTI testing
- HAM-SAS will be ‘wound down’ to complete PhD thesis effort, but not pursued further

- The low-natural-resonant-frequency should work, and is the right solution for some problems, but is not for Advanced LIGO.