Quad Interface Issues

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Version 00:	*Discussed at a teleconference 12/2/2004.*
Version 01:	*Added some comments based on the discussion from the meeting, as well as some updates as of 1/20/2005 regarding some of the interfaces and a contribution from Ken Strain on potential thermal interface issues.*

Below we outline a few interface issues that have arisen and propose, for discussion, resolutions and/or actions to resolve.

1. Management/Systems: Quad Design Flexibility for Sapphire or Fused Silica Optics

Management asked for the impact to design in the flexibility for the quad suspension to support fused silica optics in the future (if sapphire is chosen now, or vice versa), as an 'upgrade' path. The intent is that we minimize the impact (schedule and cost) to switch to the alternate COC substrate after the instrument has been observing for some period of time. (This upgrade could consider the structure as an expendable/replaceable element if needed.) SUS provided the impact (a lot of design time now, essentially all non-recurring cost; see T040016-09. The DCC has an earlier version.).

Questions to be resolved:
Is this design flexibility required or not?
If so, then confirm that this is to be implemented in the noise prototype, but not the controls prototype?

D. Coyne's ~~response (need input from~~ and David Shoemaker's response ~~, et. al.~~):
Yes, we want to impose the requirement to design in the flexibility,
~~Management does not understand the significant design time (7 person-months) estimated to allow for this flexibility.~~
Confirmed that this is not a requirement imposed on the controls prototype. This would be implemented for the noise prototype only.

~~Follow-up actions and/or decision?~~ 1/20/2005 follow up: Justin Greenhalgh summarizes the (minimal) impact to the SUS design effort to allow for this design flexibility, following the LIGO project decision to proceed with Fused Silica as the substrate, in this email message:
http://mm.ligo.caltech.edu/archive/aligo_sus/msg00350.html

2. SEI/Systems: Revised payload dynamics requirements

SUS started with a 150 Hz minimum frequency requirement. To meet this requirement SUS had to exceed its allocated mass budget and it's envelope. SUS then took the same requirement that SEI imposed on the dynamics for it's stage 2 (optics table) structure (found in section C.8 of E030179-A). SUS found it impossible to meet. ASI (SEI's mechanical design contractor) also failed to meet these requirements. (The requirement in E030179-A is basically no phase lag greater than 90 degrees below 150 Hz for non-colocated sensing & actuation points on stage 2.)

The current SUS working baseline assumption/goal with regard to resonances for quad structure sections is as follows:

A) The first resonance limits, with all mass, including non-structural mass, and assuming a perfectly support (i.e. rigid optics table), not coupled dynamics:

- > 200 Hz first resonance for the upper structure
- > 100 Hz lower structure
- > 100 Hz combined upper and lower structure

Ideally the above would be achieved with realistic attachment compliance included. No specific requirements or provisions are made for damping in these modes (so just intrinsic structural damping in these metallic structures, or Q ~ 100). The above is to be confirmed initially by finite element analysis with a 15% safety margin. Later confirmation is via modal testing on a prototype.

B) It is hoped that the above conditions will result in a phase lag, between non-collocated stage 2 sensors and actuators, due to quad structure modes that will not exceed 90 degrees below 100 Hz and not exceed 180 degrees below 150 Hz. This will be checked by coupled finite element dynamics analysis of the quad structure and the stage 2 SEI structure (ASI design version).

C) SUS has incorporated a design requirement to allow for de-coupling the lower structure from the upper structure. This will enable the lower structure to be mounted from either from the upper structure or the "ground" (vacuum chamber structure) or the support tubes (isolated by the HEPI SEI subsystem).

Follow-up actions:

1) SEI to confirm that the above re-stated payload dynamic requirements are acceptable.
2) Systems to explore the practicality of mounting arrangements for the lower structure supported from the support tubes.
3) Systems to confirm that the coupled dynamics of a quad suspension meeting requirements in (A) above will also meet the requirements in (B) above.

1/20/2005 Update:

Joe Giaime points out that the requirement found in section C.8 of E030179-A is for structural stiffness of the SEI platform and a more relevant requirement for the payloads is the phase introduced below 150 Hz in sensed modal degrees-of-freedon, when stage 2 (the inner SEI stage, with the optics table) is moved in a modal coordinate with achievable levels of cross-coupling (~1%) introduced into the other modes (rather than actuation at a single point). The analysis for this condition is underway.

3. AOS: No permanent mounting of baffles or dumps unless little to no affect on resonances. Minimize glints.

The maximum mass of any AOS component (other than the compensation plate assembly, which includes a ring heater and shielding, etc.) is approximately 1 kg if placed near the elevation of the test mass or penultimate mass. If the intended AOS hardware exceeds this mass, then an alternate means for attachment (e.g. from the support tubes) must be pursued in conjunction with the Systems group.

The SUS structures should minimize glints by ensuring that very little surface area of the structure, or components mounted to the structure, in the vicinity of the test mass can retro-reflect light from the main laser beam. AOS is to set appropriate limits.

AOS takes an action to define a vacuum compatible surface treatment, or low mass applique, for aluminum and stainless steel to minimize scattered light. It is intended that SUS use this surface treatment for the suspension structures.

4. ISC: Global control requirements for quad? What assumptions we've made for the controls prototype.

For ISC group information and concurrence:
It is understood that SUS is working to Peter Fritschel's global control force requirements stated in G010086-00. This has been used to define the magnet and coil parameters. ISC has an action to refine or re-examine these global control forces and the proposed global control topology. This study requires e2e modeling. The anticipated date for an update is about mid-2007. In the interim, SUS will continue to work to requirements defined in G010086-00. It is understood that this is too late to ~~effect~~ affect any of the planned SUS prototypes. If significant changes occur in these requirements, there may not be adequate time to re-optimize the design.

5. Management/Systems/LASTI: Controls prototype will be sapphire geometry unless directed otherwise.

Even if the COC substrate downselection is for fused silica, we intend to proceed with a sapphire-sized controls prototype. The noise prototype will then be the first instance of a quad prototype in a fused silica configuration. No other prototypes are envisioned. Confirm that this is acceptable.
Confirmed.
See also Justin's recap here:
http://mm.ligo.caltech.edu/archive/aligo_sus/msg00350.html

6. SUS/US – SUS/UK: Choice of Wire / wire clamps with respect to noise / creep issues for drum end wires.

In principle maraging steel wires with "drum-ended" attachments are lower noise design options than wires of other materials and clamped (shear/friction-force) connections.

Since we will not be able to confirm that the design is low enough in creep noise until the AL interferometer is operational, we should pursue the better design option if there are no fundamental obstacles, significant research risk or exorbitant cost.

A switch to drum-ended, maraging steel wire is anticipated to cost about $120K additional for the test masses alone.

This design option (if selected) would be employed only partially on the controls prototype, but fully (to the extent practical) for the noise prototype. The question of whether a wire loop should still exist at the penultimate mass still remains.

Do we have concurrence?
All at the meeting concurred that we should implement maraging steel wires with "drum-ended" attachments since this is likely to improve the creep/creak noise, even though we cannot determine apriori that this is a necessary design feature.

7. Management/LASTI: what prototypes do they really want?

Our understanding is that LASTI will issue a revised test plan (taking into consideration the results of the SEI critical design review in Jan/Feb and the COC substrate downselect in Dec?!!). This plan is needed ASAP and planned for review in early Mar. This plan will have top level schedule defined. We ask that a RODA be issued for all involved parties to agree to the new LASTI test plan, schedule and subsystem deliverables/support.
Agreed?
1/20/2005 update: All at the meeting agreed to the timeline and the stated need to resolve the LASTI test plan. The SEI critical review is underway. It is not currently clear whether the SEI critical review will be completed in Feb, or if this will slip a month or so.

8. Temperature Sensitivity

The following are notes from Ken Strain on potential thermal interface issues, not addressed at the 12/2/2004 meeting.

During the process of testing our proposed new OSEM emitters, Nick was stimulated to remind us that these, like all IR LEDs have a negative temperature coefficient of emission (for fixed current). He also advised that we take care that the case temperature of the LED is well coupled to the body temperature of the OSEM (so lets assume that we achieve that for the rest of the discussion). After some thought I believe that there should not be a big problem, and if it is a problem at any level the solution is **not** to look for another emitter type (unlikely to change the situation very much).

The OSEM sensor is used primarily to generate the damping signal for the local control - a signal with little meaning outside the 0.1 Hz to ~3 Hz band - but possibly also used to track drifts while the ifo is out of lock (not sure about this - we do it in GEO).

The thermal environment near the top of the suspensions should be relatively stable (certainly on timescales shorter than 10s). Indeed I can only think of two heat inputs that could vary on short timescales. Lets consider these in turn.

1) OSEM coils - these carry quite large (pitch) bias currents generating significant heat, near the emitter - were this to change rapidly that would almost certainly cause a measureable change in emission. Clearly it is within the UK scope to characterise this, and we plan to do so in a few weeks. The rest of the heat change will come when the suspension is disturbed and the damping must work hard for a while. This will be a considerably smaller effect and it will be associated with times the ifo is out of lock. I can't see the (likely very minor) temporary sensor sensitivity change being a problem. (Provided we avoid any strong enhancement of the effect by poor thermal design of the OSEM.)

2) Active thermal correction and beam heating - one way or another when we lock the ifo there will be a change in power radiated from the TMs and possibly also the heaters. Given sufficiently strong and rapid coupling to the OSEMs one can imagine this disturbing the sensor sufficiently that it causes unwanted "adjustment" of the suspension. I imagine (but without much serious thought) that we can avoid this being a problem by suitable shielding and some thermal engineering (especially if the lower SUS structures are mounted from the support tubes). It is, however, probably worth having a think about this at systems level. The contribution from SUS being some characterisation of the effect of temperature changes on the sensor response.

The effects are at the couple of % level for degree changes in temperature. We are going to have to take care that these effects are not magnified by improper heatsinking of the LEDs themselves, but that is being dealt with internally.

Dennis Coyne's response: I agree that with

(a) proper shielding of the SUS from the Thermal Compensation System (TCS) ring heater and IR heating beam (see also RODA M040005-01, still in signature review), and
(b) proper beam dump locations for "parked" positions for intentionally mis-aligned primary beam,

this interface thermal management problem should be manageable.