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Subject:	Comments on Responses to AdL HAM ISI Review Committee		
To:	Ben Abbott, Stephany Foley, Brian Lantz, Jeff Kissel, Ken Mason, Fabrice Matichard, Brian O'Reilly, Andy Stein		
From:	David Shoemaker, Rich Abbott, Dennis Coyne, Matthew Evans, Mick Flanigan, David Nolting, Janeen Romie, Bill Tyler, John Worden	Tel: 617 253 6411	

Comments on the responses to the HAM ISI PDR questions follow. Those which rise to the level of actions for the SEI group will be quoted in in the HAM ISI PDR Report.

General Questions/Comments

1. FMEA to be an action for the team – Nolting and Flanigan to work with SEI team on this.

2. Are the basic performance requirements still appropriate -- have subsequent studies of the ground noise spectra changed our best estimate of the input spectrum from that used in setting the requirements?

We are still working to the original requirements. These requirements apply to the total SEI system, i.e. HEPI plus ISI. We believe that ground tilts at 0.1 Hz and below will cause the combined system motion, in absolute motion terms, to be larger than the requirement for some part of the time. However, at these frequencies it is the relative motion, and not the absolute motion, which is the issue. Since all the HAM tables are in the same building, the relative motion may be acceptable, this will not address the same issue when applied to the BSC ISI systems between the corner and end buildings. To help address this issue, the SEI team is working to develop low frequency tilt sensing and also to develop seismic platform interferometers. The current design for the HAM ISI is probably the best design to deal with these issues, because it has been designed for control at low frequencies.
At 10 – 20 Hz, recent work by the systems group has indicated that additional vertical isolation above 10 Hz would be helpful. We are looking at this issue, and trying to organize a meeting with Peter Fritschel and Norna Robertson to talk about possible solutions.

3. PDR Checklist -- there is no entry for completion of action items from the DRR. I believe that the closest thing to a set of actions is found in
http://www.ligo.caltech.edu/docs/M/M060062-00/M060062-00.pdf
and the status of those actions ("The committee also notes", and "Considerations not yet studied") should be reported upon.

- *Q: Do we meet the requirements at 10 Hz and at 0.6 Hz?*
  A: I think we have answered this, but maybe we need the final performance before we can say yes.

- *Q: What is the strategy for dealing with noise caused by the relative motion of the platforms?*

A: We have already dealt with this issue in iLIGO particularly with regards to HEPI. The new Borkspace approach to designing controls allows the end-user to add extra inputs, re-direct control signals from or to the suspensions etc. This is currently used at LLO for tidal feedback of the long arms. We are confident that we have both the sensors and controls to implement similar controls for advanced LIGO.

- Q: Are there applications in LIGO for a single-stage ISI system without HEPI?
A: We believe that the ability to offload control authority to the HEPI system will continue to be a critical part of the system functionality. In particular we do not want to run large currents through the actuators for long periods of time. This is due to concerns about in-vacuum heating.

- Q: How much relative motion, at low frequencies, for the different degrees of freedom do we allow?
A: We hope to be limited by displacement sensor noise at low frequencies. How much the ISC group can tolerate is a question for them.

- Q: What is the effect of the HAM platform motion on the Output Mode Cleaner?
A: For eLIGO this does not appear to be a concern. If there is a requirement that is more stringent that the current design requirement then we should get that (again from ISC or SUS).

- Q: Effect of HAM platform motion on (non-suspended) beam reducing telescopes?
A: There is currently a fixed steering mirror on the ISI platform to direct light into the OMC. This is being swapped for a tip-tilt mirror. We might have data from LHO with isolation loops running that we can use to make a projection; otherwise we have to wait for the test at LASTI. In any case this is
More of a question for the SUS team. If we reach our requirements then that should hopefully allow them to reach theirs.

- Q: How much position control is needed for the HAM platforms?
A: We provide ~1 mm vertical motion with less than that in translation (due to geometry). Since the intent is to use the ISI in combination with HEPI we believe that this motion is sufficient for advanced LIGO purposes.
DHS: please put these comments into the DCC as a response to M60062

4. Please present a one- or two-sentence plan to fill in each TBD in the PDR checklist.

Electromagnetic compatibility considerations – A detector was purchased for use on the BSC ISI at LASTI and no adverse effects to the instruments were found. This test has not been done on the HAM and will be performed on the first article to be delivered to LASTI.

Fault detection, Isolation, and Recovery strategy – This will need to be developed with the experiences from eLIGO and LASTI.

QA Involvement – QA will be involved throughout the procurement, assembly, and testing.
Dhs: please update the PDR checklist accordingly.

5. Are the estimates for assembly and installation hours used in our overall schedule correct in light of the prototype effort? Is the logic (activities and their interdependence) in the overall schedule correct? In a general sense, does the team 'own' that schedule and plan to work to it?

The current schedule is informed by our experiences on advanced LIGO. We have yet to refine the manpower requirements, and availability. We intend to 'own' the schedule.
Dhs: update the estimates for the FDR, please

6. pg 26 of T080236-01: Should cite P. Fritschel, "HAM Seismic Isolation Requirements", T060075-00 for performance requirements in addition to E030180-02
http://www.ligo.caltech.edu/docs/T/T060075-00.pdf

- Done-

7. pg 20 of T080236-01: A calculation/simulation which shows the predicted isolation performance based on a model which combines the measured performance of the eLIGO plant together with the HEPI system and a model for the

stiffer HAM crossbeams would be more convincing than speculations that it should be better. Is such a model available or almost available?

A simple model for the X and rY directions of ISI is almost done. This is an analytic model based on "Simple Calculation of Active Platform Performance" Brian Lantz, T080119-00-R (now on the HAM ISI PDR page). This calculation framework will also be applied to a simple model of the HEPI system, and the product of those models should be a good estimate of the SEI performance, if we can get good numbers for the ground tilts. A more complicated modeling framework was distributed several years ago, but since no one in the lab has ever used it, it is not a high priority. A model of the ISI based on Hua's model is also available. The utility of that model is the ability to try different variations of the mechanical structure. Since the structure is done, and the use of that model outside Stanford has been minimal, I believe a simple model which allows good prediction of the impact of the controls is the most practical way forward.
ME: a more complete model is needed by the time of the FDR. One needed element is a noise model of the system.

8. pg 20 of T080236-01: Do you have conjectures for the cause of the excess motion at ~ 0.1 Hz, and might these conjectures suggest changes to the current design? What is the total rms motion associated with the excess motion at ~ 0.1 Hz; does the rms meet the requirements/goals for the HAM-ISI performance?

The excess horizontal motion at 0.1 Hz is a result of the noise of the vertical GS-13s used differentially to measure tilt. Reblending the loops can dramatically improve this noise, at the cost of slightly worse performance at higher frequencies. This will be done. The total low-frequency differential rms motion will be dominated by ground tilt. There is no change which can be made to the HAM ISI mechanical design, per se, which will improve this performance. Improvements can be made by: optimizing the control laws based on better understanding of the lab environment; better tilt sensing of the LIGO technical slab; and seismic platform interferometers. Work on these topics is underway.

Mechanical Design and plans:

1. E030180 refers to shipping complete ISI assemblies and calls out shock load design of 1g and 0.5 g. - Is this sufficient for the long haul between LHO and LLO?

These specifications (1g vertical, .5g horizontal) were derived prior to kick-off of the ISI detail design phase and account for cross-country shipping. The limits are given with the assumption that the ISI shipping containers will provide the additional attenuation of external shocks.
Dhs: Please confirm by the FDR that shipping firms and containers can deliver this environment

2. There is a plan to use neon as a tracer gas in the pod assemblies. This may be of limited use in the LIGO observatories for a number of Reasons:

- The system pumps are ion pumps and may not pump the neon effectively - resulting in a persistent background signal. We see some of our RGA calibration gases even though the leaks are all turned "off".
- The corner station volumes will have many pods in one isolatable volume and there will be no way to find the leaking pod. Perhaps a simple TC pressure gauge in each pod would be useful.

The neon tracer gas allows us to ensure that the pods are leak-tight after assembly. When the platforms are installed it may be of some use in establishing if we acquire a leak during operation.
We will need to have a baseline scan of the corner station volumes, and look for excess. Adding a pressure gauge to each pod would significantly increase the complexity and cost. We did think of using different types of gas in different pods in order to more quickly find a leak (see T070047 by M.Zucker), but our approach relies mostly on careful leak-checking before installation. We are open to more sophisticated ideas for tracer gases, but it would be something of a research project to establish what works.
Dhs: Action for the VRB to make a recommendation for a tracer gas, or a more general statement on approach.Dhs: is the thermal conductivity of the gas important to maintain thermal equilibrium (for low frequency seismometer performance) and to carry away heat from electronics? Could note if so.

JW, VS: why not operate in vacuum? Difficult to track problems. Venting is needed from time to time.
RA: people who made OMC vacuum system pods – they do this for a professions
JW: can find smallstand-alone absolute sensors, may find one which gives useful diagnostic info; must also be reliable/redundant to avoid false positives
DHS: are there spare pins (from the locker??) on the feedthroughs? Sounds valuable in any event – possible to add if not there already?

JW: if the leak is large (few percent per month?) we have a chance to find the bad pod long before the GS 13 electronics begins to act up in some unexplained fashion. An inexpensive Omega transducer has a repeatability of 0.3% of FS so I think we could detect losses of a few percent if we trend the data and if we trust the transducer. My guess is that we would only chase a bad transducer when we are in the chambers for another reason.
I mentioned the conflat at the meeting but the electrical feedthrough is more likely to fail.

Another thing we could do is build or buy a gas sniffer for the neon for use once the chambers are open - but again this would be useful only with sufficient access to all pods either by removing many doors and BSC domes (big task) Sniffing for leaks requires that you put the probe almost on top of the leak - say within several cms or less.

3. How are the pods assembled and leak tested? Is there a document describing this process?

GS-13 pod assembly is described in detail in LIGO-T080086 found in the DCC.
Dhs: link, if not done already, in your documentation

4.E080012 is the ISI install procedure - during the LHO installation process it appeared to me that there were too many "helpers" making it difficult for the installation supervisor to keep track of all hands and feet - the procedure should address this as I view this as a serious hazard.

Currently two parts of the process require several helpers.
- pushing the ISI on the cart. The wheels will be replaced in order to make it easier to push it and to reduce the number of helpers.
- sliding the installation fixture into the chamber. For this step, no more than 5 persons should be required: 4 persons pushing at the posts, plus the supervisor in charge of coordinating.

The SEI team is considering several options for reducing the manpower required to move an assembled ISI from the test stand to the installation fixture. Some alternatives include: 1) different wheels for the cart, to reduce rolling resistance and improve control; 2) “hovercraft” pads, which are commonly used in industry for moving heavy equipment across flat surfaces; 3) forklift for pulling/pushing the ISI across the floor. Whatever changes are made will be reflected in the installation procedure.

5. Helicoils in barrel nuts - what is the timing of the test and results for the test about whether the helicoils make an appreciable difference in system performance? Will it be in time to coincide with start of procurement? Stated concern in the non-helicoiled system at LHO: Statement made that the bolts were often galled by hard aluminum shards upon insertion or extraction. What if we gall going in and cannot extract, the bolt is seized or the head spins off during extraction attempts? Is this risk high enough to warrant the mind numbing task of installing helicoils? Has pricing/quotes been obtained for buying automated helicoil insertion services? (T080236-01, pg. 8). (Although mind-numbing, two people in a single 8 hr shift per chamber to install helicoils into barrel nuts does not sound outrageous.)

Preliminary results indicate that a baseline of not helicoiling the barrel nuts is acceptable, however more data is needed to confirm. A definitive answer should be ready by the FDR. "Often" is an overstatement of the concern. Of the over 2000 bolts that is in the ISI, only 50 or so failed, and was mostly due to defects of the bolt or barrel nut itself, not the insertion or extraction. Hence, the risk is well below the threshold of helicoiling the barrel nuts.

Brian and Jeff will be looking at the data before the FDR, and the SEI team will make a recommendation based on the relative performance of the LLO and LHO structures above 200 Hz. The galling I've experienced with non-helicoils are only on repeated use of the same threads. In this case the bolts just get progressively more difficult to install, as the grit builds up in the hole, and should not be a risk for catastrophic failure – unlike the stainless-on-stainless galling problems. This small size was installed at LLO with cordless drills, and the tang removed with a hammer. I don't know of clean services which will do the job for us in a reliable way. Much of the fancy tooling is for the 'tangless' helicoils, which are easier to use, but don't come in the small size used in the barrel nuts. The 'tangless' helicoils are used elsewhere in the design. Mike Meyer has sketched up a little stand which should make the process simpler, but it's only an incremental improvement on the current method.

6. In ILIGO we did a poor job of routing and strain relieving cable both inside and outside of vacuum chambers. These items should have drawings and specs to aid the installation effort. Preferably, cable routing all the way to the electronics racks should be addressed. Cables should be strain relieved at each vacuum feed through as a minimum.

We have gained ample experience on cable-routing and strain relief with the eLIGO prototypes, allowing cable routing for in-vacuum cables for the HAM ISI will be specified in detail. These drawings and documentation will be ready for the Final Design Review. Strain relief on the prototypes has been addressed with two types of cable clamps, which hold HAM ISI cabling in place at many points before the vacuum feed through. Both clamps were successful. Their design will be further improved for aLIGO, for possible application to all aLIGO subsystems.
JR: Solidworks will have a module for this – Mike Myers is contact

7. At LHO there was uncertainty as to the operation of the "lockers" - apparently the tactile feedback did not provide confidence that the device was properly set to the released position prior to putting the HAM doors on. Can these lockers be improved or the instructions clarified?

We can and will clarify the instructions for locking the table. Adding a stepper motor to operate the lockers would require a significant engineering effort, which we do not feel is feasible at this stage.
We think it is best to proceed with the current design, even though it requires multiple door removal.
We can use the LASTI prototype to establish our sensitivity to work on the table, this may reduce the frequency of locking/unlocking.
JW: Building an airplane. Ball joints/linkages may be possible.
Dhs: there is a stepper motor? SEI: Also talk with Janeen

8. (T080236-00 p.8) Stainless on Stainless galling issues: Are there any reusability concerns if there is a need to disassemble and reassemble?

We are changing the hardware in some places, to eliminate all stainless-on-stainless threaded interfaces. Instead, we will use silver-plated screws and/*or nuts, where appropriate. However, this will affect a very small percentage of the overall hardware total - the vast majority of female threads in the ISI are either Nitronic 60 or Aluminum, neither of which gall with stainless screws. Where we plan to use silver-plated hardware, there is a very low likelihood of needing to remove screws after they are first installed. The lone exception is the screws used to fasten the GS-13 Stabilizers to Stage 1. We should plan to have extra silver-plated screws for these interfaces, in case any of the GS-13's need to be pulled from the ISI (e.g., for trouble-shooting on a bench). Beyond that, there is little concern about reusing hardware.*

9. (T080236-00 p.8) Silver is softer than stainless, is there a particle concern even without galling issues?

There may be some particle contamination created by the silver-plated hardware, but this concern is insignificant compared to the galling that inevitably occurs when clean stainless screws are run into clean stainless threaded holes.

Using silver as a solid lubricant is by far the best solution we know for eliminating galling. Also, as mentioned above, there are actually very few interfaces within the ISI that require silver-plated hardware, compared to the overall hardware total. JR: cite T040111

10. Concerned about the payload budget for the HAM2 chamber. Each HAM has a total payload of 510kg. In HAM2 there's a large triple at 120kg and three small triples at 81 kg. So, just SUS stuff is 363 kg. (I was looking at Dennis's mass budget document, E040136-00, and confirmed those mass budget numbers.) So, the big question is - what else is on the table, what is the total mass (including balance mass) and is this still within the 510 kg limit? [action for Systems Engineering/Coyne]

Brian Lantz will get a list of the actual loads on the existing two systems for the FDR
JR: Luke and Janeen worked up budget for real stuff (not payloads) of HAM2: 444 kg -- Calum will carry this information officially

11. When will Ken Mason and co. get experimental results with the new, low crossbeam?

We are still receiving parts for the prototype of the new Crossbeams. We plan to begin installing them in the LASTI X-end HAM in early November. We should have some accelerometer data from this system ready before Thanksgiving, which will give a preliminary indication of how much the structure's dynamics have improved with the new design. We then must wait until the LASTI HAM ISI is assembled and installed in this chamber, before we can make direct comparisons between the HAM6 ISI dynamics at the sites - with the old "Gull wings" - and the LASTI ISI on the new Crossbeams. This will not be ready until mid-2009.
JR: do you have pre-deconstruction data on old-fashioned gull wing? Get some if not, maybe from HAM SAS installation – also pretty light compared to final system so reasonably comparable

12. T080236-01, page 7, natural frequency data. Please confirm that the HPD, LLO and LHO data is with the 510kg load?

Yes, this has been done with full payload at HPD, LLO, and LHO using dummy masses.

13. Is there a document that explains why the load on the springs is at 30% of yield?

We only load the average top and bottom of the spring to 30% because we are being conservative with the loads. This way the system is safer and can tolerate more shenanigans without adverse effects. Dan DeBra recommended this approach, and since we can fit the larger springs resulting from the lower stress levels into the design without any major problems, we have done so. We expect that the tables will be treated more roughly than the suspensions, so it doesn't seem crazy to make the design a bit more rugged.
Dhs: Please point explicitly (Dan: Personal Communication…) in the documentation to the various resources used to establish the design stress level

14. How much range in payload c.g. vertical shift is tolerable? same question for horizontal range?

We have modeled acceptable performance with vertical shifts up to 100 mm. The HPD design can move the cg from about 27 mm above the LZMP to about 32 mm cm below the cg by moving 150 kg from the table to the keel. The nominal payload HPD used for the high case is described in their FDR report G070156. This is 510 kg, including 75 kg of 'suspended' payload which only contributes to the spring load, and 435 kg of 'non-suspended' payload which contributes to the body dynamics of the table. The non-suspended payload has a moment of 112 kg-m above the optical table, which is equivalent to putting the whole load about 26 cm above the optical table.

15. Are there attachment provisions for a conceptual damping mechanism to address the resonant features below 250 Hz mentioned in T080236-01, pgs 7-8?

There is currently no plan to damp the various features we see on the table. Except - we may damp the peak at 104 Hz with a viton o-ring on the spring of the GS-13. We expect the largest features to come from the payload. There is no play to have

damping struts for the payloads, although this would be great, as we showed in the tests of the quad pendulum frame. Viton has been identified as a vacuum compatible damping material which could be used for this application, although water absorption is an issue with that material. If provisions exist to attach one end of the strut to the suspension frames, it would be a simple matter to attach the other end to the optical table..
Dhs: action to SUS to incorporate an attachment provision for struts on the HSTS and HLTS, in the measure that this does not compromise excessively the stiffness of the frames
DC: MAKE A RODA FOR THIS, Dennis to do
MF – ensure that the o-ring damper is 'engineered' to be reproducible, and with robust placement through the installation process.

16. pg 13 of T080236-01: What is the plan for determining if the completed assembly is adequate packaging for shipment of the GS-13?

We plan on removing the GS-13's and shipping them safely. We have shipped these between LLO, LHO, and MIT safely on the prototypes. If we determine that the shipment crate is capable of safely shipping the ISI with GS-13's we may consider not shipping them separately.

17. pg 13 of T080236-01: Are there other corrosion concerns during storage such as connector contacts? Aluminum oxide from condensation (especially in the event of an HVAC failure in the storage area)? Can you plan to charge the storage crates with a slight overpressure of dry nitrogen or dry air, with a constant small make-up gas source to prevent moisture intrusion into the crate?

We plan on speaking with a supplier of storage containers who have built containers for satellites built at MIT. These storage containers are charged with nitrogen and contain an indicator should pressure be loss.
Dhs: ensure by FDR that you have a concept (related to above, shipping which does not produce excessive accerlerations)

18. pg 16 of T080236-01: What is the plan to resolve the proposed or potential changes to the GS-13 and will a decision be made by the time of the FDR (in a couple of months)?

We are currently pursuing several issues with the GS-13.
O-ring damping – we plan to ask the vendor to put orings onto the offload springs of the GS13. If we decide to use them, we can roll the oring into the spring gap, otherwise we will leave it at the base of the spring. We should have a performance evaluation by the FDR, but if not there is no impact on schedule.
Locker motors – we are anxious to not have to use the locker motors, and instead use tougher flexures. Testing of the new flexure designs is underway at Stanford, and we think we have a workable design for a BeCu flexure. We will make a set of these are use them in an S13 and GS13 to evaluate the performance and robustness.
If successful, we can install the flexures when we prepare the GS13s for use. This is much easier than installing the existing locker motors. We should know by the end of 2008 if the new flexures will be used.
Dhs: need to be check having the vendor undertake these modifications as an alternative to in-house effort. Need to have a significant step forward in the approach by the FDR (post vendor visit).
May prefer to do a good job on the locker!!

19. pg 16 of T080236-01: No mention is made of the alternative interferometric sensor (Euclid) to potentially replace the ADE capacitive position sensor. Is there a plan for evaluation which permits the Euclid to be considered for production, or is this strictly a fall-back, risk reduction R&D effort completely decoupled from the production schedule?

Yes, we are currently evaluating the interferometric sensors to replace the capacitive position sensor but it is not currently used in the baseline design for the HAM ISI.

Cleaning and UHV Compatibility

1) It is not entirely correct to state that cleaning was done per E960022 (ref T080236-01, pg. 8), nor is it precise enough. E960022 states that large parts may be cleaned per several procedures. The procedure and chemicals used for the HAM-ISI

is not (to my knowledge) precisely as defined in E960022. What is the precise procedure used to clean and bake the HAM-ISI parts? This must be documented.

All HAM-ISI parts have associated travelers which detail the procedure used for cleaning. The aluminum and stainless steel parts were cleaned as per E960022. The other parts are cleaned and tested for cleanliness to LIGO specifications in consultation with D. Coyne and others.
DC: needs followup, needs real documentation. The cleaning did not follow this prescription – not that it was not acceptable, but the right procedure needs to be documented and called for.

2) pg 16 of T080236-01: The ADE capacitive sensor heads were not (to my knowledge) designed for LIGO (except perhaps the addition of yet more objectionable adhesive to improve the strain relief); The ADE head design was a pre-existing commercial unit and ADE refused to consider any material substitutions. Are we sure that the ADE capacitive sensors are truly UHV compatible (provide the test data)? [action from Coyne, for Coyne]

We have asked ADE to redesign their sensor heads to add a strain relief that minimizes the use of epoxy. SEI Ilog entry 1303 shows their proposal and contains a list of materials used in the sensor head.

3) pg 16 of T080236-01: It is stated that testing reported in T080148 shows that the polyimide resin which replaces the approved Cycom 3001, PI-2525 resin, is UHV compatible. This is not correct. T080148 only addresses the proper preparation and curing cycle. It is speculated in T080148 that as a high temperature polyimide, PI-2525 resin should be LIGO UHV compatible. Have material samples or parts comprised of this new resin gone through the RGA and optical contamination cavity testing as yet? (Not likely a problem, but should be addressed before committing to production.)

Yes, this is currently being addressed. A sample of the PI-2525 resin is being cured currently (Oct 2008) by PSI and will then go through the standard LIGO vacuum compatibility testing.
DC: follow these two Q-Answers up – need explicit request for optical testing (not just RGA), may be too late for pre-order approval.

Systems and Electronics Design:

1) Figure 10 of page 11 of the PDR document shows a picture of the GS-13 pods installed onto the ISI structure. For an installed ISI platform, how long does it take to replace the worst case orientation pod? Is there an existing procedure for this? Using the MTBF of the GS-13 and its electronics, the number of installed units, the time to replace/retune, what is the anticipated impact on the availability of the complete AdL observatory?

Time to replace the worst-orientation pod is at best an educated guess. It depends on what the table payload is, which chamber the pod is in etc. There is no existing procedure aside from reversing the assembly instructions. Most of this question is too vague to answer definitively, or contains too many things which are unknown and will not be known until we have the experience of dealing with them. The best we can say at present is that the instruments are accessible and removable when installed
Dhs: 1) make an estimate anyway. 2) consider taking out and reinstalling one of the pods in the eLIGO installation – these prototypes are there to allow us to make these sort of real-world tests. Use a target of opportunity when eLIGO is open for something else. Yes, there is a risk…the next chance will be at LASTI, a year from now, and post volume fabrication. Fold estimate of time for replacement into the reliability study to determine need for a real test.

2) In general, after reading the document, I still don't have much insight into how mature the reliability study is regarding the in vacuum sensors and electronics. Are there any statistics that are worth examining? This relates directly to Charge 15 put to the committee.

We have used many of the sensors and electronics on prototypes outside of the vacuum with good reliability after they are in place and not handled. We hope to obtain better statistics from the eLIGO HAM's and prototype BSC.
Dhs: Work with Mick Flanigan to get something together on our experience to date, and anticipated lifetimes as installed, by the FDR. Refer to this report.

3) ISI is a good place to create some more stringent engineering rules for "High Reliability LIGO Electronics" suitable for insertion into a vacuum system. Key points here are: Reverse power protection, transient suppression (lightning etc.), high reliability parts, extra ESD precautions during manufacture etc. etc.

We agree that the electronics being put into the vacuum system should be as bulletproof and robust as is feasible. The only active, in-vacuum electronics in the HAM ISI system is the GS-13 Preamp board whose schematic is shown below.
Dhs: the locker motor counts, maybe not as 'electronics', but as a device that needs consideration (if it is part of the design, of course). Is it's function 'bulletproof'?

Dhs: Action to CDS/Rich/Ben Abbott: Create a document (if it does not exist) laying out rules for "High Reliability LIGO Electronics" for reference in evaluating future designs. Better sketchy than nothing at all. QA/Flanigan to lend a hand.

RA: checklist exists for standard. Action for Rich/Mick/Vern.

The OpAmp selection is very robust, consisting of the Linear Devices LT1012 (whose failure analysis document is attached), and the venerable and vetted Analog Devices OP27 OpAmp. There are several minor changes to this design that I would propose, in keeping with the committee's suggestions. These are:

a) *Reverse polarity protection on the incoming power supplies.*
b) *Transient Voltage suppressors on the power supplies.*
c) *Replace the jumpers with hard-wired traces. (They have never, to my knowledge, been used to bypass the OpAmps, and they introduce the possibility of incorrect stuffing, contact corrosion, and jumper omission.)*
d) *Examine the input power supply capacitors to see if the 35V tantalum caps could be switched to something more reliable.*

SEE PDF FOR CIRCUIT DIAGRAM

4) In section 2.8 under "Installation" details of the insertion tooling are shown. I was on site at LLO during the installation of the platform into HAM6, and I was wondering if an adjustable rail system would be prudent. Such a system might consist of two V tracks and associated cleverness that would permit adjustment of the insertion angle of the platform into the HAM. It could also distribute the load more effectively so as not to damage the floor at LHO. As it is now, calibrated grunting is applied by the team of 6 or so installers. Given the need to revisit the casters, I thought it was the time for such a suggestion.

We agree that the casters need to be bigger and have looked into other ways to transport the ISI below the rail system (see 2.4 above) however we feel the rail system as designed worked well and does not require a redesign.

5. In examining the grounding and shielding plan, I see that some of the shields are simply unattached, some are potential ground loops, and some don't yet reflect the technologies developed for the OMC vacuum cabling. This bears more in-depth attention.

The shielding on the actuator cables was left unconnected to the in-vacuum cable shield because, as built, the in-vacuum cable shield was fully exposed, and would contact the metallic seismic structure. If the shield had been tied, there would have been many ground loop possibilities. In the future, the actuator cable will have the OMC-style PEEK overbraid that eliminates this possibility. All grounding and shielding practices will be scrutinized to be sure that they are in accordance with current practices. In addition, all in-vac cabling will employ lessons learned, and technologies developed by the OMC group. An example of their new standard is shown below:
Dhs: Action to CDS/Rich/Ben Abbott: ensure that current practices (and any evident practical improvements thereupon) are documented as references against which to check future designs.

SEE PDF FOR CABLE PHOTOGRAPH

Next is another picture which shows the black PEEK overbraid, and demonstrates how it will prevent the cable shield from shorting to the seismic structure.

SEE PDF FOR CABLE PHOTOGRAPH

6. I notice that Ben Abbott is not on the distribution list, so I have added him. He should be in-the-loop on all things electronic relating to ISI.
Agreed.

7. Bottom of page 16 mentions the PEEK connectors on the voice-coil actuators. It's really important to design things so the installer/commissioner can quickly figure out if things are polarized correctly. Good work has gone into test jigs for the GS-13 etc, but there is a consistent worry that two (or greater) conductor cables cause sign flips or worse. It happened during the ISI installation at LLO. If we use the right type of connectors, and have built-in features that make it easy to identify wires, we might reduce the probability of reversed wires to a mere 1:2.

The plan is to build a test stand that will supply a regulated current to the actuator under test. The resultant actuation will be measured with a load cell, and the polarity and force constant can then be scribed onto the copper heat sinking bar. Once scribed, the ambiguity of the wiring polarity will be eliminated.
Dhs: a responsibility of the vendor as part of their QA.I think all actuators should be identical at least at the level of polarity of force.

8. Under section 2.10 there is mention of having the ability to turn power on and off separately for the GS-13s. What about the STS-2s? I know Joe G. had concerns about these devices being turned on and off unnecessarily, so should they be powered separately from the chassis that feeds them?

I believe that the proposal was to have a power switch on the STS-2 chassis that could turn off the chassis and the STS-2 at the same time. Until now, the only way to turn off an STS-2 was to shut off, or unplug the main power supply from the rack, or unplug the STS-2 host box from the chassis. A switch has now been implemented so the STS-2 Interface chassis can be powered down, bringing the STS-2 Host box with it.

9. In the paragraph on Binary I/O chassis, there is mention that this chassis has never been working. What are the details of this?

For a long time, the function of the Binary I/O has been accomplished by a small switch board that was plugged on the back of the ISI Interface chassis. This started when we were testing the system, before the code was written to control the Binary I/O remotely. As these switches are seldom (if at all) switched, this configuration was an easy one to continue. For completeness, however, this was recently addressed at Hanford. After getting over an issue with the style of Binary I/O module installed (16-channel vs. two 8-channel modules), the system now functions correctly. Rolf will be propagating the new code to LLO shortly.

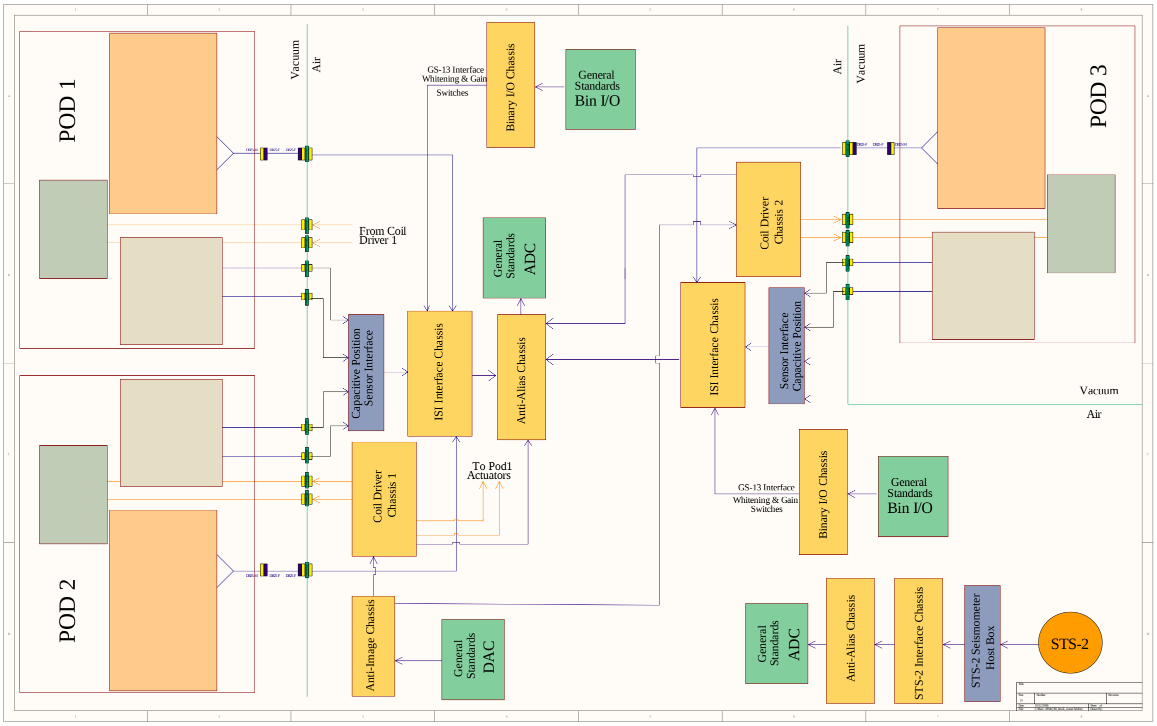
10. In the commissioning section 10, there is a statement relating schedule slips to "teething problems" in the CDS real-time system. While this may be true, it can also become a poisonous catch-all for the problem-du-jour. I want to encourage all who feel this way to jot down notes and ensure Rolf is up to date. Complaining about it while standing at the water cooler will do nothing to solving the problem.

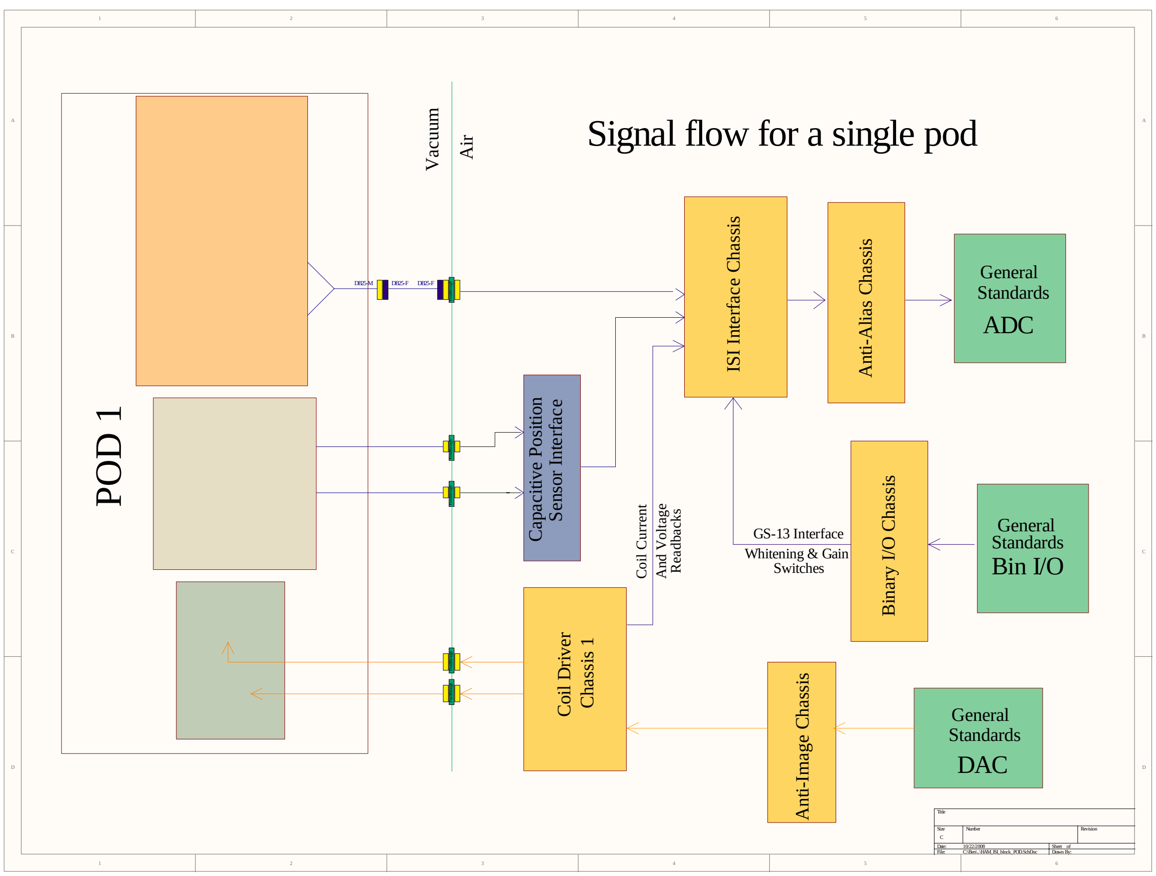
Agreed.

11) a top level block diagram of the system (analog and digital) is needed.

Shown below is a block diagram for a single HAM chamber:

This diagram doesn't give an easy flow to follow, so the next diagram is the signal flow for a single pod. As might be evident from the above diagram, some chassis are split between several pods, but this sharing is not called out on the next figure, for simplicity.


POD 1
POD 2
POD 3
Vacuum
Air
GS-13 Interface Whitening & Gain Switches
Binary I/O Chassis
General Standards Bin I/O
From Coil Driver 1
General Standards ADC
Capacitive Position Sensor Interface
ISI Interface Chassis
Anti-Alias Chassis
Coil Driver Chassis 2
Sensor Interface Capacitive Position
Coil Driver Chassis 1
To Pod1 Actuators
Anti-Image Chassis
General Standards DAC
STS-2 Interface Chassis
STS-2 Seismometer Host Box
STS-2


Signal flow for a single pod
POD 1
Vacuum
Air
DB25-M
DB25-F
DB25-F
ISI Interface Chassis
Anti-Alias Chassis
General Standards ADC
Capacitive Position Sensor Interface
Coil Current And Voltage Readbacks
GS-13 Interface Whitening & Gain Switches
Binary I/O Chassis
General Standards Bin I/O
Coil Driver Chassis 1
Anti-Image Chassis
General Standards DAC

12) I see no reference to a noise/dynamic range model. In addition to the transfer functions of each part (analog and digital), I would expect a model with at least sensor, ADC, DAC and coil driver noises along with estimated ground motion. The dynamic range limits for each part of the chain should also be noted. With such a model in hand, one can justify the choice of whitening and dewhitening filters required to ensure that we are not limited by ADC or DAC noise, and that we do not run into saturation problems. (Conversely, without such a model it is hard to say much about the system.

The analog electronics are set up so that the DAC and ADC noise are only minor contributors to the system. A new discussion of the sensors' ADCs can be found at T080276 – now on the PDR page. An old discussion of the actuator DAC noise [T080025] can also be found on the PDR page
ME: merge with model, present at FDR.

13) pg 18 of T080236-01: It is noted that if we switch to the newer version of the capacitive position sensor ADE gauging module (8800), then the two HAM-ISI systems installed for eLIGO (which use the older 4800 module) would be different. I strongly recommend upgrading to common hardware (with the understanding that this does not involve changing the heads -- limited to electronics outside the vacuum system).

We may switch the electronics to create a common hardware situation. The only factor that might mitigate this is that the sensors and electronics have been matched at ADE, so swapping the current electronics for an unmatched unit might introduce an offset, or gain difference. If these effects are minimal, or re-calibration is easy, then the switch will be made. At this point, we don't know enough about the impact of this change to say for sure which way we will go.

Quality Assurance, Test Plans:

1) Design: (T080236-00 p.3) Allocation of authority of the vibration control systems: This is stated as a potential area of uncertainty, what are the specifics test plans for determining the hierarchy of control, and what are potential alternate solutions?

The two possibilities are that either:
a) All low frequency isolation from the sensor correction will run to HEPI. Low frequency offload signals from ISI will also run back out to HEPI. This will be tested at MIT.

b) If that causes trouble, we could run the sensor correction signals to ISI, and then offload the low frequency control to HEPI. This could also be tried at LASTI, time or priorities permitting.
Dhs: Is the time scale of these tests consistent with our schedule and the need to know what to build? The LASTI HAM ISI will not be in place for another 9 months or so – do you plan to test this on the BSC ISI in some measure?

2) Analysis The only question I had on analysis of data from the system is what systems are in place to verify data integrity? Do we have instrumentation redundancy?

No, there would be no easy way to add additional instrumentation to the existing structure.
Dhs: Action to DAQ to invent and implement a way to make an independent measure of some signals to have an independent measure of the data integrity for the new DAQ. To be installed for long-term tests on a few of the implementations of the DAQ system planned for AdL.

3) Test plans are needed for
a) the eLIGO prototypes (at the PDR) to confirm that the design is satisfactory and that testing is finite and can be finished

We have actual performance data from these units, and a commissioning plan. We expect to be finished with this process by the FDR. This will validate the design.

b) the production units (at the PDR) to ensure that the design and assembly procedures are amenable to a satisfactory test procedure

We're not sure what this means. The production units will go through the same tests that we have performed on the prototype units. If anything they will be more exhaustive. The main cause for delays in our initial testing was due to software issues. For production we will require a robust front-end and associated electronics so as to avoid such delays.
Dhs: the intention here was to make sure that you plan to update your prototype plans so that they will be used in production, that's all.

c) diagnostics for the installed units, using 'remote sensing' (at the FDR)

Standard diagnostics for sensors and actuators on the project, such as transfer functions and amplitude spectra, will also be used to evaluate the health of the installed units. Our iLIGO experience is that we can use information from suspensions installed on the platform and/or from the interferometer degrees of freedom to diagnose the performance of the isolation system.

Test procedures use the following process flow:

- Test plan written in a chronological order (can indicate independent forks, e.g., electronics modules and mechanical systems)
- Reviewed by team members to validate is clear and no steps are missing.
- Document is loaded to DocDB or DCC, whichever system is in use at the time, linked to the Parts DB assembly when available
- Test plan acts as a process checklist, where each step as performed is checked off.
- Clear specification targets are described up front
- Detailed instrumentation requirements including performance (accuracy and precision, dynamic ranges, sensor interfaces, calibration, output formats, etc.)
- Test plan results are documented and saved to DCC, linked appropriately. Would it be helpful to design a standard test plan template?
- All issues and defects are reported, assigned and tracked to disposition. A defect database is being built now for this purpose, and will be ready in the next few weeks. QA team will train personnel on use.

We have gone through system testing three times; once at the manufacturer and twice at the sites. We will use this experience to produce a test plan for the HAM-ISI production and a checklist. The process flow listed above should be a project-wide template, we will make sure our plan fits into such a framework. We should remember that we are building quite a small number of units, so we shouldn't design test procedures of the rigor necessary for production of thousands of items.
Dhs: Can't help but note that the fact that we can tolerate zero faults, whereas Apple or GM can afford 0.1% or something – no unhappy customers allowed, and no 'double your money back' for defective units—, means that our testing program needs probably to be more complete than theirs. This question though is mostly for Mick to answer (since he posed it!), establishing a uniform approach which he then imposes on this and other efforts.

4) Software testing: Need to ensure we use a version control system, defect tracking system, and have in place a system for testing software functionality. I am not sure how this process for testing is handled today, but should include detailed functional requirements and step by step procedures to test each requirement. Interoperability is also important to consider and is common practice to map and test associations.

We will align our methods with global advanced LIGO system. The aLIGO production facility will help assure this happens.
DC: We need specific plans for the SEI-unique software which is in fact compatible with the standards mentioned above. By the FDR – a plan on how to flesh it out.
VS: need a crisp definition on what is in the scope of SEI and what is more general DAQ.

5) What types of accommodation are being made for the possibility of installation breakage of any system, or instrument failure at early startup stage?

Any catastrophic failure at install will inevitably lead to delays. In the worst case scenario where we irreparably damage a HAM-ISI table we would use the prototype at LASTI as a spare. We are not building a complete spare for storage, nor are we procuring parts for one.
Dhs: link this to the reliability study and recommendations to ensure adequate spares – need to think about small parts and their fragility

6) I assume we are cross training all installation and maintenance engineers for LLO and LHO or the test facilities?

Yes.

7) We should ensure that a member or two of the installation team thoroughly documents the install and commissioning process, store in DCC. I see there is reference to isolation performance in the PDR, but we also need step by step install document and lessons learned.

Yes.

8) Reliability: Ensuring we have properly trained and involved staff. It is a clearly identified issue in the PDR (p.22) and there needs to be a more concrete plan with a skills assessment identifying key person and areas we are deficient so we ensure we get people cross trained.

We will have at least two skilled members of the operation staff at each site who will be experts on assembly, testing and installation of the platforms. Joe Hanson at LLO and Hugh Radkins at LHO are expected to play lead roles in this process. Commissioning and operation of the platforms will follow the usual LIGO model i.e. the commissioning team will become expert in the subsystem. Since everything we use is standard for LIGO and will be clearly documented, we do not anticipate any areas of deficiency.

9) Maintenance: I would like to see some comments in the PDR about the need for periodic inspections, maintenance requirements, and predictive methods for catching a failure early. There is a brief statement asking that this be done, I think as part of the final design package the document must include information to the operations and maintenance teams on how to test, how to repair, or contain a reference to O&M (ops and maintenance) documents.

We will have a set of regular diagnostics for the ISI subsystem which will be run periodically by the operator(s) on duty. This is our best chance for catching a problem early and is standard procedure for existing subsystems. The final arbiter of performance is of course the interferometer. Beyond this it doesn't seem reasonable to ask for maintenance documents for an instrument which has not yet been assembled and installed.
Dhs: time plan for when these diagnostics will be developed and reviewed.
DC: Have any of the manufacturers indicated that there is any maintenance required for their instruments?Please enquire and note any deviations from the recommendations and why we should feel comfortable.
MF: Bayesian analysis or other predictive stuff?

10) Identify the need for critical spares, how many, when to supply, and where to stage.

We have included in the cost book 10 to 15% spares for instruments, sensors, and electronics which may require replacement. Each facility will be responsible for repair of any component that is damaged.
Dhs/DC: don't give a generic answer for special cases – capacitive sensors, actuators, etc.

11) Use a defect tracking tool: QA is developing a defect tracking system allow for easy input and tracking of identified issues and defects. By using this database, it allows QA to support resolving problems, tracking statistics such as vendor performance, installation deficiencies, design deficiencies, etc. It also provides a good historical record in a format that enables querying and correlation.

We will use this system when it is available.

12) Upon the commissioning of the parts DB, be active in linking drawings, imaging, etc to the parts or assemblies to ease future reference.

This will be part of our S.O.P.

13) Perform planned inspections and document inspection results. QA is still working on a process for writing, storing these inspection documents, but in the meantime should be loaded to DCC and linked out to relevant spaces like Wiki's or databases.

This is sufficiently vague that it covers many routine operations. We currently have a line item on parts travelers for inspection. We also plan to test all sensors and actuators prior to assembly, these inspections and tests are all documented. We look forward to using a QA database.

BT: ensure that vendor and incoming inspections are established.

MF: please reference section 4 and section 5 in document M080331-01-P, inspection and testing requirements.

14) LIGO-T080148 Use of PI-2525 resin and solvent T-9039

- Have test parts with the same configuration and surface finish/cleaning been coated and baked to establish and qualify a procedure/process ?
- What is the duration of the shelf life for these materials ?
- How are the materials applied and how is this process "controlled" to assure reproducible results ?
- How are the "coated" parts inspected and what are the pass/fail criteria ?
- Can rejected parts be reworked ?

The process for this particular resin is being testing by our vendor, PSI. Thus far however it has not proved significantly different from the previously used polyimide. This means the process that PSI created for coating the actuator windings will still hold true for this new round of Advanced LIGO actuators.

For production pieces the coating is visually inspected for any obvious flaking and for any overrun of the coating onto mating surfaces of the coil bobbin. If a coil is rejected the windings must be removed from the bobbin and the winding and coating process begun anew. Since PSI is now very familiar with LIGO's requirement for neat coatings we've been assured by the vendor that this will not be a problem.

The shelf life of the PI-2525 is three weeks at 21ºC and up to two years at -18ºC.

15) LIGO-E080497 Cleaning Procedure Magnetic Actuators

- Is this procedure used in conjunction with the LIGO cleaning document and only intended to high light special requirements/safeguards ?
- Missing are handling, packaging and shipping requirements/restrictions ?
- Miscellaneous document # 28 Seismometer Inspection Checklist
- Need to assign a document number.
- When doing the visual inspection, what does an inspector use to compare for acceptance, drawing, photo, or ?
- Specify all test equipment to be used by model number and vendor and record on inspection sheet the specific item used and if it has been calibrated.
- Specify test wiring harnesses used, identify by S/N, part number, inspect all electrical connectors before use, look for bent pins, make sure correct connectors are being used/mated.
- When testing and inspection are completed, how should the item be packaged and stored ?

The cleaning procedure document does highlight cleaning procedures since the overall cleaning document E960022 is out of date for some of the Advanced LIGO materials.
Handling and packaging requirements will be added to the cleaning document as requested.

A visual inspection of any machined parts including the actuator pieces can be done against a drawing.
A SN is assigned to the actuators and a data sheet is provided for each one by the vendor (PSI). Any resistance checking or magnetic field testing can be recorded on the individual actuator's datasheet.
The seismometer document will get a DCC number.
Dhs: maybe just missed it, but are there adequate procedures to avoid that magnetic crumbs can be picked up by the permanent magnets in the actuators, both at the vendor's site and after delivery? Do we have a good test for this both for acceptance and for pre-installation checks?

16) GS-13 Mod and Pod Assembly T080086

- After parts are modified, should they have some kind of cleaning before their next use ?

No. The GS-13s are inherently dirty instruments, and put into UHV vacuum pods for this very reason. However, once modified and assembled, efforts are made during assembly to keep the GS-13s as clean as possible. They're wiped thoroughly with alcohol before they're inserted into the pod.

- Are all of the "seals" replaced and/or visually inspected before re-assembly ?

We do not expect the GS-13 to remain hermetically sealed once LIGO modifications are implemented, nor is it necessary. Copper gaskets are used to ensure a proper seal between the base plate and chamber, and between pod feed through and chamber. These visually inspected before use, are used only once, and replaced if either seal needs breaking.

- Do fasteners need to be "torqued" and if so, what are the values to be used and what kind of thread lubricants ?

Any fasteners that must be torqued have their torque valued called out in T080086. Otherwise, "tool tight" is sufficient, which is also called out. Isopropyl alcohol is used when necessary as lubricant (but is often not necessary).

- The use of this document requires at least one experienced/trained individual ("been-there, have-the-tee-shirt" type) involved.

This will be the case. However, the author has attempted to write the document with as much detail and simplistic instructions as possible.

- When installing electronic boards, inspect connectors for damage before installation.

Each board and its connectors are inspected before installation.

- Only install electronic hardware that has been inspected and tested and has been "accepted", visually inspect for damage before installing.

LIGO electronics are inspected for nominal performance before they are delivered for assembly by Ben Abbott at Caltech. They are visually inspected before installation. Once installed, we perform huddle tests with a STS-2 to ensure the electronics (and the seismometer as a whole) performs as expected.

- Specify and record identification of all test equipment, note if it has been calibrated or not.

Sections 4 and 5 of T080086 clearly specify any necessary non-generic test equipment. For the level of testing done, it is merely convenient that equipment is calibrated, but not necessary. All generic LIGO testing equipment is regularly inspected for functionality.

- Need to specify/describe the test configurations ?

See sections 4 and 5 of T080086.

Safety

(1) E0700330-00-D Rev. B - Hazard Analysis / Assembly of ISI

a. Item #2--Add pre-job inspection of 5-ton over head crane, and be documented prior to use.

b. Item #3--The National Institute for Occupational Safety & Health (NIOSH) has established guidelines for safe lifting by workers. The safe limit for one person is 50lbs.

c. Item #5--Technician tooling tension on blade spring should wear impact resistant safety glasses and a face shield for added face and neck protection from flying pieces if a failure should occur.

d. Add an (Item #6) to include the need for technicians working on and around the assembled ISI to wear safety-toed shoes to prevent crushing / amputation if the ISI were to fall to the ground.

We will work with David Nolting to assure we comply with all safety guidelines.

(2) E080187-01-W - Hazard Analysis / Installation into HAM

a. Hazard Analysis should include the requirement that the 5-ton overhead crane and any other mechanical lifting/moving equipment be inspected for rigging, movement, and over all safe and reliable operation, and be documented prior to use.

We believe periodic inspection of the crane should be the responsibility of the site safety personnel.

b. Cart wheels inspected to ensure easy and precise movement abilities.

OK.

c. Include a "Critical Lift Plan" document to ensure that all personnel involved in the ISI assembly into the HAM are all on the same page, and that all have read document <u>E070154-01</u> as required.

We will follow the "Critical Lift Plan" document which David N. has agreed to write.

(3) I see where the "stress points" are loaded regarding the Blade Springs when tested…at the wide end, where it meets the bolting bracket.

a. Did the destructive testing reveal what direction the pieces flew, and the size of parts at failure?

There was no destructive testing of the springs, nor will there be. The only spring failures we know of occurred due to corrosion and on a different system (HAM-SAS). We are taking steps (nickel plating, storage precautions), to guard against this from happening here. In addition we are designing a protective cover to use when loading the springs.

(4) I cannot find the assembly procedure for the attachment of the Trolley Pad onto the ISI Optical Table for lifting.

a. I see the assembly diagram and procedure on rigging apparatus, but there is no instruction for the attachment to the Optical Table…other then the type of bolts used and torque required.

E080012-A-HAM_ISI_Installation_Procedure.pdf, page9: the position, orientation and tolerances are specified such as the bolts types, numbers and torque. No other instruction should be necessary.

b. Is the Optical Table capable of handling the stresses once lifted up to the Trolley system?

Although not included in the current version of dimensioning document, this study has been done.
The static FEA results show a maximum stress of 65MPa (safety ratio ~ 4.25).

Every other aspect of the assembly process regarding lifting / rigging has been thoroughly thought-out and planned. I am impressed with the analysis and calculations for the OTP Hoist Rings…since the lift stress angle on the eye bolts are off center.

(5) The GS-13 Pod Assembly Procedure: This document should reflect the hazards associated with handling and storage of Methanol for the cleaning process.

We will comply with site safety regulations concerning cleaning fluids.

(6) T080148-00-E - Use of PI-2525 Resin with T-9039 Solvent on Vacuum Parts for LIGO: This document describes the investigation into the use of a specific Polyimide Coating and a Pyralin Thinner, both manufactured by HD Micro Systems. Both have toxic properties; with the good news being that both are considered to be combustibles with flash points above 120°F. The concern is the need to develop safe handling and storage procedures. In addition, consideration should be given to the method of application and point of use quantities. Proper ventilation is required and (depending on the exposure levels after engineering controls in place) possible personal protection equipment (PPE) requirements. At a minimum, splash proof goggles, gloves and long sleeved clothing should be worn to protect the worker(s) involved when handling these products. Additionally, according to the MSDS, both products should be stored indoors in a chemical storage cabinet at a temperature not to exceed 90°F.

We are working with Dennis to be sure that the actuator vendor (PSI) is aware of the safety issues associated with this potting agent. The goal is to be sure that the vendor is aware of the safety issues without incurring unnecessary liability. DC/BT: Don't want to tell them how to do it; looking at vendor's safety process – then Bill or David N to give feedback, but any member of the AdL team can send an MSDS or note that a hood or whatever is 'a good idea' – just don't say anything that makes it appear that we are taking on the responsibility for their safety procedure. Contact Bill/DavidN if have questions.

(7) E080497-00-D - Cleaning Procedure for Magnetic Actuators used in Seismic Isolation "Ultrasonic in methanol for 10 minutes or spray out gaps and holes with methanol if ultrasonic cleaner is insufficient"

a. This handling process should prescribe special safety precautions and procedures, in particular to the fire hazards that exist with methanol.
b. Will this process be performed inside a fume hood environment?

We will comply with site safety regulations concerning cleaning fluids

1. LIGO-T080148 Use of PI-2525 resin and solvent T-9039
   - What safety procedures and processes are required when handling and using the resin and solvent, i.e., safety glasses, fume hood, gloves, bake oven and venting gases ?

2. LIGO-E080497 Cleaning Procedure Magnetic Actuators
   - Personnel safety warnings, i.e., use fume hood and/or adequate ventilation, safety glasses, gloves, protective clothing, hot surfaces, etc.
   - Is this procedure used in conjunction with the LIGO cleaning document and only intended to high light special requirements/safeguards ?

4. GS-13 Mod and Pod Assembly T080086
   - Any personnel safety warnings when doing this procedure, like safety glasses, gloves, etc. ?

We will comply with site safety regulations.