Laser Interferometer Gravitational Wave Observatory

- LIGO -

LIGO Science Collaboration

Evaluation Criteria for the LIGO-II Seismic Isolation System

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Distribution of this draft:

Isolation Working Group, LIGO Science Collaboration

Introduction

The evaluation criteria for alternative seismic isolation system concepts and designs are presented. These criteria will be used to guide design efforts and to select among alternative approaches. There are many factors which should be taken into account in the evaluation of the seismic isolation system. In order to include all of these factors in a balanced appraisal, a numerical value, or weighting factor, indicating the relative importance of each evaluation criteria is assigned. In the evaluation of the design, a score is given for each evaluation criteria. The sum of the product of the evaluation scores and the weighting factors is the overall score for the design.

Criteria

The criteria are divided into the following categories:

- Pre-Requisites: It is essential that all of these items be met or provided.
- Functional Requirements: These requirements are generally evaluated on a “go” or “no-go” basis.
- Performance Requirements: The isolation performance and actuation requirements comprise this category. The evaluation of these performance factors allow reduced credit for not quite meeting the performance requirement (or goal) and additional credit for exceeding the performance requirement.
- Risk Assessment: This category of criteria is intended to evaluate the risk in the development of the concept based upon the maturity of the design and required components, the test or experimental basis for the design, the credibility of the staffing plan, etc.
- Cost & Schedule: Estimated costs and schedule for the development and the production of the design are evaluated.
- Flexibility/Extensibility: The capability of the system to be modified in the event that unforeseen problems appear in either full scale development or in installation is evaluated. The capability to extend or adapt the system in the future is evaluated as well.

In each category a number of evaluation factors are defined and given weighting factors. The criteria matrix is shown in the following table. For all evaluation criteria other than the performance criteria, the intent is to assess if there is a difference between alternative designs with regard to that particular criterion; for the performance criteria, an evaluation is to be made against the requirements.

Score

For criteria for which the assessment is "yes" or "no", the score is binary: either 0 or 1. However, many of the criteria require an analog score to recognize nearly achieving a performance "goal", or to credit the fact that a requirement has been exceeded. For these cases a nonlinear evaluation function such as shown in the Figure is used for scoring. Judgement must be used to apply the scores.

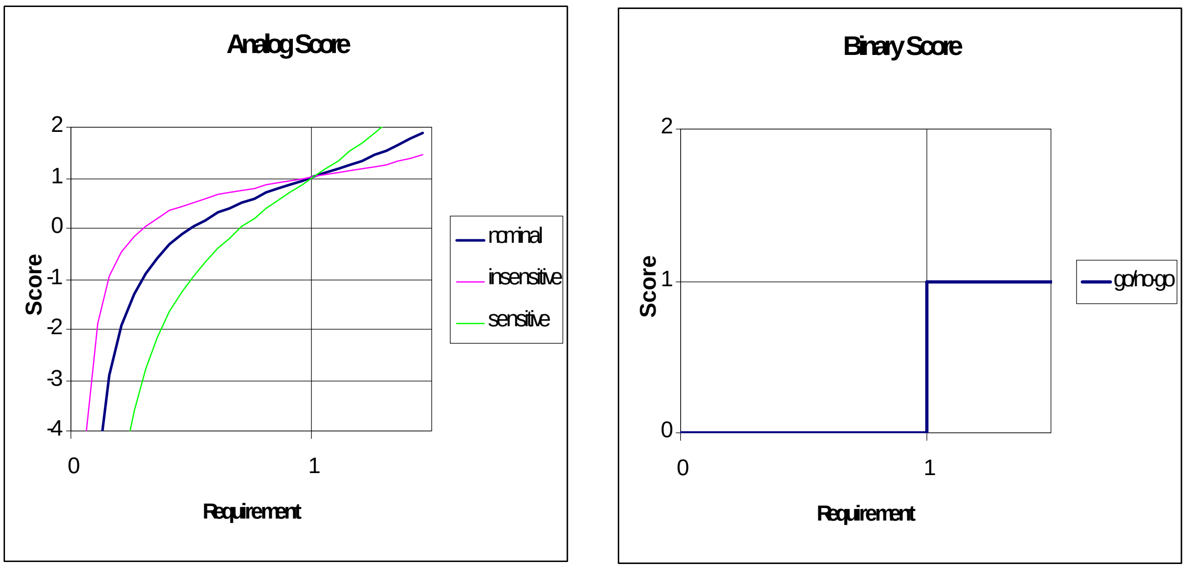

Figure 1. Score Functions

Procedure

The initial activity will be a request for the status of each of the elements in the evaluation criteria. In some cases, responses, or preliminary responses, will be available; in other cases, a plan (in a sentence or two) to prepare materials should be given including dates. If LIGO Lab resources are needed to help respond, that should be indicated. **This 'first pass' should be finished on August 11**, and will be shared with the Suspension Working Group.

The 'second pass' should be finished on August 18, in which all are invited to comment on the 'first pass' materials.

The plan for evaluation will be supplied on August 25 to the Suspension Working Group. Questions and comments are welcome at any time. To set the time scale, a downselect to a single design must be made by April '00, but an earlier decision is highly desirable.

A group of LSC members will be asked to review the alternative seismic designs and based upon the data given to the group, they will be asked to use the evaluation criteria and scoring defined herein to compare the alternative designs. The average of the evaluation board's scores will be used as the overall score. This information will be used in forming a recommendation for the isolation system design.

LIGO-2 SEISMIC ISOLATION DESIGN EVALUATION CRITERIA

	Category	Criteria	weighting factor	Evaluation Score	comments
1	Pre-requisites	Description of design	NA	NA	One specific 'point' design should be described. Options and fallback schemes to be documented in appendices.
2		Definition of SEI/SUS interface details incl. Required SUS modifications (if any)	NA	NA	The reference design is the GEO triple pendulum. Any deviations from this design to accommodate interfacing with the SEI system must be defined.
3		3D simulation results (incl. SUS model and coupling terms)	NA	NA	The 3D model shall incorporate the GEO triple pendulum model. If this model is ported into another simulation engine, documentation must exits to demonstrate that the ported model performs identically to the original. The 3D model must model all rigid body modes and their cross-couplings. The model must be documented and validation of the results must be performed to the extent possible.
4		control system description	NA	NA	A narrative description of the control system for alignment control and active isolation must be provided. The narrative should define the basic concept(s), include a schematic(s), define the sensed and controlled modes and indicate the overall control topology (SISO or MIMO, feedback and/or feed-forward, etc.). Define for each stage of the isolation system: sensor positions, range, sensitivity & noise, actuator range & noise, and the transmissibility. Define the control loops and their bandwidths and cross-over frequencies.
5		physical layout drawing	NA	NA	Show that the payloads can be supported in the range of positions required for both the HAM and BSC chambers.
6		development plan	NA	NA	Define the required R&D, indicate what small-scale and/or full-scale prototypes are required, define the development team (staff/institutions & their roles/commitments by individual's name, responsibility and fraction of time to be devoted) Define support needed/expected from the LIGO laboratory (Note: General engineering/technical LIGO Lab involvement does not require individual's names.)
7		Traceability to previous work	NA	NA	A description of how this system is similar to, and also differs from, previous SEI designs. Reference the documentation which demonstrates the performance and maturity of these existing SEI designs.
8	Functional Requirements	vacuum compatibility	NA	NA	Just an assurance that there are no show stoppers or significant development risks associated with making the system vacuum compatible.
9		Fits into LIGO BSC vacuum chamber	9		Without modification to the vacuum chamber.
10		Fits into LIGO HAM vacuum chamber	8		Without modification to the vacuum chamber.
11		Supports LIGO payloads (weights, positions)	9		Demonstrate with layout sketches that the range of LIGO payloads and their positions can be accommodated by the design.
12	Performance Requirements	Modular Assembly for rapid installation	5		It is important that the SEI system be pre-assembled and pre-tested prior to hand-off for installation in order to minimize observatory downtime.
13		Meets noise spectrum requirements (X, Y & Z)	10		It is essential to show through 3D simulation that the required isolation performance can be achieved. The simulation must include all rigid body degrees of freedom and all cross-coupling effects. Internal resonances must also be analyzed to demonstrate that the frequencies, Qs and coupling to excitation is such that the requirements can be achieved.
14		Meets total rms noise requirement (X, Y, Z, pitch & yaw)	10		Ibid
15		Meets longitudinal velocity requirement	5		Ibid
16		Meets Actuation requirements for alignment, earth tide and thermal compensation	10		
17		Meets actuation requirements for microseismic peak suppression	10		
18		All internal Modes are damped adequately	8		
19		Drift and Thermal Expansion are within Acceptable Limits	5		
20		Validation & completeness of 3D simulation	8		

LIGO-2 SEISMIC ISOLATION DESIGN EVALUATION CRITERIA

	Category	Criteria	weighting factor	Evaluation Score	comments
21		Pedigree or traceability to previous working SUS design	5		In particular, since the GEO Triple pendulum is the baseline design, deviations from this design to meet a compatible interface must be weighed against the significant development time/investment made to date in this suspension system.
22		Pedigree or traceability to previous working SEI design	5		In particular, evaluate the similarity and disparities between the proposed designs and "similar" SEI designs.
23		Successful prototype tests of parts or whole	8		Extent and importance of tests of critical aspects of the design
24		simplicity/commonality (mechanical & electronic)	3		
25	**Risk Assessment**	development(s) required (maturity of design)	5		
26		development(s) required (maturity of components)	5		
27		Testability	2		At the component, assembly and installed system level, are there any issues with regard to testability which differentiate the alternate designs?
28		Robustness of the Development Team	8		Is the assembled team adequate for the development task? Have personnel with critical talents and capabilities made sufficient time commitments to the project?
29		Ease of Installation	2		Judgement on how easy or difficult (and costly) it will be to design filtering and installation procedures to install the system. Consider if tasks can be done in parallel and the likely duration of installation tasks.
30		Risk of Non-Gaussian Noise	5		Taking into account applicable test data and/or materials utilization and electronics design, evaluate whether there is any serious risk of generations of unacceptable levels of non-Gaussian noise.
31		Robustness of Design	5		How sensitive is the design to the precision of the fabrication and the assembly? How dependent is the design on cancellation of couplings by precise balancing or symmetry, servo-system margin, or precisely tuned filters?
32	**Cost & Schedule**	research & development cost	3		evaluate and judge uncertainty
33		production cost	3		Ibid
34		assembly & installation tooling costs	2		Ibid
35	**Flexibility/Extensibility**	schedule	2		Compare/evaluate the schedule for development and production up to the point of installation. Is there a clear difference in the duration which cannot be made up by increased cost (e.g. manpower)? Is the schedule riskier for one approach or another?
		Flexibility/Extensibility	3		Are there any factors which lead one to belief that the design either provides flexibility or limits the flexibility?
		TOTAL	163		