

Advanced LIGO 2007 Baseline Update Review
NSF Headquarters, June 5-6, 2007

A review of the Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO) was held in Arlington, Virginia June 5-6, 2007 in order to assess its readiness to move forward to the construction phase. The focus was on developments and refinements in planning, design, and costing of AdvLIGO since the last baseline review held May 29-June 2, 2006, and on progress by the project team in dealing with specific issues, questions, and concerns from that review. Most of the members on the baseline update review committee also participated in the 2006 baseline review, which facilitated a focus on changes and progress since 2006. Presentations from the AdvLIGO team covered a general LIGO overview, AdvLIGO summary, changes since 2006, technical status, and management systems. The committee members would like to thank the AdvLIGO team for their efforts in providing clear presentations, forthright discussions, and advance availability of materials via the website all of which made for a straight-forward review task.

I. Summary:

Overall the committee was confident that AdvLIGO was prepared to move into the construction phase. The cost estimate and schedule have been updated in response to Baseline review recommendations, changes in overhead and escalation, and improved information as R&D and design have progress. The revised cost estimate is essentially unchanged in fixed 2006 dollars although there have been a number of ups and downs at the detailed level. The overall contingency level has increased slightly to 28%, which the committee feels is reasonable and offers reduced risk compared to the earlier 26% contingency level. The budget in escalated dollars has increased modestly due to changes in the official (NSF/OMB) escalation tables. The scheduled completion date is unchanged but the working schedule has been resequenced in response to a baseline review recommendation to show an explicit 11 months of float at the end – accelerating the start of installation by six months. This is a welcome change but has the effect that the funding profile is now out of sync with the schedule. The decrease in funding in 2011 followed by an increase in 2012 was tied to the earlier schedule and needs to be revised (moving funds into 2011) to support the earlier installation. The largest technical risk (and an important determinant of scientific performance) is in the optical coatings. While qualification of a third vendor will reduce risk somewhat, this area should be a high priority for risk reduction R&D with a goal of developing solutions that could lead to future performance improvements and possibly provide a backup option for AdvLIGO should problems arise.

II. Changes to the 2006 Baseline:

II.1 Management, Costing, & Integration

There were several changes in the cost estimate due to a variety of factors. The 2006 Baseline review identified the vacuum systems as likely underestimated due to the use of inflation factors that did not reflect recent market experience. A revised estimate was performed which led to an increase of ~\$3M. The incorporation of Moore's Law into projected computing costs together with a reevaluation of data storage needs and the analysis scope with AdvLIGO led to a comparable cost reduction. There were other changes in detailed estimates in response to better market data or R&D and design results, but in general they were less than a percent and a combination of increases and decreases. This indicates that the overall budget is quite stable. There were two changes that were derived from changes in the basis of determining fully-burdened, escalated dollars. Caltech has relieved AdvLIGO of overhead costs with the project picking up directly the cost of providing overhead-type functions (admin, procurement, etc.). This has two benefits: 1) savings to the project, which increased contingency from 26% to 28%, which is welcome given the feeling at the baseline review that 26% was adequate but tight and 2) insuring that the level of support is more directly controlled by AdvLIGO, which should help insure responsiveness in support functions. The other change is in the escalation factors from NSF/OMB, which are updated annually to reflect market conditions.

The management structure for AdvLIGO is now well established with key positions filled by experienced staff. The relationships between LIGO and AdvLIGO have been clearly defined. Policies and procedures that will govern AdvLIGO activities exist or are in near final form.

The main change in the schedule was the adoption of the recommendation from the 2006 baseline review to collect the schedule float at the end of the project. As a result the full 11 months of schedule float is manifested at the end of the project. This is adequate for a project of this complexity and duration. It has the effect of accelerating the start of installation by ~6 months. Working to the earlier date will reduce project risk; installation is one of the most difficult activities to estimate. Approximately 20 Project Execution Plan milestones have been identified with dates that are backed off from the early finish schedule by varying amounts (2-11 months depending on when in the project they occur). These milestones will be useful for NSF as key indicators of project performance. There are also about 80 milestones (including the PEP milestones) tied to the early finish schedule that the project will use to manage the baseline schedule. The number and frequency of these milestones, as well as their significance to project activities are appropriate. One byproduct of the schedule change is that the funding profile is now out of sync with the project schedule. The current funding profile reflects a decrease in funding in 2011 with an increase in 2012. This was tied to the six months of float prior to the start of installation that had been in the 2006 baseline schedule. With the removal of float it is now necessary to adjust the funding profile to move those funds from 2012 into 2011 in order for the funding profile not to preclude the faster start on

installation. It would be prudent to make this change now since it will become harder to implement further on in the funding cycle.

II.2 Seismic Isolation & Suspension

The Seismic Isolation and Suspension systems are on track for the start of construction of AdvLIGO. The team has many experts and has solved some significant vibration isolation challenges in the past. Based on this track record, we expect that they will successfully implement the proposed system. This review panel does not see any show-stoppers at this time.

The total vibration isolation is made up of three parts: 1) an external hydraulic pre-isolator; 2) an internal (to the vacuum) one- or two-stage active isolator; and 3) a mirror suspension mounted on the internal isolator.

In the 2006 baseline plan, two options for seismic isolation internal to the vacuum were being considered: the high-gain servo internal seismic isolation (ISI) approach and the lower-gain seismic attenuation system (SAS). The SAS option was built, tested, and deselected. The ISI has been and will be the baseline, and will be tested in Enhanced LIGO.

We feel that there is no significant impact incurred by sticking with the baseline, but that risk has been reduced by investigating an alternative.

There are two changes in the suspension:

- 1) There will likely be a steel wire suspension for the beam splitter.
- 2) There will be actively sensed ribbon damping on the test mass suspensions.

We do not believe that either of these changes will impact the cost or schedule.

II.3 Optics

Pre-stabilized Laser

At the 2006 review, both an injection locked laser and master-oscillator power-amplifier approach were considered. At this review, the MOPA configuration was presented as the final configuration. This is most clearly shown as a modification of the front-end medium power stage of the PSL. This approach will provide the necessary optical power with the required laser oscillator frequency stability using an approach that should be simpler than the injection-locked approach, thus improving the likelihood of success.

Sufficient progress has been made on the PSL stage. A laboratory prototype of the PSL laser that incorporates the MOPA configuration has been developed. An improved

output beam has also been achieved. Many of the functional prototypes of PSL and pre-mode cleaner optics have been designed and ordered.

Input Optics

The primary change in the technical approach of the Input Optics Task is that a segmented ring heating element has been chosen to invoke an adjustable input mode-matching condition into the recirculating cavity as compared to the previously suggested approach of using a CO₂ laser-based heating approach to deal with thermal lensing problems. Additional changes were made in the oversight on tasks associated with light baffling of the input optics, which were previously under the auxiliary optics systems task area, but now under the Input Optics Tasks. Successful design and deployment of the input mode cleaning optics alleviated the need for active beam wander stabilization. Each of these changes have had a positive impact in the overall likelihood of success owing to the use of a simpler approach to realize a similar functionality by eliminating previously considered approaches of increased complexity.

Progress has been made on the Input Optics Tasks. One minor concern relates to in-vacuum isolation between the mode cleaner and the recycling mirror. For example, the Faraday isolator provides ~45 dB of isolation at low power, but the isolation is reduced to 25 dB at high input power. It should be noted that additional isolation is provided by calcite polarizers, but it was not clear to the Review team what level of isolation is required for AdvLIGO. It was noted amongst team members that optical isolation of 50-60 dB is typical for low noise laser applications. It should be stressed that the 2007 team is not suggesting that this level of isolation is needed for AdvLIGO, however, the AdvLIGO team should have an estimate of the overall isolation needed.

Core Optics

Test Masses

The ultra-low-OH fused silica from Heraeus is being considered for the test masses, beamsplitter, and compensation plates. The absence of OH vibrations should improve performance and the residual halide ions should not be an issue at the wavelengths of interest. However, even if this material is not qualified, the existing silica material is suitable for Advanced LIGO.

Point defects, surface micro-roughness, cleanliness and handling damage may be significant contributors to optical loss. Currently one potential polishing vendor is CSIRO, however CSIRO is in the process of transitioning from a government agency to a commercial enterprise. This change may or may not affect their performance as a vendor for LIGO. LIGO has prudently begun to investigate additional vendors to mitigate supply-line risk. Currently they are testing QED, who is well known for innovative magneto-rheological polishing and they hope to find a third potential vendor. The panel supports this broad effort. "First Contact" protective polymer is promising to prevent handling damage and keep the test masses clean.

Dielectric Coatings

The optical coating material (silica/titania-doped tantala or $\text{SiO}_2/\text{TiO}_2\text{-Ta}_2\text{O}_5$) and mechanical loss (2×10^{-4}) have not changed since the last review. This coating material had been previously tested in small samples and a larger test mass has recently been coated for testing in LASTI. While this level of loss is not expected to prevent attainment of the AdvLIGO design sensitivity, it remains the limitation in the critical frequency range of 50-100 Hz. Reduction of the loss to 3×10^{-5} is required to make it no longer a limiting factor and to give AdvLIGO some headroom to work with.

The two coating vendors CSIRO and LMA-Lyon both have some issues. CSIRO (see above) may be undergoing a change of structure and LMA-Lyon has had very limited capacity in the past year. Neither appears to have much experience with $\text{SiO}_2/\text{HfO}_2$ coatings and have not had good results with this potentially low mechanical loss material. Negotiations with REO are ongoing as a possible third source. While LIGO personnel are not the limiting factor in coating development, the costs of coating are.

Testing of silica/silica-doped tantala ($\text{SiO}_2/\text{SiO}_2\text{-Ta}_2\text{O}_5$) in the past year did not have as good a loss as $\text{SiO}_2/\text{TiO}_2\text{-Ta}_2\text{O}_5$. Future testing of $\text{SiO}_2/\text{SiO}_2\text{-TiO}_2\text{-Ta}_2\text{O}_5$ is planned as well as different ion-assist strategies. LMA-Lyon has formulated a fast turnaround method for testing coating dissipation on thin samples.

Theoretical work on thermo-optic noise, thermoelastic terms, the thermorefractive effect and thickness optimization is ongoing.

Auxiliary Optics Systems

The Auxiliary Optics Systems are varied and not always completely optical. The LIGO team has these systems and subsystems well in hand and has responded appropriately to all panel comments from 2006.

The thermal compensation system has been optimized and finalized with Hartmann sensors, compensation plates heated by the nosier CO_2 laser and the test masses heated with ring heaters.

Stray light control has been found to have additional complexities requiring suspension of some of the baffles, but is being pursued vigorously.

Cost, schedule and technical risks in these systems seem low.

Interferometer Sensing and Controls

The steadily improved lock acquisition and retention of Initial LIGO is indicative that ISC is well developed. Additional work has continued, particularly in the DC readout design, which will be incorporated in Enhanced LIGO.

The panel recommendations from last year on optical aspects of ISC included:

- 1) Exercising the hardware with simulations. The hardware is not yet ready for this to occur.
- 2) Clarification of the test plan. Some outside vendors have been engaged with mixed results. Additional engagement of the LSC is planned and should be pursued.

Cost, schedule and technical risks in optical ISC systems seem low.

Parametric Instabilities

Clear progress has been made in addressing the parametric instability problems. At the time of the 2006 review, parametric instabilities were being noted as potential problems that were not well understood, in terms of how these effects would impact the overall performance of AdvLIGO sensitivity.

II.4 Data Systems, Data Acquisition, Controls, and Computing

There was a complete re-analysis this year of the computing requirements for Advanced LIGO leading to an update of the computing plans for the Data and Computing Systems (DCS). The presentation and documents (including internal documents) were especially good and provided an excellent understanding of the scope and cost; the documents are considerably more mature than those of a year ago. This re-analysis was done in response to the 2006 Baseline Review, and details are included in section III.4 below. This re-analysis resulted in increased computing requirements, but the cost was more than offset by cost savings pointed out a year ago.

III. Response to 2006 Baseline Review:

A detailed response to the 2006 Baseline review was provided that listed each recommendation and the AdvLIGO response. Overall the project has been responsive to the recommendations. Many are closed while others are being worked – depending on the specifics of the recommendation.

III.1 Management, Costing, & Integration

AdvLIGO was fully responsive to the recommendations in this area. The plans regarding QA, procurements, project budget and schedule, management plans, and staffing have progressed and AdvLIGO is well positioned in all of these areas to progress to construction.

In the original 2006 Baseline Review, under Project Risks, p. 19, the Panel commented that:

“The quality assurance and the procurement process risks need specific attention. Members of the Panel suggest that the project consider combining some aspect of the two – for example with a “parts acceptance” program. Some of the optics parts undergo

testing as they are received to be sure their properties match requirements. This is a “low-volume/high value-per-part” screening. It may be advisable to extend this testing to “high volume/low value-per-part” components (such as sensors) to reduce the risk of building up high-added value subsystems such as suspensions with parts that may be functional but do not meet noise specifications.”

These comments, and others in the June Review, led to a detailed recommendation under the heading Quality System to implement an overarching quality system.

The AdvLIGO project has taken appropriate steps to address this risk. They have developed a draft procurement plan and started implementation of a QA plan with the assignment of a scientist with previous experience both with the project and with QA to an oversight role for QA, with a plan to hire an traditional quality person to assist. The QA plan appears to address both high value and low value parts, and will include “lessons learned” from experience with the initial LIGO installation. In addition, cost estimates already include the additional cost of asking the vendors to take on some of the QA testing. The QA plan and actions taken by the Project are appropriate and reasonable.

III.2 Seismic Isolation & Suspension

There were three summary recommendations and three detailed recommendations from the last review. The recommendations are paraphrased below.

Summary (1 – number 15 in the formal response) Noise from charging of the test masses should be studied. Also, the violin mode of the fiber suspension should be studied as a possible excess noise source.

Significant progress has been made on understanding the charging problem since the last review. One possible solution involves illuminating the masses with UV radiation. Tests are underway to see if such illumination will damage the coatings. In addition LIGO has organized a workshop for this July with the LIGO/LISA/VIRGO/GEO and experimental gravity communities to discuss charging of the test masses and possible solutions. No specific information was provided to indicate that the violin mode of the suspensions has been studied, but the status report indicates that active damping is known to be required. In addition the vibrational and torsional modes of ribbon suspensions are under study. We believe this part of the recommendation is in the process of being addressed adequately.

Summary (2- number 16 in the formal response) Are there a sufficient number of people being trained to test and assemble the seismic isolation and suspension systems?

This is being addressed by the Project, but remains a concern and is not something that can be solved overnight. Since the seismic isolation is on the critical path, it is important to stay on top of the issue.

Summary (3 – number 17 in the formal response) Targeted testing of some of the suspension parts, including sensors, before installation may be a good investment.

The project has developed some hardware simulators to facilitate testing of the sensors and the computer-ADC-analog filter-cable sets. They plan to implement testing of the electromagnetic actuators as well. We think this is an excellent step, but would just gently caution that sometimes it is important to test some of the low-cost-per-part commodity items as well as proposed in the QA plan.

Detailed recommendation (SEI – WBS 4.02) A cost saving analysis of the up-front effort vs. possible down time should be performed for the unit components that can be qualified before assembly.

Fully addressed. Please see comments for Summary recommendation 3 above.

Detailed recommendation (SUS – WBS 4.03) An overall test plan starting in the prototyping phase should be developed. There are a number of places where early testing could benefit the program.

Addressed.

Detailed recommendation (Test Masses Electrostatic Charging) The understanding, and, if necessary, elimination of the impact of electrostatic charging on Advanced LIGO performance should be prioritized.

Addressed. Note that this is substantially the same as the first summary recommendation discussed above.

III.3 Optics

Pre-stabilized Laser

The primary recommendations associated with the PSL from the 2006 review focused on addressing noise generated in the photodetection process of detecting high power optical signals. Since that time, several technical contacts between NIST, NRL and the LIGO team have been initiated to address this issue. In addition, to maintain a dialogue between the PSL developers at AEI, the LIGO team has initiated bi-weekly teleconferences to keep abreast of developments and progress of the PSL.

Input Optics

The primary concerns of the 2006 report focused on a) power control, b) input mode cleaning, and c) optical isolation of the master laser from the interferometer. The LIGO team made adequate progress addressing the recommendations of the 2006 Review panel concerning the Input Optics Tasks.

The LIGO team conscientiously addressed both the theoretical and modeling aspects of the parametric instability effects occurring at high input powers. In addition, a workshop was established to focus on the PI problem and determine the magnitude of the effect, the level of risk, address methods of controlling/mitigating and possible implementations of these ideas.

Core Optics

The 2007 Review Team noted that the LIGO team made excellent progress in understanding the cause and effect of parametric instabilities. The LIGO team developed a simple solution of realizing a quality factor reduction of the acoustical modes by incorporating a ring damper around the recirculating cavity mirrors to provide a Q reduction of more than an order of magnitude while only increasing the thermal noise by 2%. Prototypes of these mirrors will be made and tests will occur at Caltech TNI and at the Gingin facility in Australia.

Electrostatic Charging

LIGO has aggressively addressed electrostatic charging in the last year as recommended by the 2006 panel. This effort is ongoing. A UV mitigating scheme is possible. The panel applauds the team for their effort in this area.

III.4 Data Systems, Data Acquisition, Controls, and Computing

Data Acquisition, Diagnostics, Network & Supervisory Control (WBS 4.9)

All recommendations from the 2006 review have been implemented or planned for implementation or investigation. In particular, plans are in place to hire another real-time programmer, and to investigate Infiniband as a replacement for Myrinet. The basis of estimate document for DAQ still reflects some older data, and would benefit from a scrubbing as has been done for DCS (cost of commodity networking, compute nodes, disk storage components are all high and lack Moore's Law extrapolations).

Data and Computing Systems (WBS 4.10)

The major change from last year has been a complete review of the requirements and costs for the computing systems. This re-analysis increased the defined computing requirement, clarified to scope (to prevent requirements creep), fixed the basis of estimate, and in the end yielded a significant cost reduction (roughly the same as the 2006 review anticipated). The cost book basis of estimate has been updated to show the details of the new extrapolations, which look quite reasonable and only slightly conservative.

The current cost estimates for DCS are robust, with the following caveats:

1. Current DCS schedule & cost is for deployment in Fall 2014. As schedule contingency is used, the computing plan should be adapted to maintain a just-in-

time delivery strategy, with corresponding cost savings (4% / month, Moore's Law effect).

2. Network costs are conservative: \$360/node for network/LAN for a cluster of <600 nodes is high if one uses leaf and spine switch topology. Current plan is for higher performance full cross bar switch (not motivated by requirements), which is about twice the cost of leaf and spine, even using 4x trunked uplinks (5:1 oversubscription instead of 23:1). Since the plan's network costs are 9% of node cost, this is only a few percent effect – negligible.
3. Similarly, \$4,000 per compute node today is conservative, by perhaps only 10%-20%.
4. Offsetting this conservatism is the sporadic performance of Moore's Law, which comes in discrete steps, with occasional flat-tops of 3-6 months, which represents steps of up to 25%. Since the cost book assumed a full 7.5 years of Moore's Law in going from 2006 to 2014, it would seem that the extra 0.5 years (total of 8 years) to account for the flat-top is already in place, but extrapolating out that many doublings has an uncertainty associated with it, which is probably of order 25% (larger than the assigned contingency). Since the clusters can be build-to-cost, there is no real need to increase assigned contingency. Instead, one can recognize that the delivered performance at fixed price has an uncertainty of 25%. This same philosophy is presented in LIGO internal documentation. (This reviewer's best guess is that it is unlikely to come in lower performance than the plan, and most likely to come in with 10%-20% higher performance). In any case, the software performance uncertainty (requirements) is probably a good bit larger.
5. Deploying a full 3 year disk cache on day 1 is cost inefficient. Moving part of this to an "annual 25% refresh" in the operating budget would allow growing capacity as the data comes in. Shrinking from 3 years to 1½ year would save \$0.2M.

The excellent work done in refreshing the requirements and computing plans and costs should be updated every 2 years to track evolutions in requirements and market experience. If a gap (or even a significant savings) emerges, the change control process should be exercised, either to adjust scope or to change costs.

Advanced LIGO is explicitly moving more towards a grid computing model, and that entails significant additional manpower. It was clarified in the discussion that this support is not within scope of the Advanced LIGO project. It would be useful to state this carefully within the Advanced LIGO Computing Plan (and perhaps other documents) in order to avoid future scope creep.

IV. AdvLIGO-related R&D:

IV.1 Management, Costing, & Integration

The separation of R&D into activities clearly related to AdvLIGO scope, and therefore part of the project and risk reduction R&D that is not part of the project but may provide options for future performance improvements and provide fallback options for AdvLIGO should problems arise is sensible. It is not practical for the project to support parallel track activities some of which may not pay off in the timeframe of AdvLIGO construction. Experience with LIGO was that the presence of ongoing technology base R&D has paid off both by providing a basis for Enhanced LIGO and Advanced LIGO and by developing technical solutions that could be adopted by LIGO when difficulties arose with the Livingston site.

IV.2 Seismic Isolation & Suspension

Activities associated with suspensions over the past year have made significant progress and serve primarily to reduced risk. We see no change in the confidence level in the schedule and the costs. In particular, the AdvLIGO project has:

- 1) Added a suspension to the output mode cleaner and included testing as part of Enhanced LIGO. This appears straight forward and will reduce risk.
- 2) Started to investigate charging of the test masses.
- 3) Tested an alternative SEI design (the SAS) and decided to stick with the baseline.

IV.3 Optics

The panel strongly believes that risk management R&D of the dielectric coatings should be part of the R&D program not just up until the procurement date of January 2009 and coating date of September 2009, but on a continuing basis because the current coating is only adequate and the development interval for a new coating may exceed the available time. This is a very challenging problem and requires a commensurate broad and intense commitment of resources. A large number of coating runs and coating materials is needed. An additional coating vendor such as REO may be critical to the long term success of this effort. Additionally, we recommend seeking out coating expertise beyond what is available in LIGO or this panel. A solution might be to convene a coating summit or seek out coating experts in academia, government and in industries not directly supplying coatings.

IV.4 Data Systems, Data Acquisition, Controls, and Computing

There were no significant risks in these systems identified in the 2006 review, and none have emerged in the year since.

CHARGE TO THE REVIEW PANEL

Advanced LIGO 2007 Baseline Update Review

The NSF asks that you review the Advanced Laser Interferometer Gravitational-Wave Observatory (AdvLIGO) project as to its readiness to move forward to the construction phase. The review should focus on developments and refinements in planning, design, and costing of AdvLIGO since the last baseline review held May 29-June 2, 2006, and on progress by the project team in dealing with specific issues, questions, and concerns from that review. The new review will be held at NSF headquarters in Arlington, VA on June 5-6, 2007. We ask that you provide an Executive Summary of your findings and recommendations by the end of the review so that preliminary feedback can be provided to the project at the scheduled closeout session on June 6. A full report describing your findings, assessment, and recommendations should be provided to the NSF by June 27, 2007.

The lead institution in the project is the California Institute of Technology, with the Massachusetts Institute of Technology acting as a subawardee. The AdvLIGO project is a planned major upgrade of LIGO, and it will fully exploit the capabilities of the signal-recycled Fabry-Perot Michelson interferometer approach to detecting gravitational waves. The AdvLIGO interferometers promise an improvement over initial LIGO in the limiting sensitivity by more than a factor of 10 over the entire initial LIGO frequency band. It also extends the bandwidth of the instrument to lower frequencies (from ~40 Hz to ~10 Hz) and could be configured to allow high-sensitivity narrowband operation at frequencies above ~300 Hz.

Funding for AdvLIGO is requested in the Presidents FY 2008 budget. If the funds are appropriated and NSF gives its final approval, NSF would provide funds for the associated construction project and, later, the cost of operating the Observatory. After the AdvLIGO interferometers achieve sustained lock (the end of the MREFC project), the operations phase will most likely be dedicated to activities needed to bring the Observatory up to full design sensitivity that can only be accomplished after installation and commissioning of the new equipment, interleaved with engineering and science runs.

At the 2006 Baseline review, the Panel reviewed the project cost, schedule, scope, technical deliverables, and management. The Panel felt that plans were sufficiently well-developed to proceed to the construction phase (i.e., there were no 'show-stoppers' to AdvLIGO). The Panel did, however, have a number of questions and concerns, so the 2007 review should focus on three points: the response of the AdvLIGO project managers to those questions and concerns, the appropriateness of any planned deviations from that baseline plan, and the progress of AdvLIGO R&D.

Specifically, the Panel is requested to consider the following questions:

- 1) Are deviations from the 2006 baseline plan, if any, reasonable, and what is their impact on the likelihood of a timely and successful completion of the construction project?
- 2) Have the concerns and recommendations expressed by the 2006 baseline review panel been adequately addressed by the Advanced LIGO project? (Note that NSF formally asked the AdvLIGO project managers to address this question; their detailed response is included in the review materials package.)

Has AdvLIGO-related R&D in the past year progressed sufficiently that risks to the baseline project cost and schedule can be managed with a high confidence level within the proposed contingency and schedule float?

PANEL ROSTER

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