LIGO-
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Final Report of the NSF Review Panel on the LIGO Australia Project

Arlington, VA
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1. Executive Summary

Three different scenarios have been proposed to encourage the development of a gravitational wave detector in Australia with sensitivity comparable to the two Advanced LIGO (AdvLIGO) sites in the US, forming, with the Advanced Virgo detector in Europe, a global network of four detectors with near optimal sky coverage and source location ability. This network would enable real gravitational astronomy for sources in the frequency range accessible to ground based detectors.

The first scenario, Option A, requires no additional investment and involves setting aside components originally intended for LIGO's second Hanford interferometer and shipping them to Australia when that site is ready, leaving one interferometer operating at each of the two LIGO sites in the meantime. The loss of one of the two interferometers at the Hanford site presents no significant risk that the first credible detection of a gravitational wave event would be delayed.

The components will be set aside only if Australia successfully meets funding and logistics milestones established by both sides by September 2011. If the conditions are not met, then construction of AdvLIGO proceeds as originally planned with two interferometers at Hanford and one at Livingston.

The other two scenarios require either additional investment (Option C) or disruption of an operating detector facility (Option B).

The panel concludes that the case for the installation of the 3rd LIGO detector in Australia is extremely compelling, and that the scientific advantages for option A greatly outweigh its drawbacks and risks, and in particular the possibility of delaying a first detection.

Therefore, the panel recommends proceeding with Option A. In the event that Option A cannot be completed as originally outlined, the panel does not recommend implementing Options B or C.

2. Outline and Main Issues

This summary report contains the conclusions and recommendations of a Panel convened by the National Science Foundation to examine the issues surrounding a proposal by the LIGO Laboratory to build a third LIGO laboratory site in Australia.

The report first discusses the main issues raised by the proposal as viewed by the panel, and then addresses the specific issues in the NSF charge to the panel for each one of the scenarios in turn. A summary with recommendations to the NSF is in the next to last section.

In addition, there was an unexpected development announced on June 25, 2010 – approximately a week after the Panel met. Funding for the first half of the Japanese Large Cryogenic Gravitational Wave Telescope (LCGT) was announced. The impact of this announcement and why it does not affect the conclusions of the Panel is discussed briefly in the final section.

The NSF's charge to the panel, the panel participants, and the advice of a previous AdvLIGO review panel are included as appendices.

2.1 Main Issues: Science Case

The value of a third LIGO site in Australia, combined with the Virgo site in Europe to form a network of four detectors of comparable sensitivity, is without question extremely high. A detector in Australia, in a network with the two LIGO detectors in the USA and Virgo in Italy, will provide tremendous gains in sky coverage; the ability to localize a source and recover its physical parameters; resolve degeneracy in parameter values; and significantly increase the network's prospects to search for sources such as stochastic backgrounds that cannot be done effectively without a fourth detector outside the present LIGO-Virgo plane

Of particular importance is the increased capability to localize the source. With a detector in Australia, sky localization improves by factors of 5-10 for both modeled and unmodeled sources. This allows angular localization of sources throughout the sky to within a degree, which would improve the ability to identify electromagnetic counterparts to the gravitational wave source. As a result, gravitational wave astronomy would benefit tremendously from an Australian component in the network.

However, to get to the routine astronomy stage it is first necessary to convince the larger scientific community that there are genuine, detectable signals. Thus the main question concerning the panel is to understand what the risks are, if any, to achieving a first detection within the proposed plans.

Under the preferred scenario, Option A, the LIGO observatories operate without a second Hanford interferometer for a time period that is difficult to predict with certainty, but which ranges from 2.5 to 4 or more years. The Weiss report analyzed in depth the impact that one fewer detector will have on the community's ability to claim detection. Two scenarios were considered: modeled and unmodeled sources.

For modeled sources, the report indicates the impact on detection is not severe. This is due to improved data analysis coupled with a good understanding of the most likely sources – compact binary systems - for which good signal-to-noise levels can be achieved with the HLV network. On the other hand, the prospects for detection of unmodeled sources are significantly reduced by a factor of 10 to 50. However, without the identification of an electromagnetic or neutrino counterpart, a detection claim of an unmodeled burst is not likely to be accepted by the scientific community even with a second Hanford detector. Consequently, the panel felt there is no significant risk to the detection prospects and there are major scientific gains allowed by the Australian detector.

2.2 Main Issues: Incremental risks to a first detection

Of the three proposed scenarios, the only option that potentially compromises Advanced LIGO's capability to make first direct detection of gravitational waves is Option A. The chief risk is from the loss of a detector in the network. The loss of a detector has two main effects: (1) a reduction in the signal to noise ratio that degrades as the square root of the ratio of the number of detectors in the network, and (2) a reduction in the ability to reject the non-Gaussian chance events in the tail of the noise distribution.

The level of risk depends on several unknowns: (1) the nature of the most readily detected gravitational wave sources; (2) the frequency of detectable events; (3) the status of the advanced VIRGO detector during early operation of the advanced Hanford and Livingston detectors.

LIGO's current strategy assumes that a binary neutron star inspiral is the most likely candidate for a first detection. The existence of tight binary neutron star systems is well established; only the number of mergers per unit time per unit volume is uncertain. A realistic estimate for detection rates with the original Hanford-Hanford-Livingston (HHL) configuration, at design sensitivity, is 30/yr, with an uncertain lower limit of 0.3/yr (Abadie et al., http://arxiv.org/abs/1003.2480, Table V has values of 40/yr and 0.4/yr). New data processing algorithms can make the noise approximately Gaussian for these sources and the false alarm rate for a signal-to-noise ratio of 8 would be small. If advanced Virgo is available the loss in signal to noise ratio is at most $\sqrt{(3/4)} = 0.87$, and the effective volume probed by HLV would be nearly identical to HHL, and reduced by $(\sqrt{(3/4)})^3 = 0.65$ in comparison to HHLV. Note that the reduction in signal to noise ratio would be somewhat less than the $\sqrt{(3/4)}$ quoted here because the shared vacuum system of the two interferometers at Hanford means that some of the noise is likely to be correlated, and therefore the two Hanford interferometers do not contribute as much as two geographically separated detectors. If advanced Virgo is for some reason unavailable, then the absence of the second Hanford detector would reduce the signal to noise ratio by $\sqrt{(2/3)} = 0.82$, and the volume probed by LIGO reduced by a factor of $(\sqrt{(2/3)})^3 = 0.54$ (Table 1 of LIGO-M1000115). At 3 events/yr for HHL, this scenario would still yield 2 high quality detections over a 1.5 year run time. Similar sources, such as tight stellar-mass black hole-black hole binaries, may exist and would only increase the detection rate.

The absence of the second Hanford detector during the initial run has a large effect on the network's ability to detect burst sources such as supernovae. This poses a risk to the first direct gravitational wave detection only if the neutron star-neutron star merger rate is unexpectedly low, and if the LIGO team is willing to claim a first detection from such a source or set of sources. According to the current rules for processing the data the team would be unlikely to make such a claim without an identified electromagnetic or neutrino counterpart to the burst. For these sources, non-Gaussian noise leads to a significant penalty from losing the second Hanford detector due to an increase in the false alarm rate by a factor of 10 to 50. However, most of this loss is recovered if advanced Virgo is available.

2.3 Main Issues: Impact on AdvLIGO

In its review of the proposal, the Panel agreed that the overall impact on AdvLIGO ***must*** be kept to a minimum no matter which option is followed.

There are major scientific gains from locating one of the AdvLIGO Detectors in Australia. (See Section 2.1 of this report.) However, there would be some impact on the AdvLIGO construction project. On the positive side, the installation of one less Hanford interferometer could possibly free up project contingency funds of $4 to $8 million. It could also move up the operational commissioning time by of order 6 months. However, the Panel recognizes some potential for distraction of the staff that makes it difficult to quantify the actual cost and time savings for AdvLIGO at this early stage.

In particular, the project would need careful consideration and monitoring of the following possible impacts:

- An examination of the construction schedule would need to begin as soon as Australia provides a credible proof of funding/approval. A proposed “Go” or “No Go” deadline of September 2011 may cause strain on the staff as the date approaches. The project will need to prepare for a possible short adjustment of this date due to finalization of documentation and agreements.

- The project should also be aware that possible down scoping might require staff re-assignments and/or reductions earlier than planned.

- AdvLIGO staff would also need to spend time in consultation with the LIGO-Australia team to insure that the development of the infrastructure and equipment modifications is acceptable. The panel recommends that any contingency funds identified by examining the schedule be used to support such pre-operational advisory activities. Since all phases of LIGO-Australia would occur after the corresponding phase for AdvLIGO, the AdvLIGO experienced personnel would be able to provide advice without negatively impacting the project.

The Panel agrees that the impact of Option A to the AdvLIGO Project would be minimal. The more quickly a decision comes from Australia, the less impact is expected because there will be more time to plan. However the Panel recognizes the need for LIGO to set up clear formal agreements, channels of communication and procedures for budget approvals. We encourage the NSF to provide a timeline for the project that includes the necessary assurances that commitments will be met.

3. Option A

3.1 Statement of the Option

Option A: (LIGO's scenario) Components originally intended for LIGO's second interferometer at LHO are set aside and shipped to Australia when that site is ready, leaving one interferometer operating at each of the two LIGO sites.

3.2 Advantages

The most important advantage of Option A is that the placement of a gravitational wave detector in Australia (as compared with a second detector at Hanford) will greatly improve the determination of the angular position of the gravitational wave source. The Weiss Committee estimated this improvement in angular position as being a factor of 5 to 10. Improvement in angular resolution greatly increases the likelihood of finding an electromagnetic counterpart to the source. This, in turn, is key to extracting critical physical, astrophysical and cosmological information from the sources of gravitational radiation that are discovered.

The placement of a gravitational wave detector in Australia will also significantly improve the ability to reconstruct the gravitational radiation waveform and polarization. This, in turn, will enable more accurate and reliable determination of the parameters of binary inspiral sources and other sources whose waveforms can be modeled.

Another important advantage is that the placement of the LIGO detector at a different site from the first Hanford detector will eliminate some important correlated sources of noise. This will significantly reduce the rate of false signals. Also, distributing the instruments reduces the risk of damage to more than one detector from catastrophic natural events such as earthquakes, fires, and storms.

An additional advantage is that, under Option A, the single Hanford detector will likely be online earlier than if two detectors were located at Hanford. Since the Livingston detector and the VIRGO detector are likely to be operating at this time, this allows a realistic possibility of earlier discovery of gravitational wave sources than under the baseline plan.

Another important benefit of Option A is that it will deeply and extensively involve the Australian gravitational wave community. This will increase the pool of scientists involved in gravitational wave research. It will help develop gravitational wave astronomy as a global enterprise.

Finally, we note that Option A can be implemented at very small cost, disruption, and risk as compared with Options B and C.

3.3 Drawbacks and Risks

The main drawback of Option A is that LIGO would have to operate with only two detectors until at least 2017. In assessing the possible negative impact of this for the first discovery of a gravitational wave source, it is important to distinguish between "modeled' and "unmodeled" sources. Modeled sources are ones for which one has definite (multi-parameter) predictions of the waveform that can be used to provide templates for the signal; the prime example is binary coalescences of neutron stars or low mass black holes. Unmodeled sources are bursts of unknown origin that can be discovered only by coincident detection by multiple gravitational wave detectors and/or detection of electromagnetic (or neutrino) counterparts.

For modeled sources, the Weiss Committee has determined that by weighting the signal-to-noise with how closely the data matches the expected chirp waveform and applying the same type of vetoes as in prior science runs, it is possible to approach Gaussian statistics. In this case, the loss of sensitivity from having only one Hanford detector is quite minor (less than a factor of 2 in volume $(\sqrt{(3/2)})^3 = 1.8$). This is unlikely to have an important impact with regard first discovery, where a signal well above threshold will be needed.

For unmodeled sources, the sensitivity mainly depends upon keeping the “false alarm rate” acceptably low. In this case, having a third, independent, detector can make a very significant difference. It was reported to us by Rai Weiss at the panel meeting that the volume sensitivity of 3 independent detectors (as compared with 2) for unmodeled sources would be roughly a factor of 10-50. However, the two Hanford detectors would share many correlated sources of noise and would not be independent, so the improvement of HHL over HL (or HHLV over HLV) would be much smaller. The Weiss committee estimated the improvement in sensitivity for unmodeled sources for HHL over HL would be a factor of 10-50 if the non-Gaussian noise in the two Hanford detectors is uncorrelated, but that the likely level of correlation would reduce this factor to approximately 5. While this is still significant, it should be noted that it is unlikely that it will be possible to make a credible claim of first discovery for an unmodeled source without an electromagnetic counterpart. Thus, even for unmodeled sources, it is unlikely that operating with only one Hanford detector will have a negative impact on first discovery.

Finally, the negative impact of operating LIGO with only two detectors is greatly mitigated by the high likelihood that advanced VIRGO will be operating in 2014 at comparable sensitivity. The HLV network should be at least as capable of making a discovery as was originally envisioned for the HHL network.

The remaining drawbacks and risks of Option A concern practical matters. Many management and funding issues will have to be carefully worked out. There are greater chances of installation problems as compared with the baseline plan, such as construction delays at the Australian site. There is also a risk that the many complex issues arising from Option A could result in a distraction to the LIGO staff during the time period in which the Hanford and Livingston detectors are being installed.

3.4 Logistics Issues

Assess the LIGO requirements transmitted to the Australians. Should anything be added or modified?

The panel agrees with the requirements as described in the White Paper. In particular, we support the requirement that any proposed deviations from the AdvLIGO design should be considered only under exceptional circumstances and should require review and approval by the LIGO Lab. We also agree that it is imperative that a LIGO Lab expert be included on all reviews for the AIGO infrastructure. Clear “rules of the game” need to be defined up front for communications, the review and approval timelines, the handling of risks, the process for exceptions, how to handle disagreements, and all roles and responsibilities. However, the panel does not feel it is in a position to propose these rules.

Assess, to the extent possible, the likelihood that Australia can deliver the necessary infrastructure.

Australia has had a longstanding (more than 30 years) interest in gravitational wave research. It has a significant pool of well-trained gravitational wave scientists. We therefore feel that it should be able to provide the necessary manpower and University-level infrastructure. Australia also appears to have the industrial expertise and some similar experience in vacuum system construction.

Identify critical milestones and how they should interface with NSF decision points.

The truly critical milestone is that a decision to install the optics in AdvLIGO has to be made on or about September 2011 to avoid delaying that project. Given that September 2011 may be somewhat soft decision point in terms of schedule impact for AdvLIGO, some contingency planning for a short delay (i.e. 2-3 months) may be advisable.

Identify, to the extent possible, missing information needed for NSF decisions and advise how to obtain it.

Many issues and details remain to be worked out. At a fundamental level, it is necessary to get a better understanding of the level of agreements that need to be in place: To what extent do agreements need to be negotiated between the Australian and US governments, the ARC (the Australian institution closest to the NSF in portfolio) and the NSF, or Caltech and the University of Western Australia? It would be advisable to formulate a draft timeline of required agreements and approvals. It will be necessary to clearly spell out the ownership of the equipment being provided by AdvLIGO. At a finer level of detail, it will necessary to determine the cost of shipping, export, and storage and determine who will bear these costs.

4. Option B

4.1 Statement of the option

Option B: Construction and installation proceed as originally planned for the three Advanced LIGO interferometers. At some later time determined by the projected readiness of the Australian site to install it, one of the LHO interferometers will be de-installed and the components shipped to Australia.

4.2 Advantages

This option provides extra time for all parties to evaluate potential availability of resources for future US-Australian collaboration. It completes the baseline plan for installing 2 detectors at Hanford and yields the largest number of online detectors for the initial period of the discovery phase.

4.3 Disadvantages

Once the 3rd LIGO detector is installed at Hanford, the de-installation will be risky, costly, and disruptive. It could shut down the Hanford site during some period of the discovery era. There would be a difficult decision as to 'when' to do it if initial detections lead to important new science. The lack of a firm schedule to provide the hardware would make the case more difficult for the Australian government to commit the resources needed to build the infrastructure for the LIGO detector.

4.4 Science Issues

Assuming that Australian support cannot be finalized within the September 2011 time frame required to pursue Option A, any further delay in pursuing LIGO's initial plans to install the second Hanford detector would jeopardize the discovery phase. The first science runs with the HHL detectors are scheduled to begin in 2015. The timescale for a definitive first detection depends upon the range of estimates of the event rate for binary neutron star inspirals which produce waves with signal to noise ratio greater than 8. The first detection is estimated to take place within the first year of science runs given a reasonably optimistic event rate of 30 per year; or it might take as long as 3 years at the worst case event rate of 3 per year. This uncertainty makes it unrealistic to enter into a firm Option B timeline with Australia. Event rates for other well-modeled scenarios are even more uncertain. Furthermore, although the above estimates for a first detection are only slightly affected by whether VIRGO participates in the early science runs, the sensitivity for detecting unmodeled bursts, such as those from supernovae, would be greatly enhanced by the second Hanford detector, as well as by the planned participation of VIRGO. As a result, there would be further potential conflict between Option B timelines and the continuation of scientifically important observations.

4.5 Logistics Issues

Both Hanford detectors would have to be shut down for up to a year during de-installation. This would be a severe sacrifice during the discovery phase. There is a compelling long term science case for a fourth detector in Australia but if Option A cannot be pursued then the new information gained in the early science runs would be invaluable input for designing other options and securing financial support for a next generation international antennae array.

4.6 Recommendation

The panel believes that the disadvantages of Option B far outweigh its advantages and that it should not be adopted.

5. Option C

5.1 Statement of the Option

Option C: Construction proceeds as originally planned for the three US-based LIGO interferometers. An entirely new set of components (equivalent to a fourth Advanced LIGO instrument) is purchased for shipment to Australia.

5.2 Advantages

Option C provides the least risk in both the short and long term for LIGO, in ensuring that the three interferometers originally envisioned will be developed and operated as planned. In adopting Option C, NSF would indicate serious interest in development of a new international collaboration that would build on the experience of LIGO, and importantly extend the global observational capabilities in gravity wave measurements by development of a detector in the southern hemisphere

5.3 Disadvantages

Option C suffers from lack of an existing plan for implementation, and essentially suggests that an entire new collaboration be investigated and negotiated.

5.4 Science Issues

An additional set of components simply means that there is no question of any impact to an initial discovery, although as noted below there would likely be a delay in getting the Australian detector operating at comparable sensitivity just due to the delay in obtaining parts.

5.5 Logistics Issues

There appears to be no compelling urgency for Option C, as the urgency appears to come (1) from interest in associating an Australian detector with the early stages of the LIGO program, yet it is not clear that an Australian detector under this option could contribute to the discovery phase of LIGO, and (2) a desire to take advantage of the LIGO Project skill set, which will evolve and erode as AdvLIGO is completed, yet it is not clear that the international negotiations associated with this project could be completed in time to take advantage here.

5.6 Recommendation

The panel believes that Option C is not viable at this time.

6. Summary

The Panel feels that the overwhelming scientific benefit to having an additional gravitational wave detector of comparable sensitivity in a near-optimal location (Australia) is well worth accepting a possible short-term incremental risk in achieving a first detection. Most of this incremental risk is compensated by additional operating time, and by including Virgo in the network looking for a first detection.

Once a decision is made to proceed with this proposal, most of the responsibility for implementation is with the Australians and the LIGO Laboratory, not the AdvLIGO Project. This leaves the AdvLIGO Project free to either move forward as originally planned if the Australians do not come forward, or with two interferometers if they do. The Advanced Virgo Project remains unaffected in either case.

6.1 Recommendations

1) The Panel recommends proceeding with Option A
2) In the event that Option A cannot be implemented as originally outlined, the panel does not recommend Options B or C.
3) NSF/LIGO should be prepared to defend the reasoning for why it was important to include a second interferometer at LHO in the original AdvLIGO project, but which can now be set aside.

In addition, the Panel suggests that the LIGO Laboratory may want to ask the VIRGO Project for a letter of support for this course of action.

7. Note Added during Preparation of this Report

There was one important announcement that occurred after the Panel Review and during the preparation of this report. The announcement is reported here for completeness, but is not considered significant enough to change the substance of the conclusions or recommendations, particularly the risk to a first detection.

7.1 LCGT Funding Announcement

It was announced on June 25, 2010 that the Japanese Large-Scale Cryogenic Gravitational-wave Telescope (LCGT) received ~$110M in funding, approximately half of the estimated funding required to complete the project. Even with a fairly optimistic assumption that the funding would enable the detector to come online at room temperature within one year of the completion of AdvLIGO (and therefore at or about the same time as the Australian detector), this announcement does not change the Panel's conclusions. The reason is that one of the primary advantages of the Australian detector is the improvement in sky coverage and the ability to better localize sources on the sky. The Japanese detector also improves the sky localization of the LIGO/Virgo network, but will not provide the same out-of-the-plane baseline for sky localization that an Australian detector would and therefore does not replace it in the network. The benefits of sky localization are cumulative, and another detector on the network can only serve to reduce the risk to a first detection.

Therefore, this new development reduces the risk of the proposal to develop an Australian detector without detracting from the advantages and thus does not affect the conclusions.

Appendix A: Review Panel Charge

LIGO-Australia Review — June 16–17, 2010

Charge to the Panel

NSF is discussing with the LIGO Laboratory whether to entertain a proposal to establish a third LIGO site in Australia (LIGO-Australia). LIGO has provided documents describing the science case for such a site and scenarios for how such a site could be established. An Australian collaboration, possibly with foreign partners, would provide the infrastructure, following the plans used to establish the beam tubes, buildings, and other physical infrastructure at the existing LIGO sites. LIGO would furnish the components of the interferometer and favors using one of the three Advanced LIGO instruments now being constructed.

The LIGO Lab's preferred scenario would modify the Advanced LIGO Project Execution Plan (PEP) to install only one interferometer, rather than the originally planned two, at the LIGO site in Hanford, WA (LHO). In parallel, the Australian consortium would seek funding to develop the site infrastructure and to guarantee operations of the facility. The start of installation of the second LHO interferometer is planned for the autumn of 2011, so the decision to go forward with this scenario must be made before then.

Early operations and science running for Advanced LIGO (as currently planned) will begin as early as the end of 2013, with the main goal being the first direct detection of gravitational waves. This discovery phase will be followed (in 2017 or later) by an observation phase that initiates the era of true gravitational-wave astronomy. The French-Italian Virgo gravitational wave detector project plans to upgrade to Advanced Virgo on a similar timescale as LIGO.

Based on experience with initial LIGO, construction of the LIGO-Australian infrastructure will require 2 to 3 years from the start of construction before installation of the interferometer components, and, in the most favorable case, the facility could begin with operations at sensitivity comparable to the US sites as soon as 2017.

We envision three possible scenarios that might occur with respect to an Australian interferometer constructed with the assistance of LIGO, NSF, and international partners:

- Option A: (LIGO's scenario) Components originally intended for LIGO's second interferometer at LHO are set aside and shipped to Australia when that site is ready, leaving one interferometer operating at each of the two LIGO sites.
- Option B: Construction and installation proceed as originally planned for the three Advanced LIGO interferometers. At some later time determined by the projected readiness of the Australian site to install it, one of the LHO interferometers will be deinstalled and the components shipped to Australia.
- Option C: Construction proceeds as originally planned for the three US-based LIGO interferometers. An entirely new set of components (equivalent to a fourth Advanced LIGO instrument) is purchased for shipment to Australia.

We ask the panel to advise NSF as to whether the scientific gain accomplished through any of the proposed options (or another that the committee might identify) outweighs the risk to the successful realization of Advanced LIGO as proposed, and how that risk might be minimized. We ask the panel to address the following specific points:

SCIENCE ISSUES

1. Is the science case for LIGO-Australia sufficiently compelling that NSF should pursue some scenario to this end?

2. Assess the strengths and weaknesses of the science case for each of the above options. This assessment should be independent of logistics or costs but should include possible timelines.

3. Discuss potential impacts of Advanced Virgo on the various science cases.

LOGISTIC ISSUES

4. Assess the LIGO requirements transmitted to the Australians for LIGO-Australia. Should any conditions be added or modified?

5. Assess, to the extent possible, the likelihood that Australia can deliver the necessary infrastructure.

6. Identify critical LIGO-Australia milestones and how they should interface with NSF decision points.

7. Identify, to the extent possible, missing information needed for NSF decisions and advise how to obtain it.

8. Assess the logistic, risk, and cost issues of the three options. Are the presented timelines realistic? Have all the risks been considered? Compare the cost-benefit of each scenario.

Appendix C: Prior Review Panel Recommendations

ADVANCED LIGO REVIEW PANEL RECOMMENDATIONS

April 2010 Review

The Panel was given a short briefing on the concept of relocating one of the Hanford interferometers to Australia. Although we had a very short time to consider this idea, we agree that this is an exciting and potentially game-changing idea for the international gravitational wave (GW) community. With an instrument in the southern hemisphere operating in concert with one each in Hanford and Livingston, sources across a substantially greater fraction of the sky could be located with much higher accuracy. The value of follow-up measurements to an AdvLIGO GW detection using electromagnetic and neutrino telescopes would also be enhanced. According to the briefing, Australia has an active GW community and appears to be the only viable option for a southern hemisphere observatory. It is clear that for this to be achievable in the context of the AdvLIGO schedule, decisions and plans must be made very quickly. A LSC committee was formed to study the scientific benefits and will be submitting its report to the NSF shortly. The Panel suggests NSF undertake a formal review of this idea as soon as possible. In addition to confirming the scientific upsides, this review should validate the assumptions that this could be accomplished without adding cost, schedule or performance risk to execution of the AdvLIGO Project. At this point it appears the NSF would be partnering with a loosely organized group of Australian universities. The drafting of a U.S-Australian partnership agreement will undoubtedly be a complex and time consuming activity, and therefore must be taken on early and as a high priority.

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