

1. The PAB is most impressed with the accomplishments of the KAGRA team in successfully installing in the tunnels and running the 3-kilometer iKAGRA interferometer. This represents the completion of a major program milestone on the KAGRA schedule. Much was accomplished in this run including achieving stable periods of operation of the interferometer, angular control, environmental monitoring, tracking tidal distortions, successful data management and developing a team experienced in interferometer operation and performance improvement. This is a good foundation for the next phase of KAGRA development, the bKAGRA implementation.
2. The iKAGRA run provided an opportunity for many lessons to be learned. The team described these lessons and their self-assessment has been echoed in many places in this PAB report.

Purpose of this PAB and Status of KAGRA - Kajita

- The KAGRA leadership believes that the available 2016 construction and operations funds, and the requested outyear operations funds are adequate to support the planned bKAGRA phases 1, 2, and 3 activities through 2021. The PAB believes that this match should be carefully monitored and folded into the bKAGRA planning.

Project management and SEO activities – Saito

Improvement of project management - Saito

- The full time on-site Project Manager has played a pivotal role in the installation and commissioning of iKAGRA. An important lesson that was learned is that the Project Manager must be better supported by full time on-site next-level managers of installation and commissioning activities, scheduling and robust liaison with the subsystem teams. These crucial roles cannot be adequately supported by commuting team members. If a single full-time on-site person cannot fill each of these roles, a pair of people can alternate. However, success is measured only by consistent, clear and active performance of these roles in support of the Project Manager. This

mode of leadership must be in place for the bKAGRA phase of activity.

- The iKAGRA run demonstrated that basic elements of system engineering were not adequately implemented resulting in significant delay, rework and deferral in the run. These included poor work breakdown definition and scheduling, poor version control of drawings, inadequate or absent quality and trial fit checks, poor management of documentation and document dissemination, inadequate interface definition and control, and insufficient effort estimates and labor assignments. Some of this was due to the small team size relative to the tasks required. The iKAGRA run would have been much smoother had adequate attention to these been carried out, where possible.

Response to last PAB report - Ohashi

- Despite our vigorous recommendations in the last PAB report, no significant effort has been made to improve the unsafe situation at the x-end arm. This is of great concern. While KAGRA may not be able to muster the resources and institutional attention to provide safe emergency egress from the area, the effort to address this must be vigorously pursued.
- In the meantime, even the small efforts at provisioning the shelter area with survival materials is not adequate, in our estimation. Communications must be provided in this area. Suitable technology can be implemented. Breathing gas supplies are very inadequate. Substantial increases in the breathing gas supply and equipment must be made. Training for survival in the shelter area must be obtained and all workers should be subjected to the training as a prerequisite for working the tunnels.
- Furthermore, regarding safety, the PAB has recommended safety drills. No such drills have taken place in the 11 months since we made our recommendation. This is not an adequate response and suggests the absence of a true safety culture.
- During the tunnel visit by the PAB, with all PAB members and escorts dressed in appropriate personnel protective equipment, and all workers in sight similarly dressed, one worker appeared in a tee shirt, slacks and soft shoes, casually working on a subsystem in full view of

the PAB in who were in protective garb. That worker ignored the presence of the PAB. When a KAGRA leader advised the worker to comply, he donned a hard hat and went back to work with no other personnel protective equipment, seemingly insensitive to safety culture. Such a worker should be removed from work at the tunnel location until appropriate training and corrective actions have been completed. A worker like that suggests a lack of safety culture and undermines the safety culture of compliant workers. This is a very serious matter.

- All installations should start in the safer y-arm.
- There should be a safety presentation at every PAB meeting.

Report of iKAGRA run - Kawamura

- Though successful, the iKAGRA run required significant descoping and rework to achieve an operational interferometer system on the required schedule. Some of the descopes could have been anticipated at earlier stages of preparation, as the PAB had recommended. By descoping and simplifying at the last stages of the iKAGRA installation, the team carried out unnecessary work requiring additional resources that could have been focused on earlier and fuller operation of an iKAGRA system. The PAB strongly recommends that, in working towards the March 2018 bKAGRA operation milestone, the team should plan on implementing the simplest system possible to achieve the milestone, minimizing discretionary effort and expense. Deferred elements of the system may be implemented after that milestone, informed by lessons learned during the initial bKAGRA run.

bKAGRA plan and schedule - Ando

- A solid project plan is important for bKAGRA. As soon as the boundary conditions for the goals of Phase 1 (Ando's talk) have been set, then each subsystem MUST submit a detailed planning. This planning should take the lessons learned from iKAGRA into account. Every subsystem should come up with clear milestones (say 1 per 2 months). Resource conflicts, tasks sharing, influence on other

subsystems, should then be clarified by SEO. If needed then KAGRA management should decide on the way forward.

- For bKAGRA installation and commissioning, the PAB feels that use must be made of contracted technical and housekeeping effort to support KAGRA team members in installation and in cleaning in the tunnel environment. Significant assistance to the VIS and CRY teams can be provided by adding contracted effort. Team members report spending significant time and effort in cleaning in the tunnel environment. This crucial activity can better be done by contracted cleaning personnel who must be locally available.
- bKAGRA planning must include significant schedule and manpower contingency to avoid the emergency descopes and deferrals experienced in iKAGRA. Simplification of the plan underpins such planning for robustness.
- The phase 1 plan should try to accelerate testing of subsections of the interferometer where ever possible, instead of concentrating on installation followed by a burst of commissioning after everything is installed.
- Plan-alpha could be very beneficial in that it decouples the Type-A VIS from being in line with the main program.
- The Intermediate 300 K option sounds attractive, but it goes against the notion of concentrating resources on the required phase 1 bKAGRA deliverable. Unless significant NEW manpower can be found, the PAB recommends against it.
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VIS - Aso

CRY - Tomaru

- The PAB is pleased to hear of the renewed and continued commitment by KEK to the crucial cryogenic work being carried out by the expert KEK team.
- The PAB appreciates the support and encouragement from the KEK Director General and the possibility to add KAGRA into KEK's long term planning.
- The Cryo team should consider options to accelerate one ETM installation at KAGRA, both to reduce risk for their systems and to allow other systems to be commissioned early.

MIR – Hirose

- Progress is excellent (i.e., much better than some of the PAB members had feared)
- The lack of spares for the sapphire optics is a major concern

DGS – Miyakawa, Kokeyama

- Ensuring accurate time synchronization for all DAQ units is important and a task that should not be put off until commissioning starts.
 - Other GW projects have paid significant attention to software security (particularly as it relates to remote access) to protect sensitive operational systems from hackers. It might be useful for KAGRA to consult with computer security experts for advice
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