May 22, 2013

Dear Electronics Group Godparents,

The electronics group wishes to thank the Godparent Committee for their recommendations following the Electronics Godparent Review of April 6, 2013. In this document, we list these recommendations, as stated in the committee's report of April 15, and collect our responses. By doing so, we hope to better document our positions and plans for the future.

Best regards,

Electronics and Integration Group

[Recommendation:1]
`Making a well-documented compact demonstration system for early adopters is an important goal for the electronics/integration group. We recommend that the group carefully consider what the expectations of the proposed early adopters might be, and focus effort on making sure that the system can easily meet these goals. It should be laid out clearly what the system can and cannot do, so that there are no unmet expectations.`

[Response:1] Yes, we agree entirely about the danger of unmet expectations. We will continue to document the performance of the system in published refereed papers: two papers have been published, one is in the refereeing process, and a paper on test performance is in an advanced state. We expect to publish further results on systems once we have working tiles. The goal is to have a well-documented summary of the basic working parameters of resolutions, lifetimes and stability, power consumption, and other performance specs of general interest.
At the same time, we have been asking the groups who have contacted us with regard to becoming early adoptors to start by simulating their application at the parametric level, using typical input parameters provided by us as needed. We want to have a clear spec on the required performance for exactly the reason the committee is concerned- making sure that what we provide is well-matched to the specific application.
There are 2 such groups working on simulation, for collider time-of-flight, and for medical imaging. For a third, the beam test (LArIAT), we will do just what the committee has requested, but are fairly confident that there are no problems, as the application is relatively benign. For others we have sent them away to do simulation; we presume if our tile production is successful they will be back.

[Recommendation:2] `Five potential applications were presented as targets for future development. The committee is concerned about the logistics of supporting development on multiple simultaneous fronts, especially given the current limits on available manpower. As such, we recommend strongly that the group focus on one particular application for the immediate future. We recommend the following criteria be used in this selection:`

a. The requirements should be well specified.

b. The specifications should generally be achievable with existing electronics. For instance, the system should be based around an existing ASIC, such as the PSEC4 or IRS3B, as opposed to an ASIC that still needs to be designed, like the PSEC5. If it has not already been done, we recommend that the group investigate the possibility of purchasing additional samples of PSEC4 from MOSIS, which may be available from a previous run but not yet diced.

c. The working system should demonstrate some significant improvement over existing technologies.

d. The target user(s) should be enthusiastic about the development, with clear expectations, such that after successful deployment they are expected to become a powerful third party endorsement.

Details of the selection process are of course up to the group, but regardless of the chosen application, we recommend the group prepare more specific documentation on the goals and requirements, along with some justification for the choice and how these specifications will be achieved.

[**Response:2**] We agree that the group should focus on one particular application for the immediate future and are doing so. Of the 5 presented, the test beam setup of 4 independent stations is the one that is the most attractive, as described below in our responses to the individual criteria.

a. The bare-bones requirements for this application were presented in the review. Further work is needed; in particular the interface to the trigger and DAQ need to be worked out. Once we have fulfilled the highest priority present tasks - making working and tested (in test-stands) tubes we will ask the LArIAT group to work out the details with us. We have looked into it enough to believe that there are no show stoppers; it's a set of detailed implementations for which the most efficient path is to do them on understanding them. In the mean-time, our priority (and hence our manpower!) is to make and test actual tubes.

b. Yes, the specifications should generally be achievable with existing electronics such as the PSEC4 or IRS3b. This is our plan. We requested a quote for all additional PSEC4 dies from MOSIS soon after receiving the original lot of 40 chips. An additional 14 PSEC4 chips were available and were purchased at that time.

c. The proposed LArIAT application is expected to improve the TOF resolution by an order-of-magnitude.

d. Yes; we have gotten a good reception from the the group through our colleague at UC, David Schmitz. In response to the "endorsement", a clear success in the LArIAT beam as a working component, not just a test, will be a big step toward confidence in the technology.

[**Recommendation:3**] There was some discussion over the choice of the TSMC process versus the IBM process for future ASIC submissions. The benefits of switching to the TSMC process are considerable, with lower potential fabrication cost, more frequent

submission cycles, and a generally more reliable turnaround time. The TSMC process has also been selected by CERN as either a replacement or complement for the current IBM 0.13 um process. The main disadvantage to switching to TSMC is the inability to use existing design elements from the PSEC4. As the timeline for the PSEC5 is not tightly constrained, and because the design may be undertaken by those not already familiar with the IBM design rules anyway, there seems to be low risk overall to switching to the TSMC process. The committee recommends that this be the baseline process for future ASICs. Some design studies should be undertaken to see if the process is truly suitable for PSEC5, and the decision can be revisited at the next godparent review.

[Response:3] We completely agree that this is a logical time to make the switch. We have installed the TSMC package at UC, and are in the middle of doing it at Hawaii. Starting June 1 we will start working on the chip design and simulation to determine if the TSMC process is truly suitable for the PSEC5 implementation.

[Recommendation:4] Though there was some discussion of system synchronization, the committee recommends that a detailed plan be prepared or presented for how synchronization is performed between various boards and ASICs, as this will become essential as the systems grow from the existing prototypes.

[Response:4] The system synchronization specifications are application-specific, so it is difficult to write a detailed plan that applies to all the proposed applications. Instead, we will focus on implementing the synchronization in a simple early application, e. g. the beam spectrometer in the LArIAT experiment. We plan to document this system framework in a paper describing the clock distribution and system synchronization specs and performance. Later more complex applications can build from this example.

[Recommendation:5] Some of the component decisions on existing cards seem to be based on relatively minor money savings, for example a few hundred dollars on FPGA costs. The committee recommends evaluating whether such savings are truly significant or "in the noise." Higher performance FPGAs may make the design work easier, for example, which could save precious time for those working on the system development, as well as allow increased flexibility for future evolution of the system. We encourage continued effort in assessing and developing architectures for the readout system that will be open and adaptable.

[Response:5] Yes, in hindsight this was silly. We learned a lot from designing and implementing this first system, with this being one of the lessons.

[Recommendation:6] As the program moves toward deploying systems in target applications, stable long-term support will be required for these applications. This could be obtained, for example, by bringing national lab or company resources onto the project. Other sources of funding could (continue to) be investigated in order to facilitate these additions.

[**Response:6**] We appreciate this need. In the process of preparing for this review, and considering the needs of future applications, we realize that most future, large-scale applications will probably want to develop a readout tailored to their particular measurement needs and would provide project-specific resources to make this happen. This is a 2-part question, addressed further in response to [**Recommendation:8**].

[**Recommendation:7**] `The list of potential early adopter applications is already quite full. However, for longer term planning purposes, it may be fruitful to develop relationships with potential collaborators in the cosmic frontier, if this can be done without detracting from the immediate need to focus on the first delivered system.`

[**Response:7**] Yes, we agree, and have begun. There is interest from colleagues working in searches for dark matter at both ANL and UC, two of our senior members work in gamma-ray astronomy, and several of us are actively looking at using the detectors for non-accelerator experiments such as double-beta decay (the question of Majorana vs Dirac may or may not be a cosmic frontier question- but in any case many of the detector issues are germane). However, given the need to focus and the limited manpower and funding within LAPPD, it will require a pro-active interested group to join us for this to make progress beyond the present pace. [1]

[**Recommendation:8**] `In order to provide a broad impact and potential cost savings to a variety of large experiments that may utilize LAPPD devices, we encourage the ongoing efforts to assess and expand generic features that are broadly desired. Initial electronics may serve as an "evaluation platform" or "demo kit" for other potential users, some of whom may decide to create their own custom readout infrastructures. However, it seems less likely that they will want to fabricate their own custom ASICs. With this in mind, we strongly encourage the group's continuing research into generically desirable features on the PSEC5, including deeper analog memory to enable a longer trigger latency (while maintaining excellent bandwidth demonstrated by the PSEC4), use of internal DACs to provide more flexibility for sampling rates and Wilkinson ADC timing, and other investigations into the trade space involving dynamic range, dead time, and other details of the ASIC trade space.`

[**Response:8**] We strongly agree that it is vital to provide an "evaluation platform" that is flexible and allows users a chance to get started quickly with LAPPD devices as they become available. However it is unlikely that a one-size-fits-all approach can address the needs of all likely users. Performance trade-offs and issues such as support for and control of the underlying intellectual property will be important to future, large-scale applications. Support for these *"demo kits"* is a concern and would ideally be provided either commercially or through a national laboratory.

[1] The LAPPD model of adoption presented at the DOE review is that we require a a strong outside group to put enough 'sweat-equity' into developing the requirements, in close collaboration with interested members of LAPPD. We would be delighted if we can find an interested cosmic frontier group.