

<b>Type of Review:</b>	Final Design Review (FDR)	
<b>Title of the Review:</b>	LCLS-II Low Level Radio Frequency Final Design Review	
<b>WBS:</b>	1.02.07.10	
<b>Presented By:</b>	M. Boyes (SLAC), C. Hovater (JLAB), L. Doolittle (LBNL), B. Hong (SLAC), G. Huang (LBNL), G. Brown (SLAC), J. Einstein (FNAL), B. Chase (FNAL), A. Benwell (SLAC), R. Bachimanchi (JLAB)	
<b>Report Prepared By:</b>	Mark Crofford (ORNL)	
<b>Reviewers / Lab :</b>	Mark Crofford – Chair (ORNL), Andrew Burrill (SLAC), Ken Fong (Triumf), Kevin Smith (BNL), Uros Mavric (DESY)	<b>Date:</b> July 27-28, 2017
<b>Distribution:</b>	Presenters, Darren Marsh, Matt Boyes, Joe DeLong, Jose, Chan, Lori Plummer.	

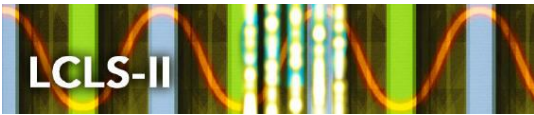
<b>Attachments:</b>	<input type="checkbox"/> Review Slides	<input type="checkbox"/> Design Checklist	<input type="checkbox"/> Calculations
	<input type="checkbox"/> Other _____		

**Purpose and Goal of the Review**

Review Outcome Summary

Response to charge questions:

- 1 Technical Scope
  - a. Are the designs mature and technically sound to satisfy design specifications?  
**Yes, the hardware is technically sound. As expected, the firmware will need to continually evolve. Active compensation must be part of the overall design.**
  - b. Is the design likely to meet performance expectations?  
**Yes**
  - c. Have installation issues been adequately addressed?  
**Yes, there is a plan for fabrication, testing and loading of the LLRF racks. The actual installation into the gallery relies on Davis Bacon workers and is not completely defined at this stage.**
  - d. Have all the major interfaces been identified and incorporated into the design?  
**Yes**
  - e. Are all design specifications, requirements, performance, and interface documents reviewed, approved and released?  
**Yes, the ICD with Physics needs to be completed and approved.**
  
- 2 Design Management
  - a. Is the design team organized and staffed to successfully complete the project?  
**Yes, the design team is very solid. The SLAC LLRF team is growing and must continue to do so in order to fill out key positions and take ownership of the entire system.**
  - b. Have all of the major risks been identified and managed?  
**There was no specific presentation or discussion on project risk and the risk registry**



**Purpose and Goal of the Review**

- was not reviewed.
- c. Are procurements appropriately planned?  

No. It appears that significant additional resources are needed to make the procurements successful. There are still make/buy decisions to be made.
- d. Is the development of associated drawing packages sufficiently mature?  

Yes! The level of detail for many of the drawing packages is excellent.
- 3 Cost and Schedule
  - a. Is the cost and schedule reasonable to achieve the planned scope?  

This is a reasonableness assessment by technical experts, not a detailed cost/schedule review.

No, the labor resources for the extensive work to be done seem very low. The cost estimates need to be refined to facilitate the make/buy decision.
- 3 ES&H
  - a. Are all related ES&H aspects being properly addressed?  

Yes. The NRTL and EIP programs at SLAC seem appropriate at this stage of the project.
- 4 Miscellaneous
  - a. Have all the previous design review action items/comments been addressed?  

Yes, they have been addressed. There are responses to all recommendations from the PDR, however it is not clear which ones are closed or who is responsible for the recommendation.
  - b. Have lessons learned been addressed?  

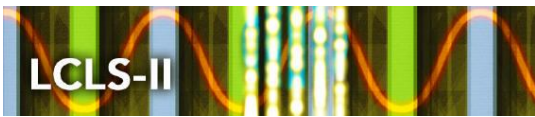
Yes. It is clear that things have been learned in early prototypes and applied to the design revisions. No explicit lessons learned document was presented.
  - c. Are there any other issues that have been identified that need to be addressed?  

No
- 5 Overall Readiness
  - a. Is the design sufficiently mature so as to allow Final Design Review approval?  

Yes, the design is excellent. The focus must now shift to procurement, vendor oversight and integration of all of the components.

**Introduction and Outcome Summary of the Review**

The review committee is charged to evaluate the system design readiness of the LCLS-II Low Level Radio Frequency (LLRF) system to approve implementation, procurement, fabrication and installation activities.



### Introduction and Outcome Summary of the Review

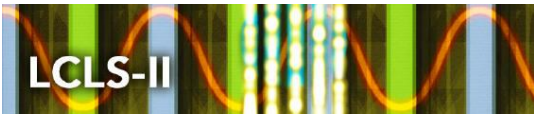
We believe that the hardware designs for the LLRF system appear to be solid and that the project should move forward with the procurement of the LLRF systems. The team developed, presented and demonstrated a LLRF design that is state of the art and addresses the challenges of a high-Q SRF CW cavity operation with stringent field stability.

### Requests for Action/Recommendations

1. Continue as planned to demonstrate active compensation on a full cryomodule in the test stand at FNAL and JLAB.
2. The team should review possible options in the event drifts are larger than expected or tolerable during commissioning, beam based feedback is late, etc.
3. Install a reasonable set of spare cables from each equipment rack to the tunnel for future use.
4. Maintain a permanent LLRF test stand for debugging, software and firmware development for the duration of the machine operation.
5. Two fully assembled LLRF systems should be delivered to FNAL to demonstrate operation of the full cryomodule using the LCLS-II LLRF system.
6. Demonstrate, through testing, the overall integration of all of the systems that interface with the LLRF system.
7. Build a spare LLRF system for the gun and buncher.
8. Build appropriate spare LLRF components for the 3.9 GHz system.
9. Hire additional Engineering staff for the LLRF team to ensure adequate coverage and the ability to support, and advance the LLRF systems as well as properly manage the procurement, installation, and operation of the LLRF systems.
10. Ensure the LLRF system is on the risk registry as appropriate in terms of both technical and staffing needs.
11. Hire/appoint a full time CAM/System Lead dedicated to the LLRF system.
12. The make/buy decisions need to be completed by September 30<sup>th</sup>, 2017.
13. Perform a new "bottoms up" cost estimate across all 4 labs to ensure the accuracy of the M&S cost estimate for procurements.
14. Perform a new "bottoms up" labor estimate for all 4 labs to ensure sufficient labor hours to complete delivery of the LLRF systems. This should include adequate vendor oversight, assembly, system integration, installation, and testing.
15. Plan for yield issues during the procurement cycle and factor in a minimum of 10% yield loss.
16. Close or update all of the previous review recommendations in the tracking system.

### Comments

- The technical design is excellent and the team is applauded for their effort.
- The design is well thought out and provides adequate margin for operation of a CW SRF Linac.
- Active compensation will likely be necessary for operations and work should continue on this feature.
- Having no spare cables in the installation plan does not seem prudent for a machine designed for 20 year operation.
- Stabilization against drift depends heavily on rack temperature stability, presumed matched

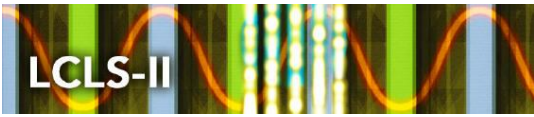


**Comments**

drifts in cable runs through the penetrations, etc. Ultimately, the plan is to rely on beam based feedback.

- Producing a single LLRF system (no spares) for the gun and buncher does not align with long term operation of a user facility.
- The collaboration is working very well and is a great model for future large scale projects.
- The SLAC LLRF team is doing excellent work and establishing a well-rounded team at SLAC needs to remain a high priority.
- The LLRF CAM is doing an excellent job, however he appears to have too many areas of responsibility.
- The team needs to move forward with the make/buy decisions.
- Many of the chassis present complex assembly challenges and will require proper oversight and support to ensure successful delivery.
- The cost and labor estimates seem very low for the scale and complexity of the work involved.
- The lack of spares in the project plan is a risk to the long term reliability and operation of the machine. The procurement of spares during the production run should be a much more cost effective way to ensure a robust reliable system is delivered by the project.
- Due to yield issues during fabrication, a minimum 10% margin would be prudent.
- A complete system test should be performed that powers all 8 cavities in a cryomodule at the FNAL/JLAB test stand. This should include the interlocks and all control chassis.
- The committee was very impressed with the overall quality of the work presented and feels this should deliver a robust system for LCLS-II.

**Findings**



## Design and Milestone Review Report

<ul style="list-style-type: none"><li>▪ The title of the item or system</li><li>▪ A description of the item</li><li>▪ WBS Number</li><li>▪ Type of design review</li><li>▪ Date of the review</li><li>▪ Names of the presenters</li><li>▪ Names, institutions and department of the reviewers</li><li>▪ Names of all the attendees (attach sign-in sheet)</li><li>▪ Completed Design Checklist (if utilized)</li></ul>	<ul style="list-style-type: none"><li>▪ Requests for Action/Recommendations – require action by the design/engineering team and are tracked to closure. Criteria:<ul style="list-style-type: none"><li>○ Concise sentence starting with an action verb (Consider..., Analyze..., Evaluate..., Compare..., etc.)</li><li>○ Based only on material presented or note if necessary material is missing</li><li>○ Supporting information leading up to a recommendation should exist in the Findings and Comments sections</li><li>○ Only make recommendations that relate to the project taking a different course of action</li><li>○ Group items into a single recommendation when possible</li></ul></li><li>▪ Comments – personal opinion or thoughts of reviewers related to a Finding</li><li>▪ Findings – factual restating of important points presented and require no response</li></ul>
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