PROCUREMENTS FOR LCLS-II CRYOMODULES AT JLAB*

E. F. Daly#, G. Cheng, G.K. Davis, T. Hiatt, N.A. Huque, F. Marhauser, H. Park, J.P. Preble, K.M. Wilson

Thomas Jefferson National Accelerator Facility, Newport News, VA 23606, U.S.A.

Abstract

The Thomas Jefferson National Accelerator Facility (Jlab) is currently engaged, along with several other DOE national laboratories, in the Linac Coherent Light Source II project (LCLS II). The SRF Institute at Jefferson Lab will be building one prototype and seventeen production cryomodules (CMs) based on the TESLA / ILC / XFEL design. Each CM will contain eight nine cell cavities with coaxial power couplers operating at 1.3 GHz. Procurement of components for cryomodule construction has been divided amongst partner laboratories in a collaborative manner. JLab has primary responsibility for six procurements including the dressed cavities, cold gate valves, higher-order-mode (HOM) and field probe (FP) feedthroughs, beamline bellows cartridges, cavity tuner assemblies and HOM absorbers. For procurements led by partner laboratories, JLab collaborates and provides technical input on specifications, requirements and assembly considerations. This paper will give a detailed description of plans and status for JLab procurements.

INTRODUCTION

The Linac Coherent Light Source (LCLS)-II project at the SLAC National Accelerator Laboratory (SLAC) requires a 4 GeV continuous-wave (CW) superconducting radio frequency (SRF) linear accelerator in the first kilometer of the SLAC tunnel as part of a high repetition rate X-ray free-electron laser. The collaborative project brings together six US institutions, which in alphabetical order are Argonne National Laboratory (ANL), Cornell University, Fermi National Accelerator Laboratory (FNAL aka Fermilab), Thomas Jefferson National Accelerator Facility, Lawrence Berkeley National Laboratory (LBNL), and SLAC [1].

As part of shared responsibilities Fermilab and JLab will build the 1.3 GHz accelerating cavity cryomodules (CMs) concurrently in two assembly lines in order to meet the overall project schedule. In preparation for CM assembly, Fermilab has been leading the CM design efforts based on extensive experience with TESLA-style CM design and assembly. The starting point for the design is existing models and drawings of similar ILC CMs (e.g. Type III+) with modifications to enable continuous-wave (CW) operation [2]. JLab and Cornell are partners in R&D and design contributing to development activities, design reviews, integration, cost estimation and production. Both Cornell and JLab have valuable CW CM design experience. JLab has directly applicable recent 12 GeV Upgrade production experiences which will be applied to both procurement and production efforts for LCLS-II.

Currently, activities and preparations are underway for assembling two prototype CMs, one at each laboratory. Following the prototyping efforts, thirty-three production CMs are planned - sixteen at Fermilab [3], seventeen at JLab – for a total of thirty-five CMs in order to provide reliable 4 GeV energy gain.

LEVERAGING XFEL/ILC CM EXPERIENCE

A very important part of the CM procurement plan is to leverage XFEL's existing CM experience ("know-how") gained during procurement activities [4]. DESY has entered into licensing agreements to share their successes, current issues and supply-chain challenges for key areas of cavity, main coupler and cryomodule component procurement. This allows LCLS-II to learn from DESY's experiences and to adjust both procurement and production plans accordingly.

In addition, CEA Saclay colleagues responsible for the production of ~100 XFEL CMs [5] have hosted workshops for the SRF community and several focused meetings with LCLS-II staff to share their experiences with production in order to understand the staffing, technical and logistics issues related to such a large scale production effort. This experience includes integration issues related to procured components and can be directly applied to LCLS-II procurement efforts.

Finally, LCLS-II can leverage Fermilab's ILC-style CM production development activities and experience during integration activities for components utilized to build two pre-production CMs – CM1 and CM2 – from kits of subassemblies and components provided by DESY.

PROCUREMENT STRATEGY

The procurement of CM components is distributed between Fermilab and JLab, with the exception of SLAC who will procure the main RF power couplers [6]. The goals for CM assembly are that the two prototype CMs will be identical and the thirty-three production CMs will be identical, and that all CMs will meet or exceed the

* Authored by Jefferson Science Associates, LLC under U.S. DOE Contract No. DE-AC05-06OR23177 with supplemental funding from the LCLS-II Project U.S. DOE Contract No. DE-AC02-76SF00515. The U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce this manuscript for U.S. Government purposes.

edaly@jlab.org

ISBN 978-3-95450-178-6

same performance requirements. The two partner labs plan to receive identical parts and sub-assemblies based on final drawing packages, requirements and specifications that are well-developed.

SOTRs

To ensure that components are identical, procurement activities are coordinated between technical leads at JLab, Fermilab and SLAC who work together during all phases of the procurement process. These technical leads, called subcontracting officer's technical representatives (SOTRs), play an important role by providing technical expertise for sub-system components during the entire process including design, prototyping, procurement and assembly phases. The SOTR's responsibilities include developing technical specifications from higher level requirements, developing and procuring prototypes from industry/partner labs, providing technical leadership and being a point of contact with manufacturers, and providing sustaining engineering during manufacturing, assembly and integration, and resolving any non-compliance issues [7].

Acceptance Criteria Strategy

In addition, at the direction of the LCLS-II QA Manager, an acceptance criteria strategy is being developed for each of the procurements. SOTRs from each lab review and approve these criteria in order to ensure that common criteria are used at both labs. Receiving inspection activities are developed by the SOTRs based on the common inspection criteria. As part of the procurement strategy, inspection activities are shifted to the vendors where practical to ensure that acceptance criteria can be met. For example, the vendor can demonstrate that leak checking has been accomplished on a vacuum component. A choice can then be made to reduce incoming inspections as quality assurance verification rather than a quality control inspection.

Split Shipments

In most cases, receipt inspection will be performed at each lab based on ~50/50 split shipments from vendors. In cases where one lab has inspection or acceptance testing capabilities, all components will be shipped to that laboratory first, and then onto the other lab.

Lessons Learned from C100 Experience

A technical note was written at the conclusion of the 12 GeV to capture lessons learned from the C100 CM procurement experiences [8]. As part of the production plan for the C100 CMs, subcomponents were procured by JLab SOTRs. After the conclusion of the production run, an analysis was prepared to rank non-conformances for each CM component (Table 1). The SOTRs responsible for a select group of components provided narratives of their experience during the procurement phase. In the narratives, quantities of components ordered, inspected, used and rejected were generally provided. Some narratives include a further breakdown of the types of non-compliance reports (NCRs) found during receipt inspection.

Table 1: List of C100 Components with Type of Inspection, Quantity Inspected and NCRs Found.

Component Name	Type of Inspection	# Inspected	# NCRs	% of parts w/NCRs
Waveguide	Visual	125	175	140%
Supply Beam Pipe	CMM	10	12	120%
Cavity	Visual	86	86	100%
Tophats (Single)	Visual	20	20	100%
HOM Feedthru	Visual	268	237	88%
Cavity CMM Post-Tuning	CMM - inc. straightening	86	75	87%
Vacuum Vessel	CMM	10	7	70%
Ceramic Window Adapter	Visual	199	126	63%
Helium Vessel	CMM	54	34	63%
Tuners - Cold (Detailed)	CMM - Detailed	2	1	50%
Helium Header	Visual	2	1	50%
Magnetic Shield - Outer	Visual	10	5	50%
Double Sided Flange	Visual	228	103	45%
Tophats (Double)	Visual	7	3	43%
Thermal Shield	Visual	10	4	40%
Magnetic Shield - Inner	Visual	10	4	40%
Magnetic Shield - Outer	Visual	10	3	30%
Return Beam Pipe	CMM	99	23	23%
Tuners - Cold (Brief)	Inventory - gage check	93	19	20%
Return End Can	Set-up	10	1	10%
Ceramic Window	CMM	188	13	7%
Space Frame	CMM	10	0	0%
Tuners - Warm	CMM	41	0	0%
Field Probe Feedthru	Electrical	12	0	0%
Supply End Can	Set-up	10	0	0%

The narratives include each SOTR's evaluation of the issues, concerns and successes for each component. Issues and concerns were grouped by topic for a subset of the components (Table 2). All components had design issues and concerns that if improved could result in fewer NCRs. Specific lessons learned have root causes that originate in design, procurement, vendor performance and in some cases even receiving inspection strategy. Looking forward to LCLS-II CMs, these experiences can be taken into account when completing designs, developing specifications for shipping and handling, performing receipt inspection and assembling components into CMs.

Table 2: Areas of Improvement Identified for Each C100 Component in SOTR Comments and Recommendations.

Component	Design	Packaging	Handling	Fabrication	Receipt Inspection	Assembly
Helium Vessel	X	X	X	X		
Vacuum Vessel	X				X	X
HOM Feedthroughs	X		X	X	X	
Warm-Cold Beampipes	X	X	X	X	X	
Waveguides	X			X	X	
Warm Windows	X			X		X
Cavities	X			X		

JLAB PROCUREMENTS

Next, plans and status are provided for each of the six JLab procurement efforts: production dressed cavities, cold gate valves, HOM and FP feedthroughs, beamline bellows and spool pieces, production cavity tuners and production HOM absorbers.

Production Cavities Including Materials

One of most critical procurements for LCLS-II is the dressed cavities. The project adopted a strategy that closely follows the XFEL approach to procure fully dressed cavities, built-to-print and specifications, ready for cold testing from commercial suppliers. While the cavity shape remains unchanged from the XFEL design, a key processing step to improve the cavity's cryogenic efficiency, "nitrogen doping", has been introduced. In addition, the helium vessel design has been modified for continuous-wave (CW) operation and fast cool-down to enhance magnetic flux expulsion. One important difference is that the cavities will be fabricated and tested in order to comply with 10CFR851, essentially ASME Boiler and Pressure Vessel code, rather than the Pressure Equipment Directive specified for XFEL.

The procurement and qualification plan [9] has been divided into three phases: Phase I - Vendor Qualification (VQ), Phase II - First Article Production (16 cavities) and Phase III - Full Production (250 cavities). The project reserves the option for a Phase IV to acquire additional cavities depending on upgrade needs.

Niobium and niobium titanium materials have been procured by Fermilab and will be provided to the cavity vendors in order to support first article and full production activities.

Following the XFEL approach, intermediate hold points during production are defined as a means to confirm that in-process steps have been successfully completed prior to continuing with fabrication or processing. Three distinct hold points ensure that the cavity as-welded geometry, the processing steps prior to helium vessel welding, and the final mechanical and electrical checks are completed and meet acceptance criteria. The vendor is required to demonstrate that procedures have been followed up to each of the hold points prior to receiving approval from the JLab SOTR to proceed. Upon final approval, cavities are then shipped to JLab and Fermilab, ~50% to each lab, for vertical testing and subsequent integration into cavity string assemblies.

Prototype and Production Gate Valves

The gate valves required for LCLS-II must be all-metal to avoid radiation damage, low particulate generators to avoid sources of field emission and contain a radio-frequency (RF) liner to avoid heating induced by the short-bunch-length beam. An RF lined, all-metal gate valve has been selected from VAT, incorporated in accordance with VAT drawing 215008 Rev C (ordering number 472XX-XE01-X). Six units have been ordered and received for the prototype CMs, two each for each CM and two spares. A total of sixty-six units are planned for production. Since the design for the gate valve is identical for prototype and production, pricing has been requested for the production units as an option during the proposal phase. This option will be awarded for the production quantity once funding approval is provided by LCLS-II management. Receipt inspection steps for the gate valves used in the prototype CM include 100% visual inspection and 100% ultra-high vacuum (UHV) leak check.

HOM & FP Feedthroughs

The XFEL design has been specified for the HOM and FP feedthroughs required for LCLS-II CM. HOM and FP feedthroughs (Table 3) have been ordered and received from Kyocera Industrial Ceramics.

Table 3: HOM & FP Feedthroughs – Drawing Numbers and Quantities.

Component	Dwg. No.	Prototype CM Qty.	Production CM Qty.
HOM Feedthrough	GMM-B0877D	50	560
FP Feedthrough	GMM-A9223	22	280

Since the designs for the HOM and FP feedthroughs are identical for prototype and production, pricing has been requested for the production units as options during the proposal phase. These options will be awarded for the production quantities once funding approval is provided by LCLS-II management.

Receipt inspection activities for the feedthroughs used in the prototype CM include 100% visual inspection, 100% dimensional inspection, three cryogenic cycles to 4K and 100% UHV leak checking. The HOM feedthroughs receive additional electrical measurements of capacitance and RF transmission properties. Approximately 50% of these components will shipped to each lab.

Beamline Bellows and Spool Pieces

Each prototype CM requires seven long bellows, one short bellows, one long spool piece and one short spool piece that along with the cavities complete the internal beamline vacuum envelope. The long bellows are located between cavities. The short bellows is located between the last cavity and beam position monitor (BPM). The superconducting magnet is attached to the long spool piece using locating pins. The short spool piece is located between the upstream gate valve and first cavity.

The required quantities (Table 4) have been ordered and received for the prototype CMs in accordance with engineering specification ED0002112-A. In addition, testing coupons have been ordered to monitor and evaluate plating quality. The quantities for the production CMs include two spares of each component, one for each partner lab.

Receipt inspection activities for the bellows and spool pieces used in the prototype CM include 100% visual inspection, 100% dimensional inspection, 100% blister

ISBN 978-3-95450-178-6

testing in a vacuum furnace at 400°C and 100% UHV leak checking.

The approach used for the prototype components include two separate procurements – one for hardware and one for copper plating. The approach for the production components is to order copper-plated components in a single procurement in order to improve coordination and logistics. A request for information (RFI) has been released to determine vendor interest in responding to a request for proposal (RFP). The quantity of testing coupons and frequency of receipt inspection activities is still under discussion. Approximately 50% of these components will be shipped to each lab.

Table 4: Beamline Bellows and Spool Pieces – Drawing Numbers and Quantities.

Component	Dwg. No.	Prototype CM Qty.	Production CM Qty.
Long Bellows	F10023434	18	233
Short Bellows	F10023437	4	35
Long Spool Pieces	F10009424	4	35
Short Spool Pieces	F10009417	4	35

Production Cavity Tuners

Fermilab is leading the effort on the procurement of the prototype CM cavity tuners. Initial design verification tests have been successfully conducted. In order to evaluate long term performance, accelerated life testing is on-going at JLab [10]. The prototype and production tuner designs are identical. JLab plans to order 280 tuner assemblies for the production CMs. The effort will be split into three procurements – one for the piezo-electric actuator assemblies, one for the stepper motor and transmission and one for the mechanical frame assembly. The procurement process is beginning in September 2015.

HOM Absorbers

The HOM absorber resides in the interconnect region between cryomodules. The design is identical to the XFEL design and has been reviewed as part of the production CM final design review. A total of thirty-five units are planned for procurement. The acceptance criteria are currently being developed. The procurement process is beginning in September 2015. The components will be shipped directly to SLAC for receipt inspection as they are not needed for CM acceptance testing at Fermilab or JLab.

SCHEDULE

The components for the prototype cavity string have been received at both partner labs as of this conference. The prototype CMs assemblies are planned for completion in the spring of 2016. Where appropriate, options on components needed for production CMs are planned for award in the next few months (e.g. cavities, gate valves and HOM & FP feedthroughs). The procurement process for the remainder of the components (e.g. beamline bellows, tuners and HOM absorbers) is beginning in September 2015.

SUMMARY

Through a strong collaboration with XFEL and Fermilab colleagues, the LCLS-II project team has developed and implemented plans for procurement of components for prototype and production CMs. This plan shares the procurement activities. JLab is moving forward with key procurements in order to support the schedule for both prototype and production CM assembly work at JLab and Fermilab.

ACKNOWLEDGEMENTS

We wish to thank the team at Fermilab, in particular Tug Arkan, who has contributed his time, experience and knowledge in support of procurement efforts. We would also like to express our sincere gratitude to DESY and CEA Saclay colleagues for their generosity providing insight and experience related to the monumental XFEL CM production efforts.

REFERENCES

[1] J.N. Galayda representing the LCLS-II Collaboration, Proceedings of LINAC2014, Geneva, Switzerland, TUIOA04.
[2] T. J. Peterson et al., "LCLS-II 1.3 GHz Cryomodule Design – Modified TESLA-style Cryomodule for CW Operation", Proceedings of SRF2015, Whistler BC, THPB119.
[3] T. T. Arkan et al., "LCLS-II Cryomodules Design Integration and Assembly at Fermilab", Proceedings of SRF2015, Whistler BC, TUPB110.
[4] D. Reschke, "Recent Progress with EU-XFEL", Proceedings of SRF2015, Whistler BC, MOAA02.
[5] O. Napoly, "Module Performance in XFEL Cryomodule Mass-Production", Proceedings of SRF2015, Whistler BC, FRAA02.
[6] 1.3 GHz Cryomodule Components Procurement, LCLS-II Document LCLSII-4.1-PM-0229-R0.
[7] E. A. McEwen et al., "Status of LCLS-II QA Systems Collaboration for Cryomodule Construction at TJNAF and FNAL", Proceedings of SRF2015, Whistler BC, THPB120.
[8] E. F. Daly et al., "Lessons Learned from C100 Cryomodule Procurements", TJNAF Technical Note JLAB-TN-15-030.
[9] F. Marhauser et al., "Cavity Procurement and Qualification Plan for LCLS-II", Proceedings of SRF2015, Whistler BC, TUPB003.
[10] N. A. Huque et al., "Accelerated Life Testing of Cavity Tuner Motor", Proceedings of SRF2015, Whistler BC, THPB062.