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15 September 2014

Dear Dr. Ben-Zvi,

RE: ERL ARR REPORT JULY 29-31, 2014

The Accelerator Readiness Review (ARR) team for Energy Recovery Linac, gun and beam transport to the dump, has completed its work by reviewing the current status of this facility at Brookhaven National Laboratory. Team members visited relevant areas of the facility, and discussed a wide variety of technical issues, processes, policies, and procedures as part of this review. The attached report summarizes observations, pre-start and post starts findings, opportunities for improvement, and other comments from their review.

The committee found the C-AD and ERL management and staff to be open, helpful, and very willing to provide explanations or demonstrations to support our inquiries. Their efforts made our visit pleasant and productive.

On behalf of the ARR committee, I wish ERL a safe, efficient and productive commissioning.

Sincerely,

Sayed Rokni

Enclosures (1)
CC:
ARR Committee
Chuck Schaefer
Don Cossairt
Ian Evans
Jessie Wilke
Roger Erickson
BNL
Berndt Mueller
Edward Lessard
Gail Mattson
Thomas Rosen
DOE BHSO
Patrick Sullivan

ACCELERATOR READINESS REVIEW REPORT

FOR

ENERGY RECOVERY LINAC (ERL) COMMISSIONING

JULY 29-31, 2014

BROOKHAVEN
NATIONAL LABORATORY

ERL Accelerator Readiness Review Team

LEAD Sayed Rokni

MEMBER Ian Evans

MEMBER Don Cossairt

MEMBER Roger Erickson

MEMBER Jessica Wilke

MEMBER Chuck Schaefer

Signed for the Committee S. H. Rokni 9/15/2014
Sayed Rokni, Chair, ARR ERL

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EXECUTIVE SUMMARY

An Accelerator Readiness Review (ARR) has been conducted for Collider-Accelerator Department's Energy Recovery Linac (ERL) per the Charge (see Appendix A) from the Associate Chair for the C-AD Accelerator R&D Division. The objective of the ARR was to provide assurance that commissioning the ERL gun to the dump can be performed in a safe, secure and environmentally sound manner. The ARR was conducted in accordance with DOE Order 420.2C, *Safety of Accelerator Facilities,* using an approach consistent with the draft DOE Guide 420.2-1A, *Accelerator Facility Safety Implementation Guide for DOE Order 420.2C, Safety of Accelerator Facilities*[1].

The ARR Team was led by Sayed Rokni from SLAC National Accelerator Laboratory and membership consisted of Don Cossairt (FNAL), Ian Evans (SLAC), Roger Erickson (SLAC), Jessie Wilke (BNL) and Chuck Schaefer (BNL) with extensive and diverse accelerator safety expertise (See Appendix B). The site visit portion of the ARR emphasized a performance-based approach with a strong focus on field activities that included walk-downs and inspections of systems and structures, inspections of safety systems, interviews, and roundtable discussions with staff. A comprehensive set of Lines of Inquiry (LOIs) was provided to guide the review. The committee also used their own professional expertise to focus on specific areas.

For each topical area, pre-start and post-start findings are presented along with opportunities for improvements and noteworthy practices. The ARR Team identified 9 pre-start and 2 post-start findings, 3 opportunities for improvement and 4 noteworthy practices. All pre-start findings are to be resolved prior to the commissioning activities at beams powers higher than 70 Watts. Post-start findings may be resolved in a reasonable timeframe after the commissioning activities have started and should be tracked to completion. Opportunities for improvement are offered as recommendations from the review team, but should not be considered mandatory requirements.

The ARR team noted that an extensive set of mature policies, processes, procedures, documents and methods to implement the requirements of the Accelerator Safety Order has been established by C-AD that will be applied to the ERL. C-AD has a well-established history of carrying out technically challenging accelerator programs and complex operations safely and effectively within the structure of these processes. The ARR team assumes that the C-AD organization will apply the same management and review processes to the ERL as have been applied to the AGS and RHIC facilities.

Based on this review, the ARR team concludes that in the area of ERL commissioning, from the gun to the dump (scope of this ARR), C-AD has in place processes, procedures and qualified staff necessary to complete the installation and commissioning of ERL safely and in compliance with the DOE Order 420.2C requirements. Completion of the pre-start findings will ensure a safe and compliant commissioning from gun to the dump at planned high currents.

The ARR committee members recognize that the unique high-current superconducting RF Energy Recovery Linac will primarily function in a commissioning and testing mode. Based on this review, ARR committee members recommend that commissioning of ERL gun to the dump proceed in phases. Namely, with the completion of specific pre-start findings, we recommend approval for commissioning at beam powers of up to 70 Watts, consistent with the previously approved low current mode by DOE BHSO.

[1] DOE Guide 420.2-1A was approved August 01, 2014.

Completion of pre-start findings 1 and 7 are not required for commissioning at average beam power of less than 70 Watts. All pre-start findings need to be completed and their completion verified before commissioning at higher beam powers.

A member of the ARR team, Mr. Chuck Schaefer will verify the completion of the pre-start findings on behalf of the committee. The ARR chair will recommend approval for commissioning after the pre-start findings are completed and verified.

1.0 Documentation and Procedures, Program Operations

1.1 Safety Assessment Document (SAD)

1.1.1 Observations

- The C-AD Safety Assessment Document (SAD), dated May 2011, has been properly developed in accordance with DOE O 420.2C requirements, and has been approved by the C-AD and BNL management.
- The C-AD SAD contains the safety analysis performed to support ERL ASE.

1.1.2 Opportunities for Improvement

- None

1.1.3 Pre-Start Findings

- Prior to exceeding 70 Watts of average beam power additional controls to mitigate radiological hazards related to the adequacy of ERL shielding and other systems for high-power operations need to be formally documented per C-AD procedures and implemented as per the Commissioning Sequence, OPM 18.5.8 and relevant RSC procedures in OPM Chapter.

1.1.4 Post-Start Findings

- None

1.1.5 Noteworthy Practices

- None

1.2 Accelerator Safety Envelope (ASE)

1.2.1 Observations

- ERL has an approved ASE that defines the credited controls for the maximum credible beam incident. It defines the maximum credible beam power and beam energy (3.5 MeV for gun, 1.5 MW of power to gun and 1.5 MW of beam power on beam dump). The ERL ASE was approved by the BHSO on June 6, 2012.
- ERL ASE defines the physical and administrative bounding conditions and controls for safe operations based on the safety analysis documented in the SAD.
- Approved OPM procedures are in place describing the ASE for High Current Commissioning and for the commissioning ASE for Low Power Test.

1.2.2 Opportunities for Improvement

- None

1.2.3 Pre-Start Findings

- None

1.2.4 Post-Start Findings

- None

1.2.5 Noteworthy Practices

- The distinction between the Credited safety systems and defense in depth that supports compliance with ASE requirements has been clearly documented.

1.3 Unreviewed Safety Issue (USI) Process

1.3.1 Observations

- The ARR committee reviewed one example of use of USI process; specifically the request for exemption leading to the BHSO approval of the Low Power Testing.
- C-AD has a well-established and strong USI Process that is described in C-AD (OPM 1.10.1) "Procedure for Identifying Unreviewed Safety Issues", Revision 07, Dated November 2012 and 1.10.1.a C-A USI Determination Form. This process will be employed for operations of the ERL.
- New projects or accelerator facility modifications, procedure changes and discovery of unplanned issues are reviewed through the USI determination process for potential impact on Credited Controls.
- The ARR team interviewed ERL operation staff and management; the management was knowledgeable about the USI process and requirements, but the operators were not familiar with the details. However, operators were knowledgeable and trained on escalation mechanisms.

1.3.2 Opportunities for Improvement

- C-AD should evaluate ERL staff understanding and use of the USI Checklist as a support to work planning and ensure its use is meeting management's expectations.

1.3.3 Pre-Start Findings

- None

1.3.4 Post-Start Findings

- None

1.3.5 Noteworthy Practices

- None

1.4 Resolution of Past Action Items

1.4.1 Observations

- All Pre-start items from the ERL IRR performed in April 2014 have been completed, verified by the Quality Assurance group and closed.
- There were seven Post-start Findings from the ERL IRR performed in April. One item is Closed, two are Completed waiting independent verification (planned for August and September), four are open with due dates in December 2014.
- The C-AD uses several methods to track actions. The Institutional Assessment Tracking System (ATS) is used for high level reviews as required by the BNL Standards Based Management System (SBMS). C-AD Committee Checklists are used for near term, life

safety items. A C-AD Family ATS is used to for internal assessment findings that do not require immediate attention.

1.4.2 Opportunities for Improvement

- None

1.4.3 Pre-Start Findings

- None

1.4.4 Post-Start Findings

- Complete the remaining Post-Start Findings from the ERL IRR as currently planned and verify completion prior to commissioning for the mission begins

1.4.5 Noteworthy Practices

- None

1.5 Commissioning Plan and Related Documents

1.5.1 Observations

- Draft commissioning plans have been developed which appear adequate to guide initial commissioning activities. As a new machine that promises to extend the frontiers of accelerator technical capabilities, this facility will evolve as tests are conducted and design details are refined. It is important that commissioning plans be developed and carefully thought through, but that they remain flexible to adapt to changing requirements. The ARR Team recognizes the importance of managing this program to be open to innovation, while always remaining vigilant to ensure that the program is conducted safely and that the integrity of the equipment is reasonably well protected. The commissioning sequence, OPM 18.5.8, which was draft at the time of the ARR, has been approved by C-AD after the review.

- The RSC Checklist provides a single document to collect signatures from SMEs that their required systems for radiation protection are ready for operations with a radiation source, including x-ray generating devices and beam. However, the actual specific technical prerequisites for safe commissioning, including the specific devices subject to rigorous control, are listed elsewhere and not immediately available to the persons carrying out the control room activities. The team was favorably impressed when shown the State Table document, which appears to be a clear and well-controlled list of credited devices needed to ensure radiation safety.

- When asked about these devices and their specific functions and settings, most of the persons involved in beam operations were aware of the existence and importance of the State Tables document, but were not conversant with the contents. As an opportunity for improvement, the team recommends that staff awareness of the significance of the controlled devices critical to radiation safety should be enhanced. Having a single brief document in the control room that summarizes the specific safety devices would ensure that the control room staff will be sensitive to the importance of these devices and would provide them with the formal assurance that they have approval to commence beam operations.

1.5.2 Opportunities for Improvement

- A single brief document in the control room should be prepared that summarizes the specific safety devices and any trip thresholds or other device settings that must be controlled to meet the approved safety limits. This document would help provide the control room staff with the formal assurance that they have approval to commence beam operations.

1.5.3 Pre-Start Findings

- The ERL Commissioning Sequence, OPM 18.5.8, which was in draft form at the time of the ARR, needs to be finalized, reviewed and approved by C-AD management.

1.5.4 Post-Start Findings

- None

1.5.5 Noteworthy Practices

- None

1.6 C-AD ESH Programs

1.6.1 Observations

- Based on interviews and visit/walk down of the ERL facility, there appears to be a strong and positive ESH influence on the scientific mission, with an adequate level of support for this stage of the project. R2A2's are complete and are suitable to support activities into and beyond commissioning. ESH staff and functions are supported within C-AD by a number of safety committees that are charged with providing an independent review of systems and sub-systems, providing assurance to C-AD senior management that the ERL meets the standards required to operate. The committees include the Accelerator Systems Safety Review Committee (ASSRC) and the C-AD's Radiation Safety Committee (RSC).
- There are many procedures in place that govern how C-AD and by extension the ERL will operate. These reflect a high level of knowledge and formality with respect to Conduct of Operations, and afford continuity across C-AD operated accelerators. I reviewed the ASSRC Checklist, C-AD 1.11.2 "F&O Interface Document" and many OPM's. It is clear effort and thought have been put into their development, as they come across clear and concise.
- The ERL remains a research project, but by having distinct roles (Operations Coordinator, Shift Team Leads & Shift Technicians) in the control room, provides assurance that the required processes to commission the ERL safely and efficiently are being followed.
- We reviewed engineering drawings, placement of ODH sensors in the ERL for both Liquid Helium and Liquid Nitrogen losses, System State Tables that reflect access permits during routine operations and under an ODH fault conditions, credited controls that respond to an ODH events and configuration management of these systems. Procedures governing use and response to abnormal events were available for review.
- Hydrogen and Ozone production have been analyzed in BNL-97122-2012-IR "Analytical approximate radiation effects due to Bremsstrahlung". Even in a worst case scenario,

Hydrogen production is capped at <6 liters per hour. This will be vented automatically within the ERL building (not the ERL cave). Normal HVAC air changes are more than sufficient to suitably dilute and remove Hydrogen vented to the room and remove this hazard. Ozone production was analyzed for a 1 MW beam with 0.25 m of iron shielding. Ozone production was conservatively calculated to be 1E-04 ppm (parts per million), which is well within established exposure limits of 0.1ppm averaged over 8 hours.

- There is an institutional Lock Out – Tag Out (LOTO) program in place that is established in BNL's Standard Based Management System (SBMS). This is augmented by a Radiation Hold (RS Hold) program that allows hardware to be locked out for radiological purposes. It carries over the fundamental philosophy of LOTO. Tracking is via a system of locks and tags, while placement and communication of RS Holds is further supported by an electronic log available to operations staff.
- The appropriate section within SBMS, which incorporates the prevailing ANSI standard, covers lasers. The Laser Lab has a "Standard Operating Procedure for the ERL Laser", which is the vehicle for implementing required standards. It defines line management responsibility and has the requisite laser system hazard analysis, conditions to operate and system configuration, established hardware controls, required personal protective equipment (PPE) and minimum training requirements. Items under configuration control such as shutters, attenuator (for low power running) and items in the PASS are well secured and labeled as such. There is a procedure in place that covers removal or alteration of these items. Access control is covered via a proximity card that is linked to current training profiles of ERL staff.
- It was observed that a pressurized gas manifold adjacent to the dump inside the ERL enclosure lacked any process fluid labeling. As all piping needs to be labeled, this should be rectified and a thorough inspection of other process piping within the ERL should be performed.

1.6.2 Opportunities for Improvement

- None

1.6.3 Pre-Start Findings

- Label process piping to/from the gas manifold adjacent to the dump

1.6.4 Post-Start Findings

- None

1.6.5 Noteworthy Practices

- None

1.7 Document and Record Control

1.7.1 Observations

- C-AD OPM 1.4.3 for Issuing, Revising, or Changing the Status of Permanent Procedures is thorough and implemented in the department, applies to the ERL, and is being implemented to document ERL specific procedures (Chapter 18 of the C-AD OPM).

- The ESSHQ group assigns reviewers and reviews procedures for format and usability
- Assessments performed by QA/QC management review procedure adherence.

- C-AD OPM 13.4.1 provides instruction on Records Management for all of C-AD, including ERL and is in concert with the BNL SBMS requirements.
- OPM 13.4.2d is the list of C-AD Records including the description, retention plan and responsible party.
- One or two of each of the following records were reviewed for evidence of procedure compliance:
  - Design Drawings
  - Engineering Change Notices
  - Procedure development and revision tracking sheet
  - Employee R2A2 (QA Manager, ERL Technician)
  - Internal Assessments/Audits

1.7.2 Opportunities for Improvement

- None

1.7.3 Pre-Start Findings

- None

1.7.4 Post-Start Findings

- **Practices** None

1.7.5 Noteworthy

- None

1.8 Assurance System

1.8.1 Observations

- A high level review of several QA processes was performed:
  - QA function in C-AD
  - Document / Procedure Management (OPM1.4.3)
  - Procurement (OPM 13.7.1)
  - Design, Drawings (OPM 13.6.1)
  - Records Management (OPM 13.4.2, 13.4.2d)
  - Independent Assessment and Nonconformance and Corrective/Preventive Action Tracking (OPM 13.10.1)

For each process, the relevant procedure was reviewed. ERL records indicating the procedure was being followed were reviewed. The processes are well established in the C-AD and are being applied to the ERL as they are to other accelerators and equipment in the department.

- The objective of the C-AD Independent Assessment program is to verify the implementation of the C-AD OPM, OSH, EMS programs, specifically that procedures are being followed. All OPMs are scheduled for review on a prescribed basis (annual, 24, 36,

48 months). The QA Group reviews documents and records required by the OPM and interviews staff who implements the OPM. Assessments are documented. Findings are assigned to the responsible Group Leader / Technical Supervisor for corrective action. Actions are tracked in the C-AD Family ATS.

- Observation of work performance is accomplished via weekly C-A management walk-throughs. These are documented in a C-AD database as well as the BNL database. Items requiring follow-up are tracked in the C-AD Family ATS.
- Assessments are performed as scheduled, documented and corrective actions tracked as prescribed in OPM 13.10.1.
- The QA manager is involved in the review of suppliers, review and approval of SOWs, Tech Specs, requisitions greater than $10K, and is a member of RFP Review Boards.
- Requirements for Design, Drawing and Specification Requirements and Configuration Management are complete and implemented. QA Level A1 drawings are reviewed by QA, the relevant safety committee chair, and the C-AD chair in addition to the reviews performed for QA Level A3 and A3 drawings.
    - ECNs are prepared for A1 drawings

1.8.2 Opportunities for Improvement

- The 2013 Assessment of OPM 13.4.1 Records Management reviewed QA records. There were no findings. It is recommended that future assessments of this OPM focus on other C-AD records.

1.8.3 Pre-Start Findings

- None

1.8.4 Post-Start Findings

- None

1.8.5 Noteworthy Practices

- None

1.9 IFM Work Planning and Control

1.9.1 Observations

- There exists a Memorandum of Understanding (MOU) and Operations Procedures Manual (OPM) section covering Work Planning and Control of the North Facility Complex of which the ERL falls within. The interaction between both groups is vital, especially with respect to management of credited controls that are required for ERL operations and maintained by F&O, or controls that have been established by C-AD for access etc. Examples would be the maintenance of the ERL Fan which is part of the credited controls for oxygen deficiency or implementation of radiation barriers that might prevent access to areas needed by F&O.
- Strong communication is a must and takes place via routine planning meetings; this includes establishment of roles to ensure work and work packages are reviewed and authorized.

- Memorandum of Understanding (MOU) regarding Accelerator Safety and Conduct of Operations Requirements for C-AD Accelerator Facilities by the F&O North Facility Complex team, September 10, 2010.
- C-A Operations Procedures Manual – 1.11.2 Accelerator Safety and Conduct of Operations, Configuration Control Requirements and Facility Modifications for C-AD Accelerator Facilities Managed by the Facilities & Operations (F&O) North Facility Complex team, or the F&O Modernization Project Office.

1.9.2 Opportunities for Improvement

- None

1.9.3 Pre-Start Findings

- None

1.9.4 Post-Start Findings

- None

1.9.5 Noteworthy Practices

- None

2.0 Accelerator Facility Safety

2.1 Configuration Management (CM) of Credited Controls

2.1.1 Observations

- The C-AD has processes and procedures to maintain configuration of safety credited and other accelerator equipment accelerators. Configuration Management – Shielding, Access-Control Systems, radiation monitors, ODH, shielding drawings, Access Control Systems Drawings and State Tables, Access Control System Testing Procedures were reviewed and found to be clear, reviewed, staff trained and knowledgeable about their use.
- Configuration management of radiation monitors was also reviewed; responsible SMEs were knowledgeable, documents were current.
- Procedures for conducting prompt radiation measurements (fault studies) were discussed with SMEs. These procedures are not clearly synchronized to assure proper coordination with the progress of commissioning activities, most prominently the planned increases in beam power.
- Due to past decisions and for what appear to be historical reasons the bulk shielding for the ERL was not designed in a coherent manner with a well-developed shielding assessment that was peer-reviewed.
- The present shielding is adequate for the initial stage of the commissioning plan. Additional shielding, analysis and verification is needed for high beam powers and may necessitate radiation measurements coordinated with fault studies at each "hold point" in the Commissioning Sequence, OPM 18.5.8.

- The present shielding analysis is largely the work of one individual using conservative methodologies not completely documented. A complete list of the shielding analyses performed to this point was not available.
- There is no clear plan for the management of local shielding on the beam line that might be needed as commissioning begins. As the beam power is increased, it is plausible that local shielding may be employed to control prompt radiation fields in proximity to the beamline to achieve shielding goals. This will potentially raise configuration management issues that should be anticipated and addressed in advance.

2.1.2 Opportunities for Improvement

- None

2.1.3 Pre-Start Findings

- Procedures and plans for conducting prompt radiation measurements (fault studies) should be reviewed and synchronized with Commissioning Sequence to assure proper coordination with the progress of commissioning activities, most prominently the planned increases in beam power and relevant fault study procedures.
- Update and/or develop appropriate Procedures for Shielding/Barrier Removal, Removal of Primary Area Beam Components, or Modifications, and ensure a clear plan for the management of local shielding is reviewed and implemented.

2.1.4 Post-Start Findings

- To assure availability of the shielding calculations to others for continuity of operations, the preparation of a comprehensive shielding assessment for the ERL should be prepared and made readily available.

2.1.5 Noteworthy Practices

- The system for managing the state tables was thorough.
- The system for referencing design drawings was thorough and straightforward to use.

2.2 Conduct of Operations

2.2.1 Observations

- The ERL program draws heavily on a well-established system of policies and procedures developed over many years for managing the conduct of operations at the other accelerator facilities operated by C-AD. This system has proven to be effective and has now been extended to cover the proposed ERL operations. The documentation supporting this system is extensive and appears to provide the procedures necessary to ensure safe operation of the new facility.
- In the course of interviewing various persons involved in the conduct of operations, the ARR team members noted some ambiguity about the lines of responsibility for day-to-day safe operation and whether management authority was adequately aligned with responsibility for safety. The persons interviewed all seemed to be comfortable with the organizational structure and R2A2's, but several persons seemed to be hesitant when asked how specific hypothetical questions of responsibility would be resolved.

The ARR team recommends that the ERL management should be attentive to the potential for problems that could arise from a lack of clear lines of responsibility. In particular, care should be taken to ensure that programmatic pressures do not lead to compromises in the high standards of conduct of operations. The team recognized the importance of the Operations Coordinator and felt that management must take care to ensure that this role is not diminished in the ERL organization.

2.2.2 Opportunities for Improvement

- None

2.2.3 Pre-Start Findings

- C-AD Management should ensure that lines of authority and responsibility for the conduct of operations of the ERL facility are clear. The authority of the Operations Coordinator must be clearly defined and established.

2.2.4 Post-Start Findings

- None

2.2.5 Noteworthy Practices

- None

2.3 Safety Review Committees

2.3.1 Observations

- The C-AD SAD lists review by a number of safety committees as Minimum Administrative Controls for Safe Operations. For ERL commissioning, these include C-AD's Accelerator Systems Safety Review Committee (ASSRC), and the C-AD's Radiation Safety Committee (RSC) for review and approve the changes.
- The Radiation Safety Committee (RSC) reviews radiological issues relevant to each accelerator start-up annually and reviews new or modifications to Access Control Systems (ACSs) and to shielding.
- The Accelerator Systems Safety Review Committee (ASSRC) completes a walkthrough of each accelerator facility before it starts up or moves on to different configurations or power levels. Checklists specify facility and equipment conditions that need to be met before starting up and need to be signed off by the subject matter expert. This inspection includes standard ESH housekeeping items such as, daisy chained extensions cords, removal of combustibles, trip hazards etc.
- BNL's institutional safety committees such as Pressure and Cryogenic Safety Subcommittee (PCSS) are relied upon for expertise outside the Department.
- The Radiation Safety Committee has reviewed the generic plans for the mitigation of radiation hazards, and general plans for fault studies for the commissioning of the ERL. However, the specific fault study plans for each fault study are reviewed and approved by the RSC once ERL has control of the beam at low power but prior to commissioning for the mission.
- RSC chair also is the lead SME designing the shielding and the planning for fault studies.

2.3.2 Opportunities for Improvement

- None

2.3.3 Pre-Start Findings

- Perform a review of shielding and faults studies by RSC and independent SMEs as per Commissioning Sequence, and Fault Study Procedure and plans.

2.3.4 Post-Start Findings

- None

2.3.5 Noteworthy Practices

- None

3.0 Facility Additions and Modifications

3.1 Safety Review for Accelerator Hardware (Controls)

3.1.1 Observations

- Instruments set up to detect prompt radiation, known as "Chipmunks", are recognized as critical to the safe commissioning and operation of the ERL facility. If radiation levels exceed specified thresholds the device either alarms or interlocks. The condition is indicated on computer screens in the ERL control room, but does not currently generate an audible alarm for the alarm condition. The interlock threshold turns the radiation off. The committee recommends that the potential hazard associated with a Chipmunk alarm justifies the implementation of an audible warning to ensure that the operator immediately recognizes the condition.
- The strategy for deployment of Chipmunks is documented, and the processes for changing their locations and/or alarm and interlock set points is proceduralized and well understood by staff.
- The Controls Group produced a list of action items that are still in progress. Several of these are necessary prior to Commissioning (e.g., ERL Laser Power Limit, Beam Loss Monitor Plots, etc.).
- C-AD is planning to correlate ERL power levels with Chipmunk response for two Chipmunks (NMO181 and NMO182) internal to the ERL enclosure so that the Chipmunks can be used as a type of power-limiting device. Additional local shielding around the chipmunk is planned to ensure the detectors do not saturate. as part of the commissioning sequence.

3.1.2 Opportunities for Improvement

- None

3.1.3 Pre-Start Findings

- An audible alarm in the ERL Control Room is needed to alert the Operators should a Chipmunk go into alarm.

- Complete installation and testing of controls that are required to support Commissioning (e.g., ERL Laser Power Limit, Loss Monitor Plots, etc.).

3.1.4 Post-Start Findings

- None

3.1.5 Noteworthy Practices

- The Controls Group recently issued an ERL Machine Protection Systems (MPS) Test Procedure (OPM 18.8.6.5). This test procedure will help ensure the MPS operates as intended to provide equipment protection and minimize machine down time.

4.0 Summary of Pre-Start and Post-Start Findings

TABLE 1: Summary of Pre-Start Findings

IDENTIFIER	REVIEW AREA	FINDING
Pre-Start 1*	Documentation & Procedure Safety Assessment Document (SAD)	Prior to exceeding 70 Watts of average beam power additional controls to mitigate radiological hazards related to the adequacy of ERL shielding and other systems for high-power operations need to be formally documented per C-AD procedures and implemented as per the Commissioning Sequence, OPM 18.5.8 and relevant RSC procedures in OPM Chapter.
Pre-Start 2	Commissioning Plan and Related Documents	The ERL Commissioning Sequence, OPM 18.5.8, which was in draft form at the time of the ARR, needs to be finalized, reviewed and approved by C-AD management.
Pre-Start 3	C-AD ESH Programs	Label process piping to/from the gas manifold adjacent to the dump.
Pre-Start 4	Configuration Management (Shielding)	Procedures and plans for conducting prompt radiation measurements (fault studies) should be reviewed and synchronized with Commissioning Sequence to assure proper coordination with the progress of commissioning activities, most prominently the planned increases in beam power and relevant fault study procedures.
Pre-Start 5	Configuration Management (Shielding)	Update, and/or develop appropriate Procedures for Shielding/Barrier Removal, Removal of Primary Area Beam Components, or Modifications, and ensure a clear plan for the management of local shielding is reviewed and implemented.
Pre-Start 6	Conduct of Operations	C-AD Management should ensure that lines of authority and responsibility for the conduct of operations of the ERL facility are clear. The authority of the Operations Coordinator must be clearly defined and established.
Pre-Start 7*	Safety Committee reviews	Perform a review of shielding and faults studies by RSC and independent SMEs as per Commissioning Sequence, and Fault Study Procedure and plans.
Pre-Start 8	Facility Safety Modification	An audible alarm in the ERL Control Room is needed should a Chipmunk go into alarm.
Pre-Start 9	Facility Safety Modification	Complete installation and testing of controls that are required to support Commissioning (e.g., ERL Laser Power Limit, Loss Monitor Plots, etc.).

* Completion of Pre-Start conditions 1 and 7 are not required for commissioning at average beam power of less than 70 Watts, but these conditions must also be completed, and their completion verified prior to commissioning at higher beam powers.

TABLE 2: Summary of Post-Start Findings

IDENTIFIER	REVIEW AREA	FINDING
Post-Start 1	Resolution of Past Action Items	Complete the remaining Post-Start Findings from the ERL IRR as currently planned and verify completion prior to commissioning for the mission begins
Post-Start 2	Configuration Management (Shielding)	To assure availability of the shielding calculations to others for continuity of operations, the preparation of a comprehensive shielding assessment for the ERL should be prepared and made readily available.

5.0 Charge to the Committee and the Committee Responses

Charge to Committee	Committee Response
Please perform an independent Accelerator Readiness Review of ERL gun and beam transport to the dump for high-current commissioning	Completed; please see the report
Please identify actions that are needed for a successful Phase II Accelerator Readiness Review of the complete ERL later in the year	A comprehensive shielding assessment should be performed and peer reviewed for successful Commissioning
	A report summarizing progress and the technical challenges encountered should be prepared and made available to the Phase II ARR committee
	Incorporate lessons learned from the phase 1 into the planning for phase 2

APPENDIX A: ARR TEAM CHARGE

Dear Sayed:

Thank you for agreeing to head the Accelerator Readiness Review for Phase I of ERL commissioning on July 29, 30 and 31, 2014. Based on your recent email, the team members will be Don Cossairt (FNAL), Ian Evans (SLAC) and Roger Erickson (SLAC). Please check if their schedules will work out. Additionally, Chuck Schaefer from BNL's ESH Directorate will join the team.

Phase I includes commissioning with high current beam from the gun to the dump, but does not include the complete ERL loop, which will be the subject of a Phase II ARR. You and your team's expertise and work is greatly appreciated and is needed to move this project forward. Below is the charge and some details about the BNL ARR process. A draft agenda and lines of inquiry for the on-site review are attached.

Pam Manning (631-344-4072) will be your contact for information regarding access to web based documents and other administrative matters. It is necessary for you to go to the BNL website: http://www.bnl.gov/guv/gis.asp and register on the Guest Information System at BNL for your visit here (please choose Collider-Accelerator Department as 'department to be assigned' and Ed Lessard as the 'host'). Also, please contact Pam regarding travel arrangements.

Thank you again for this effort.

Regards.

Ilan Ben-Zvi
C-AD Accelerator R&D Division Head
April 23, 2014

Charge:
- Please perform an independent Accelerator Readiness Review of ERL gun and beam transport to the dump for high-current commissioning
- Please identify actions that are needed for a successful Phase II Accelerator Readiness Review of the complete ERL later in the year

Please focus on the following areas:
- Areas identified in the Accelerator Safety Order (training, procedures, CAS, AB documents, USIs)
- Records of past reviews, incidents, actions
- Conduct of Operations procedures
- QA (assurance systems)
- Interlocking safety systems
- Controls system
- Conventional safety practices such as LOTO

The following summarizes focus areas and BNL counterparts:
SAD, ASE, USIs, Activities and Records
Counterparts: D. Kayran, E. Lessard

Past Actions and Reviews, Quality Assurance, Configuration Management, Documents and Records, CAS, Drawings
Counterpart: D. Passarello

Controls System
Counterparts: Charles Theisen, J. Jamilkowski

Conduct of Operations, Commissioning Plan, Commissioning Sequence, Fault Studies
Counterparts: L. Hammons, D. Kayran

Alarming and Interlocking Area Radiation Monitors
Counterparts: D. Beavis, J. Reich

Radiation Protection and Safety, Ozone, Hydrogen, Fault Study Plan
Counterparts: D. Beavis, P. Bergh, R. Karol

Conventional Safety, ODH, Lasers, LOTO
Counterpart: P. Cirnigliaro, L. Hammons

Personal Protection Systems: Interlocks for ACS, ODH, Laser
Counterparts: J. Reich, A. Etkin

The review process should consider:
- Lines of Inquiry
- Document reviews
- Counterpart discussions
- Observations

Please report the following action items:
Pre-Start – actions that should be addressed prior to the Phase I approval by DOE
Post-Start – actions that may be completed after Phase I approval; the ARR team should recommend that these actions be identified to the ERL management, and that management's plan and schedule for completing the actions be provided to and discussed with the Accelerator Readiness Review team
Opportunities for Improvement – actions that the ARR team believe would significantly enhance the Phase II Accelerator Readiness Review process

Please prepare a report as follows:
Contents
- Brief discussion of the Findings and Observations within each area of the ARR
- Brief comments on opportunities for improvement
- Pre-start and post-start action items and opportunities for improvement

Schedule
- Please prepare a draft report drafted within 7 to 11 days following the on-site work
- Please submit the draft to counterparts for factual accuracy and comments
- Please submit the final report to C-AD management within approximately one week after comments received

APPENDIX B: ARR TEAM MEMBERS

Sayed Rokni
Team Lead

25 years at SLAC National Accelerator Laboratory. Ph.D. in Nuclear Physics from Utah State University, and a Certified Health Physicist. Current Position: Radiation Protection Department Manager, Radiation Safety Officer, Radiation Physics Group Leader, 2001–present. Prior Positions: Acting Director for ESH Division, 2005-2007; Radiation Physicist, 1991-present; Engineering Physicist, Research Division, 1989-1991; Faculty Research Associate, Nuclear Physics Group, University of Massachusetts, Amherst, 1987-1989.

J. Donald Cossairt

36 years at Fermi National Accelerator Laboratory. Ph.D. in Physics from Indiana University Bloomington, and a Certified Health Physicist. Current Position: Associate Head, ESH&Q Section 1996-present. Previously: Radiation Protection Manager 1996-present, ES&H Section Head, 1989-1996. Widely known as an instructor in accelerator radiation protection at sessions of the U. S. Particle Accelerator School. Distinguished Emeritus Member of the National Council on Radiation Protection and Measurements.

Roger Erickson

34 years at SLAC National Accelerator Laboratory. Ph.D. in Experimental High Energy Physics from Cornell University. Current Position: Director of Accelerator Operations and Safety Division. Prior Positions: Deputy System Leader of SLC Final Focus System; Project Manager of A-Line 50 GeV Upgrade Project.

Ian Evans

Over 25 years of technical and management experience, primarily in the areas of operational and experimental safety at accelerator based DOE user facilities. Current Position: Directorate ESH Program Manager for the Linac Coherent Light Source (LCLS) and Stanford Synchrotron Radiation Light source (SSRL). Responsibilities include development, implementation and oversight of staff and user based ESH and Work Planning and Control programs.

Chuck Schaefer

20 years at Brookhaven National Laboratory (BNL). M.S. in Health Physics from the University of Florida, and a Certified Health Physicist. Current Position: Accelerator Safety Officer and BNL Radiological Waste Characterization Analyst, Radiological Control Division. Prior Positions: BNL Radiological Control Manager 2003-2008, Facility Support Manager 2001-2003, BNL Radiological Field Supervisor 1995-2001.

Jessica Wilke

20 years at Brookhaven National Laboratory (BNL). MBA in Business Information Systems Management, Hofstra University. Certified Quality Manager, Quality Engineer, Quality Auditor, Six Sigma Green Belt (ASQ). Current Position: Deputy Manager Quality Management Office, Contractor Assurance System POC. Prior Position: Quality Program Engineer 1994-2013. Responsibilities have included Verification of the BNL QA Program, development of assessment and performance processes, leader of the Human Performance Improvement initiative, causal analysis team lead. Experienced facilitator.

APPENDIX C: PLAN OF ACTION

ERL ARR TEAM
PLAN OF ACTION

COLLIDER-ACCELERATOR DEPARTMENT
ERL GUN TO DUMP COMMISSIONING

OBJECTIVE/SCOPE

The objective of this Accelerator Readiness Review (ARR) is to ensure that commissioning of the ERL superconducting RF gun to the beam dump can be performed in a safe and environmentally responsible manner. The scope of this ARR includes all activities associated with ERL commissioning of the 3.5 MeV beam from the gun to the dump at the Building 912 ERL accelerator enclosure.

The supporting policies and procedures will be among the deliverables to the ARR team.

This plan of action was developed with the ARR Team and is required prior to commissioning and operations of new accelerators, and is a BNL prerequisite to conducting the ARR.

The ARR is a process for ensuring that facility conditions and operations with the potential to affect worker or public safety and health, or to have a negative impact on the environment, have been evaluated, and the appropriate safeguards established. This plan guides the ARR process to be conducted in accordance with DOE Order 420.2C using an approach consistent with the draft DOE Guide 420.2–1A (August 2013) and the BNL Standards Based Management System (SBMS) Accelerator Safety Subject Area. In accordance with DOE Order 420.2C, the ARR ensures the following processes are in place:

1. An appropriate Contractor Assurance System that maintains an internal assessment/review program
2. An appropriate Facility Configuration Management Program that is related to accelerator safety
3. Credited Controls and appropriate administrative processes related to accelerator safety (e.g. training, procedures, etc.)

Additionally, consistent with the DOE Guide 420.2–1 and draft DOE Guide 420.2–1A, the ARR should verify:

1. An acceptable Safety Assessment Document (SAD) has been properly developed in accordance with DOE O 420.2C requirements, and has been reviewed and approved in accordance with the BNL internal safety review system
2. An adequate Accelerator Safety Envelope (ASE) has been developed, is supported by the SAD, and approved in accordance with BNL and Brookhaven DOE Site Office (BHSO) requirements

3. The facility to be commissioned is in compliance with ASE requirements
4. An appropriate Commissioning Plan has been developed
5. An appropriate Unreviewed Safety Issue (USI) process has been developed and is being utilized
6. Procedures necessary for the safe operation of the facility have been developed, reviewed, and approved, and an appropriate process for the development, review and approval of new and revised procedures is in place
7. Procedures to deal with abnormal and emergency situations have been prepared and are approved for use
8. Records important for commissioning activities are properly controlled
9. Equipment and systems having safety importance, as described in the SAD, have been installed and have been appropriately tested
10. Personnel training and qualification programs relevant to safe commissioning have been established
11. Clearly defined roles and responsibilities have been established for accelerator commissioning activities, including those for training and procedures related to safety
12. An appropriate assurance process for the review of the accelerator safety program elements as specified in the CRD of DOE Order 420.2C is in place

The ARR is not an extensive wall–to–wall assessment of all aspects of commissioning, but a performance based assessment of the proposed commissioning activities designed to ensure the facility will be commissioned in a safe, secure, and environmentally sound manner. Weaknesses identified as part of the ARR process should become part of an overall lessons learned program.

ERL ARR TEAM MEMBERS AND TOPICAL AREAS

NAME	AFFILIATION AND CONTACT INFORMATION	TOPICAL AREA
Sayed Rokni (Team Lead)	**Email: rokni@slac.stanford.edu**	**SAD, ASE, USIs, , Configuration Management,**
Roger Erickson	Email: roger@slac.stanford.edu	Conduct of Operations, Commissioning Plan, Commissioning Sequence, Controls Systems
Don Cossairt	**Email: cossairt@fnal.gov**	**Radiation Protection and Safety, Ozone, Fault Study Plan, Configuration Management.**
Chuck Schaefer	Email: schaefer@bnl.gov	Alarming and Interlocking Area Radiation Monitors, Controls Systems
Ian Evans	**Email: evans@slac.stanford.edu**	**Conventional Safety, ODH Lasers, Loto, Work Planning and Control, C-AD ESH Programs**
Jessie Wilke	Email: jessie@bnl.gov	Past Actions and Reviews, CAS, Quality Assurance, Documents and Records,

A DOE Site Office (BHSO) representative will observe and provide DOE oversight of this ARR.

- Patrick Sullivan, DOE BHSO Observer [ptsullivan@bnl.gov, (631) 344–4092]

C-AD Administrative support for the ARR team:

- Pamela Manning, [pmanning@bnl.gov, (631) 344–4072]

APPENDIX D: LINES OF INQUIRY

1.0 Documents and Procedures, Program for Operations	
1.1 Safety Assessment Document (SAD)	
1. Interview selected management /staff involved in SAD development	Adequate
2. Determine adequacy of safety analysis performed to support SAD	Adequate
3. Determine if SAD meets DOE O 420.2C requirements	Adequate
4. Determine if SAD provides adequate technical basis for ASE	Pre-Start 1
5. Determine adequacy of process to review and approve SAD	Adequate
6. Interview selected management /staff to determine knowledge of SAD requirements	Adequate
7. Determine adequacy of SAD to support commissioning	Adequate
1.2 Accelerator Safety Envelope (ASE)	
1. Interview selected management/staff involved in ASE preparation	Adequate
2. Determine if ASE addresses required controls and operating limits	Adequate
3. Determine if ASE meets DOE O 420.2C requirements	Adequate
4. Determine adequacy of process to review and approve ASE	Adequate
5. Interview selected management/operational staff	Adequate
6. Determine adequacy of ASE to support commissioning	Adequate
1.3 Unreviewed Safety Issue (USI) Process	
1. Determine if USI process meets DOE O 420.2C requirements	Adequate
2. Determine if USI process is consistent with commissioning SAD	Adequate
3. Interview those involved in USI process development and management	Adequate
4. Determine if USI process will be adequately linked to Configuration Management program	Adequate
5. Determine adequacy of USI process to support commissioning	Adequate
1.4 Resolution of Past Action Items	
1. For open items, ensure that planned closure actions are appropriate and responsive to the findings	Not reviewed
2. Determine if the processes are implemented or whether there is a credible, resource-loaded plan for implementation	Not reviewed
3. Determine adequacy of resolutions of past items to support commissioning	Post-Start 1
1.5 Commissioning Plan and Related Documents	
1. Commissioning Plan fully describes roles, responsibilities, accountabilities, and authorities that establish the expectations and duties of managers, supervisors, and operators for carrying out the commissioning and any related documented authorizations	Adequate
2. 2. Commissioning Plan addresses staffing schedules, authority and reporting chain for operational, safety, and scheduling issues procedures (normal and emergency/contingency), administrative controls, and personnel training	Adequate *
3. 3. Commissioning Plan identifies or properly references engineered safety systems that will be operable for the accelerator	Pre-Starts 4,5
4. 4. Commissioning Plan identifies the operational characteristics for specific modes of commissioning needed to support the safety case for	Pre-Start 4

progressively higher power commissioning	
5. 5. Determine adequacy of Commissioning Plan and fault studies to support commissioning	Pre-Starts 4,5,6
1.6 C-AD ESH Programs and ERL Functional Organization	
1. Determine if the ERL organization is developed that supports all functions necessary to support commissioning	Adequate
2. Determine if the C-AD organization includes committees that have a functional role in ERL processes	Adequate
3. Determine if charters, chairs, and members for all committees that have a role in ERL commissioning are in place	Adequate
4. Determine if policies and procedures are in place to ensure committees and their charters and charges are appropriately aligned.	Adequate
5. Determine that the ERL organization is consistent with commissioning SAD and ASE	Adequate
6. Determine if an ES&H organization is in place with fully qualified staff and appropriate R2A2s to support commissioning	Adequate
7. Determine if all procedures needed to effectively support commissioning are in place including implementation of the following SBMS requirements: **a.** Worker Safety & Health **b.** Conventional Health and Safety **c.** Radiological Protection and Control **d.** Environmental **e.** Waste Management **f.** Emergency Preparedness and Response **g.** Security (including Cybersecurity).	Adequate for areas reviewed (SBMS, RADCON, Acc Systems Safety Review Committee)
8. Interview C-AD Chair, C-AD ESSHQ Associate Chair, C-AD ESSHQ Division Head and selected C-AD ESSHQ staff	Adequate
9. Determine if a C-AD ES&H program is in place to support cryogenic operations	Adequate
10. Determine if R2A2s developed for ESSHQ staff are aligned with the ERL organization	Adequate
11. Determine adequacy of C-AD ESSHQ organization to support commissioning	Adequate
1.7 Document and Record Control	
1. Determine if key records are identified	Adequate
2. Determine if Records Custodians for key records are identified and interviewed	Adequate
3. Interview records custodians	Adequate
4. Determine if records management and storage complies with all applicable requirements	Adequate
5. Determine if records management program effectively supports routine operation	Adequate
6. Determine if records related to credited controls in the C-AD document control system are readily available?	Adequate
7. Determine if staff can access records they need for commissioning	Not Reviewed
8. Ensure records management is consistent with commissioning ASE	Not Reviewed

1.8 Assurance System	
1. Determine if a process is in place for comprehensively assessing ERL commissioning performance against goals, monitoring and analyzing performance data and information, and identifying and correcting unfavorable trends or deviations	Adequate
2. Determine if external assessments are planned, used and employ peer reviews and assessments that include accelerator subject matter experts from other accelerator facilities	Pre-Start 5
3. Determine if the performance management system includes a process for investigation and analysis of events and incidents and their associated causes.	Adequate
4. Ensure the assurance process meets the requirement of DOE O 420.2C requirements and SBMS and is consistent with the commissioning SAD	Adequate
5. Determine if the assurance programs are adequate to support commissioning	Adequate
1.9 IFM Work Planning and Control	
1. Determine if an Integrated Facility Management (IFM) model to support the C-AD facility complex during ERL commissioning is effectively deployed	Adequate
2. Interview selected management/staff on their role in the Integrated Facility Management system	Adequate
3. Determine adequacy of work planning on conventional facilities associated with ERL	Adequate

2.0 Accelerator Facility Safety	
2.1a Maintenance of Credited Controls (CCs) and Safety System and Components (SSCs)	
1. Determine if there is a process to manage the maintenance of CCs and SSCs	Adequate
2. Determine if the processes for maintaining CCs (radiation monitors, shielding, and the ACS) and SSCs (e.g. fire detection and suppression systems) for accelerator are clearly defined and documented, including process change control	Adequate
3. Determine if responsibilities for process execution are clearly and formally assigned in R2A2s and/or organizational procedures	Adequate
4. Determine if procedures are in place for removing and placing CCs and SSCs back in service	Adequate
5. Determine if approved alternatives to CCs have been defined	Adequate
6. Determine if program meets the requirements of DOE 420.2C and the draft AS Guide	Adequate
7. Determine if the program is fully implemented	Post-Start 2
8. Determine adequacy of the maintenance program for CCs and SSCs to support commissioning	Adequate
2.1b Configuration Management (CM) of Credited Controls	
1. Determine if the configuration of ASE required controls (credited controls	Adequate

and supports) will be properly managed during accelerator commissioning	
2. Evaluate effectiveness of configuration management program	Adequate
3. Determine if the accelerator credited control systems are protected against un-authorized access	Adequate
4. Determine if configuration management is applied to defense-in-depth controls on a graded approach	Pre-Start 3
5. Determine if the configuration management program is adequate to support commissioning	Adequate
2.2 Conduct of Operations	
1. Interview C-AD and ERL management and staff involved in the development and implementation of the Conduct of Operations program	Adequate
2. Review Conduct of Operations procedures to determine overall adequacy of program	Adequate
3. Determine if Conduct of Operations program is adequately implemented at the ERL	Adequate
3.1 Are the proposed performance criteria in place to satisfy the required guidelines for the following: 3.2 Commissioning Organization and Administration 3.3 Operating Practices 3.4 Control Area Activities 3.5 Communications 3.6 Control of On-Shift Training 3.7 Notifications 3.8 Control of Equipment and System Status 3.9 Log keeping 3.10 Operations Turnover 3.11 Required Reading 3.12 Timely Orders to Operators 3.13 Operations Procedures 3.14 Work Planning and Controls	Adequate *
4. Interview staff at ERL to assess knowledge of and implementation of the Conduct of Operations program	Adequate
5. Review sample copies of R2A2s and JTAs for ERL Operators	Adequate
6. Determine if a staffing plan for commissioning has been established	Adequate
7. Determine if a commissioning organization has been established consistent with the organization described in the Conduct Operations Matrix	Not Reviewed.
8. Determine appropriate procedures are in place to address industrial safety concerns	Pre-Start 3
9. Determine adequacy of the Conduct of Operations program to support commissioning	Adequate
2.3 Safety Review Committees	
1. Determine if a safety review program is prepared, approved and implemented	Pre-Start 6
2. Determine if applicable procedures are in place for C-AD safety committees	Adequate

3. What staff qualifications are required to manage and implement the safety review committee program	Adequate
4. Interview C-AD managers and staff to determine their knowledge of the requirements of the safety review program	Adequate
5. Determine adequacy of safety review committees to support commissioning	Pre-Start 6

* This determination of adequacy is based on a limited sampling of information and on recognition that the C-AD organization has well-established policies and procedures for controlling operations of the AGS and RHIC programs. The ARR committee assumed the same level of rigor will be applied to the ERL program.

3.0 Facility Additions and Modifications	
3.1 Safety Review for Accelerator Hardware	
1. Determine if a process is established by C-AD for safety oversight and review for modifications to the ERL	Adequate
2. Determine if the process is consistent with SAD/ASE requirements	Adequate
3. Determine if supporting documents and procedures are in place to implement the process	Adequate
4. Determine if the process is adequately linked to USI process	Adequate
5. Determine if the process meets DOE O 420.2C requirements and is consistent with the Accelerator Safety Guide	Adequate
6. Interview selected management/staff to determine knowledge of accelerator safety review process requirements for accelerators	Adequate
7. Determine if a process is established by C-AD to perform pre-operational acceptance testing of hardware, including procedure development and implementation of required training	Pre-starts 7, 8
8. Determine if guidelines are in place for deciding on the appropriate level of review	Adequate