

**Report of the**

**Safety Review for the**

**Upgrade Injector Test Facility**

**May 10, 2016**



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# Executive Summary

An internal Safety Review Team (“The Team”) was assembled and asked to determine if Jefferson Lab (JLab) Injector staff and the Upgrade Injector Test Facility (UITF) accelerator, after an extensive redesign, are ready to safely undertake a commissioning and running plan consistent with the requirements of DOE Order 420.2C, *Safety of Accelerator Facilities*.

The Team was assembled on May 10th, 2016 to review the status of the project and prepared a report summarizing findings, opportunities for improvement, and other comments from the review. The Team was given information on the status and plans for completing all the elements needed to commence commissioning and experimental activities. Where the actual installation or preparations for operations were incomplete, the Team reviewed the plans and activities to complete the work. The Team based its observations and conclusions on a series of formal presentations, reviews of documents, interviews of JLab management and staff, and various performance-based elements. The schedule of review activities is shown in Appendix A.

The Team reviewed the physical progress by taking a tour of the Upgrade Injector Test Facility. This visit focused primarily on equipment and facility readiness with impromptu discussions with members of the JLab staff.

During the UITF Safety Review, the UITF project team showed that they have thought through the majority of the hazards associated with the operation of the UITF, and are in the process of mitigating those hazards. One outstanding hazard is the control of beam operation above 100nA and the controls are still being vetted at the time of the review. A few minor hazards were not considered and need to be addressed in final plans. Once these hazards have been addressed, The Team feels that all understood safety concerns for the UITF will have been met.

Hazard assessment for ODH & Radiation concerns has been met. Radiation assessment is commensurate with intended operations at keV and MeV energies and planned use of time to take deliberate baseline measurements is commendable and encouraged.

Issues identified during the UITF Safety Review are summarized below and explained in further detail in Section 4.0 of this report.

1. Hazards which were not addressed were, Fall Protection when working on the raised beamline components; a Life Safety Assessment needs to evaluate the UITF to ensure safety of workers and code compliance; and trip hazards due to the installed Earthquake bracing should be addressed.
2. Further attention is needed for the following mitigations: other means of accessing and working on the components in the raised beamline section needs to be evaluated; a separate review of beam components which address > 100nA beam is needed; Laser Safety Shutter details need to be finalized; mechanical means of locking the UITF cave needs to be evaluated; Lock Out Tag Out needs to be addressed during Gun High Voltage power supply connections; a design review for the downconverter will need to be performed for proper safety function and effectiveness; and Pressure Vessel sign off needs to be clearly defined for the SF6 Tank.
3. Radiation shielding needs to be further evaluated and developed to ensure the identified gaps are mitigated.
4. Sign usage and posting plans need further development.
5. Specific procedures for operation and maintenance (COO, ESAD, OPSs, etc.) need to be further developed and finalized before commencement of commissioning and beam operation of the UITF.

The Team recommends that established Jefferson Lab internal processes be used to address the issues mentioned in this report before commencement of commissioning and beam operation activities.

This report summarizes the results of the UITF Safety Review.

# Charge to the Review Team

In the fall of 2016, the Upgrade Injector Test Facility (UITF) will be ready to start commissioning followed by internal testing and experiments. The original Injector Test Cave and its operations center were completely dismantled and are currently in the process of being outfitted with upgraded technology.

There are a series of three reviews which will evaluate the UITF status and its readiness for operation. The first review was held on March 18th, 2016 and evaluated the accelerator with respect to beam requirements for the HDIce experiment. The second review (this review) is an evaluation of safety aspects of the facility and is explained below. A future review will evaluate the status and effectiveness of the Conduct of Operations for the UITF.

The review committee was asked to evaluate a list of understood hazards as well as review presentations regarding safety aspects of the facility in order to ascertain if all safety aspects have been considered and addressed to allow for safe running of the facility.

In addition to making comments and recommendations on this broad view, the committee should address the following charge questions:

1. *Does the list shown below capture all the hazards associated with the UITF?*
2. *Do the planned mitigation measures assure safety of personnel during all access levels (Restricted and Beam Permit)*
3. *Does the assessment for ODH and Radiation safety capture the risks adequately? Have we assigned the appropriate designations (ODH-0, ODH-1)?*
4. *Is the Radiation assessment commensurate with the intended operations (keV and high current, MeV and low current)*
5. *Are the intended postings and beacons adequate and appropriately placed? Too much signage or too little?*
6. *Is the intended documentation adequate?*

***List of Hazards***

*Gun System*

*1. High Voltage (350 kV)*

*2. Pressure Vessel containing SF6 (60 PSI)*

*3. SF6*

*Laser System*

*1. Class 4 laser at 1560 and 780 nm*

*Vacuum Systems*

*1. Pumps (noise level?)*

*2. Beam line terminations (flanges capped off?)*

*Electrical and Magnets Systems*

*1. Ion pumps*

*2. Magnet terminals*

*3. Magnetic fields*

*Cryogenic fluids*

*1. Liquid Helium to ¼ cryomodule*

*2. 500 L and 1000 L liquid Helium for HD-ice*

*3. Nitrogen gas line*

*Non-ionizing Radiation*

*1. Warm RF (Buncher and Chopper systems)*

*2. High Power RF to ¼ cryomodule*

*Ionizing Radiation*

*1. Due to beam during UITF operation*

*2. Residual radiation after turning off the beam*

***UITF Operations***

*Access Controls*

*1. Levels of Access (Restricted/Beam Permit)*

*2. Sweep procedures (prior to beam operations)*

*3. Access control procedures post-beam operations*

*4. CARMs*

*5. Beam Current Monitors (BCMs) (<1 microA into Cave 2)*

*Defined operational modes*

*1. Low energy operations (restricted to Cave 1, beam current 10 mA, beam energy <350KV)*

*2. High energy operations (for HD-Ice, beam current , <1 μA, BCMs)*

*3. Maintenance, no beam*

*Signage*

*1. ODH posting*

*2. HV*

*3. Laser*

*4. Magnetic fields (if higher than 5G, about 1 ft from the magnet)*

*5. Beacons, if needed (perhaps at the gate when running beam in UITF)*

*6. Beacons above the cave (restrict access when RF/Beam on)*

*Other*

*Crash button*

*Training*

*Operator Training (includes scientists, engineers and technicians)*

*Documentation*

*DILO SF6 Cart Manual, SF6 Information, Electronic Logbook, applicable TOSPs, OSPs*

***Individual Presentations***

1. *UITF Introduction – Matt Poelker*
2. *Personnel Safety System – Henry Robertson*
3. *Radiation Shielding Assessment – Vashek Vylet*
4. *ODH Assessment – Hari Areti*
5. *Laser System, High Voltage, SF6 – John Hansknecht*

The Team’s responses to the six items above are summarized in Section 4.0 of this report.

# UITF Safety Review Team

Jefferson Lab assembled a team for the UITF Safety Review consisting of selected individuals from JLab Accelerator, Physics and ESH Groups as well as an outside observer from the Facility for Rare Isotope Beams or FRIB. This team consisted of individuals who had particular experience and expertise in hardware installation and safety related issues.

The UITF review team members are listed in the following table:

|  |  |  |
| --- | --- | --- |
| **Member** | **Affiliation** | **Role** |
| Matt Poelker | Accelerator CIS | Review Facilitator |
| Harry Fanning, (Chair) | Accelerator Division Safety Officer | JLab Internal Reviewer |
| Ed Folts | Physics Division Safety Officer | JLab Internal Reviewer |
| Bob May | ESH&Q Division Safety Officer | JLab Internal Reviewer |
| Mike Aiken | Accelerator Operations | JLab Internal Reviewer |
| Steve Benson | Accelerator Division | JLab Internal Reviewer |
| Peter Grivins | FRIB ESH&Q Manager | External Observer |

# Response to the Charge to the Team

The Team was charged with determining whether each of six specific statements was true, based on criteria provided in the Safety Review plan and on information gathered during the review process. The complete charge to the committee appears in Section 2.0 of this report. The Team response to each charge is summarized below.

*1) Does the list shown below capture all the hazards associated with the UITF?*

**Committee Response:**

Partially Met

As of the review, the list of hazards was nearly comprehensive with a few exceptions noted by The Team. The following were noted as needing to be evaluated:

1. Work from heights and fall protection were not covered in regards to the raised beamline components.
2. Having a Life Safety Assessment for the facility, especially for the Cave would be advantageous.
3. Trip hazards associated with the Earthquake braces were not accounted for. Investigate method to clearly mark them to reduce risk.

*2) Do the planned mitigation measures assure safety of personnel during all access levels (Restricted and Beam Permit)*

**Committee Response:**

Partially Met

As of the review, the planned mitigations were nearly comprehensive with a few exceptions noted by The Team. The following were noted as needing to be further evaluated:

1. For gun operation up to 100nA there should be no concerns with Target damage or excessive radiation hazards. Operation above that relies on the new beam current monitor system, which should be reviewed separately. In addition, the Laser safety shutter operation and placement should be finalized.
2. It is important to start fleshing out a specific design for the PSS Beam Current Monitor (BCM), and to use as much CEBAF-tested equipment as possible, limiting the amount of new hardware that must be reviewed for reliability. Bob May also suggested a PSS BCM design review be scheduled soon (Omar, Trent, Henry, Matt, others?)
3. Because the High Voltage Power Supply (350 kV) is contained and is delivered to the gun via a cable it is a rather safe system. There is a risk of radiation when it is connected to the gun and there is some potential personnel hazard when the cable is disconnected. Power supply operation is only permitted when the vault is locked up and personnel are excluded. Lock and tag must be used whenever the power supply cable is disconnected. These accommodations are in place now.
4. A design review for the downconverter is needed to evaluate effectiveness.
5. Original idea of a work platform with a staircase access adjacent to the raised beam line and HDIce apparatus appears to not be planned at this time. The use of a ladder to access these areas is not a preferred method. A rolling staircase would allow for access and carrying equipment up to the working level.
6. Having mechanical means of locking out the personnel entry points to the Cave would be a good idea especially in the event of a power outage where Oxygen Deficiency Hazard (ODH) concerns are the highest or other situations where personnel access should be restricted.
7. By using commercial components everywhere within the SF6 pressure system, it is possible to maintain safe operation with this pressure vessel. It was not clear who signs off on the pressure vessel compliance. This should be done by an engineer familiar with pressure vessel specifications. Since all parts are commercial, this should not be difficult to generate.

Good Practice:

The commercial SF6 recovery system that has been purchased for implementation should allow UITF personnel to prevent significant loss of SF6. As long as the instructions of the system are followed, there should be little environmental hazards. The amount of gas to be utilized is also not sufficient to produce much of a personnel ODH concern.

Good Practice:

Even though the PSS BCM design needs to be fleshed out, the plan to use as much of the design and equipment manufacture from the main machine as much as possible will save time and improve reliability.

*3) Does the assessment for ODH and Radiation safety capture the risks adequately? Have we assigned the appropriate designations (ODH-0, ODH-1)?*

**Committee Response:**

Met

As of the review, the ODH and Radiation assessments capture the risks adequately. The ODH designations for the UITF appear to be assigned appropriately.

Egress from laser table could be an issue the wall side of the beam line should be considered ODH1 in keeping with the accelerator standard.

The ODH assessment appears to have captured most plausible events within the facility. There was some discussion regarding the ODH level requirment around the proposed laser alignment table within the Injector cave due to egress challenges during alignment tasks. C100 style cryomodule venting plans may reduce ODH issues. However, future C50 style cryomodule venting may not allow for this reduction and may require further evaluation.

Good Practice:

During commissioning, radiation measurements will be taken while intentionally steering and losing beam. This will help RadCon evaluate assumptions like, “1% continuous loss.” Vashek noted that the planned 10 BLMs will be very useful during the x-ray radiation assessment, with the additional monitoring provided by RadCon. The Radiation assessment appears to be well thought out and RadCon’s proposal to perform radiation baseline tests is an endorsed suggestion.

*4) Is the Radiation assessment commensurate with the intended operations (keV and high current, MeV and low current)?*

**Committee Response:**

Met

As of this review, the radiation assessment was commensurate with the intended operations at both keV and MeV energies.

However, some concerns raised during the Radiation Assessment presentation need to be addressed prior to startup of beam operations.

1. It was unclear if the Radiation Assessment took into consideration 100nA average current at 10MeV delivered to the elevated beamline and stopping just upstream of the HDIce target.
2. There is a question of radiation safety above the height of the wall and inside the Control Room and shielding will need to be in place to mitigate this concern.
3. Localized or shadow shielding was discussed at length for different locations but the amount, shape and exact placements were not discussed in detail.
4. RadCon suggested baseline measurements to be conducted to evaluate the effectiveness of the proposed shielding. Concerns were with higher currents and were associated with all proposed Energies within the UITF plans. Baseline measurements would also aid in the decision to exclude personnel access to the mezzanine during UITF operation at any current.
5. The trenches leading from the cave to exterior areas (like the Control Room) may need additional shielding to reduce radiation potential. RadCon will need to further analyze to propose mitigation.
6. Operation at low voltage and current are fine. However higher voltages and currents rely on new beam current monitor system, which should be reviewed separately. Laser Safety Shutter system needs to be finalized.

*5) Are the intended postings and beacons adequate and appropriately placed? Too much signage or too little?*

**Committee Response:**

As of this review, The Team was not presented with the exact plan for sign and posting placement so this charge cannot be answered. However, several committee members wanted to express the following comments:

1. It was not clear what the intended signage would be. Recommended postings include ODH, High Voltage, Laser, Magnetic Fields (if higher than 5G, about 1ft from the source), and Radiation warning beacons, and beacons outside cave at both entrances to restrict access when RF/Beam is on.)
2. The placement of signs and beacons were briefly discussed in individual topical areas during the review. The types of signs to be utilized and the nature of the beacons were not discussed but if similar to CEBAF, LERF or GTS applications, they may be adequate based on final placement.
3. Signage may need to expand to mezzanine access point based on RadCon measurements.
4. Beacons for high-voltage indication for the Klystrons and other high-voltage supplies on the mezzanine were discussed and need to be reviewed before continuing.
5. A concern was noted due to the volume of the PSS klaxon and its proposed placement within the Injector Cave as it may exceed local hearing exposure levels if the radiation shielding does not dampen the noise level outside the Cave. An Industrial Hygiene assessment may be in order after installation.
6. One of the biggest challenges to signage is to advertise known hazards without adding so many signs that they are all ignored. The hazards here are fairly minor so not that many signs may need to be displayed. Since the caves will only be cleared on rare occasions for laser alignment purposes, for example, the only laser safety signs necessary are on the laser enclosures outside the cave and the one box in the cave. Temporary signs can be put up during laser alignment. Beacons should be designed to be informative as well. Lighted signs are preferred over just a flashing light.

6) *Is the intended documentation adequate?*

**Committee Response:**

Partially Met

As of this review, The Team was presented with limited documentation and procedures. However, The Team believes that the documentation will be adequate if they utilize safety documentation and operational guidance already in existence in other JLab accelerators. Comments from The Team are shown below.

1. Specific documentation was not shown as they are not yet complete. However the plan for the documentation (COO, TOSPs, OSPs) seems to be conceptualized, understood and once complete, should be adequate. These should be in place before operation.
2. There will be one LOSP to cover both the Cave and the laser room.

# Review Committee Comments

The Team had a number of additional comments or discussion points from the individual presentations and UITF tour which may not have direct correlation to the six charge questions above but are summarized below.

1. Operational concern: Though not a safety issue the parked status of the ¼ cryomodule shield was not clear. LN2 vs. He at 80K
   1. If 80k is to be used as the shield temperature the heat load on the He circuit will be higher and may affect cryomodule operation.
2. Training was shown to be important but an actual required training list for UITF workers was not presented.
3. While a Rapid Access System could provide a time savings during entries into the Cave, it is not projected to be needed as the beam energy is low enough as not to produce activation. The expense, lack of labor resources and limited return on investment were concerns.
4. How will people know we are running keV beam or MeV beam? Good question – We do not have this for the main machine and the practice is to exclude personnel regardless of machine energy or beam power.
5. A crash button will live inside the Control Room as part of the PSS.
6. Assuming the top of Cave is excluded during beam delivery, is it sufficient to simply add a chain across the stairway, at the bottom of the stair. e.g. With the chain suspended across the stair as part of a sweep procedure? – This should be sufficient as it is done elsewhere at the lab with proper postings.
7. We must agree upon a current threshold for the PSS BCM to trip OFF beam. Vashek suggested 200nA is a good trip set point, for allowed operation at 100nA
8. Question: Do BCMs read average current while in Tune Mode? Or do they read peak current, 8uA in Tune Mode? In which case we will trip OFF beam whenever we go to Tune Mode. Must ask Trent
9. Steve Benson recommends tallying up the Voltage and Current values of all of the UITF power supplies, which would be part of the general hazard assessment.
10. Class 4 Laser at 780 and 1560 nm – The use of armored fibers for beam delivery greatly reduces the risk for accidental exposure. During the presentation, the location of the safety shutters was not fully developed. This should be decided upon as soon as possible. The use of a fiber injected class 3R laser is also a great idea for allowing detailed alignment of the optics in the vault without the presence of a laser hazard. This should minimize the time necessary to clear the vault for laser alignment. This is a necessary feature of the system since they do not have any “laser permit” state in the PSS. They will have to do laser alignment under administrative control. This is not ideal but is allowable if done very infrequently.
11. Vacuum Systems – Pumps (Is there a need for hearing protection?) Most oil free pumps are pretty quiet. They should provide and exhaust for the roughing pumps, especially those pumping on the SF6 system. For the most part, the vacuum system is very standard and hazards can be addressed by SOPs.
12. Electrical and Magnets Systems:
    1. Ion pumps – Ion pumps are run in a standard fashion with red HV cables and approved connectors. Assuming that OSPs are followed during construction, maintenance, and repair work on the vacuum system, there should be no new hazards present.
    2. Magnet terminals and fields – The magnetic fields are moderate and the magnet power supplies are generally low voltage. Some of the dipole supplies are relatively high current and should have their leads covered. The solenoid and corrector supplies are low current and voltage and so do not present much of a hazard.
13. Cryogenic fluids
    1. Liquid Helium to differing ¼ cryomodules to be used during life of facility
    2. 500 L and 1000 L liquid Helium for HDIce
    3. Nitrogen gas line

The caves are very well ventilated. The idea of venting the C100 guard vacuum back into the exhaust lines enhances the safety as well. The ODH hazards have been adequately mitigated.

1. Non-ionizing Radiation
   1. Warm RF (Buncher and Chopper systems)
   2. High Power RF to ¼ cryomodule

Standard OSPs for RF should be adequate for safe operation. There are no additional hazards that we deal with all the time in CEBAF.

1. Ionizing Radiation - During UITF beam operation, or field emission from ¼ CM and gun, the shielding calculations are messy due to the complicated nature of the caves. Measurements of the radiation dose rates outside of the caves should be done during commissioning to verify that dose rates are reasonable.
2. Access Controls
   1. Levels of Access (Restricted/Beam Permit)
   2. Sweep procedures (prior to beam operations)
   3. Access control procedures post-beam operations

The access controls, for the most part, are quite similar to those used in the GTS. These have been very safe and reliable. Since there is no risk of activation in the vault the system can be rather simple.

1. BCMs (<100 nA into Cave 2) – Since the energy from the UITF is low, no activation should occur. The hazards are then from the prompt radiation during operation. The key element here is the addition of a beam current monitor (BCM) into the PSS. Jefferson Lab normally does not rely on BCMs to keep radiation levels low. The design and implementation of the current monitor should be the subject of a separate review with a good representation by subject matter experts. An example of such a review for a new system is the review of the Alignment Mode system in the LERF. This was an entirely new system that had to be reliable, redundant, and safe under all circumstances. The same is true for this BCM.
2. Further discussion is needed regarding Credited Controls for the UITF that result in the selection of technology.
3. There needs to be a follow up on the design, testing, and implementation of the Credited Control technology according to the Conduct of Engineering Manual if it is not in current use as a Credited Control in the CEBAF or LERF accelerators.
4. The Safety Configuration Management Board (SCMB) needs to review the Credited Control choice and concur that it mitigates the unacceptable hazard to an acceptable hazard.

# Conclusions

The Team found that the UITF Project has thought through the majority of safety concerns with regard to the operation of the UITF. One outstanding issue to be resolved is the control of beam operation above 100nA to limit beam generated hazards to equipment and personnel exposure. Follow up is needed for the design, testing, and implementation of the Credited Controls technology according to the Conduct of Engineering Manual if it is not in current use as a Credited Control in the CEBAF or LERF accelerators.

Other issues identified during the UITF Safety Review are summarized below and explained in further detail in Section 4.0 of this report.

1. Hazards which were not addressed were, Fall Protection when working on the raised beamline components; a Life Safety Assessment needs to evaluate the UITF to ensure safety of workers and code compliance; and trip hazards due to the installed Earthquake bracing should be addressed.
2. Further attention is needed for the following mitigations: other means of accessing and working on the components in the raised beamline section needs to be evaluated; a separate review of beam components which address > 100nA beam is needed; Laser Safety Shutter details need to be finalized; mechanical means of locking the UITF cave needs to be evaluated; Lock Out Tag Out needs to be addressed during Gun High Voltage power supply connections; a design review for the downconverter will need to be performed for proper safety function and effectiveness; and Pressure Vessel sign off needs to be clearly defined for the SF6 Tank.
3. Radiation shielding needs to be further evaluated and developed to ensure the identified gaps are mitigated.
4. Sign usage and postings plans need further development.
5. Specific procedures for operation and maintenance (COO, ESAD, OPSs, etc.) need to be further developed and finalized before commencement of commissioning and beam operation of the UITF.

With the exception of the BCM and beam limiting controls, the remaining hardware items are well defined and the work is progressing. The Team endorses operation following completion of these remaining items.

# Acknowledgements

The Team would like to thank the JLab staff and management for arranging walkthroughs of the UITF facility, the individual and safety specific presentations, and the presenters’ thorough responses to our questions throughout the safety review. We appreciate the opportunity to contribute to this research project.

Thanks to all the JLab staff who helped to make this review an educational experience. Special thanks to Matt Poelker for making this review process enjoyable and productive.

Harry Fanning, Chair

Thomas Jefferson National Accelerator Facility

# Appendix A: Schedule of the UITF Review Activities

|  |  |
| --- | --- |
| **Tuesday, 10 May 2016** | |
| **SESSION** | **Test Lab (Rm 1227)** |
| **1300-1340** | **UITF Tour (Committee Only) – Matt Poelker et al.** |
| 1340-1450 | UITF Safety Review In-Brief – Matt Poelker |
| **1450-1500** | **BREAK** |
| 1500-1540 | UITF Shielding Assessment – Vashek Vylet |
| 1540-1635 | ODH Assessment for UTIF and HDIce – Hari Areti |
| **1635-1645** | **BREAK** |
| 1645-1720 | Laser Safety for UITF – John Hansknecht |
| 1720-1730 | Conclusions – Matt Poelker |