

Operation Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops



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1. PURPOSE

The University of Pennsylvania, in coordination with the Office of Environmental Health and Radiation Safety, is committed to provide the Penn community with a safe and healthful environment. The Operation Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops provides information to assist faculty, staff and students operate and use these facilities safely.

2. APPLICATION

This procedure applies to all makerspaces, robotics laboratories and academic/research support shops at Penn.

3. GLOSSARY OF TERMS

- 1.1. **Academic/Research Shops** - Shops that support academic, research, athletic, museum and performing arts programs. Includes vehicle maintenance shops and facilities support shops at the Morris Arboretum and New Bolton Center campuses. Facilities & Real Estate Services shops are not covered under this program.
- 1.2. **Control of Hazardous Energy - Lockout/Tagout (LOTO)** - A machine/equipment-specific procedure to control hazardous energy and ensure that it is locked out in a zero-energy state.
- 1.3. **Engineering Controls** - Physical controls such as guards, partitions/barriers, and ventilation to reduce hazards.
- 1.4. **Hot Work** - Work that involves burning, welding, cutting, brazing, soldering, grinding, using fire or spark producing tools or other work that produces a source of ignition.
- 1.5. **Makerspace** - A place in which people with shared interests, especially in computing or technology, can gather to work on projects while sharing ideas, equipment, and knowledge.
- 1.6. **Qualified** - Has the appropriate background, knowledge and skills for the safe operation of the machine and equipment involved.
- 1.7. **Robotics Laboratory** - A makerspace or laboratory where multi-axis robots or other autonomous aircraft or vehicles are used.

- 1.8. **Supervisor** - Faculty or staff with documented professional-level experience and who have completed EHRS Shop Safety Training module.
- 1.9. **Student Project Assessment (SPA)** - A written summary of the tasks, potential hazards and materials required for the completion of a proposed student project. The SPA is completed by the student and submitted to the appropriate faculty, advisor, or shop/makerspace/robotics lab manager. The SPA facilitates proactive collaboration between all appropriate parties, including EHRS, to mitigate identified potential hazards and identify training, methods and procedures and the appropriate facilities to permit safe completion of the project.

4. RESPONSIBILITIES

- 4.1. **Environmental Health & Radiation Safety (EHRS):**
 - 4.1.1. Develop and periodically review and update the Operation Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops.
 - 4.1.2. Conduct periodic audits of makerspaces, robotics laboratories and academic/research shops to ensure use of safe work practices and compliance with applicable environmental health and safety standards.
 - 4.1.3. Complete or coordinate completion of equipment-specific control of hazardous energy-lockout/tagout (LOTO) procedures and provide training.
 - 4.1.4. Assist with selection of proper personal protective equipment (PPE). Complete and provide PPE assessment posters for the facility. Provide training on limitations and use of PPE.
 - 4.1.5. Coordinate or complete industrial hygiene services including exposure assessments, noise surveys and assessments of engineering controls.
 - 4.1.6. Review and provide recommendations on proposed renovations and new construction projects. Includes the facility, infrastructure, machinery, and equipment.
 - 4.1.7. Coordinate or provide required health and safety training.
- 4.2. **Faculty, Management and Supervisors:**
 - 4.2.1. Implement the applicable components of this program in the facility.
 - 4.2.2. Ensure that new makerspaces, robotics laboratories, shops and those that are to be renovated, comply with current health and safety design standards and Penn's Design Guidelines for Makerspaces, Robotics Laboratories and Academic/Research Shops.
 - 4.2.3. Restrict facility access to those who have been trained and qualified.
 - 4.2.4. Provide supervision of students working in the facility.

- 4.2.5. Halt unsafe operations.
 - 4.2.6. Require completion of and review Student Project Assessments. Provide authorization to student prior to allowing the project to commence.
 - 4.2.7. Coordinate completion of initial and updated personal protective equipment posters for the facility with EHRS.
 - 4.2.8. Provide required personal protective equipment and enforce correct usage.
 - 4.2.9. Store materials including chemicals and combustible materials properly.
 - 4.2.10. Inspect, service and maintain machinery and equipment according to the manufacturer's recommendations.
 - 4.2.11. Maintain housekeeping to prevent clutter and buildup of dust and other combustible materials. Keep isles and areas around emergency eyewash and shower equipment clear.
 - 4.2.12. Notify EHRS of new acquisitions and installations of machinery, 3D printers or robots to facilitate completion of an equipment-specific risk assessment and safety analysis.
 - 4.2.13. Remove from service and restrict use of machines, equipment and robots discovered to be damaged or have safety deficiencies. Coordinate repairs or replacement.
 - 4.2.14. Maintain Safety Data Sheets (SDS) for hazardous chemicals, 3D printing feedstock and welding rods.
 - 4.2.15. Cooperate with EHRS to resolve any issues identified during health & safety audits.
- 4.3. **Students:**
- 4.3.1. DO NOT WORK ALONE.
 - 4.3.2. Comply with the applicable components of this program and rules of the facility.
 - 4.3.3. Receive training and demonstrate competency on the machines, equipment, robots or tools used in the facility.
 - 4.3.4. Report damaged machinery, equipment, robots or tools or those with other safety deficiencies to the facility supervisor or management.
 - 4.3.5. Use appropriate personal protective equipment.
 - 4.3.6. Complete and submit a student project assessment (SPA). Typically, a SPA is required for projects that include the use of hazardous chemicals, electricity, hot work, or other potentially hazardous tasks. The SPA is also required for projects where the end product may behave unexpectedly during startup or use. Submit to the appropriate faculty, advisor or makerspace/shop manager for review and approval prior to commencement of the project. See section 7.2 for additional details on the SPA.
 - 4.3.7. Eat and drink in designated areas only.

5. TRAINING/QUALIFICATIONS

This section highlights the training and qualifications required for those using makerspaces, robotics laboratories and academic/research shops.

5.1. **Supervisors:**

- 5.1.1. Supervisors must have demonstrated experience with the machinery, equipment or robots and related safety systems within the facility. This may include formal or technical training combined with experience and training provided by or coordinated by the manufacturer or distributor.
- 5.1.2. Complete online EHRS Shop Safety training module.
- 5.1.3. Machinery & equipment manuals shall be reviewed and maintained on site. The manuals shall be used as a reference to develop standard operating procedures (SOPs) for the safe use of the specific machine, equipment, or robot as it will be used in the facility. The SOP shall be used as a reference to assist with the hands-on training provided to staff and students.
- 5.1.4. Supervisors may require Control of Hazardous Energy-Lockout Tagout (LOTO) training to place and maintain machinery, equipment, or robots in a safe state for maintenance or service. EHRS will assist with development of appropriate LOTO procedures and training.
- 5.1.5. Use of chemicals requires completion of EHRS Hazard Communication Training. Contact [EHRS](#) to identify the appropriate training course.
- 5.1.6. Personal protective equipment - Understand the limitations of and how to wear and store personal protective equipment properly. Know the location of and be familiar with the personal protective equipment poster in the facility so it can be used for future reference.
- 5.1.7. Emergency procedures, including the location of and how to use the emergency eyewash and safety shower and how to respond to injuries.

5.2. **Staff:**

- 5.2.1. Complete the online EHRS Shop Safety training module and the appropriate hands-on training for the machinery, equipment or robots used in the facility.
- 5.2.2. Personal protective equipment - Understand the limitations of and how to wear and store personal protective equipment properly. Know the location of and be familiar with the personal protective equipment poster in the facility so it can be used for future reference.
- 5.2.3. Use of chemicals requires completion of EHRS Hazard Communication Training. Contact [EHRS](#) to identify the appropriate training course.

5.2.4. Emergency procedures, including the location of and how to use the emergency eyewash and safety shower and how to respond to injuries.

5.3. **Students:**

5.3.1. Combination of academic/programmatic and hands-on training by the academic program and the facility supervisor or designated staff. The student must demonstrate proficiency to the trainer to be deemed qualified to operate the machinery, equipment, or robot within the facility.

5.3.2. Where hazardous chemicals are used, receive training from EHRS. Use of hazardous chemicals should be identified in the Student Project Assessment.

5.3.3. Personal protective equipment - Understand the limitations of and how to wear and store personal protective equipment properly. Know the location of and be familiar with the personal protective equipment poster in the facility so it can be used for future reference.

5.3.4. Emergency procedures, including the location of and how to use emergency eyewash and safety shower and how to respond to injuries.

6. ACCESS CONTROL and SUPERVISION

6.1. **Facility Access** - Access to facilities that contain hazardous machinery, equipment or robots shall be restricted to those who have been qualified by the supervisor or designed staff member(s) of the facility. Qualification includes a signed copy of the student code of conduct/facility rules and the specific machinery, equipment, power tools or robots the individual is qualified to operate within the facility.

6.2. **Machinery, Equipment and Robot Access** - Higher risk machinery including milling machines, lathes, woodworking machinery, robots and welding equipment must have the capability to be locked out of service either by restricting access to the facility or by isolating the power to the individual machine, equipment, or robot. This will typically include restricting access to or locking out the higher hazard equipment in facilities that permit unsupervised access for completion of low-risk tasks.

6.3. **Supervision** - Students shall be supervised by a qualified makerspace, shop, or robotics laboratory staff member. Undergraduate students may not supervise other students.

6.4. **Buddy System** - A buddy system must be implemented when anyone is working with hazardous machinery, equipment, or robots or while performing potentially hazardous tasks, including those using chemicals within a makerspace, robotics laboratory or shop.

There must be a properly qualified person within sight and sound of the other person that can turn off the machine or otherwise control the hazard, render assistance, and contact help.

- 6.5. **Hours of Operation** - Since fatigue has been shown to be a major contributor to accidents and injuries, access to hazardous machinery, equipment or robots shall be restricted after 12:00 AM.

7. GENERAL INFORMATION and SAFE WORK PRACTICES

7.1. **Proper Attire:**

- 7.1.1. Long pants, closed-toe sturdy shoes, short or long sleeve shirts with tight cuffs.
- 7.1.2. Jewelry including rings, necklaces, bracelets, wristwatches, and identification badges hanging from chains or lanyards shall not be worn while operating machinery and power tools.
- 7.1.3. Drawstrings associated with jacket or sweatshirt hoods must be secured.
- 7.1.4. Tie back and tuck loose hair completely inside the collar when operating machinery with rotating parts. Hair nets or hats that fully contain the hair are other options to secure hair.
- 7.1.5. Headphones and earbuds shall not be used in makerspaces, robotics labs or shops.

7.2. **Student Project Assessment (SPA):**

- 7.2.1. The purpose of the SPA is to have the student consider and document the tasks and materials required to complete the project prior to its commencement. The SPA facilitates collaborative health and safety review by the student and the appropriate faculty, shop/makerspace management and if needed, EHRHS. The collaborative review of the proposed project aids in identifying potential hazards and ensures that the student has the appropriate training /qualifications and that the facilities used are appropriate for the safe completion of the project.
- 7.2.2. Requirement for SPA completion:
 - 7.2.2.1. A SPA shall be completed when the project requires the use of hot work or tools, equipment, machinery, or chemicals that differ from those routinely used in the facility or within the course of study. Completion of a SPA is also required for students who must complete projects but are not affiliated with a shop or makerspace. In this case, the SPA shall be submitted to and reviewed by the appropriate faculty or advisor that assigns the projects. The faculty or advisor may refer the student to the appropriate shop, makerspace or EHRHS to identify a pathway to complete the project safely. Example: Completion of a carbon fiber composite bird

house in a wood shop would require completion of a SPA since carbon fiber composites are not typically used in a wood shop.

- 7.2.2.2. A SPA is not required for projects that are considered routine and within the student's level of training/qualifications and consistent with those typically completed within the shop or makerspace. Example: Completion of a wood bird house in a wood shop.
 - 7.2.3. Faculty, advisor, or makerspace/shop supervisor or designee shall review and sign each SPA and maintain it for the duration of the project.
 - 7.2.4. EHRS shall be consulted for identified hazards outside the areas of expertise of the faculty, advisor, or makerspace/shop staff, and when the need for additional safety training is identified.
 - 7.3. **Machine Guarding and Robot Risk Assessments:**
 - 7.3.1. Contact EHRS for assistance in developing equipment specific risk assessments if required. Refer to Penn's [Machinery, Robotics and Power Tool Safety Program](#) for additional procedures and information.
 - 7.4. **Machinery, Equipment and Robot Condition Assessment:**
 - 7.4.1. Machines, equipment, and robots shall be inspected prior to each use to ensure that safeguards and safety systems such as emergency stops, and brakes are in place and functional. Detailed information on machinery, equipment and robot safety guarding and safety systems is available in Penn's [Machinery, Robotics and Power Tool Safety Program](#).
 - 7.4.2. A program must be in place to remove machinery, equipment, power tools or robots that require service or do not pass the pre-use safety inspection from service. Power should be isolated and secured under administrative lockout/tagout and a conspicuous tag or signage installed indicating it has been removed from service.
 - 7.5. **Control of Hazardous Energy-Lockout/Tagout (LOTO):**
 - 7.5.1. A lockout/tagout (LOTO) procedure must be established for all equipment, machines, and robots capable of unexpectedly releasing stored energy. The LOTO procedure is used to place systems in a zero-energy state to allow safe performance of repairs, maintenance, or adjustments. The procedure must be developed in accordance with [Penn's Control of Hazardous Energy-Lockout/Tagout Program](#). Contact EHRS for assistance in developing equipment specific LOTO procedures if required.

7.6. **Battery Charging:**

- 7.6.1. Charging of lead acid and lithium polymer batteries may only occur in designated areas. Contact [EHRS](#) to review specific requirements.
- 7.6.2. Please refer to the [EHRS Lithium Battery Safety Program](#) for information about setting up designated charging areas and other safety information related to charging and use of lithium polymer(LiPo) batteries.

7.7. **Hoists & Gantry Cranes:**

- 7.7.1. Only designated personal may operate hoists or gantry cranes and must complete EHRS hoist safety training.
- 7.7.2. Hoists and associated lift chains and slings shall be inspected prior to each use according to the manufacturer's instructions.
- 7.7.3. Electrically powered hoists shall be inspected at least annually by a qualified person. A hoist/crane service vendor completes this inspection.
- 7.7.4. Hoists and gantry cranes shall be serviced and maintained according to the operations and maintenance manual.

8. DESIGN of NEW FACILITIES or RENOVATIONS

The presence of high-tech equipment and machinery on campus is rapidly expanding. The facilities where the equipment and machinery are installed must be evaluated to ensure they are appropriate to allow for safe operation. [The Design Guidelines for Makerspaces, Robotics Laboratories and Student/Research Shops](#) exists to assist design professionals and end users within the schools and centers to proactively consider health and safety in their selection of machines and equipment and the design of the facilities where they are used.

9. MACHINERY, EQUIPMENT & ROBOT PROCUREMENT

- 9.1. EHRS should be notified of plans to purchase machinery, robots and equipment including laser cutters and 3D printers prior to committing to the purchase. This is to ensure that the equipment is suitable for the application and use location from a safety perspective. Certain types of robots may require extensive safety guarding and interlock systems. Equipment including 3D printers, laser cutters and woodworking machinery may have specific and sometimes extensive, ventilation/exhaust and dust capture requirements.
- 9.2. All electrically-powered machines, equipment and robots must be listed or labeled by a [Nationally-Recognized Testing Laboratory \(NRTL\)](#). This is primarily driven by Occupational Safety & Health Administration (OSHA) standards and the Philadelphia Fire Code, which requires minimum safety requirements for machines and equipment used in the workplace.

It is important to note that many popular lower-cost 3D printers do not carry a NRTL listing or labeling. It is important to inquire about this prior to procurement.

10. HAZARDOUS WASTE & BATTERY MANAGEMENT

- 10.1. No chemicals shall be disposed of in sinks or drains. Waste chemicals such as 3D printing processing baths shall be collected in a container provided by EHRS. EHRS will also provide a secondary containment basin and chemical waste identification hang tags to be attached to the container.
- 10.2. EHRS will also dispose of unwanted oil-based paints and other chemicals in their original containers. Latex paints should be left open to dry and once solid, disposed of in the regular trash.
- 10.3. Request waste chemical collection by completing the [online form](#) on the [EHRS web site](#).
- 10.4. EHRS will collect and recycle lead acid and rechargeable batteries for recycling. More detail on this program is available on the [EHRS battery disposal page](#) on the [EHRS web site](#).

11. PERSONAL PROTECTIVE EQUIPMENT (PPE)

Each makerspace, robotics laboratory or academic/research shop shall coordinate completion of a personal protective equipment assessment poster and post it in conspicuous locations within the facility. The PPE assessment identifies the PPE required for the use of each tool, machine, robot or completion of a particular task. Contact [EHRS](#) to develop the poster for the use of the machines equipment and tasks completed within the facility. Notify EHRS of additions of machines, equipment, robots or new or changed tasks that may require updating of the poster.

12. RECORDKEEPING

- 12.1. The supervisor shall document and maintain all classroom and/or hands-on training and qualification records of students and staff who use the facility. The qualification record must indicate the machinery, equipment, or robots that the individual is authorized to use. Training documentation must include curriculum and training dates. Training records shall be maintained for as long as students and employees use the facility.
- 12.2. The supervisor shall maintain each Student Project Assessment (SPA) for the duration of the student project.

- 12.3. Safety Data Sheets (SDS) for hazardous chemicals, welding rods and 3D printing media shall be maintained in a binder at the facility. EHR will assist with the initial inventory and provide a binder. Supervisor or designee is responsible for maintaining the SDS binder as new materials are added.
- 12.4. The supervisor shall maintain all hoist or gantry crane inspection and service records.
- 12.5. Control of hazardous energy-lockout/tagout procedures shall be posted by each machine that requires one. EHR also maintains a copy of each procedure in a database.
- 12.6. EHR/Knowledge Link shall maintain training records of any EHR-coordinated training.

13. HEALTH & SAFETY AUDITS

- 13.1. EHR shall complete routine safety audits of shops, makerspaces, and robotics laboratories. Safety audits are typically completed at least annually.
- 13.2. Shop supervisors are encouraged to use the [EHR Machine & Power Tool Checklist](#) to routinely complete self-audits of their facilities.

14. EMERGENCIES & INJURIES

- 14.1. **Chemical splash to the eyes or body** - Use the emergency shower or eyewash in the facility and rinse for 15-minutes. Seek medical care.
- 14.2. **Medical care** - Emergency - Contact PennComm at 511 from a campus phone or 215-573-3333 from a cell phone to request an ambulance. For non-emergency injuries, Faculty and staff should visit Occupational Medicine located at HUP - 3400 Spruce Street - Ravdin Building 2nd floor during normal work hours and the HUP emergency department located on Ravdin ground floor after hours. Students should visit Student Health Services located at 3535 Market Street during normal business hours and the HUP emergency department located at HUP Ravdin ground floor after hours.
- 14.3. **Chemical spill** - Contact EHR at 215-898-4453 at any day or time.
- 14.4. **Injury reporting** - Notify EHR of all injuries. Injuries requiring medical treatment must be reported to EHR at 215-898-4453 as soon as possible.

- 14.5. **Close call/near miss incidents** - Please notify EHRS of any close calls/near miss incidents. In many cases, lessons learned can be shared to improve health and safety within our community. EHRS can anonymize information so that only the relevant safety information is shared within our community.

15. RELATED PENN SAFETY PROGRAMS

The following safety-related programs may apply:

- 15.1. [Machinery, Robotics and Power Tool Safety Program](#) - Provides specific safety information and requirements related to machinery, robots and power tools.
- 15.2. [Control of Hazardous Energy – Lockout/Tagout Program](#) - Adjustment, maintenance or repairs that pose a risk to the individual performing the work in the event of the release of stored release or activation while the work is being performed require specialized training and procedures.
- 15.3. [Hearing Conservation Program](#) - Contact EHRS to assess noise exposure associated with equipment.
- 15.4. [Personal Protective Equipment Program](#) - Contact EHRS to perform hazard analysis of tasks to assist in recommending specific personal protective equipment.
- 15.5. [Lithium Battery Safety Program](#) - Comprehensive lithium battery safety program and checklist.
- 15.6. [Penn Electrical Safety Program](#) - Penn's program includes specific information and requirements for research and development laboratories.
- 15.7. [Design Guidelines for Makerspaces, Robotics Laboratories and Student/Research Shops](#) - Provides safety-related information to be incorporated into the planning and design of new facilities or those undergoing renovations.

16. SHOP SAFETY LISTSERV

EHRS maintains an email Listserv to help facilitate communication within the Penn makerspace, robotics laboratory and academic/research shop community. EHRS shares safety and other timely information to the community and encourages the community to use the Listserv to reach out with any questions or other information. The goal is to provide an easy method for the community to share information and resources with one another. Contact [EHRS](#) to be added or removed from the Listserv.

17. REFERENCES/RESOURCES

- 17.1. NIOSH Science Blog - [Characterizing 3D Printing Emissions and Controls in an Office Environment](#)
- 17.2. Robotics Industry Association (RIA) - [Safety standards](#)
- 17.3. [Penn 3D Printing Fact Sheet & Guide](#)
- 17.4. [EHRS Machine & Power Tool Checklist](#)
- 17.5. [Student Project Assessment \(SPA\) Form](#)