

NIST Collaborative Robotics Testbed

Standard Operating Procedure: Human-Subject Testbed Setup and Adjustments

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Last modified author (name and contact email): Jeremy Marvel, jeremy.marvel@nist.gov

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- First draft of the SSOP

1 Overview

This document outlines the safe standard operating procedures for the setup and modification to the human subject studies testbed for the collection of data for human-robot interaction research. This and related processes require the use of powered tools, some of which are considered hazardous to use. Operators of these tools shall be trained in their use. Training includes reading and demonstrating understanding of this document.

The standard operating procedures described in this document are provided to ensure the safety of activities involving constructing and modifying the human study testbed. This document is intended to serve as both training, and as a reference guide for the handling of materials and equipment. A copy of this document shall be kept present with the human study testbed for reference during setup and future modifications.

Access to the testbed and related components and tools is considered restricted to authorized personnel only.

2 Before You Begin: Safety

Be aware that the construction process includes the use of powered tools, which can cause injury if misused. Proper safety precautions shall be taken. The specific hazards associated with these tools and other related equipment are provided in the First Level Hazard Review (FLHR) repository (<https://mmlweb.nist.gov/safety/>).

The following FLHRs are specifically identified for the following activities, and are not covered in this SOP:

Activity Name (ID)	Associated Activities	Link
Collaborative Robotics Research (735.13.0001)	Installing or modifying the testbed's attached robot	https://mmlweb.nist.gov/safety/activities/10355
Collaborative Robotics Laboratory Laser Cutter (735.13.0059)	Using the laser cutter to create components for the testbed	https://mmlweb.nist.gov/safety/activities/6464
Material Machining Using a CNC Mill (735.13.0084)	Using the CNC mill to manufacture parts for the testbed	https://mmlweb.nist.gov/safety/activities/10328
Resin-Based 3D Printing (735.13.0096)	Using resin-based 3D printers to create parts for the testbed	https://mmlweb.nist.gov/safety/activities/9707
FDM-Style 3D Printing (735.13.0021)	Using filament-based 3D printers to create parts for the testbed	https://mmlweb.nist.gov/safety/activities/9992

2.1 Tool Storage

All tools, when not in use, shall be stored in the appropriate tool chests to ensure easy location, access, and protection against accidental activation or contact with personnel. These tool chests include locks to prevent unauthorized access to tools with specific hazards (e.g., utility knives, drill bits, and power tools).

Locking tools in the tool chests to prevent unauthorized access/use is recommended, but not required, as additional activities in the laboratory may require their use.

2.2 Eye Safety

2.2.1 Material Contact with Eyes

Some tasks associated with this activity, such as cutting and drilling, may present hazards that could result in eye injury. The use of eye protection is required for personnel working on or near the human subject testbed during setup and maintenance. Eye protection includes the proper use of PPE such as safety glasses.

Proper PPE removal procedures shall be used.

Safety glasses shall be disposed of properly if damaged.

2.2.2 Laser Safety

Some tasks may involve the use of class 1 lasers for alignment and measurement purposes. Even though class 1 lasers are considered "eye safe," care shall be taken to avoid accidental direct exposure of the eyes to the laser beams. Lasers shall be turned off while not in active use, and the use of safety glasses that include laser protection is strongly recommended.

Proper PPE removal procedures shall be used

Safety glasses shall be disposed of properly if damaged.

2.3 Hand/Skin Safety: Metal and Plastic Particulates and Shavings

Skin contact to materials removed from component parts of the testbed may result in small cuts, lacerations, punctures, or other injuries. The use of skin protection is strongly recommended when using drills or cutting tools so long as the use of PPE does not introduce new hazards (e.g., protective gloves and clothing may become engaged with cutting surfaces of power tools, resulting in significant injury). Skin protection includes the use of gloves (nitrile gloves are provided for general purpose use) and protective clothing (lab coats are provided for general purpose use).

Nitrile gloves shall be disposed of after use.

2.4 Respiratory Safety

Some tasks may generate particulates that may become airborne cause respiratory irritation. Dust masks are provided and required when drilling, cutting, grinding and sanding using powered tools.

Tasks involving lubricants, paints, or other chemicals shall be conducted in a well-ventilated area, preferably outdoors in fair weather. Aerosols, sprays, or related application mechanisms shall be used outdoors while wearing a provided dust mask.

Respirators are not required.

3 Activity: Drilling, Cutting, and Grinding

Always wear appropriate eye protection when using drills, cutting tools (hand saws, rotary tools, utility knives, etc.), and grinding tools (orbital sanders, rasps, rotary tools, sand paper, etc.).

3.1 *Drilling:*

1. Always keep hands and fingers away from the drill bit.
2. Properly secure all loose parts/components before attempting to drill materials.
3. Clean up any material waste by vacuuming any loose particulates from the floor and work surface.

3.2 *Cutting:*

1. Always cut away from yourself and others.
2. Properly secure all loose parts/components before attempting to cut materials.
3. Keep limbs and loose clothing away from the cutting surface.
4. Clean up any material waste by throwing large waste pieces into the trash, and vacuuming any loose particulates from the floor and work surface.

3.3 *Grinding:*

1. Always remove material away from yourself and others.
2. Properly secure all loose parts/components before attempting to grind surfaces.
3. Keep limbs and loose clothing away from the grinding surface.
4. Do not use grinding tools near flammable materials, as metal parts may eject hot sparks that could ignite and create a fire hazard.
5. Clean up any material waste by vacuuming any loose particulates from the floor and work surface.

4 Activity: Manufacturing Component Parts

Refer to the appropriate FLHR(s) discussed in Section 2 for SOPs involving the laser cutter, CNC mill, and 3D printers. All other manufacturing processes will be added to this section when they are identified and defined.

5 Activity: Moving/Removing Component Parts

When component parts are to be added to or removed from the testbed, the activity may involve handling parts that are heavy or sharp, and may therefore present pinching, cutting, or scraping hazards. Occasionally, cutting or striking tools may be required to separate parts from the testbed. During the removal process, nearby, unsecured parts may fall or be ejected from the testbed surface, presenting hazards to lower extremities. **Always ensure a clean working surface around the source and destination of the parts being handled.**

Specific equipment may require detailed instructions for proper handling when installing, moving, or removing. These details are provided in this section.

5.1 Robot: UR3e (mass: 11.2 kg ~17.7 lb; reach 500 mm)

1. The robot and its controller shall be disconnected from power sources (including electrical and pneumatic) before attempting to move. The robot shall be disconnected from the robot controller before attempting to move.
2. The robot shall be properly stored when not actively being used. Proper storage includes: 1) a mounting plate secured to a heavy and stable work surface, and 2) the original packaging in which the robot was shipped.
3. Before moving, ensure the proper storage solution is selected, installed correctly, and is free from nearby debris or obstructions. The travel path from the robot's current location to its destination shall also be free from debris and obstructions.
4. It is recommended, but not required, that two people work together to move the robot to ensure proper management of connected components such as ancillary equipment, tooling, and cables/hoses.
5. If the robot is currently mounted to a plate, carefully remove the bolts securing the robot to the surface. The robot must be supported during this task, as it may be in an unstable configuration that could result in the robot falling when the securing bolts are removed. Supporting the robot can be done with a single hand given its low mass.

5.2 Robot: Robotiq 2-finger adaptive gripper (0.925 kg)

1. The robotic gripper attaches to the tool flange of the robot using four retaining bolts. During installation and removal, use one hand to support the gripper while using the other to loosen and remove the bolts.
2. The robotic gripper has a rubberized signal cable that attaches to the robot arm's tool-flange I/O port. The gripper came with a plastic gasket that goes over the I/O port of the robot arm, and prevents accidental contact with the signal cable during operation.
3. The robotic gripper may remain attached to the robot while moving the robot.
4. The stock metal fingers have been replaced with 3D printed finger tips. If these finger tips break, carefully remove the retaining bolt from the finger tip and replace the damaged part with a new, undamaged finger tip.

6 Activity: Electronics Work

All work involving the construction or modification of electronic components shall be conducted at the electronics workbench at the end of the room. The electronics workbench has the appropriate tools and safety equipment to ensure personnel safety against risks of electric shock, and hazards associated with soldering processes.

When constructing or servicing electronic components, all power sources must be disconnected and/or discharged prior to working with the equipment to eliminate risk of electric shock. Personnel shall also use appropriate electrostatic discharge (ESD) equipment to prevent damage to electronic components.

Specific equipment may require detailed instructions for proper execution of electronics tasks. These details are provided in this section.

6.1 *Soldering*

1. Any activity involving melting solder (e.g., soldering components, or using a heat gun to reflow solder) requires the use of a desktop fume extractor. Fume extractors are already installed and powered at the electronics workbench.
2. The soldering irons in the human-robot interaction lab have adjustable heat settings. Set the soldering iron temperature to the lowest setting required to melt the solder.
3. To avoid burn hazards, use clamps or helping hands to hold parts being soldered, and allow the parts to cool for several minutes before attempting to handle with bare hands.

6.2 *Cutting, Stripping and Crimping Wire*

1. Always use wire cutters to cut wire and cable. Do not use scissors or knives.
2. Always use wire strippers to remove the protective sheathing from wire and cables. Do not use a knife.
3. Always use a dedicated wire crimper to affix connectors, plugs, and attachments. Do not use pliers, tweezers, hemostats, or other grasping tools.

7 Activity: Laser Measurement and Alignment

Laser equipment may be used for measurement (e.g., distance measures) and alignment (e.g., laser pointers) purposes. Only class 1 (eye safe) laser equipment may be used during testbed setup and adjustment activities.

Laser-cutting shall be done in accordance with NIST FLHR 735.13.0059.

8 Activity: Moving the Testbed

When changing the location of the testbed within the human-robot interaction laboratory, loose objects may fall from testbed surface and become tripping hazards. The robot, controllers, and all ancillary equipment and sensors shall be rigidly affixed to the testbed.

9 Emergency Response Plan

9.1 Event: Fire

In the event of fire, immediately contact NIST Safety at x2222 to report the fire.

Authorized personnel may use an approved ABC fire extinguisher (combustible materials, flammable liquids, and flammable gases) to attempt to extinguish the fire. Acceptable fire extinguisher types include dry powder, alcohol-resistant foams, and carbon dioxide.

Do not use water to combat fires. Water may spread the flames.

9.2 Material Hazards

9.2.1 Event: Contact with Hot Tools or Parts

Cutting, drilling and grinding processes generate heat, and certain materials may retain a high temperature after cutting for several minutes. Should accidental contact occur, immediately check all impacted personnel for potential injuries such as cuts or burns, contacting NIST Safety at x2222 if there has been an injury.

9.2.2 Event: Tool Breaks or Loose Workpiece

Operations involving powered tools may result in cutting implements breaking or workpieces being forcibly ejected. If such events occur, recover any lost pieces of the damaged tools or parts and properly dispose of them; these pieces may have extremely sharp edges/points, so proper PPE is required when handling broken components.

Contact NIST Safety at x2222 if there has been an injury.

9.2.3 Event: Removed Material Contact with Skin or Eye

The removed material from the workpiece—and the workpiece, itself—are likely to have extremely sharp edges, and may result in skin or eye damage if contacted directly.

If contact with skin, immediately wash hands with warm water and soap and flush the affected region of skin with warm water. Do not brush or rub the affected region, as it may drive small slivers into the skin.

In contact with eye, immediately wash hands with warm water and soap. Flush eyes with gently-flowing water immediately for several minutes. Remove contact lenses, if present and easy to do.

DO NOT USE AN EYE WASH, as the high flow of water may cause chipped material to imbed in the eye and surrounding soft tissue. Seek medical attention to ensure that all material has been removed from the eye. This can be preformed by the NIST Health Unit during normal business hours.

9.2.4 Event: Removed Material Embedded in Skin or Eye

If removed materials are embedded in the skin, immediately wash hands with warm water and soap. Flush the affected region with warm water. Do not brush or rub the affected region, as it may further embed the material. If possible, gently remove the material from the skin.

If removed materials are embedded in the eye, immediately contact NIST Safety at x2222 and/or report to the Health Unit in building 101. **DO NOT TOUCH OR RUB EYE, OR ATTEMPT TO REMOVE THE OBJECT.**

9.3 Chemical Hazards

This activity does not require the regular use of chemicals or materials with chemical hazards. However, some tasks may include the use of chemicals that present specific hazards.

9.3.1 Event: Chemical Contact with Eyes

Flush eyes immediately for several minutes using the eye wash station next to the fume hood or a sink in a nearby restroom. Remove contact lenses, if present and easy to do. Continue rinsing.

When possible, report to the Heath Unit in building 101 for a full evaluation.

9.3.2 Event: Chemical Contact with Skin

Remove any contaminated clothing immediately, and rinse skin in the closest restroom for several minutes.

When possible, report to the Heath Unit in building 101 for a full evaluation. Be prepared to describe chemicals used and their quantities/concentrations.

9.3.3 Event: Chemical Spill

In the event of a chemical spill, use the following steps to eliminate the hazard.

9.3.4 If the chemical agent is known

Always wear appropriate PPE.

Use the clean-up instructions specified in the agent's SDS.

9.3.5 If the chemical agent is unknown

Always wear appropriate PPE.

Use the spill kit located to the left of the fume hood.

9.3.6 Event: Chemical Contact with Eyes

Flush eyes immediately for several minutes using the eye wash station next to the fume hood or a sink in a nearby restroom. Remove contact lenses, if present and easy to do. Continue rinsing.

When possible, report to the Heath Unit in building 101 for a full evaluation.

9.3.7 Event: Chemical Contact with Skin

Remove any contaminated clothing immediately, and rinse skin in the closest restroom for several minutes.

When possible, report to the Heath Unit in building 101 for a full evaluation. Be prepared to describe chemicals used and their quantities/concentrations.

9.3.8 Event: Inhalation of Chemical Vapors

The inhalation of chemical vapors may result in symptoms such as:

- Coughing,

- Shortness of breath,
- Eye/nose/throat irritation,
- Headache, and
- Dizziness.

If any of these symptoms manifest, immediately leave the laboratory and breathe fresh air. If others are in the laboratory, advise them to do the same.

When recovered, contact NIST Safety at x2222, and report the circumstances under which you were operating when the exposure occurred. Be prepared to describe the chemicals used and their quantities/concentrations.

When possible, report to the Heath Unit in building 101 for a full evaluation. Be prepared to describe chemicals used and their quantities/concentrations, and any symptoms experienced.

Do not return to the laboratory until breathing fresh air for a few hours, and having been given the all-clear by emergency personnel. Avoid closed spaces with poor air flow.

9.4 Building Related Hazards

9.4.1 Event: Fire

If a fire event occurs in the building and the building fire alarm sounds, immediately immediately turn off any powered equipment, place any tools/parts on the floor in a safe and stable position, and then evacuate the building per NIST guidelines for building evacuation

9.4.2 Event: Hazardous Weather

If a fire event occurs in the building and the building fire alarm sounds, immediately immediately turn off any powered equipment, place any tools/parts on the floor in a safe and stable position, and then move all personnel to the shelter-in-place zone in the building.

9.4.3 Event: Power Outage

Activate the E-stop button for any active robotic equipment, and turn off the power to the robot. If no emergency lighting source is activated, exit the room safely using a hand-held light source.