Safe Work Procedure

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Document Details

Enter the details of the document. The Safe Work Procedures Guideline (HS027) should be consulted to assist in the completion of this form.

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Title * Operation of UR5e Robot Arm System

Faculty * Engineering

School * School of Mechanical and Manufacturing Engineering

Approver * Mark Whitty

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Next Review Date Reminder ☐ 1 day ☐ 5 days ☑ 10 days ☐ 15 days ☐ 30 days ☐ 45 days ☐ 60 days ☐ 90 days

Safe Work Procedure Details

Safe Work Procedure Description: Operation of UR5e Robot Arm System for collaborative operations.

Locations: KENC-J18-L2-213; KENC-J18-L2-214; KENC-J18-L2-204

Related Legislation, Standards, Codes of Practice etc. *

WHS Act 2011
WHS Regulations 2017

Australian Standard AS4024 Safety of Machinery Parts:
1201: General principles-Basic terminology and methodology
1202: General principles-Technical principles
1301: Risk assessment-Principles of risk assessment
3301: Safety of machinery Robots and robotic devices - Safety requirements for industrial robots - Robots (2017)
3302: Safety of machinery Robots and robotic devices - Safety requirements for industrial robots - Robot systems and integration (2017)
3303: Safety of machinery Robots and robotic devices - Collaborative robots (2017)

Universal Robots e-Series User Manual (v5.1)

Related Safety Documents: ENG-MECH-RMF-15979

Related Equipment: -

Related Activities -

Hazards and Risks
Use this section to list each task/scenario and its associated hazard and risk. You can choose multiple tasks by clicking on 'Add new hazard' at the end of this box

Hazard Category * Plant & equipment - Auto start-up

Controls * Hazard: Enabling Power to the Robot Arm

Associated Harm: Robot arm behaving in an unexpected manner, impacting user or surrounding object causing injury to user and/or damage to equipment.

Existing Controls:

All users should familiarize themselves with the robot arm by reading 'Universal Robots e-series User Manual V5.1'.

A special 'safety profile installation' is implemented to limit the maximum joint speeds and forces of the robot and to ensure that the robot arm deactivates when any part of the robot comes close to the surface of the operating table.

Additional virtual safety planes are implemented to ensure that the robot arm does not operate outside the table area.

By default, a robot program can not be started without enabling power to the robot arm.

Hazard Category * Moving object - Equipment

Controls * Hazard: Movement of Robot Arm

Associtated Harm: Robot arm trapping or impacting person or object causing injury to person or damage to equipment.

Existing Controls:

A special 'safety profile installation' is implemented to limit the maximum joint speeds and forces of the robot and to ensure that the robot arm deactivates when any of the joints come close to the surface of the operating table.

Limiting the joint speeds and forces ensures that,
1. the user has adequate time to move away from the robot if the robot arm comes into contact with the user.
2. the user can easily disable the robot but applying a smaller counter force if the robot arm comes into conact with the user.
3. The user has adequate time to move away from the working envelope of the robot.
An emergency stop button is available on the teach pendent which can be used at any time during operation to stop the robot.

The joint speeds and forces are password protected so that students are not able to override these settings.

Hazard Category * Temperature

Controls * Hazard: Manipulator parts like drive motors, gears and surrounding parts may become hot after extended operation

Associated Harm: Person touching hot part being burnt

Existing Controls:

Robot arm use is generally intermittent so it should not become hot enough to burn a person.

If it is necessary to touch the robot, move hands slowly toward the parts to be touched to feel for radiant or convective heat before touching the Robot.

When in freedrive mode, move the robot by holding the wrist of the robot.

Hazard Category *	Electrical - Exposed wires
Controls *	Hazard: Opening Robot Controller Cabinet Associated Harm: Electric shock from power terminals which can be accessed when the controller cabinet is open. Existing control: Always keep the controller cabinet locked. Any modification inside the controller cabinet should only carried out by suitably qualified UNSW staff or Universal Robots service personnel.
Hazard Category *	Moving object - Equipment
Controls *	Hazard: Movement of Robot Arm in freedrive mode Associated Harm: Robot Arm coming into contact with the user or operating table, causing injury to user and/or damage to equipment. Existing Controls: The user should continuously press a switch underneath the teach pendent to operate the robot in freedrive mode. Releasing this button disables the freedrive mode. Additional joint angle and speed limits ensure that the user is not able to move the robot in a rapid manner.
Hazard Category *	Moving object - Equipment
Controls *	Harm: Movement of Robot Arm operating table Associated Harm: The table mae move and injure the user if wheels attached to the table are not locked. Existing Controls: The wheels attached to the table are lockable.
Hazard Category *	Moving object - Equipment
Controls *	Hazard: Robot tool causing damage to user or equipment Associated Harm: A sharp tool attached to the robot arm can come into contact with the user and cause cut injuries. Existing Control: No sharp tool should be attached to the robot for any teaching purposes. The attached tool should either be made with soft material or rounded edges. When a new tool is attached, a user with administrator privileges should update the Tool Center Point (TCP) settings in the 'safety installation'.
Hazard Category *	Plant & Equipment
Controls *	Hazard: Unauthorised operation of any part of the robot system Associated Harm: Personal injury or damage to equipment

Existing Controls:
Hard copy of SWP to be attached to equipment in close proximity to the robot system.
Only approved staff are allowed to open the robot control box.
Warning Signs will advise that only authorised users are allowed to modify the robot system.

Hazard Category *

ZOther

Controls *

Hazard: Use of robot after hours

Associated Harm: Assistance not available in event of problem and person unable to get medical attention for illness or injury.

Existing Controls:
The Robot must only be used while at least one additional person other than the operator is present in the immediate vicinity of the Robot Cell. After hours the additional person must be someone who has read and understood this Risk Management Form.

The Robot must only be used between the hours of 8:00am and 6:00pm on University working days, except that it may be used between 8:00am and 9:00pm when classes run – in line with UNSW School of Mechanical and Manufacturing Engineering After Hours Protocol.

Safe Work Procedure Instructions

Resources Required

Footwear that effectively covers and protects the toes and instep.

Long hair should be tied back.

No loose jewelry or clothing.

Instructions *

1 Definitions

Emergency Stop Button means the Red button located on the teach pendent attached to the Robot Arm.

Freedrive Button means the push button located on the back of the teach pendent.

Robot Arm Power Icon means the circular icon located at the bottom left corner on the teach pendent screen. To turn ON the power to the robot, first click on this button (which shows up in RED when power to the arm is disabled), and then click **ON** icon on the screen. When the Robot boots up to **Robot Idle** position, press the **START** icon. To turn OFF the Robot click the **OFF** button. See 11.1.3 and 11.1.4 in UR5e User Manual.

Virtual Safety Plane means a virtual plane created with the aid of the teach pendent. Whenever the robot tool or the elbow touches this virtual plane, the robot would come to an abrupt stop. Virtula safety planes ensure that no part of the Robot lies outside the predefined operational envelope.

2 Preliminary Requirements

2.1 Students

- Students should read, understand and sign the corresponding Risk Management document and this Safe Working Procedure document.
- Students should always operate the robot under the active supervision of a qualified instructor.
- Students should have access to the UR5e User Manual when using the Robot Arm. It is recommended that they go through PART-II of the User Manual before operating the Robot.
- Students are not allowed to erase any program except for the ones created by them. Teaching and technical staff has the right to revoke access to the robot if a student is found

guilty of any malicious activity.
- Students should always use the Robot Arm in **'default'** safety installation, and the safety setting at '**Most Restricted**'.

2.2 Staff

- Staff should read, understand and sign the corresponding Risk Management document and this Safe Working Procedure document.
- Staff should actively supervise when working with the Robot Arm with students.
- Staff may gain administrator privileges which allows them to modify safety settings.

IMPORTANT: **For use cases which are not captured by this SWP and the corresponding RW, users should amend the current documents or introduce new documents which addresses the safety concerns involved with the new use case.**

3 Start Up and Operation

3.1 For Students

1. IMPORTANT: A staff member should be present if a student is using the Robot Arm.

2. Ensure the wheels attached to the robot table are locked.

3. Ensure the Robot Control Box has access to power by switching ON the powerpoint on the wall. If the power cable of the UR5e unit is not connected to a wall socket, the robot maybe down for maintenance. Please contact the teaching or technical staff before connecting the power cable to the wall socket if this is the case. The instructor/supervisor will then use a 'power key' to enable power to the control box. Robot can not be turned ON without the 'power key'

4. Ensure the area around the robot table is not congested. The users should be able to freely move towards and away from the Robot Arm during operation. All users should wear enclosed shoes inside the lab. Long hair should be tied back. No loose jewelry or clothing allowed.

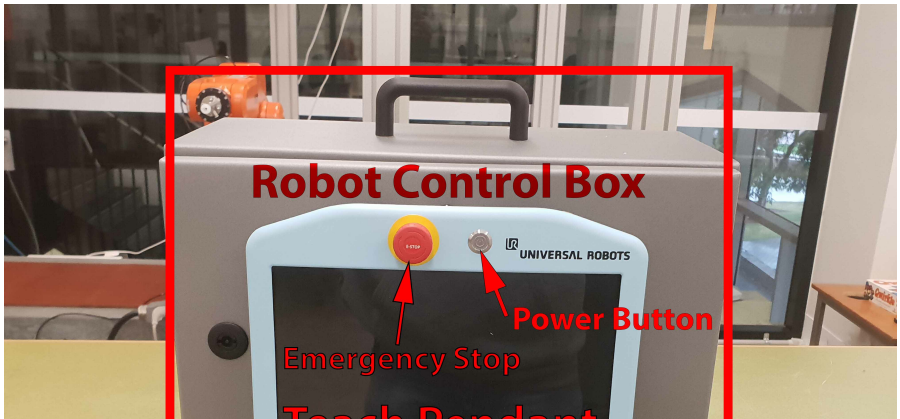
5. Make sure that no unnecessary items are placed on the table inside the robot working envelope.

6. Undock the teach pendent from the Robot Control Box and securely hold-on to the teach pendent by using the strap attached to the back of the teach pendent (See Figure 1).

7. Press the Power button located next to the Emergency Stop button. Allow 10-20 seconds for system boot-up. If the system doesn't power-up, it may mean that the power to the control-box is cut-off using a key-switch which is located on the control-box. Only technical and teaching staff have access to the key which unlocks the key-switch. The interactive interface of the teach pendent can be now accessed.

8. Ensure that the **INSTALLATION** setting is set to default (This is displayed on the top center of the screen). If this is not the case, contact the teaching or technical staff.

9. The user interface boots up in **Automatic** mode. To program the robot and introduce additional safety settings such as safety planes, users must switch to **Manual** mode. Switch to Manual Mode by pressing the **Automatic** icon on the top right corner on the screen and enter the password provided (See Figure 2).



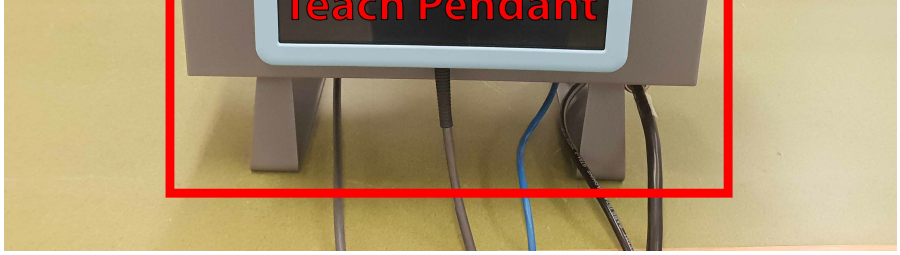


Figure 1 Robot Control Box and Teach Pendant

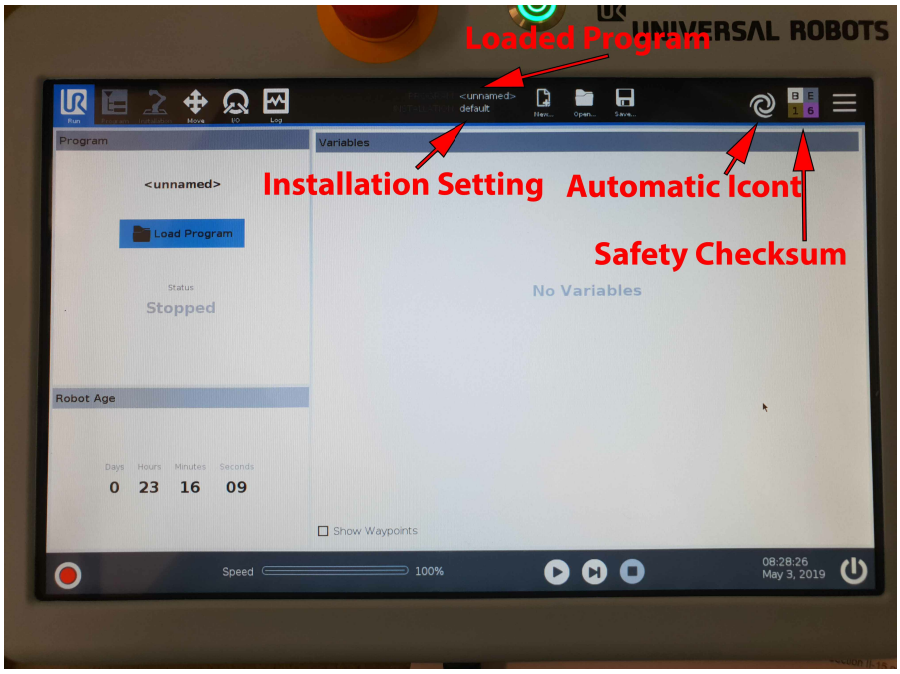


Figure 2 UR5e User Interface

10. Go to **INSTALLATION** tab and press the **Safety** dropdown menu on the left-hand side of the screen. Check whether the Safety setting is set to **Most Restricted** and **Factory Presets** radio button is selected**.** See section II-13.1.1 of UR5e User Manual for more information. See Figure 3

11. If the settings don't match the values provided above, contact the teaching staff since students are not allowed to modify these settings.

12. Once the safety settings are checked, the user can enable power to the Robot Arm.

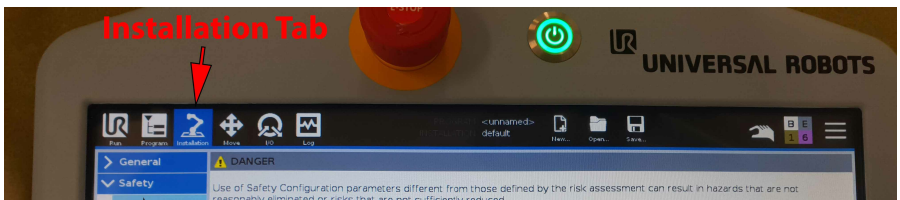
13. Keep clear of the Robot Arm work envelope before enabling power. **IMPORTANT**: If the initial position of the robot arm happens to lie outside the virtual safety planes, the robot may start moving when power is enabled, and arrive at a safe pose inside the safety planes.

14. Robot Arm Power icon on the bottom left corner of the screen power up the robot. To turn ON the power to the robot, first click on this icon (which shows up in RED when the robot is switched off), and then click **ON** dialog box on the screen. When the Robot boots up and **'Robot Idle'** text changes to **'Robot Active'**, click the **START** button. Click the **OFF** button to disable power to the Robot. See 11.1.3 and 11.1.4 in UR5e User Manual (See Figure 4)

15. Once the Robot Arm is powered-up, exit the initialize panel by pressing the **Exit** icon.

16. Once the robot is powered up, the user can either;

    1. Run an existing robot program using the **RUN** tab (Section II-14).
    2. Jog the Robot arm by using the touch screen via the **MOVE** tab (Section II-17).
    3. Move the robot in Freedrive mode by pressing the Freedrive button on the back of the teach pendant.
    4. Program the Robot Arm using the **PROGRAM** tab (Section II-15).



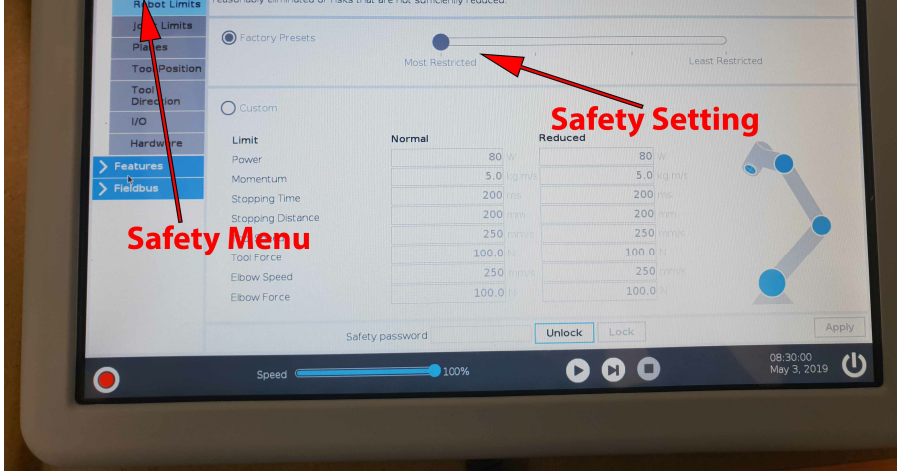


Figure 3 The INSTALLATION Menu

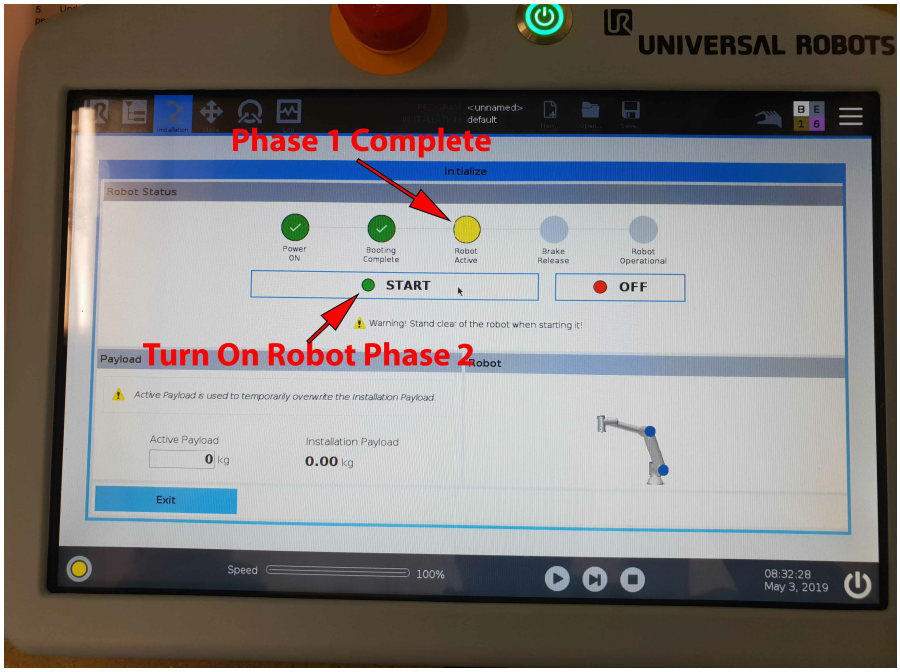


Figure 4 Robot Arm Initialize Panel

General Operation

17. **IMPORTANT:** Users are not allowed to erase any program on the teach pendent (which are not created by them). The teaching and technical staff has the right to revoke the access to the Robot Arm if a user is found guilty of deleting someone else's program from the teach pendent.

18. Always backup your programs to a flash drive.

19. A detailed description on how to program the robot can be found in Section II-15 on the UR5e User Manual.

20. Before executing the program, make sure the corresponding safety installation of the program is set to **default**.

21. Before executing the program, make sure there is no unnecessary objects or users inside the robot working envelope.

22. Control signal to the robot is temporarily disengaged and the robot stop abruptly in following situations;

1. If the any part of the robot touches a virtual safety plane
2. A given waypoint causes a robot joint to move at an angular speed beyond the specified limit.
3. If the Robot comes to contact with a person or an object, and the force felt by the robot exceeds the specified safety limit.

In such cases, a dialog box appears on the screen prompting the user to make a decision regarding the Robot Arm control. To continue operation, the user can press **Enable Robot** icon after making

sure that the initial threat is not present anymore.

23. Pressing the **Emergency Stop** button located on the teach pendent disables the power the Robot Arm. To enable power,

1. Make sure the threat which initially triggered the Emergency Stop is no longer present.
2. Twist the Emergency Stop button to bring it to neutral position.
3. Enable power to the Robot Arm using the Robot Arm Power icon.

Shutting Down

24. Stop the execution of any program running on the teach pendent.

25. Ensure the Robot Arm is returned to **Home** position. This can be done by pressing the **Home** icon on the bottom of the **Move** tab

26. Make sure the Robot tool is pointed downwards. Rotate the wrist of the robot using the **MOVE** tab if this is not the case.

27. Press the green circular icon on the bottom left corner of the screen. A window which provides the current status of the robot will appear. Press the **OFF** button located on the window. This action will disable power to the Robot Arm and brakes would be engaged.

28. Ensure your programs are saved and backed up.

29. Shut-down the unit by first pressing on the **Menu** icon on the top right corner of the screen and select **Shutdown Robot**. Then click **Power Off** on the dialog box which appears. The unit will shut down in a few seconds.

30. Dock the teach pendent securely onto the Robot Control Box and switch OFF the power from the wall powerpoint.

3.2 For teaching staff

31. Teaching staff may move the Robot Arm to lecture theatres for demonstration purposes. Please adhere to the safe working procedure defined for students in using the robot. However, since teaching staff have administrator privileges, they may modify the safety settings of the Robot Arm and work with different safety installations if required.

32. The teaching staff is allowed to move the Robot table by unlocking the wheels attached to the table.

Modifying Safety Settings

33. Virtual safety planes, joint angle and speed limits may be modified with users with administrator privileges. See Section II-13 in the User Manual for more information.

1. First access the **INSTALLATION** tab by switching to manual mode.
2. On **INSTALLATION** tab, click the **Safety** drop-down menu.
3. Enter the administrator password in the textbox at the bottom of the screen and press the **unlock** icon.
4. Modify the safety settings accordingly.
5. Go to **Save** tab and click **save as installation**.
6. **IMPORTANT**: Do not modify the **default** safety installation. Save the safety installation with a different name other than **default**. Default safety installation is intended for the use of students and is set to **Most Restrictive** mode.

Moving the Robot

34. Disconnect the power cord from the wall socket and securely place it on the table ensuring that it doesn't get caught in the wheels or become a tripping hazard when the table is moved.

35. Make sure the robot table is not connected with any other equipment and no unnecessary objects are placed on the table.

36. Unlock the wheels of the table.

37. Carefully push the robot to destination. Be aware of people and vehicles. Push the table at a reasonable speed to avoid injury through contact. Additional personnel to assist with foot traffic is recommended.

38. Ensure the robot is covered and water proofed if the robot table is moved across an open area under adverse weather conditions.

39. Once the robot is used for teaching, move it back to the lab and place the table at the correct location and lock the wheels.

Introduction of New Tools

40. The Risk Management form and this Safe Working Procedure should be amended incase a new tool is introduced to the Robot Arm.

41. After using the Robot Arm for research work, remove the tool specific for the research work, and re-attach the tool aimed for undergraduate coursework. IMPORTANT: Tool removal and attachment should be carried out when the Robot Arm is powered OFF.

4 Opening the Robot Control Box

42. The Robot Control Box should be kept locked whenever power is provided from the wall socket.

43. Only qualified technicians can open the Robot Control Box for additional wiring or maintenance. See Section I-5 of the User Manual for more information.

44. The teaching and research staff may open the robot control box to access a specific communication port with the permission of technical staff.

45. In case a communication port is accessed (ex: Ethernet port), run the communication cable through the openings specifically designed to run cabling, so that the lid can be kept locked.

Emergency Procedures *

Emergency Stop
An emergency stop button will stop the movement of the robot, regardless of the mode of operation.
Robot Emergency Stop is located on the teach pendent.
The user should always hold the teach pendent while operating the robot, so that the user can easily access the emergency stop button.

Password Protection

Password protection ensures that unauthorized personnel are unable to change the safety profiles implemented with the robot.
The user requires a password to change between Manual and Automatic modes. The Automatic mode doesn't allow the user to access program and installation tabs.
The user requires an additional password to access safety settings. This ensures no unauthorized personnel are able to change any safety settings.

Break Release via Freedrive Mode

In the highly unlikely event that a user is trapped by the robot arm, the freedrive button on the teach pendent can be used to release the brakes and safely move the robot arm away from the user.

Fires

Only use a CARBON DIOXIDE extinguisher in the event of a manageable fire – such a fire extinguisher is located on the south wall of Room 213 near the entrance door. If there is time and it is safe to do so turn off power to equipment in the vicinity of the fire.

Cleanup and Waste Disposal Instructions

Follow the UNSW HS321 Laboratory Hazardous Waste Disposal Guideline

Competency and Training Required

Read and acknowledge that they have read and fully understoon the Risk Management Form ENG-MECH-RMF-15979.

Competency Levels *

1. Read Document; 2. Training Required

Only add descriptions below for competency levels chosen above

Training Description	Complete online training for the UR5e Robot Arm at: https://www.universal-robots.com/academy/
Knowledge Test Description	TBD
License/Cert Description	
Other Competency Description	
Additional Documents	UR5e_User_Manual_en_Global.pdf

Declare As Read

Close