Guideline for 3D Printer Safety

1 PURPOSE

3D printers have become an essential tool in prototyping, research, and manufacturing. This guideline is intended to provide users with the best practices for the safe setup and operation of 3D printers in spaces across UBC Campus, including considerations for electrical, thermal, and material hazards.

Common incidents related to 3D printers often involve inhalation hazards, entanglement, or dermal contact. Careful attention to machine placement, ventilation, material storage, and maintenance can mitigate these risks to ensure the users are safe. This document also aims to educate users on the proper safety measures, in order to prevent injury, property damage, and environmental harm.

Safety & Risk Services (SRS) can be contacted in order to conduct full risk assessment before or after installing 3D printers.

Purchase/use only 3D printers that have Canadian Standards Association (CSA) Group electrical certification to ensure they meet Canadian electrical safety standards. 3D printers used for medical device applications also have specific licensing and validation requirements from Health Canada.

2 HOW TO USE THIS GUIDELINE

This guideline is structured to help users at UBC understand and manage risks associated with 3D printing technologies. Throughout this guideline, three different colors are used:

Green corresponds to printers that mainly use filaments,

Yellow corresponds to printers that use resins,

Blue corresponds to printers that use metal powders.

If you are only concerned about a certain printer type, follow the colouring that corresponds to the type of interest.

Below are shortcuts to some relevant sections of the document:

- Section 3: general information and an overview of the most common materials and printing types, description of different materials such as filaments, resins, and metal powders, as well as the types of printers that use them.
- Section 4: a list of potential hazards associated with specific 3D printing processes and a table of the recommended control measures.
- Section 5: things to consider when installing a 3D printer
- Section 6: cleaning resin prints
- Section 7: storage and disposal of the different 3D printing materials.
- Section 8: emergency response
- Appendix: table of hazards and recommended controls
- Glossary: definitions of the terminology used in this guideline.

3 PRINTING TECHNIQUES AND MATERIALS

3D printers are advanced manufacturing devices that, by adding material layer by layer, can create objects in 3D space. They use processes such as Fused Deposition Modelling (FDM), stereolithography (SLA), or metal powder sintering (SLS, SLM, DMLS) to print objects.

3.1 Polylactic Acid and Acrylonitrile Butadiene Styrene (FDM):

Polylactic Acid (PLA) and Acrylonitrile Butadiene Styrene (ABS) are two of the most used plastics in 3D printing. They each offer different properties and considerations, but both are used in FDM printing, where the plastic is heated and extruded to create different layers. PLA is biodegradable and easy to print with, as it melts at about 130^{o}C. However, exposure to moisture or UV light reduces its structural efficiency. ABS, on the other hand, is a petroleum-based plastic. It offers higher durability in comparison to PLA, making it more ideal for functional parts. ABS is harder to print with, as it has a much higher melting point at about 200^{o}C.

3.2 Polyethylene Terephthalate Glycol-Modified, Thermoplastic Polyurethane, and Nylon (FDM):

Polyethylene Terephthalate Glycol-Modified (PETG), Thermoplastic Polyurethane (TPU), and Nylon are three other types of 3D printing filaments that are less popular than PLA and ABS, but still widely used. Each of these filaments are also used in FDM-type printers and provide different material properties. PETG strikes a middle ground between PLA and ABS, offering strength closer to ABS but with easier printability and lower emissions. TPU allows for rubber-like prints but can susceptible to clogging. Due to this, they should only be used in printers that are labelled by the manufacturer as having the capability to print using TPU. Nylon provides the highest strength and durability, often used for industrial applications. It requires a very high temperature, generally ranging between 240-275^{o}C. It absorbs moisture very easily and must be stored with care.

3.3 Composite Printing (FDM):

Composite printing uses of thermoplastic or resin-based materials reinforced with additional fibers or particles, such as carbon fiber, fiberglass, or metal-infused filaments. The printing process is also done using FDM, where the filament is heated and extruded to create each layer. These materials improve mechanical strength and durability when compared to using PLA or ABS.

3.4 Resin (SLA, DLP):

Resins are liquid materials that solidify when exposed to UV light. Resin prints use the process of stereolithography (SLA), where a UV laser inside the printer draws each layer, while the print bed is slowly lifted to reveal the print, or digital light processing (DLP) which has a projector that cures the entire layer at once. SLA printing allows for prints with much higher definition. Although cured resin is safe for handling, any uncured, liquid resin is toxic and emits volatile organic compounds (VOCs), which are an inhalation and dermal contact hazard. Any uncured resin and resin waste has to be disposed of safely.

3.5 Metal Powder Printing (SLS, SLM, DMLS):

Metal powder printing includes additive manufacturing techniques such as Selective Laser Sintering (SLS), Selective Laser Melting (SLM), and Direct Metal Laser Sintering (DMLS). In each of these cases, fine metal powders are fused using a high-powered laser or electron beam to produce metal parts.

3.6 Multi-Jet Fusion (MJF):

MJF is like metal powder printing in SLS but uses a fusing agent alongside infrared energy to fuse the material selectively. It is becoming increasingly popular for consumers and industries and is very often used for nylon parts.

Binder Jetting:

Binder jetting does not involve heat binding, but deposits a liquid binder onto a powder bed that fuses powder layers together to create the object. This process often requires a lot of post-processing. It is often used for sandcasting molds, ceramics, and metal parts due to its ability to create complex geometries and large-scale prints.

4 HAZARDS AND CONTROLS

3D printing involves a variety of hazards, which change depending on the method of printing being used. The list below highlights the most common risks associated with 3D printing.

A table of common mitigation strategies for the various types of hazards can be found in the Appendix. These strategies are organized according to the Hierarchy of Controls. There are 5 levels of the hierarchy:

- Elimination: Physically removing the hazard. Not included in the table on the premise the 3D printing is necessary.
- Substitution: Replacing the hazard with a less hazardous alternative.
- Engineering controls: Using physical devices that isolate the hazard from people.
- Administrative controls: Rules or guidelines that change the way people work.
- Personal Protective Equipment (PPE): Gear or clothing that protects the individual.

4.1 Particle Emission (FDM, SLS, SLM, DMLS, MJF, Binder Jetting):

During the printing process, filaments generate particles that may cause eye and respiratory tract irritation. Adequate ventilation, use of enclosures, and air filtration systems are essential to minimize exposure. In metal powder-based printing methods, such as SLS and DMLS, airborne metal dust can pose additional risks, including skin irritation and the potential for more severe health effects if not handled with care.

4.2 Toxicity, Skin Irritation, and Sensitization (SLA, DLP):

Resins are respiratory and/or skin sensitizers. Damage may not always be visible. Resins have chronic toxicity through dermal contact and by inhalation. Early symptoms of resin skin sensitization include redness, swelling, itching, or rashes. Respiratory sensitization manifests as difficulty breathing. Sensitization requires repeated exposure but once a user becomes sensitized, it cannot be reversed. More information can be found in the sensitization webinar hosted by SRS. If a user shows symptoms of skin sensitization, they must immediately stop handling resin and contact OPH for an assessment.

4.3 Burns (FDM):

The extruder and print bed both heat up to very high temperatures. They should not be touched while the printer is in use. Additionally, the plastic may not be fully cooled once the printing process finished. Touching the printed object can cause the plastic to stick to fingers and cause burns.

4.4 UV Light Exposure (SLA, DLP):

SLA and DLP printers use ultraviolet light to cure the resin which is harmful to skin and eyes with prolonged exposure.

4.5 Mechanical Hazards (FDM):

Most FDM printers have open designs, making it possible for fingers, hair, or loose clothing to get pinched or entangled in the moving parts of the printer. Stepper motors and belts operate with significant force and can cause injury if contact is made during operation.

4.6 Fire and Explosion Hazards (FDM, SLS, SLM, DMLS, MJF, Binder Jetting):

Certain 3D printing materials and components can pose a fire risk. Overheating, electrical malfunctions, or combustible materials can contribute to potential fires. Malfunctions can cause the heating element to overheat uncontrollably, melting components or burning nearby materials.

Many of the powders that are used in metal powder printing are highly reactive and can be an explosion hazard. When improperly handled, these powders can ignite under static discharge. Powders like titanium, aluminum, and magnesium, can self-ignite even in low oxygen environments. They should be stored in special inert gas storage systems.

4.7 Support Structure Removal Hazards: (FDM, SLA, DLP, SLS, SLM, DMLS, MJF, Binder Jetting):

Removing support structures, especially in metal and resin 3D printing, can pose safety risks due to sharp edges, airborne particulates, and tool-related injuries. Improper handling can lead to cuts, inhalation hazards, and exposure to toxic materials.

5 THINGS TO CONSIDER WHEN SETTING UP A 3D PRINTER

Always read and follow manufacturer's guidelines for installing and operating the specific make and model in question. Additional best practices for setting up printers include:

- Purchase/use only 3D printers that have Canadian Standards Association (CSA) Group electrical certification to ensure they meet Canadian electrical safety standards. 3D printers used for medical device applications also have specific licensing and validation requirements from Health Canada.
- Ensure the 3D printer is installed in a well-ventilated room.
  - If printer setup is in a wet lab space, the room should be considered well-ventilated as per UBC's Technical guideline.
  - If the setup is in a room not designed as a wet lab, users should contact their facilities manager to check the level of ventilation (how many exchanges per hour) in the room.
- 3D printers are heavy
  - Ensure that the printer is placed on a stable, fixed platform that will not shift while printing is in progress.
  - Secure shelves and benches.
  - Caution needs to be exercised when moving the printer as it can cause musculoskeletal strain.
- Inspect power cords for damage and do not use damaged cords. Safely route or secure cables to prevent tripping or accidental unplugging.
- For working with resin printers:
  - setup in an area that is easy access for routine cleaning and that has less traffic
  - workstation must be made of non-porous material that can be cleaned by wet methods

    - PPE used for work with resins must remain in the designated “resin” work area
- Before working with any material, read the Safety Data Sheets (SDS). SDSs provide information on emergency procedures, handling, storage, exposure controls and personal protection. Keep all safety data sheets physically in the room. Contact manufacturer if an SDS is not readily available.
- Ensure that gloves, safety glasses, and respirators are readily accessible and used when necessary.
- Have emergency equipment such as spill kits in an easy to access spot in the room or have clearly marked labelling for where they are located if outside of the room.
- Regularly inspect printers for signs of wear.

6 CLEANING RESIN PRINTS

Printers using resins pose an additional dermal exposure risk that others model do not.

- Wear a lab coat, goggles, and gloves to reduce the amount of skin contact with the resins.
- The print will be dripping as it is taken out of the printer. Use disposable liners to catch drips and avoid contamination.
- Using an isopropyl alcohol (IPA)soaked paper towel, clean up excess resin from the print.
- If IPA bath setup is available, follow the manufacturer’s instructions for operating the setup.
- If no IPA bath setup is available, create a lab specific procedure for IPA curing
- Keep absorbent materials close to the resin station to have it available in case of spills.
- Dispose of paper towels or other absorbent materials used to clean resin in a segregated waste container.

7 STORAGE AND DISPOSAL OF PRINTING MEDIA

Appropriate storage of chemicals is critical for reducing the risk of exposure, spills, and fires. Follow the storage guidelines described in the material’s SDS to ensure proper storage. Always store materials in tightly sealed, dry containers and ensure that manufacturer recommendations are always being followed.

7.1 Filaments (FDM):

- Keep spools properly wound to prevent tangling and deformation
- Material-Specific Considerations:

Filament Type	Considerations
PLA	• Keep dry and in cool storage
ABS	• Keep dry and away from UV light
PETG, TPU, Nylon	• Keep very dry, in a sealed container • Store with desiccants such as silica gel
Composites	• Keep dry, in a sealed container • Keep away from dust-sensitive electronics.

Different filaments have different disposal considerations.

- PLA, ABS and PETG are recyclable and should be put in a separate waste container
- TPU can be thrown into general waste
- Nylon and any composite materials should be treated as hazardous waste and disposed of separately.

7.2 Resins (SLA, DLP):

- Store UV-curable resins away from sunlight.
- Store within the temperatures defined by the manufacturer

Uncured resin can be toxic and must be treated as hazardous waste.

- Never pour uncured resin down drains or into the regular trash
- Fully cure resin before disposal
- Fully cured resin can be discarded in the regular trash

7.3 Metal Powder Storage (SLS, SLM, DMLS, MJF, Binder Jetting):

- Use grounded containers to prevent sparks from occurring.
- Keep highly reactive powders, such as titanium, aluminum and magnesium in inert gas storage to prevent oxidation.
- Ensure all containers are labelled with clear hazard warnings and expiration dates.
- Keep storage away from flammable materials or oxidizing agents.
- Avoid exposure to open flames, sparks or electronics.

Metal powders can be highly flammable and reactive if exposed to moisture.

- Dispose of powders as hazardous waste.
- Whenever possible, re-store unused powders for reuse.
- Use sealed, grounded disposal containers.
- Clean up work areas using a HEPA vacuum.

7.4 Other Chemical Waste

Chemicals may be used in post-processing, such as IPA or acetone. These must be treated as hazardous waste.

- Never pour chemicals down the drain.
- Have a clearly labelled waste container for each type of waste. If an empty container is used, make sure the old label is crossed out to avoid confusion

8 EMERGENCY PROCEDURES

It is important to always know the location of the on/off switch and electrical plug/socket for each printer model in the room, in case of an emergency. A spill kit should be kept in any room that contains a resin printer.

After the emergency response, any incident must be reported immediately to your supervisor and a CAIRS report filed.

8.1 Spills:

If a spill is less than 1L and trained personnel are available, follow procedures for clean-up. For large spills or for spills you are not equipped to handle or pose a safety risk, evacuate the area and call Campus Security (604-822-2222). If you are in a life-threatening situation, call 911.

8.2 Personal Exposures:

If a personal exposure to a chemical occurs (dermal, oral, inhalation), it is important to immediately call First Aid (604-822-4444). Have the SDS of the chemical available for the first aid responders.

8.3 Physical Injuries (Entanglements, Pinces, Burns, etc.):

If hair or other materials get caught in the printer while it is in use, immediately turn off or unplug the printer before trying to free yourself. If assistance is necessary shout for help.

If someone receives a burn from a printer, place the affected area under running cold water for ten minutes to soothe the pain. Call UBC First Aid (604-822-4444).

8.4 Fires:

If a printer catches fire, if it is safe to do so, immediately unplug or turn off the printer. Evacuate the immediate area and pull the fire alarm to evacuate the building. Call 911 for assistance. If you have been trained to use a fire extinguisher:

- For metal fires, use a class D fire extinguisher,
- for electrical fires, use a class C fire extinguisher, and
- for other general fires, use a class A fire extinguisher.

9 ADDITIONAL INFORMATION

- UBC Safety and Risk Services: The central resource for all things related to safety and risk management at UBC. There is information for safety training, incident reporting, hazardous waste disposal, and much more. SRS can also conduct on site risk assessments.
- NIOSH Approaches to Safe 3D Printing: The National Institute for Occupational Safety and Health (NIOSH) provides comprehensive safety information tailored to 3D printers. This resource covers hazards such as ultrafine particle emissions, chemical exposures, laser risks and controls for mitigating these hazards.
- Health Canada 3D Printing and Health Risks: Health Canada outlines potential health risks associated with 3D printing. It emphasizes proper ventilation and material handling to minimize exposure.

10 APPENDIX

Printer Type / Controls	Hazard 1: Health Hazards Particle Emission, VOCs, Toxicity, Skin Irritation, and Sensitization			
	Substitution	**Engineering Controls**	**Administrative Controls**	**PPE**
Filaments (FDM)	• Select a filament with the lowest emission rate that achieves the desired result • Out of the common filament types, PLA has the least amount of emissions	• Connect 3D Printers to rigid or flexible exhaust, routing them outdoors. • If possible, place the printer into a fume hood or a ventilated enclosure.	• Visit the manufacturer's website for SDS information. • Limit the time spent inside of the printer room while a printer is working. • Develop Safe work Procedures for using the printer	• Use a fit tested respirator when engineering controls are not available. • Contact SRS for an assessment to determine appropriate cartridges and usage.
Resins (SLA, DLP)	• Chose a resin that poses less hazards	• Use a printer enclosure that is designed for resin printers and has a carbon filter to capture the VOCs, or evacuates fumes outdoors. • Maintain and replace filters regularly. • If possible, place the printer into a fume hood.	• Visit the manufacturer's website for SDS information. • Wash hands immediately after handling resin. Clearly label resin bottles	• Wear gloves made from disposable materials, such as nitrile, when handling resins. • Wear safety glasses to prevent splashes to the eyes from resins and IPA. • Use a fit tested respirator when engineering controls are not available.
Powders SLS, SLM, DMLS, MJF, Binder Jetting	• Select a powder that poses less hazards	• Connect 3D Printers to rigid or flexible exhaust, routing them outdoors.	• Visit the manufacturer's website for SDS information. • Limit the time spent inside of the printer room while a printer is working. • Develop Safe work Procedures for using the printer	• Use a fit tested respirator when engineering controls are not available. • Contact SRS for an assessment to determine appropriate cartridges and usage.

Printer Type / Controls	Hazard 2: Temperature			
	Substitution	**Engineering Controls**	**Administrative Controls**	**PPE**
Filaments (FDM)	• Select a filament with the lowest printing temperature that achieves the desired result. • Out of the common filament types, PLA has the lowest print temperature.	• Utilize enclosures or guards that prevent the user from contacting the various parts that pose a rise of burn, such as the nozzle and heated bed.	• Wait 5-10 minutes or until the bed has cooled to room temperature before touching the print.	• Use heat resistant gloves when necessary
Powders SLS, SLM, DMLS, MJF, Binder Jetting	• NA	• Utilize enclosures or guards that prevent the user from contacting the various parts that pose a rise of burn, such as the nozzle and heated bed.	• Visit the manufacturer's website for SDS information. • Limit the time spent inside of the printer room while a printer is working. • Develop Safe work Procedures for using the printer	• Use heat resistant gloves when necessary

Printer Type / Controls	Hazard 3: UV Light Exposure			
	Substitution	**Engineering Controls**	**Administrative Controls**	**PPE**
Resins (SLA, DLP)	• Consider printers that might use other curing methods than UV.	• Use an enclosure that blocks UV-Light.	• Always make sure the printer or curing device is closed when the printing is in progress. • Regularly inspect the printer or curing device for cracks that could release UV light.	• Wear a pair of UV-blocking safety glasses for cases where access might be needed

Printer Type / Controls	Hazard 4: Mechanical Hazards and Flying Debris from Support Removal		
	Engineering Controls	**Administrative Controls**	**PPE**
Filaments (FDM)	• Enclosures can mitigate some of these risks; using an enclosed printer can reduce the likelihood of entanglements.	• Tie back long hair and avoid wearing loose clothing and/or accessories • Keep hands clear of the print bed, belts, and moving parts while the printer is in operation.	• Cut resistant gloves could be useful depending on the specific task
General to all types	• Use local exhaust ventilation when sanding down parts to reduce inhalation risks.	• Heat the print up before removing supports to help the pieces to break cleaner. • Remove the supports in a designated area to contain the debris	• Wear cut-resistant gloves and wear eye protection to prevent debris from getting into eyes. • Wear a respirator if sanding is required to smooth out a part.

Printer Type / Controls	Hazard 5: Fire and Explosion Hazard		
	Engineering Controls	**Administrative Controls**	**PPE**
Filaments (FDM)	• Maintain clearance from combustibles and installing fire suppression sprinklers. • Use a smoke detector in the printing area.	• Have correct type of fire extinguisher based on the printing material used • Develop an emergency response plan to address fire emergencies	• NA
Resins (SLA, DLP)	• Store isopropyl alcohol in flammable safety cabinets.	• Use spark-proof fans and equipment • Keep isopropyl alcohol away from FDM and metal powder printers. • Ensure labels on the bottles are clearly marked	• NA
Powders SLS, SLM, DMLS, MJF, Binder Jetting	• Install smoke detectors in the room • Do not clean workspaces with compressed air: use HEPA-filtered vacuums to clean the powder.	• Have class D fire extinguishers on hand • Develop a fire safety plan and an emergency response plan • Store powders away from flammables	• Use static-proof PPE and fire-resistant clothing engineering controls are not available.

11 GLOSSARY

Term	Abbreviation	Details
General Terms		
Occupational Preventative Health	OPH	UBC service focused on preventing occupational illness and promoting workplace health.
Safety and Risk Services	SRS	Department at UBC responsible for ensuring safe practices and managing workplace risks.
Volatile Organic Compound	VOC	Organic chemicals emitted as gases from materials like filaments and resins, potentially hazardous when inhaled.
Printer Types		
Binder Jetting		Liquid binder fuses powder layers together
Direct Laser Processing	DLP	UV projector cures entire resin layer at once
Direct Metal Laser Sintering	DMLS	Metal additive manufacturing method similar to SLM, fusing metal powder particles without fully melting them.
Fused Deposition Modelling	FDM	Thermoplastic material is extruded out of a nozzle
Multi-Jet Fusion	MJF	Fusing agent alongside infrared technology fuses the material selectively
Selective Laser Melting	SLM	3D printing process that fully melts metallic powders using a high-powered laser, creating solid metal parts.
Selective Laser Sintering	SLS	Powder-based 3D printing technique using a laser to fuse powder particles, typically nylon or polymers.
Stereolithography	SLA	UV laser draws out each resin layer
Material Types		
Acrylonitrile Butadiene Styrene	ABS	Sturdier plastic filament used in FDM printing. Has higher emissions than PLA.
Composite		Thermoplastic or resin-based material reinforced with additional fibers or particles to change their physical properties.
Nylon		Durable and flexible thermoplastic commonly used in powder-based (SLS) and filament 3D printing.
Polyethylene Terephthalate Glycol-Modified	PETG	Plastic filament that has properties in between PLA and ABS.
PLA	Polylactic Acid	Most common plastic filament for FDM printing.
Resin		Liquid-based material that cures when exposed to UV light
TPU	Thermoplastic Polyurethane	Rubber-like material used in FDM printing. Difficult to work with due to clogging.