



TEXAS A&M UNIVERSITY
ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Tools, Project, and Process

TURTLE Hatchling



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Design Process

This is a problem solving strategy that can apply to **any problem**. It is a bunch of mini steps that tailor towards the creation of a product or process.

Problem Statement



- Define the problem
- Outline objectives
 - List what is needed to have a “final” solution (Minimum viable product)
 - Keep it simple, stupid! (KISS)
- Perceive end user interaction
- Establish constraints
 - Size
 - Weight
 - Environment
 - Manufacturing capability
 - Budget
 - Time
 - Interaction between components



Idea Generation



- **Brainstorm**
 - Write down every idea
 - Combine and improve ideas
- **Research**
 - People have been inventing for thousands of years. Use their knowledge.
 - Most people innovate. They best connect unrelated ideas to make a combined idea
- **Group ideas**
 - Refine concepts
- **Sketch**
 - Great for visualizing your design
 - Understand how components interact
 - Try to sketch a full sized version

Evaluate Concepts



- Narrow down to feasible options
 - Can be done using a Design Matrix
- Design Matrix (Excel)
 - Grade solutions based on weighted factors, typically:
 - Simplicity
 - Cost
 - Development time
 - Ease of use
 - etc
 - Try to remove weighted bias
- Reflect on decision

WS - Weighted Score R - Rating		RC Lazer Turret		Catapult Game Set		Pinball Skee Ball		Customizable Music Box	
Selection Criteria	Weight	R	WS	R	WS	R	WS	R	WS
Number of Parts	0.1	1	0.1	3	0.3	2	0.2	3	0.3
Cost	0.15	1	0.15	4	0.6	2	0.3	4	0.6
User Benefits	0.4	5	2	4	1.6	3	1.2	3	1.2
Size	0.1	4	0.4	3	0.3	1	0.1	3	0.3
Ease of Use	0.25	4	1	3	0.75	2	0.5	4	1
	Total Score	3.65		3.55		2.3		3.4	
	Rank	1		2		8		3	
	Continue?	Yes		Yes		No		Develop	

Designing



- Design for ...
 - Manufacturing
 - Streamlining the process
 - Assembly
 - Modularity
 - Modification
 - Make features likely to change easy to do so
- Minimum Constraint vs Redundancy
- Failure Mode
 - How and where the part will fail
 - Want failure in the safest/cheapest area

Prototyping and Testing



1. Focus on critical parts first
2. Record quantifiable data
3. Analyze that data
4. Test edge cases
 - It is OK if the prototype is destroyed. It is called destructive testing

Iteration



- This is a **PROCESS**. It is **NOT** a checklist. Your success will depend on your ability to adapt
- Iteration is the most important part of the process. It was put at the end but should be in every step
- The difference between a proof of concept and a finished product is the iteration

Design Process Summary



1. Problem Statement - End User/Goal, Constraints
2. Idea Generation - Brainstorming/Research, Sketch
3. Evaluate Concepts
4. Designing - Design for Manufacturing and Modifications
5. Prototyping and Testing

Iterate

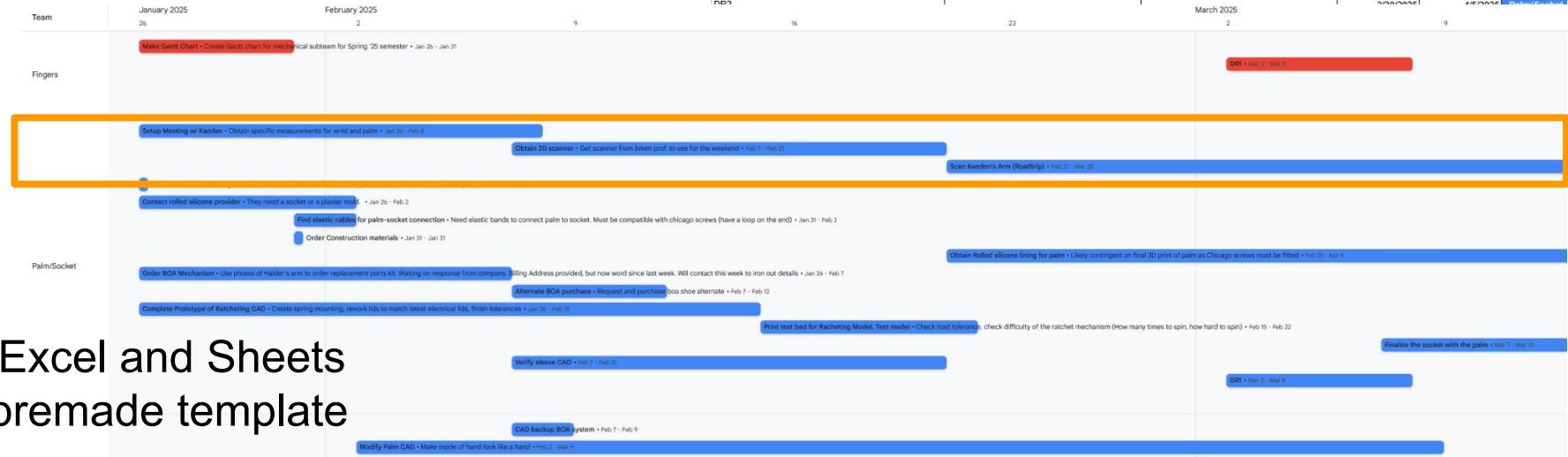
A red curly brace is positioned on the right side of the slide, spanning from the bottom of the fifth step up to the word "Iterate". It indicates that the process involves multiple cycles or iterations.

Project Management - GANTT Charts



1. Decide team, task, contributors, and timeline
 - a. Fancier versions may include allowable timeline stack
2. Visualize in chart and determine the critical path

OLSN Spring '25 Semester GANTT						
Task	Description	Contributors	Start Date	End Date	Team	
Mechanical						
Fingers + Thumb						
Make Gantt Chart	Create Gantt chart for mechanical subteam for Spring '25 semester	Everyone	1/26/2025	1/31/2025	Fingers	
Profile for sheet metal to Zach	extract profile sketch and extrude 1/16 and get to Zach for machining		3/2/2025	3/8/2025	Fingers	
DR1			3/3/2025	4/5/2025	Fingers	
DR2				4/18/2025	Fingers	
Project Showcase?				4/24/2025		
Palm/Socket						
Setup Meeting w/ Kaeden	Obtain specific measurements for wrist and palm		1/26/2025	2/8/2025	Palm/Socket	
Obtain 3D scanner	Get scanner from bmen prof. to use for the weekend		2/7/2025	2/21/2025	Palm/Socket	
Scan Kaeden's Arm (Roadtrip)			2/21/2025	3/28/2025	Palm/Socket	
Contact [REDACTED] to get contact information for rolled silicone palm	Send email and wait for response		1/26/2025	01/26/2025	Palm/Socket	
Contact rolled silicone provider	They need a socket or a plaster mold.		1/26/2025	2/2/2025	Palm/Socket	
Find elastic cables for palm-socket connection	Need elastic bands to connect palm to socket. Must be compatible with chicago screws (have a loop on the end)		1/31/2025	2/2/2025	Palm/Socket	
Order Construction materials			1/31/2025	1/31/2025	Palm/Socket	
Obtain Rolled silicone lining for palm	Likely contingent on final 3D print of palm as Chicago screws must be fitted		2/2/2025	4/4/2025	Palm/Socket	
Order BOA Mechanism						
Alternate BOA purchase	Use photos of Haider's arm to order replacement parts kit. Waiting on response from company. Billing Address provided, but now word since last week. Will contact this week to iron out details		1/26/2025	2/7/2025	Palm/Socket	
CAD backup BOA system				2/7/2025	Palm/Socket	
Modify Palm CAD	Make inside of hand look like a hand		2/2/2025	3/9/2025	Palm/Socket	
Complete Prototype of Ratcheting CAD	Create spring mounting, rework lids to match latest electrical lids, finish tolerances		1/26/2025	2/15/2025	Palm/Socket	
Print test bed for Ratcheting Model, Test model	Check load tolerance, check difficulty of the ratchet mechanism (How many times to spin, how hard to spin)		2/15/2025	2/22/2025	Palm/Socket	
Finalize the socket with the palm			2/15/2025	3/31/2025	Palm/Socket	
Verify sleeve CAD			3/7/2025	2/7/2025	Palm/Socket	
DR1			3/2/2025	3/8/2025	Palm/Socket	
DR2				3/8/2025	Palm/Socket	





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3D Printing

Additive Manufacturing

How does 3D Printing work?

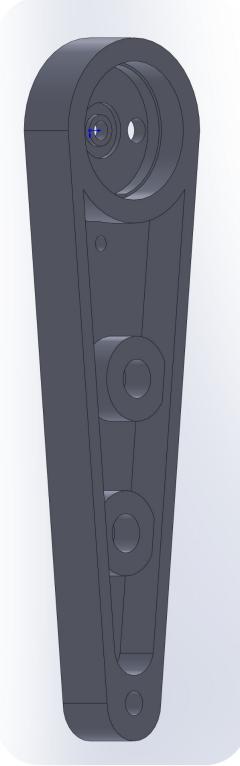


- Fused Deposition Modeling (FDM)
 - Extrudes melted filament through a nozzle layer by layer
 - Think of a sliced loaf of bread. To make a full loaf (model) you stack up the slices (layers)
 - Most common at consumer level due to low cost
- Stereolithography (SLA)
 - Uses a laser to cure liquid resin into hardened plastic
 - High-accuracy parts with smooth watertight surfaces
- Selective Laser Sintering (SLS)
 - Uses a laser to cure powder into a solid structure
 - Expensive but gives the most design freedom

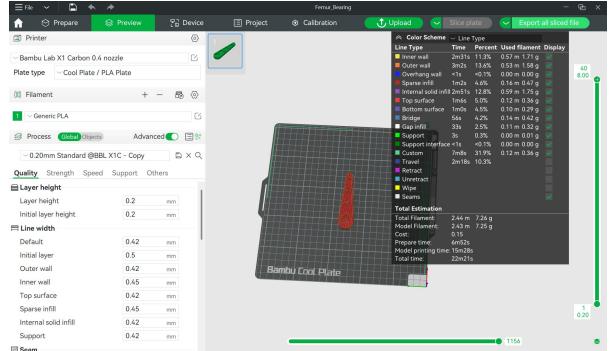
3D Printing Process



Model
.stl or .3mf



Slicer
(Bambu Studio)



3D Printer
(X1C,P1S)
0.4mm



FDM Printer

Finished!



Remove the microSD card from the side of the screen, grab an adaptor, and save your gcode



Slicing with Bambu Studio

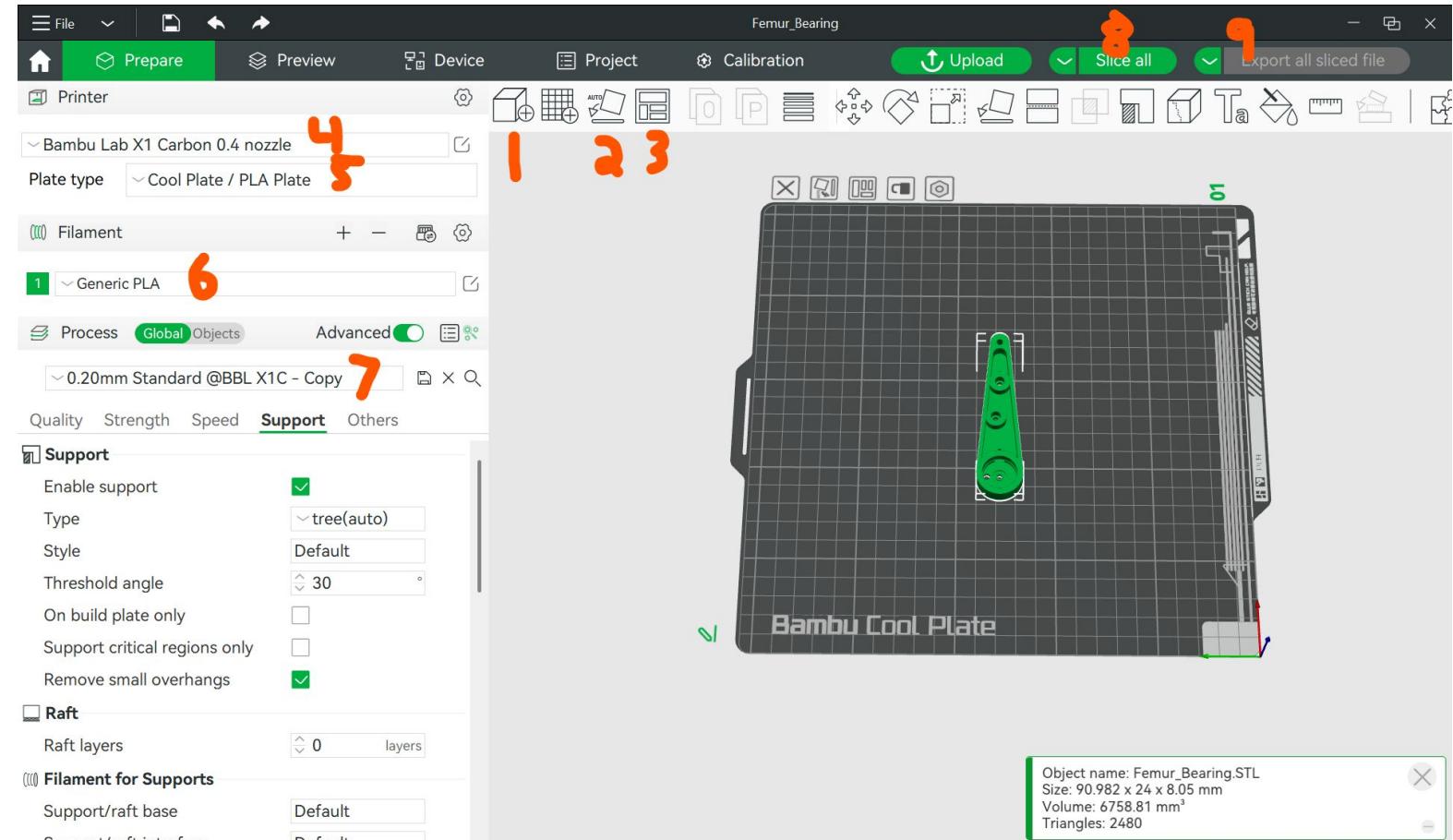


1. Add .STL, .STEP, or .3MF files
2. Auto orient parts
3. Auto arrange all objects
4. Select the type of printer (X1 Carbon 0.4 nozzle, P1S 0.4/0.6)
5. Select the bed type
6. Select the filament type
7. Select the slicing settings
8. Click Slice to generate the gcode (sliced file)
9. Export file to microSD card

*Keep infill to 15-25%

**If supports are needed, use
tree(auto)

***The slicer auto orient and arrange
may not align in the most optimal
layout.



****If you are unsure about what
something does, keep the default settings

Bambu Lab FDM 3D - Printers

X1 - Carbon and P1S



- Two of the fastest FDM printers available
- Build volumes of $256 \times 256 \times 256 \text{ mm}^3$
 - (Approximately $10.07 \times 10.07 \times 10.07 \text{ in.}^3$)

X1 - Carbon



- Available Filaments
 - PLA, PETG, TPU, ABS, ASA, PVA, PET
 - PA (Nylon), PC, Carbon / Glass Fiber Reinforced Polymer
- Has automated calibration and print failure detection
 - **Please stay in the lab until completion of the first layer**

P1S

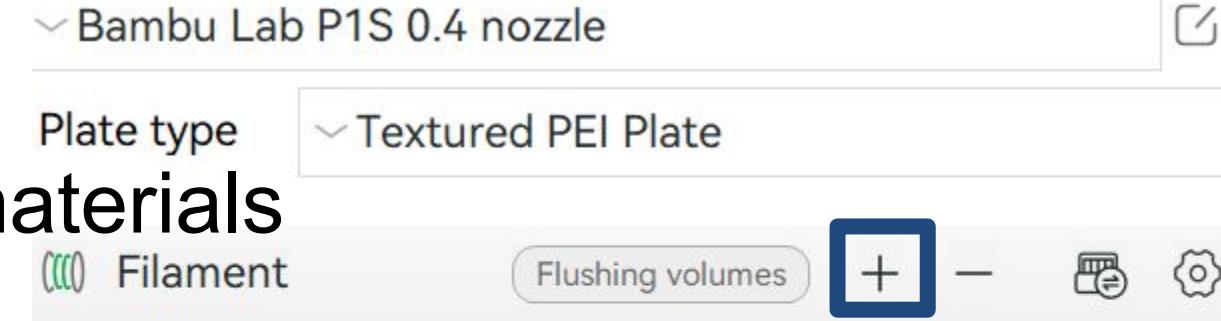
- Available Filaments
 - PLA, PETG, TPU, PVA, PET, ABS, ASA
- Has automated calibration
 - **Please stay in the lab until completion of the first two layers min.**
- Spool 1 (Left) is AMS default unless chosen while slicing
 - Please keep that slot PLA



P1S Notes



- No print failure detection



- Can **NOT** print carbon fiber materials

- To choose AMS slot
 - 1. Click the Filament “+”
 - 2. Choose the material in AMS
 - 3. Click corresponding <#> on keyboard
 - a. Should change the color of the part



***Double check
your filaments**

Common Filaments



PLA (Cool Plate, Textured PEI)

Polylactic acid

- Cheap
- Easy to print / Great for prototyping
- Brittle and prone to cracking
- Will soften at around 60°C (140°F)
 - Don't leave outside or in a car
- Absorbs water and weakens

PETG (Engineering Plate, Textured PEI)

Polyethylene terephthalate glycol

- Cheap
- Print may have stringing
- More impact resistant than PLA
- Will soften at around 80°C (176°F)
- UV and water resistant

Reserved for Project Teams

- Carbon fiber reinforced versions indicated by -CF
- Polycarbonate (PC) - Engineering-grade
- Polyphthalamide (PPA) - High Performance Nylon engineering-grade filament
- Thermoplastic Polyurethane (TPU) - Flexible

ASA / ABS (Engineering Plate, Textured PEI)

Acrylonitrile styrene acrylate / Acrylonitrile butadiene styrene

- Prone to build plate adhesion warping
- Higher strength and durability
- Parts are heat, water, and *UV resistant
 - * Only ASA
- Toxic fumes
 - Close the door while printing (you won't die but you might get a massive headache)

Other Notes - Cleaning

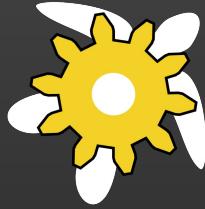


- Use a glue stick on the build plate to help with print adhesion
(Non PEI Plates)
 - If that fails clean plate and wipe with isopropyl alcohol.
- Wipe PEI Plate with isopropyl alcohol before print
 - Limit touching the surface
 - **DO NOT USE THE SCRAPER on PEI plate**
- **Clean the build plate whenever switching between engineering and cool plate**
 - Use the sink and soap in the corner of the TURTLE Lab (Make sure it is dried)

Other Notes - Set Up



- Run your sliced prints by an officer before loading to the machine
- Listen to the printer if it asks to leave the door open
- Always wait a few minutes before removing the prints, to allow cooling down for easy removal and to avoid damaging the print surface.



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Design for Manufacturing and Assembly (DFMA)

An engineering method where components are designed such that features reduce the cost and time required to manufacture and assemble the product.



Teaching best practices for every manufacturing method is infeasible. Refer to a DFMA textbook when you need it.

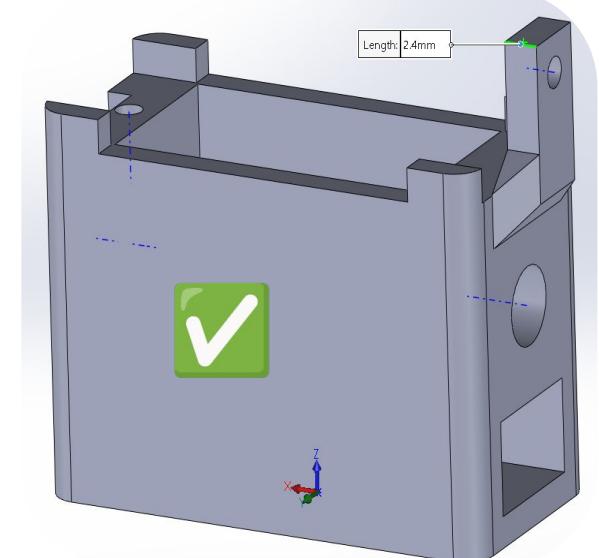
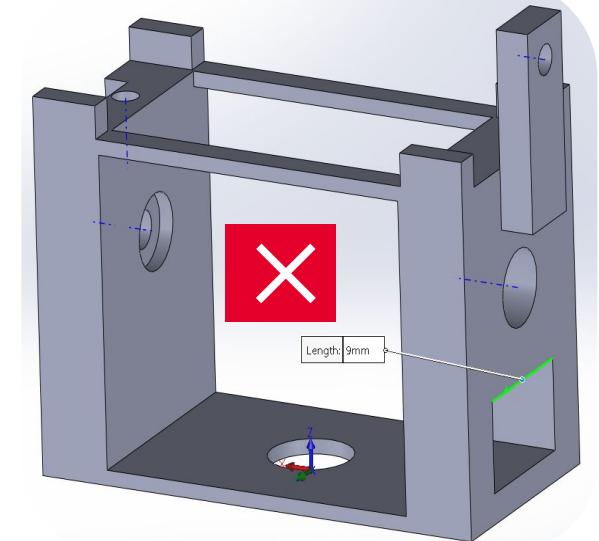
But typically these include:

- Use standard stock sizes and tooling
- Limit part reorientation and tooling switches
 - 3-axis vs 5-axis machine
- Choose largest viable tolerance
- Reduce part count and modulate assemblies
- Listen to whomever is manufacturing the product :)

Best Practice for FDM 3D Printing



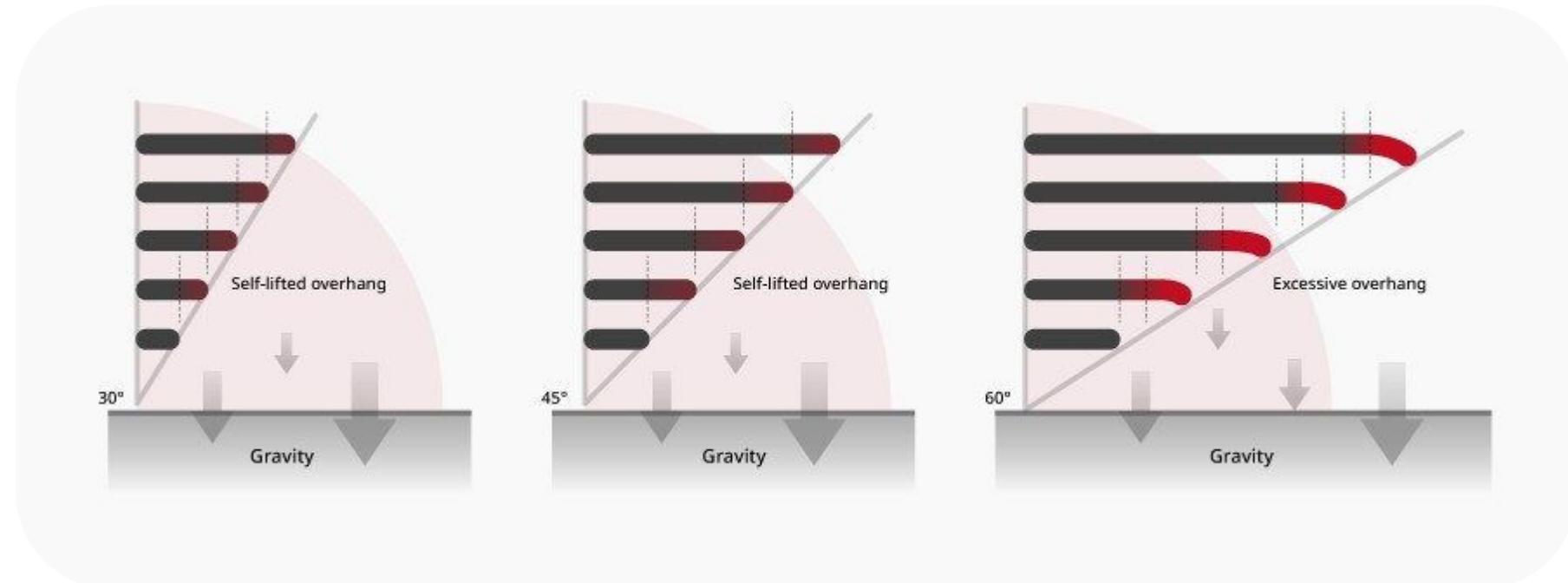
- Use multiples of nozzle diameter for **wall thickness** (**0.4mm** for us)
- Minimum wall thickness of **2mm thickness** for load bearing parts
- **Weakest** part orientation is the printers **Z-axis**
- Mitigate stress concentration with fillets, chamfer, or ribs



Best Practice for FDM 3D Printing



- Avoid overhanging/unsupported features that are greater than 45°
 - Adding 45° chamfers can prevent the need for supports





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Tools

General Lab Rules



- An officer must be present in the lab at all times while the lab is in use.
- Any behavior deemed disrespectful or inappropriate can result in disciplinary action or a request to vacate
- During a project's reserved lab time, the project lead may ask anyone to leave the lab for any reason.
- Project tasks always have priority over personal or school projects when it comes to lab tools and space.
- **Misuse or unsafe lab practice will result in the revoking of privileges.**
- If you need training or supervision for a tool and cannot receive it from those present, send an @Officer in the Discord
- If at any time, common sense would defy any of the rules detailed in this document, ask an officer for help.

Note: Refer to your organization's rules

General Lab Rules



While in the lab, your safety is first and foremost your own responsibility. You are surrounded by resources and experienced people who can help you use them. If you are at any point unsure of what you are doing, ask. If you feel unsafe with a tool, stop what you are doing immediately and do not resume work until you have received clarification.

Tools Requiring Training:

- Angle Grinder
- Dremel
- Drill Press
- Hand Drill
- Impact Driver
- Jig Saw
- Power Supply
- Printer (3D)
- Soldering Iron

Tools that require Supervision:

- Angle Grinder
- Dremel

Safety Gear

- PPE is required for all tools listed in the training section excluding the 3D printers. Proper PPE includes: closed toe shoes, bottoms that cover to the lower leg, a sleeved shirt, and safety glasses. All loose items and hair must also be properly secured up and out of the way.

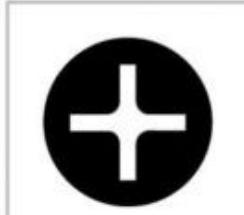
Trainings

- Any individual may be trained by an officer. This training is tool specific and is not all encompassing.

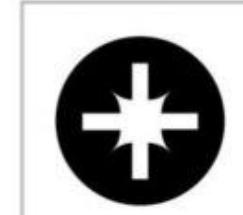
Common Types of Screw Heads



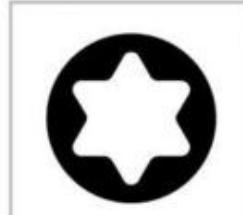
Slotted
/flathead



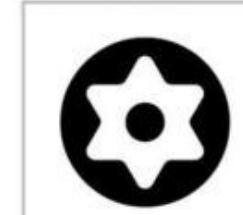
Cross Slot/
Phillips



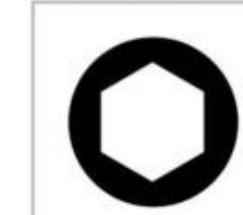
Pozidriv



Torx



Security T



Hexagon



Note:
TURTLE
stocks hex
metric screws
ranging from
M2 - M6

Screws go into
threads.

Bolts go into
nuts.

Common Hand Tool Terminology



Hex Key / Hex
Wrench / **Allen**
Key / **Allen**
Wrench



T-Handle with
Ball End



Flush Cutters



Needle Nose
Pliers



Wire
Strippers



Crimping Pliers

Note: Names may vary



Vise Grips



Retaining Ring
Pliers

Available Power Tools



TURTLE is a DeWALT Family in this lab
Well kinda :)

List of power tools in our lab:

- Drill press (RYOBI)
- Hand drill
- Impact Drivers (One Milwaukee)
- Dremel (Dremel)
- Jig Saw
- Variable Speed Drill



Common Hand Drill Types



Traditional -

- General Purpose drilling of holes in wood, metal, other materials

Impact - Uses a small hammer motion

- Great for screws

Hammer - Uses a hammering motion

- Masonry
- Unnecessary



Traditional



Tips:

- Use the lowest torque setting that completes the task
- Properly secure items when drilling holes.
Large drill bits are hard to control
- Spin chuck to (un)clamp



Impact Driver



Note:

- To secure a bit, pull out bit collar outwards
- Dewalt impact works the same way
- You can just use the drill in most cases



Bit collar

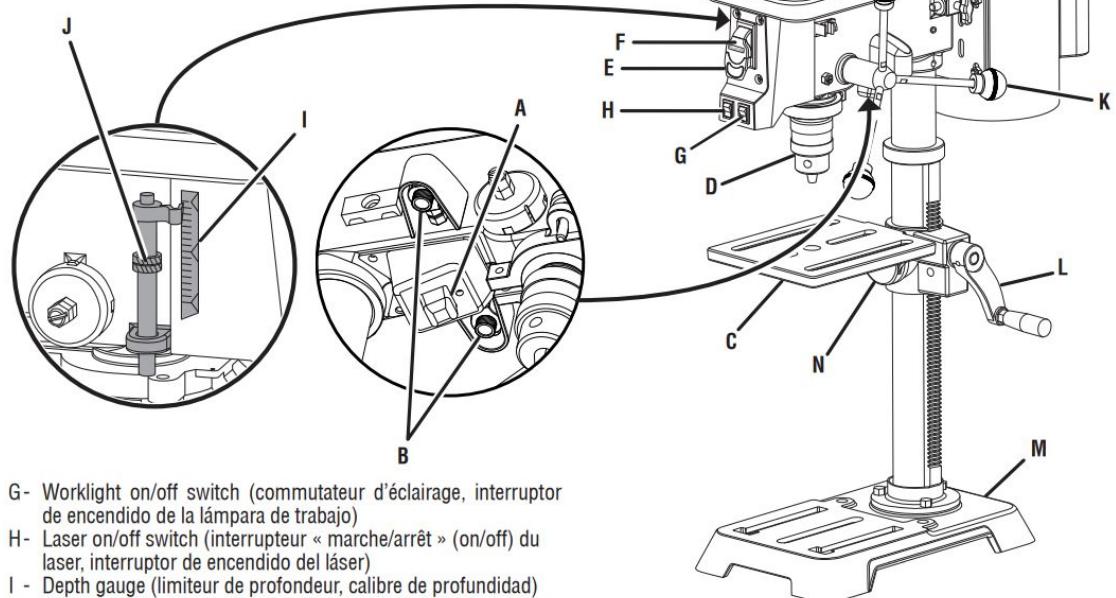
Drill Press



*Immediately remove chuck key after use

**Use the vice to secure items
***Do not lose the key

- A - LED worklight (lampe de travail à DEL, luz de trabajo con diodo luminiscente)
- B - Laser (laser, láser)
- C - Table (table, mesa)
- D - Chuck (mandrin, portabrocas)
- E - Power switch (commutateur de moteur, interruptor de corriente)
- F - Switch key (clé du commutateur, llave del interruptor)



- G - Worklight on/off switch (commutateur d'éclairage, interruptor de encendido de la lámpara de trabajo)
- H - Laser on/off switch (interrupteur « marche/arrêt » (on/off) du laser, interruptor de encendido del láser)
- I - Depth gauge (limiteur de profondeur, calibre de profundidad)
- J - Depth stop locking collar (collier de fixation de la butée de profondeur, anillo de fijación para tope de profundidad)
- K - Feed handle (levier de commande, palanca de avance)
- L - Table adjustment handle (manivelle de réglage de la table, manivela de ajuste de la mesa)
- M - Base (base, base)
- N - Bevel scale (échelle de biseau, escala de inclinación)

Dremel & Angle Grinder



DREMEL

- Spins a bit at insane RPM.
- Can be used for sanding or cutting depending on the bit

Extremely Dangerous

Please be supervised and smart



Angle Grinder

- “DREMEL on steroids”

Jigsaw



Used to cut large flat materials via an oscillating blade

*Material depends on blade type

**Be careful of not cutting unintended objects



Shop Vacuum (Missing)



Industrial vacuum that can pick up debris and dust.

*Very loud

**I hope we find ours



Vertical Bandsaw (Don't Have)



Used to cut flat materials via an oscillating blade

*Material depends on blade type and internal speed ratio

**Requires the key (yellow) to turn on

*****Please be careful of fingers**

****We don't have one of these



Belt/Disc Sander (Don't Have)



Motorized sandpaper

*Quickly removes material

**If in doubt, use pliers to hold small items

***We don't have one of these



Machines (Don't Have)



Lathe



Spins material on an axis while a cutting tool shapes it into cylindrical or symmetric forms

CNC

(Computer numerical control)



Often linked to tabletop 2D machining, but CNC covers all computer-controlled machining tools

Mill



Uses a rotating cutter that moves in multiple axes to remove material and create 3D shapes



Handheld Multimeter

● Measures

- AC/DC Current (Amps)
- Resistance (Ohms)
- AC/DC Voltage (Volts)
- Capacitance (Farads)
- Continuity (Closed Loop)
- Diode Functionality (Voltage loss across a diode)

%	Duty Cycle	APO	Automatic Power-Off
°F	Fahrenheit Temperature	H	Data Hold
°C	Celsius Temperature	MAX	Maximum Reading
hFE	Transistor hFE	MIN	Minimum Reading
• •	Continuity Test	---	DC (Direct Current)
→+	Diode Test	~	AC (Alternating Current)
Ω	Resistance	—	Negative Reading
□	External Current Test (Clamp)	—	AC and DC
↔	Capacitance	Hz	Frequency
△	Relative Mode	AUTO	Auto-range Mode
±	Earth Ground	—	Low Battery
□	Double Insulated	—	Fuse
⚠	Warning	CE	Complies with EU directives

Note: For non-automatic range detecting devices, use the lowest setting that is greater than your approximate value

- I.e. Use 20 V if you anticipate 12 V

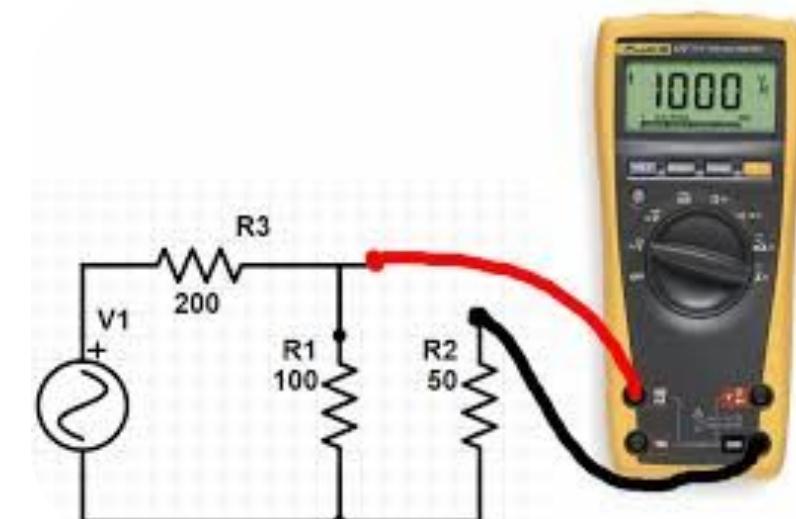
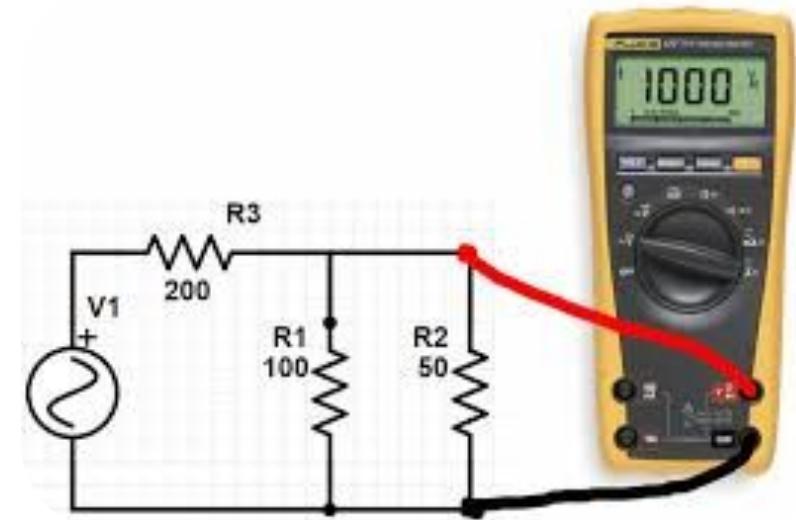


Using Multimeters



- Measuring Voltage (Parallel)
 - Red lead to place you want to measure and the black lead on the ground
 - In Parallel (put leads next to the components)
 - You are measuring the voltage difference between the red lead and black which could result in negative values

- Measuring Current (Series)
 - Place the red lead “first” and then the black lead as to let the current through the red lead and out the black
 - In series (leads become part of the circuit)



Electronic Devices



Soldering Station



Allows for precise temperature control of a soldering iron and may have additional features

Oscilloscope



Displays and analyzes electrical signals by graphing voltage waveforms over time

DC Power Supply



Provides stable, adjustable direct current voltage and current for powering and testing electronic devices

General Rules



Always wear safety glasses

Don't wear sleeves or gloves with moving part tools

If in doubt, turn the device off

High speed for soft materials

- Make sure to not melt material

Low speed and oil lubricant for metallic materials



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Project Time

Lab Resources Available



- All lab tools with proper training
- All items not claimed by a project team
- 3D-Printers
 - PLA non CF
 - PETG non CF
 - ABS/ASA (Ask first)

Note: We may be able to supply additional resources if requested during the week 5 design review. Approval will be on a case by case basis.

Hardware



Note: These are general guidelines. Additional electronics may be utilized if supplies allow

- 2 L298N (Motor driver)
- 4 tt-motors (DC-Motor)
- 2 SG90 or MG90 Micro Servos
- HC-SR04, AS5600, MPU6050 (Sensors)
- 1 ESP32-WROOM-32D
- 1 Buck Converter (Steps down 7.2V to 5V)
- 1 7.2V 2200mAh NiMH Battery Pack (Stays in the lab)

Reference Documentations



- **ESP32-WROOM-32D:** <https://randomnerdtutorials.com/getting-started-with-esp32/>
- **Motion:**
 - L298N: <https://lastminuteengineers.com/l298n-dc-stepper-driver-arduino-tutorial/>
 - tt-motors: <https://www.adafruit.com/product/3777>
 - MG90: : <https://www.adafruit.com/product/3777> (Follow SG90 documentation for code)
 - SG90: <https://protosupplies.com/product/servo-motor-micro-sg90/>
- **Sensors:**
 - HC-SR04: <https://lastminuteengineers.com/arduino-sr04-ultrasonic-sensor-tutorial/>
 - AS5600: <https://www.instructables.com/AS5600-Magnetic-Angle-Encoder/>
 - MPU6050: <https://lastminuteengineers.com/mpu6050-accel-gyro-arduino-tutorial/>

Motion Devices



tt-motor (DC Motor)

- Continuous rotation
- Low torque / High speed
- Requires a L298N Motor Driver to stop/start/change directions



SG90/MG90 (Micro Servo)

- 180° limited rotation
 - Goes to programmed angle
- High torque / Low speed
- Controlled directly from ESP32 through PWM



HC-SR04 Ultrasonic Distance Sensor



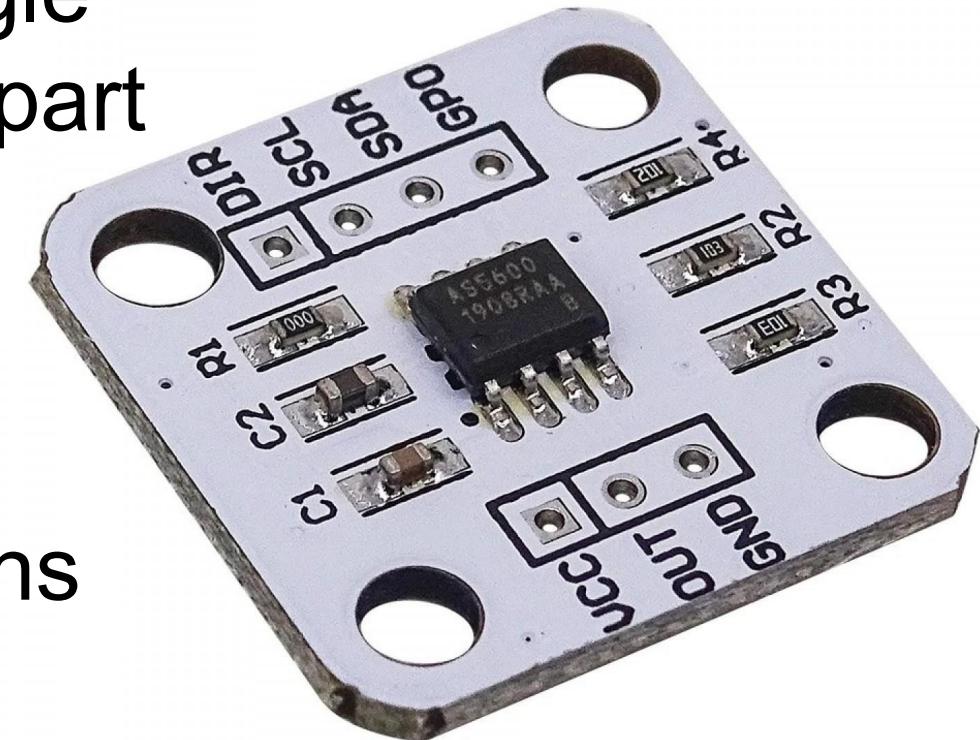
- Detects object distance by timing the echo of an ultrasound wave burst
- Ultrasound waves are sounds with frequencies above human hearing range
- Range of 4 cm to 4 m
- Accuracy of 3 mm



AS5600 Magnetic Encoder



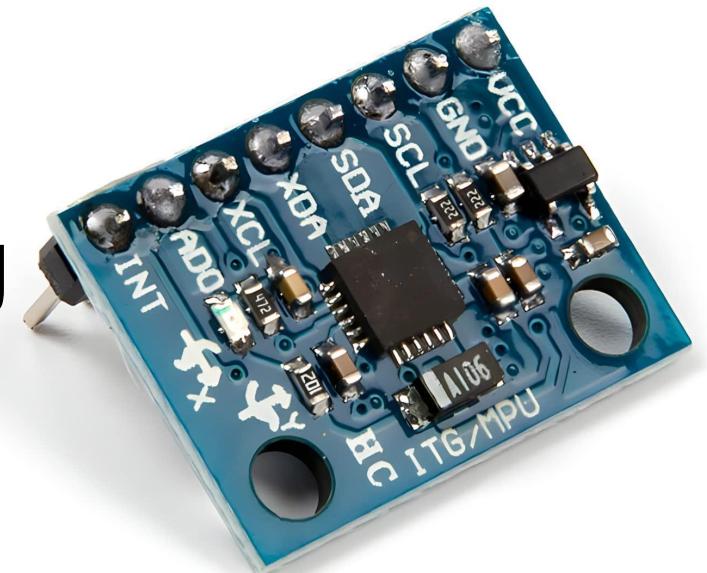
- Uses a magnet to determine angle without making contact with the part (digital potentiometer)
- Returns absolute angle measurements from 0° to 360°
- Programmable start stop positions
- Uses I²C interface
- Variations up to 2°



MPU6050



- Gyroscope, Accelerometer, and Digital Motion Processor
- Gyroscope can read up to $\pm 2000^\circ/\text{sec}$
- Accelerometer can read up to $\pm 16\text{g}$
- Programmable filters
- Uses I²C interface
- Programmable range





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TURTLE Towers

Introducing Milestones



Purpose: Keep member on track to complete the project. It also allows us to use meeting time to improve your robot.

Why: Making a robot takes an unexpected amount of time. We want everyone to finish their robots.

Expectation: The expectation should be completed **before** the milestones meeting.

How many: Four (Weeks 5,7,9,10)

Missing a deadline: We will try to accommodate you, however, time may limit our ability to provide the personalized learning opportunity.

Next Milestone



Milestone: Design Review

Date: Week 5 - Design Review and C++ (1 week from today)

Expectation: Have robot and mechanisms sketched out.

Impact: We will review design viability and suggest improvements.



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Design Review and C++

Friday 10/17, off 10/24

Wednesday and Thursday
off Fall Break, on 10/22 and 10/24



“The engineer's first problem in any design situation is to discover what the problem really is”

Sir Henry Royce



Hatchling