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ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Tools, Project and Process

TURTLE Hatchling

Attendance

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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. The 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

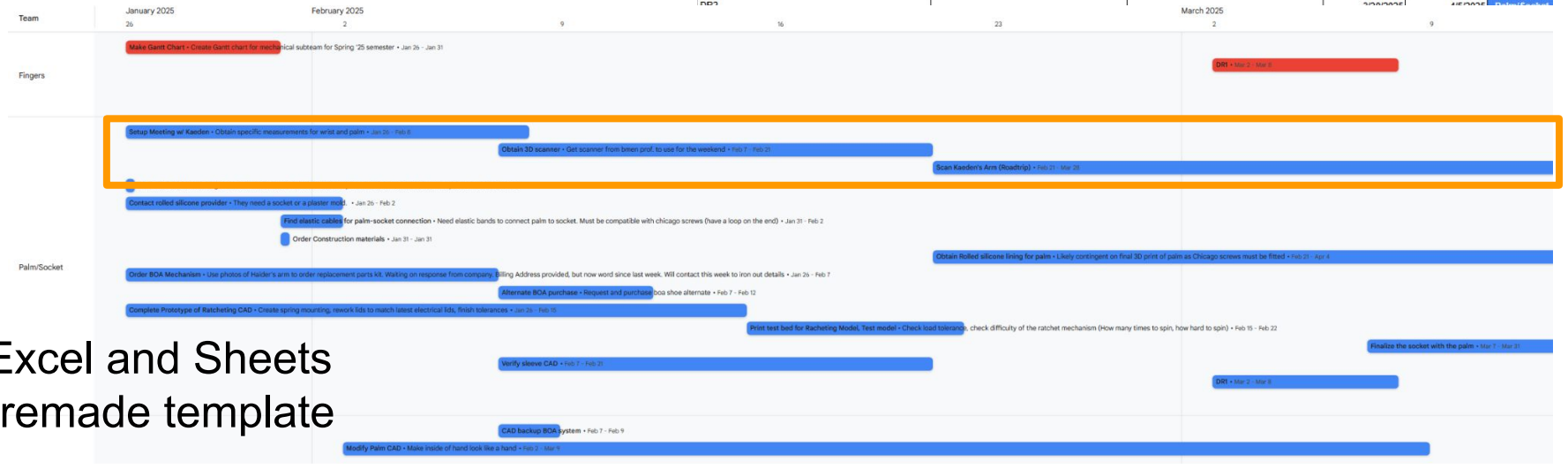
Iterate

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				Fingers
DR1			3/2/2025	3/8/2025	Fingers
DR2			3/30/2025	4/5/2025	Fingers
Project Showcase?			4/18/25	4/24/25	Fingers
Palm/Socket					
Setup Meeting w/ Kaeden	Obtain specific measurements for wrist and palm	[redacted]	1/26/2025	2/8/2025	Palm/Socket
Obtain 3D scanner	Get scanner from bmen prof. to use for the weekend	[redacted]	2/7/2025	2/21/2025	Palm/Socket
Scan Kaeden's Arm (Roadtrip)		[redacted]	2/21/2025	3/28/2025	Palm/Socket
Contact [redacted] to get contact information for rolled silicone palm	Send email and wait for response	[redacted]	1/26/2025	01/26/25	Palm/Socket
Contact rolled silicone provider	They need a socket or a plaster mold.	[redacted]	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)	[redacted]	1/31/2025	2/2/2025	Palm/Socket
Order Construction materials		[redacted]	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	[redacted]	2/21/2025	4/4/2025	Palm/Socket
Order BOA Mechanism	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	[redacted]	1/26/2025	2/7/2025	Palm/Socket
Alternate BOA purchase	Request and purchase boa shoe alternate	[redacted]	2/7/2025	2/12/2025	Palm/Socket
CAD backup BOA system		[redacted]	2/7/2025	2/9/2025	
Modify Palm CAD	Make inside of hand look like a hand	[redacted]	2/2/2025	3/9/2025	
Complete Prototype of Ratcheting CAD	Create spring mounting, rework lids to match latest electrical lids, finish tolerances	[redacted]	1/26/2025	2/15/2025	Palm/Socket
Print test bed for Racheting Model, Test model	Check load tolerance, check difficulty of the ratchet mechanism (How many times to spin, how hard to spin)	[redacted]	2/15/2025	2/22/2025	Palm/Socket
Finalize the socket with the palm		Everyone	3/7/2025	3/31/2025	Palm/Socket
Verify sleeve CAD		[redacted]	2/7/2025	2/21/2025	Palm/Socket
DR1			3/2/2025	3/8/2025	Palm/Socket



Critical path:
The longest stretch of dependent tasks

Note: Excel and Sheets have premade template

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3D Printing

Additive Manufacturing

How does 3D Printing work?

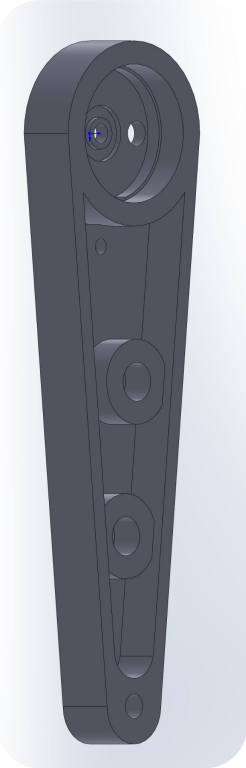
- Fused Deposition Modeling (FDM)
  - Extrudes melted filament through a nozzle layer by layer
    - Think of a sliced loaf of bread. To make a full loaf (model) you stack up the slices (layers)
  - Most common at consumer level due to low cost

- Stereolithography (SLA)
  - Uses a laser to cure liquid resin into hardened plastic
  - High-accuracy parts with smooth watertight surfaces

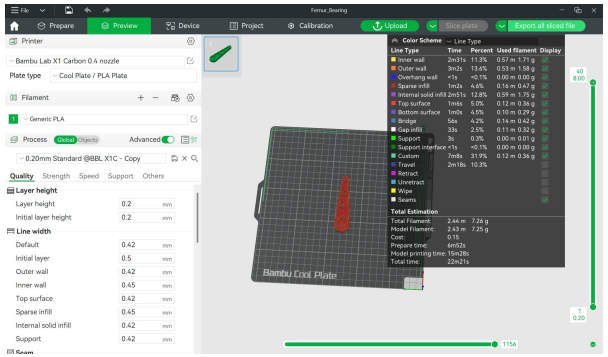
- Selective Laser Sintering (SLS)
  - Uses a laser to cure powder into a solid structure
  - Expensive but gives the most design freedom

3D Printing Process

Model
(.stl or .3mf)



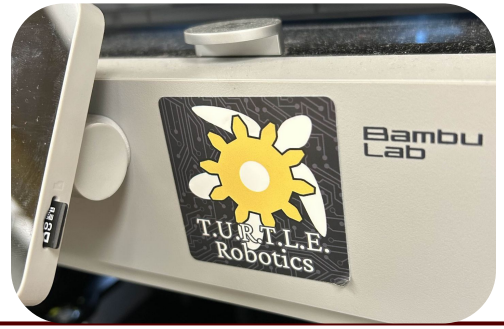
Slicer
(Bambu Studio)



3D Printer
(X1C,P1S)
0.4mm

FDM Printer

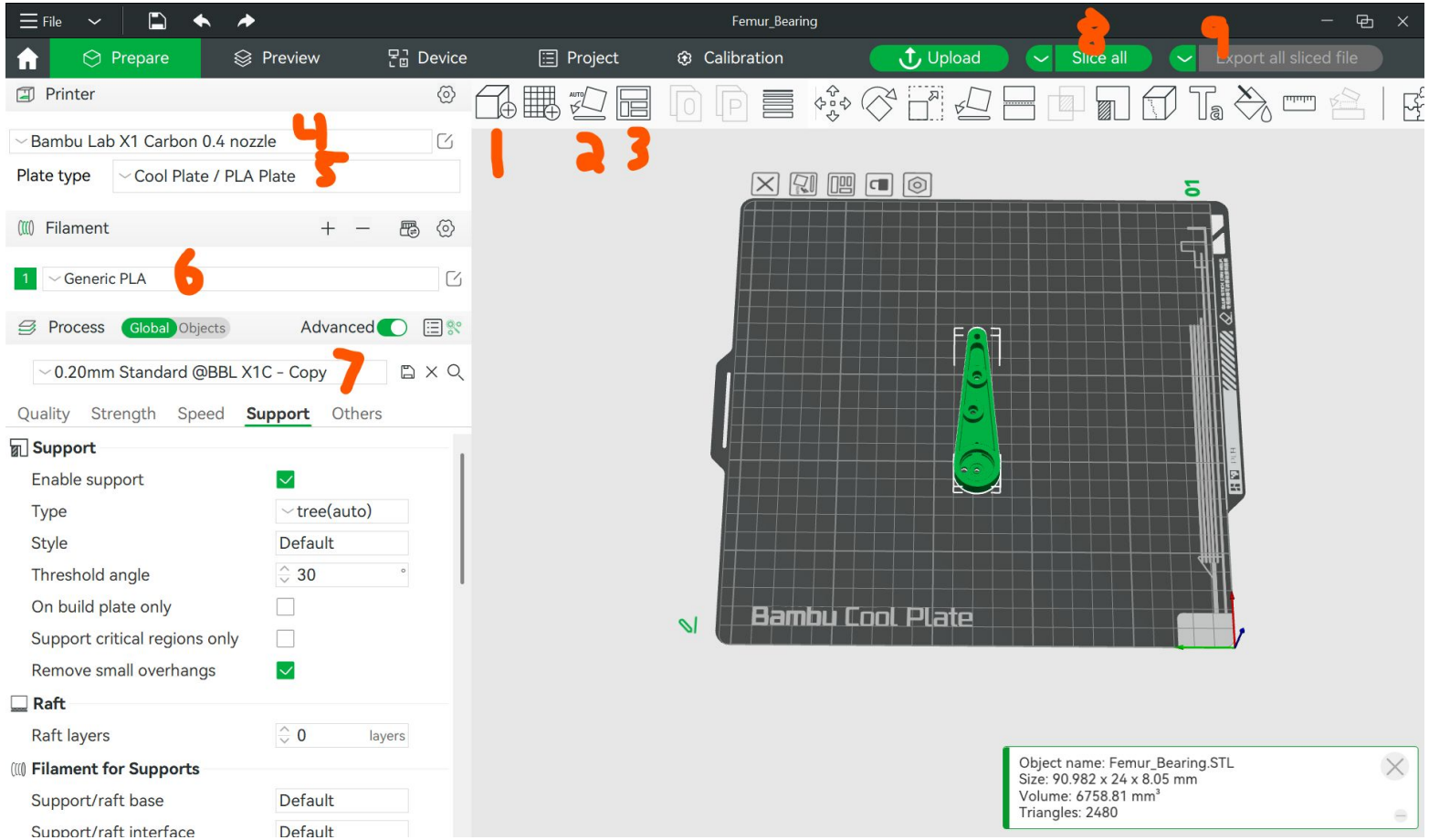
Remove the microSD card from the side of the screen, grab an adaptor, and save your gcode



Finished!

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 × 256 × 256 mm³
  - (Approximately 10.07 x 10.07 x 10.07 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 second layer**

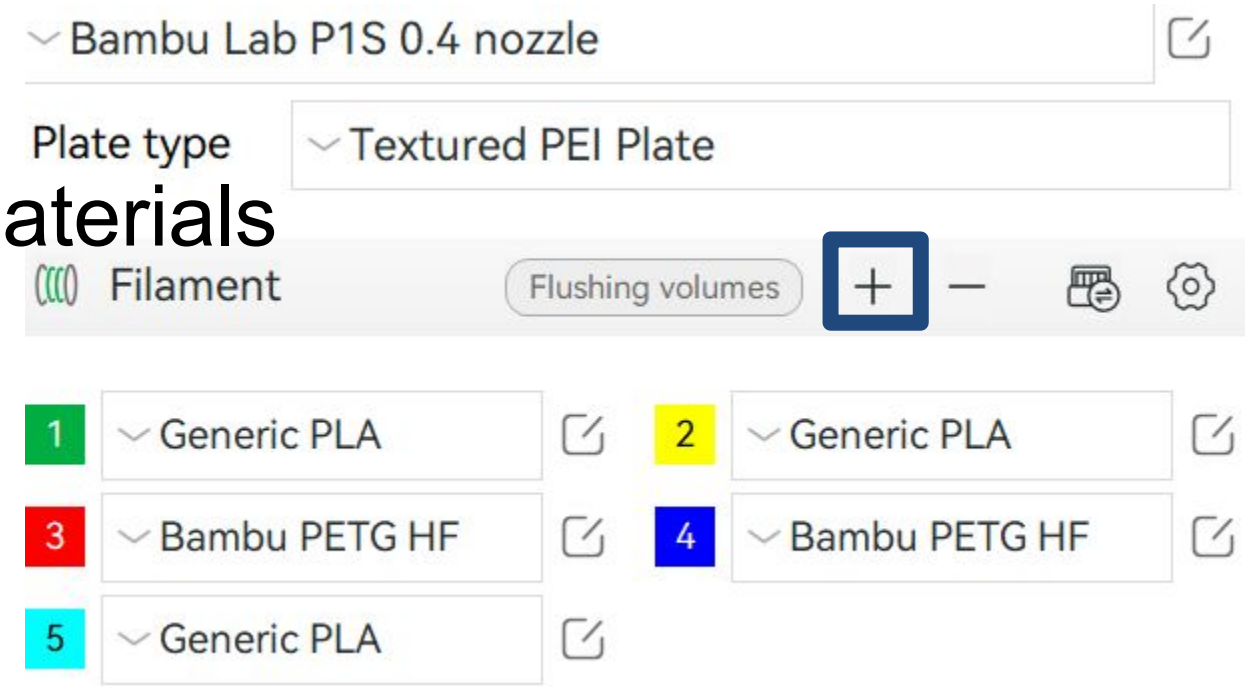
P1S

- Available Filaments
  - **PLA, PETG**, TPU, PVA, PET, ABS, ASA
- Has automated calibration
  - **Please stay in the lab until completion of the second layer**

- 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. Chose 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
- Toxic fumes

* Only ASA

  - 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**
- **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.

DFMA

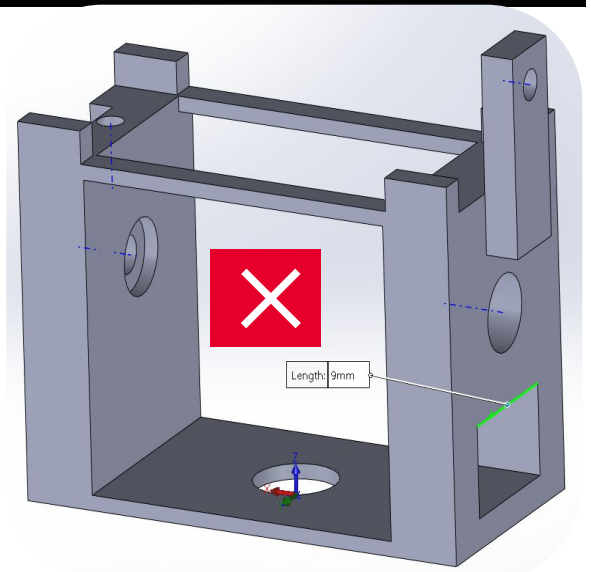
Teaching best practices for every manufacturing method is infeasible. Refer to a DFMA textbook when you need it.

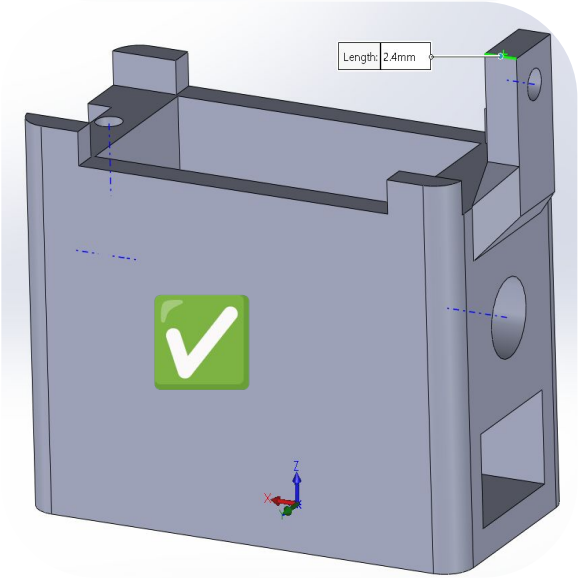
But typically these include:

- 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

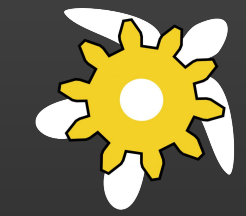
- Use multiples of nozzle diameter for **wall thickness (0.4mm** for us)
- Minimum wall thickness of **2mm thickness** for load bearing parts
- **Weakest** part orientation is the printers **Z-axis**
- Mitigate stress concentration with fillets, chamfer, or ribs





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 privilege**s.
- If you need training or supervision for a tool and cannot receive it from those present, send an @Officer in the
- 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.

Safety

OSHA Power Tool Rules

• Never carry a tool by the cord or hose.

• Never yank the cord or the hose to disconnect it from the receptacle.

• Keep cords and hoses away from heat, oil, and sharp edges.

• Disconnect tools when not using them, before servicing and cleaning them, and when

changing accessories such as blades, bits, and cutters.

• Keep all people not involved with the work at a safe distance from the work area.

• Secure work with clamps or a vise, freeing both hands to operate the tool.

• Avoid accidental starting. Do not hold fingers on the switch button while carrying a plugged-in tool.

• Maintain tools with care; keep them sharp and clean for best performance.

• Follow instructions in the user's manual for lubricating and changing accessories.

• Be sure to keep good footing and maintain good balance when operating power tools.

• Wear proper apparel for the task. Loose clothing, ties, or

jewelry can become caught in moving parts.

• Remove all damaged portable electric tools from use and tag them: "Do Not Use."

Be Safe & Smart

- Ask questions if you are unsure
- Wear PPE
  - safety glasses
- No loose clothing or hair >:(
- If an incident occurs, let an officer know promptly

https://www.osha.gov/sites/default/files/publications/osha3080.pdf

Common Types of Screw Heads

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

Vise Grips

Retaining Ring Pliers

Note: Names may vary

Available Power Tools

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

<u>List of power tools in our lab:</u>

- 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:

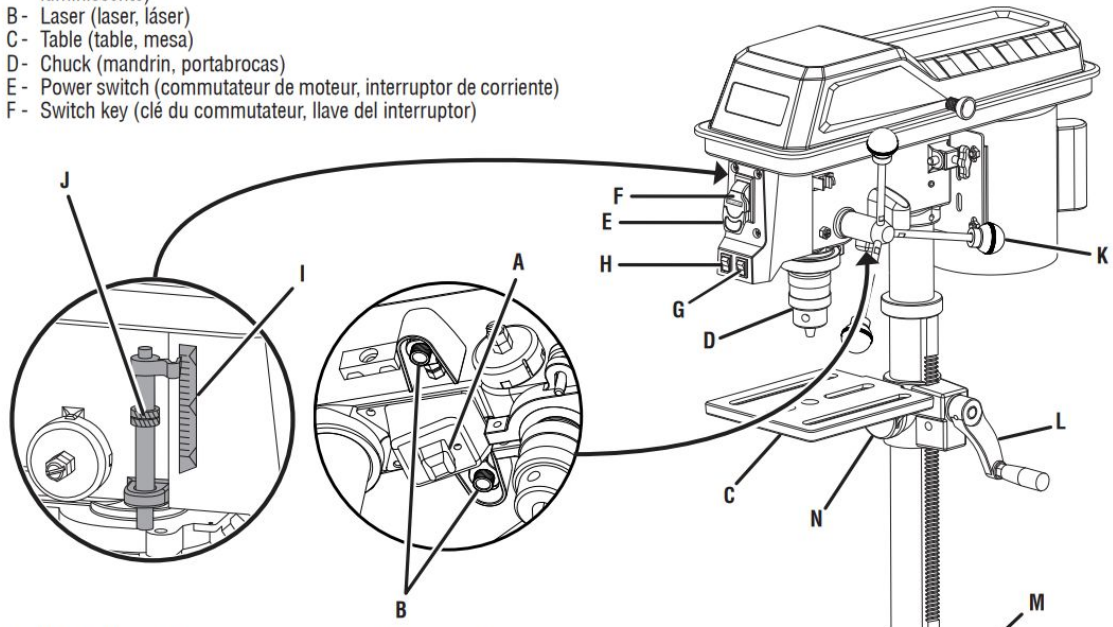
- To secure a bit, pull out bit collar outwards
- Dewalt impact works the same way
- You can just use the drill in most cases

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 profunidad)
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

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)

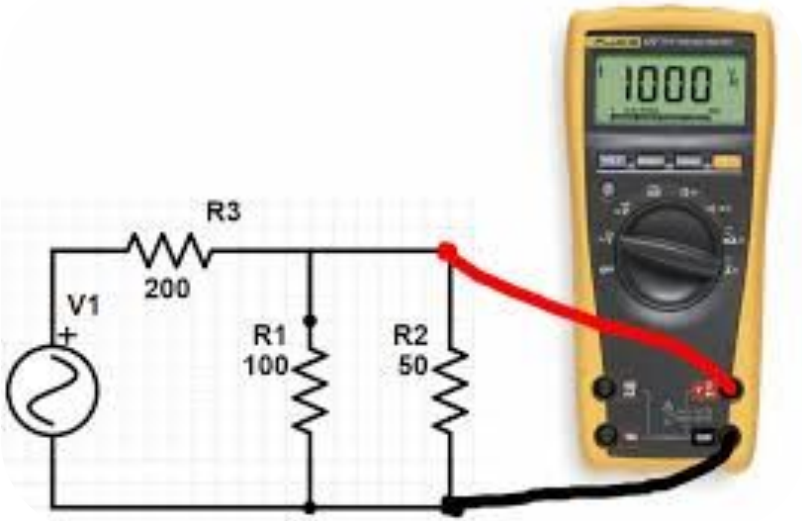
%	Duty Cycle	APO	Automatic Power-Off
°F	Fahrenheit Temperature	H	Data Hold
°C	Celsius Temperature	MAX	Maximum Reading
hFE	Transistor hFE	MIN	Minimum Reading
•))	Continuity Test	⎓	DC (Direct Current)
▶|	Diode Test	~	AC (Alternating Current)
Ω	Resistance	−	Negative Reading
⊃	External Current Test (Clamp)	≂	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

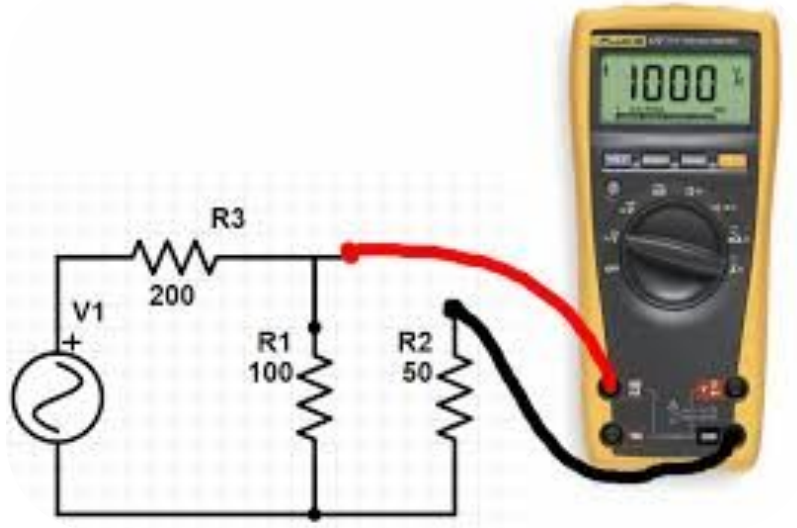
Note: For non-automatic range detecting devices, use the lowest setting that is greater than your approximate value

- 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 an Advanced Project
- 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

- 1 L298N (Motor driver)
- 2 tt-motors (DC-Motor)
- 2 SG90 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
  - 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 (Micro Servo)

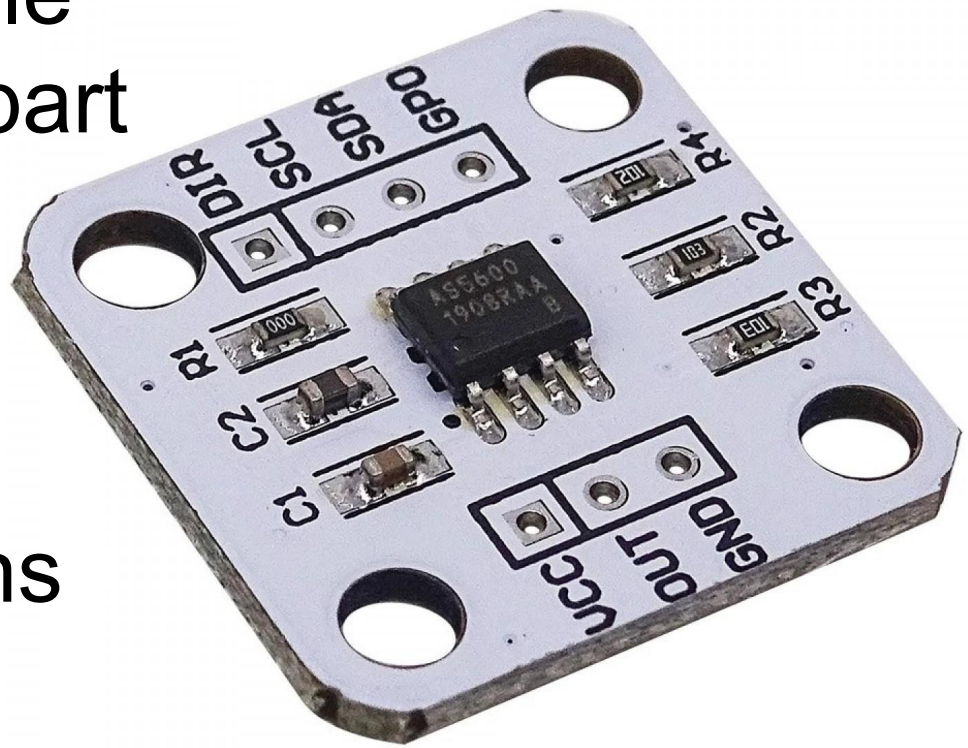
- 180° limited rotation
  - Goes to programmed angle
- High torque / Low speed
- Controlled directly from ESP32 through PWM

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

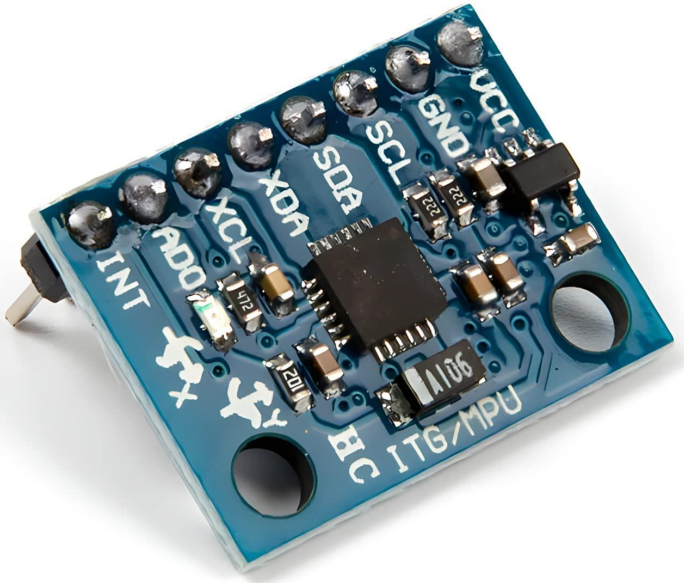
AS5600 Magnetic Encoder

- 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 I^2C interface
- Variations up to 2°



MPU6050

- Gyroscope, Accelerometer, and Digital Motion Processor
- Gyroscope can read up to ±2000° /sec
- Accelerometer can read up to ±16g
- Programmable filters
- Uses I^2C interface
- Programmable range

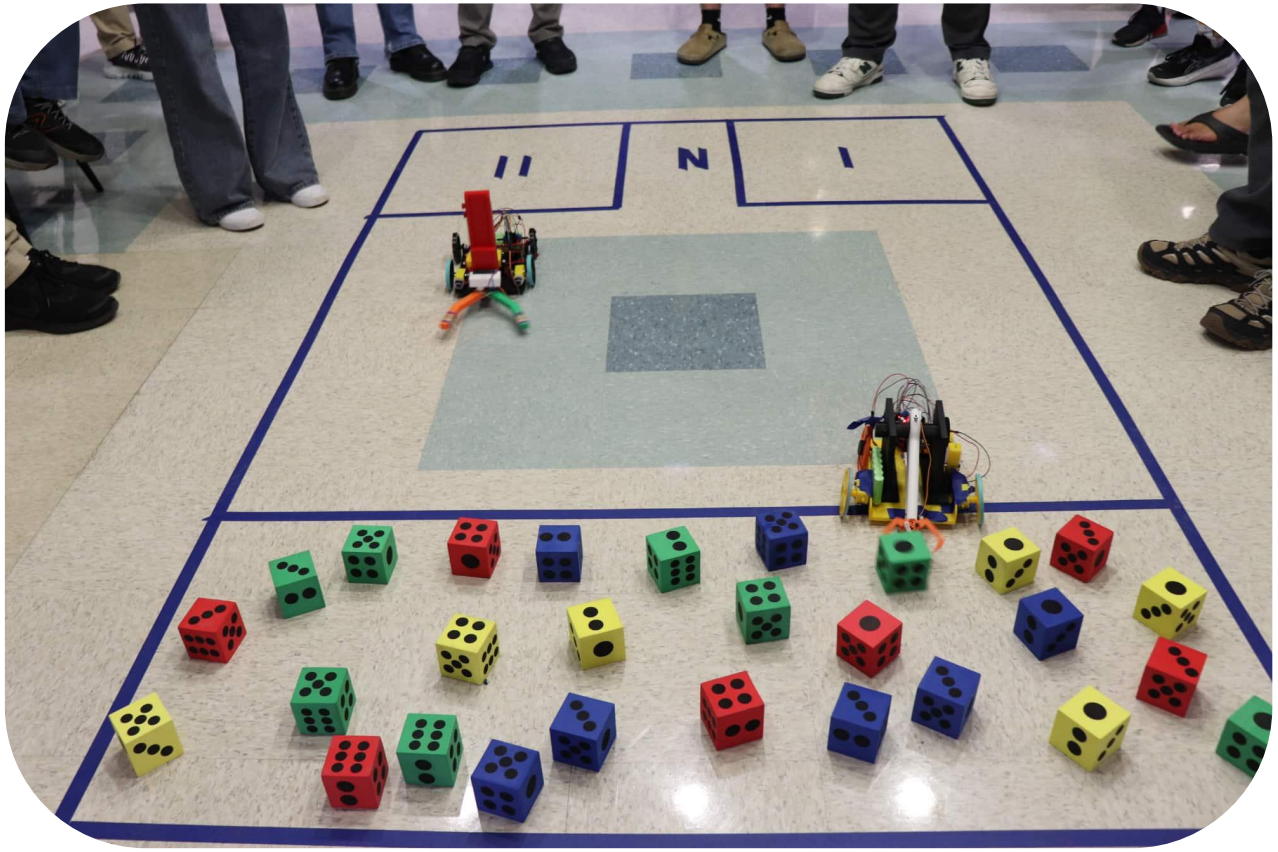


TEXAS A&M UNIVERSITY

ROBOTICS TEAM & LEADERSHIP EXPERIENCE

TURTLE Towers

Introduced: Spring 2025



Records:

Tallest Stack: 5

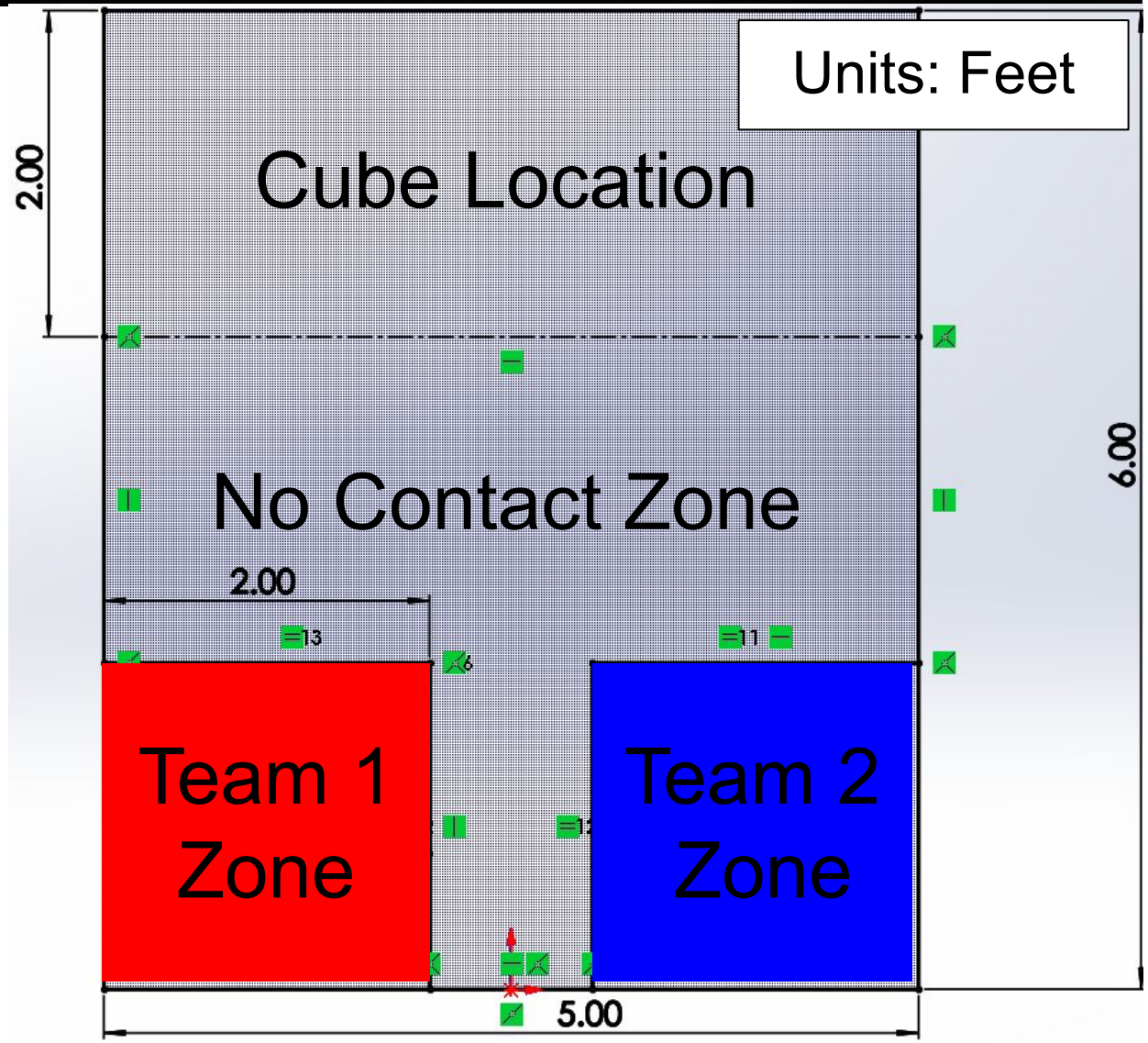
Most Blocks: 16

Story

Squeeze Enterprises has recently acquired rights to build student housing in College Station. The contractor chosen to develop their properties will be whomever can acquire the most points in three minutes. The contract states that points are awarded on the number of living areas (blocks) and the height of the tallest skyrise. You are contractors trying to win the lucrative contract. May the best contractors' robot win.

Gameplay

- 2:30 Minute Match
- Robots begin in their respective “Team Zone”
- Robots will traverse to the “Cube Location” and bring blocks back to their “Team Zone”
- Building blocks are randomly distributed within the “Cube Location”



Points

- 1 Point per block in Team Zone
- 10 Points per stack level (Only on highest stack greater than 1)
  - Stack: Extra Points -> 1:0, 2:10, 3:20: 4:30, 5:40
- 1 Extra point **per** block if robot integrates sensor data
  - Must have a software function
- 2 Points if your robot doesn't rely on adhesives, zip ties, or similar assembly securement solutions (One time at start of match)
  - Sometimes these solutions are the best option. Please provide justification for these exceptions.

Rules

- Building Blocks are 2.5 in x 2.5 in x 2.5 in
- You may intentionally move one building block at a time. N/A in “Team Zone”
- You may not collide/interfere with an opposing team in the “No Contact Zone” or enter the opposing “Team Zone”
  - Priority goes to robots returning to their “Team Zone”
- Points are scored at the end of the match
  - Blocks that enter into opposing “Team Zone” are scored for the opposing team
- Blocks must be completely within the “Team Zone”
  - “Team Zone” includes the tape
- Good Sportsmanship Rules
  - Play fair and be respectful

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.

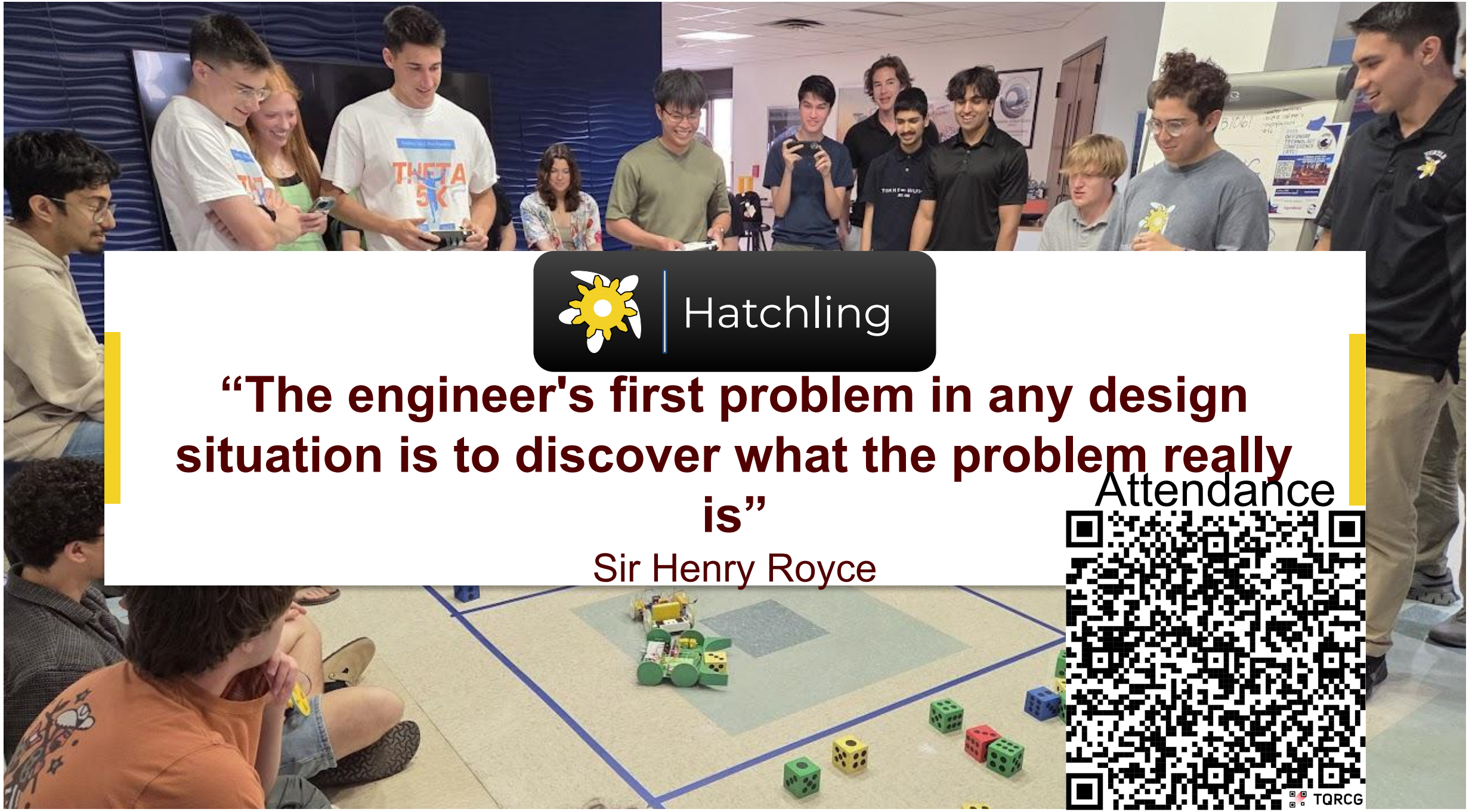
Impact: We will review design viability and suggest improvements.

TEXAS A&M UNIVERSITY

ROBOTICS TEAM & LEADERSHIP EXPERIENCE

Design Review and C++

Week after Fall Break



Hatchling

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

Sir Henry Royce

Attendance

TQRCG