# Lab 2 – Mechanical Prototyping

## Overview:

In this lab, you will learn to use the LaserCutter, build a prototype robot chassis from wood and foamcore, and 3D print parts. The goal is to develop a working understanding of CAD (Onshape) and mechanical prototyping. You will cut your platform and wheels on the laser cutter, design motor mounts in Onshape, and cut a foamcore tower and sensor platform to explore the strengths and weaknesses of each prototyping method. Finally, you will assemble the base, tower, and motor mounts.

### Comments:

**Lab checkoff:**

- Check off each part with a tutor or TA to verify functionality and each team member's understanding. **You need to print out the last page to get signed off. Include this sheet in your lab report.**
- Strongly recommended to check off each part before moving to the next.

**Lab2 specific comments:**

- This lab focuses on hands-on work and Onshape design.
- You will create and build a design using sharp knives and hot glue—exercise caution.
- Experienced Onshape users should let less experienced teammates take the lead to learn.
- Assistance will be available, but proactive preparation is strongly encouraged.

## PreLab:

1. Select a partner and join a group on CANVAS. For each lab, you must join a new group. **Navigate to People → Lab2 Group and register with your teammate.** If you need assistance finding a partner, use Piazza to connect with others. If you do not select a partner by the prelab deadline, one will be randomly assigned to you.
2. **Complete the required training for the laser cutter, 3D printer, and Fabrication Lab through BELS.** Without this training, you will not be permitted to use the fabrication tools necessary for this lab.
3. Complete prelab exercises and submit a PDF file individually on CANVAS. Follow the requirements detailed in each section. Part2.

# Part 0 – Onshape Basics

**Overview:**

This section provides essential background material to help you get started with Onshape. Carefully review this information to ensure you understand the platform and its settings. You will use Onshape extensively to design your parts, so proper setup and familiarity are crucial.

**Reference Material:**

- Onshape learning center – Introduction to CAD
  - (Optional) Introduction to Parametric Feature-Based CAD
  - Introduction to Part Studios
  - Introduction to Assembly Design
  - Introduction to Drawings

**PreLab:**

- Make a Student Onshape Account (Education license Free).
- Read the Background below.
- Complete the tutorials in the Reference Material above:
  - Go through each Onshape learning center module listed above.
  - Take screenshots of your learning center page, showing at least 90% progress status on each module.

**Background:**

**Onshape is a powerful and widely-used cloud-based CAD platform** that is popular both in education and in industry. In this class, we'll primarily use Onshape to design parts for creating 3D assemblies, with a focus on flat parts intended for laser cutting. Onshape's toolset is extensive, but only a subset is needed for our purposes. Fortunately, Onshape has built-in tutorials, help documents, and a supportive user community, so most questions can be quickly answered. This section will introduce the core tools you'll use in Onshape and help build a foundation for modeling effectively.

Onshape is built around the concept of **sketches, features, parts, and assemblies**—much like other parametric CAD programs.

- **Sketch**: This is where you define the 2D outline of your part. Onshape provides a robust sketch environment, including tools for lines, rectangles, arcs, splines, circles, and more. You'll also use constraints and dimensions to lock down the geometry of your sketch. Construction geometry (shown as dashed lines) can be used to assist in positioning and aligning features. Naming sketches (e.g., "base plate," "slot cutout") is helpful for organization.

- **Features**: Once a sketch is complete, you can use features to turn the 2D profile into a 3D object. The most common features we'll use are **Extrude** (to give the sketch thickness) and **Extrude Remove** (to cut shapes out of existing material). Because laser cutting is 2D, most of your work will be in a single plane, and thickness will correspond to the material you're cutting.
- **Parts**: In Onshape, a part is a single solid 3D object, and multiple parts can be created in a single Part Studio. Each part must be accurately dimensioned so that it fits correctly into the larger assembly and is ready for fabrication. For laser cutting, your parts must have precise outer profiles and any necessary internal cutouts, like holes or slots.
- **Part Studio**: This is where you build parts using sketches and features. You can create multiple related parts in the same Part Studio if they share common geometry or references. This can be useful for creating interlocking laser-cut parts that align precisely.
- **Assemblies**: Assemblies are used to bring together multiple parts (or subassemblies) and define how they fit together using **mates**. This is where you can test how parts align, check fit, and simulate limited motion. You can also define variables or configurations that affect all parts, such as material thickness or spacing.
- **Mates**: Mates define relationships between parts in the assembly. Onshape supports planar, cylindrical, slider, revolute, and more advanced mate types. For example, you might mate one face of a tab into a slot, or use a fastened mate to fix two parts together rigidly.
- **Drawings**: Onshape lets you create technical drawings from parts and assemblies. In this class, you'll mainly use drawings to lay out your parts for laser cutting. You'll export the drawing (usually as a DXF or PDF) to send to the laser cutter. Make sure to set the correct scale (typically 1:1) and arrange all cuttable parts on a sheet dimension to match the laser cutter's bed size.

**Tasks:**

- Get checked off on your understanding of Onshape backgrounds. (No need to complete it before the prelab is due.)

## Part 1 – A Simple Gearbox

**Overview:**

This lab assignment is to use Onshape to create a virtual gearbox assembly. You will learn how to use global and local equations as well as a wide variety of mates in order to ensure your assembly can easily be cut from both foamcore and MDF (although you will not do any cutting for this part of the lab).

**Reference Material:**

- Gearbox starter project from Onshape Classroom (you should already be invited).
- Gearbox Demo Video on Canvas Assignment page:

  - Link to Gear Feature used in the video.

- Laser Joint Demo Video on Canvas Assignment page:
  - Link to Laser Joint Feature used in the video.
  - Link to Auto Layout Feature used in the video.

- Edit in Context and Assembly Demo Video on Canvas Assignment page:

- Variable Tutorial Video Series from Onshape:
  - Link to Variable Tutorial Series in Youtube.
  - Watch Variable Studio in Onshape in particular.

**PreLab:**

Nothing on the prelab for this part.

**Tasks:**

- Begin your assignment in the Onshape classroom by copying the template project. Note that the Onshape project itself will not be graded; only your report will be evaluated.
- Use the Gearbox starter project, which includes a PDF with a dimensioned drawing of the Gearbox. Follow this drawing as a guide to create the gearbox assembly in Onshape.
- Define a Material Thickness variable in your Onshape variable studio. Ensure that this variable can be adjusted and that the assembly rebuilds without errors.
- Utilize the provided motor and gear parts (modifying gears as necessary) to construct the gearbox using laser joint construction. You may need to create additional parts that are not provided (e.g., bearings).
- Verify that your Onshape assembly is complete, with no undefined relations. Perform an interference check after varying the Material Thickness variable by a factor of 2 in either direction.
- Create a drawing that includes all laser-cut parts of the gearbox in a 1:1 scale.
- Demonstrate to the TA/tutors that the Material Thickness variable can be adjusted and that the assembly rebuilds without interference for checkoff.
- Include the following in your final report:
  - A printout of the assembly model from three perspectives, annotated with five key dimensions of your choice.
  - A screenshot of your laser-cuttable drawing.
  - A short paragraph describing the process of building the gearbox.

## Part 2 – Designing a Motorized Platform

**Overview:**

This assignment involves designing and prototyping a small motorized platform (base of a mobile robot). You will use Onshape to model the platform, incorporating both foamcore and wood sheet materials. This will require careful planning and the use of equations to ensure precision and compatibility between the different materials.

**Reference Material:**

- CKO Ch. 29
- Fabulous Foamcore handout

**PreLab:**

The sketch of your motorized platform, hand drawn (not Onshape). No need to specify the dimensions.

**Bumps and Road Hazards:**

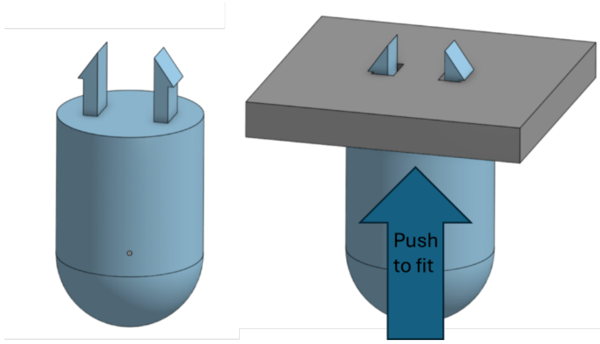
- Include tolerances in your design when parts need to fit together. For laser-cut components, account for the laser kerf, which naturally introduces a gap. It's best to test-fit small pieces first to verify alignment and make adjustments to your design as needed.
- Intricate shapes take longer to cut. The cutting time on the laser cutter is proportional to the total length of cuts in the design.
- For 3D printing, enable "support" if necessary and carefully consider the best print orientation on the printer bed.

**Tasks:**

You are going to design a basic motorized platform (e.g.: the roach). The base plate, motor mounts, and wheels will be cut from wood sheet (in Part 3), and it will include a tower with a small square mounted to it made out of foamcore.

The design requirements for your motorized platform are as follows:

1. The platform base must fit within an 11x11" rectangle (it is not necessary to use the full size).
2. The platform base is constructed from a single layer of wood sheet.
3. The motorized platform must move without tipping over or dragging parts on the ground (except for skids, spacers, or skegs).
4. Include one dome-shaped dragging skeg that can be inserted via snap fit. This skeg must be 3D printable and should not exceed a volume of 1.5 in$^3$. An example skeg design is shown below (you are not limited to this design).




5. The platform has two 76mm wheels cut from a single layer of MDF.
6. Motor mounts use tab in slot construction and are made to secure the drive motors against torque (dummy motors will be available in the labs for inspection, don't mount them).
7. Motor mounts are such that motors can be removed from structure without destroying the motor mounts or the motors themselves.
8. The platform has a circular cylinder out of foamcore mounted to the center using tab in slot construction.
9. The foamcore cylinder is 6" in height, and 4.5" in diameter.
10. A square box mounts to the top of the circular cylinder, centered on the cylinder.
11. It is 1" deep, side length greater than 5" (up to you to specify exactly)
12. Box is open on top, no lid required.

- Collaborate with your teammate using Onshape. Share the Onshape document and design together.
- Inspect the dummy motors and plan motor mounts for easy assembly and disassembly.
- Ensure proper wire routing to the motors.
- Design the chassis to provide adequate support during acceleration and deceleration.
- Keep the design compact and avoid etching on the laser cutter; focus on simple cuts.
- Use two materials: foamcore (nominally 3/16") and wood sheet (nominally 1/4"). Measure actual thicknesses before designing.
- Ensure the design includes all components: motor mounts, wheels, base, tower, and box.
- Demonstrate the Onshape design to TA/tutors for checkoff. The design must rebuild without errors when material thicknesses (both wood sheet and foamcore) are adjusted.
- Include three views and a perspective of the assembly with five key dimensions annotated in the lab report.
- Provide a description of the design and justify your implementation choices.

## Part 3 – Prototyping the Motorized Platform

**Overview:**

In this assignment, you will use the laser cutter to fabricate your base, wheels, and motor mounts from a wood sheet, 3D print the skeg, and hand-cut the tower and box from foamcore. After performing a trial fit, you will assemble and secure all components using hot glue.

**Reference Material:**

- CKO Ch. 29
- Fabulous Foamcore handout

**PreLab:**

Ensure that all of your safety training is complete. You cannot use the laser cutter, Fab lab, and 3D printer unless you have completed training through BELS.

**Bumps and Road Hazards:**

- Laser cutter uses a 130W laser; mishandling can cause fires. Safety training will cover fire prevention and response.
- Knives for foamcore are sharp; cut away from yourself to avoid injury. Replace dull knives promptly.
- Hot glue guns and glue can cause burns; handle with care.
- Test small laser-cut pieces first, especially for snap-fit parts, to ensure proper fit.
- After the parts are cut out, you will remove them and the scrap from the laser cutter. You will take the scrap with you to store in your own location or throw away in the dumpsters outside of Baskin. **DO NOT LEAVE SCRAP** in BE-138.
- Test fit all parts and make sure things fit together nicely. Don't glue anything together yet until you have made the foamcore parts.

**Tasks:**

- Use the laser cutter to cut out the wood sheet platform designed in Part 2. 3D print the skeg and hand-cut the foamcore tower and box on top.
- After checkoff for Part 2, lay out the base, motor mounts, and wheels onto a wood sheet and export it as a .DXF file. **Have the layout checked off by a TA/tutor before proceeding**.
- 3D print your skeg.
- Use construction skills and the fabulous foamcore handout to create the box and cylinder. Hand-cut the foamcore components using razor blade knives. Build the box first, ensuring neatness and straight edges with lap joints at the edges. Construct the cylinder with at least 16 sides for a circular cross-section, using tabs, slots, and a lap joint to close it. Test fit the column and box into the base without gluing to ensure proper alignment.

- **Show the test fit parts to the TA/tutors for approval before gluing**. Glue the parts together, ensuring motors are not glued in and motor mounts allow motor removal without damage.
- **Demonstrate the glued assembly to the TA/tutors for checkoff**.
- Return the motors to the benches after checkoff.
- Include pictures of the finished platform in the lab report, along with a detailed description of construction methods, difficulties encountered, and insights for design improvement.

## Checkoff and Time Tracking

Student Name:____________________________________ CruzID______________@ucsc.edu

| Time Spent out of Lab | Time Spent in Lab | Lab Part - Description |
|---|---|---|
| | | Part 0 – Onshape Basics |
| | | Part 1 – A Simple Gearbox |
| | | Part 2 – Designing a Motorized Platform |
| | | Part 3 – Prototyping the Motorized Platform |

| Checkoff: TA/Tutor Initials | Lab Part - Description |
|---|---|
| | Part 0 – Onshape Basics |
| | Part 1 – A Simple Gearbox |
| | Part 2 – Designing a Motorized Platform |
| | Part 3 – Prototyping the Motorized Platform |