Spring 2025 ASME CADathon

WaferWave

Group 17

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Overview

The design presented in this report outlines a modular and ergonomic cart designed to provide a robust solution for precision handling and contaminant-free transportation of sensitive materials within a cleanroom environment. At its core, the WaferWave is a cart that features a height-adjustable hydraulic tabletop, patterned with vacuum clamping modules, retractable rubber rollers for maneuverability of heavy loads, all resting upon a bed of vibration-damping silicone gel pads. These features make the WaferWave safe and easy to use, and it can handle the majority of use cases within a semiconductor fabrication environment.

Design Evolution

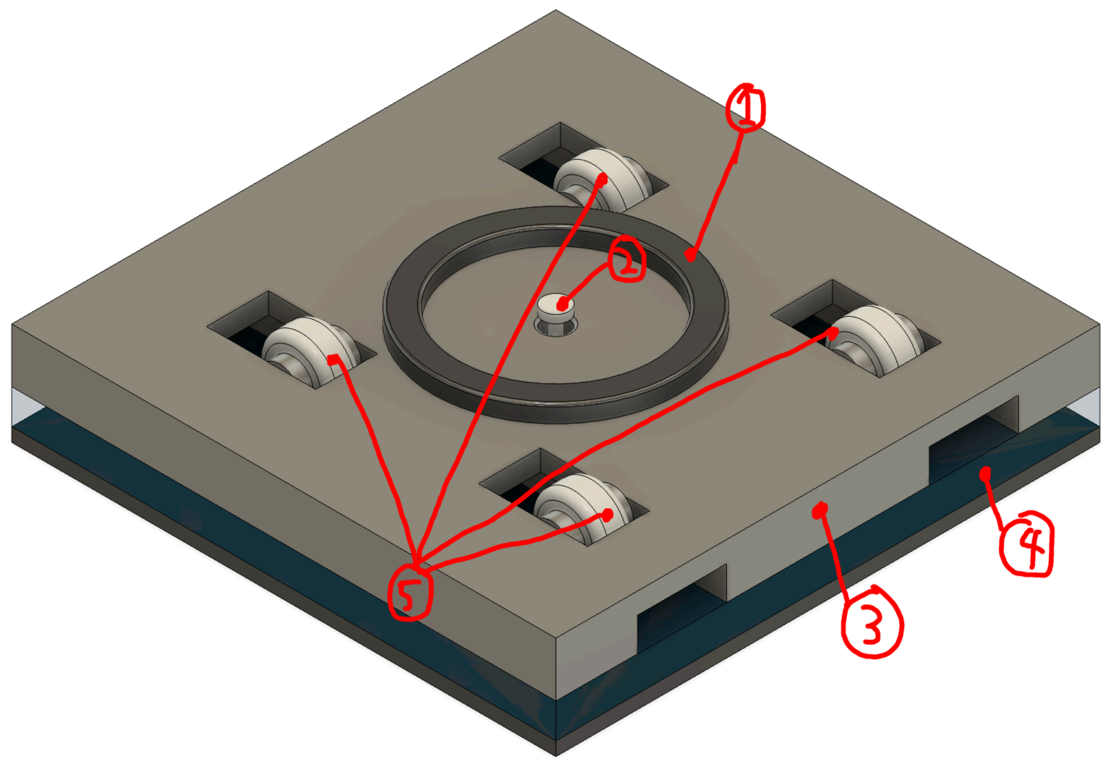
The WaferWave began as a simple cart that would feature some form of robotic arm that could carefully pick up heavy or delicate objects like a box of tools or a carrier full of silicon wafers off of the user's workstation and place them onto its countertop. The idea was to have the WaferWave take care of moving things that the user couldn't while letting the user take care of the lighter, more robust items. This idea quickly sank as it wasn't clear how we could make the arm observe the world and know what to pick up and where to put it. Furthermore, making the arm bulky enough to handle 50 lbs felt too impractical. While the idea of the robotic arm was dead, we still wanted something that could assist the user with moving delicate or heavy objects onto a cart for transportation. After brainstorming, we came up with the idea to use freely spinning ball bearings embedded into the cart and workstation surface to facilitate lateral movement without having to pick the item off of the workstation or the cart. A height-adjustable countertop would bring the cart perfectly flush with the workstation and allow the user to simply slide the object onto the cart. This can allow for the easy and safe transfer of wafer containers (and other sensitive materials). Though there were still obvious issues with the idea, we thought the concept had potential, and after more brainstorming, we arrived at the final design.

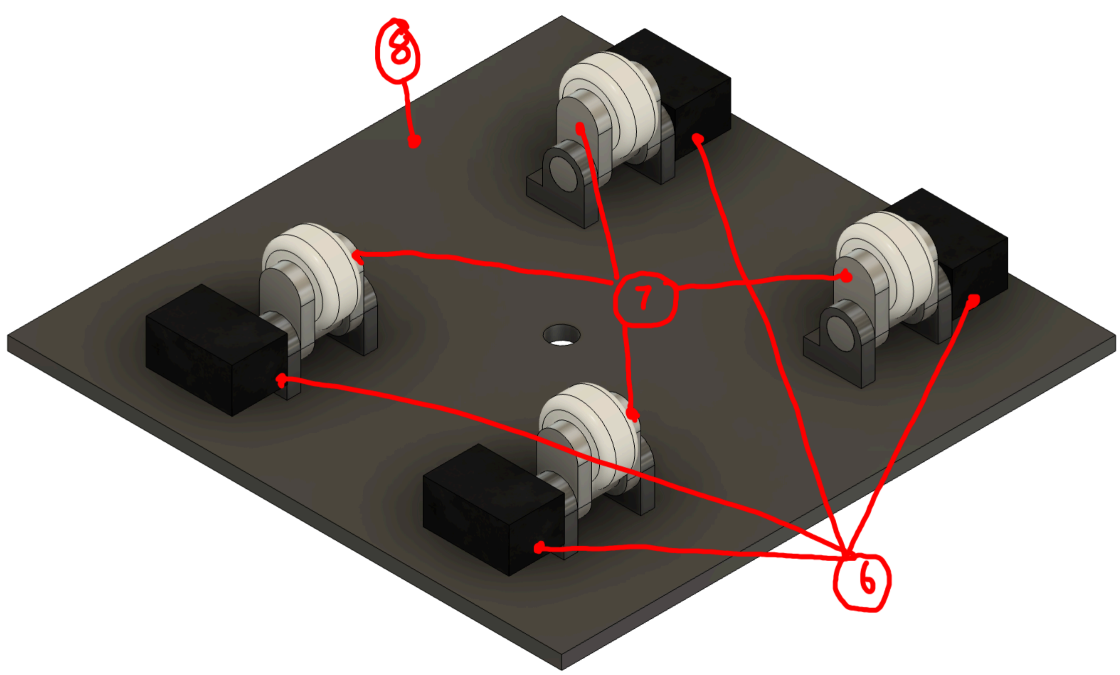
The Final Design and Justification

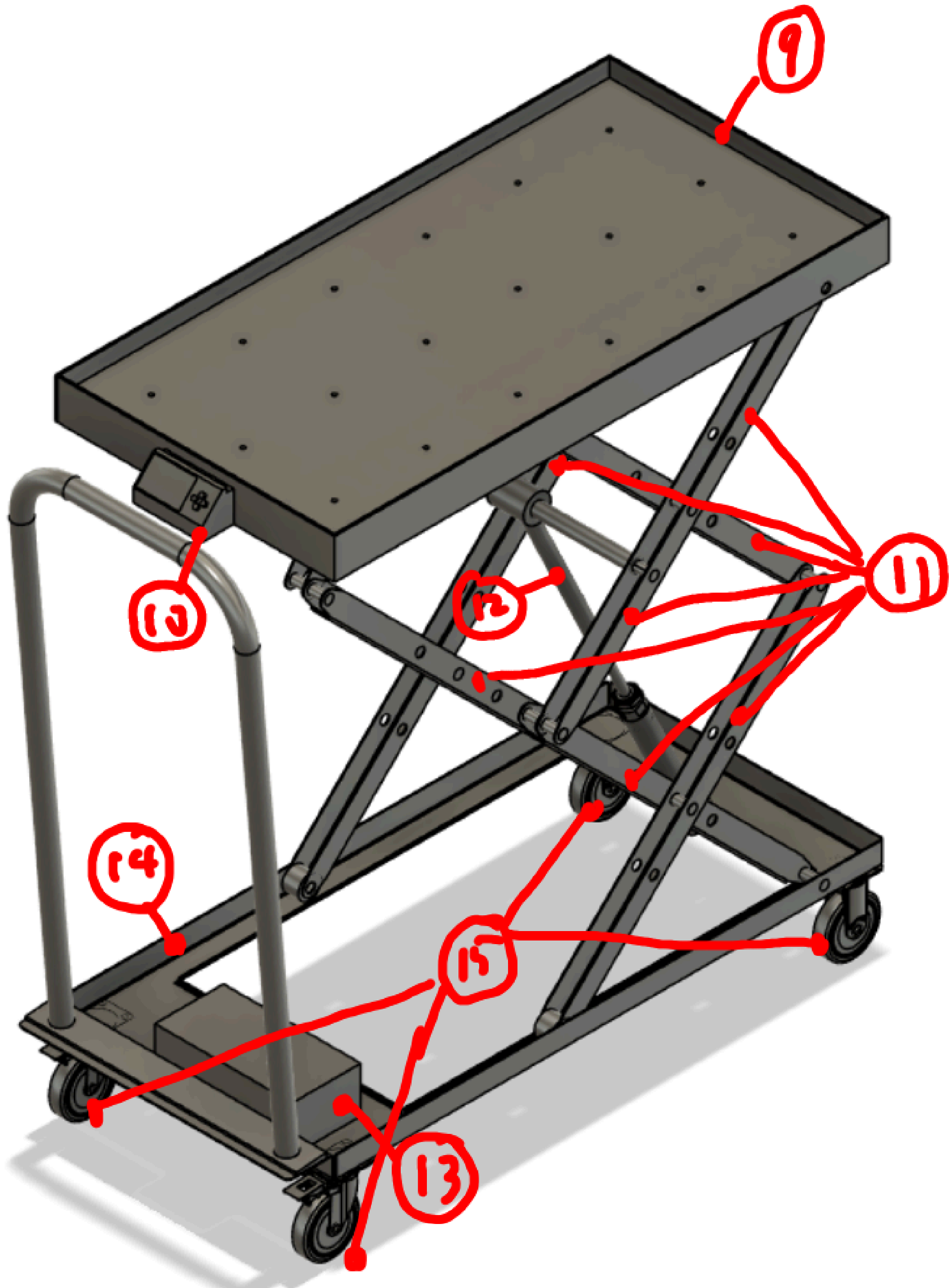
The final form of the WaferWave is a modular masterpiece. Constructed using 20 cm x 20 cm x 3.77 cm flat functional pieces, the cart could be any size divisible by 20 cm. Each module consists of a 5 mm thick anodized aluminum bed where a set of four retractable rubber wheels powered by four servo motors are mounted around a hole. The space in between these components is filled with 1.27 cm of silicone gel, which provides the module with a passive damping effect to protect against normal vibrations during transport atop a cart. On top of the silicone gel, a 2 cm thick 304 stainless steel sheet acts as the table surface where the user places items for transport. A wire electrically connects the steel sheet to the aluminum. When fully extended, the rubber wheels reach just above a 6.35 mm thick anti-static EPDM rubber ring acting as a seal for a vacuum clamp in the center of the module. These modules cover the entire surface of the WaferWave cart, which features hydraulic height adjustment and static control castor wheels that ensure that the entire cart stays electrically grounded at all times.

Picture this: a worker at a semiconductor fab cleanroom needs to move a heavy 50-pound container of delicate semiconductor wafers from their workstation to somewhere down the hall. Instead of roughly picking up the container and subjecting the entire container to rough shaking and building static electricity, the worker fetches the WaferWave and pulls it next to their workstation. With a vacuumless version of a WaferWave module built into the worker's workstation, the worker presses a button that engages the servos in the module, lifting the container onto freely rotating rubber wheels. With ease and smoothness, the worker swiftly pushes the container onto the WaferWave. The container comfortably covers the centers of four of the modules on the WaferWave before the user presses a button, instantly retracting the module wheels on the WaferWave before engaging a vacuum pump, safely securing the container to the top of the WaferWave. The worker rests easy knowing that damaging vibrations will be absorbed by the silicone gel and any static buildup is safely discharged into the ground as every component on the cart has a direct path to electric ground. Pushing the cart along, the worker gets careless and clips a wall. Oops! Hope their boss didn't see that. But no matter, the containers are completely safe as there's enough suction force to keep any reasonably sized 50 lb container firmly stuck to the tabletop.

CAD and BOM



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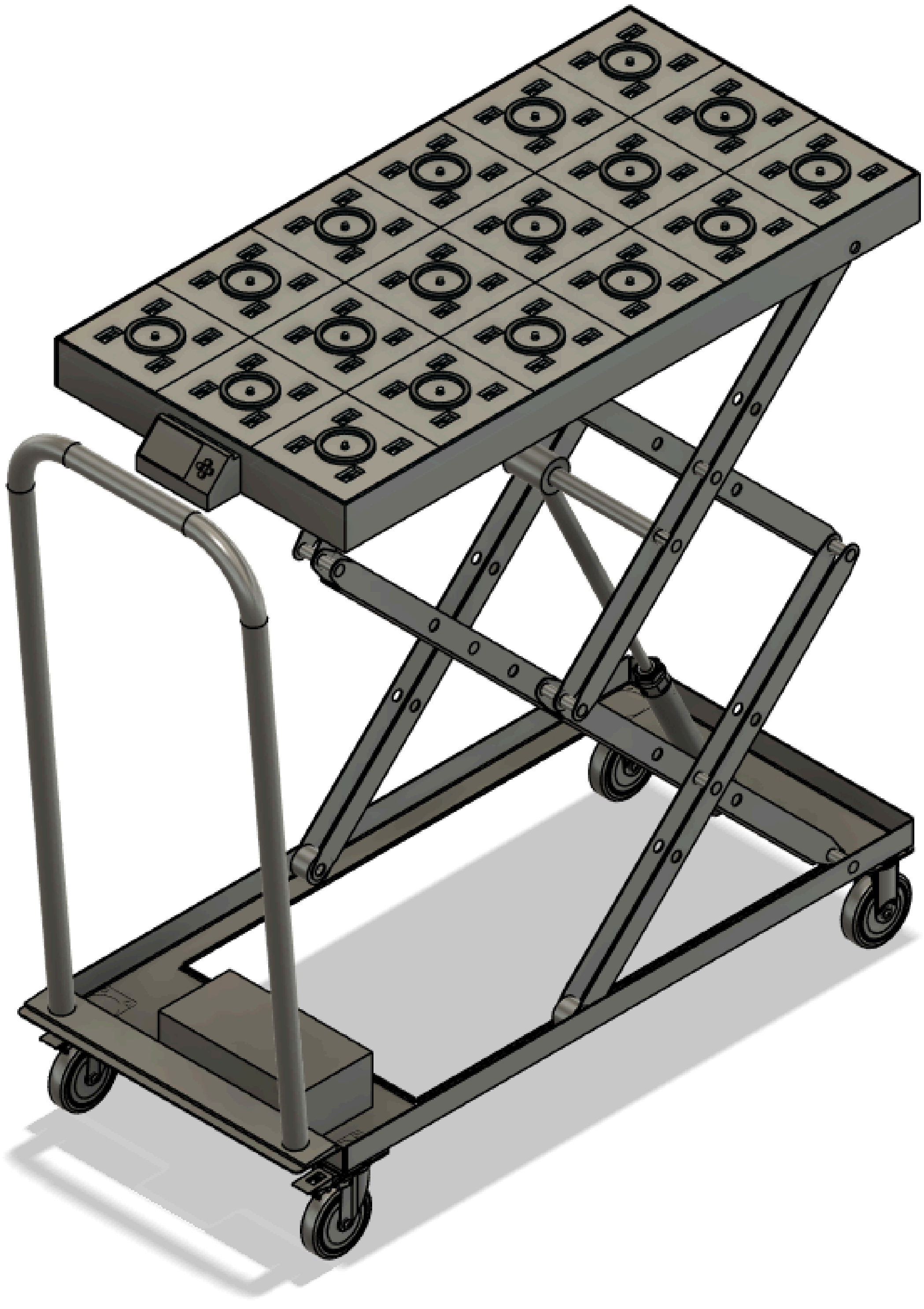
Collapsed Position

Part Number	Item	Description	Quantity
1	Rubber Seal for Vacuum Clamp	Anti-Static EPDM Rubber Gasket	1 for each module
2	Debris Shield	PVC plastic shield that prevents the vacuum hole from being covered	1 for each module
3	Stainless Steel Plate	20 x 20 x 2 cm 304 Stainless Steel plate	1 for each module

4	Vibration Damper	20 cm x 20 cm x 1.27 cm thick silicone gel pad	1 for each module
5	Wheel	2.7 cm diameter, 1.27 cm wide, 8 mm bore Anti-static nylon wheels	4 for each module
6	Servo	Servo motor	4 for each module
7	Wheel Turner	316 Stainless steel holders for the wheels. Designed to take a lot of load.	4 for each module
8	Aluminum plate	20 cm x 20 cm x 5 mm anodized aluminum sheet	1 for each module
9	Stainless Steel Module Basket	304 Stainless Steel basket designed to hold 3x6 modules	1
10	Interface	Electronics interface to control module servos, hydraulic, and vacuum pump	1
11	Scissor lift beams	304 Stainless Steel beams, bent	8
12	Hydraulics	40mm Bore Diameter Round Body Hydraulic Cylinder, 6024N36	1
13	Vacuum pump	2.5 CFM vacuum pump with 3*6 electric solenoid valves leading to each individual module	1
14	Aluminum Cart	Anodized aluminum Cart	1
15	Anti-Static Castors	Static Control Caster, 23065T43	4



Full Assembly

Additional Processes and Materials to Consider

The modules were designed in such a way that each “layer” of material could easily be cut out of a single sheet of raw material bar part 7. Thus, most of the modules can be manufactured using subtractive machining before assembly. Furthermore, most of the components of the cart were designed to be pieces of raw material that are bent accordingly. As such, the core processes involved would either be waterjet or laser cut, and then metal bending. Many more complicated items, such as the wheels, servos, vacuum pump, hydraulic cylinder, electronics, and solenoid valves, can be bought off-the-shelf from other suppliers and don’t need to be specially manufactured.

Additional materials that can be considered for the cart platform are Polypropylene, Polycarbonate, and PTFE, which are resistant to chemicals and have low particle generation. Additional processes that can be taken into consideration while manufacturing are the ease of manufacturing through tool selection and the ergonomics of maneuvering the cart. Since the cart is meant to be used for a range of 5 lb to 50 lb loads, there are additional processes that would need to be considered to limit the strain on the worker. Ease of maintenance is a process that is a priority for devices used in cleanrooms, as they need to be cleaned daily and parts need to be maintained up to the ISO classification standards.

Misc. Calculations

Coefficient of friction for EPDM rubber seal is 1.0

Examine pressure needed to withstand crash cases where a torque is applied to the max load distributed across 4 vacuums

- Time taken to decelerate: 0.1s
- Walking pace: 1.4 m/s
- Deceleration: $1.4/0.1 = 14 \text{ m/s}^2$
- COM is 0.15 m above table
- $F_d = 25 \text{ kg} * 14 \text{ m/s}^2 = 350 \text{ N}$
- $T = 350 * 0.15\text{m} = 52.5 \text{ N*m}$
- $0.2\text{m} * PA = 52.5$
- $P*2*0.07^2\pi = 52.5$
- $P = 1.7 \text{ kPa}$

Examine pressure needed to withstand lateral forces experienced during crash

- $F_{friction} = 25\text{kg}* 14\text{m/s}^2 = 77.25 \text{ N}$

- $P(Pa) = 77.25\ N / (0.015393804*4(m^2)) = 1.25\ kPa$

Need at least 1.7 kPa of negative pressure from the vacuum module

Chamber volume: Due to the small chamber volume and small pressure requirements, pretty much any vacuum pump will suffice.

Examine what the max load is for part 7:
- The wheels are very strong and will take well over 100 lb each.
- The shear strength of an 8mm diameter 316 stainless steel rod is roughly 290 MPa
  - 0.004*0.004*π= 0.00005026548246 m^2
  - 290000000 Pa = F/0.00005026548246
  - F = 14576.9899134 N

Future Improvement

Future improvements could focus on developing vacuum seals in a variety of shapes. This innovation would allow the system to securely stabilize objects with irregular surfaces, eliminating the need for flat-bottomed containers. Furthermore, integrating mechanical clamps on both sides of the cart would offer an additional layer of stability, especially for heavy or uneven-shaped objects. Additionally, reducing the number of servos from 4 to only 2 will not only reduce manufacturing cost but also simplify the design. It could be achieved by introducing a system of rods that can mechanically push and pull the roller. It streamlines the stabilization process while maintaining precision and efficiency. Combined with a variety of vacuum seals, mechanical clamps, and the reduction of servo, this setup would maximize versatility and operational performance during transportation. Finally, the cart design can be optimized to ensure the best balance between structural integrity and cost; for this component, simulations and calculations weren’t conducted due to time constraints.