Final Design Review
ME 463 - Senior Design

ASTRANEW

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Executive Summary:

Astranew addresses a critical challenge in long-duration space missions: the substantial waste from disposable clothing. Currently, astronauts discard approximately 500 pounds of clothing per three-year mission with launch costs of $10,000 per pound. Traditional laundry systems remain impractical in microgravity, while experimental water-efficient solutions are unproven for space applications.

The Astranew system—a closed-loop, water-free clothing sanitation appliance—fits within four NASA EXPRESS-Rack double lockers. This innovative device combines engineering excellence with practical functionality: the 12"×21"×22.5" chamber, milled from 1/8" 5052-aluminum, features dual high-efficiency fans, a deodorizing cartridge, custom 3D-printed airflow hanger, and germicidal UV-C lamps—all managed by an intuitive Arduino interface. Drawing just 131 Watts, the system operates well within spacecraft energy constraints while maintaining uniform airflow with minimal crew effort.

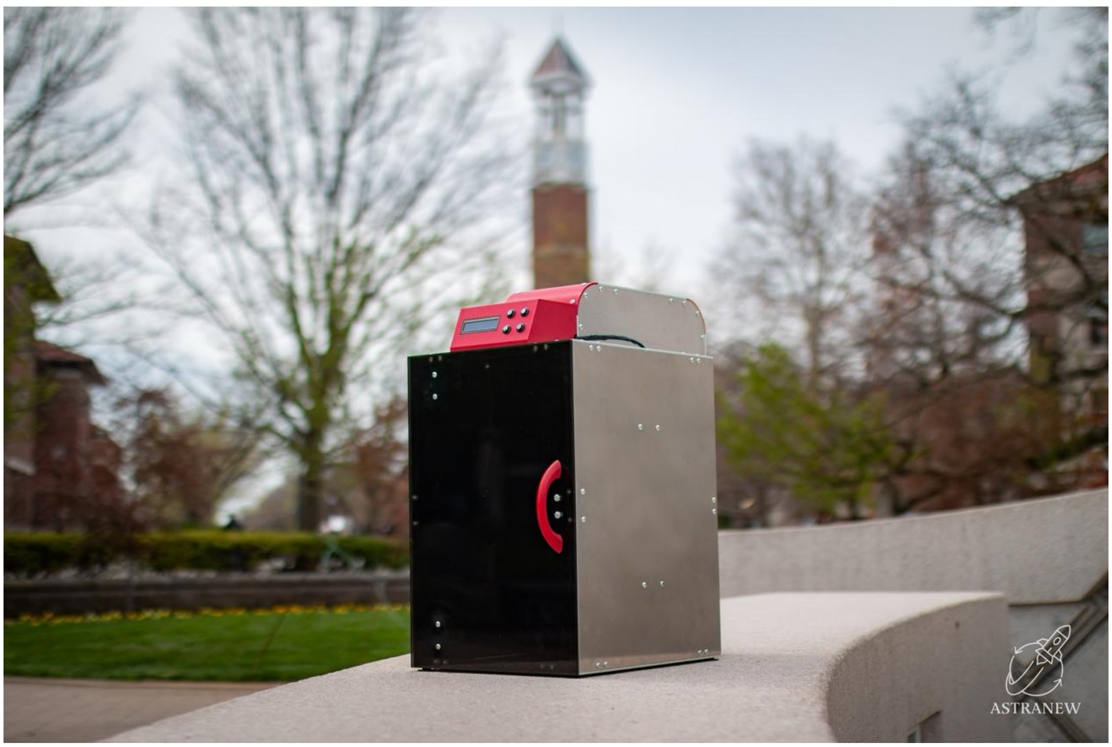


Figure 1: Astranew's Product

Performance testing demonstrates impressive results: ≥99.9% bacterial reduction in under five minutes, with complete sterilization and deodorization cycles completed in twenty minutes—four times faster than required. The system eliminates the need for water, chemicals, or consumables in maintaining garment hygiene.

Market analysis confirms strong demand from both government space agencies and private aerospace companies. Priced at $1 million per unit with projected annual sales of 8-10 units, Astranew delivers exceptional value by reducing clothing payload requirements by 80%—generating approximately $4 million in launch cost savings per astronaut during a standard three-year mission. Despite its sophisticated capabilities, the scaled down prototype's bill of materials totals only $722, leveraging commercial-off-the-shelf components and additive manufacturing.

Comprehensive failure mode analysis has identified and mitigated key risks through targeted interventions including UV-resistant door, reinforced structural elements, and robust electronics systems. The development roadmap includes further research and development to optimize the system, endurance testing, vibration qualification, and thermal-vacuum microbial trials to achieve NASA-STD certifications before integration proposals to space agencies and commercial operators.

By solving the textile hygiene challenge without consuming precious resources, Astranew removes a significant barrier to sustainable human presence beyond Earth while offering parallel benefits for remote terrestrial environments where water scarcity or resupply challenges exist—demonstrating exceptional dual-use value both on and off our planet.

Main Body:

Introduction

The sustainability of life on Earth faces increasing challenges due to the depletion of natural resources, rising global temperatures, and environmental pollution. As a result, space exploration and colonization have emerged as potential solutions for ensuring the long-term survival of humanity. Governments and private enterprises are investing heavily in space missions aimed at establishing permanent human settlements beyond Earth. However, sustaining life in space presents significant challenges, particularly in resource management. One of the most critical aspects of long-duration space habitation is the ability to recycle and reuse essential materials to minimize waste.

One major source of waste in space missions is clothing. Currently, astronauts have no means of effectively washing clothes, resulting in a significant accumulation of textile waste. Given that each astronaut is allocated approximately 500 pounds of clothing for a three-year mission, the inability to clean and reuse apparel places a heavy burden on mission logistics. The high cost of launching payloads—estimated at $10,000 per pound—further emphasizes the need for a more efficient solution. Additionally, astronauts engage in an average of 2.5 hours of physical exercise per day to mitigate muscle and bone loss in microgravity, further emphasizing the issue of sweat-soaked clothing. While space habitats maintain a controlled climate that minimizes excessive perspiration, workout attire must be changed frequently. Addressing these inefficiencies is a crucial step toward reducing waste and optimizing resource utilization in long-duration missions.

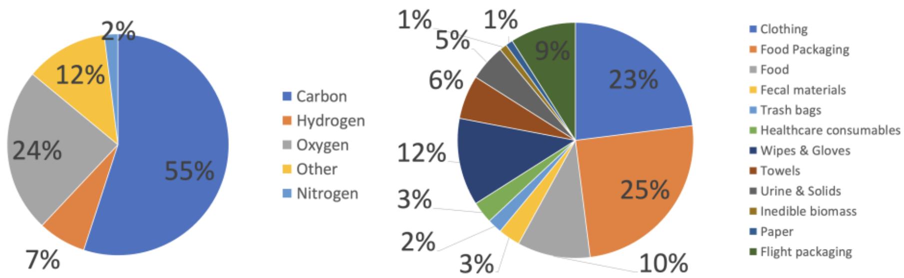


Figure 2: Visualization of Waste Generated in a Long-term Space Mission

This project aims to develop a novel clothing sanitation and recycling system that restores clothes to a reusable state using a waterless, UV-C-based sterilization and deodorization method. The proposed system is designed to function in microgravity environments, minimizing resource consumption while maintaining efficiency. By reducing the need for single-use clothing, this system will significantly lower payload mass requirements and enhance sustainability in long-duration space missions.

Background and Benchmarks

The current methods for addressing textile sanitation and reusability in space are highly limited. NASA has partnered with Tide to develop a fully degradable detergent designed for use in microgravity environments, but this solution remains in the experimental phase. Other commercial solutions, such as the Samsung AirDresser, use steam and air for garment sanitation but are not designed for space applications. Similarly, Asko's W2084C washing machine offers high water efficiency but relies on gravity-dependent water flow, rendering it impractical for space missions. Manual solutions like The Wonder Wash eliminate electricity consumption but still require significant amounts of water, which is a scarce resource in space.

Given these constraints, a waterless clothing sanitation system offers a significant advantage over existing methods. UV-based sterilization and deodorization technologies have been used in medical and industrial applications for eliminating bacteria and odors. By leveraging this technology, the proposed system will provide an effective and sustainable method for cleaning clothes for reusability in microgravity environments. This approach aligns with the growing demand for sustainability in space missions by reducing the need for disposable clothing and optimizing resource utilization.

Design Considerations and Constraints

The development of the system requires a clear understanding of design requirements and constraints to ensure feasibility in space habitats. Several key considerations were identified during the initial brainstorming and design phases:

- <u>Minimal water and energy consumption</u>: Since water is a limited resource in space, the system must operate without any liquid-based cleaning agents. Additionally, power consumption must be optimized to function efficiently within the spacecraft's energy budget.

- Recycling efficiency: While clothes do not need to be restored to their original state, they must be cleaned to a level that allows for practical reuse. The system must effectively remove sweat, bacteria, and odors without damaging fabric integrity.
- Microgravity compatibility: The device must function in an environment with a gravity of 1.625 m/s^2, an atmospheric pressure of 57.2 kPa, and temperature ranges of 18–27°C. Gravity-independent operation is essential for usability in space habitats.
- Compact design: The system must fit within four EXPRESS Rack double lockers, each measuring 48.26 cm in height, 41.91 cm in width, and 24.13 cm in depth. Space constraints necessitate a compact and modular design that integrates seamlessly into existing spacecraft infrastructure.
- Non-toxic emissions: The system must not release harmful byproducts such as PFAS or microplastics. It should be compatible with the closed-loop air and water systems of the spacecraft, ensuring that any waste generated can be safely managed within the habitat.

Concept Development and Selection

The design process began with an extensive evaluation of potential recycling and sanitation methods. Initial brainstorming sessions explored a range of concepts, including fabric repurposing, thermal treatment, and chemical-based sterilization. Various concept sketches were developed to visualize different approaches, each assessed against key performance criteria.

A weighted decision matrix was employed to systematically evaluate and compare each concept. The assessment criteria included energy efficiency, cleaning effectiveness, material compatibility, scalability, and integration feasibility within a spacecraft environment. Through this evaluation, a UV-C-based cleaning system with airflow was identified as the optimal solution due to its ability to eliminate bacteria and odors without requiring water or chemical agents.

Further refinement was conducted using a subfunction design matrix, which involved breaking down the overall system into essential components and evaluating multiple solutions for each subfunction. Specific design elements such as stain removal, deodorization, and bacteria elimination were analyzed in detail. Ultimately, the most effective approaches were integrated into the final design, ensuring a balance between performance, efficiency, and usability in space environments.

Preliminary Prototype Insights

Our preliminary prototype focused on validating key operational concepts and identifying potential design challenges. Through this process, we successfully:

- Optimized airflow distribution: We tested various fans and their configurations to determine the optimal orientation for effective air circulation through clothes. This experimentation confirmed that strategic airflow ducting significantly improves the cleaning process by ensuring that air reaches the interior of clothing for uniform deodorization.

- Evaluated material selections: We assessed various materials for their durability, efficiency, and space-environment compatibility, considering factors like weight and longevity. The aluminum enclosure was chosen due to superior heat dissipation and lower costs compared to alternative materials.
- Refined user experience: We used a simplified control interface to minimize astronaut workload, incorporating intuitive controls that can be easily operated with minimal training requirements.
- Validated scalability potential: The preliminary testing confirmed that our design approach can be effectively scaled to accommodate different mission durations and crew sizes, ensuring adaptability for future applications beyond the current scope.

Figure 3: Preliminary Prototype

Final Prototype Design

Based on these insights, our final prototype design incorporates the following specifications:

- Dimensions and structure: The system measures 12 inches × 21 inches × 22.5 inches, utilizing an enclosure constructed from 1/8-inch aluminum 5052 alloy for durability and ease of manufacturing. The system is scaled down to meet senior design size constraints. At roughly

1:3 of the full-scale product size, this compact form factor ensures it fits within the EXPRESS Racks while maximizing internal cleaning capacity when at full scale.

- Cleaning mechanism: The system uses a waterless cleaning method using UV-C sterilization coupled with an optimized airflow system. COTS UV-C lights provide effective microbial reduction, while the integrated fan system ensures thorough air circulation for deodorization.
- Material compatibility: The cleaning technology has been designed to be compatible with common athletic wear fabrics, including polyester, nylon, and cotton blends, without causing material degradation over repeated cleaning cycles.
- Resource utilization: The system will operate within the spacecraft's power budget, with energy consumption optimized to prevent strain on the habitat's electrical systems while achieving effective cleaning results.
- User interface: The control system provides intuitive operation through a simplified Arduino-based interface with four control buttons and a liquid crystal display for cycle time indication. This design requires minimal training for effective operation.
- Integration requirements: All components have been selected to ensure operations within the spacecraft’s closed loop air systems.

Final CAD Model and System Layout

The final CAD model was developed to ensure all components fit within the allocated dimensions while maintaining optimal functionality. The system measures 12 inches × 21 inches × 22.5 inches and features an enclosure constructed from 1/8-inch aluminum 5052 alloy for durability and ease of manufacturing.

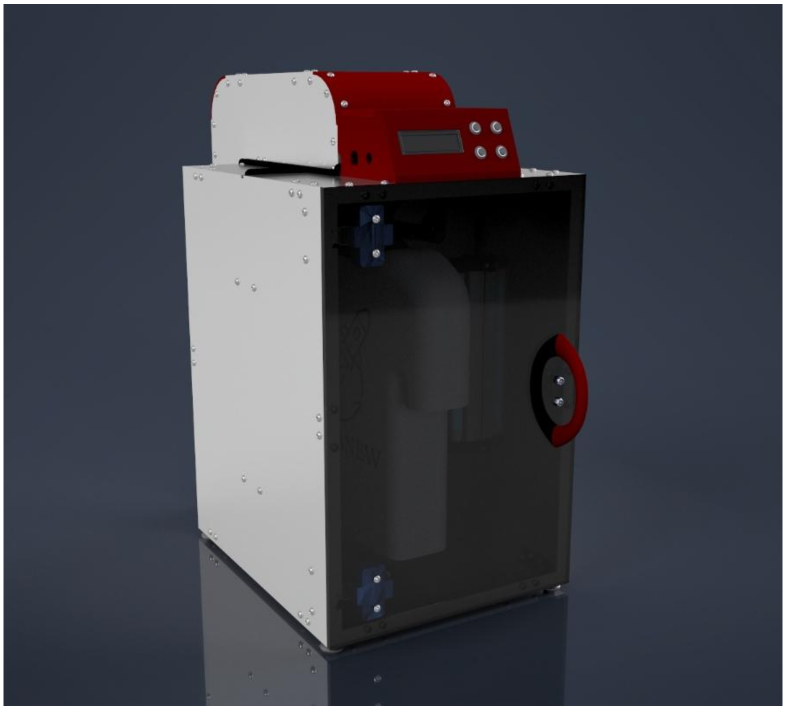


Figure 4: Isometric view of the product

The front door, made from smoked 1/4-inch acrylic, provides visibility of the cleaning process while ensuring the user is not exposed to any UV-C light. The door integrates a plastic grab latch with a roller grab mechanism and two half-mortise concealed cabinet hinges for secure closure. The enclosure is sealed using rubber washers at every bolt connection point, with a flat rubber gasket around the door to ensure an airtight environment during operation.

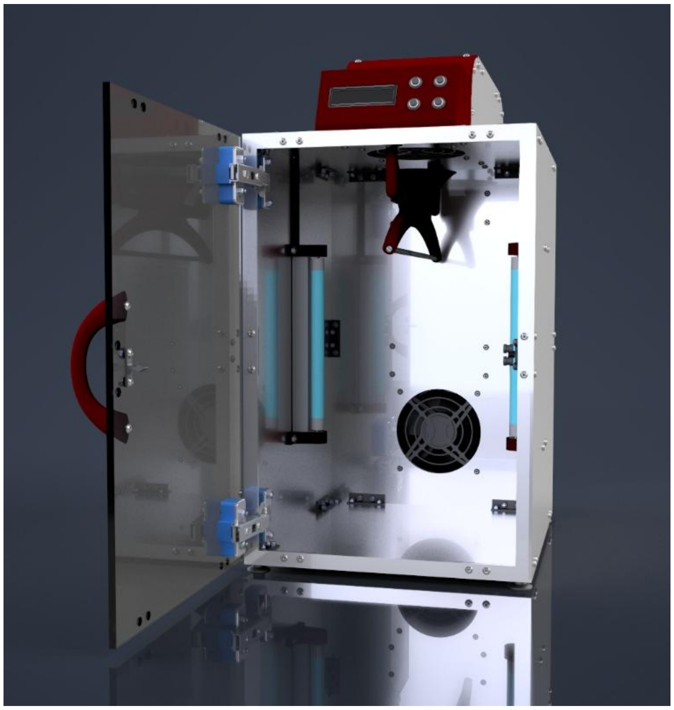


Figure 5: Front view of the product

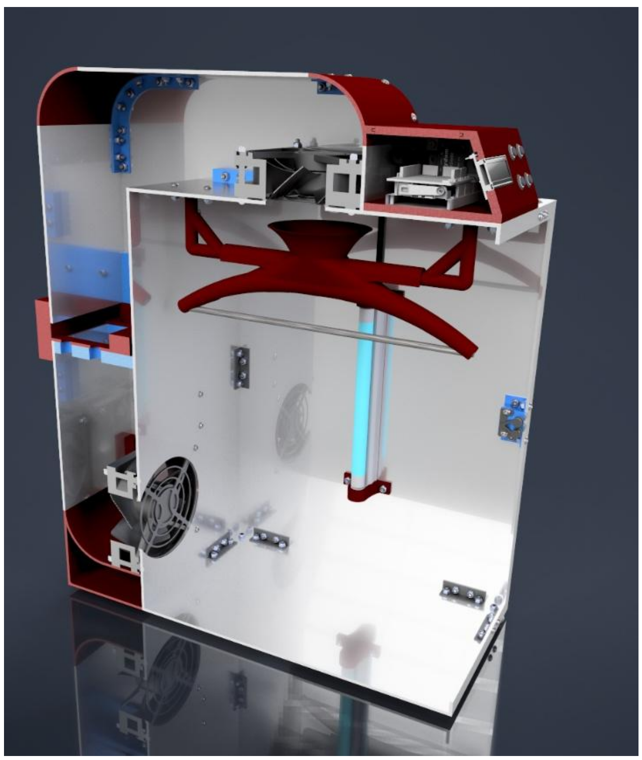


Figure 6: Cross Section View of Product to Display Air Flow Path Without Shirt

The system contains dual high-output electronic fans, each capable of generating max 133 CFM airflow, strategically positioned to distribute air evenly. Airflow is directed through a replaceable deodorizer filter housed in a sliding tray mechanism, ensuring uniform distribution while eliminating bacteria and odors.

The UV-C sterilization system consists of two light sources, positioned to expose the major fabric surfaces uniformly. These lights ensure effective microbial elimination without the need for chemical agents or water-based cleaning.

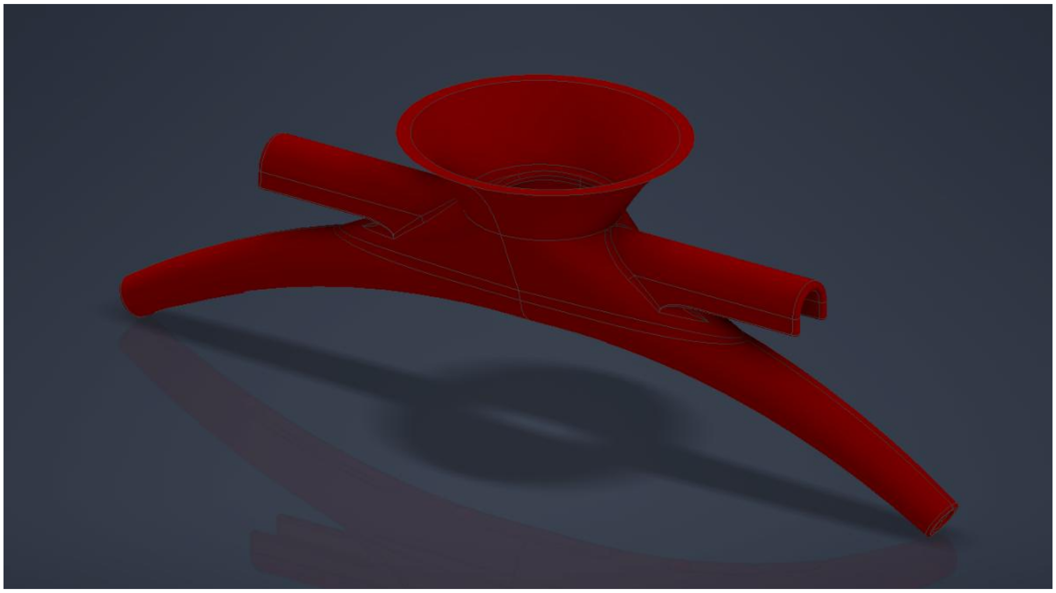


Figure 7: Custom made hanger to optimize airflow inside the clothes

A custom 3D-printed airflow hanger is integrated into the system to support clothing and aid in air distribution inside the shirt while optimizing both UV-C exposure and airflow circulation. The hanger is mounted using side tabs, ensuring stability while allowing airflow to pass through the clothing. All blue-colored components in the assembly—including the hanger, duct elbow, tray holder, tray, hinge adapters, door handle, and hanger supports—are 3D-printed to precise specifications.

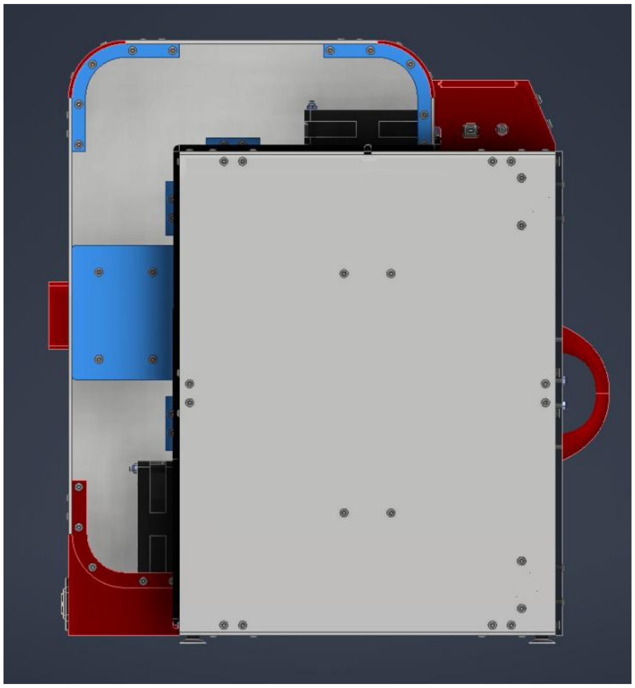


Figure 8: Side View of Product

The entire system is assembled using #8-32 bolts, nuts, and screws, ensuring mechanical stability under operational conditions. To minimize vibrations and maintain position in various environments, the unit is mounted on threaded-stud-mount protective feet.

The air duct elbows were designed with curved geometries to improve airflow dynamics, reducing turbulence and ensuring consistent air distribution throughout the chamber.

Electrical System and Automation

The system consists of an Arduino-based control circuit designed to manage the fans and UV-C lights using a solid state relay module. The electrical schematic features an Arduino as the central controller, connected to a push-button input for user control, a LCD for real-time runtime indication, and a relay to switch power to the fans and UV-C lights.

The user interface includes four control buttons:

1. Start/Pause button – toggles system operation.
2. Emergency stop button – instantly shuts off the system.
3. Cycle Time increase button – adjusts cleaning duration.
4. Cycle Time decrease button – reduces cycle time.

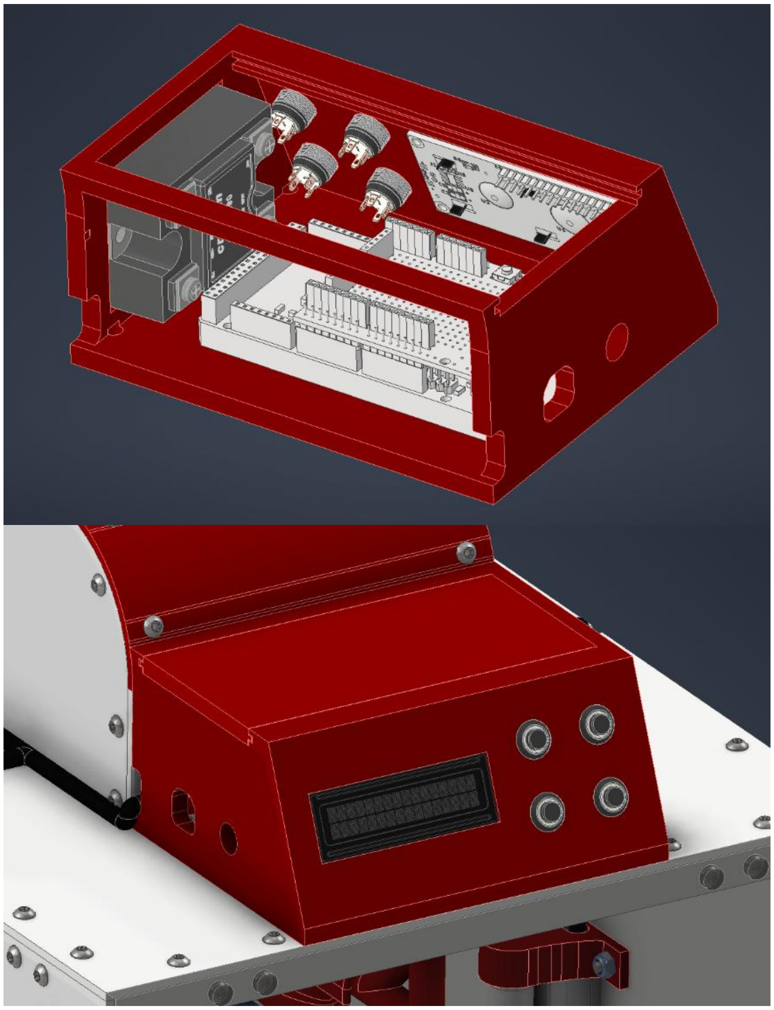


Figure 9: CAD Renders of Electronics and UI packaging

The solid state relay module is responsible for simultaneously controlling both the fans and UV-C lights, ensuring coordinated operation.

The LCD is driven by the Liquid Crystal library, updating the cycle countdown in real time. The Arduino firmware implements debouncing for the push buttons to prevent false triggers due to mechanical noise. When the start button is pressed, the system state toggles, either energizing or de-energizing the relay. The counter begins at inputted cycle time and decrements every second, displaying the remaining cycle time. The system remains operational until cycle time is elapsed or manually turned off by the user.

For prototyping, components will be arranged on a perf board, with the Arduino providing 5V power to logic components. The push buttons are wired with an internal pull-up resistor to ensure a stable signal, while the LCD is connected through current-limiting resistors to prevent excessive power draw.

The relay module isolates the Arduino from the high-power components, with its normally open (NO) contacts used to switch power to the fans and UV-C lights. This configuration ensures safe operation while allowing full manual control.

The electronics are powered by 120 V AC power, ensuring compatibility with various spacecraft and mission modules. The power module is directly plugged into the wall which splits the power into high voltage (120V) routed to the solid state relay and low voltage (5V) routed to the Arduino. The power module also comprises of an 8 amp fuse switch to prevent current overload and provide an additional safety mechanism.

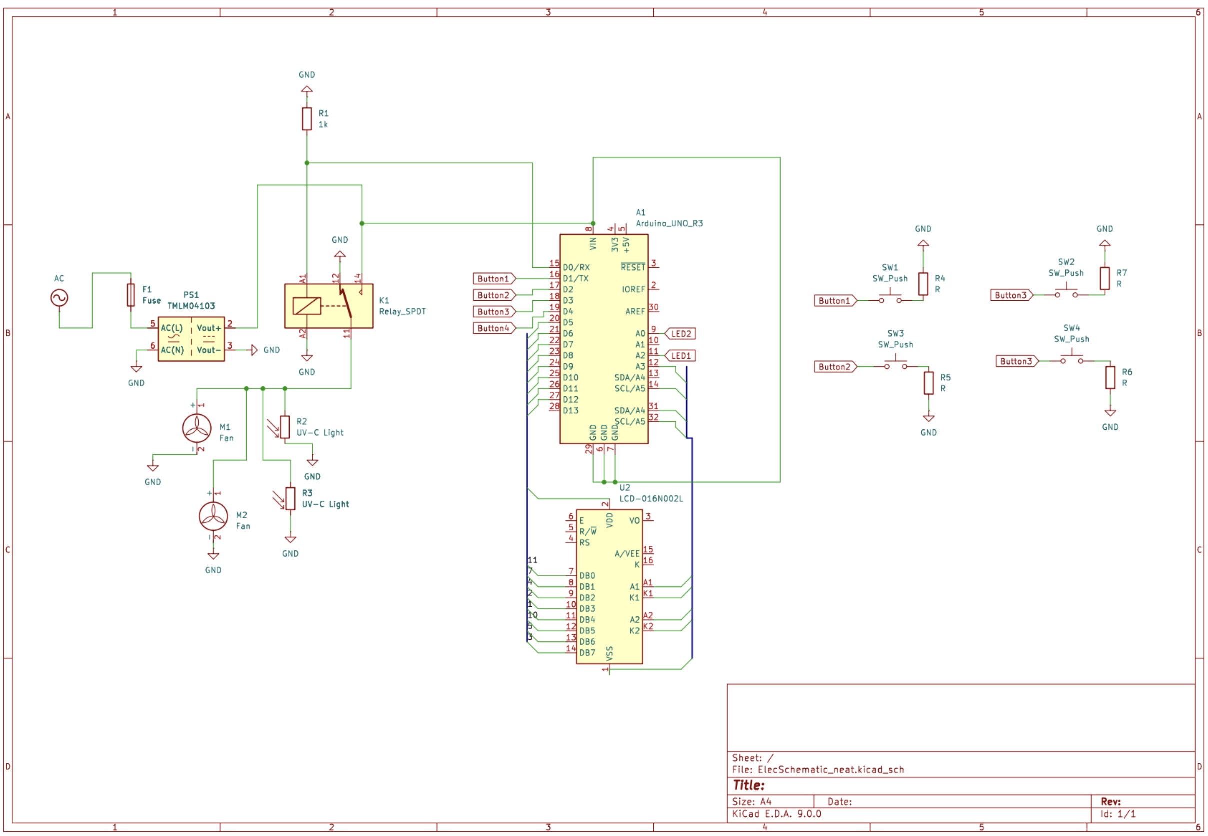


Figure 10: Electrical Schematics

Analysis

Computational fluid dynamics (CFD) analysis

The central airflow component of the system involves the hanger and shirt subassembly. The custom-designed hanger was specifically developed to intake and distribute air through its structure, directing airflow into the shirt for efficient odor and bacteria removal. A computational fluid dynamics (CFD) simulation was conducted using ANSYS Workbench 2022 to analyze airflow patterns within the hanger and shirt. The objective was to assess how well air flows through the fabric and determine whether the current design effectively distributes airflow across all shirt surfaces.

The simulation was performed within an enclosure that modeled the exact dimensions of the system's cleaning chamber. Several assumptions were made to simplify the analysis, including neglecting radiation effects, assuming laminar airflow through the shirt, and considering air at a uniform room temperature of 300 K. Additionally, it was assumed that the UV-C light maintained a constant surface temperature of 333 K and that no reverse flow occurred at the bottom of the shirt.

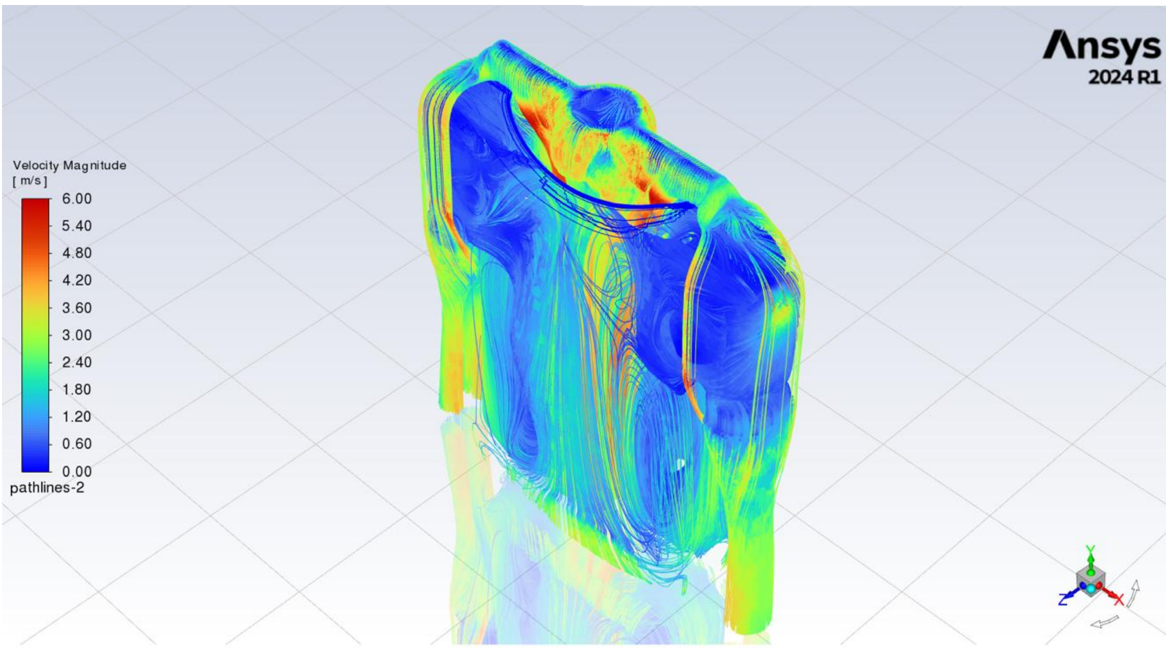


Figure 11: CFD Results – Velocity path lines

Results from the CFD simulation demonstrated that the airflow design allows for optimal air movement through the shirt, with air exiting efficiently through the sleeves and torso opening. Areas of localized acceleration were observed within the fabric, further enhancing the removal of bacteria and odors. While the analysis assumed laminar flow conditions, the actual system is expected to generate turbulent airflow, which would likely improve the effectiveness of bacteria removal by increasing surface agitation and reduce dead zones seen in the simulation. These results confirmed that the current hanger design supports the project's objective of ensuring efficient garment sanitation in microgravity environments.

Finite element analysis (FEA) of the latching mechanism

A finite element analysis (FEA) was conducted to evaluate the mechanical performance of the roller grab latch mechanism, which serves as a critical component of the door system. The latch must operate reliably throughout the product's lifespan, ensuring a secure enclosure while allowing astronauts to access clothes easily.

The simulation was conducted using a low-density polyethylene material model under static loading conditions. The analysis aimed to determine the pull force required to achieve the necessary displacement for effective operation. The latch design incorporates a 120-degree angle with a displacement requirement of 0.035 inches for proper functionality.

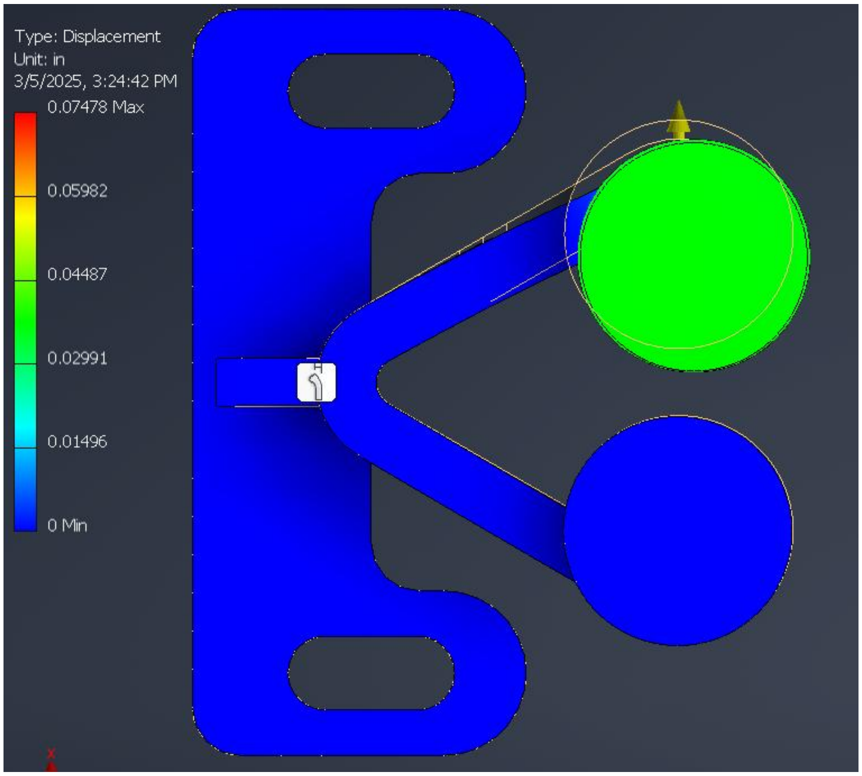


Figure 12: FEA Results – Displacement

FEA results indicated that a 7-pound pull force was required to achieve a displacement of 0.075 inches. The displacement mapping showed that mechanical stresses remained well within acceptable limits, with the maximum displacement of 0.07478 inches occurring at the roller contact points. These findings validated that the latch mechanism is ergonomically feasible, ensuring that users can operate the system without excessive force while maintaining secure closure.

Power consumption analysis

A MATLAB script was developed to calculate the total power draw of the system, ensuring compatibility with standard spacecraft power sources. The script first defines the power consumption of critical components, including the UV-C lights, fans, and Arduino control system. Using these values, the script determines the total power consumption and calculates the required current at 110V AC.

The power consumption breakdown includes two UV-C lights operating at a combined power of 120W, two high-output fans consuming an additional 120W, and the Arduino drawing approximately 2.5W. The total system power requirement was calculated to be 262.5W, with a current draw of 2.86A at 110V AC.

The script also incorporates a logical check to verify whether the system's total power draw remains within the limits of a standard wall outlet. The results confirmed that the system can safely operate using direct wall power without requiring additional power management. This validation step ensures that the electrical system is designed within safe operating limits while maintaining sufficient power for all components to function reliably.

Risk and Failure Mode Analysis

A failure mode and effects analysis (FMEA) was conducted to identify and mitigate potential risks associated with the system's operation. The analysis considered 17 distinct failure scenarios, each evaluated based on severity (SEV), occurrence (OCC), and detection (DET) to calculate a risk priority number (RPN). This assessment helped prioritize failure modes that could significantly impact system functionality, safety, or user experience.

The highest-risk failure modes identified in the analysis included seal wear, improper hanger placement, and hanger stress failure. Seal wear was assigned an RPN of 280 due to the potential for air leaks that could compromise the system's airtight environment, reducing cleaning efficiency. Improper hanger placement received an RPN of 252, as incorrect positioning could lead to uneven airflow distribution, diminishing the effectiveness of odor and bacteria removal. Hanger stress failure had an RPN of 216, highlighting concerns about structural integrity and potential breakage under repeated use.

The UV-C light sterilization system also presented a high severity risk, with an SEV rating of 8. If the UV-C lights failed prematurely, the system would be unable to achieve proper bacterial disinfection, compromising the effectiveness of the sanitation process. However, since light failure is easily detectable, the overall RPN for this mode remained lower than other critical risks.

Mitigation strategies were developed to address these high-risk failure modes. Reinforced latch mechanisms and corrosion-resistant materials are to be selected to improve durability and reduce wear-related risks. Structural components, including the hanger and enclosure, will be subjected to stress testing to ensure long-term reliability. Electrical safeguards, such as conformal coating for circuit protection and redundant power circuits, could be implemented to enhance system robustness. Routine inspections and scheduled seal replacements were also introduced as preventive measures to minimize air leakage issues.

The combination of engineering improvements and procedural safeguards is expected to significantly reduce RPN values across all critical failure modes. These mitigation efforts will improve the system's reliability, ensuring that it performs as intended in long-duration space missions where maintenance opportunities are limited.

ME 463 Senior Design
Project Name: ASTRANEW

Line No.	Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) / Mechanism(s) of Failure	OCC	Current Controls	DET	RPN	Mitigation Action (s)	by Who	by When	New SEV	New OCC	New DET	New RPN
1	Fans	Fan stops working due to motor failure, bearing failure, or power issue	Overheating and poor ventilation due to fan malfunction	6	Motor burnout, debris blockage, electrical faults, bearing wear.	5	Thermal sensors, regular maintenance schedules, protective grilles.	3	90	Install thermal sensors and implement scheduled motor maintenance to prevent blockages.	Maintenance Technicians	During installation; quarterly	6	3	2	36
2	Deodorizer	Deodorizer falls out of the tray due to improper fit or vibration	Odor buildup and potential component displacement	4	Weak tray design, vibration, improper installation, user error.	7	Snap-fit tray locks, user installation guides, vibration dampeners.	5	140	Redesign tray with snap-fit locks and vibration-resistant materials.	Design Engineers	Product redesign phase	4	5	3	60
3	Deodorizer	Deodorizer filter life runs out, reducing effectiveness	Reduced odor control and contamination risks	5	Lack of maintenance alerts, prolonged use, poor airflow monitoring.	8	Filter life indicators, automated usage timers.	2	80	Integrate automated filter-life alerts and usage-tracking software.	Software Developers	Software update cycle	5	5	1	25
4	Door	Latch failure causing improper sealing or inability to close	Unsecured door leading to disrupted space enviroment	6	Mechanical wear, misalignment, corrosion, excessive force.	4	Reinforced latches, alignment guides, routine inspections.	4	96	Reinforce latch mechanism and conduct routine alignment inspections.	Quality Assurance + Maintenance	Pre-production; bi-annual inspections	6	3	3	54
5	Door	Hinge failure leading to difficulty in opening or closing	Door misalignment or detachment risks	5	Metal fatigue, overloading, rust, poor lubrication.	3	Corrosion-resistant hinges, lubrication ports, weight limits.	5	75	Use corrosion-resistant alloys and add lubrication access points.	Manufacturing Team	During component fabrication	5	2	4	40
6	Hanger	Hanger experiences stress failure	Improper cleaning of fabrics	6	Overloading, material defects, corrosion, impact damage.	6	Weight capacity labels, stress-testing during manufacturing.	6	216	Label weight limits clearly and use stress-tested materials.	Product Designers	Pre-production labeling/testing	6	4	5	120
7	Hanger	Hanger is not hung correctly, causing imbalance or detachment	Instability or improper device function	4	User error, unclear instructions, unstable mounting surface.	9	Visual mounting guides, instructional videos, alignment markers.	7	252	Provide visual mounting guides and simplified instructional content.	Technical Writers/UX Team	Before product launch	4	6	5	120
8	Hanger Supports	Hanger supports fail under stress	Structural collapse or component damage	7	Excessive weight, poor weld joints, material degradation.	4	Load testing, welded joint inspections, material certifications.	6	168	Perform load testing on welds and certify material durability.	Quality Assurance	Pre-production validation	7	3	4	84
9	UV-C Lights	UV-C lights burn out, reducing sterilization effectiveness	Inadequate sterilization and increased pathogen exposure	8	End-of-life bulb, power surges, faulty ballast, overheating.	6	Bulb lifespan tracking, surge protectors, auto-shutoff.	1	48	Add surge protection and bulb lifespan tracking with auto-shutoff.	Electrical Engineers	During hardware upgrades	8	4	1	32
10	Deodorizer Tray	Deodorizer tray experiences stress failure	Spillage or damage to internal components	5	Overloading, brittle material, thermal expansion, impact.	3	Impact-resistant materials, tray load limits.	5	75	Use impact-resistant polymers and enforce tray load limits.	Material Engineers	Component manufacturing stage	5	2	4	40
11	UI	User interface functions improperly	User confusion or operational inaccuracies	3	Software bugs, firmware glitches, touchscreen calibration errors.	7	Pre-release testing, firmware updates, touchscreen diagnostics.	3	63	Roll out firmware updates and pre-release software testing protocols.	Software QA Team	Pre-release testing; ongoing updates	3	5	2	30
12	Electronics	Electronics short out due to moisture, dust, or component failure	System failure or fire hazards	9	Moisture ingress, damaged insulation, solder bridging, overheating.	2	Conformal coating, insulation checks, sealed enclosures.	3	54	Apply conformal coating and conduct insulation integrity checks.	Production Technicians	During assembly; post-repair checks	9	1	2	18
13	Electronics	Power shortage due to insufficient supply or system overload	Intermittent operation or shutdowns	5	Faulty power supply, loose connections, voltage spikes.	5	Redundant power circuits, connection integrity tests.	4	100	Implement redundant power circuits and connection stability tests.	Electrical Engineers	During system integration	5	3	3	45
14	Electronics	Wire comes loose	Inconsistent performance or connectivity issues	4	Vibration, poor crimping, thermal cycling, improper strain relief.	4	Strain relief clamps, vibration testing, crimp integrity checks.	5	80	Add strain relief clamps and perform vibration resistance testing.	Manufacturing Engineers	Pre-production testing	4	3	4	48
15	Electronics	Wire gets cut due to mechanical interference or wear	Complete loss of electronic functionality	7	Abrasion, pinching, rodent damage, accidental cutting during maintenance.	2	Protective conduits, wire routing guides, maintenance protocols.	3	42	Route wires through protective conduits and enforce maintenance guidelines.	Maintenance + Installers	Installation; during repairs	7	1	2	14
16	Seals	Improper seal	Leakage or environmental contamination	7	Installation error, uneven surfaces, incompatible gasket material.	6	Installation training, gasket alignment tools, leak tests.	4	168	Train installers on gasket alignment and perform post-installation leak tests.	Facilities Management	Post-installation; after repairs	7	4	3	84
17	Seals	Seals wear out over time	Gradual leaks and reduced efficiency	5	Aging, chemical exposure, UV degradation, repeated compression.	8	Scheduled seal replacements, chemical-resistant materials.	7	280	Schedule periodic replacements and use chemical/UV-resistant compounds.	Maintenance Team	Annual maintenance schedule	5	5	5	125

Figure 13: FMEA

Bill of Materials (BOM) and Sourcing Plan

The project required selection of components to balance cost, functionality, and durability. The BOM was developed to ensure that all necessary parts were sourced efficiently while staying within the allocated budget of $1,000.

- <u>Structural components</u>: The enclosure is constructed from 1/8-inch aluminum 5052 alloy, sourced from Online Metal Supply for approximately $478.74. CO2 laser processing will be used to achieve precise cuts for assembly.
- <u>UV-C lights</u>: Two UV-C lights from Amazon were selected for bacterial disinfection, costing a total of $41.98.
- <u>Airflow system</u>: Two high-output fans were sourced from McMaster-Carr at a total cost of $76.92. These fans ensure effective air circulation within the cleaning chamber.
- <u>Electronics and controls</u>: The control system is managed by an Arduino, with additional components, including a LCD, will be bought for $45.99. An additional mechanical relay will be bought for $22, having a total electronics cost of $66.99.
- <u>3D-printed components</u>: Custom-designed airflow ducting, hanger supports, and mounting brackets will be fabricated in-house using 3D printers to reduce costs and improve system modularity.

Part	Purpose	Make / Buy / Provided	Vendor	Link	Qt.	Unit Price	Est. Price	Tooling
UV-C Light	Disinfect / Elimate Bacteria	Buy	COOSPIDER UV (Amazon)	------	2	$ 20.99	$ 41.98	
Mechanical Relay	Regulate Voltage	Buy	MZBYDLM (Amazon)	------	1	$ 22.00	$ 22.00	
Fan	Air circulation through system	Buy	McMaster Carr	------	2	$ 38.46	$ 76.92	
Deodorizer Filter	Trap / Remove odor in system	Buy	ShuRex (Amazon)	------	1	$ 21.99	$ 21.99	
Contol Electronics	User interface	Buy	Amazon	------	1	$ 44.99	$ 44.99	
12mm Momentary Push Button	User interface	Buy	Amazon	------	1	$ 7.99	$ 7.99	
#8/32 0.375" Screw	Structural integrity	Buy	Robosource	------	1	$ 4.99	$ 4.99	
#8/32 0.500" Screw	Structural integrity	Buy	Robosource	------	1	$ 5.49	$ 5.49	
#8-32 Threaded Inserts	Structural integrity	Buy	Amazon	------	1	$ 10.99	$ 10.99	
#8/32 Thin Nylock Nuts	Structural integrity	Buy	Robosource	------	2	$ 4.99	$ 9.98	
#8/32 Rubber Washers (50 pack)	Air sealing	Buy	McMaster Carr	------	2	$ 10.10	$ 20.20	
1/8"x24"x18" Aluminum Sheet Metal	Key Structual Component	Buy	Online Metal Supply (Amazon)	------	6	$ 48.23	$ 289.38	CO2 Laser
1/8"x24"x24" Aluminum Sheet Metal	Key Structual Component	Buy	Online Metal Supply (Amazon)	------	1	$ 58.11	$ 58.11	CO2 Laser
1/4" Acrylic Sheet (24" x 24") Smoke	Key Structual Component	Buy	SIBE-R (Amazon)	------	1	$ 51.34	$ 51.34	
1/4" x 12" Metal Rod (1 foot)	Hanging system	Buy	McMaster Carr	------	1	$ 1.45	$ 1.45	
1/16" Aluminum L-Channel (4ft)	Structural integrity	Buy	McMaster Carr	------	1	$ 6.18	$ 6.18	Band Saw/Drill
Cabinet Hinges	Door open/close	Buy	McMaster Carr	------	2	$ 5.27	$ 10.54	
Grab Latch	Closes door	Buy	McMaster Carr	------	1	$ 1.42	$ 1.42	
#8-32 Rubber Feet (10 pack)	Feet for device	Buy	McMaster Carr	------	1	$ 16.20	$ 16.20	
20 ft Seal	Seal door	Buy	Kingdder (Amazon)	------	1	$ 11.99	$ 11.99	Cut down
Robosource Shipping	Shipping	Buy	Robosource	------	1	$ 7.95	$ 7.95	
Box Hinge Spacer	Hinge spacer adapter	Make						3D Printer
Door Hinge Spacer	Hinge spacer adapter	Make						3D Printer
Handle	Door Handle	Make						3D Printer
Bracket Latch Mount	Door latch bracket	Make						3D Printer
Top Bracket	Hanger support bracket	Make						3D Printer
Hangar	Hanger	Make						3D Printer
UI	Main UI Box	Make						3D Printer
UI Case Top	Top of UI box	Make						3D Printer
Uno Case Base	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Top	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Button	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Cap I	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Cap II	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Cap III	Ardiuno Uno Protective Case	Make						3D Printer
Duct Corner	Curved Duct Corner	Make						3D Printer
Heatset Bracket	Bracket with heatsets for duct	Make						3D Printer
Bracket Duct	Standard curved duct bracket	Make						3D Printer
Bracket Duct Fan Bottom	Special curved duct bracket	Make						3D Printer
Bracket Duct Fan Top	Special curved duct bracket	Make						3D Printer
Airduct Filter Drawer Holder	Holds the air filter in duct	Make						3D Printer
Filter Drawer	Drawer to remove/place filter	Make						3D Printer
						Total Est. Price	$ 722.08	

Figure 14: BOM & Sourcing Plan

The total estimated cost of the system is $722.06, leaving a sufficient budget buffer for potential modifications or unforeseen expenses.

System Validation and Testing Plan

The validation of the system will focus on verifying the functionality of its key components, including the electronics, UV-C sterilization, air circulation, odor removal, and proper seal function. Each subsystem will undergo testing to confirm that it meets performance requirements under conditions that closely simulate the space environment.

The electronics subsystem, which consists of the Arduino-based control system and relays, will be tested for functionality, reliability, and response to user inputs. The validation process will include powering the system with a standard 120V AC source, activating the relays, and confirming proper operation of the UV-C lights and fans. Voltage and current measurements will be recorded to ensure all components receive the required power. System endurance testing will be conducted to evaluate long-term performance and reliability under repeated use.

The UV-C lights will be assessed for their effectiveness in germicidal irradiation. Validation will include observing the intensity and wavelength of the emitted UV-C light. Additional biological testing may involve applying bacterial or fungal contaminants to fabric samples, exposing them to the UV-C cycle, and analyzing microbial reduction through petri dish cultures. These tests will determine the system's ability to disinfect clothing effectively.

The air circulation system, composed of high-output fans and airflow ducts, will be tested for consistency and uniform distribution within the cleaning chamber. The validation process will include testing under different power levels and operational durations to optimize both energy efficiency and air distribution. Excessive turbulence and noise levels will also be evaluated to ensure smooth operation.

The deodorizing function, enabled by replaceable filters, will be validated through qualitative odor assessments. Subjective odor testing will be conducted with a panel of evaluators to assess real-world effectiveness. Long-term testing will be performed over multiple cycles to evaluate filter durability and sustained deodorization performance.

The air seals will be validated through a smoke test, where we will introduce visible smoke into the sealed system and observe potential leaks. This method will allow us to quickly identify areas where air may be escaping and ensure the seals maintain an airtight environment.

All validation tests will be conducted in a controlled environment designed to replicate operational conditions. Data and qualified subjective opinions collected during testing will be analyzed to assess overall system performance, identify potential failure points, and refine the design as necessary. The results will ensure that the system is both reliable and effective for use in long-duration space missions, where resource efficiency and operational dependability are critical.

Final Prototype

The final prototype was built with production-grade processes that mirror our envisioned flight hardware. All structural panels and the internal frames were cut from 1/8-inch 5052 aluminum on a laser system, then edges were deburred to remove slag. Complex duct brackets and hanger were additively manufactured in PLA on an enclosed FDM printer, allowing quick iteration while holding tight dimensional tolerances. These printed parts press-fit into the laser-cut metal, giving the assembly the strength of aluminum where it matters and the shaping freedom of polymer where airflow paths become intricate.

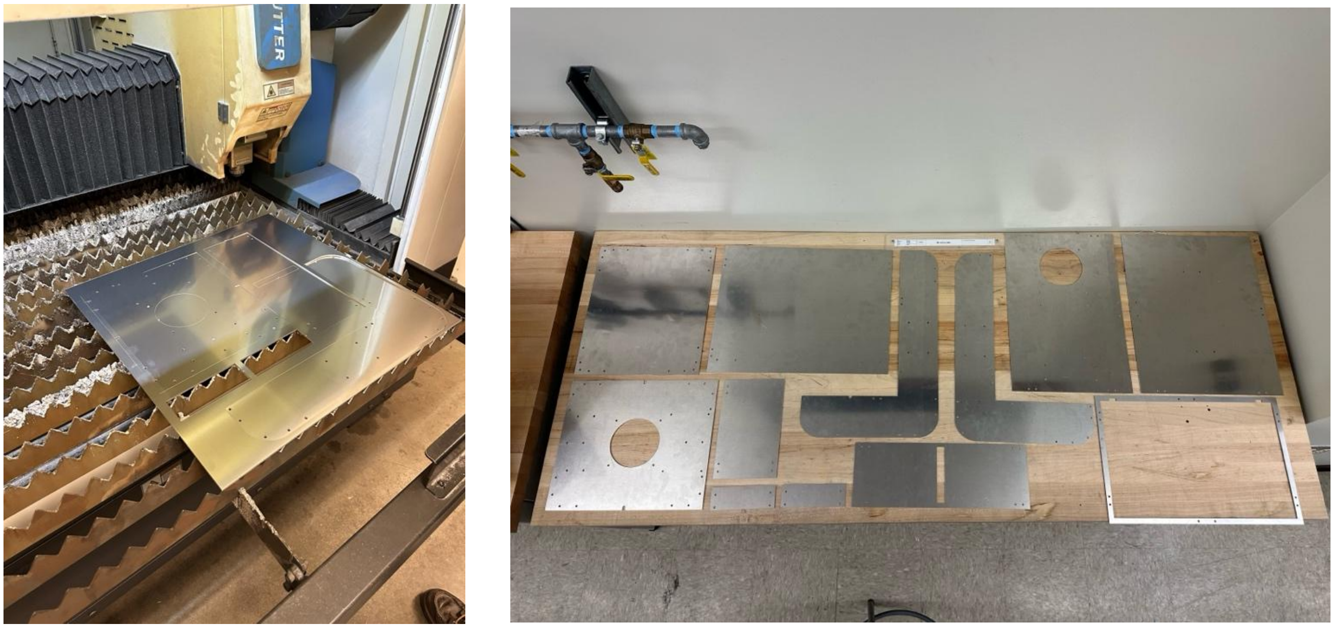


Figure 15: Laser Cutting Process & Parts

Electronics were consolidated into two purpose-built enclosures: a shielded power module mounted behind the rear bulkhead and a front-access user-interface box that houses the microcontroller, status LEDs, and low-voltage wiring. Both enclosures use lids and keyed connectors so the interior remains serviceable yet clean and well organized.

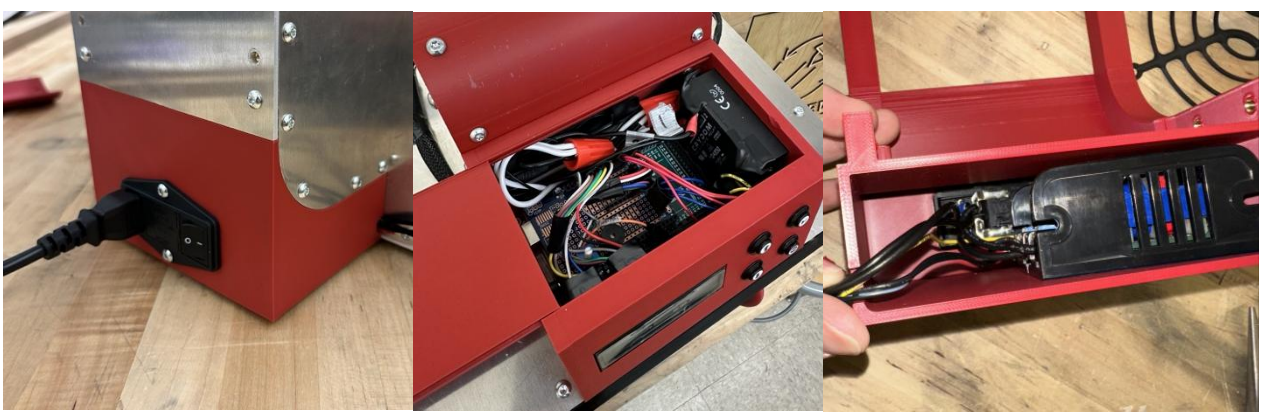


Figure 16: Electronics Packaging

The overall unit presents tight flush seams, perfectly aligned fasteners, and a smoked acrylic door that sits level with the aluminum front bezel, reinforcing a cohesive, commercial aesthetic. Every bracket, screw, and wiring clip matches the digital CAD model one-for-one, proving the fidelity of the design workflow and showcasing a level of craftsmanship consistent with professional aerospace hardware.

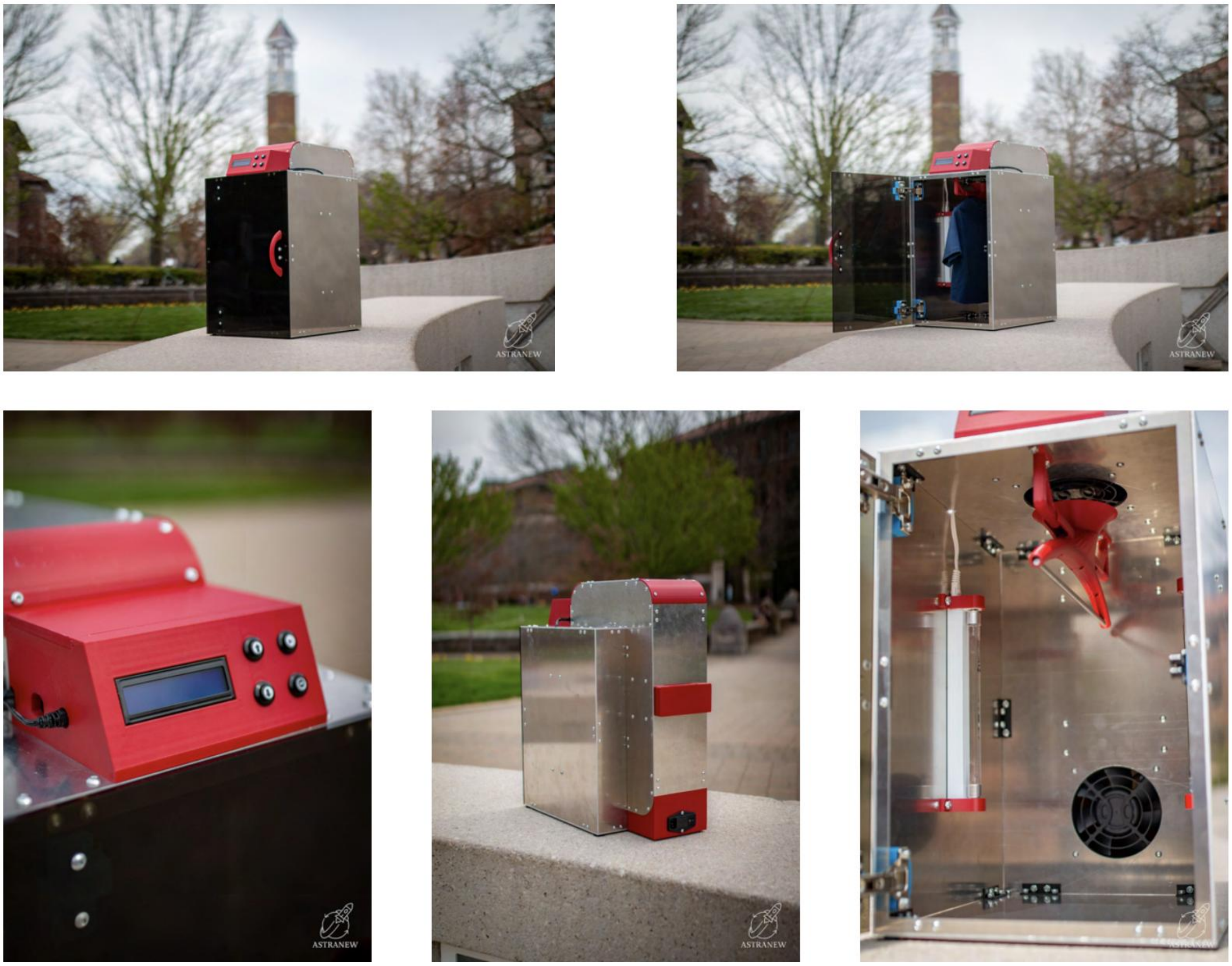


Figure 17: Final Product Photos

System Validation Results

The effectiveness of the UV-C chamber in neutralizing surface microbes was verified through a staged exposure test using live garments. A cotton shirt was first worn during intensive aerobic activity to embed realistic sweat-borne bacteria and odorants. Identical 60 mm Petri dishes pre-filled with tryptic soy agar were gently pressed against the same marked region of the fabric immediately before treatment and then after 2.5 min, 5 min, 10 min, and 20 min of UV-C exposure inside the chamber. Following contact sampling, all plates were sealed, incubated at 37 °C for 48 hours, and colony-forming units (CFUs) were observed to quantify viable bacterial load at each time point.

Baseline plates taken prior to exposure averaged an intense CFU count, confirming substantial contamination. After just 2.5 minutes in the chamber, CFUs fell by roughly one order of magnitude to. Crucially, plates sampled at the 5-minute mark exhibited zero detectable colonies, and all subsequent 10- and 20-minute samples remained sterile. The rapid drop to non-detectable levels demonstrated a ≥99.9 % kill rate within five minutes, satisfying the project requirement that garments be fully sanitized in under a single standard cycle. These results validated both the irradiance level of the UV-C emitters and the hanger geometry's ability to deliver uniform light coverage across the garment surface.

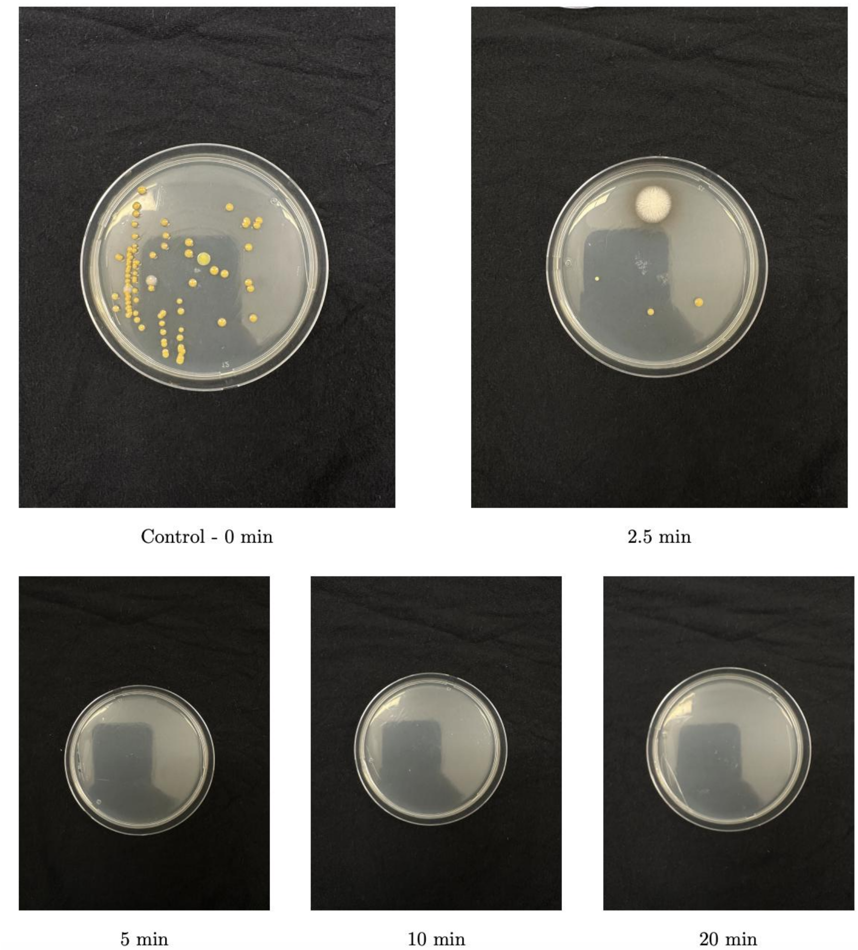


Figure 18: Petri Dish Samples w/ Bacteria Cultures

The influence of the filter on system airflow was quantified with a hot-wire anemometer positioned at three representative locations: the ambient inlet, the top of the hanger, and the point of peak jet velocity inside the garment cavity. Readings were recorded first with the filter removed, then repeated after installing the filter while all other operating conditions—fan speed, duct geometry, and environmental temperature—were held constant.

Introducing the filter noticeably attenuated velocity at every measurement point. Ambient inlet speed fell by 73 percent, confirming the expected pressure drop across the filter media. The most pronounced effect occurred at the top-of-hanger outlet, where velocity decreased by 81 percent, indicating that the filter's flow resistance translated directly to reduced impact on delicate collar seams. Even the system's maximum internal jet speed declined 41 percent, demonstrating that attenuation was not confined to a single region. Collectively, these reductions showed that the filter imposed a consistent damping effect on the airflow path, validating its dual role of particle capture and gentle air delivery critical for odor extraction without fabric abrasion.

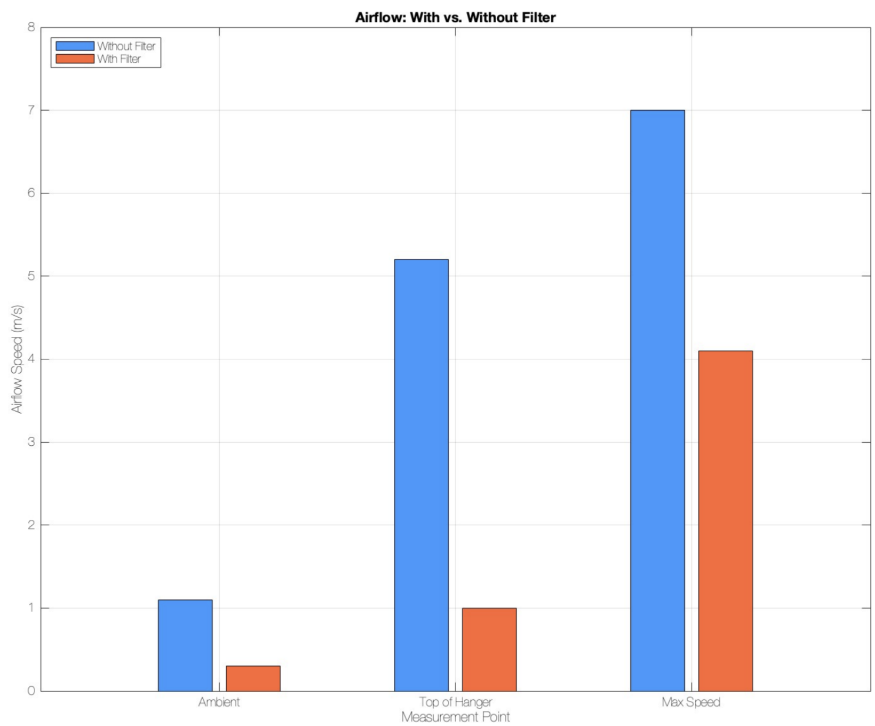


Figure 19: Anemometer Readings for Airflow

Perceived odor removal was evaluated with a ten-person sensory panel using a simple 1-to-10 intensity scale, where 1 meant no detectable scent and 10 indicated strong odor. A cotton shirt was worn during a regular day of campus activities, then placed in the unit. Panelists smelled the marked fabric area at seven checkpoints: before treatment and after 5, 10, 15, 20, 25, and 30 minutes of operation. Scores from all panelists were averaged for each time stamp.
The starting average was high, near the top of the scale, confirming a realistic level of sweat and body odor. After only five minutes in the chamber, the average score had already dropped by roughly one-third. By the ten-minute mark it was less than half of the original value, and at fifteen minutes the panel rated the shirt in the low-odor range that previous interviews identified as "wearable again."

Beyond fifteen minutes the curve began to flatten; additional runtime yielded smaller and smaller improvements, with scores converging toward the lower limit by 25 to 30 minutes. The sharp early decline followed by diminishing returns showed that most deodorization occurred within the first quarter-hour, demonstrating that the system could refresh everyday garments well inside a standard cycle.

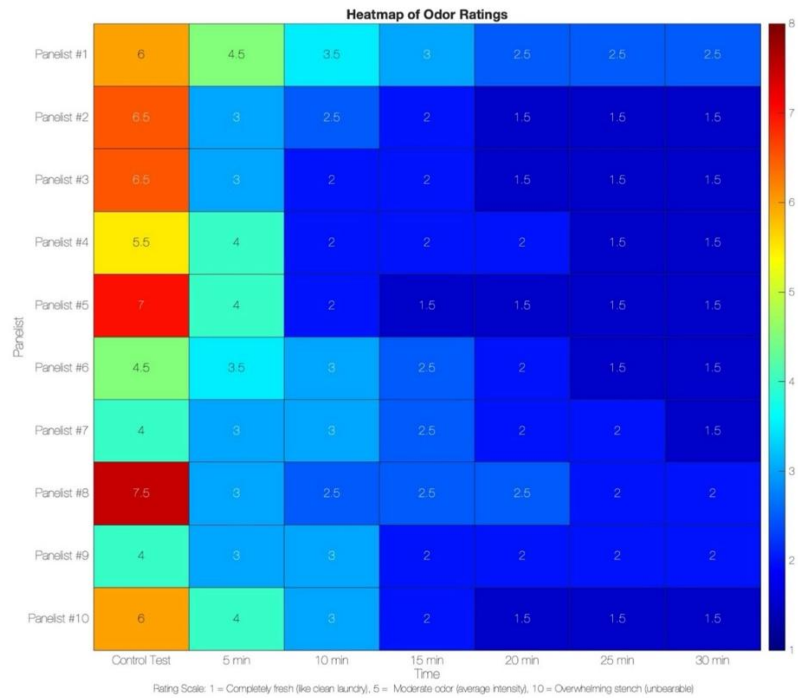


Figure 20: Heat Map of Panelist Rating throughout Duration of Deodorization Testing

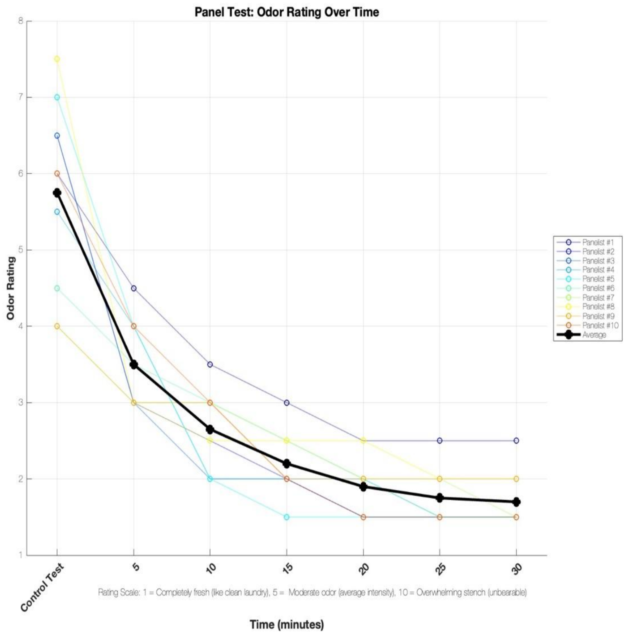


Figure 21: Line Chart of Panelist Rating throughout Duration of Deodorization Testing

Table 1: Target and Actual Metrics

Metric	**Target**	**Actual**
Sterilization efficacy	95%	99 %
UV-C bacteria kill time	$\leq$ 10 min	5 min
Deodorizing Cycle Time	$\leq$ 60 min	20 min
Airflow output	$\geq 0.1\ m/s$	0.3 m/s
Footprint	24" x 24" x 24"	20.88" x 12" x 22.44"
Weight	$\leq$ 50 lbs	25 lbs
Power consumption	$\leq$ 300 W	262.5 W
UI Success rate	99%	100%

Overall performance testing confirmed that the prototype satisfied every key requirement and, in most cases, delivered results well beyond the original benchmarks. UV-C sterilization achieved a 99 percent kill rate, comfortably above the 95 percent goal, and eliminated bacteria in just five minutes—half the maximum allowed time. The combined sterilization and deodorizing cycle finished in 20 minutes, far shorter than the one-hour limit. Measured airflow of 0.3 m s^{-1} tripled the minimum specification, supporting rapid drying and odor removal. Physical constraints were also met: the enclosure occupied roughly 21 × 12 × 22 inches, fitting inside the prescribed footprint; it weighed only 25 pounds, well under the 50-pound cap; and it drew 262.5 watts, staying below the 300 watt ceiling. Finally, user-interface tests logged a flawless 100 percent success rate versus the 99 percent target. Collectively, these results demonstrated that the system not only met but exceeded all stated design objectives.

Conclusion & Next Steps

The prototype proved the concept sound and commercially promising. It tackled the long-standing challenge of garment hygiene on extended missions with a waterless, closed-loop approach that no current system offers. All critical performance metrics—sterilization rate, cycle time, airflow, size, weight, power draw, and user-interface reliability—were not only met but surpassed by wide margins, demonstrating that the design is both technically robust and mission-ready. These results confirm that the project delivered an innovative, practical solution to a pressing logistics problem while setting new benchmarks for efficiency and effectiveness in crew clothing maintenance.

Moving from prototype to a full-scale flight unit will center on boosting capacity, ruggedness, and system integration. Development testing will explore higher-performance filters and larger, quieter fans so the chamber can move more air while remaining 99.9 percent airtight. The frame will be resized to accept standard crew garments and multiple hangers, and the control panel will be upgraded with more durable buttons, clearer status lights, and fault logging. All wiring and electronics will be swapped for space-rated parts, and the team will transition to proprietary UV-C emitters and filter cartridges to improve consistency and lower long-term cost.

Early budget work suggested that a flight-ready build using full space-grade materials could be produced for about 100 thousand dollars. With margins and integration support, the unit would list near one million dollars, yielding eight to thirteen million in revenue if launched on the missions already booked for 2025 and up to twenty million per year as flight cadence grows later in the decade. The product will be marketed directly to launch providers and habitat designers as a turnkey, capsule-compatible appliance that slots into existing environmental control loops without hardware changes.

Appendix 1 - Project Management.

A. Charter (.xlsx)

Updated per feedback from PDR

PURDUE UNIVERSITY
Mechanical Engineering

ME 463 Senior Design

Project Title: Recycling Technology for Deep Space Missions
Team Name: Astranew
Team Members: Sean MacDonald, Joe Lach, Aditya Pimplikar, John Carter, Thomas Tilford

Vision Statement: Enabling sustainable habitats for humanity's next frontier.

Problem Statement (Current State)

Our project aims to develop a novel recycling system, process, or device which can be used to recycle/reuse clothing and fabric materials accumulated over the course of long-term space missions.

Key Stakeholders (Role, Influence, Interest)

Key stakeholders for this project include Aerospace companies, which require recycling solutions to reduce clothing waste and ensure mission sustainability for long-term space exploration. Government space agencies also play a role by supporting technologies that align with objectives for operations in space. Likewise, engineering and manufacturing firms are interested in using these technologies for space travel and missions.

Business / Society Benefit (Future State)

Astranew's recycling system contributes to a more sustainable future for long-term and deep-space missions by creating the ability to wash clothes in space. The proposed technology is designed to maximize efficiency and minimize resource input, ensuring that even in extreme environments, waste management remains effective and eco-friendly.

Project Scope

IN Scope	OUT of Scope
Mechanical recycling system	Addressing chemical reactions
Suitable for low-gravity conditions	Generating resources (electricity / water)
Avoiding harmful byproducts	Transporting resources to space missions
Utilizing available resources only	

Key Milestones

Week 3 - Final solution selection	Week 9 - CDR (written and oral)
Week 4 - PDR (written and oral)	Week 11 - Manufacturing (additive/subtractive)
Week 6 - Prototype demonstration	Week 12 - Assembly/wiring
Week 8 - Complete CAD/Electronics	Week 15 - FDR (written and oral)

Key Assumptions & Risks

Key assumptions include the availability of materials and resources, like electricity to support the proposed recycling process. It is assumed that the system will perform effectively in both low-gravity and variable temperature conditions. Risks include challenges with energy efficiency with a washing maching utilizing UV-C lights and fans, the possibility of material deterioration with UV-C exposure, and general electrical risks that arise with any electronic device in space.

Team Members & Roles

Aditya Pimplikar - Chief Engineer
John Carter - Manufacturing Manager
Joe Lach - CAD Lead and Buyer
Sean MacDonald - Project Manager
Thomas Tilford - Business Manager and Customer Eyes

Key Resources Required

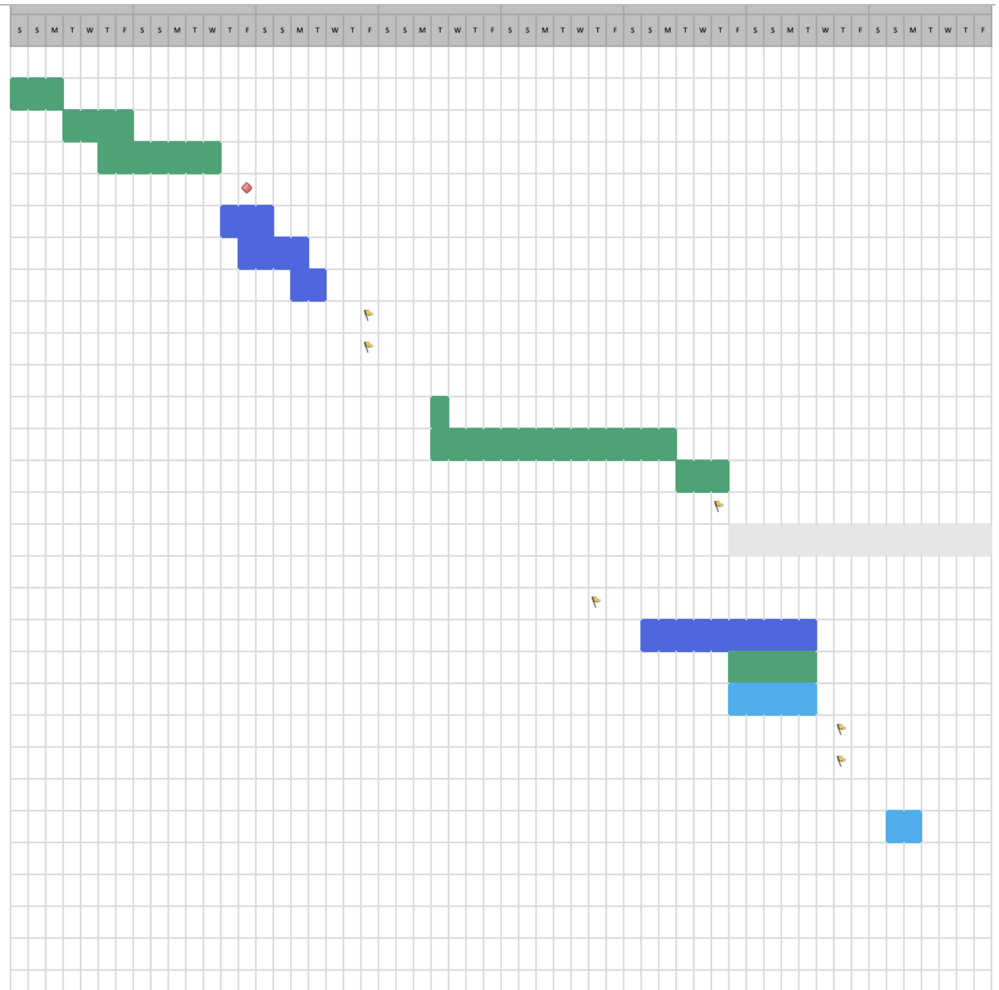
Waste items / commercial equivalent inputs
CAD softwares
3D printer
Machine shop resources

Version: 02

Last Updated: 3/5/2025

B. Schedule (.xlsx)

Milestone description	Category	Progress	Start	Days
Pre-PDR				
Project charter	On Track	100%	1/14/25	7
Market Analysis	On Track	100%	1/21/25	4
Concept Generation	On Track	100%	1/23/25	7
Concept Downselection	Goal	100%	1/31/25	1
Preliminary BOM	Med Risk	100%	1/30/25	3
Preliminary Budget	Med Risk	100%	1/31/25	4
Value Proposition	Med Risk	100%	2/3/25	2
Written PDR	Milestone	100%	2/7/25	1
Oral PDR	Milestone	100%	2/7/25	1
Post PDR				
Final Concept Selection	On Track	100%	2/11/25	1
Design proposal	On Track	100%	2/11/25	14
Design finalization	On Track	100%	2/25/25	3
Design freeze	Milestone	90%	2/27/25	1
Finalize			2/28/25	24
CDR				
Preliminary Protoype	Milestone	100%	2/20/25	1
CAD	Med Risk	100%	2/23/25	10
Electronics Deisgn	On Track	100%	2/28/25	5
Final BOM	Low Risk	100%	2/28/25	5
Written CDR	Milestone	100%	3/6/25	1
Oral CDR	Milestone	100%	3/6/25	1
FDR				
Purchase Orders	Low Risk	100%	3/9/25	2
Fabrication Start	Low Risk	100%	3/23/25	15
Assembly & Validation	On Track	100%	4/5/25	10
Prototype Demo	Milestone	100%	4/24/25	1
FDR	Milestone	100%	4/28/25	7



C. Preliminary Budget (.xlsx)

Part	Make or Buy	Vendor	Link	Est. Price
UV-C Light	Buy	BAIMNOCM	----	$ 30.00
Baking Soda	Buy	ARM & HAMMER	----	$ 2.00
Wipes	Buy	Contec	----	$ 20.00
Fan	Buy	McMaster Carr	----	$ 20.00
Deodorizer Filter	Buy	ShuRex	----	$ 20.00
Contol Electronics	Buy	Amazon	----	$ 50.00
Switches	Buy	Amazon	----	$ 10.00
General Hardware	Buy	McMaster Carr		$ 100.00
Vacuum Seal Bags	Buy	Amazon	----	$ 20.00
Heating Source	Buy	McMaster Carr		$ 20.00
Cooling Source	Buy	McMaster Carr		$ 20.00
Piping	Buy	McMaster Carr	----	$ 15.00
Actuators	Buy	SMC/McMaster Carr		$ 200.00
Seals	Buy			$ 10.00
Case/Box	Make			$ 100.00
End Effector	Make			$ 20.00
		Total Est. Price		$ 657.00

D. Risk Register (.xlsx)

	1. IDENTIFICATION					2. CURRENT ASSESSMENT			3. TREATMENT		4. RESIDUAL ASSESSMENT		
	RAISED	DATE RAISE	CAUSE (IF...)	EFFECT (THEN...)	RISK OWNE			Current Ri Score	STRATEG	TREATMENT DESCRIPTION			Residu Risk Sc
	The originator of the risk	When the risk was first identified	If **uncertain event** occurs due to (or because of) specified **root cause(s).** Tip: ask "why, why, why..." to drill down to root cause	then the **ultimate impact** to our objectives are. Tip: ask "so what, so what, ..."	Single named owner	Probability of the event occurring	'Worst' impact	Calculated risk score	Select overall approach to treatment (Mitigate or Accept)	Summary of the treatment responses (actions, controls, fallbacks) that treat the risk.	Probability of the event occurring	'Worst' impact	Calculated risk score
1		30-Jan-25	Fabrics don't wash properly	Clothes remain dirty or unhygenic, leading to discomfort and odor	John	H	H	20	Mitigate	Implement advanced airflow design to improve washing effectiveness.	H	H	20
2		30-Jan-25	Energy consumption too high	Depletion of power resources, causing operational issues to other spacecraft systems	John	M	M	10	Mitigate	Optimize power usage with energy-efficient components and operational scheduling.	M	M	10
3		30-Jan-25	UV light burns out	Loss of sanitizing effectiveness, leaving clothes and towels potentially unhygienic	Thomas	M	L	5	Mitigate	Use long-lasting UVC bulbs and include redundancy for replacement.	L	L	1
4		30-Jan-25	User exposed to UV light	Health risk from UV exposure, including skin damage or eye injury	John	H	H	20	Mitigate	Shield UV sources and implement automatic shutoff when the door is open.	L	H	11
5		30-Jan-25	Device causes vibrations	Disruption to sensitive equipment or research, damaging systems or causing misalignment	Sean	L	L	1	Mitigate	Incorporate vibration dampeners and secure mounting to reduce disturbances.	L	L	1
6		30-Jan-25	Vacuum seal fails	Jeopordizes efficiency of the device	Aditya	H	H	20	Mitigate	Design a reinforced vacuum seal with leak detection and backup locking mechanisms.	M	H	15
7		30-Jan-25	User is unable to operate machine due to external reason	Inability to clean clothes, causing hygiene issues	Thomas	M	M	10	Mitigate	Provide multiple control options, including manual overrides and remote access.	L	M	6
8		30-Jan-25	Electronic failure in device	Complete malfunction of the washing machine, making it unusable and leaving clothes dirty	John	H	H	20	Mitigate	Use high-reliability electronics with redundancy and surge protection.	M	H	15
9		30-Jan-25	Bacteria accumulates in device	Risk of contamination and health issues from bacteria or mold growth inside the machine	Sean	H	H	20	Mitigate	Integrate self-cleaning cycles and antimicrobial surfaces to prevent bacterial buildup.	M	M	10
10		30-Jan-25	Door mechanism failure	Water leakage or inability to access clothes, potentially damaging machine and clothing	Joe	M	M	10	Mitigate	Implement a reliable locking mechanism with manual override options.	L	M	6
11		3-Mar-25	Ventilation clogs	Poor drying or air circulation, leading to damp clothes and potential mold growth	Joe	M	M	10	Mitigate	Use clog-resistant ventilation designs and accessible filters for easy maintenance.	M	M	10
12		3-Mar-25	Control panel or user interface failure	Ability to control or operate the machine, leaving clothes unwashable	Aditya	M	M	10	Mitigate	Develop a robust user interface with intuitive controls and multiple access points.	L	M	6
13		3-Mar-25	UV damages fabrics	Clothes / towels deteriorate and reduce life span of recycled clothes	Aditya	M	M	10	Mitigate	Select UV-resistant fabrics or limit exposure duration to prevent material degradation.	L	M	6
14		3-Mar-25	Inconsistent airflow distribution	Uneven airflow may leave certain areas unclean, causing hygiene issues.	Thomas	M	M	10	Mitigate	Optimize airflow pathways and monitor flow distribution to maintain cleaning effectiveness.	L	M	6
15		3-Mar-25	Ozone generation	Ozone byproducts could pose health risks and reduce air quality, affecting efficiency	Sean	H	M	14	Mitigate	Ensure ozone containment or use ozone-free deodorization methods.	L	M	6
16		3-Mar-25	Heat generation	Excessive heat from UVC lights and fans may damage spacecraft systems or disrupt operations	John	M	M	10	Mitigate	Implement thermal management systems and heat-resistant components.	L	M	6
17		3-Mar-25	Filter or deodorizer degradation	Over time, filters may lose effectiveness, reducing sanitization and odor removal	Thomas	M	M	10	Mitigate	Use replaceable filters and deodorizers with wear indicators for timely maintenance.	M	M	10
18		3-Mar-25	Fan malfunction	Fan failure may disrupt airflow, leading to poor deodorization and potential mold growth	Joe	M	L	5	Mitigate	Include redundant fans and diagnostics for early failure detection.	L	L	1
19		3-Mar-25	Electrostatic discharge risk	Static buildup could damage electronics, causing complete machine failure	Thomas	L	M	6	Mitigate	Protect electronics with grounding, shielding, and static discharge prevention.	L	M	6
20		3-Mar-25	Microgravity-induced airflow disruptions	Unpredictable airflow in microgravity may reduce cleaning effectiveness	Thomas	M	L	5	Mitigate	Test airflow behavior in microgravity and adjust design accordingly.	L	L	1
21		3-Mar-25	Limited scalability for crew size	The system may not support large crews, leaving some clothes unwashable	Aditya	L	L	1	Mitigate	Scale system capacity or provide backup units for larger crews.	L	L	1

Updated per feedback from PDR (including separate technical and human factor registers)

	1. IDENTIFICATION					2. CURRENT ASSESSMENT				3. TREATMENT		4. RESIDUAL ASSESSMENT		
	RAISED E	DATE RAISEL	CAUSE (IF…)	EFFECT (THEN…)	RISK OWNER	P	I	F	Current Ris Score	STRATEG	TREATMENT DESCRIPTION	F	I	Residual Ri Score
	The originator of the risk	*When the risk was first identified*	*If **uncertain event** occurs due to (or because of) specified **root cause(s)**. Tip: ask "why, why, why…" to drill down to root cause*	*then the **ultimate impact** to our objectives are. Tip: ask "so what, so what, …"*	*Single named owner*	*Probability of the event occurring*	*'Worst' impact*	***DO NOT MODIFY***	*Calculated risk score*	*Select overall approach to treatment (Mitigate or Accept)*	*Summary of the treatment responses (actions, controls, fallbacks) that treat the risk.*	*Probability of the event occurring*	*'Worst' impact*	*Calculated risk score*
1	Team	30-Jan-25	Team member shows up late	The project timeline and coordination are delayed, impacting progress.	John	M	L	ML	5	Mitigate	Set clear expectations for attendance, use project management tools to track timelines, and adjust schedules if necessary	L	L	1
2	Team	30-Jan-25	Team member unable to make it to lab or meeting	Critical input is missed, which slows down overall progress.	John	M	L	ML	5	Mitigate	Provide virtual meeting options, ensure backup work is available, and assign alternative tasks to prevent delays	M	M	10
3	Team	30-Jan-25	CAD files corrupt	Design work is lost due to corruption, causing delays in development.	Thomas	M	H	MH	15	Mitigate	Regular backups of CAD files, use cloud storage, and implement version control systems to avoid major data loss	L	H	11
4	Team	30-Jan-25	Team member laptop breaks	Work is disrupted, leading to delays in completing tasks and milestones.	Joe	M	M	MM	10	Mitigate	Ensure access to backup equipment, maintain cloud storage for data recovery, and have spare laptops on hand	M	L	5
6	Team	30-Jan-25	Miscommunication within the team	Miscommunication results in inconsistent work, leading to wasted effort and time.	Sean	H	M	HM	14	Mitigate	Improve team communication by holding regular check-ins, using collaboration tools and documenting decisions	L	M	6
7	Team	30-Jan-25	Equipment malfuntion in lab or workshop	Malfunctioning equipment delays testing or prototype development, extending the project timeline.	Thomas	M	M	MM	10	Mitigate	Regularly service and maintain equipment, ensure availability of backup tools, and create contingency plans for equipment failure	M	L	5
8	Team	30-Jan-25	Unexpected change in project requirements	Unexpected changes require rework, pushing the project off schedule.	Aditya	M	M	MM	10	Accept	Adjust project scope and resources accordingly, maintain flexibility in timelines, and update deliverables based on new requirements	L	L	1
9	Team	30-Jan-25	Lack of team member expertise	Lack of expertise results in poor-quality work, causing inefficiencies and errors.	John	L	M	LM	6	Mitigate	Pair the team member with a more experienced colleague for guidance and support	L	M	6
10	Team	30-Jan-25	Miscalculation on team budget	Miscalculated budget leads to insufficient resources, causing delays and cutting into the project timeline.	Sean	L	L	LL	1	Mitigate	Conduct regular budget reviews, maintain a buffer for unexpected costs, and adjust scope if necessary to stay within budget	H	H	20
11	Team	30-Jan-25	Team member conflict or lack of cooperation	Conflicts or lack of cooperation reduce team efficiency and morale, affecting project progress.	Sean	M	L	ML	5	Mitigate	Foster a collaborative environment, mediate conflicts, and ensure alignment on project goals through regular team meetings	M	M	10
12	Team	30-Jan-25	CAD software crashes during work	Lost progress due to software crashes results in time spent recovering lost work, delaying the project.	Aditya	L	M	LM	6	Mitigate	Use auto-save features, implement regular file backups, and ensure technical support is available for software issues	H	L	9
13	Team	30-Jan-25	Delivery delays on materials or components	Delays in receiving materials or components halt work and cause missed deadlines.	Joe	M	M	MM	10	Mitigate	Establish backup suppliers, order materials well in advance, and maintain flexibility in project timeline to accommodate delays	M	M	10

Appendix 2 - Business / Marketing.

E. Market Analysis

Target Customers:

Astronauts:

- Age range: Around 30-40 years old, selected by space agencies and corporations
- Types of users: Astronauts on long-term space missions, researchers in similar environments, and potential commercial space tourists in the future.

Stakeholders:

- People who will buy product: Government space agencies, private space exploration companies, and research labs
- People who manufacture similar products that are used with our product: Aerospace manufacturing companies, sustainable engineering firms, and advanced materials producers
- Users of the product: Astronauts and crew members responsible for waste management in space, engineers overseeing system maintenance, and researchers studying recycling outcomes
- The design team: Astranew's engineering team
- ME 463 instructors: Faculty advisors guiding the project and ensuring its alignment with academic goals.

Benchmarks:

Updated per feedback from PDR

Tide Detergent designed for Space
Price: N/A
Fully degradable detergent with outstanding stain and malodor removal that meets NASA's requirements for space use. Allows for water to be recycled
Pros: Used with recyclable water, removes stains and smell, Approved by NASA
Cons: Uses water, still in testing phase

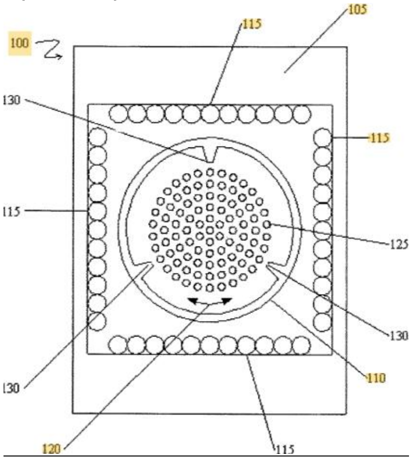
Asko W2084CW
Price: $1999
Efficient front loaded washing machine that uses around 40L of water per load (avg is 50-90L)
Pros: Water efficient
Cons: Uses water, which is not desirable in space, Expensive for earth applications

The Wonder Wash
Price: $79.99
Manually powered washing machine that uses no electricity. Utilizes a spinning handle to wash clothes with water and detergent.
Pros: No electricity used, minimal water usage
Cons: Requires constant human attention, Uses water and detergent

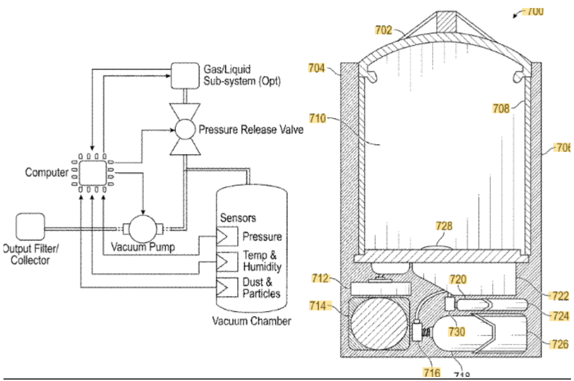
Samsung Bespoke AirDresser Grand Clothing Care System with Steam Refresh in Crystal Mirror Finish
Price: $1439.00
Utilizes steam and air to sanitize and remove dust and odor from clothes. Does not necessarily wash the clothes.
Pros: Utilizes an air system, Removes smells, Minimal water usage
Cons: Uses water, oversized for space application, Cost, Not airtight, Open air system

Patents:

Updated per feedback from PDR



Patent US11885064B2
Apparatus for drying laundry or other items using ultraviolet radiation
Drying Method: UV light with rotation
Pros: Dry's clothes effectively, Automated
Cons: No cleaning solution, Size



Patent US12121200B2
Apparatus that has a vacuum-based method for de-odorizing, disinfecting, or cleaning articles such as clothing.
Drying Method: Vacuuming out odors
Pros: Dry's clothes effectively, Automated
Cons: No cleaning solution, Size

F. Value Proposition

The Astranew waterless washing system provides critical value to space agencies and commercial space companies by reducing payload requirements for long duration space missions. Currently, each astronaut requires approximately 500 lbs of clothing for a 3-year mission due to the lack of efficient washing capabilities. With our UV-based cleaning technology, we estimate reducing this requirement by around 80%, allowing astronauts to reuse clothing and bring only 100 lbs of garments. With launch costs averaging $10,000 per pound to low Earth orbit, this represents a potential savings of $4 million per astronaut per 3-year mission in launch costs alone. At an estimated unit cost of $200,000 and anticipated annual sales of 8-10 units to major space agencies and private space companies, we project annual revenue of $1,600,000-2,000,000. Beyond direct cost savings, our system provides significant societal value through advancing sustainable space exploration technology and developing innovations in resource efficient cleaning that could have applications in extreme environments on Earth where traditional washing methods are impractical.

Appendix 3 - Design Process:

G. Engineering Requirements and Constraints

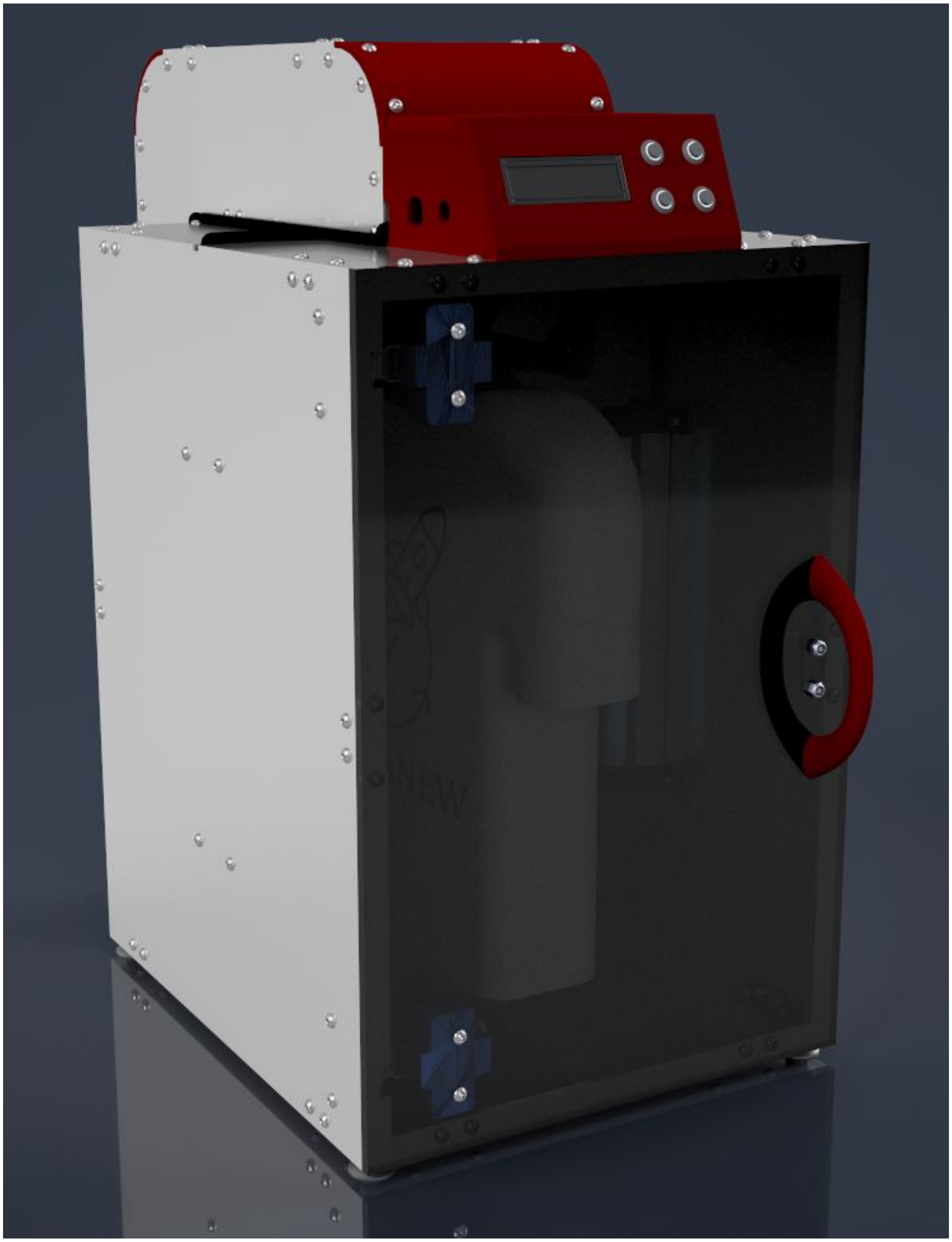
Requirements

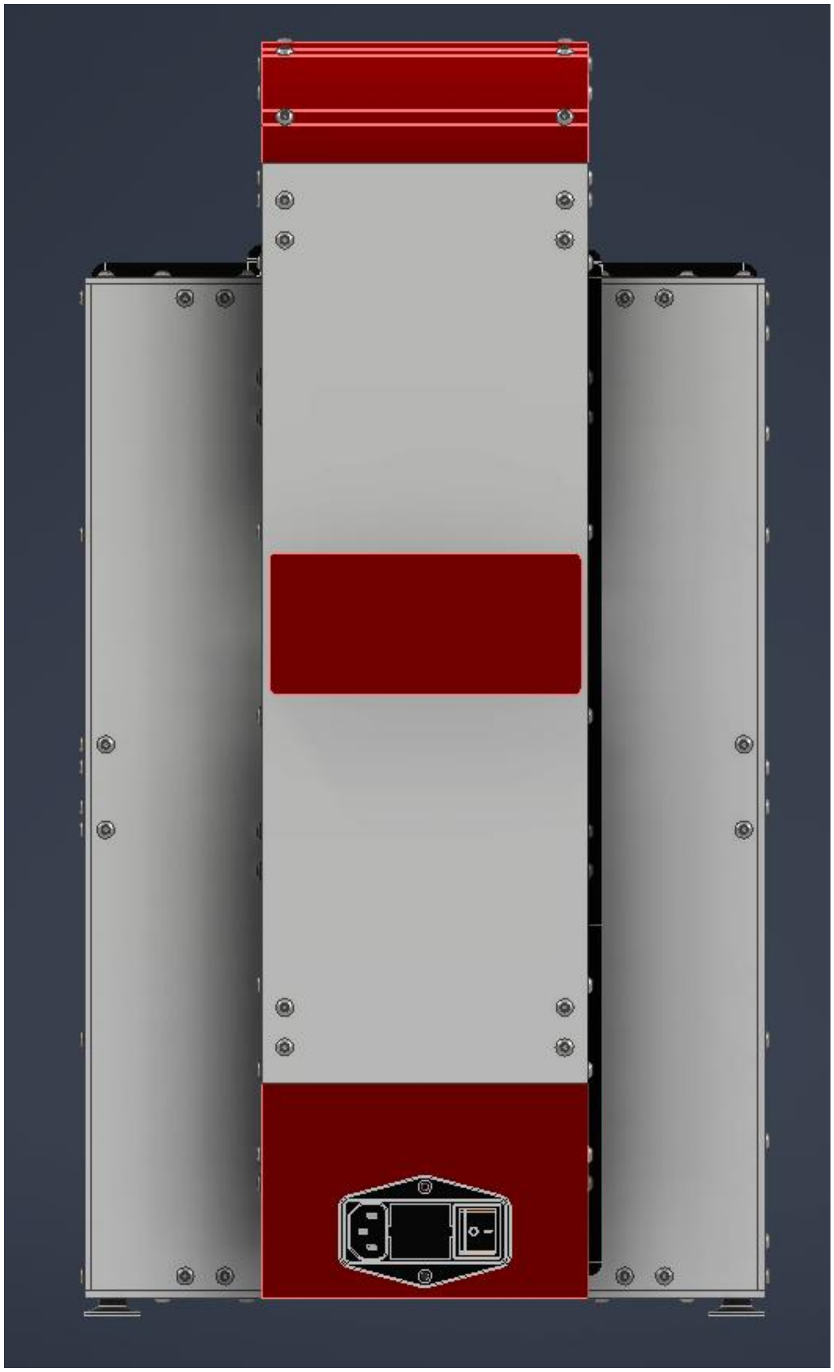
- Minimal water usage
- Minimal energy usage
- Maximize recycling efficiency
- Minimize waste
- Minimize device weight
- Minimize required user interaction
- Effectively clean athletic clothing material
- Minimize cleaning and processing time
- Get recycled material not back to new but into a useable state

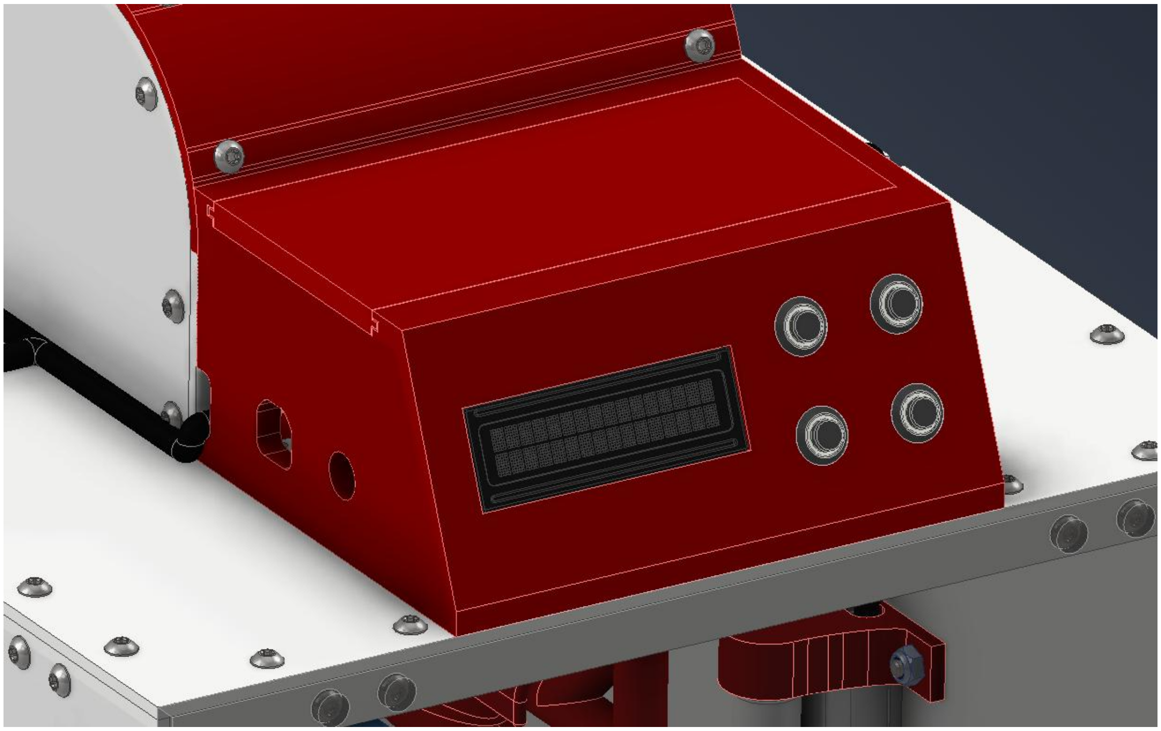
Constraint

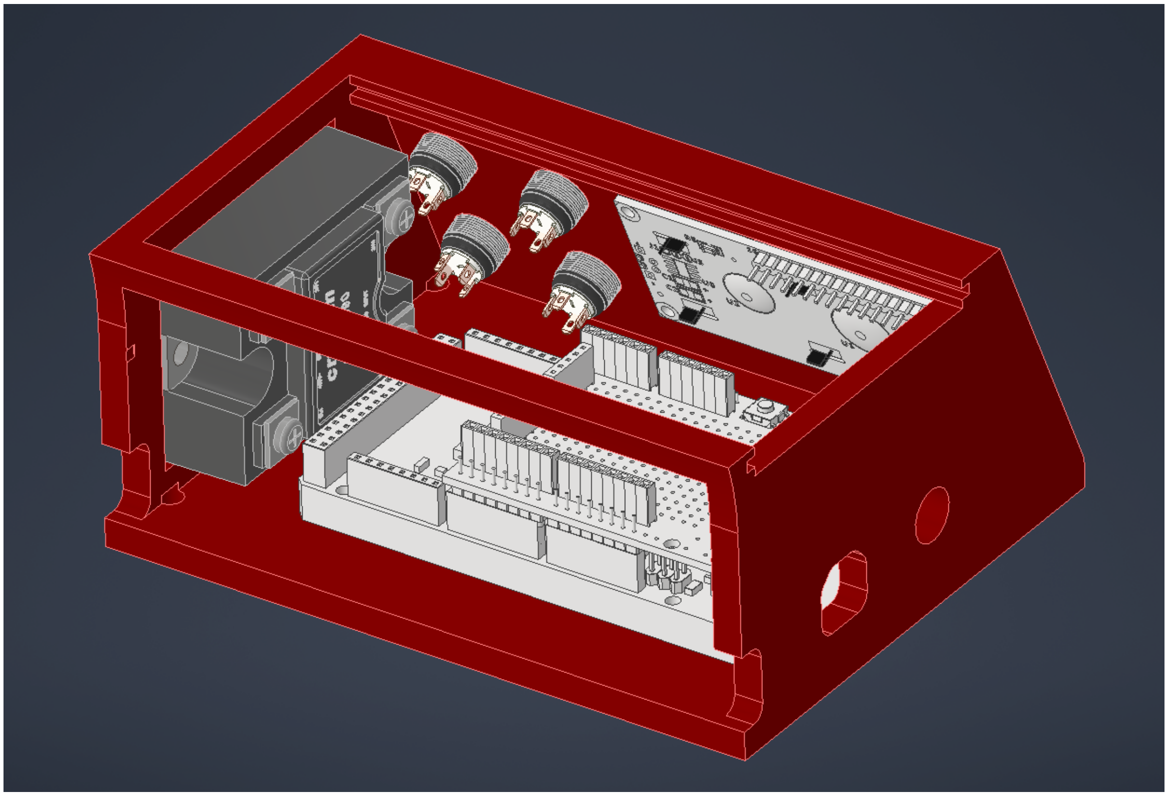
- Size, 4 EXPRESS Rack double lockers (each 48.26 cm H × 41.91 cm W × 24.13 cm D).
- Work with gravity 1.625 m/s^2
- Atmospheric pressure 57.2 kPa
- Temperature range 18 – 27 C
- No toxic emissions, PFAS, microplastics
- Compatible with closed loop air system
- Compatible with close loop water system

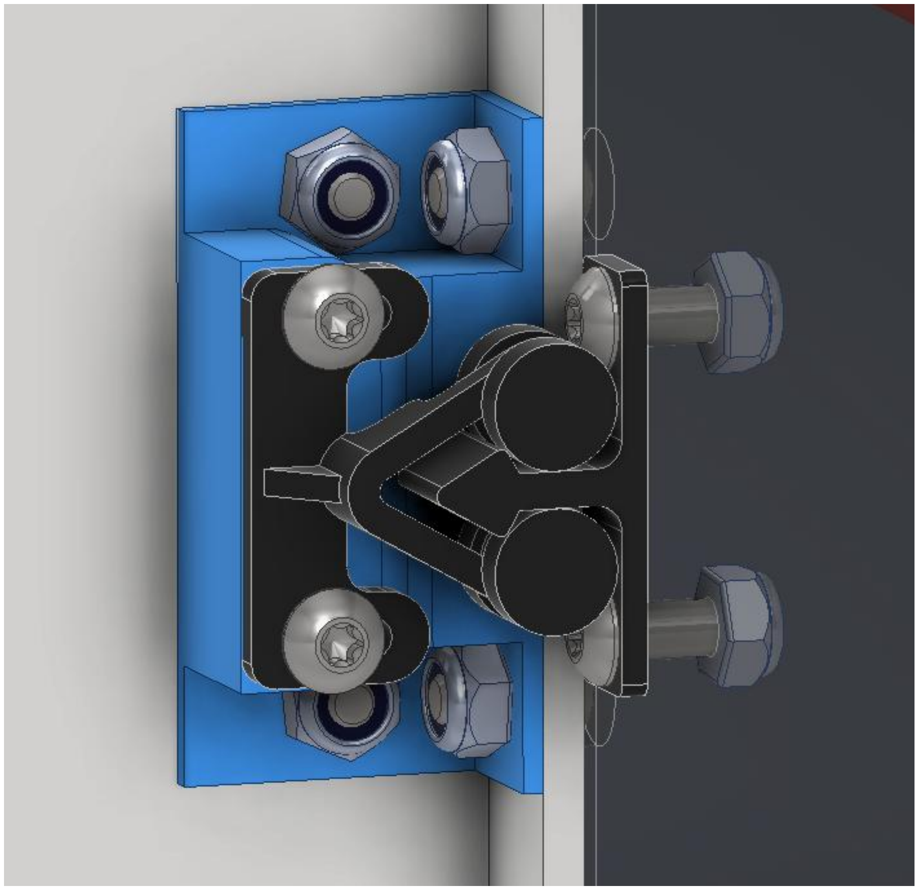
H. CAD

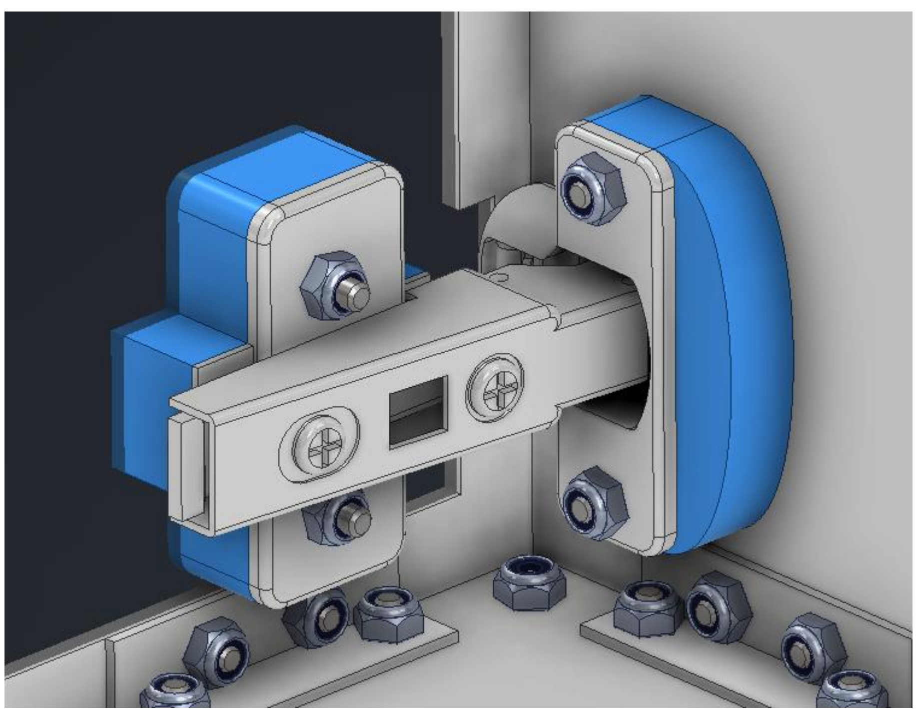


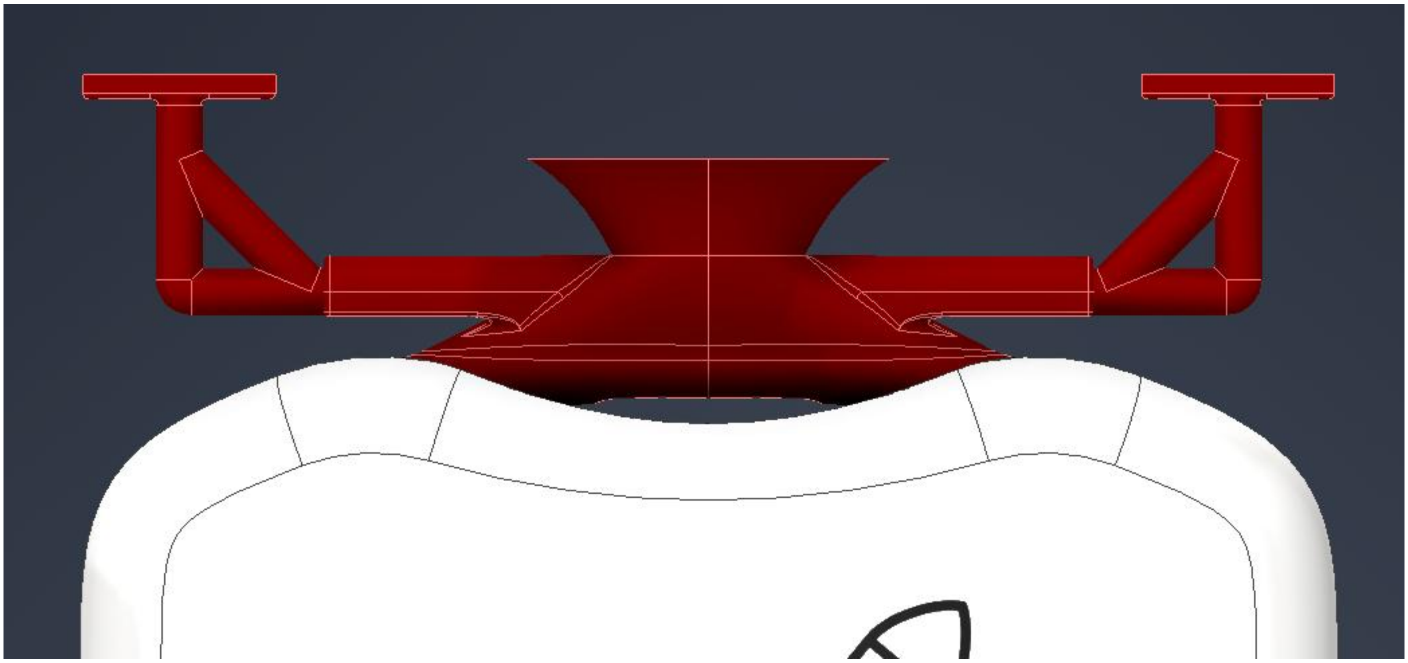


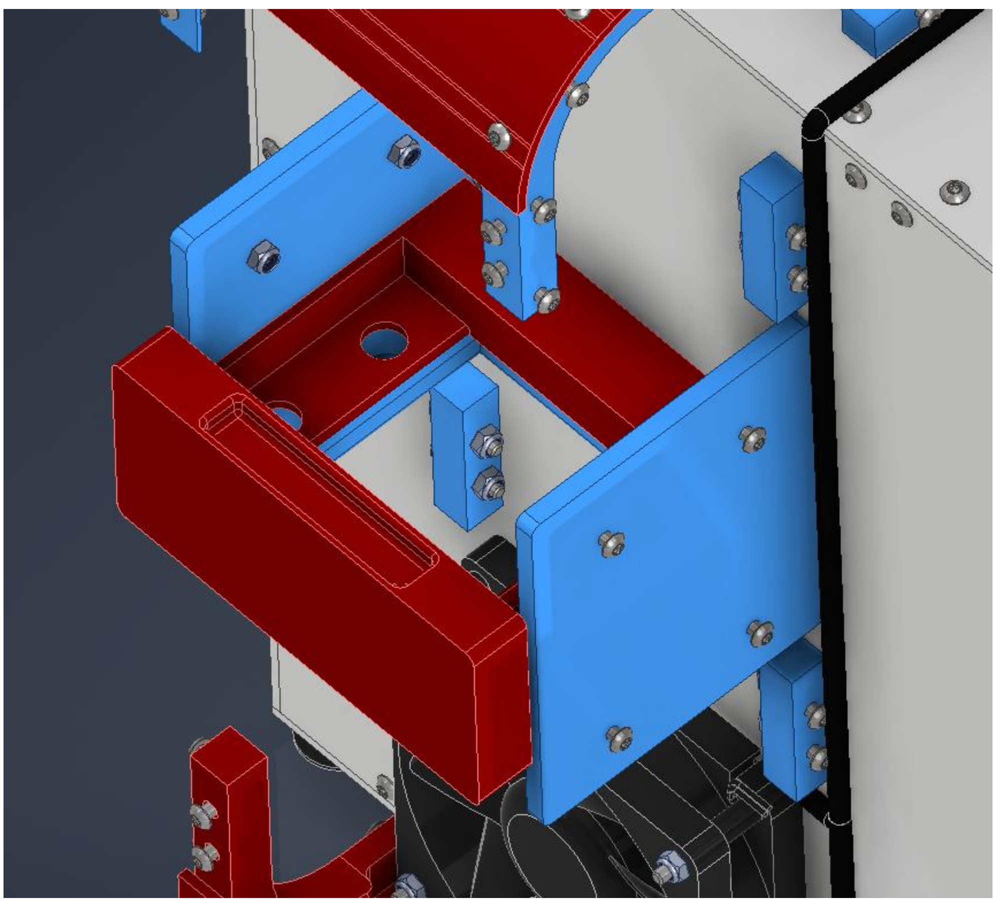


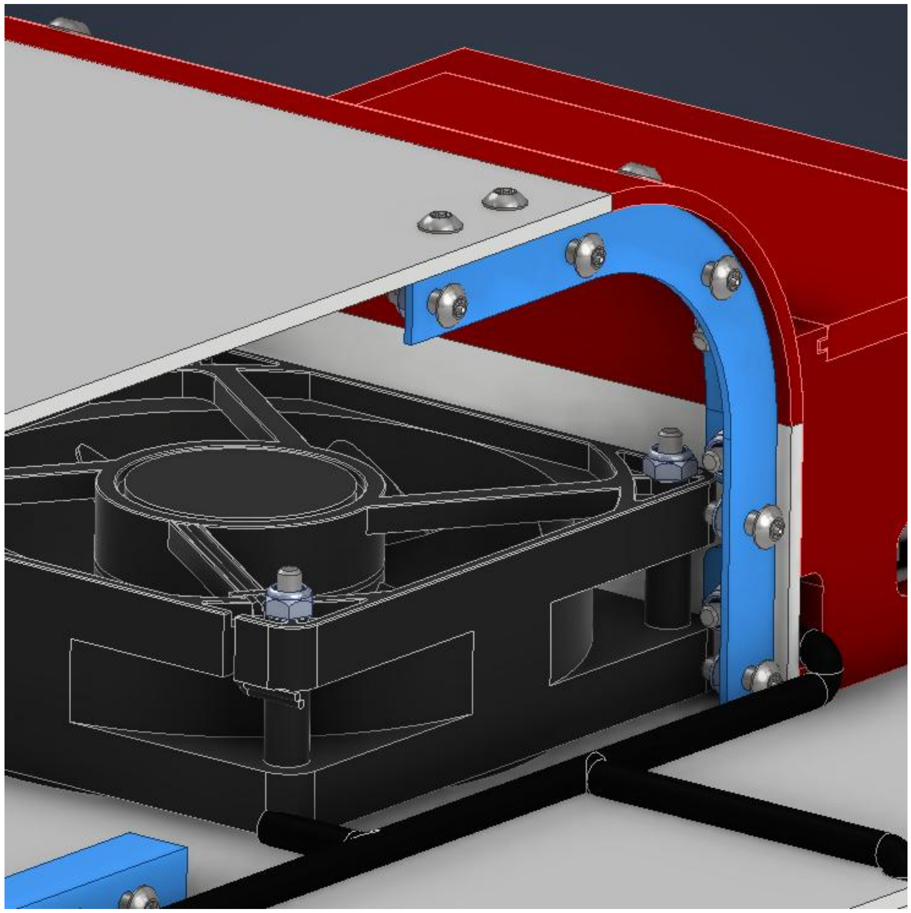


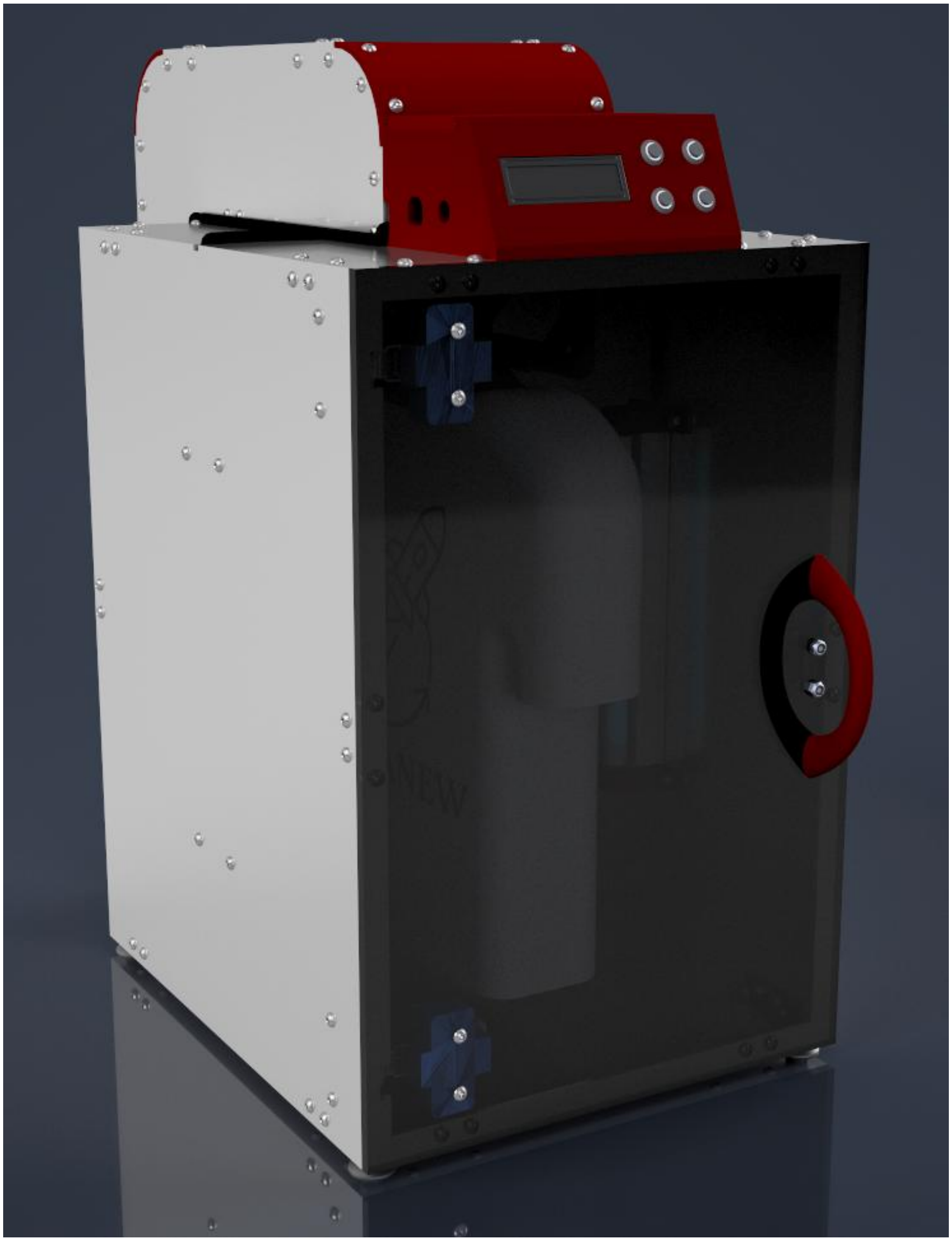


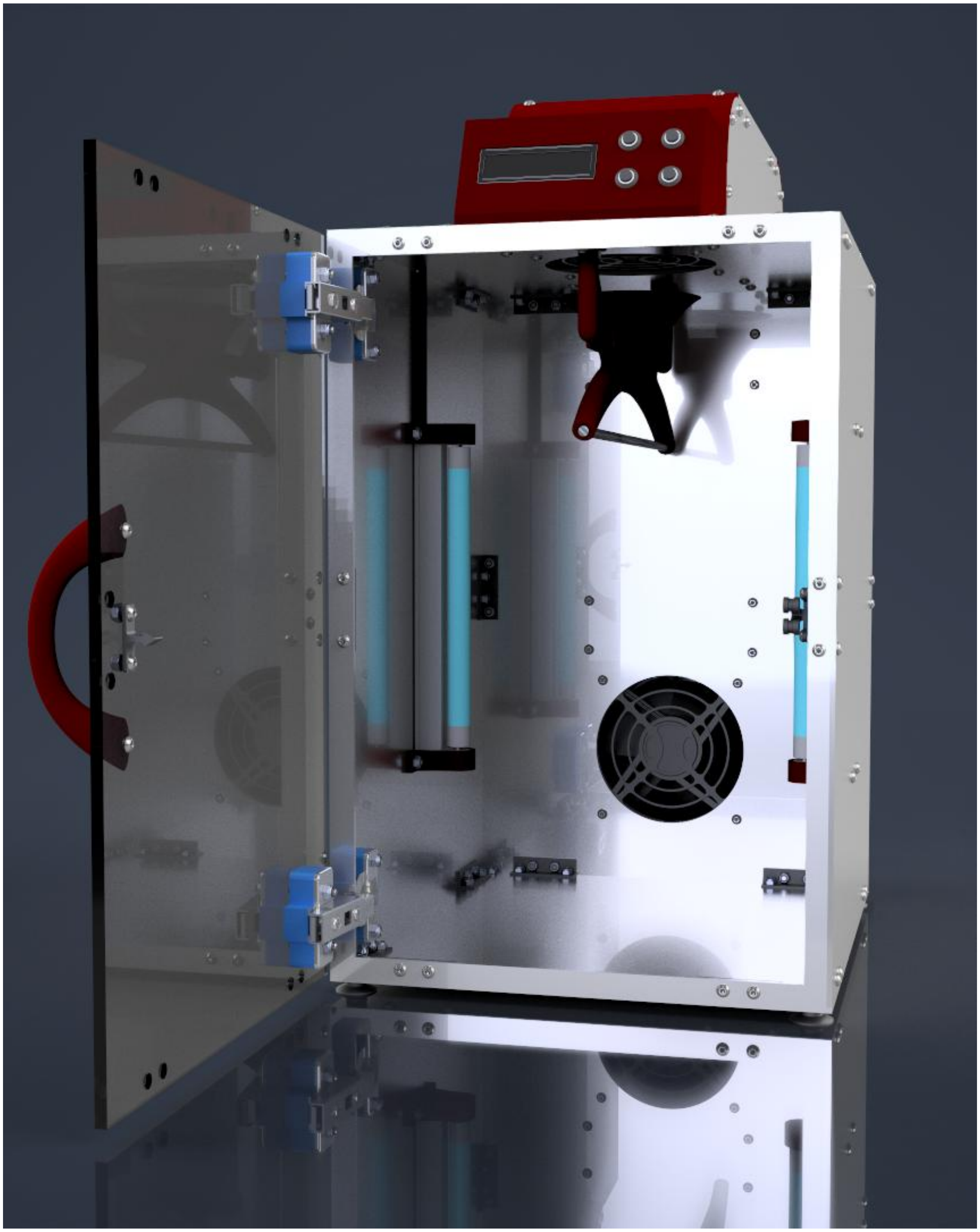


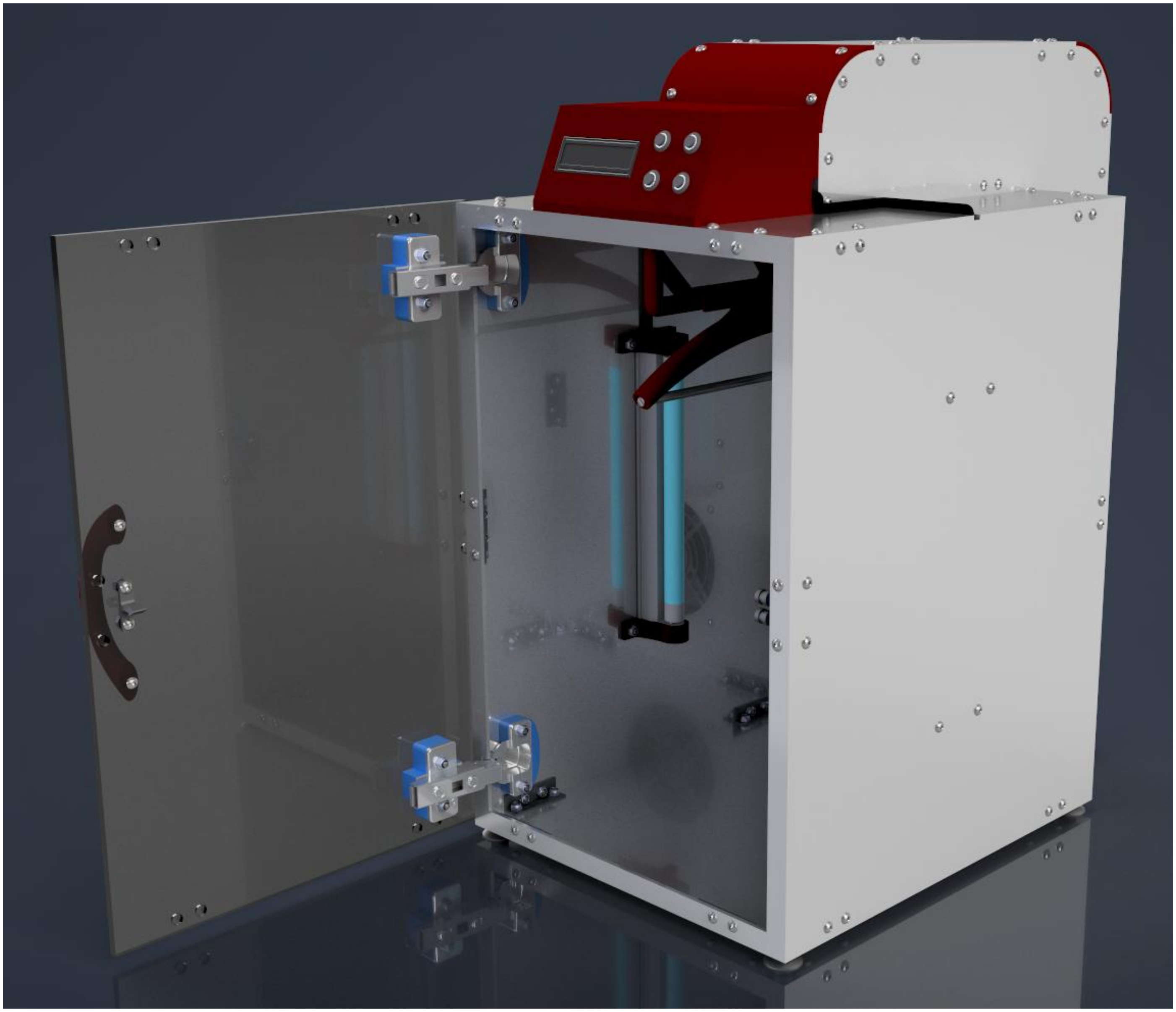


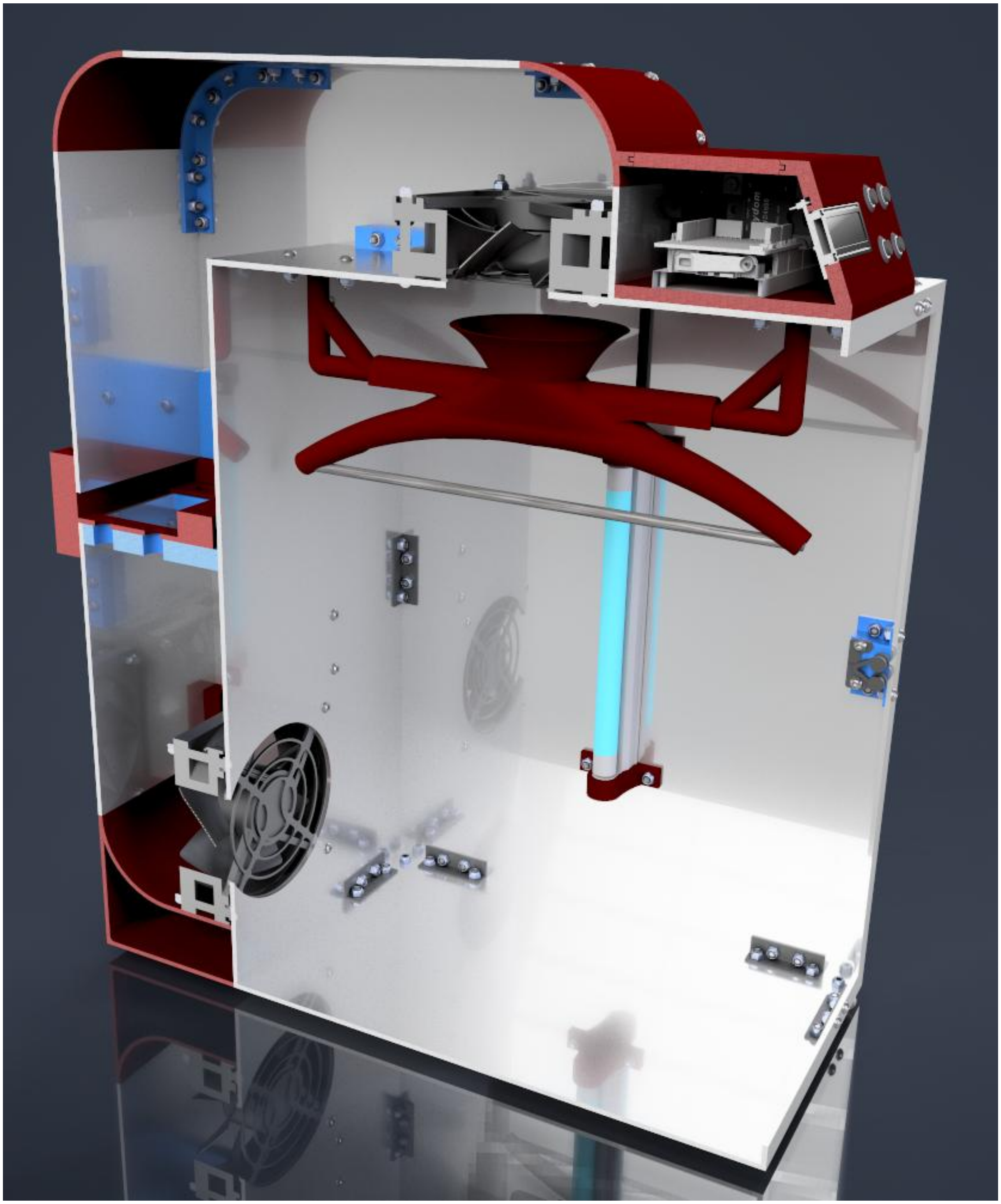




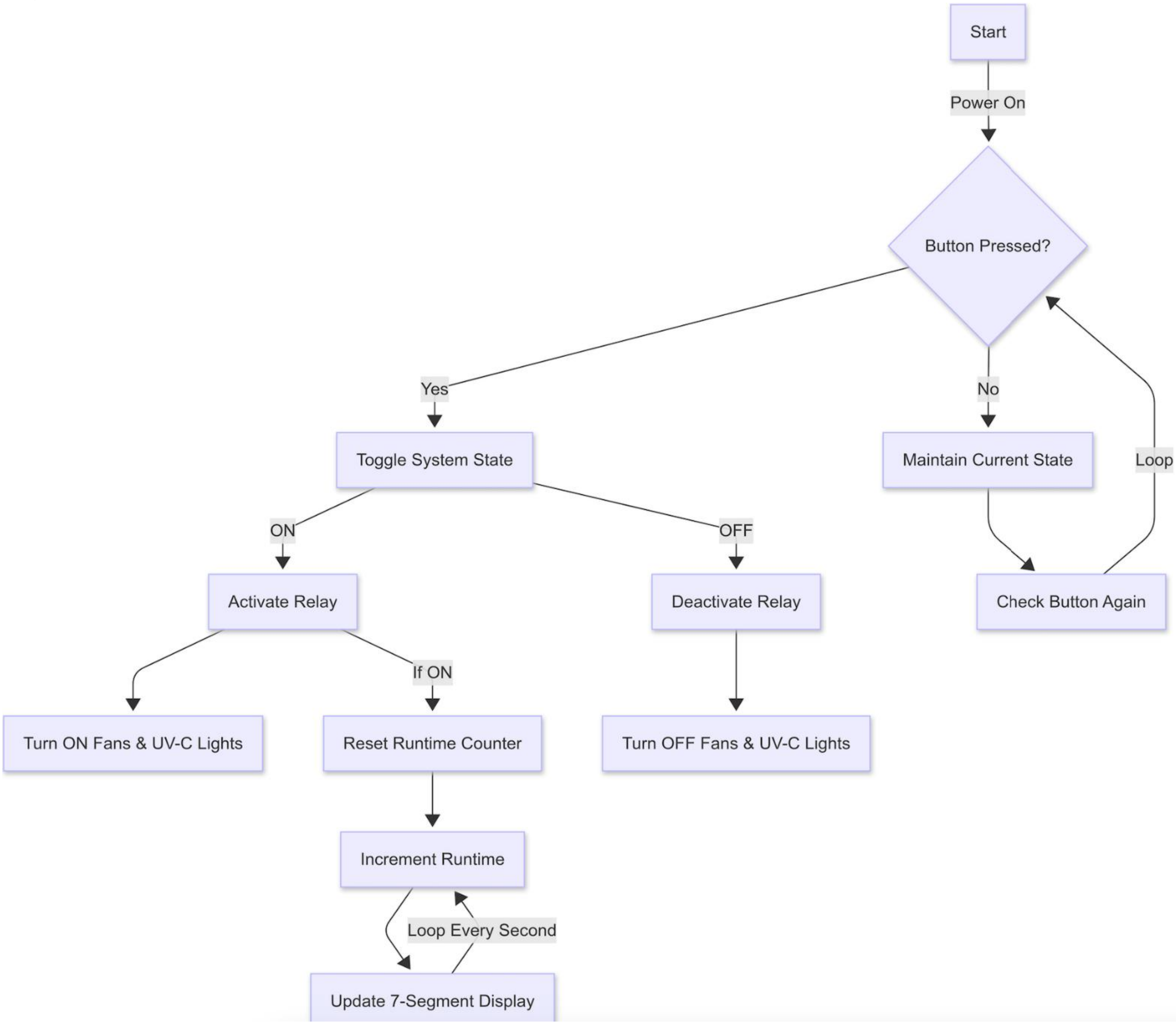




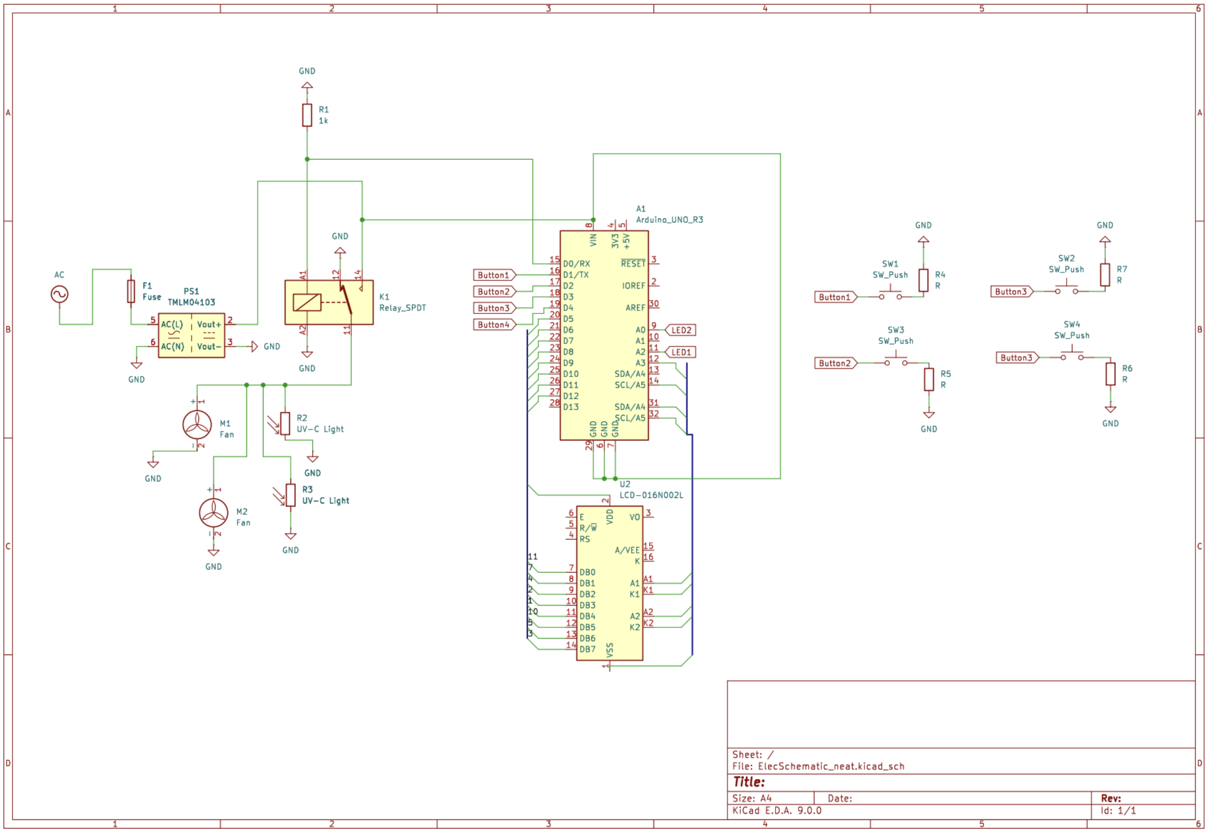




High level Electrical workflow



Electrical Wiring Diagram:



Arduino logic code:

```
#include <LiquidCrystal.h>

LiquidCrystal lcd(7, 8, 9, 10, 11, 12);

// Pin Definitions
const int addButtonPin = 2;    // Add minute button
const int subButtonPin = 4;    // Subtract minute button
const int startButtonPin = 3;  // Start/pause button
const int eStopButtonPin = 5;  // Emergency stop button
const int relayPin = 52;       // Relay control
const int buzzerPin = 13;      // Buzzer control

// Timer variables
unsigned long elapsedTime = 0;
unsigned long lastUpdate = 0;
bool isRunning = false;

// Buzzer control (NEW PATTERN SYSTEM)
const int beepPattern[] = {HIGH, LOW, HIGH, LOW, HIGH};  // 3 beeps with pauses
const unsigned long beepDurations[] = {300, 300, 300, 300, 300};  // 0.3s each
const int totalBeepSteps = sizeof(beepPattern)/sizeof(beepPattern[0]);
int beepStep = -1;  // -1 = inactive
unsigned long beepStartTime;
bool cycleCompleted = false;

// Button states
int addButtonState;
int lastAddButtonState = HIGH;
unsigned long lastAddDebounce = 0;

int subButtonState;
```

```
int lastSubButtonState = HIGH;
unsigned long lastSubDebounce = 0;

int startButtonState;
int lastStartButtonState = HIGH;
unsigned long lastStartDebounce = 0;

int eStopButtonState;
int lastEStopButtonState = HIGH;
unsigned long lastEStopDebounce = 0;

// Emergency stop state
bool emergencyStop = false;

// Function prototypes
void updateDisplay();
void updateRelay();

void setup() {
 lcd.begin(16, 2);
 pinMode(addButtonPin, INPUT_PULLUP);
 pinMode(subButtonPin, INPUT_PULLUP);
 pinMode(startButtonPin, INPUT_PULLUP);
 pinMode(eStopButtonPin, INPUT_PULLUP);
 pinMode(relayPin, OUTPUT);
 pinMode(buzzerPin, OUTPUT);

 digitalWrite(relayPin, LOW);
 digitalWrite(buzzerPin, LOW);

 lcd.setCursor(4, 0);
 lcd.print("Timer:");
 updateDisplay();
}

void loop() {
 unsigned long currentMillis = millis();

 // Handle buzzer sequence (MODIFIED)
 if (cycleCompleted) {
  if (beepStep == -1) {
   // Start beeping
   beepStep = 0;
   beepStartTime = currentMillis;
   digitalWrite(buzzerPin, beepPattern[0]);
  }
  else {
   if (currentMillis - beepStartTime >= beepDurations[beepStep]) {
    beepStep++;

    if (beepStep >= totalBeepSteps) {
     // End of sequence
     digitalWrite(buzzerPin, LOW);
     cycleCompleted = false;
     beepStep = -1;
    }
    else {
     digitalWrite(buzzerPin, beepPattern[beepStep]);
     beepStartTime = currentMillis;
    }
   }
  }
 }

 // Debounce and read buttons (UNCHANGED BUT WITH BUZZER RESETS)
 int addReading = digitalRead(addButtonPin);
 int subReading = digitalRead(subButtonPin);
 int startReading = digitalRead(startButtonPin);
 int eStopReading = digitalRead(eStopButtonPin);
```

```
// Add minute button (WITH BUZZER RESET)
if (addReading != lastAddButtonState) lastAddDebounce = currentMillis;
if ((currentMillis - lastAddDebounce) > 50) {
  if (addReading != addButtonState) {
    addButtonState = addReading;
    if (addButtonState == LOW) {
      elapsedTime += 60;
      cycleCompleted = false;
      digitalWrite(buzzerPin, LOW);
      beepStep = -1;  // Reset beep sequence
      updateDisplay();
    }
  }
}
lastAddButtonState = addReading;

// Subtract minute button (WITH BUZZER RESET)
if (subReading != lastSubButtonState) lastSubDebounce = currentMillis;
if ((currentMillis - lastSubDebounce) > 50) {
  if (subReading != subButtonState) {
    subButtonState = subReading;
    if (subButtonState == LOW) {
      elapsedTime = (elapsedTime >= 60) ? elapsedTime - 60 : 0;
      cycleCompleted = false;
      digitalWrite(buzzerPin, LOW);
      beepStep = -1;
      updateDisplay();
    }
  }
}
lastSubButtonState = subReading;

// Start/Pause button (WITH BUZZER RESET)
if (startReading != lastStartButtonState) lastStartDebounce = currentMillis;
if ((currentMillis - lastStartDebounce) > 50) {
  if (startReading != startButtonState) {
    startButtonState = startReading;
    if (startButtonState == LOW) {
      isRunning = !isRunning;
      cycleCompleted = false;
      digitalWrite(buzzerPin, LOW);
      beepStep = -1;
      updateRelay();
    }
  }
}
lastStartButtonState = startReading;

// Emergency Stop button (WITH BUZZER RESET)
if (eStopReading != lastEStopButtonState) lastEStopDebounce = currentMillis;
if ((currentMillis - lastEStopDebounce) > 50) {
  if (eStopReading != eStopButtonState) {
    eStopButtonState = eStopReading;
    if (eStopButtonState == LOW) {
      emergencyStop = !emergencyStop;
      if (emergencyStop) isRunning = false;
      cycleCompleted = false;
      digitalWrite(buzzerPin, LOW);
      beepStep = -1;
      updateRelay();
      updateDisplay();
    }
  }
}
lastEStopButtonState = eStopReading;

// Update timer (MODIFIED COMPLETION TRIGGER)
if (isRunning && (currentMillis - lastUpdate >= 1000) && !emergencyStop) {
  lastUpdate = currentMillis;
  if (elapsedTime > 0) elapsedTime--;
```

```
    if (elapsedTime == 0) {
      isRunning = false;
      cycleCompleted = true;  // Triggers beep sequence
      updateRelay();
    }
    updateDisplay();
  }

  updateRelay();
}

// Rest of your existing functions remain unchanged
void updateDisplay() {
  lcd.setCursor(0, 1);

  if (emergencyStop) {
    lcd.print("Emergency Stop  ");
  } else if (elapsedTime == 0) {
    lcd.print(" Cycle Complete ");
  } else {
    int minutes = elapsedTime / 60;
    int seconds = elapsedTime % 60;

    lcd.print("                ");
    lcd.setCursor(5, 1);
    if (minutes < 10) lcd.print("0");
    lcd.print(minutes);
    lcd.print(":");
    if (seconds < 10) lcd.print("0");
    lcd.print(seconds);
  }
}

void updateRelay() {
  digitalWrite(relayPin, (isRunning && !emergencyStop && elapsedTime > 0) ? HIGH : LOW);
}
```

I. Analysis

Ia. CFD on Hanger and Shirt Sub-Assembly

The central air flow component of our device involves the hanger and shirt sub assembly. With the clothes hanger designed to intake and distribute air through the hanger and into the shirt, we wanted to gain some insight on how air flowing through the shirt within the device. Air flow is crucial within the shirt to ensure the air is blowing bacteria, germs, and odors out of the shirt to allow for the air to go through the closed loop and be disinfected by the UV lights. A CFD simulation, with assumptions to simplify the analysis, was ran in ANSYS 2022 to get an understanding of air flow. To complete this simulation an enclosure was placed around the shirt and hangar system that models the exact dimensions of the team's box enclosure, see details below.
Given:

Material Properties

Property	**Cotton**	**Filament**
Density (kg/m^3)	558.3	1250
Specific Heat $(\frac{J}{kg*K})$	1273	1800
Thermal Conductivity $(\frac{W}{m*K})$	.020	.13

Air Properties

Property	Air
Dynamic Viscosity $\left(\frac{m^2}{s}\right)$	35.02 * 10^-6
Specific Heat $(\frac{J}{kg*K})$	1005
Pressure (Pa)	101325
Gas Constant $(\frac{J}{kg*K})$	287

Enclosure Dimensions to Reflect Physical Box Dimensions

Direction	Length from Shirt/Hanger (mm)
Positive X	11.91
Negative X	8.74
Positive Y	47.63
Negative Y	38.1
Positive Z	106.15
Negative Z	106.15

Assumptions:

- Laminar flow through shirt
- Shirt geometry remains constant
- No air flow through shirt surface
- No reverse flow at bottom of shirt
- Air is at room temperature (300 K)
- Uniform flow from fan
- UV light has a constant surface temperature (333 K)
- Ignoring gravity

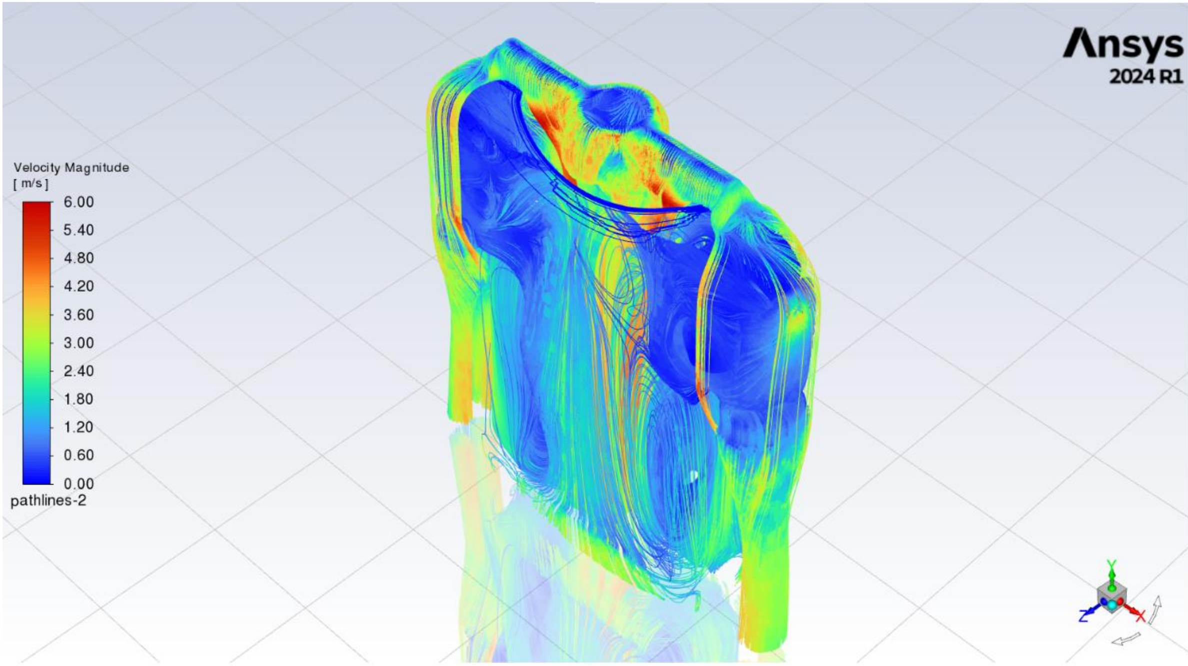
Calculation for max wind speed:

$$Fan\ Cross\ Sectional\ Area: .016129\ m^2$$

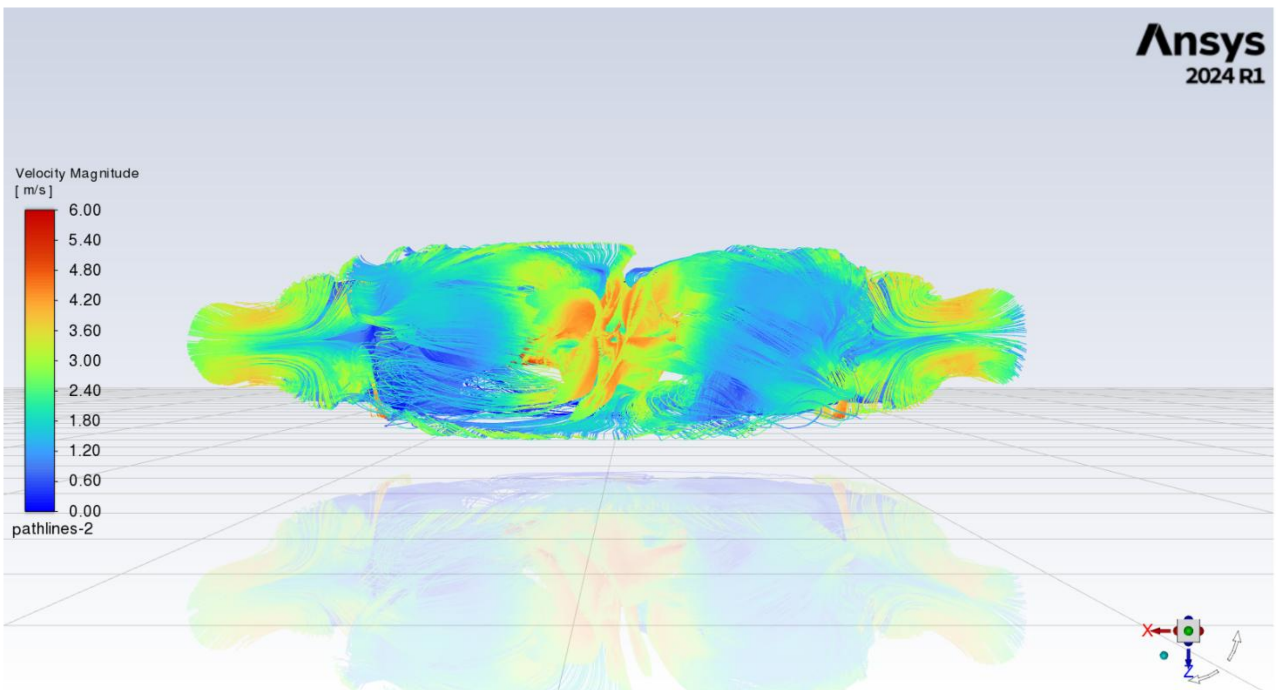
$$Max\ CFM\ accoridng\ to\ spec: 133\,\frac{ft^3}{min} = .06276901085\,\frac{m^3}{s}$$

$$Velcoity\ of\ air: \frac{.06276901085\,\frac{m^3}{s}}{.016129\ m^2} = 3.89\,\frac{m}{s}$$

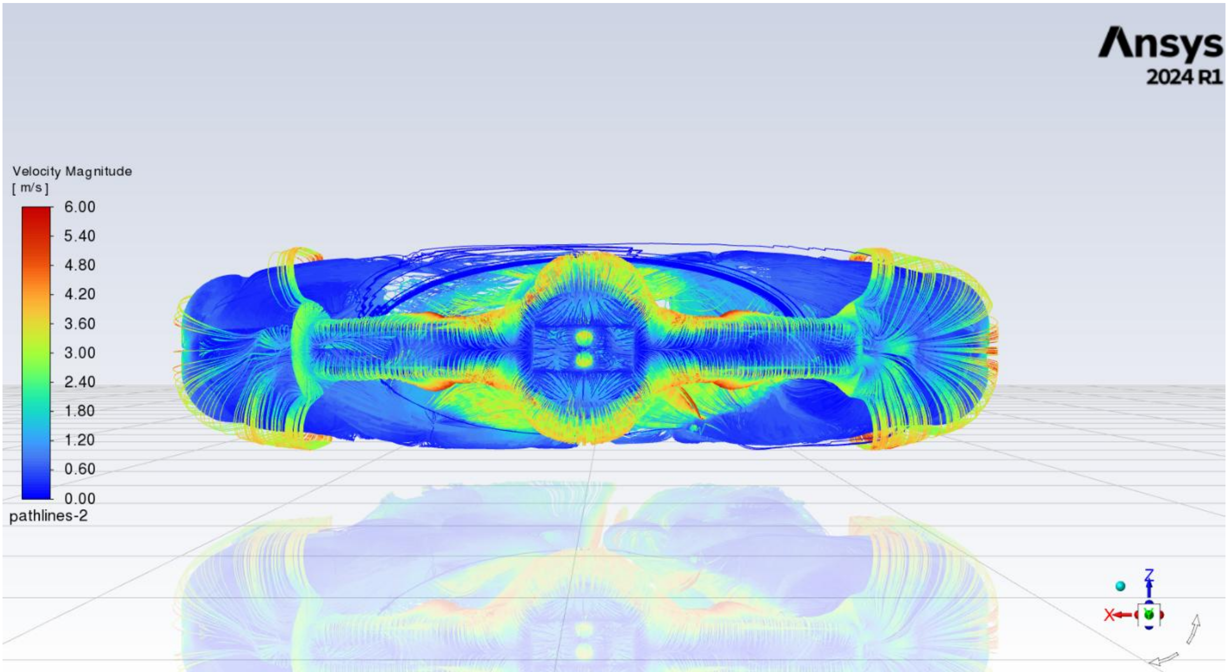
Results:



Isometric View of Air Flow within Shirt



Bottom View of Air Flow within Shirt



Top View of Air Flow over Hanger

From the CFD, the team can see that the hanger design allows for optimal air flow through the shirt and out the sleeves, this will be key to enhance bacteria and odor removal. Flow also accelerates in certain spots within the shirt, which will also help the teams' goals within the shirt. It is worth nothing that this model assumes laminar flow, the flow is likely more turbulent which will be even more effective in removing germs and bacteria off the surface of the shirt. Therefore, we expect this hanger design to be optimal for the team's project.

Ib. MATLAB Power Analysis

The MATLAB script calculates the total power and current requirements for the product, ensuring that all components receive the necessary power for proper operation. It first defines the power consumption of key components, including two UV-C lights, two fans, and an Arduino. Using these values, the script determines the total power consumption and calculates the required current at 110V AC. Additionally, it includes a logical check to verify whether the system's total power draw is within the limits of a standard wall outlet, providing a clear indication of whether direct wall power is feasible.

The script serves as a validation step in system design, preventing power supply issues that could lead to underperformance or failure of components. By quantifying power needs, it ensures that the relays, fans, and UV-C lights receive sufficient energy while keeping the total draw within safe operating limits. The final output confirms that the system, requiring approximately 262.5W and 2.86A at 110V, can operate safely through a standard wall outlet, ensuring practical feasibility without the need for additional power management.

```matlab
V_main = 110; % Main supply voltage (V)
V_fans = [85, 255]; % Fan operating voltage range (V)
V_UV = 110; % UV-C lamp voltage (V)
V_arduino = 5; % Arduino operating voltage (V)
I_arduino = 0.5; % Assumed max current for Arduino (A)

% Power ratings
P_fan = 30; % Power per fan (W)
n_fans = 2; % Number of fans
P_UV = 100; % Power for UV-C lamps (W)
n_UV = 2; % Number of UV lamps

% Power calculations
P_fans_total = P_fan * n_fans; % Total fan power
P_UV_total = P_UV * n_UV; % Total UV power
P_arduino = V_arduino * I_arduino; % Power for Arduino

% Total system power requirement
P_total = P_fans_total + P_UV_total + P_arduino;

% Current calculations
I_fans = P_fans_total / V_main; % Fan current at main voltage
I_UV = P_UV_total / V_main; % UV lamp current
I_arduino = P_arduino / V_arduino; % Arduino current

% Total current required
I_total = I_fans + I_UV + I_arduino;

% Wall outlet capacity
V_wall = 120; % Wall outlet voltage (V)
I_wall = 15; % Typical 15A circuit
P_wall_max = V_wall * I_wall; % Maximum power a wall outlet can provide

% Display results
fprintf('-------\n');
fprintf('Total Power Requirement: %.2f W\n', P_total);
fprintf('Total Current Requirement at %dV: %.2f A\n', V_main, I_total);
fprintf('Fan Power: %.2f W | UV Power: %.2f W | Arduino Power: %.2f W\n', ...
    P_fans_total, P_UV_total, P_arduino);

fprintf('-------\n');
```

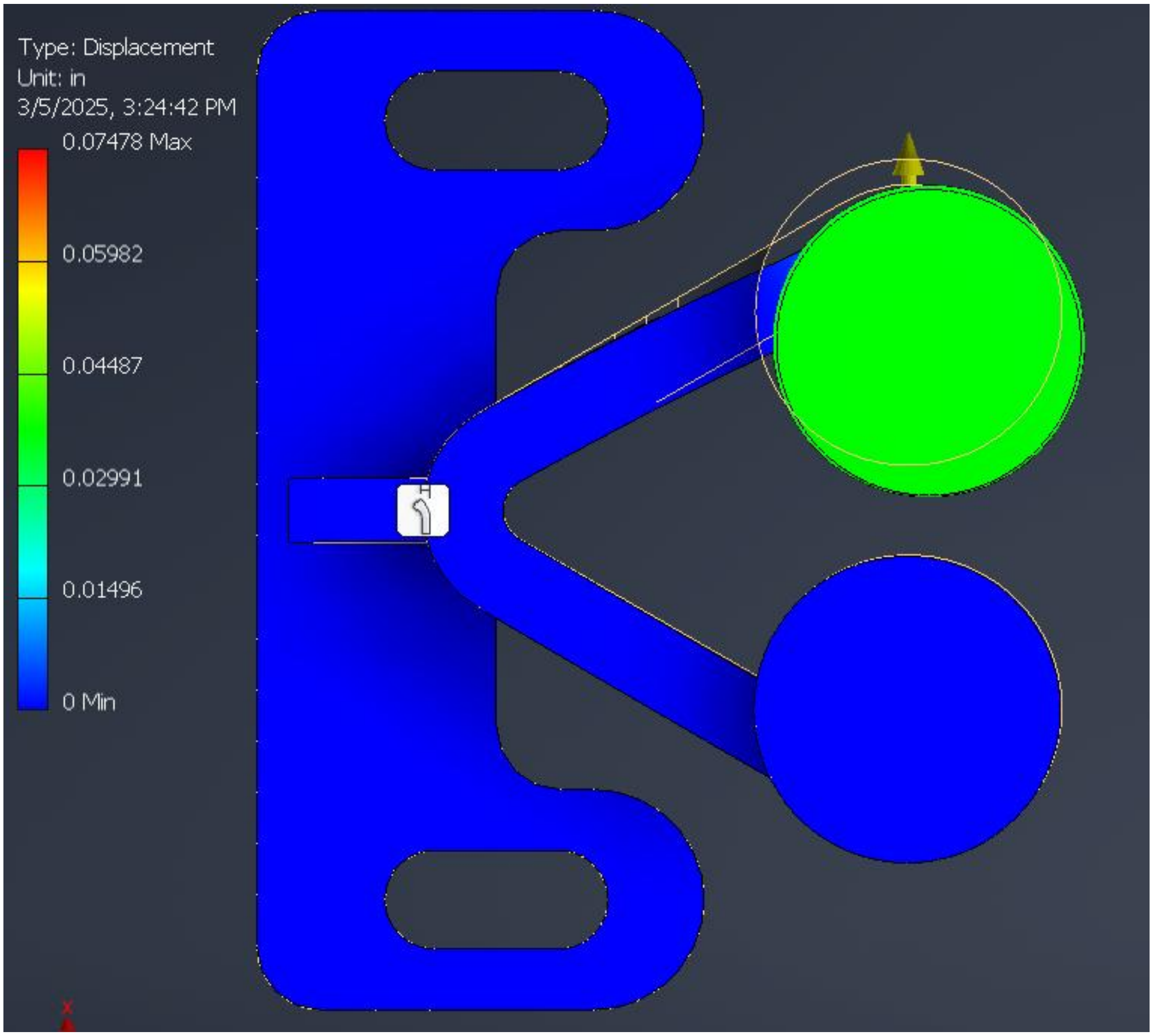
Command Window

```
>> PowerCalc
-------
Total Power Requirement: 262.50 W
Total Current Requirement at 110V: 2.86 A
Fan Power: 60.00 W | UV Power: 200.00 W | Arduino Power: 2.50 W
-------
The system can safely run through a standard wall outlet.
It requires only 262.50 W, which is well below the 1800.00 W a standard 15A outlet provides.
-------
```

Ic. FEA on latching mechanism

A Finite Element Analysis (FEA) was conducted on the roller grab latch mechanism, which serves as a critical component in the project's door system. This analysis was necessary to determine the pull force required to operate the latch effectively, as the door mechanism represents one of the most frequent user interaction points and must function reliably throughout the product lifecycle. The latch design incorporates a 120° angle with a 0.035" displacement requirement for proper operation.

The analysis was performed using low-density polyethylene as the material choice. Key assumptions in the simulation included static loading conditions and linear elastic material behavior. The FEA results indicate that a 7 lb pull force is required to achieve the necessary 0.075" displacement for latch operation, as shown by the color-coded displacement map where green areas experience approximately 0.045" of displacement. This 7 lb force requirement falls well within ergonomic guidelines for door operation, making it comfortably usable for the intended user population without causing strain or difficulty. The maximum displacement observed was 0.07478", primarily concentrated at the roller contact points, which aligns with the design intentions and validates the mechanism's operational parameters.


Type: Displacement
Unit: in
3/5/2025, 3:24:42 PM
0.07478 Max
0.05982
0.04487
0.02991
0.01496
0 Min

J. FMEA

The FMEA analysis for the project thoroughly examined potential failure modes across the system's components, identifying critical risks that could impact functionality and safety. The analysis evaluated 17 failure scenarios including mechanical issues with fans, hangers, and doors; electrical problems like shorts and power failures; and operational concerns with UV-C lights and seals. Each potential failure was assessed using a standardized ranking system for Severity, Occurrence, and Detection, resulting in Risk Priority Numbers (RPN) that highlighted the most critical areas requiring attention. The highest risk items identified were seal wear (RPN 280), improper hanger placement (RPN 252), and hanger stress failure (RPN 216), all of which could significantly compromise the system's effectiveness and safety.

The analysis established comprehensive mitigation strategies involving multiple engineering disciplines to address these risks. For high-priority mechanical failures, solutions include using corrosion-resistant materials, implementing stress-tested components, and providing clearer mounting instructions. Electrical system risks will be mitigated through protective measures such as conformal coating, redundant power circuits, and improved wire routing. The most critical improvement targets seal maintenance, with scheduled replacements using chemical/UV-resistant compounds and enhanced installation training. The FMEA demonstrates that these targeted interventions should significantly reduce risk across all components, with projected RPN reductions of up to 75% for the most critical failure modes, ensuring greater system reliability and safety throughout the product lifecycle.

ME 463 Senior Design

Project Name: ASTRANEW

Line No.	Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	SEV	Potential Cause(s) / Mechanism(s) of Failure	OCC	Current Controls	DET	RPN	Mitigation Action (s)	by Who	by When	New SEV	New OCC	New DET	New RPN
1	Fans	Fan stops working due to motor failure, bearing failure, or power issue	Overheating and poor ventilation due to fan malfunction	6	Motor burnout, debris blockage, electrical faults, bearing wear.	5	Thermal sensors, regular maintenance schedules, protective grilles.	3	90	Install thermal sensors and implement scheduled motor maintenance to prevent blockages.	Maintenance Technicians	During installation; quarterly	6	3	2	36
2	Deodorizer	Deodorizer falls out of the tray due to improper fit or vibration	Odor buildup and potential component displacement	4	Weak tray design, vibration, improper installation, user error.	7	Snap-fit tray locks, user installation guides, vibration dampeners.	5	140	Redesign tray with snap-fit locks and vibration-resistant materials.	Design Engineers	Product redesign phase	4	5	3	60
3	Deodorizer	Deodorizer filter life runs out, reducing effectiveness	Reduced odor control and contamination risks	5	Lack of maintenance alerts, prolonged use, poor airflow monitoring.	8	Filter life indicators, automated usage timers.	2	80	Integrate automated filter-life alerts and usage-tracking software.	Software Developers	Software update cycle	5	5	1	25
4	Door	Latch failure causing improper sealing or inability to close	Unsecured door leading to disrupted space enviroment	6	Mechanical wear, misalignment, corrosion, excessive force.	4	Reinforced latches, alignment guides, routine inspections.	4	96	Reinforce latch mechanism and conduct routine alignment inspections.	Quality Assurance + Maintenance	Pre-production; bi-annual inspections	6	3	3	54
5	Door	Hinge failure leading to difficulty in opening or closing	Door misalignment or detachment risks	5	Metal fatigue, overloading, rust, poor lubrication.	3	Corrosion-resistant hinges, lubrication ports, weight limits.	5	75	Use corrosion-resistant alloys and add lubrication access points.	Manufacturing Team	During component fabrication	5	2	4	40
6	Hanger	Hanger experiences stress failure	Improper cleaning of fabrics	6	Overloading, material defects, corrosion, impact damage.	6	Weight capacity labels, stress-testing during manufacturing.	6	216	Label weight limits clearly and use stress-tested materials.	Product Designers	Pre-production labeling/testing	6	4	5	120
7	Hanger	Hanger is not hung correctly, causing imbalance or detachment	Instability or improper device function	4	User error, unclear instructions, unstable mounting surface.	9	Visual mounting guides, instructional videos, alignment markers.	7	252	Provide visual mounting guides and simplified instructional content.	Technical Writers/UX Team	Before product launch	4	6	5	120
8	Hanger Supports	Hanger supports fail under stress	Structural collapse or component damage	7	Excessive weight, poor weld joints, material degradation.	4	Load testing, welded joint inspections, material certifications.	6	168	Perform load testing on welds and certify material durability.	Quality Assurance	Pre-production validation	7	3	4	84
9	UV-C Lights	UV-C lights burn out, reducing sterilization effectiveness	Inadequate sterilization and increased pathogen exposure	8	End-of-life bulb, power surges, faulty ballast, overheating.	6	Bulb lifespan tracking, surge protectors, auto-shutoff.	1	48	Add surge protection and bulb lifespan tracking with auto-shutoff.	Electrical Engineers	During hardware upgrades	8	4	1	32
10	Deodorizer Tray	Deodorizer tray experiences stress failure	Spillage or damage to internal components	5	Overloading, brittle material, thermal expansion, impact.	3	Impact-resistant materials, tray load limits.	5	75	Use impact-resistant polymers and enforce tray load limits.	Material Engineers	Component manufacturing stage	5	2	4	40
11	UI	User interface functions improperly	User confusion or operational inaccuracies	3	Software bugs, firmware glitches, touchscreen calibration errors.	7	Pre-release testing, firmware updates, touchscreen diagnostics.	3	63	Roll out firmware updates and pre-release software testing protocols.	Software QA Team	Pre-release testing; ongoing updates	3	5	2	30
12	Electronics	Electronics short out due to moisture, dust, or component failure	System failure or fire hazards	9	Moisture ingress, damaged insulation, solder bridging, overheating.	2	Conformal coating, insulation checks, sealed enclosures.	3	54	Apply conformal coating and conduct insulation integrity checks.	Production Technicians	During assembly; post-repair checks	9	1	2	18
13	Electronics	Power shortage due to insufficient supply or system overload	Intermittent operation or shutdowns	5	Faulty power supply, loose connections, voltage spikes.	5	Redundant power circuits, connection integrity tests.	4	100	Implement redundant power circuits and connection stability tests.	Electrical Engineers	During system integration	5	3	3	45
14	Electronics	Wire comes loose	Inconsistent performance or connectivity issues	4	Vibration, poor crimping, thermal cycling, improper strain relief.	4	Strain relief clamps, vibration testing, crimp integrity checks.	5	80	Add strain relief clamps and perform vibration resistance testing.	Manufacturing Engineers	Pre-production testing	4	3	4	48
15	Electronics	Wire gets cut due to mechanical interference or wear	Complete loss of electronic functionality	7	Abrasion, pinching, rodent damage, accidental cutting during maintenance.	2	Protective conduits, wire routing guides, maintenance protocols.	3	42	Route wires through protective conduits and enforce maintenance guidelines.	Maintenance + Installers	Installation; during repairs	7	1	2	14
16	Seals	Improper seal	Leakage or environmental contamination	7	Installation error, uneven surfaces, incompatible gasket material.	6	Installation training, gasket alignment tools, leak tests.	4	168	Train installers on gasket alignment and perform post-installation leak tests.	Facilities Management	Post-installation; after repairs	7	4	3	84
17	Seals	Seals wear out over time	Gradual leaks and reduced efficiency	5	Aging, chemical exposure, UV degradation, repeated compression.	8	Scheduled seal replacements, chemical-resistant materials.	7	280	Schedule periodic replacements and use chemical/UV-resistant compounds.	Maintenance Team	Annual maintenance schedule	5	5	5	125

DESIGN FAILURE MODES AND EFFECTS ANALYSIS
RANKING CRITERIA

SEVERITY

Ranking	Description
1	No impact: Failure has no noticeable effect on performance, safety, or user experience.
2	Minor inconvenience: Slight annoyance or temporary disruption with no safety or functional risk.
3	Minor functional impact: Noticeable reduction in efficiency or usability, but easily resolved.
4	Functional disruption: Intermittent system issues requiring user intervention or adjustments.
5	Operational downtime: Partial system failure causing pauses in functionality or minor delays.
6	Safety/performance risk: Potential minor injuries, property damage, or persistent system flaws.
7	Severe safety hazard: High risk of injury, significant property damage, or critical system failure.
8	Critical system failure: Complete operational collapse with irreversible damage or safety threats.
9	Life-threatening danger: Immediate risk of severe injury, fire, or toxic exposure.
10	Catastrophic failure: Total system destruction, life-threatening harm, or irreversible environmental/legal consequences.

OCCURRENCE

Ranking	Description
1	Virtually impossible: Failure has never occurred and is theoretically improbable.
2	Remote: Extremely rare, with no recorded instances in similar systems.
3	Very unlikely: Rare occurrence, possible only under extreme/unusual conditions.
4	Unlikely: Occurs infrequently, but documented in isolated cases.
5	Occasional: Happens sporadically in similar systems (~1% of instances).
6	Possible: Occurs occasionally under normal use (~5% likelihood).
7	Frequent: Regular occurrence in a subset of units (~10-20%).
8	Highly frequent: Common issue across many units (~30-50%).
9	Near-certain: Expected to occur in most units (~70-90%).
10	Inevitable: Guaranteed to happen in all units over time.

DETECTION

Ranking	Description
1	Design/process controls reliably detect failure: Automated systems (e.g., sensors, alarms) or rigorous testing ensure >95% detection.
2	Very high detection likelihood: Automated monitoring or strict process checks catch failures 90-95% of the time.
3	High detection with minor gaps: Manual inspections or semi-automated tools detect most failures (~80-90%), but minor oversights occur.
4	Moderate detection: Routine checks or basic diagnostics identify failures ~70-80% of the time.
5	Partial detection: Periodic inspections or user feedback catch failures ~50-70% of the time.
6	Low detection: Relies on inconsistent user reports or reactive troubleshooting (~30-50% success).
7	Minimal detection: No automated tools; failures often go unnoticed until harm occurs (~10-30% detection).
8	Poor detection: Controls are poorly designed or rarely used; failures frequently escape notice.
9	Near-undetectable: No proactive measures; failures are only found after severe consequences.
10	Undetectable: No controls exist; failure is impossible to identify until catastrophic outcomes occur.

K. BOM & Source Plan

The most significant cost drivers in the BOM are the structural components, particularly the aluminum sheet metal which accounts for approximately $480 from Online Metal Supply, requiring CO2 laser processing. Other critical components include two UV-C lights from COOSPIDER ($41.98) for bacterial disinfection, two fans from McMaster Carr ($76.92) for air circulation, control electronics and an Arduino microcontroller for $66.99 to manage system operations.

The sourcing strategy employs a mix of purchased and manufactured parts. While most electronic and hardware components are sourced from vendors like Amazon and McMaster Carr, several custom components are designated for in-house production via 3D printing. These include functional elements such as the air flow duct elbow, filter tray system, door components, and hanging supports. The total estimated cost for this project is $722.08, which remains well under the designated and assigned budget of $1,000, providing a comfortable buffer for any unforeseen expenses or potential design modifications during development.

Part	Purpose	Make / Buy / Provided	Vendor	Link	Qt.	Unit Price	Est. Price	Tooling
UV-C Light	Disinfect / Elimate Bacteria	Buy	COOSPIDER UV (Amazon)	------	2	$ 20.99	$ 41.98	
Mechanical Relay	Regulate Voltage	Buy	MZBYDLM (Amazon)	------	1	$ 22.00	$ 22.00	
Fan	Air circulation through system	Buy	McMaster Carr	------	2	$ 38.46	$ 76.92	
Deodorizer Filter	Trap / Remove odor in system	Buy	ShuRex (Amazon)	------	1	$ 21.99	$ 21.99	
Contol Electronics	User interface	Buy	Amazon	------	1	$ 44.99	$ 44.99	
12mm Momentary Push Button	User interface	Buy	Amazon	------	1	$ 7.99	$ 7.99	
#8/32 0.375" Screw	Structural integrity	Buy	Robosource	------	1	$ 4.99	$ 4.99	
#8/32 0.500" Screw	Structural integrity	Buy	Robosource	------	1	$ 5.49	$ 5.49	
#8-32 Threaded Inserts	Structural integrity	Buy	Amazon	------	1	$ 10.99	$ 10.99	
#8/32 Thin Nylock Nuts	Structural integrity	Buy	Robosource	------	2	$ 4.99	$ 9.98	
#8/32 Rubber Washers (50 pack)	Air sealing	Buy	McMaster Carr	------	2	$ 10.10	$ 20.20	
1/8"x24"x18" Aluminum Sheet Metal	Key Structual Component	Buy	Online Metal Supply (Amazon)	------	6	$ 48.23	$ 289.38	CO2 Laser
1/8"x24"x24" Aluminum Sheet Metal	Key Structual Component	Buy	Online Metal Supply (Amazon)	------	1	$ 58.11	$ 58.11	CO2 Laser
1/4" Acrylic Sheet (24" x 24") Smoke	Key Structual Component	Buy	SIBE-R (Amazon)	------	1	$ 51.34	$ 51.34	
1/4" x 12" Metal Rod (1 foot)	Hanging system	Buy	McMaster Carr	------	1	$ 1.45	$ 1.45	
1/16" Aluminum L-Channel (4ft)	Structural integrity	Buy	McMaster Carr	------	1	$ 6.18	$ 6.18	Band Saw/Drill
Cabinet Hinges	Door open/close	Buy	McMaster Carr	------	2	$ 5.27	$ 10.54	
Grab Latch	Closes door	Buy	McMaster Carr	------	1	$ 1.42	$ 1.42	
#8-32 Rubber Feet (10 pack)	Feet for device	Buy	McMaster Carr	------	1	$ 16.20	$ 16.20	
20 ft Seal	Seal door	Buy	Kingdder (Amazon)	------	1	$ 11.99	$ 11.99	Cut down
Robosource Shipping	Shipping	Buy	Robosource	------	1	$ 7.95	$ 7.95	
Box Hinge Spacer	Hinge spacer adapter	Make						3D Printer
Door Hinge Spacer	Hinge spacer adapter	Make						3D Printer
Handle	Door Handle	Make						3D Printer
Bracket Latch Mount	Door latch bracket	Make						3D Printer
Top Bracket	Hanger support bracket	Make						3D Printer
Hangar	Hanger	Make						3D Printer
UI	Main UI Box	Make						3D Printer
UI Case Top	Top of UI box	Make						3D Printer
Uno Case Base	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Top	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Button	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Cap I	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Cap II	Ardiuno Uno Protective Case	Make						3D Printer
Uno Case Cap III	Ardiuno Uno Protective Case	Make						3D Printer
Duct Corner	Curved Duct Corner	Make						3D Printer
Heatset Bracket	Bracket with heatsets for duct	Make						3D Printer
Bracket Duct	Standard curved duct bracket	Make						3D Printer
Bracket Duct Fan Bottom	Special curved duct bracket	Make						3D Printer
Bracket Duct Fan Top	Special curved duct bracket	Make						3D Printer
Airduct Filter Drawer Holder	Holds the air filter in duct	Make						3D Printer
Filter Drawer	Drawer to remove/place filter	Make						3D Printer
						Total Est. Price	$ 722.08	

L. Validation Plan

The validation of the system will focus on verifying the functionality of its major components: electronics, UV lights, air circulation, and odor removal. Each subsystem will be tested to ensure it meets performance requirements under conditions that simulate the space environment as closely as possible.

The **electronics** subsystem, including the Arduino-based control system and relays, will be tested for functionality, reliability, and response to user inputs. The validation will involve powering the system through a standard 120V AC source, activating the relays, and verifying that the UV lights and fans operate as expected. Voltage and current measurements will be taken to confirm that all components receive the required power. System endurance testing will be performed to ensure long-term reliability.

The **UV lights** will be evaluated for their ability to deliver effective germicidal irradiation. The primary validation will include observing the intensity and wavelength of the emitted UV-C light. Additional biological testing may involve exposing fabric samples contaminated with bacteria or fungi to the UV light and measuring microbial reduction through petri dishes. These tests will determine the system's effectiveness in disinfecting clothing.

The **air circulation** system, which consists of fans designed to distribute air evenly within the cleaning chamber, will be tested for airflow consistency and distribution. The validation process assesses whether the fans maintain adequate circulation without causing excessive turbulence or noise. Testing under different power levels and operational durations will help optimize energy consumption and efficiency.

The **odor removal** function, enabled by deodorizing filters, will be validated by subjective odor tests, conducted with a panel of evaluators, may complement these measurements to assess the effectiveness of odor reduction in a real-world context. Long-term filter performance testing will also be conducted to determine the durability and efficiency of the filtration system over multiple cleaning cycles.

Each test will be conducted in a controlled environment. Data and opinions from these tests will be analyzed to assess system performance, identify potential failure points, and refine the design. The results will provide critical insights to ensure the system is both effective and suitable for space missions, where reliability and efficiency are important.

Validation Targets vs Actual Performance Metrics

Metric	Target	Actual
Sterilization efficacy	95%	99 %
UV-C bacteria kill time	$\leq$ 10 *min*	5 min
Deodorizing Cycle Time	$\leq$ 60 *min*	20 min
Airflow output	$\geq 0.1\ m/s$	0.3 m/s
Footprint	24" x 24" x 24"	20.88" x 12" x 22.44"
Weight	$\leq$ 50 *lbs*	25 lbs
Power consumption	$\leq$ 300 *W*	262.5 W
UI Success rate	99%	100%

Validation Results

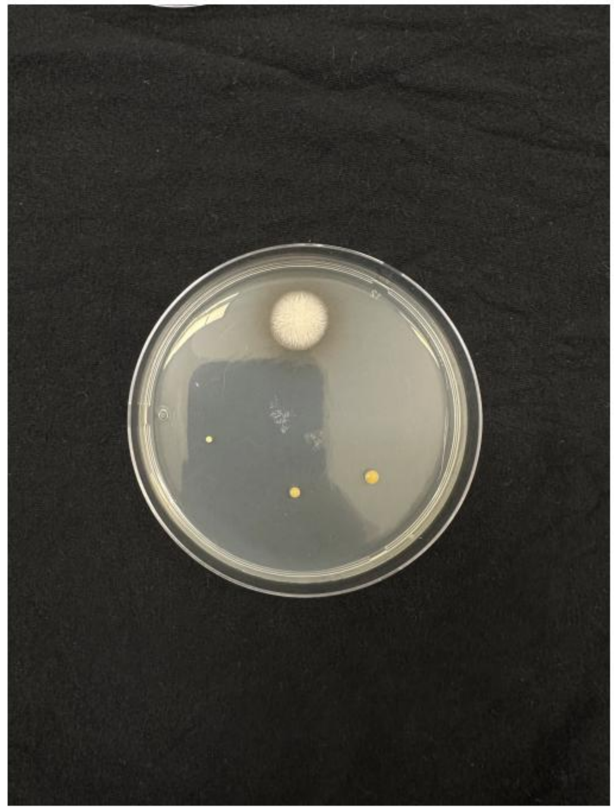
UV-C Microbial Samples:

Test procedure:

- Sample microbial content from the same spot on the shirt surface using Petri dishes:
    - Before sterilization
    - After 2.5 minutes, 5 minutes, 10 minutes, and 20 minutes of exposure inside the UV-C chamber
- The shirt was worn under physical activity conditions to simulate real-world contamination with sweat and general unpleasant odors
- Incubate and analyze colony growth to assess microbial load at each time point

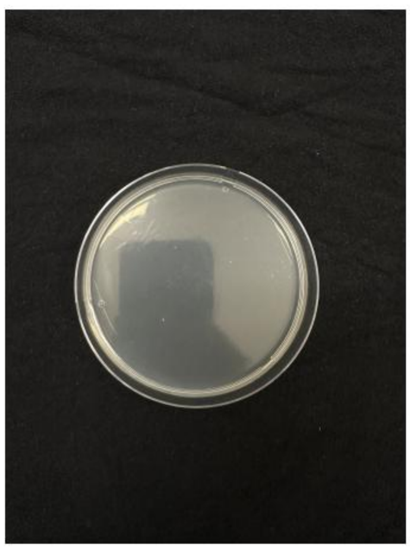
Results:

Control - 0 min

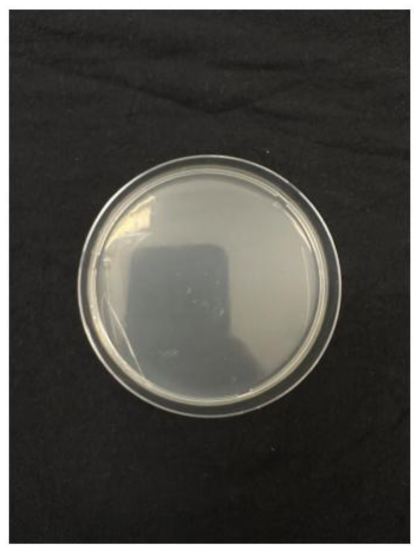


2.5 min

5 min



10 min



20 min

Anemometer Readings for Airflow:

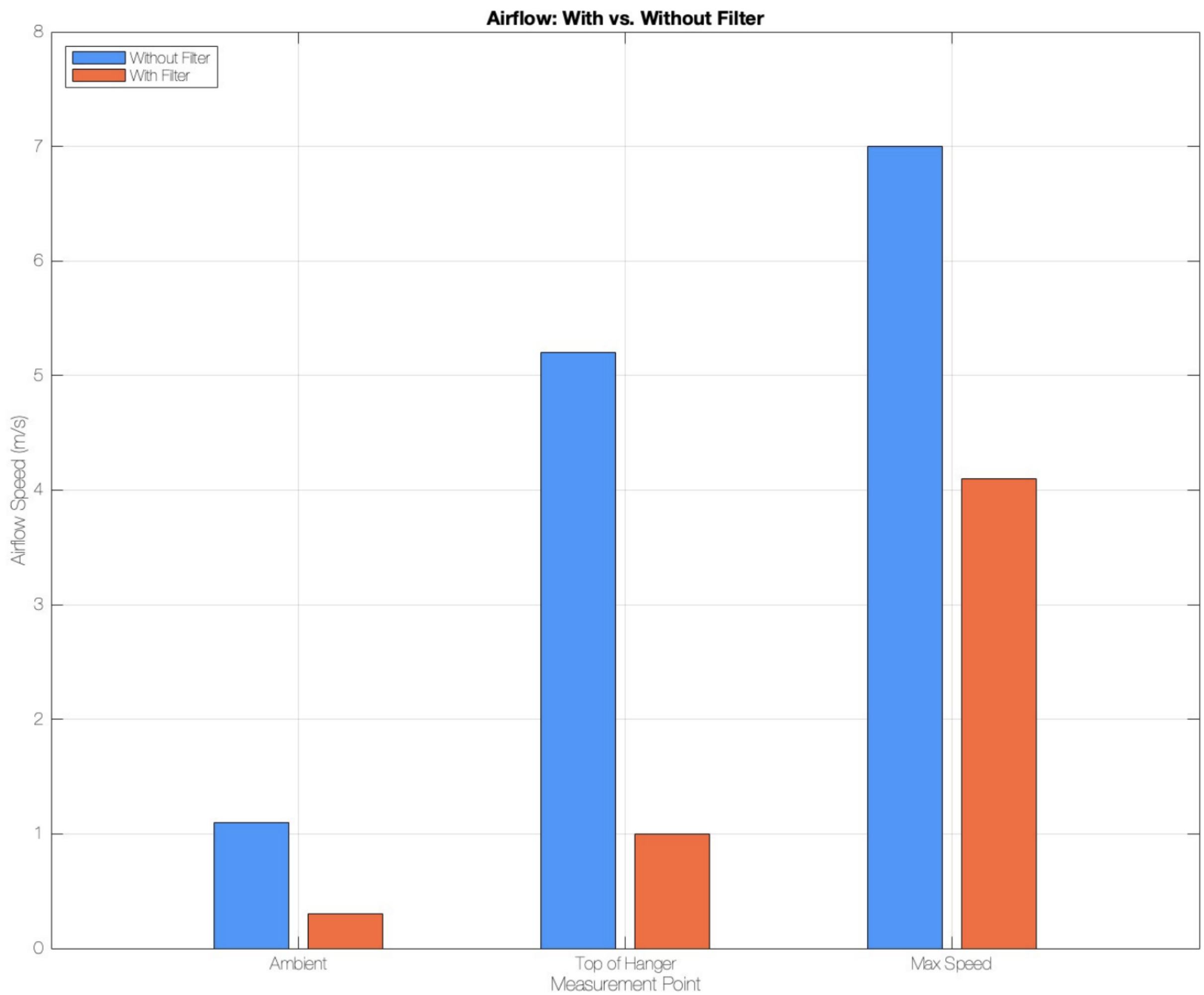
Key Findings:

- Filter reduced ambient wind speed by 73%
- Filter reduced wind speed at the top of the hanger by 81%
- Filter reduced maximum wind speed by 41%
- Greatest reduction observed at the top of the hanger location

Implications:

- Filter technology demonstrates wind speed reduction across all measurement points
- Demonstrates filter efficacy in purifying airflow

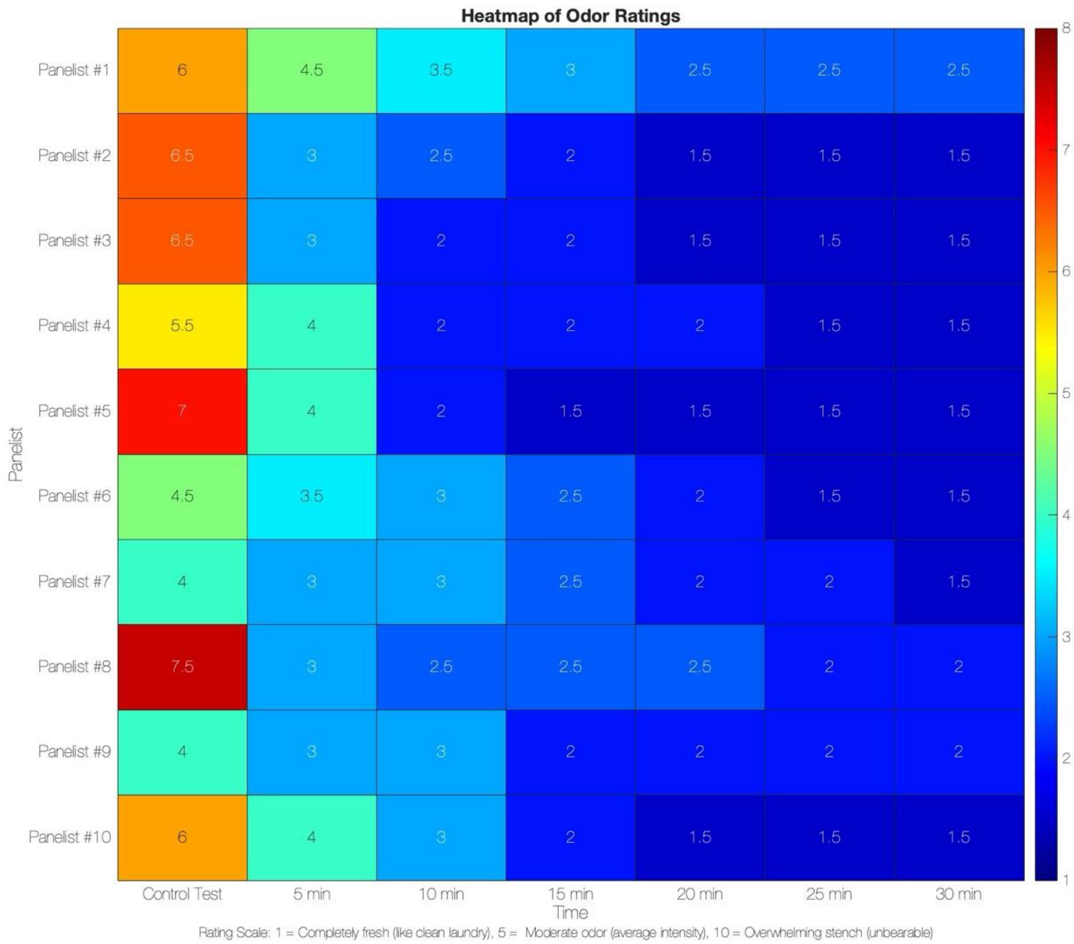
Results:



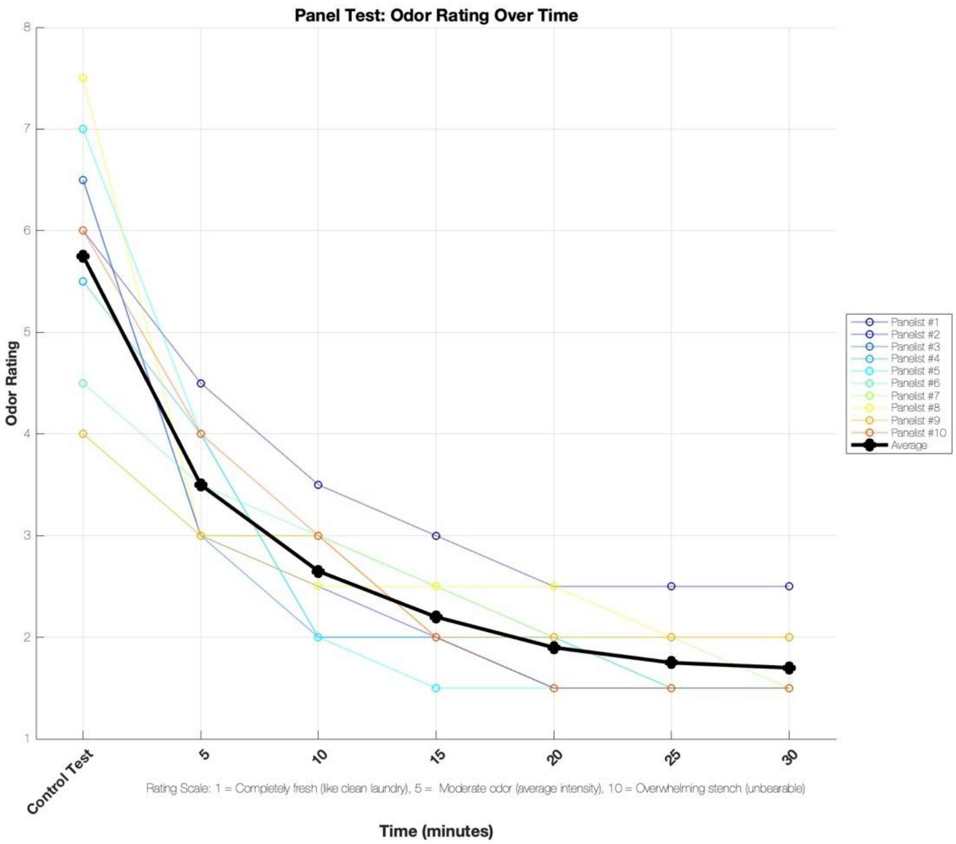
Controlled Panel Odor Testing:

Test Procedure:

- Shirt worn under normal conditions to simulate typical sweat and odor build up
- Sample odors at key intervals:
    - Before deodorization
    - After 5 minutes, 10 minutes, 15 minutes, 20 minutes, 25 minutes, and 30 minutes of exposure inside the system
- A panel of 10 participants rates odor intensity on a scale from 1 to 10 (1 = no odor, 10 = strong odor)
- Results are averaged across the panel to track perceived odor reduction



Heat Map of Panelist Rating throughout Duration of Deodorization Testing



Panelists Ratings over time for Deodorization Testing

M. Standards Applied

Throughout development the team treated the prototype as flight-inspired hardware and tied every drawing, material choice, and test plan to recognized engineering standards. All mechanical parts were modeled in inches and fully dimensioned in accordance with ASME Y14.5-2018, using true-position call-outs and bilateral tolerances to guarantee fit and functionality between printed and laser-cut components. Structural analyses referenced ANSI/AIAA S-120-2006 launch-vehicle factors of safety, while electrical schematics adopted IPC-2221B generic design rules to maintain adequate trace spacing, creepage, and clearance around the 120-volt UV-C drivers. The aluminum 5052 alloy and tinted acrylic door satisfy the outgassing limits of NASA-STD-6016 for non-metallic materials.

Because the prototype is intended for enclosed crewed environments, its wiring, fusing, and grounding layout followed NASA-STD-8739.4 workmanship guidelines.

Several mission-specific standards will be fully implemented in the next phase. These include thermal-vacuum acceptance testing per ECSS-Q-ST-20-07C, electromagnetic compatibility verification under MIL-STD-461G, and fault-tolerant controller firmware that meets NASA-STD-8719.13 software safety requirements. Likewise, the current ABS additively-manufactured ducts will be replaced with PEEK or PEKK parts qualified to ASTM F3574 flammability and smoke-toxicity limits. By front-loading mainstream ANSI, ASME, IPC, and NASA workmanship rules in the prototype, the project is already positioned for a streamlined compliance path once space-flight certification testing begins.

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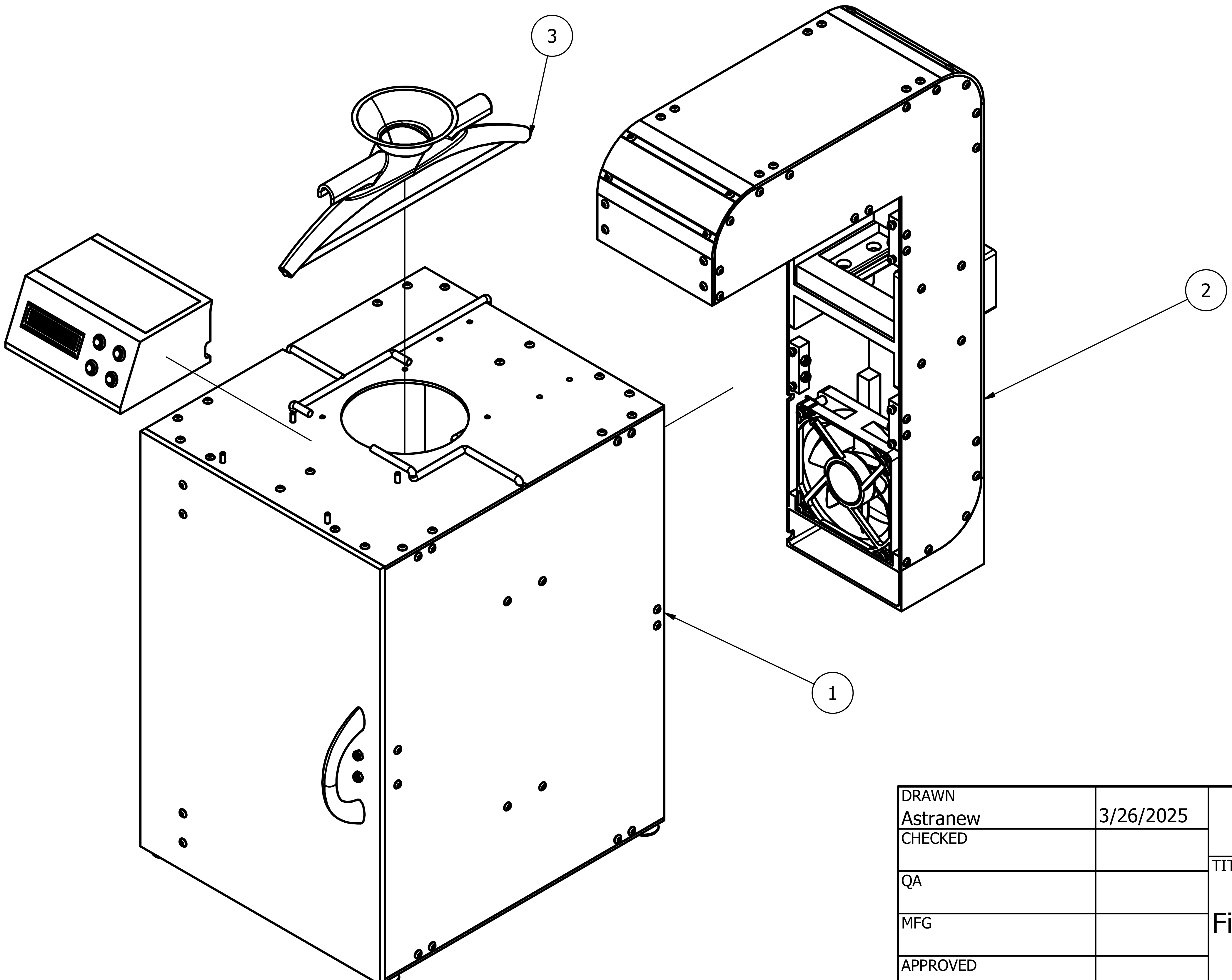
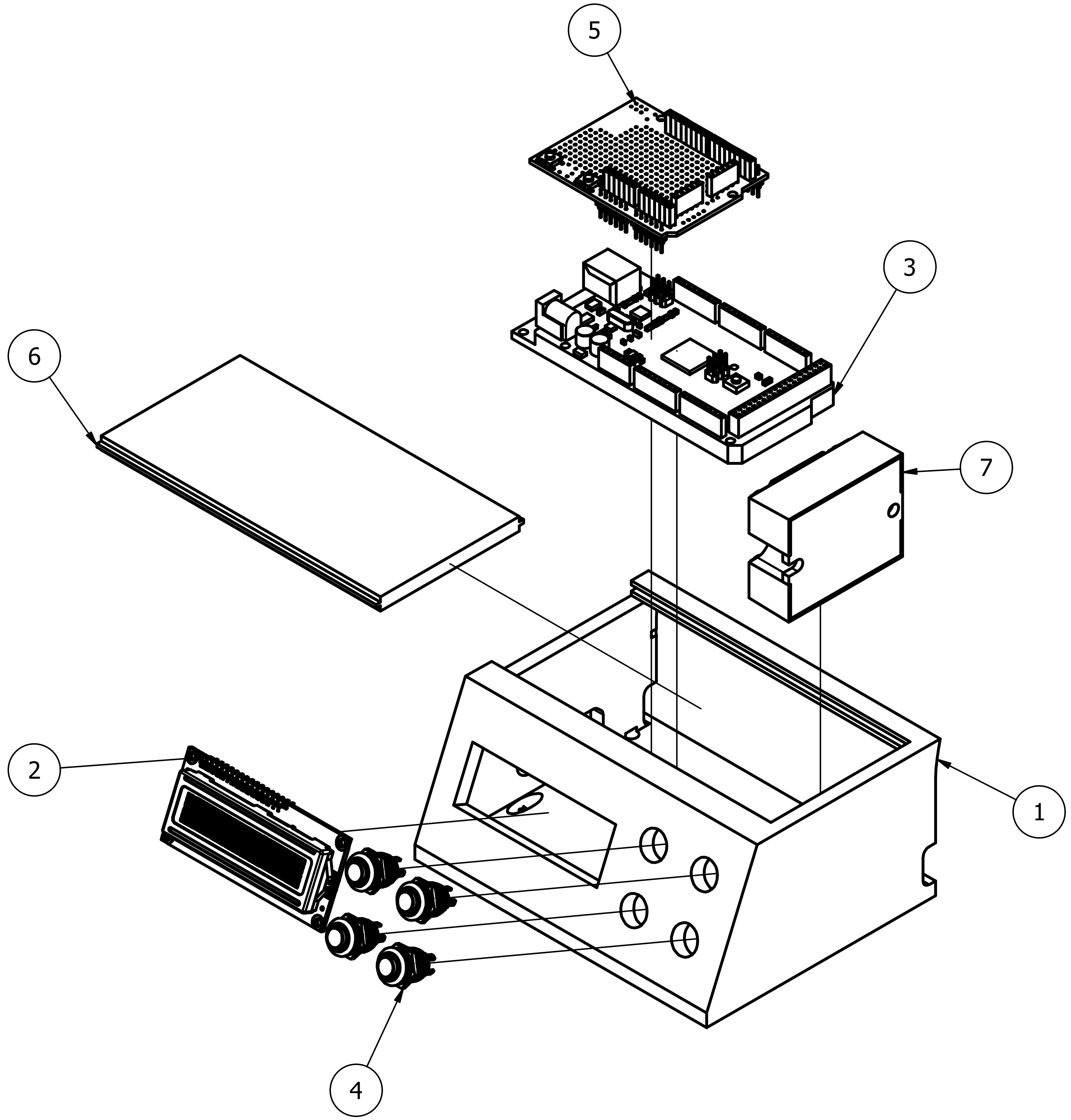


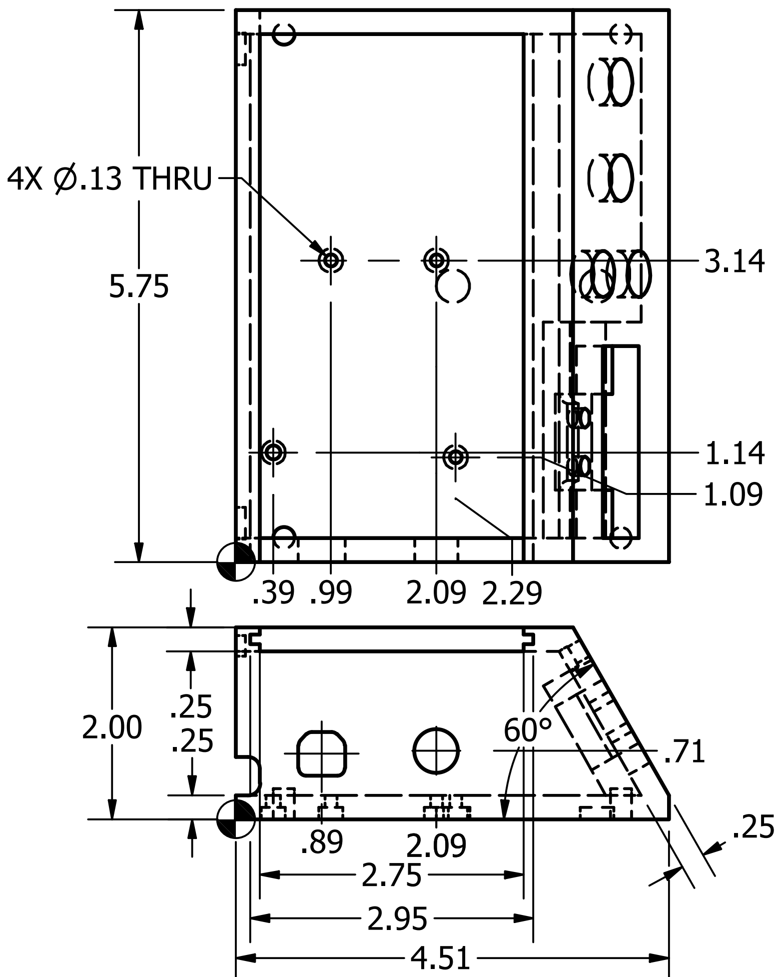
PARTS LIST		
ITEM	PART NUMBER	QTY
1	boxSubAssembly	1
2	ductSubAssembly	1
3	hangarSubAssembly	1
4	UIAssyV2	1

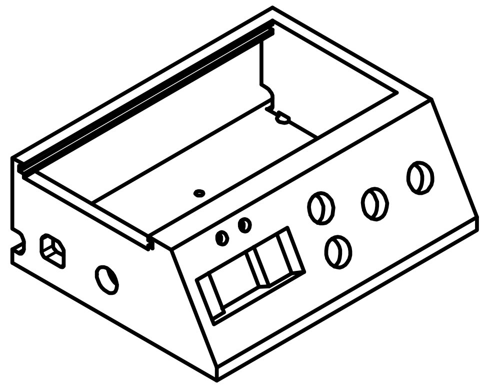
DRAWN Astranew	3/26/2025	
CHECKED		TITLE Final Assembly
QA		
MFG		
APPROVED		SIZE B / DWG NO mainWithSubAssembliesEXP / REV
		SCALE 1 / 4 / SHEET 1 OF 1



PARTS LIST		
ITEM	PART NUMBER	QTY
1	UIwithLCD	1
2	STEP 1602 Serial LCD Module	1
3	ArduinoMega	1
4	12mm Illuminated push button switch	4
5	Prototype_Shield_v5	1
6	UIcaseTop	1
7	CWD4890 - CRYDOM	1

DRAWN Astranew	4/18/2025	
CHECKED		TITLE UI Sub Assembly
QA		
MFG		
APPROVED		
		SIZE B — DWG NO UIAssyV2EXP — REV
		SCALE 1 / 2 — SHEET 1 OF 1





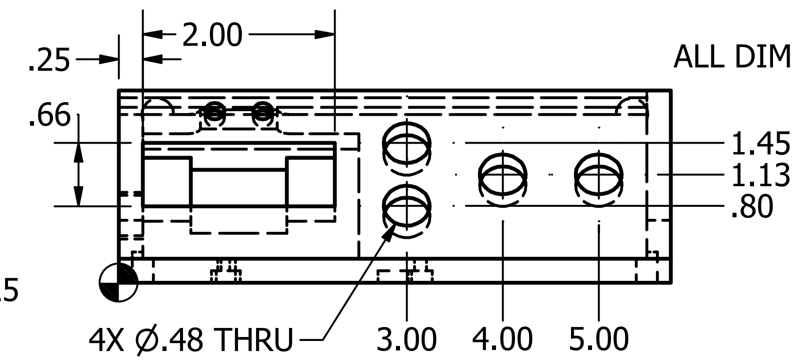
NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES



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APPROVED TT	03/26/2025	UI
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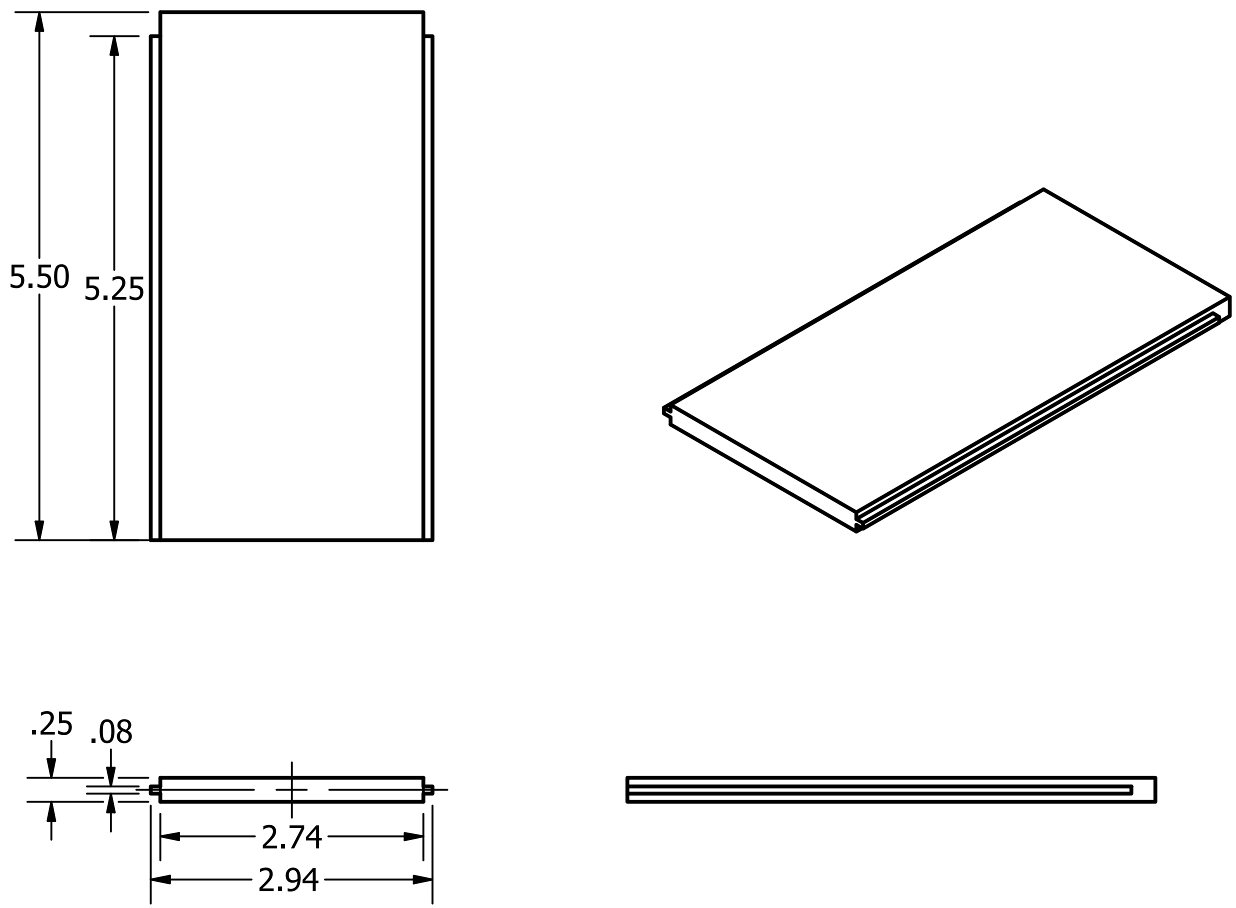
		DWG NO UI
		REV A
		SCALE 1 : 2
		SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

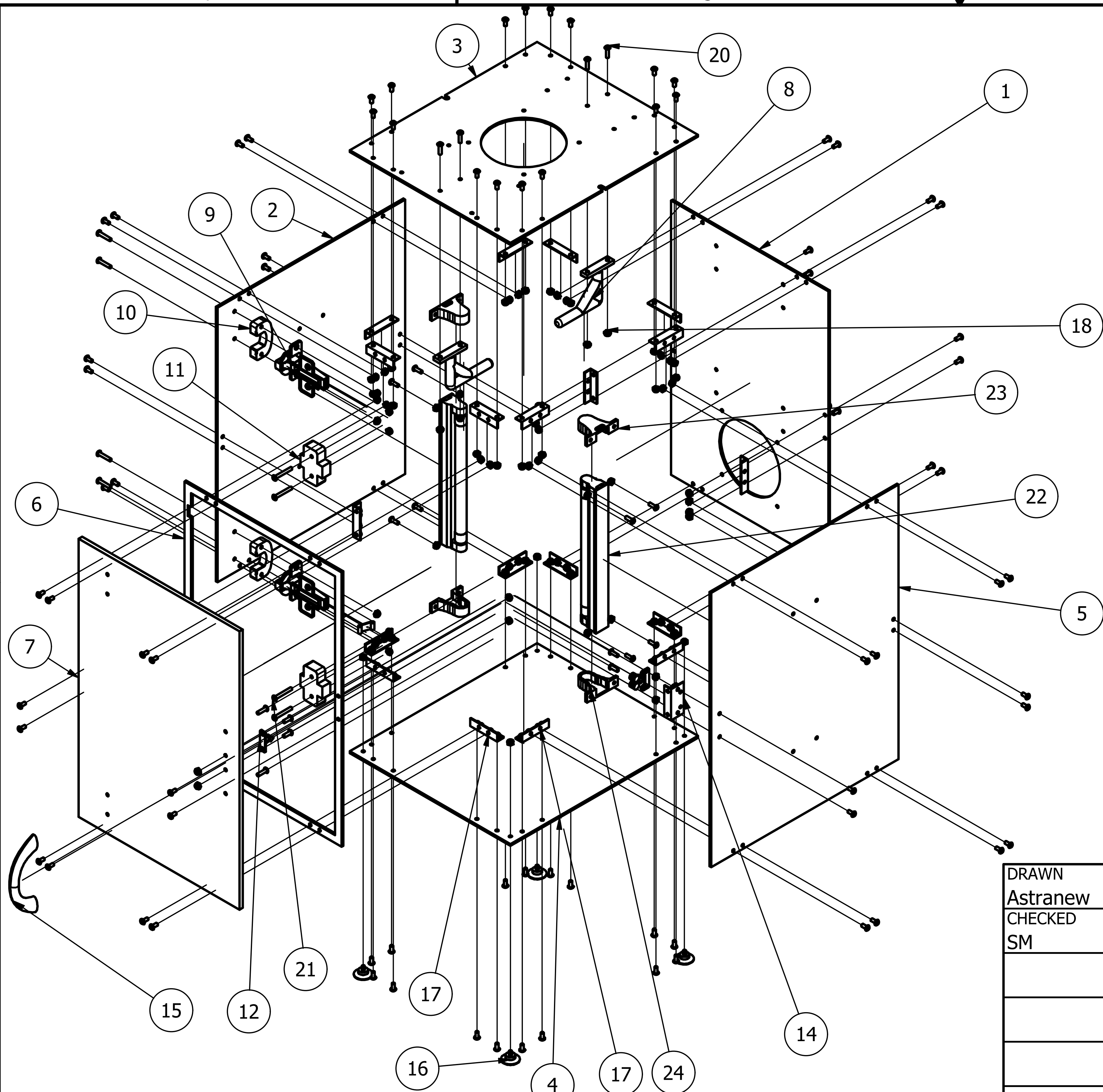
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	UI CASE TOP
		SIZE A — DWG NO UIcaseTop — REV A
		SCALE 1 : 2 — SHEET 1 OF 1



PARTS LIST		
ITEM	PART NUMBER	QTY
1	backWall	1
2	sideWalls	1
3	topWall	1
4	bottomWall	1
5	sideWallsRight	1
6	doorFrame	1
7	door	1
8	TopBracket	2
9	Half-Mortise Concealed Cabinet Hinge	2
10	boxHingeSpacer	2
11	doorHingeSpacer	2
12	Grab Latch Male	1
13	Grab Latch Female	1
14	bracketLatchMount	1
15	handle	1
16	Rubber Foot	4
17	Bracket	19
18	Nut Thin Nylock	102
19	Screw 8-32 Steel 0.500	80
20	Screw 8-32 Steel 0.675	6
21	Screw 8-32 Steel 1.250	4
22	uvcLight	2
23	uvcLightHolderTop	2
24	uvcLightHolderBottom	2

DRAWN Astranew	3/25/2025	ASTRANEW
CHECKED SM	3/28/2025	TITLE BOX SUB ASSEMBLY
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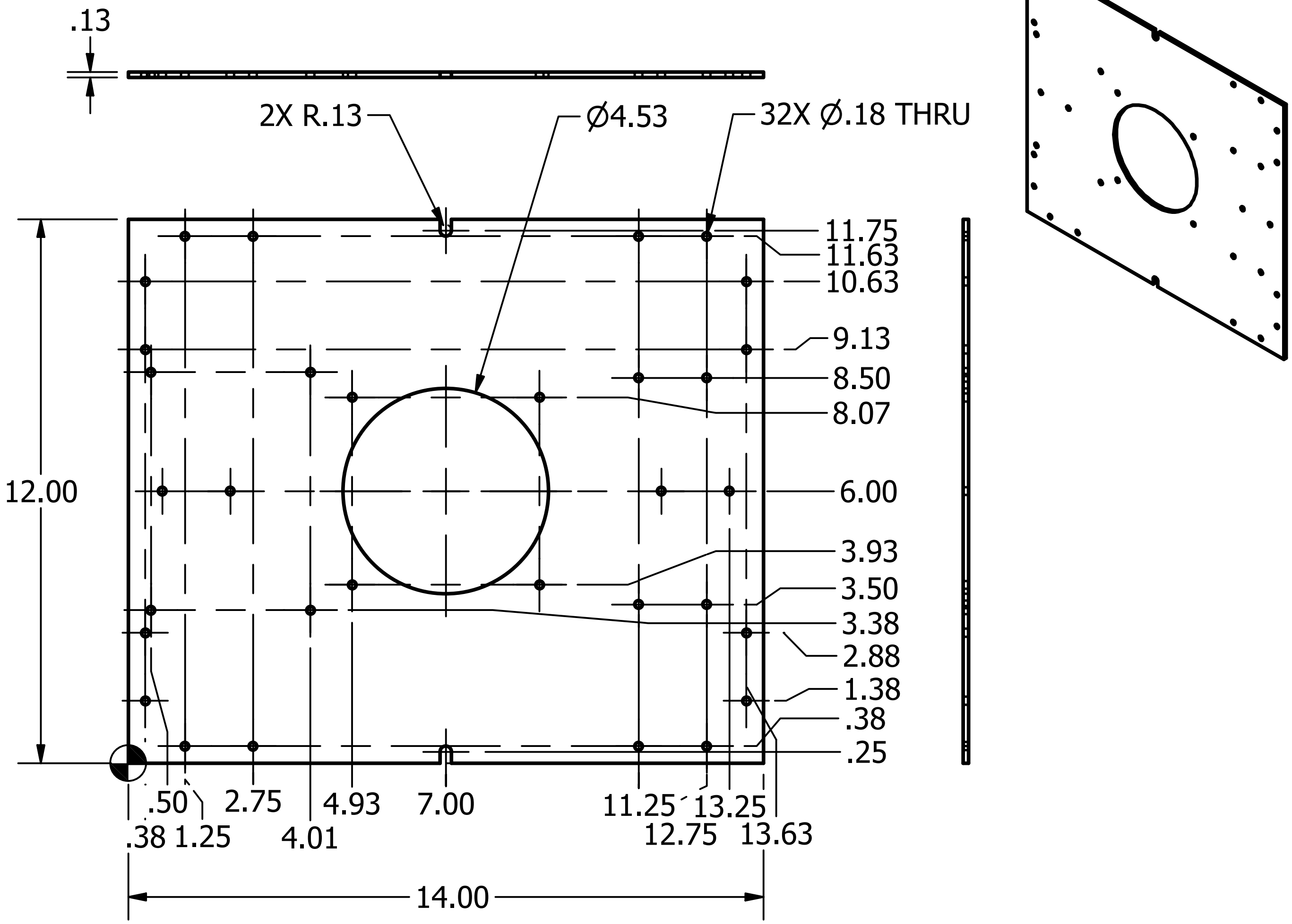
SCALE 1 / 6.25		SHEET 1 OF 1

4 3 2 1
B A



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

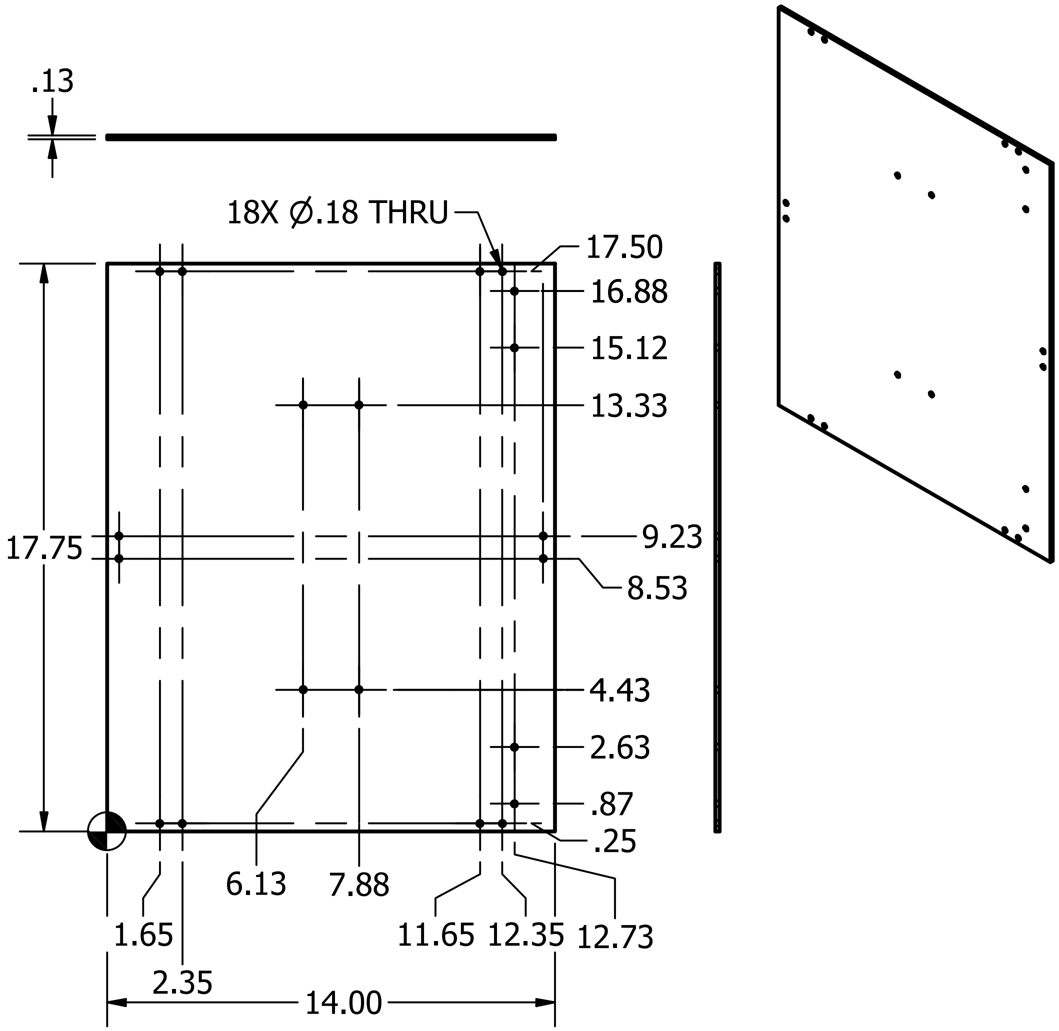
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	TOP WALL
		SIZE A · DWG NO topWall · REV A
		SCALE 1 / 4 · SHEET 1 OF 1



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

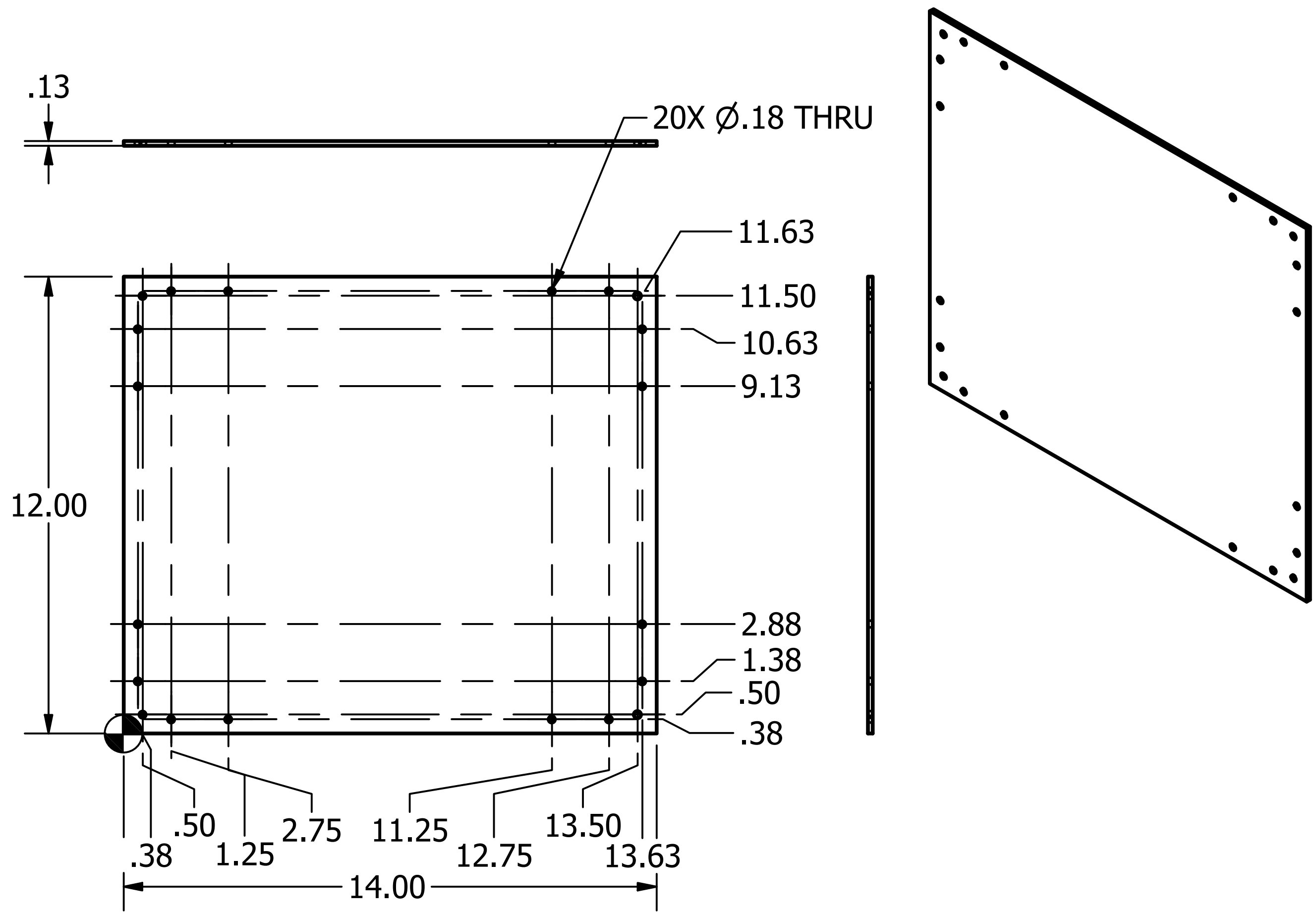
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW			
CHECKED JC	03/26/2025	TITLE			
APPROVED TT	03/26/2025	SIDE WALL			
		SIZE A		DWG NO sideWalls	REV A
		SCALE 1 / 6		SHEET 1 OF 1	



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

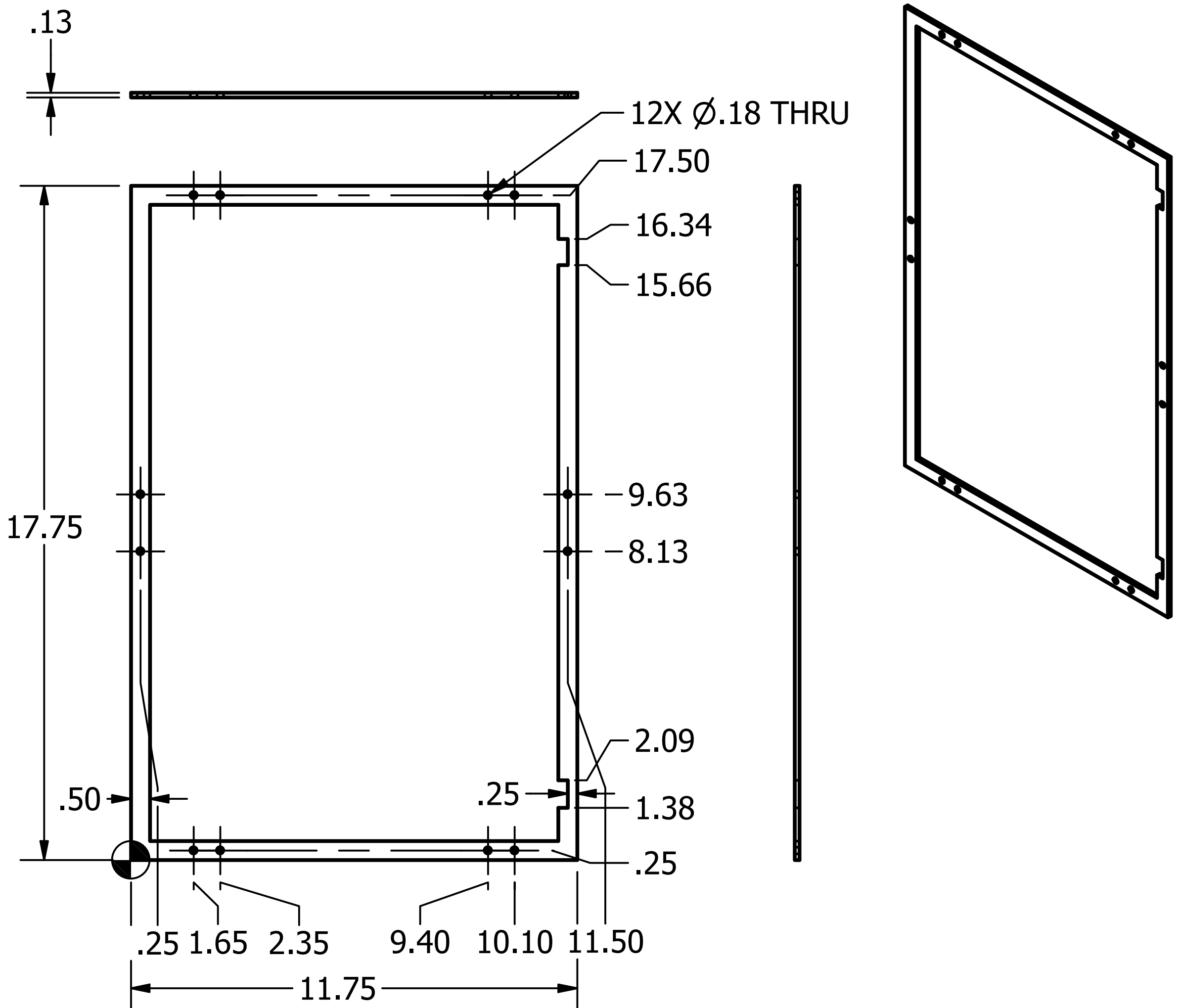
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW			
CHECKED JC	03/26/2025	TITLE			
APPROVED TT	03/26/2025	BOTTOM WALL			
		SIZE A		DWG NO bottomWall	REV A
		SCALE 1 / 5		SHEET 1 OF 1	



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 μIN
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025
CHECKED JC	03/26/2025
APPROVED TT	03/26/2025

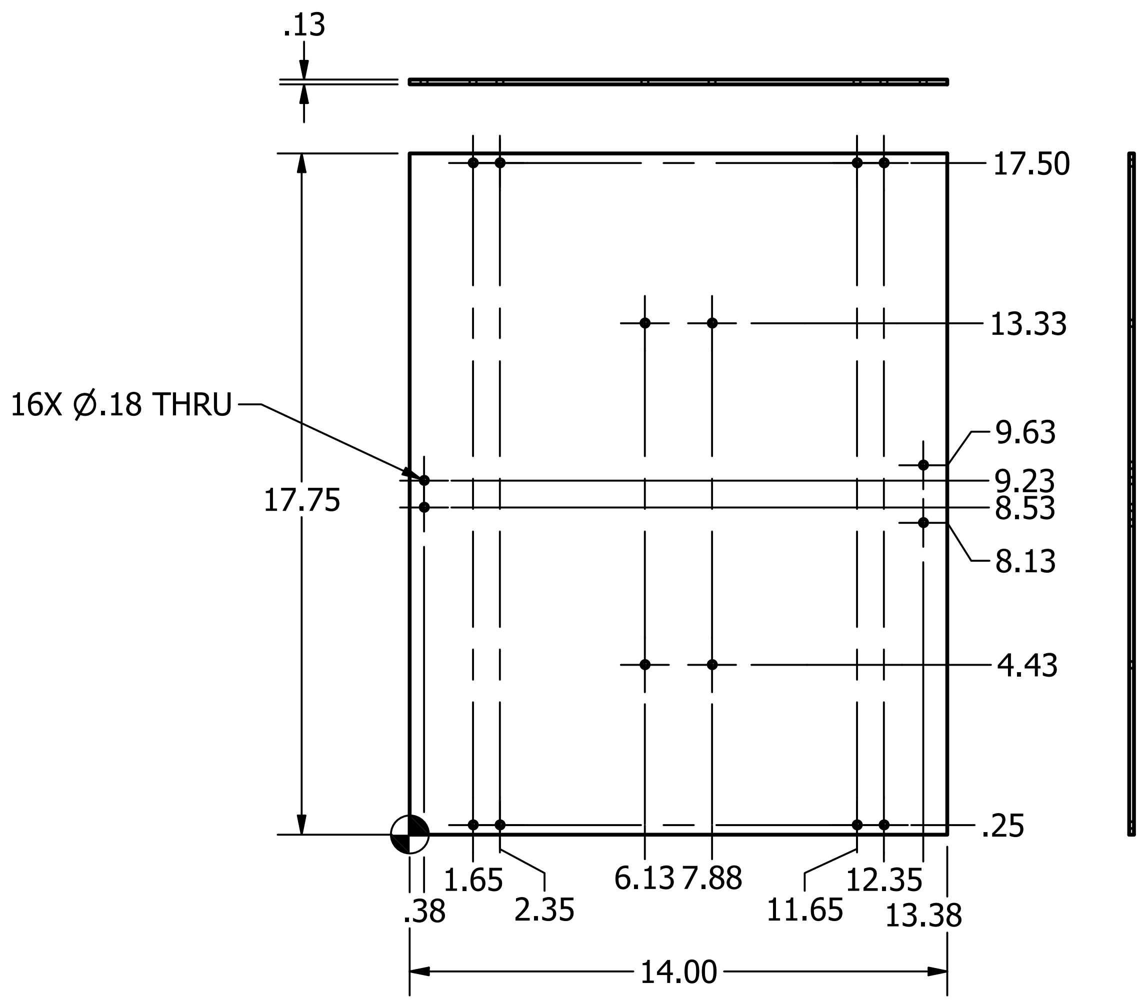
ASTRANEW

TITLE

DOOR FRAME

SIZE	DWG NO	REV
A	doorFrame	A

SCALE 1 / 5 SHEET 1 OF 1



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

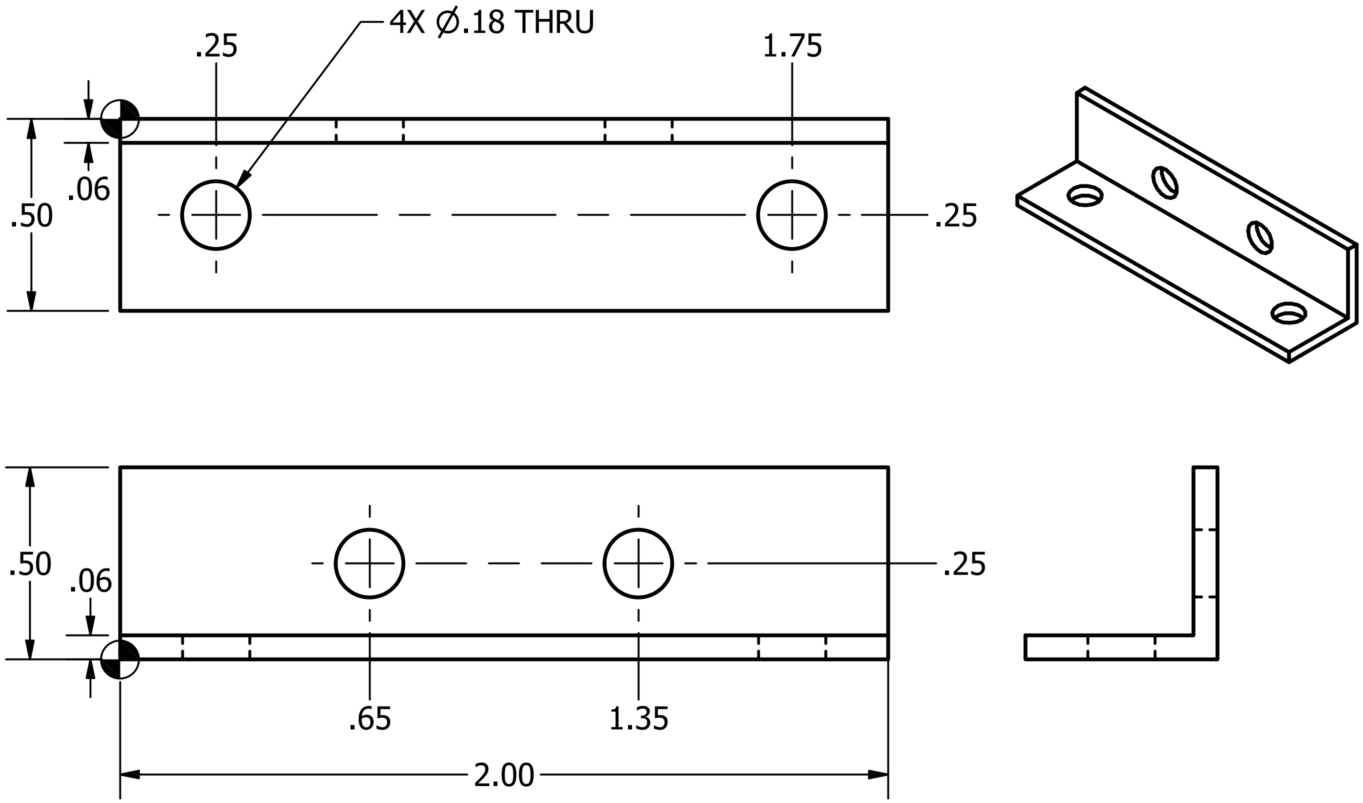
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW			
CHECKED JC	03/26/2025	TITLE			
APPROVED TT	03/26/2025	SIDE WALLS RIGHT			
		SIZE A		DWG NO sideWallsRight	REV A
		SCALE 1/5		SHEET 1 OF 1	



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

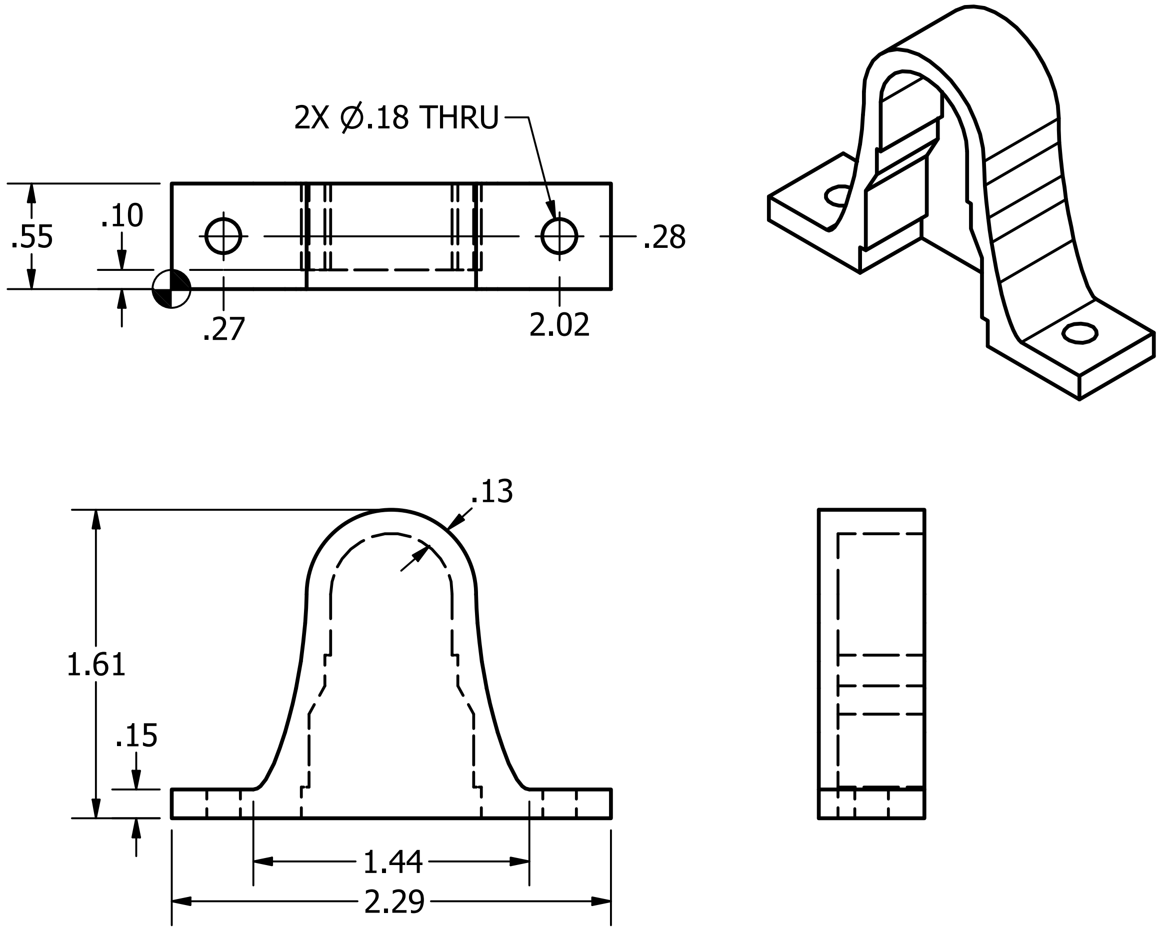
TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE BRACKET
APPROVED TT	03/26/2025	

SIZE	DWG NO	REV
A	bracket	A

SCALE 2 : 1 SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

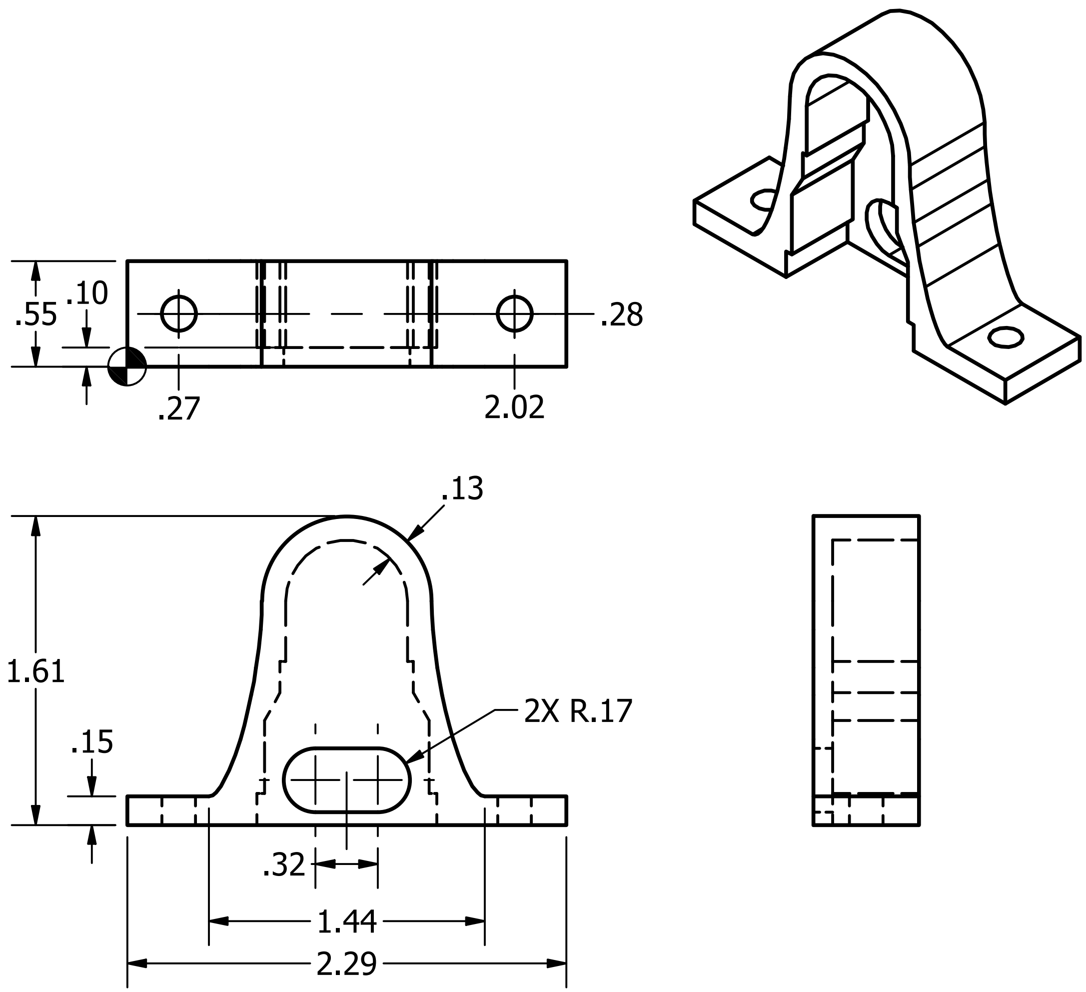
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	UVC LIGHT HOLDER BOTTOM
		SIZE A
		DWG NO uvcLightHolderBottom
		REV A
		SCALE 1 : 1
		SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

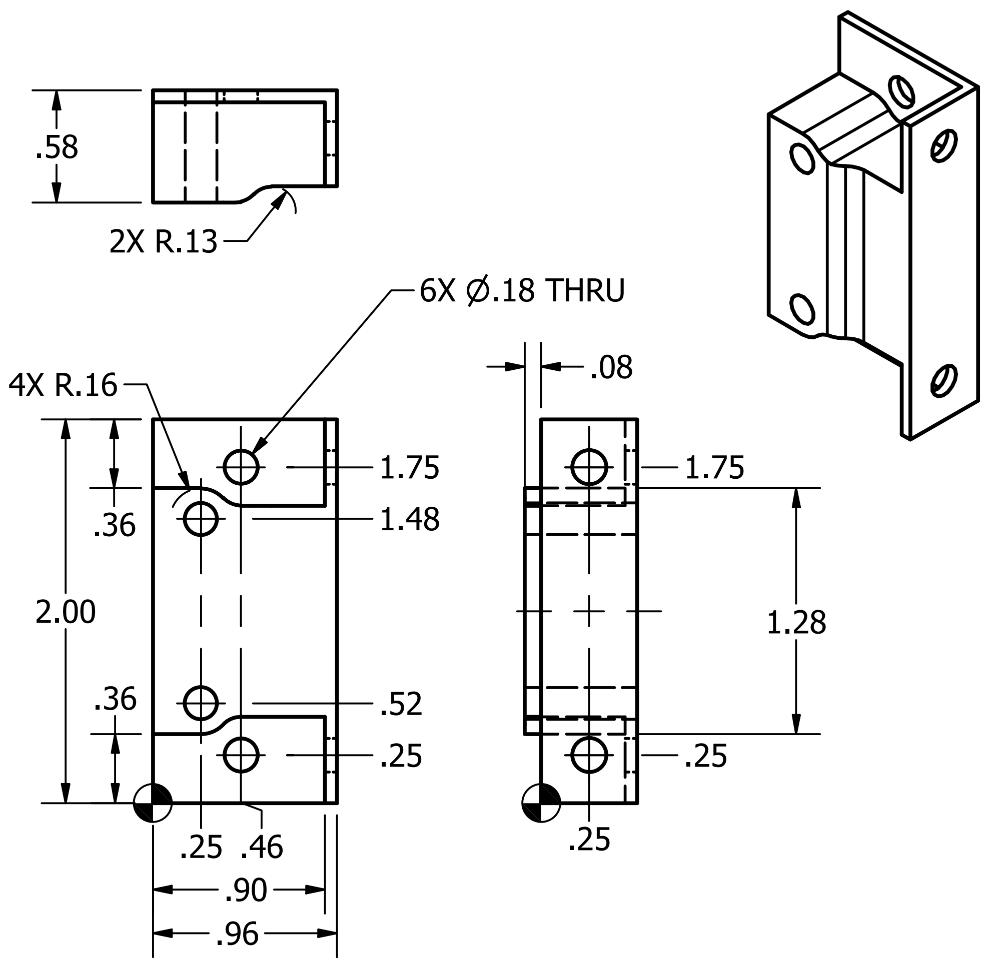
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE UNC LIGHT HOLDER TOP
APPROVED TT	03/26/2025	
		SIZE A · DWG NO uvcLightHolderTop · REV A
		SCALE 1 : 1 · SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

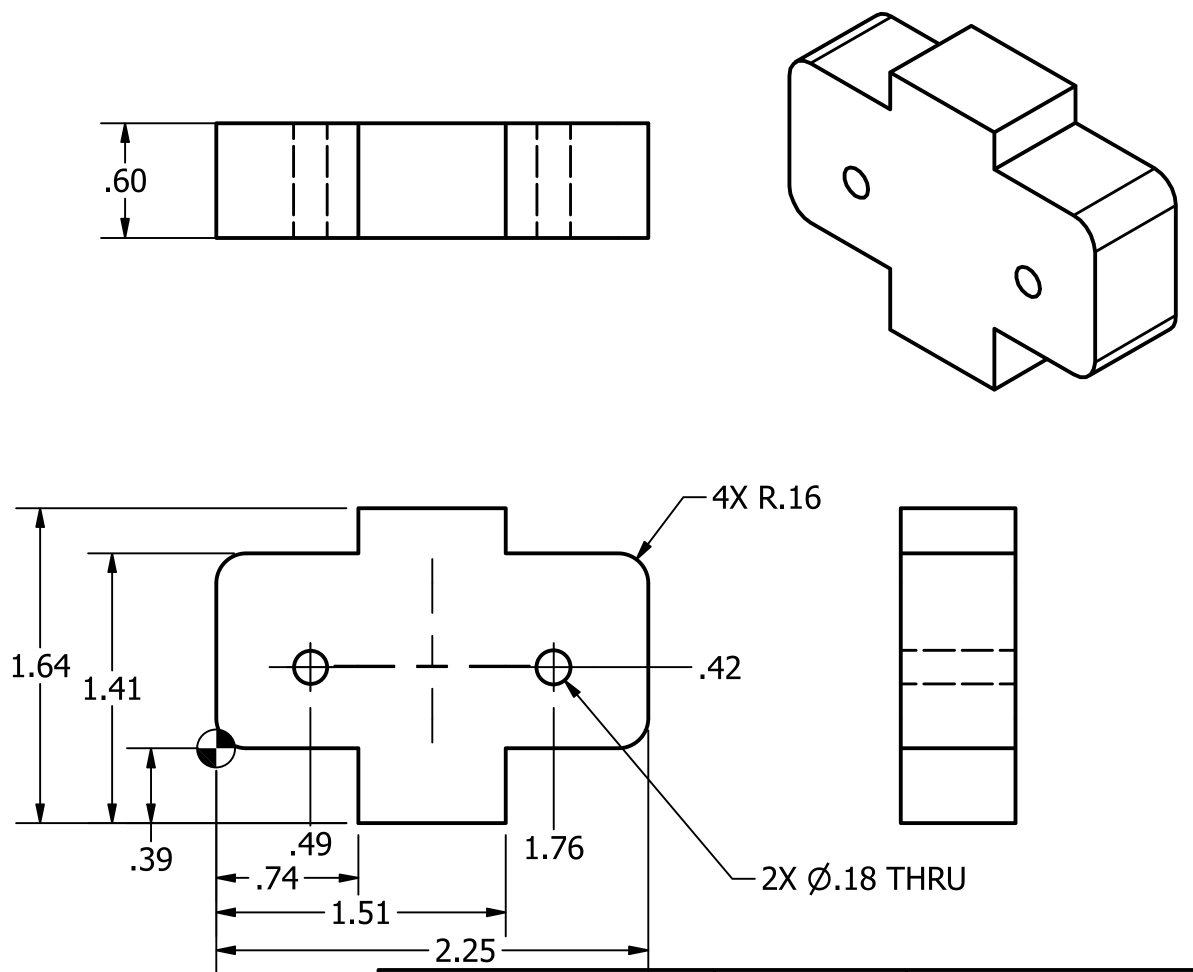
TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	BRACKET LATCH MOUNT

SIZE	DWG NO	REV
A	bracketLatchMount	A

SCALE 1 : 1 SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

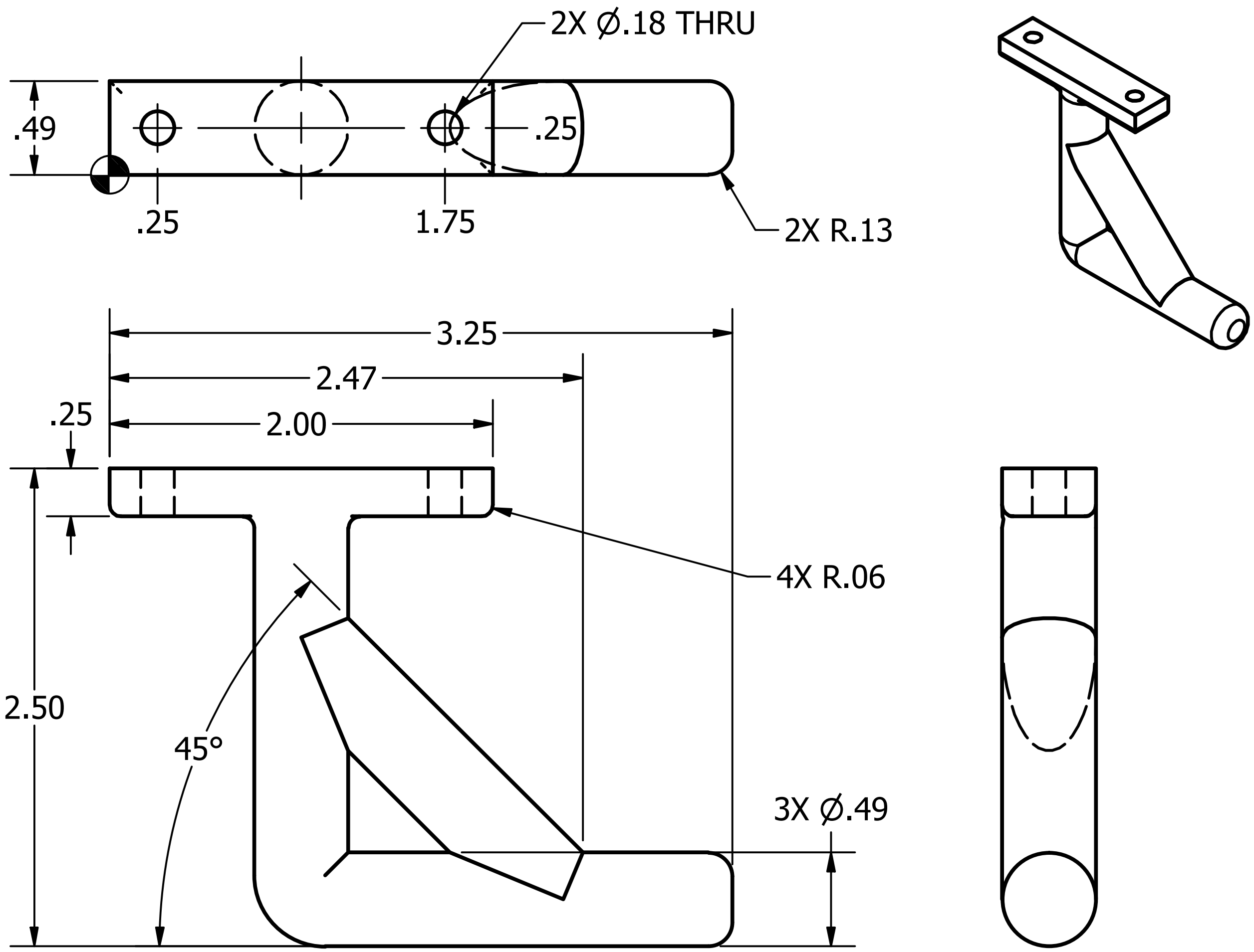
X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE DOOR HINGE SPACER
APPROVED TT	03/26/2025	

SIZE		DWG NO	REV
A		doorHingeSpacer	A
SCALE 1 : 1		SHEET 1 OF 1	



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

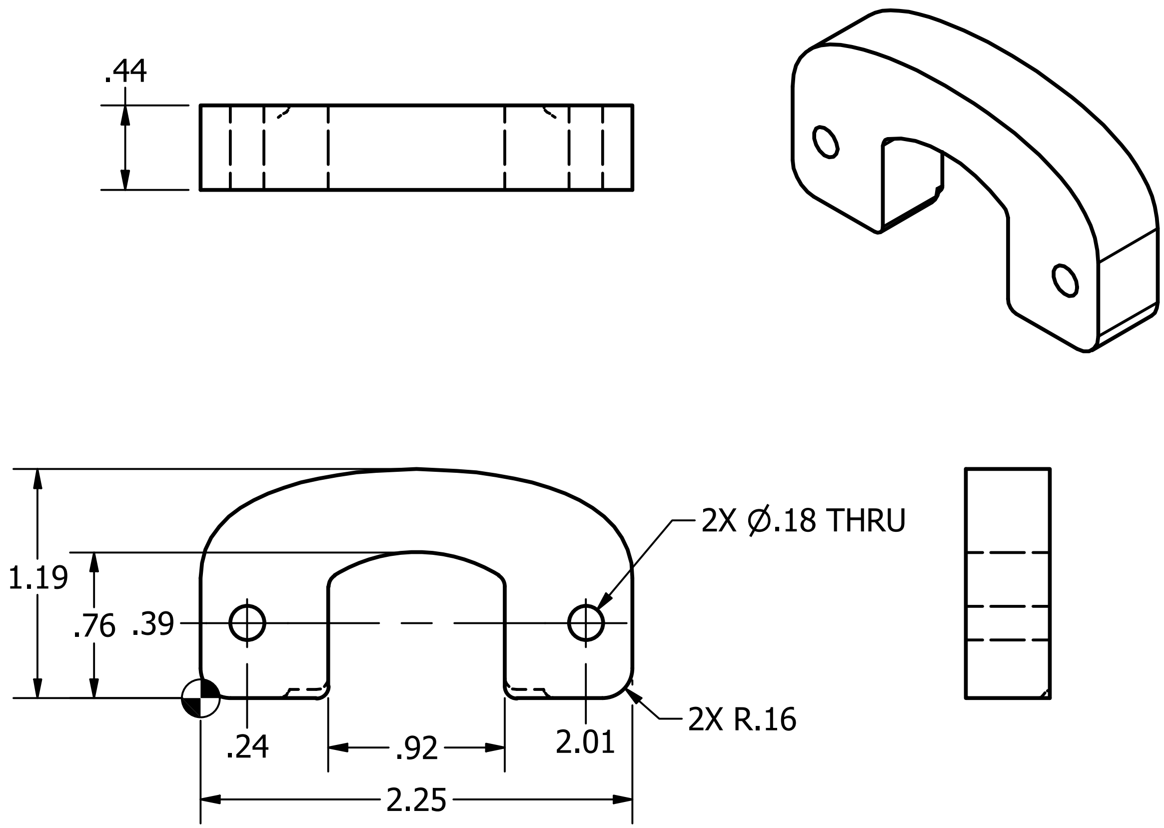
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	TOP BRACKET
SIZE A	DWG NO topBracket	REV A
SCALE 1 : 1		SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025
CHECKED JC	03/26/2025
APPROVED TT	03/26/2025

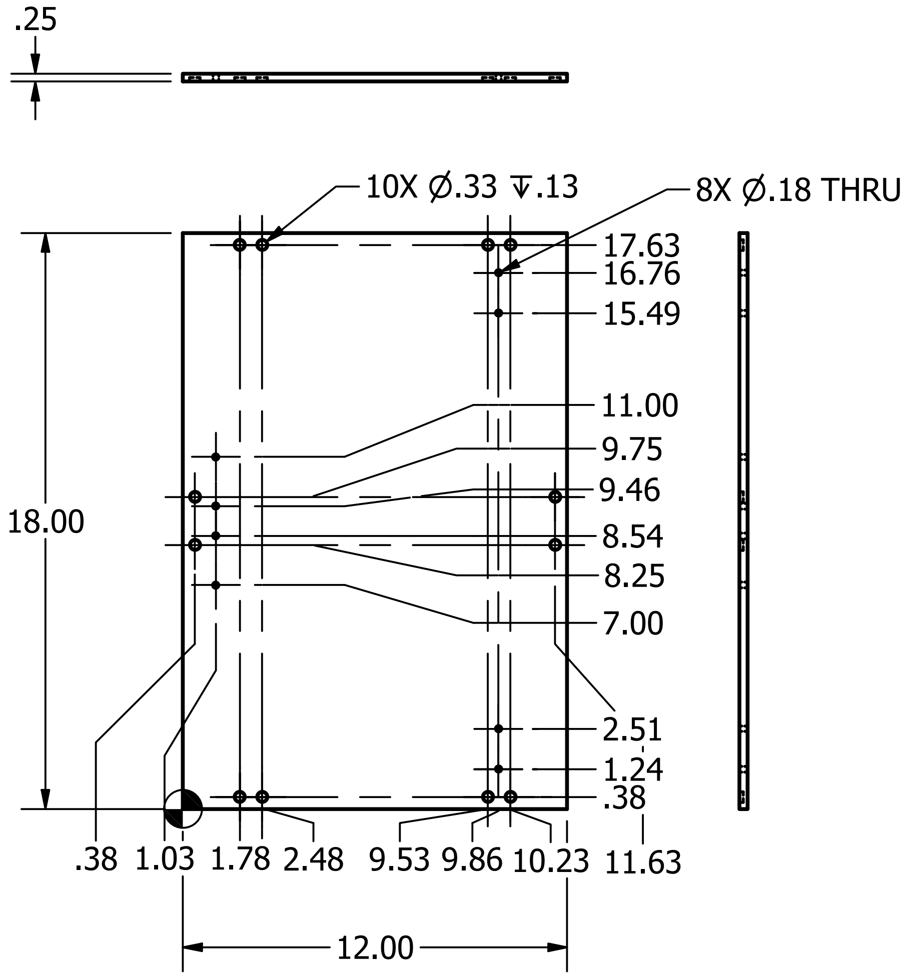
ASTRANEW

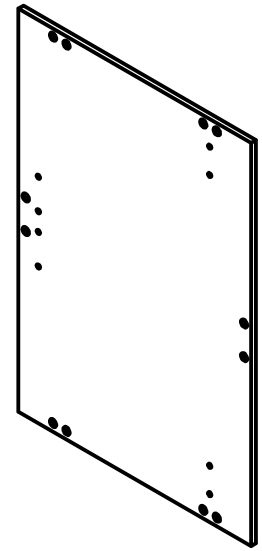
TITLE

BOX HINGE SPACER

SIZE	DWG NO	REV
A	boxHingeSpacer	A

SCALE 1 : 1 SHEET 1 OF 1





NOTES
1. MATERIAL ACRLYIC
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

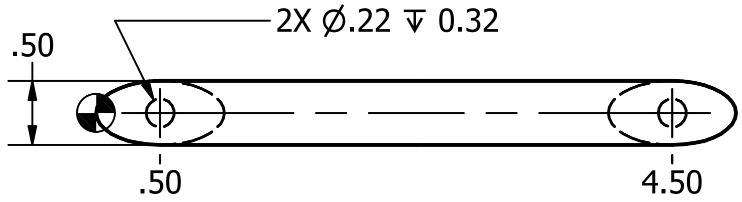
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

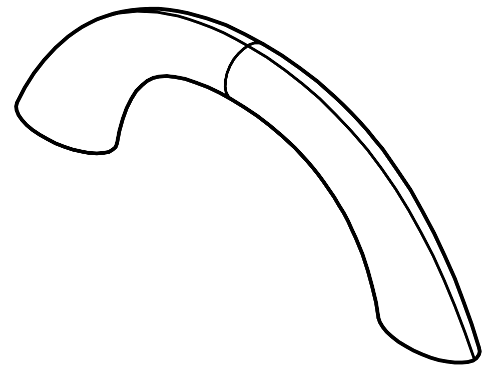
X° ± 0.5°

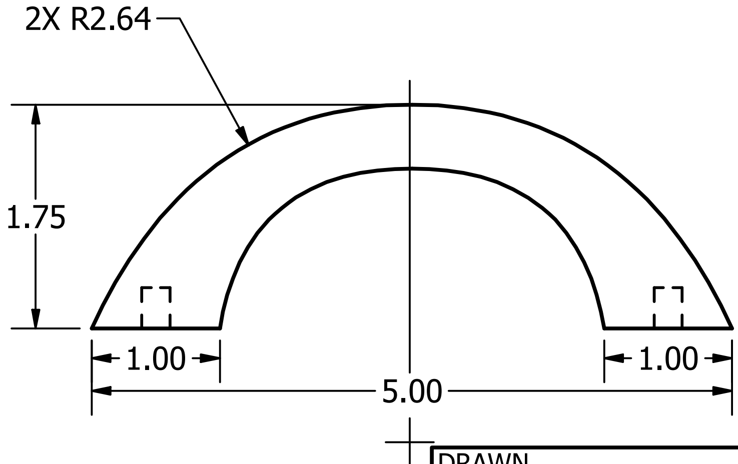
TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

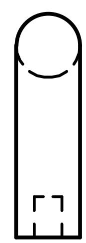
ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	DOOR
		SIZE A · DWG NO door · REV A
		SCALE 1 / 6 · SHEET 1 OF 1









NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

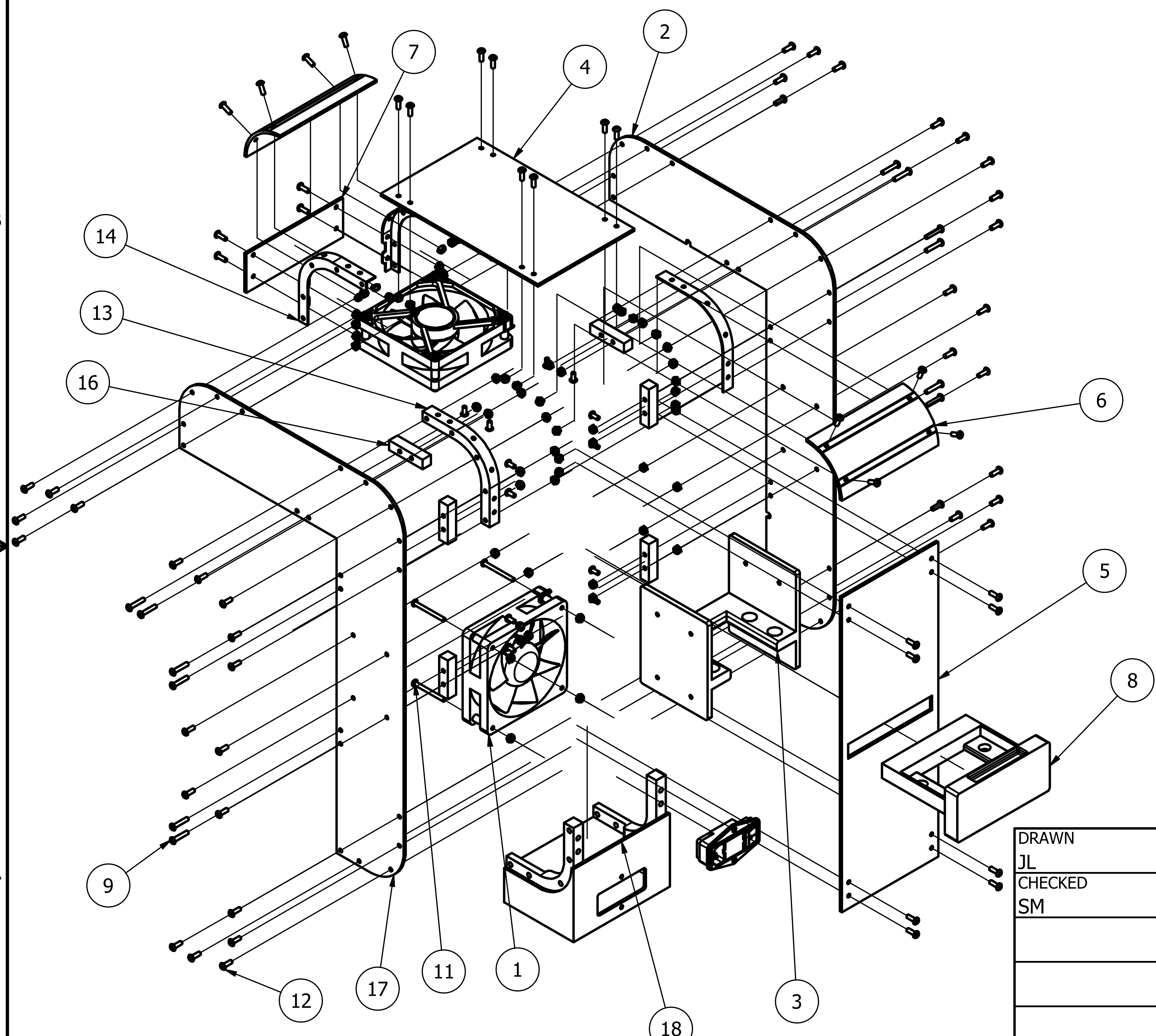
X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

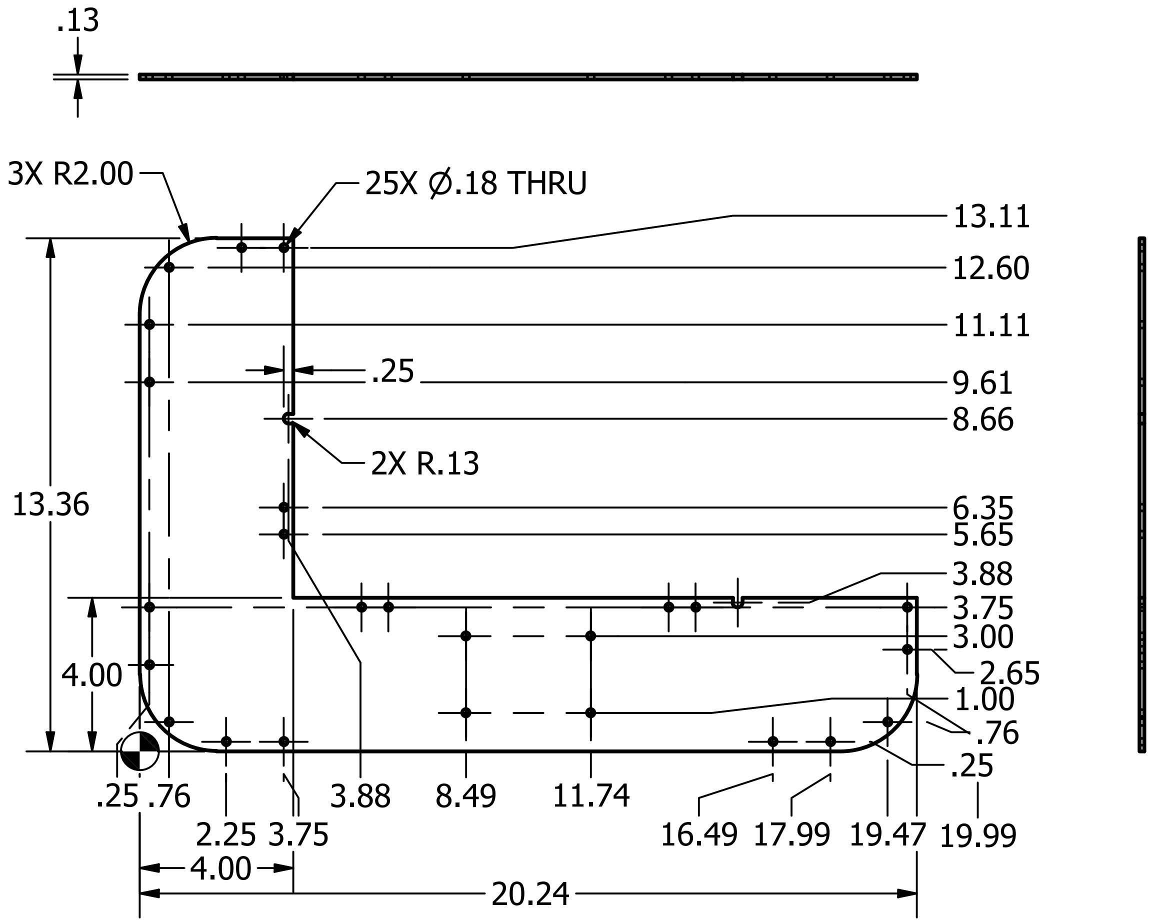
DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	HANDLE

SIZE		DWG NO	REV
A		handle	A
SCALE 2/3		SHEET 1 OF 1	



PARTS LIST		
ITEM	PART NUMBER	QTY
1	3988N22_High-Output Equipment-Cooling Fan	2
2	ductSide	1
3	airduct_filter_drawer_female	1
4	ductTop	1
5	ductBack	1
6	ductCorner	2
7	ductFront	1
8	filterDrawer	1
9	Screw 8-32 Steel 0.875	12
10	Nut Thin Nylock	94
11	Screw 8-32 Steel 1.750	8
12	Screw 8-32 Steel 0.500	74
13	bracketDuct	2
14	bracketDuctFanTop	1
15	bracketDuctFanBottom	1
16	heatsetBracket	6
17	ductSideNoWireHole	1
18	fuseSwitchBoxAssy	1

DRAWN JL	3/25/2025	ASTRANEW
CHECKED SM	3/28/2025	TITLE Duct Assembly
		SIZE B — DWG NO ductSubAssemblyEXP — REV
		SCALE 1 / 5 — SHEET 1 OF 1



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

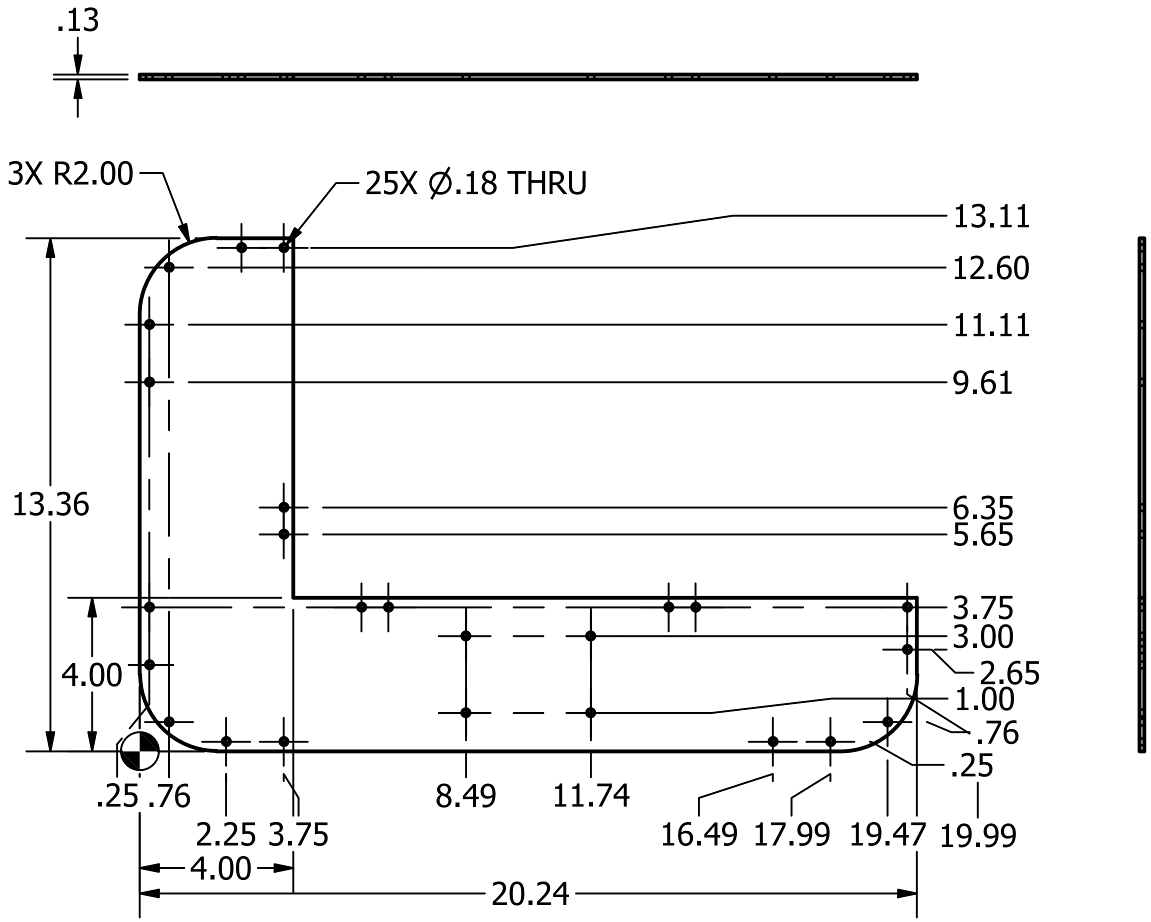
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	DUCT SIDE
		SIZE A / DWG NO ductSide / REV A
		SCALE 1 / 5 / SHEET 1 OF 1



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

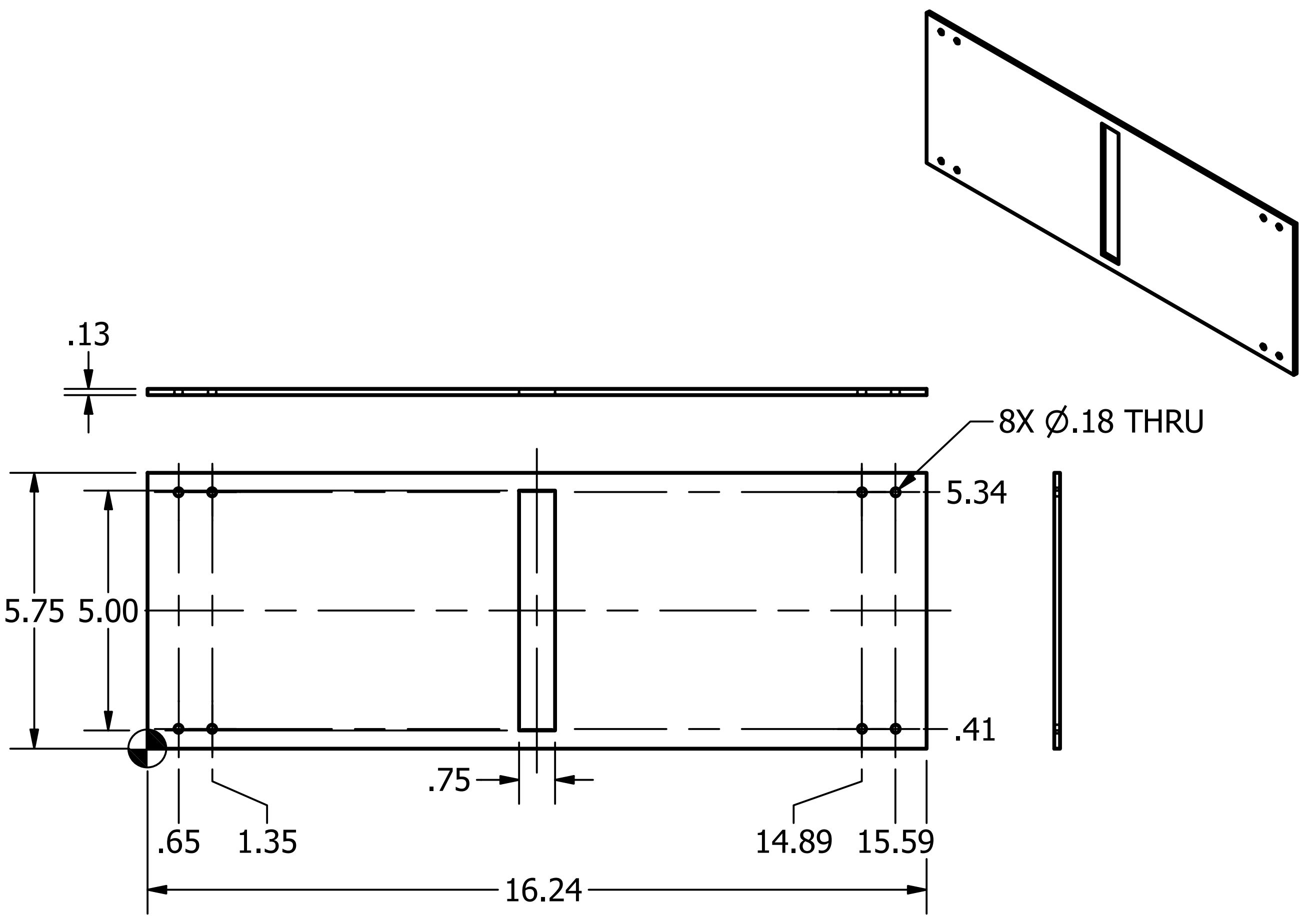
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW			
CHECKED JC	03/26/2025	TITLE			
APPROVED TT	03/26/2025	DUCT SIDE NO WIRE HOLES			
		SIZE A		DWG NO ductSideNoWireHole	REV A
		SCALE 1 / 5		SHEET 1 OF 1	



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

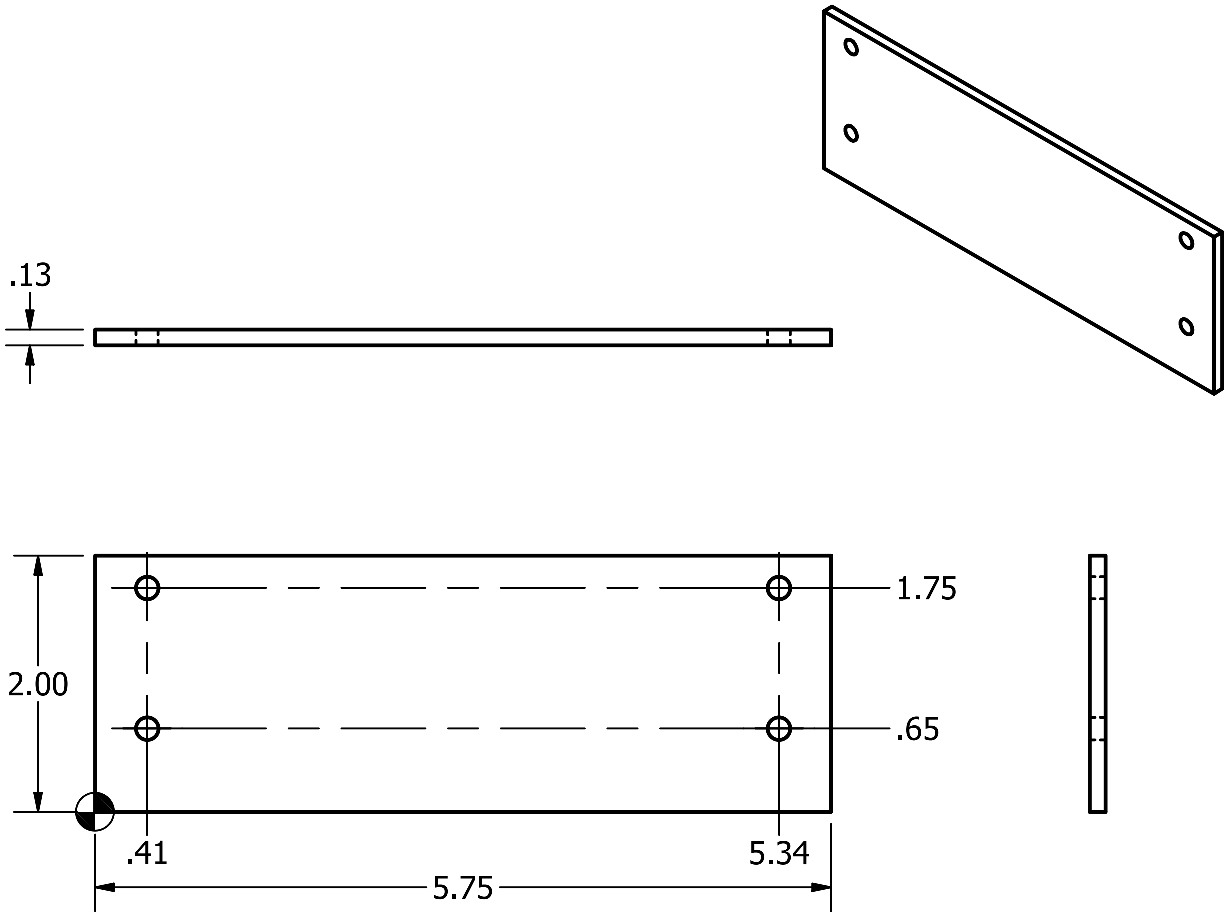
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	DUCT BACK
		SIZE A · DWG NO ductBack · REV A
		SCALE 1 / 4 · SHEET 1 OF 1



NOTES
1. MATERIAL ALUMINUM
2. FINISH ALL OVER: 125 µIN
3. REMOVE ALL SHARP EDGES

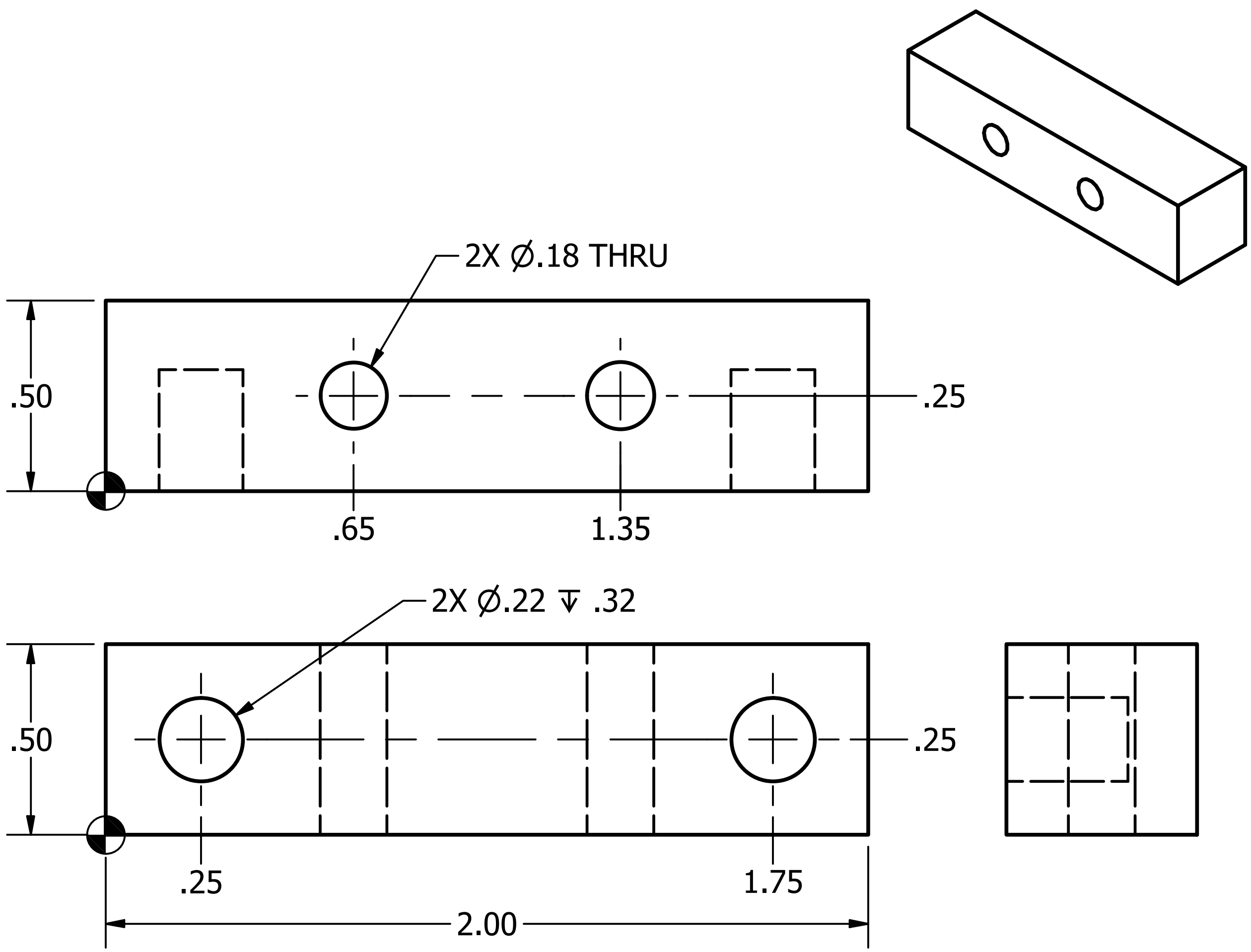
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	DUCT FRONT
		SIZE A · DWG NO ductFront · REV A
		SCALE 2/3 · SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

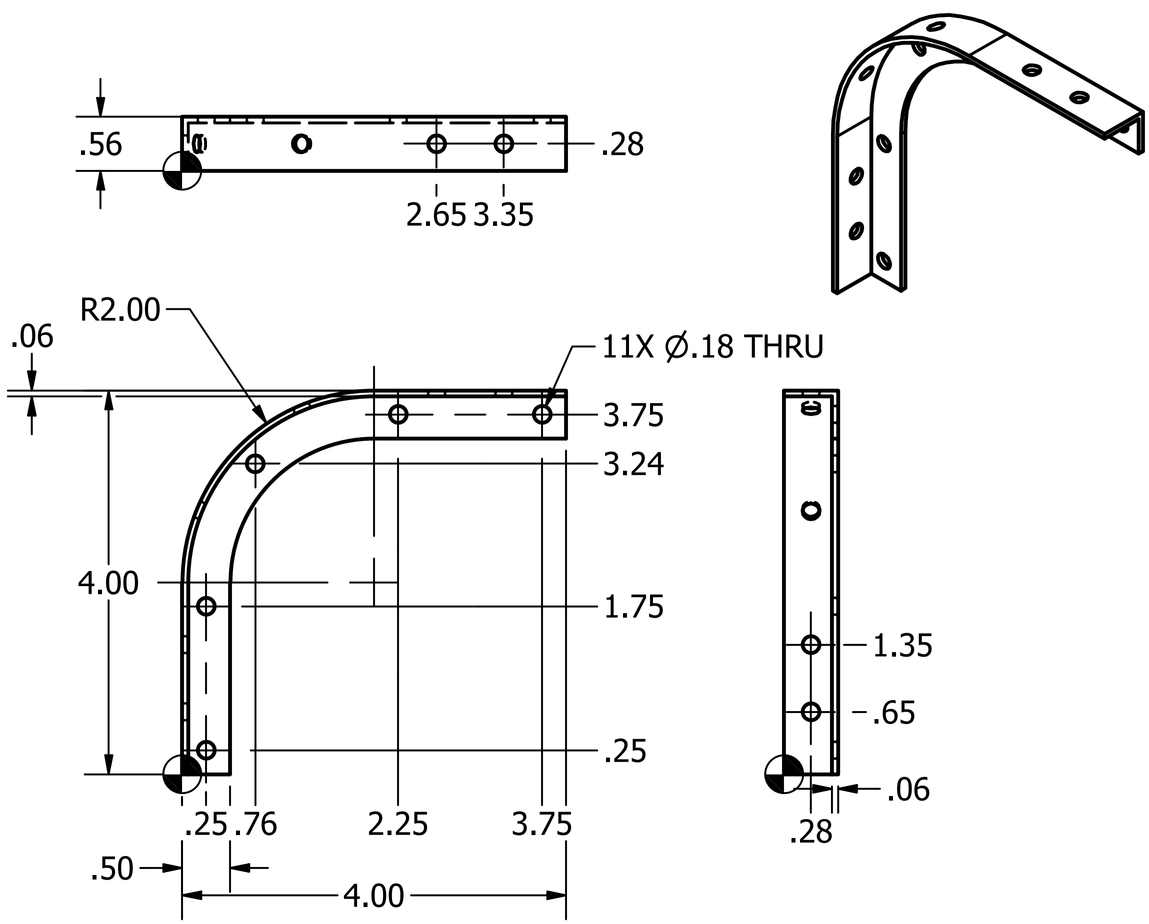
TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE HEATSET BRACKET
APPROVED TT	03/26/2025	
SIZE A	DWG NO heatsetBracket	REV A
SCALE 2 : 1		SHEET 1 OF 1

2 1

B B



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

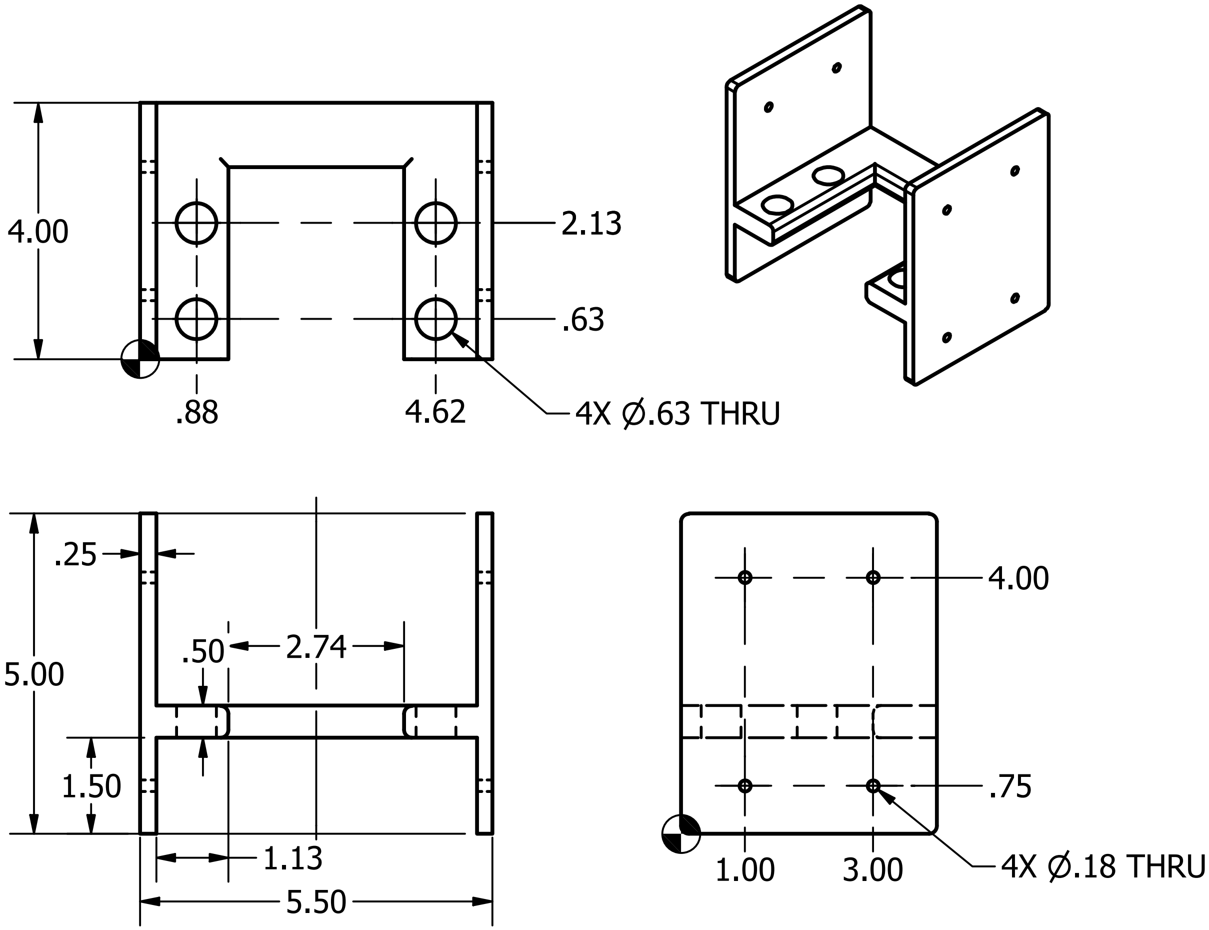
TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

A A

DRAWN SM	03/26/2025	ASTRANEW			
CHECKED JC	03/26/2025	TITLE			
APPROVED TT	03/26/2025	BRACKET DUCT			
		SIZE A		DWG NO bracketDuct	REV A
		SCALE 1 / 2		SHEET 1 OF 1	

2 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

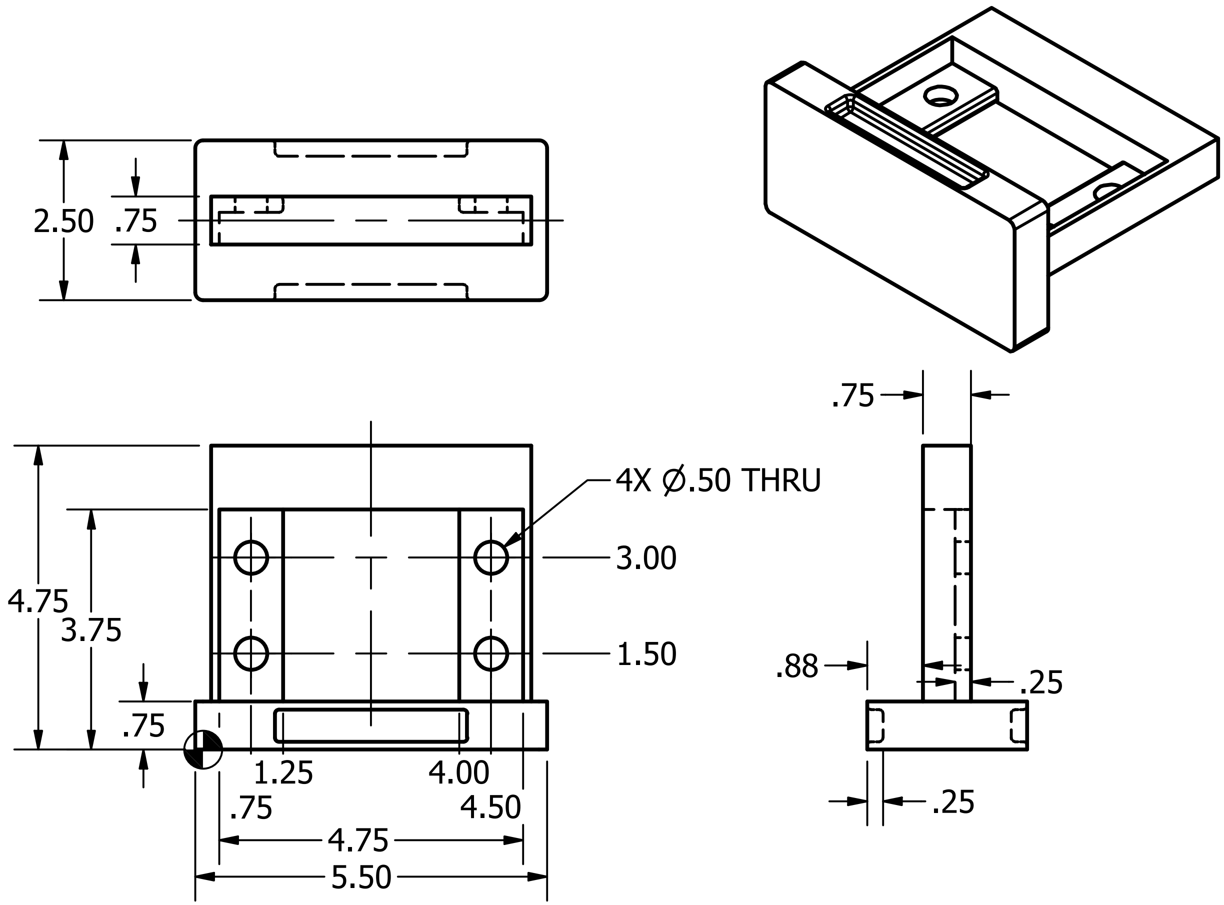
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	AIR FILTER DRAWER
		SIZE A
		DWG NO airFilterDrawer
		REV A
		SCALE 1 / 3
		SHEET 1 OF 1



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

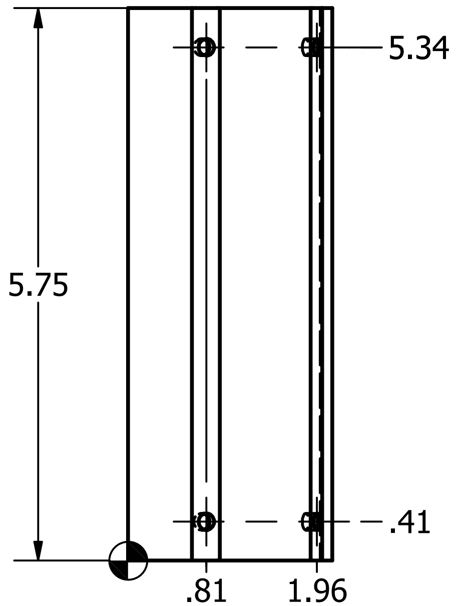
X° ± 0.5°

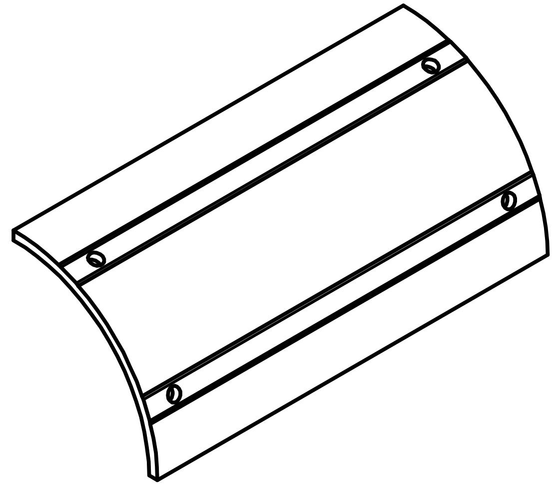
TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE AIR FILTER SLIDE
APPROVED TT	03/26/2025	

SIZE	DWG NO	REV
A	airFilterSlide	A
SCALE 1 / 3	SHEET 1 OF 1	





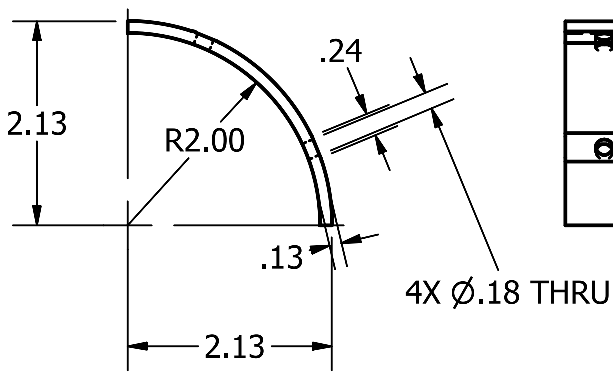
NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

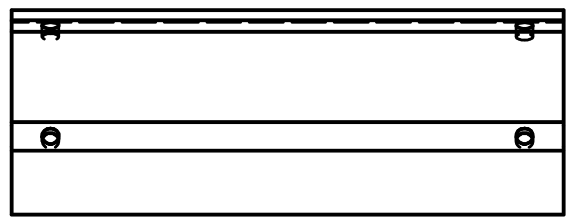
GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

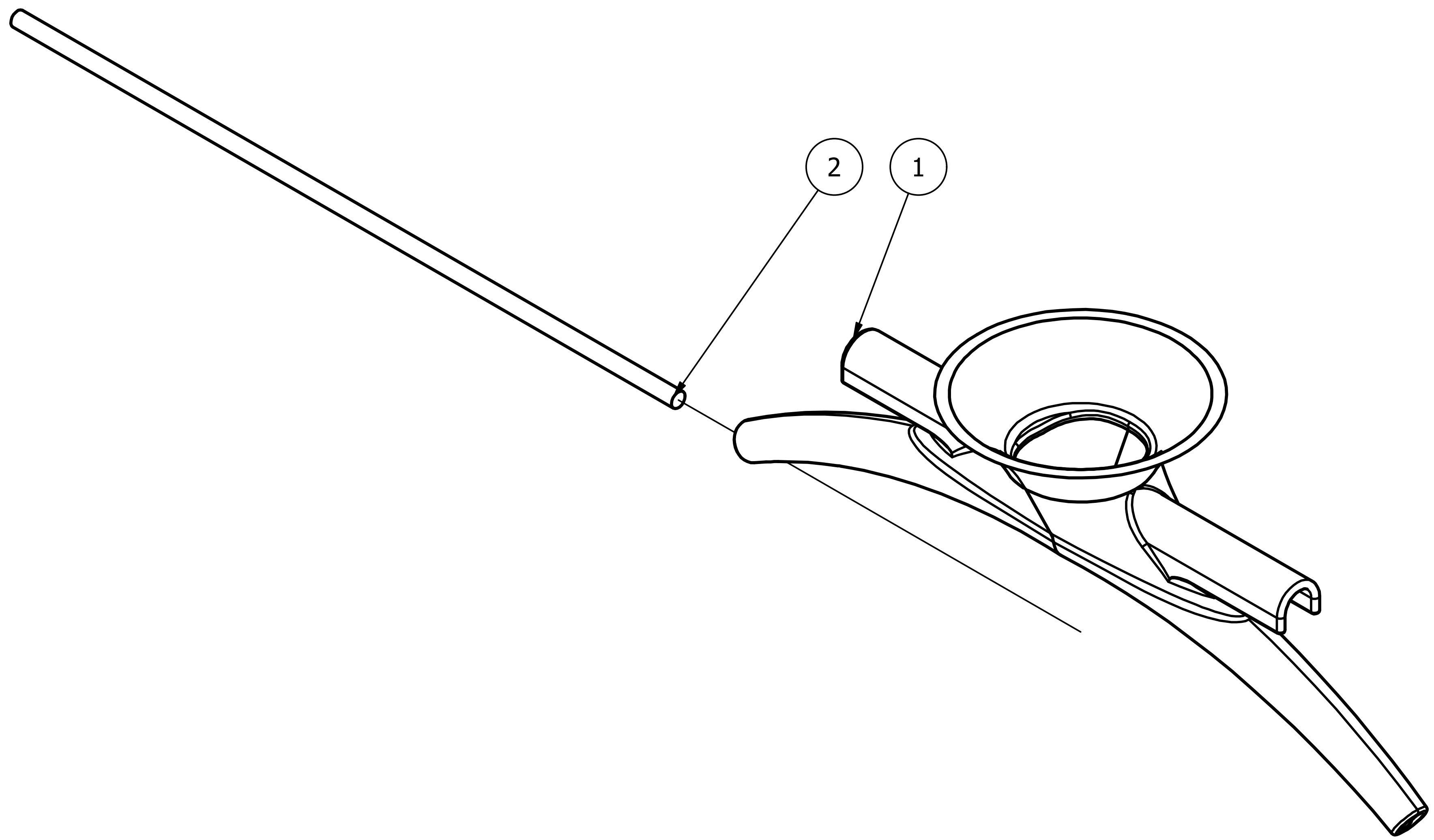




DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	DUCT CORNER

SIZE	DWG NO	REV
A	ductCorner	A

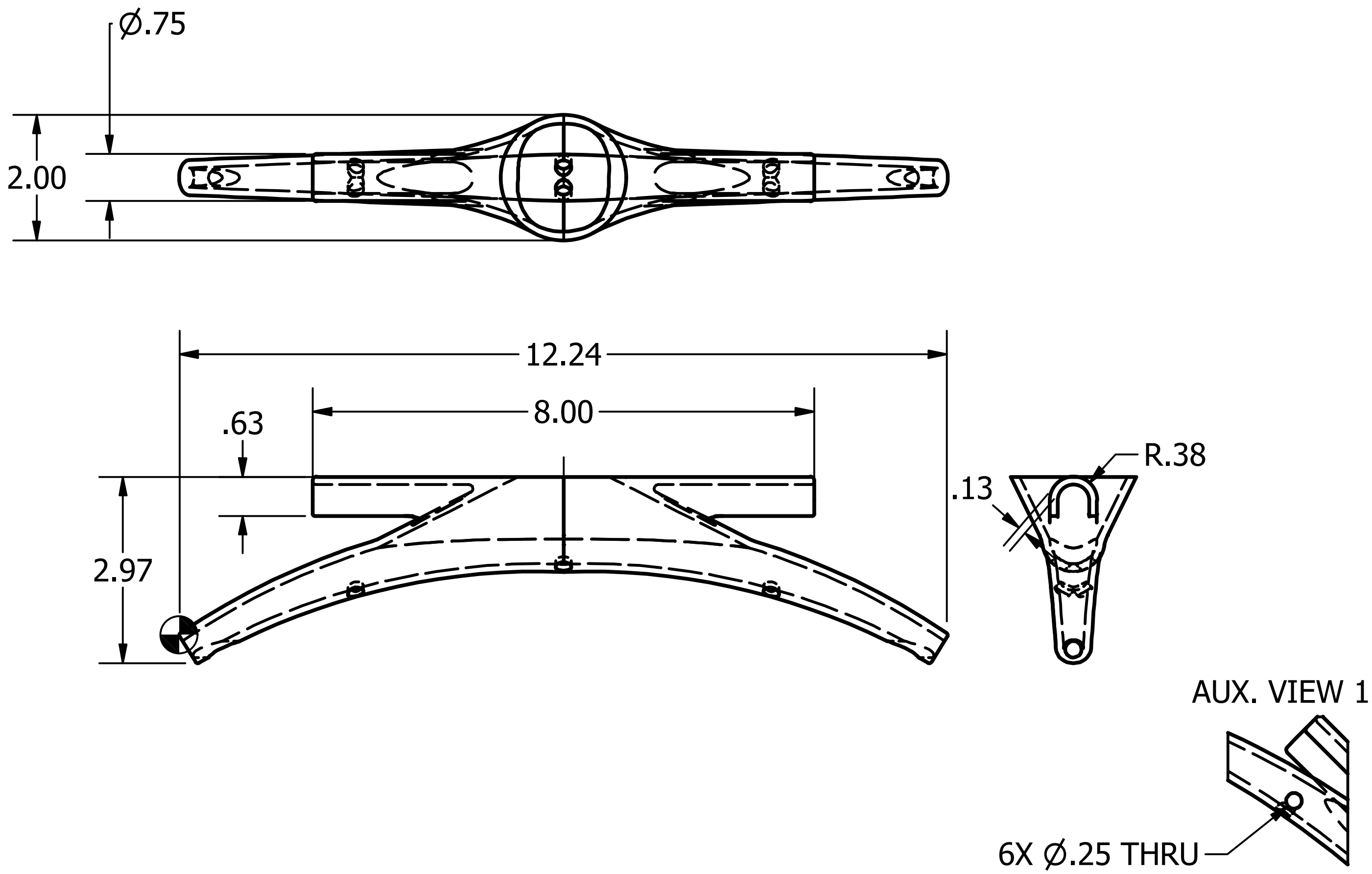
SCALE 1 : 2 SHEET 1 OF 1



PARTS LIST		
ITEM	PART NUMBER	QTY
1	Hanger	1
2	0.25x12inRod	1

DRAWN Astranew	3/26/2025	ASTRANEW
CHECKED SM	3/26/2025	TITLE HANGER SUB ASSEMBLY

SIZE	DWG NO	REV
B	hangerSubAssemblyEXP	
SCALE 1 / 2	SHEET 1 OF 1	



NOTES
1. MATERIAL PLA
2. FINISH ALL OVER: AS BUILT
3. REMOVE ALL SHARP EDGES

GENERAL TOLERANCES
X.X ± 0.1
X.XX ± 0.03
X.XXX ± 0.005

X° ± 0.5°

TO BE USED IN CONJUNCTION WITH 3D MODEL FOR FULL DEFINITION

ALL DIMENSIONS IN INCHES

DRAWN SM	03/26/2025	ASTRANEW
CHECKED JC	03/26/2025	TITLE
APPROVED TT	03/26/2025	HANGER
		SIZE A · DWG NO hanger · REV A
		SCALE 1 / 3 · SHEET 1 OF 1