Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

Payload Display Stand

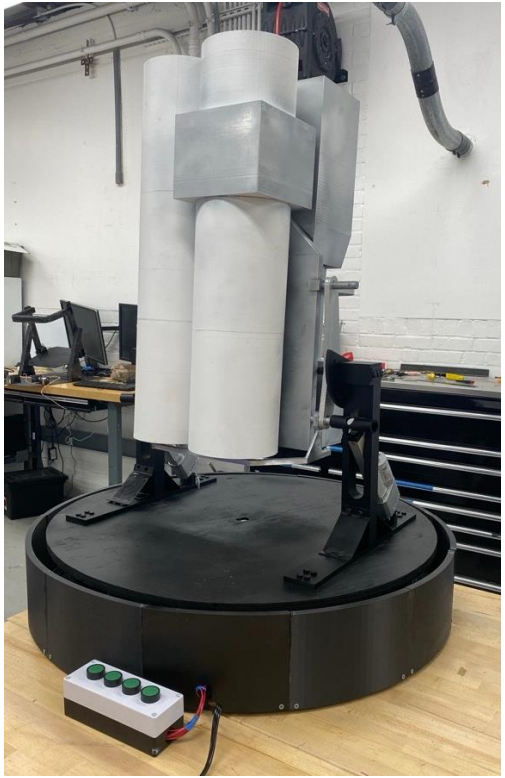
EML4502 MT0C-2
AstroBuilds Team

Ana Jo Fong, Layali Bazar, Angelina Herrero, Dhruvin Modi, Daanish Shauib, Andrew Pham, William Jorgensen, Brandon Stone Garver, Matthew Farrell

Mechanical Design 3, 2024 Spring

Presentation Outline

1. Hedgehog Concept
2. Product specifications
    - Subsystems & mechanical ratings, need mapping
3. Product Highlights
    - What sets us apart
4. Design Evolution
    - What we adapted
5. CAD
6. Testing
    - Performance evaluations
7. Cost Breakdown
8. Potential Areas for Development
    - What we learned

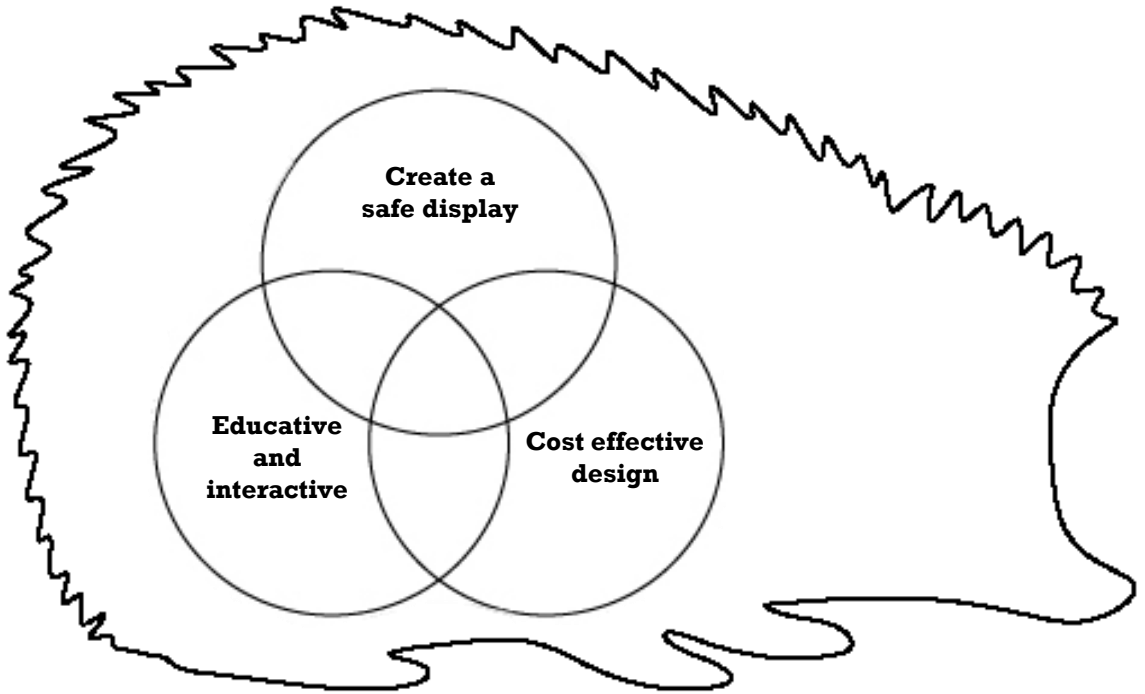


Hedgehog Concept

Create a safe display:
Have locking capabilities to ensure product safety

Educative and interactive:
Make something simple to use and accurate to the full scale

Cost effective design:
Create an accurate one-fifth scaled display for less than $1500



"An interactive and educational display presentation which incorporates a single-step lock and pin mechanism and utilizes 3D printing to create a cost-effective and accurate design."

Product Specifications

Dual linear actuators located on stands provide tilting of the payload

- 12V actuators each rated for 110 lb dynamic load

Locking mechanism device to lock display at desired tilt

- Two locking pins allow for selected angle to be chosen
- Linear actuators will also hold the load without power (rated 500 lb static load)

Motor and gear system provides rotation of the payload on a wooden turntable

- 4.8 Nm stepper motor with keyed shaft
- Gear ratio of 3.0
- Small gear 20 teeth, large gear 60 teeth

Linear actuator (mounted to support beam) providing tilt

Motor & Gear System providing rotation

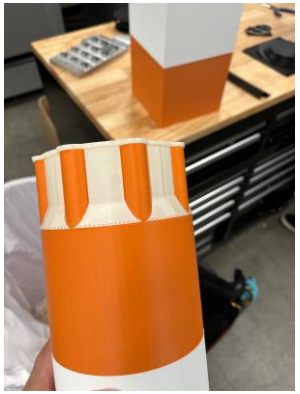
Customer Needs

Product Spec.	Description
1	Material budget of $1500 for the 1/5 scale artifact and full scale budget of $25,000
2	The turntable facilitates a full, continuous 360-degree rotation for the scaled ADS and astro payload
3	Total ADS footprint is minimized to fit within the 20 ft x 25 ft x 25 ft museum exhibit area
4	ADS supports the payload in multiple configurations: vertical, horizontal, and also at 15°, 30°, 45°, 60°, and 75° from the horizontal position
5	Minimum factor of safety for all full-scale ADS components has a value of 3.0
6	The turntable must facilitate a full 360-degree rotation for scaled ADS and Astro system.

Unique Highlights

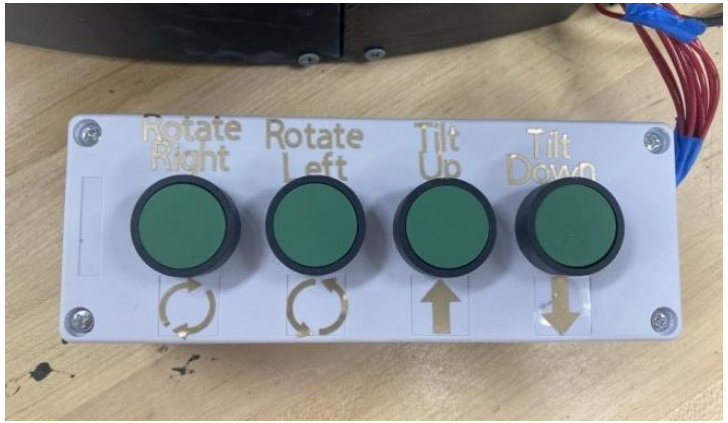
Use of 3D-printed material

- Payload, cruciform, and turntable components
- Keep overall weight down
- Cost effective
- Easily painted to replicate the full-scale payload and generate visual interest



Control Panel

- Labeled to show functions
- Allow for full 90 degree tilting and 360-degree payload rotation
- Wired to the motor and linear actuators, powered by Arduino



Unique Highlights

Wooden turntable houses the display

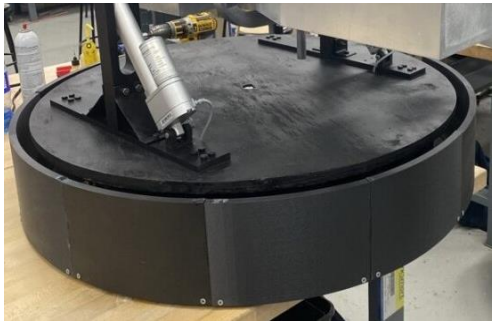
- CDX Grade Plywood, 0.75” thickness
- Four castor wheels mounted for weight distribution
- 3D-printed track for wheels to follow
  - Maintains weight distribution and allows space for service

Visually appealing 3D-printed cover

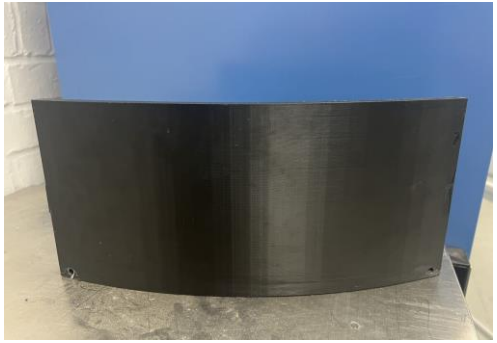
- Removable cover in multiple pieces around turntable hides the track for serviceability
- Turntable has a “floating” appearance while cover is in place

Motor & gear reduction system

- Simple & controllable



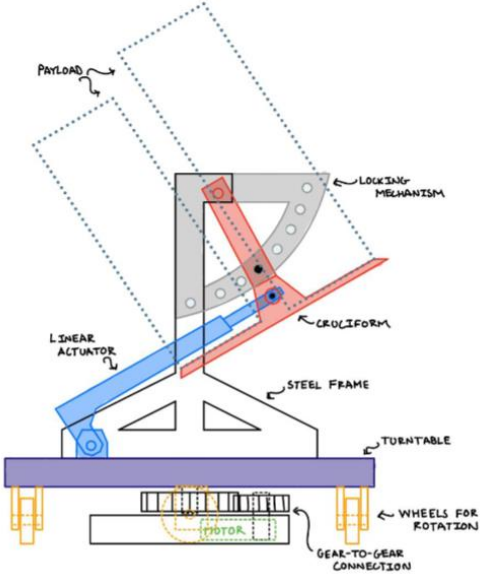
Turntable with covers in place



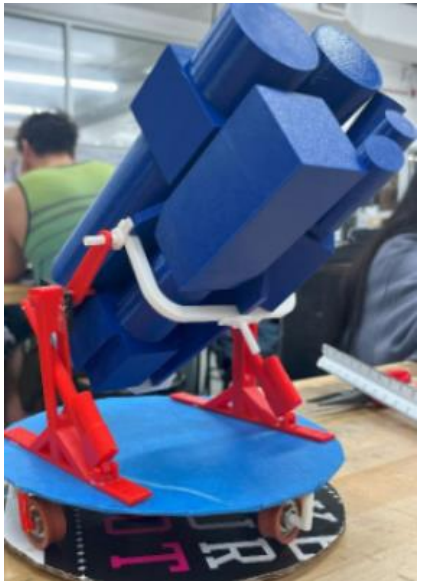
3D printed cover

Covers and top removed

Design Evolution



Concept Sketch



Functional Prototype

1/5th Prototype

Final Assembly

Design Evolution

Calculations to determine gear ratio needed to achieve the necessary torque for the turntable load.

Total Mass Per Wheel: 100 *lbs*.

Radius to Wheel: 16 in

Coefficient of Rolling Friction: 0.002

Normal Force = $m * g = 3220\ lb * ft/s^2$

Friction Force = $\mu * N = 6.44\ lbs.$

Torque Load = $F * r = 11.63\ Nm$

Required Gear Ratio for 4.8 Nm Stepper Motor:

$$\frac{11.63\ Nm}{4.8\ Nm} = 2.4$$

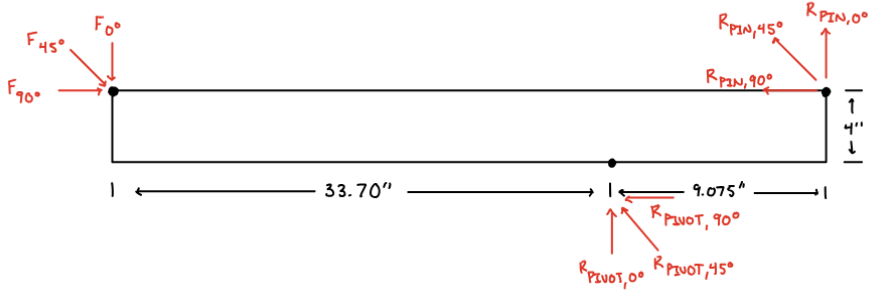
To Achieve Gear Ratio of 3:

Small Gear Tooth # = 20 teeth

Large Gear Tooth # = 60 teeth

Design Evolution

Calculations to determine max load on a single pin for the full-scale locking pin.



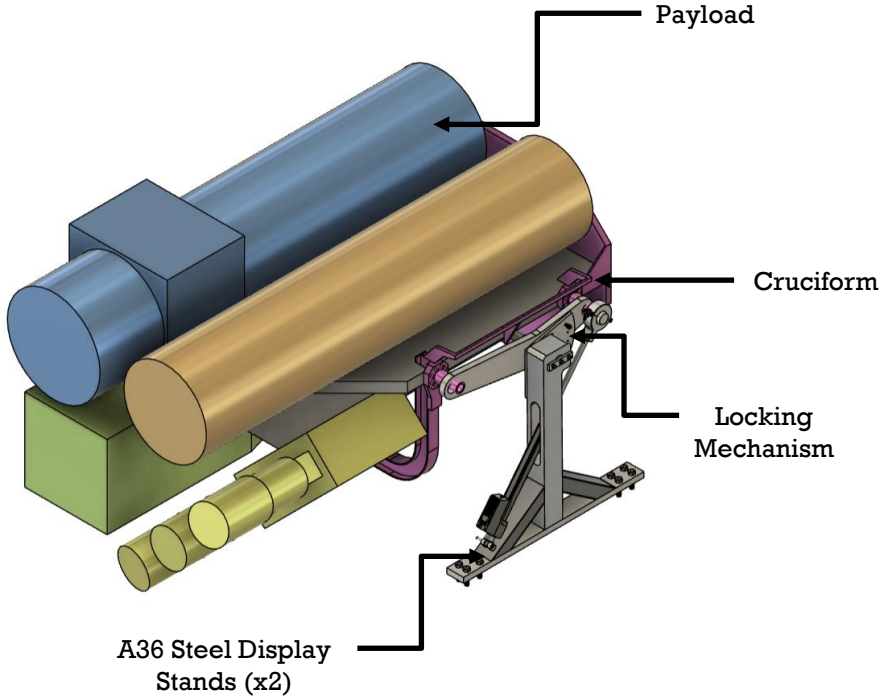
Full Scale Locking Pin Load:

0-degree Tilt: $-F_{0^\circ}(33.7\ in) = 32500(9.075\ \text{in}) \therefore F_{0^\circ} \approx 8{,}750\ lbs$

45-degree Tilt: $-F_{45^\circ}(\sin(45))(33.7\ in) - F_{45^\circ}(\cos(45)\ (4\ in) \therefore F_{45^\circ} \approx 11{,}800\ lbs$

90-degree Tilt: $-F_{90^\circ} * (4\ in) = 32500 * (4\ \text{in}) \quad \therefore F_{90^\circ} = 32{,}500\ lbs$

Full Scale CAD



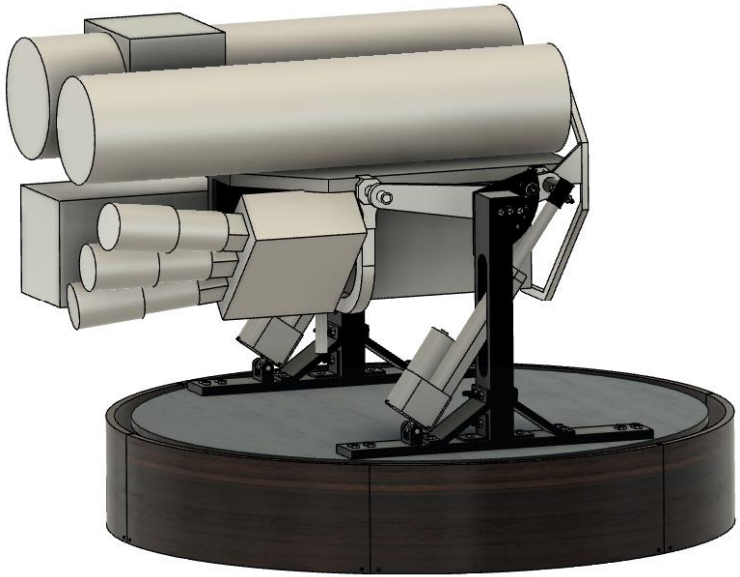
Two Display Stands

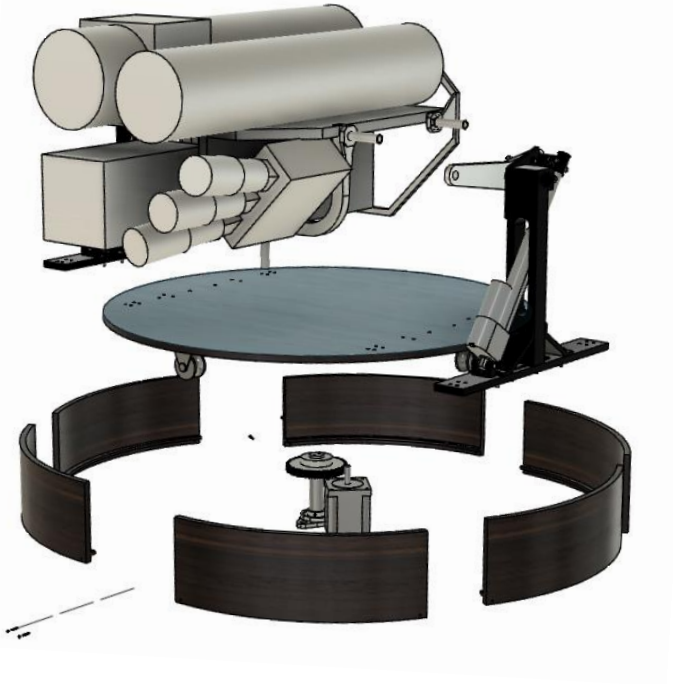
- A36 middle columns mounted to A36 support plates
- Thomson Electrak XD Linear Actuators
  - Actuator clamp that would allow rotation of cruciform during tilting
- Trunnion beam that will connect stands to cruciform

Locking Mechanism

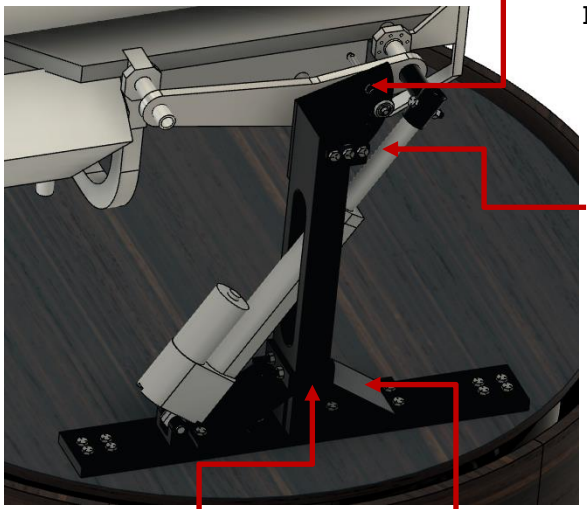
- Radial piece that moves with actuator
- Locking pins (with 2 lanyards and 2 keys)
  - Keyed Double-Locking Quick-Release Pin
    - Breaking strength: 32,500 lbs

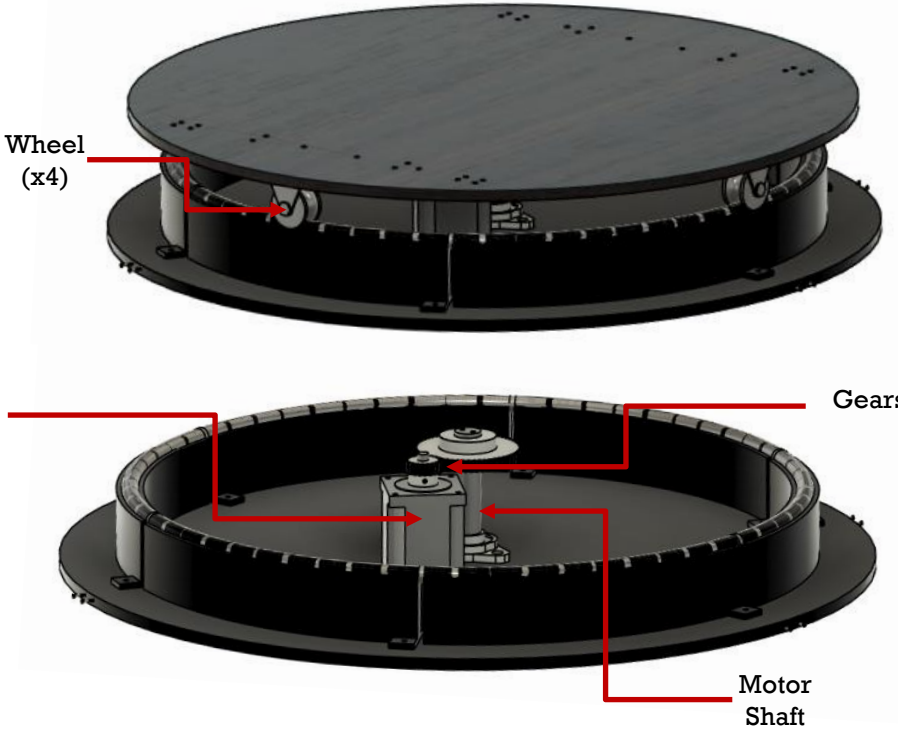
1/5th Scale CAD



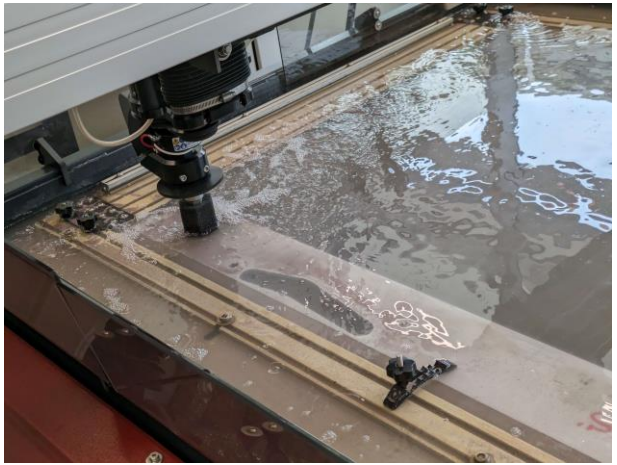


1/5th Scale CAD





Manufacturing Process and Product Testing



System Manufacturing Challenges

Tolerance Issues

- FDM parts did not fit as designed, the wood used experienced warping due to heat exposure

$1500 cost cap

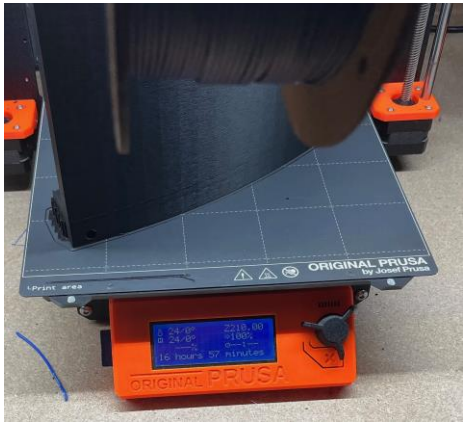
- Strict budget made implementing the planned design challenging and led to design changes

Inconsistencies in Prototyping

- Payload pieces and purchased OTS parts arrived randomly and occasionally late, not allowing for a seamless assembly process, introducing inefficiency

Implementation

- Realizing CAD design into the product needed to accommodate for manufacturing limitations



Testing

Tested whether linear actuators could hold payload from deflecting without locking pins in place, as well as tracking tilt speed and rotation speeds

$\Delta x = 0.43$ mm

Tilting Speed = 0.37 deg/s

Rotating Speed = 0.42 deg/s

Displacement (mm)	0	0.1	0.2	0.3	0.4	0.5	> 0.5
Point Value	20	18	16	14	***12***	10	0

Tilting (deg/s)	< 0.5	0.5 - 1.0	> 1.0
Point Value	***15***	7.5	0

Rotation (deg/s)	< 0.5	0.5 - 1.0	> 1.0
Point Value	***15***	7.5	0

Final Score:
42/50

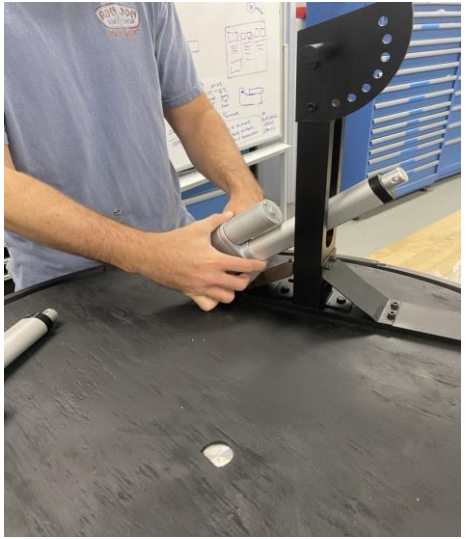
Testing

Tracked total assembly time of the product to determine time needed to set up display

Total Assembly Time: 43 minutes

Assembly Time	t ≤ 1 hour	1 hour < t ≤ 2 hours	t > 2 hours
Point Value	***50***	25	0

Final Score:
50/50



Cost Analysis

Product Spec.	Description
1	Material budget of $1500 for the 1/5 scale artifact and full scale budget of $25,000

One-fifth scale product was assembled under budget

- Labor was factored into cost of EML 4502 course

Full scale product material falls within budget

- With estimated labor, goes over $25,000 constraint outlined by Astro Restoration Program

	One-Fifth Scale	Full Scale
Material Cost	$ 1,266.35	$ 21,390.17
Labor	$ 0	$ 8,226.34
Grand Total:	**$ 1,266.35**	**$ 29,616.51**

Future Development

Turntable cannot rotate continuously one way

- Wires will tangle

Incorporate mounted lighting system

- This was initially planned but was dropped due to wiring challenges

Different materials

- Rubber wheels and aluminum track instead of steel wheels and 3D printed track

Tweak full scale display design to improve efficiency

- Reduce material used and cost

Create removable panels to hide some fasteners

- Increase visual appeal

Why Choose AstroBuilds?

Value, Safety, Education, and Visual Appeal!

With our product, we provide

- Educational experience with our product with an accurately modeled cruciform that maximizes the payload's visibility
- Simple, inexpensive, and easy to manufacture design
- Maximize interactivity for all audiences with the intuitive control panel
- Implement safety features with fail-safes such as the dual keyed locking pin system
- Provide value with a reliable, easily serviceable product

Herbert Wertheim College of Engineering
UNIVERSITY of FLORIDA

Payload Display Stand

EML4502 MT0C-2
AstroBuilds Team

Ana Jo Fong, Layali Bazar, Angelina Herrero, Dhruvin Modi, Daanish Shauib, Andrew Pham, William Jorgensen, Brandon Stone Garver, Matthew Farrell

Mechanical Design 3, 2024 Spring

Thank you!

POWERING THE NEW ENGINEER TO TRANSFORM THE FUTURE