

**MECHANICAL ENGINEERING DEPARTMENT
OUTCOMES SPECIFIC ASSIGNMENT COVER SHEET
MCEG 4248 SENIOR DESIGN & PROFESSIONALISM II P01, P02, & P03
SPRING 2022**

Instructors: Dr. P.O. Biney, Dr. X. Peng, & Dr. C. Duan

Title of Assignment

**Demonstration of ability to communicate Orally using summary
of PowerPoint slides selected from final project presentation**

Outcome Measured Using this Assignment

Outcome 3

**An ability to communicate effectively with a range of audiences
(Oral Communication)**

Check the communication characteristics related to this assignment

✓	Involves ability to organize, plan, design/prepare and use appropriate visual aids for communication/presentation to a range of audiences (executives, technical and non-technical).
✓	Involves ability to demonstrate technical knowledge and understanding of the subject, prepare and display prototypes or models when they are necessary, respond clearly to questions in a professional manner
✓	Requires use of correct grammatical English and technical terms appropriate to technical area and audience type; ability to speak with clarity and confidence, maintain good posture and eye contact with the audience
✓	Geared to diverse groups of stakeholders (students and industrial representatives, etc.)

Brief justification of why this assignment is suitable for this outcome

These are selected slides from the final Power Point Presentation showing communication abilities of the students in Group 3 for the design of 3D printer. This section demonstrates the students' ability to prepare and make oral presentation using PowerPoint slides on their project design to an audience.
(The original PowerPoint Presentation available upon request)

MCEG 4247

SENIOR DESIGN & PROFESSIONALISM II

Fall 2021

“Design of a Lightweight Deployable Thermal Shield”

Submitted by:
George Brunfield
Wendell Smith
Leonardo Herrera
Justin Murcia
Jesse LeBlanc

Overview

- Project Scope
- Project Planning and Task Definition
- Literature Review
- Preliminary Design
- Detailed System Design
- Results and discussion
- Conclusion and Recommendation

1

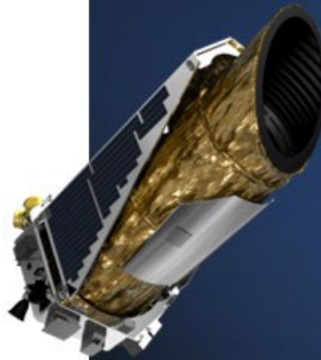


Previously Discussed

2

Project Scope

- **Problem statement**
 - The task is to develop a large lightweight deployable thermal shield that can be stowed into a small volume for the launch ascent then be deployed to unfold into a large structure to provide thermal protection to payload components.
- **Client Identification & Recognition of need**
 - Ball Aerospace designs and builds instruments and spacecraft that require thermal shielding once in orbit.
- **Project Goals and Objective**
 - The goal is to Design and build a Lightweight Deployable Thermal Shield that can be incorporated onto a space instrument



Previously Discussed

3

Performance	Reliability	Economical	Convenience
Easily deployable umbrella-like structure	Capable of withstanding launch conditions	Easily stowed and lightweight	Capable of having an open section for payload sensor field-of-view
Stowed shade height not to exceed payload height	Capable of withstanding high temperatures	Minimize stowed thickness of the device	Adaptable to various instrument sizes
Capable of having a controlled deployment			



Design Objectives

Previously Discussed

4

No.	Requirements	Values	Description
1	Number of Sides	4,6, or 8	Capable of being adaptable to various payload form factors.
2	Width	15-60 inches	The width should fall within the given parameters.
3	Height	(0.5-1.0) inches	For the given payload width how does the height affect the design?
4	Payload Field of View	One side unobstructed	N/A
5	Shade Deployable Angle	0-90 degrees	The deployed angles should fall within the given parameters.



Project Constraints

Previously Discussed 5

Project Planning



The tasks for fall 2021 & Spring 2022 were created by using the senior design template as a guide in properly following through with the creation of the project. By researching each major task to discover the correct engineering method for the task to be completed.

Fall 2021

- Problem Formulation
- Project Planning
- Literature review
- Functional Decomposition
- Preliminary Design
- Detailed Design

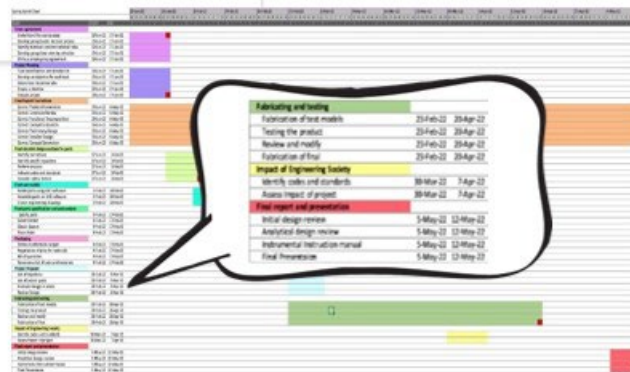
Spring 2022

- Detailed parts Specifications
- Budget & project cost
- Purchasing
- Fabrication and Testing
- Final Report and presentation

Previously Discussed 6

Gantt Chart Details

- Previously Discussed



Timeline

Fall 2021

Spring 2022



Previously Discussed 7

Current Technology



Hypersonic Inflatable Aerodynamic Decelerator



Designed to be a protective shield for spacecraft headed to mars. The whole shield can fit inside a bag around half a meter in diameter.

Multi-Arm Radial Composite (MARCO)



(a) Deployed

(b) Stowed

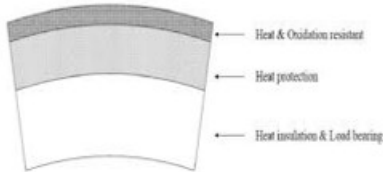
The radial arm contains a rotating joint at the center location, as well as the radial arm mid-span, which causes the structure to open and close.

Previously Discussed 9

Current Technology

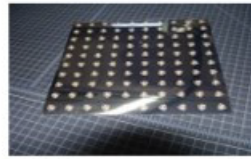


Load Bearing Multi-layer Insulation



Load bearing multi-layer insulation is advanced insulation that utilizes discrete polymer spacers to keep up with layer thickness that supports warm safeguards and diminishes heat loss through the protection framework.

Launch Vehicle multi-layer insulation



Launch vehicle multi-layer insulation upholds an inside vacuum that expands its protecting abilities.

Previously Discussed 10

Linear Actuators

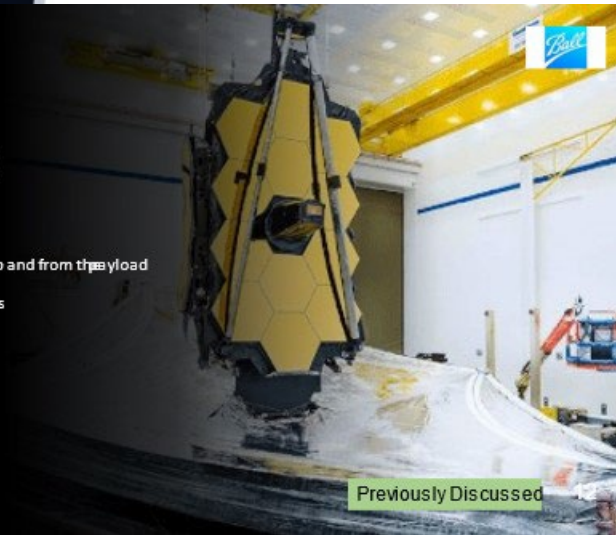
- A linear actuator converts rotational motion into push or pull linear motion, which can be used for lifting, dropping, sliding, or tilting of machines or materials.
- Electric linear actuators use a DC or AC motor with a series of gears and a lead screw to push the main rod shaft.



11

Design Characteristics (Thermal Shielding Materials)

- Material: Aluminized Kapton (AK)
- Minimizes the heat flow transfer to and from the payload
- Withstands extreme temperatures
 - Operating temperature 250°C to 290°C
- Lightweight structure



Previously Discussed

Design Characteristics (Foldable Deployment Mechanism)



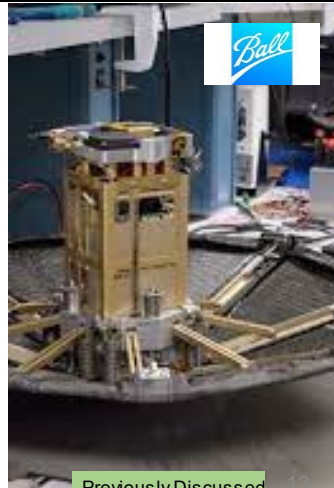
Motor command system incorporated on the device.



No binding throughout rods allowing for reliability and redundancy.



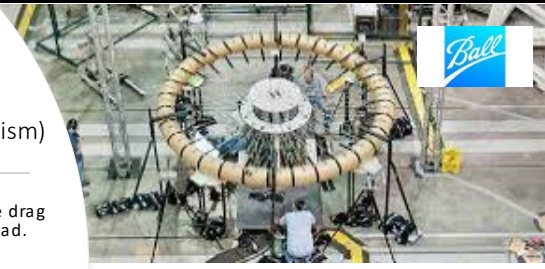
Possible increase in deployed length of shade to protect from various sun angles.



Previously Discussed

Design Characteristics (Inflating Deployment Mechanism)

- Allows the shield to produce more drag while saving on mass in the payload.
- Deploys through a series of vertical booms.
- Needs a tank and a pressurized valve system which makes the structure not practical due to weight requirements.



Previously Discussed

14

Fabrication

3D Printed Mechanism

Structure Material → Ab Plastic

- The brackets and arms were 3D printed
- All other parts will be purchased with the appropriate sizing.

Shield Material → Thermal Blanket

Actual Mechanism

Structure Material → Metal

- All aspects of the design will be made to withstand deployment and the environment (space).

Shield Material → Aluminized Kapton



Previously Discussed 15

Preliminary Design

- Functional decomposition describes in detail and divides the major function into simpler subfunctions
- Each function addresses the problems which creates the guidelines for the entirety of the system
- The problems are divided in terms of flow energy, materials, and forces to have an understanding of the function

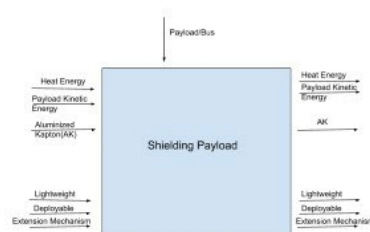


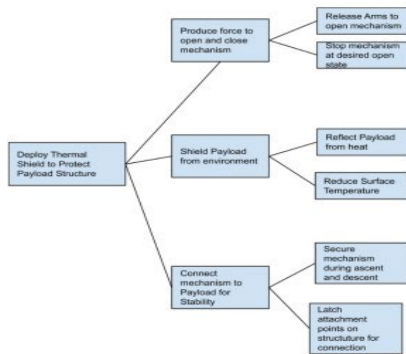
Figure 4.2 Overall Function of Thermal Shield

Previously Discussed

16



Functional Decomposition



- Figure shows the overall functional decomposition for the thermal shield.
- Using electronic sticky notes, each member decomposed the overall function into level 1 sub-functions
- The actions were repeated for the decomposition of all sublevels until they reached the simplest form

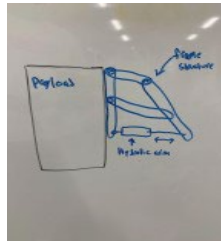
Previously Discussed 17

Concepts Generation

Three group members were assigned to each lowest level subfunction

For every assigned function the group member created 3 concepts

After collecting all concepts the best 4 for each function were chosen.



Previously Discussed 18

Concepts Evaluation and Selection

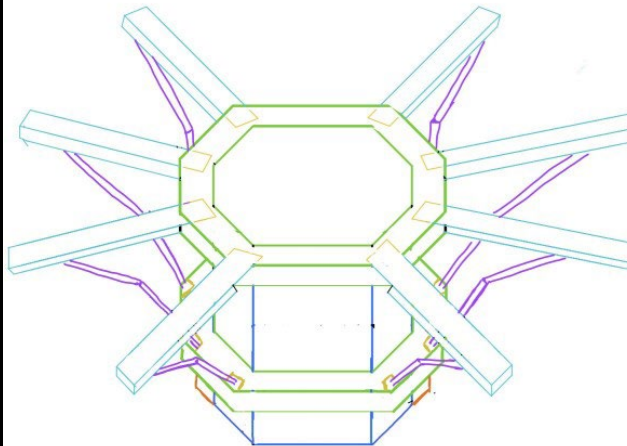
- An exhaustive list of requirements/criteria was used to evaluate the concepts for all of the functions that the group has identified.
- From the criterion list a table was made which provides a list of the requirements from the table that are directly related to or affect each sub-function which was used to evaluate the concepts for that sub-function.
- Used Go-No-Go evaluation to evaluate the concepts based off of the criteria.
- Created weighted decision matrix to further score concepts

Criterion #	Criterion Description
1	Is it capable of having 4,6,8 Sides on a payload?
2	Is it usable on a payload with a width of 1560 inches?
3	Is it usable on payload height (0.3.0)*payload width?
4	Is the shade deployment angle 90 degrees?
5	Is the shade angle accuracy +/-1 degree?
6	Can it prevent sun illumination on the payload surface?
7	Is Aluminized Kapton used as shade material?
8	Is the shade system mass minimized?
9	Is it deployable at least 50 times?
10	Does the deployment temperature have a range from -60 to +60C?



Previously Discussed

19



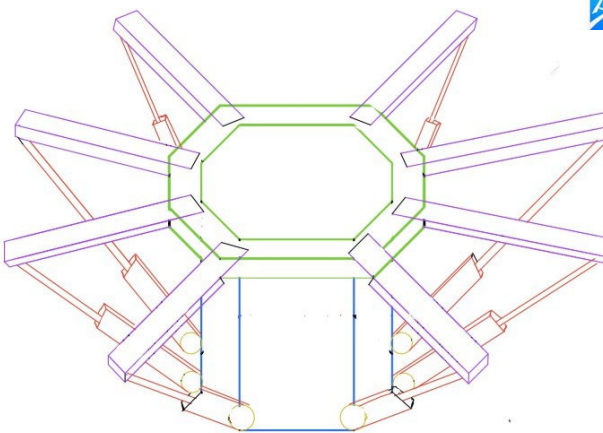
System Sketches and Description for Two final Designs

- Using the decision matrix lead to choosing 2 final designs
- The first system involved the use of an electric arm composed of electronic actuators guiding and adjustable frame.
- As the actuators move the the frame up and down, they will guide the outer rods from a lowered stowed positions to a raised open position.



Previously Discussed

20





System Sketches and Description for Two final Designs Cont.

- The second system represents a hydraulic lift mechanism
- The hydraulic arms are to expand and push the arms directly from a lowered closed positions to an extended open position
- The outer rods are connected via hinges on the top collar and have slots within them so that the guiding arms can extend the reach of the outer rods.

Previously Discussed

21



Codes and Standards

To accurately represent our system, we utilized industry standards such as:

- Standard ES44** Which outlines the best drafting practices to have a properly drawn part drawing
- ES3 Fabricating Tolerances**, to allow for consistent parts during fabrication
- General ASME** standards for design development and fabrication

These standards were chosen to make our part both structurally sound and universally compatible

8.1.2.3 Mechanical	1	Field joints shall, where practical, be provided to permit disassembly of all MHA's, deployables, and other movable systems from the open higher assembly to facilitate testing or replacement of parts.	8.1.2.1 Clearance	1	The clearance requirements within the MHA and between the MHA and any other structure, component, and field of view shall be established and maintained.
--------------------	---	--	-------------------	---	--

Table 1.1 ASME 5-214-2002

Section Identification	Requirement Description	8.1.2 The Deployable Environment	1
5.1 General Performance Requirements	1	Deployables and other movable systems shall, where practical, be designed so that they are self-supporting when placed in any orientation relative to gravity, while in either the stored or deployed configurations.	1 MHAs shall be designed to function within performance specifications following or, if required, during exposure to the specified environments. These environments include thermal, vacuum, shock, vibration, and acceleration.
	2	They shall be designed with sufficient reserve force to permit full operation during ground testing without depending on the assistance of gravity to demonstrate deployment. Off loading devices to simulate a zero (0) condition are allowed so that the movable system is adequately supported.	
	3	For all deployables, the deployment motion shall, where practical, be controlled for the full range of travel.	
	4	Where two or more deployables are used on a space vehicle, the deployment operation of one shall, where practical, be independent of the successful deployment operation of the other.	
	5	Deployables and other movable systems that require discrete sequential motions, such as initiated by separate commands, or any mission-critical deployable shall, where practical, have a backup ground command for each event.	

Previously Discussed

22

Detailed System Design



Detailed Engineering Analysis



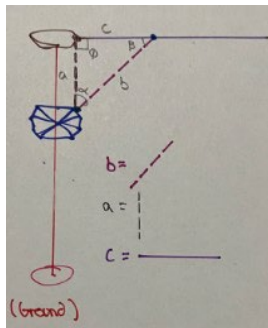
- The group prioritized a list of system components for a full engineering analysis.
- Subject areas necessary for each components analysis were identified

Item #	System Component or part description	Description of analysis needed for the design, sizing, specifying or selecting component	Subject Area	Reference Source for Analysis
1	Frame (Base, Hinged, Moving Slider)	Geometric analysis to define shape and size	Machine design	Machine design Textbook
2	Linear Motor	Using force analysis and power equations to find the power of the motor.	Machine Design, physics	Progressive automations
3	Shade Inner and Outer Rods	Kinematic analysis of moving elements. Force analysis. Geometry	Kinematic Design and Analysis	Kinematic Professor
4	Shade Structure	Material analysis to determine the weight of the structure.	Machine 1, Machine 2	NX Tutorial

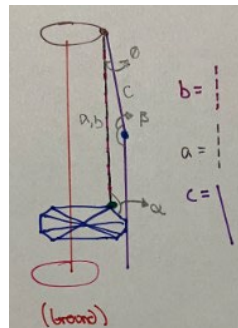
24

Previously Discussed

Kinematic Analysis of Deployable Mechanism



Open Orientation @ 90



Closed Orientation @ 0°

25

Analysis To determine power of motor

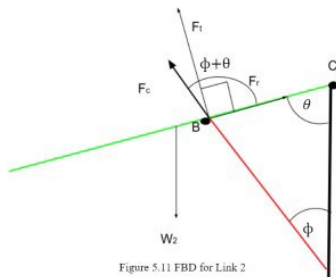
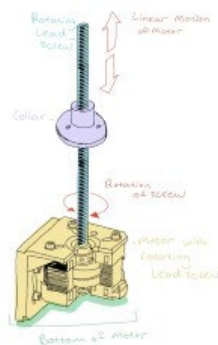


Figure 5.11 FBD for Link 2



26

Analysis To determine power of motor

On Earth	1	2	3	4	5	6	7	8	9
1.18	θ	α	d	F_{LA}	F_t	g	$\dot{\theta}$	$\dot{\phi}$	T_c
Run 1	5	0.1	0	84.47	3.291	9.799	3.533	0.04456	
Run 2	10	0.1	0	83.78	6.34	9.799	7.053	0.04456	
Run 3	15	0.1	0	83.63	9.342	9.799	10.55	0.04456	
Run 4	20	0.1	0	83.63	12.28	9.799	14	0.04456	
Run 5	25	0.1	0	83.73	15.12	9.799	17.39	0.04456	
Run 6	30	0.1	0	83.9	17.84	9.799	20.7	0.04456	
Run 7	35	0.1	0	84.14	20.44	9.799	23.93	0.04456	
Run 8	40	0.1	0	84.46	22.88	9.799	27.03	0.04456	
Run 9	45	0.1	0	84.87	25.14	9.799	30	0.04456	
Run 10	50	0.1	0	85.39	27.22	9.799	32.8	0.04456	
Run 11	55	0.1	0	86.04	29.09	9.799	35.4	0.04456	
Run 12	60	0.1	0	86.86	30.75	9.799	37.76	0.04456	
Run 13	65	0.1	0	87.87	32.17	9.799	39.86	0.04456	
Run 14	70	0.1	0	89.13	33.34	9.799	41.64	0.04456	
Run 15	75	0.1	0	90.7	34.27	9.799	43.08	0.04456	
Run 16	80	0.1	0	92.62	34.93	9.799	44.14	0.04456	
Run 17	85	0.1	0	94.96	35.33	9.799	44.78	0.04456	
Run 18	90	0.1	0	97.8	35.47	9.799	45	0.04456	

27

Motor Force Analysis

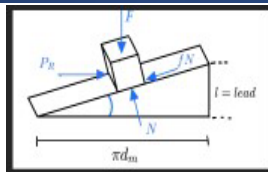


Figure 5.11: Free body diagram of lead screw forces raising the load.

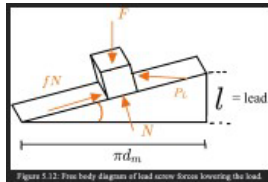


Figure 5.12: Free body diagram of lead screw forces lowering the load.

Mathcad Software - C:\Users\jmurad\Downloads\Senior Design Motor Torque EE

File Edit Search Options Calculator Tables Windows Help Examples

Formulated Equations

Known information

$F = 280$ [N] Force of Load

$\theta = 0.2$ Subtension coefficient

$l = 0.001579$ [m] Lead vertical increase from one rotation

$d_m = 0.007471$ [m] d_m mean diameter

$P = 0.001588$ [m] Pitch

$V = 0.02$ [m/s] Linear velocity

$\lambda = 3.848$ [degrees] Lead angle

$\omega = 2 \cdot \pi \cdot \frac{V}{P}$ Angular velocity

$T_r = \frac{F \cdot d_m}{2} \left[\frac{1 + \theta \cdot \tan(\lambda)}{1 - \theta \cdot \tan(\lambda)} \right]$ Torque required to raise

$T_l = \frac{F \cdot d_m}{2} \left[\frac{1 - \theta \cdot \tan(\lambda)}{1 + \theta \cdot \tan(\lambda)} \right]$ Torque required to lower

$P_r = T_r \cdot \omega$ Power required to raise

$P_l = T_l \cdot \omega$ Power required to lower

Solution

Unit Settings: SI C MPa kJ mass deg

$d_m = 0.007471$ [m] $F = 280$ [N] $\theta = 0.2$

$l = 0.001579$ [m] $\lambda = 3.848$ [degrees] $\omega = 79.58$ [rad/s]

$P = 0.001588$ [m] $P_r = 10.5$ [W] $P_l = 22.55$ [W]

$T_r = 0.137$ [N·m] $T_l = 0.2634$ [N·m] $V = 0.02$ [m/s]

No unit problems were detected.

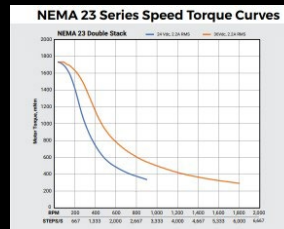
Compilation time = 31 ms Calculation time = 0 ms

28

Lead Screw Assembly - NEMA 23 with RCF



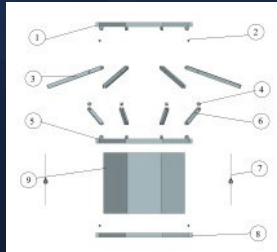
- Permanently fixed screw & motor provides the most accurate alignment possible



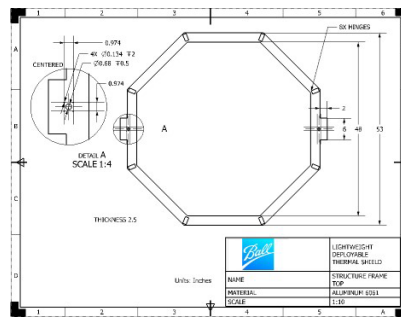
29

CAD Models & Detailed Drawings

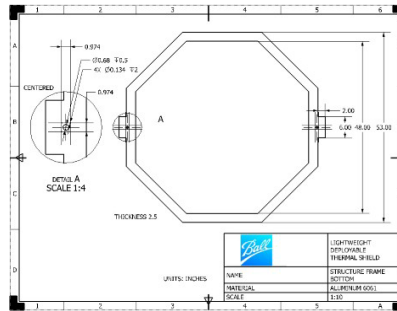
30



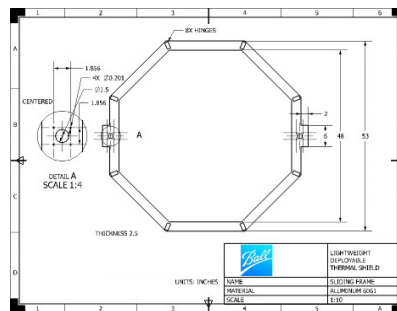
31



Previously Discussed

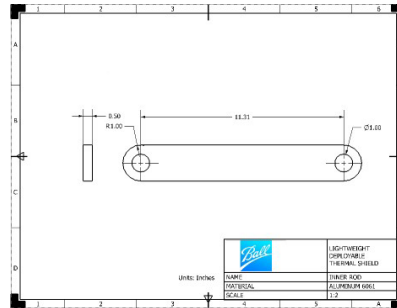
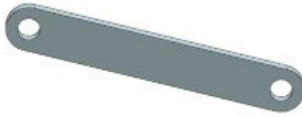


33



34

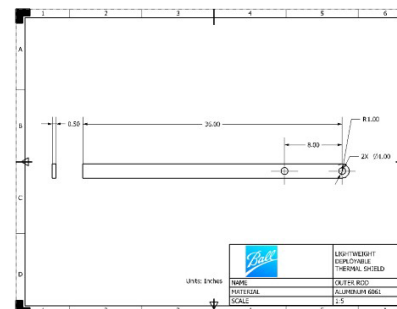
Inner Rod



Previously Discussed

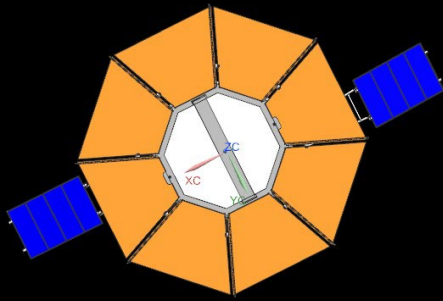
35

Outer Rod

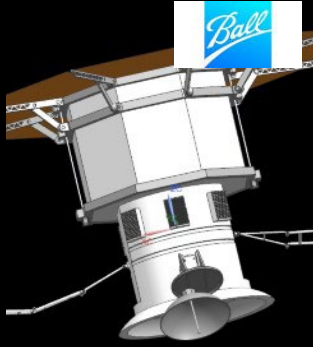


Previously Discussed

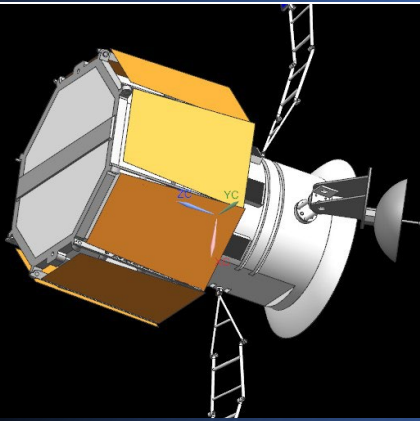
36



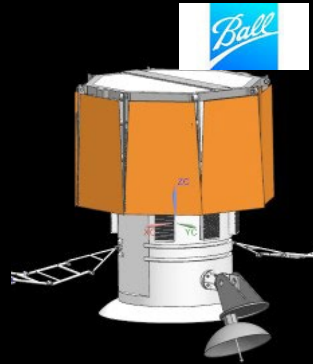
Updated Cad Models



37

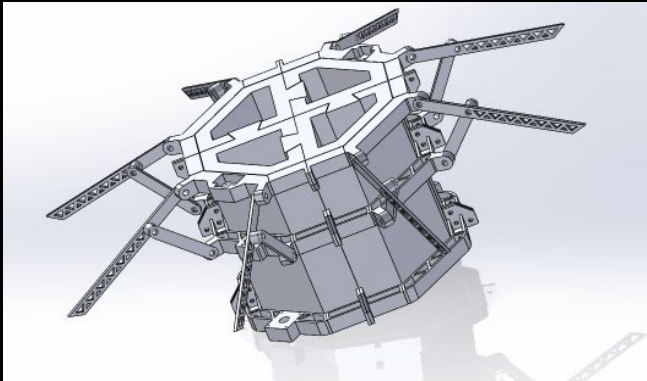


Updated Cad Models



38

What we are printing

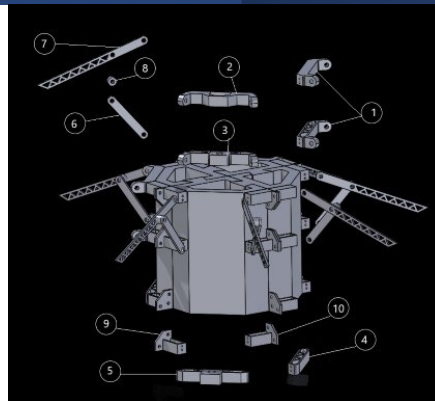


40

Parts List

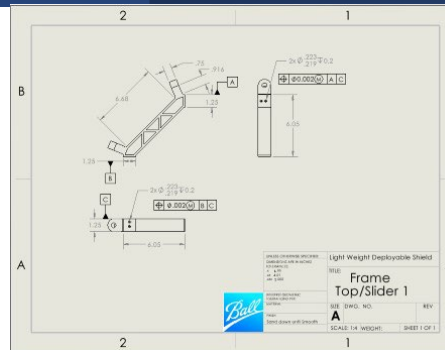
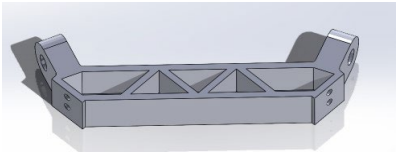


1	Top and Slider Frame	4x
2	Top Frame 2	2x
3	Slider Frame 2	2x
4	Bottom Frame (Part 1)	2x
5	Bottom Frame (Part 2)	2x
6	Inner Rods	8x
7	Outer Rods	8x
8	Spacers	8x
9	Frame Join 1	12x
10	Frame Join 2	12x



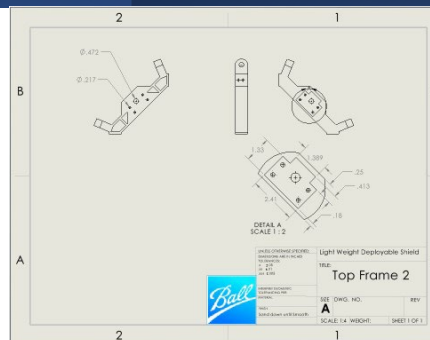
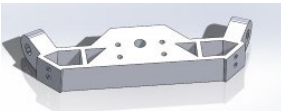
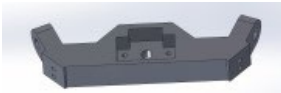
41

Top Frame Part 1



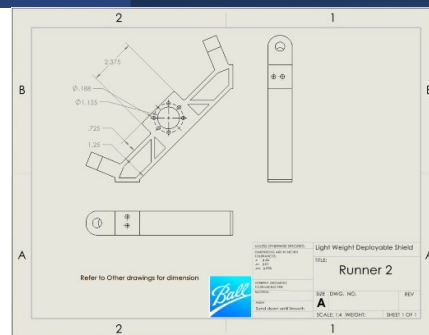
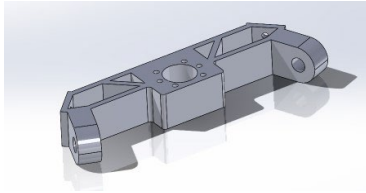
42

Top Frame and Slider



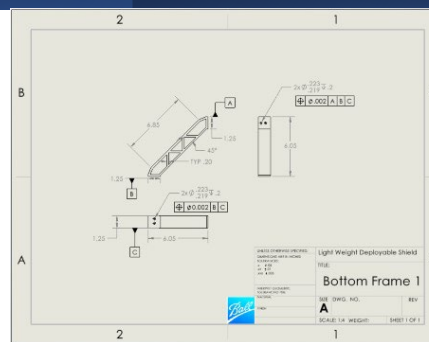
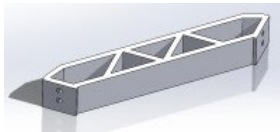
43

Slider Frame 2

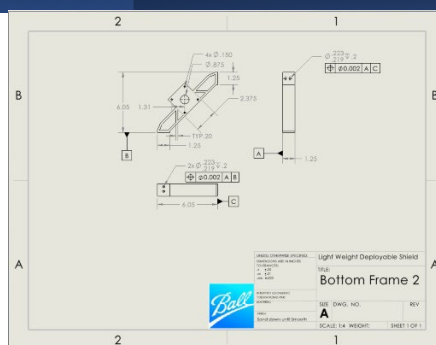
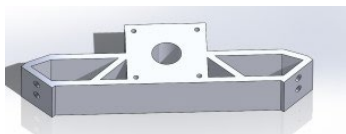


44

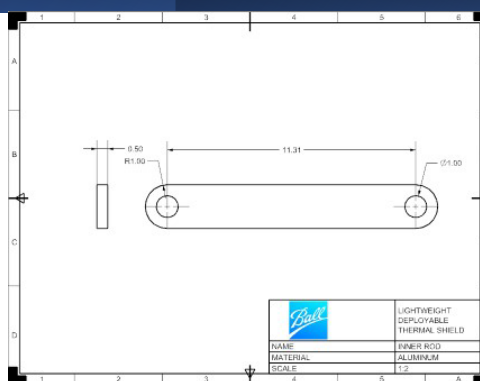
Bottom Frame Part 1



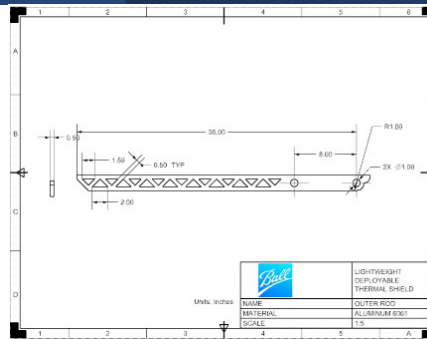
45



46

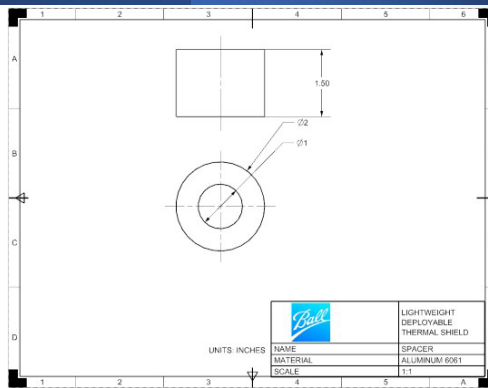


Outer rod

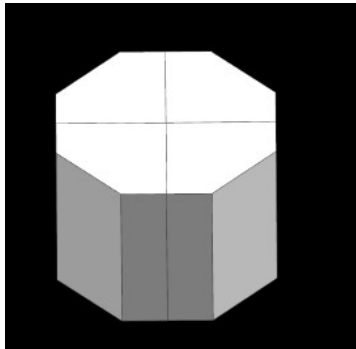


48

Spacer

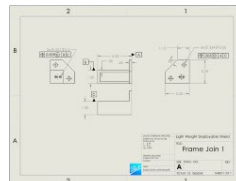
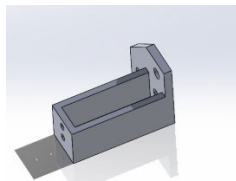
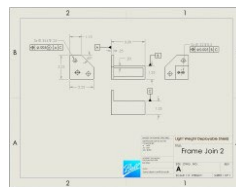
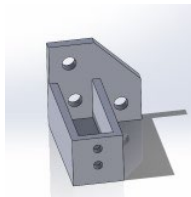


Payload



50

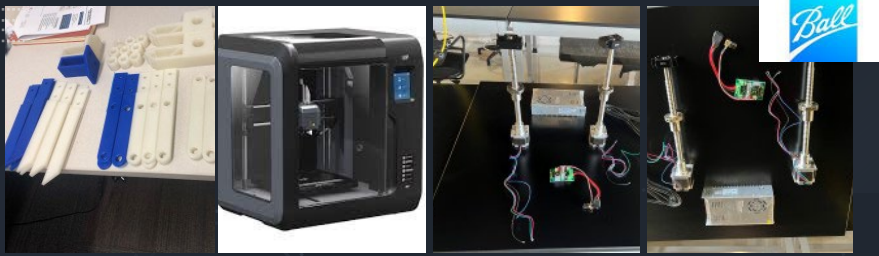
Frame Joins



51

[illegible]

27



Fabrication and Assembly

54

Results and Discussion



Summary of Goals and Objectives

- Minimize mass and size of working device
- Easy Deployment accessibility
- Ability to be controlled remotely
- Cover an arbitrary shape with 4, 6, and 8 sides
- Capable of being stowed or attached to the payload

With the designed structure being built, the operation of the mechanics will proceed into the testing phase. Upon completion will direct the team to the implementation of the Aluminized Kapton

55

Results and Discussion Cont.



Discussion of Completed work

- In the designing of the Lightweight Deployable Thermal shield the group has completed all reports from the Fall and Spring semester from the acceptance of the project and are currently in the building phase.

Summary of Constraints and codes Identified for project

- The American Institute of Aeronautics and Astronautics created the AIAA S114-2005 Requirements Verification matrix which outlines requirements and standards for the building of Moving Mechanical Assemblies (MMAs).

56

Conclusions

& Recommendations



- Currently 3D printing and assembling a lightweight deploya thermal shield to protect a payload from sun exposure in sp
- Using Linear Actuator Stepper motors for motion
- Wiring motors and assembling mechanics for our structure
- Chosen material used for shielding is a substitute for Aluminized Kapton (AK), militarygrade 12micron aluminized polyethylene mylar
- Built a working 3D CAD model that reassures our design
- Chose specific parts to be purchased and assembled

- Access to a current deployable shield to observe and analyze firsthand.
- Faster process for ordering parts through the university
- General idea of what the payload will be so that better ideas for attachment can be created
- Easier access to 3D printers provided by the University or company
- Access to other projects that are not deployable shields but have similar mechanisms and material. Does not have to be the same function.
- Testing equipment to measure the effectiveness of the Aluminized Kapton.
- Enabling a track to the motor path and couplers so that they can take on any deflection from movement due to outside forces.

57