GA Presentation 3

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Project Description

Design a test fixture that attaches a 12U CubeSat to a spherical air bearing

Fixture must align the center of gravity with the center of rotation of the bearing

The intention is to design a test mount fixture for GA to use for testing their satellite

Design Description

- Currently in prototyping stage
- Functions
  - Fixture relocates center of gravity using the X, Y, and Z axis adjustments
  - X and Y axis move the mass of the CubeSat horizontally
  - Z axis moves the masses of weights vertically
  - Shifting these masses alters the location of the center of gravity balancing the fixture CubeSat assembly

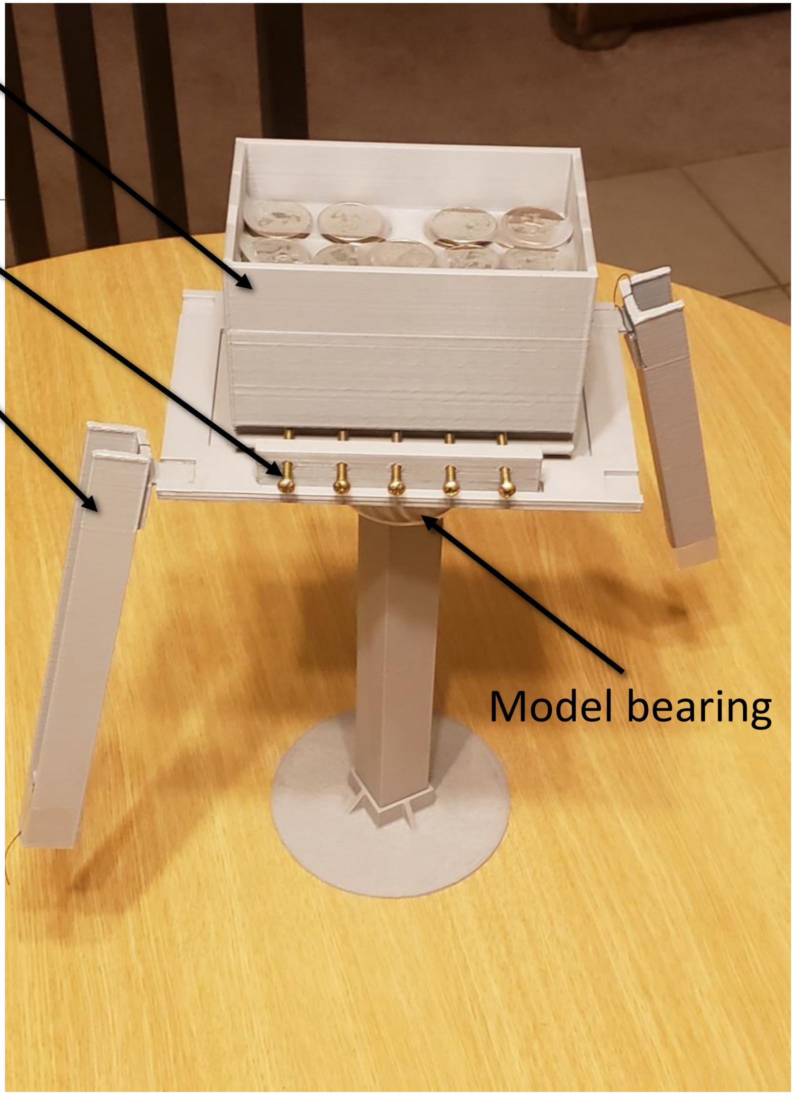

Figure 1: 3D printed Prototype Model

Design Requirements

- Important Customer Requirements
  1. CubeSat-fixture assembly is secure
  2. Adjustable position of center of gravity
  3. Lightweight
  4. Allows rotation and tilt of CubeSat

- Seen in Figure 2, requirements 1, 2 and 3 are satisfied
- Seen in Figure 3, requirement 4 is satisfied

Figure 2: CubeSat Clamps and Adjustments

Figure 3: Model Bearing

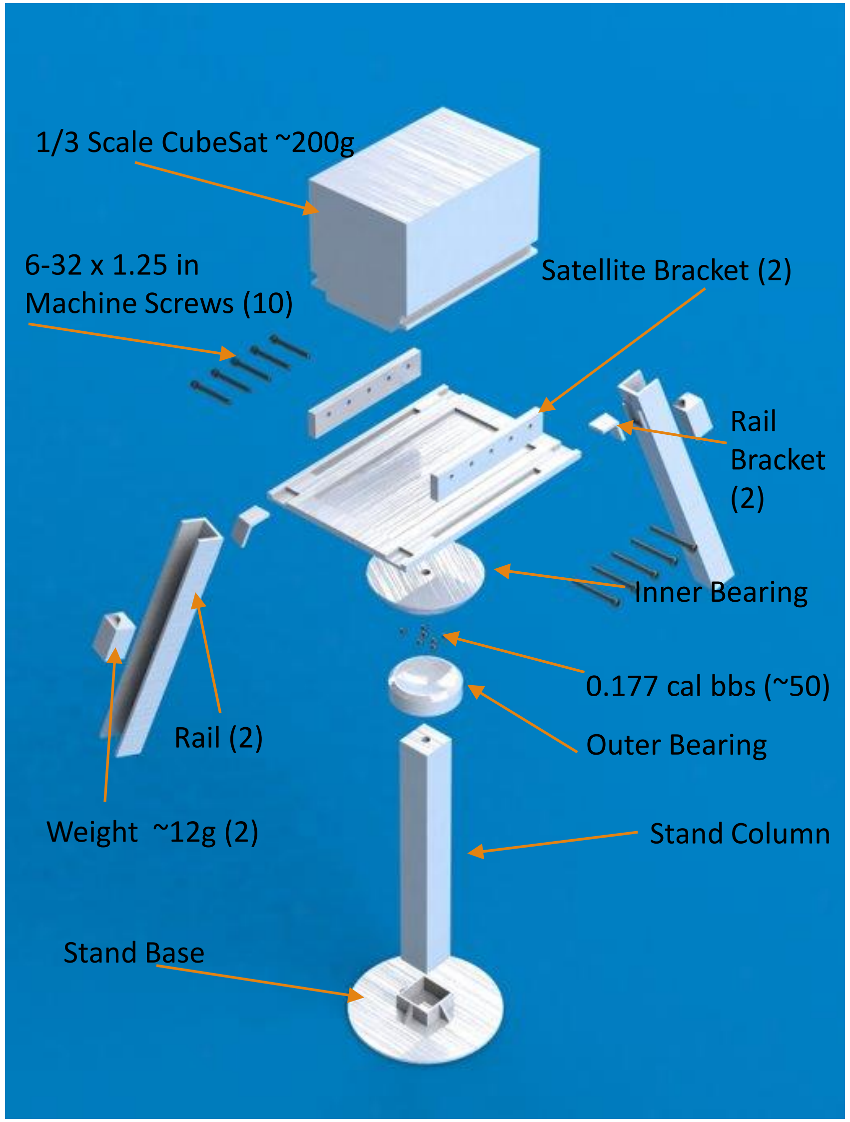

Figure 4: Exploded View of CAD Model

CAD (prototype)

- The full concept is too complicated to be tested at this point and several subsystems are being discussed and analyzed separately for the individual analysis assignment, so redesigns are still possible.
- To help test some of the subsystems before constructing the full thing, a 1/3 scale model was designed.
- This was intended to be primarily 3D printed with the use of machine screws to adjust the CubeSat location and 0.177 cal bbs as a scale replacement for ball bearings to replicate the functionality of a spherical air bearing.


Figure 5: Finished Prototype

Prototype

1/3 Scale

Objectives:

- Rough estimate of bearing effectiveness
  - Surprisingly smooth, rotates easily and freely
- Identify potential issues, conflicts
  - Rails must be shorter or angled to allow range of motion
- Assess importance of automation
  - Manual adjustment is tedious and difficult to set up, automation is strongly preferred

https://www.youtube.com/watch?v=GiU3P0_KwF4

(video is roughly 1.5 min. long)

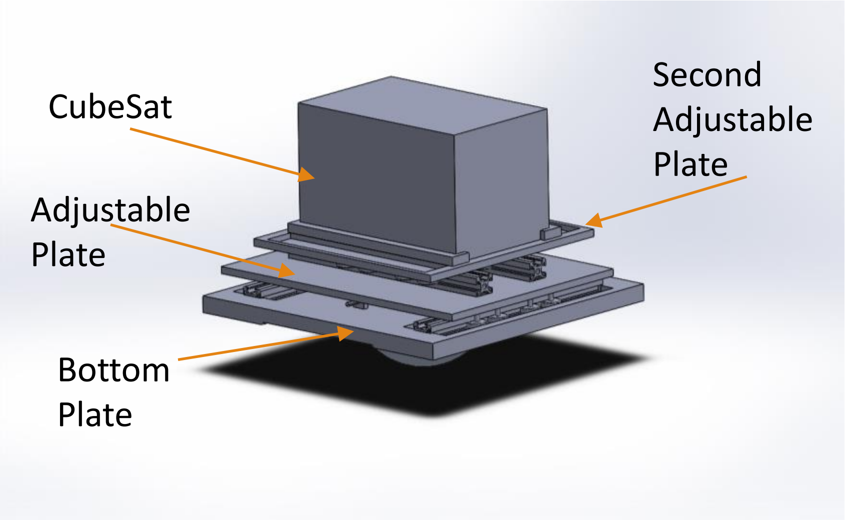

Figure 6: Isometric View

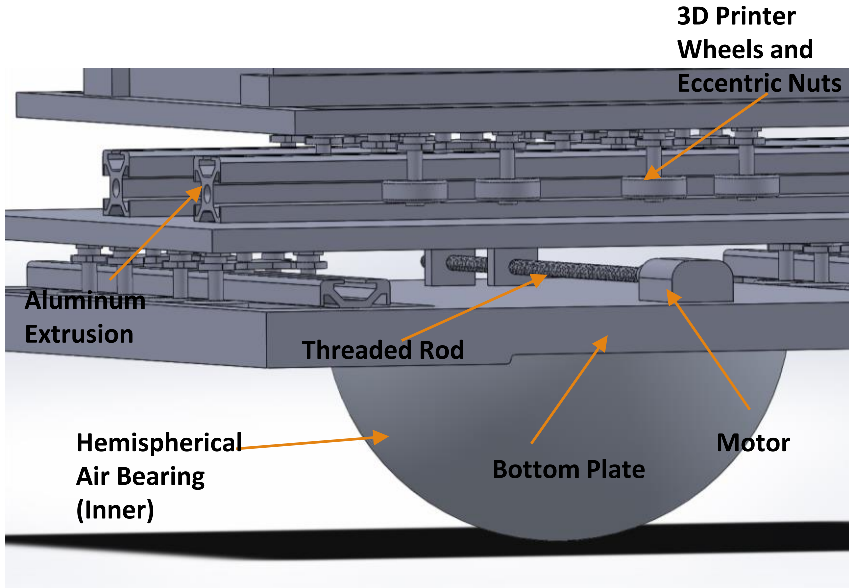

Figure 7: Side View

CAD (Updated)

- After testing the prototype, additional work has been done on the CAD model based on the efficacy of the results.
- The current iteration is still incomplete and is waiting on the decision to either use the worm gear setup or lead screws.
- It is our intention to imitate the way that a 3D printer shifts the bed around layered twice to allow movement in both the x and z directions.
- This will allow for further movement than the original CAD model in these directions and the use of automation to lessen the effort to align the CubeSat properly.
- Significant redesigns are planned to lower the CubeSat location and optimize placement of key parts as well as cutting weight wherever possible.

Subsystem	Component	Specifications	Manufactured or purchased?	Qty	Units	Cost /ea.	Cost
Test platform	Outer bearing surface	CNC aluminum, 5"x5"x3"	Mfg.	1		$300.00	$ 300.00
	Inner bearing surface	CNC aluminum, 8"x8"x3"	Mfg.	1		$150.00	$ 150.00
	Ball bearings	Stainless, 6mm, packs of 50	Purch.	4	pack (x50)	$12.03	$ 48.12
	Pedestal base	3/4"x36"x36" Plywood	Mfg.	1	sheet	$20.00	$ 20.00
	Pedestal post	2x4x8'	Mfg.	2			
						Subtotal	**$ 518.12**
Safety system	Cable	Braided steel, 6mm	Purch.	10	ft.	$1.00	$ 10.00
	Ferrules	Aluminum, 6mm	Purch.	10		$0.10	$ 1.00
	Hooks	2", screw thread	Purch.	2		$5.00	$ 10.00
	Swivel hook	2", D-ring	Purch.	2		$5.00	$ 10.00
	Square tubing	Extruded aluminum, 25mmx25mm	Purch.	8	ft.		
						Subtotal	**$ 31.00**
Fixture assembly	Platform	Garolite/other, 12"x24"x1/2"	Mfg.	1	sheet	$ 50.00	$ 50.00
	Satellite clamps	Milled aluminum	Mfg.	6		$ 20.00	$ 120.00
	Rails	2"x2"x8'	Purch.	4		$ 20.00	$ 80.00
	Weights	Brass, 2"x2"x4"	Mfg.	4		$ 100.00	$ 400.00
	Motors	Induction, ~10W?	Purch.	4		$ 40.00	$ 160.00
	Microcontroller	Arduino Mega?	Purch.	1		$ 20.00	$ 20.00
	Motor controllers	Relays? H-bridges? Dedicated controller?	Purch.	4		$ 10.00	$ 40.00
	Sensors	Tilt sensors? Force transducers?	Purch.	4		$ 10.00	$ 40.00
						Subtotal	**$ 870.00**
Option: Gear train	Worm gear	Mod. 1, 20deg PA, 18mm length	Purch.	2		$ 50.00	$ 100.00
	Spur gear	Mod. 1, 20deg PA, 60mm PD.	Purch.	2		$ 50.00	$ 100.00
	Gear rack	Mod. 1, 100mm length	Purch.	2		$ 20.00	$ 40.00
	Shafts	(6) 8mmx100mm, keyed	Mfg.	1	(1m length)	$ 50.00	$ 50.00
	Keys	2mmx2mmx10mm	Purch.	1	pack (x10)	$ 10.00	$ 10.00
	Gear case	CNC aluminum, 3"x6"x2"?	Mfg.	2		$ 100.00	$ 200.00
	Bushings	Oilite/similar	Purch.	12		$ 1.00	$ 12.00
						Subtotal	**$ 512.00**
Option: Lead screw	Lead screws	1/4"-16 ACME thread	Purch.	1	(6' length)	$ 20.00	$ 20.00
	Lead screw nuts	1/4"-16 ACME int. thread	Purch.	4		$ 15.00	$ 60.00
	Shaft supports	5/8" ID	Mfg.	4		$ 15.00	$ 60.00
	Linear rods	3/8" dia., steel	Purch.	1	(4' length)	$ 30.00	$ 30.00
	Linear bearings	3/8"x5/8"x7/8", PTFE	Purch.	8		$ 15.00	$ 120.00
						Subtotal	**$ 290.00**
						Total	**$ 1,820.12**
						Budget	$ 8,000.00
						Budget remaining	$ 6,179.88

Table 1: Bill Of Materials

BOM

FMEA – Lead Screws

Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Sev. (S)	Potential Causes and Mechanisms of Failure	Occ. (O)	Current Design Controls Test	Det. (D)	RPN	Recommended Action
Base plate	Fracture/excessive deformation, fatigue	Satellite crash	8	Failure to analyze base design moment of area, Young's mod.	4	FEA, test loading	2	64	Stronger, stiffer material, more substantial thickness
In. bear. fasteners	Fracture/yield	Satellite crash	8	Failure to analyze internal stresses	2	Int. stress calcs, testing	1	16	Increase fastener diameter
Motors	Insufficient power, excessive EMF	Failure to reposition, interferes with measurements	7	Improper power analysis, EMF analysis	5	Test with dummy satellite	2	70	Increase motor power output
Lead screws	Flexing, not self-locking	Insufficient locational accuracy	6	Improper lead screw angle	4	Test with dummy satellite	2	48	Change lead angle, switch to worm gear
Lead screw nuts	Not self-locking	Insufficient locational accuracy	6	Improper lead screw angle	4	Test with dummy satellite	2	48	More substantial, switch to worm gear
Guide rods	Flexing	Insufficient locational accuracy	6	Insufficient force, dynamics analysis	5	Test with dummy satellite	3	90	Increase diameter, use additional guide rods
Guide rod bearings	Excessive friction	Insufficient locational accuracy, excessive power required	6	Poor bearing quality, allowing debris into bearings	2	Test with dummy satellite	2	24	Use higher-quality bearings, implement better bearing seals
Satellite clamps	Fracture/yield, fatigue	Satellite crash	8	Failure to analyse internal stresses	3	FEA, test with dummy satellite	3	72	Increase thickness, change materials
Safety harness	Detaches from base	Satellite crash	8	Attachment points insufficient	3	Force analysis, test with dummy satellite	3	72	Improve attachment points
Safety cable	Snaps	Satellite crash	8	Tensile strength insufficient	1	Force analysis, test with dummy satellite	1	8	Increase diameter, number of strands
Weight rails	Excessive friction, insufficient length	Insufficient locational accuracy	6	Failure to analyze dynamics, CG, moment of inertia	3	Test with dummy satellite	2	36	Improve tolerances, surface finish, increase length
Weights	Insufficient to adjust CG	Insufficient locational accuracy	6	Failure to analyze dynamics, CG, moment of inertia	2	Test with dummy satellite	2	24	Increase mass

Table 2: FMEA Lead Screw

FMEA - Gears

Part	Failure Mode	Potential Causes	Potential Impact	S	O	Current Design Controls Test	D	Risk Level	Recommended Action
Pinion	Bending Fatigue	Time and Stress	Bent Rod/Crack Propogation	8	1	Stress Calculations	1	8	Increase Diameter
Pinion	Pitching	Time and Stress	Slipping	7	4	Test Surface Hardness	3	84	Avoid Sudden/High Stress
Pinion	Scores	Imperfect meshing or Lack of Tolerance	Dislodged Gear/Critical Failure	9	3	Surface Coating Analysis	2	54	Improved Tolerances/Dilligence
Pinion	Wear	Time	Lack of Precision	5	5	Precision Testing	1	25	Replacement
Gear	Bending Fatigue	Time and Stress	Bent Threading/Crack Propogation	8	1	Stress Calculations	2	16	Replacement
Gear	Pitching	Time and Stress	Jams Gears	7	4	Test Surface Hardness	3	84	Avoid Sudden/High Stress
Gear	Scores	Imperfect meshing or Lack of Tolerance	Dislodged Gear/Critical Failure	9	3	Surface Coating Analysis	2	54	Improved Tolerances/Dilligence
Gear	Wear	Time	Lack of Precision	5	5	Precision Testing	1	25	Replacement

Table 3: FMEA Worm Gear

Testing Procedures

Testing Procedures			
Part # and Functions	**Potential Failure Mode**	**Procedures**	**Required Equipment**
Base plate	Fracture/excessive deformation, fatigue	Apply torsion force to base plate using cantilever and weights to record deformation and force for analysis	Steel cantilever beam, weights, ruler, wire/cable
In. bear. fasteners	Fracture/yield	Calculate the weight of assembly to compare to bolt ratings	N/A
Motors	Insufficient power, excessive EMF	Determine required torque and power needed then create dyno using a pony brake for testing	Pony Brake, tachometer
Lead screws	Flexing, not self-locking	Set lead screw into a cantilever position then apply force using weights and record deformation and force	Weights, wire/cable
Lead screw nuts	Not self-locking	Apply force to lead screw nut using hanging weights then observe for movement	Weights, wire/cable, ruler
Guide rods	Flexing	Set guide rod into a cantilever position then apply force using weights and record deformation and force	Weights, wire/cable, ruler
Guide rod bearings	Excessive friction	Move CubeSat on rods for multiple cycles to test for binding	N/A
Satellite clamps	Fracture/yield, fatigue	Determine mass of CubeSat and friction coefficient of clamps to determine minimum required force of clamps	N/A
Safety harness	Detaches from base	Drop assembly with harness attached and asses damage	Space
Safety cable	Snaps	Drop weight that is heavier than assembly and asses damage	Weight, cable, space
Weight rails	Excessive friction, insufficient length	Move weight through rail for multiple cycles to test for binding	N/A
Weights	Insufficient to adjust CG	Test for minimum and maximum weight to accurately adjust CG loaction	Weights, scale

Table 4: Testing Procedures

Schedule

- Working On: Individual Analysis, Final B.O.M. and C.A.D. Model, Website, and Final Report
- Anticipated Work: Final Prototype
- Summer Work: General Research, Problem Solving, and Prototyping
- Future Work: 2 additional prototypes before completing the final build

Gantt Chart

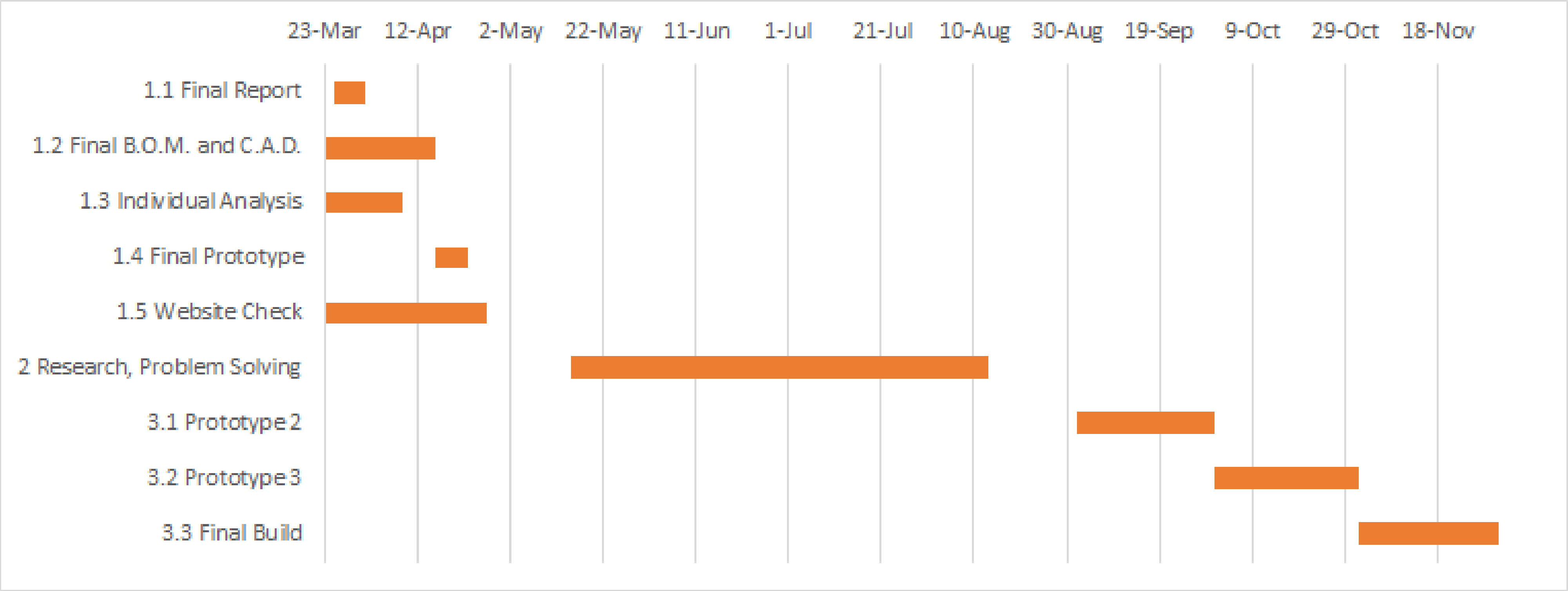

Table 8: Gantt Chart

Budget

Total Budget: $8,000

Cost of Model: $38.18

- Filament: $22
- Bbs: $8.72
- Superglue and Machine Screws: $7.46

Current Budget: $7,961.82

Anticipated Budget: $6,419.12

- Test Platform: $518.12
- Safety System: $31.00
- Fixture Assembly: $870
- Additional Prototypes and Repairs: $2,000
- Final Design: $1,000
- GA University Symposium: $2,000

Final Anticipated Balance: $1,542.70

Questions