Preliminary Presentation: General Atomics CubeSat Bearing Mount Fixture

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Project Description

- The Team must create a fixture to connect a 12U CubeSat to a spherical air bearing
  - *Support a maximum of 26 kg*
  - *Capable of adjusting in all the dimensions*
  - *Use nonmagnetic materials*
- The Client is General Atomics
  - *Based in San Diego, CA*
  - *Operates in a wide range of fields for innovative technology*
- CubeSats are used to demonstrate space technology and present new innovative ideas
  - *Allowing these to become operational will push human knowledge and achievement*

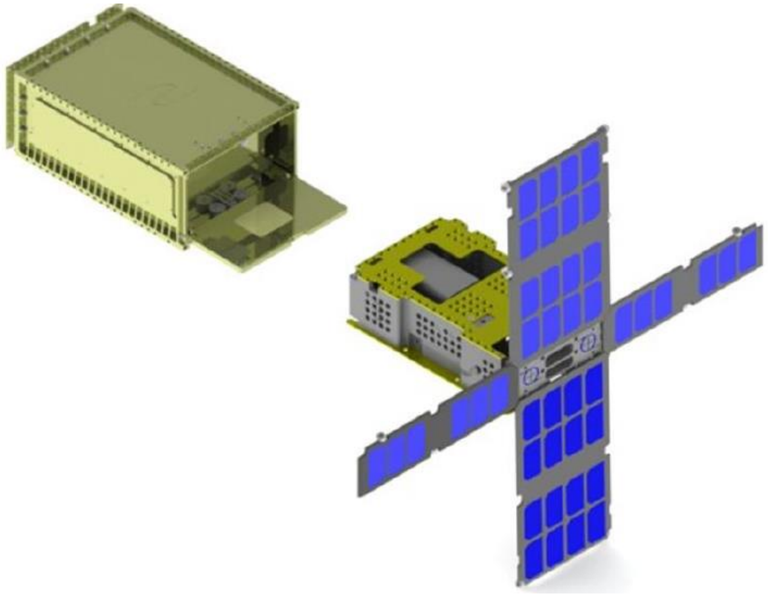


Figure 1: 6U CSD and CubeSat
Source: [1]

Background and Benchmarking

- NASA's twin Gravity Recovery and Climate Experiment Satellites (GRACE) were used to measure gravitational field values in orbit of the Earth.
    - *Through use of accelerometers, these satellites used a tool called a Center of Mass Trim Assembly (MTA) to adjust the center of mass of the satellite during flight [3]*
- Several systems not inherently designed for this purpose can be used to accomplish the same goal with some slight modification.

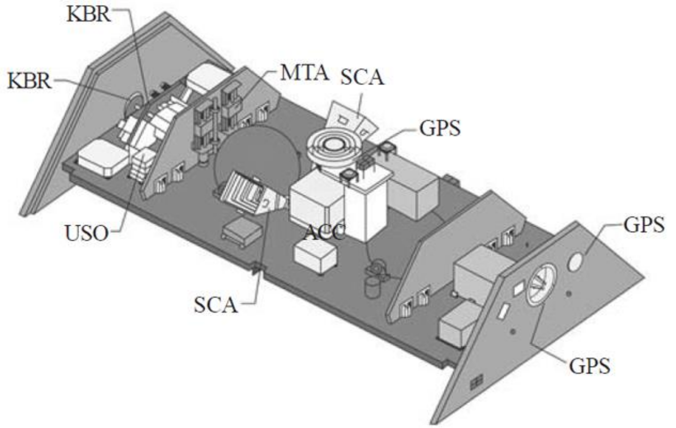


Figure 1: NASA GRACE system
Source: [2]

Background and Benchmarking

- The previous Capstone group's design was completed in 2020.
  - *The design uses threaded rods with weights attached to relocate the center of gravity as is necessary.*
  - *The system is controlled externally though Arduinos and pneumatic motors to avoid any unnecessary electromagnetic field generation.*
  - *GA wants this design to be modified and improved upon.*

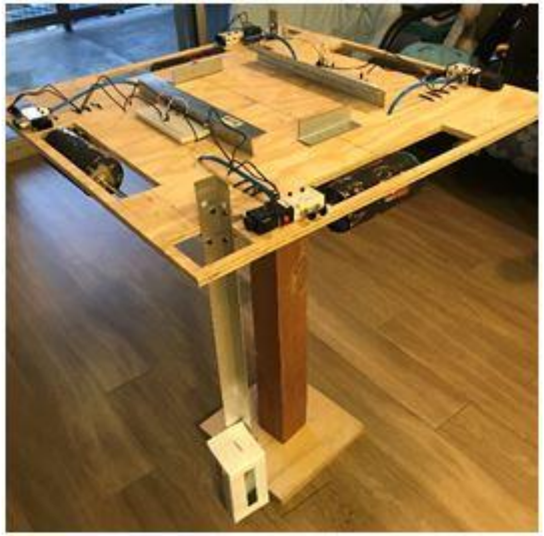


Figure 2: Previous group's design
Source: [4]

Literature Review – Existing Designs (Travis)

- F. Wang, "Study on center of mass calibration and K -band ranging system calibration of the GRACE mission," Ph.D. dissertation. The University of Texas at Austin, Austin, TX, 2003.
  - *Studies the use of the calibration tools and center of gravity displacement on the NASA GRACE satellites. This source will be used as a comparison for our design to one that successful.*
- D. Modenini, G. Curzi, and P. Tortora, "Experimental Verification of a Simple Method for Accurate Center of Gravity Determination of Small Satellite Platforms", *International Journal of Aerospace Engineering,* vol. 2018, Article ID 3582508, 10 pages, 2018. https://doi.org/10.1155/2018/3582508.
  - *Discusses options for accurately determining the center of gravity of a satellite platform with experimental confirmation. This method can be adapted to our design to achieve the same goal and have an accurate center of gravity location for any scenario the satellite could encounter.*
- G.A. CubeSat Team, NAU ME Capstone, 2020. [Online]. Available: https://www.ceias.nau.edu/capstone/projects/ME/2020/20Spr2_GACubesat/ [Accessed January 30, 2021].
  - *The previous group for this capstone project produced a design that uses threaded rods attached to pneumatic motors that shift weights around. There are inherent flaws to this method and design, but it is a good starting place for future designs to build from.*

Literature Review –Dynamics (Connor)

- F. Costanzo, M. E. Plesha, and G. L. Gray, *Engineering mechanics: statics & dynamics*. New York, NY: McGraw-Hill, 2013.
    - *Standard textbook regarding the analysis and implementation of statics and dynamics. Will be utilized for the design of dynamic systems of the CubeSat fixture.*
- R. G. Budynas, J. K. Nisbett, and J. E. Shigley, *Shigley's mechanical engineering design*. Boston: McGraw-Hill, 2019.
    - *Standard textbook regarding mechanical design of parts and assemblies. Will be utilized for the manufacture of the CubeSat fixture.*
- Ross, C. T. F. *Dynamics of Mechanical Systems*. 1997. Horwood Engineering Science Ser. Web.
    - *Outlines basic principles of dynamics within mechanical systems. This will be used to review and analyze the dynamics of the CubeSat fixture.*

Literature Review – CubeSats (Sean)

- *CubeSat 101: Basic Concepts and Processes for First-Time CubeSat Developers*, NASA, Washington, DC, 2017.
  - *NASA's introductory guide to CubeSats and associated requirements and procedures. This gives the team some background to CubeSats and provides information regarding launch requirements and testing procedures. While the team is not performing the tests or designing the CubeSat itself, the requirements thereof will motivate the design of the bearing mount to permit the client to design and test the satellite with sufficient precision and accuracy.*
- *Payload Specification for 3U, 6U and 12U*, rev. 2002367F, Planetary Syst. Corporation, Silver Spring, MD, 2018.
  - *Provides specifications for 3U, 6U, and 12U CubeSats to be launched and deployed from CSDs. This document includes dimensions of standard 12U satellite mounting rails, which the bearing mount must mate with to retain the satellite during use. It also provides specifications for maximum envelopes for satellite center of mass and geometry, keep-out zones, and mass.*
- J. Li, M. Post, T. Wright, and R. Lee, "Design of Attitude Control Systems for CubeSat-Class Nanosatellite," *Journal of Control Science and Engineering*, vol. 2013, Apr. 2013, Art. No. 657182, doi: 10.1155/2013/657182.
  - *Describes the design and implementation of torque rods and reaction wheels used to reorient satellites, as well as testing these devices on air-bearing stands. This informs the design of the bearing mount regarding maximum applied torque and rotational speed.*

Literature Review –Electromagnetic Fields (Scott)

- A. M. Helmenstine, "10 Examples of Electrical Conductors and Insulators," *ThoughtCo*. [Online]. Available: https://www.thoughtco.com/examples-of-electrical-conductors-and-insulators-608315. [Accessed: 31-Jan-2021].

  - *This is a list of 10 conductors and insulators. The client has asked the team to reduce the amount of electromagnetic interference. In order to have a field, electricity needs to be able to run through it. By making sure the materials used do not conduct electricity, the interference can be reduced to zero.*

- R. E. Collin, *Field theory of guided waves*. New York: IEEE Press, 1991.

  - *This is a comprehensive textbook about electromagnetic fields. It will answer most if not all of the questions we have about this particular subject.*

- R. Serway, *College Physics, 11E, Global Edition*. Cengage Learning Custom P, 2017.

  - *This is an introductory textbook for physics. It has an introduction to electromagnetic fields. Using this it will allow the team to use and understand Field Theory of Guiding Waves.*

Customer and Engineering Requirements

- Clients are engineers, so some CRs were already in the form of ERs
  - *"The fixture will be limited to 35 degrees of tilt for 360 degrees of rotation from the normal axis."*
- Others lend themselves naturally to ERs
  - *"The fixture weight should be minimized."*

Customer and Engineering Requirements

Customer Requirement
1. Reliable
2. Durable
3. Securely mate with CubeSat rails
4. CubeSat position adjustable
5. Fixture remains securely on stand
6. As lightweight as possible
7. Easy CubeSat installation, removal
8. Retains CubeSat securely
9. Allows rotation, tilt of CubeSat
10. All components nonmagnetic
11. Mount securely mates with bearing
12. Minimize mount's effect on CubeSat dynamics
13. STRETCH GOAL - Adaptable to 3U, 6U

Engineering Requirements	Units
1. Reliability of components (↑)	%
2. Endures typ. wear for multiple uses (↑)	Cycles
3. Mount fixture dims. compatible with rails (*)	mm
4. CubeSat position adjustable in 3 axes (↑)	mm
5. CG of mount must be at/below bearing CR (↓)	mm
6. Minimize weight of mount assembly (↓)	N
7. Reduce time, tools needed for CubeSat install (↓)	mins, #
8. Maximize force needed to dislodge CubeSat (↑)	N
9. Range of motion of mount (*)	deg
10. Minimize magnetic flux of components (↓)	µT
11. Bearing mount dims. compatible with bearing dims. (*)	mm
12. Minimize mount's moment of inertia	$kg*mm^2$
13. CubeSat mount fixtures compatible w/ 3U,6U dims. (*)	mm

HoQ

House of Quality (HoQ)	General Atomics CubeSat Bearing Mount	ME-476C-001, Spring 2021	1/30/2021

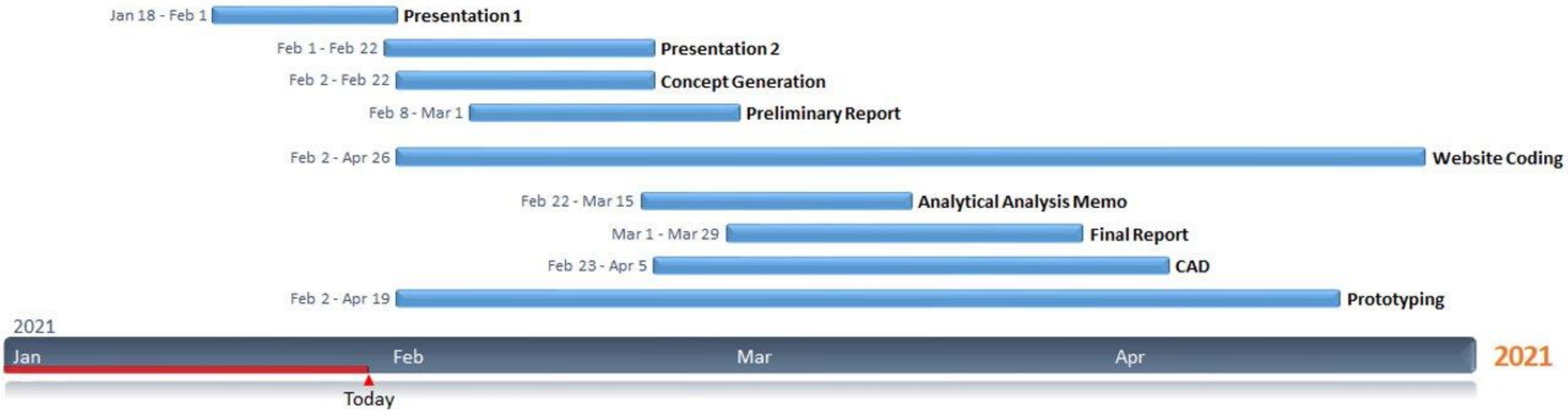
Engineering Requirements	Units	Interaction of Engineering Requirements *												
1. Reliability (↑)	%													
2. Endures typ. wear for multiple uses (↑)	Cycles	++												
3. Mount fixture dims. compatible with rails (*)	mm	++	++											
4. CubeSat position adjustable in 3 axes (↑)	mm	-	-											
5. CG of mount must be at/below bearing CR (↓)	mm				-									
6. Minimize weight of mount assembly (↓)	N	-	-		--	+								
7. Reduce time, tools needed for CubeSat install (↓)	min, count	-	-	+	--		++							
8. Maximize force needed to dislodge CubeSat (↑)	N	+	+	+	-		-	-						
9. Range of motion of mount (*)	° tilt, rot.	++												
10. Minimize magnetic flux of components (↓)	μT	+												
11. Bearing mount dims. compatible with bearing dims. (*)	mm	+	+							++				
12. Minimize mount's moment of inertia	kg*mm^2	-	-	-	-	+	++	+	-					
13. CubeSat mount fixtures compatible w/ 3U,6U dims. (*)	mm	-	-	-	-	+		-	-					

Customer Requirement	Weight	ER #1	ER #2	ER #3	ER #4	ER #5	ER #6	ER #7	ER #8	ER #9	ER #10	ER #11	ER #12	ER #13
1. Reliable	3	5	5	5	3		1	1	5			3	1	1
2. Durable	3	5	5	5	3	3	3	3	5			5	3	
3. Securely mate with CubeSat rails	5	5	5	5	3		1	3	1				1	1
4. CubeSat position adjustable	4	1	3	3	5	3	5	5	1				1	1
5. Fixture remains securely on stand	4		3			5	3	1					3	3
6. As lightweight as possible	3	3	3	1	3	1	5	1	1				5	3
7. Easy CubeSat installation, removal	2	1	3	5	3		1	5	3				1	3
8. Retains CubeSat securely	5	5	5	5	3	1	1	3	5				1	3
9. Allows rotation, tilt of CubeSat	3	5								5		5		
10. All components nonmagnetic	3	3				1	1				5			
11. Mount securely mates with bearing	5	3	5			1	1		1	1		5	1	
12. Minimize mount's effect on CubeSat dynamics	4	1	1	1	5	5	5	1	3			1	5	1
13. STRETCH GOAL - Adaptable to 3U, 6U	1	1		3	3		3	5					3	5
Absolute Technical Importance (ATI)		139	148	112	106	77	102	88	90	20	15	68	83	63
Relative Technical Importance (RTI)		**12.5%**	**13.3%**	**10.1%**	**9.5%**	**6.9%**	**9.2%**	**7.9%**	**8.1%**	**1.8%**	**1.4%**	**6.1%**	**7.5%**	**5.7%**
Ranked Technical Importance		**2**	**1**	**3**	**4**	**9**	**5**	**7**	**6**	**12**	**13**	**10**	**8**	**11**
Target ER values		>99%	>10,000	*Per dwg.*	=50mm	<0mm	<500N	<3mins, 3 tools	<100N	=35° tilt, 360° rot.	<10μT total	*Per dwg.*	<40,000 kg*mm^4	*Per dwg.*
Tolerances of Ers		±1%	±1,000	*Per dwg.*	±1mm	+1mm	±10N	±30s	±10N	±1°	±1μT	*Per dwg.*	±1,000 kg*mm^4	*Per dwg.*

Schedule and Budget

- Currently on Schedule
- Budget
  - *Currently stands at $8,000 with the option for increased funds*
- Expected Expenses
  - *Estimated to be around $2,000 – $5,000*
- Budget Utilization
  - *Potentially; Arduinos, 3D filament, Specialty parts/tools, Measurement equipment, Basic hardware, etc.*

Gantt Chart



Jan 18 - Feb 1
Presentation 1
Feb 1 - Feb 22
Presentation 2
Feb 2 - Feb 22
Concept Generation
Feb 8 - Mar 1
Preliminary Report
Feb 2 - Apr 26
Website Coding
Feb 22 - Mar 15
Analytical Analysis Memo
Mar 1 - Mar 29
Final Report
Feb 23 - Apr 5
CAD
Feb 2 - Apr 19
Prototyping
2021
Jan
Feb
Mar
Apr
2021
Today

References

- [1] *Payload Specification for 3U, 6U and 12U*, rev. 2002367F, Planetary Syst. Corporation, Silver Spring, MD, 2018.
- [2] Spacecraft, NASA, February 15, 2012. [Online]. Available: https://www.nasa.gov/mission_pages/Grace/spacecraft/index.html [Accessed January 30, 2021].
- [3] F. Wang, “Study on center of mass calibration and K -band ranging system calibration of the GRACE mission,” Ph.D. dissertation. The University of Texas at Austin, Austin, TX, 2003.
- [4] G.A. CubeSat Team, NAU ME Capstone, 2020. [Online]. Available: https://www.ceias.nau.edu/capstone/projects/ME/2020/20Spr2_GACubesat/ [Accessed January 30, 2021].