Jaxon Liebeck
Engineering Portfolio (CV)

BS. in Aerospace Engineering (Dec 2021)

Cert. in Computational Science and Engineering (Dec 2021)

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(512) 808 8006

Design Experience

Program Knowledge

Solidworks
AutoCAD
OpenRocket
Structural analysis
Finite Element Analysis

Skills

Drawing
Drafting
Measuring
Manufacturing
Dimensional Analysis

Internship Experience

Mining Engineering (Summer 2017, 2018)

Reverse Designing of Gas Turbines (COVID cancelled, Summer 2020)

Extracurricular Activities

Longhorn Rocketry Association

Texas Spacecraft Laboratory

Relevant Coursework

Solidworks Design

Physics: Mechanical

Electromechanical Systems Lab

Low Speed Aerodynamics Lab

Strength of Materials Lab

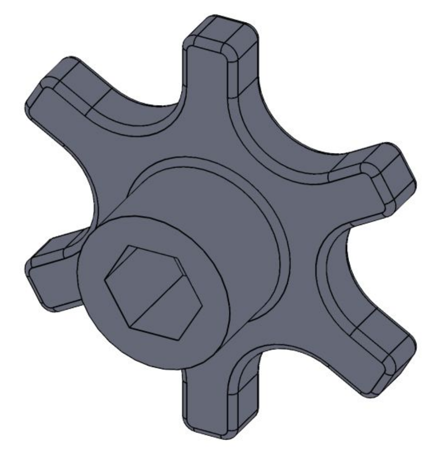
Applied Thermodynamics

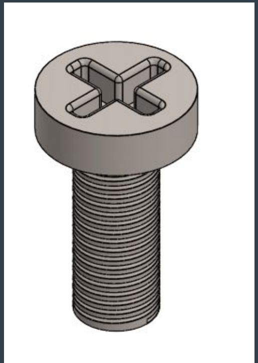
Space Systems Design & Lab

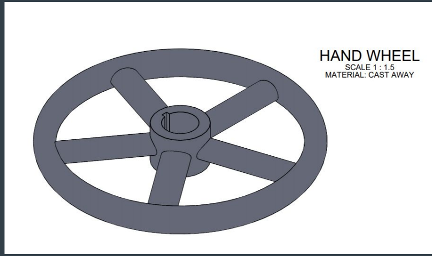
Computational Methods for Structural Analysis

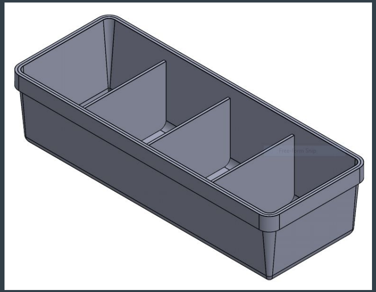
Manufacturing Parts

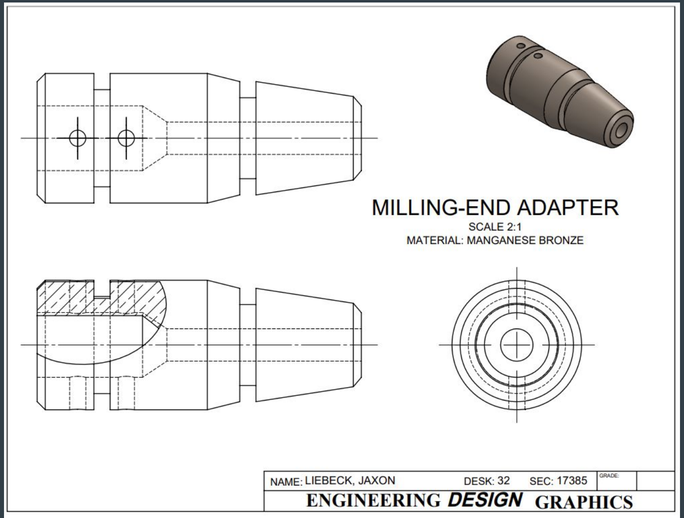
I was first introduced to Solidworks in sophomore year of college. I decided to design a range of parts and pieces to learn as seen on the slide. This included measuring, drafting and then designing. Most of these were small simple designs useful for manufacturing processes.





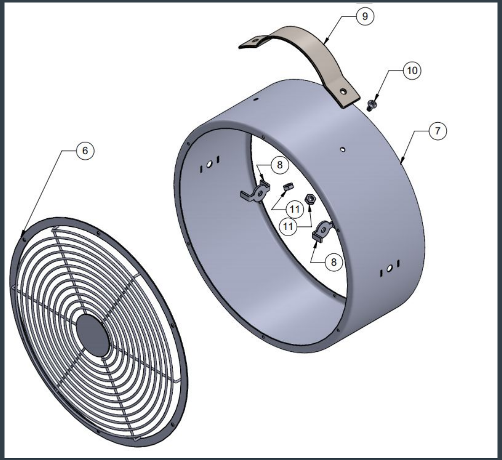


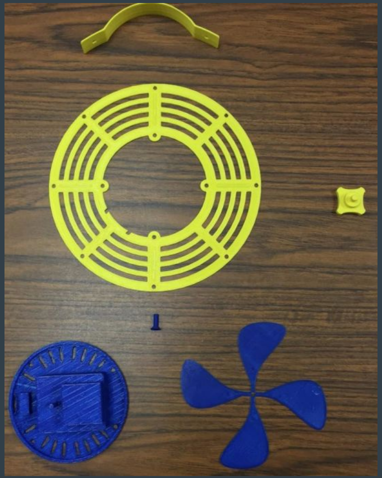


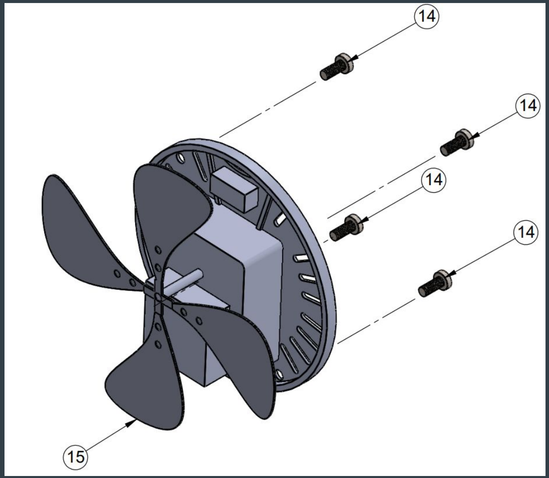


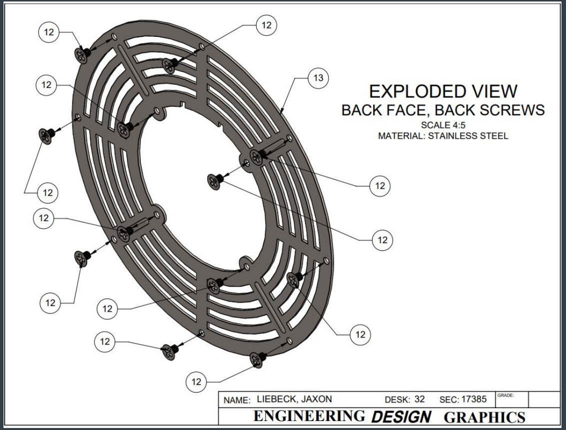
Reverse Engineering of a household fan:

This project involved choosing a household appliance to reverse engineer which included, dismantling, measuring, sketching, Solidwork designing, 3D printing, then assembling. I chose a desk fan to challenge myself on designing obscure shapes and a wide range of parts. As seen on the slide, the fan was broken up into 3 main assemblies, the casing (top right), the back (bottom right), and the fan/motor (bottom middle). Parts were then 3D printed to test their integrity, as seen down the bottom left.

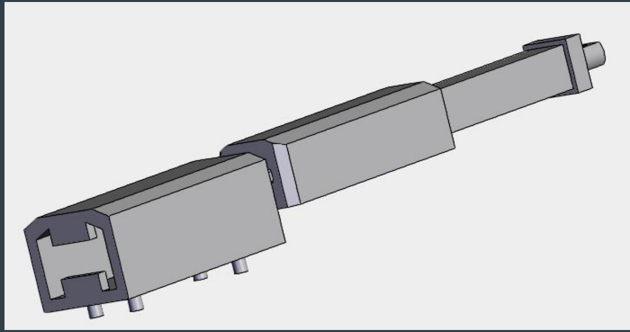




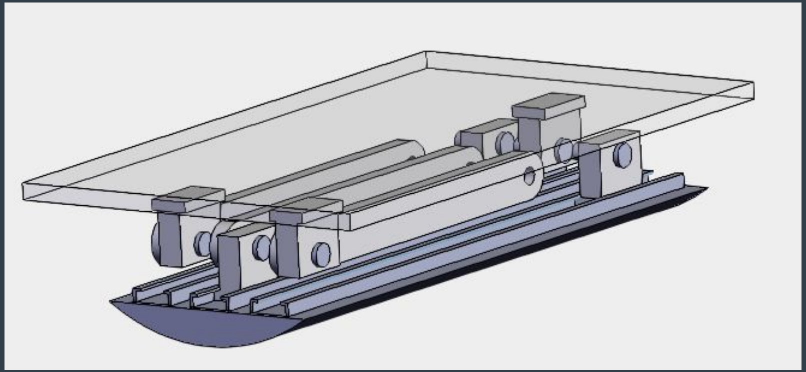


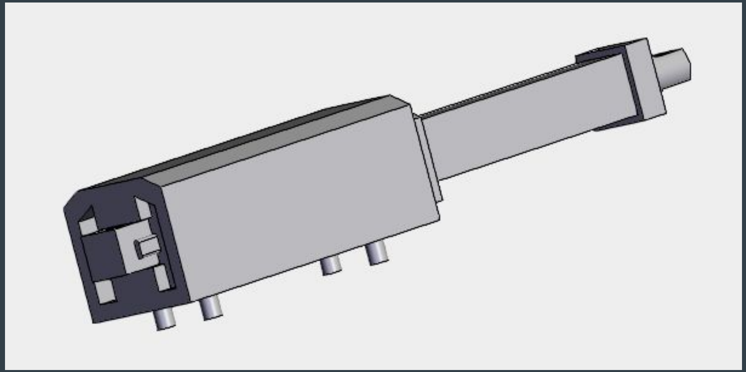


Longhorn Rocketry Component Design: Actuator and Lift Design & Assembly



For a semester I was a design engineer at LRA working on the SLI Nasa Rocket competition design. For our rocket, the goal was to fire a drone out of the top once peak altitude was reached. I worked with 2 other students to design the platform below that was a 3-lever extending platform but only needed one lever to move, to lift the platform. I was then solely responsible for designing the actuator casing and attaching it to the side of the rocket as seen to the right. When activated the actuator would push the middle lever, extending the platform upwards. (COVID halted comp.)





Academic Experience

Skills & Programs

Matlab & Simulink
C++
Microsoft Office Programs
Git
Labview
Geometric Dimensioning & Tooling
Verbal communication skills
Teamwork
Leadership

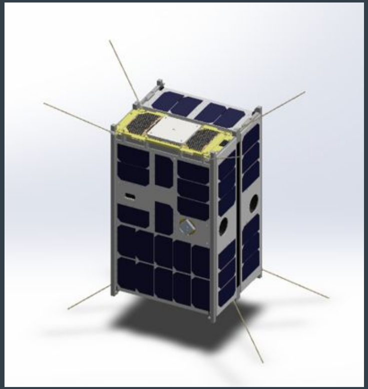
Relevant Coursework

Computational Engineering Matlab
Linear Systems Analysis
Feedback Control Systems
Physics I & II
Calculus I & II
Propulsion
Compressible Flow
Flight Dynamics
Spacecraft Dynamics
Orbital Mechanics

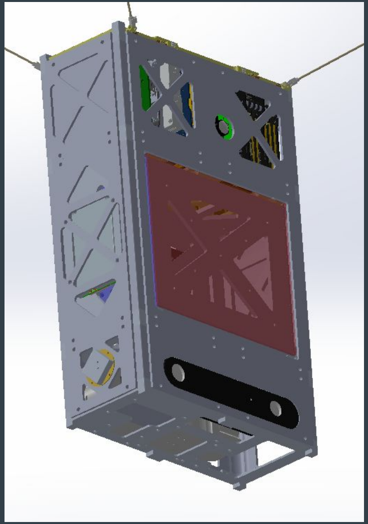
Engineering Communications
Engineering Design Graphics
Differential Equations
Attitude Dynamics
Intro to Scientific Computation
Spacecraft/Mission Design
Space Applications Lab

Academic Project: Texas Spacecraft Laboratory

Due to ITAR constraints the specific designs and models I contributed to cannot be shown. Only images from https://sites.utexas.edu/tsl/serpent can be shown



V1 - Serpent Model

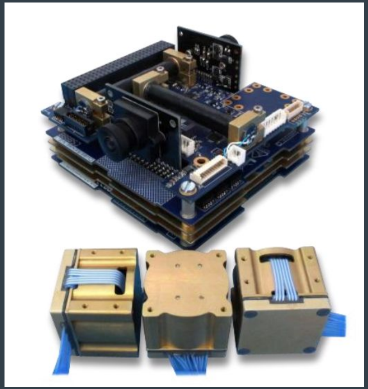


V2 - Serpent Model

Role: Lead Flight Dynamics and Controls Engineer

Obtained the ADCS hardware from Cubespace for the SERPENT mission. I set up and logged each piece of hardware individually, then assembled it on the in-house made FlatSat to integrate with satellite software components.

Once setup I performed the health check on each component and then ran the ADCS under different types of modes. I then wrote verification test procedure reports for each component.



Similar ADCS Model from Cubespace

Academic Project: Lucy Mission (L'Space)

Obtained a Certificate in the NASA L'Space Mission Concept Academy in the spring semester of 2019.

End goal was to create a mission concept while completed a number of tasks given to us by NASA. We then had to pass the Preliminary Design Review (PDR) to obtain the certificate.

Role: Lead Safety Analysis Engineer

I was responsible for analyzing each aspect of the concept mission and determining its risk, whether it was statistically safe, and if we would go ahead with the idea.

Risk No.	Risk Title	Classification
1	Cost Overrun	Internal Risk
2	Decent and Landing	Internal Risk
3	Atmosphere and Terrain	External Risk
4	Weather	External Risk

LIKELIHOOD					
	7	16	20	23	25
	6 R[1]	13	18	22	24 R[4]
	4	10 R[2]	15	19	21
	2	8	11 R[3]	14	17
	1	3	5	9	12
	LOW - CONESEQUENCE - HIGH				

Attached on the next slide is an Attitude Determination and Control System simulation poster, made using Matlab and Simulink on a low-earth orbit satellite.

Attitude Determination and Control for a Low Earth-Orbiting Satellite using Reaction Wheels

The University of Texas at Austin
Aerospace Engineering and Engineering Mechanics
Cockrell School of Engineering

Jaxon Liebeck liebeck.jaxon@utexas.edu

Introduction

The Attitude Determination and Control (ADAC) system is a primary piece of hardware aboard a spacecraft. The ADAC system is responsible for attaining the desired orientation of the spacecraft by calculating the current position with respect to a coordinate frame and then running an algorithm to change the orientation if needed. This poster will describe and simulate the ADAC system for a typical low Earth orbiting (LEO) spacecraft. Specifically the spacecraft simulated will bare similar orbit trajectory properties as the earth observing satellite TERRA [1]. The ADAC system simulation will be created and run in Simulink using MATLAB software. This simulation is comprised of a controller, initial conditions, reaction wheels (RW) and dynamics subsystem. Two tests will be run over the span of one hour, the first with an assumed 0% RW error for the reaction wheels, the second with an assumed 1% RW error. The angular velocity, quaternion and error rate will be monitored.

MATLAB SIMULINK

Image Credit: MathWorks

Attitude Estimation Method

The attitude of a spacecraft can be determined using several different methods. The Euler method is a simple and intuitive 3 dimensional way analyze the attitude of the spacecraft. However, it is limited because of 'gimble lock' when the pitch angle approaches ±90°. While this is an appropriate method for aircraft unlikely to reach a pitch angle of ±90°, it is unsuitable for Earth-orbiting spacecraft.

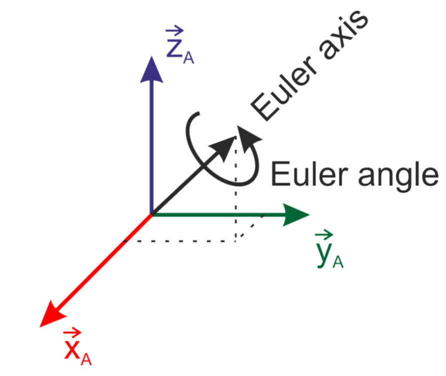


Image Credit: [2]
Technical University of Berlin

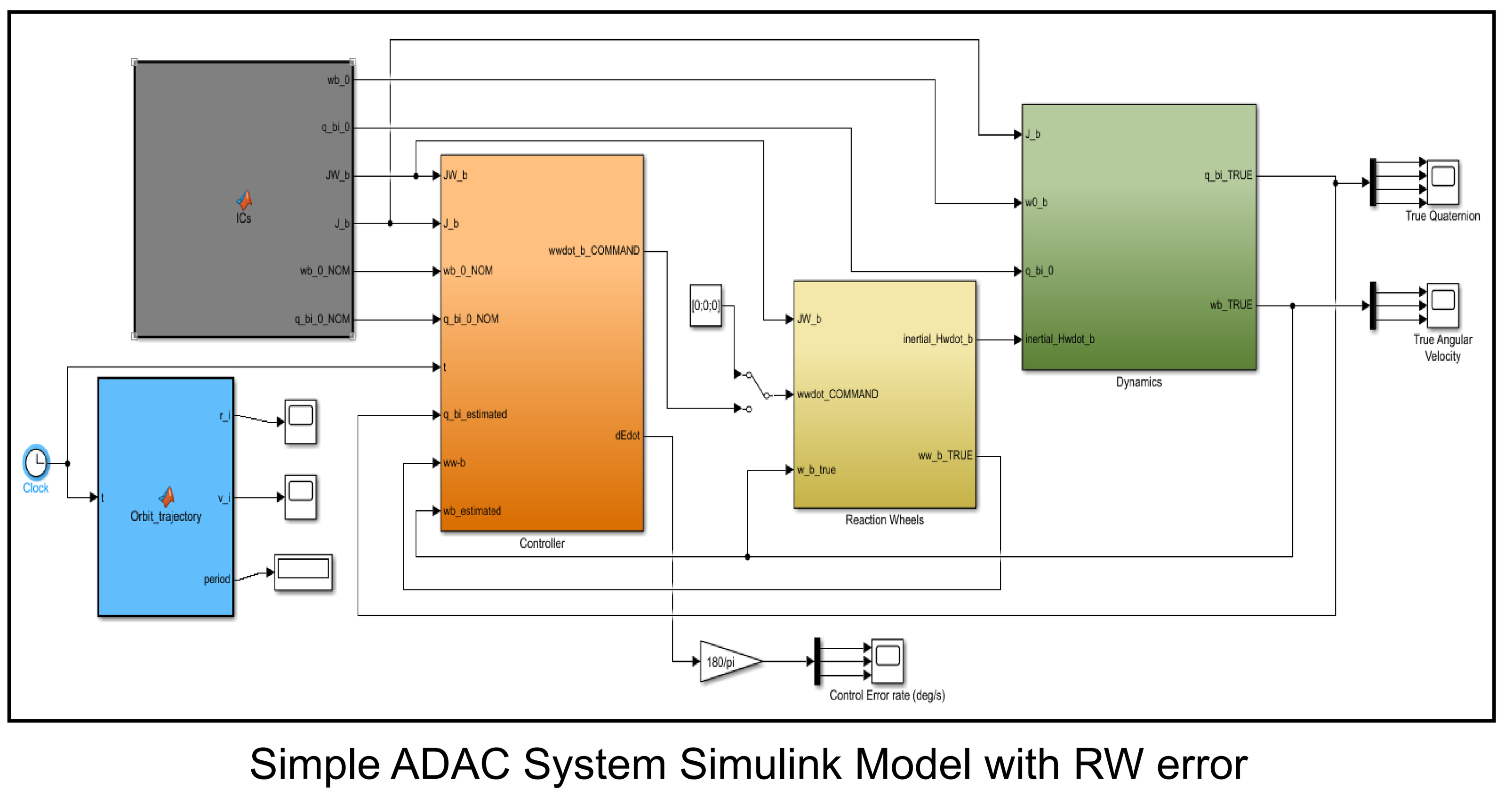
An alternative method is to use quaternions which provide a way to analyze the attitude of the spacecraft without 'gimble lock'. A quaternion is a 4 element vector using the Euler vector.

$$\bar{q} = \begin{bmatrix} -q_s \\ -q_x \\ -q_y \\ -q_z \end{bmatrix} = \begin{bmatrix} \cos\frac{2\pi-\theta}{2} \\ \|-\vec{e}\| \cdot \sin\frac{2\pi-\theta}{2} \end{bmatrix}$$

Equation Credit: [2]
Technical University of Berlin

Modeling an ADAC System

Attitude dynamics generally focuses on rigid body, rotational dynamics such that the spacecraft experiences torques at its center of mass. Common representations in simple attitude dynamics include the use of quaternions or Euler angles relative to a reference frame.



Simple ADAC System Simulink Model with RW error

- [Blue] Orbit Trajectory: Calculates the instantaneous position and velocity of the spacecraft, as well as the orbit period.
- [Grey] ICs: Imported input data related to the spacecrafts center of mass.
- [Orange] Controller: Calculates the torque acted on the center of mass of the spacecraft with respect to the center of mass using the nominal angular velocity and quaternion. It then uses the torque and estimated angular velocity to calculate a RW command, essentially controlling the RWs.
- [Yellow] Reaction Wheels: The primary mechanism responsible for correcting the satellites attitude by using the movement command given by the controller to calculate the rate of momentum.
- [Green] Dynamics: This subsystem calculates the true quaternion and angular velocity to input back into the controller to start the process again.

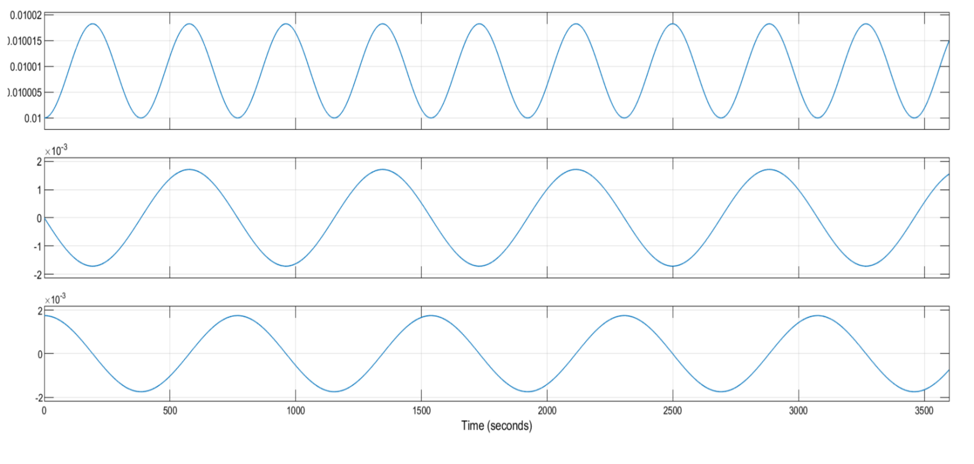
- Note: A sensors subsystem can be added to the system after the dynamics to incorporate actuator, gyro and wheel speed error. This would then require a TRIAD system to efficiently determine the spacecrafts attitude.

Simulation Results for a Low Earth Orbiting Satellite

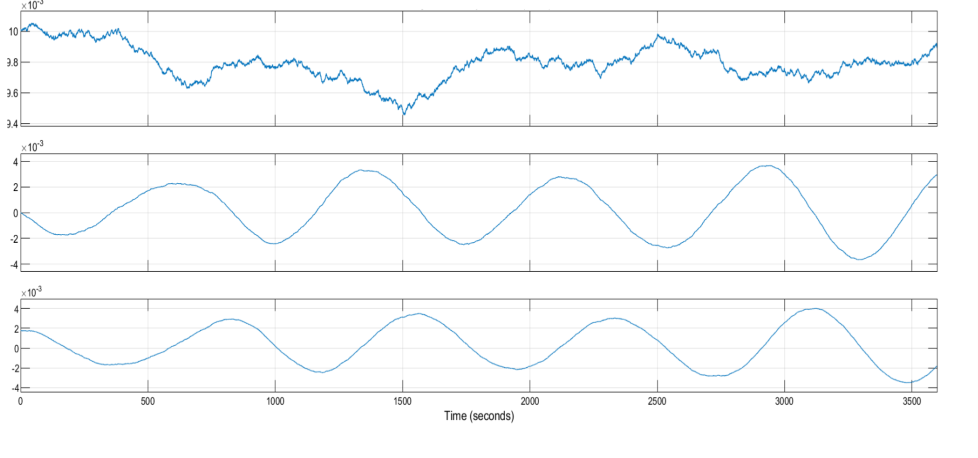
Time Evolution of Spacecraft Angular Velocity

The two plots to the right demonstrate the angular velocity of the spacecraft with or without error over the time span of 1 hour. The X coordinate variation is negligible, which is observable for both plots due to is small amplitude compared to Y and Z. When 1% RW error is introduced, the Y and Z angular velocities are affected more within the first 1000 seconds while still keeping periodical motion. As time progresses the angular velocity recovers to a more stable state.

Angular Velocity (X,Y,Z): 0% Error



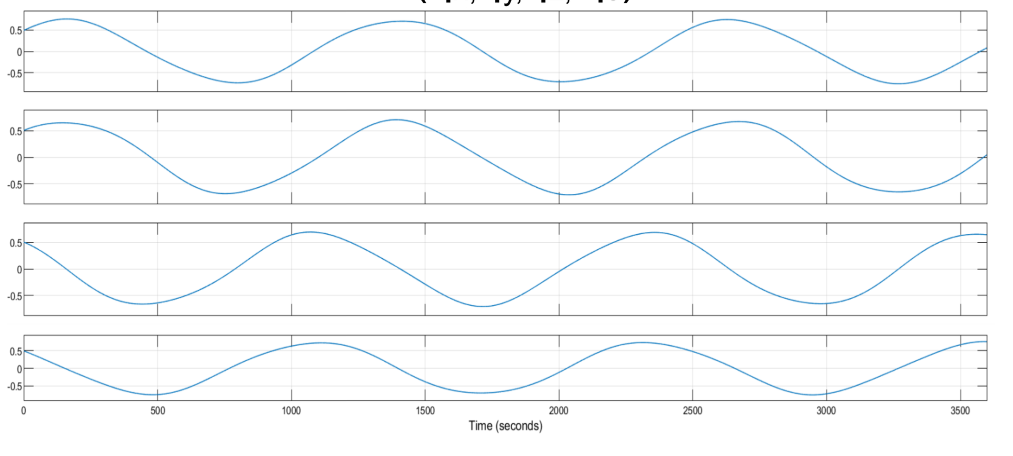
Angular Velocity (X,Y,Z): 1% Error



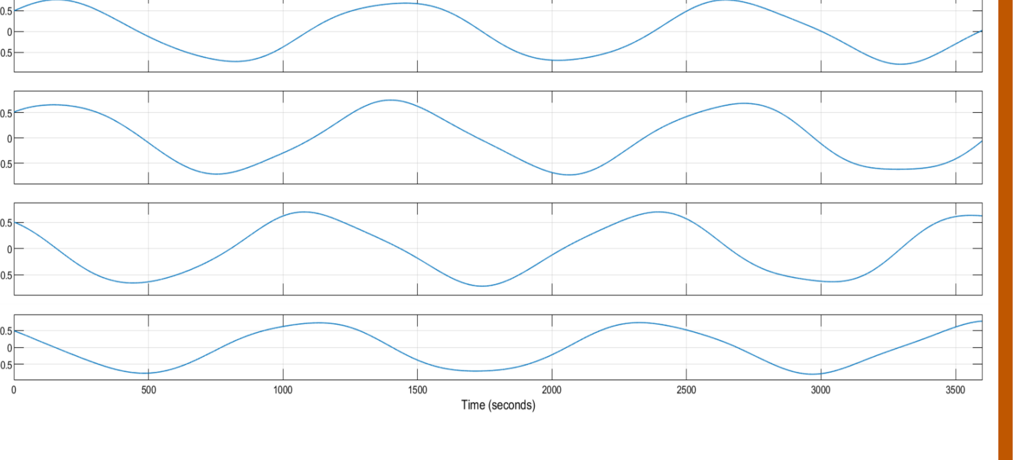
Time Evolution of Quaternion based Attitude

There is little to no observable difference between the 0% and 1% error quaternion vector. This demonstrates why the quaternion method of determining attitude is safer and more reliable compared to the Euler angle method. Euler angles would not be suitable for this simulation due the periodical angle change in each coordinate with the consistent passing of ±90° in the pitch angle.

Quaternion (q_x, q_y, q_z, q_s): 0% Error



Quaternion (q_x, q_y, q_z, q_s): 1% Error

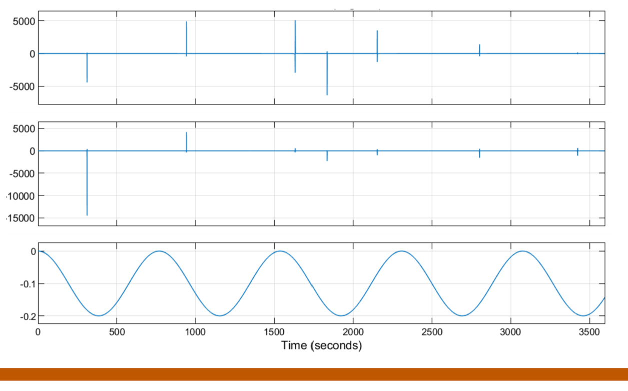


Time Evolution of Controller Error Rate

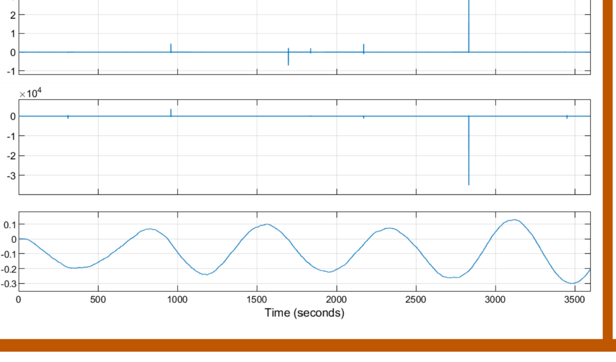
The error in the X and Y direction for the controller is 0 except for the random negligible spikes as time progresses. These are due to conversion error anomalies [3].

The Z coordinate varies similar to angular velocity when error is introduced.

Controller Error Rate: 0%



Controller Error Rate: 1%



Conclusion

The attitude determination and control system designed for spacecrafts best estimates the current attitude through stochastic methods. The model used in the poster is a basic example of how 1% error associated with RW can affect the attitude determination of a LEO spacecraft using the quaternion method. Other methods exist such as the Kalman method which uses a near nonlinear least squares formulation to realistically use signals from the sensor to estimate the attitude. [4]

References

[1] NASA eoPortal Directory"About Terra | Terra." *About Terra*, NASA, 29 Apr. 2021, terra.nasa.gov/about.

[2] Groÿekatthöfer, Karsten, and Zizung Yoon. "Introduction into Quaternions for Spacecraft Attitude Representation." *Technical University of Berlin*, 2012, www.tu-berlin.de/fileadmin/fg169/miscellaneous/Quaternions.pdf.

[3] Microcontroller Division Applications. "UNDERSTANDING AND MINIMISING ADC CONVERSION ERRORS." *AN1636 APPLICATION NOTE*, 2003, www.st.com/resource/en/application_note/cd00004444-understanding-and-minimising-adc-conversion-errors-stmicroelectronics.pdf.

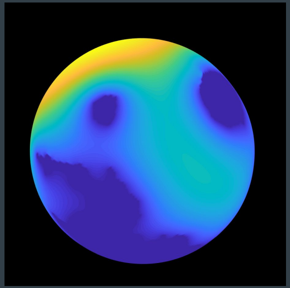
[4] Markley, F. L., & Crassidis, J. L. (2014). Fundamentals of Spacecraft Attitude Determination and Control. Springer New York. https://doi.org/10.1007/978-1-4939-0802-8

Computational Geosciences Research - Dr. Marc Hesse (ongoing)

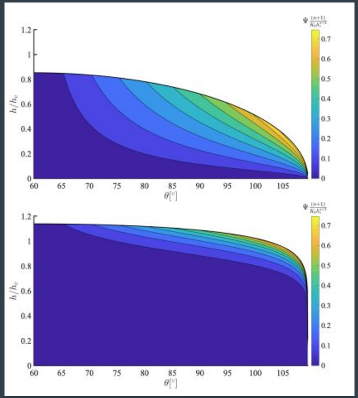
Developing a numerical model for the coupled evolution of Mars groundwater and putative ocean

Introducing numerical solutions using a Newton-Raphson iteration method to discretize the non-linear equation

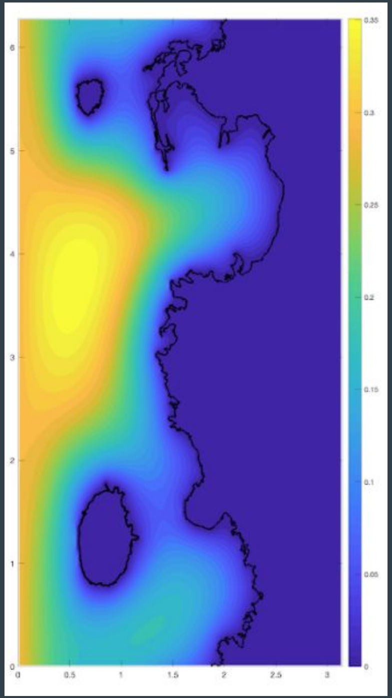
- A scientific publication will be written to answer the following questions: Does groundwater have a significant effect on sea-level?
- How much precipitation is needed to raise the groundwater table to elevations of observed lake deposits?
- What is the response timescale of the groundwater system to global water loss.



Mars Surface Depth 3D



Mars Hydraulic Conductivity with Depth



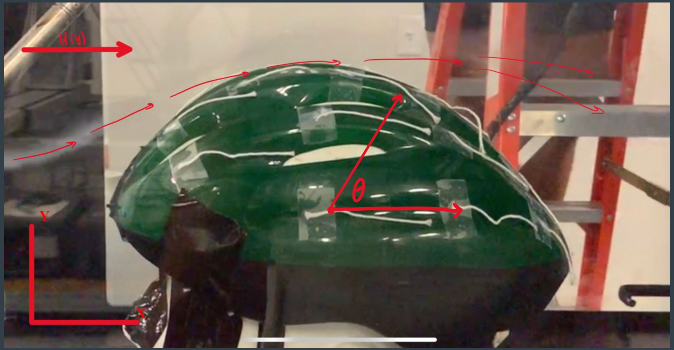
Mars Surface Depth 2D

Aerodynamics Lab Project: Helmet Shapes

Designed a lab test to prove that racing bike helmets are more aerodynamically efficient than a mountain bike helmet.

The test was conducted by attaching streamlines to each helmet, placing them in a low-speed (subsonic) windtunnel, and then measuring the velocity, pressure, and temperature of the air around the helmets. This was done by placing pitot tubes on, in front, and behind the helmets.

As seen in the images to the right, the mountain bike helmet creates a large wake due to its higher separation point, which increases drag. The racing bike helmet has a much lower separation point, eliminating the size of wake that can form at the rear.



The drag coefficient of each helmet, shown on the graphs, highlight the difference in aerodynamic properties.

(c)

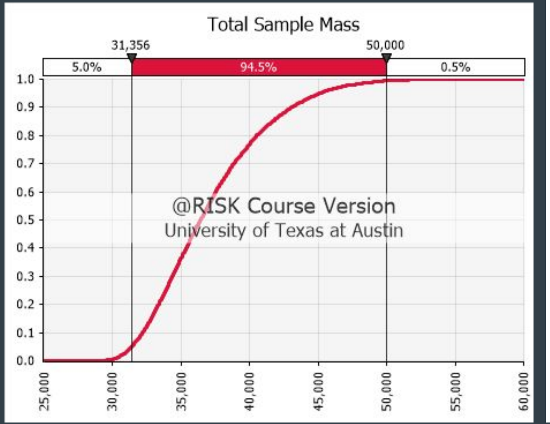
(c)

Space Mining Concept Mission

Designed a space mining concept mission for my senior design class. The mission consisted of sending autonomous mining equipment and hydrogen refining equipment to the near-earth asteroid Ryugu.

The data on the right is the final mass estimation spreadsheet for a 2040 launched mission.

The graph on the right is a payload mass risk analysis assessment with a 94.5% confidence level. The CDR mass is at 50000kg and the PDR mass is just above 30000kg, with the goal mass being 40000kg.



Mass Estimation Spreadsheet

		Level 2			
Element	Level 3	CBE	Contingency	Allocated	Level 1
1.0 Payload (scientific instruments, etc)		7000	1300	8300	
2.0 Spacecraft Bus (dry)					25388.83
2.1 Propulsion		782.65	227.63	986.41	
2.1.1 Mass of Engines	600				
2.1.2 Mass of Thrusters	54				
2.1.3 Fuel Tank	15.5				
2.1.4 Oxidizer Tank	20.3				
2.1.5 Pressurant Tank	7.4				
2.1.6 Pressurant	14.3				
2.1.7 Lines, Valves, Fittings, Regulators, etc	71.15				
2.2 ADCS		6.7	1.3	8	
2.3 Communications		42.4	4.24	46.64	
2.3.1 Low/Medium Gain Antennas	3				
2.3.2 High Gain Antenna	12				
2.3.3 Transponders	12				
2.3.4 Diplexers	2.4				
2.3.5 RF Switches, Cables, etc	13				
2.4 C&DH		4.5	0.5	5	
2.5 Power		22129.8	2212.98	24342.78	
2.5.1 Solar Arrays / RTG(s)	11076				
2.5.2 Batteries	4000				
2.5.3 PMAD	6000				
2.5.4 Wiring	1053.8				
2.6 Structure		5712.48675	634.72075	6347.2075	
2.6.1 Solar Arrays actuator mass	396				
2.6.2 Antenna mechanism mass	32				
2.6.3 Landing equipment	5141.24				
2.6.4 Other (backup equipment etc)	143.25				
2.7 Thermal Control System		92.29164	9.229164	101.520804	
2.7.1 Surface Finishes	2.118				
2.7.2 Insulation (MLI)	33.8876				
2.7.3 Radiators	10.88				
2.7.4 Heaters	4.39484				
2.7.5 Louvers	41.0112				
2.7.6 Heat Pipes	0				
2.8 Other (ECLSS, etc.)		100	0	100	
3.0 Spacecraft Dry Mass					30943.1483
4.0 Consumables					0
5.0 Propellant					600
5.1 Fuel		158	31.6	189.6	189.6
5.2 Oxidizer		342	68.4	410.4	410.4
6.0 Loaded Mass					31543.1483
7.0 3rd Stage (aka Kick Stage)					N/A
8.0 Injected Mass					189.6
9.0 Launch Vehicle Adapter					124
10.0 Boosted Mass					313.6
11.0 Margin					2447
12.0 Total Launch Vehicle Capacity					28149.43 kg

Other Experience

Building Supervisor & Lifeguard

Lee and Joe Jamail Texas Swim Center

- Provide oversight of Texas Swimming Center facilities, pools, and swimmers, consistently enforcing all policies and procedures
- Utilize excellent problem solving, flexibility, and adaptability when resolving issues with peer employees and participants
- Assist with highly-organized and detail-oriented tasks, such as incident descriptions and injury report

Mathematics and Physics Tutor

Berkeley2 Academy & Mathnasium

- Prepare students for the SAT math test and the ACT math and science test.
- Both online and in person tutoring.
- 1 on 1 tutoring and teaching a class.

United Space School: Volunteer

Clear Lake Campus, Houston

- Help interview and pick international students to participate in the program.
- Contribute to the student subsystem placement decisions.
- Answer college related questions and provide insight to international students who plan to study in america