Mechanical Engineering Undergraduate Honors Research

Ian Turner, Elijah Sech

Fall 2022

TVC Rocket

Professor Mark Bedillion

**Project:** Thrust Vectoring Control (TVC) Model Rocket

**Purpose:** To advance low orbit small payload rocket technology

**Research goals:** Minimum weight TVC gimbal design, open source safe rocket testing environment

**Funding:** TBD, we have $500 from Alumni Association but it is unclear whether we can use this for anything other than Techspark prints, Spring SURG (Deadline October 26th), Crowdfunding?

**Why is TVC important?**

* In order to achieve an orbital path a rocket needs precision control
* As a rocket ascends into space, air density decreases and aerodynamic control becomes less effective and eventually impossible
* Thrust control is needed to steer a rocket into orbit, this can be achieved in a number of ways but currently TVC gimbal control has proved to be the most weight efficient

**How can we apply our research to the future of rocketry?**

* Smaller rockets = more launches = cheaper satellite systems
* If we can work to reduce the materials required for an orbital launch it could help advance space development
* Even though our model rockets can’t achieve orbit, we can theorize that by scaling with higher powered engines and longer rockets the technology we are researching could be applied to scaled up rocket systems

**Some References:**

1. Most space vehicles use inertial control or gimbaled nozzles. Other forms of control include vernier rockets (Atlas missile), moveable fins (inapplicable to less dense atmosphere), or thrust vanes (used on V2 rocket).

<https://www.grc.nasa.gov/www/k-12/rocket/rktcontrl.html>

1. Video of gimbaled TVC engine used in NASA Ares rockets[J-2X Rocket Engine Gimbal Test | NASA Stennis Space Center Science Full HD](https://www.youtube.com/watch?v=i2gU4CVDV6Y)
2. Conceptual single engine gimbaled TVC low orbital rocket startup <https://payloadspace.com/spaceryde-tests-gimbaling-rocket-engine/>
3. Information of the history of rocket guidance systems <https://forum.nasaspaceflight.com/index.php?topic=31053.0> <https://engineering.purdue.edu/~mjgrant/aiaa-guidance-navigation.pdf>
4. Pendulum method for measuring MMOI

<https://www.me.psu.edu/sommer/me481/notes_07_03.pdf>

9/8/2022

* Need to figure out how to “close the loop”
* Test Rig?
* Hardware/Simulink combo?
* PCB
* Matlab demos look at
* Look into testing rigs
* **Aerospace blockset. Believing dynamics of model first.**
* Gimbal in simulink model
* From workspace block
* Chapter 21 in hibbler
* Saturation block for gimbal angle
* Eagle Software Design

9/15/2022

* Clarification between 3dof and 6dof
* How best to implement PID
* Funding
* Wind disturbance in model/other kinds of disturbances?
* Test rig
* Add drag to 3dof block
* for wind drag, V\_wind would be controlled by a sin wave or noise block
* Cold gas testing? 2 axis gimbal design is dominant
* thruster/electronic verification testing to see what servo outputs. Or use encoders on gimbal which would likely be better (ian)?
* Motor model
* Acrylic testing rig two axes.
* Measure force via load cells? (2 goals, measure stability and force)
* Use real life data to update simulink model
* Matlab tests?

For next week

* Preliminary Test Rig Design
  + Cad and sensor selection
  + 3 axis force testing

09/22/2022

* Thoughts on material for structure? (Wood, metal etc.)
* Welded square tubing for structure?
* Thoughts on sensor choice (kinds of load cells)
* Thoughts on sensor organization/placement (need 4 or 2?)
* Types of encoders
* Thoughts on shaft for gimbal mount (We were thinking of shoulder screws);
* What to do with data
* Next steps
* Structure for fan at the top?
* Recommendations for transportable design
* Think about moments and forces at various points of rocket
* Maybe put load cells on rollers/rockers to alleviate shear?
* Scale is higher optically
* Optical encoders would be the best move
* 512 PPR is a decent amount , 1024 would be better
* Quadrature with index or quadrature, represents direction;
* 360/PPR/4 = resolution in degrees
* Angle brackets for inner square
* Restraining system is a priority
* Enclose structure with acrylic
* Make it able to survive 200 Newton

October 6

* thoughts on electronics holding
* Thoughts on rocket securing system (do we need one in the bottom)?
* Will this give us data necessary for model
* Safety?
* Bearings should be thought about for test rig gimbal
* Impulse response means everything
* Impact hammer to measure impulse response
* Figure out a way to secure rig to the ground
  + Weights, Ian has 10lb concrete weights at cantina
* Impact hammer to measure impulse response
* Spice for circuits

* Net at the top of rocket?
* Rubber coating on inner ring
* Mount will change MMOI but nothing that cant be processed out in the end.
* Angular stroke vs slip ring with respect to wire strain
* 4 wires.
* Finalize BOM
* Spruce up simulation by november 29th, show that aerodynamic control is ineffective when rocket gets to orbit.
* Digikey has fast lead time
* Have parts ordered
* Get a PCB fabbed
* Put together the structure of wood, test electronics before implementing 3d printing parts.
* Should use mega instead of uno.
* Calibrate load cell by using known weights

10/27/2022

* We need Mega for our encoders, each has 2 signal channels that need interrupt pins so we need 4 interrupt pins. Uno has 2 and Mega has 6. Mark gave us one so we are good
* Plug the encoder into the oscilloscope first to get a sense of what the signals are doing.
* How does the servo interact with the linkage such that it provides enough torque to counteract the thrust force.
* Giving day on November 29th
* Simulation of aerodynamics vs TVC with atmospheric density.
* Fuse the tvc board so that it doesn't surge
* Redesign schematic on rocket so that it’s safe

11/10/2022

* Got all electronics. Tested load cell, calibrated it. Buit test rig, wood cut it, assembled wood structure, got 3d printer working, printed inner ring, tested e
* ncoder on oscilloscope to see square waves but we were not getting square waves. Wrote code for test rig schematic. Need help with pin management/schematic.
* Moving average
* Post gets rid of delay.
* Digital filter
* Filtfilt matlab to filter before and after no phase shift
* Measuring mass moment of inertia with impact hammer.
* Use brushed servo
* Do brushless servos need a controller?
* 7805 5v regulator
* LM7806 regulator for 6v, LM7805 regulator

11/16/2022

-change LM7805 to LM1085 and caps, then order

-encoder interrupt from 1 to 2 ins

12/4/2022

* LM1085 GND and VOUT pins switched, 1k Ohm resistors not connected, 7.4v Vin pin on LM1085 was connected to the ground plane net

12/14/2022

* Outer ring, 3D print or not. Needs to be made
* Need to figure out the research topics better
* As atmosphere diminishes the aerodynamic steering diminishes due to drag force diminishing
* We need to back up why TVC is necessary with citations/numbers
* Need to get impact hammer amplifier box to use impact hammer
* Start new gimbal design
* Fix calibration of gyros
* To add in Sim: atmosphere, auto PID Tuner

1/12/2023

Current goals: minimize mass of gimbal/rocket, create a testing rig to tune rocket pre-launch without crash for safety

New research ideas for TVC:

* Extinguish solid motor if rocket spins out of control
* See if a TVC gimbaled rocket can follow non-linear paths accurately to prove significance for orbital flight paths
* Gimbaled nozzle vs gimbaled motor, could just replace the TVC subassembly within one new rocket design
* Rocket recovery systems for TVC - is this really specific to TVC though
* Avionics sensor design, filtering and/or two MPUs
* Electromagnetic hold down pad

1/17/2023 Agenda:

* Finalize research project goals
* SURG funding, we want to chose option to have the department manage
* Impact hammer amplifier?Goals: Build test rig, we have all hardware and electronics only constraint is non-adaptable ring design
* Then, Elijah can work on work on fine tuning test rig data/adding transfer function to simulink while ian improves rocket maybe?
* Model system dynamics

1/19/2023

* Ballistic parachute design
  + Black powder vs mechanical mechanism in terms of reliability and safety
* Combine aerodynamic and TVC, if rocket can’t stabilize with TVC deploy fins
  + Fins on top TVC on bottom
  + Could use the fins just to slow the rocket down
* Anti-spin control
* Safer launch pad design
* TVC Rocket Safety
  + Test rig
  + Rocket design
* Need to submit the units form, figure out surg funding, fully define research paper titles and goals

2/8/2023

Recovery Research: http://www.aircommandrockets.com/recovery\_guide.htm#\_49