NORTHERN ARIZONA UNIVERSITY

Department of Mechanical Engineering

ME 476C

1/19/24

Grace Morris, Andrew King, Remy Dasher and Shannon Comstock

Project Management Assignment ME 486C

Reflection

Engineering Team Achievements and Continued Focus

Within this section, the team aims to outline significant accomplishments from the Fall semester and identify practices to be sustained and improved upon in the upcoming Spring semester. The following traits outline the team's successes in teamwork.

1. Emphasis on Effective Communication:

- Prioritizing clear communication, the team consistently conveyed ideas thoroughly and respectfully.

2. Regular Team Meetings:

- Maintaining active engagement by conducting frequent meetings with client, EE and ME team.

3. Punctual Time Management:

- Prioritizing completion promptly by beginning assignments and building with a buffer period before the due date.

4. Equal Workload Distribution:

- The workload was evenly distributed throughout the semester, with each team member finishing the semester with a similar number of hours logged.

5. High-Quality Deliverables:

All tasks were accomplished to a high standard, achieving an A grade for all team members.

6. Meeting Preparedness:

- The team approached meetings well-prepared with organized lists of questions, tasks, and agendas. These traits will be identified for continued focus in the Spring semester and for potential improvements.

Room For Improvement

This section identifies the areas that the team needs to improve. Improving these areas will allow the team to be more successful. This section also details the team's plan for how to improve these issues.

1. Staying within Gantt Chart metrics and team-designated due dates

   Plan of Action:

   - Reference the chart more often (a weekly basis) to be reminded of necessary actions, this will be done during the team meeting part of the capstone class

   - Create the Gantt chart with a more realistic time frame for each of the tasks, all team members will review the Gantt chart in the first few weeks of the semester of ensure that timeline is adequate for all teammates

2. The team's timecards could be made more in-depth and accurate. Currently, the team tends to write most of the week's work on Monday, the day it's due.

   Plan of Action:

   - Write the working times each day work is done, not filling out the timecard in one sitting the day it is due

   - Remind other team members to fill out timecard before the end of meetings

3. The Mechanical Engineering (ME) team needs to improve communication with the Electrical Engineering (EE) sub-team. Over the winter break, it became apparent that the EE team has difficulty contacting the necessary members of the ME team.

   Plan of Action:

   - The ME team will designate one team member to manage communication between the two teams to ensure no correspondences are lost as the team members become busier

   - Both teams will resume weekly meetings with the client starting in the second week of the semester. This will allow the ME and EE team to communicate regularly while updating the client.

Remaining Efforts

This section covers the remaining components that the team must design. These are primarily subsystems of other systems or iterating on current designs.

1. Design and build motor casing
2. Design bulkhead fastening method for motor casing
3. Design additional nozzles for testing
4. Redesign upper supports of the test stand to ensure all-threads are not in compression and the motor has more than 4 points of contact
5. Complete attachment of load cell to the test stand and ensure calibration
6. Assemble all components of motor and secure in the rocket body

Deliverable Modifications

To accommodate our client's requirements, we are modifying our assignments' timeline in order to have a final launch in March of 2024. The requirements of the capstone course specify due dates for 33%, 66% and 100% build, however these due dates do not comply with our requirement for completion in March. Therefore, we have determined that we will work in steps of 50% completion and 100% completion which will replace the due dates for 33% and 66% build respectively. These changes will be shown in the Gantt Chart below as well.

Concluding our final launch ahead of schedule in the capstone course timeline, we will redirect our focus towards the completion of our final report and thorough preparation for the UGRADS event. Achieving an early completion of the rocket-building and launching processes within the capstone course's timeframe allows us to have an extended timeframe for wrapping up our project. This extended period will be dedicated to crafting a high-quality final report and ensuring comprehensive readiness for our presentation at UGRADS.

Gantt Chart

To streamline the second half of the team's project, an updated Gantt Chart has been constructed (Figure 1). The chart includes the following:

- ME486C major assignment deadlines
- Client meetings
- Undergraduate symposium deadlines
- Test dates for 54mm and 75mm rocket motors
- Launch day, according to Tripoli Phoenix's launch window
- Timeline for the production of safety checklists

The team's client requires for the project to be completed by late February or early April, so the class due dates for 33% and 67% build completion are replaced with 50% and 100% build completion.

After spring break, the team will primarily focus on preparation for the undergraduate symposium. Because the build will be completed earlier than scheduled for the class, the team is considering adding time to the schedule for continuing research, or teaching Rocket Club what we have learned throughout this project.

Spring Semester Tentative Schedule

NAU Rocket Capstone: Major Events Timeline

Project Start: 01/16/24 05/15/24

Display Week: 1

PROGRESS	PROGRESS	START	END	Focal
Semester Kick Off				
Spring Kickoff Meeting	100%	01/16/24	01/16/24	
First Client Meeting	100%	01/18/24	01/18/24	
First Faculty Advisor Meeting	0%	01/19/24	01/19/24	
Project Management Assignment	40%	01/15/24	01/19/24	01/19/24
Strand Testing Safety Checklist	0%	01/17/24	01/21/24	
Complete Strand Testing	25%	01/10/24	01/21/24	
Have Test Stand Motor Holder Built	0%	01/15/24	01/26/24	
Engineering Calculations Summary Assignmer	0%	01/19/24	01/26/24	01/26/24
Set Up Mandrel Casting Table	0%	01/22/24	01/29/24	
Self Learning/ Individual Analysis Assignment	20%	01/16/24	02/02/24	02/02/24
Final Build Phase 1				
Meet with Client Prior to Testing	0%	02/02/24	02/02/24	
Have all Parts Ordered for 75mm Motor	0%	01/22/24	02/04/24	
Build final test motor 54 mm	0%	01/25/24	02/04/24	
Test Fire Safety Checklist	0%	01/31/24	02/04/24	02/05/24
Test Fire 54mm test motor	0%	02/04/24	02/04/24	
Hardware Status Update	0%	02/01/24	02/06/24	02/06/24

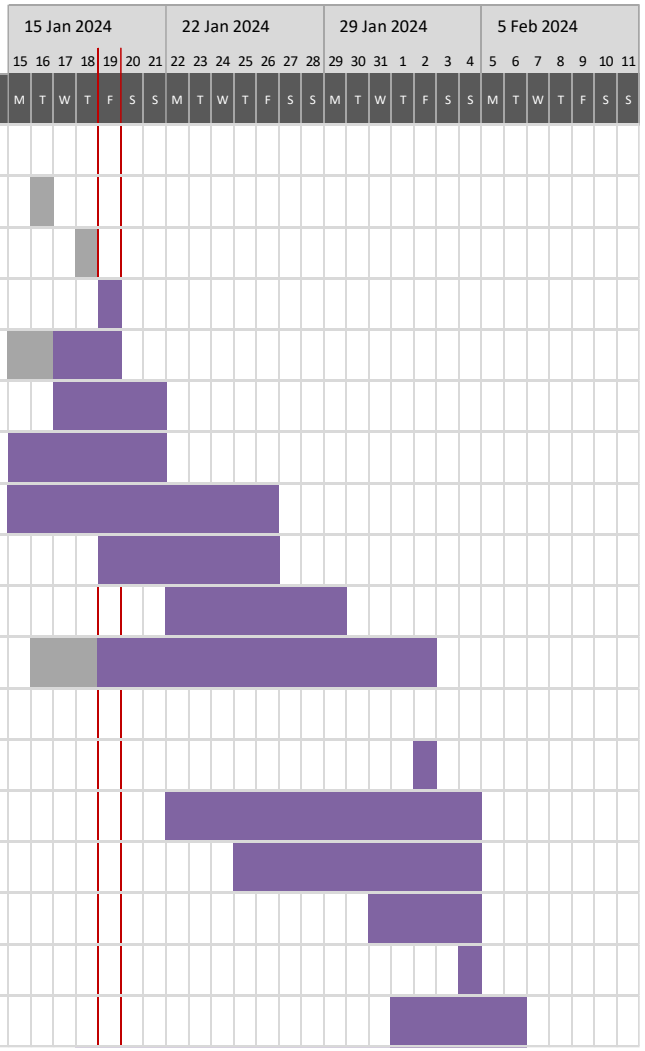

Figure 1: Spring Semester Gantt Chart

Purchasing Plan

Table 1. Bill of Materials Sorted by Part Status

Item	Part Status	Quantity	Cost from Primary Vendor	Total Cost	Primary Vendor
Lampblack	Completed	1	$9.72	$9.72	skylighter.com
Silicon Oil	Completed	2	$13.00	$13.00	Hobby Lobby
Spatulas	Completed	2	$0.99	$0.99	Thrift Stores
Mixing Cups	Completed	1	$0.99	$0.99	Thrift Stores
Popsicle Sticks	Completed	1	$0.99	$0.99	Hobby Lobby
Strand Molds	Completed	1	$5.99	$5.99	amazon.com
Pressure Release Valve	Completed	1	$166.07	$166.07	McMaster-Carr
Pressure Transducer	Completed	1	$42.48	$42.48	amazon.com
3/4in NPT Plug	Completed	3	$3.37	$10.11	McMaster-Carr
3/4in NPT Steel Cross	Completed	1	$48.65	$48.65	McMaster-Carr
3/4in NPT Nipple	Completed	3	$6.10	$18.30	McMaster-Carr
2in NPT Connector	Completed	1	$23.02	$23.02	McMaster-Carr
2in NPT Plug	Completed	1	$17.78	$17.78	McMaster-Carr
3/4in NPT Ball Valve	Completed	1	$52.09	$52.09	Grainger
3/4in NPT Tee	Completed	1	$18.12	$18.12	McMaster Carr
1/4in x 3/4in NPT Adapter	Completed	1	$7.48	$7.48	Grainger
Pressure Vessel	Completed	1	$71.80	$71.80	Gas Cylinder Source
1/4" Washer	Completed	2	$8.51	$17.02	McMaster Carr
1/4"-20 1/2" Bolt	Completed	3	$8.41	$25.23	McMaster Carr
1/4"-20 5/8" Bolt	Completed	2	$9.90	$19.80	McMaster Carr
4040 Lite Extrusion	Completed	4	$28.58	$114.32	80/20

1/2"-13 All Thread (36in)	Completed	1	$24.27	$24.27	Home Depot
10' 2x2x1/8 Angle Iron	Completed	1	$30.82	$30.82	Industrial Metal Supply
5/16" Eye Bolt	Completed	4	$3.38	$13.52	Home Depot
1/4-20 T-Nuts	Completed	180	$0.32	$57.60	80/20
Aluminum Plate	Completed	1	$0.00	$0.00	Dr. Wade
Knobs	Completed	4	$0.00	$0.00	3D Printed
Solar Shack Extrusion	Completed	12	$0.00	$0.00	Solar Shack
Load Cell	Completed	1	$157.78	$157.78	ATO
2"x1/8" Flat Bar	Completed	1	$21.21	$21.21	Mayorga's Welding
7/16" Mandrel	Delivered	1	$10.50	$10.50	rocketsaway.com
5/8" Mandrel	Delivered	1	$11.30	$11.30	rocketsaway.com
7/8" Mandrel	Delivered	2	$31.00	$31.00	rocketsaway.com
7/16" Non-Vented Alignment Cap	Delivered	3	$10.20	$10.20	rocketsaway.com
7/16" Vented Alignment Cap	Delivered	3	$11.10	$11.10	rocketsaway.com
5/8" Non-Vented Alignment Cap	Delivered	3	$12.00	$12.00	rocketsaway.com
5/8" Vented Alignment Cap	Delivered	3	$13.80	$13.80	rocketsaway.com
7/8" Non-Vented Alignment Cap	Delivered	4	$18.40	$18.40	rocketsaway.com
7/8" Vented Alignment Cap	Delivered	4	$20.80	$20.80	rocketsaway.com
38mm Liner + Casting Tubes	Delivered	1	$24.00	$24.00	alwaysreadyrocketry.com
54mm Liner + Casting Tubes	Delivered	1	$25.00	$25.00	alwaysreadyrocketry.com
6in K-Type Thermocouple	Delivered	1	$158.89	$158.89	McMaster-Carr
Mini Lathe	Delivered	1	$444.99	$444.99	vevor.com
Respirators	Ordered	2	$36.00	$36.00	harbor freight
Ammonium Perchlorate 90u	Partial	1	$14.50	$43.50	firefox-fx.com
Ammonium Perchlorate 400u	Partial	1	$14.00	$42.00	pyrochemsource.com

Atomized Aluminum 6-3u	Partial	1	$16.86	$50.58	skylighter.com
R45 HTPB	Partial	1	$100.00	$200.00	Mixing Instructors
DOA	Partial	0.5	$38.00	$76.00	csrocketry.com
MDI	Partial	1	$14.00	$42.00	rocketmotorparts.com
Mold Release Spray	Partial	1	$15.00	$75.00	Hobby Lobby
Nitrate Gloves	Partial	1	$25.00	$75.00	Home Depot
Isomolded Graphite Rod	Partial	1	$87.12	$87.12	graphitestore.com
Phenolic	Partial	1	$72.27	$72.27	boedeker.com
Mineral Spirits		1	$20.00	$20.00	homedepot.com
76mm Liner + Casting Tubes		1	$29.59	$29.59	alwaysreadyrocketry.com
Stand Mixer		1	$500.00	$500.00	Donated
Internal retaining ring		1	$14.47	$14.47	McMaster Carr
O-ring		2	$0.75	$1.50	theoringstore.com
16-Series Aluminum Tubing:		1	$45.00	$45.00	MAPerformance
Inner Lining		1	$59.00	$59.00	MAPerformance

The bill of materials (BOM) is shown above. The materials with red next to their name are the ones that have not been purchased yet these are at the bottom of the list. The items that still need purchasing are primarily for the subsystems that still need more planning before purchasing, these are listed below. All materials that still require purchasing and are not part of the subsystems listed below will be purchased in the next purchasing order.

- The casing needs more design planning before purchasing parts
    - Plan of Action:
    - **1. Do pressure analysis for casing based on data from strand burns**
    - **2. Complete CAD model for final casing design**
- The nozzle parts need to be verified before purchasing
    - Plan of Action:
    - **1. Check the quality of parts in BOM to ensure they are up to spec**
    - **2. Check the budget to make sure the parts are within budget**

Manufacturing Plan

Motor Casing & Bulkhead:

The casing will be made from a pre-made aluminum 6061-T6 tube. The outer diameter must remain fixed at 76 mm, or just under 3 inches (2.99 in). This means that the aluminum tube must be minimally machined to fit inside the motor bay in the rocket. With the thickness we calculated, we must opt for a half inch thickness tube. This will allow us to machine the tube to fit the rocket liner. The liner that we are using has an outer diameter of 2.734 inches. This means that we need to bore out the aluminum tube to fit the liner. This will allow for the most amount of thickness while also fitting all the necessary requirements for the casing to work with all the interior components. This will be done simply with the metal lathe and a boring tool. We also must machine in snap ring grooves into the bottom of the casing to secure the nozzle into the casing. Lastly, threads must be made in the top of the casing to secure the forward bulkhead. This part should take around three days inside the machine shop.

The bulkhead will be designed to fit into the upper part of the motor casing. It will be manufactured using the metal lathe in the machine shop. Half of the team is certified to use this equipment, which will allow us to be the ones to machine it. The bulkhead will be made from aluminum as well. The billet used for this part will be left over from the motor holder manufacturing, which will be described later. This part can easily be made on the lathe and should take no longer than a day in the machine shop.

All this work will be conducted by both Grace and Remy because they have lathe training. This will occur after propellant testing is around 75% complete and when we are ready to cast a full-scale motor.

Strand Burner:

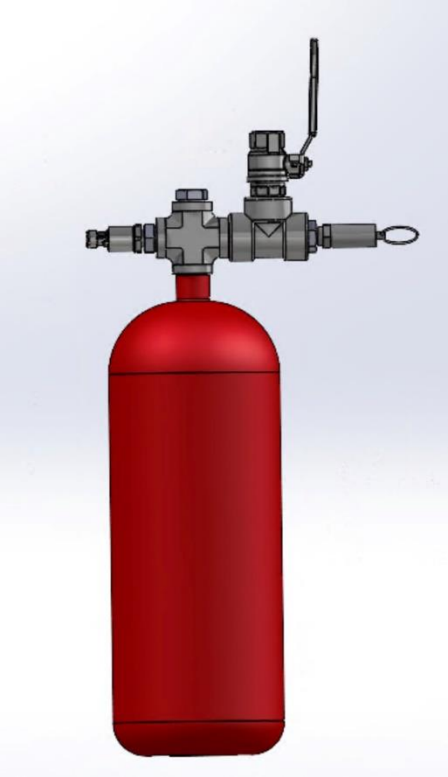

Figure 2. 3D Model of Strand Burner

Figure 2. Completed View of Strand Burner

The strand burner has officially been 95% completed. For this part of the manufacturing plan, we will cover what must be completed. We need to JB Weld the thermocouples in place in the strand holder and seal up the hole with the thermocouple leads coming out of the burner. This can be done very quickly and will be done by Remy once the electrical engineering team is done getting them to work and getting them calibrated. We also must secure a rope to the ball valve so we can open the vessel after burning. This is as easy as drilling a hole into the ball valve handle and attaching a rope. This will allow us to depressurize the vessel from a safe distance. Lastly, a stand must be made to hold the vessel horizontally and hold it appropriately during burning. This part will be 3D printed by Remy and will utilize a simple clamping apparatus. The rest of the manufacturing should take no longer than two days.

75 mm Rocket Motor:

The 75 mm rocket motor body will be manufactured from casting grains of propellant using the 75 mm caps and mandrels ordered in the first week of the semester. The propellant grains will then go into a casting liner which will fit into the motor casing. This should take about a week from mixing, casting, and curing. The whole team will participate in mixing and casting and that should take no longer than an afternoon. Mixing will occur near the solar shack in the enclosed fencing to minimize those who should not be there for their safety.

Motor Holder for Test Stand:

The rocket motor holder will be made from a billet of aluminum and be manufactured using the CNC a in the machine shop. This means that a work order must be put into the machine shop, which usually takes 3-4 weeks.

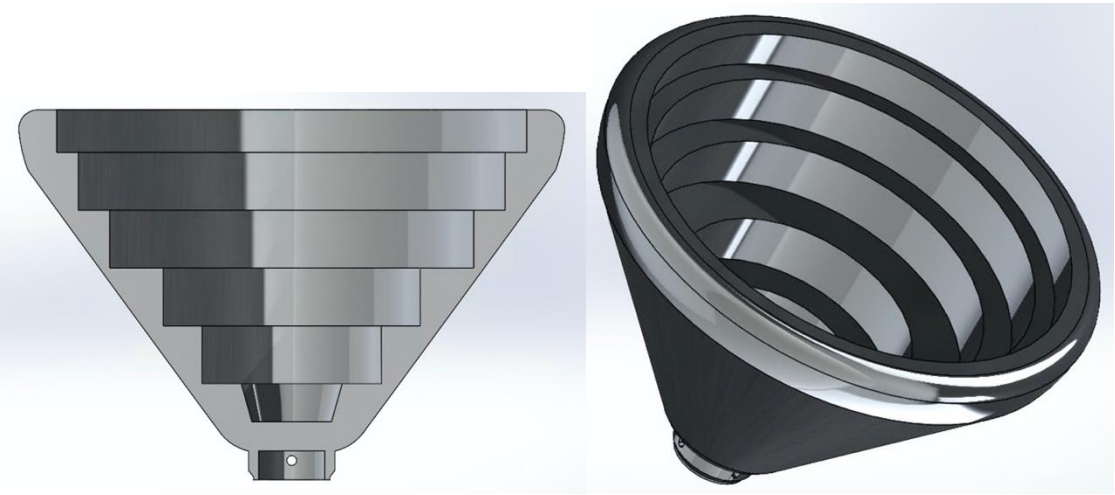

Figure 4. 3D Model of Motor Holder

The motor holder for the test stand should be one of the easier parts to create. It will be made from a billet of aluminum round. The entire part consists of five concentric rings inside the actual part. Each one of the rings fits a different motor size. This operation will be done on the CNC in the machine shop to maximize accuracy. Lastly, four M2 threads must be cut into the bottom hole to fasten set screws to clamp onto the load cell nipple. These threads combined with the solid piece of aluminum before the concentric rings start will allow for minimal deformation of the holder. The process should take about a day, but due to how much material we must remove, this could easily turn into a day or two long projects.

With the team working on it, we should be able to get this part done correctly and as accurately as possible.

Nozzle:

The nozzle will be made from phenolic rounds with a graphite insert which encompasses the throat of the nozzle. The phenolic part of the nozzle will be made from a round of phenolic and use a lathe that Andrew purchased with his undergraduate research fund. The graphite insert will need to be machined which as well will also be made from Andrew's lathe.