MMAE-414

AIRCRAFT DESIGN - GROUP THREE

IMT-22
PROJECT MORBIUS

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ILLINOIS INSTITUTE OF TECHNOLOGY
ARMOUR COLLEGE OF ENGINEERING
MMAE-414 AIRCRAFT DESIGN REPORT
AIAA HYBRID ELECTRIC TURBOPROP

Project Morbius
August 25th, 2022

Team Structure

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ILLINOIS INSTITUTE OF TECHNOLOGY

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1.2 Team Organisation

2 Mission Overview

The mission of this project is to

2.1 Mission Objectives

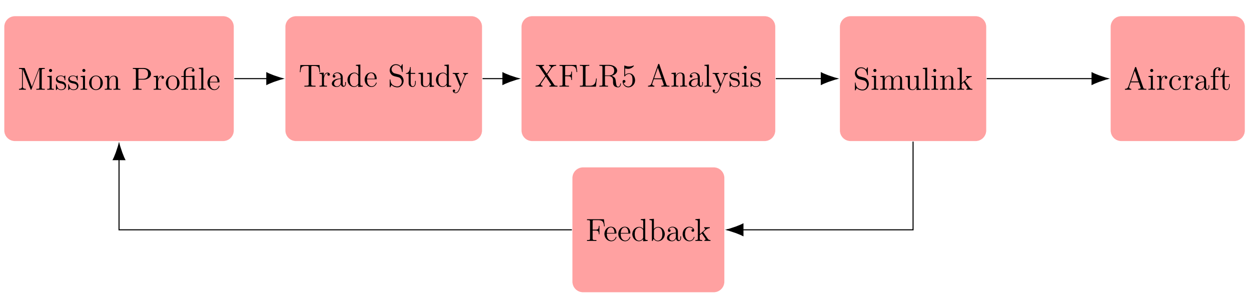
Our primary and secondary mission objectives are as follows.

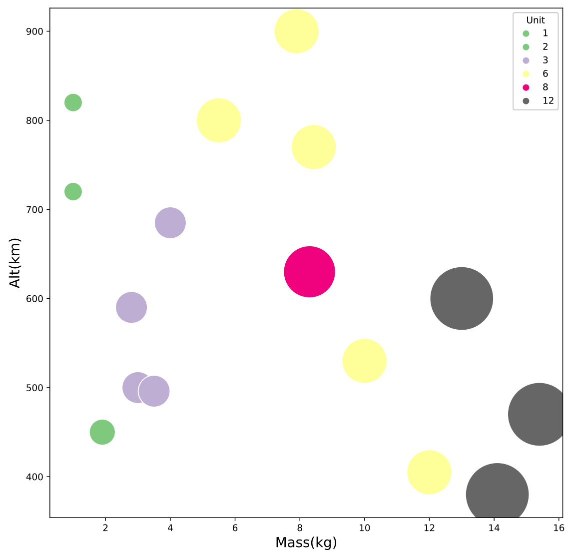
2.2 Mission Requirements

2.3 Analysis and Trade Studies

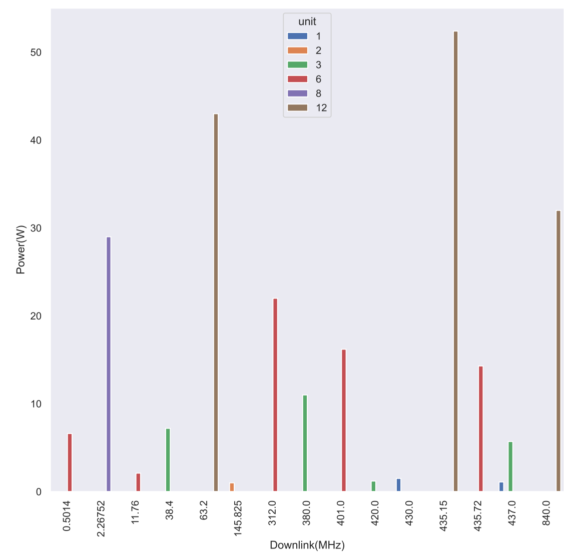
To ensure our project results in designing an effective and efficient cubesat, we have made a project plan to provide the best out put parameters in Figure 2.1. After initial mission definition the project is closely followed by trade studies. Numerous data for previous successful missions were collected firsthand. It shows ——- are commonly used for a wide range of altitude. Once we select the performance metrics, we use —– software analysis to test the values in the simulation. After reading the feedback from the simulation; if the findings are feasible, we proceed to component design phase. If not, we go back to refine our mission definition and operational requirements. This is an agile project managing system where we select the performance parameters and perceive the coverage, operation orbit and bypass simultaneously to decide the best fit. This allows us to be flexible with the little time provided.

Figure 2.1 – Mission Analysis

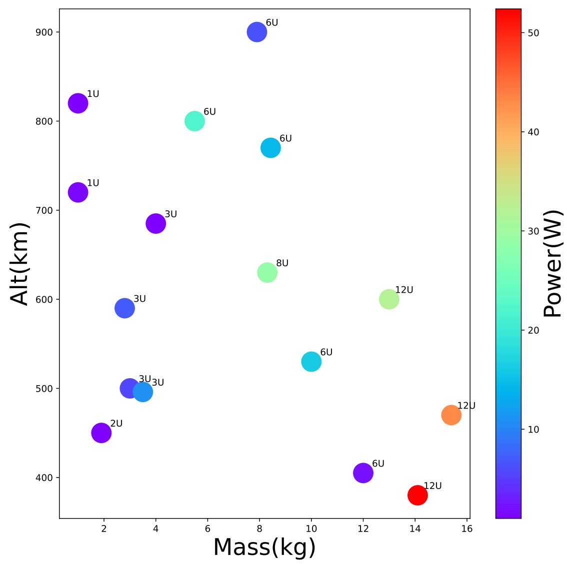




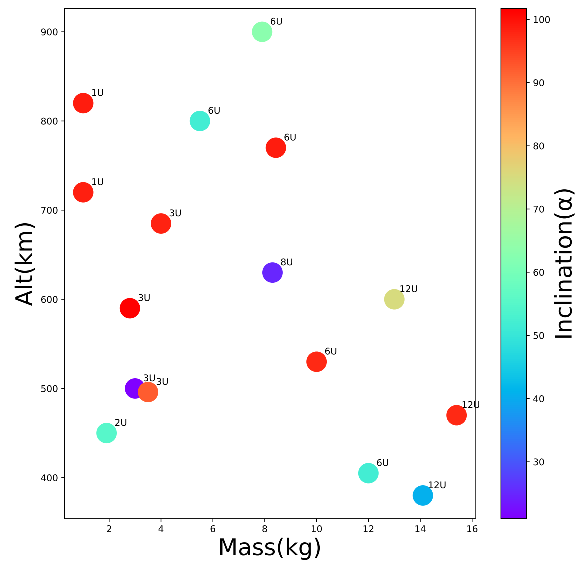
(a) Cubesat size scatter vs altitude.



(b) Downlink Freq over power per unit size.



(c) Power Loading



(d) Inclination

Figure 2.2 – Trade Studies

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Structure configuration for any CubeSat requires a lightweight material capable of withstanding the environmental elements it would be exposed to such as aerodynamic, gravitational, and solar torques that could arise during liftoff and transonic periods.

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The mass estimate

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8 Feasibility & Risk Control

8.1 Feasibility and Success Criteria

The success of this project depends on meeting the performance metrics and thereby achieving the goals mentioned in the mission statement. Table 8.1 indicates how those metrics will be for measured and whether the proposal holds true during testing phase.

Based on feasibility Table on the right and the project analysis provided shows the importance of orbital flight for ....

8.2 Risk Assessment

Risk assessment assures the stakeholders whether our cubesat is on track to be hazard free, secure, safe, and scientifically feasible. It is impossible to avoid risks completely. Thus, the team has provided a risk assessment definition in Table 8.2. Those definitions are basic guideline to help assessing the risks and provide some mitigation mechanisms. They are divided in to two sections:

Table 8.1 – Mission Success Criteria

Objective	Effective Measure	Control Method
Coverage of 110000 square miles (2400x1300 square km)	Variable setting camera lens (Wide and Narrow)	STK Simulation
Hurricane recognizing, Tracking and Alerting	Active tracking using Arcse Sagitta star tracker from ADCS	STK Simulation
Project Lifetime (15 years)	DHV-CS Solar Arrays and EXA BA0 high energy battery. Al 7075-t Support structure casing	STK Simulation, Solidworks for stress analysis
Updating every 15-20 min	ISIS S band, BPSK Modulation	STK Simulation
Data content (Image, Location, velocity)	ARM Cortex M7 OBC	STK Simulation
Atmospheric Data (Temp, Humidity, Wind)	Infrared Spectrum Camera	Sentinel toolbox, STK simulation

probability and severity. Probability is the likelihood of risk to occur, while severity is the effect of the risk. To determine the risk assessments a color grading scale is provided in Table 8.3. Bright red is a high probability and extremely severe. This risk will definitely hinder all types of operation and may even lead to complete failure of the mission. Green on the other hand is quite the opposite.

Table 8.2 – Risk Definitions

Risk Probability	Description
Frequent	Consistent threat to mission. Requires deliberate and active planning.
Occasional	May occur a couple-three times.
Improbable	Highly unlikely to occur.

Risk Severity	Description
Catastrophic	Would cause complete mission failure. It's a no-go situation.
Major	Would cause significant complication to mission.
Minor	Would causes a minor hindrance to mission.
Negligible	Minimal effect on mission.

Table 8.3 – Risk Color-grading

		Risk Severity			
		Catastrophic (4)	Major (3)	Minor (2)	Negligible (1)
Risk Probability	Frequent (A)	A4	A3	A2	A1
	Occasional (B)	B4	B3	B2	B1
	Improbable (C)	C4	C3	C2	C1

Updated risk assessment are shown below. Risk assessment assures the stakeholders whether our cubesat is on track to be hazard free, secure, safe, and scientifically feasible. It is impossible to avoid risks completely. Table 8.4 is where we listed out every possible risk. While most of the risks are accounted for, there might still be an unforeseeable event due to sudden radiation exposure or unaccounted space debris. HurriSat will still be utilizing its propulsion driven ADCS guided by the active software tracking to avoid debris. It will also feature a double wall bumper in the structures to sustain slight damage. Similarly, some parts of the IC transistors will have to be embedded with carbon Teflon shielding to resist radiation and thermal exposure.

Table 8.4 – Risk Assessment

Hazard	Assessment	Risk	Mitigation
Pre Launch			
Operational Cost	B3	Delayed project timeline	Clear focus on fund acquisition
Environmental (Dust,Humidity, Weather)	A1	Hinder launch-day, minor damage to Cubesat	Controlled and designated-construction environment
Transportation	A1	Damage to CubSat or team	Route Planning, safe access to traffic
Team injury	B1	Damage to team member and legal liability	Safe workspace guidelines
Technology Limitation	B1	Longer time and overhead	Mindful design
Post Launch			
Space Debris and Micrometeoroids	B4	Fatal destruction or damage of the Cubesat	Double Wall Bumper, Active space debris tracking software
Radiation Exposure	A3	Electronic systems, causing circuit damage or system shut downs	Transistors, IC's and circuits will be embedded with carbon nanotubes.
Thermal Damage	A2	Electrical, mechanical component damage	Selecting the best Thermal resistant shield
Solar Flares	C3	Damage or destruction of CubSat	Active tracking of solar threats. Selective Solar flare resistant design, Course correction mechanisms.
Foreign Satellites	C4	Longer time and overhead	Active tracking of other Satellites
Launch			
Initial Acceleration	B2	Damage due to increasing drag and friction	Minimized induced drag, using thrusters and controllers
Mechanical Vibration	B3	Structural and payload damage	Incorporate shock observant if possible. Distribute static loads.
Acoustic Energy	B2	Structural damage	Use sound suppression system and pressurized leveling.

8.3 Risk Control

Project Morbius is designed by taking the main anticipated risks in to account. The components are designed and selected in a manner they can mitigate ad avoid the potential risk as listed in Figure 8.5. The Risks anticipated column are color graded based on probability of that hazard occurring. (i.e. Red is frequent, while yellow is less likely to occur). The values how ever are assigned based on that specific risk severity.(i.e. 4 is catastrophic while 2 is minor). The risk plot Graph 8.1 the weights (risk severity) of those risks and what we did to mitigate them. Our two main catastrophic hazard concerns are space Debris and radiation. Those can penetrate cubesat's components and cause a major failure . However we can counter space-debris using active tracking software mechanism installed on the OBC computer and maneuvering using propelled thruster. A double wall bumper is also installed around the casing that can potentially shield most of the radiation and flares.

Of course there's a trade off of slight weight increase and steeper price for OBC processor. But those were the main reason that were chosen first hand. Other small scale risks are also anticipated but not shown (such as mechanical vibration, overhead and launching risks). Those however were found severe enough to halt the mission.

Table 8.5 – Mission Risks

Main Risks anticipated	Mitigation Plan Utilized	Value
B4 - Space Debris	Use onboard active tracking software maneuvering	4
A3 - Radiation	Use a double wall bumper. Cheaper than carbon nanotube components	3
A2 - Thermal	Silver-coated teflon instead of optical solar reflector	2
B3 - Cost	Compared components over several commercial sites	3
B2 - Launching Risks	Selected Falcon heavy as the safest possible option	2
C4 - Foreign Satellite	Effective communication using ARM Cortex with other satellites	4
C3 - Solar Flare	Course correction using BiSon64 and 2U propulsion for ADCS	3

8.4 Alternatives

- Optical solar reflector to counter solar flares can be used as cheaper alternatives instead of nanotube coating.
- Double wall bumpers were considered be used to further avoid thermal limitations.
- Alternate possible design considered as seen in Figure 8.2. Even if they can be used by switching up the axis of symmetry, there isn't enough area to put the solar cells on the side of frame. It can be possible considering lowering down the power budget for the cubesat.

8.5 Technology Gaps and Trades

Project Morbius is designed by focusing on detailed component requirement and constraint in mind. Although goal is to aim for the safest and efficient aircraft design possible, we are very limited on basis of cost and technological gap. The trade off is finding cheap yet good enough components, ... The list below highlights some of the challenges faced during this project.

- Launching mechanisms can only be determined by NASA and SpaceX mechanics.

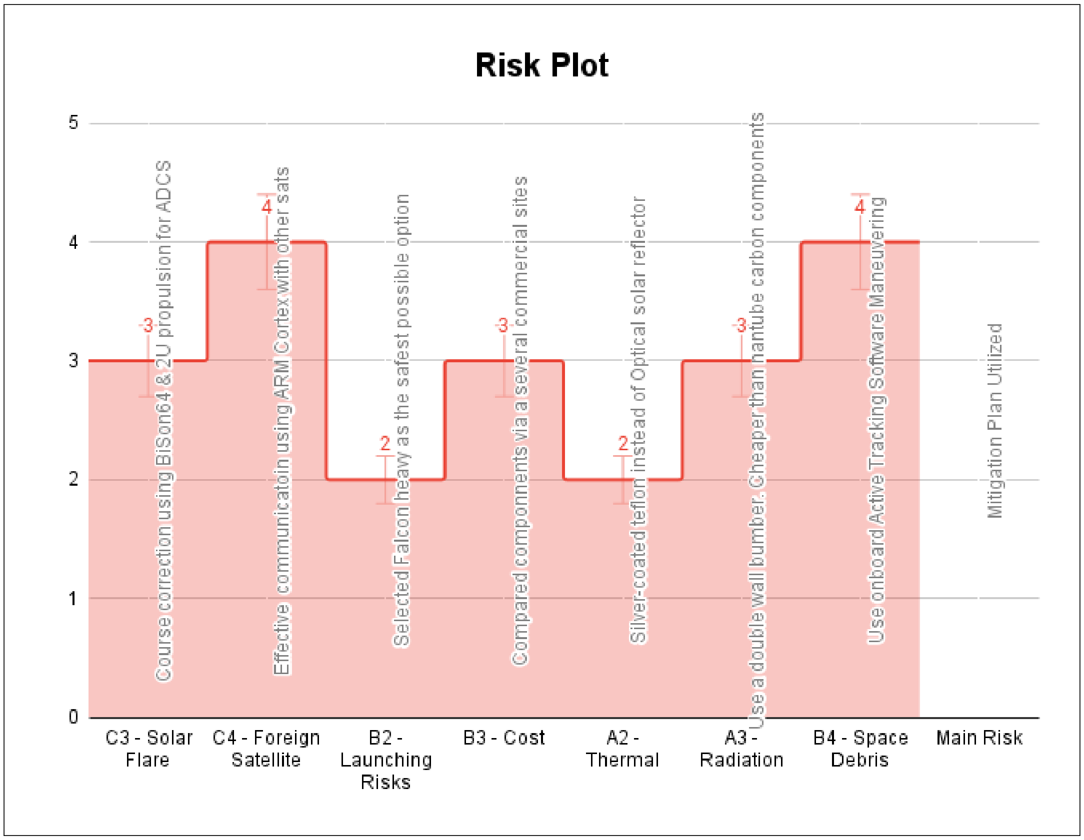

Figure 8.1 – Risk Control

- The ADCS and OBC can be combined for a an advanced all in one components, had there been no halt in electronics production due to the pandemic.
- Actual stress, thermal and radiation values may vary since we're not manufacturing the cubesats.
- Prices are subject to change based on demand and supply

9 Conclusion

9.1 Impact

9.2 Summary

9.3 Conclusion

Images/a1.png

(a) Set up 1

Images/a2.png

(b) Set up 2

Figure 8.2 – Alternative frames considered

10 Appendix

10.1 Additional

10.2 Codes and Scripts

10.2.1 Script for Trade Study

```
import numpy as np
```

10.3 Keywords

AF-M315E: Hydroxyl Ammonium Nitrate fuel/oxidizer blend

ADCS: Attitude Determination and Control System

10.4 List of Tables

10.5 List of Figures