FMEA and Hazard Analysis

Introduction

In any system, whether complex or simple, failure is bound to occur in their components. This Failure Mode Effect Analysis (FMEA) serves to quantify the importance of the components being used relative to our whole system, and address the modes of failures to achieve a more robust design. Along with looking at failure, hazardous materials utilized in this project will be addressed to ensure that the proper safety precautions are taken when handling them.

Hazard Analysis

The motor will be bought from contrail rockets and no modifications will be made. The motor, which includes the solid fuel grain, will be housed by Florida State University in a non-hazardous location. This location will ensure the motor is not in risk of accidental ignition. The same applies to the storage of the explosive charge used for the recovery system deployment. The Florida State University currently has nitrous oxide and is stored in a high pressure rated tank in a safe location. A dolly with ratchet straps will be used to relocate the nitrous oxide tank when necessary. This tank includes a regulator to ensure the supply is easily turned on or off. The regulator will feed into a long tube that will fuel the motor for launch.

Failure Mode Effects Analysis Background

In our FMEA, different mission phases are referred to. Below is a list of all the phases for the launch of the rocket.

Systems Set-up	**Assembly of systems, includes launch site and rocket**
Ignition	Ignition of motor
Launch	Rocket is launched from launch site
Flight	Rocket's flight from launch to apex and beginning of descent
Recovery System Deployment	Recovery system is deployed
Descent	Rocket descends from apex to ground
Landing	Rocket makes landing
Recovery	Rocket is recovered by team

Risk Level is calculated in our FMEA to determine which failure modes are most important to deal with. Risk Level is calculated based on structural severity, project severity, rate of detection and probability estimate. The formula and its variables are displayed in the following section.

Risk Level Calculation:

$$\boldsymbol{Risk\ Level} = (Average: \boldsymbol{Structural\ Severity}, \boldsymbol{Project\ Severity}, \boldsymbol{Rate\ of\ Detection}) * Percent\ \boldsymbol{Probability\ Estimate}$$

Rate of Detection is scaled to a 5 point scale for these calculations.

Probability Estimate

Probability Estimate is graded on a percent scale (0 -100).

Structural Severity

Structural Severity:	Brief Description	Description
1	No damage	Little to no damage.
2	Limited Damage	Minor damage to system. Easily replaceable and fixable.
3	Moderate Damage	One or two subsystems are damaged
4	Severe Damage	Multiple components are destroyed
5	Catastrophic failure	Rocket is destroyed

Project Severity

Project Severity:	Brief Description	Description
1	No Effect on Target	Goal is achieved
2	Slight Deviance from Target	Goal is achieved within an acceptable tolerance
3	Moderate Deviance from Target	Goal is not achieved and is outside acceptable tolerances
4	Severe Deviance from Target	Rocket got off the ground and goal is not achieved
5	Catastrophic failure	Goal is not remotely achieved

Rate of Detection

Rate of Detection:	Brief Description	Description
1	Before	Failure detection occurs before failure.
2	During	Failure detection occurs during failure.
3	After	Failure detection occurs after failure.
4	Never	Failure is undetected.

Failure Mode Effects Analysis

1. Body

POTENTIAL FAILURE MODE	BODY CATCHES FIRE	STRUCTURAL INTEGRITY COMPROMISED	MOTOR MISALIGNS	MOTOR DETACH
POTENTIAL CAUSES	Flammable Materials, motor leaks	thrust forces greater than material can sustain	Centering Rings fail, rigid connections to the body break	Rigid engine block mount loosens or fractures
MISSION PHASE	Ignition	Launch	Ignition or launch	Ignition or launch
LOCAL EFFECTS OF FAILURE	burnt material	Body material failure	Body and Motor damaged	Internal components and motor damages
NEXT HIGHER LEVEL END EFFECT	Internal Combustion	Internal Components are affected, Aerodynamics are affected	Rocket catches fire or explode, inaccurate trajectory, instability	Rocket catches fire or explodes, aerodynamic inefficiency, inaccurate trajectory, instability
SYSTEM LEVEL END EFFECT	Rocket Doesn't get off the ground, Rocket explodes, Internal Components damaged	Unstable trajectory, low apex, broken internal components	Unknown trajectory	Rocket doesn't leave ground, multiple internal components are damaged, motor is damaged
MITIGATION	Utilize more flame retardant material for the body	Use material capable of withstanding forces associated with launch	Measure motor possible motor offset from the center of the body opening to confirm proper alignment	Use mounting system rated for thrusts of G Class motor

2. Fins

POTENTIAL FAILURE MODE	BODY CATCHES FIRE	STRUCTURAL INTEGRITY COMPROMISED
POTENTIAL CAUSES	Flammable Materials, motor leaks	Drag forces greater than material can sustain
MISSION PHASE	Ignition	Flight
LOCAL EFFECTS OF FAILURE	Burnt material	Fin Material failure
NEXT HIGHER LEVEL END EFFECT	Damage to outer body of rocket, rocket is no longer stable	Aerodynamics are affected
SYSTEM LEVEL END EFFECT	Damage to outer rocket body, unstable trajectory, increased drag	Unstable trajectory
MITIGATION	Utilize more flame retardant material for the fins	Utilize a stronger fin material and or mounting method

3. Nose Cone

POTENTIAL FAILURE MODE	NOSE CONE PREVENTS RECOVERY SYSTEM DEPLOYMENT	NOSE CONE FALLS OUT TOO EARLY
POTENTIAL CAUSES	Drag Forces are greater than the ejection force of the recovery system, internal friction forces are greater than ejection force of the recovery system	Nose Cone tolerances mismatched, internal vibration loosens nose cone, recovery system misfires, nose cone breaks
MISSION PHASE	Recovery System Deployment	Ignition-Recovery System Deployment
LOCAL EFFECTS OF FAILURE	Nose Cone stays in place	Nose Cone falls out early
NEXT HIGHER LEVEL END EFFECT	Recovery system is not ejected	Recovery system is ejected to early
SYSTEM LEVEL END EFFECT	Hard landing of rocket, damage to multiple components	Recovery system catches fire, low apogee, unstable trajectory, damage to multiple components
MITIGATION	Increase force of nose cone ejection or decrease the force required for ejection.	Design and test proper tolerances for fitment

4. Electronics

POTENTIAL FAILURE MODE	BOARD FAILS TO EXECUTE CODE	DATA IS NOT STORED PROPERLY	INCORRECT ALTIMETER READINGS	INCORRECT ACCELEROMETER READINGS
POTENTIAL CAUSES	Poor programming, board defects, disconnected wires, damage from ignition, outside heat tolerances	Storage unit (SD Card) not mounted properly, board fails to recognize the storage component	Loose wires, faulty altimeter, damage from ignition, outside heat tolerances, poor programming, failures in board, bad calibration	Loose wires, faulty accelerometer, damage from ignition, outside heat tolerances, poor programming, failures in board
MISSION PHASE	Launch Site Setup, Recovery System Deployment	Flight	Safety System, Recovery System Deployment	Launch Site Setup, Recovery System Deployment
LOCAL EFFECTS OF FAILURE	The code runs improperly	Altitude data is not stored from flight	Altimeter reads false or no values	Accelerometer reads false or no values
NEXT HIGHER LEVEL END EFFECT	Recovery doesn't deploy or deploys too early, ignition fails, data isn't recorded	N/A	Early or late deployment of the recovery system, unstable trajectory, low apex	Early or late deployment of the recovery system, unstable trajectory, low apex
SYSTEM LEVEL END EFFECT	Rocket doesn't fire, data isn't recorded, hard landing of rocket, multiple if not all components destroyed, unstable trajectory	Disqualified from competition	Recovery system might catch fire, low apogee, unstable trajectory, no data recorded, multiple components are damaged	Recovery system might catch fire, low apogee, unstable trajectory, multiple components are damaged
MITIGATION	Test practice code before launch to ensure success	Test data storage with random values to ensure success	Ensure coding is correct and testing	Ensure coding is correct and testing

5. Recovery System

POTENTIAL FAILURE MODE	RECOVERY SYSTEM DEPLOYS EARLY	RECOVERY SYSTEM DEPLOYS LATE	RECOVERY SYSTEM DOESN'T DEPLOY
POTENTIAL CAUSES	Altimeter or accelerometer reads bad values, nose cone falls out, board malfunctions, loose wires, damage from ignition	Altimeter or accelerometer reads bad values, nose cone stays in, board malfunctions, loose wires, damage from ignition	Altimeter or accelerometer reads bad values, nose cone stays in, board malfunctions, loose wires, damage from ignition
MISSION PHASE	Launch Site Setup-Recovery System Deployment	Recovery System Deployment-Landing	Recovery System Deployment-Landing
LOCAL EFFECTS OF FAILURE	Unstable trajectory, recovery system break	Recovery system deploys late	Recovery system stays in rocket
NEXT HIGHER LEVEL END EFFECT	Body failure, recovery system catches fire	Higher landing velocity, body failure	Higher landing velocity
SYSTEM LEVEL END EFFECT	Recovery system might catch fire, low apogee, unstable trajectory, multiple components are damaged	Unstable trajectory, multiple components are damaged, rocket is destroyed	Rocket is destroyed
MITIGATION	Test out various deployment of recovery system to ensure it deploys at the right time	Test out various deployment of recovery system to ensure it deploys at the right time	Test out various deployment of recovery system to ensure it deploys at the right time

6. Motor

POTENTIAL FAILURE MODE	NO IGNITION	UNCONTROLLED IGNITION
POTENTIAL CAUSES	Incorrect coding, wiring, ignition not sparking, oxidizer injection failure	Incorrect Coding, wiring, ignition not sparking, oxidizer injection failure, oxidizer and fuel grain not mixing well
MISSION PHASE	Ignition	Ignition
LOCAL EFFECTS OF FAILURE	No motor ignition	Motor explodes
NEXT HIGHER LEVEL END EFFECT	No starting velocity	Multiple components are damaged
SYSTEM LEVEL END EFFECT	Rocket doesn't leave ground	Rocket is destroyed or multiple components are damaged
MITIGATION	Check wiring and coding. Check motor status.	Check wiring and coding. Check motor status.

Risk Level

Item	Potential Failure Mode	Probability Estimate [%]	Structural Severity	Project Severity	Rate of Detection	Risk Factor
Body Material	Body catches fire	1	5	5	2	4.17
Body Material	Structural integrity compromised	5	3	4	3	17.92
Engine Mount	Motor misaligns	5	2	3	3	14.58
Engine Mount	Motor detach	5	4	5	2	19.17
Fin Material	Body catches fire	1	2	4	2	2.83
Fin Material	Structural integrity compromised	10	2	3	3	29.17
Nose Cone Design	Nose cone prevents recovery system Deployment	5	5	5	2	20.83
Nose Cone Design	Nose cone falls out too early	3	3	4	2	9.5
Electronic Boards	Board fails to execute code	10	5	5	3	45.83
Electronic Boards	Data is not stored properly	1	1	5	3	3.25
Altimeter	Fails to read altitude or read it incorrectly	1	4	3	4	4
Accelerometer	Fails to read acceleration or reads it incorrectly	1	4	2	4	3.67
Recovery System Deployment	Recovery system deploys early	15	4	3	3	53.75
Recovery System Deployment	Recovery system deploys late	15	5	3	3	58.75
Recovery System Deployment	Recovery system doesn't deploy	10	5	5	3	45.83
Motor	No ignition	1	1	5	2	2.83
Motor	Uncontrolled ignition	1	5	5	2	4.17

Conclusion

The failures that need to be specially addressed and concentrated on are the possible failures that have the highest risk factors. These failures impose the greatest risks to our progress in the competition. The failures that have the largest risk factors are that the recovery system deploys late, early or not at all and the electronic board failing to execute its given code correctly. Additionally, the failure of the fin material's structural integrity and the failure of the nose cone not ejecting and preventing recovery system deployment have high risk factors too. As previously mentioned we have planned for mitigation of these failures, but extra effort must be made to prevent these failures to occur in the first place. This can be done with attaining a deep understanding of why each failure may occur and how to prevent it. Designs to prevent failures will be tested to ensure no failures occur and allow us to fulfill our greatest potential.