The DORIS Project

Finalized Testing Plan

Dylan Boeholt – Flight Test Engineer & Frame Expert
Andre Bonillas – Logistics Chief & Payload Engineer
Connor Davidson – Project Manager
Jeremy Malmo – Fabrication Engineer
Michael Zielinski – Finance Manager & Electronics Engineer

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Project Sponsor: The Boeing Company
Instructor: Professor James Clark
Faculty Advisor: Professor David Willy

1. Design Requirements Summary

1.1 Customer Requirements (CRs)

CR1. High Mobility – The drone needs to be highly maneuverable. Able to turn sharply and easy to control to be able to pick up and drop the payload at the waypoints.

CR2. Small – The drone needs to be small and still fit all essential parts such as battery and receivers as well as the payload pick-up system.

CR3. Complete Recon Mission – The drone must be able to fly to and pick-up a payload then fly it to another waypoint to drop it off. The drone must also be capable of flying with a camera and taking at minimum one photo of the team below. Lastly, it must be able to carry and launch a steerable cruise missile.

CR4. Payload Capacity – The drone can carry a significantly heavy payload, a third of its own weight.

CR5. Battery Capacity – The battery must be efficient/large enough to power the full mission and land back at home point. It must also have an endurance of at least 10 minutes.

CR6. Cost Efficiency – There is a limited budget for this project, so the team needs to watch their purchases and look for cheaper options if possible.

CR7. Thrust Efficiency – The drone should have a high thrust to weight ratio to be able to move easily and lift heavy payloads.

1.2 Engineering Requirements (ERs)

ER1. Thrust to Weight Ratio – The goal ratio is for the thrust to be at least 3 times the weight of the drone. This goal was set so that we can lift the payload and still fly with high mobility.

ER2. Compact Design – The drone should be under 5 feet in height, width, and length. If the drone gets too large it will become heavier which gets harder to counter with thrust. Also, maneuverability will be more difficult.

ER3. Payload Weight – The payload must be at least 30 % of the weight of the drone. To do this, the drone needs to have powerful motors with efficient propellors to give it high thrust.

ER4. Time of Flight – The minimum requirement for the time in the air is 10 min. This test will be done with a full battery and keeping the drone at a hover.

ER5. Total Cost – The budget is $3,000 so all purchases must be tracked to make sure the spending does not exceed the limit. An additional 10% ($300) must be fundraised by the team.

ER6. Meet FAA Requirements - The team must meet the regulations set by the Federal Aviation Administration for Unmanned Aircraft Systems (UAS). The most important ones are that the team cannot fly it above 400 ft and the drone must weigh less than 55 lbs. If necessary, the drone should be registered with the FAA.

2. Top Level Testing Summary

Experiment/Test	Relevant DRs	Testing Equipment Required	Other Resources
Exp 1: Take-off Test	ER – 4 ER – 6 CR – 3 CR – 5	-Drone System -FlySky Remote -Recording Device (iPhone) -stopwatch	-Good weather or large indoor location -certified drone pilot -Level Ground
Exp 2: Landing	ER – 4 ER – 6 CR – 3 CR – 5	-Drone System -FlySky Remote -Recording Device (iPhone) -stopwatch	-Good weather or large indoor location -certified drone pilot -level ground
Exp 3: Thrust Dyno Testing	ER – 1 CR – 7	-Strain gauge test stand/dynamometer -Motor + propeller -Digital multimeter	-excel spreadsheet -Ear Protection -Eye Protection -Video Camera
Exp 4: Side-to-side mobility test	ER – 2 CR – 1 CR – 2	-Drone System -FlySky Remote -Recording Device (iPhone)	-Good weather or large indoor location -certified drone pilot
Exp 5: Payload pickup and deployment	ER – 3 CR – 4	-Drone System -FlySky Remote	-weighted payload (hand weight) -camera payload

3. Detailed Testing Plans

Test #1 – Basic Lift off:

Experiment/Test Summary:

This test aims to determine whether the drone can generate sufficient lift to take off and hover stably. It will evaluate motor and propeller performance, overall stability, and any potential imbalances. The design requirements being tested include achieving a smooth takeoff and verifying that the motors provide adequate thrust relative to the drone's weight.

Equipment Needed:

- Fully assembled drone
- Fully charged battery
- Flight controller
- Remote controller and receiver
- Safety gear (protective eyewear)
- Open test area with minimal wind interference

Variables Measured:

- Throttle percentage required for takeoff
- Hovering stability (qualitative assessment)
- Any unexpected yaw, pitch, or roll movements

Variables Calculated from Results:

- Actual lift force at takeoff
- Expected throttle percentage for takeoff based on thrust-to-weight ratio
- Power consumption during takeoff

Procedure:

1. Perform a pre-flight check to ensure all components are secure and properly connected.
2. Power on the drone and calibrate the flight controller if necessary.
3. Arm the motors and gradually increase throttle.
4. Observe the throttle percentage at which the drone achieves lift-off.
5. Monitor stability, looking for any unexpected tilts, oscillations, or uneven lift.
6. Maintain a low hover for a few seconds before gradually reducing throttle to land.
7. Record observations and analyze power consumption.

Results:

Expected Results:

- The drone should lift off at approximately 33% throttle, based on a 3:1 thrust-to-weight ratio.

- The total system weight is 21 lb, meaning each motor must generate at least 5.25 lb (2.38 kg) of thrust for takeoff.
- Based on previous thrust tests at ____**%** throttle, each motor should generate around ____**g** of thrust, confirming takeoff feasibility.
- Hovering should be stable, requiring only minor tuning adjustments.

Observed Results:

- Actual throttle percentage at lift-off: _____**%**
- Stability: [Stable/Unstable]
- Any anomalies (e.g., unexpected drift, imbalance, high power consumption)

Conclusion:
The take-off test [was/was not] successful. If successful, the drone demonstrated proper lift capability and control, confirming that the motors and propellers provide adequate thrust. If issues occurred, adjustments such as PID tuning, weight distribution, or propeller balancing will be made before retesting. Future tests will include hover duration testing, maneuverability assessments, and power efficiency analysis.

Test #2 – Basic Landing:

Experiment/Test Summary:
This test aims to evaluate the drone's ability to land smoothly and safely. It will assess motor response during descent, stability upon touchdown, and any potential imbalances or control issues. The design requirements being tested include achieving a controlled descent, maintaining stability, and ensuring that all motors respond correctly to throttle adjustments during landing.

Equipment Needed:

- Fully assembled drone
- Fully charged battery
- Flight controller
- Remote controller and receiver
- Safety gear (protective eyewear)
- Open test area with minimal wind interference

Variables Measured:

- Throttle percentage required for a controlled descent

- Stability upon touchdown (qualitative assessment)
- Any unexpected yaw, pitch, or roll movements during landing

Variables Calculated from Results:

- Rate of descent during landing
- Expected throttle percentage required for a stable descent
- Power consumption during landing

Procedure:

1. Perform a pre-flight check to ensure all components are secure and properly connected.
2. Power on the drone and calibrate the flight controller if necessary.
3. Take off and stabilize the drone at a safe altitude.
4. Gradually decrease throttle to initiate descent.
5. Observe how the drone responds to throttle adjustments and whether it remains level.
6. Monitor stability upon touchdown, looking for any bounces, tilts, or abrupt stops.
7. Record observations and analyze power consumption during the descent and landing.

Results:

Expected Results:

- The drone should achieve a smooth descent at an estimated ____% throttle reduction from hover.
- The rate of descent should be gradual and controlled, avoiding sudden drops or instability.
- The drone should land with minimal bouncing or tipping, ensuring even weight distribution.

Observed Results:

- Actual throttle percentage for a controlled descent: ____**%**
- Stability upon landing: [Stable/Unstable]
- Any anomalies (e.g., bouncing, tipping, uneven motor response)

Conclusion:

The landing test [was/was not] successful. If successful, the drone demonstrated proper control during descent and a stable touchdown, confirming that the motors and flight controller effectively manage the landing phase. If issues occurred, adjustments such as PID tuning, descent rate calibration, or weight distribution adjustments will be made before retesting. Future tests will include precision landing assessments, autonomous landing validation, and energy efficiency analysis during descent.

Test #3 – Thrust Analysis:

Experiment/Test Summary:
This test aims to measure the thrust output of the drone's motors and propellers using a thrust dynamometer (dyno). The data collected will help determine the actual thrust-to-throttle relationship, power consumption, and efficiency of the propulsion system. This test ensures that the motors provide the necessary thrust for stable flight and payload capacity.

Equipment Needed:

- Thrust dynamometer capable of measuring up to 10 kg of thrust
- iFlight XING X4214 660KV motor
- HG 16x8 propeller
- Fully charged battery (specify type and capacity)
- Electronic speed controller (ESC)
- Power meter (to measure voltage, current, and power consumption)
- Data logging system for recording thrust and electrical measurements
- Safety gear (protective eyewear, gloves)
- Secure test stand for mounting the motor and dynamometer

Procedure:

1. Secure the motor to the thrust dynamometer on a stable test stand.
2. Connect the motor to the ESC and power supply, ensuring all electrical connections are secure.
3. Calibrate the dynamometer and power meter before testing.
4. Gradually increase throttle in 15% increments (e.g., 15%, 30%, 45%, etc.) up to a maximum safe limit.

5. Record thrust output, voltage, current, and power consumption at each throttle level.
6. Monitor for any abnormal vibrations, excessive heat, or irregular motor behavior.
7. After reaching the highest test throttle, gradually reduce throttle and shut down the system.
8. Analyze the recorded data to determine efficiency, thrust-to-power ratio, and performance trends.

Expected Results:

- The motor should generate at least _____g of thrust at _____% throttle, matching or exceeding expected values from manufacturer data.
- The thrust-to-power ratio should be consistent with previous tests and theoretical calculations.
- Power consumption should remain within safe operating limits, avoiding excessive current draw or overheating.
- The motor and propeller combination should exhibit smooth, stable performance with minimal vibration throughout the test.

Conclusion:

The thrust dyno test [was/was not] successful. If successful, the data confirms that the motor and propeller combination can generate sufficient thrust efficiently, supporting the drone's flight requirements. If issues occurred, adjustments such as motor tuning, propeller balancing, or ESC calibration will be considered before retesting. Future tests will focus on full-scale power efficiency analysis, endurance testing, and fine-tuning motor performance for optimal flight characteristics.

Experiment/Test #4 – Side-to-Side Motion

Experiment/Test Summary:
This test aims to evaluate the drone's ability to perform controlled lateral (side-to-side) movement. It will assess motor and propeller responsiveness, stability, and flight controller tuning for precise horizontal motion. The design requirements being tested include smooth and controlled lateral transitions without excessive drift or instability.

Equipment Needed:

- Fully assembled drone
- Fully charged battery

- Flight controller with properly configured stabilization settings
- Remote controller and receiver
- Safety gear (protective eyewear)
- Open test area with minimal wind interference
- Measuring markers or a motion tracking system (optional)

Variables Measured:

- Throttle and control input required for lateral movement
- Stability during side-to-side motion
- Response time to control inputs
- Any unexpected drift or instability

Variables Calculated from Results:

- Maximum lateral speed achieved
- Efficiency of lateral movement (power consumption vs. distance covered)
- Potential need for PID tuning adjustments

Procedure:

1. Perform a pre-flight check to ensure all components are secure.
2. Power on the drone and calibrate the flight controller if necessary.
3. Take off and stabilize the drone at a safe hover altitude.
4. Apply small lateral control inputs to move the drone left and right over a fixed distance.
5. Observe and record the drone's response to control inputs, checking for any drift or instability.
6. Gradually increase movement speed while maintaining control and stability.
7. Land the drone safely and analyze power consumption and motor response data.

Expected Results:

- The drone should respond smoothly to lateral control inputs with minimal delay.
- Side-to-side motion should be stable and predictable, without excessive drift or oscillations.

- The power consumption should remain within expected limits, and motor temperatures should not rise excessively.
- Any need for flight controller tuning (PID adjustments) or weight balancing should be identified based on performance.

Conclusion:

The side-to-side motion test [was/was not] successful. If successful, the drone demonstrated stable lateral movement and precise control, confirming proper motor responsiveness and flight controller settings. If issues occurred, adjustments such as PID tuning, weight distribution, or control sensitivity refinement will be made before retesting. Future tests will include faster lateral movements, automated path-following, and fine-tuning stability at different speeds.

Experiment/Test #5 – Payload Pickup and Deployment

Experiment/Test Summary:
This test evaluates the drone's ability to pick up and deploy a payload using a magnetic attachment system activated by a servo motor. The test will assess the system's reliability, stability during flight, and control precision when engaging and disengaging the payload. The design requirements being tested include successful payload acquisition, secure transportation, and controlled release without excessive swinging or instability.

Equipment Needed:

- Fully assembled drone with magnetic payload attachment system
- Fully charged battery
- Flight controller with integration for servo activation
- Remote controller and receiver
- Test payload (tennis ball or equivalent object with a compatible magnet)
- Safety gear (protective eyewear, gloves)
- Open test area with minimal wind interference

Variables Measured:

- Success rate of payload pickup and release
- Stability of the drone while carrying the payload
- Servo motor activation response time
- Power consumption during payload handling

Variables Calculated from Results:

- Maximum payload weight the magnetic system can securely hold
- Effect of payload weight on flight stability and battery life
- Optimal throttle percentage for stable flight with payload

Procedure:

1. Perform a pre-flight check to ensure all components, including the magnetic attachment system and servo motor, are functional.
2. Power on the drone and calibrate the flight controller if necessary.
3. Take off and hover over the payload placement area.
4. Activate the servo motor to engage the magnetic attachment, securing the payload.
5. Observe and record whether the payload is securely attached and lifted.
6. Transport the payload to a designated drop zone while maintaining stable flight.
7. Activate the servo motor to deactivate the magnet and release the payload in a controlled manner.
8. Land the drone safely and analyze the magnetic system's performance, power consumption, and flight stability.

Expected Results:

- The magnetic system should securely attach and lift the payload without unintended detachment.
- The drone should maintain stable flight while carrying the payload.
- Power consumption should increase proportionally to the added weight, remaining within safe operating limits.
- The payload should be cleanly released when the servo motor deactivates the magnet, minimizing swinging or instability.

Conclusion:

The payload pickup and deployment test [was/was not] successful. If successful, the drone demonstrated reliable magnetic payload handling capabilities, confirming the effectiveness of the servo-actuated system. If issues occurred, adjustments such as increasing magnet strength, optimizing servo response time, or improving weight distribution will be made before retesting. Future tests will focus on lifting different payload weights, optimizing power efficiency, and testing automated pickup and drop sequences.

4. Specification Sheet Preparation

Table 2: CR Summary Table

Customer Requirement	CR met?	Client Acceptable
CR1 - High Mobility		
CR2 - Small		
CR3 - Complete Recon Mission		
CR4 - Payload Weight		
CR5 - Battery Capacity		
CR6 - Cost Efficiency		
CR7 - Thrust Efficiency		

Table 3: ER Summary Table

Engineering Requirement	Target	Tolerance	Measured/ Calculated Value	ER met?	Client Acceptable
ER1 - Thrust to Weight Ratio	3:1	+/- 100 g			
ER2 - Compact Design	3X3X3 ft / 50 lbs	1 in/ 5lbs			
ER3 - Complete Course in Time Limit	9 minutes	+/- 1 minute			
ER4 - Payload Weight	30% weight of the system	+/- 1 pound			
ER5 - Time of Flight	10 minutes	+/- 30 seconds			
ER6 - Total Cost	$3000	+/- $717.70			
ER7 - Meet FAA Requirements	Met	N/a			

5. QFD

After discussion with our Boeing sponsors, it was determined that the engineering and customer requirements for our project could remain as they were from last semester, with the exception of the cruise missile requirement which we have appealed and removed. We have also determined that since our drone weighs less than 55 lbs. and is not flown for commercial purposes, it is defined as a recreational small Unmanned Aircraft System (sUAS). This means it does not need to be registered through the FAA with an ID number, and the team will continue to follow FAA regulations by keeping the drone's weight and size within the current spec. The QFD links our ERs to our CRs. The most relevant ER to accomplish our CRs is having a thrust to weight ratio greater than 3:1. All mission objectives depend on this ER. The ER that related least to CRs was following FAA requirements. This is essential but it did not correlate to most CRs because none push the limits of recreational sUAS except that it could not be larger than 55 lbs.

3 Highest on scale

	Thrust : weight > 3:1	Compact Design under 3'x3'x3'	Complete Course < 10 min	Payload > 30% of weight	Time of flight > 10 min	Total Cost under $3,000
Thrust : weight > 3:1						
Compact Design under 3'x3'x3'						
Complete Course < 10 min	3					
Payload > 30% of weight	1		1			
Time of flight > 10 min	3		1	1		
Total Cost under $3,000		3			1	
Meets FAA requirements (weight < 55 lbs)	3	3		1	3	3

Technical Requirements

Customer Needs	Customer Weights: 1-5	Thrust : weight > 3:1	Compact Design under 3'x3'x3'	Complete Course < 10 min	Payload > 30% of weight	Time of flight > 10 min	Total Cost under $3,000	Meets FAA requirements (weight < 55 lbs)
High mobility	4	5	5	5	1	2	1	
Small	1	4	5	3		5	5	5
Complete Boeing Recon Mission	5	5	3	2	4	2		
Payload Capacity	5	5	1	2	5	1	2	
Battery Capacity for small mission	4	3	2	4	4	5	1	1
Cost Efficiency	3	1	2	3		2	5	4
Thrust Efficiency	4	5	3	5	4	5	2	

Technical Requirement Units		Feet	minutes	% weight	minutes	USD	pounds
Technical Requirement Targets	3:1	< 3x3x3	< 10	> 30	> 10	>3000	< 55
Absolute Technical Importance	28	24	24	18	22	16	15
Relative Technical Importance	1	3	3	5	4	6	7

Figure 1: Quality Function Deployment Diagram

Commented [DB1]: I cropped the picture to take out FAA registered CR. That is why there is 2 halves of the QFD.