AL-37 Flight Report

Battery Consumption Flight
April 9, 2022

Boeing Experimental Flight

Iowa State University of Science and Technology

IOWA STATE UNIVERSITY

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by

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Project Duration: January, 2022 - May, 2022

Cover: The AL-37 when the electronics were inspected just after flight.

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Abstract

Before the flight, the Pixhawk 4 system was installed to gather flight data, specifically looking for data about battery discharge rate, flight time, telemetry, and aircraft velocity. This data was needed to calculate variables such as maximum rate of climb, maximum range/endurance, and other vital calculations relative to optimal craft performance. This led to scrapping the manufacturer's power module and replacing it with specific components that support the Pixhawk control capabilities. That system would become the powerhouse leading up to the flight.

The days leading to the flight were quite simple. Preliminary tests of the controls to make sure everything was running properly. Because these precautionary measures were taken, the flight was very successful. The Pixhawk system was able to record the proper data needed, and this data was converted into a readable file. This data was interpreted and used to draft charts and graphs displaying those chosen parameters with respect to the passing time.

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Introduction

1.1. Overall

The Boeing Experimental Flight Project is a group that is part of the Make to Innovate program at Iowa State University. The project's main objective is to develop and test new parts for an electric aircraft. This meant developing new wings and testing them using computational fluid dynamics or a wind tunnel in previous semesters. This semester it means developing a remote control aircraft to collect data in flight conditions.

1.2. About the AL-37

The AL-37 is a remote control aircraft by Freewing. It is a 1/19 scale of the Boeing 737. It is 78.74 inches long and has a wingspan of 72.04 inches. It is powered by two 6S 2952-2100Kv inrunner motors with a 12-Blade EDF. It also features a fully operational LED lighting system and retractable landing gear, like an actual Boeing 737. The project's version of the AL-37 has some modified electronics. These include a Pixhawk system to track and record data for the aircraft. The wiring was also modified to allow for the Pixhawk to eventually take automated control over the aircraft.

1.3. About this flight

The effectiveness of the voltage-based estimation with the load compensation system was tested for this particular flight test. The system works by measuring the voltage and current leaving the battery. With that real-time information and preprogrammed values, like the number of cells, empty voltage, and internal resistance of the battery, the Pixhawk calculates a remaining real-time percentage of the battery. This system was needed because the aircraft nearly crashed after not having a way to express low battery indication in the flight test conducted last semester. This system then reports the correct values in a post-flight log for further review. The aircraft was taken to a nearby airfield and assembled. The drone pilot was briefed on the controls of the aircraft. The plane took off and landed after less than five minutes of flight time. The flight test went without any major issues.

2 Methodology

2.1. Assembly

The AL-37 had three overall parts that needed to be assembled. These parts were the fuselage and both of the wings.

1. Ensure that there is no power running through the aircraft
2. Insert the carbon fiber rod into the designated hole in the side of the aircraft where the wing should go
3. Two people hold up the fuselage while another person plugs in the electronics
   (a) The three connectors for the motors are connected
   (b) The overall electronics connector for the ailerons and flaps are connected
4. Power and arm the aircraft
5. Check if all systems are operating as intended

2.2. System Checks

Before departing the university, the aircraft was checked for issues through pre-flight tests. The aircraft was armed, and the following systems were tested:

- **Flaps:** Utilizing different notches of a switch on the controller, each of the three levels of flaps was tested. The flaps on the aircraft's left wings were sluggish due to a faulty servo motor but were operational for the flight.
- **Ailerons:** These were tested by pointing the controller's right stick to the right and left. Both ailerons responded as intended.
- **Rudder:** This was tested by pointing the left stick of the controller to the right and left. The rudder responded as intended.
- **Landing Gear Toggle:** Using another switch on the controller, the landing gear could be brought down or retracted. This system was working as intended.
- **Engine Thrust:** This was tested by pointing the right stick up and down. Both of the engines were operating as intended.
- **Voltage-Based Estimation system:** This was tested by monitoring electrical current changes on the computer that was connected to the systems of the aircraft. This was working as intended.
- **Lighting:** Although this was not important for this flight, the landing, navigation, strobe, and beacon lights were inspected to verify proper operation. The entire lighting system was working as intended.

This check was done once again upon arrival at the airfield to ensure the proper function of aircraft systems prior to flight.

2.3. Safety Procedures

Safety was the highest priority of Boeing Experimental Flight when testing the aircraft. Proper communication was something that all of the members practiced when working in the lab. When connecting the battery:

1. The person connecting the battery announces their intentions to other members
   (a) If a person is working on electronics, they must immediately tell the person with the battery
   (b) If there is an agreement, then an understanding is established that the battery will be connected
2. All hands are off of the electronics within the aircraft when the battery is connected
3. If an electronics component is operating dangerously or there are signs of overheating, the battery is immediate to be disconnected is immediately disconnected

There are also special procedures for testing. For this, members are to utilize key phrases.

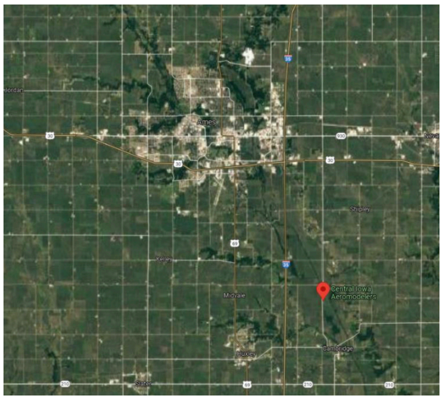
1. The operator announces that they will arm the aircraft. The other members repeat the message back to the operator as a confirmation.
2. The operator announces each system they are testing right before testing them.
   (a) Special procedures are needed for testing the engine as members will need to hold the aircraft in place while the aircraft is running at a high rpm rate.
   (b) Safety glasses are required for all members around the aircraft.
   (c) The operator announces that the safety mode has been turned off. The other members repeat the message back to the operator as a confirmation.
   (d) When increasing thrust, the operator announces that they are increasing thrust to their intended level thrust (for example. "increasing thrust to 50 percent"). The other members repeat the message back to the operator as a confirmation.
   (e) When decreasing thrust to 0, the operator announces that they will kill the thrust.
   (f) The members cannot let go of the aircraft until the operator has announced that the safety mode has been turned back on.
3. The operator announces that they will disarm the aircraft. Once the aircraft is properly disarmed, the battery may be removed.

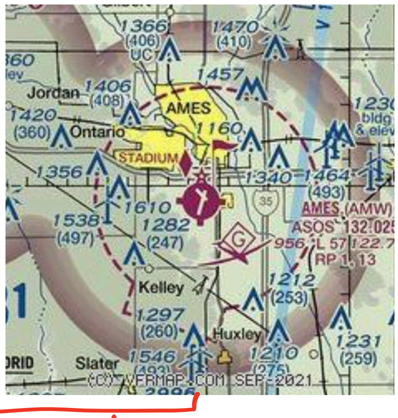
2.4. General Flight Information

Flight Date and Time: April 9, 2022 at 12:35
Flight Duration: 3-4 min
Weather Conditions: Clear and Sunny
Temperature: 49° F
Wind: 8 mph 150° SE
Visibility: 10 mi

Table

Airfield: Central Iowa Aeromodelers AMA field
Distance from KDSM (Class C Airspace): 26 mi
Airspace: Class G up to 700 ft AGL, Class E above
Restrictions: Flight ceiling is 400 ft due to Part 107 restrictions
Pilot in Command: Dennis Goodrich, drone pilot with part 107 license and membership in Central Iowa Aeromodelers AMA Club.





captions

2.5. At the Airfield

The following procedure was followed upon arrival at the airfield:

1. The aircraft was assembled using the assembly procedure
2. The battery was plugged in, and the aircraft was armed
3. All aircraft systems were tested to ensure that the aircraft was operational prior to flight
4. The pilot was debriefed on the major controls of the aircraft
5. The aircraft was taken out to the runway, and there was a final communications check to ensure that the aircraft was communicating with the telemetry system on the ground
6. Once communication was confirmed, the safety mode was turned off, and everyone went to the edge of the runway
7. At 12:38, the aircraft took off successfully
8. The aircraft was flown around the airfield while the pilot provided feedback on the controls
9. At 12:42, the aircraft landed successfully
10. The safety mode was turned on, and the electronics were disarmed immediately after the aircraft came to a stop
11. The electronics and exterior were checked for damage
12. The aircraft was taken back to the assembly station, where the battery was disconnected
13. The aircraft was disassembled while the pilot provided final feedback

3

Data Analysis

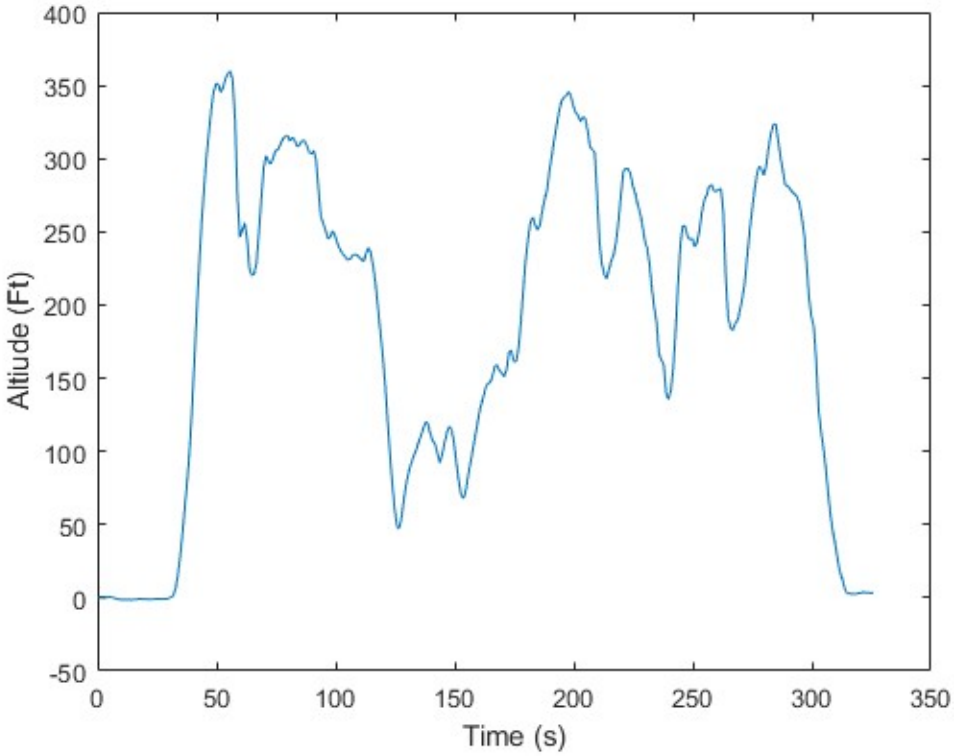
3.1. Acquisition

The Pixhawk automatically collects data while turned on. This data contains everything that the Pixhawk interacts with, from voltages of the battery to commanded inputs to the utilization of computing and memory onboard. All of this is then available in a ULog file. This file was then decoded using PlotJuggler. Also, in PlotJuggler, a new data set was created. That data set was the backward difference approximation of instantaneous milliamp-hour per second while powered on. The entire ULog file, including the new discharge data set, was exported in a comma-separated values(CSV) format. With this CSV file, a MATLAB script was created to pull data out of the CSV and graph it.

Cite github page

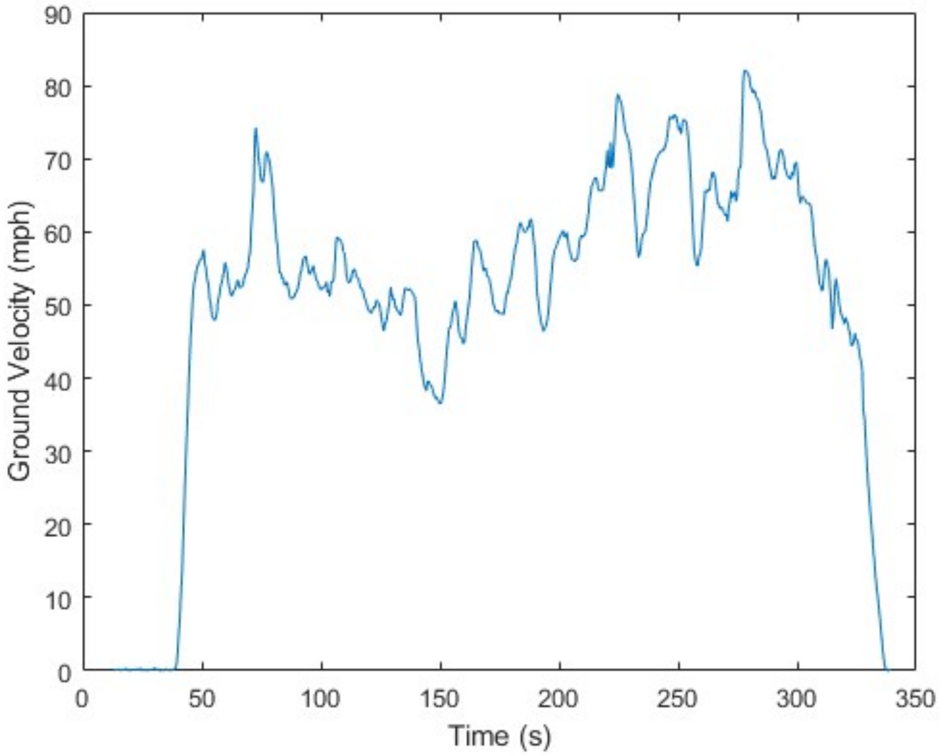
Include matlab script in Appendix (use 361 report knowledge to import it correctly)

3.2. Flight Data



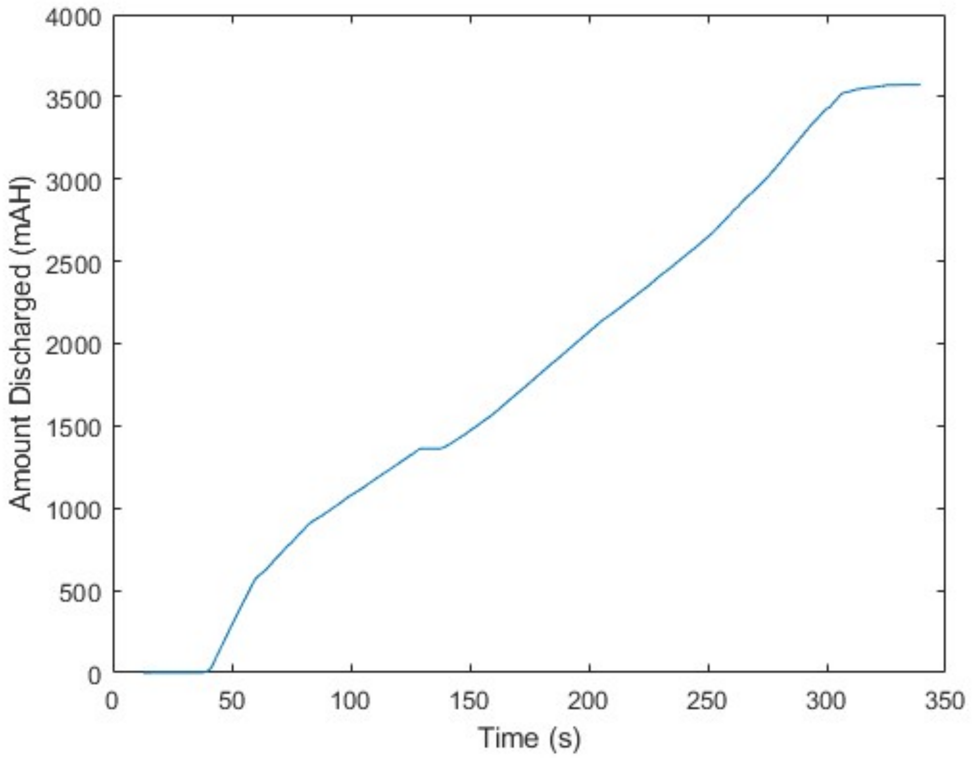
Caption

This graph shows the flight altitude as a function of time since battery connection, measured by the onboard GPS module and using the runway as a datum. The flight reached a maximum altitude of 359ft above the datum and a minimum of 47ft above the datum. An average altitude of 260ft was achieved over the window of 180 seconds to 300 seconds since the system was on. In addition, this graph was used to calculate the flight time of 4 minutes and 42 seconds using an altitude of at least 3ft to declare the start and end of flying.



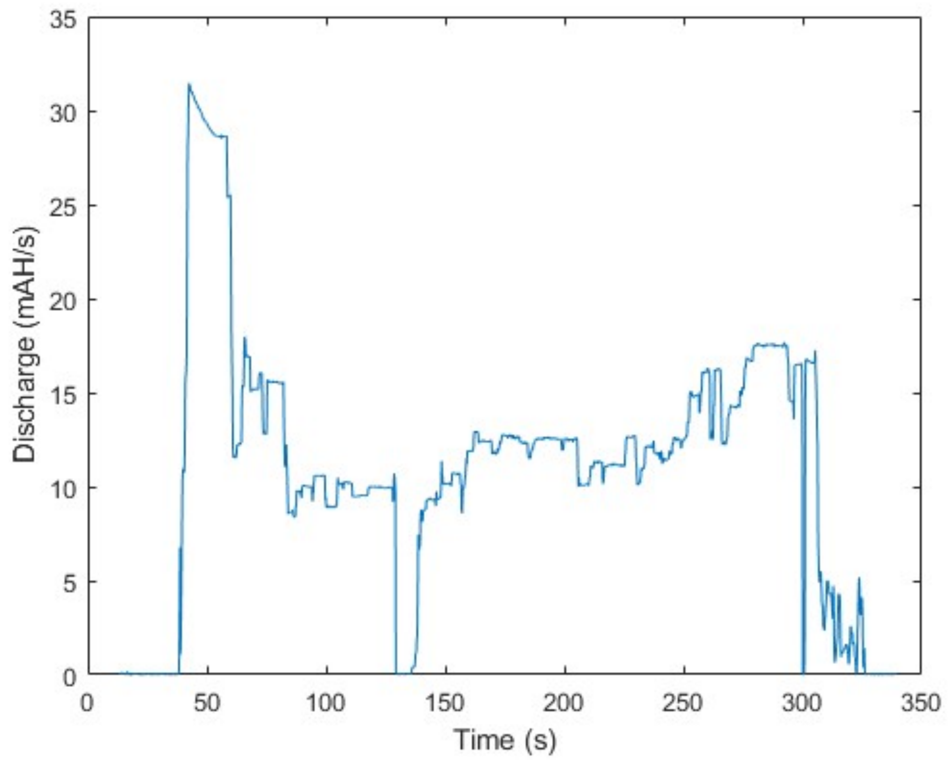
Caption

This graph shows the flight speed as a function of time since battery connection, measured by the onboard GPS module. There is no airspeed data for this flight. Thus ground speed is the only metric available to discuss. The flight reached a maximum of 82mph and a minimum of 36mph. From system time of 45 seconds to 325 seconds, the flight averaged a speed of 58mph.



Caption

This graph shows the total lost milliamp-hours(mAH) vs. time since battery connection. This is primarily useful when further processing is completed. Although, the battery did end with 3572 mAH depleted from the 5000 mAH rated battery.



Caption

This is a graph of milliamp-hours per second(mAH/s) battery connection. This was accomplished by using the backward difference approximation for the instantaneous derivative. For this flight, the mea-

include equation for ref.

sured discharge rate was averaged at 13 mAH/s during the time interval of 150 to 300 seconds. During takeoff, the maximal rate was observed at 31 mAH/s.

3.3. Rational

For many of the averages, large sections of the flight were withheld from being processed; this is due to the nature of this flight. This aircraft was hand flown by a pilot who has very little experience with this particular aircraft. Due to this hand flying and other compounding real-world test conditions, the data is not stable. Any of the windows used for calculations were chosen to minimize the effects of these inconsistencies and remove any effects from takeoff or landing. Of particular note would be two events, one occurring around the 130-second mark and the other occurring around the 300-second mark. The first was when the pilot lost sight of the aircraft as it flew in front of the sun. This event can be seen in the altitude, discharge rate, and velocity plots. For that reason, any averaging was done once the steady-level flight was reattained. The second event was when the throttle safety cutoff was temporally turned on. This event was short enough to only be seen in the discharge rate graph.

4

Results

The primary goal of this flight was to validate the AL-37 as a test platform in addition to gathering baseline data. In this regard, the flight was a success. There were a few things learned from this flight and a few benefits resources created.

4.1. Noteworthy Data

Time of Flight: 4 minutes 42 seconds
Average Flight Altitude: 260ft
Maximal Flight Altitude: 359ft
Average Ground Speed: 58mph
Average Battery Discharge Rate: 13 mAH/s
Percentage Remaining in Battery: 28%

Put into table

4.2. Beneficial Results

- Flight time validated at a maximum of 5 minutes.
- Average battery drain of 13 mAH/s during steady level flight was observed. This value will be foundational to any future data analysis regarding this aircraft.
- AL-37 with Pixhawk main electronic system is flight tested and validated.
- A procedure for translating ULog files from the Pixhawk to Matlab for graphing and data processing was created.

4.3. Improvable Issues

- Pilot complained of a strong roll left effect while flying. Cause suspected to be a warped right wing.
- Landing was rough enough to cause some damage to the aircraft. Procedure is to now only land at maximal flaps.
- Pitot tube was send back into the aircraft during takeoff. Caused by poor mounting of the probe. New 3d printed bracket is now affixed to the aircraft.
- Flight time is significantly lower than manufacturer's listed flight time of ten minutes. Cause suspected to be the battery's poor internal resistance.

5

Conclusion

The primary goal of this flight was to validate the AL-37 as a test platform and gather baseline data. In this regard, the flight was a success. From this test, the project group learned a lot about the aircraft's flight characteristics on top of the battery data. The issue that the group expected to have was the decreased flight time due to problematic batteries. The project fixed this issue by buying new batteries of the same specifications. While most aspects of the flight went according to plan, a few unexpected issues are currently being fixed. The group was unaware of the warped wing issue until the drone pilot pointed it out. Since it would be difficult to warp the wing back into position using traditional methods, the project is buying two new wings to replace the current wings. Something that was not noticed until the end of the flight was that the pitot tube went inside the aircraft due to poor mounting standards. A brace mount was designed, and 3D printed for the pitot tube to remedy this issue. This will prevent it from going inside the aircraft in future test flights. Lastly, the aircraft was damaged upon landing due to the low flaps settings used when landing. The aircraft was repaired a few days after the flight test. The project plans to use the newer batteries and the pitot tube mount for future flights. This should increase flight time to about 10 minutes and keep the pitot tube in place to collect further data. Despite these issues, the flight achieved its goal of testing the voltage-based estimation system, which made this flight test successful.