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Technical Analysis 3: Flight Test

Flight test #1:

Name: Ajay Mohan

Description: First flight test of initial prototype design.
Goals: Prove airfoil selection and lift generation.

Analysis Details: Flight test was conducted on October 26, 2019 at Brian Unwin Field in Adair Village.

Results: The first flight test proved that the airfoil selection was correct and there was plenty of lift available. We learned that we will need a very strong wing in terms of bending, due to the high amount of wing flutter observed. After one test flight, the wing flutter caused one of the control surfaces to fall off of the wing which resulted in decreased roll control, but the aircraft was able to land with advanced piloting skills resulting in minor damages.

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Flight test # 2:

Name: Ajay Mohan

Description: First flight test of the second prototype design.

Goals: Validate wing strength, decrease wing flutter, fly with intended number of passengers, fly
with a banner to test flight characteristics.

Analysis Details: Flight test was conducted on November 16, 2019 at Brian Unwin Field in Adair Village.

Results: Aircraft was able to take off successfully during an empty weight flight. After the first turn, the wing experienced a delamination of carbon fiber reinforcement that resulted in the wing buckling and resulting in catastrophic failure. The crash ended the flight test and we were unable to gather the information needed for mission simulations. There was a large lesson learned in regards to the need of significant wing reinforcement and overall wing strength.

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Flight Test #3:

Description: First flight test of competition representative airplane.
Goals: Test subsystems and flight characteristics. Verify new composite wing design.

Analysis Details: Flight test was conducted on December 7, 2019 at Brian Unwin Field in Adair Village.

Results:

Flight #1: Too much vertical pitch which resulted in no control of the aircraft and an immediate Crash.

Flight #2: After making repairs, we adjusted the angle of incidence of the wing to raise the angle of attack which was approximately 3 degrees negative which resulted in too much pitch. Since the landing gear was unable to be repaired, the airplane was hand launched. The airplane flew successfully and the pilot had good control. The pilot suggested that we increased rudder size to
have more control. This flight was with 4S batteries and the pilot only had to throttle about 55% of the maximum to get the plane going.

Flight #3: This was a test to see how the plane flew with 8S batteries. This time the pilot had to use about 25% of the throttle. This was hand launched again and when landing the motor broke off the nose cone from impact.

Flight # 4: After repairing the nose cone, the team was ready to fly again and test the banner deployment mechanism. The plane still had to be hand launched and after the first turn the banner was released by the pilot. The banner started to unravel, however the impulse felt when
opening a banner mid-flight led to the line breaking immediately and the banner falling from the plane. The pilot was able to also check the release mechanism which was successful. We then ran a timed lap on an approximate representation of the course layout and completed it in 41 secs. At a certain point, the ESC cut power to the motors and servos due to low battery readings and the airplane crashed.

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<u>Key takeaways from flights</u>:

-More elevator authority
-Program ESC cutoffs
-Nylon landing gear bolts to shear if large impact is felt
-Approx 5mm decrease in throw from the flaps
-Flap endpoints need to be level with wing
-Move motor incidence to be more towards the right
-Fix wing incidence

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Flight Test #4:

Description: First flight with new manufactured wing and symmetrical airfoil empennage. Goals: Verify new flight stability and characteristics. Also dynamic test banner release mechanism.

Analysis Details: Flight test was conducted on March 4, 2020 at Brian Unwin Field in Adair Village.

Results:

Flight #1: Flight characteristics were good and the plane's stability was great during flight. During landing, the landing gear sheared some of the foam fuselage off and the plane took a harsh landing. Dave, our pilot, suggested that we need to add more elevator authority. During this flight, our transmitter started communicating that it was losing connection with the receiver in the aircraft so an immediate landing was attempted. After inspection and range testing, we determined that the receiver was damaged prior to the flight and would need to be replaced.

Flight #2: After repairs we attempted to fly again to get more verification of flight characteristics however there were some damages to the motor that were not able to be seen or inspected at the airfield. This led to the motor spinning up and feeling a lot of vibrations which led to the motor fracturing on the ground. This also damaged another nose cone.

Key Takeaways:

- Verify range of receiver before every flight.
- Stability analysis was correct for volume of empennage compared to wing.
- Wing and empennage relative locations are also correct.

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Flight Test #5-8:

<u>Description:</u> Competition flights
Goals: Complete customer requirements and show off the plane to peers and family.

<u>Analysis Details:</u> Flight test was conducted from March 15-18, 2020 at Brian Unwin Field in Adair Village.

<u>Results:</u>

Flight #1: This was an attempt at mission 1. There were some issues with the propulsion system that led to us not being able to use the battery we had planned for. This meant that less thrust was available and meeting the sub-20ft takeoff distance would be a challenge. We did pass that rule and then we flew the three laps required for mission 1. When coming in for landing, we fell on our nose and damaged a propellor as well as the wing.

Flight #2: After repairs we attempted to fly again to complete mission 1. This time we did not get up in the 20ft required so the mission was immediately a failure. When coming back into land, the same problem happened where the propeller struck the ground and broke.

Flight #3: After replacing the propeller with a spare, we were able to get up within 20 ft and complete the laps. When landing, the plane did fall a little bit on the nose and the landing gear did shear off, however these damages are outlined as “non-critical” in the rules, therefore, it is a mission success.

Flight #4: Two days later, we returned to the airfield and attempted mission 2, the passenger payload mission. With our change in propulsion system, we were limited on how many passengers we would be able to take off with. Also landing continued to be a struggle for our plane. This meant that we were only able to carry 2 passengers instead of our anticipated 12 passengers.

Flight #5: The next day we came with a new propeller that would be able to produce a little bit more thrust than before to help our plane get up in the distance requirement. We had the predicament of getting the CG correct while also trying to use a smaller battery which was nearly impossible without flipping around the banner. There were a couple of flights where we tested and the banner did not release correctly, one due to the incorrect throw on the servos and the other due to a failure of the store bought retractable cable that is used to help dampen the impulse loads. After these issues were fixed, we had to settle on a heavier 6S battery which made taking off more difficult, however we did get it within 20ft. This flight we were able to successfully deploy and fly with the banner for multiple laps. Once the battery screamer was signalling low voltage per cell, we released the banner and started to return to land. When landing, the propeller broke as well as the nose cone. This means that the mission is technically a failure and we were unable to reattempt that day due to not having a propeller with the dimensions to provide enough force.

Key Takeaways:

- Propulsion system still needs to be optimized to meet all customer requirements.
- Aircraft might be too heavy to take off with a weaker propulsion system.
- More airfoil area might be necessary to generate more lift.
- Banner mechanism became loose, so better fastening down methods need to occur.

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Technical Analysis 1: Scoring Analysis

Analyst: Jehad Aljasem

ES: #6

Description: Analyze scoring equations as presented in the DBF 2019-2020 rules to determine which mission has the highest impact on the total mission score. Identify parameters of mission(s) that are most influential on competition score. Create conceptual design parameters for aircraft to maximize score.

Analysis Details: Based on the scoring equations stated in 2019-2020 DBF competition rules, a MATLAB script was built to determine how missions 2, 3, and ground mission impact the total mission score since they are dependent on the best possible competitor result at the competition. To perform the analysis, several assumptions were made based on previous year's competition results:

Ground Mission	**Assumption**
Minimum time to finish ground mission	6 s
Mission 2	**Assumption**
Minimum time to complete three laps	90 s
Maximum number of passengers	40 passengers/luggage
Mission 3	**Assumption**
Maximum banner length	240 in
Maximum number of laps covered in 10 minutes	20 laps

The equations used are listed below:

$$GM = \frac{Min_{time}}{N\_time}$$

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$$M2 = \frac{N\_(\frac{\#\ passengers}{time})}{Max(\frac{\#\ passengers}{time})} + 1 \qquad M3 = \frac{N\_(\#\ passengers * BannerLength)}{Max(\#\ passengers * BannerLength)} + 2$$

```
clear
clc
clf
% DBF Scoring Analysis
% Author: Jehad Aljasem
%..............................

Max_Passegers = 40;
Min_time = 90; %s
Max_time = 300; %s
% time12 = Min_time12:Max_time12;
time = linspace(Min_time,Max_time,231);
N_p1 = linspace(1,40,length(time));
N_p = 0:8:40;
Max_time3 = 600;  %s

% Ground Mission
tt = 6:0.1:200;
ft = 6;

Gm = ft./tt;
t_g = linspace(0,200,length(tt));

plot(t_g,Gm)
xlabel('Time','fontsize',18)
ylabel('GM Score','fontsize',18)
title('GM Score vs time','fontsize',18)
figure
% Mission1
m1 = 1;

% Mission2


for i = 1:length(time)
   M21(i) = 1 + [(N_p(2)./time(i))./(Max_Passegers./Min_time)];
   M22(i) = 1 + [(N_p(3)./time(i))./(Max_Passegers./Min_time)];
   M23(i) = 1 + [(N_p(4)./time(i))./(Max_Passegers./Min_time)];
   M24(i) = 1 + [(N_p(5)./time(i))./(Max_Passegers./Min_time)];
   M25(i) = 1 + [(N_p(6)./time(i))./(Max_Passegers./Min_time)];
```

```
end


time1 = Min_time:42:Max_time;

for k = 1:length(N_p1)
   M26(k) = 1 + [(N_p1(k)./time1(1))./(Max_Passegers./Min_time)];
   M27(k) = 1 + [(N_p1(k)./time1(2))./(Max_Passegers./Min_time)];
   M28(k) = 1 + [(N_p1(k)./time1(3))./(Max_Passegers./Min_time)];
   M29(k) = 1 + [(N_p1(k)./time1(4))./(Max_Passegers./Min_time)];
   M210(k) = 1 + [(N_p1(k)./time1(5))./(Max_Passegers./Min_time)];
   M211(k) = 1 + [(N_p1(k)./time1(6))./(Max_Passegers./Min_time)];
end


plot(time,M21,'k')
 hold on
plot(time,M22,'k')
plot(time,M23,'k')
plot(time,M24,'k')
plot(time,M25,'k')
 %.........................................
ylabel('M2 Score','fontsize',18)
xlabel('Time','fontsize',18)
title('M2 Score vs # of passenegrs/luggage over time','fontsize',18)
% ,'t=90 s','t=132 s','t=174 s','t=216 s','t=258 s','t=300 s'
X = legend('8 passengers','16 passengers','24 passengers','32 passengers','40 passengers');
set(X,'FontSize',14);
set(X,'FontName','Times New Roman');
%..............................................................................
figure
Max_BL = 20 * 12; %in (Banner Length)
Min_BL = 10; %in
B = Min_BL:Max_BL;
laps = 20;
Nlaps = linspace(1,20,length(B));
Nlaps1 = 10:2:laps;

%Mission3

for d = 1:length(B)
   M31(d) = 2 + (Nlaps1(1) .* B(d))./(laps * Max_BL);
   M32(d) = 2 + (Nlaps1(2) .* B(d))./(laps * Max_BL);
   M33(d) = 2 + (Nlaps1(3) .* B(d))./(laps * Max_BL);
   M34(d) = 2 + (Nlaps1(4) .* B(d))./(laps * Max_BL);
   M35(d) = 2 + (Nlaps1(5) .* B(d))./(laps * Max_BL);
   M36(d) = 2 + (Nlaps1(6) .* B(d))./(laps * Max_BL);
end
```

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```
B1 = Min_BL:46:Max_BL;
for j = 1:length(Nlaps)
   M37(j) = 2 + (Nlaps(j) .* B1(1))./(laps * Max_BL);
   M38(j) = 2 + (Nlaps(j) .* B1(2))./(laps * Max_BL);
   M39(j) = 2 + (Nlaps(j) .* B1(3))./(laps * Max_BL);
   M310(j) = 2 + (Nlaps(j) .* B1(4))./(laps * Max_BL);
   M311(j) = 2 + (Nlaps(j) .* B1(5))./(laps * Max_BL);
   M312(j) = 2 + (Nlaps(j) .* B1(6))./(laps * Max_BL);
End
plot(B,M31,'k')

hold on

plot(B,M32,'k')

plot(B,M33,'k')

plot(B,M34,'k')

plot(B,M35,'k')
plot(B,M36,'k')
%.............................
plot(Nlaps,M37,'r')
plot(Nlaps,M38,'r')
plot(Nlaps,M39,'r')
plot(Nlaps,M310,'r')
plot(Nlaps,M311,'r')

plot(Nlaps,M312,'r')
xlabel('Number of Laps & Banner Length (BL)','fontsize',18)
ylabel('M3 Score','fontsize',18)

Y = legend('10 laps','12 laps','14 laps','16 laps','18 laps','20 laps',...
   'BL = 10 in', 'BL = 56 in', 'BL = 102 in', 'BL = 148 in', 'BL = 194 in','BL = 240 in');
set(Y,'FontSize',14);
set(Y,'FontName','Times New Roman');
title('M3 Score vs banner length & # of laps','fontsize',18)
```

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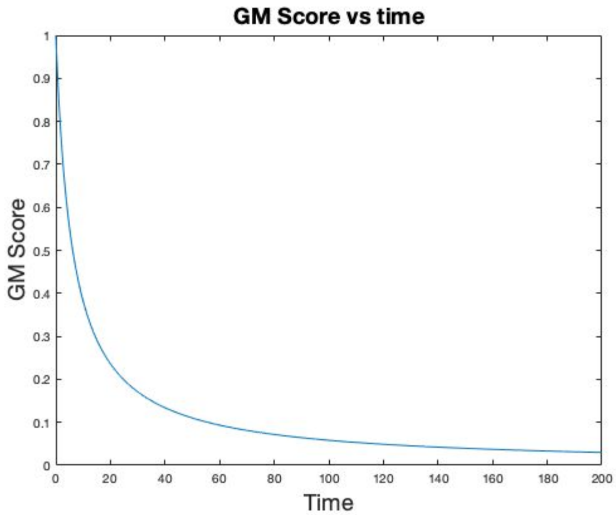

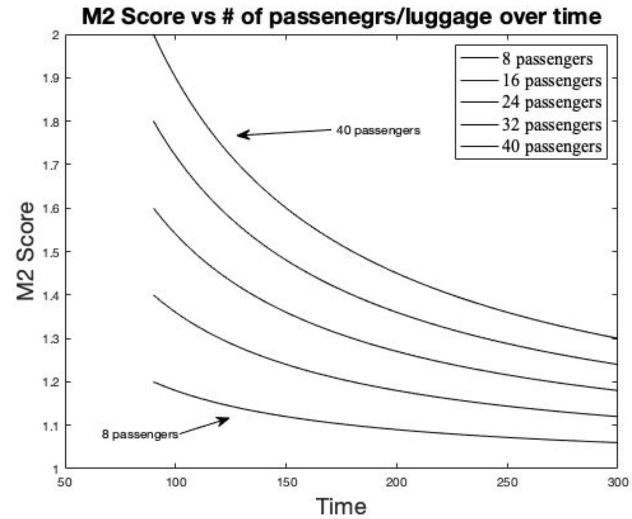

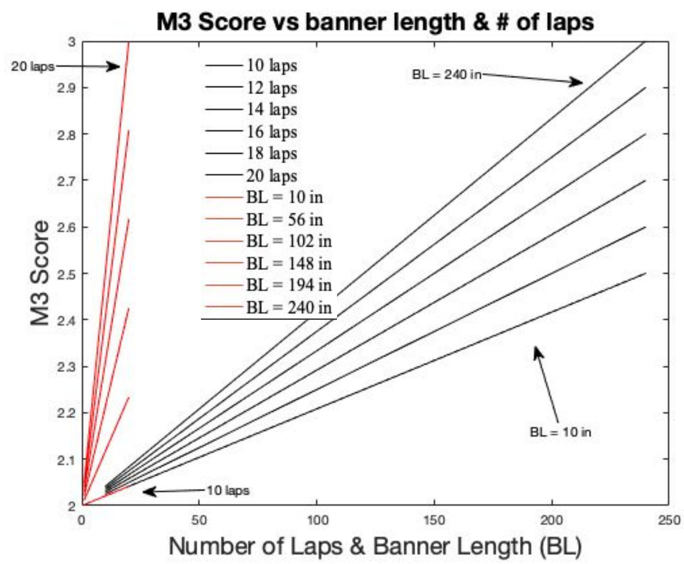

Resources: AIAA DBF 2019-2020 Competition Rules

Results: Based on the scoring analysis, it was determined that total mission score is heavily affected by the total number of passengers/luggage carried in mission 2, the length of the banner towed in mission 3, and the time required to complete the ground mission. Therefore, focusing on all factors is mandatory to optimize total mission score.

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Technical Analysis 2: Airfoil Selection

Analyst: Edgar Jimenez

ES: #10

Given: The plane will be tasked with multiple missions that will require an airfoil selection that can maximize lift with a max allowable wingspan of five feet. In order to select an aerodynamic airfoil that best suits the needs of the aircraft, we need to create goals for what we want the aircraft to achieve. These goals include a cruise speed of 60 mph, a coefficient of lift of 0.4 at cruise speed, a max aircraft weight of 4.7 kg, an airfoil thickness of about 14% of the chord length, and a relatively high aspect ratio wing. These goals were selected as a team with the help of our advisor, Dr. Albertani, after reading the competition rules and what is expected of the aircraft. The expectations of the aircraft is that it would have a fast cruise speed to be competitive in all timed missions, could carry a minimum of 12 passengers, and have a high aspect ratio to increase the efficiency of the wing.

To Do: The goal is to select an airfoil that will provide sufficient lift while optimizing a reduction in drag with the set goals for the aircraft.

Solution:
In order to move forward with finding an airfoil, it was necessary to calculate the expected Reynolds number. $Re = \rho vc/\mu$, Where ρ is the density of air at sea level, v is the velocity in m/s, c is the chord length in meters, and μ is the dynamic viscosity of the air. The values for density and viscosity are known, and the velocity was assumed by the goal of a 60 mph cruise speed. The aspect ratio was the last variable in determining the Reynolds number and was determined to be about 10. This aspect ratio was recommended by our advisor to give adequate wing area but

still maintain a high efficiency high. After all of the variables were set, our Reynolds number yielded to about 300,000. From steady level flight equations, we are able to calculate what our cruise lift force will be. $L = 0.5\rho v^2 SC_L$ where ρ is the density, v is the velocity, S is the wing area, and C_L is the coefficient of lift, All of the variables are known or can be assumed with the goals set for the aircraft. With an aspect ratio of 10 and a 5 foot wingspan we get a wing area of about 0.23 square meters. With this calculation we determine the amount of lift generated at steady level flight in order to know how much payload we can carry. Continuing with what airfoil selection is best for these characteristics, we take our Reynolds number and start comparing airfoil data that results in a high coefficient of Lift. With the help of a document

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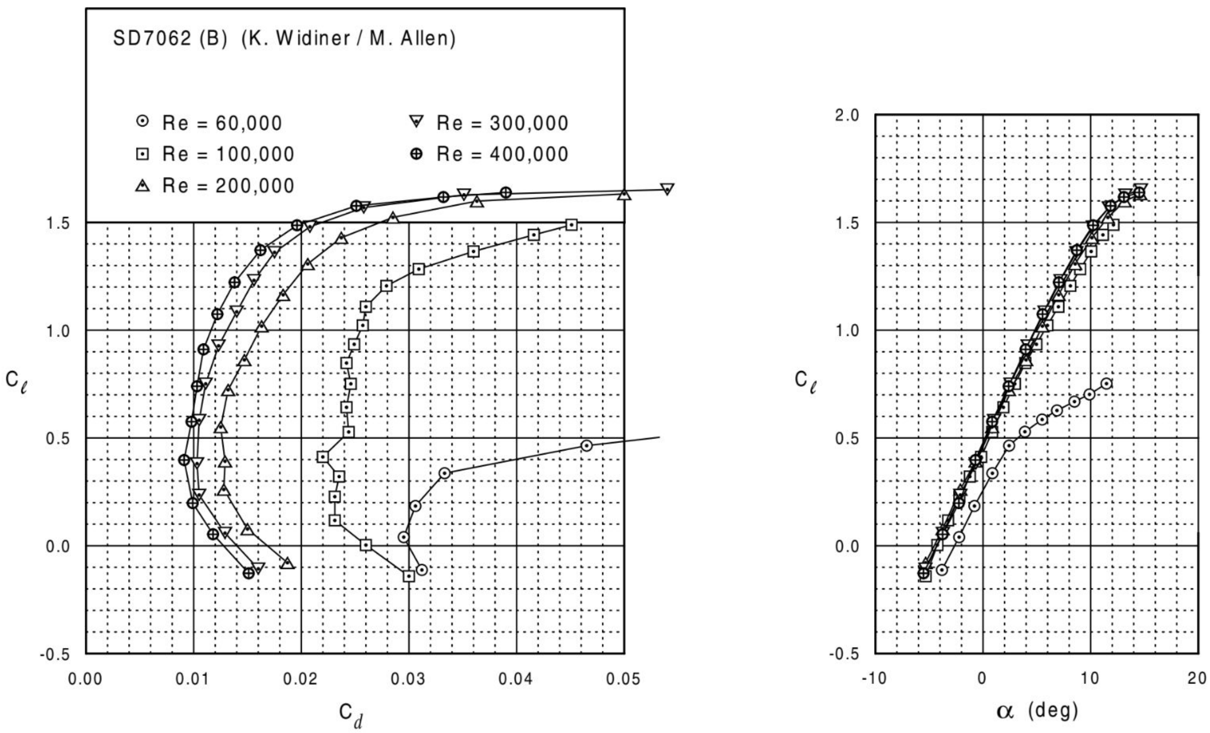
named "Summary of Low-Speed Airfoil Data" by Christopher A. Lyon, Andy P. Broeren, Philippe Giguere, Ashok Gopalarathnam, and Michael S. Selig; we were able to find an airfoil that proved promising results for the aircraft wing.

Answer: Airfoil SD7062



This airfoil selection provides a C_L max of approximately 1.7 for a Reynolds number while also providing a C_L of approximately 0.4 at steady level flight with an angle of attack of 0. This airfoil has a slightly higher thickness than expected but it provides and exceptional C_L max value. This airfoil was selected because it showed efficient lift characteristics with low drag values.