1. Introduction

This report contains two integral parts, the first of which being the preliminary sizing of a UAV. This is completed using data from reference aircraft as well as the given requirements of the aircraft. The second part will center around sizing and selection of propulsion for the UAV. Chapter 2 will explore the calculations behind estimating the takeoff weight. The following chapter 3 will explore the creation of the aircraft T/W – W/S graph. Chapter 4 will detail the generation of the drag polar. Chapter 5 will discuss the optimal takeoff weight as a function of the payload range diagram.

Part two of this report details the proposal for a propulsion system for the UAV to make an order to motor manufacturers. Initially in chapter 5 the required thrust for the aircraft at several weight conditions will be calculated. Next chapter 6 details a selection of engine type, weight, and dimensions. Following this in chapter 7 the engine type that most closely meets the needs of our requirements will be selected and scaled to better fit the needs of the aircraft. Chapter 8 will detail optimization of the thermodynamic cycle of the motor and it energy expenditure. In this chapter validation of previously selected design values will also be performed.

1. Determining the takeoff weight

To determine the takeoff weight, the different parts of the overall aircraft weight have to be identified. The takeoff weight often consists of operational empty weight, fuel weight, and payload weight. Because our aircraft is battery powered UAV, fuel weight is a fixed value, consisting solely of the weight of onboard batteries. Thus, in this chapter fuel weight will be calculated using 2 different static battery conditions that were briefly described in assignment 1. The battery weight is inversely proportional to the payload weight thus the 2 separate battery conditions will also entail 2 separate payload conditions as a result. At the end of this chapter the total takeoff weight will be calculated using the equation below.

W TO = W PL + WF + W OE Eq 2.1

* 1. Payload

As already calculated in the last assignment, the payload will be calculated as the total weight of all components of the sensor package deployed with the UAV. The likely payload weight of the aircraft based on similar reference aircraft will be 11.02 lbs. However, due to the previously mentioned ability for the aircraft to have battery space exchanged for additional payload space a secondary large payload arrangement can also be made for the aircraft. This secondary payload configuration would see one of the two 8.82 lbs. batteries removed sacrificing aircraft range for increased payload leaving us with a second payload weight of 19.84 lbs.

|  |  |
| --- | --- |
| Payload Weight 1: | 11.02 lbs. |
| Payload Weight 2: | 19.84 lbs. |

* 1. Batteries

Unlike hydrocarbon powered aircraft where total fuel weight is the combined weight of both the actual used fuel and the reserve fuel electric aircraft fuel weight consists solely of the weight of the aircraft battery pack. These battery packs see negligible changes in weight during the totality of flight time thus their weight can be considered a static value. However, as mentioned in Section 2.1 the battery weight is tied to the payload configuration within the LAHE UAV. Since the LAHE UAV has two payload weight configurations it will also have two battery configurations, using 1 and 2 40Ah batteries, each weighing 8.82 lbs. As mentioned earlier, in a standard hydrocarbon fueled aircraft used fuel is a fraction of the takeoff weight and typically consists of three parts. Though this aircraft will not see changes in fuel weight over time as it flies it still will use variable amounts of battery charge in different parts of its flight. Thus, calculations for normal, cruise, and loiter flight fractions will still be calculated in order to understand aircraft energy consumption even though the battery weight of the aircraft will remain static throughout the operation of the aircraft.

|  |  |
| --- | --- |
| Battery Weight 1: | 8.82 lbs. |
| Battery Weight 2: | 17.64 lbs. |

* + 1. Normal Flight Fraction

The normal flight fraction typically consists of the non-energy use intensive stages of aircraft flight. The individual components of the flight fraction are listed in the table below. Using the data provided in the lecture notes on page 32 the values were found. (Since there is no direct equivalent for UAV values for homebuilt aircraft were used for calculations.) It is important to note that values for the descent and climb phases were multiplied by two since in Assignment 1 the aircraft mission profile details a small descent and climb when entering the loitering stage as well as a small descent and climb for the diversion cruise both of which must be accounted for in the normal flight fraction calculations.

|  |  |
| --- | --- |
| Engine start and warm-up | 0.998 |
| Taxi | 0.998 |
| Take off | 0.998 |
| Climb | 0.995 |
| Descend | 0.995 |
| Landing taxi shutdown | 0.995 |
| Normal flight, with adjustment for additional climbs an descents | 0.9694 |

* + 1. Cruise Fraction

To calculate the cruise fraction, the following equation must be used.

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This equation can be further simplified in the following manner.

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W7/W4 represents the power consumed while in cruise, R is the cruise range, g is the gravitational constant (9.80665 m/s2), V is the cruise-speed and L/D is the lift-drag ratio while in cruise. From our requirements R = 6.21 mi or 9.994206 km, V = 49.21 ft/s or 14.999208 m/s , the specific fuel consumption during cruise Cp will be 0.4 lb/lb/hr or 0.000011 kg/Ns in SI. Lastly for L/D ratio our group chose to use a value of 20 as our aircraft is designed to function in similar fashion to a glider thus requiring a higher ratio. However, it is still a prop powered aircraft and limitations exist on our ability to machine an airfoil that could produce an incredibly high L/D ratio thus the value of 20 was chosen as an achievable target ratio.

After putting all these values into the equation, it can be calculated that the fraction used during the cruises is 0.996413.

* + 1. Loiter Fraction

In a similar manner the loiter fraction can be calculated with the equation below. E is for aircraft endurance, g is still the same gravitational constant, cp is the constant fuel consumption during loiter, and L/D the lift drag ratio in loiter.

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Description automatically generated

The aircraft endurance as written in the aircraft requirements in Assignment 1 is 3 hours. The gravitational constant is still 9.80665 m/s2 and the cp will remain 0.4 lb/lb/hr or 0.000011 kg/Ns since the aircraft AOA is incredibly resulting in minimal difference in specific fuel consumption between the two fractions. L/D ration will be slightly higher at 22 as in loiter the aircraft will be to take full advantage of its large glider based wingspan.

Using this equation and the listed variables the loiter fraction of the aircraft can be calculated to be 0.9484.

* + 1. Total Battery Fraction

As stated earlier, the use of battery power on the aircraft will not change the weight of the batteries at any point during the duration of flight. Thus, the battery weight will remain static at one of the two possible battery configurations weights.

* 1. Operational Empty Weight

The Woe can be calculated using the following equation. This equation sums the aircraft empty weight, the weight of trapped fuel and oil, as well as the weight of the crew.

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Description automatically generated with medium confidence

As an electric UAV our aircraft has both a Wtfo and Wcrew of 0, leading to Woe being equal to We. We is a fraction of the aircraft empty take off weight and can be found through plotting a graph of the Maximum takeoff weight versus empty weight of our reference aircraft. Using the trendline found in this graph an equation to find the proportion of Wto equal to We can be derived.

From this graph the formula of the empty weight as a function of the takeoff weight was derived and can be seen below.

We = 0.7276Wto+4.4274

* 1. Total Weight Estimation

Using the previous calculated values and equations Wto can be calculated as,

Wto=4.9985879+8.0920879+0.7276Wto+4.427

This gives us a Wto of 64.3086kg or 141.7761943lbs