* Mission Definition and Analysis of Requirements:
  + Define the typical mission for the assigned aircraft, including an exhaustive illustration and description of all its segments.
  + Perform a critical analysis of the requirements for the aircraft design, including assumptions and estimations for missing requirements.
  + Identify and discuss the driving or most critical requirements for the design.
* Reference Aircraft Data Collection:
  + Collect and organize reference data of existing aircraft similar to the assigned one, aiming for around 20 reference aircraft.
* Concept Generation and Selection:
* Propose at least three different aircraft configurations with sketches and descriptions5.
* Select the best concept and explain the selection process6.
* Study and Generation of the Complete Fuselage Layout:
* Perform a study of possible fuselage layouts using the inside-out approach, including calculations and dimensions7.
* Make sketches of different possible payload configurations to demonstrate the flexibility of the design8.
* Generation of Technical Drawings:
* Provide technical drawings of the fuselage design, including top, side, front views, and relevant cross and longitudinal sections9.

# Aircraft Design 1 – Fall 2024

Assignment 1

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Group 6

Instance [first delivery]

Hours spent on assignment: [35]

Aircraft Type: UAV

Aircraft Number: Glider UAV Project

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| --- | --- | --- |
| Reference Type: | Value | Unit |
| Payload | 2 | kg |
| Range | 100 | km |
| Altitude | 121.92 | m |
| Cruise Speed | 10 | m/s |
| Ceiling | 1219.2 | m |
| Endurance | 3 | Hours |
| Max Speed | 15 | m/s |
|  |  |  |

Table of Contents

**1. Introduction**

The following report consists of 5 chapters, each guiding the reader through the aircraft design process. This first chapter will provide a definite mission for the aircraft and will analyze its design requirements. The second chapter will analyze reference aircraft similar in specifications to those required by the design mission, as well as including an appendix with the relevant reference material within. Chapter 3 discusses the concept generation for the aircraft design and details the process of selection between the three concepts we had created, and how the selected concept best meets the mission requirements. Chapter 4 will show the complete fuselage layout for the aircraft. And Chapter 5 will contain technical drawings of the concept aircraft design.

**2. Mission Definition and analysis of requirements**

In the introduction the basic requirements for a Low Altitude High Endurance UAV were given. This list of requirements, however, is insufficient in relaying the totality of the requirements needed for the execution of this design mission. FAA requirements considering low altitude UAV systems, specifications surrounding payload packages, and necessary considerations for the compacted design all will be explored and accounted for within the following chapter.

**2.1 The Mission**

A diagram of a diagram

Description automatically generated

For the LAHE UAV the mission typical mission profile is one built around observation. Initially the aircraft must be launched by a single operator in a remote environment. Following launches the aircraft must climb to its cruising altitude of 400m where it will maintain a cruise speed of 10 m/s. The mission profile sees very little change once cruising altitude and cruising speed are reached and observation can begin. Since the primary objective of the mission is to employ a microphone sensor package to survey wildfires, the observation stage of the mission profile sees very little deviation from its cruising altitude during this stage of the mission. Observation will continue until aircraft endurance is exhausted to a point of required landing. The craft will then be flown back to its operator where it will descend in a spiral before landing for operator recovery.

* + 1. **Start Motor/s and Takeoff**

Due to its small nature and the necessity for rapid deployment in remote environments the LAHE UAV motor will be powered using electricity provided by its internal solid state lithium-ion battery system and then launched from a catapult system in order to remove the necessity for ample runway space and ensure capability of rapid remote deployment.

* + 1. **Climb to cruise altitude**

The aircraft will then slowly climb at a low angle of attack under its own power to its cruise altitude of 400 ft. This must be completed at a low angle of attack due to the glider airfoil design being susceptible to stalling at high angles of attack.

* + 1. **Cruise to Survey Area**

Under its own power it will then travel at its cruise speed of 10 m/s to the survey area.

* + 1. **Deploy Sensor Package During Loiter**

Once the LAHE UAV has reached its destination it will deploy its surveillance package and begin to fly in an endurance extending formation. The craft will glide unpowered while activating its sensor package and collecting relevant mission data. Once it falls to an altitude of 300 ft it will resume powered flight and return to its cruise altitude of 400 ft and will then again enter a state of unpowered gliding while collecting data. This cycle will be repeated by the aircraft until its endurance is depleted or the full survey area is covered.

* + 1. **Return from Survey Area**

After completing its loitering period, the aircraft will return under powered flight to its launch position.

* + 1. **Descend for landing**

Once within range of the launch position the aircraft enter a minimal angle of attack descent. Slowly descend until it is close to coming in contact with the ground. Here the motors are turned off to prevent extensive damage in the case of a prop to ground strike.

* + 1. **Landing**

Due to the LAHE UAV’s low weight and airspeed the necessary distance required for landing is minimal. And once in contact with the ground the aircraft will slide on its belly to a stop where it can then be recovered by the operator.

* 1. **Requirement Analysis**

Once the required function of the aircraft is ascertained, a set of requirements must be made to meet the needs for such function. In this section, the given requirements will be critically analyzed to understand how each will affect the aircraft. Additional requirements must also be accounted for to properly configure the design.

* + 1. **Payload Analysis**

It is noted that the express purpose of this aircraft is to deploy a microphone listening package for data collection. This listening package makes up the whole of the aircraft payload and though this payload is static within the aircraft the design of the fuselage must accommodate the needs of the payload for data collection. The primary requirement is that the payload microphone must be exposed outside of the aircraft so that it can be utilized. Thus, the aircraft fuselage must be open. The exposed microphone will be of the dimensions \_\_\_\_\_\_\_\_\_\_\_, and weigh \_\_\_\_\_\_. As a result of the necessity for payload exposure the overall drag on the aircraft will be increased. To make up for the excess drag an increase in wingspan will be required. Along with the data collection aspect of the payload, accessibility for data recovery is also required. The fuselage must be designed with an access panel so that the payload can be removed. Further adjustments for the payload must also be made as a data storage device and an independent power supply must be accounted for. These aspects of the payload would be of the dimensions \_\_\_\_\_ and \_\_\_\_, and will weigh \_\_\_\_\_ and \_\_\_\_\_\_.

The aircraft’s main power supply must also be accounted for in the payload as during use the LiPo batteries that power the craft will see a change in weight as their energy is expended. At full charge the two LiPo batteries that make up the power supply weigh 1.44 kg, and when fully expended weigh\_\_\_\_.

As a UAV remote control is critical to the operation of the craft, thus an external antenna must be mounted to the fuselage of the aircraft. This will create additional drag on the aircraft in a similar manner to the microphone payload and thus will require an increase in the wingspan to account for the excess drag.

**2.2.2 Propulsion Analysis**

With a proposed cruise speed of 10 m/s and a payload weight of 2 kg, propulsion can easily be achieved using electric engines. Thus, the proposed method of propulsion will be that of a brushless electric motor. The primary issue however in deciding the type of brushless electric motor for the aircraft lies in balancing its weight to torque output. A motor that weighs very little and outputs a high torque would be ideal these motors however are not common. Thus, for this assignment the aircraft will be powered by a brushless electric motor with a high torque to motor weight ratio.

**2.2.3 Certification Analysis**

According to FAA regulations small UAS must weigh under 55 pounds, the operator must pass an FAA provided knowledge test and requires registration of the craft with the FAA. UAS less than 55 pounds may be registered under the FAA's newer 14 CFR Part 48 online system.[1] The craft must also fly within visible line of sight which is defined as within 3 miles of the operator. The operator is also required to fly under 400 ft as well as remain in compliance with all airspace restrictions and prohibitions. For any flights beyond the distance and altitude limits licensed operators are required to apply for a exemption waiver with the FAA in order to fly legally. The FAA will provide a certificate of registration to the operators which must be available for inspection at any time that the craft is in operation. Along with the certificate UAS must also have a registration number visible on the aircraft.

**2.2.4 Range, takeoff, and landing distance.**

This aircraft is a fixed wing UAV designed to weigh under 55 pounds to remain within FAA regulations. As a result, takeoff and landing distances are mostly arbitrary due to the lightweight nature of the aircraft and the necessity for rapid deployment. The required range for the aircraft is 100 km. With this range in mind the craft will be designed to maximize its airtime endurance and minimize power expenditure to remain in the air as long as possible. To achieve this range, the aircraft endurance will be extended via the use of a large airfoil allowing for the aircraft to glide while using minimal battery power for propulsion.

**2.2.5 Additional Requirements**

**2.3 Driving Requirements**

The critical requirements for this aircraft will be range, endurance, and payload. All three of these requirements have an impact on the cruise speed and max speed requirements for the craft as their balance will dictate the type of electric motor that can be utilized.

**3. Reference Aircraft Data Collection**

During the concept creation process it is critical to have a range of reference craft from which you can draw inspiration as well as use for comparison to your own craft requirements. All reference aircraft used in this design are included in Appendix \_\_ below. The scope of the specification of these craft varies in all aspects to provide a range of understanding how increases in certain requirements may impact overall craft design. Ultimately, however, the majority of the reference aircraft retain similar characteristics to those required for our design as they provide useful insight into how issues with our design solutions may have been included in the designs of others. It is important to note that blank areas of the table represent design aspects for which no information was found. This appendix will be continuously updated throughout the whole of the design process as additional references are added or additional requirements are necessitated for further progress in the design process.

**4 Concept Generation and Selection**

**4.1 Concept Generation**

In this section considered designs for the aircraft will be discussed. Analysis of their merits and flaws will be explored in order to explain the reasoning behind the selection of the final design selection. The main differences in design characteristics consisted of changes in motor orientation and number as well as tail configuration. The considered conceptual designs are:

|  |
| --- |
| BAYKAR Technology | Bayraktar TB2  https://baykartech.com/en/uav/bayraktar-tb2/ |

-Mono-pusher with inverted V-tail

Wing configuration: High

Tail Configuration: Inverted V tail mounted separately from fuselage

Engine Configuration: Rear facing single motor/single prop

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| <https://en.wikipedia.org/wiki/>  Piaggio\_P.180\_Avanti  <https://lukeattubato.com/long-range-fpv-plane-v10> |

-Dual pusher with V tail

Wing configuration: High

Tail Configuration: V tail

Engine Configuration: Dual rear facing outboard

motors/props

|  |
| --- |
| Bayraktar TB2 or Akinci? Turkey train Nigeria's drone pilots ahead of  delivery  https://www.military.africa/2022/04/bayraktar-tb2-or-akinci-turkey-train-nigerias-drone-pilots-ahead-of-delivery/ |

-Dual puller with cross tail

Wing Configuration: High

Tail Configuration: Cross tail

Engine Configuration: Dual front facing outboard

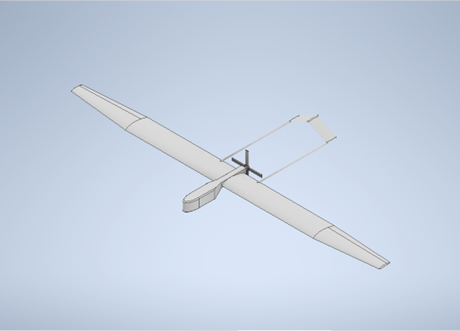
motors/props

For all concepts the same internal layout of the fuselagen(apart from the motor/s and prop/s) will be used. This layout includes two solid state lithium-Ion batteries, the independent power source and electronic components required to power and collect data from the microphone listening package, camera, antenna, as well as the aircraft’s own electrical control package.

High mounted wings were used in all 3 designs due to the need to isolate the microphone package from the noise causing turbulence created by the wings. The use of props for propulsion also requires them to be mounted higher on the airframe to prevent prop strike during landing. Due to the lack of human occupants the loss of fuselage space to cabin intersection is a non-issue.

In the following subchapters each concept will be discussed in detail.

**4.1.1 Mono-pusher with inverted V-tail**



This is a concept mainly centered around the implementation of a single prop. To keep the tail control surfaces out of the line of the disturbed airflow coming off the prop an inverted V tail was used in the concept. The large wingspan allows for the aircraft to achieve a high coefficient of lift allowing for longer undisturbed periods of unpowered gliding, attributing to the high endurance required from its design. Inspiration for the design came primarily from the Turkish Bayraktar TB2 UAV and its unique mono prop and inverted V tail design.

|  |  |
| --- | --- |
| Pros:  -Single prop design limits overall weight of propulsion system attributing to higher endurance  -Inverted V tail places the tail outside of the propeller’s slipstream reducing overall drag  -Inverted V tail provides increased structural rigidity to the aircraft as well as reduces the size and weight of the aircraft fuselage allowing for the installation of a larger wingspan.  -Single prop design removes outboard weight on the wingspan in a dual prop design | Cons:  -Inverted V tail can produce pro-spinning yawing moments, increasing the potential for aircraft stall at high angles of attack  -The structure of the Inverted V tail can also be responsible for unstable dihedral effect reducing overall stability of the aircraft in the air.  -Designing control surfaces is more difficult on the inverted V due to its complex geometry.  -Motor will be located within the fuselage limiting internal space  -No redundancy, with motor failure the craft will become a true glider. |

**4.1.2 Dual pusher with V tail**

A model of a glider

Description automatically generated

This concept combines the increased power of a dual prop configuration with that of high mounted wings and a V tail configuration. Drawing on aspects of both the Piaggio P.180 Avanti and its twin pusher propulsion system as well as the V-tail configuration of the MQ-9 Reaper drone. A twin pusher design was pursued for the increased propulsion created by the aircraft, and a V tail configuration was pursued as a regular cross shaped tail would leave the control surfaces directly in the props’ slipstreams.

The advantages and disadvantages of the design are discussed below.

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| --- | --- |
| Pros  -Dual prop configuration provides increased thrust  -Dual props can be configured to eliminate each other’s torque  -V tail configuration eliminates the need to create an extra tail surface as well as decreases the overall drag on the aircraft  -Dual props provide increased redundancy | Cons  -The rear facing dual props will see some interference of their turbulence with the V tail.  -Dual prop increases the overall weight of the aircraft by adding another motor and prop reducing range  -V tail configuration requires a longer fuselage, increasing weight and length of the fuselage and increases the overall aircraft drag |

**4.1.3 Dual puller with cross tail**

A model of a glider

Description automatically generated

This concept sought to take the aspects of the previous twin prop design and increase overall aircraft efficiency and improve aircraft endurance. The primary two changes to the aircraft are that of the engine and tail configuration. The engines now in a front facing configuration will now operate more efficiently since they encounter undisturbed airflow unlike their rear facing counterparts which must take in turbulent air that flows over the wing. The cross-tail configuration was also chosen as an alternative to the V tail as it keeps the rear control surfaces out of the slipstream of the two engines ensuring that there is no increase in drag or loss of overall stability due to such interference. The primary inspiration for concept comes from the design of the Turkish made Bayraktar Akıncı.

|  |  |
| --- | --- |
| Pros  -Higher prop efficiency in forward facing configuration  -Cross tail ensures tail surfaces are fully out of the turbulent prop and wing flows  -Dual props eliminate each other’s torque  -Dual props/motors provide aircraft redundancy | Cons  -Dual prop increases overall weight and energy consumption of aircraft, endurance is decreased as a result.  -Cross tail configuration requires an extension of the fuselage increasing both the drag and weight of the aircraft  -Cross tail configuration also requires the addition of a third tail surface increasing drag and overall aircraft weight. |

4.2 Concept Selection

The Dual pusher with V tail concept was eliminated for a variety of reasons. First and foremost, the intersection between the tail surface and the turbulent flow coming off the props was unacceptable by every metric. Loss of such a critical control surface could not remain as a possibility within our final conceptual design and immediately relegated the concept as defunct. On top of this the twin engine configuration as well as the extended fuselage required for the V tail configuration both increased the drag, weight, and length of the aircraft all of which greatly affect the potential maximum endurance of the aircraft. A twin motor/prop configuration would also double the rate of energy depletion in the aircraft battery supply. All these factors combined led us to eliminate this concept.

The Dual puller with cross tail concept was the second concept that was eliminated. While it did not suffer from the inherent design flaw of the Dual pusher with V tail motor/prop and tail configuration it shares the same problems concerning the rates of energy consumption and the increased drag and weight. When endurance lies at the center of the design requirements for our aircraft any hinderance to maximizing the potential endurance must be minimized or eliminated if possible. Thus, while this concept saw less inherent flaws in its design and would have the highest efficiency of any of the three concepts due to its forward facing motor/prop configuration it was still eliminated due to the limitations placed upon aircraft endurance as a result of its design.

The Mono-pusher with inverted V-tail was selected as our design concept for a litany of reasons. First and foremost, the aircraft has the highest endurance potential of any of the three concepts. With a single motor/prop and inverted V tail configuration weight, fuselage length, and drag are all significantly decreased. The mono prop configuration also decreases the overall energy consumption of the aircraft providing a further boost to craft endurance. The motor/prop being positioned on the fuselage instead of the wings also allows for a further compact design and removes potential for airflow disturbance around the airfoils further decreasing drag. While the inverted V tail can cause stability issues as well as increase stall risk these issues are more prevalent at high angles of attack and higher operational speeds. With an airfoil designed around gliding and a cruise speed of 10m/s neither of these problems will be likely to present themselves. The use of wing mounts to attach the tail to the fuselage instead of a fuselage extension also greatly increases overall structural stability by leaving none of the tail surfaces in cantilever.



Sources:

[1]https://www.faa.gov/air\_traffic/publications/atpubs/aim\_html/chap11\_section\_2.html