MICROLIGHT AGRICULTURE AIRCRAFT WITH SPRAYING MECHANISM

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Submitted by

KARNAM PRANATHI (19101138)
KURUBA MAMATHA (19101144)
PRAVEEN KUMAR R(19101129)

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HINDUSTAN
INSTITUTE OF TECHNOLOGY & SCIENCE
(DEEMED TO BE UNIVERISTY)

BONAFIDE CERTIFICATE

Certified that this project report titled **"DESIGN OF AGRICULTURE AIRCRAFT WITH SPRAYING MECHANISM"** is the bonafide work of **"KARNAM PRANATHI-19101138, KURUBA MAMATHA-19101144, PRAVEEN KUMAR R-19101129"** who carried out the project work under my supervision. Certified further that to the best of my knowledge the work reported here does not form part of any other project / research work on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

Dr. R. ASHOKAN
Senior Professor & Head of the Department
School of Aeronautical Sciences HITS,
Chennai 603 103

Ms. KRUSHNA GOWDA
Assistant Professor
School of Aeronautical Sciences
HITS, Chennai 603 103

The Project Viva-Voce Examination is held on _______________

INTERNAL EXAMINER

EXTERNAL EXAMINER

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Rubric for ADP-1

SL.No	Method of Evaluation	Marks	Mark obtained
	Report	20	
	Calculation	30	
	Presentation	20	
	Vice voce	30	
Total marks			

Signature of the faculty

(Name & Date)

ABSTRACT

Agricultural is an important sector because it provides essential nutrients for human, and consequently is among the biggest sector for economic growth worldwide. It is crucial to ensure crops production is protected from any plant diseases and pests. Thus aerial spraying system on crops is developed to facilitate farmers to for crops pests control and it is very effective spraying method especially for large and hilly crop areas. However, the use of large aircraft for aerial spraying has a relatively high operational cost.

Therefore, micro light aircraft is proposed to be used for crops aerial spraying works for several good reasons. In this paper, a preliminary design of aerial spraying system for micro light aircraft is proposed. Engineering design methodology is adopted in the development of the aerial sprayer and steps involved design are discussed thoroughly. A preliminary design for the micro light to be attached with an aerial spraying system is proposed.

Microlight aircraft has a good potential to be used for aerial spraying in order to minimize all these challenges. The use of microlight aircraft for aerial spraying is because it can move at low speed and ease of spraying evenly on the crop. Microlight aircraft can usually land on a relatively small site to refill the chemical tank rather than flying back to an airport. Furthermore the use of microlight aircraft is expected to increase spraying effectiveness because the ability of low flying speed and low altitude allows the spraying can be done more evenly on the crops and minimize the spray drift. Additionally, because of microlight aircraft is using normal gasoline fuel, this will further reduce the operational cost.

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SYMBOLS AND ABBREVIATION

- A.R - Aspect Ratio
- B - Wing span(m)
- C - Chord of the Aerofoil (m)
- C_{Root} - Chord at Root (m)
- C_{Tip} - Chord at Tip (m)
- C_d - Drag Co-efficient
- $C_{D,0}$ - Zero lift Drag co-efficient
- C_P - Specific fuel consumption (lbs / hp / hr)
- C_L - Lift Co-efficient
- D - Drag(N)
- E - Endurance (hr)
- e - Oswald efficiency factor
- L - Lift (N)
- $(L/D)_{Loiter}$ - Lift-to-drag ratio at loiter
- $(L/D)_{Cruise}$ - Lift-to-drag ratio at cruise
- M - Mach number of aircraft
- M_{FF} - Mission fuel fraction
- R - Range (km)
- R_e - Reynolds number
- S - Wing area (m^2)
- S_{Ref} - Reference surface area
- S_{Wet} - Wetted surface area
- S_a - Approach distance (m)
- S_f - Flare distance (m)
- S_{fr} - Freeroll distance (m)
- S.C - Service ceiling
- A.C - Absolute ceiling
- T - Thrust (N)
- T_{Cruise} - Thrust at cruise (N)
- $T_{Take\text{-}off}$ - Thrust at take-off (N)
- $(T/W)_{Loiter}$ - The thrust-to-weight ratio at Loiter

- $(T/W)_{\text{Cruise}}$ - The thrust-to-weight ratio at cruise
- $(T/W)_{\text{Take-off}}$ - The thrust-to-weight ratio at take-off
- V_{Cruise} - velocity at cruise (m/s)
- V_{Stall} - velocity at stall (m/s)

- V_t - Velocity at touch down (m/s)
- W_{Crew} - Crew weight (kg)
- W_{empty} - Empty weight of the aircraft (kg)
- W_{Fuel} - Weight of fuel (kg)
- W_{Payload} - Payload of the aircraft (kg)
- W_0 - Overall weight (kg)
- W/S - Wing loading (kg/m^2)
- ρ - Density of air (kg/m^3)
- μ - Dynamic viscosity (Ns/m^2)
- λ - Tapered ratio
- R/C - Rate of Climb
- η - Kinematic viscosity (m^2/s)

CHAPTER 1
INTRODUCTION TO DESIGN

1.1 INTRODUCTION TO DESIGN

Modern aircraft are a complex combination of aerodynamic performance, lightweight durable structures and advanced systems engineering. Air passengers demand more comfort and more environmentally friendly aircraft. Hence many technical challenges need to be balanced for an aircraft to economically achieve its design specification. Aircraft design is a complex and laborious undertaking with a number of factors and details that are required to be checked to obtain optimum the final envisioned product. The design process begins from scratch and involves a number of calculations, logistic planning, design and real-world considerations, and a level head to meet any hurdle head on.

Aerodynamics is the study of how air flows around an airplane. In order for an airplane to fly at all, air must flow over and under it's every airplane goes through many changes in design before it is finally built in a factory. These steps between the first ideas for an airplane and the time when it is actually flown make up the design process. Along the way, engineers think about four main areas of aeronautics: *Aerodynamics*, *Propulsion*, *Structures and Materials*, and *Stability and Control*.

Wings. The more aerodynamic, or streamlined the airplane is, the less resistance it has against the air. If air can move around the airplane easier, the airplane's engines have less work to do. This means the engines do not have to be as big or eat up as much fuel which makes the airplane more lightweight and easier to fly. Engineers have to think about what type of airplane they are designing because certain airplanes need to be aerodynamic in certain ways. For example, fighter jets maneuver and turn quickly and fly faster than sound (supersonic flight) over short distances. Most passenger airplanes, on the other hand, fly below the speed of sound (subsonic flight) for long periods of time.

Propulsion is the study of what kind of engine and power an airplane needs. An airplane needs to have the right kind of engine for the kind of job that it has. A passenger jet carries many passengers and a lot of heavy cargo over long distances so its engines need to use fuel very efficiently. Engineers are also trying to make airplane engines quieter so they do not bother the passengers onboard or the neighborhoods they are flying over. Another important concern is making the exhaust cleaner and more environmentally friendly. Just like automobiles, airplane exhaust contains chemicals that can damage the earth's environment.

Structures and Materials is the study of how strong the airplane is and what materials will be used to build it. It is really important for an airplane to be as lightweight as possible. The less weight an airplane has, the less work the engines have to do and the farther it can fly. It is tough designing an airplane that is lightweight and strong at the same time. In the past, airplanes were usually made out of lightweight metals like aluminum, but today a lot of engineers are thinking about using *composites* in their designs. Composites look and feel like plastic but are stronger than most metals. Engineers also need to make sure that airplanes not only fly well but are also easy to build and maintain.

Stability and Control is the study of how an airplane handles and interacts to pilot input and feed. Pilots in the cockpit have a lot of data to read from the airplane's computers or displays. Some of this information could include the airplane's speed, altitude, direction, and fuel levels as well as upcoming weather conditions and other instructions from ground control. The pilot needs to be able to process the correct data quickly, to think about what kind of action needs to be taken, and to react in an appropriate way. Meanwhile, the airplane should display information to the pilot in an easy-to-read and easy-tounderstand way. The controls in the cockpit should be within easy reach and just where the pilot expects them to be. It is also important that the airplane responds quickly and accurately to the pilot's instructions and maneuvers.

When you look at aircraft, it is easy to observe that they have a number of common features: wings, a tail with vertical and horizontal wing sections, engines to propel them through the air, and a fuselage to carry passengers or cargo. If, however, you take a more critical look beyond the gross features, you also can see subtle, and sometimes not so subtle, differences. This is where design comes into play. Each and every aircraft is built for a specific task, and the design is worked around the requirement and need of the aircraft. The design is modelled about the aircraft role and type and not the other way around. Thus, this is why airplanes differ from each other and are conceptualized differently. Aircrafts that fall in the same category may have similar specifications and performance parameters, albeit with a few design changes.

Design is a pivotal part of any operation. Without a fixed idea or knowledge of required aircraft, it is not possible to conceive the end product. Airplane design is both an art and a science. In that respect it is difficult to learn by reading a book; rather, it must be experienced and practiced. However, we can offer the following definition and then attempt to explain it. Airplane design is the intellectual engineering process of creating on paper (or on a computer screen) a flying machine to (1) meet certain specifications and requirements established by potential users (or as perceived by the manufacturer) and/or (2) pioneer innovative, new ideas and technology. An example of the former is the design of most commercial transports, starting at least with the Douglas DC-1 in 1932, which was designed to meet or exceed various specifications by an airplane company. (The airline was TWA, named Transcontinental and Western Air at that time.) An example of the latter is the design of the rocket-powered Bell X1, the first airplane to exceed the speed of sound in level or climbing flight (October 14, 1947). The design process is indeed an intellectual activity, but a rather special one that is tempered by good intuition developed via experience, by attention paid to successful airplane designs that have been used in the past, and by (generally proprietary) design procedures and databases (handbooks, etc) that are a part of every airplane manufacturer.

1.1 DEFINING A NEW DESIGN

The design of an aircraft draws on a number of basic areas of aerospace engineering. These include aerodynamics, propulsion, light-weight structures and control. Each of these areas involves parameters that govern the size, shape, weight and performance of an aircraft. Although we generally try to seek optimum in all these aspects, with an aircraft, this is practically impossible to achieve. The reason is that in many cases, optimizing one characteristic degrades another.

There are many performance aspects that can be specified by the mission requirements. These include:

- The aircraft purpose or mission profile
- The type(s) and amount of payload
- The cruise and maximum speeds
- The normal cruise altitude
- The range or radius with normal payload
- The endurance
- The take-off distance at the maximum weight
- The purchase cost

1.1.1 Aircraft Purpose

The starting point of any new aircraft is to clearly identify its purpose. With this, it is often possible to place a design into a general category. Such categories include combat aircraft, passenger or cargo transports, and general aviation aircraft. These may also be further refined into subcategories based on particular design objectives such as range (short or long), take-off or landing distances, maximum speed, etc. The process of categorizing is useful in identifying any existing aircraft that might be used in making comparisons to a proposed design. With modern military aircraft, the purpose for a new aircraft generally comes from a military program office. For example, the mission specifications for the X-29 pictured in figure 1.1 came from a 1977 request for proposals from the U.S. Air Force Flight Dynamics Laboratory in which they were seeking a research aircraft that would explore the forward swept wing concept and validate studies that indicated such a design could provide better control and lift qualities in extreme maneuvers. With modern commercial aircraft, a proposal for a new design usually comes as the response to internal studies that aim to project future market needs. For example, the specifications for the Boeing commercial aircraft (B-777) were based on the interest of commercial airlines to have a twin-engine aircraft with a payload and range in between those of the existing B-767 and B-747 aircraft. Since it is not usually possible to optimize all of the performance aspects in an aircraft, defining the purpose leads the way in setting which of these aspects will be the ―design drivers.‖ For example, with the B-777, two of the prominent design drivers were range and payload.

1.2 DESIGN MOTIVATION

Fundamentally, an aircraft is a structure. Aircraft designers design structures. The structures are shaped to give them desired aerodynamic characteristics, and the materials and structures of their engines are chosen and shaped so they can provide needed thrust. Even seats, control sticks, and windows are structures, all of which must be designed for optimum performance. Designing aircraft structures is particularly challenging, because their weight must be kept to a minimum. There is always a trade-off between structural strength and weight. A good aircraft structure is one which provides all the strength and rigidity to allow the aircraft to meet all its design requirements, but which weighs no more than necessary. Any excess structural weight often makes the aircraft cost more to build and almost always makes it cost more to operate. As with small excesses of aircraft drag, a small percentage of total aircraft weight used for structure instead of payload can make the difference between a profitable airliner or successful tactical fighter and a failure. Designing aircraft structures involves determining the loads on the structure, planning the general shape and layout, choosing materials, and then shaping, sizing and optimizing its many components to give every part just enough strength without excess weight. Since aircraft structures have relatively low densities, much of their interiors are typically empty space which in the complete aircraft is filled with equipment, payload, and fuel. Careful layout of the aircraft structure ensures structural components are placed within the interior of the structure so they carry the required loads efficiently and do not interfere with placement of other components and payload within the space. Choice of materials for the structure can profoundly influence weight, cost, and manufacturing difficulty.

The extreme complexity of modern aircraft structures makes optimal sizing of individual components particularly challenging. An understanding of basic structural concepts and techniques for designing efficient structures is essential to every aircraft design

1.3 DESIGN PROCESS

The process of designing an aircraft and taking it to the point of a flight test article consists of a sequence of steps, as illustrated in the figure. It starts by identifying a need or capability for a new aircraft that is brought about by (1) a perceived market potential and (2) technological advances made through research and development. The former will include a market-share forecast, which attempts to examine factors that might impact future sales of a new design. These factors include the need for a new design of a specific size and performance, the number of competing designs, and the commonality of features with existing aircraft. As a rule, a new design with competitive performance and cost will have an equal share of new sales with existing competitors. The needs and capabilities of a new aircraft that are determined in a market survey go to define the mission requirements for a conceptual aircraft. These are compiled in the form of a design proposal that includes (1) the motivation for initiating a new design and (2) the ―technology readiness‖ of new technology for incorporation into a new design. It is essential that the mission requirements be defined before the design can be started. Based on these, the most important performance aspects or ―design drivers‖ can be identified and optimized above all others. Following the design proposal, the next step is to produce a conceptual design. The conceptual design develops the first general size and configuration for a new aircraft. It involves the estimates of the weights and the choice of aerodynamic characteristics that will be best suited to the mission requirements stated in the design proposal. The conceptual design is driven by the mission requirements, which are set in the design proposal. In some cases, these may not be attainable so that the requirement may need to be relaxed in one or more areas. This is shown in the iterative loop in the flow chart. When the mission requirements are satisfied, the design moves to the next phase, which is the preliminary design.

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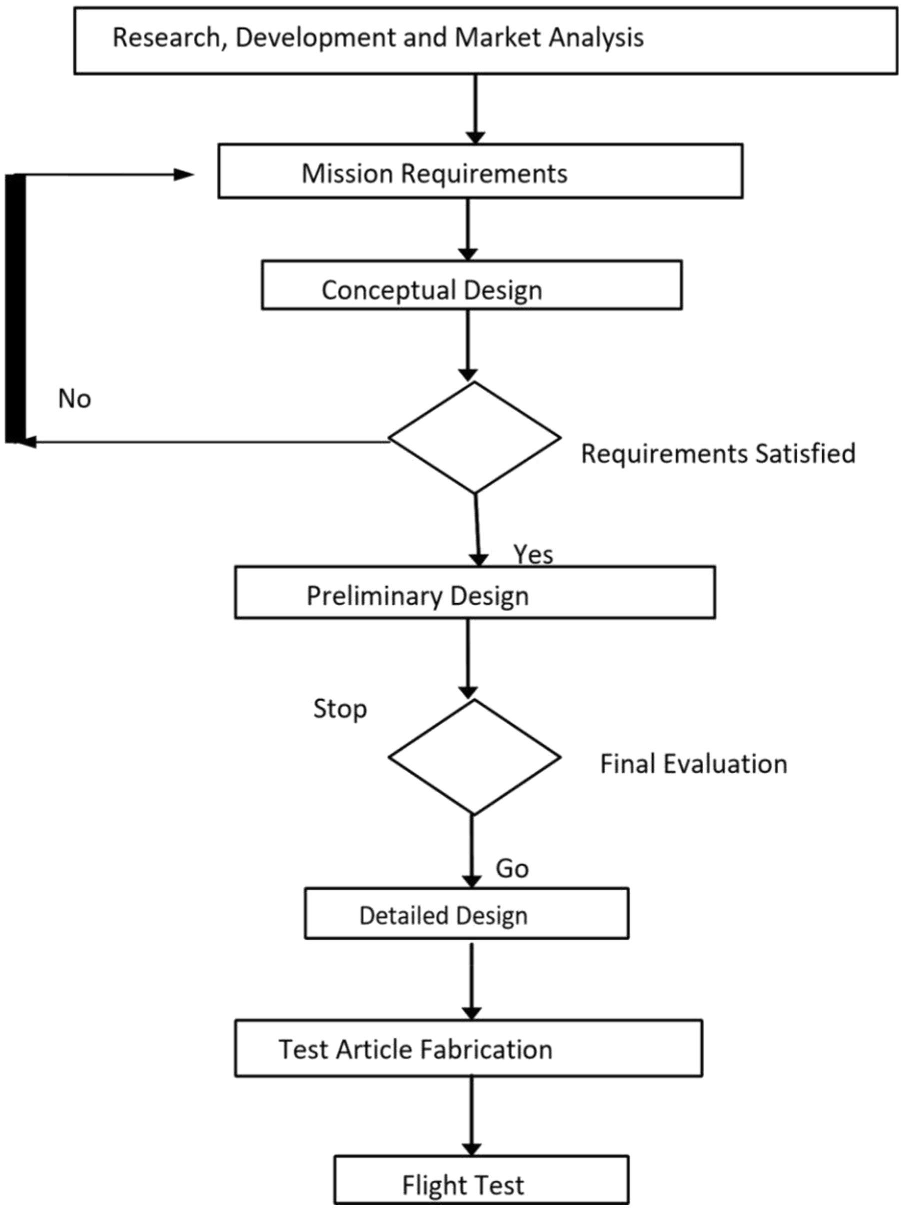

Figure. 1.1 Design Process flow chart

Conceptual design

This article deals with the steps involved in the conceptual design of an aircraft. It is broken down in to several elements, which are followed in order. These consist of:

1. Literature survey
2. Preliminary data acquisition
3. Estimation of aircraft weight
    a. Maximum take-off weight

   b. Empty weight of the aircraft
   c. Weight of the fuel
   d. Fuel tank capacity
4. Estimation of critical performance parameters
   a. Wing area
   b. Lift and drag coefficients
   c. Wing loading
   d. Power loading
   e. Thrust to weight ratio
5. Engine selection
6. Performance curves
7. 3 View diagrams

1.4 DESIGN PROCESS BREAKDOWN

• **Conceptual Design:** - Competing concepts evaluated Performance goals established - Preferred concept selected	What drives the design? Will it work/meet requirement? What does it look like?
• **Preliminary Design:** • Refined sizing of preferred concept tests	- Do serious wind tunnel tests

• Design examined data/establish parameters - Some changes allowed	- Make actual cost estimate
• **Detail Design:** - Final detail design - Drawings released - Detailed performance - Only —tweaking‖ of design allowed	Certification process Component/systems tests Manufacturing Flight control system design

Table 1.1 Design Process Breakdown

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CHAPTER 2

INTRODUCTION TO AGRICULTURE AIRCRAFTS

1. PIPER PA-36 PAWNEE BRAVE

The Piper PA-36 Pawnee Brave is a specialty agricultural aircraft with space for a pilot only. It can reach speeds of up to 117 knots, and has a maximum capacity of 4,400 lbs . The aircraft was a development of the original Piper PA-36 Pawnee, and has a larger hopper, a more powerful engine, and a better ventilation system. It first entered service in 1973. The most recent model was renamed the New Brave, and is currently being manufactured by WTA Incorporated.

Figure 2.1 Piper Pa-36 Pawnee Brave

Configuration and Component

- **Capacity:** 38 cu ft (1.08 m^3)
- **Length:** 27 ft 6 in (8.38 m)

- **Wingspan:** 38 ft $9+\frac{1}{2}$ in (11.824 m)
- **Height:** 7 ft 6 in (2.29 m)
- **Wing area:** 225.65 sq ft (20.964 m^2)
- **Aspect ratio:** 6.7:1
- **Airfoil:** NACA 63_3-618
- **Empty weight:** 2,465 Lb (1,118 kg)
- **Max takeoff weight:** 4,800 Lb (2,177 kg)
- **Fuel capacity:** 86 US gal (72 imp gal; 330 L) usable fuel
- **Powerplant:** 1 × Avco Lycoming IO-720-D1C flat-eight air-cooled piston engine, 375 hp (280 kW)
- **Propellers:** 3-bladed Hartzell constant-speed propeller 7 ft 2 in (2.18 m) diameter

Performance

- **Maximum speed:** 142 mph (229 km/h, 123 kn) (crop sprayer)
- **Cruise speed:** 136 mph (219 km/h, 118 kn)
- **Range:** 452 mi (727 km, 393 nmi)
- **Rate of climb:** 920 ft/min (4.7 m/s)
- **Takeoff run to 50 ft (15 m):** 1,500 ft (460 m)
- **Landing run from 50 ft (15 m):** 1,440 ft (440 m)

2. CESSNA 188 AG WAGON

The Cessna 188 was first flown on 19 February 1965. The aircraft was certified and entered production in February 1966, with 241 aircraft delivered the first year. The initial design of the Cessna 188 was so successful that over its 17-year production run the basic airframe remained unchanged. Only the engines and the agricultural products dispensing systems were

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upgraded, other than some minor changes to the ventilation systems .The main use for the Cessna 188 series was for agricultural purposes.

Figure 2.2 Cessna 188 Ag Wagon

Configuration and Component

- **Capacity:** Hopper: 280 US gal
- **Length:** 26 ft
- **Wingspan:** 41 ft 8 in
- **Height:** 7 ft 8+^{1}⁄2 in
- **Wing area:** 205 sq ft •**Airfoil:** NACA 2412 modified
- **Empty weight:** 2,059 lb.
- **Gross weight:** 3,300 lb. (1,497 kg)
- **Max takeoff weight:** 4,200 lb. (1,905 kg)
- **Fuel capacity:** 56 US gal (47 imp gal; 210 L)

- **Propellers:** 2-bladed McCauley metal constant-speed propeller **Performance**
- **Maximum speed:** 121 mph (195 km/h, 105 kn)
- **Cruise speed:** 113 mph (182 km/h, 98 kn) (75% power)
- **Stall speed:** 57 mph (92 km/h, 50 kn)
- **Range:** 295 mi (475 km, 256 nmi)
- **Service ceiling:** 11,100 ft (3,400 m)
- **Rate of climb:** 690 ft/min (3.5 m/s)
- **Takeoff distance to 50 ft (15m):** 1,090 ft (330 m)
- **Landing distance from 50 ft (15 m):** 1,265 ft (386 m)

3. AIR TACTOR

Air Tractor Inc. is a United States aircraft manufacturer based in Olney, Texas.

Founded in 1978, the company began manufacturing a new agricultural aircraft derived from the S-2B aircraft Designated Model AT-300 Air Tractor, the new aircraft first flew in 1973.

Figure 2.3 Air Tactor

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4. PAC FETCHER

The Fletcher FU-24 is an agricultural aircraft made in New Zealand. One of the first aircraft designed for aerial topdressing, the Fletcher has also been used for other aerial applications as a utility aircraft, and for sky diving.

Figure 2.4 Pac Fetcher

Component and configuration

- **Capacity:** 6 passengers *o*
- **Length:** 31 ft 10 in (9.70 m)
- **Wingspan:** 42 ft 0 in (12.80 m)
- **Height:** 9 ft 4 in (2.84 m)
- **Wing area:** 294.0 sq ft (27.31 m^2)
- **Airfoil:** NACA 4415
- **Empty weight:** 2,620 lb. (1,188 kg)

- **Gross weight:** 4,860 lb. (2,204 kg) normal maximum
- **Max takeoff weight:** 5,430 lb. (2,463 kg) agricultural
- **Fuel capacity:** 67 US Gallons, 254 L (normal)
- **Powerplant:** 1 × Textron Lycoming IO-720-A1A air-cooled flat-eight engine

Performance

- **Maximum speed:** 145 mph (233 km/h, 126 kn) at sea level
- **Cruise speed:** 130 mph (210 km/h, 110 kn) 75% power
- **Stall speed:** 57 mph (92 km/h, 50 kn) flaps down
- **Never exceed speed:** 165 mph (266 km/h, 143 kn)
- **Range:** 441 mi (710 km, 383 nmi)
- **Service ceiling:** 16,000 ft (4,900 m)
- **Rate of climb:** 805 ft/min (4.09 m/s)

5. EMBRAER EMB 202 IPANEMA

The Embraer EMB 202 Ipanema is a Brazilian agricultural aircraft used for aerial application, particularly crop dusting. It is produced by Indústria Aeronautical Neiva, a subsidiary of Embraer located in Batucada, Brazil. The latest version of this aircraft is the first ethanolpowered fixedwing aircraft, which could give it an economical advantage over the and the 1,000th delivery was completed on 15 March 2005. gasoline version. The aircraft is widely employed in Brazil, having market share of about 80%,

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Figure 2.5 EMBRAER EMB 202 IPANEMA

Component and configuration

- **Capacity:** 950 liters (250 US gal; 210 imp gal) liquid or 750 kilograms (1,650 lb.) dry chemicals
- **Length:** 7.43 m (24 ft 5 in) (tail up)
- **Wingspan:** 11.69 m (38 ft 4 in)
- **Height:** 2.20 m (7 ft 3 in) (tail down)
- **Wing area:** 19.94 m^2 (214.6 sq ft)
- **Aspect ratio:** 6.9:1
- **Empty weight:** 1,020 kg (2,249 lb.)
- **Max takeoff weight:** 1,800 kg (3,968 lb.) (restricted category)
- **Fuel capacity:** 264 liters (70 US gal; 58 imp gal) usable fuel
- **Powerplant:** 1 × Textron Lycoming IO-540-K1J5D air-cooled flat-six, 224 kW.

Performance

- **Maximum speed:** 230 km/h (140 mph, 120 kn)
- **Cruise speed:** 213 km/h (132 mph, 115 kn) (75% power)
- **Stall speed:** 92 km/h (57 mph, 50 kn) (power off)
- **Never exceed speed:** 272 km/h (169 mph, 147 kn)
- **Range:** 938 km (583 mi, 506 nmi)
- **Service ceiling:** 3,470 m (11,380 ft)
- **Rate of climb:** 4.7 m/s (930 ft/min)
- **Take-off run to 15 m (50 ft):** 332 meters (1,089 ft)
- **Landing run from 15 m (50 ft):** 412 meters (1,352 ft)

6. PZL-106 KRUK

The **PZL-106 Kruk** is a Polish agricultural aircraft designed and built by WSK PZL Warszawa-Okezie. The PZL-106 was developed as a modern agricultural aircraft for Poland and Comecon countries to replace the less-capable PZL-101 Gawron and aging PZL Antonov An-2. (According to Comecon decisions, Polish industry was responsible for developing agricultural aircraft). There were several agricultural plane designs proposed in the early 1960s by a group of young designers from WSK PZL Warszawa-Okezie, led by Andrzej Frydrychewicz. These proposals were made on their own initiative, but they were never realized because the USSR was content with the An-2 and was planning to replace it with a jet aircraft (later PZL M-15 Belphegor). The first was the PZL-101M Kruk 63 of 1963. That remained a paper airplane, but it did give its name to later designs. Next were the PZL-106 Kruk 65 (1965), PZL-110 Kruk-2T (1969), and PZL M-14 Kruk (1970, which was planned to produce this variant in PZL-Mielec). Only in 1971 did the authorities decide to start development of new agricultural design such as the PZL-106 Kruk 71. Despite this decision, its development was quite protracted due to

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economic and political factors. The work, led by Andrzej Frydrychewicz, started in 1972 and was based on earlier designs.
The first prototype was flown on April 17, 1973.

Figure 2.6 Pzl-106 Kruk

Component and Configuration

- **Capacity:** 1 seat for mechanic (optional) / 1,300 kg (2,900 lb) / 1,400 l (370 US gal; 310 imp gal) hopper for chemicals
- **Length:** 9.25 m (30 ft 4 in)
- **Wingspan:** 14.9 m (48 ft 11 in)
- **Height:** 3.32 m (10 ft 11 in)
- **Wing area:** 31.69 m^2 (341.1 sq. ft)
- **Aerofil:** NACA 2415
- **Empty weight:** 1,790 kg (3,946 lb)

- **Max take-off weight:** 3,000 kg (6,614 lb)
- **Fuel capacity:** 560 l (150 US gal; 120 imp gal) in two integral wing tanks with an optional 390 l (100 US gal; 86 imp gal) auxiliary tank in the hopper compartment
- **Powerplant:** 1 × PZL-3SR 7-cylinder air-cooled geared and supercharged radial piston engine, 450 kW (600 hp)
- **Propellers:** 4-bladed PZL US-133000 constant-speed propeller

Performance

- **Maximum speed:** 215 km/h (134 mph, 116 kn) at sea level
- **Operating speed:** 150–160 km/h (93–99 mph; 81–86 kn) with max chemical load
- **Stall speed:** 100 km/h (62 mph, 54 kn)
- **Never exceed speed:** 145 km/h (90 mph, 78 kn)
- **Range:** 900 km (560 mi, 490 nmi) with max standard fuel
- **Rate of climb:** 3.8 m/s (750 ft/min)
- **Wing loading:** 108.86 kg/m^2 (22.30 lb/sq. ft) (restricted category)
- **Take-off run:** 250 m (820 ft) (with agricultural equipment)

7. ANTONOV AN-2

The Antonov An-2 ("kukuruznik"—corn crop duster; USAF/DoD reporting name Type 22, NATO reporting name Colt) is a Soviet mass-produced single-engine biplane utility/agricultural aircraft designed and manufactured by the Antonov Design Bureau beginning in 1946. It's remarkable durability, high lifting power, and ability to take off and land from poor runways have given it a long service life. The An-2 was produced up to 2001 and remains in service with military and civilian operators around the world.

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The An-2 was designed as a utility aircraft for use in forestry and agriculture. However, the basic airframe is highly adaptable and numerous variants of the type have been developed; these include hopper-equipped versions for crop-dusting, scientific versions for atmospheric sampling, water bombers for fighting forest-fires, flying ambulances, float-equipped seaplane versions and lightly armed combat versions for dropping Para troops. The most common version is the An-2T 12seater passenger aircraft. All versions (other than the An-3 and the An-2-100) are powered by a 750 kW (1,010 hp) nine-cylinder Shvetsov ASh-62 radial engine, which was developed from the Wright R-1820. The An-2 typically consumes 2.5 l/min (0.66 US gal/min; 0.55 imp gal/min). The Antonov An-2 is a mass-produced single-engine biplane that has been commonly used as a utility and agricultural aircraft. It is deliberately furnished with a minimum of complex systems. The crucial wing leading edge slats that give the aircraft its slow flight ability is fully automatic, being held closed by the airflow over the wings.

Figure 2.7 ANTONOV AN-2

Component and Configuration

- **Crew:** 1–2
- **Capacity:** 12 passengers / 2,140 kg (4,718 lb)
- **Length:** 12.4 m (40 ft 8 in)

- **Upper wingspan:** 18.2 m (59 ft 9 in)
- **Lower wingspan:** 14.2 m (46 ft 7 in)
- **Height:** 4.1 m (13 ft 5 in)
- **Wing area:** 71.52 m^2 (769.8 sq. ft)
- **Airfoil:** TsAGI R-11 (14%)
- **Empty weight:** 3,300 kg (7,275 lb)
- **Gross weight:** 5,440 kg (11,993 lb)
- **Fuel capacity:** 1,200 l (320 US gal; 260 imp gal)
- **Powerplant:** 1 × Shvetsov ASh-62IR 9-cylinder air-cooled supercharged radial piston engine, 750 kW (1,010 hp)
- **Propellers:** 4-bladed constant-speed propeller

Performance

- **Cruise speed:** 190 km/h (120 mph, 100 kn)
- **Stall speed:** 50 km/h (31 mph, 27 kn) circa
- **Range:** 845 km (525 mi, 456 nmi)
- **Service ceiling:** 4,500 m (14,800 ft)
- **Rate of climb:** 3.5 m/s (690 ft/min)
- **Power/mass:** 0.136 kW/kg (0.083 hp/lb)

8. PZL-MIELEC M-18 DROMADER

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The PZL-Mielec M-18 Dromader is a single engine agricultural aircraft that is manufactured by PZL-Mielec in Poland. The aircraft is used as a Cropduster or firefighting machine.

PZL-Mielec, then known as WSK-Mielec, began to design the Dromader in the mid-1970s, with help of United States aircraft manufacturer Rockwell International. PZL-Mielec asked for Rockwell's help because of the political situation at the time: operating in an Eastern Bloc country, PZL wanted the aircraft to sell well worldwide, and the company realized that certification by the United States Federal Aviation Administration would be important in reaching that goal. Rockwell on the other hand wanted to fit Polish high-power radial engines into its agricultural planes. As a result of this cooperation the Rockwell Thrust Commander aircraft was fitted with the PZL-3 engine, and the Polish designers created the higher payload M-18 Dromader by introducing the more powerful ASz-62 engine, making structural changes to the airframe, and increasing dimensions. The cooperation led to the Dromader sharing outer wing panels and part of the fuselage with the Thrush Commander. The first prototype of the aircraft flew on August 27, 1976. In September 1978, the aircraft was given certification to fly in Poland. Certifications from many countries around the world followed soon.

Many aircraft of the M-18 type and its variations can still be seen around the world. They were sold to 24 countries, over 200 are used in the US. In 2008, fifteen were sold to China. In 2012, PZL-Mielec was still selling models M-18B and M-18BS, with 759 built in total. As of 2017, the Dromader was sold by PZL-Mielec, but the production has been halted. The produced aircraft are still refurbished instead, with new engines (produced by WSK "PZL-Kalisz"). There are plans to acquire rights and renew the production in WZL-2 in Bydgoszcz

Component and Configuration

- **Crew:** 1 / 2 (M18BS)
- **Capacity:** 2,500 l (660 US gal; 550 imp gal) liquid or 2,200 kg (4,900 lb) dry chemical in fiberglass hopper forward of the cockpit (smaller hopper in M18BS)
- **Length:** 9.47 m (31 ft 1 in)
- **Wingspan:** 17.7 m (58 ft 1 in)
- **Height:** 3.7 m (12 ft 2 in) to tailfin on ground
- **Wing area:** 40 m^2 (430 sq. ft)
- **Aspect ratio:** 7.8
- **Airfoil:** ACA 4416; tip: NACA 4412 outer wing panels
- **Empty weight:** 2,710 kg (5,975 lb)
- **Max take-off weight:** 4,200 kg (9,259 lb)
- **Fuel capacity:** 510 kg (1,120 lb) max fuel weight
- **Powerplant:** 1 × PZL Kalisz ASz-621R 9-cylinder air-cooled radial piston engine, 731 kW (980 hp)
- **Propellers:** 4-bladed PZL Warszawa AW-2-30, 3.3 m (10 ft 10 in) diameter constant speed aluminum alloy propeller

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9. GRUMMAN AG CAT

The Grumman G-164 Ag Cat is a single-engine biplane agricultural aircraft, developed by Grumman in the 1950s.

The Ag Cat was the first aircraft specifically designed by a major aircraft company for agricultural aviation, and the first aircraft designed according to the regulations of Civil Aeronautics Manual Part 8, which had been written especially for agricultural aircraft.

In 1955, Grumman preliminary design engineers Joe Lippert and Arthur Koch proposed the design for a "purpose-built" crop-dusting airplane as a means of fulfilling a pressing need in the agricultural community, as well as the perceived need for Grumman to diversify its product lines. The initial market survey indicated that 100 to 200 of this type could be sold each year. Lippert's initial proposal was made under the project name "Farm air 1000".

The first G-164, which was built by Grumman (N74054), was equipped with a Continental W670 Series 6A-16 powerplant. The aircraft had its maiden flight on May 27, 1957, with Grumman test pilot Hank Kurt at the controls. This initial flight test consisted of three short familiarization hops with the take-off weight set at 3122 lb and the centre of gravity at 31.2%. Flight tests 2 and 3, with test pilot Victor Eble, were accomplished on May 28, 1958, to evaluate its general flight characteristics. In total, 46 test flights were completed by the end of August 1958 with a general finding that this was a well-behaved aircraft with only minor refinements needed before production.

When the decision was made to authorize production, Leroy Grumman suggested marketing the aircraft under the name "The Grasshopper"; however, Dick Reade suggested "Ag Cat" following Grumman's naming tradition using the suffix "cat" in aircraft names (e.g., F4F Wildcat and F6F Hellcat). Mr. Grumman agreed and the Grumman G-164 became the "Ag Cat". Large military orders prevented the production of the Ag Cat at Grumman's Bethpage facility. Grumman's board of directors chose to subcontract the entire program to the Schweizer Aircraft Corporation of Elmira, New York. Initial production was through a contract between Schweizer and Grumman. The first Schweizer-built Ag Cat, bearing registration number N10200, flew on October 17, 1958, under the control of Schweizer test pilot Clyde Cook. Full production began in January 1959, with Schweizer delivering 12 FAA-certified airplanes to Grumman by March 1959. The FAA granted type certification on January 20, 1959.

Component And Configuration

- **Capacity:** 400 US gal (333 imp gal; 1,514 l) in forward hopper
- **Length:** 27 ft 7.25 in (8.4138 m)
- **Wingspan:** 42 ft 4.5 in (12.916 m)
- **Height:** 12 ft 1 in (3.68 m)
- **Wing area:** 392.7 sq. ft (36.48 m^2)

  Empty weight: 3,150 lb (1,429 kg)
- **Max take-off weight:** 7,020 lb (3,184 kg)
- **Powerplant:** 1 × Pratt & Whitney Canada PT6A-34AG turboprop, 750 shp (560 kW) • **Propellers:** 3-bladed constant-speed propeller

Performance

- **Maximum speed:** 113 kn (130 mph, 209 km/h)
- **Stall speed:** 56 kn (64 mph, 104 km/h)

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- **Never exceed speed:** 136 kn (157 mph, 252 km/h)
- **Range:** 172 nmi (198 mi, 319 km)

Figure 2.9 Grumman Ag Cat

10. KAMOV KA-26

The Kamov Ka-26 (NATO reporting name Hoodlum) is a Soviet light utility helicopter with coaxial rotors. The Ka-26 entered production in 1969. 816 have been built. A variant with a single turboshaft engine is the Ka-126. A twin turboshaft-powered version is the Ka-226. (All the Ka26/126/128/226 variants are code-named by NATO as "Hoodlum").

The fuselage of the Ka-26 consists of a fixed, bubble-shaped cockpit containing the pilot and copilot, plus a removable, variable box available in medevac, passenger-carrying, and crop duster versions. The helicopter can fly with or without the box attached for flexibility.

It is powered by two 325 hp (239 kW) Vedeneyev M-14V-26 radial engines mounted in outboard nacelles. The Ka-26 is small enough to land on a heavy truck bed. The reciprocating engines are more responsive than turboshaft engines, but require more maintenance. It runs mostly at 95% power in crop dusting with usually excess payload, leaving little reserve power for emergencies. Due to frequent overloads, the interconnect shaft joining the two engines is prone to breakage and requires frequent inspection.

The standard instrumentation of the Ka-26, like larger naval Kamovs, may be overkill for civilian or crop-dusting use. The 18-dials cockpit panel masks a part of the right-downwards view, needed to avoid telephone and power lines at low altitudes. The instrument panel may be simplified to retain the six main dials. As there is a low rotor clearance at the aircraft front, it is approached from the rear when the rotors are turning. Due to the limitations of the Ka-26, USSR and Romania agreed under the Comecon trade to build a single-turboshaft engine version, the Kamov Ka-126, with better aerodynamics and range.

Component And Configuration

- **Capacity:** 6 or 7 pax when passenger module fitted / 2 stretcher patients, 2 seated patients and medical attendant / 900 kg (1,984 lb) pax or liquid chemical / 1,065 kg (2,348 lb) dusting or with platform / 1,100 kg (2,425 lb) with slung load.
- **Length:** 7.75 m (25 ft 5 in) fuselage
- **Width:** 3.64 m (11 ft 11 in) over engine pods
- **Height:** 4.05 m (13 ft 3 in)
- **Empty weight:** 1,950 kg (4,299 lb) sans passenger pod / platform / agricultural equipment **Gross weight:** 3,076 kg (6,781 lb) passenger version

2,980 kg (6,570 lb) other versions

-

- **Max take-off weight:** 3,250 kg (7,165 lb)
- **Fuel capacity:** 360 kg (794 lb) with pax; 100 kg (220 lb) agricultural
- **Powerplant:** 2 × Vedeneyev M-14V-26 9-cylinder air-cooled radial piston engines, 242.5 kW (325.2 hp) each
- **Main rotor diameter:** 2 × 13 m (42 ft 8 in)

Performance

- **Maximum speed:** 170 km/h (110 mph, 92 kn)
- **Cruise speed:** 150 km/h (93 mph, 81 kn) max

90–110 km/h (56–68 mph; 49–59 kn) economical

- **Agricultural operating speed:** 30–115 km/h (19–71 mph; 16–62 kn)
- **Range:** 400 km (250 mi, 220 nmi) with 7 pax,30 minutes reserve
- **Ferry range:** 1,200 km (750 mi, 650 nmi) with auxiliary fuel tanks
- **Endurance:** 3 hours 42 minutes at 90–110 km/h (56–68 mph; 49–59 kn)
- **Service ceiling:** 3,000 m (9,800 ft)
- **Service ceiling one engine inoperative:** 500 m (1,640 ft)
- **Hover ceiling IGE:** 1,300 m (4,265 ft) at 3,000 kg (6,614 lb) AUW
- **Hover ceiling OGE:** 800 m (2,625 ft) at 3,000 kg (6,614 lb) AUW
- **Disk loading:** 12 kg/m^2 (2.5 lb/sq. ft)

Figure 2.10 KAMOV KA-26

11. CAC CERES

The Commonwealth Aircraft CA-28 Ceres was a crop-duster aircraft manufactured in Australia by the Commonwealth Aircraft Corporation (CAC) between 1959 and 1963. The aircraft was a development of the Wireway trainer of World War II.

In the 1950s most crop-dusting aircraft in Australia were conversions of military types that met with varying success. Two CAC types so converted were the Wackett and the Wireway. Neither type was successful in this role, the Wackett because it was underpowered and the Wireway because it was not designed for low-level slow-speed flight. Following a market survey conducted together with ICI, CAC determined there was a need for a purpose-built aircraft optimized for agricultural work. Once the board approved the project a number of surplus Wirraways were purchased from the RAAF for use in the production of this new aircraft.

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Component And Configuration

- **Capacity:** 2,380 lb (1,080 kg) max payload / 40 cu ft (1.1 m^3) hopper
- **Length:** 30 ft 9 in (9.36 m)

  Wingspan: 46 ft 11 in (14.3 m)
- **Height:** 9 ft 0 in (2.74 m)
- **Wing area:** 312 sq. ft (29.0 m^2)
- **Empty weight:** 4,400 lb (1,996 kg)
- **Gross weight:** 6,720 lb (3,048 kg)
- **Max take-off weight:** 7,350 lb (3,334 kg)
- **Powerplant:** 1 × Pratt & Whitney R-1340 S3H1-G 9-cyl. air-cooled radial piston engine, 600 hp (450 kW)
- **Propellers:** 3-bladed variable-pitch propeller

Performance

- **Cruise speed:** 105 kn (121 mph, 194 km/h) at4,950 lb (2,250 kg)
- **Operating speed:** 96.5 kn (111.1 mph; 178.7 km/h) with max payload
- **Stall speed:** 63.9 kn (73.5 mph, 118.3 km/h) at max AUW
- **Ferry range:** 450 nmi (520 mi, 830 km) with 80 imp gal (96 US gal; 360 l) fuel
- **Rate of climb:** 725 ft/min (3.68 m/s) at max AUW
- **Take-off to 50 ft (15 m):** 2,185 ft (666 m) with max payload
- **Landing from 50 ft (15 m):** 585 ft (178 m) at 5,500 lb (2,500 kg) AUW

Figure 2.11 CAC CERES

12. YEOMAN CROP MASTER

The Yeoman Crop master was an Australian agricultural aircraft developed from the CAC Wackett trainer of World War II.

The type was developed by Yeoman Aviation, a company set up by Kingsford Smith Aviation Services Pty. Ltd. (KSA) at Bankstown Airport to engage in agricultural aircraft production.

KSA had obtained a number of Wacketts following the type's retirement from Royal Australian Air Force service and had converted four for agricultural use as KS-3 Crop masters in the second half of the 1950s. The conversion involved little more than the installation of a hopper located in the rear cockpit of the Wackett, the cutting of a hole in the centre section of the Wackett's wooden wing to allow the dispersal of the chemical load, and re-routing controls to bypass the hopper.

Component And Configuration

- **Capacity:** 23 cu ft (0.65 m^3) capacity hopper, 1,456 lb (660 kg) payload

-

- **Length:** 26 ft 4 in (8.03 m)

  Wingspan: 35 ft 0 in (10.67 m)

- **Height:** 9 ft 9 in (2.97 m)
- **Wing area:** 179 sq. ft (16.6 m^2)
- **Empty weight:** 1,800 lb (816 kg)
- **Max take-off weight:** 3,530 lb (1,601 kg)
- **Fuel capacity:** 34 imp gals (41 US gal; 150 L)
- **Powerplant:** 1 × Continental IO-470-R six-cylinder air-cooled horizontally-opposed engine, 250 hp (190 kW)
- **Propellers:** 2-bladed McCauley constant-speed

Performance

- **Maximum speed:** 152 mph (245 km/h, 132 kn) at sea level
- **Cruise speed:** 129 mph (208 km/h, 112 kn) (econ cruise, 60% power)
- **Never exceed speed:** 240 mph (390 km/h, 210 kn)
- **Endurance:** 3 hr
- **Rate of climb:** 1,100 ft/min (5.6 m/s)
- **Take-off run to 50 ft (15 m):** 1,200 ft (370 m)

13. GIPPSLAND GA200

The Gippsland GA-200 Fatman is a low-wing single-engine agricultural aircraft built by Gipps Aero. Based loosely on the Piper Pawnee, the first two prototypes used damaged Pawnee frames. The third prototype, built in 1992, was the first all-original airframe. The GA-200 was fully certificated on 1 March 1991.

Certificate of Type Approval No. 83-6 for the GA200 was issued by the Australian Civil Aviation Authority on that date; the first to be issued for a totally new aircraft design in Australia since the GAF Nomad, 20 years earlier. The certification basis was the Australian certification standards, Civil Aviation Orders, Sections 101.16 and 101.22. These standards in turn incorporated the airworthiness standards of Part 23 of the US Federal Aviation Regulations.

Component And Configuration

- **Capacity:** 1 pax / student / assistant / 776 l (205 US gal; 171 imp gal) hopper 726 l (192 US gal; 160 imp gal) in trainer versions)
- **Length:** 7.48 m (24 ft 6 in)
- **Wingspan:** 11.93 m (39 ft 2 in)
- **Height:** 2.33 m (7 ft 8 in) static
- **Wing area:** 19.6 m^2 (211 sq. ft)
- **Aspect ratio:** 7.3
- **Empty weight:** 770 kg (1,698 lb)
- **Gross weight:** 1,315 kg (2,899 lb) normal
- **Max take-off weight:** 1,700 kg (3,748 lb) agricultural
- **Fuel capacity:** 214 l (57 US gal; 47 imp gal) in two integral wing tanks and small header tank in fuselage

-

- **Powerplant:** 1 × Ly coming IO-540-H2A5 6-cylinder air-cooled horizontally-opposed piston engine, 190 kW (250 hp) (de-rated from 260hp)
- **Propellers:** 2-bladed McCauley IA200/FA 84 52, 2.13 m (7 ft 0 in) diameter fixed-pitch metal propeller

Performance

- **Cruise speed:** 185 km/h (115 mph, 100 kn) at 305 m (1,001 ft)

Stall speed: 100 km/h (62 mph, 54 kn) flaps up 91

km/h (57 mph; 49 kn) flaps down

84 km/h (52 mph; 45 kn) at typical landing weight flaps up

76 km/h (47 mph; 41 kn) at typical landing weight flaps down

- **Rate of climb:** 4.917 m/s (967.9 ft/min)
- **Wing loading:** 86.73 kg/m^2 (17.76 lb/sq. ft) agricultural
- **Take-off run:** 340 m (1,115 ft) at 1,600 kg (3,527 lb) AUW and 15° flat

- *Figure 2.12 GIPPSLAND GA200*

14. AUSTER AGRICOLA

The Auster B8 Agricola was a commercially unsuccessful British agricultural aircraft designed for the aerial topdressing market which opened in New Zealand in the early 1950s.

Constructed of fabric over a corrosion-proofed steel frame, the design featured a large high-lift lowset monoplane wing, external control cables, fixed tailwheel undercarriage and a somewhat angular fuselage. It had an aft cabin that could seat two passengers, a hopper over the centre of the wing which could hold 750 kg of superphosphate in the topdressing role, or 654 litres of spray as a crop duster.

The pilot sat forward of the hopper over the wing leading edge, a position which gave a good field of view compared with the American practice of placing the pilot behind the hopper, though this view was restricted by the extensive canopy joinery and bulky rear decking.

Component And Configuration

- **Capacity:**
- 144 imperial gallons (650 L) insecticide
- 1,700 lb; 760 kg
- **Length:** 28 ft 1 in (8.56 m)
- **Wingspan:** 42 ft 0 in (12.80 m)
- **Height:** 8 ft 4 in (2.54 m)
- **Wing area:** 254.7 sq. ft (23.66 m^2)
- **Aspect ratio:** 6.93:1
- **Empty weight:** 1,920 lb (871 kg)
- **Max take-off weight:** 3,840 lb (1,742 kg)
- **Powerplant:** 1 × Continental O-470-B air-cooled flat-six engine, 240 hp (180 kW)

Performance

- **Maximum speed:** 127 mph (204 km/h, 110 kn)
- **Cruise speed:** 101 mph (163 km/h, 88 kn)
- **Stall speed:** 35 mph (56 km/h, 30 kn) (flaps down, power off)
- **Range:** 220 mi (350 km, 190 nmi)
- **Service ceiling:** 20,000 ft (6,100 m) (No payload), 10,500 ft (3,200 m) (3,675 lb (1,667 kg) weight)

Figure 2.13 AUSTER AGRICOLA

CHAPTER 3

PREPARATION OF COMPARATIVE DATA SHEET OF DIFFERENT AIRCRAFTS

3.1 DATA COLLECTION

We have collected data for from the previous chapter. The data are collected and tabulated for further analysis and the graphs are also plotted based on all the 10 Aircrafts as selected the tabulated data.

3.1.1. GENERAL CHARACTERISTICS

Aircraft /data	Cruising speed kmph	crew	Length m	Height m	Wing area m2	Wing span m	Aspect ratio
Piper PA-36 Pawnee Brave	219	1	8.38	2.29	20.964	11.824	6.7:1
Cessna 188 AG WAGON	182	1	7.9	2.35	19.045	12.7	8:9:4
PAC FETCHER	210	6	9.7	2.84	27.31	12.8	10:1
Embraer EMB 202 Ipanema	92	1	7.43	2.20	214.6	11.69	6.9:1
PZL-106 Kruk	180	1 or 2	9.25	3.32	31.69	14.9	7:38:1
Antonov An-2	190	1 or 2	12.4	4.1	71.52	18.2	12:13
PZL-Mielec M-18 Dromader	237	1 or 2	9.47	3.7	40	17.7	7.8:1
Grumman Ag Cat	210	1	8.4	3.68	36.48	12.916	3:13
Kamov Ka-26	150	1	7.75	4.05	-	-	16:13
CAC Ceres	180	1	9.36	2.74	29	14.3	12:13

Yeoman Crop Master	208	1	8.03	2.97	16.6	10.67	6:13
Gippsland GA200	185	1	7.48	2.33	19.6	11.93	7.3:1
Auster Agricola	163	1	8.56	2.54	23.66	12.8	6.93:1
HA-31 Basant	185	1	9	2.55	23.34	12	6:9

Table 3.1 General Characteristics

3.1.2. WEIGHT CONFIGURATION

Aircraft\Data	**Cruising speed, *kmph***	**Empty weight, *kg***	**Maximu m Takeoff weight, *g k***	**Loaded weight/ operating weight, *kg***
Piper PA-36 Paw ee Brave	219	1118	2177	1845
Cessna 188 AG WAGON	182	934	1905	1497
PAC FETCHER	210	1188	2463	2204
Embraer EMB 2 02 Ipanema	213	1020	1800	1453
PZL-106 Kruk	180	1790	3000	2658
Antonov An-2	190	3300	5500	5440
PZL-Mielec M-18 Dromader	237	2710	4200	3965
Grumman Ag C at	210	1429	3184	2980
Kamov Ka-26	150	1950	3250	3076
CAC Ceres	105	1996	3334	3048

Yeoman Crop master	208	816	1601	1246
Gippsland GA200	185	770	1700	1315
Auster Agricola	163	871	1742	1356
HA-31 Basant	185	1200	2600	2270

Table 3.2 Weight Configuration

3.1.3. PERFORMANCE

Aircraft\Data	**Cruising speed, *kmph***	**Maximum speed, *Mach***	**Maximum altitude, *m***	**Range, *Km***	**Rate of climb, *m/s***
Piper PA-36 Pawnee Brave	219	229	4572	727	4.7
Cessna 188 AG WAGON	182	195	3400	475	3.5
PAC FETCHER	210	233	4900	710	4.09
Embraer EMB 202 Ipanema	213	230	3470	938	4.7
PZL-106 Kruk	180	215	4000	900	3.8
Antonov An-2	190	225	4800	845	3.5
PZL-Mielec M-18 Dromader	237	256	6500	970	6.5
Grumman Ag Cat	210	113	3962	319	5.48
Kamov Ka-26	150	170	3000	400	5.8
CAC Ceres	105	120	7000	648	3.68
Yeoman Crop master	208	245	4500	780	5.6
Gippsland GA200	185	266	3800	740	4.9
Auster Agricola	163	204	6100	350	3.1
HA-31 Basant	185	225	3800	645	3.8

Table 3.3 Performance

CHAPTER 4
PREPARATION OF COMPARATIVE GRAPHS

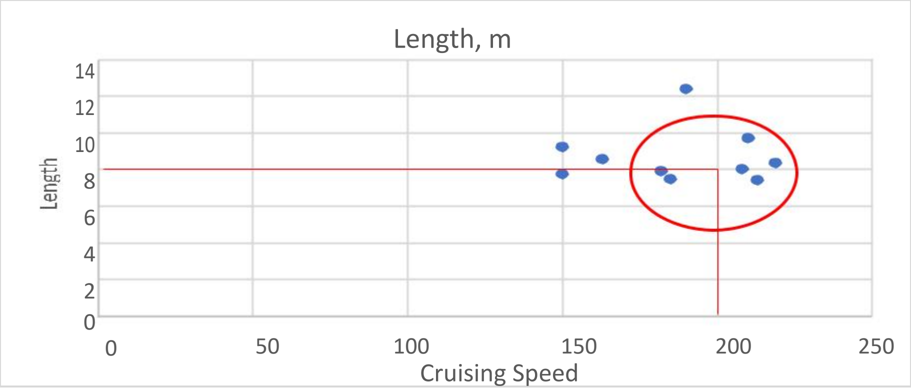
4.1 GRAPH PLOTTING

The graphs are plotted for the tabulated data from the previous section. The inference from these graphs will give us the tentative design parameters.

4.1.1. CRUISING SPEED vs CREW

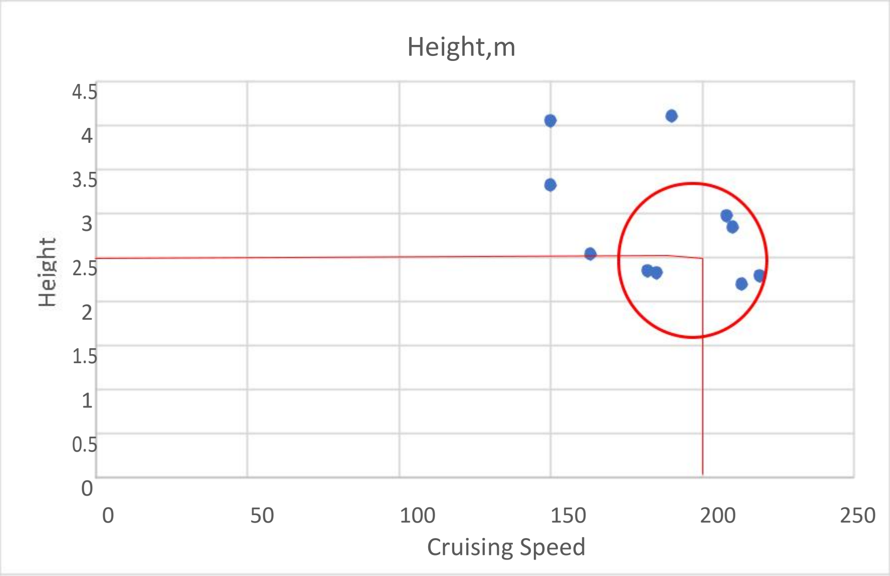
Graph 4.1 Cruising Speed Vs Crew

4.1.2. CRUISING SPEED vs LENGTH



Graph 4.2 Cruising Speed Vs Length

4.1.3. CRUISING SPEED vs HEIGHT

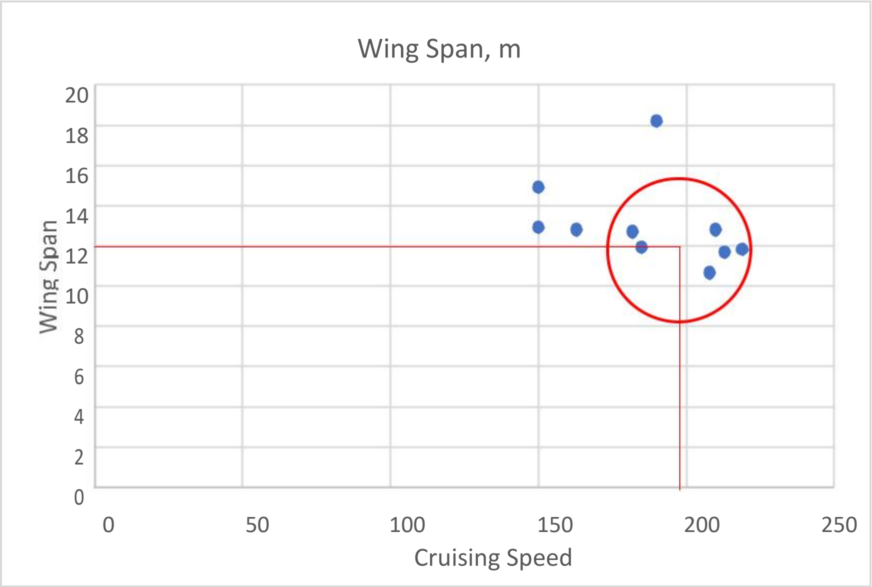


Graph 4.3 Cruising Speed Vs Height

4.1.4. CRUISING SPEED vs WING AREA

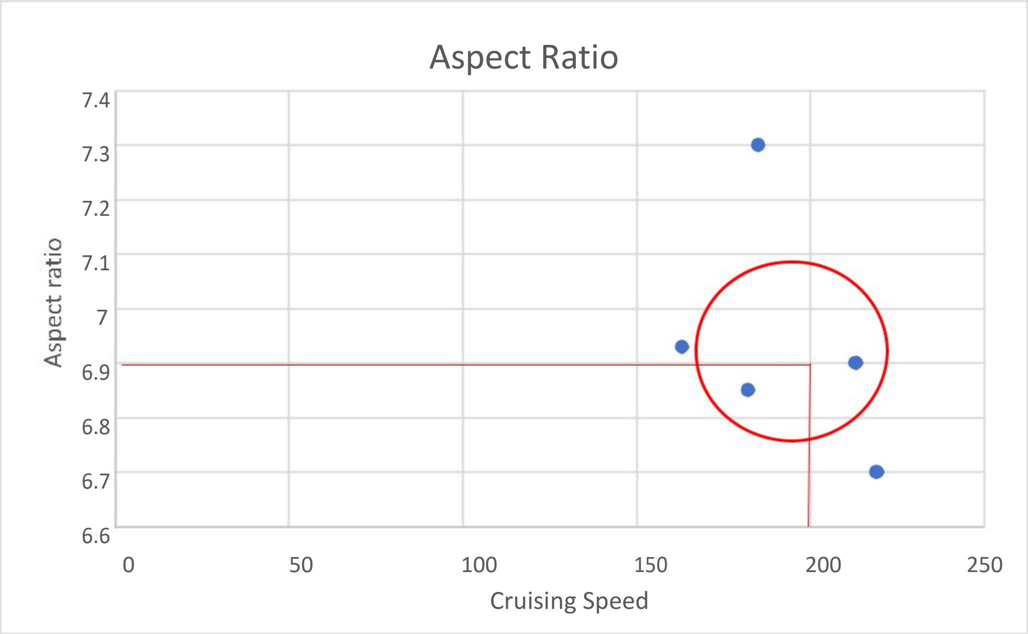
Graph 4.4 Cruising Speed Vs Wing Area

4.1.5. CRUISING SPEED vs WING SPAN



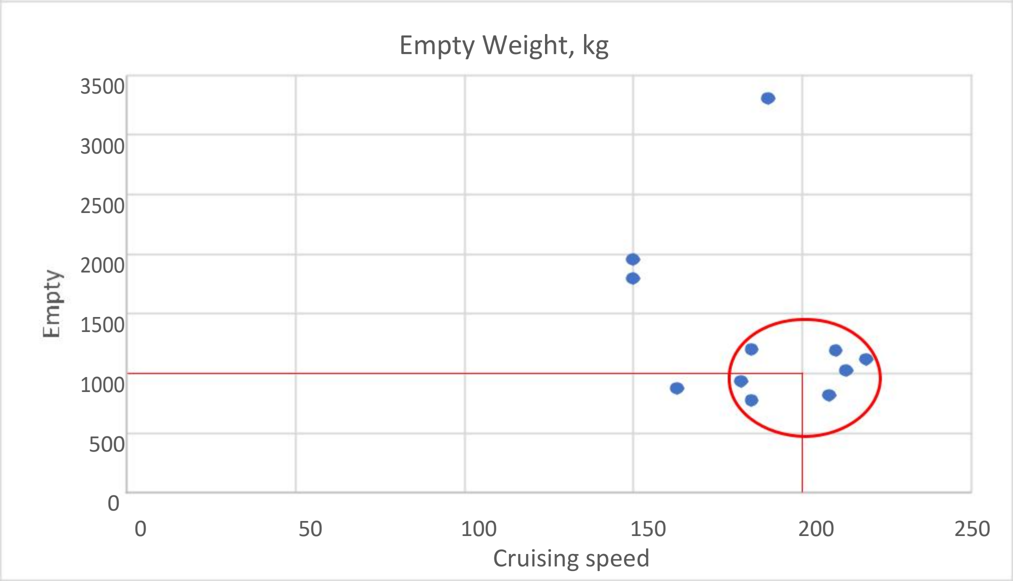
Graph 4.5 Cruising Speed Vs Wing Span

4.1.6. CRUISING SPEED vs ASPECT RATIO



Graph 4.6 Cruising Speed Vs Aspect Ratio

4.1.7. CRUISING SPEED vs EMPTY WEIGHT



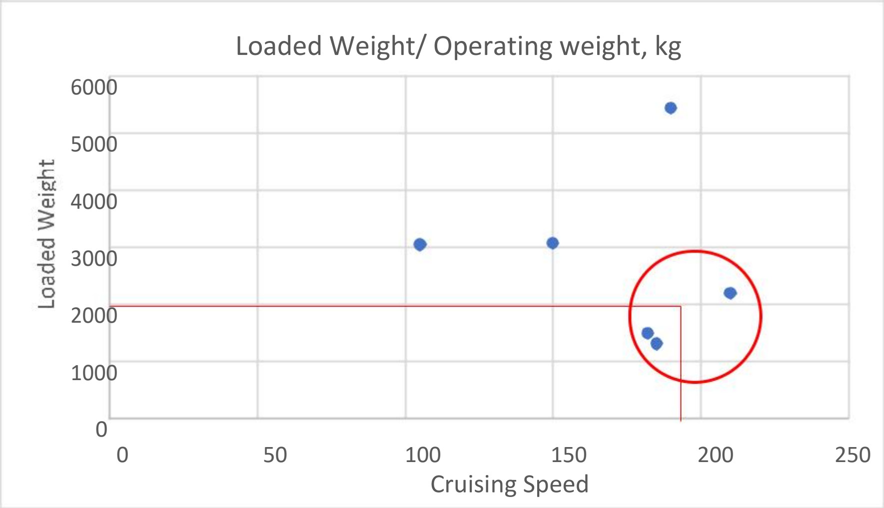
Graph 4.7 Cruising Speed Vs Empty Weight

8. CRUISING SPEED vs MAXIMUM TAKE-OFF WEIGHT

Graph 4.8 Cruising Speed Vs Maximum Take-Off Weight

4.1.

4.1.9. CRUISING SPEED vs MAXIMUM LOADED WEIGHT



Graph 4.9 Cruising Speed Vs Maximum Loaded Weight

10. CRUISING SPEED vs MAXIMUM SPEED

Graph 4.10 Cruising Speed Vs Maximum Speed

4.1.

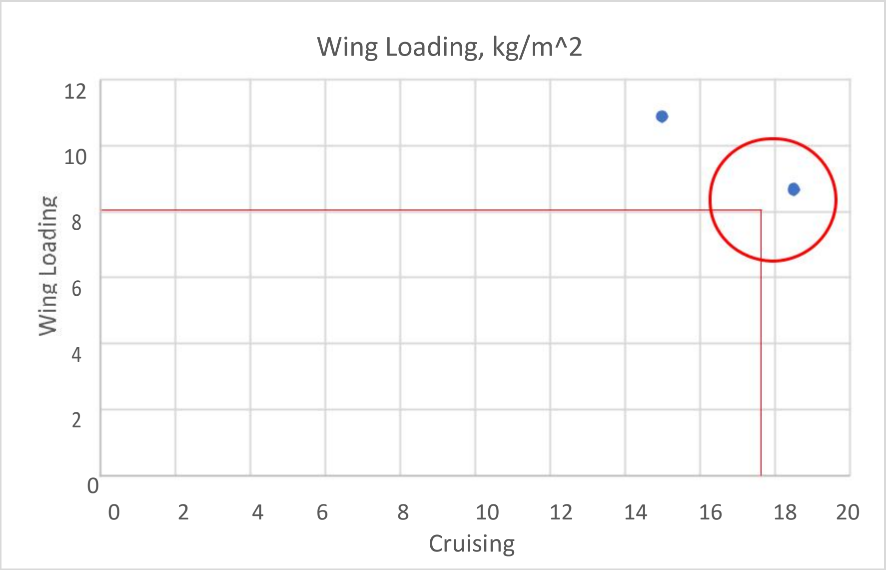
4.1.11. CRUISING SPEED vs MAXIMUM ALTITUDE

Graph 4.11 Cruising Speed Vs Maximum Altitude **12. CRUISING SPEED vs RANGE**

Graph 4.12 Cruising Speed Vs Range

4.1.

4.1.13. CRUISING SPEED vs WING LOADING



Graph 4.13 Cruising Speed Vs Wing Loading

CHAPTER 5

SELECTION OF TENTATIVE DESIGN PARAMETERS

5.1 TENTATIVE DESIGN PARAMETERS

Based on the comparative study from the literature survey as well as the graphs plotted from the tabulated data of the selected 10 aircrafts, we have selected the tentative design parameters for out aircraft. These parameters will be used to proceed with the design steps and weight estimation processes.

5.1.1 GENERAL CHARACTERISTICS

The tentative parameters for the general characteristics for the design are listed as follows,

1. Crew : 1
2. Length : 7.5 *m*
3. Height : 2.5 *m*
4. Wing area : 25 m^2
5. Wing span : 12 *m*
6. Aspect ratio : 6.9
7. Cruising speed : 124.27mile/hr

5.1.2 WEIGHT CONFIGURATION

The tentative parameters for the weight configuration for the design are listed as follows,

1. Empty weight : 1000 *kg*
2. Take-Off weight : 2500 *kg*

3. Loaded Weight : 1500 *kg*

5.1.3 PERFORMANCE

The tentative parameters for the performance for the design are listed as follows,

1. Maximum speed : 0.202 *Mach*
2. Maximum Altitude : 4000 *m*
3. Range : 3.073 *miles*
4. Wing Loading : 85 kg/m^2

CHAPTER 6

WEIGHT ESTIMATION

6.1 FLIGHT PROFILE

Flight profile can be defined as the trajectory of flight or the flight plan which consists of the altitude, speed, distance of flight and the maneuvers to be performed and the number of stops etc. A flight plan plays a very important role as it helps us to be prepared in advance. The following is the flight profile of our aircraft.

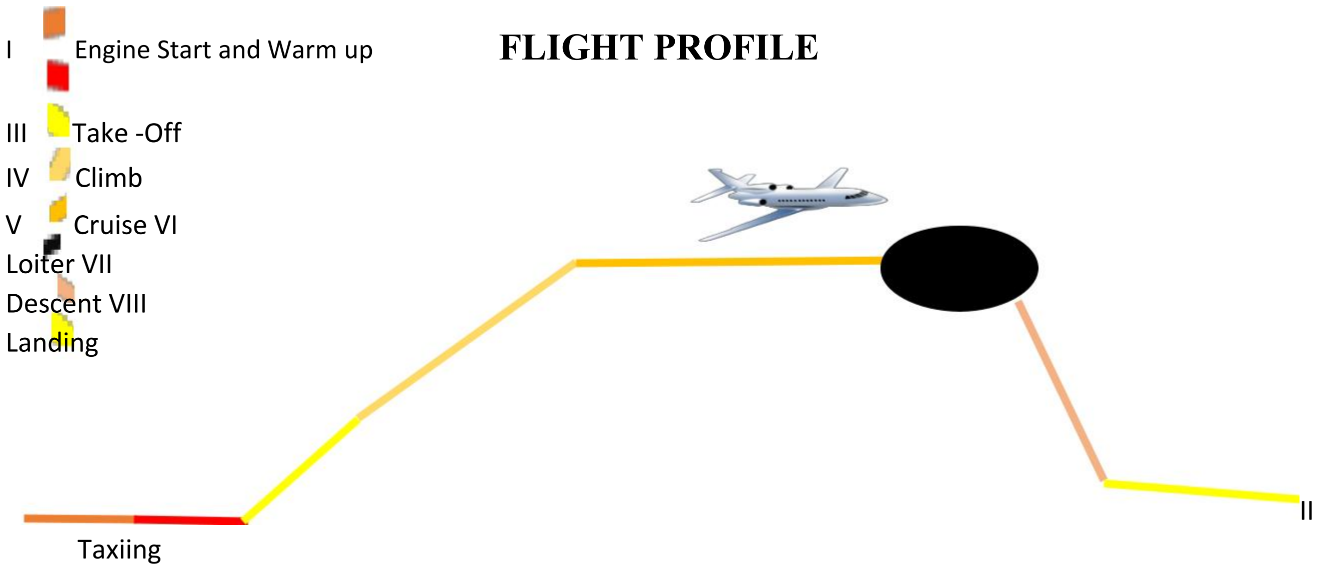


Figure 6.1 FLIGHT PROFILE

I. ENGINE START & WARM UP:

The engine is started and it is allowed to run for some time so that system warms up before the actual flight.

AI. TAXIING:

The aircraft is taxied in order to align with the runway before taking off.

BI. TAKE-OFF:

The aircraft takes off into air from the ground surface.

IV. CLIMB:

The aircraft climbs to reach its maximum altitude.

V. CRUISE:

The aircraft travels in the maximum altitude in the cruising speed.

VI. LOITER:

The aircraft is diverted for loitering when the runway in the airport is engaged.

VII. DESCENT:

After the aircraft has travelled 60% of its course, it starts to descend for landing.

VIII. LANDING:

The aircraft completes the journey and lands. After landing, the aircraft is taxied to the warehouse.

6.2 WEIGHT ESTIMATION

The following are the steps involved in weight estimation of the designed aircraft.

6.2.1 PAYLOAD WEIGHT

The following is the calculation for the maximum payload weight of the aircraft. Considering the maximum weight of 1 passenger as 175 lbs and maximum allowable fertilizer weight is 100lbs

For 10 passengers along with baggage, $W_{pl} = (W_{passenger} + W_{FERTILIZER}) * (\text{No. of passengers})$

$\Rightarrow$ WPL = 1 passenger + fertilizer

⇨ WPL = 175 + 100 = 275 lbs

6.2.2 CREW WEIGHT

The following is the calculation for the maximum weight of the crew in the aircraft. Considering the maximum weight of 1 crew member as 175 lbs and maximum allowable baggage weight for each crew member as 30 lbs,

For 1 crew members along with their baggage, $W_{cr} = (W_{crew} + W_{Baggage}) * (\text{No. of crew members})$

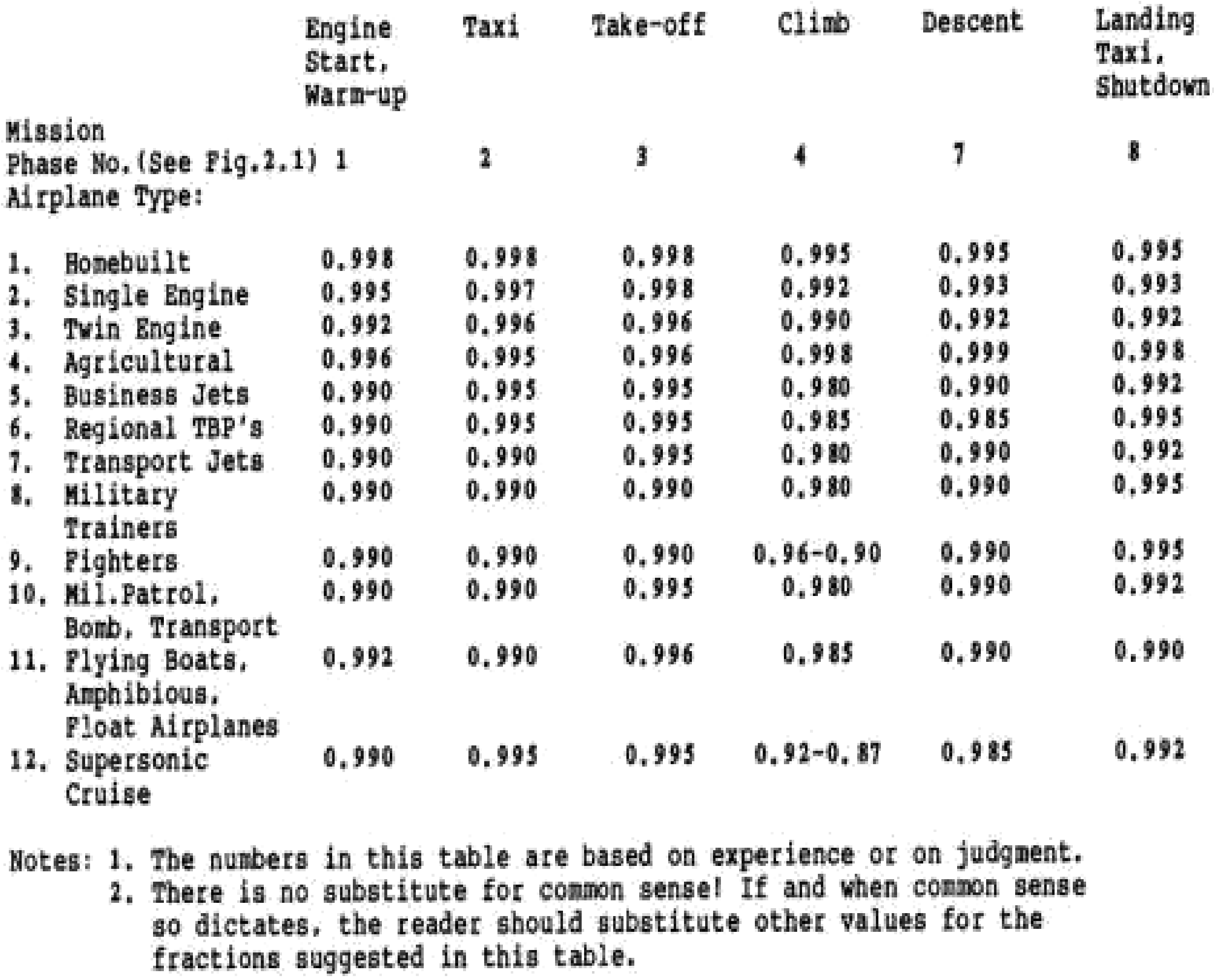
⇨ $W_{cr} = 175$

6.2.3 WEIGHT RATIO CALCULATIONS

The weight ratio are used to obtain the weight of the aircraft at various stages. It is then used to calculate M_{ff} which is used in calculation of W_{used}. The below calculations are made considering $W_{To\ Guess}$ as Take-off weight .

The following tables are used to obtain the weight ratios of respective phases along with cruise and loiter,

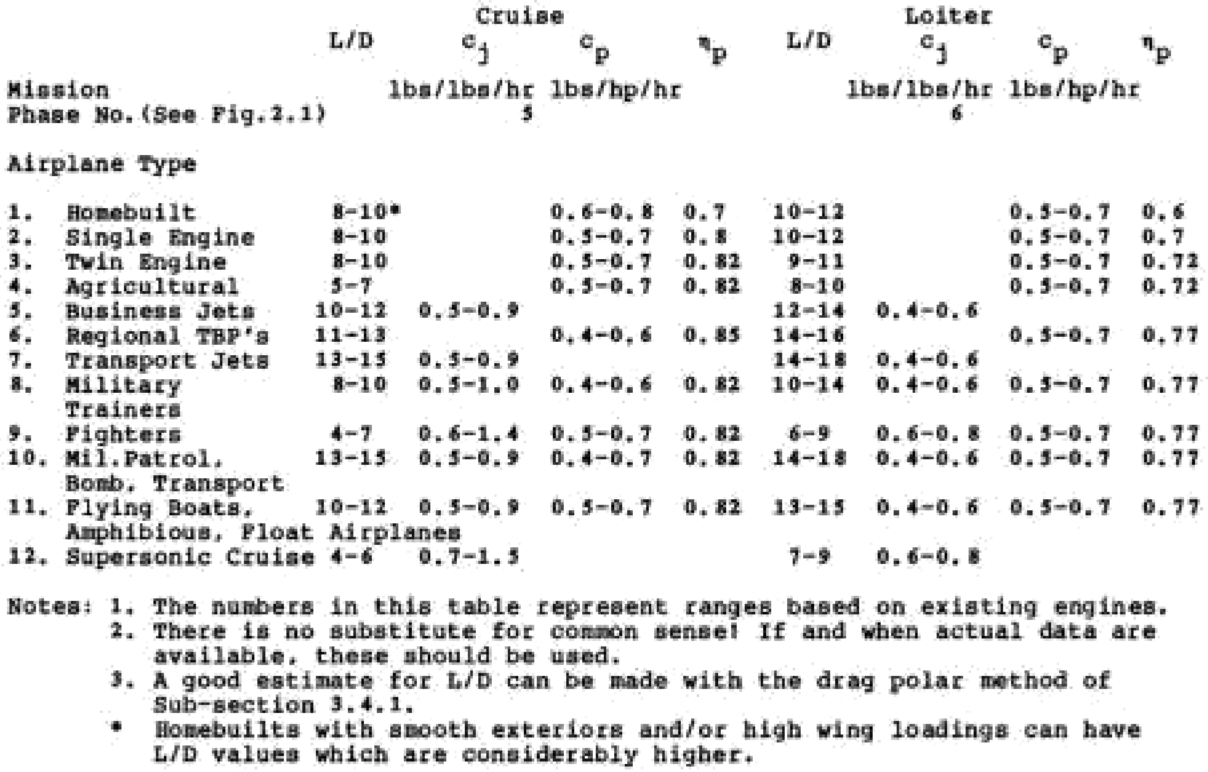
Table 6.1 Fuel –Fraction for Several Mission Phases



	Engine Start, Warm-up	Taxi	Take-off	Climb	Descent	Landing Taxi, Shutdown
Mission Phase No. (See Fig.2.1)	1	2	3	4	7	8
Airplane Type:						
1. Homebuilt	0.998	0.998	0.998	0.995	0.995	0.995
2. Single Engine	0.995	0.997	0.998	0.992	0.993	0.993
3. Twin Engine	0.992	0.996	0.996	0.990	0.992	0.992
4. Agricultural	0.996	0.995	0.996	0.998	0.999	0.998
5. Business Jets	0.990	0.995	0.995	0.980	0.990	0.992
6. Regional TBP's	0.990	0.995	0.995	0.985	0.985	0.995
7. Transport Jets	0.990	0.990	0.995	0.980	0.990	0.992
8. Military Trainers	0.990	0.990	0.990	0.980	0.990	0.995
9. Fighters	0.990	0.990	0.990	0.96-0.90	0.990	0.995
10. Mil.Patrol, Bomb, Transport	0.990	0.990	0.995	0.980	0.990	0.992
11. Flying Boats, Amphibious, Float Airplanes	0.992	0.990	0.996	0.985	0.990	0.990
12. Supersonic Cruise	0.990	0.995	0.995	0.92-0.87	0.985	0.992

Notes: 1. The numbers in this table are based on experience or on judgment.
2. There is no substitute for common sense! If and when common sense so dictates, the reader should substitute other values for the fractions suggested in this table.

Table 6.2 Mission Cruise and loiter parameter for Several Phases



	Cruise				Loiter			
	L/D	c_j	c_p	η_p	L/D	c_j	c_p	η_p
Mission		lbs/lbs/hr	lbs/hp/hr			lbs/lbs/hr	lbs/hp/hr	
Phase No. (See Fig.2.1)		5				6		
Airplane Type								
1. Homebuilt	8-10*		0.6-0.8	0.7	10-12		0.5-0.7	0.6
2. Single Engine	8-10		0.5-0.7	0.8	10-12		0.5-0.7	0.7
3. Twin Engine	8-10		0.5-0.7	0.82	9-11		0.5-0.7	0.72
4. Agricultural	5-7		0.5-0.7	0.82	8-10		0.5-0.7	0.72
5. Business Jets	10-12	0.5-0.9			12-14	0.4-0.6		
6. Regional TBP's	11-13		0.4-0.6	0.85	14-16		0.5-0.7	0.77
7. Transport Jets	13-15	0.5-0.9			14-18	0.4-0.6		
8. Military Trainers	8-10	0.5-1.0	0.4-0.6	0.82	10-14	0.4-0.6	0.5-0.7	0.77
9. Fighters	4-7	0.6-1.4	0.5-0.7	0.82	6-9	0.6-0.8	0.5-0.7	0.77
10. Mil.Patrol, Bomb, Transport	13-15	0.5-0.9	0.4-0.7	0.82	14-18	0.4-0.6	0.5-0.7	0.77
11. Flying Boats, Amphibious, Float Airplanes	10-12	0.5-0.9	0.5-0.7	0.82	13-15	0.4-0.6	0.5-0.7	0.77
12. Supersonic Cruise	4-6	0.7-1.5			7-9	0.6-0.8		

Notes:
1. The numbers in this table represent ranges based on existing engines.
2. There is no substitute for common sense! If and when actual data are available, these should be used.
3. A good estimate for L/D can be made with the drag polar method of Sub-section 3.4.1.

* Homebuilts with smooth exteriors and/or high wing loadings can have L/D values which are considerably higher.

I. ENGINE START & WARM UP:

The following calculation gives the weight of the aircraft in the engine start and warm up phase,

——— = 0.996

$W_1 = W_{To\ Guess} * 0.996$

⇨ $W_1 = 2204.5 * 0.996$ ⇨ $W_1 = 2195.68$lbs.

AI. TAXIING:

b The following calculation gives the weight of the aircraft in the taxiing phase,

— = 0.995

$W_2 = W_1 * 0.995$

⇨ $W_2 = 2195.68 * 0.995$ ⇨ $W_2 = 2184.7$ lbs.

BI. TAKE-OFF:

The following calculation gives the weight of the aircraft in the take-off phase,

— =0.996

⇨ $W_3 = W_2 * 0.996$

⇨ $W_3 = 2184.7 * 0.996$ ⇨ $W_3 = 2175.96$lbs.

IV. CLIMB:

The following calculation gives the weight of the aircraft in the take-off phase,

⇨ $W_4 = W_3 * 0.998$

⇨ $W_4 = 2175.96 * 0.998$ ⇨ $W_4 = 2171.61$ lbs.

V. CRUISE:

The Range of the jet aircraft is given by the following equation and W_5 is calculated from the same,

$$=(\quad / \quad)^{*} \left(-\right) * \ln\left(\frac{4}{}\right) \quad 5$$

The following values are taken from the table, s

$R_{cr} = 3.073$ miles

$V = 124.27$ mph

$3.073 = 375\ (0.82/0.6)\ \ln(w4/w5)$

$W4/w5=1.001$

W5/w4= 0.999

W5= 2171.61*0.999 =2177.43

VI. LOITER:

The Loiter time of the jet aircraft is given by the following equation and W_7 is calculated from the same,

6

$$= \left(\frac{1}{}\right) * \left(\frac{L}{}\right) * \ln\left(\frac{W_7}{}\right)$$

The following values are taken from the table 6.2,

E_{ltr} = 4.5 hour

V = 528.16 mph

Eltr=375(1/Vcr)(np/cp)(L/D) ln (w5/w6)

4.5 = 375 (1/ 124.27)(0.72/0.5)(10) ln (w5/w6)

W5/w6 = 1.108

W6/w5 = 0.902

W6= w5*0.902

W6=1964.04

VII. DECEND:

The following calculation gives the weight of the aircraft in the descent phase,

— = 0.999

⇨ $W_7 = W_6$* 0.999

⇨ W_7 = 1964.04* 0.999 ⇨ W_7= 1962.07 lbs.

VIII. LANDING

The following calculation gives the weight of the aircraft in the landing phase,

$- = 0.998$

⇨ $W_8 = W_7 * 0.998$

⇨ $W_8 = 1962.07 * 0.998$ ⇨ $W_8 = 1958.15$ lbs.

Calculation of M_{ff} :

The M_{ff} is given by the following formula,

$$= \left(\frac{8}{7}\right) * \left(\frac{7}{6}\right) * \left(\frac{6}{5}\right) * \left(\frac{5}{4}\right) * \left(\frac{4}{3}\right) * \left(\frac{3}{2}\right) * \left(\frac{2}{1}\right) * \left(\frac{1}{\quad}\right)$$

Mff = 0.999*0.902*0.998*0.998*0.996*0.996*0.995*0.999 Mff

= 0.884.

6.2.4 WEIGHT OF FUEL

The weight of the fuel, W_f is calculated using the following formula, $W_f = (W_{used} + W_{res})$

Where, $W_{used} = (1 - M_{ff}) * W_{To\ Guess}$

Wfused= (1-Mff)Wto guess
= (1-0.884) 2204.5
=255.72 lbs

Wresv= 15% of 255.72

$= 38.35$ lbs

$W_f = W_{fused} + W_{resv}$

$= 255.72+38.35$

$= 294.07$ lbs

6.2.5 $W_{OE\ Tentative}$

The $W_{OE\ Tentative}$ is calculated using the following formula, $W_{OE\ Tentative} = W_{To\ Guess} - W_f - W_{pl}$ Where, $W_{To\ Guess} = 2204.5$ lbs.

$W_f = 294.07$lbs.

$W_{pl} = 275$ lbs.

$W_{OE\ Tentative} = W_{to\ guess} - W_f - W_{pl}$

$= 2204.5-294.07-275$

$= 1635.4$

6.2.6 $W_{E\ Tentative}$

The $W_{E\ Tentative}$ is calculated using the following formula, $W_{E\ Tentative} = W_{OE\ Tentative} - W_{TFO} - W_{crew}$ Where, $W_{OE\ Tentative} = 1635.4$ lbs.

$W_{TFO} =$ NA for smaller aircrafts

$W_{crew} = 175$ lbs.

$W_{E\ tent} = W_{OE\text{-}tent} - W_{tfo} - W_{crew}$

$=1635.4-0-175$

$= 1460.42\text{lbs}$

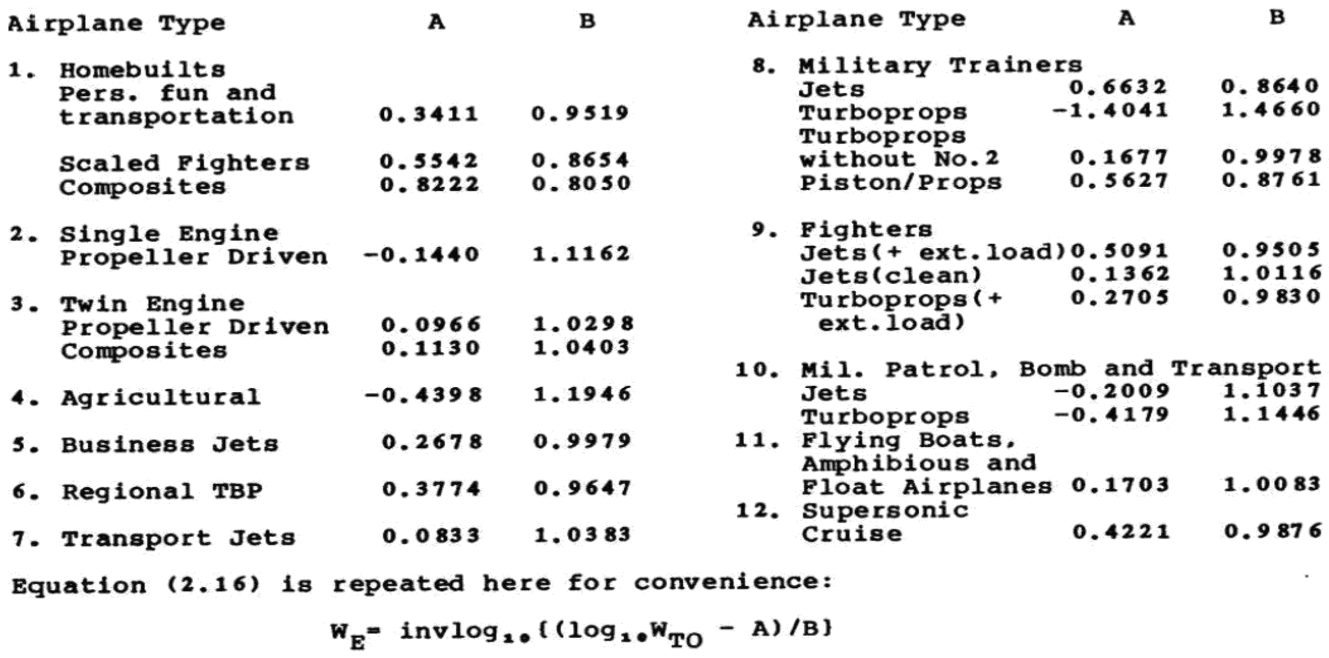
6.2.7 $W_{E\ \text{Actual}}$

The $W_{E\ \text{Actual}}$ is calculated using the following formula,

$$= \qquad \log_{10}\left[\frac{\log_{10} \quad -}{}\right]$$

The values of A and B are obtained from the following table,

Table 6.3 W_E Values



Airplane Type	A	B
1. Homebuilts		
Pers. fun and transportation	0.3411	0.9519
Scaled Fighters	0.5542	0.8654
Composites	0.8222	0.8050
2. Single Engine Propeller Driven	-0.1440	1.1162
3. Twin Engine		
Propeller Driven	0.0966	1.0298
Composites	0.1130	1.0403
4. Agricultural	-0.4398	1.1946
5. Business Jets	0.2678	0.9979
6. Regional TBP	0.3774	0.9647
7. Transport Jets	0.0833	1.0383

Airplane Type	A	B
8. Military Trainers		
Jets	0.6632	0.8640
Turboprops	-1.4041	1.4660
Turboprops without No.2	0.1677	0.9978
Piston/Props	0.5627	0.8761
9. Fighters		
Jets(+ ext.load)	0.5091	0.9505
Jets(clean)	0.1362	1.0116
Turboprops(+ ext.load)	0.2705	0.9830
10. Mil. Patrol, Bomb and Transport		
Jets	-0.2009	1.1037
Turboprops	-0.4179	1.1446
11. Flying Boats, Amphibious and Float Airplanes	0.1703	1.0083
12. Supersonic Cruise	0.4221	0.9876

Equation (2.16) is repeated here for convenience:

$$W_E = \text{invlog}_{10}\{(\log_{10} W_{TO} - A)/B\}$$

Where,

A= -0.4398

B= 1.1946

$$\Rightarrow = \log_{10}\left[\frac{\log_{10}(2204.5)+0.4398}{1.1946}\right]$$

$$\Rightarrow = 1479.1 .$$

6.2.8 Error percentage

The Error is given by the following formula,

−

$$\% = \left[\frac{}{} \right] * 100$$

% error =1.2%

6.2.9 Conclusion

Thus the weight estimation for the aircraft has been calculated and all the values can be observed from the above steps. The weight estimation has been done with an error percentage of 1.2% which ensures the accuracy of the calculations done. The following data are obtained from the calculations,

Table 6.4 Weight Parameters

Name	**Parameters**
Take Off Weight	2204.5 lbs.
Fuel Weight	294.07 lbs.
Actual weight	1461.3 lbs

CHAPTER 7

AEROFOIL AND WING SELECTION

7.1 WING SELECTION

We will select the wing and its configuration in this chapter. We have also given the appropriate reason for the selection of our components respectively.

7.1.1 NUMBER OF WINGS

There are different configurations of wings based on number of wings present in the fuselage of the aircraft. They are predominantly classified as,

- Monoplane
- Biplane
- Triplane

7.1.1.1 MONOPLANE

A monoplane is a fixed-wing aircraft with a single main wing plane. A monoplane has inherently the highest efficiency and lowest drag of any wing configuration and is the simplest to build. However, during the early years of flight, these advantages were offset by its greater weight and lower manoeuvrability, making it relatively rare until the 1930 since then, the monoplane has been the most common form for a fixed-wing.

Figure 7.1 MONOPLANE

7.1.1.2 BIPLANE

A biplane is a fixed-wing aircraft with two main wings stacked one above the other. The first powered, controlled aeroplane to fly, the Wright Flyer, used a biplane wing arrangement, as did many aircraft in the early years of aviation. While a biplane wing structure has a structural advantage over a monoplane, it produces more drag than a similar unbraced or cantilever monoplane wing.

Figure 7.2 BIPLANE

7.1.1.3 TRIPLANE

A tri plane arrangement has a narrower wing chord than a biplane of similar span and area. This gives each wing-plane a slender appearance with higher aspect ratio, making it more efficient and giving increased lift. This potentially offers a faster rate of climb and tighter turning radius, both of which are important in a fighter. A tri plane is a fixed-wing aircraft equipped with three vertical stacked wing planes.

Figure 7.3 TRIPLANE

Selected configuration MONO-PLANE

7.1.2 WING SUPPORT

The type of support of a wing can determine the strength of the aircraft during flight. Wings are also classified based on their type of support, they are,

- Cantilever
- Semi-Cantilever

7.1.2.1 CANTILEVER

A cantilever is a rigid structural element, such as a beam or a plate, anchored at one end to a usually vertical support from which it protrudes; this connection could also be perpendicular to a flat, vertical surface such as a wall. Cantilevers can also be constructed with trusses or slabs. These types of wings are mostly preferred in modern aircrafts.

Figure 7.4 CANTILEVER SUPPORT

7.1.2.2 SEMI-CANTILEVER

The semi-cantilever usually has one, or perhaps two, supporting wires or struts attached to each wing and the fuselage. Many high-wing airplanes have external braces, or wing struts, which transmit the flight and landing loads through the struts to the main fuselage structure. Since the wing struts are usually attached approximately halfway out on the wing, this type of wing structure is called semi-cantilever.

Figure 7.5 SEMI-CANTILEVER SUPPORT

Selected configuration CANTILEVER

7.1.3 WING LOCATION

The location of the wing also plays a major role in an aircraft. Wings are classified based on their location in the fuselage as follows,

- High wing
- Mid wing
- Low wing
- Shoulder
- Parasol

7.1.3.1 HIGH WING

A high wing is a configuration with the wings set on the top of the airplane's body, called the fuselage. By design they provide both shade in the sun and an ―umbrella‖ in the rain for passengers during boarding or debarking. On the ground they offer clearance over many fences.

Figure 7.6 HIGH WING

7.1.3.2 MID WING

A mid-wing configuration places the wings exactly at the midline of the airplane, at half of the height of the fuselage. The mid-wing also has neutral roll stability, which is good from the perspective of combat and aerobatic aircraft as it allows for the performance of rapid roll manoeuvres with minimum yaw coupling.

Figure 7.7 MID WING

7.1.3.3 LOW WING

Fuelling a low wing airplane usually does not involve a step ladder, and neither does checking the security of the fuel caps. The low wing being closer to the ground may allow for a shortened take-off roll and faster acceleration because of ground effect.

Figure 7.8 LOW WING

7.1.3.4 SHOULDER WING

A monoplane with a wing mounted near the top of the fuselage but not on the top; the wing is between the middle and the high position.

Figure 7.9 SHOULDER WING

7.1.3.5 PARASOL WING

A parasol wing aircraft is essentially a biplane without the lower pair of wings. The parasol wing is not directly attached to the fuselage, but is held above it, supported either by cabane struts or by a single pylon.

Figure 7.10 PARASOL WING

Selected configuration SHOULDER WING

7.1.4 WING PLANFORM

The wing planform allows the aircraft to have more control for stability and maneuverability. Wings are classified based on their planform as follows,

- Rectangle
- Elliptical
- Tapered
- Swept
  - Swept forward
  - Swept backward
- Delta
  - Ogival
  - Cranked
  - Compound
  - Cropped
  - Tailed
  - Tailless

7.1.4.1 RECTANGLE WING

Arguably the simplest wing planform from a manufacturing point of view, the rectangular wing is a straight, untapered wing.

Figure 7.11 RECTANGLE WING

7.1.4.2 ELLIPTICAL WING

Aerodynamically, the elliptical plan form is the most efficient as elliptical span wise lift distribution has the lowest possible induced drag (as given by thin aerofoil theory). However, the most important disadvantage of the elliptical wing is that its manufacturability is poor.

Figure 7.12 ELLIPTICAL WING

7.1.4.3 TAPERED WING

This is a modification of the rectangular wing where the chord is varied across the span to approximate the elliptical lift distribution. While not as efficient as the elliptical lift distribution, it offers a compromise between manufacturability and efficiency.

Figure 7.13 TAPERED WING

7.1.4.4 SWEPT WING

A swept wing is a wing that angles either backward or occasionally forward from its root rather than in a straight sideways direction. Wing sweep has the effect of delaying the shock waves and accompanying aerodynamic drag rise caused by fluid compressibility near the speed of sound, improving performance. The swept wings are classified as,

- Swept forward
- Swept backward

Swept forward:

Forward-swept wings make an aircraft harder to fly, but the advantages are mainly down to maneuverability. Wing sweep has the effect of delaying the shock waves and accompanying aerodynamic drag rise caused by fluid compressibility near the speed of sound, improving performance. They maintain airflow over their surfaces at steeper.

Figure 7.14 SWEPT FORWARD WING

Swept backward:

The leading edges of these wings are swept back. This is done order to reduce drag in transonic speeds, which is determined by the velocity normal to the wind. A swept wing is a wing that angles either backward.

Figure 7.15 SWEPT BACKWARD WING

7.1.4.5 DELTA WING

The delta wing is a wing shaped in the form of a triangle. It is named for its similarity in shape to the Greek uppercase letter delta. Although long studied, it did not find significant applications until the jet age, when it proved suitable for high-speed subsonic and supersonic flight. The delta wings are classified as,

a) Tailless
b) Tailed
c) Cropped
d) Compound
e) Cranked
f) Ogival

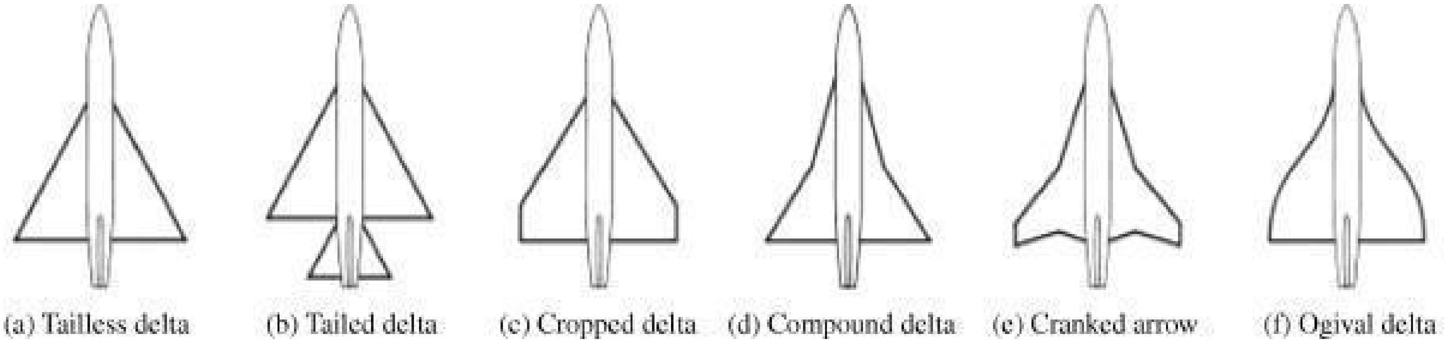


Figure 7.16 TYPES OF DELTA WING

Tailless delta:

Tailless aircraft has no tail assembly and no other horizontal surface besides its main wing. The aerodynamic control and stabilization functions in both pitch and roll are incorporated into the main wing.

Tailed delta:

A conventional tail stabilizer allows the main wing to be optimized for lift and therefore to be smaller and more highly loaded.

Cropped delta:

Wing tips are cut off. This helps avoid tip drag at high angles of attack. The Fairey Delta 1 also had a tail. At the extreme, merges into the "tapered swept" configuration.

Compound delta:

Inner section has a (usually) steeper leading edge sweep as on the Saab Draken. This improves the lift at high angles of attack and delays or prevents stalling. By contrast, the Saab Viggen has an inner section of reduced sweep to avoid interference from its canard foreplane.

Cranked delta:

The goal of the cranked arrow was to have a high sweep inboard panel for low drag at supersonic speeds, and a low sweep outboard panel to provide better handling and maneuverability at subsonic speeds.

Ogival delta:

The Ogive is a type of supersonic wing used in high speed aircraft. This is a complex mathematical shape derived for minimizing drag, especially at supersonic speeds. They offer excellent supersonic performance, with minimal drag.

Selected configuration RECTANGLE

7.1.5 WING ANGLE

The angle of the wing plays a major role in generating lift for the aircraft. The angles in a wing are classified as follows,

- Anhedral
- Straight
- Dihedral

7.1.5.1 ANHEDRAL

Anhedral angle, the downward angle from horizontal of the wings or tail plane of a fixed-wing aircraft. Anhedral angles are also seen on aircraft with a high mounted wing.

Figure 7.17 ANHEDRAL WING

7.1.5.2 STRAIGHT

The straight wing does not have any angle between the base of root chord and tip chord. These wings are naturally stable and generate enough lift in straight conditions.

Figure 7.18 STRAIGHT WING

7.1.5.3 DIHEDRAL

Dihedral angle is the upward angle from horizontal of the wings or tail plane of a fixed-wing aircraft. It has a strong influence on dihedral effect.

Figure 7.19 DIHEDRAL WING

Selected configuration STRAIGHT

7.2 REYNOLDS NUMBER

The Reynolds number for our working conditions of the aircraft can be found by using the following formula,

Re=ρ*V*l

- Re=**841,221**

Where,
l = 0.2
V = 200kmph

Thus the Reynolds number for our conditions is found to be.

7.3 AIRFOIL SELECTION

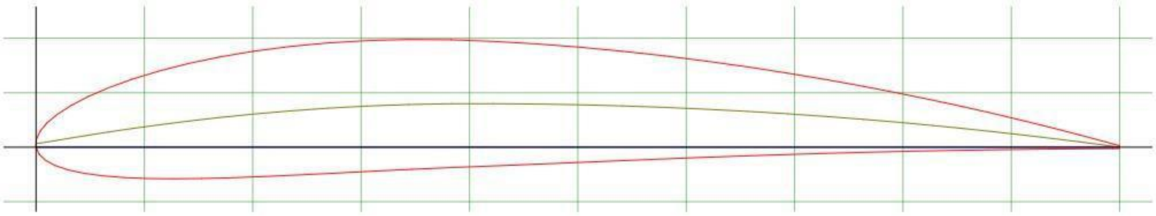
The below table gives the table of selected airfoils and their respective information,

Name of Airfoil	Thickness %	Cambered %	Alpha max	Cl_{max}	$(L/D)_{max}$	$(Cl/Cd)_{max}$	Cd_{min}	Min Coeff of moment	Stall angle	Stall quality
NACA4412	12	40	15.75	1.435	33.57	83.67	0.0058	-0.084	3.5	good
Eppler 635	11.616	2.889	4	0.964	22.283	113.4	0.0254	0.04	14	good
MH62	9.3	1.5	6.5	1.2	67.879	98.3	0.0152	-0.004	8	medium
MH60	10.28	1.8	6	0.906	65.726	94.6	0.0190	0.0175	9	medium
Langley Whitcomb integral supercritical	11	2.4	11.5	1.1312	NA	68.95	0.0046	-0.1257	11.5	medium

Table 7.1 Airfoil Selection

SELECTION:

The **NACA 4412** airfoil has been selected for the aircraft. The diagram shows the selected airfoil.



An NACA 4412 airfoil section was selected for this design since it combines a high maximum lift coefficient with a smooth stall break

•	
Thickness%	12
Camber%	40
α_{max}	9.75
Cl_{max}	1.435
Stall Angle	3.5
$(L/D)_{max}$	33.57
$(Cl/Cd)_{max}$	33.4
Stall angle	3.5
$(Cd)_{min}$	0.0058
C_m	-0.084
Stall quality	Good
Efficiency	33.1

Table 7.2 NACA 4412

PRESSURE CONTOUR

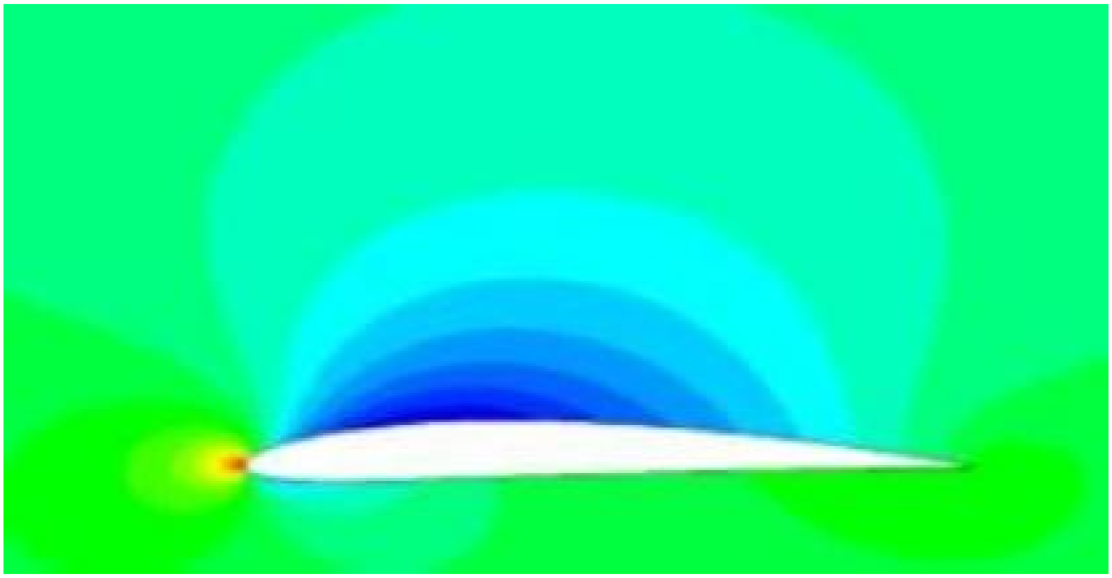


Figure 7.20 Pressure Cont

VELOCITY CONTOUR

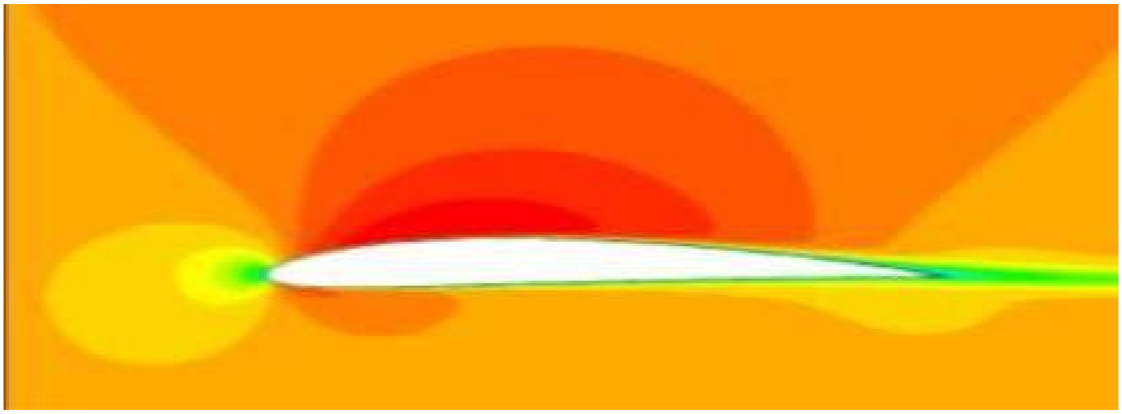
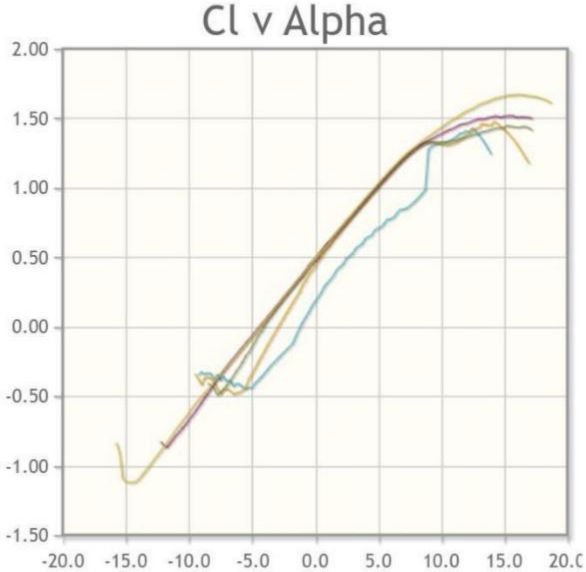


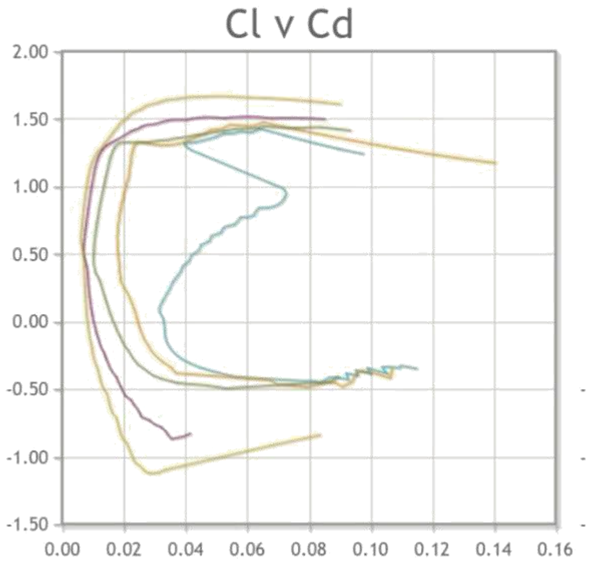
Figure 7.21 Velocity Contour

7.4 PERFORMANCE CURVES

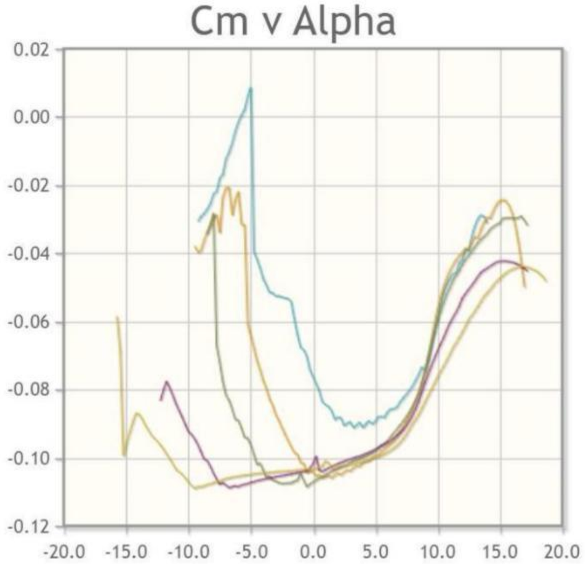
The performance curves for the selected airfoil are given as follows



Graph 7.22 Cl Vs Alpha



Graph 7.23 Cl Vs Cd



Graph 7.24 Cm Vs Alpha

7.5 WING SETTING ANGLE

The wing setting angle is initially determined to be the angle corresponding to the airfoil ideal lift coefficient. Since the airfoil ideal lift coefficient 0.57, the corresponding angle to be 2 deg. This value will be revised based on calculation to satisfy the design requirements.

The selected wing setting angle for our aircraft, $\alpha_{set} = 2$

7.6 ASPECT RATIO

The aspect ratio is selected from **Chapter 4** in the tentative parameters.

The Aspect ratio for our aircraft, A.R. = 3:2

7.7 WING AREA (S)

The wing area is selected from **Chapter 4 – 4.1.1** in the tentative parameters. The wing area for our aircraft, $S = 500m^2$

7.8 WING SPAN (b)

The wing span is calculated from the formula, AR=b^2/s

Wings span=27.3m

7.9 TAPER RATIO (λ)

The taper ratio for rectangle is 1.

7.10 C_{Root}

The Chord root is given by the formula,

$$C_{Root} = 2*S/b*(1+\lambda)C_{Root} = 2*S/b*(1+\lambda)$$

Where, λ is the Taper ratio

- $C_{Root} = 2 * 25/27.3 * (1+1)$
    - $C_{Root} = 0.915m$

7.11 C_{Tip}

The Chord tip is given by the formula,

$$C_{Tip} = \lambda * C_{Root}$$

$$CTip = 1*0.915$$

$$=0.915$$

$$C_{Tip} = 0.915\ m$$

7.12 C_{Mean}

The Chord mean is given by the formula,

$$C_{Mean}=2/3 * C_{Root} *((1+\lambda+ \lambda^{\wedge}2) \backslash (1+\lambda))$$

$$CMean=2/3*0.915*(1+1+ 1)/ (1+1)$$

$$C_{Mean}=0.915m$$

7.13 C_L

The wing lift coefficient is given by the formula,

$$C_L=2 * W/\rho * V^{\wedge}2_{Cruise} * S$$

$$CL=2 * 2204.5/200^{\wedge}2*25*0.8195$$

$$CL=5.3 *10^{\wedge}-3$$

Where, W is the Take-Off weight

ρ is the Density at cruise altitude

V is the Cruise velocity

S is the Wing area

ACCESSORIES

1. SPRAYER
2. FERTILIZER STORAGE
3. FEED LINE SYSTEM

CHAPTER 8

TAIL PLANE SELECTION

8.1 TAIL PLANE SELECTION

A tailplane, also known as a horizontal stabiliser, is a small lifting surface located on the tail behind the main lifting surfaces of a fixed-wing aircraft as well as other non-fixed-wing aircraft such as helicopters and gyroplanes. Not all fixed-wing aircraft have tailplanes. Canards, tailless and flying wing aircraft have no separate tailplane, while in V-tail aircraft the vertical stabiliser, rudder, and the tail-plane and elevator are combined to form two diagonal surfaces in a V layout.

The function of the tailplane is to provide stability and control. In particular, the tailplane helps adjust for changes in position of the centre of pressure or centre of gravity caused by changes in speed and attitude, fuel consumption, or dropping cargo or payload.

8.1.1 CONVENTIONAL TAIL

The conventional tail design is the most common form. It has one vertical stabilizer placed at the tapered tail section of the fuselage and one horizontal stabilizer divided into two parts, one on each side of the vertical stabilizer. For many airplanes, the conventional arrangement provides adequate stability and control.

Figure 8.1 CONVENTIONAL TAIL

8.1.2 T - TAIL

The horizontal stabilizer is mounted on top of the fin, creating a "T" shape when viewed from the front. T-tails keep the stabilizers out of the engine wake, and give better pitch control. T-tails have a good glide ratio, and are more efficient on low-speed aircraft.

Figure 8.2 T - TAIL

8.1.3 V - TAIL

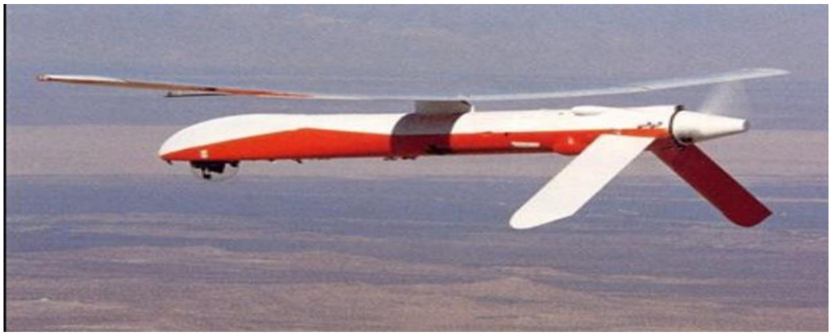
A V-tail can be lighter than a conventional tail in some situations and produce less drag. A V-tail may also have a smaller radar signature.

Figure 8.3 V - TAIL

8.1.4 INVERTED TAIL

The inverted V-tail is similar to V-tail but it is inverted and it provides more stability and manoeuvrability. It is mostly used in Unmanned Aerial Vehicles.

Figure 8.4 Inverted V – TAIL



8.1.5 CRUCIFORM TAIL

The horizontal stabilizers are placed midway up the vertical stabilizer, giving the appearance of a cross when viewed from the front. Cruciform tails are often used to keep the horizontal stabilizers out of the engine wake, while avoiding many of the disadvantages of a T-tail.

Figure 8.5 CRUCIFORM TAIL

8.1.6 TAILLESS

A tailless aircraft has no tail assembly and no other horizontal surface besides its main wing. The aerodynamic control and stabilization functions in both pitch and roll are incorporated into the main wing. A tailless type may still have a conventional vertical fin (vertical stabilizer) and rudder.

Figure 8.6 TAILLESS

SELECTED TAIL PLANE: Conventional Tailplane

CHAPTER 9

ENGINE SELECTION

9.1 ENGINE SELECTION

An aircraft engine, often referred to as an aero engine, is the power component of an aircraft propulsion system. Most aircraft engines are either piston engines or gas turbines, although a few have been rocket powered and in recent years many small UAVs have used electric motors.

9.1.1 RECIPROCATING ENGINE

A reciprocating engine, also often known as a Piston engine, is typically a heat engine. Uses one or more reciprocating pistons to convert pressure into a rotating motion. There may be one or more pistons. Each piston is inside a cylinder, into which a gas is introduced, either already under pressure or heated inside the cylinder either by ignition of a fuel air mixture or by contact with a hot heat exchanger in the cylinder. The linear movement of the piston is converted to a rotating movement via a connecting rod and a crankshaft or by a swashplate or other suitable mechanism.

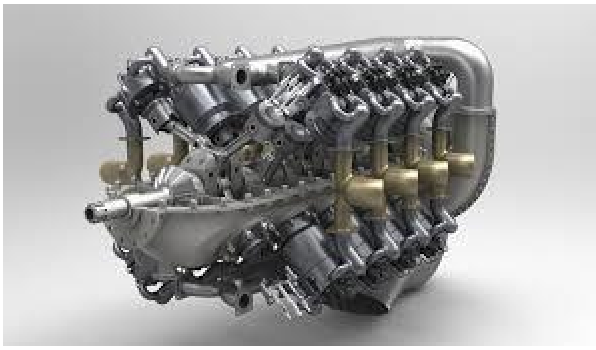


Figure 9.1 RECIPROCATING ENGINE

9.1.2 TURBOJET ENGINE

A turbojet engine is a jet engine which produces all of its thrust by ejecting a high energy gas stream from the engine exhaust nozzle. In contrast to a turbofan or bypass engine, 100% of the air entering the intake of a turbojet engine goes through the engine core. Air is drawn into the engine through the inlet and compressed and heated by the compressor. Fuel is then added in the combustion chamber and ignited.

Figure 9.2 TURBOJET ENGINE

9.1.3 TURBOFAN ENGINE

A Turbofan engine is the most modern variation of the basic gas turbine engine. As with other gas turbines, there is a core engine. In the turbofan engine, the core engine is surrounded by a fan in the front and an additional turbine at the rear. The fan and fan turbine are composed of many blades, like the core compressor and core turbine, and are connected to an additional shaft.

Figure 9.3 TURBOFAN ENGINE

9.1.4 TURBOPROP ENGINE

A turboprop engine is a turbine engine that drives an aircraft propeller. In its simplest form a turboprop consists of an intake, compressor, combustor, turbine, and a propelling nozzle.

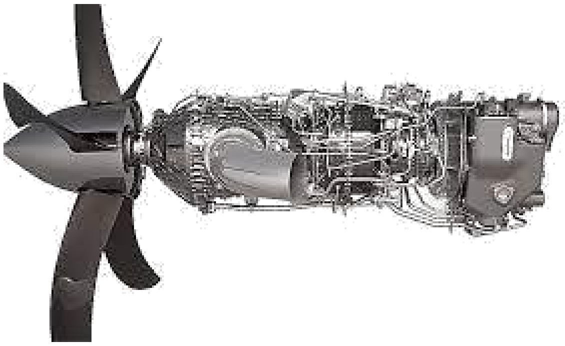


Figure 9.4 TURBOPROP ENGINE

9.1.5 RAMJET ENGINE

A ramjet, sometimes referred to as a flying stovepipe or an athodyd, is a form of air breathing jet engine that uses the engine's forward motion to compress incoming air without an axial compressor or a centrifugal compressor.

Figure 9.5 RAMJET ENGINE

9.1.6 SCRAMJET ENGINE

A scramjet is a variant of a ramjet air breathing jet engine in which combustion takes place in supersonic airflow. Scramjet relies on high vehicle speed to compress the incoming air forcefully before combustion (hence ramjet), but whereas a ramjet decelerates the air to subsonic velocities before combustion, the airflow in a scramjet is supersonic throughout the entire engine.

Figure 9.6 SCRAMJET ENGINE

9.1.7 PULSEJET ENGINE

A scramjet is a variant of a ramjet air breathing jet engine in which combustion takes place in supersonic airflow. Scramjet relies on high vehicle speed to compress the incoming air forcefully before combustion (hence ramjet), but whereas a ramjet decelerates the air to subsonic velocities before combustion, the airflow in a scramjet is supersonic throughout the entire engine.

Figure 9.7 PULSEJET ENGINE

SELECTED ENGINE TYPE: Turboprop Engine

NUMBER OF ENGINES: 1

ENGINE LOCATION: At the front.

9.2 ENGINE THRUST

Aircraft\Data	Type of engine/Power plant	Thrust (kW)

Air Tractor AT-1002	P&W PT6A-65AG	910
Cessna 188 Ag Wagon 230	Continental O470R	172
Piper Pa 36 Pawnee Brave	Continental Tiara 6-285	224

Table 9.1 Engine Data

SELECTED ENGINE: P&W PT6A-65AG

Table 9.2 Engine Performance Data

Data	Parameters
Thrust	910kW
Fan Diameter	4.64 m
Dry Weight	227 kg

Chapter 10

LANDING GEAR SELECTION

10.1 LANDING GEAR SELECTION

Landing gear is the undercarriage of an aircraft or spacecraft and may be used for either takeoff or landing. For aircraft it is generally both. For aircraft, the landing gear supports the craft when it is not flying, allowing it to take off, land, and taxi without damage.

10.2 TYPES OF LANDING GEAR

The landing gears are classified as follows,

a) Fixed
b) Retractable

Fixed Landing Gear

Landing gear employing a rear-mounted wheel is called fixed landing gear. Fixed gear is designed to simplify design and operation. The advantages are that it is always deployed and its initial instalments cost is low. Whereas its disadvantage is that produces constant drag.

Figure 10.1 Fixed landing gear

Retractable Landing Gear

A retractable gear is designed to streamline the airplane by allowing the landing gear to be stowed inside the structure during cruising flight. Retractable landing gear systems may be operated either hydraulically or electrically, or may employ a combination of the two systems.

Retractable Landing Gear

A retractable gear is designed to streamline the airplane by allowing the landing gear to be stowed inside the structure during cruising flight. Retractable landing gear systems may be operated either hydraulically or electrically, or may employ a combination of the two systems.

Figure10.2 Retractable landing gear

SELECTION:

The **Retractable landing gear** is implemented in the aircraft due to the following reasons,

- There will be less drag during cruise as the landing gear will be retracted.
- It helps in higher cruise speeds and increased climb performance.

10.3 LANDING GEAR CONFIGURRATIONS

The landing gears have different configurations based on the number of wheels and their arrangement. They are classified as follows,

a) Single wheel
b) Bicycle
c) Tricycle
d) Quadricycle
e) Multi-bogey

Single wheel Landing Gear

The single-wheel configuration, defined as a main gear of having a total of two wheels, one on each strut, the dual-wheel configuration, defined as a main gear of having a total of four wheels, two on each strut, and the dual-tandem configuration, defined as two sets of wheels on each strut.

Figure 10.3 single wheel

Bicycle

A relatively uncommon landing gear option is the bicycle undercarriage. Bicycle gear features two main gear along the centreline of the aircraft, one forward and one aft of the centre of gravity. Preventing the plane from tilting over sideways are two small outrigger gear mounted along the wing.

Figure 10.4 bicycle

Tricycle

The most commonly used landing gear arrangement is the tricycle-type landing gear. It is comprised of main gear and nose gear. Tricycle-type landing gear is used on large and small aircraft. It allows more forceful application of the brakes without nosing over when braking, which enables higher landing speeds.

Figure 10.5 tricycle

Quadricycle

Quadricycle gear are also very similar to the bicycle arrangement except there are four main gear roughly equal in size and mounted along the fuselage. Like bicycle gear, the Quadricycle undercarriage also requires a very flat attitude during take-off and landing. This arrangement is also very sensitive to roll, crosswinds, and proper alignment with the runway.

Figure 10.6 quadricycle

Multi-bogey

A final variation that is worth mentioning is the use of multiple wheels per landing gear strut. This additional tire is particularly useful on carrier-based aircraft where two nose wheels are a requirement. Multiple wheels are also often used on main gear units for added safety, especially on commercial airliners.

Figure 10.7 multi-bogey

Tail wheel or Tail dragger Gear

Tail-gear landing gear has two main wheels forward of the aircraft cg and a small wheel under the tail. The wheels in front of the aircraft cg are very close to it (compared with the aft wheel) and carry much of the aircraft weight and load; thus they are referred to as the main wheel.

Two main gears are at the same distance from the cg in the x-axis and the same distance in the y-axis (in fact left and right sides); thus both carry the same load. The aft wheel is far from the cg (compared with the main gear); hence it carries a much smaller load and thence is called an auxiliary gear. The share of the main gear from the total load is about 80–90%, so the tail gear carries about 10–20%.

In order to reduce drag, in some aircraft, a skid (vertical flat plate) is used instead of the tail wheel. Such landing gear is referred to as a tail-dragger.

Figure 10.8 tail wheel

SELECTION:

The **Tail wheel landing gear** configuration is implemented for the following reasons,

- Since the aircraft has three wheels (supporting points), the aircraft is stable on the ground. However, it is inherently directionally unstable during ground maneuver (turn).
- Most agricultural and some GA aircraft are equipped with tail gear. The aircraft is not level on the ground, due to the fact that the main gear is much larger and taller than the tail gear

CHAPTER 11

FUSELAGE CONSTRUCTION

11.1 FUSELAGE SELECTION

The fuselage construction plays a major role in reducing the total weight of the aircraft. The fuselage construction of an aircraft are classified as follows,

- Monocoque
- Semi-Monocoque
- Geodesic

11.1.1 MONOCOQUE

The Monocoque (single shell) fuselage relies largely on the strength of the skin or covering to carry the primary loads. Monocoque construction uses stressed skin to support almost all loads much like an aluminium beverage can. Because most twisting and bending stresses are carried by the external skin rather than by an open framework, the need for internal bracing was eliminated or reduced, saving weight and maximizing space.

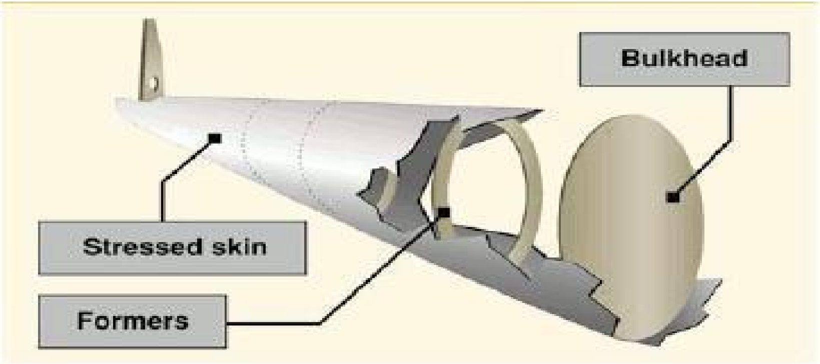


Figure 11.1 MONOCOQUE

11.1.2 SEMI-MONOCOQUE

To overcome the strength/weight problem of Monocoque construction, a modification called semi Monocoque construction was developed. It also consists of frame assemblies, bulkheads, and formers as used in the Monocoque design but, additionally, the skin is reinforced by longitudinal members called longerons.

11.1.3 GEODESIC TRUSS

Geodesic airframe is a type of construction for the airframes of aircraft developed by British aeronautical engineer Barnes Wallis in the 1930s. It makes use of a space frame formed from a spirally crossing basket-weave of load-bearing members. The principle is that two geodesic arcs can be drawn to intersect on the fuselage in a manner that the torsional load on each cancel out that on the other.

Figure 11.3 GEODESIC TRUSS

SELECTION:

The **Semi-Monocoque** fuselage is constructed for the following advantages, • The Semi-Monocoque structure is less in weight compared to Truss structures.

- The stringers and longerons are light in weight while it provides high strength.
- The skin of the fuselage is supported by bulkheads and other structures.

CHAPTER 12

3 VIEW DIAGRAMS

12.1 TOP VIEW

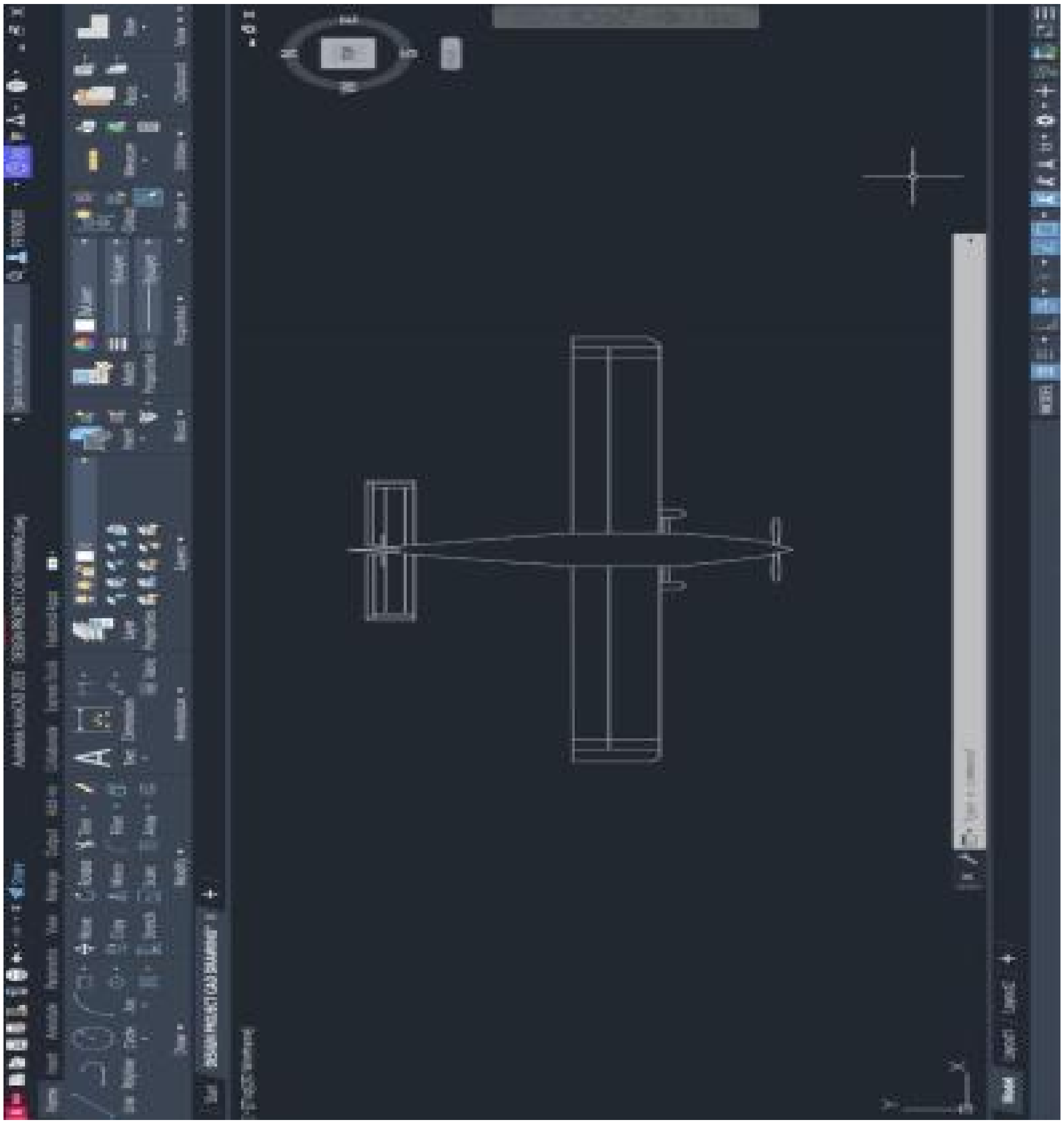


FIGURE 12.1 TOP VIEW

12.2 SIDE VIEW

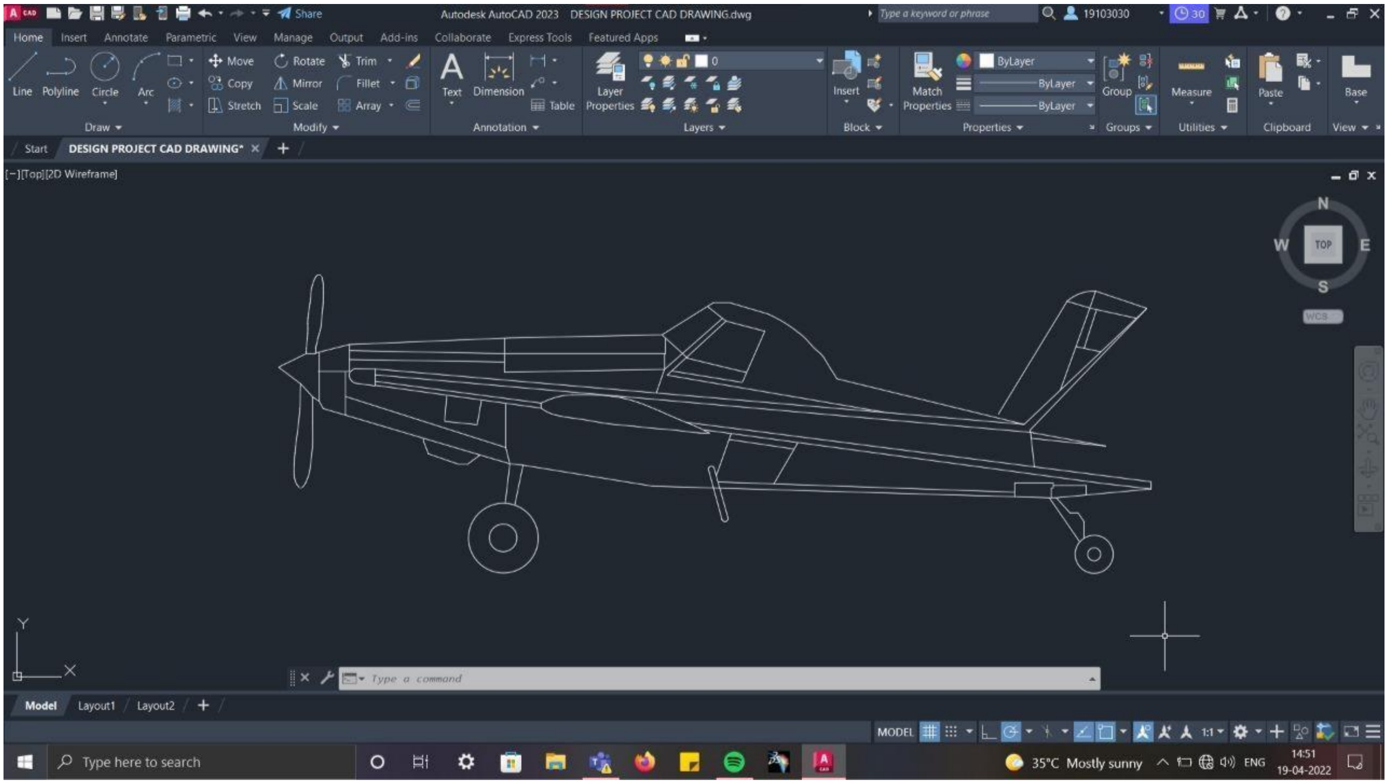


FIGURE 12.2 SIDE VIEW

12.3 FRONT VIEW

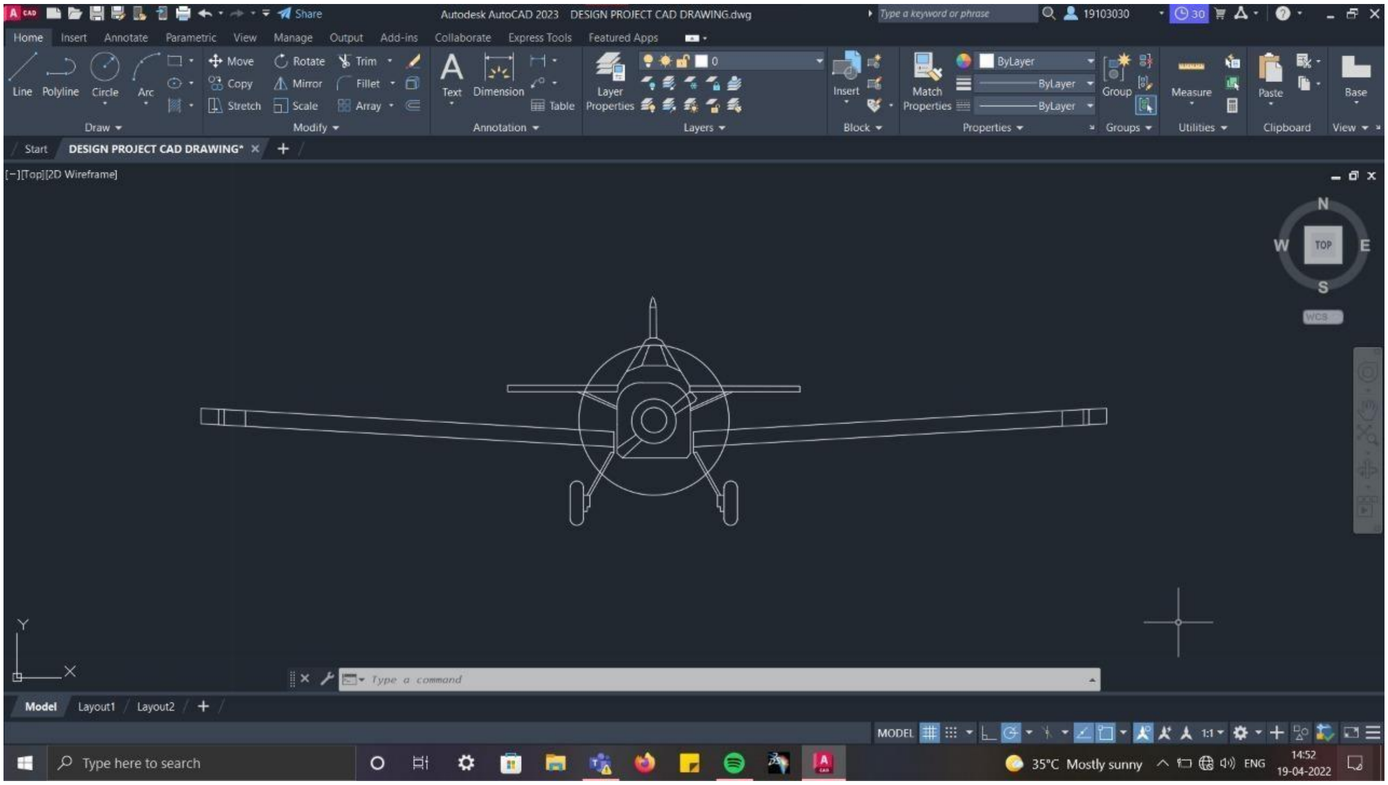


FIGURE 12.3 FRONT VIEW

INTRODUCTION

In aerodynamics the flight envelope, service envelope, or performance envelope of an aircraft or interplanetary spacecraft refers to the capabilities of a design in terms of airspeed and load factor or atmospheric density, often simplified to altitude

for Earth-borne aircraft. The term is somewhat loosely applied, and can also refer to other measurements such as maneuverability.
When a plane is pushed, for instance by diving it at high speeds, it is said to be flown "outside the envelope", something considered
rather dangerous.

Flight envelope is one of a number of related terms that are all used in a similar fashion. It is perhaps the most common term
because it is the oldest, first being used in the early days of test flying. It is closely related to more modern terms known as extra
power and a doghouse plot which are different ways of describing a flight envelope. In addition, the term has been widened in
scope outside the field of engineering, to refer to the strict limits in which an event will take place or more generally to the
predictable behaviour of a given phenomenon or situation, and hence, its "flight envelope".

CONSTRUCTION OF VN DIAGRAM

- The load on the aircraft on land is formed by the gravitational force which is 1g. The aircraft in flight is influenced by many other forces. The load is usually defined as load factor n.

n=L/W

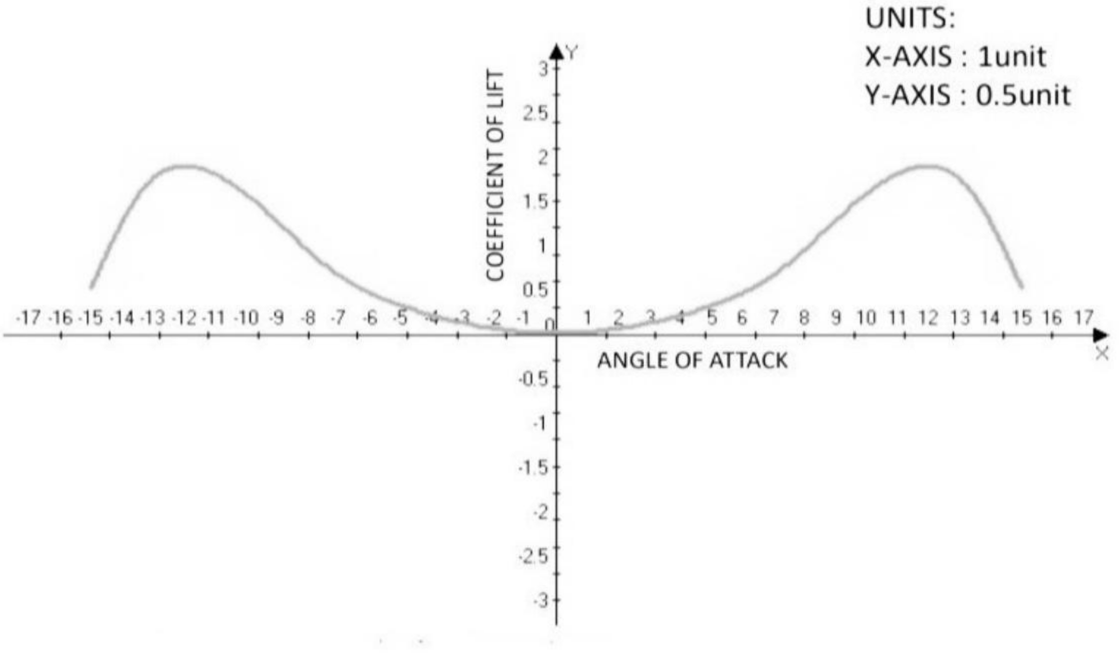
Where,
L is lift force,
W is weight of the aircraft.

GIVEN DATA

- Positive limit load=6.8
- Positive ultimate load=10.7
- Negative limit load=-2.8
- Negative ultimate load=-4.1
- Gross weight of the aircraft(W)=150000N
- Co-efficient if lift(CL)=0.325,0.666,1.585,1.756,0.525
- CL max=1.756
- Angle of attack(α)=5º 7º 10º 13º 15º 17º
  -5º -7º -10º -13º -15º -17º
- Surface Area (S)=25.2m²
- Density at Mean Sea Level(ρMSL)=1.225kg/m³
- Near Cruise density(ρCr)=0.989kg/m³ Near Ceiling density(ρCe)=0.989kg/m³

- Cruse Mach No(Mcruise)=0.85
- Ceiling Mach No(Mceiling)=0.90

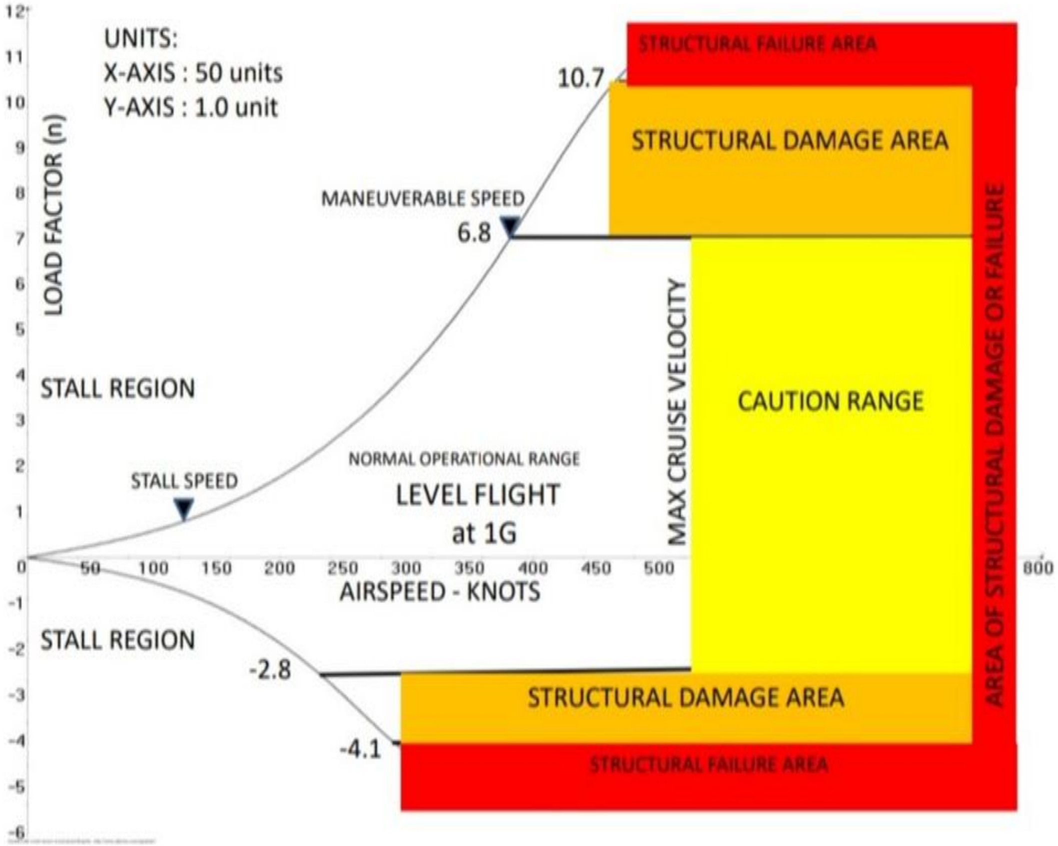
CL VS ALPHA GRAPH



VELOCITIES

- Speed of Sound=321.93 m/s=625.78 knots
- Mcruise=Vcruise/Speed of Sound
- Vcruise=Mcruise*Speed of Sound
- Vcruise=0.85*625.78
- Vcrise=531.913 knots
- Vstall=144.602knots
- Vdive=744.68knots
- Vmanure=377.08knots
- Vmax=691.48knots

LOADFACTOR(n)	SPEED (V)
1	144.60
6.8	377.08
10.7	473.01
-2.7	241.96
-4.1	292.80



CONCLUSION FROM VN DIAGRAM

The analysis of the flight envelope makes it possible to conclude that gust loads do not create much greater loads on the aircraft structure. This is feasible, because the micro class unmanned aircraft system is rather small in size, and the gust will most probably transfer the whole air vehicle structure.

1. Vcruise is the velocity at which a pilot can safely fly without any structural damage cautions.

2. Vdive is the maximum velocity an aircraft can fly with some of structural damage and when velocity crosses the value it may lead to the structural failure.
3. The structural damage and failure are calculated to give the factor of safety .

Generally the factor of safety is the ratio between maximum stress and working load stress.

FACTOR OF SAFETY

For +ve load factor:

Positive ultimate load/Positive limit load = 10.7/6.9= 1.55o72

For –ve load factor:

Negative ultimate load/Negative limit load = -4.1/-2.8 = 1.46428

LIFT

L=0.5*density*s*Clmax*v*v

L=0.5*0.989*25.2*1.756*273.64*273.64

L=1638515.34N

CHAPTER 13

LIFT AND DRAG ESTIMATION

13.1 LIFT CALCULATION

13.1.1 LIFT AT CRUISE

The lift at cruise is given by the formula,

$$L = - * p * v^2 * S * Cl$$

Where, ρ is the density at cruising altitude

V is the cruising velocity

C_L is the Coefficient of lift

⇨ $= 0.5 * 0.8194 * 200_2 * 25 * 1.435$

⇨ $\boxed{L = 58813.47N}$

13.1.2 LIFT AT TAKE-OFF

The lift at take-off is given by the formula,

$= * \qquad *^2 * \qquad *$

Where, ρ is the density at sea level

$V = 0.7 * 1.2 * V_{Stall}$

C_L is the Maximum Coefficient of lift

⇨ $V = 0.7 * 1.2 * 17.23$

⇨ $V = 14.47$ m/s

$\boxed{L = 4600.8 N}$

⇨ $= 0.5 * 1.225 * 14.47_2 * 25 * 1.435$

⇨

13.1.3 LIFT AT LANDING

The lift at landing is given by the formula,

$$= * \; - \quad *^{2} * \qquad *$$

Where, ρ is the density at sea level

V = 0.7 * 1.3 * V $_{\text{Stall}}$

C_L is the Minimum Coefficient of lift

⇨ V = 0.7 * 1.3 * 17.23

⇨ V = 15.743 m/s

⇨ $= 0.5 * 1.225 * 15.74_2 * 25 * 0.53$

⇨ $\boxed{L = 2010.6\text{ N}}$

13.2 DRAG CALCULATION

13.2.1 DRAG AT CRUISE

The Drag at cruise is given by the formula,

$$D = - * P * V^2 * S * Cd$$

$$= C_{D,0} + \frac{\emptyset * C_L^2}{. \quad .} +$$

$$\emptyset = \frac{(16 * \frac{h}{b})^2}{1 + (16 * \frac{h}{b})^2}$$

Where, b is the wing span
h is the wing from ground

$C_{D,\,0} = 0.0030$

⇨ $$\emptyset = \frac{(16 * \frac{1998.75}{12})^2}{1 + (16 * \frac{1998.75}{12})^2}$$

⇨ $\emptyset = 0.999$

⇨ $$= 0.0030 + \frac{0.999 * 1.435^2}{\pi * 6.8 * 0.8}$$

⇨ $= 0.5 * 0.8194 * 200_2 * 50 * 0.123$

⇨ $\boxed{D = 140465.5N}$

13.2.2 DRAG AT TAKE-OFF

The drag at take-off is given by the formula,

$$D = -* P * V^2 * S * Cd$$

$$= C_{D,0} + \frac{\emptyset * C_L^2}{\cdot \qquad \cdot} +$$

$$\emptyset = \frac{(16 * \frac{h}{b})^2}{1 + (16 * \frac{h}{b})^2}$$

Where, ρ is the density at sea level

V = 0.7 * 1.2 * V $_{Stall}$

C_L is the Maximum Coefficient of lift

⇨ $$\emptyset = \frac{(16 * \frac{1.25}{12})^2}{1 + (16 * \frac{1.25}{12})^2}$$

⇨ $\emptyset = 0.999$

⇨ $$= 0.0030 + \frac{0.999 * 1.435^2}{\pi * 6.8 * 0.85}$$

⇨ $= 0.5 * 1.225 * 14.47^2 * 50 * 0.0354$

⇨ $\boxed{D = 6412.29 \text{ N}}$

13.2.3 DRAG AT LANDING

The drag at landing is given by the formula,

$$D = - * P * V^2 * S * Cd$$

$$= C_{D,0} + \frac{\emptyset * C_L^2}{} +$$

* *

$$\emptyset = \frac{(16 * \frac{h}{b})^2}{1 + (16 * \frac{h}{b})^2}$$

Where, ρ is the density at sea level

V = 0.7 * 1.3 * V $_{\text{Stall}}$

C_L is the Minimum Coefficient of lift

$C_D = 0.0030$

$$\Rightarrow \quad \emptyset = \frac{(16* \frac{1.25}{12})^2}{1+(16* \frac{1.25}{12})^2}$$

$\Rightarrow \emptyset = 0.999$

$$\Rightarrow \quad = 0.0030 + \frac{0.999 * 0.8^2}{\pi * 8.5 * 0.85}$$

$\Rightarrow$

$= 0.5 * 1.225 * 15.74^2 * 50 * 0.0199$

$$\Rightarrow \quad \boxed{D = 3793.63 \text{ N}}$$

13.3 CONCLUSION

Table 13.1 Calculated Lift and Drag Data

Conditions	**Lift** (kg/m s^2)	**Drag** (kg/m s^2)
Cruise	58813.47	140465.5
Take-off	4600.8	6412.29
Landing	2010.6	3793.63

CHAPTER 14

PERFORMANCE CALCULATION

14.1 RATE OF CLIMB

The Rate of Climb is given by the formula,

$$() = \frac{(\ *\ \ )-(\ *)}{*\ 9.80}$$

Where, $V_{Stall} = 17.23$ m/s

$W_{To} = 2204.5$ kg

$D = 6412.29$ N

$T = 65000$ N

$$\Rightarrow () = \frac{(65000*17.23)-(6412.29*17.23)}{20000*9.80}$$

$$\Rightarrow \boxed{() = 15.36 \text{ m/s}}$$

14.2 GLIDING ANGLE

The Gliding Angle is given by the formula,

$$= \tan^{-1}\left(\frac{1}{()}\right)$$

Where, $(L/D)_{Max} = 33.575$

$$\Rightarrow = \tan^{-1}\left(\frac{1}{33.575}\right)$$

$$\Rightarrow = \tan^{-1}(0.02978)$$

$$\boxed{\propto = 1.71^0}$$

⇨

14.3 TAKE-OFF DISTANCE CALCULATION

The Take-Off distance is given by the formula,

$$\frac{1.44 * W^2}{* \quad * \quad * \quad *[-(\ + \quad (\quad -\ ))]*0.7*}$$

Where, $V_{LO} = 0.7* 1.2 * \bar{V}_{Stall}$

T = Mean Design Parameter

$W=W_{TO}$

$D = D_{TO}$

$L=L_{TO}$

ρ = Density at sea level

μ_r = Coefficient of friction between tyres and ground

$$⇨ = \frac{1.44*(1500*9.81)^2}{9.81*1.225*25*1.435*\left[65000-\left(6412.29+0.02(1500*9.81-108011.73)\right)\right]*0.7*7.8}$$

$= 1126$

⇨

14.4 LANDING PERFORMANCE

The Landing performance is given by the formula,

$$\frac{1.69 * W^2}{* \quad * \quad * \quad *[-(\ +(\quad -\ ))]*0.7*}$$

Where, $V_{LO} = 0.7*1.2 * \bar{V}_{Stall}$

T = Mean Design Parameter

W = Landing Weight

D = Landing Drag

$L=L_{TO}$

ρ = Density at sea level

μ_r = Coefficient of friction between tyres and ground

$$⇨ = \frac{1.69*(1166*9.8)^2}{9.81* 1.225*25*1.435*\left[65000-\left(6412.29+ 0.46(70650)\right)\right]*0.7* 70.82}$$

$= 1568.95$

⇨

14.5 CONCLUSION

Table 14.1 Performance Parameters

Data	Parameters
Rate of Climb	15.36 m/s
Gliding Angle	1.71^0
Take-Off Distance	1126m
Landing Performance	1568.95m

CHAPTER 15 FINAL DESIGN PARAMETERS

14.1 BASIC PARAMETERS

Table 15.1 Basic Parameters

Main Parameters	Optimum value
Crew	2
Length	7.5 m
Height	2.5 m
Wing Span(b)	12 m
Wing area(s)	25 m^2
Aspect ratio	6.9

14.2 WEIGHT

- Take-off weight, W_{TO} = 2500 kg
- Fuel weight, W_F = 294.07 kg
- Actual weight, W_E = 670.90 kg

14.3 WING TYPE

Our wing is tapered with Straight monoplane configuration mounted as a Shoulder-wing.

14.4 AIRFOIL

The chosen airfoil is NACA 4412.

14.5 FUSELAGE TYPE

A Semi-Monocoque fuselage has been constructed.

14.6 EMPENNAGE

A Conventional Tail configuration tail is mounted.

14.7 ENGINE

P&W PT6A-65AG is selected

14.8 LANDING GEAR

A retractable landing gears is constructed.

CONCLUSION

The preliminary design of aerial sprayer system for microlight aircraft project is intended to achieve the main objectives which are to increase the spray coverage area and improvement of existing spray equipment that available in the market. This study set out to determine and solving the problems that has been faced by the farmers. The development of aerial sprayer system on microlight aircraft need to be followed by the right design methods. The idea of this design would be compared to the existing system used on typical light aircraft to identify the advantages and disadvantages of that system. The project can be summarized as follows;

i. The spraying from the existing sprayer system is uneven and not fully sprays to the crops.

ii. ii. Most of the aerial application providers are using a minimum, high horsepower turbine engine aircraft with high cruise speed of to carry out the task. Hence, fuel consumption, maintenance and cost of aircraft are relatively high.

iii. The hilly and large acreage of the farms cause a difficult process of spraying to the crops.

iv. The existing sprayer is difficult to assemble and dismantle.

v. A conventional spraying process requires more labor to do the spraying.

vi. The knapsack sprayer is ineffective and does not have ergonomic features that can cause pain in the waist and back bone. Also, it could not accommodate the works in spraying on large acreage.

FUTURE WORKS

The following are the future works of the same project,

- Preliminary Design of an aircraft fuselage – Load Distribution on an aircraft fuselage
- Detailed design of an aircraft fuselage – Design of bulkheads and longerons, bending stress and shear flow calculations, buckling analysis of fuselage panels.
- Design of control surfaces – Balancing and manoeuvring loads on the tail plane and aileron, rudder loads.
- Landing gear design
- Preparation of a detailed design report with CAD drawings.

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