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Remote Control Fixed Wing Aircraft: F22 Raptor

Malaika Syyed[1], Vivek Verma[2]

[1]*Aerospace Engineering Department, Amity University (Lucknow Campus)*
[21]*Aerospace Engineering Department, Amity University (Lucknow Campus)*

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Abstract - Th *In this paper, we examine the development and operationalization of remote-controlled fixed-wing aircraft, specifically through a detailed case study of a scale model of the F-22 Raptor. The discussion spans the entire process from conceptual design to the integration of electronic systems and the initial flight tests. We will also highlight the obstacles and constraints faced during the project, providing insights into the complexities of designing and building UAVs in a research context. This study aims to enrich the academic dialogue surrounding UAV engineering and model aviation.*

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Key Words*: *Aviation, Drones, Scaled Models, Remote Control UAVs, Flying

1.INTRODUCTION *(Size 11, Times New roman)*

Unmanned Aerial Vehicles (UAVs) represent a dynamic frontier in modern aerospace technology, encapsulating a broad spectrum of designs including RC fixed-wing aircraft and multirotor drones [1]. Each design caters to specific operational needs ranging from aerial photography and surveillance to complex military missions[1,5]. Fixed-wing UAVs are akin to traditional airplanes, designed for long durations and high-speed flight, making them ideal for large area mapping and extended missions. Multirotor, on the other hand, excels in vertical take-off and landing, hover capabilities, and agile maneuvering in tight spaces, suited for tasks that require stationary observation and precise positional control (As shown in Fig.1)[15].

The distinction between fixed-wing aircraft and multirotor extends beyond their structural design to their aerodynamic performance and operational capacities. Refer Table.1. [2]. Fixed-wing UAVs rely on the continuous forward motion to generate lift using their wings, which contributes to their efficiency and ability to cover longer distances with less power [6]. Conversely, multirotor utilizes multiple rotors to lift and navigate through the air, offering superior control at lower speeds and the ability to remain stationary mid-air[9,15]. This fundamental difference in mechanics influences their respective applications, with fixed-wings being preferred for endurance and rapid coverage, while multirotor are favored for precision and flexibility in flight dynamics [9].

Focusing on remote-controlled (RC) fixed-wing aircraft, these models are celebrated for their efficiency and capability to mimic the flight patterns of larger, manned airplanes [10]. RC fixed-wing aircraft are propelled by an aft-mounted motor, utilizing traditional aeronautical components such as rudders, elevators, and ailerons to steer through the air. Enthusiasts and researchers favor these models for their straightforward design and the satisfying challenge they offer in manual flight control. These aircraft are typically constructed from lightweight materials (As shown in Fig.2) and are designed to be robust, offering both hobbyists and professionals a practical and accessible means to explore the principles of aerodynamics and remote piloting.

Fig -1: Quadcopter

Fig -2: RC Fixed Wing Aircraft

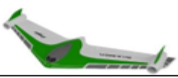
Table -1: Comparison between Multirotor UAV and RC Fixed Wing UAV.

S.No.	Feature	Multirotor UAV	RC Fixed-Wing UAV
1	Flight Duration	Shorter, typically 20-30 minutes	Longer, often 1-2 hours
2	Payload Capacity	Generally lower due to energy demands for hovering	Higher, as less energy is needed to maintain flight.
3	Operation Altitude	Lower, usually below 500 meters for safety and regulatory reasons	Higher, can operate above 500 meters depending on the model and regulations.
4	Applications	Widely used in Farming Industry, Photography etc.	Widely used for Defence military, Surveillance, Hobbyists, Research experiments

1.1. Various Models under RC Fixed wing aircraft

There is a wide range of Remote-Control Fixed Wing Aircraft depending upon their design, application Refer Table 2. [6,21].

Table -2: Different Models of Remote-Control Fixed Wing Aircrafts.

Model Type	Description	Images
Traditional Design	classic design, needs a runway, known for stability and efficiency.	
Flying Wings	Integrates the tail into the wing, designed for speed and aerodynamics.	
Glider	Relies on thermal currents, minimal motor usage, launched from elevated points.	
Scale Models	Accurate miniatures of real aircraft, with complex details.	
Jet Models	Simulate real jets, high-speed, powered by ducted fans or turbines mostly for defense purposes. [17,18]	
VTOL Aircraft	Features a mix of fixed-wing and rotor mechanisms for vertical take-off and landing.	

1.2. About F22 Raptor

The F-22 Raptor, a pinnacle of US aviation technology, is a fifth-generation fighter jet known for its stealth, agility, and advanced avionics (as shown in Fig.3). Developed by Lockheed Martin, its inception dates to the 1980s when the USAF identified the need for a new air superiority fighter to replace the aging F-15s and F-16s. Officially introduced in 2005, the F-22 has been a critical component of the United States' tactical air power. It uniquely combines stealth, super cruise capability, and integrated avionics, surpassing competitors in dogfighting skills and target interception [20,21]. Capable of executing air-to-air and air-to-ground missions, the F-22 carries sophisticated weaponry, including AIM-120 AMRAAM missiles and a 20mm cannon. Despite its high production cost leading to a limited number manufactured, the Raptor remains a formidable force in global air supremacy. Its deployment reflects a strategic military asset, ensuring the U.S. maintains an edge in modern aerial combat and technology.

Fig -3: F22 Raptor Fighter Plane

2.METHODOLOGY

2.1. Generation of lift over fixed wing Aircraft.

Lift is a critical force that allows an aircraft to rise and remain aloft, and it results from the architecture and behavior of the wing structures known as airfoils [1,3,7] As shown in Fig.4.

- **Air Speed Variation**: Wings are designed with a characteristic shape that influences how air moves around them. The top surface of the wing is more curved than the bottom, causing air to move faster over the top than underneath. This speed differential is key to lift generation.
- **Pressure Difference**: The variation in air speed above and below the wing leads to different pressure levels; higher speed on the top creates lower pressure, while slower speed below means higher pressure. This difference in pressure creates an upward force on the wing, which contributes to the aircraft lifting off the ground.
- **Angle of Attack**: This is the angle formed between the wing and the oncoming air. Adjusting the angle of attack can increase lift by enhancing the pressure differential until a critical point. If the angle is too steep, it disrupts smooth

airflow, leading to a reduction in lift, known as a stall.

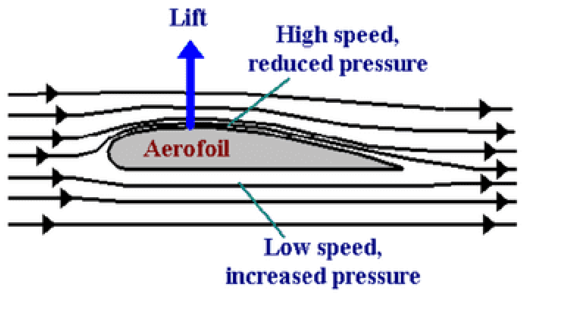


Fig -4: Lift Generation over Airfoil shape of Aircraft wings

2.2. Basic Formula to Calculate Lift

The lift force can be calculated using the lift equation (Equation1) [1], which involves a few key parameters:

$$L = C_L \times 1/2 \times \rho \times V^2 \times S \qquad (1)$$

where:

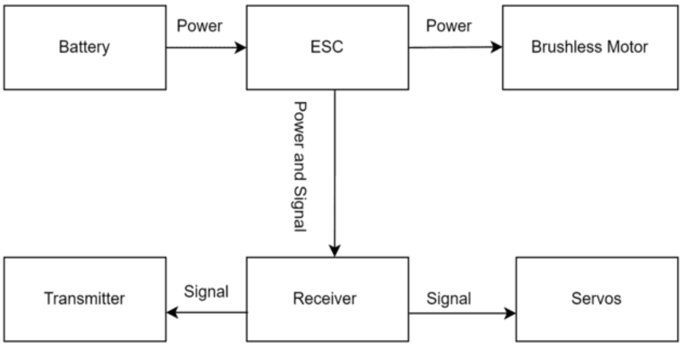
- L is the lift force (Newtons)
- C_L is the lift coefficient, which depends on the wing shape, size, and angle of attack.
- ρ (rho) is the air density (kg/m³).
- $V$is the velocity of the aircraft relative to the air (m/s).
- S is the wing area (m²).

2.3. Design Parameters

- Wingspan = 0.65 m
- Nose length= 0.48 m
- Total Length= 0.89 m
- Each Elevons Area = 0.021 m^2
- CG location = 0.04 m from the nose
- Weight without Battery=0.35 Kg
- Material= Depron Foamboard 0.005mm width

2.3. Power Connection

As Shown in Fig.5, we can see the heart of the system is the battery, which serves as the primary power source [10,11,24]. This battery is connected to the Electronic Speed Controller (ESC), to regulate the power flow to the brushless motor. On the control side, the transmitter is the hardware Ground control interface that sends user's commands to the receiver. This receiver, installed inside the aircraft, interprets the signals, and adjusts the servos accordingly. This setup ensures a streamlined flow of both power and control signals, enabling precise



management of the aircraft's movements.

Fig -5: Block Diagram for Power Connections

2.4. Electronic Components

- **Propeller**

F-22 Raptor model is a single rotor drone, so I am utilizing a specific type of propeller—the 8×4.5 Slow Fly Propeller [22] (As shown in Fig.6.). This propeller is specifically chosen for its compatibility with the 1400 kV motor installed in the drone [22]. The "8×4.5" designation refers to the diameter and pitch of the propeller, measured in inches.

Fig -6: Slow Fly 8x4.5 Propeller

- **Motor**

The second electronic component in my remote-controlled F-22 Raptor model is the DYS D2826- 10 1400kV Brushless Outrunner Motor [11] (As shown in Fig.7.) This motor is a crucial element of the drone's power system, providing the high RPMs needed for effective propulsion using the 8×4.5 Slow Fly Propeller. The "1400kV" rating indicates that the motor is capable of 1400 RPM per volt.

Fig -7: DYS D2826- 10 1400kV

- **Servos**

An integral part of my remote-controlled F-22 Raptor model involves the precise control of its flight surfaces, achieved using two TowerPro SG90 9Gm Servos (As shown in Fig.8). These compact and lightweight servos are critical for manipulating the aerodynamic control surfaces, which direct the aircraft’s movement and stability in flight [22]. Each servo is connected via a 0.29 m pushrod to wooden servo horns, which translates the rotational movement of the servo into linear motion required to actuate the control surfaces.

Fig -8: Tower Pro SG90 9Gm Servos

- **Electronic Speed Controller**

For precise control of the DYS D2826-10 1400kV brushless outrunner motor, we incorporate a 30 Amp Electronic Speed Controller (ESC). This component is pivotal, as it regulates the power supplied to the motor, adjusting its speed and responsiveness during flight [22]. The 30-amp rating ensures that the ESC can handle the motor's peak power demands without overheating or becoming a bottleneck in the power delivery system. As shown in Fig.9.

Fig -9: Brushless 30 A Electronic Speed Controller

- **Battery**

To power our RC F-22 Raptor model effectively, the next electronic component in our list is a Lithium Polymer (LiPo) battery, with a capacity ranging from 1000 to 1300 milliampere-hours. As shown in Fig.10. [23]. The selection of a 3-cell LiPo battery, which typically has a voltage of 11.1V, is ideal for balancing the energy density and weight, ensuring that our model maintains a favorable power-to-weight ratio.

Fig -10: Three cell LiPo Battery

- **Transmitter Receiver**

The final touch in our electronic assembly for the RC F-22 Raptor model is the integration of the Flysky i6 transmitter and receiver set. This 6-channel receiver is the communication backbone of our drone, bridging the gap between the pilot's inputs and the model's responses [23]. With six channels at our disposal, we have the flexibility to control not only the motor and servos for pitch, roll, yaw, and throttle but also to potentially integrate additional function of dropping mechanism or other scale features the F-22 Raptor may possess. As shown in Fig. 11.

2.4. Two-Dimensional Computer Aided Designs

Designing F22 Raptor plans was one of the most challenging parts of this project. I have built 2D plans [2] on CAD software and then get it laser cut done over Foam Board. As shown in Fig.6.

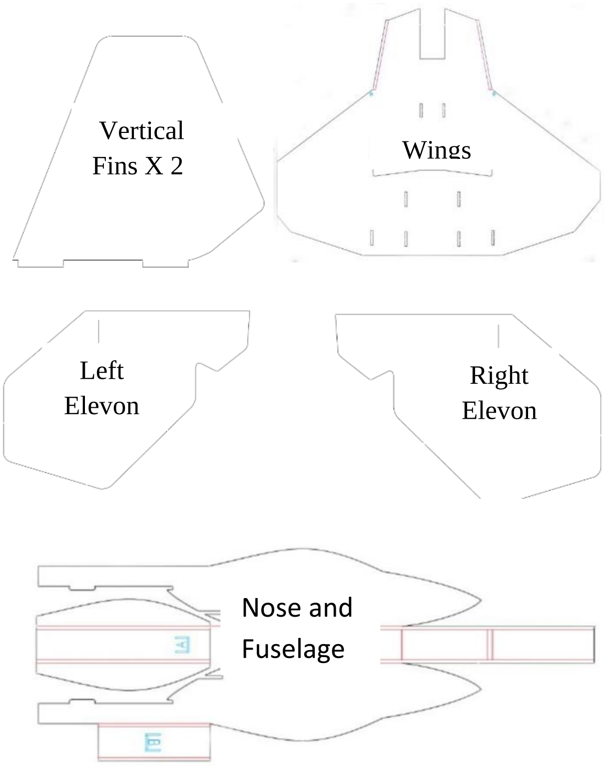


Fig -12: 2D CAD designs

3.FABRICATION AND TESTING

3.1. Building of Aircraft's Body

- For building of aircraft's body first we need LASER cut 2D drawings on Depron foamboard [9,28]. As Shown in Fig.13.

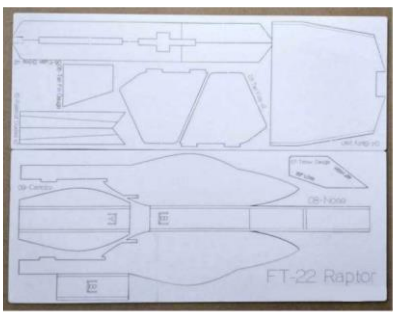


Figure -13: LASER Drawing on A2 **sheet**

Figure -14: Cut out all parts of Model.

- Take out all subparts of drawings and start joining them accordingly. As shown in Fig.14.

Figure -11: Flysky Transmitter Receiver

- For joining we can simply use Hot glue, paper cutter.
- Join all the body parts which includes- Wings, Nose, Vertical Fins, Elevons, Fuselage. As shown in Fig.15.

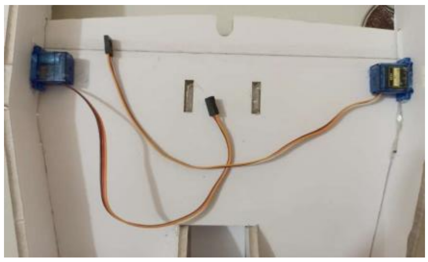


Figure -15: Paste of all Parts

- Start by fixing both servos at the bottom side of the aircraft. Add push rods and servo horn on the elevon. As shown in Fig.16.

- Next, fix the motor mount with propeller and esc at the backward of fuselage body. As shown in Fig.17.

Figure -18: Final Aircraft Body

- Add Velcro at the bottom and attach battery accordingly to CG position.
- Connect battery with ESC through bullet connectors [11,22,24].
- The aircraft body is ready now we are ready for maiden flight. As Shown in Fig. 18.

Figure -16: Attaching Servos

- We can also paint the body with spray paint or use stickers to make it more presentable.

3.2. Flying Controls

The Traditional design of RC fixed wing aircraft has three control surfaces for controlling Pitch, Yaw, Roll motions of aircraft but here F22 Raptor has special and Complex type of control surfaces which are known as “Elevons”. Refer Fig.19.

Fig -20: Elevons Pitch up.

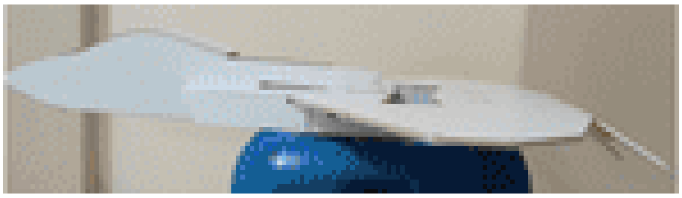


Fig -21: Elevons Pitch down.

Elevons are an ingenious hybrid of ailerons and elevators, typically found on tailless aircraft like the F-22 Raptor and are essential in controlling both pitch and roll. These control surfaces are located at the trailing edge of each wing and work in concert to execute the pilot's maneuvers [20].

When the F-22 needs to adjust its pitch, or nose orientation, both elevons move in the same direction (As shown in Fig.20.): upward deflection causes the nose to pitch up, while a downward deflection (As shown in Fig.21.) results in a pitch down. This movement alters the airflow over the wings, increasing or decreasing lift, hence changing the aircraft's angle of ascent or descent [12,21].

Figure -17: Attaching Motor and Propeller

For roll control, the elevons move differentially. One elevon goes up while the other goes down, creating an asymmetrical lift on the wings. If the left elevon rises and the right one descends (As shown in Fig.22), the aircraft rolls to the right. The opposite occurs for a roll to the left (As shown in Fig.23) [12,21].

3.3. Receiver Controls

Basic Control Surfaces design consists of four channel connection on receiver mandatory and in case if we want to add any additional functionality then we will opt for next channels i.e channel 5 and channel 6 [30].

But F22 Raptor has special controlling surface known as elevons, they need only two channels to control pitch and roll moments [19].

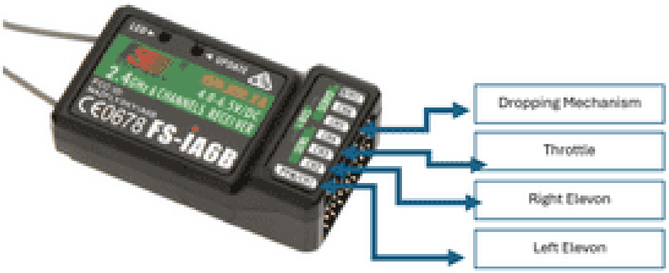


Fig -24: Receiver control explained**.**

We can depute any controlling moment to any channel by ourselves, so for this model I have executed two controlling servos for both elevons- channel 1 and channel 2 and execute channel 3 as a throttle. Refer Fig.24.

Fig -25: Maiden Flights

Fig -26: Soaring in the sky

3.4 Maiden Flight

We are flying our Scale Model F22 Raptor with a Hand Launch [8,16]. We have done several Flights for the improvement of the project. As shown in Fig. 25,26,27,28.

Fig -27: A night flight

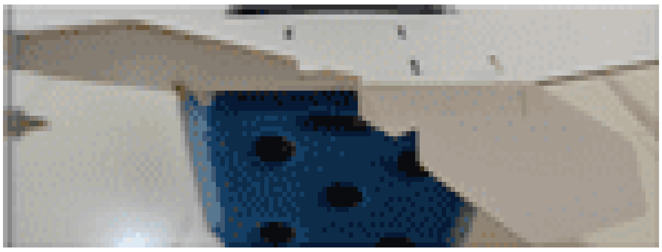


Fig -22: Rolls in Right Direction.

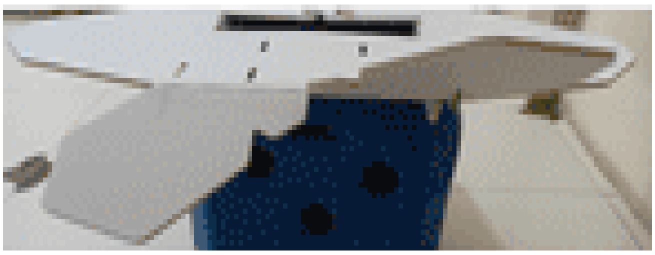


Fig -23: Rolls in Left Direction.

4. Limitations and Future Improvements

While constructing the non-autonomous, tailless F-22 Raptor RC model with a manual object-dropping mechanism, several challenges emerged, primarily linked to the limitations of manual control and navigation accuracy [25]. The reliance on direct pilot input for flight control and payload release often resulted in less precise operations, particularly in complex flight conditions or when precise targeting was required.

Looking ahead, substantial improvements can be made to enhance the model's capabilities and autonomy. Integrating a Pixhawk flight controller would be a significant upgrade, enabling autonomous flight paths and more stable control systems [12]. Coupling the flight controller with GPS and onboard cameras could transform operations, allowing for precise navigation and real-time video feedback. Furthermore, the object-dropping mechanism could be improved by mapping target areas using flight controller software, which would automate and refine the payload deployment process [12]. These advancements would not only mitigate the current challenges but also elevate the project's scope by incorporating cutting-edge technology to mirror more closely the sophisticated systems used in modern aerial vehicles [26].

CONCLUSION

This research paper has presented the comprehensive development of a scaled F-22 Raptor RC model, encapsulating the end-to-end process from initial design through to practical application and testing. It has underscored the integration of both traditional RC design principles and innovative engineering technologies, illustrating significant enhancements in model functionality [13,27]. The findings anticipate the potential for future advancements such as the integration of autonomous systems and sophisticated sensory equipment, promising to elevate the utility and precision of RC aircraft to mirror their real-world counterparts more closely. This work contributes valuable insights to the field of UAV technology, with implications for educational, recreational, and commercial applications [29,30].

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