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Semester Project Proposal

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Contents

1 Team Introduction **1**

2 Project: VTOL Drone with Foldable Wings **1**

2.1 Presentation 1
2.2 State of The Art 2
2.3 Tasks Distribution 3
2.4 Cost Estimation 7

1 Team Introduction

To meet the project's ambitious goal of delivering a functional, validated prototype, we have formed a team of four mechanical engineering students specializing in design and production and fluid mechanics. Achieving this project requires a broad set of competencies such as mechanical design, thermal and fluid simulation, control programming and physical prototyping. Each team member brings a distinct area of expertise, ensuring the technical and strategic coverage necessary for a project of this complexity.


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Given the broad scope of Xplore's work, we aim to propose a variety of projects to ensure alignment with Xplore's objectives.

2 Project: VTOL Drone with Foldable Wings

2.1 Presentation

Our project aims to design and build a Vertical Take-Off and Landing (VTOL) drone equipped with retractable wings, combining the advantages of compact maneuverability with the efficiency of extended flight performance. By integrating this morphing wing mechanism, the drone will be capable of passing through narrow gaps when the wings are retracted while also achieving longer distances and carrying heavier loads when the wings are extended.This drone could enable exploration of remote areas that are difficult to access, with narrow passages, far from a rover. The increased autonomy during vertical phases would allow for longer and more distant missions than a conventional drone. This drone would be particularly effective in dense atmospheres, such as those of Titan or Venus.

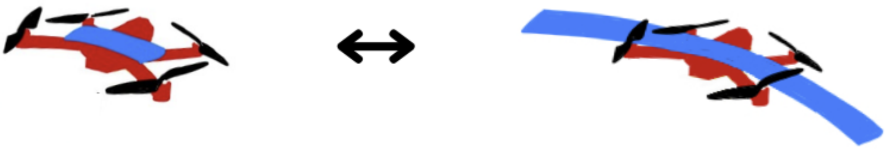

Figure 1: Drone drawing

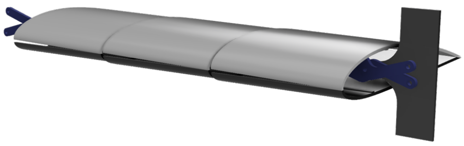

Figure 2: Rigid wing mechanism: deployed.

Figure 3: Rigid wings mechanism: folded.

The objective of this project is to develop a drone capable of flying in both static and horizontal phases, as well as deploying its wings in flight. A study will be conducted to determine the best wing mechanism and its contribution compared to a conventional drone. The drone must be capable of flying in different scenarios and resisting disturbances.

2.2 State of The Art

Hybrid drones, like the Parrot Swing [1], combine quadrotor hovering with fixed-wing efficiency but lack adaptable wing systems. Foldable designs, such as Falanga et al.'s quadrotor [2], adjust for drag but don't deploy wings for lift. Disturbance resistance in drones, as in Mellinger et al.'s control algorithms [3], ensures stability, yet fixed-wing drones like the senseFly eBee [4] struggle in turbulence.
Vertical Take-Off and Landing (VTOL) drones, such as those surveyed in [5], merge multirotor and fixed-wing advantages by enabling both hovering and efficient forward flight. Examples include the WingtraOne, Quantum Tron, and DeltaQuad Pro, which are widely used for mapping and industrial applications. However, none of these systems integrate retractable or morphing wings; their wing designs remain fixed once deployed. This limits adaptability in environments where compactness, resilience, and transition efficiency are critical.
Our project addresses these gaps by developing a drone with in-flight deployable wings, optimizing both flight modes and resilience for hazardous environments.

2.3 Tasks Distribution

Project 1 : Wing Morphing System

The development of this project is structured into four main components. The first focuses on the wing morphing mechanism, where we will test different materials such as fabric, rigid composites, and flexible TPU. Particular attention will be given to compactness, stiffness, bending strength, and the ability to maintain the aerodynamic profile of the wings throughout their span. The goal is to create and build the deployment mechanism and wings. A study will also be conducted on each wing to determine the best solution. The automatic deployment system will also be designed.

Weeks 1–2	Literature review on morphing wing mechanisms and deployment systems. Identify and compare potential materials (fabric, composites, TPU) with respect to stiffness, bending strength, and compactness.
Weeks 3–5	Conceptual design of the morphing wing structure and deployment mechanism. Selection of promising materials for prototyping. Development of CAD model for the morphing system, including integration of the deployment mechanism.
Milestone:	Completed CAD model of the wing morphing system, ready for prototyping.
Weeks 6–8	Build first prototype of morphing wing using selected materials. Perform preliminary structural tests (stiffness, bending resistance, compactness). Integrate a basic manual deployment mechanism to evaluate feasibility.
Milestone:	First physical prototype of morphing wing system constructed and tested.
Weeks 9–12	Refine morphing mechanism and deployment system based on test results. Implement modifications to improve reliability and durability. Begin integration of automatic deployment solutions (actuators, servos, or other mechanisms). Conduct repeated functional tests.
Milestone:	Improved prototype with integrated automatic deployment system and validated performance.
Weeks 13–14	Finalize morphing wing design and automatic deployment system. Prepare technical documentation, test reports, and assembly guidelines. Ensure design satisfies compactness, stiffness, and deployment requirements.

Project 2 : Drone System and Structure
The second component centers on the design of the drone's overall structure. Key objectives include determining the optimal propeller configuration, integrating wings with propulsion and flight systems, and ensuring structural rigidity while keeping the design lightweight. Consideration will also be given to the center of mass, drag effects, and landing mechanisms. To facilitate use, the structure will be designed for rapid assembly and repair, allowing for quick intervention in case of incidents.

Weeks 1–2	Literature review on drone structures and propulsion systems; identify common configurations (quad, hex, octocopter, hybrid wing–propeller designs); assess existing lightweight structural materials.
Weeks 3–5	Conceptual and detailed design: decide number and placement of propellers; define approximate size of elements (propellers, motors, wings); analyze center of mass and stability. Develop detailed CAD model of the drone structure, including landing mechanism.
Milestone:	Completed CAD model ready for prototyping.
Weeks 6–8	Build first prototype based on CAD design. Conduct initial flight and stability tests; evaluate balance, thrust, and structural rigidity. Note weaknesses (e.g., vibration, instability, landing issues).
Milestone:	Working prototype tested under basic flight conditions.
Weeks 9–12	Refine and modify prototype: strengthen weak areas, reduce weight where possible, improve aerodynamics and balance. Repeat flight tests with modifications. Assess ease of assembly and repair in practice.
Milestone:	Optimized prototype with documented improvements and performance validation.
Weeks 13–14	Finalize drone structure with all adjustments. Prepare technical documentation, structural drawings, and summary of testing results. Ensure all design objectives are satisfied.

Project 3 : Modeling

The third component involves modeling and aerodynamic analysis. Both numerical and physical models will be developed to assess the drone's performance with folded and deployed wings. This phase will include computational fluid dynamics (CFD) simulations, potentially wind tunnel experiments, and comparative tests between fabric and rigid wings. The objective is to establish a detailed understanding of aerodynamic behavior across all flight stages and to use this insight to optimize the design.

Weeks 1–2	Literature review on aerodynamic modeling methods for drones and morphing wings. Identification of suitable CFD tools and experimental setups.
Weeks 3–5	Development of simplified numerical models of the drone (folded and deployed configurations). Initial CFD simulations to establish baseline aerodynamic characteristics.
Milestone:	First CFD results available for folded vs. deployed wings.
Weeks 6–8	Refinement of CFD models with greater detail (propeller–wing interaction, transition between folded and deployed states). Preparation of scaled prototypes for potential wind tunnel testing.
Milestone:	Detailed CFD analysis completed; prototypes ready for experimental validation.
Weeks 9–12	Experimental testing phase: conduct wind tunnel tests or equivalent experimental trials. Collect performance data on fabric vs. rigid wings and compare with CFD predictions.
Milestone:	Experimental dataset collected and compared with numerical results.
Weeks 13–14	Final analysis and validation of modeling results. Consolidation of CFD and experimental findings. Provide recommendations for design optimization based on aerodynamic insights.

Project 4 : Control

The final component addresses control systems. We will design and implement PID controllers to manage the different phases of flight, including takeoff, hovering, horizontal cruising, and wing deployment transitions. Stability and reliability are priorities, especially during the critical moments of morphing between flight configurations. Additionally, we will implement redundancy and fail-safe mechanisms to ensure safety and robustness, along with remote control management to guarantee pilot oversight when necessary.

Weeks 1–2	Literature review on control strategies for drones and morphing wing systems. Study of PID tuning methods, redundancy concepts, and fail-safe strategies.
Weeks 3–5	Development of simulation environment for testing control algorithms. Design and tuning of initial PID controllers for basic flight modes (takeoff, hover, cruise).
Milestone:	Simulated control system demonstrating stable flight in basic modes.
Weeks 6–8	Implementation of control algorithms on the prototype. Real-world testing of takeoff, hover, and cruising. Adjust PID parameters based on test results.
Milestone:	Prototype stabilized in physical tests for core flight modes.
Weeks 9–12	Extension of control system to handle wing deployment transitions. Validation of stability and reliability during morphing phases. Integration of redundancy and fail-safe features. Remote control management added for manual override.
Milestone:	Reliable control of morphing transitions with safety mechanisms in place.
Weeks 13–14	Final refinement of controllers and redundancy features. Consolidation of test results and preparation of technical documentation (control algorithms, tuning parameters, fail-safe systems).

2.4 Cost Estimation

Table 1: Cost Estimation for Prototype Development

Category	Total Cost (CHF)
Hardware	
Electronics (e.g., RC Controller, Motors, Flight controller,...)	600.00
Materials (e.g., 3D Printing, Acrylic, MDF, Carbon Fiber,...)	300.00
Mechanical components (e.g., Screws, Bearings,...)	100.00
Machines and Rooms access	
Wind Tunnel	200.00
Tensile Testing Machine	100.00
Total	**1300 CHF**

Signatures

For the Project Team:

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Giovanni Ranieri Signature: ____________

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References

[1] Parrot SA, "Parrot Swing," 2016. [Online]. Available: https://www.parrot.com.

[2] D. Falanga et al., "The Foldable Drone," *IEEE Robotics and Automation Letters*, vol. 3, no. 3, 2018.

[3] D. Mellinger et al., "Trajectory Generation for Quadrotors," *Int. J. Robotics Research*, vol. 31, no. 6, 2012.

[4] senseFly, "eBee X," 2022. [Online]. Available: https://www.sensefly.com.

[5] T-Drones, "Top VTOL Drones," 2024. [Online]. Available: https://www.t-drones.com/blog/top-vtol-drones.html

[6] NASA Jet Propulsion Laboratory, "DuAxel Rover: Robotics at JPL," 2020. [Online]. Available: https://www.jpl.nasa.gov/robotics-at-jpl/duaxel/

[7] NASA, "Curiosity Rover: Mobility Systems," 2012. [Online]. Available: https://www.nasa.gov.

[8] NASA, "Mars Exploration Rover: Tethered Operations," 2004. [Online]. Available: https://mars.nasa.gov.

[9] M. Kruijff et al., "Tethered Robotic Systems for Planetary Exploration," *Journal of Field Robotics*, vol. 30, no. 3, 2013.

[10] ESA, "ExoMars Rosalind Franklin Rover," 2022. [Online]. Available: https://www.esa.int.