IPRO 317
VTOL Aircraft for the Masses: Testing and Commercialization

Final Report
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Background

The concepts behind the Volar VTOL vehicle are ease of use and reliability on the order of the common automobile, making it easily accessible to the general market. While there are several choices for personal air transport currently, helicopters and small aircraft, both are moderately expensive and involve extensive training. The Volar team looks to open a third option using a unique design which improves stability leading to less intensive training, alongside common components in broad use in other applications.

The stability of the vehicle marks the most drastic difference between the Volar aircraft and its closest comparison, the helicopter. Featuring dual interlocking rotors, the counter rotating setup cancels rotational inertia, eliminating the need for the tail rotor found on all helicopters. This greatly simplifies the controls and stability of the vehicle. Another improvement leading to improved ease of use is the fixed pitch of the rotor blades. To change directions, the entire rotor assembly moves, translating to a much simpler control scheme for the pilot.

Previous IPRO 317 teams have utilized a gas powered scale helicopter model, modified with the above design changes. However due to poor reliability, much of the time spent working with this model involves repairing the minor problems that arise as a result of the gas engine. This led to the creation of a new smaller electric model, which after thorough simulation design; parts were ordered and left to be assembled.

Objectives

The first and primary objective of IPRO 317 is to continue advancing the existing prototype towards full flight worthiness. This will be achieved through several overhauls of existing parts, as well as through consultation with outside experts in the radio control field. The team will also implement many new safety features as the prototype progresses toward the ultimate goal of free flight.

The second objective of this semester's IPRO 317 is to pick up where the previous semester left off on the construction of a second prototype design. Many parts have been ordered and are awaiting assembly; however several others must be developed and fabricated. The end result of this objective will produce a second viable alternative vehicle for use in marketing the idea of a VTOL aircraft to the public.

The final objective of IPRO 317 is to review and analyze the results of previous semesters regarding the objectives, design goals, and feasibility of a full-scale prototype, including any existing models. Once the design goals of the aircraft are made firm a new model will be created from parts available on the current market.

Methodology

The majority of the work to be completed this semester by IPRO 317 will revolve around the design and construction of scale models. To achieve this, various prototyping techniques will be discussed and implemented, with emphasis on an iterative approach to refine our functionality. Teams will also consult professionals outside of the project for aid in meeting their objectives.

In order to complete our objectives, the team has divided into 3 groups, each focusing on a particular objective. Individual group objectives are as follows

Group 1: Existing Model Testing

The primary objectives of the testing group are to:

1. Tighten and thread-lock every fastener on the VTOL.
2. Assess and implement necessary safety precautions, e.g. safety screens, safety procedures, reversing throttle.
3. Consult with “expert” to assess engine performance and tuning.
4. Learn to fly a Remote Control helicopter.
5. Verify the ability of the VTOL to successfully complete vertical take off and landing.
6. Verify the ability of the VTOL to transition from vertical to horizontal flight.
7. Demonstrate free flight of the VTOL.

Group 2: Assembly of New Prototype

The primary objectives of the assembly group are to:

1. Brief the team members on the concepts of design.
2. Establish individual goals for members that lead to the production of the second prototype.
3. Hold regular discussions on solving problems as they arise.
4. Develop CAD drawings for the synchronizing gears to be manufactured.
5. Develop CAD drawings for the power train assembly to be manufactured.
6. Assemble and test the prototype.
7. Verify that the prototype meets the requirements set forth by the design statement.

Group 3: Full-scale Design

The primary objectives of the Full-Scale Model Design Group are to:

1. Explore the capabilities of the X-Plane software as well as its limitations.
2. Review, assess, and revise the design statements and objectives set forth by previous semesters.
3. Review, assess, and revise the feasibility of previous full-scale designs.
4. Research availability of critical parts to the aircraft.
5. Using CAD software, design and blueprint required components.
6. Using the X-Plane software, evaluate the effectiveness of the new design in meeting the design statements and objectives.
7. Promote team communication by compiling sub-team documentation into final deliverables.

Accomplishments

The team accomplished much this semester towards the objectives of the IPRO as a whole. Each of the three teams had an ambitious schedule, which despite many setbacks was nearly achieved. This is due in part to the collaborative effort put forth between teams in sharing results and exchanging ideas.

The team working with the current model made great strides in securing the structure, focusing on ensuring tight connections between the joints of the gimbal mechanism. However, engine problems continued to plague the team, leading them to enlist the help of an outside expert with experience with model engines. Scheduling conflicts continued to hinder the team, but the end result of a finely tuned engine was achieved, albeit slightly behind schedule. Many tests were conducted during this time to verify the improvements being made to the engine, in many cases resulting in unanticipated lift off of the vehicle.

Once the engine had been satisfactorily tuned, the team set about using the remaining time to complete a final tethered flight test. The engine performed as expected and lift off was achieved; however while transitioning to forward flight, the main gear begin to strip, forcing an early termination of the flight. This was partially expected due to the weakness of the nylon gears, a problem which has yet to be overcome. Two more flights were attempted with similar results: successful lift off at the cost of destroying the main gear.

The second team this semester continued the work started in the spring with the design of a new test model. Construction using the parts acquired over the summer began, but it became apparent that more needed to be done as many components needed to be designed, redesigned, or replaced with more readily available substitutes. This led to continued simulation testing using the X-Plane software to verify the specifications of the new parts.

In the end, the redesigns chosen reflect well upon the goals of the IPRO: simplicity and reliability. The team chose to do away with the large gimbal mechanism and using suggestions from the team as a whole chose flexible shafts over the unreliable gears currently used. Drawings were also produced for the remaining mechanisms, including a redesigned gimbal mechanism. Using a rotating point mass, the device adjusts the center of gravity of the rotor assembly by swiveling under the control of a single servo. This improvement further reduces the complexity of the system, although much testing will be required to verify its effectiveness.

The final team this semester focused on producing drawings for a prototype full scale vehicle. Drawing from the experiences of the other teams, the group began with the full scale simulation models left by previous semesters. Analysis on the performance and stability of these models led the group to select one to simplify to meet the goals of a prototype, namely fulfilling the weight, fuel, and licensing requirements set forth by the FAA.

Taking the simulation model and applying many design principles found in the reference material left behind by previous IPRO teams, a prototype design similar to an Ultra-Light was developed. The design takes a step forward toward the completion of a full scale vehicle by allowing for an easy transition from the model test platforms to an easily modified full scale design. It does not meet the requirements determined by market studies conducted by previous semesters; however it is only a prototype meant to function similarly to the models as a test platform. From the design, research on the current market was performed to evaluate the availability of suitable components for the construction of the design. The engine proved to be the primary concern, and an ideal candidate was found to be the Mazda RX-7 rotary engine. For structure, Chromoly tubing used by Ultra-Lights was found to have sufficient strength for VTOL application. However, setbacks included the choice of rotors, as little information regarding the availability for purchase was found.

Future Work

The IPRO continues to take steps towards its final goal and more work on each of the sub-projects started this semester. The current model is now structurally sound and finely tuned; however, work must be done regarding the main gear. The remaining nylon gears have been destroyed and proved to be highly unreliable. Teams in the future must address this issue with either stronger materials, or redesigning the drive assembly. The new model continues along the path to completion, as this semester the electrical drive system was built and wired. Future work includes ordering the flexible shafts and completing the rotor assemblies, ultimately connecting them to the motor system. For the full scale prototype, the design is preliminary and needs to be verified both structurally and aerodynamically using test data from the models once it becomes available. Also, the choice of which control mechanism between the two models is best will need to be made and scaled up to be integrated into the design.