# Skripsie proposal: Tip-propelled rotary-wing aircraft

## Goal:

The goal of this project will be to design and build a rotary-wing aircraft which actuates its blades through the use of propulsion situated at the tip of the blades. The variation in propulsion should control translation in both the vertical and horizontal plane (the lift and rotor blade pitch). The aircraft should demonstrate that it is controllable and can sustain flight while being stable.

## Tentative Questions

### Can the rotary-wing aircraft be fully controlled using just the tip propulsion?

Investigate to determine if the direction of the aircraft be can controlled by adjusting the thrust generated from the tip propulsion or are external actuators and mechanisms, such as a swashplate, are required.

## Background

Traditional methods for actuating the blades consist of using a turboshaft engine to drive the rotor shaft, which rotates the blades. According to Newton's third law, the motor causes a torque on the fuselage from where the engine bevel gear connects to the rotor bevel gear and thus a tail rotor is required to compensate for this force. The tail rotor is mechanically linked to the main rotor so its rotational speed cannot change, instead to increase are decrease its force, the pitch of the blades is adjusted. Similarly, to move the helicopter in a certain direction the pitch of the blades at certain positions is adjusted using a swashplate, which would cause an increase in the pitch at one point and a decrease at the opposite point. This would create increased lift from the blade with the higher pitch and conversely, the decreased pitch would reduce lift. This creates a force upward force and a downward force located opposite to the upward force creating a moment about the fuselage. As seen with gyroscopic procession, this causes the force to act perpendicular to the applied force. Moving the helicopter in the direction of the force.

Traditional helicopters rely on the tail rotor to maintain control, if it malfunctions, it will cause the helicopter to become uncontrollable. The proposed idea to use tip propulsion to produce rotation has the benefit of eliminating the toque felt by the fuselage and thus eliminating the need for a tail rotor, with the added benefit of it being cheaper, lighter and reducing the need for high gearboxes and clutches. (Nenad Kolarević, 2020)

Research has shown most propulsion-tipped rotary aircraft make use of small jet engines placed at the tips of the blade. This was witnessed in the design of the Fairey Rotodyne. While the Rotodyne was a gyrodyne, meaning it made use of freely rotating rotor blades to produce lift, it had jet-tipped blades to allow for hovering and vertical take-off and landing. While this was intended to revolutionise air travel, the jet tips proved to be too loud for its intended purpose of inter-city travel (Mustard, 2019). Another option, which proved to be effective is demonstrated in the French helicopter the SO 1221S Djin, which made use of compressed air from a turbine-driven air compressor. (Heli archive, 2023).

As seen, this concept has been explored and has some benefits, yet is still fairly rare. Some of the disadvantages of this type of articulation are transmitting power to the rotating tips, increased noise, and the fact that there is added weight cantilevered at the end of the blade tips. These are a few of the challenges that need to be considered when creating the design for a propulsion-tipped rotary aircraft.

## Project Synopsis

### Propulsion

The first step required is a decision on the type of propulsion. These include jet engines, compressed air or by using electrical motors. It is believed that even at this time the possibility of jet engines can be ruled out for various reasons, leaving compressed air and electrical motors. Using the motors, a battery could be used to store potential energy, whereas a tank would be needed for compressed air. Controlling the speed can easily be done by increasing and decreasing the voltage to the electric motors, whereas for the compressed air, the output nozzle would need to increase and decrease in diameter, potentially with an iris mechanism and a servo motor. Lastly, the stored energy needs to be transmitted through the rotating blades, this can be achieved through a slip ring for the electric motors or using a swivel connector for the compressed air.

The only advantage of using the compressed air over the electric motors is that there wouldn’t need to be anything mounted at the tip of the wings, as it can be transmitted through tubing to the tips. While more research should be done into the matter, the electric motors have more precise control, most likely have a longer flight time and are less complicated. There is a high likelihood that this will be the chosen option moving forward.

### Designing and Controllability

Experiments need to be done to determine a method to adjust the pitch of the blade. Possible methods include the traditional use of a swashplate, actuators on each blade or by making a mechanism for which varying the individual speed of the tip propulsions adjusts the pitch. No CFD will be expected to be done.

Once the pitching mechanism has been decided on, the first prototype can be designed and created. This prototype will make use of a microcontroller and various sensors to ensure the aircraft can be controlled. A control system for this system will have to be made for this to make it possible to control the motion. Due to the complex nature and the desired control of this model, a state space controller would be the best choice, however, it may be difficult to derive an accurate model for the system and thus a PID controller might need to be used instead. The prototype will take in human input and not be autonomous.

### Testing

Once a control system has been implemented the prototype can be tested by securing it to four load cells (presumably in an ‘X’ configuration). From the load cells, it will be seen if thrust can be created such that the aircraft will go in the direction that has been instructed of it, thereby demonstrating the controllability of the prototype.

## Final remarks

The above illustrates the basic procedure that will be followed when designing and building the tip-propelled rotary-wing aircraft. Whilst care has been taken, it is anticipated that additional problems will be encountered during the course of this work, the overcoming of which will be an exciting challenge.