Development of UGS Tilt-rotor Surveillance Tri-copter UAV

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***Abstract*—**To further supplement the strategies of Prevention, Deterrence, and Detection, the Singapore Police Force (SPF) requires support from cutting-edge technology. This paper will describe the development of our tilt-rotor surveillance tricopter unmanned aerial vehicle (UAV). Its unique tilt rotor capability enables a much higher cruise speed and range as compared to conventional multirotor UAV. This design also supports a wide range of features such as waypoint navigation, first-person view cameras, and high payload. Being modular also allows for various systems to be installed based on mission requirements. Such an Unmanned Aerial Vehicle (UAV) can and will aid the SPF in the protection of life and property, along with the prevention and detection of crime.

***Keywords*—**Tilt-rotor, tri-copter, surveillance, UAV.

I. Introduction

AERIAL surveillance is a growing industry, utilized in a wide range of specialized field, from military, homeland security to marine offshore and civil engineering (Ozdemir, et al., 2014). With each application to different fields, there are different capabilities required for the job to be done. Homeland security surveillance does not require long-range operations like the military. However, it requires agility, compact body and sufficient range and endurance capabilities. Commonly utilized UAV by homeland security includes glide planes and multi-rotor copters (Close-Up Media, Inc., 2013).

Working for Singapore Police Force (SPF), which handles Singapore's homeland security, based on a combination of the design of a Vertical Take-Off and Landing (VTOL) aircraft and the design of a multi-rotor copter, a tilt-rotor tri-copter was designed. To fulfill the requirements and needs of SPF, our UAV has to achieve these capabilities.

1. To have a small acoustic emission and a small visual silhouette to avoid attracting attention
2. Reliable with minimal maintenance
3. Highly mobile with minimal preparation time required to launch
4. High endurance and range to cover duration and distance of surveillance
5. Able to accommodate future upgrades and various sensor payloads
6. Economical in resources
7. Have failsafe operations

Tri-copters are known for their high maneuverability and it has fewer rotors needed to provide lift sufficient for flight. With the proper control parameters set it place, its stability would not in any way pose as a disadvantage (Zou, Su, & Tso, 2012). Putting the advantages of two types of UAV together, a tilt-rotor tri-copter is designed. The photos of the real model are shown in **Figure 1** and **2**.

Figure 1 Tilt-rotor Tri-copter in flight

Figure 2 Tilt-rotor Tri-copter with flight equipment

II. Design & Development

A. Description

In the early stages the tri-copter was designed together with a wing. However, the wing was causing adverse issues than what it was initially planned for (Increase lift during forward flight) (**Figure 3**).

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Figure 3 Two meters span foam wing

The wing was scraped and work was done to improve on the first prototype. Firstly, the base plates were changed from acrylic to glass-fiber reinforced plywood. This made the base plates more rigid, increasing its resistance to impact as well as reduce the amount of flexing.

The reasons for using a tri-copter as the main platform is because of its vertical takeoff and landing capability, allowing it to be launched without a need for a runway, the third (rear) rotor's ability to swivel, giving the platform excellent yaw capabilities. This increases its maneuverability as compared to a quad-copter or other configurations without such yaw characteristics.

B. Key Features

The tri-copter's main feature is its rotating forward boom (**Figure 4**). This allows the two forward rotors to be tilted forward, greatly increasing the tri-copter's forward speed and covering more distance in a shorter duration, in comparison to untilted rotors (**Figure 5**). This feature also gives the tri-copter the greater forward velocity, for the same power input, when compared to other multi-copters without tilted rotors.

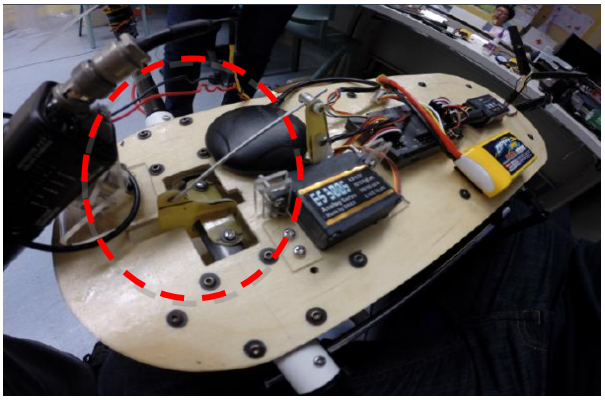

Figure 4 View of tri-copter's forward rotating arm and servo

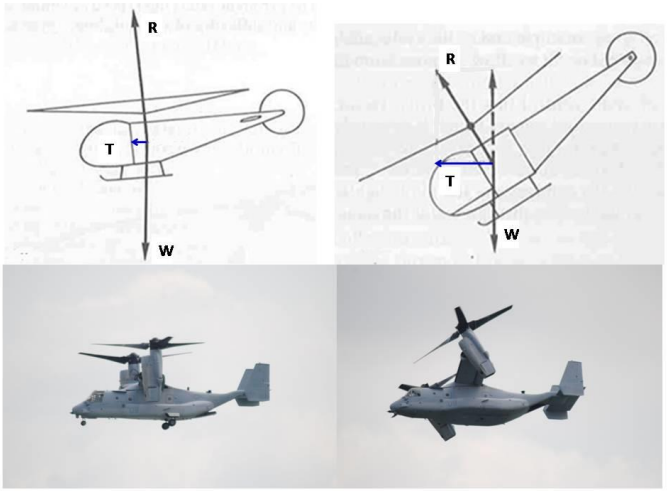

Figure 5 The tilted rotors generate more forward thrust than the untilted ones. (Boeing V-22 Osprey, Photo courtesy: Boeing)

An autopilot module is also integrated with the tri-copter. (3D Robotics Inc.)This gives the tri-copter several autonomous capabilities such as waypoint navigation, return to launch and loiter.

The Tri-copter also has a First-Person View system, with a day/night camera mounted on the platform. This allows the user to operate the platform beyond visual range, as well as the ability to conduct surveillance operations at any time, be it day or night.

Last but not least, the UAV uses a modular concept. With components strategically placed and designed in parts, it enables ease in replacement of particular parts. It also gives the user an easy means of maintenance allowing a fast turnover rate when the UAV is down. Such a key feature of our UAV allows growth potential, permitting easy modification when the need arises, to further improve sensor suites at a minimal overall cost. As such, the UAV is not limited to any current parameters set in placed but readily available for upgrade if the opportunity presents itself (**Figure 6**).

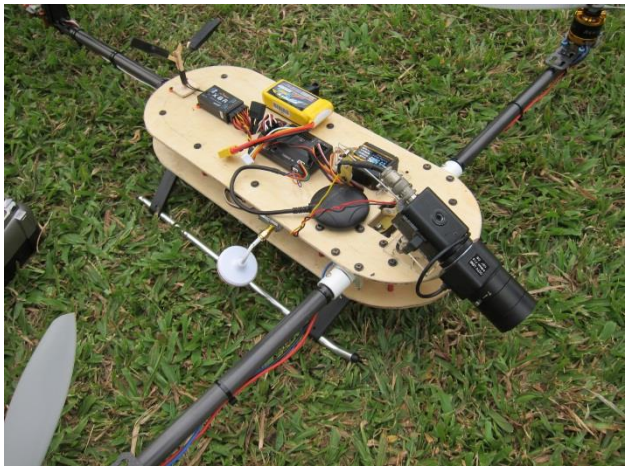

Figure 6: Tri-copter's modular concept

C. Components

Motors

- Type: RCX Brushless Motor 3608- 460kV x3
- RPM/V : 460kV
- Shaft Dia: 4mm, 5mm adapter for stability.
- Motor Dimensions: 42mm x 15mm
- Weight: 83g

Electronic speed control, 45A x3
Camera

- Flight Camera: PZ0420 600TVL Sony CCD Camera
- Night Capability Camera: High-Res. 3D-DNR Camera (0.00001 Lux Light Rating)

Radio Transmitter & receiver

- FrSky 2.4GHz with 5di antenna transmitter
- FrSky X8R receiver

Global Positioning System: LEA-6H
Video Transmitter & Receiver 5.8 GHz, 200mW
Telemetry: 433MHz Connection
Flight Control Board: ArduPilot Mega
Battery

- Zippy Compact 6s 6600mAh (Flight Battery) x2
- Zippy Compact 3s 1000mAh (Camera Battery) x1

Propellers: 13 x 5.5in. Carbon Fiber Blades
Building Materials

- Carbon fiber rods (Boom arm)
- PVC tubing (Supporting rotating arm)
- Plywood reinforced with fiberglass & epoxy (Fuselage)
- Aluminium Spacers (Arm supporting structure)

Payload: Approx. 5kg

III. Future Development

A better camera system can be integrated with the platform. Currently, the tri-copter possesses a camera with limited capability. Therefore this can be an area for improvement whereby a camera with better specifications can be substituted. A full fuselage, giving it operational capability even in adverse weather conditions, can also better protect the tri-copter's components.

The next step that is possible would be to conduct a full aerodynamic analysis on the UAV performance and structural loading in flight. Having a base platform customization, which is interchangeable based on mission requirements.

IV. Conclusion

We have developed a tricopter with a forward tilting boom that allows the front two rotors to be declined, inducing forward flight. Such a unique design gives a higher than conventional multi-rotor copter cruise speed. Having numerous flight test done on the UAV on different areas of control and capabilities, we are confident to say this concept is a stepping-stone to a new era in the unmanned aerial vehicle development industry. A demonstration video can be found at (http://youtu.be/MnmLCh_npHk).

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