Generic unmanned aerial vehicle (UAV) for civilian application-A feasibility assessment and market survey on civilian application for aerial imaging

Conference Paper · October 2012

DOI: 10.1109/STUDENT.2012.6408421

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Generic Unmanned Aerial Vehicle (UAV) for civilian application

A feasibility assessment and market survey on civilian application for aerial imaging.

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***Abstract*— UAV or commonly known as pilotless aircraft is widely known in military usage. It can perform task fully autonomous or remotely piloted or both. UAV can perform task where human life can be of risk at the same time an alternative to cost effective solution. Use of UAV in civilian application has started to become common as technology become more readily available in the civilian arena. Availability and accessibility of advance autonomous technology for civilian has encourages wide range of civilian UAVs been developed. Gathering of data shows that most Civilian used UAV have wing span around 3 meter while its total takeoff weight is less than 6kg. This is important due to the nature of mission in civilian usage which may endanger properties and life forms that includes human. Small size, low speed UAV has relatively small kinetic energy in the event of crashes. This paper will look into the existing civilian UAVs and identify demands that yet to be addressed. In this paper we have identified the design goals to fill in the existing gap while keeping affordability in mind. This paper also dealt with the parameter that will assist in the conceptual design of a slow speed, easy to fly civilian use UAV. Final goal is to build the prototype and demonstrate the capability of such craft completing the predefined mission typical of civilian usage.**

Keywords— UAV, Unmanned aerial vehicle, civilian UAV.

I. Introduction

Unmanned aerial vehicle (UAV) or commonly known as pilotless aircraft has been in the arena of air combat as early as 1915 when the concept was first introduced by Nicola Tesla [1]. Other known terms include unmanned aircraft system (UAS) or remotely piloted vehicle (RPV). Due to its potential in replacing human pilot in view of performing high risk mission and also as a cheaper alternative, it is widely used since the World War II (WWII). During the 1960s and 70s, the United State performed more than 34,000 UAV flight and in the late 70s Israel pioneered the development of modern UAV, performing mission such as real-time surveillance, electronic warfare and decoys till the present [2] [3].Today UAVs can be remotely piloted or fly autonomously. Most UAVs are designed with military mission in mind and widely defer in size and capabilities. These military purpose UAVs are not suitable for civilian usage as most of these UAVs are large in size and needing proper airfield to operate with proper supporting facilities. Both ownership cost and maintenance cost for such category of UAV are either beyond reach or not justifiable within the economic sense of most civil application.

II. Global UAV Demand

According to a report by an independent business information provider for defense industry, global spending in 2009 on unmanned aerial vehicles (UAV) reaches $5.1billion. Over the forecast period of 2010-2020, the cumulative UAV market will total nearly USD 71 billion [4]. Estimated revenues over the period of 2010 – 2015 are estimated to be USD 62 billion with calculated USD 5.5 billion spent globally in 2010 alone [5] [6]. In Australia, civil application of UAVs has been encouraging with AUS 2 million went to crop monitoring where only 10% of the 500'000 hectares agricultural land monitored are covered by manned aircraft [7]. With the steady demand of UAV across wide range of application, UAVs of different sizes and level of complexity has been developed, specifically designed according to the mission requirement and with cost consideration. It is therefore not uncommon to classify the UAVs into different types of categories. Some commonly known categories are: Micro UAV (MAV), generic UAV, tactical UAVs, unmanned combat aerial vehicles (UCAV), and civil UAV.

III. Civilian use UAV

The use of UAVs in the global civilian market is relatively low but yet UAV market surveys show that the growing trend of UAVs services in civilian market is happening right now. The use of civil UAVs has the strongest growth between the period of 2005 and 2011 [8]. There are growing research conducted for UAV designs towards civilian and commercial purposes [9] [10] as technology become more readily available in the civilian arena. Availability and easily accesses of advance autonomous technology for civilian usage further encouraging wide range of civilian's UAVs been developed.

Most civilian used UAV has wing span of less than 3 meter while its total takeoff weight is less than 6kg. This is important due to the nature of mission in civilian usage which may endanger properties and life forms which include human. Small size, low speed UAV has relatively small kinetic energy in the event of crashes.

Cost and size are crucial elements in civil usages of UAV. Field surveys [11] [12] [13] are the main focus for civilian's UAV and it has to be small, versatile, low in initial and maintenance cost [14] [15] and ease landing. Payload compartment size and the ability to carry imaging devices for photography field survey will be the focus. Small scale civilian UAVs are often having limited space for payload (Figure 1) and some require the payload to be hang beneath the wing (Figure 2) which expose the payload to outside element. In our experience in dealing with several commercial customers, mainly developer, plantation owner and researches, UAV capable of performing 20 to 30 minutes of flight with less than 1kg payload is more than sufficient. Typical 20 minutes of flight for a typical UAV (Figure 2) is capable of covering 1km^2 areas or with an equivalent range of 15 to 20km flying at an altitude of 1000 feet.

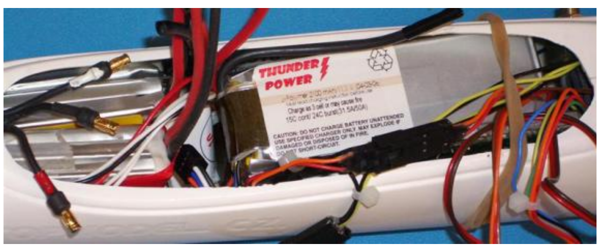

Figure 1: Cropcam UAV with small payload compartment. Source : www.topmodelcz.cz

Figure 2: Payload (camera) mount beneath the CropCam UAV's wing (circled). Source : www.Geosense.com.my

This paper will attempt to compare currently known civilian and military UAVs through performance parameters and size (Table 1), specifically: Wingspan, Total Take-Off Weight (TOW), Payload Weight (PW), total flight time or better known as Endurance and total flight distance or Range.

Study shown that CropCam UAV has been the most commonly used civilian UAV with the most affordable pricing. A complete ready-to-fly system estimated to cost around USD 15'000 [16] to USD 25'000 (according to Malaysia customer) as shown in Figure 2. Others can be around USD 60'000 and mostly dwell in the range of USD250'000 to millions as most are designed for military purposes. A typical small military UAV with wingspan of only 1.37 meter and estimated 90grams payload [17], the RQ-11B [18] can cost up to USD250'000 [19].

TABLE 1: LIST OF UAVS (CIVIL AND MILITARY) AND PARAMETERS

	Wingspan (m)	Endurance(min)	Range (km)	TW(kg)	PW (kg)
AV RQ-11B Raven [18]	1.37	60	8	1.9	0.09 [17]
AV RQ-14A Dragon Eye [25]	1.19	45	5	2.7	0.23 [17]
IAI Malat Bird Eye 400 [26]	2.20	60	10	5.6	1.20
IAI Malat Bird Eye 500 [27]	2.00	60	10	5	0.85
IAI Malat Bird Eye 650 [28]	3.00	180	20	11	1.20
EADS Tracker [29]	3.60	120	10	16	1.80
Elbit Seagull [30]	2.13	240	5	5.5	1.20
Elbit Skylark I-LE [31]	3.00	120	5	5.5	1.20
MAVinci Sirius I [32]	1.63	40	-	2.7	0.55
MAVinci Sirius II [33]	2.00	30	-	3.3	0.55
Rafael Skylite B [34]	2.40	90	10	6	1.20
Trigger Composites Pteryx UAV [35]	2.80	45	40	5	1.00
UAVER Avian [17]	1.60	90	15	3.4	0.45
Cropcom [36]	2.36	20	3 [37]	3	0.40
ZALA Aero 421-12 [38]	1.60	120	10	3.9	1.00

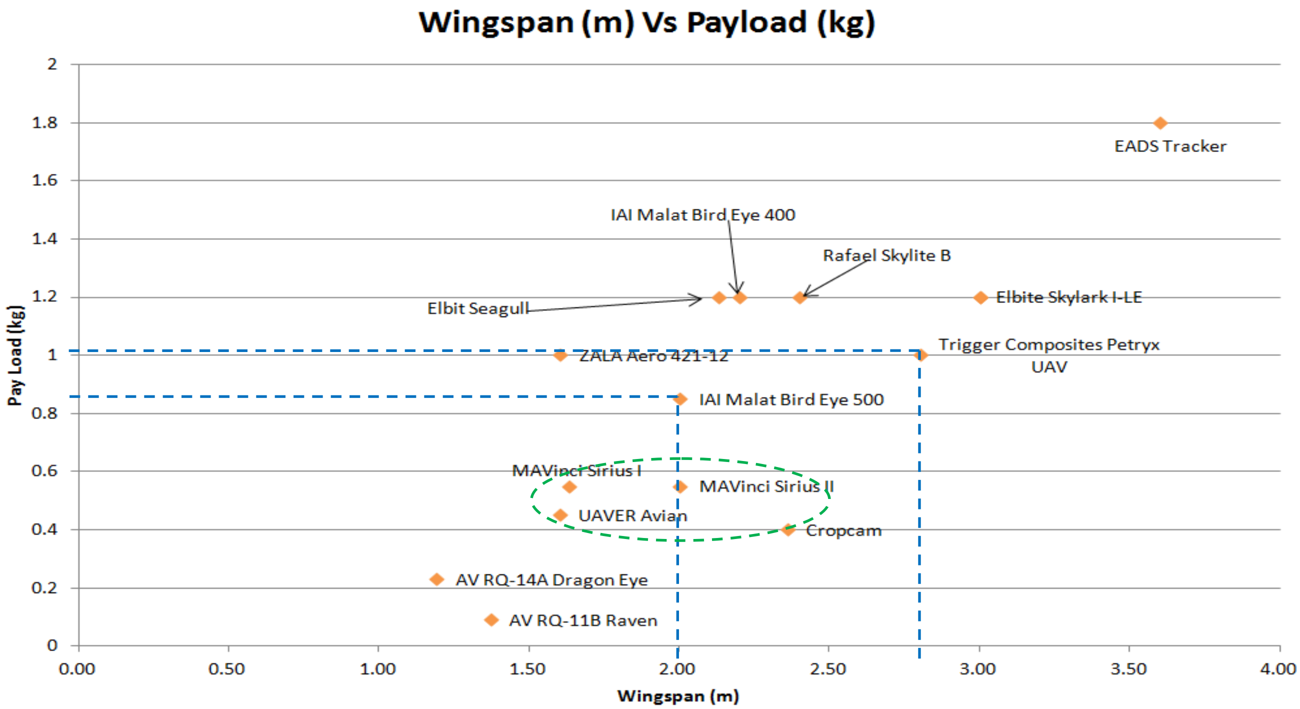

Figure 3 : Graph shows typical UAV's wingspan with 0.8 to 1 (blue, doted line) kg payload and 0.4 to 0.6kg (circled, green)

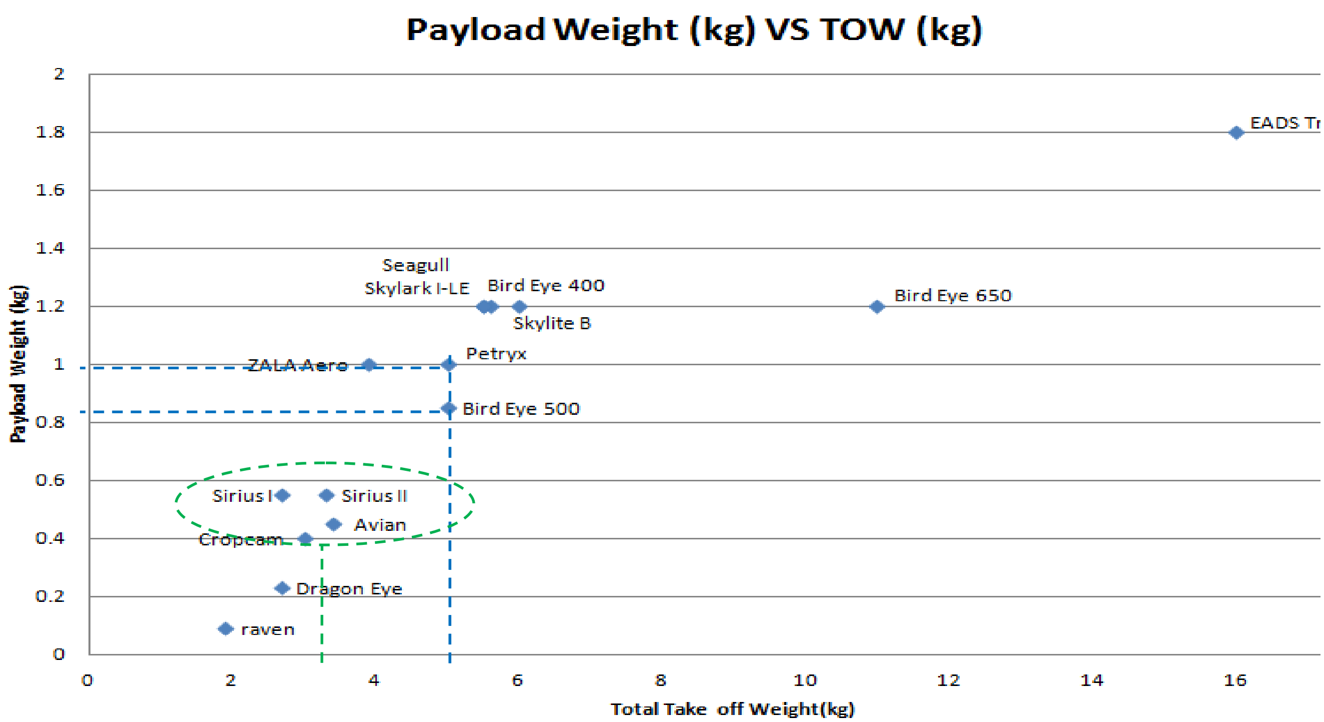

Figure 4: Graph shows typical UAVs with 0.8 to 1 kg (blue, doted line) and 0.4 to 0.6kg (circled, green) payload corresponding to their respective TOW

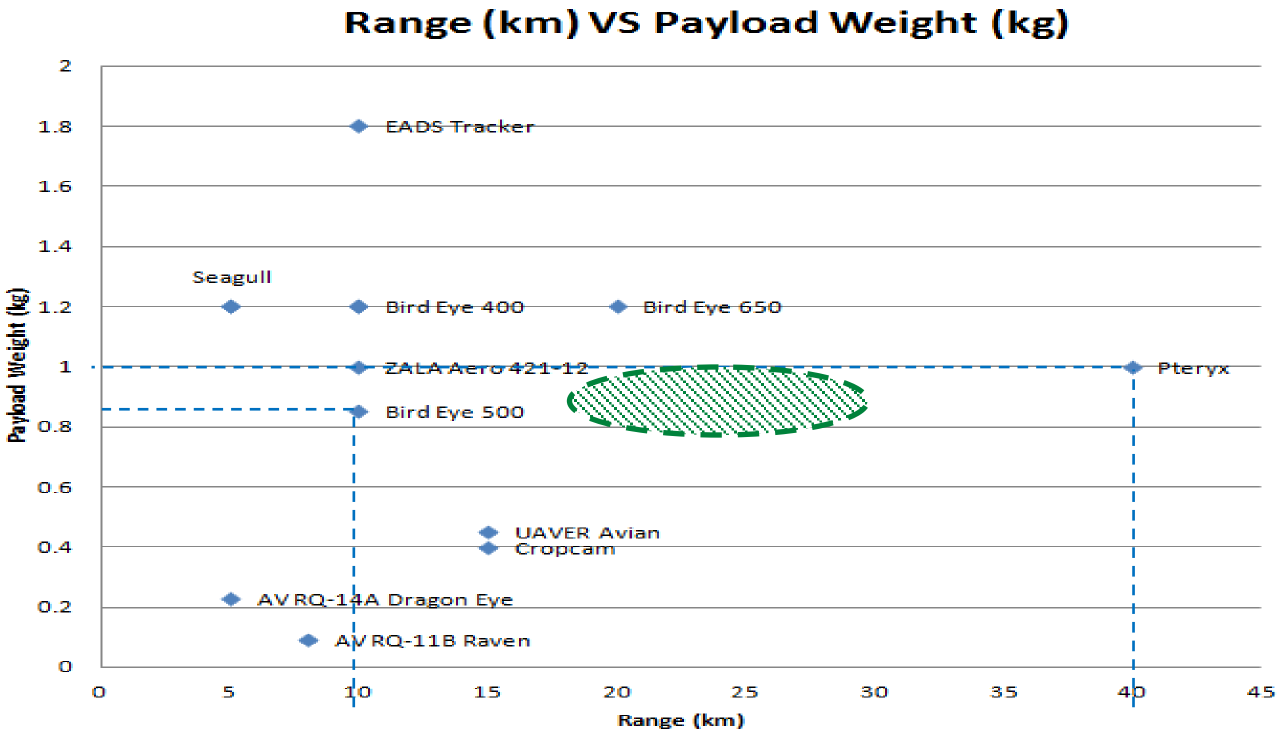

Figure 5: Green region shows gap to be filled for current low cost civilian UAV demand.

IV. Identifying current UAV's Design Gap for low cost civilian application

Figure 3 shows that UAV capable of 0.8 to 1.0 kg payload have a wingspan from 2 meter to around 2.8 meter. ZALA UAV will not be considered here as it is a special design delta wing UAV. As for minimum payload requirement taking CropCam UAV which having a 400 to 600 gram payload as guideline, typical wingspan is around 1.6 to 2.5 meter. From Figure 4, TOW of UAVs capable of 0.8 to 1.0 kg payload weight is around 5.0 kg while those that capable of 0.4 to 0.6 kg payload are around 3.0 kg TOW. This shows that UAVs with payload capacity of 0.8 to 1.0 kg can be designed within 6kg TOW which is below the requirement by Department Civil Aviation (DCA) requirement for remotely piloted aircraft. O.8 to 1 .0 kg payload range is important as this allowed the UAV to carry semi professional camera such as the Canon G11 series hence enhancing the mission outcome.

From Figure 5, the military Bird Eye 500 UAV while having much shorter range as compared to the Pteryx UAV is in fact the same category in terms of performance as shown in Figure 4. The 10km range is due the payload limitation, which in this case dependent on the ground station with the need to maintain real time downlink for military security reason. The Pteryx civilian UAV did not share the limitation of the Bird Eye UAV hence is capable of 40 km range and 45 minutes endurance (Table 1). Again, looking at the demand for 20 to 30 km range and 20 to 30min endurance, a gap exist with no civilian UAV known available to fill in this gap. This is shown in Figure 5 with green shaded region. Considering that UAV cost increases proportionally with both weight and performance, it is therefore possible to reduce the UAV acquisition cost by reducing the performance which in the Pteryx case will be the range down to the 20 to 30 km range.

The design goals therefore been established in this paper which were: 1) Capable of lifting 0.8 to 1kg payload that can be installed inside the UAV which double as protection in the event of unforeseen crashes; 2) flight endurance, at least 20 minutes; 3) wingspan not more than 2.5 meter for ease of transporting. 4) standard UAV design for good handling quality that can be flown by inexperienced pilot which will also contribute to 5) low cost production and lastly 6) Total take-off weight must be less than 6kg to comply with Department Civil Aviation (DCA) requirement for remotely piloted aircraft.

V. Conceptual Design of the alpha UAV

The conceptual flow chart for designing the Alpha UAV is presented in Figure 6. The mission profile is specifically design for commercial aerial photography: Take-Off > Climb to 1000ft > 20km Cruising range > Decent > Landing. Total estimated flight time to be 20-30 minutes. Software develops by Laminar Research known as X-Plane [20] is

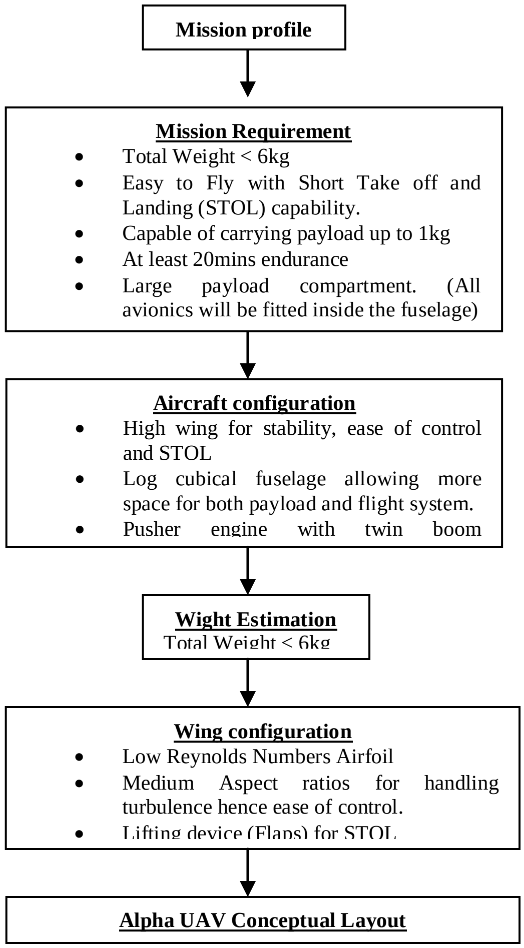

Figure 6: Conceptual design flow chart for Alpha UAV

used to assist in the conceptual layout of the Alpha UAV. The software is capable of predicts the performance and handling of fixed wing aircraft with incredible accuracy. X-Plane software has been used to develop several concept plane such as the Carter™ Copter [21], the famous MIT's Terrafugia™ [22] and Cirrus™ Vision jet [23]. Test flight done by NASA's UAV chief test pilot on the Verticopter™ [24] remote control prototype verified the accuracy of the software in predicting the actual flight characteristic including some of its controls input value. The X-Plane software has been used to conceptualize the Alpha UAV, performing flight test and refining the design till the desire handling characteristic and flight performance. Computer Aided Design (CAD) software, Solid-Work (SW) is then used to assist in the prototype design before actual construction. Optimization on the structural design and some simple flow analysis on the Alpha's nose cone are done via SW to ensure the integrity of the structure and achieving desire flow characteristic over the nose cone. Detail design on the Alpha UAV will be presented in author's other paper publication which is currently under peer review [39]. The process flow from conceptual design to actual prototyping is presented in Figure 7.

Figure 8 shows the actual design of Alpha UAV been tested via X-Plane.

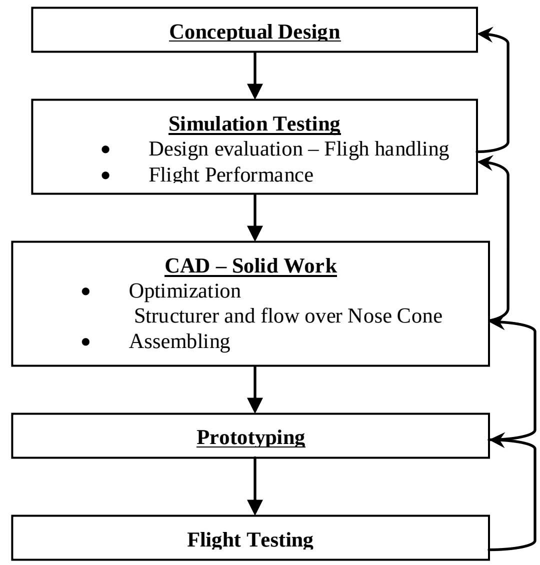

Figure 7 : Conceptual to Actual Prototyping Process Flow Chart

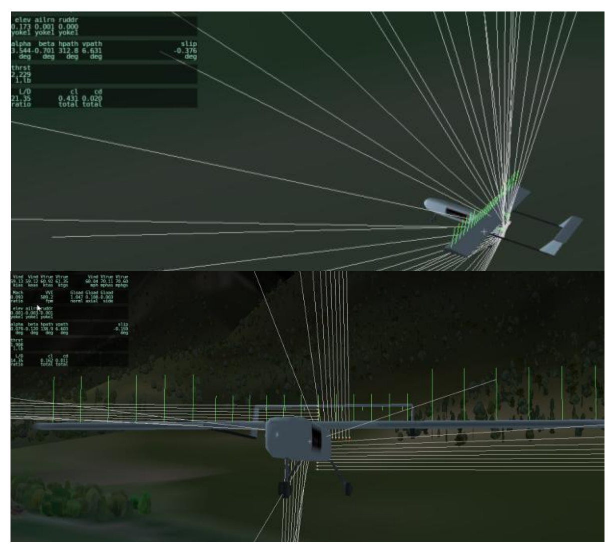

Figure 8: Simulation testing and flight evaluation of Alpha UAV via X-Plane. Design process will be presented in author's other publication which under peer review on the writing of this paper.

VI. CONCLUSION

In this paper, we have successfully indentified the current existing gap in civilian UAV, mainly used of aerial photograping activity. While military UAV respresents a solution to current comercial demand, high acquisition cost has discouraged such approach. The Alpha UAV goals is therefore been identified to fill in this existing gap. By the time of writing this paper, the Alpha UAV has been successfully built and tested. Detail design process of the Alpha UAV will be presented in author's other paper publication [39].

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