

CHAPTER 1

INTRODUCTION

1.1 Major department: Mechanical engineering

This thesis presents the preliminary design airframe dedicated for the future use of the development UAV system. The airframe will be powered by propeller electric engine placed in the back side. The airframe designed to be able to accommodate a flight control system, two high resolution cameras, onboard video recording device, GPS points and altitudes and battery system. Innovative robust construction coupled with light weight and inexpensive hardware was used in the design of the airframe and avionics. These features allow the airplane to be operated by unskilled users.

1.2 Various unmanned aerial vehicles (UAV)

Unmanned Aerial Vehicles (UAVs) have proven their usefulness in military reconnaissance in recent military conflicts ^[1]. Their practical applications have been expanding to more than military uses ^[2]. Various sizes of UAVs are designed to different levels of performance depending on their application. UAVs can be categorized into four different groups: large, medium, small, and micro as shown in Figure 1.1.

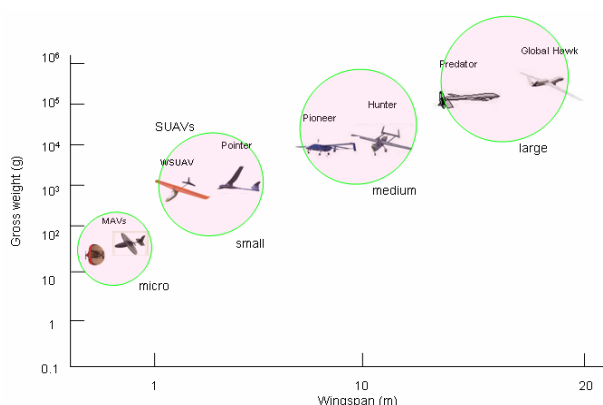


Figure 1.1: UAVs can be divided into four groups by respect to its sizes and weights

Most of the large UAVs have higher flight ceiling, speed, and endurance with more functional capabilities than small UAVs. The representative large UAVs are Northrop Grumman Global Hawk (20m wingspan) ^[3]. And General Dynamics Predator (14.8m wingspan) ^[4]. They have proven their performance in recent missions. Large UAVs are more suitable for large land or over-water surveillance. The effectiveness of large UAVs has been proven in the Gulf War and Desert Storm. Table 1.1 shows typical airframe data of large UAV.

The representative mid-size UAVs are AAI Shadow (3.9 m wingspan)^[5] And IAI Malat Hunter (8.8 m wingspan)^[6]. Most mid-size UAVs do not require runways because takeoff requires a catapult mechanism and landing uses a parachute. UAVs of this size are commonly used for tactical military missions such as target acquisition, over-the-horizon surveillance, and battle damage assessment.

Table 1.1: Typical airframe data of large UAV

	BQM-74	BQM-145A	CL-289
Weight (Kg)	123	98	78
Wing Span (m)	1.76	3.20	0.94
Length (m)	3.94	5.59	3.71
Speed (km/hr)	972	1016.75	740
Endurance (min)	68	49	15
Height (m)	0.71	0.86	0.33

Micro air vehicles (MAVs), as defined by Defense Advanced Research Programs Agency (DARPA), are miniature aircraft with a maximum wing span of 15 cm^[7]. Currently, the MAV's mission is restricted by payload capabilities such as autopilot, high resolution camera, and battery capacity. But its size benefit has the potential to overcome the UAV's accessibility in the confined area. Recently developed MAVs by the University of Florida have an 11cm wingspan and 15 minute endurance, and weigh less than 40g^[8]. The University of Florida has also developed a 15cm wingspan MAV with a reconnaissance capability within 1km range with video transmitting. The example of typical airframe data for medium UAV as shown in the Table 1.2.

Table 1.2: Typical airframe data of medium UAV

	RQ-7A/B	BQM-145A
Weight (kg)	149	98
Wing Span (m)	3.89	3.20
Length (m)	3.40	5.59
Speed (km/hr)	204	1016.75
Endurance (min)	420	49
Height (m)	0.91	0.86

1.2.1 Small unmanned aerial vehicle (SUAV)

The military has shown the most recent interest in small UAVs (SUAVs) for many reasons. A SUAV is much more portable than its large counterparts and requires only one operator. A smaller reconnaissance plane can assess ground targets at a closer range without being detected. Therefore, most SUAVs use electric motors as a propulsion system, which allows for a stealthier and more reliable flight with little engine failure. Also an SUAV is less expensive and can be considered a disposable asset. This factor allows SUAV pilots to navigate hostile areas and focus on their primary mission, rather than plane recovery. In addition to military applications, size and cost advantages are attracting civilian and private uses. Therefore, SUAVs are most suitable for use in non-military applications because they are less expensive

and less dangerous. This encounter proves the need for smaller, more invisible, and more portable SUAVs.

The Aero vironment Pointer (2.7 m) SUAV was the first generation of SUAVs in 1986 ^[9] and was designed as a tactical reconnaissance vehicle for military and law enforcement applications in confined areas. When it was released, a package of 2 airplanes and a ground station cost \$100,000. This is relatively inexpensive in comparison with mid or large size UAVs that can reach millions of dollars. The Pointer's size and reliability has already proven itself useful in Desert Storm ^[8]. Table 1.3 shows commercial SUAVs that are constructed by composites and are mostly designed for the military application.

Table 1.3: Typical micro UAV airframe data

	Bird Eye 500.	RQ-11A
Weight (kg)	5	1.9
Wing Span (m)	2	1.3
Length (m)	1.6	1.1
Speed (km/h)	22-60	95
Endurance (min)	90	80

Table 1.4, shown the wingspan and flying time of the SUAV are compared according to the manufacturer and its product.

Table 1.4: The wingspan and flying time of the SUAV.

Name	Manufacturer	Wingspan (m)	Endurance (hr)
Pointer	AeroVironment	2.7	2
Raven	AeroVironment	1.28	1.5
Dragon eye	AeroVironment	1.14	1
Casper-200	Top vision	2	1
Skylark	El bit	2	1

1.3 Back ground

In parallel of the advancement of computer technology, material, propulsion system and better understanding on the aircraft stability had made the development of autonomous flying vehicle becomes an attracted matter. The applications of UAV are widely had been recognized whether for civilian or military purposed. The military purposes may the UAV can serve for:

1. Reconnaissance surveillance and Target acquisition (RSTA).
2. Surveillance for peacetime and combat synthetic aperture radar (SAR).
3. Deception operations.
4. Maritime operations (Naval fire support, over the horizon targeting, anti-ship missile deference, ship classification).
5. Electronic warfare (EW) and SIGINT (SIGnals INTTelligence).
6. Special and psyops.

7. Meteorology missions.

While for civilian applications, the UAV can be used for:

1. Communications Relay. High altitude long endurance UAVs can be used as satellites.
2. Law Enforcement. VTOL UAVs can take the role of police helicopters in a more cost effective way.
3. Disaster And Emergency Management. Aerial platforms with camera can provide real time surveillance in hazardous situations such as earthquakes.
4. Research. Scientific research of any nature (environmental, atmospheric, archaeological, pollution etc) can be carried out UAVs equipped with the appropriate payloads.
5. Industrial Applications. Such application can be crops spraying, nuclear factory surveillance, surveillance of pipelines etc

Considering that there are a lot of application can be served through the use of UAV, it is therefore, the ability to develop the UAV based on own design is necessary in order to limit the foreign dependence in this type of technology.

1.4 Problem statements

UAV which stand for Unmanned Aerial Vehicle represents the airplane which designed without pilot onboard. With no pilot on board make the size of the airplane can be reduced to become the size of airplane just for accommodating payload and the required fuel only. As a result the size and weight of aircraft becomes smaller and lighter than ordinary aircraft. In the stage of early

development, the design purposed of UAV is for monitoring, hence the payload is the video camera and the communication system which required for sending a video data recoding to the ground. Unfortunately to obtain a long range communication system is very difficult. Such devices are very restricted and can be used without permission from the authority body. To avoid such restriction on the communication device, the purposed aircraft configuration will be designed in typical size of (RC) aircraft. Actual size of the aircraft will be determined on the size of engine, the size of the communication hardware, flight control computer board, video camera and the battery system.

1.5 Thesis objective

The purpose of this thesis is to carry out preliminary design of airframe dedicated for the future UAV developments. The airframe had been selected to be single engine with pusher type configuration. The airframe will be powered by an electric engine. The aircraft sizing developed based on the engine available, flight control system, communication system, two high resolution cameras, GPS points and altitude. There various aircraft configuration of pusher type can be developed. However the present work will focus on one possible configurations similar to the airframe configuration as shown in the Figure 1.2 bellows:



Figure 1.2: The Purposed Aircraft Configuration Model – 1.

1.6 Scope of study

The present work is attended to develop the UAV system for monitoring purposes. As the stage of early development, the UAV designed for the range of typical RC aircraft with payload is video camera. It is therefore, the scope of study will involve:

- ✓ Review on the availability autopilot devices.
- ✓ Video camera model for monitoring purposes.
- ✓ Radio Control.
- ✓ Electric engine and propeller.
- ✓ Airframe design.

CHAPTER 2

LITERATUR REVIEW

2.1 Mission profile and overview

Any aircraft designed without pilot on board called as unmanned aerial vehicle (UAV). Without pilot on board made the size of vehicle can be reduced significantly but at the same time the ability to maintain their safety flight are highly demanded. In line with the progress of aircraft technology development in respect to the design procedures, material, manufacturing and the rapid progress in electronics, communication system and computing power had made a further effort for UAV's development becomes apparent. The UAV has gained interest for military or civilian users. Military users may look the UAV with a particular design

can perform a variety of missions supporting military and intelligence purposes.

The list below presents the military applications that UAVs have served up to now [10].

1. Reconnaissance surveillance and target acquisition (RSTA).
2. Surveillance for peacetime and combat synthetic aperture radar (SAR).
3. Deception operations.
4. Maritime operations (Naval fire support, over the horizon targeting, anti-ship missile defence, ship classification).
5. Electronic warfare (EW) and SIGINT (SIGnals INTTelligence).
6. Special and psyops.
7. Meteorology missions.
8. Route and landing reconnaissance support.
9. Adjustment of indirect fire and close air support (CAS).
10. Battle damage assessment (BDA).
11. Data and data relay.

While from the point of view, civilian users, the Unmanned Aerial Vehicles may be used for the one of following mission:

1. **Border interdiction.** Patrol of the borders by aerial platforms.
2. **Search and rescue.** Looking for survivors from shipwrecks, aircraft accidents etc.
3. **Wild fire suppression.** UAVs equipped with infrared sensors can detect fire in forests and notify the fire brigade on time.
4. **Communications relay.** High altitude long endurance UAVs can be used as satellites.
5. **Law enforcement.** VTOL UAVs can take the role of police helicopters in a more cost effective way.
6. **Disaster and emergency management.** Aerial platforms with camera can provide real time surveillance in hazardous situations such as earthquakes.

7. **Research.** Scientific research of any nature (environmental, atmospheric, archaeological, pollution etc) can be carried out UAVs equipped with the appropriate payloads.
8. **Industrial applications.** Such application can be crops spraying, nuclear factory surveillance, surveillance of pipelines etc.

In more specific purposes, where the mission condition in civil application is unsafe mission, the UAV can be used to carry out to conduct such mission the mission for:

1. Surveillance over nuclear reactors.
2. Surveillance over Hazardous chemicals.
3. Fire patrol.
4. Volcano patrol.
5. Hurricane observations.
6. Rescue missions over adverse weather conditions.

Above explanation clearly indicated that there are a numerous mission can be performed by the use of UAV. Each mission may require a specific aircraft configuration, payload and size. For a long endurance UAV may require a sufficient size of UAV to accommodate the required fuel. The UAV which designed for law enforcement by authority body may require the UAV in the form of Helicopter rather than fixed wing aircraft in order to provide the ability to take off and landing vertically in crowded area and hovering over particular region may need to be investigated carefully. A good review on UAV mission for military application may be found in ^[11] [Nehme, C.E. at all]. As an example UAV which designed for Intelligence / Reconnaissance, the UAV will conduct one of three following missions: (1) mapping, (2) Battle Damage Assessments (BDA), (3) Target Acquisition or (4) Target Designation. In target acquisition may involve with static target or dynamics target. The following diagram shows a generalized Operator Functions in manner how to operate UAV designed to act as Intellegence / Reconnaissance UAV. Each of the primary missions are decomposed into mission

planning, management, and replanning segments in order to identify what the primary functions a human operator will need to perform.

Table 2.1: Mapping.

<div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 5px; text-align: center;">Intelligence/ Reconnaissance</div> <div style="border: 1px solid black; padding: 5px; text-align: center;">Mapping</div> <div style="border: 1px solid black; padding: 5px; text-align: center;">BAD</div> <div style="border: 1px solid black; padding: 5px; text-align: center;">Target Acquisition</div> <div style="border: 1px solid black; padding: 5px; text-align: center;">Target Designation</div> </div>		
	Phase goals	Function/information requirements
Mission planning	planning path of area be mapped scheduling of health and status reports	threat area information no fly zone information scheduling mechanism decision support for path planning
Mission management	tracking progress of UAVs and of health and status reports image (mpa) analysis	health and status indicators image analysis tools(zoom, panning, filtering)
Mission preplanning		
Operator functions	monitoring health and status of UAV optimal ¹ position supervision perceiving/interpreting image analysis image	

Table 2.2: BDA.

BDA.	Phase goals	Functional /information requirements
Mission planning	assessing target and routes scheduling of order of assessment if more than one scheduling of health and status reports	threat area information no fly zone information scheduling mechanism decisions support for path planning (including loiter)
Mission management	Tracking progress of UAVs and health and status reports Analysis BAD result	health and status indicators image analysis tools(zoom, panning, filtering)
Mission preplanning	- resource allocation	Asset coverage re-plan decision support.
Operator functions	monitoring health and status of uav perceiving/ interpreting image analysis image monitor network communication resource allocation & supervision Path planning supervision Notifying relevant stakeholders.	

Table 2.3: Target acquisition (static and dynamic).

	Phase goals	Functional /information requirements
Mission planning	<p>Path planning (area to search and waypoints to the area of interest)</p> <p>Scheduling of health and status reports</p>	<p>threat area information</p> <p>no fly zone information</p> <p>scheduling mechanism</p> <p>decisions support for path planning (including loiter)</p>
Mission management	<p>Tracking progress of UAVs and health and status reports</p> <p>Analysis EO image</p> <p>Image/sensor matching (e.g.,ART)</p> <p>Position tracking (only for dynamic)</p>	<p>health and status indicators</p> <p>support for viewing result and storing result</p> <p>support for sensor matching</p> <p>support for tracking position of target(only for dynamic)</p>
Mission replanting	- path preplanning	<p>- preplanning decision support</p> <p>- Rescheduling decision support</p>
Operator functions	<p>monitoring health and status of uav</p> <p>optimal position supervision</p> <p>perceiving/interpreting other sensor data</p> <p>analysis other sensor data</p> <p>positive target identification</p> <p>tracking target (only for dynamic)</p> <p>notifying relevant stakeholders</p>	

Table 2.4: Target designation.

	Phase goals	Functional /information requirements
Mission planning	Perceiving location of target to be designated Scheduling of assessment and of health and status reports	threat area information no flay zone information scheduling mechanism decisions support for path planning
Mission management	Tracking progress of UAVs and health and status reports Monitor designation	health and status indicators feedback on completion of failure of designation active communication
Mission replanting	designating replanning (cancelling designation , or designating another target) rescheduling transmission of health and status report	- preplanning decision support - Rescheduling decision support
Operator functions	monitoring health and status of uav negotiating with other stakeholders positive identification (combat ID)	

Considering above relationship between UAV and UAV's operator, it clear that there is some communication between airplane and people on the ground. The people in the ground control station able to monitor the health and status of UAV and also path planning of the interest area.

As initial stage of UAV development, the present work focus on the development of UAV for simple mission. The profile mission as depicted in the figure 2.1 bellows:

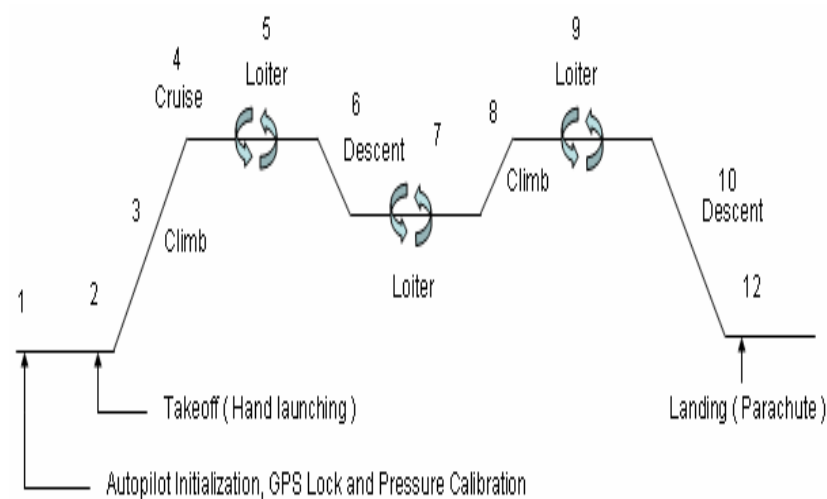


Figure 2.1: Proposed mission profiles.

While the targeted configuration and other pertinent aircraft characteristics as shown in the Table 2.5 bellows.

2.2 Initial configuration

As it had been mentioned in the previous sub chapter, the proposed aircraft will use an electric engine placed on the back side. In other word the aircraft configuration belong to the class of pusher type aircraft. The present work will adopt the proposed aircraft configuration to follow one of two following aircraft configurations as depicted in the Figure 2.2a,b.c.d, and Figure 2.2f.

Table 2.5: The proposed design requirements.

Endurance	60 min
Navigation	GPS / autopilot
Payloads	interchangeable CCD cameras, on board recording device, and sensors
Data transmission range	5-10 km
Take-off and landing	increase hand-lunching success with less danger, Short field landings (parachute recovery), water Lander able
Wing span	maximum 4 m
Cruise speed and climb rate	cruise speed 80 km/h climb rate 2 m/s
Propulsion	electric motor
Airframe	robust construction, easy repairable, inexpensive manufacturing cost, less radio communication interference due to airframe structure, major parts separately replaced (modular changeability), waterproof construction
Camera system	flight stability (for camera stabilization and unskilled pilots), camera lens in a safer location
Operation	one man operable



Figure 2.2a: Pusher type Aircraft Configuration – 1^[12].



Figure 2.2b: Pusher type Aircraft Configuration – 2^[13].



Figure 2.2c: Pusher type Aircraft Configuration – 3^[14].



Figure 2.2d: Pusher type Aircraft Configuration – 4^[15].



Figure 2.2e: Pusher type Aircraft Configuration – 5^[16].



Figure 2.2f: Pusher type Aircraft Configuration – 6^[17].

The present work will focus on the designing the aircraft configuration for the UAV will similar to the aircraft configuration – 7 as depicted in the Figure 2.2f. Engine placement on the vertical stabilizer makes the wing body configuration can be made as streamlined body as possible. Hence drag contribution from wing body part can be minimized.

2.3 UAV components

Basically UAV aircraft is Remote Control (RC) aircraft with autopilot capability. The following diagram shows in figure 2.3 bellows. The components of UAV which make the aircraft be able to fly autonomously. ^[17]

In the simplified form, the component devices which involved in the UAV system as showed in the Figure 2.4 bellows. In the aircraft will have a GPS, Autopilot, Radio Modem, Video Camera, Video transmitter while in the ground will consist computer equipped with Video receiver and radio modem.

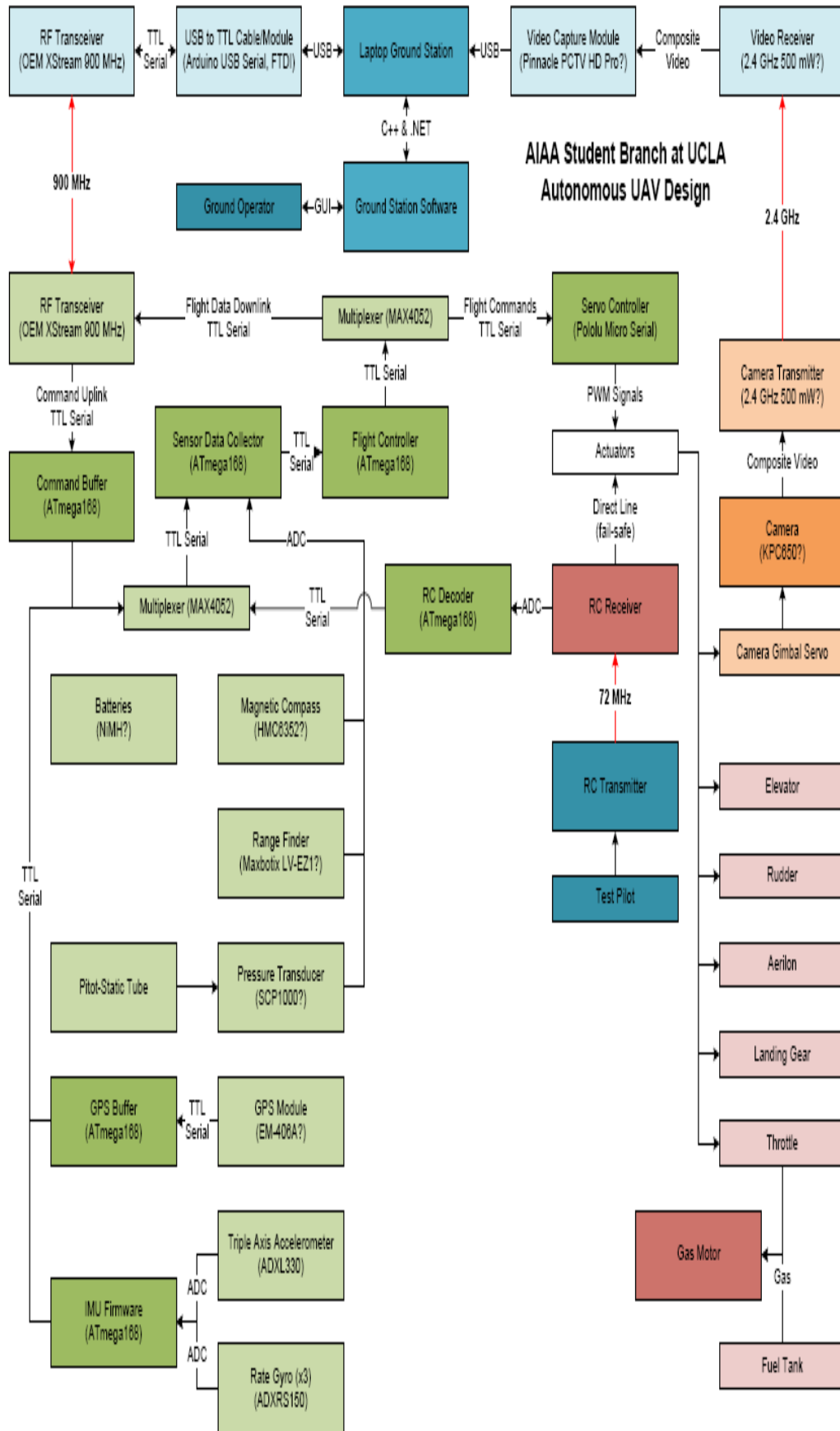


Figure 2.3: Shows how the UAV operated.

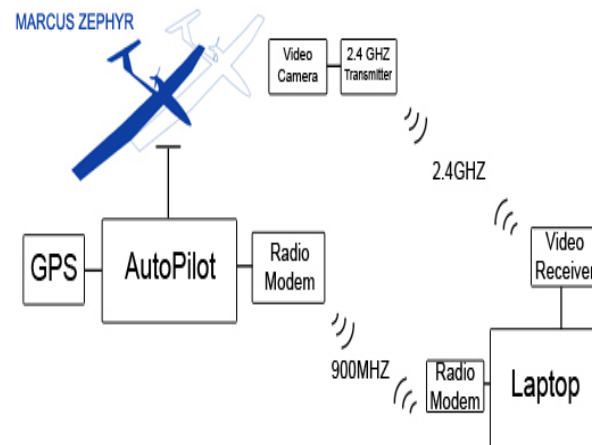


Figure 2.4: Simplified Form UAV Components.

2.3.1 Electric engine review

Basically there are two types engine can be used for powering the aircraft model; they are namely electric engine and piston engine. The size of electric engine is normally smaller than piston engine. However due to the limitation of power resources for running the electric engine, make the electric engine has a limited capability in producing the thrust. The piston engine can designed up to hundreds horse power while the electric engine just only few horse power. The size of electric engine which far below the piston engine for the same thrust has made an interested choice to use that engine. There are two type of electric engine can be used to drive the aircraft model. They are namely a Brushed and Brushless DC motor.

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