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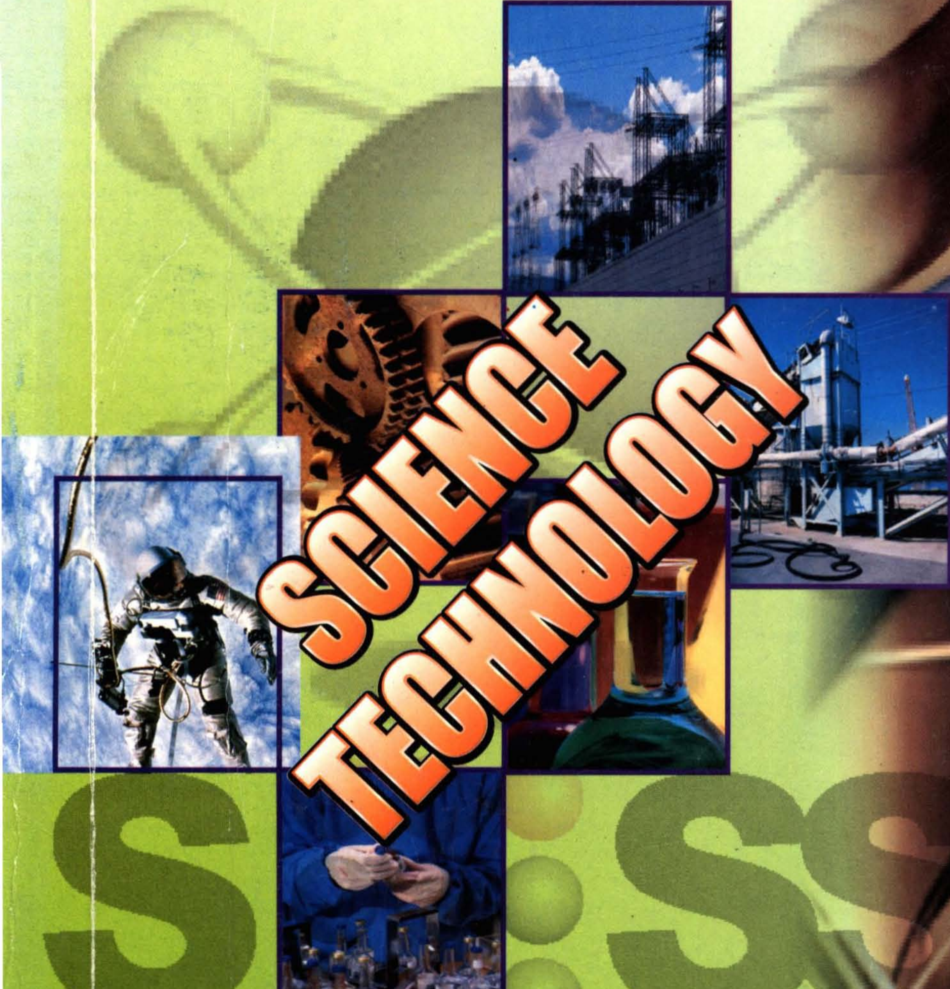

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Payload Characteristics Related to Mission Profile of Unmanned Aerial Vehicle Systems: A Preliminary Study

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ABSTRACT

This paper is a preliminary report of an ongoing study and research of the Unmanned Aerial Vehicle (UAV). The UAV is commonly used as the most effective reconnaissance or tactical method in any particular country. Currently, in the world, there are hundreds of flying UAVs, which had been developed by the government of that particular country or any private company, to compete for the most unique and versatile product for its own usage or marketing purposes. The study involves a research on the payload characteristics, capabilities and categories, which are related to a specific mission profile. Most of the common payload available in the market will be discussed. Various types of mission profile that might further improve the system efficiency will be proposed.

Keywords: *Unmanned Aerial Vehicle, Payload Characteristic, Mission Profile, System Efficiency*

Introduction

The Unmanned Aerial Vehicles (UAV) is not something new in the aviation world. It was developed as early as World War I. UAVs have been referred to with a few names such as Remotely Piloted Vehicles (RPV), drone, robot plane and pilot-less aircraft. The basic definition of UAV is defined by the Department of Defence, US as

> *powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or non-lethal payload.*

UAV System is the most life saving tactics to locate the enemy or any illegal activities being conducted at any location. Currently, in the world there are hundreds of flying UAVs, which have been developed by the government of that country or any private company, to compete for the most unique and versatile product for its own use or marketing purposes. UAVs might soon replace the role of military pilot in the event of war.

Malaysia is not left out in this technology. It has produced a manned or unmanned convertible air vehicle, as a result of the collaboration with BAE Systems and a local company, CTRM. The system, called Eagle ARV, is currently operated by the Malaysian Royal Air Force.

However, variations of purpose lead to different categories of UAV. There are large, medium, small, mini and micro sizes of UAVs in the market. Each size has its own characteristic and mission profile.

UAV Systems

A basic UAV Systems may consist of aerial vehicle, ground control station (GCS), datalink, deployment system, recovery system and payload. Extension of the systems may consist of remote receiving station, field support system, artillery system and any requirement, which required by the mission profile.

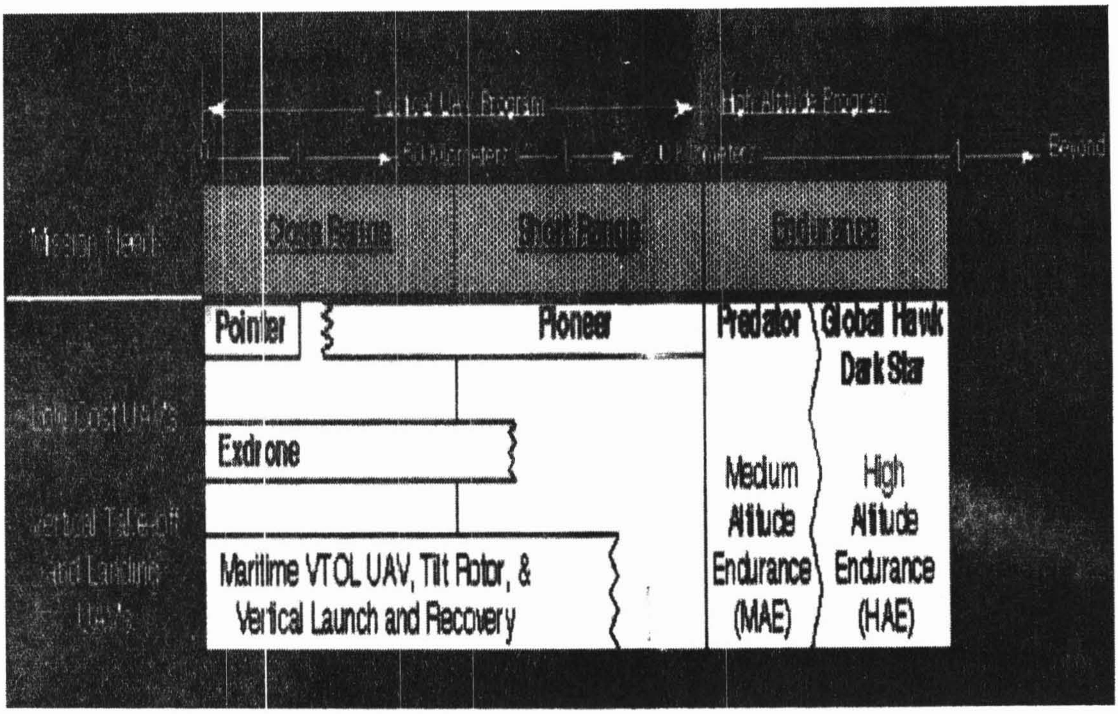

Fig. 1: UAV Categories

Aerial Vehicle

The aerial vehicle is basically a platform used to obtain the desired objectives by the operator. As a platform, the aerial vehicle has certain characteristics, which are based on the requirement of the general mission profile of a particular UAV System. The platform reflects the ceiling height, take-off weight, speed, physical dimension, propulsion system, endurance, payload weight, weight envelope, and flight envelope.

All the necessary avionics equipment installed in the aerial vehicle is to ensure a proper downlink signal can be transmitted to the ground control station for the communication, data transmission, and the most important is payload images. The basic avionics equipment ranges from transmitter, receiver, gyro-stabilizer, Electro-Optical gimballed payload, modem, data encoder, data decoder, speed indicator, height indicator, heading, Global Positioning System, transponder, data processor, servo controller, battery and other further enhancement equipment. The categories of the UAV is also determined by the size of the aerial vehicle, for instant, large scale UAV shall have wing span of 50 to 70 feet, where else, Micro UAV may have wing span around 6 inches.

The location of payload on the aerial vehicle plays the biggest role of a mission. The field of view of the payload is depending on the location of the equipment itself on the aerial vehicle. Common location of the payload is positioned at the belly of the aerial vehicle, where at this location, an average field of view is achieved. Average field of view means the gimbal can have visual on forward, but not extremely forward; and aft view, but not extremely aft. The payload may also be installed near the nose area of the vehicle, to provide an extreme visual of the forward view of the aerial vehicle. However, at this location, the payload might not have a good view towards the aft of the vehicle. Furthermore if the target has passed the vehicle, the vehicle may need to perform a loop in order to have more images on the said/point of target. After all, it depends on the designated mission of the UAV Systems.

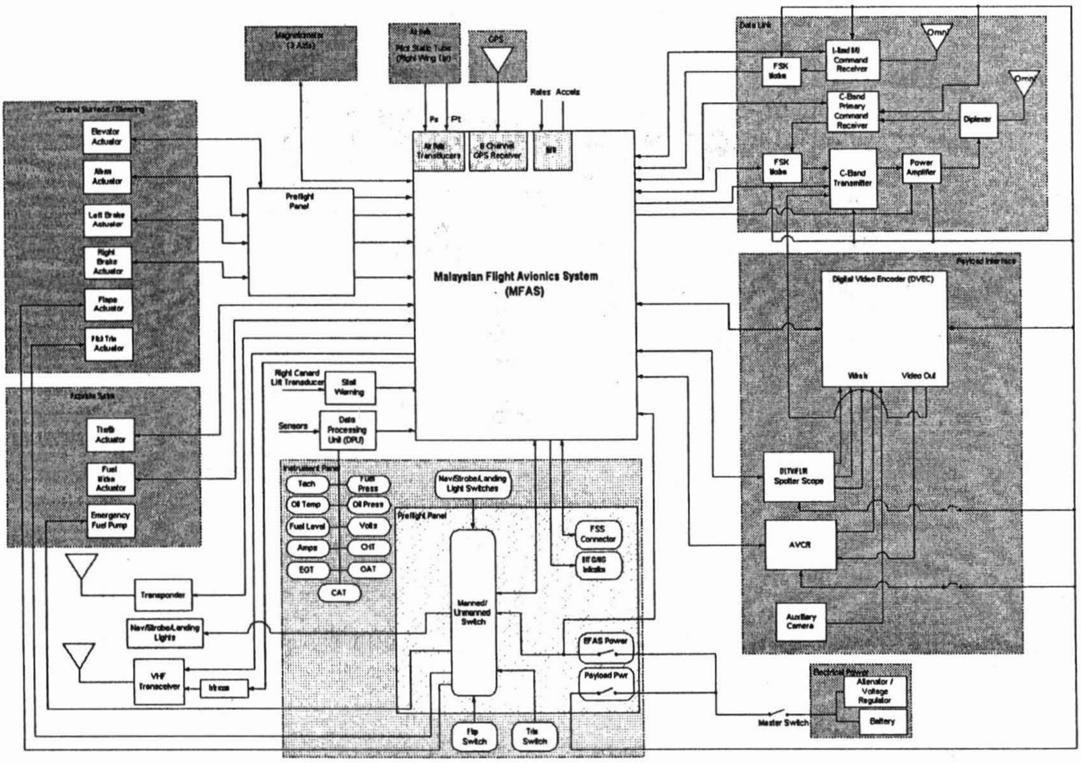

Fig. 2: Schematic Diagram for Aerial Vehicle

Ground Control Station

The Ground Control Station (GCS) is the main control unit for any UAV System. The GCS may be housed in a 4-wheel drive truck for big UAVs application, and just using a laptop as GCS for mini and micro UAVs application. GCS may also be on a fixed station such as a building for a constant monitoring system. The UAV pilot and payload operator are housed in the GCS. Normally, in the GCS there will be 3 computer bays, namely Pilot Bay, Payload Bay and Server Bay. All these computer bays are the interfaces between the operator and the aerial vehicle. At the Pilot Bay, the visual from the cockpit will be displayed and all the telemetry movements of the flight controls exist. Pilots are able to control the aerial vehicle either manually, partial autonomous or fully autonomous. In an autonomous mode, predetermine waypoints are introduced into the system during initial setting up, in order for the aerial vehicle to compute and engage whenever instructed by the pilot. During the autonomous mode, the system will have full control of the aerial vehicle and the pilot may monitor on the movement of flight controls and waypoints travel. At this point, the payload operator will have the control of the camera and perform any specific mission requirement.

The responsibilities of the payload operator are to navigate the aerial vehicle, to perform initial setting up regarding the datalink from the GCS to the aerial vehicle and also to control the Electro-Optical gimballed payload. Global Positioning System is the basic navigation tool, which is used in the UAV System. There are also other navigation tools such as Synthetic Aperture Radar used onboard the UAV. Mapping and global positioning systems will help to navigate the pilot in manoeuvring the aerial vehicle. Datalink transmissions from GCS to the aerial vehicle are made from the payload bay. These data transmissions are encoded before sending through tracking antenna. Data transmitted from GCS to aerial vehicle is called uplink and data transmitted from aerial vehicle to GCS is called downlink. The main responsibility of the payload operator is to capture the real time images from the Electro-Optical gimballed payload onboard the aerial vehicle. These images normally will be recorded as evidence against any issues arise.

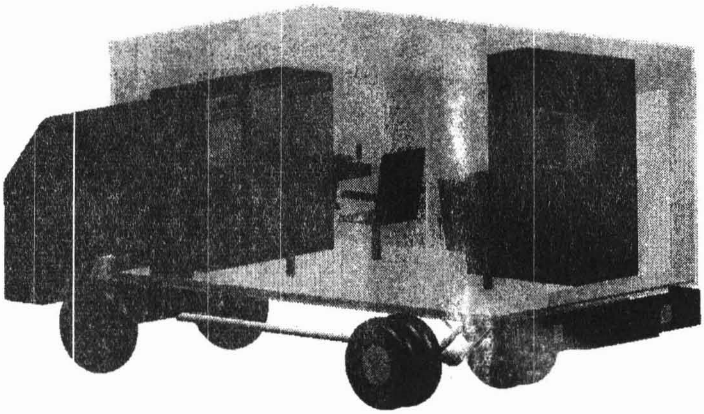

Fig. 3: Ground Control Station

Datalink

The datalink consists of the Ground Data Terminal (GDT) and the Air Data Terminal (ADT). The GDT consists of a primary command uplink; a backup command uplink, which is in a different frequency band; a video downlink; an audio uplink/downlink; and a termination downlink, which is transmitted as a sub-carrier on the video downlink. The link also includes a ranging signal, which is used by the GDT to compute a rough UAV range.

The Primary uplink is a radio frequency link, operating in certain frequency range. It is equipped with a 2x4-foot dish, tracking, antenna, and includes an audio sub-carrier and a range tone interface. The transmitted data is encoded with error detection to prevent the aerial vehicle from receiving and attempting to use erroneous data.

The Backup uplink has the same data format and modulation as the Primary uplink but is on a separate operating frequency. The backup link is continuously available to the aircraft, but contains no audio or range tone data.

The termination downlink has the same data format as the command uplink. The termination downlink is combined with the video DOWNLINK, operating in a certain frequency range. The downlink contains an audio sub-carrier, and a ranging tone. The up-linked ranging signal is looped by the aerial vehicle, and returned to the receiver where the time delay (a subsequent range) is calculated and available to the GCS computers.

The GCS is equipped with a visual display, which includes all required controls and indicators for datalink operation and management, including appropriate downlink functions.

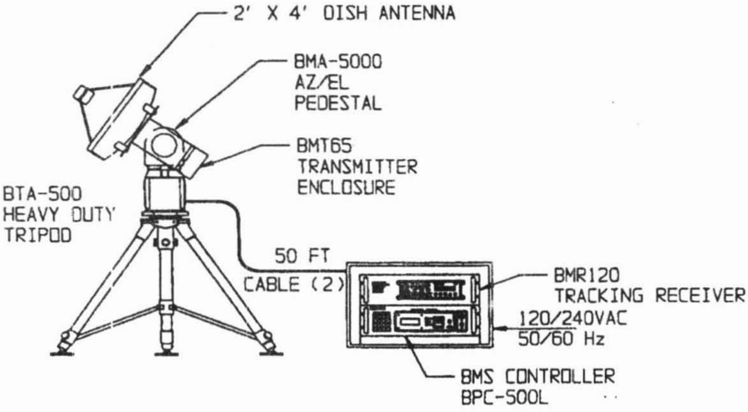

Fig. 4 : Ground Data Terminal

Deployment and Recovery Systems

Deployment of the aerial vehicle may be from a few methods. A typical method is the conventional take-off via a runaway. This method required the aerial vehicle to have landing gear, nose gear and rudder. With the UAV Systems having the aerial vehicle to take-off conventionally, the GCS is more likely to be stationed beside a runaway. However, for an operation where runaway is not available, other methods of deployments are required. The unconventional take-off method may be called as catapult launch. The catapult launcher can be categorized into bungee cord, pneumatic, rocket and hydraulic.

The catapult launcher needs to launch the aerial vehicle at certain speed where the speed is above the stall speed in order for the aerial vehicle to sustain height and climb. Considerations need to be given on the structural strength of the airframe of the aerial vehicle to absorb the force due to the acceleration to obtain the desired speed. The launcher rail is desired to be elevated at certain angle from the ground and the length of the rail will be proportionate to the take-off speed required by the aerial vehicle.

Bungee cord launcher uses an elastic rubber cord as the main energy sources. The potential energy stored during the extension of the cord will produce high acceleration force to pull the aerial vehicle along the rail during take-off. Pneumatic launcher typically uses the pressure to compress the gas and these will energise kinetic energy in the gases to create high force to move the aerial vehicle to the required take-off speed. The hydraulic launcher basically uses the hydraulic fluid to push the aerial vehicle on the rail, while the rocket launcher uses the rocket flame to generate lift for the aerial vehicle. This rocket launcher may or may not use the launcher rail for the take-off purposes since the aerial vehicle is able to manoeuvre using the control surfaces. Mini and Micro UAVs categories normally are launched using hand launch due to the fact that the weight of these UAVs scale is less and force required to produce the required speed are within the human capability.

There are a few recovery methods for the unmanned aerial vehicles. Other than the conventional landing, the aerial vehicle may be recovered by parachute, net, hook arrester, and belly landing. These recovery systems need to be suitable with the application of the UAVs. However, if the luxury of runaway is available, then, the best recovery is still the conventional recovery method.

Parachute recovery is a recovery system using onboard parachute where it will be deployed when the button for parachute deployment is triggered. Parachute also may act as a speed reducer for certain UAV during landing on the runaway. Other than that, parachute may also be used to terminate the UAV during lost of link or damage during testing. The size of the parachute has to cater for the maximum take-off weight of the aerial vehicle. On the other hand, parachute obviously contributes significant weight to the whole aircraft.

Net recovery usually will be useful under circumstances where the landing areas are very limited such as in the jungle, carrier ship or in the dessert where the ground is very unstable. The main criterion for the net recovery system is that the propulsion system of the aerial vehicle must not be at the nose of the aircraft. In other words, only a pusher configuration of aerial vehicle is applicable.

Hook arrester is used to reduce the speed of the aerial vehicle and at the same time to bring the aircraft to stop. This application may only be used at a short runaway or aircraft carrier ship. Belly landing is used for the UAV in the class of mini and micro where these UAV do not have landing gear and were launched via hand launch.

Payload

Payload for UAVs is normally referred to the onboard sensor capability in performing the mission tasked to the system. There are a few categories of UAV payloads such as electro-optical gimballed, radar, missile, Laser, Infrared and a few more. Payload plays the most important role in any mission since the images from the payloads are the core intention of the mission. Multiple payload sensors are currently highly desirable to be onboard the aerial vehicle in order for the systems to have capability of performing not only single mission profile. A few examples of multiple payload sensors are WESCAM™ MX-20 series, where this gimballed having up to five sensors such as Infrared, Daylight TV, Long-Range spotter scope, Laser Range Finder and Laser Illuminator. FLIR SYSTEMS™ having Star Shipborne Airborne Forward-looking Infrared Equipment (SAFIRE) ™ , SAGEM™ , TIS Limited and many more which keep on competing to invent high end visual images for the unmanned industries.

Furthermore, even though a multiple and good payload are used, installation of the payloads are crucial to the image quality during operation. The payload need to be mounted semi-rigid at the belly of the fuselage, or at any location with references to the mission profile and initial design specification of the systems, and shock mount is compulsory, otherwise, the vibration from engine and from wind turbulent may caused massive vibration to the images. Careful selection on the shock mount had to be made, otherwise, the vibration might get worse with a wrong kind of shock mount. Normally, vibration caused by the engine contains two kinds of frequencies. Installing a hard rubber mount at the engine mounting may eliminate the low frequency vibration. The high frequency vibration usually will not really cause the payload to vibrate as bad as the low frequency vibration, and this situation may be eliminated by using pure latex shock mount and mounted at the payload mount.

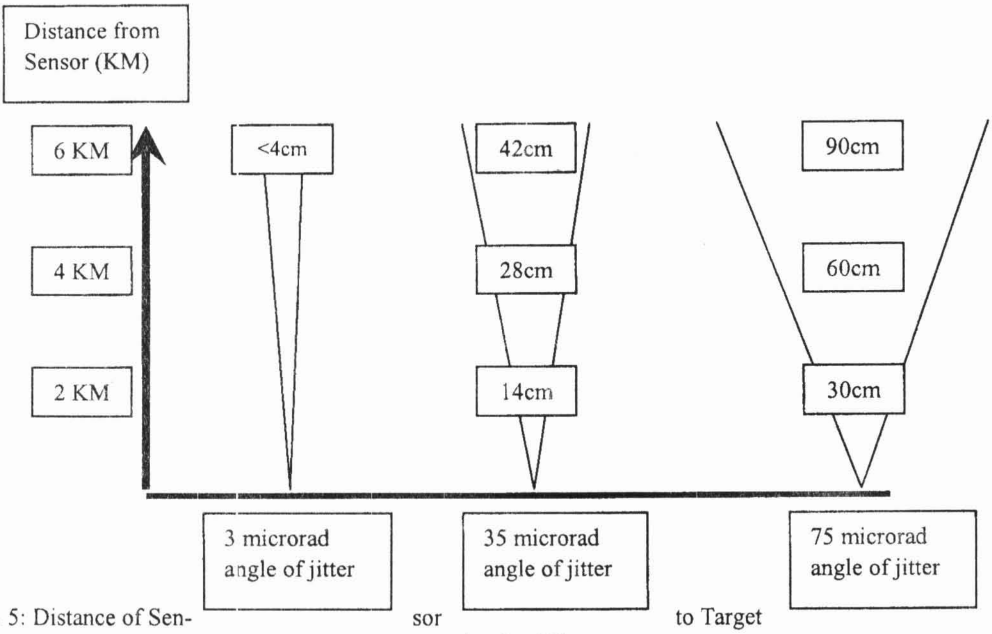

Fig. 5: Distance of Sensor to Target against Angle of Jitter

Cover for the payload is desired and it has to be air-tight to prevent air from flowing through the fuselage and causing more drag. The location of the payload installed is very important. One needs to choose a location, which has maximum angle of view with less interference with other equipment mounted in the fuselage and the landing gear. Payload is desired to have at least two degrees freedom of rotation, the pan and tilt axis. These will allow the payload operator to easily locate and focus on the desired target during any mission.

The payload operator will be based in the Ground Control Station next to the pilot, the payload operator needs to communicate with the pilot from time to time for ease of images capturing during any mission.

Mission Profile

Any particular UAV Systems are designed to fulfil the required mission profile. Mission profile varies from military to civilian application where for the military purposes, high-end UAVs profile is required for its mission. Civilian purpose ranges from agricultural, mapping system, chemical-bio reconnaissance and mine countermeasures. Where else military purpose ranges from surveillance, reconnaissance, artillery target acquisition, battle damage assessment, electronic warfare, combat Synthetic Aperture Radar, data relay, search mission, strike mission, border security and furthermore.

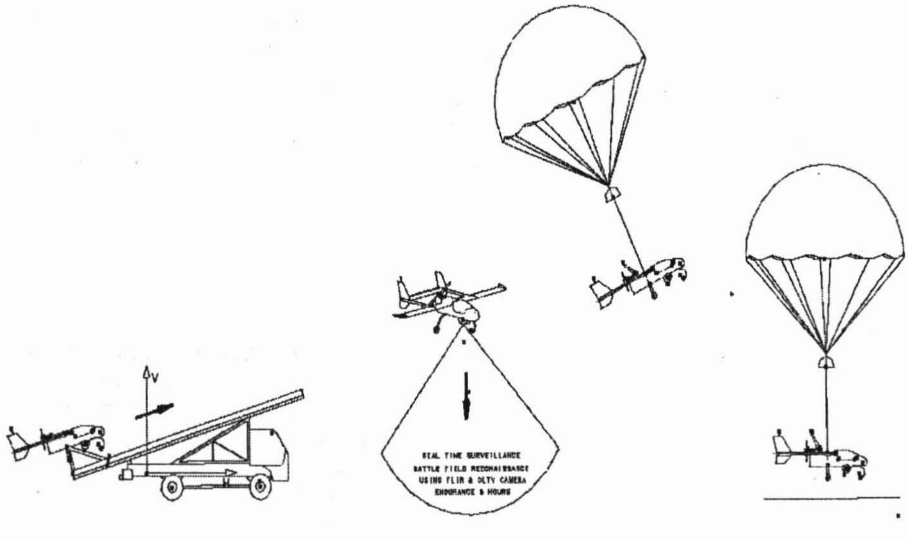

Fig. 6: Typical Mission Profile

Agricultural

UAVs applications in the agricultural sectors focuses on the crop spraying, plant growth monitoring, seeding and others. Each of the mission profile requires different kinds of payload. For example, crop spraying may need more weight on the chemical pesticide compared to the optical payload. On the other hand, plant growth monitoring mission may require an aerial vehicle that is able to hover and equipped with spotter scope optical camera capability.

Mapping Systems

Mission profile related to mapping systems may require the aerial vehicle to operate at high altitude in order to capture best coverage of images for mapping. Hyperspectral mapper is required as the payload for this mission. Spotter scope and Infrared are not applicable for this kind of mission due to the fact that the Infrared is used for night vision or to differentiate heat and cold elements, and Spotter scope is used for an optimum zoom mission.

Artillery Target Acquisition

Laser Range Finder together with accurate coordinate systems is required as the payload for the artillery target acquisition mission. The Infrared also may be required since the target mission might take place during night time. The coordinates are vital for the artillery targeting. The tolerance of error has to be very minimal from the coordinate in order for the artillery firing to take place.

Data Relay

Mission profile for the data relay does not have requirement for any kind of optical payload. The aerial vehicle only needs a communication repeater, a few sets of transmitters and receivers with different frequencies, a set of antenna with respective frequencies or one antenna with multiple frequencies transmission. UAV performing data relay mission is desirable for the tactical war strategies.

UAVs also have been considered for a mission to team up with manned aircraft to carry our operational mission and also aerial refuelling port. Another, a far more difficult future task, could be air-to-air combat. The Department of Defence, US, is experimenting with outfitting today's UAVs with the sensors and weapons required to conduct such a mission. In fact, a Predator has reportedly already been engaged in air-to-air combat with an Iraqi fighter aircraft. In March 2003 it was reported that a Predator launched a Stinger air-to-air missile at an Iraqi MiG before the Iraqi aircraft shot it down. While this operational encounter may be a "baby step" on the way toward an aerial combat capability, it appears significant. Aerial combat is often described as the most challenging mission for manned aircraft to perform, and, some say, one that UAVs will never be able to accomplish. Though embryonic, the recent Predator launch of an air-to-air missile will likely hearten UAV advocates who wish to see more aggressive missions for unmanned aircraft.

All these missions require different types of payload in order to accomplish. Payload capabilities have to be analysed in order to obtain a suitable payload that suits the mission profile. The payload specification from the manufacturer such as Wescan, FLIR, Sagem, TIS will compete to produce a payload, which may be capable of performing as many missions as possible. However, as the user of UAV, thorough consideration of all aspects and specifications of the payloads have to be done during the initial stage of the UAV mission design and detailed specification design.

Discussion

As we can evaluate from this preliminary report, not all payload may suit all the mission profiles, even though the payload manufacturer are trying their best to compete amongst themselves to produce an optimal payload for most mission profiles. However, multiple mission profiles are still limited to be carried out based on a single payload.

Installation of more than one payload onto one aerial vehicle might be considered, but weight constraint and interfaces complications need to be clarified and solved in order to avoid instability in the systems. Furthermore, good images from payload will be considered based on the quality of the installation of that payload. Poor installation will introduce vibration to the images and perhaps will limit the payload performance from its original specifications.

One of the primary concerns about UAV roles and applications is "gold plating." Some have declared that if the military does not control requirements creep, UAVs will be priced out of business. The fear is that good designs will become loaded up with more sensors, more weapons, and more missions until they become too expensive to build or too valuable to use (and risk losing) in combat. Additional potential impediments include negative aviation culture mindsets and command, control, and communications bandwidth limitations and constraints.

Conclusion

In this preliminary study on the payload characteristics related to mission profile, it can be concluded that, in order to have an effective mission, a multiple payload capability is desired. For a typical mission profile, an electro-optical gimballed payload is appropriate. However, for special mission such as electronic warfare, data relay and strike missions, specific payloads are required.

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