CHAPTER II
LITERATURE REVIEW

2.1 Definition of UAV

[1] Henri Eisenbeiss from the Institute for Geodesy and Photogrammetry explores the definition of UAVs in a photogrammetrical context and states that "the name UAV covers all vehicles, which are flying in the air with no person onboard with capability controlling the aircraft". The definition is inclusive of all similar terms such as Remotely Piloted Vehicles (RPV), Remotely Operated Aircraft (ROA), Remote Controlled Helicopter (RC-Helicopter) and Unmanned Vehicle Systems (UVS).

[2] "UAVs are to be understood as uninhabited and reusable motorized aerial vehicles." states van Blyenburgh, 1999. These vehicles are remotely controlled, semi-autonomous, autonomous, or have a combination of these capabilities. Comparing UAV to manned aircraft, it is obvious that the main difference between the two systems is that on the UAV no pilot is physically present in the aircraft. This does not necessarily imply that an UAV flies by itself autonomously. In many cases, the crew (operator, backup-pilot etc.) responsible for a UAV is larger than that of a conventional aircraft.

2.2 Historical background

Unmanned Aerial Vehicles (UAVs) have been referred to in many ways: RPVs (remotely piloted vehicle), drones, robot planes, and pilotless aircraft are a few such names. Most often called UAVs, they are defined by the Department of Defense (DOD) 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 nonlethal payload. Ballistic or semiballistic vehicles, cruise missiles, and artillery projectiles are not considered UAVs by the DOD definition. [3] UAVs differ from RPVs in that some

UAVs can fly autonomously. UAVs are either described as a single air vehicle (with associated surveillance sensors), or a UAV system, which usually consists of three to six air vehicles, a ground control station, and support equipment.

The military effectiveness of UAVs in recent conflicts such as Iraq 2003, Afghanistan 2001, and Kosovo 1999 has opened the eyes of many to the advantages and disadvantages provided by unmanned aircraft. Long relegated to the sidelines in military operations, UAVs are now making national headlines as they assume missions normally reserved for manned aircraft. UAVs are thought to offer two main advantages over manned aircraft: they are arguably cheaper to procure, and they eliminate the risk to a pilot's life. UAVs protect the lives of pilots by performing the "3-D" missions - those dull, dirty, or dangerous missions that do not require a pilot in the cockpit. However, the lower procurement cost of UAVs must be weighed against their greater proclivity to crash, while the minimized risk should be weighed against the dangers inherent in having an unmanned vehicle flying in airspace shared with manned assets.

There are a number of reasons why UAVs have only recently been given a higher priority. Technology is now available that wasn't available just a few short years ago. Some say that the services' so-called "silk scarf syndrome" of preferring manned aviation over unmanned, has diminished as UAVs entered the mainstream. UAVs might have gained momentum earlier if a crisis had occurred, such as an extreme shortage of surveillance and reconnaissance aircraft during a conflict. The lack of such a crisis, along with the paradigm shift that needed to occur before unmanned vehicles were accepted, meant that UAVs have evolved as technology has become available.

Although only recently procured in significant numbers by the United States, UAVs have had a century-old history in aviation. First included in *Jane's All the World's Aircraft* in 1920, UAVs were tested during World War I, but not used in combat by the United States during that war. Germany's use of the simple yet deadly V-1 "flying bomb" during World War II, laid the groundwork for post-war UAV programs in the United States. However, it was not until the Vietnam War that UAVs such as the AQM-34 Firebee were used in a surveillance role. The Firebee exemplifies the versatility of UAVs – initially flown in the 1970s, it was recently modified to deliver payloads and flew its first flight test as an armed UAV on December 20, 2002. [4]

The Israeli Air Force pioneered several UAVs in the late 1970s and 1980s that were eventually integrated into the United States's UAV inventory. U.S. observers noticed Israel's successful use of UAVs during operations in Lebanon in 1982, encouraging then-Navy Secretary John Lehman to acquire a UAV capability for the Navy. Interest also grew in other parts of the Pentagon, and the Reagan Administration's FY1987 budget submission included increased UAV procurement. [5] This marked the transition of UAVs in the United States from experimental projects to acquisition programs.

2.2.1 Use in military

[6] In the 1960s, the US started to develop 'drones', which were unmanned vehicles built for spying and reconnaissance. This was after they lost a manned spy aircraft to the Russians and a U-2 to Cuba. The first such drone was the 'Firebee' drone, a jet propelled by an engine made by Ryan Aeronautical Company. They were initially used heavily over Communist China in the 1960s, when major flaws were discovered and corrected.

The Vietnam War was the first time that UAVs, the drones in particular, were used extensively in reconnaissance and combat roles. A large number of Firebee drones, were launched for simple day reconnaissance activities. At first, they had simple cameras on them. Later, they were equipped with night photos, communications and electronic intelligence.

Over the last few years, it has been Israel that has been responsible for much of the development that has happened in the UAV sector. The Hunter and the Pioneer, which are used extensively by the US military, are direct derivatives of Israeli systems. The Pioneer was used in the Gulf War to good effect.

Following the Gulf War, officials recognized the importance of unmanned systems. The Predator, first an Advanced Technology Demonstration Project, demonstrated its worth in the skies over the Balkans. Some of the current versions of the Predator are loaded with Hellfire missiles for attack purposes.

Another popular UAV is the Global Hawk. This is a jet powered UAV that was used effectively in Afghanistan. It operates at around 60,000 feet, and carries a wide range of sensors.

UAVs that are in use and under development are both long-range and high-endurance vehicles. The Predator, for instance, can stay in the air for around 40 hours. The Global Hawk can stay in the air for 24 hours.

2.2.2 Commercial Applications

Unmanned aircraft are slowing finding their way into commercial applications. The US government is looking into using UAVs for surveillance over high crime areas, in order to prevent crimes from happening. They could also be used to control 'hot spots', where violence takes place habitually.

Table 2.1 UAVs are finding use in the following industrial fields

Industry.	Use of UAVs.
Agricultural industry.	UAVs equipped with fertilizer and pesticide dispersing equipment can be used to spray over large fields.
Crop monitoring.	Right now, only over 10% of the crops in the US are being monitored by aircraft. Use of UAVs would greatly increase the region or area under surveillance.
Environmental control / weather research.	Weather balloons are being used to monitor the weather on the ground.
Mineral exploration.	UAVs are being used in aerial survey and ground survey to find minerals on desolate and hard-to-reach regions.
Coast watch.	UAVs are being used by the coast guard for monitoring coastlines.
Telecommunications.	UAVs are finding use in telecommunications applications as mobile relay platforms, as well as in disaster zones for emergency telecommunications.
News broadcasting.	UAVs are finding use in providing aerial video feeds for news events where reporters cannot get to in time.
Remote sensing of marine resources.	Marine labs are using UAVs to detect the presence of resources under the sea that are inaccessible to humans.
Unexploded artillery detection.	UAVs are now being developed that can detect unexploded artillery, especially dangerous mines.
Air Traffic Control.	UAVs can be used to monitor air traffic over busy airports.
Ground traffic control.	UAVs are beginning to be used to monitor traffic and accidents over major state highways.

Source: [7]

2.3 Types of UAV

At present, there is no generally accepted classification system for UAVs. Potentially, UAVs can be classified in several ways, according to criteria such as the control system, sensor and mission. Two distinct groups result if the classification is based on the control system; The RPV and autonomous UAV. While sharing features, there operation is quite different. An RPV follows the data link commands for remote station to achieve a specific mission while the autonomous UAV is usually pre-programmed to complete a specific mission. UAV can be further classified based on weather they are either expandable (i.e. single mission, typically a missile) or recoverable to a particular friendly location (Multi mission). The modern air, land or sea launch cruise missile is an essence a sophisticated, autonomous, single mission UAV. Another sub category is the target drone or decoy which is known as unmanned aerial targets (UATs). They may be either remotely piloted or autonomously controlled, depending upon the nature of the task. The block diagram of types of UAVs shown is below

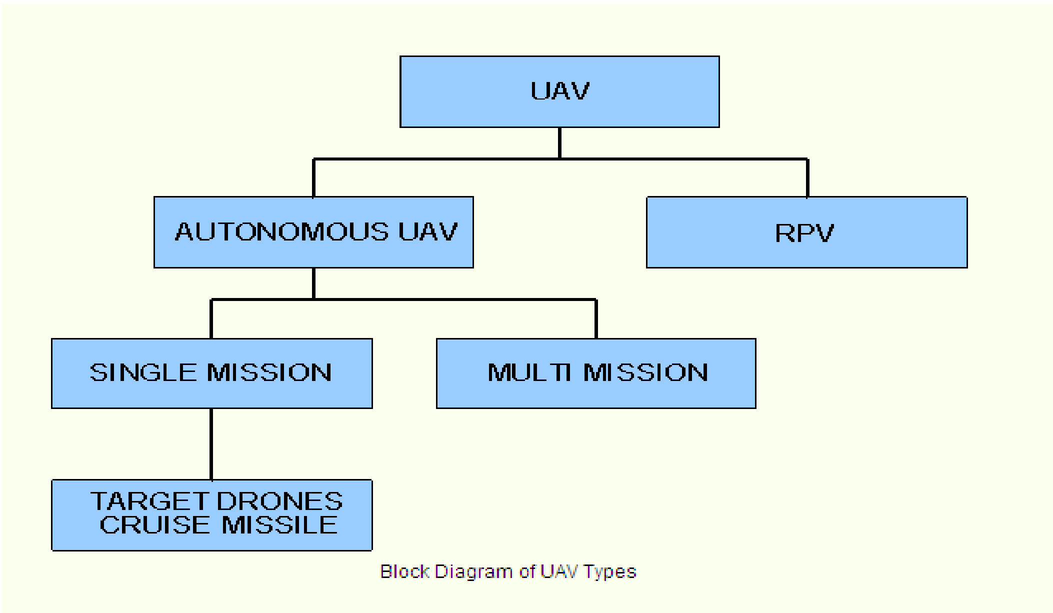


Figure 2.1 Block Diagram of UAV Types

Source: [8]

2.4 UAV System Components

From the above definition and discussion on the classification of UAV some general characteristics of UAV can be identified. These characteristics are determined by the UAV design, construction, on board and ground support systems which in turn are determined by five key operational requirements; Endurance, speed, radius of action, altitude and gross take off rate. The detailed block and system diagram of UAV is as follows.

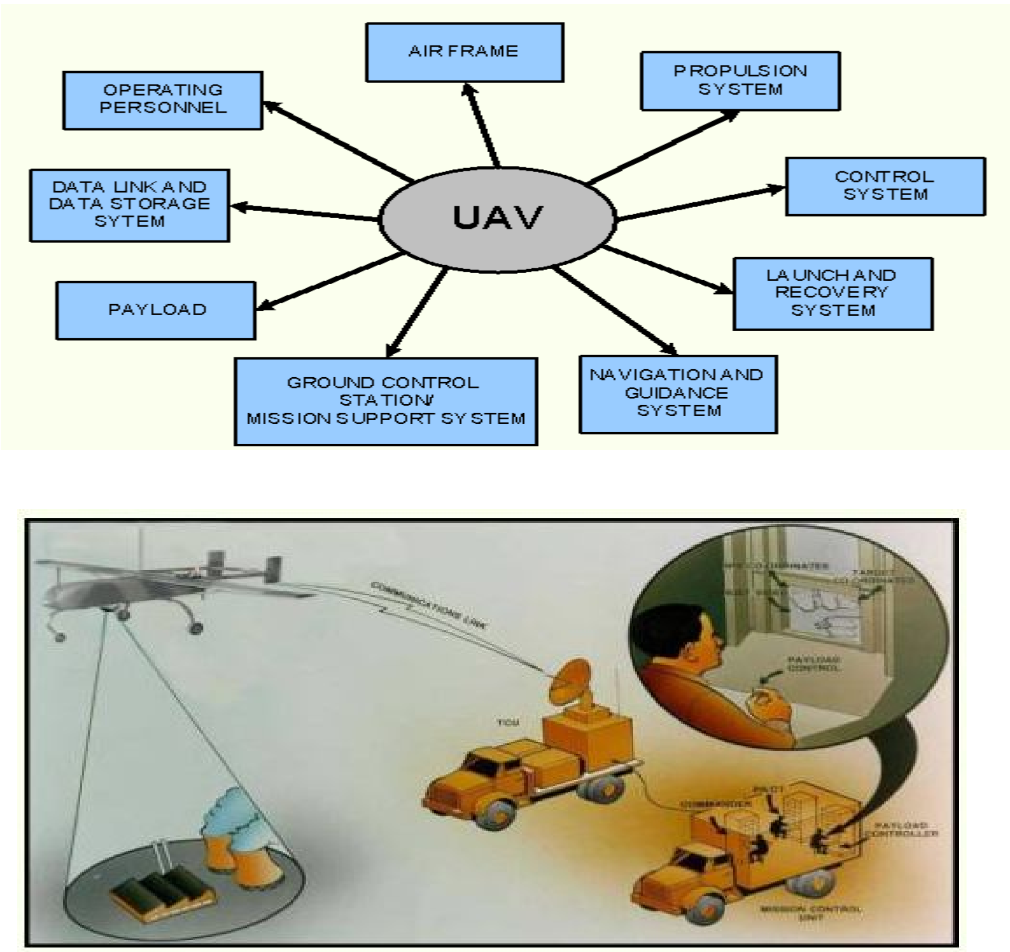


Figure 2.2 UAV System Diagram

Source: [8]

2.5 Definition of photogrammetry

Photogrammetry has been defined by the American Society for Photogrammety and Remote Sensing as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recording, measuring, and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena. As implied by its name, the science originally consisted of analyzing photographs. Although photogrammetry has expanded include analysis of other records, such as digital imagery, radiated acoustical energy patterns, laser ranging measurements, and magnetic phenomena, photographs are still the principal source of information. In this text photographic and digital photogrammetry are emphasized, but other sources of information are also discussed.

Included within the definition of photogrammetry are two distinct areas: (1) metric photogrammetry and (2) interpretative photogrammetry. Metric photogrammetry consists of making precise measurements from photos and other information sources to determine, in general, the relative locations of points. This enables finding distances, angles, areas, volumes, elevations, and sizes and shapes of objects. The most common applications of metric photogrammetry are the preparation of planimetric and topographic maps from photographs and the production of digital orthophotos from scanned photography. The photographs are most often aerial (taken from an airborne vehicle), but terrestrial photos (taken from earth-based cameras) and satellite imagery are also used.

Interpretative photogrammetry deals principally in recognizing and identifying objects and judging their significance through careful and systematic analysis. It includes branches of photographic interpretation and remote sensing. Photographic interpretation includes the study of photographic images, while remote sensing includes not only the analysis of photography but also the use of data gathered sensors, thermal scanners, and side-looking airborne radar. Remote sensing instrument, which are often carried in vehicles as remote as orbiting satellites, are capable of providing quantitative as well as quantitative information about objects. At present, with our recognition of the importance of preserving our environment and natural resources, photographic interpretation and remote sensing are both being employed extensively as tools in management and planning. [9]

2.6 Uses of Photogrammetry

The earliest applications of photogrammetry were in topographic mapping, and today that use is still the most common of photogrammetric activities. At present, the U.S. Geological Survey (USGS), the federal agency charged with mapping the United States, performs nearly 100 percent of its map compilation photogrammetrically. State department of transportation also use photogrammetry almost exclusively in preparing their topographic maps. In additional, private engineering and surveying firms prepare many special-purpose topographic maps photogrammetrically. These maps vary in scale from large to small and are used in planning and designing highways, railroads, rapid transit systems, bridges, pipelines, aqueducts, transmission lines, hydroelectric dams, flood control structures, river and harbor improvements, urban renewal projects, etc. A huge quantity of topographic maps are prepared for use in providing spatial data for geographic information systems.

Phogrammetry has become an exceptionally valuable tool in the land surveying. To mention just a few uses in the field, aerial photo can be used as rough base maps for relocating existing property boundaries. If the point of beginning or any corners can be located with respect to ground features that can be identified on the photo, the entire parcel can be plotted on the photo from the property description. All corners can then be located on the photo in the relation to identifiable ground features which, when located in the field, greatly assist in finding the actual property corners. Aerial photos can also be used in the planning ground surveys. Through stereoscopic viewing, the area can be studied in three dimensions. Access routes to remote areas can be identified, and surveying lines of least resistance through difficult terrain or forests can be found. The photogrammetrist can prepare a map of an area without actually setting foot on the ground an advantage which circumvents problems of gaining access to private land for ground surveys.

Photogrammetry has been used successfully in traffic management and in traffic accident investigations. One advantage of its use in the latter area is that photographs overlook nothing that maybe needed later to reconstruct the accident, and it is possible to restore normal traffic flow quickly. Even in the field of medicine and dentistry, measurements from X-ray and other photographs and images have been useful in diagnosis and treatment. Of course, one of the oldest and still most important uses of photography is in military intelligence. Space exploration is one of the new and exciting areas where photogrammetry is being utilized.

Photogrammetry has become a powerful research tool because it affords the unique advantage of permitting instantaneous recordings of dynamic occurrences to be captured in images. Measurements from photographs of quantities such as beam or pavement deflection under impact loads may easily be obtained photographically where such measurements would otherwise be nearly impossible.

As notes earlier, photogrammetry has become extreamely important in the developing field of *geographic information systems (GIS)*. [9]

2.7 Photogrammetry and Geographic Information Systems

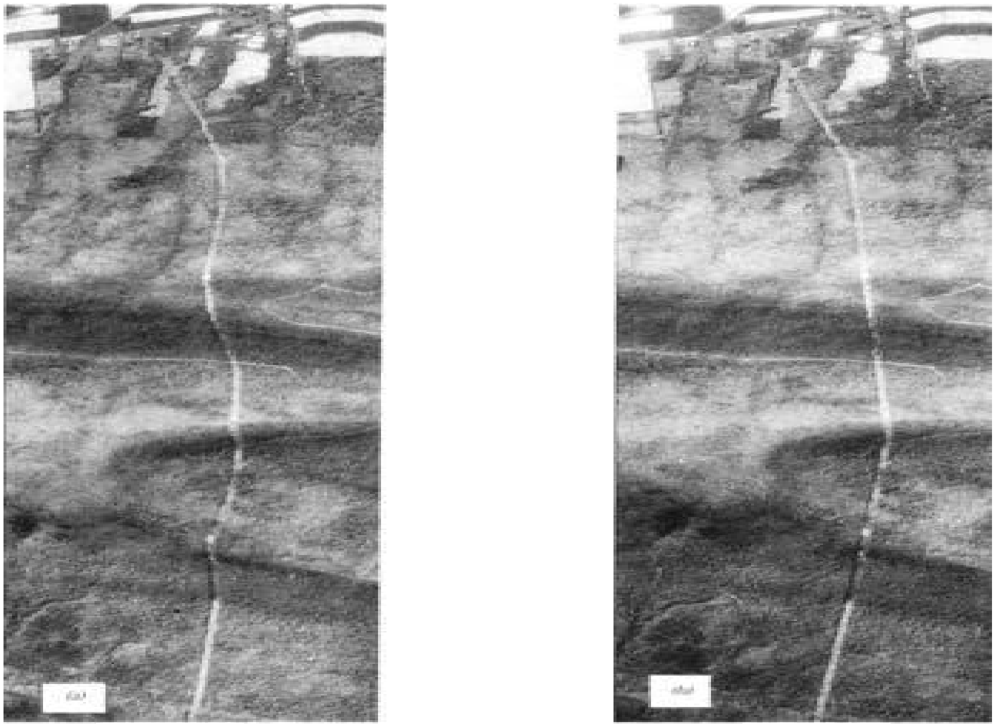
Geographic Information Systems, although relatively new, have rapidly gained a position of prominence in many fields. These computer-based systems enable storing, integrating, manipulating, analyzing, and displaying virtually any type of spatially related information about the environment. They are being used at all levels of government, and by businesses, private industry, and decision making.

An essential element of any GIS is a complex relational database. The information that comprises the database usually includes both natural and cultural features. Specific types of information, *or layers*, within the database may include political boundaries, individual property ownership, transportation networks, utilities, topography, hydrography, soil types, land use, vegetation types, wetlands, etc. To be of use in a GIS, however, all data must be spatial related; i.e., all the data must be in a common geography frame of reference. Photogrammetry is ideal for deriving much of this layered information. As noted in the preceding section, topography maps, digital elevation models, and digital orthophotos are example of photogrammetric products which are now commonly employed in developing these spatially related layers of information. By employing photogrammetry the data can be compiled more economically than through surveying methods and this can be achieved with comparable or even greater spatial accuracy. Furthermore, the data are compiled directly in digital format, and thus are compatible for direct entry into GIS databases. [9]

2.8 Orthophotos

As implied by their name, orthophotos are orthographic photographs; in essence, they are "photomaps." Like maps, they have on scale (even varying terrain), and like photographs, they show the terrain in actual detail (not by lines and symbols). Hence, orthophotos give the resource analyst the "best of both world"- a product that can be easily interpreted like a photograph, but one on which true distances, angles, and areas may be measured directly. Because features can be photo interpreted in their true, planimetric positions, orthophotos make excellent base maps for resource surveys. They also enhance the communication of the resource data, since users can often relate better to the orrthophoto than to a conventional line and symbol base map.

Orthophotos are generated from overlapping conventional photos in a process called differential rectification. The result of this process is elimination of photo scale variation and image displacement resulting from relief and tilt. Figure 2.3 illustrates the effect of this process. Figure 2.3a is a conventional (perspective) photograph of a power line clearing traversing a hilly forested area. The excessively crooked appearance of the clearing is due to relief displacement. Figure 2.3b is a portion of an orthophoto covering the same area. In this image, relief displacement has been removed and the true path of the power line is shown.



(a) (b)

Figure 2.3 Portion of a perspective photograph (a) and an orthophoto (b) showing a power line clearing traversing hilly terrain. (Note the excessive crookedness of the power line clearing in the perspective photo that is eliminated in the orthophoto.) (Courtesy USGS.)

Source : [10]

2.9 UAV photogrammetry

The new terminology UAV photogrammetry [11] describes a photogrammetric measurement platform, which operates remotely controlled, semi-autonomously, or autonomously, without a pilot sitting in the vehicle. The platform is equipped with a photogrammetric measurement system, including, but not limited to a small or medium size still-video or video camera, thermal or infrared camera systems, airborne LiDAR system, or a combination thereof. Current standard UAVs allow the registration and tracking of the position and orientation of the implemented sensors in a local or global coordinate system. Hence, UAV photogrammetry can be understood as a new photogrammetric measurement tool. UAV photogrammetry opens various new applications in the close range domain, combining aerial and terrestrial photogrammetry, but also introduces new (near-) real time application and low-cost alternatives to the classical manned aerial photogrammtery.

2.10 Limitations in the use of UAVs

UAVs, especially low-cost UAVs, limit the sensor payload in weight and dimension, so that often low weight sensors like small or medium format amateur cameras are selected. Therefore, in comparison to large format cameras, UAVs have to acquire a higher number of images in order to obtain the same image coverage and comparable image resolution. Moreover, low-cost sensors are normally less stable than high-end sensors, which results in a reduced image quality. In addition, these payload limitations require the use of low weight navigation units, which implies less accurate results for the orientation of the sensors. Furthermore, low-cost UAVs are normally equipped with less powerful engines, limiting the reachable altitude.

Existing commercial software packages applied for photogrammetric data processing are rarely set up to support UAV images, as through no standardized workflows and sensor models are being implemented.

In addition to these drawbacks, UAVs do not benefit from the sensing and intelligent features of human beings. Thus, UAVs cannot react like human beings in unexpected situations, e.g. unexpected appearance of an obstacle. In general there are no sufficient regulations for UAVs given by the civil and security authorities. [12]

Based on the communication and steering unit of UAVs, we can state that the operation distance depends on the range of the radio link for rotary and fixed wing UAVs, which is equivalent to the length of the rope for kites and balloon systems used in the past. In addition, the radio frequencies (35 and 40MHz in Switzerland) maybe subject to interferences caused by other systems (remote controlled cars and model aircrafts, as well as citizens' band radio), which use the same frequencies, or may suffer from signal jamming. Thus, depending on the local situation of the area of interest, the frequency for the communication between GCS and UAV has to be selected carefully. Nowadays, UAVs are also controlled via 2.4GHZ radio connection, while the video link has to be shifted to 5 GHz.

2.11 Related Researches

Panlop and Sutum [13]. Studies the aerial survey of mining area by RPV and remote control. The objectives of this research project are to study build a medium-sized, remotely pilotted vehicle (RPV) with a flight control range of 1600 metres. The RPV is equipped with a camera for taking aerial photographs of a mining area, of which the result is to be compared with ground survey. The project has accomplished complete aerial photographs of small quarry, one picture of which covers all benchmarks that can be used to compare with the coordinates obtained from ground survey. As a result of aerial survey at the flight height of 350 metres above ground, a mapping error between 0.38-0.83 metres are attained. In order to stabilize the RPV movement and correctly level the camera while taking a picture, the rate gyros system is installed to automatically prevent pitching in lateral axis. A future research should concentrate on the process of directly leveling the camera, and applying instruments for recording flight height and position in order to photogrammetrically determine an elevation of the object. In conclusion, the aerial survey of mining areas by using the RPV is proved to be an economic approach to achieve aerial maps that can be used for general planning.

Wanwisa [14]. Studied the software development of rotational image stabilization for UAV. The result of vibration or rotation of video frame, leading to inconvenience of object to be observed and tracked, we have to compensate vibration and rotation of video frame. This can be done by using stabilization of video display. This thesis develops computer program to stabilize rotated video frame by employing feature tracking to warping rotated video frame in order stabilize video frame. Developed computer program gives satisfying result since video frame can be completely compensated for the rotation.

Ammarin [15]. Studied a collision-free path planning for UAV in dynamic environment. The objective of this work is to develop an algorithm for UAV so that it can avoid an obstacle and fly to the given waypoint safety. Here an path planning algorithm is developed by investigating feasible paths of a UAV. The dynamic constraint of UAV and its effect on path are studied. Subsequently, a shortest path problem is explored to ensure that performance of path planning. The Dijkstra's algorithm, which is a Breadth First Search method, is chosen for its superior computational ability. With good understanding on both components of path planning, an algorithm with obstacles in consideration is developed. The collision avoidance algorithm for UAV developed here is a result from combining the two elements described above: feasible paths and shortest path problem. Given relative location of an obstacle that is detected during flying, no-fly zone is constructed around the obstacle. Collision free path that both satisfy dynamic constraint are constructed. Dijkstra's is then employed to select path with best performance. This work also studies possibility of expanding to a larger system such as more obstacles. Computational burden and a way to reduce it are also discussed.

Jutatip [16]. Studies GIS-Aided flight planning of unmanned aerial vehicle for aerial photographing. This research aims to develop ArcGIS application program for automatic flight planning. The work divided into three parts. The first, to analyze digital elevation model, sun angle and azimuth to determine the date and time during which light condition is appropriate. Secondly, the program generates the sample points above the target. These sample points are tested if they satisfy the following criteria; the target can be seen from the candidate position, look angle is checked with the camera specification, the candidate position is outside restricted area and terrain clearance is more than safe height above ground. Finally, flight path is calculated by computing visibility graph of points, interior or on boundary of flyable polygon which dangerous or restricted area is excluded. Then Dijkstra's algorithm is applied to determine shortest path between airfield and the selected UAV position in visibility graph. The shortest path will be checked for visibility and avoiding obstacles problems. If any path segments do not pass a criterion, they become no-go-zone.

Software will create flyable zone which excludes no-go-zone and calculate flight path again until path passing all criteria.

Eisenbeiss [1]. Researched a mini unmanned aerial vehicle (UAV) and image acquisition. The UAV (Unmanned Aerial Vehicle)-systems became relevant for applications in precision farming and in infrastructure maintenance, like road maintenance and dam surveillance. This paper gives an overview about UAV (Unmanned Aerial Vehicle) systems and their application for photogrammetric recording and documentation of cultural heritage. First the historical development of UAV systems and the definition of UAV-helicopters will be given. The advantages of a photogrammetric system on-board a model helicopter will be briefly discussed and compared to standard aerial and terrestrial photogrammetry. UAVs are mostly low cost systems and flexible and therefore a suitable alternative solution compared to other mobile mapping systems. A mini UAV-system was used for photogrammetric image data acquisition near Palpa in Peru. A settlement from the 13th century AD, which was presumably used as a mine, was flown with a model helicopter. Based on the image data, an accurate 3D-model will be generated in the future. With an orthophoto and a DEM derived from aerial images in a scale of 1:7 000, a flight planning was build up. The determined flying positions were implemented in the flight control system. Thus, the helicopter is able to fly to predefined pathpoints automatically. Tests in Switzerland and the flights in Pinchango Alto showed that using the built-in GPS/INS- and stabilization units of the flight control system, predefined positions could be reached exactly to acquire the images. The predicted strip crossings and flying height were kept accurately in the autonomous flying mode.

Haarbrink and Koers [17]. Researched helicopter UAV for photogrammetry and rapid response. MIRAMAP and E-Producties have developed a fully operational helicopter UAV with automatic triggering capability for photogrammetric image acquisition and rapid response operations. The helicopter UAV has a 2.8-meter rotor span and includes a state-of-the-art navigation and control system for hands-off autonomous flight with a ground control station. The platform is enhanced with a live video downlink and an automatic camera triggering system of a nadir mounted digital camera with a calibrated lens. The digital frames come with position, attitude and timing information for further photogrammetric processing. The system features were tailored to the needs of first responders for rescue and recovery operations in the event of a natural or terrorist disaster, but can be applied for other applications such as inspection work as well. A system demonstration to quickly produce 1-cm digital orthophotos was performed in the summer of 2006 in collaboration with the Dutch government.