Kamicam

Students: M. Bakker, R.H.S. Bruinen, P.D. Evers, H.G. Goossens, F.G.G. van Hellenberg Hubar, L.P. Maaskant,
J.C. Oostelbos, R.R. van der Werf,
W.H. van der Woerdt and H.M. Yildizturan

Project tutor: dr.ir. B.G.H. Gorte

Coaches: ir. G.J. van Zwieten, ir. S.S. Soudarissanane

1 Introduction

Unmanned Aerial Vehicles (UAVs) are becoming increasingly useful in society. A large spectrum of applications are covered both by aeronautical and spatial UAVs. These applications vary in military field from reconnaissance to attack and in the increasing civil market from fire fighting to crowd control and observation. Numerous designs have been build to cover this range of different applications. While large and expensive UAVs operate in many theaters, there is a need for local intelligence gathering using small, low cost and often disposable UAV platforms. The use of UAVs is currently limited by the cost of the systems and the need for skilled operators of the equipment.

This resulted in the following mission need statement:

With a group of ten students, in ten weeks time, design a small UAV that produces aerial imagery, which can be operated by untrained users and which will have such low production costs that it can be used as a disposable product.

This summary aims to give an overview of the total project and focuses on the detailed design of the system. After a review of the requirements and concept selection, a design of the different subsystems of the Kamicam will be explained. Finally some conclusions and recommendations will be made.

2 Requirements

Due to the great amount of UAVs already available on the market first an extensive market orientation was performed. The starting point for this market orientation is given by the technology segmentation, as illustrated in table 15.1. This table also provides several markets that are considered to belong to the specific technology segment. A subject as broad as UAVs can be divided in many different ways. However, table 1 offers a clear distinction between two fundamental properties of a UAV.

The first division, controllable and uncontrollable, limits the vehicle in its maneuverability. Controllable is defined to be the active control of the vehicle by either user input or preprogrammed computer algorithm. Uncontrollable means that little or no active control, as defined above, is possible. For example, a mini glider spiraling down with a fixed aileron setting is considered to be uncontrollable.

	Uncontrollable	*Controllable*
Unpowered	- News items - Amateur imagery & Gifts - Tourism - Advertisement	- Music videos - Amateur imagery & Gifts - Real estate & Architecture photography - Advertisement
Powered	- Amateur imagery - Firefighters surveillance - Scientifc research	- Security surveillance - Reconnaissance and attack (military) - Government permit control - Border surveillance - Agricultural surveillance or spread chemicals - Concert/sport event registration - Search and rescue missions - Scientifc research - Wild life Observation - Movie footage - Pipeline inspection (hazardous territory) - Construction site overview - Real estate & Architecture photography

Table 1: Technology segmentation

Considering all four technology segments, the cross-combination controllable & non-powered UAVs, is thought to be the least interesting. In the case of the segment powered & controllable UAVs, the requirements regarding controllability and portability will put a level of complexity on the design. This will make it very difficult, to make it low cost. Besides that, many UAVs already exist in this technology segment.

Hence, it is concluded that the technology segments uncontrollable & powered/non-powered UAVs provide the most interesting markets and applications for news, amateurs, tourism and advertisement. This technical segmentation is chosen for the DSE and lead to the following key requirements:

- Minimum height of 50 m
- Reusable
- Land within a circle of 25 meters radius from launch location
- Photography: take pictures
- Video: more then 15 sec.
- Carriable, mass less than 5 kg, including possible launch system
- Low material cost: less than 200 Euro
- Storage: more then 512 MB
- User should not need special training
- Not dangerous to third parties

3 Conceptual design

During the conceptual design phase of the DSE the above mentioned requirements resulted in the following six concepts.

Concept 1 and 2: Tandem rotor and conventional helicopter
The tandem rotor uses two counter rotating rotors next to each other. Also a small tail has been added for both pitch stability and to keep the vehicle facing into the wind.
The rotors can be tilted against the wind to bring the vehicle back to the user. A control system will be necessary to do so which will make the system too complex and expensive. figures 1 and 2 depict an artist impression of a tandem rotor and a conventional helicopter, respectively.

Figure 1: Tandem rotor

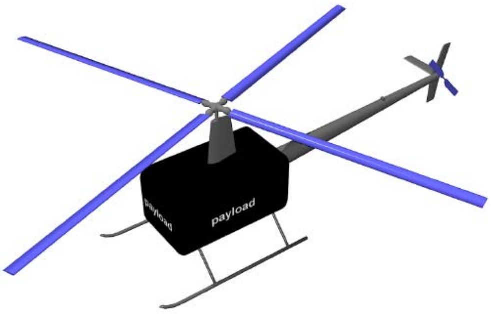

Figure 2: Conventional helicopter

The conventional helicopter is a proven concept. The size, mass and power budget for this design is very similar to those for the tandem configuration. However, the tail of this concept will take somewhat more space, compared to a tandem rotor. As with the Tandem Rotor, the conventional helicopter will require an active control system to bring it back to the user.

Concept 3 and 4: Autogyro and glider

The Autogyro is a vehicle that will need an external launcher, and will be deployed at its maximum altitude. At maximum altitude the rotor blades will deploy and automatically start rotating.

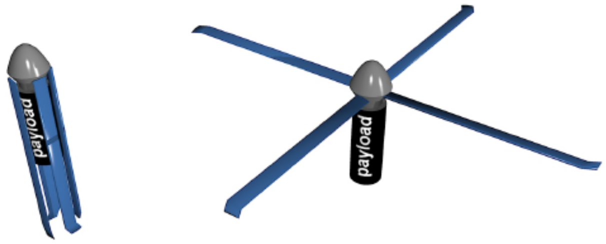

Figure 3: Autogyro undeployed and deployed

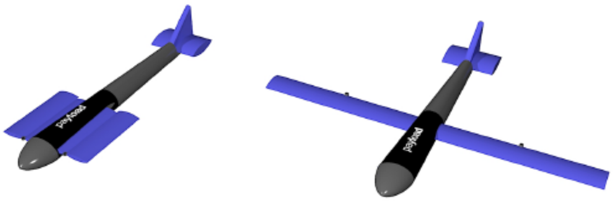

Figure 4: Glider undeployed and deployed

The glider will not use internal propulsion and hence will have to be launched. It will use wings that deploy at apogee height. Figures 3 and 4 show an artist impression of an autogyro and a glider, respectively.

Concept 5 and 6: Parachute and kite

The parachute will also need an external launcher. After the deployment the parachute creates a lot of drag to decrease the airspeed of the payload to a minimum. Due to its negative aerodynamic properties it is very susceptible to wind.

Figure 5: Paracute and kite

The kite is also externally launched and deployed. It is lightweight and offers great steering capabilities, since a kite can create lift. Furthermore, it can easily be deployed when using an open cell structure. Figure 5 shows a model of the parachute design and the kite design.

15.4 Trade-off

During the trade-off process the glider, parachute, conventional helicopter and autogyro where eliminated because they could not fulfil the requirements set. The Tandem Rotor and the Kite came out as feasible candidates. The kite finally came out as the best design option because it needs no active control system, it is a very easy system and does not weigh much.

15.5 Final design

This section will describe the final detailed design. The design of the launch system, the capsule, the imaging subsystem and the kite will be treated into more detail.

Launch system

The launch system is produced of a PET (Polyethylene) body with an Aluminum support. The user can apply the necessary pressure to the pressure chamber by either a hand pump or using CO_2 capsules. The maximum pressure of 10 bars will result in a deployment altitude of 100 meters. The pressure can be released by the diaphragm valve which is remotely controlled by the user. To return the imaging device to the user, the incidence angle has to be adjusted to the wind speed. To not endanger the user or third parties, the launcher is equipped with a tilt sensor and an approximation sensor. Figure 15.6 represents a model of the launcher.

Figure 6: Exploded view of the launcher and the launcher at maximum incidence angle

Capsule
It was calculated that the optimum inner diameter of the launch tube is 8 centimetre, due to the least pressure losses. Hence the diameter of the capsule is 8 centimetre. The capsule is build of two half spheres with a radius of 4 centimetres and a cylindrical part in the middle with a length of 1 centimetre. The cylindrical part is for guiding the capsule in the launch tube. The outer shell will be produced of the synthetic material polypropene, which is known for its lightweight and high toughness properties. A cut out in front of the lens will be made from clear Plexiglas. To handle the launch and landing loads a rubber damping system is used.

To deploy the kite, the capsule has a moment spring which tends to open the two halves of the capsule. While the capsule is in the coasting phase of its trajectory a pin will lock the upper and the bottom parts together. At apogee the linear actuator will release the pin from its lock. When the pin has been released the kite will unfold. To detect apogee, a timer will be used. This timer will be switched on by the accelerometer. An undeployed and deployed version of the capsule can be seen in figures 15.7 and 15.8 respectively.

Figure 7: Undeployed capsule

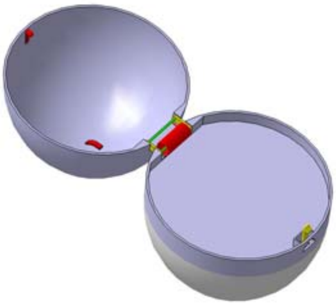

Figure 8: Deployed capsule

Imaging subsystem

In order to provide aerial imagery the payload of the capsule consists of an imaging device. In this device a lens, a photonic sensor and storage capacity are integrated as can be seen in figure 9. To avoid vulnerable moving parts in the design, the decision has been made to use a fixed camera instead of a rotating camera. To still ensure the user that a picture is taken of the desired object, the camera uses burst mode during the capsule's descent. This means 2 high resolution pictures per second are taken during the entire descent as can be seen in figure 10.

Figure 9: Exploded view of the imaging subsystem

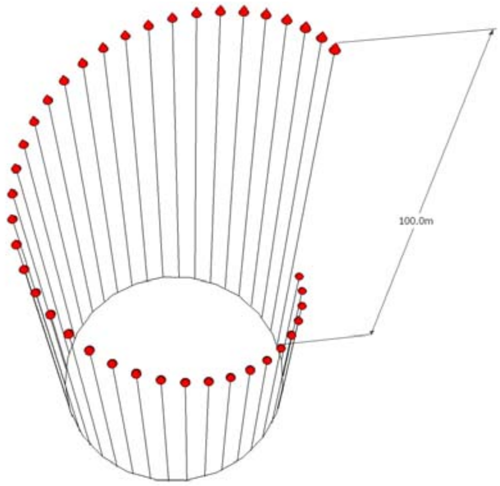

Figure 10: Camera viewpoints during descent

This allows for a large amount of pictures per launch. Now combining these pictures would provide a suitable overview of the desired area. This is done by a software program called 'Autostitch', which, as the name implies, can stitch pictures together automatically, based on image recognition technologies. Ultimately the user is provided with a large, high resolution, overview of the area from which the launch has taken place.

Kite

The kite will be of the Fast Wing type which is known for its high lift over drag ratio and easy deployment. It is built up of an upper skin, lower skin and 17 ribs in between. The ribs are airfoils of the type CIM-2016 which is a well known parafoil airfoil. It has an inlet at the leading edge for easy inflation of the kite after deployment. The fabric is of the lightweight Chikara rip-stop nylon type with a weight of 42 grams per square meter. The total weight of the kite including lines, connections and sewing is 31.11 grams. The control of the kite is in a passive way, so that the kite spirals down after deployment. Figure 11 shows an impression of the kite.

Figure 11: CATIA 3D model of the kite and capsule

6 Conclusions and recommendations

The objective of this Design Synthesis Exercise (DSE) project was to design an Unmanned Aerial Vehicle (UAV) that produces aerial imagery based on a low-cost and easy to use system. Since this assignment was very broad, the target market first had to be narrowed down, in order to make a good design. After an initial market orientation, the general consumer market and especially the tourist market was the best choice to focus on. This meant that low-cost and easy to use became even more important then stipulated in the assignment.

The complete system consists of a launcher that uses air pressure to launch a capsule to a fixed height of 100 m. The capsule holds the camera and all the required electronics as well as a kite. The kite is deployed at apogee to slow down the descent and provide enough endurance to take the desired pictures. All pictures are stored on an onboard memory card. In order to retrieve the device easily the kite is fixed in such a way that it enters into a spiralling motion and the effect of wind is countered by launching the capsule against the wind. The camera will take a picture every half a second and the user can use computer programs like AutoStitch to post process the pictures and enhance its quality.

A mass and cost estimation of the system mentioned above can be found in table 2. The system is easy to use and the price and weight are very acceptable for its main customer segment. The design satisfies most requirements and the design is ready for the manufacturing of a first prototype.

Subsystem	Mass [gram]	Cost [€]
Launcher	1556	58.57
Kite	30	9.33
Capsule	62	7.00
Deployment mechanism	53	21.60
Camera	122	100.00
Total	1823	196.80

Table 2: Mass and cost estimation of the entire system

Although the key requirements are satisfied, there are still some recommendations which can be made, given as follows:

- The kite is controlled by a passive system. A fully automatically controlled version could be designed to bring the system back to the user within a few meters. The flight path will be more stable resulting in pictures which can be processed easier in programs as Autostitch or Photomodeller.
- The launch system is designed to a bare minimum to keep the cost an mass as low as possible. It is quite likely that a more luxurious version should be available for the user that wants more. Obviously, this entails an increase in mass as well. One could think of:
    - a digital wind meter, directly coupled to the launcher
    - a digital input and display, to set the incidence angle and chamber pressure

  - a servo to tilt the barrel to the required incidence angle
  - if weight is less important: a compressor to pressurize the chamber
  - a wireless remote control to give the launch command
- Although care has been taken about the assumptions and simplifications for the required pressure of the launcher, the only real validation is of course testing the actual rig. Only then can one really say whether the pressure was adequate or not. So it is highly recommended to test the launcher in terms of required pressure.
- The deployment of the kite is hard to predict, easy deployment is accomplished by a tactically placed inlet and a porous fabric. The deployment should be tested though, because it is the most important part of the flight phase. A non-deployment can damage the whole structure and endanger third parties
- In order to broaden the means of post-processing possibilities, it would be advisable to develop a software package, specially dedicated to the Kamicam system.
- Besides software, one should also consider the possibility of developing a dedicated camera. Being perfectly suited for Kamicam, this camera would significantly increase the system's performance.