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Łukasz Sawicki, Jacek Widziszowski,
Norman Płaskociński
State School of Higher Education in Chełm, Poland

DESIGN CONCEPT OF A LONG-ENDURANCE UNMANNED AERIAL VEHICLE

The work includes concept of hybrid of a lighter-than-air and heavier-than-air aircraft. The following summary presents a rough idea of this solution. This allows the ship to fly quickly to the destination and then move like an airship.

From the beginning of an existence of aviation we can observe a development of reconnaissance. The idea is to provide the great number of information and monitor the situation in the area. The History starts during the First World War, when airplanes were used to determine positions and numbers of the enemy troops. Along with the technological development, surveillance aircrafts evolved as well. It is said that with the current level of knowledge about electronics, system of transmitting data and informatics, we are able to check everything we want. It is possible due to the use of satellites which are equipped with high resolution cameras.

However, there is a problem when clouds or fog appear. Then the ground is shadowed by them and the satellites become useless for a while. Their using is also difficult , because has only the country where they were made in has full access to them and it may not want to share information from the satellites with the others.

During the ages there were created a lot of UAVs which ideas are:

a) remote controlling by the man or fly autonomously based on pre-programmed flight plans using complex dynamic automation systems;

b) penetrating areas which may be too dangerous for piloted craft;

c) continuous data transmission;

d) great endurance of a flight;

e) small dimension;

f) lower price of manufacturing and exploitation than manned aircrafts;

g) remote sensing functions include electromagnetic spectrum sensors, biological sensors, and chemical sensors.

Majority of UAVs measure up above-mentioned criteria, but they are still aircraft or they are vehicles which are able to fly by being supported by the air, or in general, the atmosphere of a planet. An aircraft counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil or in a few cases the downward thrust from jet engines.

Previous UAVs are being useless when the ceiling of clouds is too low. The flight close to the clouds is inefficient because they are in a zone of poor visibility and the quality of a camera image would not be good . There is a possibility to fly under the clouds, close to the ground, but the camera will not be able to record anything due to its own limitations, which result from too slow refreshing.

There are also UAVs which fly at a very high altitude but, they need much more accurate equipment and much more advanced transmitting data system than usual. All these factors result in higher cost of production and much more expensive operation.

A new way of development in UAVs is a hybrid airship. This is an aircraft that combines characteristics of heavier-than-air, (HTA),and lighter than air (LTA), aerostat technology. It uses "aerostatic" lift which is a buoyant force that does not require movement through the surrounding air mass. This contrasts with aerodynes that primarily use aerodynamic lift which requires the movement of at least some part of the aircraft through the surrounding air mass. Such properties we can obtain by constructing a variable-volume fuselage. During a take off and proceed to designating place of penetrating its characteristic is HTA, but shortly after reaching checkpoint, a tight crust which is situated at the top of the fuselage, is filled by the helium. That solution has the following advantages:

a) flight with small speed;

b) high maneuverability;

c) flight at low altitudes;

d) extension of a endurance of the flight;

e) decrease in operating costs;

f) mobility.

UAV which is equipped in IR camera can be used for looking for people who are lost during bad weather conditions or for patrolling border area.

Our UAV is characterized by the variable-volume fuselage. At the top, there is an envelope which is attached with flexible carbon ribs. One of the ends is attached to the rigid part of the fuselage, however the second one to the extendable boom which allow us to change the curvature of the ribs.

Moreover in the bottom part of the fuselage there is a tank which contains compressed, gas lighter than air (about 200 m^3).We take into consideration two of them: hydrogen and helium. The first one is less dense , much cheaper but it is flammable, helium is not, so probably we will use it for safety reasons. The container is equipped with a valve which is responsible for the gas flow and it is connected via pipe with the envelope. Compression of the gas is done by compressor which is powered by battery.

It is important that the ribs have different cross sections along their length.

General description:

1) rigid part of the fuselage where the ribs are attached;

2) gas container (1300 x 60) will be made to withstand a pressure about 350 bars. The gas before it was sucked would be compressed by 3 – steps compressor;

3) interior of the envelope;

4) electric motor which is responsible for compressive of the ribs;

5) extendable boom;

6) brackets.

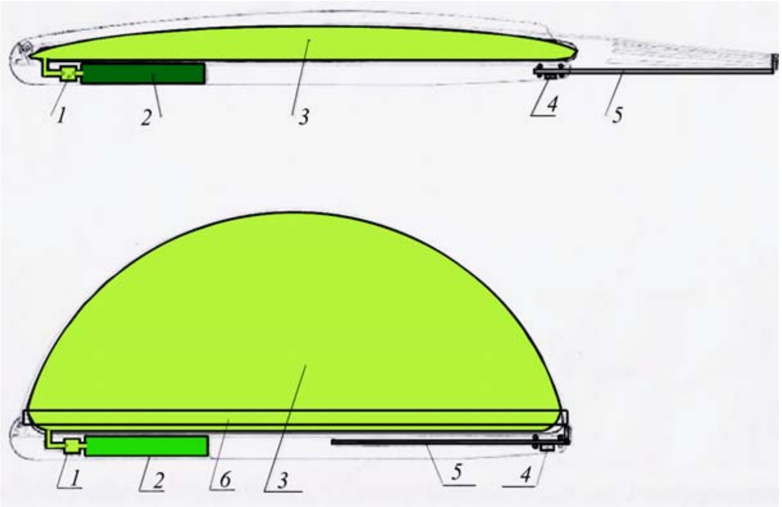

Fig. 1. Unmanned aerial vehicle with the fuselage of variable volume . Authors' own research

A fuselage of the UAV will be made entirely of laminate with a variable circular cross – section. Its length will depend on the phase of the flight and it will be adequately 9 and 12 metres. The structure will consist of openwork, laser-cut, carbon – glass frames in order to obtain high accuracy of development. It will be divided into 3 sections which are showed in the picture number two.

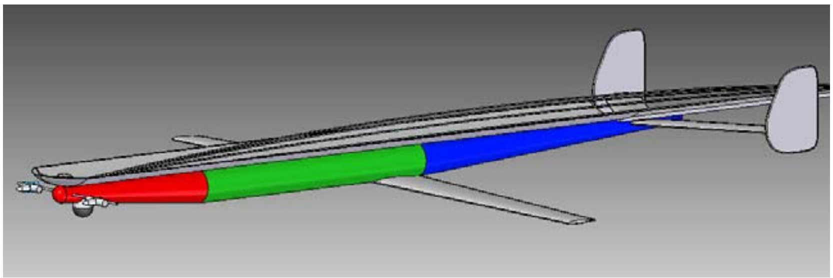

Fig. 2. Fuselage. Authors' own research

Inside the first of them (red one) there will be:

a) camera

b) GPS

c) autopilot with on-board computer

d) transmitter and receiver

e) two batteries

In the second one (green one) there will be placed container with helium and wings will be attached.

In the third section (blue one) there will be attached vertical stabilizer (slanting, span – 4000 mm and with chord 600 mm which will be made on simmetrical airfoil HQ) and dual, oval tail-plane with eliptical leading edge. Their dimensions were designed due to less effectiveness when working in aerostat configuration.

Tapered wings with 8 metres span were designed to base on RG – 15 airfoil with 600 mm chords at the fuselage and 400 mm at the end of the wing. Inside there will be stored 100 litres of fuel which will supply two internal combustions engines and will be transported by membrane pump. Uniform distribution of fuel will prevent changing a centre of gravity, which is located in one third of the chord.

During the selection of airfoil we took into the consideration the best C_l/C_d ratio of cruising speed. We considered seriously only two airfoils, namely RG – 15 and SD 7037. The first of them is suitable for gliders. It copes with thermal conditions and during migration from one thermal column to another. However the second one is much faster and it was made for heavier than usual constructions and motor gliders.

At carbon tube(diameter 50 mm), in the front of the fuselage, there will be two two-stroke engines with power of 18 horse power each and thrust about 120 kilos. Behind them there will be two alternators which will charge the batteries.

Recommended propeller: 32 x 12.

Specifications:

Displacement: 10.48 ci (171.8 cc)

Output: 18 hp

Weight: 7.85 lbs (3.56 kilos)

Bore: 2.0472 in (52 mm)

Stroke: 1.594 in (40.49 mm)

Length: 7.67 in (195 mm)

RPM Range: 1,000 to 6,500

RPM Max: 9,200

Fuel Consumption: 4 oz/min at 6,000 RPM

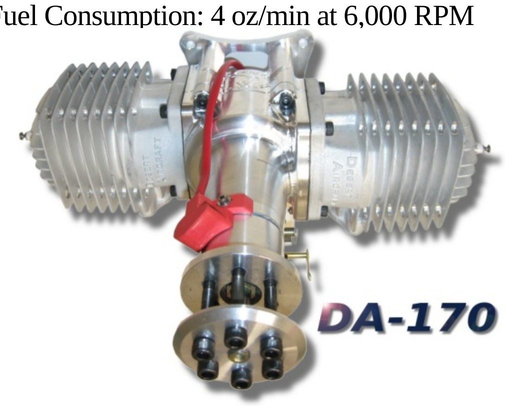

Fig. 3. Picture of DA – 170 engine
http://desertaircraft.com/engines_detail.php?Page=DA-170

Engines were chosen with the aim of low consumption (6.1 liters / h at 6000 rpm), which will ensure the endurance of the flight about 160 hours. It will be possible thanks to the shell of gas with a variable volume, the buoyant force will allow us to reduce engine speed to minimum (about 1000 rpm) and the burning of fuel to 0.25 l/h. Because of that we will be able to fly at a cruising speed about

15 – 20 km/h.

That endurance will decrease when the wind is too strong. Fuel consumption will be about 100 liters (24 liters to proceed on target and 76 on a mission), assuming that the wind speed at 300 meters will not exceed 30 knots. In comparison, the cost of operating an aircraft that is currently used by Polish Border Guard is about 800$ p/h, without the salaries of three crew members. Estimated hourly cost of one flight of our UAV will be oscillated between 100 – 200$. A big part of that expenditure will be the data transfer.

Expected take – off weight will be about 250 kilos, of which:

lp.	Element	Mass [kilos]
1	Airframe + Gas container	120
2	Engines	7
3	Fuel	70
4	Gas	17
5	Equipment on board	15
6	Battery 2 x 5AH	3
Total		238

In the landing configuration after burning fuel, UAV will weigh about 185 kilos.

The airplane, which is presented by us, would be equipped with high-end electronics to allow the exercise of flight in autopilot mode, using a GPS system to indicate areas of the task. The autopilot works based on a gyroscopes, which provides us the correct position of the aircraft in flight. It controls engines thrust and can also operates the thermal imaging camera. It will be switched on immediately after launching from the catapult and will be able to work, uninterrupted, until returning home. Then it will be taken over by the ground operator.

The specifications and software of the autopilot is presented below:

AP50 Auto-Pilot

Specifications

Weight:

50 grams

Size:

144 mm

47 mm

28 mm.

We chose that autopilot because it is small, lightweight low cost. It has three-axis sensor module with roll, pitch, and yaw gyros. In addiction there are barometric altimeter, airspeed sensor, GPS onboard, as well.

In this autopilot we are able to specify up to 24 waypoints and set speed and altitude to all of them and it has ability to change navigation and mission information during the flight. The most important thing is that the RC receiver may be disabled, then re-enabled upon return home to prevent unauthorized interference during a mission and flight data and navigation can be constantly down-linked. It is possible through the computer for a mission setup on the ground. It is Windows based and provides us a graphical display for UAV status, map integration for displaying UAV location and waypoint entry, and command functions for sending and retrieving information from the autopilot.

Fig. 5. Printscreen of autopilot`s software
http://www.chinaga.com/

At the bottom of the fuselage there will be a thermal camera. it will be suited for search and rescue, for working at night and can be captured by a recording device connected to the base station.

Fig. 6 Sample of a Small, Lightweight Gyro-Stabilized Camera Systems for UAVs

The vision system installed on the UAV can be operated in different modes. The first mode is transmission of the image (RGB or IR) in real time to the ground station to monitor the area. The second solution is the manual searching of the target on the ground. However, this requires an additional operator, who controls the entire process from the base.

In the future the UAV should be able to create a system of automatic surveillance specified area, which is diverted to specific targets (movement of individuals, for example in the vicinity of the border) or more generally (searching outbreaks of fire).

The camera we have chosen – TAU 640 – is based on infrared technology, it allows us to look for people by the body temperature. It was constructed in order to search and rescue and for thermal building inspection. A video image is transmitting through wireless connection on 5.8 GHz frequency.

The camera will be equipped with a lens with a focal length of 100 mm which will allow to detect a man from a distance of 2.4 km, the diagnosis of 650m and a detailed identification of not more than 330m. The camera is able to observe vehicles a lot closer (just 6 km), identificate and recognize them from the distance of 1750 m.

The image is displayed in the following resolutions: 640 × 480 (NTSC) 640 × 512 (PAL) at 30 (NTSC) and 25 Hz (PAL) frames per second. Power consumption is approximately 1 W. The camera has digital zoom 2 ×, 4 ×, 8 × &, can operate up to 40 000 ft, is resistant for shock and moisture and has automatic stabilization. Total weight including the lens is about 475 g.

Our project involves using two data transmitting systems:

1) via satellite systems;

2) over ground reference stations.

The first of them works on SATCOM system. Transmission is sent via satellite on-board, and then through the SATCOM, the image (including data) is received by the ground operator. It is expensive solution and can be troublesome because the satellite must be still kept in touch with the another geostationary satellite. This generates power consumption and is based on mechanical parts which fatigue very quickly, especially during intensive work.

The second system is based on the use of reference stations positioned at the vicinity of the ground in the area of operation. Such system provides us the independence from the satellites, but requires a fairly complex ground infrastructure, masts, a station data processing and transmitting, another than by satellites – for example by Fiber Optic.

Nowadays, new technological solutions are determined by improving the safety and reducing costs. Therefore, we believe that hybrid airship is a perfect connection of these two factors. In result of replacing human by intelligent computer we will eliminate a risk of losing a pilot and by increase endurance our solution permits us to reduce the costs many times. To sum-up, we state that this aeroplane will be used either in civil aviation (fire brigade, border guard, police) or military aviation.

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Scientific supervisor – Tomasz Muszyńsk