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DESIGN CONCEPT OF A LOW-COST, LONG-ENDURANCE UNMANNED AERIAL VEHICLE

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Abstract

The aim was to design a mini UAV with a flight endurance over 24 hours, payload of 6 kg and the construction price to 30000$. The take off of UAV is accomplished solely by using a launching pad, for the landing a parachute is needed. The landing-gear was not taken into account which allowed for minimizing the aerodynamic drag. Special attention was paid to aerodynamics concept and efficiency of power plant. The reduction of the battery mass was considered by using a generator motor for in-flight charging and the possibility of supporting the internal engine by the same generator motor during take-off or in case of emergency.

INTRODUCTION

Unmanned aerial vehicle market outlooks are very promising [1]. Some scientists believe that the current situation is analogous to the demand for aircrafts after the end of the First World War or helicopters in the 50s. The amount of civil aircrafts and helicopters increased a few times within a decade. Furthermore that growing trend has been sustained for a long time. This was possible due to the development of the technologies used in constructing aircrafts and helicopters such as material technology, metallurgy or new ideas for constructing light but durable structures and powerful engines that weigh as little as possible. In the case of UAVs the main obstacles hampering their further development were navigation, image processing and data transmission systems. The present level of knowledge is high enough to overcome these problems; however the civil UAV growth is limited now by such factors like high purchasing, equipment operation and insurance costs, high certification standards imposed by FAA and legal restrictions concerning the areas which are allowed for UAVs. This situation is believed not to change before 2020. The development of indirect observation can be however sped up by applying image analysis programs that make use of artificial intelligence. These programs are capable of analysing any number of objects at once, noticing large number of details and indicating recognized well-known objects. Year in, year out the capabilities of these programs are increasing while their prices are falling down. So in a few years a camera in UAVs could turn out to be a better and less expensive solution than manned aircraft.

The conducted survey showed that the UAVs available on the market are too expensive. The majority of the interviewees were also not convinced of the comparable abilities of human eye and cameras and sensors with the exception of night when the observation is mainly performed by using IR cameras. Moreover, a small range influences not only operation costs but also ergonomics of work and safety (some maintenance services are difficult to perform at night; the possibility of detecting failures is lower, the risk of an accident during the operation increases significantly). The survey also revealed that different UAV speeds are relevant for different purposes, e.g. small speeds for continuous observation of a small area or greater speed for periodic observations. Striking differences were observed in the results of the survey conducted among policemen. Small UAV speed was stated as favourable for controlling pedestrian and vehicle traffic within the city, monitoring an object and areas of special security, mass and sporting events, demonstrations and riots etc. However, in the case of highway patrols, chasing road hogs, monitoring convoys and searching broad areas high speed is desirable because it allows to complete the task in a shorter time. Respondents also indicated that they would like to have UAVs with higher speed to monitor energy transmission lines, railway tractions, pipelines etc. The same answer holds for patrolling boarders and borderland, supervising energy utilities, refineries, chemical factories and other possible entities that may pose risk to the environment. Firefighters and security agencies chose the lowest UAV speed which would enable using captive balloons.

Survey conclusions that were the foundation of the preliminary project are the following:

1. Purchasing and operation costs comparable to those of a mid-size car
2. Uncomplicated operational procedures concerning take-off and landing, only periodical overhauls (no need for employing any mechanical engineer)
3. One person to operate cameras and the aircraft, the second one only if necessary + artificial intelligence program to support monitoring
4. PC compatible and modifiable software
5. Additional security system – a parachute
6. Flight duration over 24 hours

1. MISSION ANALYSIS

In order to carry out the tasks we need to equip the UAVs with cameras and sensors suitable for the mission. Here is an example of a mission whose aim is to find people in an inaccessible area within the distance of 50 km from the launch site. The plane takes off from the launching pad on the trailer car. Then it flies over the designated area and begins observation. It will be equipped with an infrared camera and a daytime camera. The information collected will be forwarded directly to the ground station. Assuming the amount of fuel taken on board (9.500 g) and fuel consumption information provided by the manufacturer of the engine (350 g/1h) and knowing the approximate economical speed V = 20m/s, we can calculate the distance our plane will be able to cover during the flight. This will be enough for approximately 25 hours (more than 1000km) of flight over the search area and a safe return (with the reserve of 5%). The altitude will depend on the terrain and e.g. electric poles and will be 300-500 m which is a compromise between the image quality obtained from the cameras and the minimum altitude required for smooth transfer of data to the ground station. Of course, the construction of the transmitter must consider a potential break in communication, the ability to cache the data and send it at a later time.

Due to the characteristics of data transmission equipment we decided to focus on 2 basic mission characteristics: search and supervision. Search missions will need equipment with the range of about 400 km which implies using satellite devices for transmitting the data from the camera and for steering. In the case of a supervision mission we assume the range of up to

50 km which allows for using radio devices. There are many possible ways for optimizing both airframe and gearing which makes it possible to construct aircraft with a long flight range.

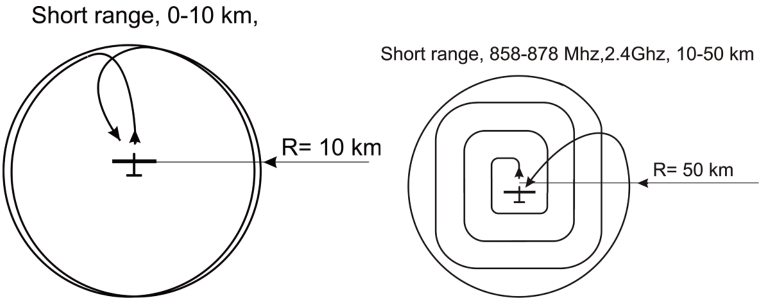

Figure 1. Short range mission depends on the type of antenna used. Authors' own research

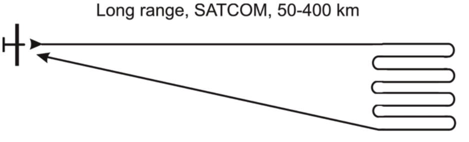

Fig. 2. Long range mission with satellite data transmission system. Authors' own research

2. ANALYSIS OF POSSIBLE DESIGN SOLUTIONS FOR LONG ENDURANCE AIRCRAFT

We did not take into account the low-power diesel engines due to lack of information about them. However we considered the following:

1. Electric propulsion with solar panel battery chargers – a very environmently-friendly solution.
2. Aircraft construction based on hydrogen fuel cells as the most efficient energy source
3. Analysis the existing concepts for a classical combustion engine

Among the solar cell aircrafts Zephyr 6 seemed to be the most interesting to us because of its mass of 30 kg that is comparable to the assumed mass of our UAV. Its payload is 2 kg. Zephyr 6 has lithium storage batteries that are thinner than a typical piece of paper. They are glued to the upper wing surface and they can be charged from the solar panel during the day. The aircraft is composed of carbon composites. However after thorough investigation our team established that there is no possibilty of using such aircraft in Poland due to high price, weather conditions, operational difficulties connected with take-off and landing of that 18-meter-wide wingspan construction.

We reached quite a different conclusion after the examination of the liquid hydrogen propulsion for UAVs of long flight range. Hydrogen has huge gravimetric energy density of 120 MJ/Kg which is almost 3 times bigger than petrol (45 MJ/Kg). Considering the improvement of storage capacity we can say that this kind of propulsion will be a solution for the future to aircraft. Currently available fuel cells have the biggest energy density of all storage batteries. However, the main deficiencies are high purchase and operation costs. The current models cost from $2400 for a cell of 300W (weight of about 1.5 Kg), for a pressure vessel of 10 Litres one has to pay about $2000. The operational costs are also significantly higher than in the case of engines powered by traditional fuel (Boeing Phantom Eye and Ray UAVs use liquid hydrogen propellant) due to applied devices that differ much from those in the current use.

Fig. 3. Solar-powered UAVs. Picture on the basis of [8]

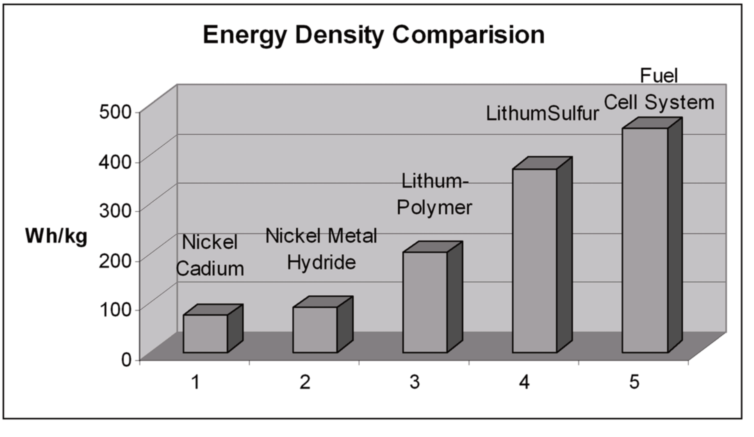

Fig. 4. Energy density for different cells. Authors' own research

The project NASA Grant No. NNX08BA44A is a big step ahead towards the implementation of the hydrogen propulsion in UAVs - ecological and effective – the future of aviation.

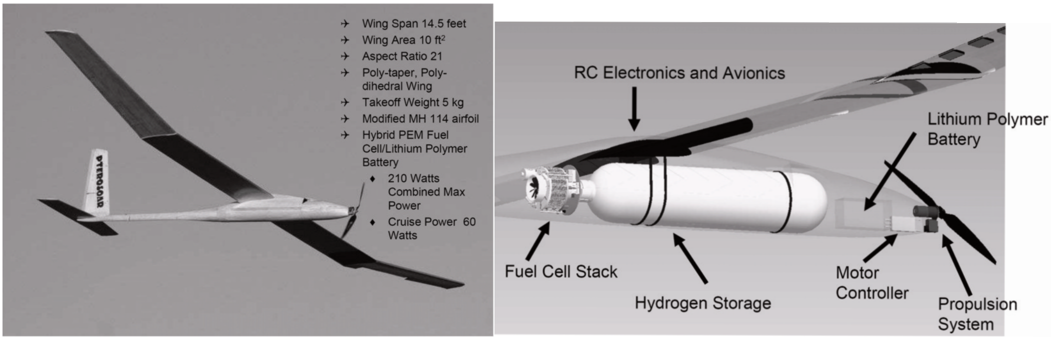

Fig. 5. Project Dr. Helen Boussalis, Dr. Chivey Wu, Dr. Charles Liu, and Dr. Darrell Guillaume, NASA Grant No. NNX08BA44A College of Engineering, Computer Science, and Technology Department of Mechanical Engineering. Picture on the basis of [2]

The aerodynamic project with the implementation of ordinary petrol engines also gives many opportunities. Being interested in constructing a conventional long flight range aircraft we have analysed the already existing constructions, also these with the minimal engine power. In the case of pilot substitution in the human-powered aircraft (HPA) Gossamer Albatros (construction weight 32 kg, take-off mass 100kg) by a 0.5 kW engine *(human power), avionics and fuel of 60 kg. Under the assumption that the Honda engines use 340 g/kWh of fuel, in other words 170 g/h of flight we would obtain the flight range of 352 hours. This is a purely theoretical case for a flight at the altitude of 10 meters and during calm weather which would be of course rather improbable. However this shows one of the possible solutions to the problem that deserves further analysis and consideration. Below Sunlight Eagle, with the propelling and steering systems located in the gondola originally designed for the pilot.

Fig. 6. Gossamer Albatros, Picture on the basis of [7]

Table 1: Human powered, solar powered and hydrogen powered aircraft, B. Rutan's record-breaking planes. Compiled on the basis [1], [7], [8]

Lp	Country/ model	Wingspan /length	MTOW	Sw, MTOW/ Sw	Celing	Range, max. Speed, cruising speed	Max power, nom.power, Power-MTOW ratio [kW/kg] for cruising	Endurance, Payload
1.	USA/ Gossamer Albatross	30m / 10,3m	100 kg	45,3 m^2 2,2 kg/m^2	30 m	36 km/ 29km/h, 15 km/h	Max 0,5kW, 0,3kW/ 0,003 kW/kg	3 h, 0
2.	USA/ SoLong	4,75 m/	12,6 kg	1,50 m^2 12,4 kg/ m^2	8 000 m	40-90 km/h	max 0,8kW nominal 0,225kW/ 0,0179	24 h, 2 kg
3.	Helios	3,5 m / 2,5 m	22 kg	1,02 m^2 21,5 kg/ m^2	12 000 ft	50 km / 55-125 km/h	b.d.	4–6 h, 4 kg
4.	USA/Aero Vironment GO-1	48,8 m / 10,9 m	1800 kg	86,4 m^2 20,8 kg/ m^2	15 000 m	b.d.	b.d.	168 h
5.	USA / Sunlight Eagle	38m/ 11m	74 kg	49 m^2 1,5 kg/m^2	b.d.	ok. 40 km/h, ok.30 km/h	Ok. 0,9 kW, 0,012 kW/kg	48 h
6	United Kingom/ Zephyr6	18m/	30 kg	5,7 m^2 5,263 kg/m^2	15000m	20 km/h	1.5kW/ 0,05kW/kg	54 h 2 kg
7	USA/Prof. Derell	4,4 m	5 kg	0,93 m^2 5,4 kg/m^2	3000m	80 km/h	0,2kW, 0,06kW/ 0,012kW/kg	b.d.
8	USA/ TAM 5	1,83/ 1,88	5 kg	0,72 m^2 6,9 kg/m^2	b.d.	ok. 110km/h 78km/h	0,7 kW, 0,3 kW/ 0,07 kW/kg	39 h 0,5 kg
9	USA/ Rutan Voyager	33,8/ 10	5137	39,44 m^2 130,2 kg/m^2	b.d.	240 km/h	177 kW, 140 kW/ 0,027KW/kg	45000 km

The record-breaking planes built by B.Rutan and used for the flight around the globe are directly connected with our project.

We have done extensive analysis of the statistics, particularly the wingspan-weight ratio, max power-weight ratio and the Power / MTOW ratio MTOW / Sw. We have concluded from the analysis that the greatest opportunities to increase flight duration exist in 1-reducing the surface-weight ratio and 2-increasing the lift to drag ratio.

Table 2: Characteristic of UAVs produced. Compiled on the basis[1], [7], [8]

Lp.	Country/ model	Wing span / Length	Max take-off weight	Bearing surface / Surface-weight ratio	Ceiling	Range/ max speed, cruising speed	Max power, nominal power, Power/ MTOW - ratio [kW/kg] for cruising	Flight duration/ Payload
1.	Aerosonde 4.4	3,45, 1.7	16,8	0,61 m² 27,5kg/ m²	5000	140km/h (max) 90 km/h	1.28kW 0,097 kW/kg	30 h
2.	ScanEagle	3.1, 1,4	18	0,8 m² 22,4 kg/m^2	5000m	136km/h 90km/h	0.97 kW 0,05 kW/kg	24 h
3.	USA/ Raptor	20 m/ 7,6m	815 kg	42,5 m² 19,176 kg/ m²	20000 m	190 km/h (max)	77 kW, 60 kW/ 0.0736 kW/kg	48 h / 68 kg
4.	Shadow 200	3.7	77	0,72 m² 106 kg/m^2	4572	207 km/h (max)	28.50 kW 0,379 kW/kg	
5.	Integrator	4.8	59	1,06 m² 55,48 kg/ m²	6000	108 km/h 166 km/h	5.97 kW 0,1 kW/kg	30 h
6.	Orbiter	2.2	6.5	0,44 m² 59 kg/ m²	5486	56 km/h 109 km/h	0,9 kW	5
7.	Silver Fox	2.4	12.2	0,70 m² 24,6 m²	3657	70 km/h 102 km/h	0.89 kW 0,07 kW/kg	
8.	Killerbee	3.04	14	0,91 m² 15,4 kg/ m²	4600	110 km/h (max)	8.20 kW 0,58 kW/kg	
9.	Neptune	2.13	59	0,35 m² 167,2 kg/ m²	2438	111km/h 156 km/h	11.19 kW 0,1899,42 kW/kg	
10	Luna x 2000	4.17	37	0,66 m² 55,8 kg/ m²	4000	70 km/h 160 km/h	5.00 kW 0,1359,42 kW/kg	

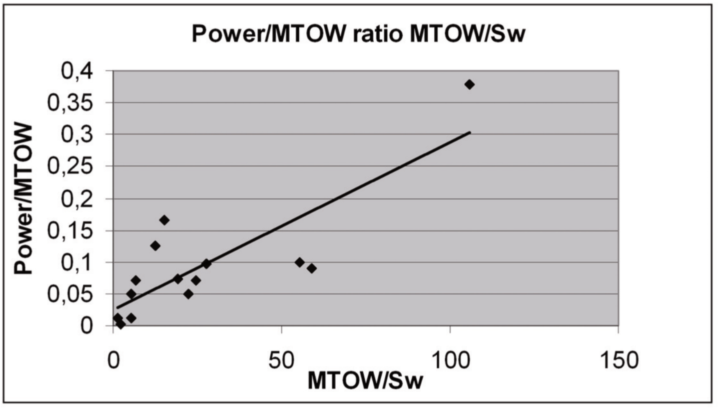

Fig. 7. (Power/MTOW) ratio (MTOW/Sw). Authors' own research.
Compiled on the basis[1], [7], [8]

3. SELECTION OF A PREFERRED DESIGN

The design process is multidisciplinary. Integration and validation of the entire UAV system involved analysis of aerodynamics, static stability mechanics, electronics, optical systems and cost minimization. Due to the expected low surface load we have also taken the possibility of using a biplane layout into account, but due to the higher drag coefficient, we got more power in the calculations necessary for the flight. Eventually, we decided to use a classic glider system, not doing the calculations for the canard layout (although it is interesting for construction reasons - beneficial deployment of components) also because of its worse aerodynamic performance. We have not used a landing gear: 1. in order to reduce the power required for take-off , 2. to adjust the characteristics of the propeller only to the cruising conditions, 3. to reduce weight. To minimise the risk of accidental aircraft damage and to decrease the necessary technical qualifications of the staff a solution that works well for other similar aircrafts was used. The takeoff of UAV is accomplished solely by using a launching pad, for the landing a parachute is necessary. The use of a landing parachute requires the use of additional protection for the equipment and airframe structure. In the first stage of testing we decided to apply absorbing rods, unfolded simultaneously with the opening of the parachute. If these safeguards are insufficient we will have to consider the use of the chassis and the classic way of landing. The use of airbags for such a large airframe seems to be very troublesome. We have considered the reduction of the battery mass by using a generator motor for in-flight charging and the possibility of supporting the internal engine by the same generator motor during take-off or emergency situations.

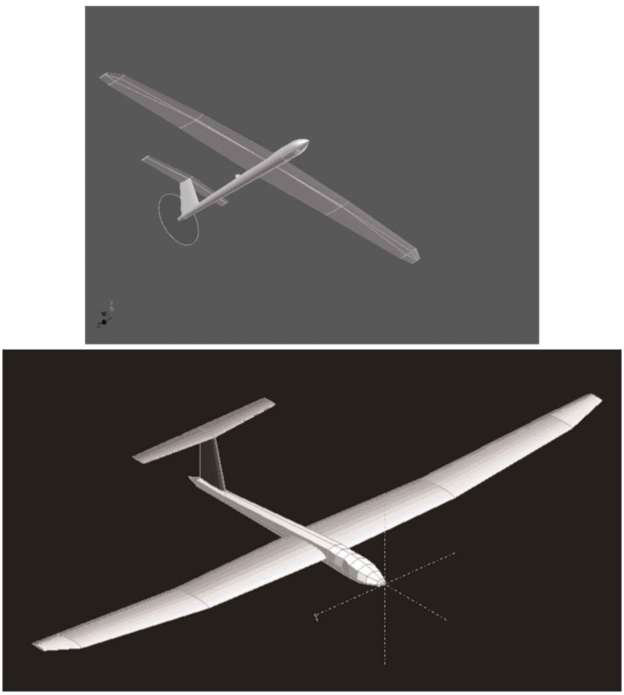

Fig. 8. Design layout powered sailplanes the tail T is generated in the program Autodesk Inventor and XFLR5 (Xfoil). Authors' own research

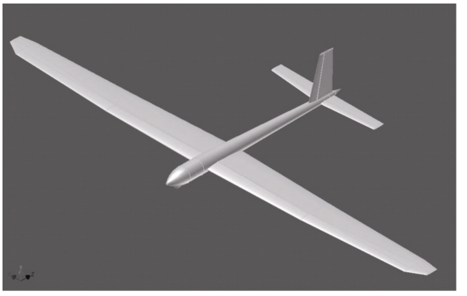

Fig. 9. Design powered sailplanes with a classic tail generated in Autodesk Inventor. Authors' own research

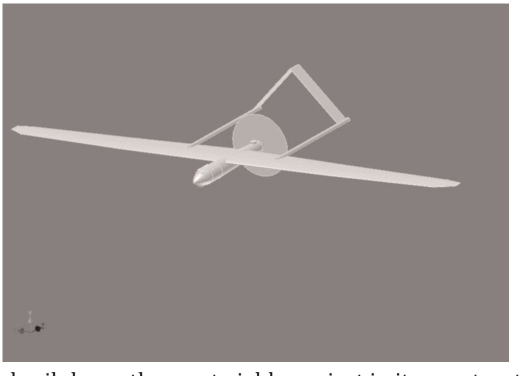

Fig. 10. Powered sailplanes the most viable project in its construction generated in Autodesk Inventor. Authors´ own research

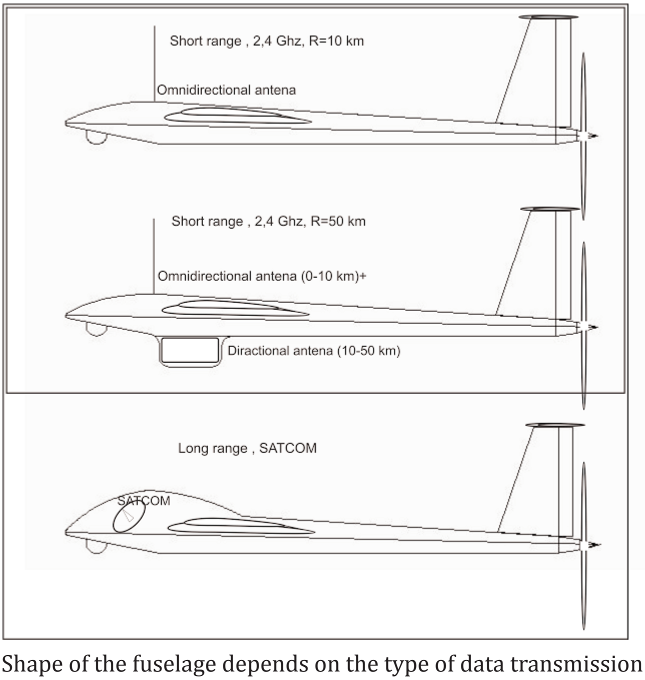

Fig. 11. Shape of the fuselage depends on the type of data transmission system. Authors' own research

Fig.12. Landing witch a parachute. Propeller is put together, dampering elements are put forward. Authors' own research

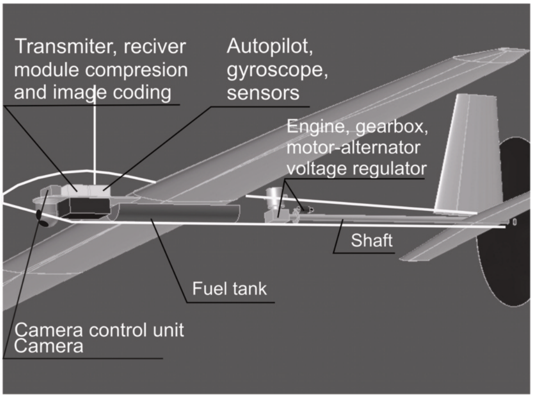

Fig. 13. Basic component of UAV. Authors' own research

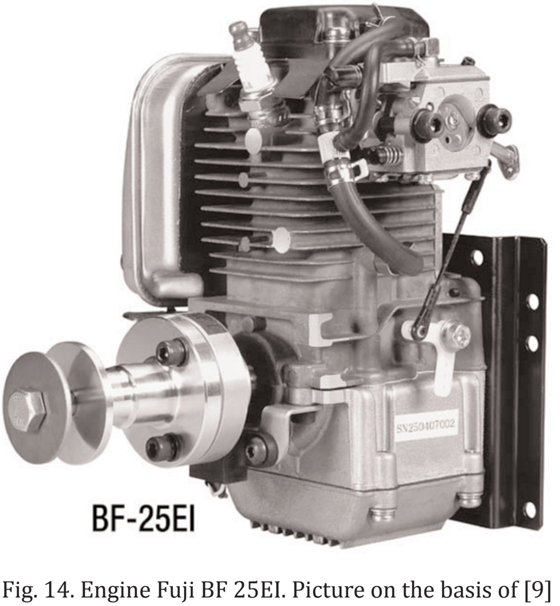

Fig. 14. Engine Fuji BF 25EI. Picture on the basis of [9]

Engine selection. We have decided not to use simple, lightweight modelling engines due to their short durability and high fuel consumption min. 1000 g / kWh. Of the available engines we only took the engines with fuel consumption below 500 g / kWh into account. At last, we have chosen FUJI, BF-25EI 25 cc due to low weight and the possibilty of adapting it to UAVs. It's four-stroke engines with electronic ignition system boast these advantages: Incredible fuel economy-less than half the fuel consumption of a comparable 2-stroke engine, for twice the flight time per fill at half the cost, amazingly quiet operation-making them welcome even at the most noise-sensitive flying fields. Power output: 1.6 hp at 7,500 rpm, weight 1,919 g.

4. THE CHOICE OF THE OBSERVATION AND COMMUNICATIONS EQUIPMENT

Currently, there are many systems available both for daytime and night observation. However, they are available separately. We managed to find only two universal day -night cameras weighing less than 3kg. At last we would like to use one of them (but they cost more than 15 000 $) - in the test period we will use a camera VH4 manufactured in Poland.

Fig. 15. Small, Lightweight Gyro-Stabilized Camera Systems for UAV. Picture on the basis of [10]

UAV imaging solution is capable of sending multi-megapixel images over the optional integrated 1 megabit 900 MHz datalink, or over other UHF datalinks such as the Microhard VIP2400/VIP5800 links, and over the Globalstar and Iridium satcomm systems. It integrates well with the Cloud Cap Piccolo avionics and/or Cloud Cap TASE family of gimbals, or can function standalone. It can provide rapid compression and transmission of images from high performance digital cameras optionally mounted in the Cloud Cap TASE family of gimbals

The MiniLink ML D900-20 Data link is mostly used to control the Pan-Tilt-Zoom camera's control function wirelessly. With ML D900-20 Data link at the base station we can set up multiple zoom camera controls. Each data link communicates with each other and each camera has its own identity so you can select which zoom you want to move and only that one camera will respond. The base and remote modems ML D900-20 offer flexibility with respect to frequencies, licenses, output power and regulations. Microhard radio modems provide an excellent range (20 km for the non-EU versions) and high data rates. They are licence free in most areas of the world. the EU versions are power limited to 100 mw to conform to European regulations and as a result, offer shorter range. Probably because our team does not have any connection with the army we could not obtain detailed information on the satellite transmission systems for UAVs which are manufactured by Intelsat General Corporation and General

Dynamics. The pictures below show professional communications satellite terminals by General Dynamics of smaller maximum speed of up to 100 km / h, but for us, they are not available because of the size and price. General Dynamics'.

Satcom-on-the-Move™ terminals offer robust voice and data wideband satellite communications from vehicles in motion. X, Ku and Ka-band modular, interchangeable payloads are available in antenna sizes ranging from 17” to 24”. Power consumption 280W cont, 800W peak, Maximum Vehicle Speed < 60 mph (100 km/hr) According to us, at the moment Thrane Explorer 300 satellite modem appears to be the only available satellite device, which, like the directional antenna would have to be retrofitted with an additional control module for setting the most advantageous direction. It has got enough bandwidth to transfer video recorded by up to 5 megapixel camera with the refresh rate of up to 4 frames per second, compressed with MPEG-4. This set is not used for vehicles in motion, so we are not sure of the final result. Power consumption is 80W cont., 200W peak with an additional control module, price transmit 15 $/min. Choose among the available autopilots also cheaper product manufactured in Poland. It costs 1, 5 thousand U.S. dolars, also enables integration with the camera.

Fig. 16. Piccolo Highly Integrated Autopilot. Picture on the basis of [11]

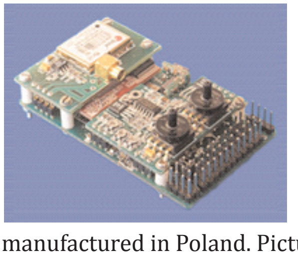

Fig. 17. Autopilot FCS 2 manufactured in Poland. Picture on the basis of [12]

Tab 5. UAV Electrical Requirements. Authors’ own research

Name of the component	Energy consumption [Wh]	sample solutions
Autopilot	30	
servos (6 pcs)	50	
data transmission system –reciever, transmitter	100-300	dependent on the type of system
camera	120	
modem RC	60	
engine (electronic ignition system)	120	
SUM	480-680	X24=11 520-16320 W

Tab. 6. Mass of the UAV components . Authors' own research

Name of the component	Mass of the component [kg]	sample solutions
Plane	7,5	
Engine, transmission, shaft, gear box	2,6	Fuji BF-25EI
Propeller	0,25	
Fuel 14 l	9,8	
high power, low power servo	0,2	C 5077 Graupner ECO C 3041, Graupner
data transmission system , module compression and image coding (flight data, video), antenna, system regulation antenna	1,1 - 4,0	dependent on the type of system
Battery capacity 10 [Ah]	0,8	Graupner
Motor-generator, voltage regulator	0,2	
Landing system (Parachute)	0,45	
Autopilot,, gyroscope, sensors, book measure the acceleration and angular velocity INS and antenna	0,6	FCS 2
modem RC	0,37	FreeWave, power 2W
living / Night Camera	1,0	
SUM	24,87-27,77	

The total weight of the UAV should be 25 kg. Of course, the weight of the UAV will depend on the final design and technology for its implementation, but as shown above it is possible to ensure the autonomous flight range of at least 400km to carry out tasks such as reconnaissance patrol for approximately 23-25 flight hours. The mobile ground station for the ground radio data system will include:

- Well-protected and immune to weather conditions laptop computer
-Band RC data transmitter and receiver
-Manipulator
-SetAntenna
- Power Battery, an electricity generator.

The weight of the ground station is not as significant as the mass of the flying device. Ground station will be based on a portable laptop to work outdoors, which has been mechanically enhanced to eliminate any damage during transport and operation and immune to weather conditions. Analysis estimates indicate that the mass of the reinforced laptop will be about 5kg. The mass of the transmitter and receiver is about 5kg. The mass of the remaining components: antennas is estimated at 15 kg, Batteries weigh approx. 1 kg (total mass of the ground station with transport packaging will be 30 kg.

5. AIRFOIL SELECTION

The greatest C_L / C_D ratio for cruising speed has been the most essential operational research criterion for the choice of the profile. Assuming the total weight of 25kg (Q=25kg x 9.81m/s^2 = 245.25 kgm/s^2), bearing area 1,8 m1,8 m^2 and economical speed 20m/s the approximate C_L for economical speed is $C_L = 2Q / (\rho v^2 S) = 0.54$, and for the return from the mission (10 kg of fuel less) C_L = 0.32. Hence, we have searched for the profiles which have the lowest resistance for CL= 0.3-0.6. Re=400 000 has been assumed (average aerodynamical chord 0.3m, altitude 300m, speed 20m/s). From the available profile databases the following glider airfoiles and professional modelling airfoiles have been chosen for more detailed analysis: S7012 (Manta glider model), MH32 (Elixir glider), NH1036 (Linea glider), HQ 3.0-12 (Ventus and Discus glider models), RG15 (most F3J class models, currently being supplanted by SD7037, better for thermal flights, S3021. The profiles whose performance is more adequate for motorgliders RG 15 and HQ 2.0 have been analysed carefully. The rest of the profiles were typical gliding profiles – high C_L necessary for circulation and low CD alongside low C_L–necessary for changing thermal columns. Having compared the influence of the thickness (which for construction reasons ought to be as high as possible) on the performance of the profiles, a little risk has been taken and the thickness has been limited to 12%. 16% profiles, at C_L<0.6, have total resistance higher by 15 %, compared to 12% profiles. Assuming that wing resistance represents 70% of the total resistance the increase of the thickness of the profile leads to the increase in the total resistance by approximately 10 % which influences the thrust, engine power and fuel consumption.

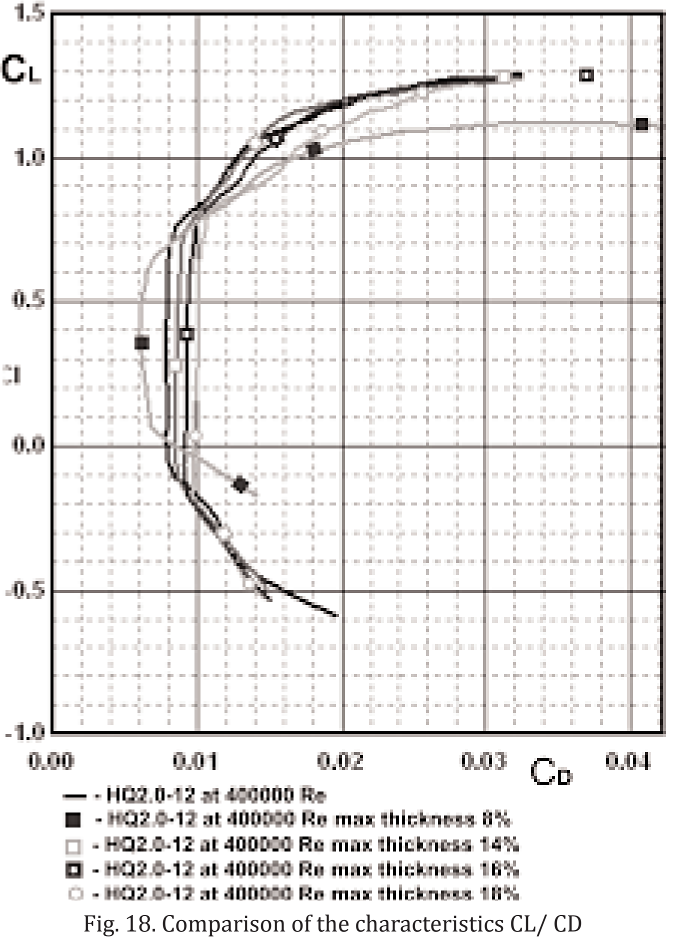

Fig. 18. Comparison of the characteristics CL/ CD
for airfoils of different thickness. Authors' own research

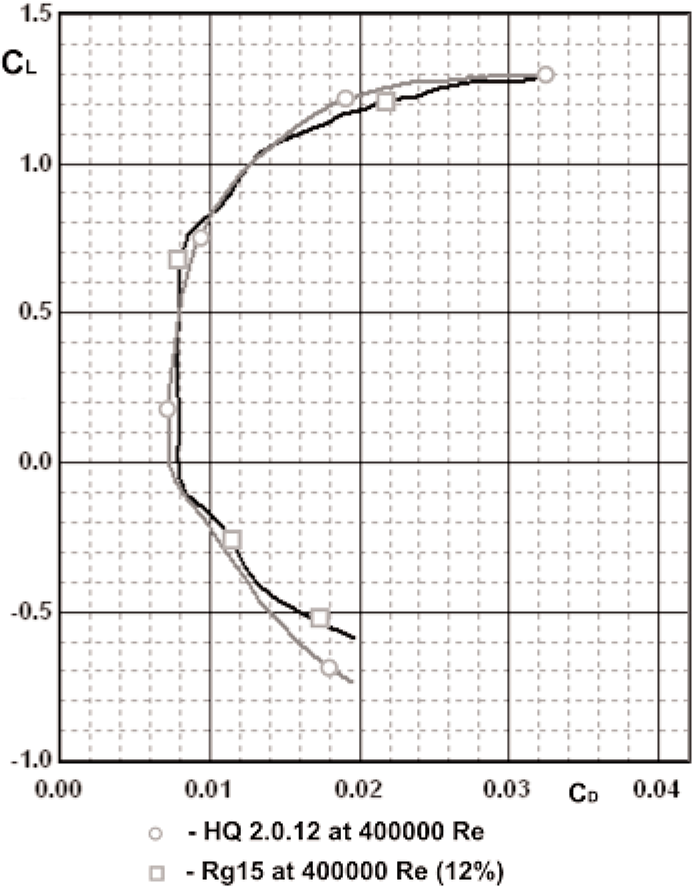

Fig. 19. Comparison of the characteristics of airfoils RG 15 and HQ 2.0 for thickness of 12%. Authors' own research

RG15 compared with HQ2.0-12 has better C_L/ C_D ratio at lower C_L =0.1-0.4, the HQ is better for C_L= 0.4-0.7. The situation is the same for 10 and 8% airfoils. Attempts have been made to modify the RG 15 airfoil aimed at increasing the excellence of the airfoil for C_L>0.3. We could not get the intended result, any change in geometry led to a significant increase in C_D beyond the range that interests us. However, we managed to modify the 2.0-12 HQ profile. The changes included the shift of the maximum deflection of the front frame by 7% and shifting the maximum thickness by 2.8% to the front which reduced the minimum resistance to approximate C_L =0.45 - the volume we are interested in (0,3-0.6). The modification was carried out by using the program Profili 2 based on Xfoil calculation method.

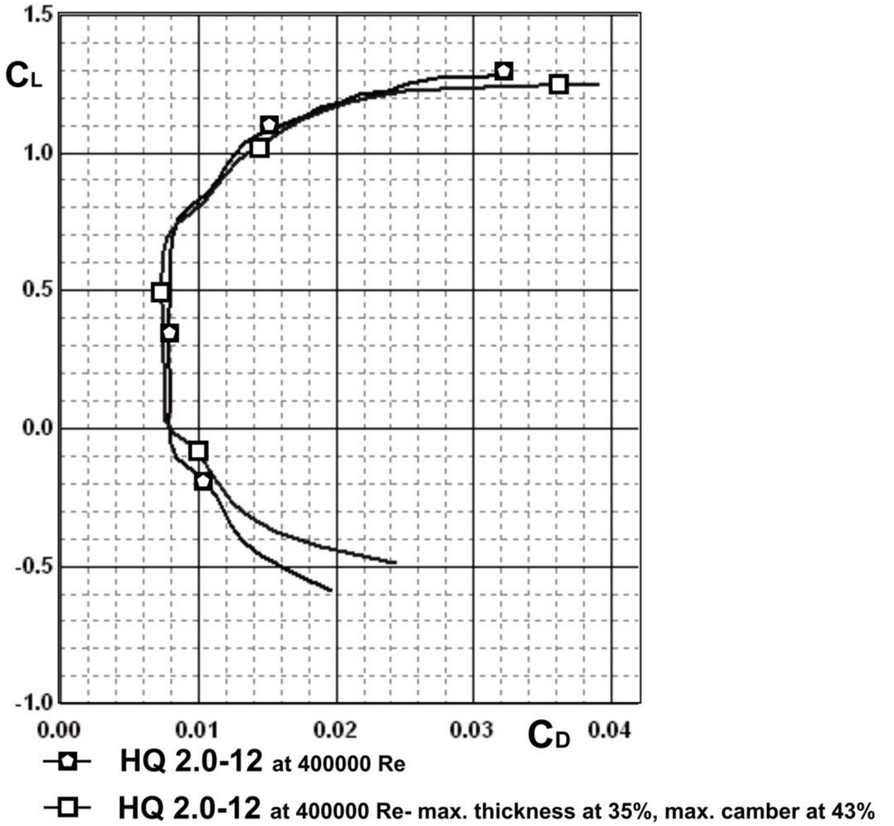

Fig. 20. Comparison of the characteristics of HQ 2.0 airfoils before modification and after modification to the thickness of 12%. Authors' own research

For construction reasons it was decided to design a variable thickness profile, from 8% on the tip to 12% near the fuselage. The HQ 2.0 8-12 profiles were selected as offering better excellence for a wider and more useful range of CD. With the noticeable changes of the UAV's weight it is of great importance and is the best choice as far as the duration of the flight is concerned.

6. CALCULATIONS

Calculation was executed in programme excel in the formulae from textbook the [3,4,5,6} as well as simultaneously in programme XFLR5 the basing on process computational XFoil. Differences did not cross 7%.

Propeller selection. The propeller selection method used is outlined in Raymer [5][4]. We have selected a two-bladed propeller profile RAF 6 from the available characteristics of the propeller blades. Assumed flight speed is 20m / s, altitude 500m, continuous power 1000 W at 5000 rpm (reduced to 2500/min = 41.6 / s). For these values C_D has been calculated, the angle β = 22 deg has been chosen[6], C_N and J = 0.7 have been calculated for which the performance efficiency ή = 0.77 has been obtained.

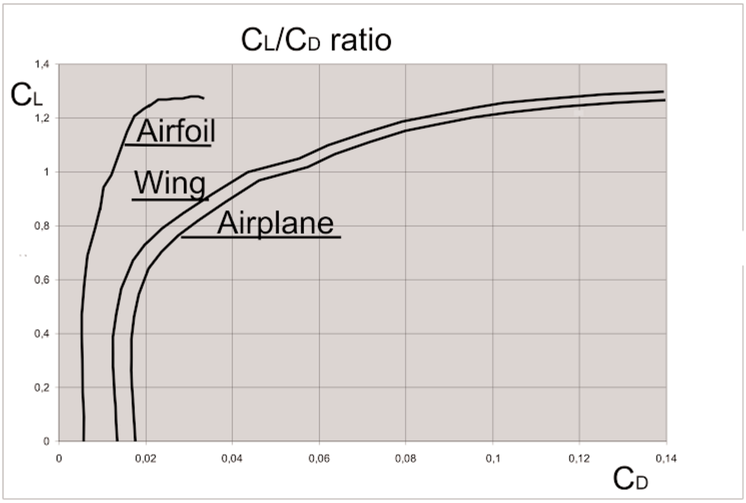

Fig. 21. CL/CD ratio. Authors' own research

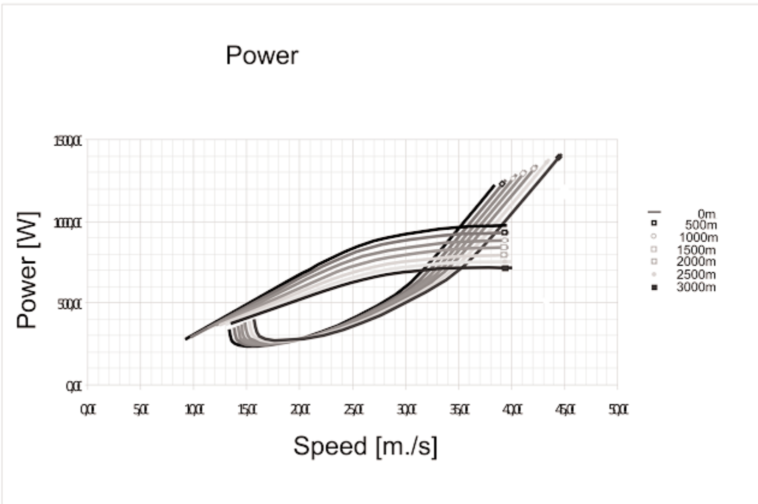

Fig. 22. Power /Speer ratio. Authors' own research

7. CONCLUSIONS

Because of the design features that allow the use of any propeller, an optimal propeller for this particular UAV should be selected. We want to calculate new propeller characteristic for higher efficiency. In case of that we could reduce the fuel consumption by reducing the engine power for the flight. The assumption of a single airframe for two types of mission seems to be uneconomical – a plane for the mass output of 3 kg could be significantly smaller. We should optimize the dimensions and geometry for lower fuel consumption. We would have to test the propeller-engine unit in the wind tunnel first. Construction complete system uav, with endurance 24 hours in price to 30 000 $ is possible but indispensable compromise will be - or stabilise gyroscope camera and range 10 km, or weaker camera and larger range.

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JAROSŁAW KOZUBA, TOMASZ MUSZYŃSKI

PROJEKT KONCEPCYJNY BSL O DUŻEJ DŁUGOTRWAŁOŚCI LOTU

Streszczenie

Artykuł zawiera analizę ankiety przeprowadzonej wśród potencjalnych polskich odbiorców BSL oraz projekt koncepcyjny BSL spełniający wymagania wynikające z ankiety. Podstawowym kryterium dla zastosowań nie militarnych została ekonomia dlatego też postawiono sobie za cel zaprojektowanie systemu bardziej wydajnego i tańszego niż dotychczas stosowane rozwiązania, z uwzględnieniem eksploatacji i amortyzacji. W artykule przeanalizowano kilka zaawansowanych technologicznie koncepcji BSL o dużej długotrwałości lotu, możliwości techniczne wykorzystania ich w Polsce, w odniesieniu do warunków pogodowych, ceny wyprodukowania oraz kosztów późniejszej eksploatacji. Po wstępnej analizie podjęto próbę optymalizacji klasycznych koncepcji już istniejących i projektowanych UAV wyposażonych w konwencjonalny napęd śmigłowy z użyciem silnika tłokowego. Szczególną uwagę poświęcono aerodynamice oraz systemowi transmisji danych, zastosowano nowatorską koncepcję dwóch anten radiowych -dookólnej do transmisji przy bliskich odległościach oraz sterowanej tylko w płaszczyźnie poziomej anteny kierunkowej dla przesyłu danych przy większych odległościach od odbiorników.