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Design the Advanced Avionics for "FanWing" UAV

Abstract. The propulsion systems of UAVs are often categorized as "outlaw" compared to their full-sized manned brothers. The reason is understandable; watching such an attractive solution as the "FanWing" appeared in the UAV business 10 years ago. The revolutionary new principle of lift generation was presented at numerous exhibitions and air shows, won awards, appeared in science reports and popular journals. This paper summarizes the main results of development and tries to open new ways for future improvement on basic avionics, payload, and user-friendly applications.

Keywords: Cross flow fan, fluid dynamic lift, autopilot, fail-safe, optimal redundancy.

Introduction

The FanWing experimental aircraft opens up a new area of aerodynamics. Designs to establish a means of integral lift and thrust using a horizontal-axis wing rotor are recorded back as far as the late 19th century. Some of the experiments started to take off but did not sustain flight. The FanWing new blown-wing solution offers both basic proof of concept and a steady trajectory of improved and controlled flight performance.

The aircraft has a cross-flow fan along the span of each wing. The fan pulls the air in at the front and then expels it over the wing's trailing edge. In transferring the work of the engine to the rotor, which spans the whole wing, the FanWing accelerates a large volume of air and achieves unusually high lift-efficiency.

The FanWing showed proof of concept in the form of actual flights before theoretical validation, academic research or explanation. The FanWing is an invention by trial and error and though certainly employing a methodology with good precedent in the history of innovation it is in no way within the normal paradigm of academic and conventional aircraft development. There is nevertheless a steady accumulation of tests and supporting documentation.

The History

First wind-tunnel tests were conducted in 1998 by Pat Peebles at the University of Rome. Several universities have carried out work since then independently, notably two wind-tunnel projects for student dissertations requested and supervised by Professor JMR Graham at Imperial College, London, completed in consultation with Pat Peebles and based on prototype wings provided by the FanWing Company. Other wind-tunnel tests were also carried out independently in the Company workshop. A

UK Government SMART Award and private investment in 2002 funded a series of wind-tunnel tests for the Company providing a basis for construction of a new prototype. The Company series of test were completed at Imperial College with Klaus Kogler assisting FanWing inventor Pat Peebles and with data consultation by Professor J M R Graham.

Documented efficiencies for the first prototypes were found to be in the order of 20 grams of lift per watt of input power indicating an initial lift of 1 –1 ½ tons of weight in the air with 100 hp. These results are supported so far by test flights where the largest prototype model flew on repeated tests with almost instant take-off and with a 20kg take-off weight.

First manned FanWing Ultralight graphics based on Pat Peebles' specifications were commissioned by FanWing in 2005 from Jon Linney, KMi, Open University UK and funded by private investment combined with a UK Government Jumpstart Connect Award from the London Development Agency. The graphics triggered a new Imperial College Simulation project. X-Plane software was used to establish flight characteristics of the first manned FanWing Ultralight.. The simulation project based on Peebles' specifications and designs was completed by Oliver Ahad at Imperial College June 2006 and supervised by Professor J M R Graham with Pat Peebles as consultant.

A UK National Award, the John Barnes Award, offered by the Association of Aerospace Universities, was presented to Oliver Ahad for his FanWing Ultralight Simulation project. The dissertation can be requested from Imperial College. See also: *Flight simulation and testing of the FanWing experimental aircraft*; Authors: O. Ahad, J.M.R. Graham; Journal: Aircraft Engineering and Aerospace Technology ISSN: 0002-2667 Year: 2007 Volume: 79 Issue: 2

During the UK Government SMART-funded 2002 wind-tunnel experiments, initially small incremental increases showed a sudden 30% improvement, with raised flight speed and improved autorotation. Other experiments showed a corresponding decrease in efficiency with a separate government-funded project to produce a scaled-down micro FanWing in 2003.

In 2007 flight tests the STOL UAV surveillance prototype showed unusually short take-off ability, leaving the ground after a 1 m roll without payload and 3m on lower power (see video on this website and Flight Magazine online archives). It is estimated that at maximum weight (12 kg) the small surveillance aircraft could leave the ground in three lengths. The new prototype was developed as an urban surveillance UAV. The aircraft flies slowly and will be able to maneuver urban 'canyons' with take-off independent of a catapult. The efficiency of the aircraft indicates that it will have autonomy of close to 80 minutes with a 2 kg payload under electric power. The short-take-off capabilities make the application useful for operations originating from a rooftop or short section of road. The aircraft will be simple to dismantle and assemble for simple transport and deployment.

This model and the newest runway independent prototype mentioned below are both registered for flight demonstration for the first time in public at the next international ParcAberporth UAV event, Wales, UK; June 25th and 26th 2008.

Development of “Runway-Independent Aircraft” started in January 2005. First positive VTOL capability based on a new design was confirmed in November 2005 with workshop tests on an indoor tethered model. A new patent application was deposited April 2006 with PCT process registered March 2007. A series of linear short-take-off flights to establish basic performance parameters have been successfully completed during 2007 at varying thrust vector angles. Most recent tests December 2007 show first full circuit flights with linear tests confirming improvements in stability and hover capability. Plans now are to extend into new configurations to exploit promising results.

Technology

Abstract of patent Patric Peebles US 6,231,004 B1 May 15, 2001

An aircraft lifting member (wing) comprises a crossflow rotor 2 formed of a core 4 having vanes 5 mounted around it, disposed in a trough 3 at the front upper part of a wing-like body 1. Rotation of the rotor includes a downwardly and rearwardly directed airflow over the upper surface 6 of the wing-like body 1 generating both lift and thrust. The upper part of the rotor vane path projects above the upper surface 6 and the lift-generating member is open at the leading edge to expose the cross-flow 2 to the incident airflow.

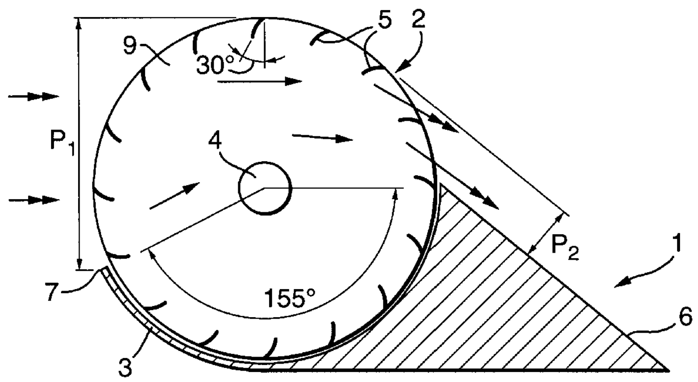

Fig 1. Fluid dynamic lift generator[1]

Applications

Unmanned Aerial Vehicles (RPV/UAV) UAV's are the fastest growing area in the aerospace industry, and design and manufacture of UAVs are an obvious first stage of FanWing commercial development. Easily adapted for use with either surface or ground-penetrating surveillance systems, applications include traffic control, irrigation/pest/fire/ecological surveillance, archaeological survey, mine-sweep and hydrology. The potential low sound emission of the aircraft has clear military, urban and environmental applications.

[1] Patric Peebles, Fluid Dynamic Lift Generation United States Patent 6,231,004 B1 May 15, 2001

Ultralight/Microlight aircraft In this potentially major commercial market, the FanWing is predicted as having no stall and simple controls.

Short-range freight delivery: the FanWing Sky-Truck FanWing opens a new market to compete with and complement truck and rail freight. Short-range freight delivery is seen as one of the largest and most fruitful long-term markets. The FanWing STOL capability and potential low sound are of particular interest here as are the new VTOL development possibilities.

Development of Advanced Onboard Systems – by NDU's principle

The ongoing stage of commercialization requires tailoring the FanWing match to airworthiness standards. The first serious challenge is to complete FanWing with more sophisticated guidance system – actually works by r/c remote control.

The research group at National Defense University, Budapest headed by author made a proposal for transformation FanWing an autonomous air vehicle. Members of this group took part in UAVNET (thematic network to advance the development of UAVs for civilian purposes), high qualified experts in air traffic management, airframe-, propulsion-, onboard electronics systems, and authors PhD dissertations (10 in last years: Kovacs L. 2003; Molnár, A. 2005.; Szegedi, P. 2005; Palik, M. 2007.; Wührl, T. 2008.; Turóczi, A. 2008.; Gácser, Z. 2008.; Restás, Á. 2008.; Koncz , M. 2009.; Horvath, Z. 2009.) connected to UAVs.

Our work is dividing for two main part:

1. The "general task" is to synchronize the highest requirement of controlled and even uncontrolled airspace with existing and future capabilities of UAV systems. The UAV means the biggest threat for air traffic when it is operating in commonly used airspace where (either civil or military) piloted air vehicles operate too. While during military flights the main objective is to execute the task successfully and flight safety is only secondary, in times of peace these aspects change places naturally.

There are researches going on in several countries in the world to eliminate the problems mentioned above and to make suggestions for legal, organizational and technical solutions. These days in our country there are already some UAV-s in operation and according to the forecasts there will be even a greater number of them in the future.

The key to the success of UAV systems lies in cheap operation, in little need for space and infrastructure, and last but not least in the trust that unmanned vehicles guarantee such high safety for humans that has never been seen before. Even if academic life argues with some of the pros of UAV, most of them agree with the fact that physical separation of human elements from hazard factors reduces the risk of special flight tasks which alone is a good argument for the application of such devices.

The separation of human elements from hazard factors does not mean that humans, as part of the UAV system, would not play a key role in the success of the system. It might seem a contradiction but unmanned systems cannot exist without human factors, „pilots”. The crew, which operates, controls the UAV from a certain distance, might be called anything but their role and importance is primary and indispensable. The crew controlling the UAV (henceforth UAV pilot) has characteristics and skills which basically determine the quality and safety of the UAV system's operation.
Our recommendations applying FanWing UAV in civil defensive areas:
Disaster prevention and management

- detecting forest fires, monitoring during fire fighting and area watching after putting out fires;
- area watching prior to floods, monitoring the state of barriers during flood, rough damage survey after flood subsides;
- if dangerous substances leak and get out to define its extensiveness, to check calculations for the model of spreading and to monitor the area of impact;
- in case of a nuclear disaster to define the spreading of radioactive substances, to check calculations for the model of spreading and to monitor the contaminated area;
- detecting bird activities near airfields and surrounding area, to prevent collision with them.

Applications by police

- to supervise forests, to prevent and reduce theft significantly;
- to prevent illegal fishing and to reduce it drastically;
- using radar speed counter from air;
- monitoring drug trafficking.

2. Much more “technical challenge” is to create a high performance airframe and propulsion system – what the FanWing is – and fit the board with a reliable, robust and failsafe energy sources, engines and avionics. The fail-safe methods are used both civilian and military UAV systems (Fig.2.).

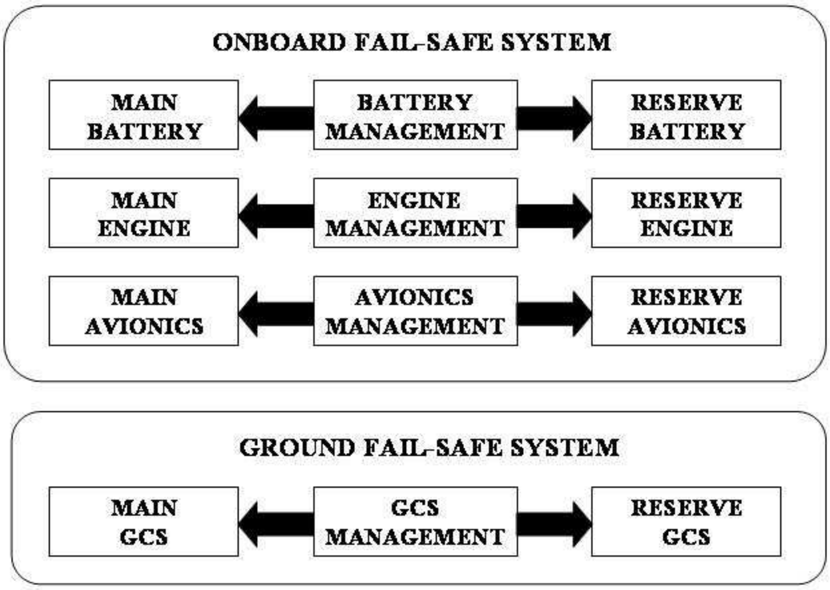

Fig. 2. Fail-safe onboard and ground control systems

The fail-safe principle is based on duplication of most important parts – for any case. The onboard and ground "health monitoring system" continuously check the worthiness of energetic, propulsion and avionics devices. In case of failure the main part the management system switch it off and on the reserve will provide the lost function.

At civilian UAV applications always "the safety is first" when at militaries mostly "the mission is first". From this fact the main/reserve proportion of components may be slightly different (Fig.3.).

	Civilian UAV	Military UAV
Battery	1 : 0.5	1 : 1
Engine	1 : 0.5	1 : 1
AVIONICS	1 : 1	1 : 1
GCS	1 : 1	1 : 1

Fig. 3. Main-reserve proportion of components

Reliability of UAVs highly depends on propulsion system. The main goal is to provide necessary thrust for mission and even if the main engine stops the mission should be completed – or finished by forced/emergency landing. The idea of fail-safe propulsion system is described on the Fig. 4. where two engines could work parallel or one of them and even if both is broken the electric motor/generator can tract/push the UAV for while safe landing.

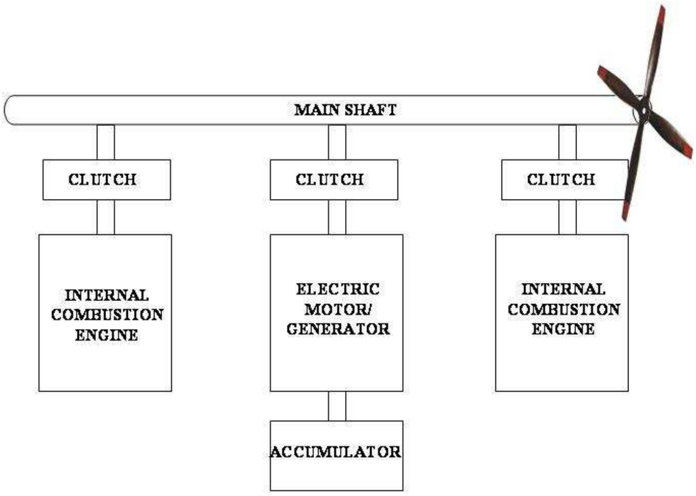

Fig. 4. Fail-safe propulsion system

The heart of UAV is the reliable autopilot. Although the r/c control sticks are similar to "normal" model airplane, the behavior is far not conventional. Perhaps that is why exploring the commercial autopilot makers (CloudCap, CrossBow Technologies, L3 BAI Aerosystems, Genova Aerospace, Micropilot, etc.) we still not have found such so called "ready for use" autopilot. Another option is to guarantee the maximum failsafe regime for large range of application. We have made numerous preliminary studies published in different forums. (Gacser, Z. et al. 2003.; Makkay, I. 2003.; Wührl, T. 2007., 2008.).

Concluding above the robust autopilot should have optimal redundancy of main sensors, ALUs and actuators. One of the possible variant of robust autopilot design is shown on the Fig. 5. where sensors and autopilots are duplicated and in case of differences the CPU is deciding which information will be denied.

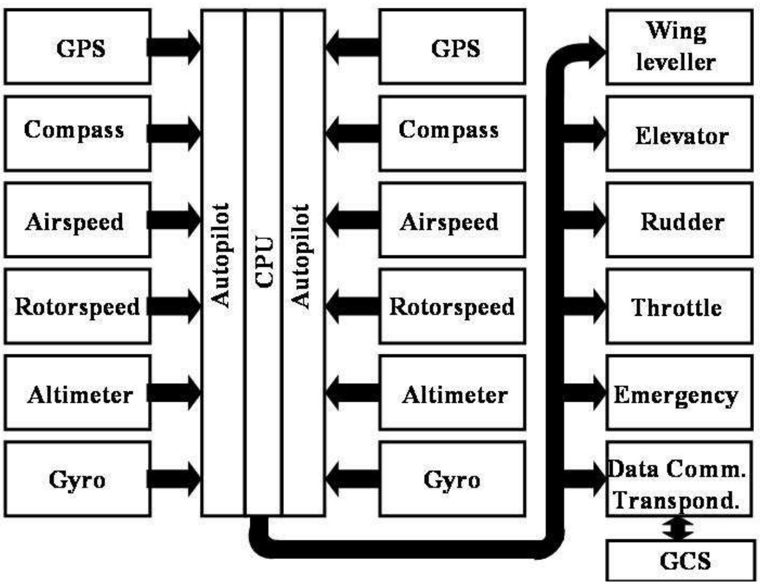

Fig. 5. Robust autopilot with optimal redundancy

For UAVs working in urban area especially important to be certified for emergency situation - duplicate of engine, avionics, battery, forced landing equipment and even ground control station. That is a common requirement for both civilian and military application.

CONCLUSION

The FanWing UAV is a unique solution by design and performance too. The extraordinary airframe capacity should be exploited along maximum safety and the same time reliability of whole system. Suggestions of NDU's researchers to build a robust and fail-safe avionics and propulsion (engine) system – based on long term experiences in theoretical and practical field.

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