UAV TESTING PLATFORM IN EDUCATION PROCESS

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Summary. The article deals with the possibility of using an UAV device as a testing platform for wide spectrum of sensors and sensor systems and also as a platform for verification of control and autonomous flight algorithms in academic conditions of Faculty of Aeronautics in Košice.

Keywords: UAV platform, air data sensors, flight control, dynamic modelling, diagnostics

1. INTRODUCTION

In the last decades the UAV´s gained their place in civil and military applications. What was once almost in exclusive sphere of interest of the armed forces, found nowadays its way into a wide range of human activities. In a simple form the UAV´s are used for entertainment, however more sophisticated UAV´s are able to fulfil search and rescue tasks and are even able to perform complicated tasks such as work in height, precise land scanning and photographing, autonomous packages delivery etc. [1, 3, 13]. Nowadays, the UAV platforms can be divided in similar way as it is on real flying devices (airplanes, airliners, helicopters), into two categories: with fixed wings and with rotary wings. Every UAV platform has its own predestined usage in a specific sphere of activities. In this article we deal with UAV of classic construction – remotely controlled aircraft, which will be used as a testing platform for wide spectrum of sensors, sensoric systems and devices and also with control algorithms used and verified in the teaching process [8].

2. SKYDOG AIRPLANE MODEL

Within the cooperation of Faculty of Aeronautics in Košice and Honeywell International, Czech Republic, an airplane model „Skydog" was borowed for educational purposes. SkyDog, the airplane model of classical conception represents a testing platform enabling research, development and testing of new control algorithms. This platform can be divided into two main parts, the virtual part and the physical part.

The physical part is composed of the aircraft itself with various sensors and sensoric systems, data acquisition and processing systems and systems for communication and control of the UAV. On the SkyDog a wide area of sensors such as accelerometers, gyroscopes, magnetometers, GPS receivers, laser scanners, aerometric sensors can be mounted, which can be used for the UAV position determination in respect to space and to the Earth. The UAV is also capable of carrying additional equipment such as aerial camera devices, radiologic survey equipment, etc. As it is obvious, UAV model can perfectly serve as a multi-usable test platform. UAV can be controlled from a ground station and in case of automatic control systems implementation it can fly in autonomous regime [3].

The virtual part can be represented as a mathematical model of the aircraft that allows us to test the designed control algorithms and also the solutions capable to transfer these algorithms into control systems of aircraft. Due the similarity between SkyDog aircraft model and big transport airplanes in physical matter, it is possible to evaluate some of the control algorithms developed for big airliners on SkyDog with none or minimal costs. Moreover, those solutions can be demonstrated to students so the UAV becomes a valuable teaching tool. The possible use of SkyDog will be discussed in more details in the following chapters.

Figure 1 Honeywell SkyDog

3. NAVIGATION SENSORS

The group of basic navigation sensors includes, for example, air data sensors. The principle of operation of these sensors is based on the fact that the barometric pressure decreases with increasing altitude. In the case of air pressure (static pressure and total pressure) and also the pressure changes monitoring we can determine the flight altitude above ground, airspeed and vertical speed. These sensors can be situated on the vehicle autonomously or they can be a part of so known Air Data Computer. The measurement errors of air data system also depends on several factors: accuracy of the particular sensor, outside temperature, position, wind speed, angle of attack or sideslip angle. Good knowledge of the aforementioned air data system's errors allows us to set up a variety of correction mechanisms achieving rapid increase in accuracy of air data parameters measurement.

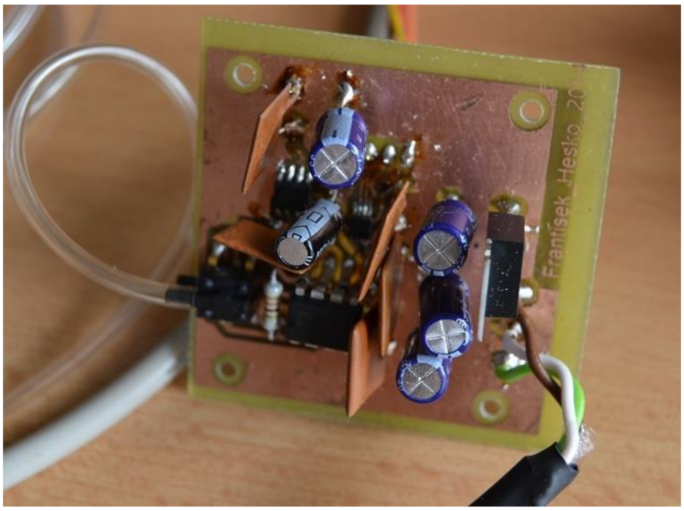

Figure 2 The demonstration of student work of measurement of air pressure sensing with MEMS differential barometer [5].

The accurate measurement of air data is very important for controlling of big airliners, jet fighters, small aircrafts, gliders, UAVs. In case of failure of Air Data Computer the related aircraft systems like Automatic Flight Control will also fail. Example of such failure is the disaster of Air France flight 447 from June, 1, 2009 when the pitot-static probes got frozen, the autopilot disengaged, the crew mistakenly decrease engine thrust and finally the aircraft stalled [17].

Accurate and precise air data measurement is one of the points of interest of Faculty of Aeronautics engineer students. After the basic set up and calibration of these sensors (with help of control and measurement devices available in closed wind tunnel), it is possible to install them into SkyDog UAV and execute a set of the measurements on the real flying object. These measurements can be confronted and compared with measurements done in the aerodynamic tunnel. The aerodynamic tunnel is in fact almost an ideal platform for measurement and testing without errors from surrounding environment like turbulences, cross wind and wind shear [14].

Figure 3 Testing of student designed MEMS aerometric system for small aircraft in a pressure chamber [6].

Another group of navigation sensors are inertial sensors: gyroscopes – angular rate measurements, accelerometers – linear acceleration measurements, magnetometers – magnetic intensity measurement, important for heading changes estimation. These sensors can be stacked into a sophisticated inertial measurement units that output the information of vehicle relative position changes. So, using these sensors, we are able to determine the change of vehicle heading- yaw, pitch and roll angles. Because the main manufacturing technology of these sensors is MEMS technology, the outputs from sensors are usually noisy. For noise suppressing, the wide scale of filtering algorithms are used. Design and implementation of filtering algorithms is also in point of interest of research not only of PhD. students but also engineer students from Faculty of Aeronautics [15].

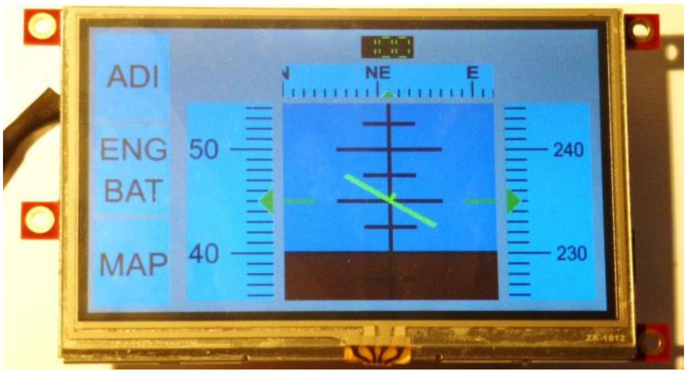

Figure 4 An example of student designed simple EFIS system with variety of visual representation modes of flight and navigation data [2].

In case the precise position of vehicle is known, it is possible to control vehicle's movement. Properly processed data of vehicle position can be sent into a control unit that is (based on previously programmed algorithms) able to stabilize the vehicle flight in separate control channels (longitudinal, transverse, lateral). This can be used for example for testing and verification of phugoid and relaxation oscillation dampers. Using the connection of inertial reference system, air data sensors and another navigation sensors - for example the GPS receiver, to the control unit, a simple autopilot able to guide the vehicle on a desired flight path can be created. Skydog vehicle can be used for practise testing of navigation and progressive control algorithms (fuzzy control algorithms, neural networks, situational control algorithms) as well as traditional approaches in flight control. Progressive control algorithms can then be compared to the classical ones, making it possible to evaluate their efficiency. The mentioned algorithms can be used in the airplane’s attitude, flight guidance and flight management forming a hybrid complex digital control system [5, 6].

For solving a specific control task, it is necessary to know the principle of operation, function and measurement errors of every simple sensor. Familiarization with these sensors and their errors is possible with help of an integrated measurement unit as is for example the MNAV100A unit.

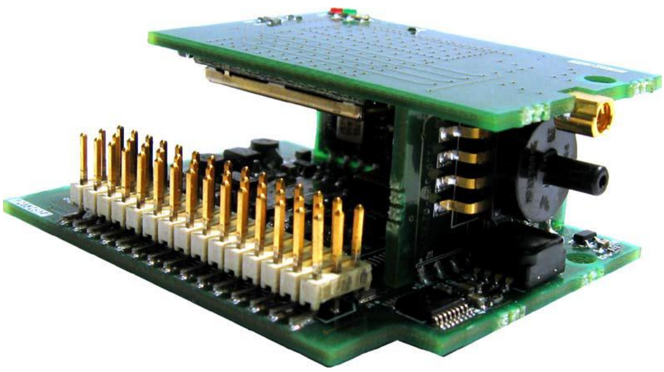

Figure 5 Inertial measurement unit MNAV100CA contains three accelerometers, three gyroscopes, air data sensors and GPS receiver.

4. VEHICLE MONITORING SYSTEMS

A very important element of vehicle’s control is the health monitoring of its own state. For solving a plenty of tasks it is needed to monitor its state – correct function of all important parts and carried equipment. Vehicle health monitoring and thus flight and vehicle diagnostics allows us to use the vehicle effectively and respond to impending danger in advance. Taking the flight envelope into consideration it is possible to respond to crossing of some boundary of flight envelope (excessive speed, excessive bank angle, excessive distance from pilot/operator where the connection to the vehicle can be lost). It is possible to monitor correct operation of navigation sensors for example by comparing its outputs with previously stored reference data or in case of sensors duplication, with voting the data from particular sensors. The power unit and its state can be monitored too (revolutions, thrust and torque of electromotor, voltage and temperature of onboard accumulator etc.) [12, 16].

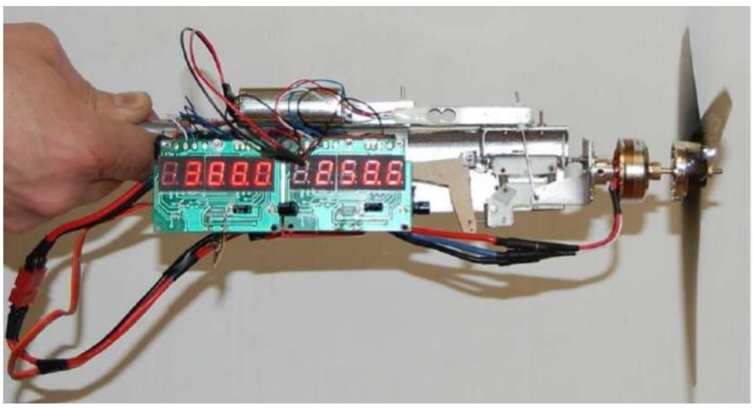

Figure 6 An example of proppeler measurment stand used for torque and thrust measurement [9].

In case of the combustion propulsion or nowadays commonly used jet propulsion units will be built in, more parameters have to be monitored (position of throttle, exhaust gases temperature, temperature in combustion chamber, turbine temperature, compressor revolutions etc.). Control unit of vehicle can be programmed to autonomously step into the control process when a hazardous state of vehicle is detected. In case of one or more limiting flight parameters or propulsion unit parameters are exceeded the control unit should be able to take the control of vehicle for necessary time to stabilize it. Significant part of UAV control process needed to be diagnosed is the "health" of communication, control and data acquisition channel. The capability of diagnosing the flight and the vehicle is also in abilities of students from Faculty of Aeronautics to realize required diagnostic algorithms and complex solutions.

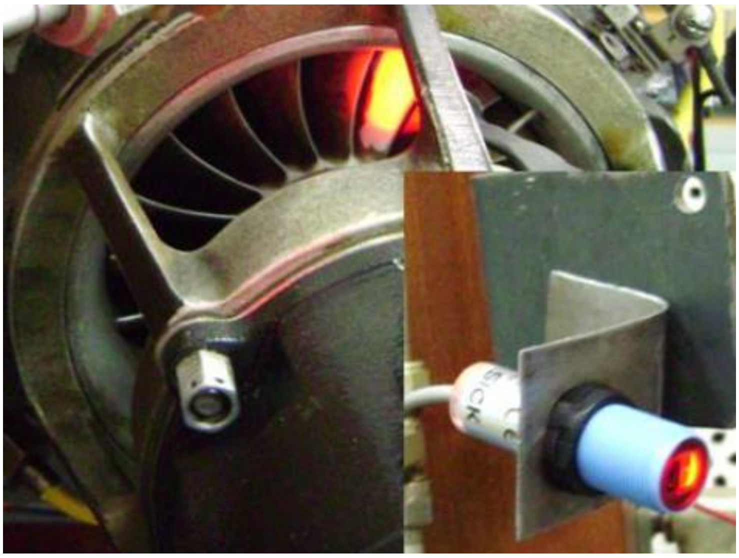

Figure 7 Student realisation of optical revolution sensing of turbofan engine [10].

5. UNCOMMON SENSORS

As it was mentioned earlier it is possible to put also uncommon sensors and avionics systems onboard of the universal testing platform. Laser scanners of surrounding environment known as LiDAR belong to this sensors' category. Laser scanners can track objects in focused area or they can take 2D or 3D pictures of monitored area.

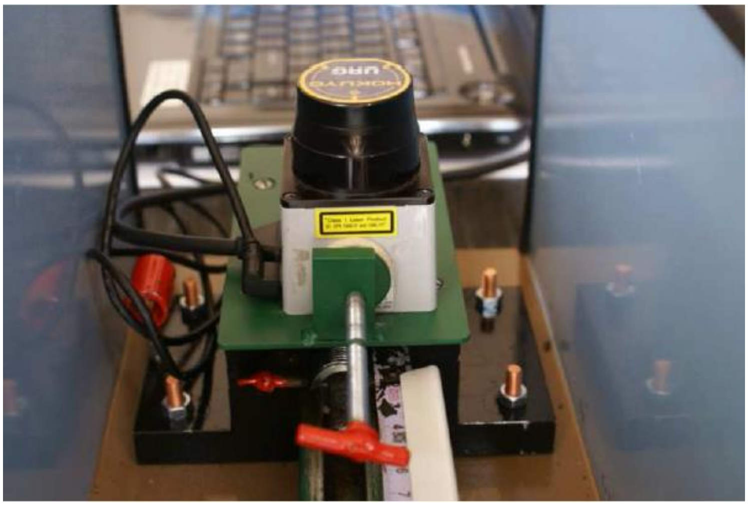

Figure 8 Stand device for laser distance measuring [11].

CONCLUSION

All in all, we can say that in the last 100 years aviation reached an unbelievable progress. The air transport is one of the safest forms of transportation. Actual high safety level couldn't be reached without corresponding, responsible and patient research and development. Every research and development needs to fulfil its own specific conditions. Within the framework of research and development at the Faculty of Aeronautics, the opportunity to test the proposed sensor architectures and aircraft control algorithms in almost real conditions has been absented. Desired flight conditions for sensors, sensor systems and solutions can be simulated with SkyDog UAV platform.

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References

Books:

[1] OSTROŽNICKÝ, J. *Unmanned aerial vehicles with three rotors*, Faculty of Aeronautics, Department of Aviation Technical Studies, Diploma Thesis, Košice, 2012. 74 p..

[2] HUČKO, M. – *Telemetric data visualization module for UAV ground station,* Bachelor thesis, 2013, 50 p.

[3] BAJÚS, J., *System of autonomous return,* Faculty of Aeronautics, Department of Aviation Technical Studies, Diploma Thesis Košice, 2013. - 76 s.

[4] MADARÁSZ, L., ANDOGA, R., FŐZŐ, L., LAZAR, T. *Situational control, modeling and diagnostics of large scale systems*, 2009. In: Towards Intelligent Engineering and Information Technology. No. 243 (2009), p. 153-164. - ISSN 1860-949X

[5] HEŠKO, F. – *Utilizing MEMS pressure sensors for measuring air data,* Faculty of Aeronautics, Department of Aviation Technical Studies, Bachelor thesis, 2014. 68 p.

[6] TURČIN, M. – *Air data system for small aircraft,* Faculty of Aeronautics, Department of Aviation Technical Studies, Diploma thesis, 2013, 65 p

[7] DRAGANOVÁ, K. *Testing and calibration of multisensor systems,* Dissertation thesis, Košice: TU, LF, 2012. 112 p.

[8] LAŠŠÁK, M. *Controlling of multisensor system*, Dissertation thesis, Košice: TU, LF - 2014. - 125 p

[9] LUKÁČ, K. *Measurement and data acquisition system for propeller measurement workstation,* Faculty of Aeronautics, Department of Aviation Technical Studies, Diploma thesis, 2013, 72 p.

[10] PATZ, T. – *Measurement of speed of aircraft engine,* Faculty of Aeronautics, Department of Aviation Technical Studies, Diploma thesis, 2011, 73 p.

[11] PALAŠČÁK, I. – *Detection of spatial objects by using an airborne laser scanner,* Faculty of Aeronautics, Department of Aviation Technical Studies, Diploma thesis, 2011, 63 p.

Journals:

[12] ANDOGA, R., FŐZŐ, L., MADARÁSZ, L., KAROĽ, T. *Progressive methods in area of turbojet engines' control systems*, 2010. In: Acta Electrotechnica et Informatica. Roč. 10, č. 1 (2010), s. 42-46. - ISSN 1335-8243

Conference proceedings:

[13] DRAGANOVÁ, K., MOUCHA,V. UAV – *Robotická avionická platforma na riešenie bezpečnostných aplikácií*. In: Bezpečné Slovensko a Európska únia : zborník príspevkov z 4. medzinárodnej vedeckej konferencie. Košice : VŠBM, 2011. S. 356-364. ISBN 978-80-89282-44-9.

[14] GAŠPAROVIČ, P. *Flat static probe insensitive to yaw*, In: 29th symposium on anemometry. - Prague : Institute of Hydrodynamics ASCR, 2015 P. 18-20. - ISBN 978-80-87117-13-2

[15] VAISPACHER, T., BRÉDA, R., ANDOGA, R. *Integration architecture design for implementation of a vector magnetometer on board of unmanned vehicle*, CINTI 2014 : 15th IEEE International Symposium on Computational Intelligence and Informatics : Proceedings : November 19-21, 2014, Budapest. - Danvers : IEEE, 2014 P. 483-489. - ISBN 978-1-4799-5337-0

[16] KURDEL P., LAZAR T., LABUN J.: *Computing skills in aviation ergatic systems* / - 2014. In: SAMI 2014 : IEEE 12th International Symposium on Applied Machine Intelligence and Informatics : proceedings : January 23-25, 2014, Herľany, Slovakia. - Danvers : IEEE, 2014 S. 375-379. - ISBN 978-1-4799-3441-6

Web sites:

[17] Air France flight 447 crash, https://en.wikipedia.org/wiki/Air_France_Flight_447