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Development of Unmanned Aerial Systems (UAS) for scientific monitoring

Creating an UAS competence centre

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1. Background

The KHBO Aerospace Engineering Department offers many types of aerospace related trainings ranging from a professional bachelor in aerospace technology (Flight Technicians) or a professional bachelor in ATPL (Commercial Pilot) to a Master in aerospace engineering. A cooperation exists between the aerospace department of Catholic University of Leuven (KULeuven) allowing their students to work on KHBO assignments. This paper reports on the work that has been performed to create an UAS competence centre in cooperation with different universities in several counties, industrial partners and federal administrations such as the Federal police and Belgian Army.

2. Growing towards the start

Over the last several years UAS were mainly used for military applications. Although KHBO Aerospace Engineering Department is a civil organization, it has seen the potential of UAS almost a decade ago. Since 2004 several bachelor theses were made such as "*Conceptual design of a mini-UAV with methanol fuel cell*" [(1)], "*UAV data monitoring*" [(2)], "*Telemetry and data acquisition for VUT 700 Specto UAV*" [(3)] and many more. It was clear by 2010 that there was a need for a thorough expansion of the UAS knowledge within KHBO in order to make sure the department could play a vital role in the Belgian civil UAS society and the acquired knowledge transferred to the students.

3. Litus project as base for an UAS competence centre

3.1. Project description

As a basis for the UAS competence centre, a large 2-year research program was set up that would utilize the capabilities of the department both from students, lecturers and researchers to the fullest: the development of a UAS platform called Litus.

The work described below has been performed during the Litus program at the Aerospace Engineering Department of the KHBO in Belgium. It is developed together with both educational, research and industrial partners. The UAS platform is aimed at performing scientific missions along the Belgian coast line above the North Sea. The main performance requirement of the 65kg UAS is a range of 160km with a very flexible payload implementation up to 15kg. A propulsion system of two electrical brushless DC motors has been selected in order to minimize the environmental impact during operation by avoiding gas emissions and reducing noise emissions. The UAS name "Litus" is derived from the Latin word for coast. Designing an entire UAS platform from scratch in two years is a very short period, therefore much parallel research was performed both by lecturers, researchers as well as students. Students from all levels within KHBO, KULeuven and foreign universities were employed to develop many aspects required for the UAS. Prof. Ivan Becuwe is project manager. The design team consists of Jon Verbeke M.Sc. and Rob De Roo M.Sc. as project leader.

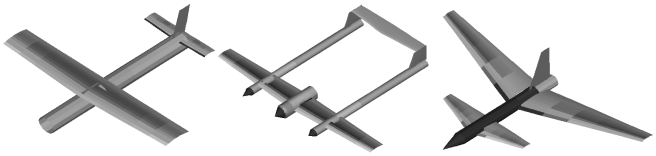

Figure 1: Configuration comparison

3.2. Conceptual design phase

The first step was to explore the current legislation[(4)]. There is no finalized Belgian UAS legislation yet but some papers are circulating on European level. Based on these papers and the project constrains, the main (essential and optional) requirements were set. The next step was to find a suitable UAS platform configuration. Initially, three configurations were conceived (**Fout! Verwijzingsbron niet gevonden.**) for which a conceptual design was performed including 3D modelling in CATIA and aerodynamic analyses by Master students during lab sessions. A lifting canard configuration was found to be most energy efficient and was selected for further development.

3.3. Detailed design phase

During the detailed design phase, the design of the aircraft was further refined and the systems developed. The main design of the aircraft was mainly done by the design team in CATIA (**Fout! Verwijzingsbron niet gevonden.**) based on input of calculations, lecturers, specialists and evaluated student data. Different types of supervision were used depending on the workload, student availability and task

difficulty. So were normal lessons used, professional bachelor/master theses, internal/external internships, Erasmus projects and integrated practicum's.

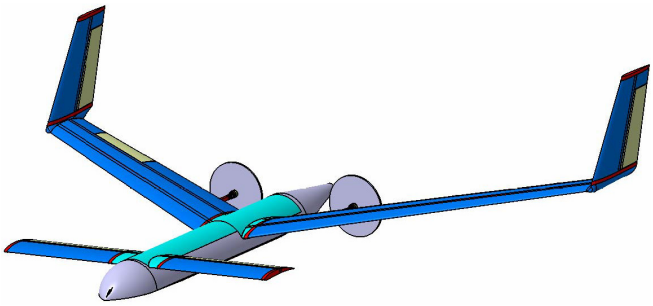

Figure 2: Litus design

After the fixation of airfoils and dimensions was a more detailed CFD analysis[5] required in combination with the evaluation of the UAS's weight & balance and its influence on stability[6]. Because the aircraft is completely made of composites, one of the main concerns was the thermal behaviour of the systems inside the aircraft. Several master students have investigated this[7,8]. First, an electrical model was developed after which thermal properties were added. These were validated in system tests. The combination of both resulted in the accurate simulation of the energy management and the optimization of systems for different flight situations (motor setting, outside temperature, flight path, …)[8].

One of the optional requirement was short take-off and landing capabilities. The idea was to use a catapult launch so 2 separate designs of the catapult were made: one by a Professional bachelor student[9], and one by 2 students of Catholic University of Leuven[10]. The aim was to combine both educational levels (practical – theoretical) in order to obtain the best combination. A retractable main landing gear would facilitate catapult launch, so this assignment was given to 2 students of Catholic University of Leuven[11]. In the end, the decision was made not to build the catapult since early test flights are safer with normal take-off and landing. This decision resulted in the need for a simple fixed composite main landing gear. The main landing gear was developed and produced by the Polymer Engineering students and their lecturer M.Sc. Geert Bekaert.

3.4. Manufacturing and testing

The brushless DC motors for propulsion were selected based on basic performance calculations found in literature, yet the actual thrust a specific propeller-motor combination could deliver was unknown. The added difficulty is that literature takes empirical data into account for large aircraft which is less applicable to small size UAVs. Accurate performance data is essential to calculate the take-off runway length, range and endurance and therefore an engine test bench was designed[12] and build [13] (**Figure 3**). The test data resulted in a motor-propeller combination that was most efficient and in addition was used in the UAV's energy management model. The production of the composite structure (wings, tails, canard and fuselage) was mainly done by the design team. The electrical system was designed and build by the project leader and an Erasmus student [14].

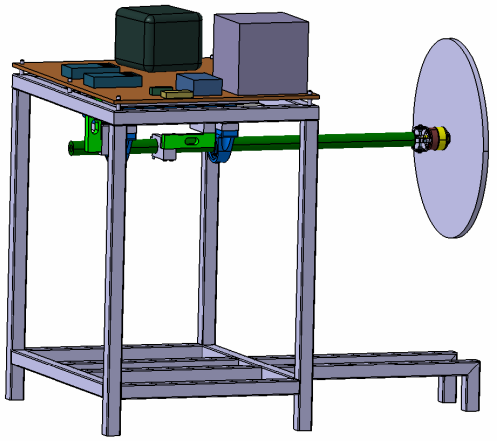

Figure 3: Engine test bench

3.5. Status

The Belgian Civil Aviation Authorities require a technical construction file, an operational manual and a safety manual to approve test flights. By using the design principles of general aviation during the development, these documents are currently close to approval by the BCAA. Since no actual legislation exists, a safety oriented approach was taken when design choices were not regulated by existing legislation. Most parts of the aircraft are finished. Unfortunately, the fuselage is currently not finished due to shortage of time of the design team. The design team plans to finish the production in the spring of 2013 and perform the first test flights by summer 2013.

4. Parallel research

In order to expand the knowledge of UAS beyond the Litus program, several other projects were performed. KHBO students designed and build a fixed wing UAS which can carry a thermal camera for forest fire monitoring[15] in cooperation with the Belgian Federal Police. KHBO's capabilities are not constrained to fixed wing aircraft. Slow (and stable) platform such as a UAS airship[16] and UAS autogyro[17] were developed and will undergo (further) test flight in 2013. Two Master students have reverse engineered and optimized an existing UAS for their thesis[18]. In order to give students a better idea of how to construct a UAS, its controls and systems, a Bachelor student was given the assignment of developing a model aircraft[19]. It is based on an existing one and upgraded to be a cheap, slow flying model aircraft that can be very easily build by amateurs as a hobby and to initiate them into remote control piloting. First year Bachelor students will be given the assignment to build and fly this model

aircraft during lab sessions. Every year, the Belgian Army builds large numbers of their own UAS, ULTIMA, to serve as flying targets for shooting practice. Currently, their drone is limited by its low endurance. A KHBO student modified the test bench for electrical motors to allow testing of small combustion engines and made a comparison of the ULTIMA engine and a possible upgraded engine for longer range and endurance[20].

In addition to the UAS research performed at Bachelor and Master level, a KULeuven PhD researcher, attached to KHBO, is designing, building and test flying a rotorcraft UAS platform for inspection of orchards and vineyards[21]. This is in cooperation with the KULeuven Production Engineering, Machine Design and Automation (PMA) section, more specifically their quadrotor research group. The platform will be able to navigate autonomously through an orchard and inspect the trees and their fruit.

5. Conclusion

UAS are a very interesting subject in education because it's a completely new type of aerospace research with its own non-described challenges (legislation, systems, advanced materials, …). The UAS industry for civil application is expanding rapidly. In addition, the education of today's students is the base for new technologic evolutions in the future. A wide and profound base was laid by involving as much students as possible each with their own background, interest and educational level. Over the past 2 years, a total of 27 students, both national and international, have been involved with the expansion of the UAS knowledge in KHBO.

The creation of the UAS competence centre over the last 2 years can be seen as successful based on the large number of successful projects, both theoretical and practical. The next step in future is a further expansion towards the industry. The first step is already taken by participating in the legislation workgroup which is writing the Belgian UAS legislation based on international documents. Parallel to this effort is a constant search for new projects with other partners such as universities and companies that will drive KHBO to become a UAS competence centre playing a vital role for both industry and academia.

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