Conference Presentation

Curriculum development of undergraduate and post graduate courses on small unmanned aircraft

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Curriculum Development of Undergraduate and Post Graduate Courses on Small Unmanned Aircraft

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Abstract—**This paper describes the development of an undergraduate and a post graduate course on Small Unmanned Aircraft (SUA). Few emerging technologies provide the potential for such a diverse application of knowledge as SUA which are more commonly referred to as "Drones". They are being used for civil purposes in a growth business sector predicted to be worth billions of pounds over the next 10 years. They are also revolutionising everything from agriculture to film-making and are increasingly being used to monitor, research and conduct data gathering missions in surveying, mining, forestry, ecology, archaeology virtual reality and computer gaming. The purpose of this paper is to present the ideas and the researched findings which informed the rationale used for the curriculum development of the first Bachelor of Engineering Degree in Drone Technology to be offered in the UK, and also that of an accompanying Master of Science Degree in Unmanned Aircraft System Technology.**

Keywords—small unmanned aircraft; SUA; unmanned air vehicle; UAV; drone technology; curriculum development; graduate; courses; unmanned aircraft system; UAS technology

I. Introduction

The origins of drones may be traced as far back as the mid-1800s when they were first used in a military application [1]. However, in the commercial aviation market they are a recent development and although no firm date has been assigned to their emergence, the European Aviation Safety Agency (EASA) seem to accept 2013 as the year of the drones [2].

Drone technology is a rapidly expanding market for which the United States Federal Aviation Administration (FAA) predict the hobbyist UAS fleet to triple in size from 1.1 million to 3.5 million units and the commercial non-hobbyist UAS fleet from 42,000 to 442,000 aircraft by 2021 [3]. At the time of writing this paper, the number of Civil Aviation Authority (CAA) registrations of commercial drone operating organisations stood at 2,825 [4]. Drone technology is also feeding into other areas of aviation, most notably into manned autonomous flight with the Ehang 184 Autonomous Aerial Vehicle (AAV) [5] and no-emission electrically powered flight [6], for which advances in brushless DC motor technology for high speed flight [7] and the increased capacity and control of electrical storage devices are key technologies.

The Legislative environment is a critical factor to the continued growth of the commercial and educational sectors of unmanned aviation. Currently, within Europe, the regulation of drones with a maximum take-off mass (MTOM) below 150 kg falls to the National Aviation Authority (NAA) of each member state, which in the UK is the Civil Aviation Authority (CAA). The CAA categorise Small Unmanned Aircraft (SUA) as those having a MTOM below 20 kg and have issued guidance for their operation both privately and commercially within UK airspace [8]. However, the Riga Declaration 2015 on Remotely Piloted Aircraft [9] empowered EASA to develop legislation encompassing all European drone operations [2] and at the time of writing this paper, it is still unclear how Brexit may affect the UK's legislative position on UAS operations. Drone operations at Wrexham Glyndwr University are conducted with SUA having a MTOM not exceeding 7 kg and are considered a commercial undertaking. As such CAA Permission for Commercial Operations has been sought [10] and insurance provisions are in place [11].

II. Background Rationale

Just as we must continuously review and update our skills to run the technology in our modern lives, universities should always review and develop their curriculums to adapt and remain relevant for the effective provision of Higher Education. Heywood [12] defines the curriculum to be the formal mechanism through which intended educational aims are achieved and also qualifies this definition by stating that the curriculum process is described by those factors that bring about learning. In most universities, engineering degrees are still offered along traditionally distinctive lines such as mechanical or electrical engineering. Although nowadays the learning required to be a successful professional engineer necessitates a multidisciplinary skillset [13]. Over the past decade there has been an increasing acceptance of this cross-over between disciplines and degree courses such as Integrated Engineering, Mechatronics and Microelectromechanical Systems (MEMS) are now very popular in Higher Educational institutions [14].

In the paper on Curriculum Design and Development McKimm [15] suggests that the development of a curriculum extends beyond the syllabus, describing the content of its programme of study, and also encompasses the entire learning process. Consideration to the individual's learning style is an important element of curriculum design and is regularly

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scrutinised during the validation process for a course. Since Kolb [16] developed the Learning Style Inventory (LSI), in which he classifies learning style preferences, there has been an increased awareness in his experiential model and a greater emphasis placed on the mantra of learning engineering by doing engineering within a higher educational context. Indeed a hands-on project based approach to learning is much favoured amongst learners and educators alike. It can engage the student and provide for a less formal approach to engineering study in which many students quickly develop problem solving skills. McGoldrick et al [17] describes how UAVs have been successfully integrated into the curriculum in Trinity College Dublin through multidisciplinary studies and provides the opinion that the full potential of drones has yet to be realised in industry and education. Indeed, owing to the wide field of application of drone technology, most universities now incorporate some aspect of the technology within their curricula. At WGU, the positive feedback received from both graduate and undergraduate students, relating to their drone based projects (outlined later in this text), has emphasised the benefits of a bespoke UAS based degree course. And in the USA some universities, such as Embry-Riddle Aeronautical University, are already offering Bachelor of Science Degrees dedicated to UAS Technology [18].

In a fast changing technical field such as UAS technology, learning can involve students visiting websites, watching YouTube videos and engaging in technical chat rooms. It also places a greater emphasis on group activities, experimentation, information sharing and the use of Open Educational Resources [19]. Although developing these information skills are fundamental to stimulating growth and prosperity in a modern knowledge society [20]. It is, however, important that such project based study is conducted within an educational framework that ensures the students are provided with the correct learning environment. It also matters that the students understand factors such as any underlying theoretical principles, ethical dimensions to their work and the productive use of their time.

The developed courses are intended to provide learners with the abilities to solve technical problems with well-founded engineering solutions and to demonstrate a comprehensive understanding of the technology and

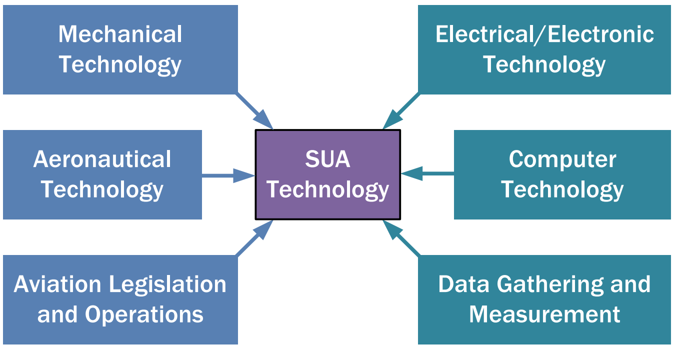

Fig. 1. Visualisation of SUA technological subject areas.

terminology relating to the component elements of unmanned aircraft systems. Also to develop the ability to critically analyse the airworthiness of a SUA, considering its role, limitations and the purpose of its constituent components. Students should also be able to analyse the flight stability, control, power and associated operational parameters required to conduct an advanced SUA mission and be able to demonstrate a systematic understanding of the knowledge and a critical awareness of the current problems associated with the successful and safe conduct of a SUA operation.

III. The Implementation of SUA Technology to Higher Educational Studies

SUA technology is based on a multitude of technological subject areas as depicted by Fig. 1 and allows the opportunity for engineers to develop in a way that has not previously been amenable or available to most educational establishments. A dedicated drone degree provides the opportunity for the student to learn a variety of differing subject areas and using a variety of methods.

A. Mechanical Technology

The complete drone design using CAD can be achieved with structural analysis using Finite Element (FE) software to determine the aircraft load and stress characteristics. Materials and their relative properties and benefits are evaluated considering a wide range of composite, metallic, plastic & wooden structure possibilities.

B. Workshop Practical Sessions

Important hand fitting techniques and safe workshop practices can be taught using various materials, metal, wood and plastics (composites) and differing equipment such as hand tools, rapid prototyping (3D printing), laser cutting, soldering and crimping.

C. Electrical/Electronic Technology

An excellent understanding of wireless transmission devices and the UK Ofcom rules and regulations can be gained by implementing the use of radio devices such as Taranis Transmitters using Open Source software and 2.4 GHz and 5.8 GHz transmission frequencies. Also important is an understanding of the latest receiver technology and Failsafe provisions and what can be done, for example, in the event of a loss of signal or drone Fly-away condition. Global navigation Satellite Systems (GNSS) can be studied and should include all the available systems, in particular GPS, GLONASS and GALILEO, the operation of their signals, stations, triangulation and atomic clocks.

A programme of drone study can also include the conventional electrical and electronic subjects such as: brushless DC motors and drives, Electronic Speed Controllers (ESCs), battery elimination circuits (BECs); Micro-electromechanical Systems (MEMS technology); control signals: Pulse Position Modulation PPM; Pulse Width Modulation PWM; Transistors, diodes, relays, resistors Signal inverters; Ancillary equipment e.g. LEDs, Piezo electric buzzers etc. Lithium polymer batteries: Construction,

TABLE I. STRUCTURE OF BENG DEGREE [21]

Bachelor of Engineering Degree (Honours) - Drone Technology and Operations UCAS Codes: A336/A337 (with Foundation Year)		
First Year BEng (Level 4)	Second Year BEng (Level 5)	Final Year BEng (Level 6)
Engineering Maths ENG461: 20 UK Credits	Further Engineering Maths ENG537: 20 UK Credits	Engineering Modelling and Simulation ENG668: 20 UK Credits
Mechanical Science ENG458: 20 UK Credits	Business Research and Professional Development ENG52F: 20 UK Credits	Aerodynamics ENG680: 20 UK Credits
Electrical Science ENG459: 20 UK Credits	Engineering Mechanics and Design ENG52G: 20 UK Credits	Advanced UAV Operations ENG693: 20 UK Credits
Engineering Design Practice ENG417: 20 UK Credits	Embedded Systems ENG52K: 20 UK Credits	UAV Sensor Technology ENG689: 20 UK Credits
Materials and Manufacturing ENG419: 20 UK Credits	Drone Design and Construction (Project) ENG52N: 40 UK Credits	Dissertation (Project) ENG654: 40 UK Credits
Drone Technology and Operations ENG481: 20 UK Credits		

performance, care and maintenance. Charging, Discharging and potential hazards and safety procedures. PCB design and construction.

D. *Aeronautical Technology*

This allows the opportunity to learn about aerodynamics, the airframe and propeller design and the associated calculations such as, lift, drag, power and efficiency. Also students can conduct studies using Computational Fluid Dynamics (CFD) and study the atmosphere and its associated calculations of pressure, temperature, density, moisture and lapse rate. Drone stability and control studies can include roll, pitch and yaw control. Lateral, longitudinal and directional stability. Definitions such as stable, unstable, neutral stability. Methods of CG determination, manoeuvres and PID calculations and tuning: proportional, integral and the differential control algorithms for the IMU Inertial Measuring Unit control software.

E. *Computer Technology*

Programming skills can be developed by incorporating Arduino or Raspberry Pie microcontroller technology to drone designs or by accessing the Open Source code for components such as the Naze 32 Flight Controller board or Electronic Speed Controllers. Applications of drone technology also provide programming opportunities in areas such as Gaming, Virtual reality (simulation) and FPV drone racing and oculus rift immersion technology.

F. *Data Gathering and Measurement*

Understanding Optical Measuring Techniques including 3D Techniques (Passive and Active). This involves learning the principles of light with a particular emphasis on coherence and lasers technology. Also Photogrammetry (2D and 3D): LiDAR, TOF (Time-of-Flight) Camera technology, Stereo-vision, Structure from Motion, Interferometry etc. Still and video photography e.g. GoPro Hero 4 camera, RED EPIC digital cinematography (top end BBC quality). Appreciate the laws relating to Data Privacy and Camera Gimbal Design and control. Students can also learn about sensor technology including Ultrasonic and IR emitters /sensors, gas sniffers, pressure (altitude) transducers, magnetometers (compass) etc.

G. *Aviation Legislation and Operations*

Of key importance is knowing how to legally operate under a CAA Permission for Commercial Operations (PfCO). Knowledge on the backdrop to current aviation legislation including the formation of the International Civil Aviation Organisation ICAO, the Chicago Convention and the roles of the Civil Aviation Authority CAA (UK), the European Aviation Safety Agency, EASA (Europe) and the Federal Aviation Administration FAA (USA). Detailed analysis of current drone legislation such as the Air Navigation Order and CAP 722 (Drone Guidance): Rules and Regulations associated with drone operations.

IV. UNDERGRADUATE COURSE STRUCTURE

The BEng in Drone Technology & Operations is designed to equip engineers of the future with the knowledge required to safely and legally design, manufacture, maintain and operate SUA (up to 20 kg MTOM) here in the UK and abroad. The course was officially validated in early 2017 and derogations relating to accreditation requirements were included. IET accreditation for the courses is coordinated via the Engineering Accreditation Board (EAB).

V. POST GRADUATE COURSE STRUCTURE

This practical orientated MSc in Unmanned Aircraft Systems (UAS) Technology has been specifically designed for professionals whose occupational fields would benefit from applications of UAS technology. These are as diverse as agriculture, logistics, surveying, mining, forestry, ecology, archaeology, emergency services, estate management, virtual reality and computer gaming. This course is also ideal for those who are keen to enter this industry sector and wish to develop a thorough understanding of UAS Technology.

TABLE II. STRUCTURE OF MSC DEGREE [21]

Master of Science Degree – Unmanned Aircraft Systems (UAS) Technology Institution Code: G53		
Taught Component		Research Component
Engineering Research Methods ENG740: 20 UK Credits	UAV Constructions ENG763: 20 UK Credits	MSc Dissertation ENGM66: 60 UK Credits
Sustainable Design and Innovation ENG706: 20 UK Credits	UAS Operation and the Law ENG762: 20 UK Credits	
UAS Technology and Applications ENG759: 20 UK Credits	UAS Sensor Technology ENG764: 20 UK Credits	

Fig. 2. V-tail Quadcopter configured with a data-logger and telemetry for validation flight testing.

UAS are frequently used for data-gathering purposes and during this course you will have the opportunity and the analytical support to gather and analyse data as part of the project dissertation. Typical forms of data gathering are 3D terrain mapping and surveying using PIX4D software.

VI. Drone Dissertations

The final year Projects completed in the year 2017 at WGU, on the existing Bachelor of Engineering courses, have been listed below. There was evident cross-over of subject areas and the project work was successfully achieved without any detriment to academic level or rigour. Feedback from the students on their project experience has been very positive and students have expressed how studying drone technology has been an interesting and enjoyable experience, which has effectively underpinned their degree subjects [22].

- Design and manufacture of a First Person View (FPV) racing drone;
- UAV Ultrasonic Sensing Technology;
- Portable Drone Design;
- Infra-red Sensor Technology for UAV applications;
- Design of a foldable photographic adventure drone;
- Drone Mounted Public Announcement (PA) System;
- Design of a V-tail Quadcopter;
- Design of a 3-Axis UAV Gimbal Mechanism;
- Design of an Agricultural Crop Spraying Drone.

Example Project Focus: Design of a V-tail Quadcopter. In this final year project a mathematical model of an x-configured quadcopter was created, using MATLAB/ Simulink, with dihedral angles included to the aft quadcopter arms to simulate a vee-tail. An actual model was also designed and manufactured as shown in Fig. 2, in order to validate the mathematical model. Flight testing was conducted and the Inertial Measurement Unit (IMU) and motor data was recorded using an Arduino UNO R3 and a Datalogger Shield. The results were compared with the mathematical model and a subsequent analysis resulted in modifications being made to the assigned Cooper-Harper rating of the aircraft's flying qualities. In conducting this practically based project a wide range of subject area skills were exercised by the student including structural CAD design, mathematical modelling, software design, hand skills, radio frequency telemetry and operational risk assessment [23].

VII. Conclusion

An undergraduate course in Drone Technology and Operations and a post graduate course on Small Unmanned Aircraft Technology have been successfully developed and validated at WGU. The background research assessed the market demand and reviewed the conventional educational practices used in the delivery of engineering based undergraduate and post graduate courses across a range of educational establishments both within the UK and internationally. In structuring these courses, attention was given to current open learning practices and to methods of developing the students' techniques for information sourcing and problem solving in a fast changing information technology environment. This has been achieved through an increased provision of practical hands-on elements to the course and the associated technical challenges.

Future course developments will be strongly influenced by the future of the UAS legislative environment. It is therefore important that the developed courses are kept abreast of any changing requirements, especially as it is considered most probable that EASA will soon be responsible for SUA operations within the UK. Under these circumstances provisions will have to be put in place to ensure that WGU, and its staff, are appropriately qualified to deliver the courses and even able to offer airworthiness authority recognised pilot training for the students. Areas for future curriculum development at WGU are envisaged in Autonomous Aerial Vehicle (AAV) technology, drone swarm technology and a wider development of the research based PhD programme in UAS technology.

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