Development of a Versatile UAV Platform for Agricultural Applications

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Abstract: This paper presents the SAE-USM's (School of Aerospace Engineering, Universiti Sains Malaysia) Unmanned Aerial Vehicle (UAV) research initiatives in designing a versatile platform for agricultural applications. The 30 kilograms UAV is designed to allow very high resolution pictures of 1-2 centimetres to be taken in durations of 6 hours of continuous flight. The cruise speed and the design flight altitude would be determined from the payload capability in producing the required resolution. As a result, several possible airframes in modular fashion are proposed and evaluated to obtain the most promising performance to meet the design criteria. From experience learnt in designing the *Mosquito* UAV platform with System Consultancy Services Sdn Bhd (SCS), the UAV research group is confident to meet the requirements demanded by local agriculture-based companies on an unmanned aerial vehicle. It is anticipated that this effort will establish some common standards in the development of very small UAV platforms for wider usage in Malaysia.

I. INTRODUCTION

By definition, an unmanned aerial vehicle (UAV) is an airplane which is designed with no pilot on board which can take over various roles of piloted aircraft. The use of UAVs in the world is envisioned as an absolute necessity for the future, for example, expanding roles covering “persistent intelligence, surveillance and reconnaissance” (ISR) for the military from just being an “eye from the sky” in the late 20th century [1]. According to UAV Systems International, nearly half the nations of the world have some type of UAVs in their arsenals, and 43 were on record as producing at least one airframe – a remarkably diverse collection of over 500 systems, including variants and those no longer in production [2]. By 2014, the market for UAV reconnaissance systems (including air vehicles, ground equipment and payloads) is expected to be worth US13.6 billion, where more than 9,000 UAVs are expected to be purchased over the next 10 years by countries in every region of the world [3].

In Malaysia, the desired use of UAVs in the military segment was highlighted by the Minister of Defence, Dato’ Seri Najib Tun Razak during a seminar organised by the Ministry of Defence of Malaysia. In his opening speech, he urged two core technologies to be developed towards the nation’s self-reliance: the UAV and Missile technologies. As for non-military applications, no known report has been officially published as yet. Potential use of UAVs in the civil sector is expected to be hampered by Department of Civil Aviation (DCA) regulations, which do not sufficiently cover unmanned platforms. This issue will stifle developments of UAVs even though the utilisation of UAVs by enforcement agencies such as the police is seen as a cost-effective solution to helicopter patrol. It is also high time that UAVs be exploited to advance the agricultural sector as a tool in the implementation of precision farming techniques. Employing UAVs is seen as a more cost-effective alternative to many satellite-based agriculture monitoring systems.

The aspiration of the nation to progress UAV development is slowly taking shape. USM can proudly claim that at least (even though not yet to the anticipated standards as required by the Armed Forces) an indigenous UAV has found its footing on Malaysian soil. USM has collaborated with SCS to produce an award winning ‘*Mosquito* UAV’ that has

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been flight tested successfully [5]. The experiences gained from the development of '*Mosquito* UAV' have catalyzed the research direction of SAE-USM.

II. UAV DESIGN INITIATIVES

Following the development of '*Mosquito* UAV' programme (since early 2004), feedback from interested parties to own an UAV system has been quite encouraging. Most of the inquiries are focused on how the UAV can help them to enhance their routine chores. The most common mission requested for the UAV is in the area of aerial photography, where the use of helicopters, passenger aircrafts as well as satellites is usually used. . At least one company has enquired on the possibility of missions related to observation of oil pipelines and another, on the enhancement to cadastral work. Recently, two more entities have enquired about the use of UAV in carrying out farming related projects. The following subsections describe examples of USM's research initiatives for agriculture, and pipeline monitoring which provide further push in the direction of versatile platform development.

Agriculture

Realising the need for the nation to expand agriculture capacity in Malaysia, the use of UAV is timely and seen as the most cost-effective solution to this region. The use of satellite-based solutions for precision agriculture is not only expensive; in addition it is not effective. Data obtained from satellite images are usually a few weeks old, even months to be of practical use in many instances. One of the main reasons for the delay can be due to the fact that Malaysia is usually covered under clouds and tropical storms, where no affordable optical sensor can penetrate from space.

The use of UAV for precision agriculture is not unrealistic. The success of IntelliTech's Vector P UAV system is proof that a cheap system can be used to better satellite resolution, mainly due to its flying height factor [6]. The images taken from this platform is qualified by U.S. Department of Agriculture (USDA) to be accurate. Further study on the system specifications reveals that it is not much different than the '*Mosquito* UAV' system manufactured by SCS [7] in collaboration with SAE-USM.

The use of airborne platforms for fertiliser and pesticide applications is common in large areas where labour cost is not justifiable. In the US, aircrafts and satellites are also used to help farmers manage land usage, as well as to observe the causes of poor plant growth and pinpointing the need for fertiliser and pesticide application at an extremely high level of resolution and accuracy. The use of passenger aircraft is no longer appealing due to high labour cost and the recent price hike in hydrocarbon cost.


Fig. 1. Multispectral image from Vector P UAV

The design of UAV for agricultural purposes can be distinguished by its missions: observation and commodity carrier. For observation mission, the UAV can be very light weight of up to 30 kilograms. The distinct feature of this UAV is that it must be equipped with low-cost imaging system, autonomous flight, stabilised by inertial navigation sensors that includes GPS system that is able to geocode aerial photographs. The desirable resolution is about 1 – 2 centimetres, a relatively better image resolution than that of any satellite-based images.

Due to plantation terrain conditions in Malaysia, it is desirable to enable the UAV to takeoff from the top of a moving vehicle. The vehicle will be driven to certain takeoff speed before the UAV flies. Recovery of the UAV should be through parachute or net capture. (In this way, the need for runway is eliminated.) Subject to the mentioned requirements, a pusher-prop engine with top mounted engine is envisioned to be the best choice for propulsion.

On the other hand, UAV for commodity carrier such as for fertiliser and pesticide applications missions should be built with at least 50 kilograms of payload capacity. This would make its weight to about 120-150 kilograms. In addition, the payload bay should be designed in such a way as to allow fast replacement of commodity and its dispersion system. Despite weight limitation, this UAV should also be flying at a relatively low speed and stable enough to fly at low altitude, to allow thorough dispersion of commodity. The challenge is to design a very stable platform for empty and fully loaded flight conditions.

III. Research Direction.

A UAV is an integrated system which consists primarily of four subsystems: airframe, control system, payloads and communication systems. Based on readily available expertise and resources, SAE-USM would focus its efforts on the development of the first two components, vis-à-vis, the air frame and the control system; the others, are dependent on its industry partner/s. The airframe design is dictated by the intended payload requirements and other design objectives set by expected customer needs – while the necessary control system is being worked on concurrently. The communication system is usually readily available in the market.

Strictly speaking, the size of the UAV's airframe depends on the specific imposed performance requirements. Maximum take-off weight (MTOW) of the UAV can be anywhere from just a few kilograms to a few thousand kilograms. MTOW would determine, to a large extent, the overall airframe configuration. Presently, the school is focusing on the development of UAV system with MTOW of not more than 30 kilograms. Aircraft under this weight could fly without any special permission from the DCA and thus would simplify its flight test procedure. However, with the 30kg constraint, payload size/volume, cruising speed, range, and the airplane endurance would be all limited. Nevertheless, experience and knowledge gained during the integration process would remain very useful for the development of bigger UAV.

The UAV's ability to fly autonomously had offered various possible applications related to civilian activities or military operations. The fact that there is no pilot onboard had also rendered the production cost of UAV's airframes to be much cheaper than their counterpart, that of a manned airplane. As a result, the UAV's airframe is normally tailored for a special purpose rather than designed as a multipurpose airframe configuration. The airframe of UAVs designed for agriculture purposes would differ significantly from the airframe designed for supporting the marine patrol activities. In addition to this, the availability of propulsion systems as well as the payload present in the market would dictate the UAV configuration to a large extent. So, to design a versatile platform would require knowledge of predetermined market requirements and judicious selection of performance parameters.

To design the required airframe, SAE-USM has been conducting some study on market needs and flight operational requirements to set the design objectives for the UAV platform. The Fig. 2 shows the flow chart which described the overall procedure in designing the UAV system.

In the design loop (Fig. 2) which includes the analyses and evaluations in aerodynamics, propulsion, structural, flight performance and flight dynamics and control, many iterations are required to reach a viable design. Structural analyses and evaluations as well as the activities related to weight and balance cannot be accomplished in a single iteration. However the aerodynamic analysis, initial airframe configuration, performance and flight dynamics analysis could be made in one single run of the codes.

The autonomous flight capability means that the airplane has capability to maintain its prescribed flight trajectory for any change of the local flight conditions. Such capability would be available if the processor to be on board can fit in the airframe. Some typical payloads that can be sourced from the market to enable autonomous flying are: VESCAM 12DS200 (VESTRON CORP.), STAR SAFIR (FLIR SYSTEM INC.), RISTA (NORTROP GRUMMAN CORP.). VESCAM 12DSD200 from VESTRON CORP had been used for Pioneer UAV (Fig. 3) with the design specification of the payload as follows (ref. http ://uav.navair.navy.mil /database/ matrix.htm):

Dual Sensor (IR / daylight)

- 3rd generation InSb (3-5 m)
  - Three (3) FOV Optics
  - 256 x 256 Staring FPA
- Daylight colour camera with 10X zoom lens
- 4-Axis Active Gyro- Stabilization
- 6-Axis Passive Vibration Isolation

- Power: 210 [W]
- Turret
  - Diameter = 12 [in] (30.5 [cm])
  - Height = 14.6 [in] (37 [cm])
  - Weight = 47 [lbs]
- Air Vehicle Mounting Unit (Platform Specific)
- Interface RS-422

Fig. 3. Payload system from VESTRON Corp

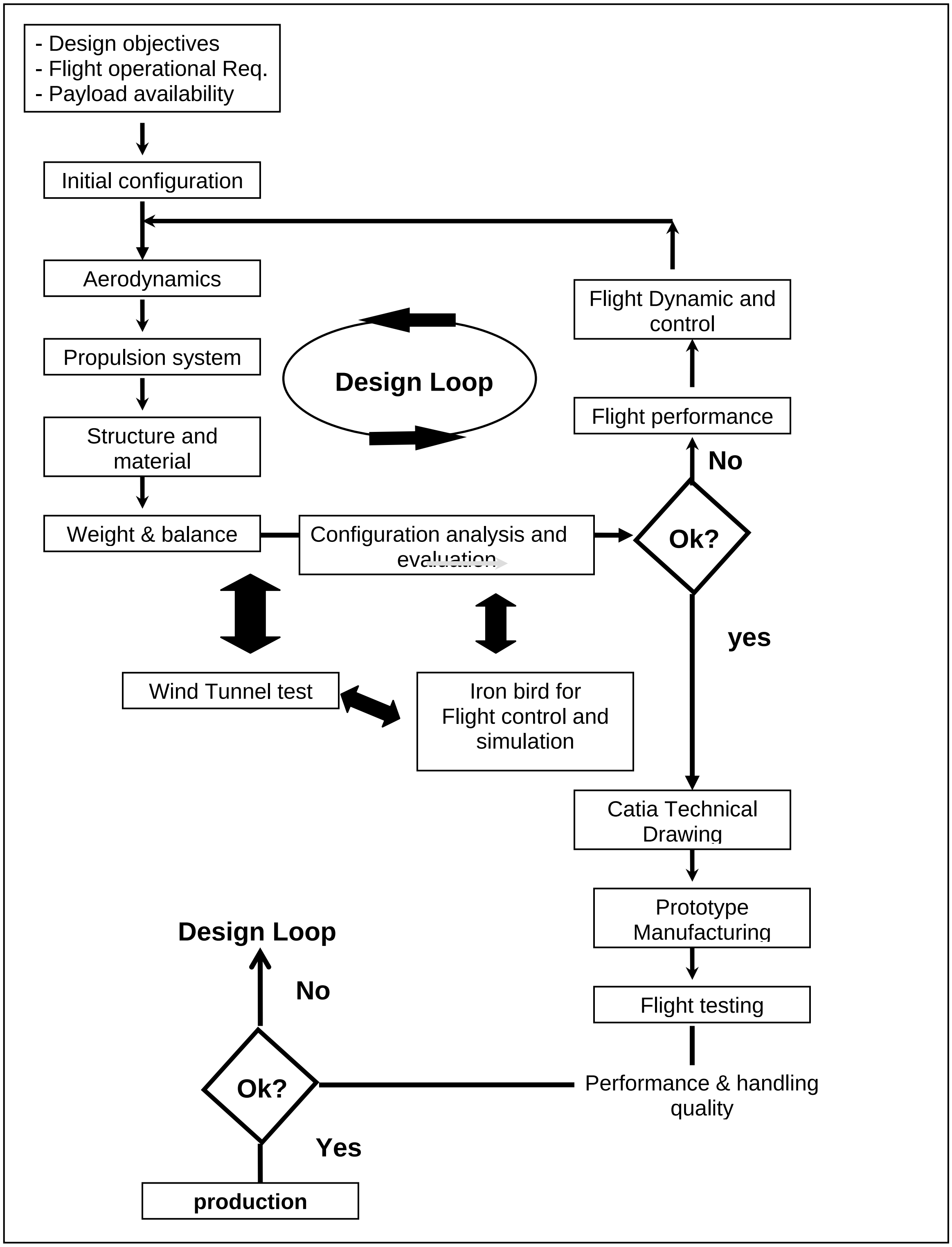

Fig. 2. The Flow chart of UAV Design procedure

With the assumption that the payload for any SAE-USM UAV would be sourced externally, the research direction of SAE – USM focuses on three parts:

1. Enhance capability in the airframe design
2. Development the iron bird as flight simulation platform
3. Development of ground control station

Efforts to enhance the airframe design capability involve:

1. The development of data base for airfoil and engine
2. The development of a code for generating aircraft geometry
3. Integration of the aerodynamic, performance and flight dynamics analysis codes into one
4. Improvement of data compatibility between aerodynamics and structure analyses and also with CATIA for the detailed technical drawing
5. The development of facilities for determining the center-of-gravity and moment of Inertia for the test articles

The development of the iron bird is intended as the platform for testing the aircraft control system on ground before putting into the real prototype. The iron bird has the same size as the model tested in the wind tunnel. Hence, flight simulation (by using the flight dynamic software which would be installed in the processor on board) can be conducted by using a complete set of aerodynamics characteristics data from aerodynamics computation and wind tunnel test. The ground control station is developed to control and monitor the UAV flight and also gather information from the payload. A lot of work remains to be done to achieve good reliability in this area.

The manufacturing of the airframe and other related hardware as well as the flight testing would be carried out with external partner/s.

IV. Issues Pertaining to Designing a Versatile Platform

The need to focus R&D resources and efforts to configuring a versatile platform for a UAV arises primarily due to budget and other resource constraints. However, it is also the school's intention to maximize returns for its efforts by targeting the type of platforms that would satisfy the UAV needs in several areas nationally. The UAV platform to be designed must be able to carry as many kinds of payloads to perform tasks and accomplish missions for the following potential areas:

a. Agriculture (Precision farming, fisheries, inventory, etc.)
b. Security (Surveillance, monitoring, tracking, searching, communications, GIS, etc.)
c. Environment (sampling, meteorology, metrology, imaging, etc.)

There are many other areas for which a UAV would be of great use; there are others of which the new configuration may be viable as a platform to accommodate the relevant instrumentation and sensors for which the services of a UAV are yet to be harnessed. It should be stated here that the USM UAV team pursue an adaptive design that caters to missions for which the UAV is believed to have a market here.

Considering the vast arrays of usage possibilities, there need to be some discriminating factors on what to design for. Specifications of the UAV that are of fundamental considerations to the designers include dimensions, weight, range and speed. As opposed to the norm in a design process whereby specific performance requirements dictate all flow-down parameters, designing to capture a wide open audience means designing subject to other environmental constraints. Some of the governing criteria, not in any particular order, dictating features of the versatile UAV platform include:

a. Basing
b. Operating altitude
c. Validation ability
d. Anticipated payload weight
e. Component modularization
f. Reliability, and

g. Cost

With this set of considerations, the UAV to be developed will be one limited to endurance of less than 10 hours, low flying – less than 8000 ft altitude, fly at less than 200 kph, weighs no more than 30 kilograms and capable of carrying a payload of 10 kilograms.

As the UAV program is still considered in its infancy state, there are many areas for which the School is weak in. Certainly, the short history and limited resources to carry out sufficient number of both ground and flight testing implies that the platform that exists today is not ready for any high value airborne assets. Reliability will remain an issue until more tests are affordable for the present generation UAV. The School is actively pursuing opportunities to integrate various mission payloads so as to support its program to develop a versatile platform. It is also exactly because of the need to secure funding for its research and development of the UAV, the School has been pursuing the course (philosophy by default) of "designing-for and to-the-market'. Payload demands and performance requirements by the anticipated impending missions will dictate the next generation configuration and define the UAV's characteristics.

In general, the program faces a couple of big constraints which also dictate what can be actually built. These constraints are due to factors that are also commonly faced by other UAV programs and impose major criteria in the ultimate design of the UAV platforms:

1. Clarity on civil air space regulations for UAV's, and
2. Funding Support for new unfamiliar product developments

As development of UAV grows in Malaysia, the first issue will be defined clearly. Meanwhile, challenges lie ahead that need to be addressed will all depend on the second factor. For the program to be successful, the School will need to improve on its test facilities; simulation and validation capabilities; modelling of sensors, sensed targets, environments and Command & Control capability; and, secure some competent partners in flight instrumentation. It is perceived that reliability will be an issue with a versatile platform and hence, system integration for various missions will be an area demanding significant resources.

Low reliability of flight critical systems coupled with human-piloted UAV's pose a serious challenge that will need to be addressed beyond the confines of the technical facilities.

REFERENCES

[1] J.R. Wilson '2005 UAV Worldwide Roundup' Aerospace America, Sept 2005
[2] "http://www.auvsi.org/" Association for Unmanned Vehicle Systems International (AUVSI)
[3] L. Dickerson 'UAV Sales Booming' Forcast International, Oct 2005.
[4] 'Enhancement of National Defence Industry Capabilities Through Competency Building,' opening speech by YAB Dato' Seri Najib Tun Razak, Genting Highlands, 26 – 28 June 2003
[5] 'USM menang lapan pingat emas di IPTA 2005' Utusan Malaysia, 6 Oct 2005.
[6] 'IntelliTech's Vector P Completes Successful Agricultural Test Flight' http://www.vectorp.com
[7] I. Mohd Yusof and B. Basuno 'Research and Development of Mosquito Unmanned Aerial Vehicle: A USM-SCS Successful Collaboration' in Proceedings of International Conference in Defence Technology, Putrajaya, Dec 2005. pp213-221