SURVEY OF REGIONAL DEVELOPMENTS: CIVIL APPLICATIONS

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ABSTRACT
The often promised widespread use of UAVs in the global civilian market has generally not yet been realised. Yet most UAV market surveys have indicated a significant upward trend in the civilian market share happening right about now. There are indeed several examples of successes in specific niche market sectors, but generally, the civilian UAV market remain elusive. This paper reviews a recent market survey, and looks at some of the more mature developments in the Asia-Pacific region, and particularly in Australia. Some promising market sectors are also briefly explored.

INTRODUCTION

Australia has had a long and distinguished history of Remotely Piloted Vehicle (RPV) and Unmanned Aerial Vehicle (UAV) developments, most notably being the GAF/ASTA Jindivik target drone, and more recently the BAE SYSTEMS Nulka decoy (which is a UAV under a broad definition). Besides these well-known systems, there has been numerous other developments both in the civilian and defence sectors which may not have entered service in notable numbers. Indeed, archival photos at the University of Sydney show RPV/UAV research activities dating back to the 1930s. Since then, various organisations, companies and universities in Australia have developed various assorted systems, usually independent of each other.

More recently, there has been attempts at a more coordinated national effort on UAV developments. In October 1996, the CSIRO Office of Space Science and Applications (COSSA) sponsored the inaugural national “Symposium on Drone Technology and Use”. The meeting presented a means of gathering and sharing data on research and development for UAVs in Australia, and explored potential applications in the scientific, academic, telecommunications, and remote sensing communities. Following this meeting, the attendance of which far exceeded the organisers’ expectations, the Australian UAV Special Interest Group (SIG) was formed in February 1997 to help disseminate relevant news and information to the national UAV community. In May 1997, the Aerospace Technology Forum (ATF - with members from the federal Department of Industry, Science and Tourism, and representatives from the aerospace industry and academia) commissioned a market report on UAVs [1]. This report compiled the desired capabilities for a range of applications, many of which were in the civilian domain. Furthermore, based on the research done then, it predicted the potential market potential of more than A$20 million between 1998 and 2003. Other than the meteorological surveillance sector, which is very ably covered by Aerosonde Robotic Aircraft Pty Ltd (the subject of a keynote address on day 2 of this conference), much of the projected potential market remains untapped.

In July 1998, the Warren Centre for Advanced Engineering at the University of Sydney organised a round table meeting on “Flying Autonomous Remote Sensing Platforms” to promote the practical exploitation of UAVs to commercial remote sensing applications. This meeting was also attended in overwhelming numbers by representatives from the mineral exploration industry, the agriculture industry, meteorological organisations, defence related organisations, academia, and scientific research organisations, all wishing to apply UAVs to their particular areas of interests. However, the general consensus from that meeting was the resignation that UAV systems were then still not technologically advanced enough and commercially viable enough for most of the market sectors.

On a more positive note, the *Aerosonde* meteorological surveillance UAV systems has matured significantly, leading to commercialisation the global market. UAV research activities are increasing significantly in universities such as The University of Sydney (eg. *Brumby* Research UAVs, *TWing* VTOL concept demonstrator UAVs, and various mini/micro UAVs), the Australian National University (eg. Micro UAVs using insect-inspired vision systems), RMIT (eg. *Jabiru* and *Sarus* UAV studies), and Monash University (eg. *Aerosonde* UAV flight control systems). Looking regionally in the Asia-Pacific, there are certainly examples of commercially viable UAV systems. The most notable of these is the Yamaha RMAX/R-50 series of aero-robots which are found in increasing usage for crop spraying in Japan.

CIVILIAN MARKET SURVEY

At the July 2000 UV2000 meeting in the UK, Frost & Sullivan, which produces well known market analysis reports, presented a summarised revenue forecast and growth rate for the period 1999-2008 [2]. This showed revenue values totalling US$40.29 billion for this time period, with double digit growth rates from 2001. This forecast compares well with an earlier Teal Group forecast reported in Flight International (19-25 July 1995) which predicted a market of US$26 billion in total between 1994 and 2003, assuming the optimistic growth trends. It has also been predicted that the civilian market share will grow significantly over the near term.

The ATF UAV report [1] analysed the scope of the Australian commercial market for air based remote sensing applications, showing market size and potential UAV share of the market in Table 1. Of those civilian market sectors, the report listed the most prominent in terms of market value to be:

- Mineral exploration;
- Media resources;
- Environmental control and monitoring;
- Telecommunications;
- Crop and aquaculture farm monitoring; and
- Unexploded ordnance detection.

UAVs were seen by survey respondents during that study to offer benefits in the forms of either reduction of operational costs in fulfilment of commercial objectives, increased efficiency of operation, and/or increased work (information acquisition) rate. Although Table 1 was compiled in 1997, current market indications appear to continue to reflect that potential. Some examples of attempts at exploiting some of these market sectors include:

- during the recent East Timor crisis, under very difficult circumstances, a news gathering organisation wanted to use small UAVs to acquire newsworthy pictures; and
- mineral exploration and exploitation organisations are known to be continuing their development of UAV systems for autonomous airborne remote sensing under tight commercial secrecy.

Table 1 The size (AUD$ per annum) of various markets identified to have potential UAV applications [1].

Market	Nationwide	Global	Potential UAV share	Notes
Environment Control / Weather Research	$5million?	$100million currently used on weather balloons	60%	Data source from Bureau of Meteorology
Mineral Exploration	$20million in aerial survey; and a conservative estimate of $3million in ground survey	$100million	30%	Data source from companies currently providing service.
Unexploded Ordnance location	$0.5million?	$100million	50%?	Data source from companies currently providing service. Market is rapidly expanding
Crop Monitoring	$2.5million based on current manned aircraft		80%?	500,000 hectares per annum need to be monitored nationwide - currently only 10% covered, using manned aircraft.
Coastwatch	$30million		5%?	Currently 14,500 hours flown by manned aircraft annually
Telecommunications	$500million?	Satellite-based market worth up to $26billion by 2005.	1%?	Rough estimate from miscellaneous sources
News Broadcasting	$15million		5%?	Based on current-estimate of operating aeroplanes and helicopters for news gathering purposes nationwide.
Remote Sensing of Marine Resources	$10million		10%	Estimates from discussions with CSIRO Marine Labs, Hobart
Miscellaneous	$1million		100%	Direct civilian UAV applications, as identified through market survey questionnaire

The miscellaneous category includes applications such as traffic control, power line surveillance, pest location and predator deterrence, and scientific research.

REGIONAL CIVIL UAV DEVELOPMENTS

Long Range Environmental Monitoring

In the civilian UAV market sector, one of the most successful applications in this region has been in meteorological surveillance, currently being met using Aerosonde UAVs. Customers around this region include the Australian Bureau of Meteorology, Taiwan's National Science Council and Central Weather Bureau, the US Department of Energy, US National Weather Service, US Office of Naval Research, and the Observation Frontier Program in Japan. As indicated earlier, this is the subject of one of the Keynote addresses of this conference, so the system will not be described in this paper. Reference information can be found at their web site:- http://www.aerosonde.com.

Airborne Research Australia (ARA) is an Australian national facility for airborne research located at Parafield Airport in South Australia. They currently operate several specialised manned aircraft for atmospheric research and would like to include UAV systems for some of their applications. Likewise, the CSIRO Division of Atmospheric Research has shown keen interest in using UAVs for their observation requirements.

Agriculture

In Japan, there is a very interesting and innovative use of UAVs to meet the niche requirements of their widespread but relatively small rice paddy farms. Data from the Yamaha Industrial Unmanned Helicopters web site (http://www.yamaha-motor.co.jp/sky-e/index.html) show the apparent commercial viability of using small helicopter based UAVs for crop dusting and spraying. Figure 1 [3] show this market, and its apparent dominance by the Yamaha RMAX/R-50 Aero Robot systems. Other crop spraying UAV systems that have been developed in this region include:

- Fuji RPH-2 (Japan); and
- Daewoo ARCH-50/Kamov Ka-37 (Korea - using a Russian helicopter design).

More information of these systems can be found in Reference [4]

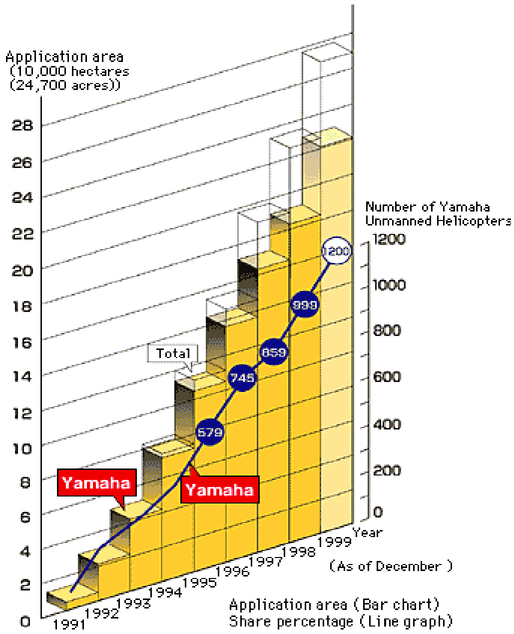

Figure 1 Registered Number of Yamaha Aero Robots and Application Record
(By Japan Agricultural Aviation Association)

Much of the following description of the Yamaha systems are taken from their web site [3], to illustrate how a UAV system can be commercially applied to a niche agriculture sector.

Having made its name worldwide for the development and manufacture of products like motorcycles and outboard motors based on outstanding small-engine technology, Yamaha Motor began developing industrial-use unmanned helicopters in the 1980s. The year 1990 saw the marketing of the Yamaha Aero Robot "R-50," the first industrial-use unmanned helicopter with a 20 kg effective load capacity.

In recent years the Japanese farming industry has been plagued with problems like the aging of the work force and a lack of younger generation successors. In light of this situation, the Yamaha industrial-use unmanned helicopters have become the focus of attention as economical, environment-friendly next-generation agriculture devices that are now being used primarily for crop dusting. For example, in the case of dusting rice paddies, an unmanned helicopter can do the job in about 1/15th the time it takes with the conventional method where a person actually enters the paddy with a spray pump. Since 1995 these helicopters have mounted the Yamaha Attitude Control System (YACS), a Yamaha-exclusive technology that greatly increases flight stability and ease of operation through the use of flight pattern control models based on extensive flight analysis. With YACS, all the flight control elements including, rudder, elevation and speed are subject to computer control that provides constant adjustments according to the parameters of three different flight modes that the operator can select from according to the type of use. Thanks to this system, helicopter operation, which was previously considered a difficult skill, can now be mastered by new operators with just a short period of training. This in turn has succeeded in expanding the demand for these helicopters.

The larger Yamaha Aero Robot "RMAX" (Figure 2) made its debut in October 1997, mounting

Figure 2 Yamaha industrial-use unmanned helicopters at work

a specially developed horizontally opposed liquid-cooled 2-stroke 246cc engine rated at 21 hp. This made possible an effective load capacity of 30 kg at an operating weight of 58 kg. A total of 1,200 units of these two models have been sold so far in Japan. The area of Japanese agricultural land presently being dusted by these helicopters has increased annually and is expected to reach a total of 200,000 hectares in the year 2000, including not only flat fields but also orchards, etc., on steep hill slopes. The number of operators of the RMAX and R-50 has reached 5,500 in Japan.

Due to the maturity and payload capacity of the Yamaha systems, they are also used in numerous robotic and remote sensing research applications. Examples include:

- The recent observation of an active volcano in Japan (March 2000), requiring the development of a fully autonomous out-of-sight flight controller for the mission (http://www.yamaha-motor.co.jp/buzz/others/flying/index.html);
- Georgia Tech Aerial Robot research (http://controls.ae.gatech.edu/labs/gtar/);
- Carnegie Mellon Autonomous Helicopter Project (http://www.cs.cmu.edu/afs/cs/project/chopper/www/heli_project.html)

Within Australia, numerous organisations are known to be exploring the use of small UAVs in applications ranging from surveillance of high value crops using precision farming techniques, to the use of "scarecrow" predator deterrent UAVs on farms with high value crops. The Farrer Centre for Conservation Farming, based in Wagga Wagga, NSW, has long had a requirement for a low cost UAV system for crop monitoring using miniature and lightweight Near Infra Red (NIR) sensors.

Mineral Exploration and Exploitation

In 1995-96, the Australian Mineral Industries Research Association Limited (AMIRA) commissioned a study into the potential use of UAVs for geophysical surveillance, resulting in the report, AMIRA Project P462, "Geophysical Autonomous Model Aircraft Acquisition - Da Gama", available to association members. Although autonomous UAVs were found to offer significant benefits, the prohibitive cost to develop such specialised systems with some very unique system requirements stalled further progress. However, there are numerous unofficial reports that several large mining organisations are covertly commissioning the development of such systems with the hope of gaining a commercial advantage.

Coastal Surveillance
Given the immensity of the Australian coastline and the need to monitor shipping, fishing and other coastal activities, there is always the desire for adequate national coastal surveillance coverage. As such, the organisations currently tasked with coastal surveillance are interested in exploring the possible use of UAVs to enhance their surveillance capabilities, currently met through the use of manned assets. Although as yet, no UAV systems have been trialed for coastal surveillance in Australia, several proposals are being investigated. Kingfisher Unmanned Aviation Systems Australia (KUASA), based in Queensland, is a company recently formed with the aim of providing complete turnkey operations to the civilian, commercial, and military markets. They intend to operate suitable UAV systems for coastwatch and remote sensing. Representatives of the company are expected to be attending this conference.

University Based Research UAVs
Several universities in the Asia-Pacific region are known to be developing UAVs for various research applications, ranging from flight platform design research, flight controller development, to the use of these flight platforms for sensor development, and flight navigation research. This paper will introduce some of these developments at Australian universities.

Monash University is probably a relative newcomer in this as they initiate a collaborative research project with Aerosonde Robotic Aircraft Pty Ltd, to investigate the next generation of flight control systems for the *Aerosonde* UAV. The Australian National University (ANU) is also involved in UAV research, particularly in the use of insect-inspired vision sensors for flight navigation of mini/micro sized UAVs. This is the subject of a presentation on Day 2 of this conference, highlighting an example of Australian ingenuity in challenging conventional thinking in developing UAV technologies. The Wackett Centre at RMIT University has been involved in UAV related research for numerous years, with projects in design studies of multi-purpose flight platforms, the shipborne launch of UAVs, avionic and flight controller developments, and sensor platform developments.

The University of Sydney's (USyd) UAV research and development activities have been most prolific in recent years. Over a period of just over ten years, several UAV flight platforms have been developed and operated, with research in the areas of aerodynamic and structural design, flight performance and control, design concept optimisation, modelling of aircraft characteristics, the use of GPS (Global Positioning System) for platform attitude reference, flight trajectory optimisation, autonomous flight controller design and optimisation, decentralised systems research, and flight mapping and navigation research. The UAV flight platforms (Figure 3) that have been developed and operated include:

- UAV *Ariel*, 36kg AUW (all-up-weight), 10kg research payload when flown remotely;
- UAV *Brumby*, 25-45kg AUW, 3-9kg sensor payload when flown autonomously;
- UAV *TWing*, a tail-sitter VTOL (vertical take-off and landing) concept demonstrator; and
- UAV *Bidule*, a mini/micro AV concept demonstrator, less than 0.3 kg AUW.

A version of the UAV *Brumby* is being developed in conjunction with BAE SYSTEMS Australia to support a collaborative (USyd/BAE) research project, which is the subject of a presentation at this conference as part of the showcase of Australian UAV systems. Similarly, the tailsitter VTOL UAV, also known as the *TWing* or *Mirli*, is the subject of collaborative research between The University of Sydney and Sonacom Pty Ltd, and will also be presented at this conference to showcase another example of emerging Australian UAV systems. Although these developing UAV systems may well see applications in the military market sectors, they are currently developed and operated as civilian systems.

Figure 3 Some of the UAVs developed at Sydney University: (l-r) *Ariel*, *Brumby Mk II*, *TWing/Mirli*, *Bidule*.

Regulatory Environment

The commercial viability of any civilian UAV system to meet market requirements also depends very much on the regulatory environment. In Australia, the Civil Aviation Safety Authority (CASA) has the responsibility for regulating the organisation and use of airspace in Australia. CASA ultimately ensures that all air operations within Australia are performed in a manner which minimises risk to the Australian public. In this role, CASA is responsible for the development of suitable regulations which involve UAVs. A project team, led by Mr Mal Walker of CASA, has led to the proposed CASR (Civil Aviation Safety Regulation) Part 101 *Unmanned Aircraft and Rocket Operations* (http://www.casa.gov.au/avreg/newrules/casr/101.htm), which is internationally recognised as a leading initiative in managing the operation of civilian UAVs. A presentation on the progress of these proposed regulations will be presented at this conference. The ongoing positive attitude by CASA towards civilian UAV operations is certainly conducive to exploiting civilian market opportunities in Australia.

CONCLUSIONS

Currently, there is potential for significant growth in operational UAV activity within the civil sectors in Australia and indeed in the Asia-Pacific region. Commercial activities of significant scale are currently limited to atmospheric monitoring, specialised crop spraying in Japan, and academic related research. There are ongoing experimental investigations into the development of systems directed toward mineral surveying applications.

The reasons for the current low levels of commercial activity appear to be associated with the risk of financial investment in as yet unproven systems. In contrast to military users, for which system developments are typically government funded, civilian operators must provide their own investment in aerial systems. There is obviously then a tendency to "buy off-the-shelf" as this provides the perception of a proven product. Potential civilian operators are often hesitant to invest in developmental projects where the level of investment required to realise an operational system is uncertain, and success may not be guaranteed. Unfortunately, the capital costs of off-the-shelf systems will typically still be high on a per unit basis. In addition, there is also a general level of unawareness in the commercial sector, of the level of technological preparedness of the UAV industry and R & D organisations to develop operationally capable systems. The requirements of many organisations will therefore only become evident after operational system demonstrations become widely publicised.

The hesitancy of the commercial sector to invest in development, explains the current quandary in which the industry sectors capable of developing operational UAV systems cannot do so. Off-the shelf purchases may also be unattractive to commercial users due to the high costs of those systems that have been designed to military specifications. From this viewpoint, the commercial sector would be more attracted to lower cost systems specifically developed with commercial needs in mind. There is motivation therefore for a UAV industry to structure itself around provision of UAVs for civilian commercial purposes.

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