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UAVs OVER AUSTRALIA

Capabilities and Opportunities

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Abstract

It is generally accepted in the global aerospace industry that technologies required for autonomous capabilities for Unmanned Aerial Vehicles (UAVs) are mature enough for more widespread use. Market surveys predict a significant increase in UAV usage over the next five years, when the strong growth in the military applications market would start to settle, while the market for civilian UAV applications is predicted to grow significantly. In the Australian context, the CSIRO Office of Space Science and Applications (COSSA) sponsored the inaugural national Symposium on Drone Technology and Use in late 1996. The meeting presented a means of gathering and sharing data on research and development for UAVs in Australia, while exploring potential applications in the scientific, academic, telecommunications, and remote sensing communities. The meeting further illustrated impending high activity in research and development of UAVs for specific applications.

One outcome of the national UAV symposium was that it prompted the Aerospace Technology Forum, an Australian federal government initiative to strengthen the linkages between Australia's major research institutions and aerospace industries, to initiate a study on the UAV market in Australia. This paper presents a partial summary of the outcomes of the study. It highlights the major findings and pose recommendations with regard to: the potential of UAV applications in Australia; the capability of the research activities and manufacturing industries to support UAV developments.

Introduction

Unmanned Aerial Vehicles (UAVs) have been around since the dawn of aviation, and Australia has been developing some form of UAVs since the late 1940s (eg. the highly successful GAF *Jindivik*). Since the 1970s, there have been repeated claims that Remotely Piloted Vehicles (RPVs) are about to take over various roles of piloted aircraft. With the exception of niche military applications, these claims have not been widely upheld for a number of reasons, one of which being that an RPV still requires a skilled pilot on the ground. Current technology allows the development of fully autonomous systems, hence the accepted use of the term, Unmanned Aerial Vehicles (UAVs), for such airborne systems. There are a number of developments, which have contributed to this situation:

- The availability of compact, lightweight, inexpensive motion detecting sensors essential to the flight control system, including carrier phase Differential Global Positioning Systems (DGPS);
- Compact lightweight low-cost computing power for autonomous flight control and development; and
- The mature aeronautical and control system design capabilities, and the ability to draw upon the extensive worldwide UAV knowledge-base.

It is more recently accepted in the aerospace industry that technologies required for autonomous capabilities for UAVs are mature enough for more widespread use. The significance of unmanned aircraft research as a national resource and potential export earner is illustrated by some aerospace industry news reports, eg. the internationally acclaimed weekly news magazine, *Flight International* reported in their 19-25 July 1995 issue the following:

> *"Nearly 8000 unmanned air-vehicles (UAVs) worth $3.9 billion [US$], will be produced worldwide between 1994 and 2003. The reconnaissance market is expected to double in size over the ten-year period, according to the Teal Group's UAV annual forecast.*
>
> *The forecast released at the 1995 unmanned-systems show organised by the Association of Unmanned Vehicle Systems in Washington DC, estimates that 5250 target drones worth $1.3 billion and 2650 reconnaissance systems worth $2.6 billion will be procured during the decade. The estimate does not consider the cost of related hardware such as*

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ground-control stations. It only covers air-vehicle costs, which constitute as little as 15% of many UAV systems."

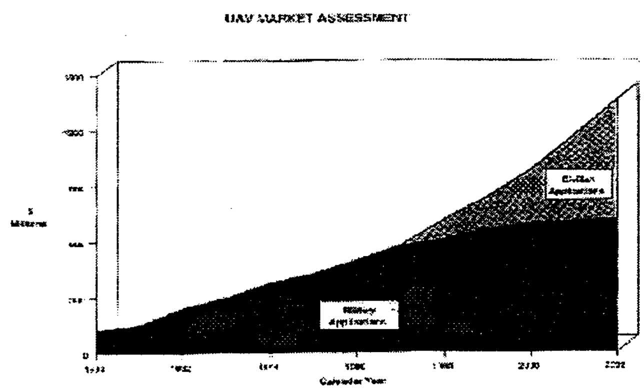

Figure 1: UAV Market Assessment (1990-2002) - presented at AUVSI '96

Figure 1 shows a 1990-2002 UAV Market Assessment by the US-based Electronics Industries Association presented at the 1996 meeting of the *Association of Unmanned Vehicle Systems International* (AUVSI '96 Symposium) in Orlando, Florida, USA. It shows the strong growth in the military applications market starting to settle over the next few years, while the market for civilian UAV applications is predicted to grow significantly over the next five years. Strong cases were presented at the AUVSI '96 Symposium promoting the use of UAVs for Environmental Monitoring, Weather Research, Agriculture Support, and Mineral Exploration. In the Australian context, the CSIRO (Commonwealth Scientific and Industrial Research Organisation) Office of Space Science and Applications (COSSA) sponsored the inaugural Australian national UAV Symposium on 30-31 October 1996 in Canberra. This meeting, attended by over 90 people from research organisations, academia, and industry, served well to indicate local interest in UAVs. A follow-on meeting in early 1997 initiated the Australian UAV Special Interest Group (SIG) to foster UAV activities in Australia. The SIG Internet web-page can be found at:
http://www.aero.usyd.edu.au/wwwuav/uavsig.html

Furthermore, the Aerospace Technology Forum (ATF) - a Federal Government initiative which funds an aerospace industry network - has recently completed a study of the UAV market[1]. Some of the findings from that study are presented in this paper.

UAVs Down Under

UAVs are highly capable unmanned aerial vehicles flown without an on-board pilot. These robotic aircraft are often computerised and fully autonomous. UAVs have unmatched qualities that often make them the only effective solution in specialised tasks where risks to pilots are high, where beyond normal human endurance is required, or where human presence in not necessary. Furthermore, UAVs offer new and cost-effective capabilities not previously attainable.

Table 1 shows a widely accepted classification for UAVs.. It is noted that the category *Tier I* is also known as ***Tactical*** UAV, *Tier II* as ***Operative*** UAV, *Tier II Plus* as ***Strategic HAE*** (High Altitude Endurance) UAV, and *Tier III Minus* as ***Strategic LO*** (Low-Observable) ***HAE*** UAV.

Table 1: UAV Tier Classification and Characteristics[2]

Category	Designation	Max Alt	Radius	Speed	Endurance	Example
Tier I	Interim-Medium Altitude, Endurance	Up to 15,000 ft	Up to 250km	60-100 kts	5 - 24 hrs	Pioneer; Searcher
Tier II	Medium Altitude, Endurance	3,000 ft to 25,000 ft	900 km	70 kts cruise	More than 24 hrs	Predator (Used in Bosnia)
Tier II Plus	High Altitude, Endurance	65,000 ft max	Up to 5,000 km	350 kts cruise	Up to 42 hrs	Global Hawk (expected to fly in early 1998)
Tier III Minus	Low Observable - High Altitude, Endurance	45,000 ft to 65,000 ft	800 km	300 kts cruise	Up to 12 hrs	Darkstar (expected to enter service in 1999)

Defence related UAVs that have been developed in Australia include the very successful GAF/ASTA/Boeing ***Jindivik*** target drone, the GAF/ASTA/Boeing ***Turana*** target drone, the HdeH ***Enmoth*** RPV, various experimental RPVs developed by the DSTO in the 1970's, and of course the recent success of the BAeA ***Nulka*** hovering rocket decoy. It is noteworthy that the ***Jindivik***, which has been in continuous production for over forty years, has been exported to Sweden, the UK, and the USA. The *Nulka* decoy appears to have the same potential, judging from recent export success to Canada. UAVs that have recently been operated for the Australian Defence Forces (ADF) in various capacities include the British ***Banshee*** target drone, and the Israeli ***Scout*** surveillance UAV.

UAVs are also active in the Australian civilian domain. The biggest success here is probably the Bureau of Meteorology (BoM)/Sencon Environmental

Systems' (SES) ***Aerosonde***, a UAV specialised for meteorological work. Besides the BoM, its sponsors have included the US Office of Naval Research, National Oceanic and Atmospheric Administration, and Department of Energy, and the Taiwan Central Weather Bureau. The ***Aerosonde*** is currently in operation and remains unique globally in its capabilities, having export customers from Taiwan and the USA. Sydney University has been working on UAVs for flight research for over 10 years, and has developed and operated several UAVs, ranging from the ***KCEXP-series*** UAVs[3], to ***UAV Ariel*** and others[4], including the recently first-flown ***UAV Brumby***. RMIT's Wackett Centre has also been involved in research studies on UAVs, such as the multi-role ***Jabiru***[5] and the atmospheric research ***Sarus***[6]. There are also numerous small organisations that have used small UAVs for aerial photography.

Australian Capabilities in UAV Technologies

Introduction

To evaluate the position of the Australian industry to support UAV activities, an internet-based survey and interview discussions were held with representatives from various organisations. These included people or companies that have the infrastructure, skills and background to manufacture or provide components, sub-systems that can be a part of a UAV system, and various potential service providers, being organisations who are in the business of providing services related to UAV or UAV applications. A number of organisations, but by no means complete, involved in UAV technology development are described in the following sections.

Figure 2: Nulka hovering rocket decoy

British Aerospace Australia (BAeA)

British Aerospace Australia (BAeA) was formerly a part of AWA Defence Industries (AWADI). BAeA's main business is avionics systems development and systems integration. Currently, the two main UAV-related projects are the *Nulka* (Figure 2) hovering-rocket decoy for ship missiles, and the Evolved Sea Sparrow Missile (ESSM). *Nulka* was initially a development by DSTO before being undertaken by AWADI. The decoy and rocket hovering systems were developed in Australia, while the payload is sourced from the USA. The system is now being sold worldwide. BAeA is now involved in further development, particularly the fire control system.

Nulka can be considered a UAV and is currently proving to be the highest level of UAV development within the Australian Defence Industry (ADI) and British Aerospace Australia (BAeA). Most recently, the Department of Defence has signed a contract to produce *Nulka* hovering rocket decoys for the Australian, American and Canadian Navies

Bureau of Meteorology/Sencon Environmental Systems (SES) Pty Ltd

Sencon Environmental Systems Pty Ltd produces and continues to develop the *Aerosonde* UAV system. The development of *Aerosonde* (Figure 3) started with the Australian Bureau of Meteorology (BoM) looking for a low-cost UAV system that could be used for meteorological applications. An agreement was then formed with the US-based **Insitu Group**, which took on the development of *Aerosonde*. The first prototype was built in 1992 and the second in 1993. SES Pty Ltd, based in Melbourne, Victoria is now responsible for further development and marketing of the *Aerosonde* UAV system. To date, *Aerosonde* has achieved an endurance of 30 hrs, reached an altitude of 5 km (16,400 ft) and a range of 2,500 - 3,000 km and has accomplished autonomous take-offs and landings. The expected performance is 60 hrs and 6000 km respectively. The vehicle will be going into full production in 1998.

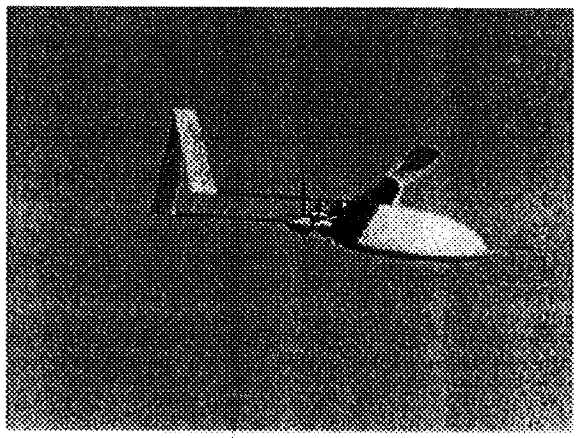

Figure 3: Meteorological Research UAV *Aerosonde*

The *Aerosonde's* sponsors include the US Office of Naval Research, National Oceanic and Atmospheric Administration, and Department of Energy, and the Taiwan Central Weather Bureau. The total funding for the development of *Aerosonde* is about $7 M of which 30% was funded by the US. The operating cost of the *Aerosonde* is about $100/hour for a leased system and $5/hour for the UAV system alone, if purchased.

SES believes there is definitely a market for UAVs for environment control applications (1000 - 2000 vehicles globally). There is also a need for larger vehicles with payloads of more than 250 kg and altitudes of 30,000 ft. A turnover of $50 - 60 million annually is believed to be achievable. The current cost of using weather balloons globally is estimated to be over $100 million dollars per annum!

Currently most development effort (60%-70%) goes into turbocharging the engine to increase altitude capability. The *Aerosonde* is currently in operation and remains unique globally in its capabilities, having export customers from Taiwan and the USA.

Boeing Australia

Boeing Australia, formerly known as the AeroSpace Technologies Australia (ASTA), and before that, the Government Aircraft Factory (GAF), and now part of the global Boeing Company, has a long distinguished history in drones and UAVs. The well-known *Jindivik* target drone was developed in the late 1940's (Figure 4) with first flight in August 1952.

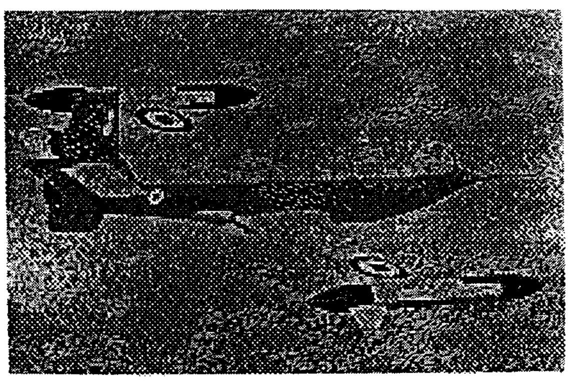

Figure 4: *Jindivik* in flight.

Customers include the Royal Australian Navy (RAN), the British Ministry of Defence (MoD), the US Navy and Swedish Armed Forces. Other UAV-related systems that GAF developed were, the *Ikara* anti-submarine missile and the *Turana* target drone. *Turana* is based on *Ikara* and was in response to a Royal Australian Navy Staff Requirement for a modern gunnery and guided weapons target. First flight of the *Turana* was made in 1971. It was one of the first UAVs to use a closed-loop autonomous flight controller, permitting controlled flight at low altitudes. Boeing Australia has just recently completed manufacturing the last 18 Jindivik target drones for the Royal Air Force (RAF). The project was completed in December of 1997, bringing to a close the extremely successful *Jindivik* target drone program that has been running for the past 25 years. Many variants and modifications have been made to the original airframe since the first design, all of which are comprehensively documented in Janes All The World's Aircraft. It is a credit to the original designers that they were able to design such a rugged airframe which will have taken well over a quarter of a century to become obsolete. Indeed the RAF plans to operate *Jindiviks* well into the next century.

Boeing Australia was also involved with the *Jindivik*-replacement program with the RAN involving acquisition of the MQM-107E target drone and developing the ground stations required to operate the drone in Australian Conditions.

Air Affairs Australia Pty Ltd

Air Affairs Australia Pty Ltd, together with its associated companies, supply specialized defence and aviation equipment together with operational, technical and support services to the Defence Forces of Australia, New Zealand and South East Asia. They are also the regional licenced manufacturers and distributers for *Hayes Targets*, USA; *Meggitt Aerospace*, UK Aerial Targets and UAVs (including *Banshee*, *Spectre* and *Phantom* UAVs); and *Kentron*, South Africa (*Skua* high speed Target Drone - candidate for the ADF's JP-7 requirement). *Air Target Services* currently operates a small fleet of *Meggitt Banshee BTT-3* target drones (Figure 5) which have been used in several recent military exercises without loss of airframes.

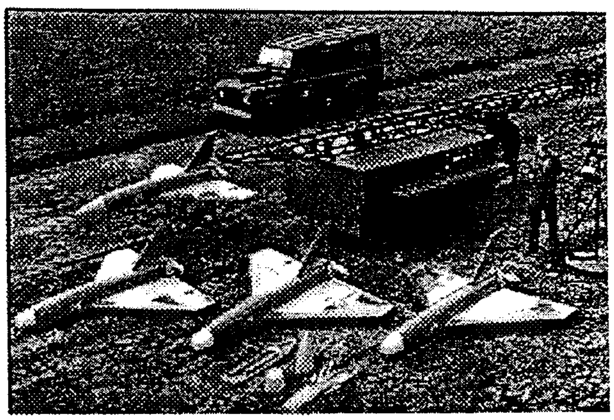

Figure 5 Variants of the Banshee target drone civilian markets within Australia.

Several Australian groups are currently known to be actively working on UAVs for academic, scientific, engineering research and industry applications. These include projects with:

- Bureau of Meteorology - The *Aerosonde* Meteorological UAV;
- British Aerospace Australia *Nulka* hovering rocket electronic countermeasures UAV;
- Boeing ASTA *Jindivik* Target UAV;
- Sydney University - UAV Project *Ariel*, VTOL Tail-Sitter UAV, UAV *Brumby*;
- RMIT and CSIRO Division of Atmospheric Research Victoria - UAV Project MAFV *Sarus*;
- Ark Associates Pty Ltd - *Softwing* UAV;
- Thin Air Communication Aircraft (Australia) Pty. Ltd. - TACA Telecommunications Project;
- Australian Mineral Industries Research Association Limited - Project P462 "Geophysical Autonomous Model Aircraft Acquisition" - feasibility study; and
- A range of companies using small remotely piloted UAVs for aerial photography and survey work.

University of Sydney, Department of Aeronautical Engineering

At Sydney University, current research in Unmanned Aerial Vehicles (UAVs) has produced promising results towards the development of fully autonomous capabilities. Previous experience with instrumented UAVs, include the experimental ***KCEXP series*** UAVs, and the ***UAV Ariel*** (Figure 6). An aircraft currently being operated is the UAV named ***Brumby***.

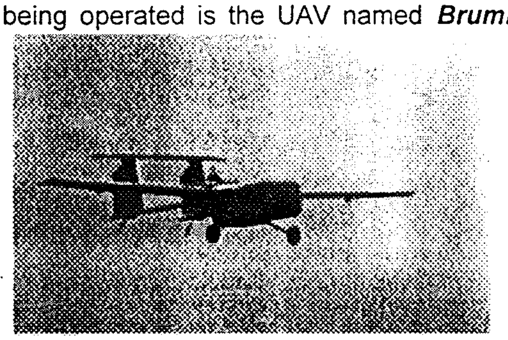

Figure 6: The RPV *Ariel.*

Like its namesake, it is designed to operate in rugged environment. Being developed primarily to provide a flight research platform in support of various research activities, ***UAV Brumby*** is also used to enhance skills in airframe design and fabrication, instrumentation, flight control systems, and operational aspects of UAVs. It forms the basis of a technology demonstrator for many aspects of aeronautical engineering.

UAV Brumby (Figure 7) is a delta wing unmanned aerial vehicle, designed with a standard dual fin, pusher propeller configuration. It employs a modular construction for simple and cost-effective manufacture, as well as high maintainability and damage recovery. Already prototyped as a multi-purpose flight research vehicle, it has been demonstrated as a stable flight platform well suited to flight navigation research. It is noteworthy that the first prototype flew successfully only 6 weeks after work commencement, and that includes tooling and composite mould fabrication. Two complete airframes would initially be available for the department's flight research programs.

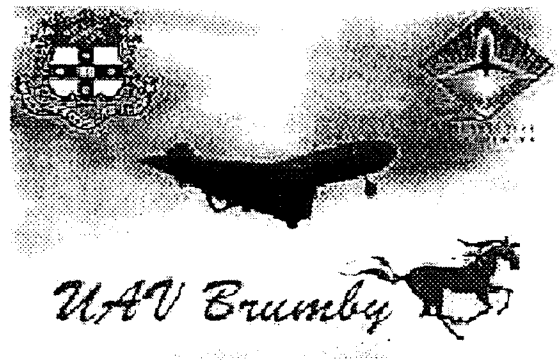

Figure 7: Sydney University's Rapid Prototype *UAV Brumby*

The vehicle is designed to fly in excess of 100 knots and currently has an endurance of ½ to 1 hour flight time. The aircraft has the capacity to carry up to eight kilograms payload when remotely piloted, or three kilograms when operated autonomously. Furthermore, the maximum design weight will be extendable by an additional 3-5 kilograms once the initial flight test program is complete. This is initially constrained to keep within the Australian Civil Aviation Orders Part 95.21, relating to model aircraft which permits a maximum Operational Empty Weight (OEW - that is maximum take-off weight minus fuel) of 25 kg. Previous UAVs operated by the research group have been flown outside these regulations (maximum weight of 36 kg), requiring a CASA Australia Permit-To-Fly. The group has also flown UAVs within controlled airspace with the co-operation of CASA and the Federal Airports Corporation (FAC), and is working with CASA to formulate new regulations specifically for UAVs. Hence, there is growth potential for the proposed airframes.

Current UAV related research activities include the following:

- Wind-tunnel and flight based experimental research in aerodynamics and flight performance;
- Modelling of engine/propeller performance and aircraft stability characteristics;
- High fidelity aircraft model development for simulation based control system validation;
- Trajectory optimisation and autonomous guidance for unmanned aircraft;
- Sensor fusion strategies for state estimation using multiple redundant sensors, including Global Po-

sitioning Systems (GPS);

- Using GPS for aircraft attitude determination;
- System Identification methods and neural networks for fault detection and reconfiguration;
- Robustness analysis of control laws in the presence of uncertain dynamics and wind gusts;
- Robust nonlinear high-performance manoeuvre tracking for autonomous aircraft;
- Autonomous launch and recovery of a UAV;
- Terrain Following and Terrain Aided Navigation;
- Integration of available UAV technologies into operational systems;
- Real-time fight control software synthesis; and
- Design and fabrication of airframe components using advanced composite materials.

Having been involved in UAV R&D since 1988, Sydney University Aeronautical Engineering's UAV Research Team endeavours to work closely with industry and other UAV research groups to facilitate the formation of a national collaborative UAV facility. The team has already been working on several UAV-related projects in collaboration with RMIT's Wackett Centre, DSTO, and various industry organisations on specific tasks. It is also currently hosting the Australian UAV Special Interest Group Internet web site. While operating on a minimal budget, its UAV research expertise and experience, complemented by several UAV-related PhD, Masters of Engineering (Research), and undergraduate Honours thesis projects, is seen to be one of the most active UAV research groups in the country.

Wackett Aerospace Centre
RMIT Department of Aerospace Engineering

The Wackett Centre for Aerospace Design Technology has been involved in UAV technologies research and development since early 1993, the key motivation being the challenging research topics, multi-disciplinary design, and the positive response from industry towards the potential of UAVs for civilian applications. The research on UAV technologies has mainly revolved around the development of a UAV concept that would, in terms of size and performance, be suitable for a wide range of remote sensing applications. The basis of this concept, the Multi-purpose Autonomous Flight Vehicle (MAFV), is that through modular design, the UAV can be configured for a specific mission. Standard interfaces ("plug in and go") and ease of pre-flight mission programming makes this concept an attractive solution for low cost remote sensing applications.

The Wackett Centre has a number of specific UAV technology related projects at postgraduate level. Currently, the following research projects are in progress:

- Configuration optimisation of UAV vehicles. The purpose of this research is to de-sign different UAV configurations and to analyse their merit with respect to particular mission requirements. Currently two configurations are being studied, the MAFV *Jabiru* and the MAFV *Sarus*;
- Shipborne launch of UAVs (in collaboration with British Aerospace Australia). The objective of this project is to design a control system that is able to fly a UAV safely from shipborne catapult launch to climb out, taking into account ship motion and turbulence from the superstructure;
- Avionics systems design for UAVs (with DSTO). The objective of this project is to design and manufacture an avionics unit, the Parallel Architecture Control Engine for Robotics (PACER), that is robust, fault tolerant and has a learning capability that will allow it to adjust to loss of system functionality, eg. CPU failure, reduced control capability, etc.;
- UAV directional payload stabilisation with flight control system interface. Directional payloads on UAVs, such as EO or IR sensors, require a stable platform for optimal target tracking. In addition, an advisory system is designed to interface with the flight control system, if the target gets out of view;
- UAV model flight test for parameter identification (completed). In this project at standard model aircraft, a Precedent T-240, was used for the purpose of parameter identification through flight dynamic testing. The experimental results were com-pared with analytical estimations.

In addition, various undergraduate projects are in progress or completed that are related to the MAFV.

The initial design concept for the MAFV vehicle, referred to as the *Jabiru*, was a canard configuration with pusher-prop powerplant arrangement. A half-scale model was built and initial flight trials were conducted. An off-the-shelf RC model (Precedent T-240) aircraft was later acquired and structurally reinforced to carry a payload of about 15 lbs. This aircraft is very stable and has docile handling characteristics. It has proven to be an excellent flying testbed for avionics testing and integration purposes. The T-240 has been used in dynamic flight test experiments for parameter identification.

In early 1996, the CSIRO Division of Atmospheric Research and the Wackett Aerospace Centre RMIT agreed to investigate the possibility to use the MAFV for atmospheric research applications, in particular for tracing and assessing the extend of the pollution plume originating from Melbourne over the Bass Strait. For the sake of this program, it was decided to adopt a well-proven flight vehicle configuration, a twin-boom tail arrangement with a pusher-prop. This design is referred to as the MAFV *Sarus* (Figure 8). The requirements and scenarios for this mission have been discussed with CASA and Air Services Australia.

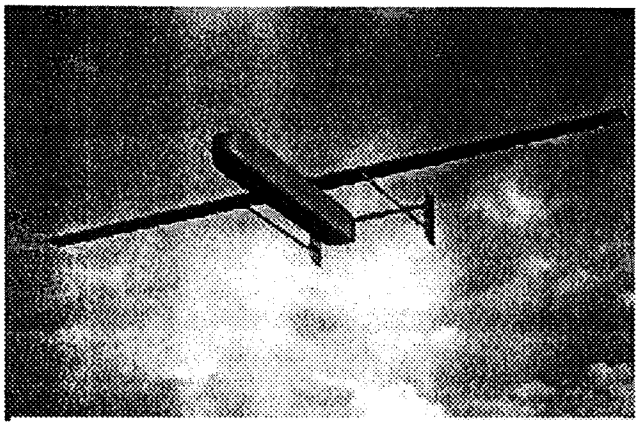

Figure 8: CAD Image MAFV *Sarus*

The focus of the research effort will gradually broaden to areas of high-level control and image processing. The results of this research will be applicable to a larger scope of autonomous and intelligent devices, such as robotic deep space probes, submersibles, terrain vehicles, mining vehicles, etc. This research involves contributions from other departments within RMIT. The Wackett Centre is committed to research in UAV technologies and sees this to be an area where Australia can excel in. The research outcomes have potential benefits to the Australian industry. To strengthen the research effort, the Wackett Centre seeks collaboration with industry and academia.

Civil Aviation and Safety Authority (CASA)

The Civil Aviation Safety Authority has responsibility for regulating the organisation and use of Australia's airspace, and ultimately for ensuring that all air operations within Australian airspace are performed in a manner which minimise risk to the Australian public. In this role, CASA is responsible for the development of suitable regulations under which all categories of air operations are performed. Currently, the only regulations, which encompass unmanned flight vehicles, are those which govern model aircraft operations.

CASA recognises that these regulations are too restrictive for routine operations of the types of aircraft that will be required by UAV operators in Australia, and is therefore taking steps to investigate the feasibility and nature of new regulation developments specifically pertaining to UAV operations.

CASA's UAV Project Team

An Unmanned Aircraft Operations Project Team has been set up by CASA to review UAV-related regulations. The team, led by Mr Mal Walker of CASA, is comprised of people from CASA, AirServices Australia, the aviation industry, and academia. The Terms of Reference[12] for this working committee are to:

- Review existing Australian legislation to determine:
- Relevance to UAVs, model aircraft, rockets, unmanned balloons and kites;
- Justification (ie. Safety based or required by other legislation);
- Consistency with foreign legislation;
- Ease of interpretation;
- Enforce-ability and appropriate level of delegation.
- Make recommendations for amendment of existing legislation, adoption of foreign legislation, and development of new legislation.

With the formation of the project team in May 1997, this is a current ongoing task.

In January 1998, a draft revision to the Australian Civil Aviation Safety Regulations Part 101, relating to Unmanned Flying Machines, was released for discussion. In the document[13], a UAV is defined as a powered, unmanned aerial vehicle used for research or commercial purposes and includes model aircraft when such aircraft are used for a commercial purpose. Subpart E and Table A of the document relates to guidelines for certification and operation of UAVs. Detail certification requirements for UAVs are still being worked on

Key Technologies for UAV Development

Core technologies required for successful development of UAVs include the following:

- Airframes - the flight platform is obviously a key component of a UAV system. Given the unique requirements for specific tasks, the airframes and their flight performance should be developed to suit them, eg. high manoeuvring performance required for low level terrain-following.
- Propulsion units - this is particularly significant for high altitude and/or long endurance requirements. Likewise, there may be special fuel or engine material-property requirements.
- Autonomous Flight Controllers - the key to wide application potential of UAVs. Globally, there has not yet been many UAVs capable of completely autonomous operations.
- Launch and Recovery - key phases of UAV flight. Launch and recovery requirements are often de-

pendant on task and operational requirements. Current launching techniques range from the use of runways, catapults, rockets, to the use of trucks. Current recovery techniques range from runway landings to the use of parachutes and nets.

- Navigation and Guidance - the common availability of Global Positioning Satellite Navigation Systems has had a prominently positive impact on navigation in general, and likewise their use in UAVs. The integration of satellite navigation and inertial sensor data with flight control systems enable wider application potential for UAVs.
- Self-Protection - safety for the possibly valuable on-board sensors and airframes, from external interference and damage, to keep costs low.
- Ground Control Station (GCS) - the UAVs would need to be monitored from base in some form, and the possibility to update task requirements midway through a mission.
- Payloads - innovation and imagination remains the key to using UAVs to carry payloads and sensors, ranging from surveillance sensors to possibly express parcel delivery systems.
- Data Communication, Storage, Processing, and Dissemination - secure data links, and information technology.

It is noted that most of the enabling technologies to develop successful UAV systems are currently available in Australia. A more detailed survey and analysis could easily identify the capabilities of specific companies and organisations.

Market Potential for UAVs in Australia

International UAV market analyses have estimated the total value of the global UAV Systems market to be worth in excess of US$19.5 billion over the next six years (1998 to 2003). Assuming that Australia might be expected to claim approximately 10% of this market, this could represent a total Australian UAV market in the vicinity of AUD$ 2.6 billion over the next few years.

Analysis of the scope of the Australian commercial market, in Australian Dollars (AUD), for air based sensing applications shows the total air operation costs to be as shown in Table 2. Of the civilian market sectors listed, there are a number of key sectors that would benefit significantly from the utilisation of UAVs. The most prominent in terms of market value are:

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

UAVs offer potential benefits to these sectors in the forms of either reduction of operation costs in fulfilment of commercial objectives, increased efficiency of operation, and/or increased work (information acquisition) rate. Through discussions with commercial aircraft operators in these fields, it has been determined that between 1% and 80% of their total business could be covered by UAVs, depending on the field. Based on these proportions, a conservative estimate places the commercial UAV market potential in the vicinity of A$20M per annum presently.

Defence projects represent substantial investment in the part of the nation. Current projects in which UAVs are potentially implementable, and in which UAVs may return significant savings in capital expenditure or increase in capabilities include those listed in Table 3.

Currently, only a very small proportion of the potential commercial UAV markets has been tapped. There has been a small amount of commercial activity in the areas of atmospheric monitoring and aerial photography in the past few years, together with some experimental activity in mineral exploration. These have shown significant promise and growth. However, large scale use of UAVs is thwarted by the hesitancy of potential commercial UAV users to invest in the development of UAVs for their purposes. In addition, many potential users of UAVs are unaware of the level of preparedness of research and development organisations to implement operational UAV systems. Without funding, these organisations are unable to demonstrate functional systems. A stalemate exists, and so external influence and direction is required to develop interest and collaborative initiative amongst potential industry participants in order to expedite rapid progress in UAV development and growth of a UAV industry in Australia.

Table 2: Civilian UAV Market Potential[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.

Table 3: Defence UAV Market Potential[1]

JP 129	WARRENDI	Airborne Surveillance for Land Operations	Phase 1: Category 3: $200m - $500m.
LAND 53	NINOX	Land Force Surveillance/Observation Equipment	Phase 3: Category 4: $20m - $200m.
JP 2044		Space-based Surveillance	Phase 1: Category 5: $20m.
JP 7		ADF Future Aerial Target System	Phase 4: Category 2: $500m - $1000m.

Total Projects containing **some** UAV element is estimated to be AUD$740m - $1700m. (US$555m - $1275m.).

Although there are many UAV systems either in operation or under development world-wide, there are few that could be considered affordable to commercial operators that have attributes suitable to operation for commercial purposes. High costs are partly because most systems have been developed for military markets and roles, and therefore subject to stringent military specifications. It is believed that developments specifically aimed at commercial operations and therefore with attributes tailored to commercial requirements, are more likely to be acceptable to the civilian UAV market.

The technologies necessary for UAV development, and the current capabilities of Australian industrial and R&D organisations to provide them, are considered mature enough to realise operational systems. Hence, there hails a broad view amongst service providers and R&D organisations that the most effective way to establish viable UAV programs is through collaborative development amongst Australian industry and R&D participants. Indeed it seems reasonable that shared resources and collective capital investment will produce the most efficacious and expedient results. If collaborative development initiatives are to be undertaken, then a widely acceptable strategy must be identified which will optimally target the requirements of UAV customers. Development should therefore be directed toward the most viable markets and their requirements. The majority of commercial UAV customer requirements, although covering wide ranges in payload, range, endurance and speed, can be loosely grouped into two categories. These are a lower weight/endurance bracket (up to 25 kg payload, 100-200 km/hr airspeed, 4-5 hrs endurance), and a medium weight/endurance bracket (~100 kg payload, 50-100 km/h airspeed, 24 hrs endurance). These broadly mirror the ***Tactical*** and ***Strategic*** military UAV categories.

While the markets are large in either category, the impetus of the mining industry in searching for high value mineral deposits, together with the political sensitivity attached to unexploded ordnance, would suggest that these might be more immediately viable. Coupled with the lower risks, lower costs, and less significant developmental problems associated with the smaller and typically shorter range applications, it is considered more prudent to encourage immediate development of a generic *tactical* category UAV capability. This would also provide a vehicle to satisfy the requirements of the myriad of smaller UAV users. *Strategic* level UAV developments would evolve from this in the medium term, thereby benefiting from lessons learned from development on the smaller scale. While a generic aircraft will not perfectly fit the requirements of any one commercial application, it is considered that an aircraft designed with characteristics that would suit most of the requirements of most customers, and in excess of the requirements of others would provide a broadly applicable and sought after facility. While a system with excess capabilities may be slightly more expensive to operate, the reduction in capital costs due to collective development of a small number of generic types would be far more significant. Accordingly, a focus on development in the *tactical* category will produce products that are more versatile and easier to sell on both the domestic and global UAV markets, and may lead to substantial export opportunities to assist developments at the *strategic* level. The products would also represent viable options for defence UAV applications, which would not require the usual large scale developmental and capital spending on the part of the government.

A unique opportunity exists for the development of a strong aerospace-based industry in Australia. Market analysis has identified that significant progress must be made within a five-year period to 2002 toward realisation of *tactical* level systems if the potential of the *tactical* UAV markets is to be optimally captured. If this need is not met, the full potential of *tactical* level UAV customers in capturing their own target markets will be substantially hindered. Accordingly, it is imperative that operationally capable and reliable UAV systems be demonstrated within this five-year period, and be ready for large-scale manufacture, sale and deployment.

It is proposed that the most effective way to expedite the proliferation of a UAV industry would be to form a consortium of industry partners, who are prepared to collaboratively engage and invest in developmental programs, and for the government, through the ATF, to set in place initiatives to promote the formation of such a body and inducements to attract potential partners to join that body. As far as potential Australian UAV operators are concerned, both civilian and defence, it may well be in the interests of potential Australian UAV operators collectively, if a national UAV development initiatives were to be directed toward provision of vehicles that could fulfil a range of roles for various operators (both civilian and defence). This would present advantages in terms of development cost minimisation and resource utilisation, involvement of a broad range of industries and R&D organisations, utilisation of Australian expertise, and the development of a national UAV capability. As a whole, this would result in growth of the UAV related aerospace industry, thereby stimulating employment growth, productivity, and export potential. Indeed, the Australian UAV industry situation, represents a case example of an aerospace industry where a burgeoning home market may justify its (re-)development, leading to substantial export potential.

From market surveys, it can be seen that the Australian UAV market is very positive. The current market atmosphere is likewise optimistic. Customer requirements, service providers, and R&D support can be fairly clearly identified. Business linkages between R & D groups and commercial organisations are not so easily identified. The way forward to take advantage of this great aerospace industry potential is to take immediate action, to demonstrate an operational UAV system by 2002. In order to take advantage of the current market atmosphere, action is being undertaken to:

- Call for support demonstrator UAV projects to better evaluate market opportunities;
- Organise UAV special interest meetings bringing together commercial, government and research organisations, to discuss levels of interest and commitment in a collaborative demonstrator UAV development, and to evaluate their preparedness to invest in the formation of a national UAV centre and to be part of a consortium that will operate it;
- Consider developing a complete demonstrator "Tactical" UAV system, based on existing Australian UAV and related R&D expertise;
- Liaise with CASA to investigate the regulatory and legal aspects for operating UAVs in Australia; and
- Take advantage of existing UAV R&D in the country, to meet local and global market opportunities.

It is evident that development of UAVs is being drawn by the potential markets rather than pushed by the availability of technologies. Nevertheless the technologies necessary for UAV developments and the current capabilities of Australian industrial and R&D organisations to provide them, are considered mature enough to realise operational systems. Whilst UAVs may not currently dominate programs within the ADF or civilian commercial organisations, further assessment of the UAV-related technologies demonstrates that there are significant synergies between UAV related technologies and other existing Australian military and civilian programs. Accordingly, Australian industry is reasonably well placed to meet the emerging needs for UAVs. Although strategic-type UAVs are viable solutions to existing capability requirements for the ADF and Australian commercial sectors, the majority of interest in UAVs, users and support industry is primarily focussed at the tactical-type UAV.

Technologies in support of a tactical-type UAV are also those enabling technologies for strategic UAVs. Although initiative is required from the industry and commercial partners to establish a program, active government support, perhaps through DIST, will be required to bring together and stimulate industry activity. As far as potential Australian UAV operators are concerned, both civilian and defence, it may well be in the interests of potential Australian UAV operators collectively, if a national UAV development initiatives were to be directed toward provision of vehicles which could fulfil a range of roles for various operators (both civilian and defence). This would present advantages in terms of development cost minimisation and resource utilisation, involvement of a broad range of industries and R&D organisations, utilisation of Australian expertise, and the development of a national UAV capability. As a whole this would result in growth of the UAV related aerospace industry, thereby stimulating employment growth, productivity, and export potential. Indeed, the Australian UAV industry situation, represents a case example of an aerospace industry where a viable and burgeoning home market may justify its (re-)development, leading to substantial export potential.

Conclusions

Australian research activities show advanced capabilities in design, construction, system development, flight control and guidance, and operation of UAVs. These capabilities and UAV technologies have either been demonstrated in-flight or through simulation. Given the positive current local market atmosphere for using UAVs for various tasks, the Australian aerospace industry is being encouraged to collaborate with local R&D organisations to launch into mission-specific UAV technology demonstrators.

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