UAVs OVER AUSTRALIA - *Market And Capabilities*

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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; and some strategies to encourage the use of UAVs for specific applications.

BIOGRAPHY

Dr. KC Wong, a lecturer of Aeronautical Engineering at Sydney University, currently leads a team of 7-10 academic staff and postgraduates undertaking research on UAVs. Dr Wong has been working on research RPV/UAV design, instrumentation, control, system integration, and management since 1988. Having completed his PhD in 1993, he has presented his work on UAVs at several international conferences. He lectures courses in aircraft configuration design, computer-aided design, engineering computation and basic aeronautics. He is also currently the coordinator of the Australian National UAV Special Interest Group (SIG) Internet web-page and mailing list.

Dr Cees Bil has an MSc and a PhD from the Faculty of Aerospace Engineering, Delft University of Technology in The Netherlands. He has been a design lecturer at the Delft University of Technology for more than 10 years. His main field of research is computer-aided design and design optimisation. He joined the Department of Aerospace Engineering at the Royal Melbourne Institute of Technology in 1995 as a senior lecturer where he is currently involved in research in UAV design, autonomous systems and dynamics and control. He is coordinator of the aviation programs at RMIT Aerospace Engineering and acting Deputy-Director of the Wackett Aerospace Centre.

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

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.

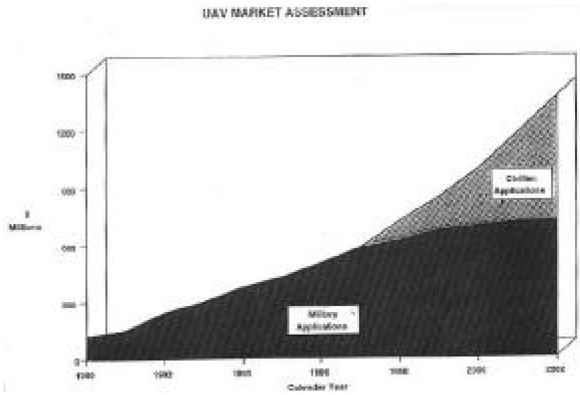

Figure 1 UAV Market Assessment (1990-2002) - presented at AUVSI '96

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.

2. 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, with examples shown in Figure 2. 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)

Figure 2 Common UAV Category Definitions and Examples

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.

UAV s 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 who have used small UAVs for aerial photography.

3. WHY UAVs FOR AUSTRALIA?

The following outlines the Strengths, Weaknesses, Opportunities and Threats (SWOT) in establishing a viable UAV industry in Australia (1):

Strengths:
Australia

- currently has good UAV-related research being undertaken in DSTO, CSIRO, Bureau of Meteorology, and universities;
- is a vast country which has:
  - clear surveillance requirements for defence, coastwatch, and the monitoring and protection of the environment and coastal natural resources;
  - rich mineral wealth deposits which needs to be exploited with due consideration to environmental impact;
  - a harsh climate, requiring understanding to support the population areas; and hence
  - potentially a good domestic market.
- has a strong UAV Research, Development and Production record, e.g. *Jindivik*, *Nulka*, and *Aerosonde*;
- has a strong aerospace manufacturing base, e.g. Boeing Australia (ASTA), Hawker de Havilland, British Aerospace Australia, Gippsland Aeronautics, Jabiru Aircraft, and several other General Aviation aircraft manufacturers;
- has a national focus on advancing Information Technology (IT), which UAVs could play a significant role;
- has a positive attitude by the Civil Aviation and Safety Authority (CASA) relating to the operation of UAVs, e.g. there is current a working group on UAVs;
- has many groups and organisations with a strong yearning for low-cost, moderately capable, and small operational airborne platforms (UAVs) to research and develop applications to:
  - build up a national UAV experience-base so that consultants could provide appropriate "smart" advice to specific customer requirements; and to
  - enable smaller organisations to have opportunities share and exploit Information Technologies derived from UAVs.

Weaknesses:

- UAV interest and activities have been fragmented due to geographical separation and lack of national coordination;
- there is a general lack of initiative;
- there is a general lack of cooperation between Australian companies to present national products resulting in over-competitiveness between companies;
- there is a general culture to purchase from overseas;
- commercial organisations generally have an over-conservative approach to the market in relation to high technology aerospace products; and
- there remains a lack of appreciation of the potentially high value use of IT for specific needs.

Opportunities:

- An undertaking to establish a national airborne research facility for applications-based UAV Research and Development;
- a complete UAV system design project for the Australian community:
  - to be complete aerospace system providers rather than just component manufacturers;
  - at an affordable investment scale;
  - to maintain and build up the national high technology expertise (Note: a lot of high technology aerospace expertise has already been lost through the closing of major programmes, e.g. *Jindivik*, *Nomad* and others.);
  - a national collaborative aerospace undertaking, based on UAVs, could provide the “glue” for high technology companies to work together;
  - for the ADF to become “smart” customers for specific requirements, e.g. JP-129.
- CASA, being one of the world leaders in having a working group on national UAV regulations could provide regional Asia-Pacific expertise;
- there are potentially numerous spin-offs to other high technology industries in:
  - Robotics and Mechatronics;
  - Image and signal processing;
  - Software engineering;
  - Miniature sensor technologies; and
  - Information Technology (IT).

Threats:

- Overseas competition - the general attitude to buy from overseas;
- the gradual loss of national aerospace capabilities;
- the poor history of taking innovative products from concept to commercial production and operation;
- Research and Development funding is very constrained and limited.

4. IS AUSTRALIA READY FOR UAVs?

4.1 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 dependant 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 mid-way 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.

4.2 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
Telecom-munications	$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.).

Consultations with potential UAV users, service providers and research and development organisations have been made through surveys and discussions. The outcome was a clear indication that there is significant interest from all elements in establishing developmental programmes aimed at implementing viable UAV systems to service the commercial market. 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 programmes 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/h 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.

Apart from mission-specific system characteristics, the fundamental flight and navigation systems technologies are common between these categories. Given that the sensing payload will typically be supplied by the customer, the main differences between the categories lie in their sizes, and accordingly, the technologies required in their construction, performance and propulsion.

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.

4.3 Market Survey Conclusions

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.

5. AUSTRALIAN CAPABILITIES
- UAV Manufacturers and Service Providers

5.1 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 include 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.

5.2 Defence Science and Technology Organisation (DSTO)

The DSTO's **Aeronautical and Maritime Research Laboratory** (AMRL), based in Fishermens Bend, Victoria, has an extensive capability in a wide range of technical areas, including flight dynamics, aerodynamics, propulsion and flight/ground testing. Their prime focus is responding to requirements from the Australian defence forces and providing research and development capability to fulfill those requirements. AMRL will most likely be involved in providing technical support for the acquisition of UAV systems for the Australian Defence Forces (ADF). A feasibility study is currently being conducted on UAVs technologies relevant to AMRL, but this project is still in the preliminary stage. There is also interest in using flight-test instrumented UAVs for research in advanced techniques in flight testing.

DSTO's primary objective is to assess the equipment needs and capability of the ADF and to assist the forces in buying the right equipment, and advising on the upgrading of this equipment. Any research undertaken by DSTO is driven by the needs of the ADF. A DSTO report by Duus and Sutherland (7) gave a broad overview of the UAV scene, and looked at potential now and in the next 20 years. The report also mentioned the Global Hawk program and that a trial would be conducted by DSTO in the near future.

DSTO Weapon Systems Division in Salisbury is the largest facility of the defence research organisation. In the 1970s DSTO experimented with several RPVs, for example the XM-1A/3 pictured below (Figure 3). This project was eventually terminated and the airframes recently disposed of.

Figure 3 DSTO's XM-1A/3 RPV (8)

DSTO has in the past been involved in various other UAV projects, including the *Nulka* project (control system design and dynamics modelling). UAVs are also viewed by DSTO personnel as a platform to advance communication Research and Development within DSTO.

To do their task effectively, DSTO must accumulate knowledge and experience of a wide range of technologies. More emphasis is put on the acquisition and application of advance intelligent systems to fulfil the AFD requirements. As systems are becoming more and more complex and expensive, it becomes increasingly important to understand the technologies involved.

5.3 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 4) 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.

Figure 4 Nulka hovering rocket decoy

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. The recent contract is estimated to bring AUD$58M to Australian Defence Industries (9) and includes work on:

- manufacture of rocket motors canisters and flight control systems;
- assembly of the decoys using US-sourced payloads;
- application of advanced technologies involved in the development of rocket motors and the decoy flight control systems; and
- systems integration work to fit the payloads to the motors.

Phase 1 of this project was the design and testing of the *NULKA* system, and Phase 2 was a Project Definition Study of an Australian payload. Phase 3 of Project *Nulka* aims to enhance the *NULKA* payload to enable it to counter a broader range of threat missiles.

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

Figure 5 Meteorological Research UAV *Aerosonde*

Sencon Environmental Systems Pty Ltd produces and continues to develop the *Aerosonde* UAV system. The development of *Aerosonde* (Figure 5) 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.

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!

The development effort of the *Aerosonde* has been:

- Airframe (1%);
- Avionics (10%);
- Software (50%);
- Engine (20%); and
- Miscellaneous (19%).

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.

5.5 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 6) with first flight in August 1952. 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.

Figure 6 *Jindivik* in flight.

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. The *Jindivik* is capable of flight altitudes of 40ft to 65000ft (with wing extensions) and has a top speed of Mach 0.85. It is used to represent *Exocet* anti shipping missiles and other airborne craft in naval exercises. It is also used by the RAF as a airborne target or target tug for combat training. *Jindivik* also has the capability to conduct aerial surveillance.

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.

5.6 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 7) which have been used in several recent military exercises without loss of airframes.

Figure 7 Variants of the Banshee target drone

Air Affairs also provides a commercial airborne Remote Sensing service with a Daedalus 1268 Airborne Line Scanning system, which can be used for imagery ranging from visible to infra-red. The airborne sensor, mounted in a modified Learjet, is capable of high speed acquisition of 1.5 m pixel resolution and 0.1 degree Celsius temperature resolution data. Applications of thermal imaging have included crops and vegetation mapping and classification, water quality mapping, mineral surveys, mine site rehabilitation surveys, bushfire mapping and detection, geothermal mapping, soil erosion monitoring, water catchment mapping, and geological characteristics surveys. The market for airborne thermal imaging data is seen to be optimistic, even though the marketing of data remains difficult.

An example of the high speed and wide coverage capability of the Learjet/Daedalus combination is that a mapping of the entire Shoalhaven, NSW area, would only take approximately one hour at altitudes between 3500 and 4000 ft, relating to a pixel resolution of 5 to 7.5 m, at a cost of approximately $2500 per hour. It has been noted that most Daedalus users have previously been more used to cheaper satellite data with greater than10 m pixel resolution. UAVs could have a role in offering higher definition data for very specific applications. Global Positioning Systems (GPS), especially the Differential GPS, is seen as having the potential to greatly improve positioning accuracies of aerial mapping and surveys and eliminate the need for ground reference markers, which can be used with both manned and unmanned aerial systems.

One problem with aerial imagery is the very large amount of data which needs to be processed. For example, with the Daedalus data, this processing for specific requirements could double the cost of data. The marketing of data, even of high quality, remains difficult due to a general lack of understanding of their usefulness in users' specific applications. Likewise, end-users sometimes have unrealistic expectations of imagery data. Hence there is a need for education of the end-user market. Experience with the Daedalus system suggest the need for regular "bread-and-butter" work, as one-off projects cannot maintain the feasibility of a service provider.

5.7 Australian Aerial Surveillance Service

The **Australian Aerial Surveillance Service** is based in Phillip Island, Victoria. The *heli-kite* is a UAV technology demonstrator developed by the organisation, the idea of which was successfully presented to HQ ADF, Force Development (Land) and a small research grant was given to develop the idea in January of 1995. Part of the demonstration included footage of a demonstrator Heli-kite in tethered counterweight flight. The *Heli-kite* has an MTOW (maximum take-off weight) of 18.5Kg and is powered by four ducted fan units which can pivot about the horizontal axis to transfer the lifting body from hovering to forward flight. The self stabilizing craft is fitted with two gyros and twenty-four servos for control. The Heli-kite is designed to operate out of and be recovered via a net mounted in its launcher box . The Heli-kite is still protected by a secrecy contract which must be signed by any person wishing to view the demonstrator model, hence not much is known of its current status. *Heli Kite* was written up in the March 1997 edition of the "***Australian Aviation***" magazine.

5.8 CSIRO Division of Atmospheric Research

The primary objective of the CSIRO Atmospheric Research Division (ARD), based in Aspendale, Victoria, is to conduct research into global warming and to take atmospheric samples at different locations above the earth's surface. This information is then processed and used to generate computer models that accurately predict climate change across the globe due to various effects such as greenhouse and global warming.

The atmospheric research division's interest in UAVs stems from a need to streamline costs due to budget cuts. A well-developed UAV is considered to be cheaper to run and thus allow more extensive analysis for the same or lower cost as compared to the current method of using a twin engine Cessna. Currently, samples are taken once a month in a pressurised Cessna at altitudes up to 8 km. Including hire of the aircraft, oxygen and a mission time of between 3 and 8 hours, a single sampling flight costs in the order of $2500. The lack of frequency of these flights leads to statistically poor results when analysed.

There are two main issues involved if the ARD of CSIRO are to use UAVs. The first issue relates to cost. In order for the conversion from full size manned aircraft to remote craft to be viable, a cost reduction of around 50% would be needed. This would cover conversion of equipment and administration costs. In the long run, longer and more frequent missions could be conducted. Secondly, money would need to be made available to design and manufacture payload modules which would fit into a UAV. A typical ARD payload module would be in the order of tens of thousands of dollars to manufacture, with an upper limit of approximately $50,000 per module. Other requirements of a UAV were that it had to be reliable, able to operate at altitudes up to 8000m, carry a payload of at least 24kg and have an endurance of in excess of 24 hours.

ARD CSIRO has not the interest, expertise, nor funding to operate and maintain their own UAVs. They are however interested in hiring a UAV platform to complete their atmospheric research, provided financial assistance is given to develop payload modules. Indeed ARD would be very interested in participating in a program which addresses the needs, requirements and manufacture of payloads for UAVs.

ARD is currently working with RMIT AEROSPACE on the MAFV *Sarus* (Figure 11), a UAV which could potentially fulfill the divisions needs. A joint venture with RMIT was seen as a cheap means of becoming involved with UAV technology. Recent budget cuts has meant that the Division has had to lower their commitment to this project.

5.9 Australian Flight Test Services Pty Ltd (AFTS)

The Australian Flight Test Services Pty Ltd (AFTS), a privately owned Australian company, provides a range of services ad products to the civil and defence aerospace communities. AFTS is approved by CASA Australia to design, develop, and flight test aircraft and aircraft modifications and systems.

AFTS, under the facility known as Airborne Research Vehicles Australia (ARVA) and in conjunction with its associates, is responsible for the ongoing operations, engineering, and maintenance support of dedicated research aircraft. The main platform being the AFTS Fokker F27 research aircraft used in conjunction with the CSIRO. AFTS holds a CASA Air Operator's Certificate and is approved to act as a coordination and tasking authority for these aircraft. Thus, AFTS can provide a sophisticated aeronautical, atmospheric, and scientific research capability as well as the ability to carry out comprehensive environmental survey programs and the airborne testing of a wide range of aircraft related equipment. AFTS pilots and flight-test personnel crew the dedicated research aircraft which can be configured to customer specific requirements.

UAVs are featured strongly in ARVA's strategic plans, as it intends to have UAVs provide for low cost and flexible platforms carrying relatively small payloads, to complement its manned aircraft. This requirement still exists and AFTS would support, and actively participate in, a national UAV development program. This vehicle would be offered to the research and development community, both civil and military, for test and evaluation purposes.

AFTS emphasised that they would be very interested in making direct contributions to appropriate UAV development without necessarily requiring immediate return on their contributions, providing they could see a reasonable prospect of longer term returns.

5.10 Airborne Research Australia (ARA)

Airborne Research Australia (ARA) is a National Facility for airborne research established under the Major National Research Facilities Program (MNRF) of the Federal Government. The facility is based at Flinders University of South Australia in Adelaide with nodes at Parafield Airport and within the University's Faculty of Science and Engineering on the campus at Bedford Park. The Flinders Institute for Atmospheric and Marine Sciences (FIAMS) contributed two of the aircraft to ARA. ARA currently operates a fleet of research aircraft. Their interest is to apply their expertise in airborne instrumentation and associated data evaluation strategies to UAVs.

5.11 Aerospace Technical Services Pty Limited (ATS)

Aerospace Technical Services Pty Limited (ATS) is a wholly owned Australian company, which specialises in flight test services, systems engineering, avionics integration, specialist aerospace consultancy, range operations and representation of overseas aerospace companies in Australia. ATS has been monitoring the UAV market in Australia, South East Asia and elsewhere and believes that there are going to be significant number of substantial market opportunities in both the military and civilian markets within Australia. The military market will utilise, in the short to medium term, larger, more complex and more expensive UAVs that will probably come equipped with sensors, flight control systems, and data links. There may be little that could be conducted by Australian Industry, other than life of type support, software engineering to satisfy ADF specify requirements and some limited sensor integration.

However the field of civilian UAVs holds great promise with the possibility of providing low-cost customer specific sensor integration and operation for a range of different customers. ATS also believes that the reason the use of UAVs by civilian agencies is limited at the moment is because potential civilian customers have not been appraised of the uses, and dramatic cost benefits savings, that could be attained through the use of customer-requirement tailored UAVs. ATS believes that it has a number of skill sets that directly relate to the UAV field, these being:

Flight Test Services, including:

- Design, development, integration, installation and operation of data acquisition systems;
- Data Transfer and Control. These skills could be utilised in either the data control and storage in either the UAV or on a Ground Control Station, or in the transfer of data through real-time datalinks (either secure, such as Tactical Data Links, or unsecured). The use of data compression technology would also be useful depending on the volume of data requiring transfer, such as real time video images; and
- Systems Engineering, including the design, integration, and installation of complex avionics systems.

ATS is already investigating UAV opportunities that include system and sensor integration, installation of remote flight control mechanisms, and data link systems. It is of note that these opportunities are overseas because of a lack of a defined approach by Australian Industry to UAV development.

5.12 Hawker de Havilland (HdeH), Bankstown

Hawker de Havilland (HdeH) has no immediate plans to be involved in UAV activities, as the company's main activity is in commercial aero-structures. HdeH was however, involved in several small target UAVs in the 1970's (eg. Enmoth Aerial Target - Figure 8 (8) - and other Moth-series Target UAVs).

Figure 8 Enmoth aerial target

5.13 Summary

All participants were keen to take part in the survey, as they saw it as a realistic and fair means of voicing their opinions as to what they would like their involvement in an Australian UAV programme to be. The majority participants were keen for an Australian UAV industry, collectively identify over 30 different applications for UAVs in a commercial environment. They all saw the benefit of UAVs to be a low-cost alternative to manned aircraft, and that there would be significant commercial spin-offs from such programs. Most respondents indicated that they would be happy to work in cooperation with other organisations to see that UAV technology would be designed, developed, marketed and kept in Australia, with sales of the end products expanded to a world market. They also firmly believed that Australia has the resources, technology and manpower to successfully implement a UAV industry - however it must be acted upon immediately, coordinated through a central organisation which has relevant aerospace experience, and must have funding allocated to it to implement projects, marketing and the likes.

All respondents felt that the Australian Government should offer more support for Aerospace/UAV industry in Australia in the form of funding and major reforms in the policies and bureaucracy of issues pertaining to aviation Research and Development and manufacturing within Australia. Those that were hesitant to become involved in joint projects indicated that it was through lack of current research into the potential for UAVs and the lack of immediate demand for the use and implementation of UAVs.

With proper reform it would be attractive for organisations to become involved in UAV projects, which in turn would instill confidence and allow a UAV industry to develop and reach its full potential. There is no doubt that there is eagerness, a long term vision, and a high level of excitement amongst aerospace organisations in Australia when it comes to establishing a national UAV Industry, their common desire is that it happens sooner rather than later.

6. AUSTRALIAN CAPABILITIES
- UAV Research and Development Organisations

6.1 UAV Related Development Programmes

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*;
- Australian Aerial Surveillance Services - *Heli-Kite* UAV;
- 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.

6.2 Defence Science and Technology Organisation

It was recently reported in the *Australian Defence Science News* (10) that DSTO Weapons Systems Division, Salisbury SA, is part of a research team led by ANU's Professor M.V. Srinivasan, to develop autonomous navigation and control systems based on image sensors. The chief of DSTO's Weapons Systems Division, Dr D. Nanda Nandagopal, noted that the research team had two aspects: basic research to improve understanding of the principles of visually guided flight and navigation in insects; and to investigate the feasibility of using these principles for the visual guidance and control of airborne platforms. The $300,000 project, which is jointly funded by Australia and the USA, will run until mid-1999. This research could have direct and significant applications in both µAVs and UCAVs.

There were significant developments for a specialised

UAV engine by DSTO-Aeronautical Research Laboratory up to the early 1990s (11). The engine showed good potential for applications in a "*Tactical*"-sized UAV. For some reason, the programme was terminated. However, given sufficient interest, some research or commercial organisations may be able to negotiate further developments to that work.

6.3 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 9). An aircraft currently being operated is the UAV named ***Brumby*** (Figure 10). 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.

Figure 9 Sydney University's Rapid Prototype *UAV Brumby*

Figure 10 *UAV Ariel*

UAV Brumby (Figure 10) 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 programmes.

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 Positioning 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.

6.4 RMIT Department of Aerospace Engineering /Wackett Centre

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 11). The requirements and scenarios for this mission have been discussed with CASA and Air Services Australia.

Future direction of UAV technology research at the Wackett Aerospace Centre:

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

Figure 11 CAD image of MAFV *Sarus*

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.

6.5 Summary

All of the aerospace related academic and defence research organisations have shown significant eagerness to be involved in UAV development programmes. DSTO has a proven record of UAV development interest and expertise. Academic aerospace departments are currently deeply involved in mature research and development programmes which are near to realising operational UAV systems. These organisations and other academic departments are engaged in cutting edge research into the technologies required for autonomous UAV operations. These cover such diverse areas as:

- use of GPS for high precision navigation and attitude measurements;
- data fusion and INS/GPS integration;
- advanced guidance and control strategies, and flight path optimisation;
- advanced airframe design and construction technologies;
- design optimisation; and
- artificial intelligence.

The research and development organisation surveyed are advancing with their respective UAV programmes successfully, albeit slowly. Despite having proven capabilities in advanced technologies, their progress is hindered by lack of funding, and lack of industry involvement in research and development. Clear requirements and direction on a national level towards future UAV implementations in Australia would draw on the capabilities of R&D organisations to the advantage of both themselves and the UAV industry as a whole.

In the current economic and industrial climate, there is a high level of willingness and motivation for academic involvement with industry, in the interests of realising functional UAV systems for the benefit of the nation.

7. CIVIL AVIATION AND SAFETY AUTHORITY (CASA) AUSTRALIA

7.1 Introduction

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.

7.2 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:

a. 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.

b. 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.

7.3 Summary

CASA is prepared to work closely and cooperate with industry and Research and Development organisations in relation to the development and operation of UAVs within Australia. It is generally willing to encourage the development of a UAV industry, and is keen to assist through the development of suitable regulations and legislation, provided that public safety can be ensured.

8. 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.

Hence, the authors believe that the time for wider use of UAVs is indeed here, and that Australian R & D work on UAVs is mature enough to develop mission-specific systems. However, it still remains unclear as to specific industry and government commitment to be involved in this very exciting field of robotic aircraft.

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