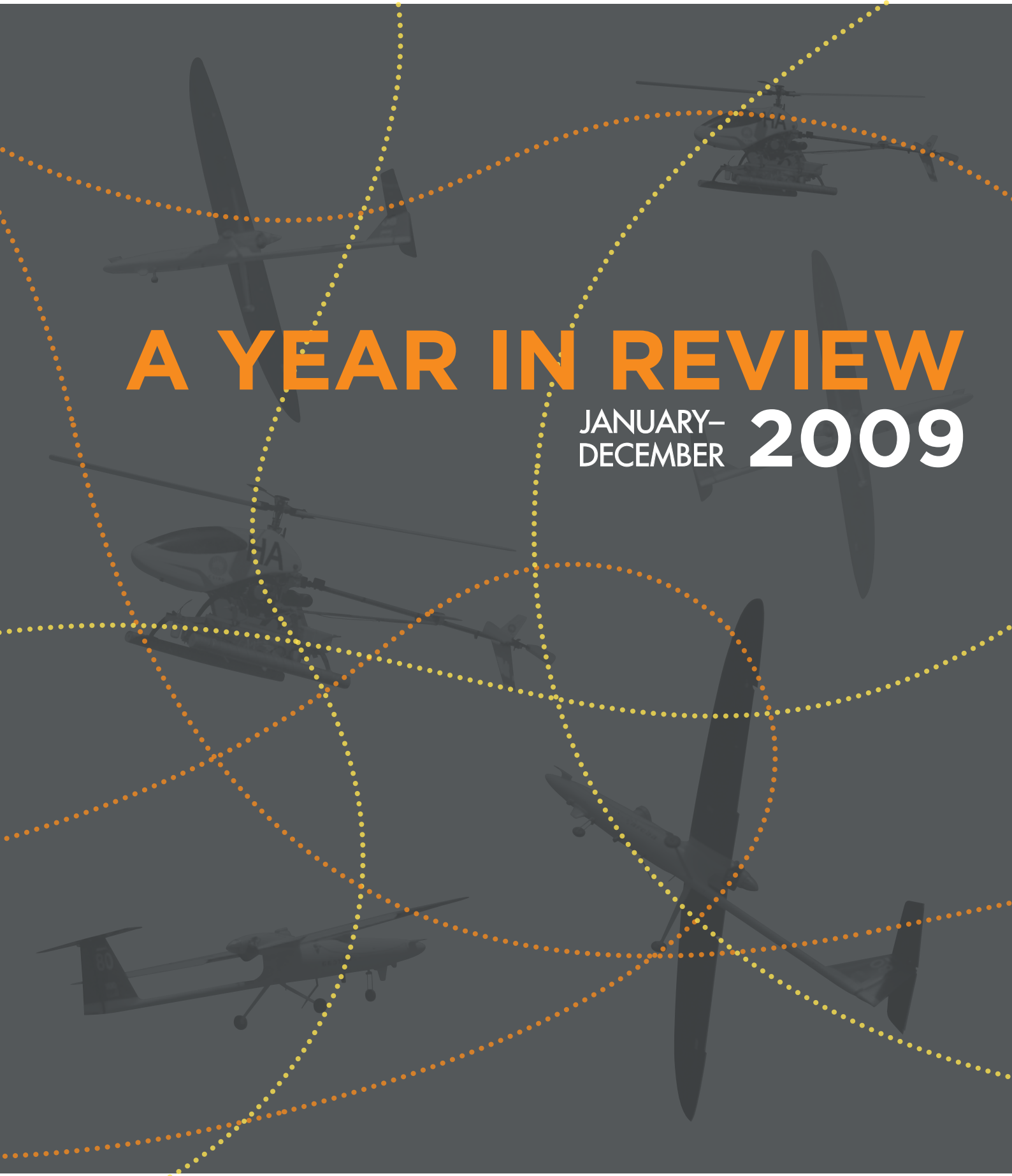
arcaa

AUSTRALIAN RESEARCH CENTRE FOR AEROSPACE AUTOMATION



A YEAR IN REVIEW

JANUARY–DECEMBER 2009

QUT

CSIRO

CONTENTS

Queensland Government

ARCAA acknowledges the funding support provided by the Queensland State Government.

GLOSSARY OF TERMS

AAIF
Australian Aerospace Industry Forum

ASL
Airborne Systems Laboratory or the Cessna Plane

AUVS-AUSTRALIA
Association of Unmanned Vehicle Systems Australia

AUVSI
Association of Unmanned Vehicle Systems International

BAC
Brisbane Airport Corporation

BR&T
Boeing Research & Technology

BR&TA
Boeing Research & Technology, Australia

CASA
Civil Aviation Safety Authority

CRCNPB
Cooperative Research Centre for National Plant Biosecurity

CRCSI
Cooperative Research Centre for Spatial Information

CSIRO
Commonwealth Scientific, Industrial and Research Organisation

DEEDI
Queensland State Government Department of Employment, Economic Development and Innovation

DIISR
Commonwealth Department of Innovation, Industry, Science and Research

DSTO
Defence Science and Technology Organisation

IEEE-AESS
Institute of Electrical and Electronic Engineers - Aerospace and Electronic Systems Society

QUT
Queensland University of Technology

UAS
Unmanned Aircraft System

UAV
Unmanned Aerial Vehicle


Queensland University of Technology
Commonwealth Scientific & Industrial Research Organisation
CRC for Spatial Information
CRC for National Plant Biosecurity
Centre for Marine Studies
Undergraduate Students
Higher Education Students
RESEARCH & EDUCATION
INDUSTRY
Boeing
Insitu Pacific
Ergon Energy
V-TOL Aerospace
Australian Aerospace Industry Forum
ARCAA
Queensland Government (DEEDI)
Australian Government (DIISR)
Defence Scientific and Technology Organisation
Civil Aviation Safety Authority
GOVERNMENT
COMMUNITY
UAVS Australia
IEEE-AESS
UAV Challenge
Trade Shows
High Schools
Enthusiasts
arcaa

The Australian Research Centre for Aerospace Automation (ARCAA) is a joint venture between the Queensland University of Technology (QUT) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO).

The ARCAA mission is to provide research excellence in the area of automation in the aviation environment. The centre undertakes research and development activities in advanced technologies for Unmanned Aircraft Systems (UAS) both fixed wing and rotor wing, next generation air traffic management (ATM) systems and future Global Navigation Satellite Systems (GNSS) concepts for Australia.

ARCAA has sprung from a QUT/CSIRO common interest in automating aerospace vehicles and from a loose agreement in 2003 to co-supervise PhD students. The centre has subsequently progressed and has now attracted in excess $20 million in research funding, including $6 million for the ARCAA research facility at Eagle Farm in Brisbane.

With more than 30 engineers and researchers, ARCAA has become the largest group in Australia in this research field. ARCAA's research is addressing some of the key challenges facing the management and delivery of Unmanned Aerial Vehicle (UAV) applications in the area of powerline surveillance, maritime and ecological surveys, collision avoidance, separation management and emergency landing.

Since 2007, through our community engagement, ARCAA has coordinated Australia's first aerial robotics competition, which attracts competitors from around the world, and also plays a leading role in assisting the Australian aviation industry to formalise the development of policy and regulatory reform in the area of Unmanned Aircraft Systems.

ADVANCING AIRSPACE UTILISATION THROUGH FLIGHT-TEST PROVEN ICT RESEARCH

"The ARCAA vision is to see autonomous aerospace technologies increasingly serve the needs of humanity, and to enhance Australia's economic, social and environmental prosperity."

Rodney Walker, ARCAA CEO.

The title for our annual report was an issue of some internal discussion, and based on our activities in 2009 a more appropriate title may have been "A year of flight-test in review"; for flight-test we did.

We logged over 170 hours on our Airborne Systems Laboratory Cessna and over 100 hours on the UAVs. These hours do not reflect the even greater amount of time that our staff have spent in remote locations to support these flights.

As with many organisations engaged in solving complex problems through field-work, a great deal of camaraderie has developed within the team. Most of us have inherited a nickname (some have inherited many!) and all with good reason; "Beagle 1", "Online", "D-Man", "Torino Boy" and many others earned their stripes in 2009.

Some may wonder why I bring this up in the executive summary, but it is an important indicator of performance. ARCAA's stated aim is to "Advance airspace utilisation through flight test proven ICT research". Anyone involved in experimental flight test research will tell you that this is a complex process.

It requires a continuum of skills from the theoretical to the practical, coming together in a series of flight experiments and ultimately through to commercialisation. In 2009 I have observed that this requires a great deal of personal sacrifice from a team of people, spending many hours over computers, in discussions, on the road, or in remote airfields waiting for problems to be resolved, or for the weather to improve.

The pressures of schedule, budget, progress, publication or commercialisation, risk management and safety have resulted in many heated debates – but always professional and by the end of the year I felt I understood the definition of the term "the right stuff". We met our milestones, got the job done to the satisfaction of our sponsors and customers, and did it to a world-class professional standard.

This achievement cannot be attributed to any one person but to the fantastic creative and resourceful group that is ARCAA.

In this annual report you will read a summary of what we achieved in the year. I hope you will see that ARCAA is a multifaceted organisation with significant achievements not only in research, but also in the equally important areas of education, community engagement and last, but not least, inspiring and creating tomorrow's aerospace leaders.

"There are significant market opportunities for the use of UAVs in commercial applications, however the technology barrier of gaining routine access to civilian airspace must be overcome.

ARCAA's world-class research and development, along with their industry and regulatory initiatives, are critical to achieving this goal and opening up these new markets."

David Gray, Chair of ARCAA

ARCAA is governed by a Board comprising senior management from QUT and CSIRO. The Board is chaired by David Gray, a leading figure in the aviation industry with a strong business and industry background.

THE BOARD

David Gray

Chair

David has held a number of senior posts in the power electrical engineering field and later in telecommunications and aviation. Following his move to Australia in 1984, and a stint as Chief Executive of GEC Heavy Engineering and General Manager of Exicom, David became the Managing Director of GEC Marconi Australia. In 1995, he was appointed Managing Director of Boeing Australia Limited until 2007. Additional to his current ARCAA duties, David is Chairman of Queensland Motorways, WaterSecure and Queensland Cyber Infrastructure Foundation (QCIF), and deputy Chairman of the Civil Aviation Safety Authority (CASA). He received the Centenary Medal for his services to the aviation industry and was awarded an Honorary Doctorate from the Queensland University of Technology.

Arun Sharma

Member

Professor Arun Sharma is the Deputy Vice-Chancellor (Research and Commercialisation) at the Queensland University of Technology. He has played a leadership role in development of national research capacity in ICT. He was a co-founder of National ICT Australia Limited (NICTA), and was the inaugural Director of its largest research laboratory. Prior to establishing NICTA, he was the Head of the School of Computer Science and Engineering at the University of New South Wales in Sydney where he co-founded the Cooperative Research Centre for Smart Internet Technology.

He is a member of the Queensland Premier's Smart State Council and of the Premier's Business Roundtable. His other advisory roles have included Independent Advisory Council of the Australian Research Council (2008-2009), Interim Advisory Board of the Manufacturing Centre of the Enterprise Connect Program (2008-2009), ICT Sector Advisory Committee of the CSIRO. He is currently President of the Australia India Business Council (Queensland Chapter).

Gary Morgan

Member

Gary Morgan is the Deputy Director, CSIRO ICT Centre and the $55 million dollar per annum operations of the ICT Centre which is CSIRO's hub for innovative ICT research. In his most recent role, Gary was the founding CEO of the Australian e-Health Research Centre where he grew the Centre from its inception to 2009 where the Australian e-Health Research Centre was internationally recognised as a leading National research facility in ICT for healthcare innovations. Prior to this, Gary was the founding CEO of Wedgetail Communications, a spin-off company from the CRC for Distributed Systems Technology Centre.

A senior technology executive with deep experience driving innovation and growth, Gary has held senior executive, change management, technology research and product development, business development and project management roles in public and private sectors. He has a MBA and Graduate Diploma from Queensland University of Technology and a Bachelor of Commerce degree from Griffith University.

John Bell
Member

As the Assistant Dean, Research for the Faculty of Built Environment and Engineering at QUT, John Bell has over 20 years research experience in industry focussed research, and 10 years Senior Research Management Experience. He has published over 130 refereed publications and has secured over $10 million in competitive funding. John has also served on the board of the Sustainable Energy Industry Association (1999- 2003), as well as the Australian Nanotechnology Alliance (2008-current) and the Rail CRC (2009-current).

Michael Brünig
Member

Dr Michael Brünig is the Research Director of CSIRO's strategic research program in Sensors and Sensor Networks. With an uninterrupted experience in R&D in academia, industry, and governmental agencies since 1996, Dr. Brünig has worked in high tech areas in Europe, the USA, and Australia. Before working for CSIRO, he was with Robert Bosch Corp., USA, where he led a research program that connected technology scouting with the company's strategic interests.

Through his passion for bringing together multidisciplinary teams to combine efforts and resources for optimal and relevant outputs, he strives to find synthesis between technology trends and the team's research strengths.

Dr Brünig obtained his PhD from RWTH Aachen University, Germany and he holds an Adjunct Professor appointment with the University of Queensland. He is a senior member of the IEEE and a graduate member of the Australian Institute of Company Directors. Besides his engagement in ARCAA, Dr Brünig is a non-executive director of the German Couplink Group AG.

Prof Rodney Walker, CEO
Non-Voting Member

Since completing his PhD in Satellite Navigation and Electromagnetics, Rodney has strived to advance the opportunities available to young Australian engineers with an interest in aerospace. From 1997 to 2005 he was the program leader for GNSS on "FedSat" – at the time Australia's first satellite mission in over 32 years. From 1999 – 2009 he was a lecturer in QUT's Bachelor of Aerospace Avionics, instigating a number of reforms within the course, particularly the area of Systems Engineering and rose to the position of Professor of Aerospace Avionics at QUT and training over 300 aerospace engineers.

For more than a decade, Rodney has worked with his partners to create ARCAA, which now has over 30 staff members, and since November 2009, its own dedicated research facility. In the last 5 years he and his collaborators have attracted over $20 million in research funding (cash and in-kind), published over 70 refereed papers and book chapters, and provided media comment on aerospace issues over 40 times. A passionate advocate in progressing automation in aviation and its application in the civil aviation environment, Rodney has been granted several UAV approvals by the civil aviation safety authority and is also a pilot with night VFR and aerobatics endorsements.

Jonathan Roberts,
Deputy CEO
Non-Voting Member

Jonathan currently leads the CSIRO ICT Centre's Autonomous Systems Laboratory, an 80 person research lab focussing on field robotics and wireless sensor networks. His research interests encompass the area of Field Robotics and include UAVs, autonomous ground vehicles, underwater robots and mining robots. He has an Honours Degree in Aerospace Systems Engineering and a PhD in computer vision, both from the University of Southampton, UK.

Jonathan has 100 publications in refereed journals and conferences and currently serves on the editorial board of the International Journal of Field Robotics and has previously served as an associate editor of the IEEE Robotics and Automation Magazine. He is also currently an adjunct Professor at Queensland University of Technology and the University of Queensland. Jonathan is a past president of the Australian Robotics & Automation Association (2006-2008).

ACADEMIC STAFF FOR 2009

Luis Mejias Alvarez
Wageeh Boles
Duncan Campbell
Jason Ford
Felipe Gonzalez
Peter O'Shea
Rodney Walker

PROFESSIONAL STAFF FOR 2009

Troy Bruggemann
Jinhai Cai
Reece Clothier
Lennon Cork
George Curran
Ryan Fechney
Dennis Frousheger
Marcos Gerardo Castro
Richard Glassock
Duncan Greer
Stefan Hrabar
Carmel Johnson
Ritesh Kapoor
John Lai
Scott McNamara
Brenden Menkens
Torsten Merz
Steven Mills
Rhys Mudford
Lyn Pearson
Jonathan Roberts
Nicholas Rutherford
Chris Tomkins
Christopher Turner
Alexander Wainwright
Rhys Ward
Paul Wu

BOARD OF DIRECTORS' MEETINGS FOR 2009

Inaugural Board Meeting	26 March
Strategic Planning Meeting	27 July
Board Meeting	20 November

The following persons attended Board of Directors meetings as observers or executives for their respective organisations:

Michael McArdle – QUT
Carmel Johnson – QUT
Lyn Pearson – QUT
Darrell Williamson - CSIRO

ARCAA RESEARCH FACILITY

"This state of the art facility will be a great complement to the ground breaking research ARCAA is currently undertaking."

The Hon. Andrew Fraser, Queensland State Treasurer and Minister for Employment and Economic Development – 16 Nov 2009.

Professor Peter Coaldrake (Vice Chancellor of QUT), The Hon. Andrew Fraser (Queensland State Treasurer and Minister for Employment and Economic Development), Mr Koen Rooijmans (CEO Brisbane Airport Corporation), Professor Rodney Walker (CEO ARCAA).

In late 2009 ARCAA moved into its new purpose built research facility at Brisbane Airport. This facility provides space for 30 researchers, along with three dedicated avionics laboratories and a large indoor working space to support field deployments.

Aside from the human resource, the facility is home to our avionics hardware and software simulators, along with the mobile operations centre and the UAVs.

Key dates;

* Sod Turning Ceremony 15th April
* First Site Walk-through 29th July
* Second Site visit 23rd September
* Third Site Visit 16th November
* Certificate of Occupancy 19 November 2009
* ARCAA moved in 23 November 2009

MOBILE OPERATIONS CENTRE

A Mobile Operations Centre (MOC) was delivered in November 2009. The design and development of the vehicle proceeded from broad initial concepts though several iterations and upgrades to yield a very practical unit which has already proven valuable for field operations and industry demonstrations.

The MOC plays a fundamental role for ARCAA UAV operations. It facilitates sustained field testing operations at remote sites, being capable of transporting and providing ground support for the ARCAA UAV personnel and platforms.

The Mobile Operations Centre (MOC) is a light rigid 4x4 crewcab truck. The Pantec back is of dimensions: approximately 4.5m x 2.5m x 2.4m. Included here is workspace for laptops, communications equipment, kitchen-type facilities (fridge, microwave, tea/coffee), battery/power monitoring and storage space. The MOC includes a section that is able to slide out and form a large workspace with glass viewing windows. This gives operators a 180 degree field of view. The area seats 3 persons plus equipment, computers, screens and controls.

A UAV transport and storage compartment capable of containing airframes up to 2.5m long and 1m high is accessible from within the main crew compartment as well as directly from outside to facilitate easy loading and onboard testing.

A 10 metre high extendible mast and antenna installation is stored within a weatherproof compartment and deployed with a pneumatic power system, VHF, UHF radio and Telecommunications equipment is located on racks adjacent to the antenna compartment and connected to computer equipment anywhere in the MOC by modular data cable conduit assemblies.

External items include the power system (generator, battery backup, inverter), lockable storage for batteries, lockable storage for fuel, 240 V power outlets, roll-out awnings, tow bar and water storage.

AIRBORNE SYSTEMS LABORATORY

"ARCAA's Airborne Systems Laboratory is a unique system for conducting 'proof of concept' flight automation tests that will lead to long term cost savings, through reduced crew workload and improved use of airspace."

Mr Ted Whitley, Manager, Global Tracking and Control Systems, Boeing Research & Technology.

The Airborne Systems Laboratory (ASL) is a Cessna 172 aircraft which has been specially modified for flight testing of the future aviation technologies developed at ARCAA.

The key features of the ASL are:

1. The ability to carry a wide range of payloads;
2. Provide reliable and continuous power;
3. Have access to good quality aircraft state data (position, velocity, attitude and other derivatives);
4. The ability to 'close-the-loop' on aircraft control inputs (i.e. interface to the aircraft's autopilot);
5. Provide multiple heterogeneous communications links to the outside world;
6. Include a modular and pluggable software framework for implementation of experimental software;
7. Be safe, simple and cost effective to operate;

Physical Modifications

A number of physical modifications were initially made to the aircraft. The major structural modification made was the installation of air-transport style seat tracks normally only found on much larger aircraft (sometimes referred to as Douglas rail). This modification allows the secure fitment of a wide range of payloads, thus satisfying the requirement of flexibility and adaptability. A custom designed 19" equipment rack was manufactured and is installed in these seat tracks, replacing the two rear seats. The rack is certified to safely carry up to 55kgs of payload.

Other modifications include running aircraft power to a convenient connector on the rear bulkhead for powering the research payload; various antennas and associated cabling for the research communications links; a 10.4" daylight readable LCD screen in the cockpit. These are discussed in further detail below.

Networked Flight Management System

The Networked Flight Management System (N-FMS) is one of the core research payloads on the ASL. This system provides a modular and pluggable software interface allowing various software to be easily integrated into the ASL's systems. The N-FMS also provides the usual FMS functions of navigation and guidance through user definable flight plans, but can be easily extended to test new algorithms as has been done with the CRCSI project for power line tracking.

ASL Cockpit Panel With N-FMS Interfaces shown on right.

Crew Interfaces

The N-FMS includes two primary crew interfaces. The first of these is a 10.4" daylight readable LCD installed in the right hand side cockpit panel. This is in the primary field of view of the right hand seat crew member. For research purposes, this crew member operates the aircraft whilst the pilot-in-command (in the left hand seat) maintains a situational awareness lookout and takes over if required.

Crew input to the N-FMS is achieved via a touch-screen PDA attached optionally to the yoke or the crew member's kneeboard. This is referred to as the Controller Display Unit (CDU). The CDU includes all of the controls necessary for interaction with the N-FMS including selecting, activating and deactivating flight plans, choosing waypoints, selecting display components etc. The CDU can also be configured to display custom inputs for research payloads.

Autopilot Interface

The aircraft is factory fitted with a Honeywell KAP140 analog autopilot. An interface to the autopilot was designed, certified and installed in to the ASL, allowing the aircraft's Networked Flight Management System to command the aircraft's autopilot directly, without the need for crew interaction. This is a significant capability as it allows true autonomous operation during cruise phases of flight (the autopilot is not certified for operations below 1000 feet above ground level).

Operations

The ASL has been designed for simple and safe operation. Even so, achieving safe operations is dependant upon a structured approach to flight testing.

A safety management system has been developed which helps ARCAA to manage the research flight test process and ensure all operations are conducted safely and effectively.

To date, in the first 12 months of operation, the ASL has achieved over 160 operational hours, of which over 100 were engaged directly in research flying, with the remainder being capability development and other operations. During this time, the ARCAA ASL team has learnt a great deal about the operation of such a research asset and has proven the operational concept of a safe, simple, cost effective and efficient flight test capability.

The Airborne Systems Laboratory (ASL) at Redcliffe Aerodrome, with the new paintwork.

The ASL with its new paintwork

The ASL in flight with its original paintwork

The ASL with its new paintwork

UNMANNED AERIAL VEHICLES (UAVs)

"Carla"

The ARCAA Flamingo UAV system represents the mid-sized fixed wing UAV capability for the Smart Skies project, which has successfully completed Phase II and III flight test requirements. Carla is fitted with satellite and terrestrial communication links, allowing a connection to Boeing's global air traffic management system. This system can detect conflicts with other aircraft and provide updates directly into the air vehicles flight management system to resolve those conflicts. Carla and her crew completed 40 operational flight hours in 2009 and approximately 60 launch and recoveries without incident.

"Lurch"

ARCAA's larger platform, Lurch is based on an Integrated Dynamics Shadow mk-1. Lurch participated in a static display in October 2009 at the Coolum Top Gun jet weekend in association with Department of Employment Economic Development and Innovation. This UAV has successfully undergone initial testing and has benefited from significant re-engineering from the basic supplier specification. The aircraft will be fitted with the ARCAA standard networked flight management system (N-FMS) and is capable of carrying up to 12kg payloads. This aircraft is slated to be the primary host for the computer vision collision detection sensor under evaluation in early 2010.

" Charlie"

Charlie is an extensively modified Commercial Off The Shelf (COTS) Radio Controlled Model Aircraft kit capable of carrying 2kg payloads. The modifications include;

* Increased wing span and tube joiner system
* Low wing configuration and undercarriage mounting system
* Increased engine size, vibration mount and Centre of Gravity fuel system
* Autopilot, GPS and Datalink Communications installation
* Custom PC104 flight computer integration

Charlie acted as the intruder aircraft in the UAV collision data collection flight trials in December 2009.

The "Hotels"

The development and extension of capabilities of the ARCAA helicopter UAS has continued throughout 2009, progressing from basic capabilities of attitude and altitude control at the start of the year to full flight control beyond visual range by November. Between the two helicopters, Hotel Alpha and Hotel Charlie, in 2009 over 54 flight hours and 340 landings were logged including test flights and autonomous operations, with the longest flights a circuit of 6.5km, extending to a range of beyond 2km from the ground station. Unfortunately while conducting a beyond visual range practice flight prior to the Smart Skies Phase 3 flight trials Hotel Charlie crashed and was destroyed, highlighting that despite the previous record of reliable flights by the platform, the challenge and complexity of creating and operating a dependable autonomous helicopter should not be underestimated. The year ended with the completion of the sensor characterisation flights of the static sense and avoid system.

"Eleanor"

Eleanor is an up-scaled version of Charlie. Avionics and basic modifications are the same however, a further increase in engine capacity and wingspan enables Eleanor to carry up to 4kg payloads. Eleanor was created by marrying two commercial aeroplane fuselages together.

CASA Approved Flight Area

ARCAA's flight test site near Kingaroy was successfully approved by the Civil Aviation Safety Authority for UAV operations up to 1500ft. This approval allows for an expanded series of flight test scenarios to be evaluated. This site is the primary region of operations for all integrated flight tests that occur under Smart Skies. "Moggill Field" is another site that ARCAA makes use of for flight testing the helicopter UAV.

ARCAA Research Projects are conducted in collaboration with a diverse range of external stakeholders including;

* Boeing is a major international aerospace and defence corporation
* CRC for Spatial Information (CRCSI) is identifying the questions of future spatial information needs - who needs it, in what form and when
* Ergon Energy provides electricity related services to more than 650,000 customers across Queensland. Ergon has partnered with the CRCSI to conduct research into improving business processes through spatial information
* The Defence Science and Technology Organisation (DSTO) is the Australian government's lead agency charged with applying science and technology to protect and defend Australia and its national interests
* CRC for National Plant Biosecurity provides leadership in the development, execution and delivery of plant biosecurity research
* The Centre for Marine Studies conducts leading edge research and teaching into the diverse marine ecosystems of Queensland

MARINE MAMMAL SURVEY PROJECT

Project Leader

Dr. Luis Mejias

Project Team Members

Rodney Walker,
Amanda Hodgson
Duncan Greer

Introduction

Aerial surveys for marine mammals are important for monitoring the populations of these animals and to help us understand their habitat needs. Surveys for species such as dugongs and humpback whales are regularly conducted at many locations around Australia. Surveys are also used to assess and monitor the potential impacts on marine mammals, of some coastal developments and industry activities such as oil and gas exploration and mining.

Current aerial survey techniques involve trained observers flying for many hours over coastal waters in remote areas. Previous safety incidents have occurred overseas and new UAV technology could remove the human risk involved in aerial surveys. UAVs also have the potential to increase the accuracy of detection, location and identification of species, provide a permanent record of the survey, reduce costs, and enable surveys in remote regions where manned surveys are the most logistically challenging.

This project aimed to determine the most efficient method for detecting marine mammals using aerial imagery. We trialled UAV imaging systems using a manned plane and found that high resolution images are needed to reliably identify marine mammals to species.

We also aimed to automate the detection of marine mammals in the images collected using a UAV, rather than having a human observer review the many thousands of images collected during a survey. We have conducted the initial stages of developing an algorithm that detects marine mammal candidates in images. We tested the algorithm using two image-sets collected during a manned aerial survey for marine mammals. An analysis, discussion and recommendations for further development of the algorithm were presented in light of the complexity of detecting marine mammals in images differing water quality and bottom visibility.

Milestones and Achievements

1. First flight: September 2008, Redcliffe – Moreton bay coast

   Images and data associated were collected with first hardware configuration onboard a Partenavia twin engine aircraft.

2. Second flight: October 2008, Redcliffe – Moreton bay coast

   Similar data collected but with different camera lens.

3. Software and report delivered: May 2009. Matlab software for automatic mammal detection was delivered to the customer.

Other Related Activities

Discussions with University of South Australia researchers about collaboration and data sharing.

Collaboration discussions with French based ActiMar continue.

"Our collaboration with ARCAA has provided us with important knowledge about the image resolution needed to survey marine mammals using UAVs."

Amanda Hodgson, Centre for Marine Studies, University of Queensland

Output from the ARCAA Marine Mammal Detection Software

SMART SKIES PROJECT

"The Department of Employment, Economic Development and Innovation is the agency responsible for economic development in Queensland and is a proud supporter of the research undertaken by the Australian Research Centre for Aerospace Automation in the field of unmanned aerial systems integration into national airspace. We see this project as being important in helping us understand the future of integrated airspace for manned and unmanned aerial vehicles.

The Department recognises the hard work and invaluable research being undertaken through the Smart Skies project, and the project's employment of researchers and highly skilled graduates, as well as the Queensland and International benefits of such research for civilian and military applications."

The Hon. Andrew Fraser, Queensland State Treasurer and Minister for Employment and Economic Development – 16 Nov 2009.

Project Leader

Reece Clothier

Project Team Members

Duncan Greer, Rhys Mudford, Richard Glassock, Ryan Fechney, Scott McNamara, Torsten Merz, Dennis Frousheger, Stefan Hrabar, Jonathan Roberts, Daniel Fitzgerald, Chris Turner, Farid Kendoul, Lennon Cork, Bilal Arain, Volker Hilsenstein

Boeing Team Members

Michael Wilson, Richard Baumeister, Regina Estkowski, Ted Whitley, John Kautzky, Graham Spence, Brendan Williams

Organisations Involved

Boeing Research & Technology
Boeing Research & Technology Australia

Introduction

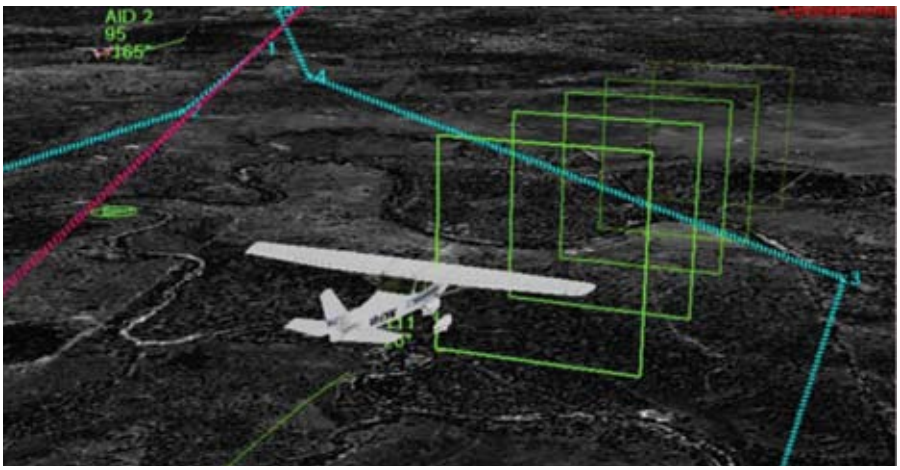
The Smart Skies Project is a research collaboration between Boeing Research & Technology (BR&T), BR&T Australia, and ARCAA. The three-year, AUD$10M project, is partly funded by a successful grant under the Queensland State Government National and International Research Alliances Program.

Aims and Objectives

The vision of the project is the safe, efficient and routine operation of Unmanned Aircraft Systems (UAS) in non-segregated airspace. The aim is to develop and demonstrate future aviation technologies which will promote the more efficient utilisation of airspace by both manned and unmanned aircraft, and to disseminate the information and experiences gained to support the further development of standards, regulations and safe operating practices for civil UAS.

The three high-level objectives of the project are to research, develop and flight test:

1. A mobile aircraft surveillance system;
2. Autonomous onboard systems for detecting and avoiding ground-based obstacles and other aircraft;
3. A global and automated air traffic separation management system.



Flight Path Planning over Burrandowan

Milestones and Achievements

The project commenced in 2008, with the first year of activity focussed primarily on the engineering of flight testing capabilities. March 2009 marked the commencement of the second year of the project and also the first of four comprehensive flight trial campaigns completed in 2009.

Flight Trials

The focus of the first three flight test campaigns was to verify the performance of the automated separation management system for a range of complex conflict scenarios involving up to six aircraft at a time. The campaigns involved the simultaneous deployment of the three ARCAA flight test aircraft in Kingaroy, the simulation of aircraft from the UK and the provision of a separation management capability from the USA. Over the three campaigns, more than 80 flight test conflict scenarios were completed with the Cessna accumulating over 85 flight hours in support of Smart Skies flight testing.

Flight testing in support of the sense and act research program was commenced in December 2009. Over 60 image and LiDAR data sets were collected using the ARCAA UAS helicopter on a range of static obstacles. This data is being used by researchers to characterise the performance of the static sense-and-act sensors. In addition, flight data for six different collision scenarios were captured using the ARCAA fixed wing UAS. The vision data captured will be used to support the ongoing refinement of the dynamic sense-and-act algorithms.

Significant Engineering Achievements

The primary flight test platform has been the Cessna 172, Airborne Systems Laboratory. Over the course of the year, ARCAA researchers have turned a standard light aircraft into a CASA-approved advanced flight test asset capable of being flown autonomously from computers located on the other side of the world.

The UAS platforms have both achieved a high level of robustness allowing them to be flown on missions beyond visual range. The UAS fixed wing and helicopter flight test teams have accumulated considerable operational experience and it is this experience which contributed towards a CASA approval for extended operations at the Burrandowan test site.

Other Activities

The project has had great media exposure, with the creation of a website and two formal media releases. It has also featured in four magazine articles and countless newspaper articles. An invited presentation on the project was also made at the AUVSI North America Conference. The project was considered a hot topic at the largest conference on unmanned systems in the world.

Summary

The Smart Skies project team have proven themselves to be a highly-competent flight test research team. The significant achievements for 2009 have established the necessary foundations for continued high quality research: an experienced and innovative team of engineers and researchers, unique flight testing capabilities, and a strong relationship with industry partners.

Intellectual Property

ARCAA has established Intellectual Property (IP) in the predictive flight management hardware and software which is deployed across the flight test platforms. This includes the development of custom displays and interfaces. This IP has been further leveraged within the project to develop an ARCAA separation management system, and a software interface for the BR&TA mobile aircraft tracking system. The same framework has been used to support the development of an advanced flight management system for the CRCSI project.

ARCAA background IP in the field of vision and LiDAR-based sense-and-avoid systems has been further refined throughout the course of the project. ARCAA researchers have also developed a robust helicopter autopilot, flight management system and ground control system.

Carla (Fixed Wing) and Hotel Charlie (Helicopter)

INFORMATION BUSINESS IMPROVEMENT APPLICATIONS AT ERGON ENERGY PROJECT
AUTOMATED AERIAL INSPECTION

"We are looking at developing a system of aerial management, which is safe, more efficient and enables us to provide better customer service.

Safety is our first priority: among the major things we are researching are automatic flight control systems that ensure the UAVs will operate accurately and safely along a remote power line corridor."

James Bangay, Manager of Information Strategy, Ergon Energy, Landmark Magazine, December 2009.

Project Leader

James Bangay, Ergon Energy

Project Team Members

Marcos Gerardo Castro, Jinhai Cai, Troy Bruggeman, Steven Mills, Ryan Fechney, Eric Li, Luis Mejias, Jason Ford, Ross Hayward, Jinglan Zhang, Rodney Walker

Organisations Involved

CRC for Spatial Information
Ergon Energy
Queensland University of Technology
V-TOL Aerospace

Introduction

This project is a close collaboration between ARCAA researchers and Ergon energy through the CRC for Spatial Information, and is funded to the value of $1M over 3 years.

Aims and Objectives

Ergon Energy has over 600,000 customers spread over 1.7 million square kilometres, or 97% of the state of Queensland. Their principal asset is over 150,000km of powerline and almost 1,000,000 power poles. A significant component of their cost of supply is in the condition monitoring of the powerline assets and the vegetation in the powerline corridor.

In Ergon's endeavours to improve service, and to reduce costs over such a vast service area, the opportunities provided by routine aerial surveying have become of interest. As such three main research areas have emerged within this project:

1. Precision Guidance of UAVs and manned Aircraft over Powerline networks
2. Powerline and Vegetation Detection in LiDAR and Imagery
3. Tree species detection and classification

The focus on each of these areas is on increased levels of automation, whilst keeping the scope of the large survey problem in context and focusing on reducing costs of data collection and data processing.

Milestones and Achievements

The project commenced in late 2007 with trials of commercially available UAV systems to assess, first hand, the performance of these machines as sensor platforms for powerline corridor inspection. For 2009, a series of flight trials were conducted, evaluating the latest aerial survey sensors and also testing ARCAA's new concepts in precision aircraft guidance.

In November 2009, ARCAA conducted its first precision automated survey flight test in the Airborne Systems Laboratory. This, and a series of subsequent flight tests, confirmed the significant improvements in aircraft guidance that had been observed in the desktop simulation environment. Additionally, route planning algorithms were implemented in the Airborne Systems Laboratory software framework and these were compared to the performance of existing aerial survey vendors. It was found that the automated route planning algorithms typically provided a 20% saving in flight time. The cost savings to a routine whole of state survey campaign quickly mount with such technologies.

In addition to reducing the costs associated with the collection of the spatial information, ARCAA is also working towards reducing the costs

associated with the processing of this data for Ergon business purposes.

To this end a comprehensive evaluation of the performance of existing aerial survey providers was completed. This involved the contracting of several providers to fly a variety of sensors of areas of relevance to Ergon. In one test case, a ground-based calibration of the test site was undertaken to provide a ground-truth of the 3D powerline corridor environment. This testing was conducted over a 1.6km stretch of powerline near the small town on Murgon in outback Queensland.

Analysis of the data collected from the aerial survey providers found that powerlines and vegetation are most robustly detected when fused imagery and LiDAR data sets are used. Work commenced on automatically classifying and detecting powerlines and vegetation in these data sets. These algorithms were developed with real-time implementation in mind for future guidance concepts that make use of active real-time powerline tracking. The aim of the automated processing is to extract vegetation management clearance problems automatically and robustly, thus saving on labour costs associated with the manual processing of the voluminous data sets.

Finally a series of algorithms to automatically identify individual tree crowns from images were developed. The data collected during the ground-truthing process was used to evaluate the performance of automatic tree detection and classification algorithms.

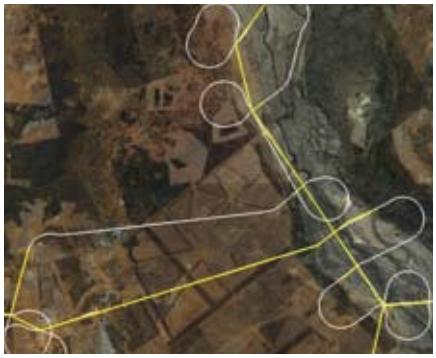
Major milestones and Dates

* Completion of Murgon-Wondai calibration field work.
* Quantified reliability and accuracy of airborne data collection sets, (LiDAR and Photogrammetry) (Feb - March 2009).
* Data collection Capture II. Over Toowoomba, St George, Emerald, Bundaberg, Dolby and Mackay (June – November 2009).
* Data Analysis and object extraction preliminary results. (September 2009) 3D View of LiDAR combined with high resolution Images
* Three flights in the Airborne Systems Laboratory over powerlines in St George and Kingaroy, QLD were conducted for testing new automatic control/autopilot solutions for flying powerline corridors (Nov - Dec 09).

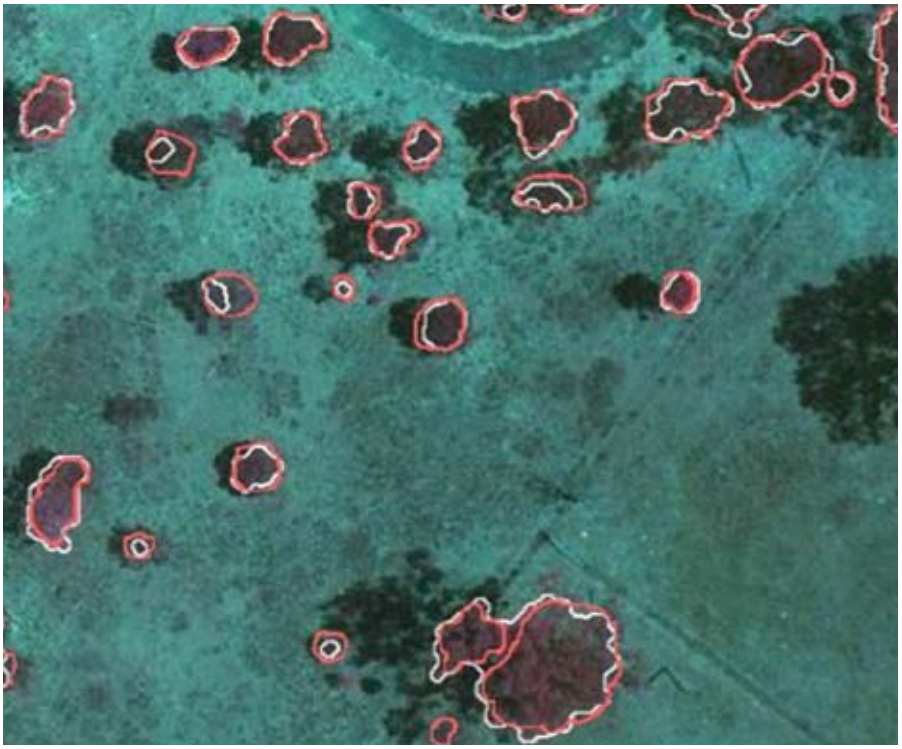
Intellectual Property

ARCAA and the CRCSI have established Intellectual Property in the aircraft precision guidance system that has been implemented and tested in manned aircraft. This includes the development of a novel pilot interface. Additionally IP in the processing of the sensor data for Ergon purposes has been developed and demonstrated on data sets collected and evaluated in a calibrated environment.

Human pilot cornering attempt



ARCAA automated flight over powerlines. White indicates flight path. Yellow indicates powerlines.



Tree Crown Delineation Results (Manual - Red, Automatic - White)

The figure above provides an example of some of our results with detection rate of 96%, and a segmentation accuracy of 75% - which is a significant improvement over previous attempts.

FLYING SPORE TRAP PROJECT

"The Science Committee recognises the success of the team in successfully integrating the spore trap with an aircraft."

David Eagling, Research Leader, CRC for National Plant Biosecurity – Reporting Period October to December 2009.

Project Leader

Dr Felipe Gonzalez

Project Team Members

Rodney Walker
Pritesh Narayan
Francesco Tamagnone Cosmelli
Zoran Ristovski

Organisations Involved

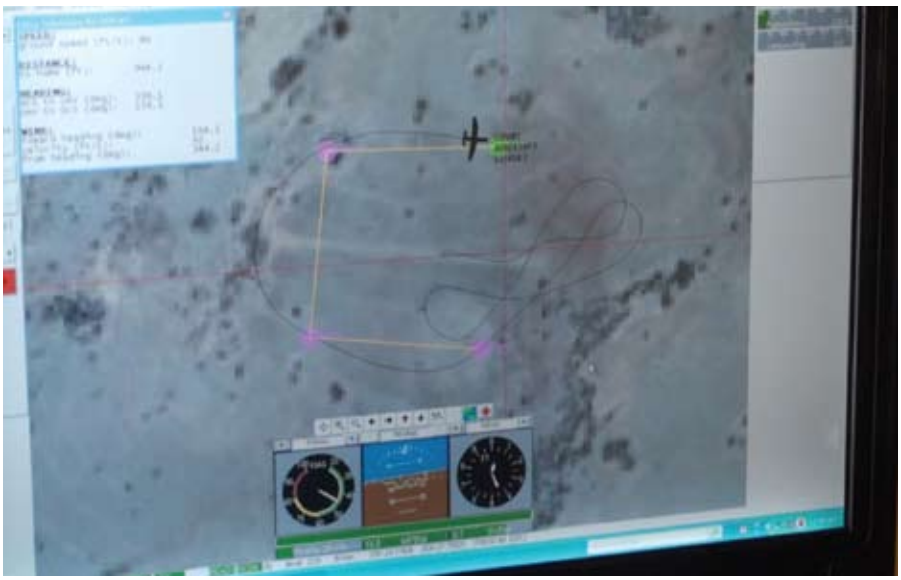
Cooperative Research Centre for National Plant Biosecurity
Queensland University of Technology
Queensland Primary Industries and fisheries.
Department of Agriculture and Food, Western Australia

Introduction

Australia's agriculture industry enjoys a respected global reputation for being of high quality. However with an ever-shrinking world, protecting our agricultural products from disease and pests is an ongoing problem.

One component of the protection program is routine surveillance, which in the Australian context is difficult to conduct cost-effectively. One approach is to make use of spore-traps, which are devices at fixed locations that capture airborne particles. These particles are routinely collected and examined as an early indicator for the presence of disease. There are limitations to the effectiveness of this approach, mostly since the devices are stationary at the sampling location. This project is a scoping study to determine the potential of using unmanned aerial vehicles, fitted with a spore trap, to detect and monitor spores of plant pathogens.

We aim to develop a sampling system that will have the ability to spatially monitor fungal spores, and protocols to interpret their spatial distribution. This tool will greatly enhance the ability to detect new incursions of fungal pathogens and to enable more accurate delimiting of the distribution.



Horizon UAV Flight Plan with Autonomous Spores Indexing System

The technology will allow for earlier detection of plant pathogen incursions in difficult areas and provide efficient and effective airborne surveillance.

The main output of this project is to design and develop a lightweight, compact spore sampling device, and to demonstrate it's utility on a UAV that will traverse a predetermined survey path. To date the project has successfully integrated the spore trap to the Flamingo UAV Carla and conducted a series of flight tests to evaluate the soundness of the approach. Flights through plumes of sugar crystals have demonstrated that particles of the expected size and concentration can be detected in the current configuration.

Work is continuing with the guidance and sensing issues associated with routine low-altitude surveys for UAVs.

Milestones and Achievements

M1) Literature review completed August 2009

M2) Controlled experimental process for Wind Tunnel finalised September 2009

M3) Detailed Wind tunnel test completed October 2009

M4) Finalised hardware integration concept and document, October 2009

M5) Flight trials 1 completed Flight test November 2009

Benefits to Industry

Existing spore sampling devices are stationary at the sampling location. Location is important due to prevailing climatic conditions, and use of sampling devices in remote locations and where topography is severe or almost impossible. Where the disease is in the canopy of trees, using existing spore sampling technologies is almost impossible. Should this scoping study prove successful further research will be conducted to refine the flying spore trap for use by surveillance staff employed in state and federal agencies.

Intellectual Property

* A methodology and system for geo-locating air particles and spores using unmanned aerials systems.
* An air sampling device that self regulates the air intake needed for accurate sampling.

Spore Trap onboard the Flamingo UAV During Autonomous Flight

Spore Trap UAV Collecting Data

Spore Trap UAV Integration Unit

UAS RISK HAZARD ASSESSMENT TOOL PROJECT

Project Leader

Reece Clothier

Project Team Members

Paul Wu
Prof Rodney Walker

Organisations Involved

Defence Science and
Technology Organisation
Queensland University of Technology

Introduction

UAS are expected to be a significant component of Australian Defence Force capability in the short term; if not already. A particular issue for the ADF is making informed strategic procurement and operational decisions relating to risks associated with operating UAS over populated regions. The Unmanned Aircraft System (UAS) Risk Assessment Tool Project was sponsored by the Defence Science and Technology Organisation (DSTO) in direct response to this need.

The project commenced in June 2009 with the objective to develop a tool that would allow the Australian Defence Force to quickly quantify the risk of different operational UAS scenarios.

Utilising the PhD research of Mr Reece Clothier and with Dr Paul Wu as the principle researcher, a concept for the solution was proposed to DSTO staff. An implementation plan was agreed to and the system was successfully delivered to DSTO staff on the 3rd December.

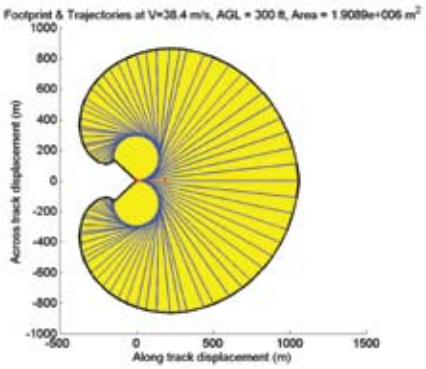
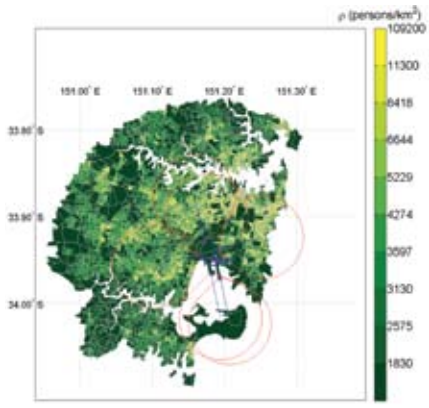
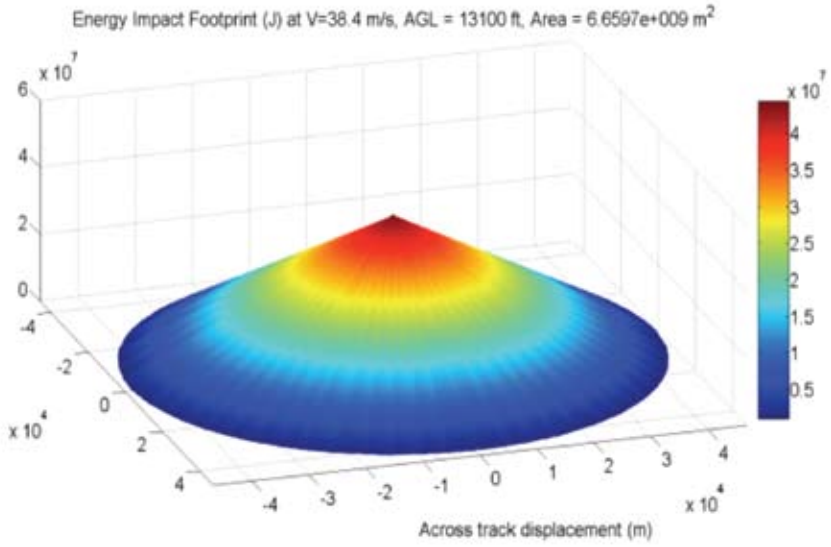


Illustration of the calculation of a ground impact boundary



Ground impact boundary plots for different runways at Sydney airport



Spatial Plot of Aircraft Impact Energy

AERIAL PHENOTYPING PROJECT

"Imagery from autonomous vehicles has great potential in plant breeding research, and we are excited about harnessing these new technologies to deliver new varieties faster to Australian farmers."

Dr Scott Chapman, Principal Research Scientist, CSIRO Plant Industries .

Project Leader

Dr.-Ing. Torsten Merz

Project Team Members

Lennon Cork

Organisations Involved

CSIRO Plant Industries
High Resolution Plant Phenomics Centre

Introduction

Phenomics is the study of how the genetic makeup of an organism determines its appearance, function and performance; for crops this involved measurements of plants throughout their lifecycle. By linking these measurements to the plant's genetic makeup, new plant varieties can be selected with better performance for farmers.

The aerial phenotyping project is a pilot program to examine the feasibility of utilising the ARCAA helicopter UAS, known as the Phenocopter in this application, to capture low altitude images of plantings of different varieties of wheat and other crops. This program is in support of research being conducted by CSIRO Plant Industries in Gatton Queensland and at the High Resolution Plant Phenomics Centre in Canberra.

A colour still camera and a thermal imaging camera are mounted to the helicopter UAS offering an immediate way to make simultaneous observations across the entire experimental area. This overcomes problems inherent in using ground-based sensors to observe each plot, where measurements are affected by changes in weather conditions over the minutes and hours needed for large experiments.

Milestones and Achievements

M1) 1 October 2009: First phenotyping flight at CSIRO Lawes site near Gatton using colour still camera

M2) 13 October 2009: Phenotyping flight at CSIRO Lawes site

Aerial image of a wheat experiment at CSIRO's Lawes site, near Gatton in Queensland. The different coloured plots (ca. 7m x 2m in size) are different varieties of wheat, being grown under irrigated, high temperature conditions. These images can be processed to determine how 'green' each variety is, and whether their growth is affected by the high temperatures. 'Holes' in the plots are where samples have been taken to validate the image analysis.

UAV CHALLENGE – OUTBACK RESCUE 2009

"The technical expertise and support that ARCAA and its staff have provided for the UAV Challenge over the past three years is to be applauded and has gone a long way to ensuring the event's growth and success over this period. The quality of ARCAA research staff and students together with industry member experts is also an indication of the strength of the unmanned systems industry in Queensland."

The Hon. Andrew Fraser, Queensland State Treasurer and Minister for Employment and Economic Development – 16 Nov 2009.

In 2007 ARCAA, with the help of the Queensland State government, launched the UAV Challenge – Outback Rescue. This event was nearly two years in the making and was developed to address a number of critical issues in the developing commercial UAV area. Firstly, until recently, the public have only been exposed to military UAV activities, typically in the popular press and in Hollywood movies. An exciting UAV competition with an open invitation to the public and associated media attention could address this issue.

Secondly, one of ARCAA's aims is to help create a UAV industry in Australia and initially in the South East corner of Queensland. Key to such an industry's development is a pool of staff with relevant technical skills. Robot competitions typically attract technical savvy young people, keen to show off their skills and who ultimately could take up tertiary education in engineering and other technical disciplines that could serve the new UAV industries.

Finally, the ultimate aim of the routine operation of UAVs in civilian airspace, had in front of it a number of road blocks, such as how to operate UAVs at a regional airport with manned aircraft, the issue of how to obtain insurance for UAVs and a number of other non-technical, but critical, issues that could impede the development of a UAV industry. A UAV competition would have to address these issues if it was to be viable.

The UAV Challenge – Outback Rescue was launched at the beginning of 2007 with the event to take place in late September 2007. The Challenge, as it has become known, is split into two events, both located at Kingaroy regional airport in South East Queensland. The first event, known as the Airborne Delivery Challenge, is targeted at high school students and they compete for $15,000 in prize money. The winners are the team that can deliver a payload closest to a designated spot on the airfield. The challenge is that the pilot of the aircraft may not make the drop. Instead the drop must be automatic or must be initiated by a second team member located approximately 50m away and with no direct line of sight to the aircraft. Teams must use technology, such as video cameras and radio transmitters to solve the problem.

The second event is the Search and Rescue competition. The challenge here is to drop an aide package to a

MUROC Brumbies

MUROC Bush Bashers

AV8 – Aviation High - Accepting the rescue payload for Outback Joe from Reece Clothier

lost bushwalker, Outback Joe, who is located approximately 3 to 9ft from the airfield. The teams are given a sketchy idea of where the Joe was last seen and they are expected to launch a UAV, have it find Joe, drop him a water bottle and successfully return to the airfield, all in the space of one hour. This event is aimed at university students and RC hobbyists and the prize for completing the mission is $50,000.

Safety is the primary concern of organisers and of the teams in the run up to the Challenge. Each team must demonstrate to a panel of UAV industry professionals that they can operate their UAV in a safe manner. They must provide documentary and video evidence of competency followed by scrutineering flights immediately prior to the competition flights.

In 2007, the first year of the Challenge, only four Search and Rescue teams, from the original field of twenty from around the world, made it through to the competition flight. Again, in 2008 only four teams from an initial field of thirty-four took to the air at Kingaroy. In both years, teams did not locate Outback Joe. In September 2009, at the third running of the Challenge, two teams made commendable efforts at locating Joe. Team Melbourne's UAV crashed close to the search area after having encountered strong turbulence. Team Galah's UAV crashed just 134m from Outback Joe having suffered an unplanned engine shutdown. The $50,000 prize is still up for grabs and Joe is still lost in the bush.

The public day of the Challenge is dedicated to the Airborne Delivery Challenge and the high-school teams. For the three years that the event has been held, this event has been very well attended. In the first two years, teams from Mueller College won this event and they were hot favourites in 2009. However, the Aviation High Team – Cloud 9 won by a clear margin after they scored a direct hit on the target in the field. 2009 saw a dramatic increase in the sophistication of most of the teams. 2009 also saw the introduction of the Robot Airborne Delivery Challenge where teams had to fly the main circuit autonomously. The $10,000 prize was won by Look mAh, no hands – a team from Brisbane Grammar School.

The Challenge will be on again in 2010 when finally Outback Joe may be rescued and the $50,000 prize won.

"CASA is a major sponsor of this year's Unmanned Aerial Vehicle challenge. The UAV Challenge, called "Outback Rescue 2009", is a competition to foster innovation and development in the Australian aviation industry... The competition is certain to be both instructive and enjoyable for everyone involved and CASA is proud to be a sponsor."

John McCormick, Director Civil Aviation Safety Authority, CASA Briefing newsletter, August 2009.

Wynnum North State High School

Team Melbourne UAV

USQ Team Galah

QUT SRUAV2009

AUVS-AUSTRALIA

"The Association for Unmanned Vehicle Systems International (AUVSI) is grateful for your crucial and ongoing support in the establishment of AUVS-Australia."

Gretchen West, Deputy Executive Director, Director of Global Business Development, AUVSI.

With over 6,000 members from government, defence, industry and academia, the Association of Unmanned Vehicle Systems International (AUVSI) is the largest representative body in the world dedicated to the advancement of unmanned systems. In 2009, Prof Rodney Walker and Mr Reece Clothier, in conjunction with representatives from Australian academia and industry, took a leading role in the formal establishment of an Australian Chapter of AUVSI called AUVS-Australia. The objective of this national group is to foster the Australian unmanned systems community, through industry advocacy, events, networking, and education.

Over the course of the year, seven teleconferences and three face-to-face committee meetings were held over with the purpose of formalising the establishment and intended activities of the Australian Chapter. Prof Rodney Walker and Mr Reece Clothier published an information brochure to promote AUVS-Australia. In addition to this, both Rodney and Reece travelled to Washington D.C. to represent the Australian industry on an AUVS-Australia stand at the AUVSI North America Exhibit and Conference. This conference attracted over 5,000 delegates and provided an excellent opportunity for ARCAA personnel to foster new international networks and to promote the Australian industry and its research activities. An information stand was also established at the UAV Outback Rescue Challenge, this provided a great opportunity to engage with budding robotics enthusiasts and local industry. 2009 activities concluded with the first annual general meeting, and the completion of interviews for the position of Executive Director.

AAIF

"On behalf of the Forum's Executive Committee I wish to thank you and your sub-committee for your outstanding efforts this year in working through the very complex issues surrounding the effective regulation of the commercial use of unmanned aerial systems."

Malcolm J Robertson, Chair, Certification & Regulation Working Group, Australian Aerospace Industry Forum. 25 November 2009.

The absence of suitable regulations for civil UAS is viewed as one of the greatest challenges facing the widespread adoption of UAS technologies. Since 2007, Prof Rodney Walker and Mr Reece Clothier have undertaken a leading role in industry-initiatives focusing on the regulation of civil UAS in Australia. These informal activities were formalized in April 2009 through the creation of a sub-committee to the Australian Aerospace Industry Forum (AAIF), Certification & Regulation Working Group. Prof Rodney Walker accepted the role as Chair of the sub-committee which comprises members from industry, the Civil Aviation Safety Authority (CASA) and defence. Over the remainder of the year a number of teleconferences and two workshops were convened (Canberra and Hobart). These meetings were focused on the identification of key regulatory issues and the drafting of formal recommendations on how these issues could be addressed. The preliminary recommendations were presented at the annual AAIF Forum, at which the good work of the sub-committee was formally acknowledged. The finalised recommendations are expected to be formally presented to CASA in early 2010.

KPI	PERFORMANCE MEASURE	2009 OUTCOME
Commercialisation	1 Patent application, copyright, trade mark or new licence generated on average every 2 years	Discussion continues with QUT Bluebox to prepare ARCAA for future commercialisation opportunities
Employment of Professional Staff	Increase the number of research, technical or business development staff and post graduate students engaged in ARCAA by 5% per annum to the capacity of the facility (around 25 including post-graduate students) within 5 years of practical completion.	27 Professional Staff 7 Academic Staff
Education and Skills Development	At least 3 PhD and/or Masters Degree students graduating per annum averaged over any 5 year period	Enrolled: 15 PhD, 1 Masters Completions: 2 PhD, 1 Masters
Collaboration	Average of 1 visiting national or international visiting scientists per annum, averaged over 5 years. 1 new collaboration every two years	Dr Richard Baumeister – Boeing Research & Technology Dr Regina Estkowski – Boeing Research & Technology Dr Didier Herve – Telecom Bretagne France Defence Science and Technology Organisation Australian Aerospace Industry Forum
Research and Development Excellence	3 refereed scientific papers, published in national or international journals or books per annum (averaged over 5 years). 8 conference papers, articles or industry reports published per annum (averaged over 5 years)	3 Book chapters 19 Journal Articles 20 Refereed Conference papers 4 Non- refereed Conference papers
Technology Transfer	3 policy submissions, information publications, media releases or events promoting uptake of ARCAA Research results on average per annum. 2 conferences, seminars, forums or workshops, professional education activities organised per annum.	2 media releases 1 invitation to research workshop on UAS and regulations – AUVSI Nth America 3 AAIF meetings – Hobart, Canberra, Sydney 3 AUVS Australia meetings – Sydney, Adelaide, Brisbane
Investment in Research	Secure $200,000 per annum of external funding for ARCAA activities for the five year period following practical completion of the ARCAA Building. From 5th to 10th Year of the term, maintain external funding for ARCAA Activities at not less than $250,000 per annum (adjusted annually to reflect changes in the Consumer Price Index).	Occupancy of building 23 Nov 2009. $1,442,792 in external funding. Not applicable
Community	Average of 2 presentations per year to community groups:	8 presentations
Engagement	Average of 6 presentations or publications per year to avionics industry groups, schools, TAFE's, government bodies, etc; Involvement in QUT Train displays every two years; Hold Open Day at ARCAA Building at Brisbane Airport Annually.	24 presentations and conducted the 2009 Outback Challenge with 300 International, Australian, High School and Industry participants. UAV display – 12 May to 20 June 2008. Not applicable for 2009. Open day planned for 2010.

Pillar Eng

Participation in Project ICPUAS – PIRSES-GA-2008-230797 - a UAS related collaboration between the Polytechnic University of Madrid, Cranfield University in England, and ARCAA.

2 September – 15 December 2009
University Polytechnic of Madrid

Duncan Greer

Night Flight Training

May – July 2009, Redcliffe Aero Club

Reece Clothier

Collaborative study with Defence Science and Technology Organisation researchers exploring suitable regulatory structures for civil UAS.

August 2009, Melbourne, Australia

Scott McNamara

Awarded a Boeing scholarship and part funded by ARCAA for travel and attendance at meetings, workshop and industry show. Including visit to the Boeing Technology Centre in Seattle and meeting Dr. John Vain a Boeing Research and Technology project lead working on UAV technologies. Also a VIP tour of the Boeing 'wide-body aircraft' Everett Factory just north of Seattle which assembles the 747 and the new 787. Finally took part in Smart Skies workshop 7.

July – August 2009. Seattle Washington
USA and Denver Colorado USA

Richard Glassock

Attended Friedrichshafen Aero Expo 2009

5 April 2009 Friedrichshafen Germany

Felipe Gonzalez

Flight Lessons for Private Pilots Licence

August - December, Redcliffe Aero Club

Luis Mejias Alvarez

Special Summer School on Animal Navigation

23-27 November 2009, University of Qld

Prof Rodney Walker

Avidyne Flight Management System and Cirrus SR20 Flight Training

September – December 2009, Archerfield Aero Club

Prof Rodney Walker, Duncan Greer

Attended EAA AirVenture 2009, Oshkosh, USA

1 August, 2009

Dennis Frousheger

Aircraft Radio Operators Certificate of Proficiency

BOOK CHAPTERS

PUBLICATION NAME	TITLE OF CONTRIBUTION	CONTRIBUTING AUTHORS
100 Volumes of Notes on Numerical Fluid Mechanics (NNFM 100)	Evolutionary Optimisation Methods with Uncertainty for Modern Multidisciplinary Design in Aeronautical Engineering	Dr Dong Seop Lee, Dr Felipe Gonzalez, Prof Jacques Periaux, Dr Karkenahalli Srinivas
Aerial Vehicles, Thanh Mung Lam Editor, ISBN 978-953-7619-41-1, 320 pages, Publisher IN-TECH	Forced Landing Technologies for Unmanned Aerial Vehicles: Towards Safer Operations	Dr Luis Mejias Alvarez, Dr Daniel Fitzgerald, Pillar Eng, Xi Liu
GNSS Applications and Methods, Scott Gleason and Demoz Gebre-Egziabher, Editors, Publisher Artech House, - "Space Applications" Chapter, Glenn Lightsey.	Reprinted Figure from, "Single Antenna Attitude Algorithm for Nonuniform Antenna Gain Patterns," AIAA Journal of Spacecraft and Rockets, Vol. 44, No. 1, Jan.-Feb. 2007, pp. 221-229.	Charles Wang, Prof Rodney Walker and Prof Miles Moody

JOURNAL ARTICLES

PUBLICATION NAME	TITLE OF CONTRIBUTION	CONTRIBUTING AUTHORS
The Aeronautical Journal, Notified Dec 8 2009	Invited: Multimodal Hybrid Powerplant for Unmanned Aerial Systems (UAS) Robotics	Richard Glassock, Jane Hung, Dr Felipe Gonzalez and Prof Rodney Walker
ASME Journal of Dynamic Systems, Measurement and Control	UAS Mission Path Planning System (MPPS) Using Hybrid-Game Coupled to Multi-Objective Optimiser	Dr Dong Seop Lee, Dr Felipe Gonzalez, Prof Rodney Walker, Prof Jacques Periaux
Australian Journal of Mechanical Engineering, 6(2)	Design, Modelling and Measurement of a Hybrid Powerplant for Unmanned Aerial Systems	Richard Glassock, Jane Hung, Dr Dr Felipe Gonzalez and Prof Rodney Walker
Concepts in Magnetic Resonance Part B: Magnetic Resonance Engineering	Reducing MRI Gradient Coil Vibration with Rib Stiffeners	Dr Terry Ran Lin, Prof Peter O'Shea, A/Prof Chris Mechefske
ECCOMAS Multidisciplinary Jubilee Symposium, Isbn 978-1-4020-9230-5, Springer, 2009	New Aerospace Design Challenges: Robust Multidisciplinary Evolutionary Techniques	Dr Kkarkahenalli Srinivas, Prof Jacques Periaux, Dr Dong Seop Lee, Dr Felipe Gonzalez
EURASIP Journal on Advances in Signal Processing	Realization of Ternary Sigma-Delta Modulated Arithmetic Processing Modules	Dr Amin Sadik, Prof Peter O'Shea
IEEE Robotics and Automation Magazine	Guided Chaos – Path Planning and Control for a UAV Forced Landing	Pillar Eng, Dr Luis Mejias Alvarez, Prof Rodney Walker, Dr Daniel Fitzgerald
IEEE Transactions on Aerospace and Electronic Systems (TAES), Accepted 29 July 2009 (In press).	GPS Fault Detection with IMU and Aircraft Dynamics	Troy Bruggemann, Duncan Greer and Prof Rodney Walker
IEEE Transactions on Geoscience and Remote Sensing, Accepted Nov 16 2009 (In Press)	Evaluation of Aerial Remote Sensing Techniques for Vegetation Management in Power Line Corridors	Steven Mills, Marcos Gerardo Castro, Zhengrong Li, Dr Jinhai Cai, Dr Ross Hayward, Dr Luis Mejias Alvarez and Prof Rodney Walker
IEEE Transactions on Geoscience and Remote Sensing, 47(3). pp. 709-721	Investigation of Fish-Eye Lenses for Small-UAV Aerial Photography	Alex Gurtner, Duncan Greer, Richard Glassock, Dr Luis Mejias Alvarez, Prof Rodney Walker, Prof Wageeh Boles

PUBLICATION NAME	TITLE OF CONTRIBUTION	CONTRIBUTING AUTHORS
IEEE Transactions on Signal Processing	A New Class of Multilinear Functions for Polynomial Phase Signal Analysis	Prof Peter O'Shea, Dr Richard Wiltshire
IEEE Transactions on Signal Processing	Relative Entropy Rate Based on Multiple Hidden Markov Model Approximation	John Lai, Dr Jason Ford
IET Computer Vision, 3(4). pp. 176-188 (Featured Paper)	Robust Video Stabilisation Algorithm Using Feature Point Selection and Delta Optical Flow	Dr Jinhai Cai, Prof Rodney Walker
Journal of Field Robotics, Vol 26, Issue 5, May 2009	Vision-Based Navigation Through Urban Canyons	Dr Stefan Hrabar and Gaurav Sukhatme
Journal of Intelligent and Robotic Systems	Automating Human Thought Processes for a UAV Forced Landing	Pillar Eng, Dr Luis Mejias Alvarez, Xi Liu, Prof Rodney Walker
Machine Vision and Applications, Springer, Published online: 1 September 2009	Towards Automatic Power Line Detection for a UAV Surveillance System Using Pulse Coupled Neural Filter and an Improved Hough Transform	Zhengrong Li, Yuee Liu, Prof Rodney Walker, Dr Ross Hayward, Dr Jinglan Zhang
Marine Structures	A Study of Vibration and Vibration Control of Ship Structures	Dr Terry Ran Lin, M J Pan, Prof Peter O'Shea, Prof Chris K Mechefske
Special Issue Journal of Computational and Applied Mathematics (JCAM), Vol 232 ISSN 0377-0427, 2009	Fast Reconstruction of Aerodynamic Shapes Using Evolutionary Algorithms and Virtual Nash Strategies in a CFD Design Environment	Prof Jacques Periaux, Dr Dong Seop Lee, Dr Felipe Gonzalez, Dr Karkenahalli Srinivas
The International Journal of Robotics Research	Wide-Angle Visual Feature Matching for Outdoor Localization	Peter Hansen, Adj/Prof Peter Corke, Prof Wageeh Boles

REFEREED CONFERENCE PAPERS

PUBLICATION NAME	TITLE OF CONTRIBUTION	CONTRIBUTING AUTHORS
13th Australian International Aerospace Congress (AIAC13), March 2009, Melbourne	Nash Game Strategies for Aerospace Design Optimisation	Dr Dong Seop Lee, Dr Felipe Gonzalez, Prof Jacques Periaux, Dr Karkenahalli Srinivas
Australasian Conference on Robotics and Automation, December 2009, Brisbane	Towards Flight Trials for an Autonomous UAV Emergency Landing Using Machine Vision	Dr Daniel Fitzgerald, Dr Luis Mejias Alvarez, Pillar Eng, Xi Liu, Prof Rodney Walker
Australasian Conference on Robotics and Automation, December 2009, Brisbane	Simulation of a Fixed-Wing UAV Forced Landing with Dynamic Path Planning	Pillar Eng, Dr Luis Mejias Alvarez, Prof Rodney Walker, Dr Daniel Fitzgerald
Design Engineering Technical Conference & Computers and Information In Engineering Conference, September 2009, San Diego	UAS Mission Path Planning System (MPPS) Using Hybrid Game Coupled to Multi-Objective Optimiser	Dr Dong Seop Lee, Prof Jacques Periaux, Dr F Gonzalez
Digital Image Computing : Techniques and Applications Conference (DICTA 2009), 1-3 December 2009, Melbourne, Victoria.	A Context-Based Approach for Detecting Suspicious Behaviours	Arnold Wiliem, Dr Vamsi Madasu, Prof Wageeh Boles, Prof Prasad Yarlagadda

PUBLICATION NAME	TITLE OF CONTRIBUTION	CONTRIBUTING AUTHORS
Digital Image Computing: Techniques and Applications Conference (DICTA 2009), 1-3 December 2009, Melbourne, Victoria.	Classification of Airborne LiDAR Intensity Data Using Statistical Analysis and Hough Transform with Application to Power Line Corridors	Yuee Liu, Zhengrong Li, Dr Ross Hayward, Prof Rodney Walker and Hang Jin
IEEE International Conference on Image Processing, 7-11 November 2009, Grand Hyatt Hotel, Cairo.	Towards Automatic Tree Crown Detection and Delineation in Spectral Feature Space Using PCNN and Morphological Reconstruction	Zhengrong Li, Dr Ross Hayward, Dr Jinglan Zhang, Yuee Liu and Prof Rodney Walker
Evolutionary Methods for Design, Optimization and Control, EUROGEN 2009, June 2009, Cracow	Coupling Hybrid-Game Strategies with Revolutionary Algorithms for Multi-Objective Design problems in Aerospace	Dr Dong Seop Lee, Dr Felipe Gonzalez, Prof Jacques Periaux, Prof E Onate
IEEE International Conference on Robotics and Automation, May 2009, Kobe Japan	High Dynamic Range Stereo Vision for Outdoor Mobile Robotics	Dr Stefan Hrabar, Dr Peter Corke, Dr Mike Bosse
IEEE International Conference on Robotics and Automation, May 2009, Kobe Japan	A new Framework for Force Feedback Teleoperation of Robotic Vehicles Based on Optical Flow	Dr Robert Mahoney, Felix Schill, Peter Corke and Yoong Siang Oh
IEEE International Conference on Robotics and Automation, May 2009, Kobe Japan	Generic Decoupled Image-Based Visual Servoing for Cameras Obeying the Unified Projection Model	Omar Tahri, Youcef Mezouar, Francois Chaumette and Peter Corke
International Conference on Computation Methods for Coupled Problems, InScience and Engineering, COUPLED PROBLEMS 2009, Ischia Island, Italy June 2009	Effective Shape Reconstruction of A BI-NACA Aerofoil Using Advanced Evolutionary Algorithms Coupled to Game Strategies	Dr Dong Seop Lee, Dr Felipe Gonzalez, Prof Jacques Periaux, Prof E Onate
13th International Symposium of Robotics Research	Outdoor Localization Using Wide-Angle Visual Feature Matching and Image Retrieval	Peter Hansen, Adjunct Prof Peter Corke, Prof Wageeh Boles
The 3rd International Conference on Imaging for Crime Detection and Prevention, 3 December 2009, London	Adaptive Unsupervised Learning of Human Actions	Arnold Wiliem, Dr Vamsi Madasuv, Prof Wageeh Boles, Prof Prasad Yarlagadda
The 2009 IEEE Aerospace Conference, 7-14 March 2009, Big Sky Montana	Computationally Adaptive Multi-Objective Trajectory Optimization for UAS with Variable Planning Deadlines	Pritesh Narayan, Assoc. Prof Duncan Andrew Campbell, Prof Rodney Walker
IEEE Aerospace Conference, 7-14 March 2009, Big Sky Montana	On-Board Multi-Objective Mission Planning for Unmanned Aerial Vehicles	Paul Wu, Assoc. Prof Duncan Campbell, Dr.-Ing. Torsten Merz
IEEE Aerospace Conference, 7-14 March 2009, Big Sky Montana	Tensor Field Guidance for Time-Based Waypoint Arrival of UAVs by 4d Trajectory Generation	Shane Degen, Dr Luis Mejias Alvarez, Dr Jason Ford, Prof Rodney Walker
The 24th International Unmanned Air Vehicle Systems Conference, 1-4 April 2009, Bristol, UK	Multimodal Hybrid Powerplant for Unmanned Aerial Systems (UAS) Robotics	Richard Glassock, Jane Hung, Dr Felipe Gonzalez, Prof Rodney Walker
The 3rd Australasian Unmanned Air Vehicles Conference, 9-12 March 2009, Melbourne,.	Mission Optimisation and Multi-Disciplinary Design of Hybrid Unmanned Aerial Systems (UAS) Using Advanced Numerical Techniques	Jane Hung, Dr Felipe Gonzalez, Prof Rodney Walker, Prof Jacques Periaux
The International Conference on High Performance Computing & Simulation, 24 June 2009, Leipzig	Improved Maritime Target Tracker Using Colour Fusion	Paul Westall, Prof Peter O'Shea, Dr Jason Ford, Dr Stefan Hrabar

NON-REFEREED CONFERENCE PAPERS

PUBLICATION NAME	TITLE OF CONTRIBUTION	CONTRIBUTING AUTHORS
44th AIAA Aerospace Sciences Meeting and Exhibit, 9-12 January, 2009, Reno Nevada,	Aerodynamic Optimisation Using a Robust Evolutionary Algorithm and Grid- Free Flowsolver	Dr Narayan Srinarayana, Dr Felipe Gonzalez, Dr Eric J Whitney, Dr Karkenahalli Srinivas, Prof Jacques Periaux
American Institute of Aeronautics and Astronautics (AIAA) Modelling and Simulation Technologies Conference, 10-13 August 2009, Hyatt Regency McCormick Place, Chicago	Evaluation of Separation Management Algorithms in Class G Airspace	Richard Baumeister (PhD), Regina Estkowski (PhD), Dr Graham Spence and Reece Clothier,
AUVSI Unmanned Systems North America 2009, 10-13 August 2009, Washington D.C.. (Unpublished)	The Smart Skies Project.	Reece Clothier and Prof Rodney Walker
Council of European Aerospace Societies 2009 European Air and Space Conference, 26-29 October 2009, Manchester Central Exchange Hall, Manchester. (Unpublished)	Test Architecture for Prototyping Automated Dynamic Airspace Control.	Richard Baumeister (PhD), Regina Estkowski (PhD), Dr Graham Spence and Reece Clothier

INDUSTRY AND COMMUNITY ENGAGEMENT

DATE AND LOCATION	TITLE	AUDIENCE	PRESENTER(S)
10-16 March, Avalon, Victoria	General Discussions about ARCAA	The Avalon Air Show Trade attendees	Prof Rodney Walker, Reece Clothier, Dennis Frousheger, Torsten Merz, Stefan Hrabar and Lennon Cork
11 March, Avalon, Victoria	Representing ARCAA	Ms Heidi Fourie, BAE Systems (BAE Systems Chalet)	Prof Rodney Walker, Reece Clothier
27-28th March, Brisbane	ARCAA CUAS on Display	Attendees to Queensland Centre for Advanced Technology Student and Public Open Day	Stefan Hrabar, Torsten Merz, Jonathan Roberts, Dennis Frousheger and Lennon Cork
20-24th April, Brisbane	Smart Skies Workshop #6	Boeing Research and Technology	Smart Skies team
25 May, Linkoping, Sweden	Invited: Thesis Opponent	PhD Candidate Gianpaolo Conte, Thesis defence	Prof Rodney Walker
26 May, Linkoping, Sweden	Invited: What we do not know about Robotic Aircraft	MOV III seminar series	Prof Rodney Walker
26 May, Brisbane	Invited: GNSS at ARCAA	IGNSS Workshop Series 2009 -GNSS for Aviation	Troy Bruggeman, Duncan Greer
4 June, Brisbane	Young Endeavour Sailing Expedition	Industry and aerospace students	Duncan Greer

DATE AND LOCATION	TITLE	AUDIENCE	PRESENTER(S)
5 June, Brisbane	Future Problem Solving Program Australia Program	60 students from school years 5 to year 11	Dr Luis Mejias
8-10 June, Ischia Island Italy	Efficient Shape Reconstruction of a Bi-NACA Aerofoil Using Advanced Evolutionary Algorithms Coupled to Game Strategies	Computational Methods for Coupled problems in Science and Engineering	Dr Felipe Gonzalez
11 June, Fisherman's Bend, Melbourne	Invited Presentation – ARCAA Overview	DSTO Seminar Series	Prof Rodney Walker, Reece Clothier
15-17 June, Cambridge, Massachusetts	New Global University Initiatives in Engineering Systems:- Queensland University of Technology School of Engineering Systems	Engineering Systems Symposium, MIT	Assoc Prof Duncan Campbell
15 June, Brisbane	The Smart Skies Project	Greg Dunstone and Bob Peake, Airservices Australia	Prof Rodney Walker, Reece Clothier and Michael Wilson (BRT&A)
3 July, Bundaberg, QLD	Invited: Overview of ARCAA and QUT Avionics Course	Aerospace Industry Leaders Council Meeting	Prof Rodney Walker
6 July, Kilcoy, QLD	Invited: Participation in the Insitu Pacific Flight Demonstration Day	Insitu Pacific User Community	Prof Rodney Walker, Reece Clothier
8th July, Brisbane	Overview of ARCAA	100 high school students at the Australian Youth Aerospace Forum	Dr Felipe Gonzalez
14 July, Kingaroy, QLD	Discussions about UAV Airspace	Kingaroy Regional Council	Prof Rodney Walker, Mr Chris Hess (Qld Govt), Ms Liesl Larson (Qld Govt)
28 July, Brisbane	Interview on UAVs for the Meat and Livestock Industry	Meat and Livestock Australia Consultant	Prof Rodney Walker
3-7th August, Denver, USA	Smart Skies Workshop #7	Boeing Research and Technology, Jeppeson	Smart Skies team
10 August, Washington DC	Invited: AUVSI Board of Directors Dinner	2009 AUVSI Board of Directors	Prof Rodney Walker, Reece Clothier
27 August, Adelaide	Detection of Marine Mammals from Aerial Imagery	University of South Australia Suthep Gururatsakul (PhD Candidate), Assoc Prof David Kearney	Prof Rodney Walker, Dr Luis Meijas
8 September, Brisbane	ARCAA PhD Information Evening	Students interested in PhD	Prof Rodney Walker, Dr Luis Meijas, Dr Jason Ford, Dr Felipe Gonzalez, Assoc Prof Duncan Campbell, Reece Clothier, Rhys Mudford and Paul Wu
9 September, Brisbane	Representing ARCAA at the QUT Faculty of BEE Dean's Scholars Dinner	Aerospace industry staff and Dean's scholars	Prof Rodney Walker

DATE AND LOCATION	TITLE	AUDIENCE	PRESENTER(S)
10 September, Brisbane	Representing ARCAA at the Celebration of the 10 year relationship	QUT and Brisbane Airport Corporation Staff	Prof Rodney Walker
11 September, Brisbane	Representing ARCAA for a media event associated with Aviation High School's participation in the UAV Challenge	Qld Treasurer, The Hon Andrew Fraser, media and students of Aviation High	Prof Rodney Walker, Dennis Frousheger, Brett Wood
15 September, Madrid	Path Planning a Guidance for a Fixed Wing UAV forced Landing	Universidad Politecnica de Madrid, Computer Vision Group	Pillar Eng
15-16 September, Brisbane	ARCAA ASL Capability Demonstration Flights	Dr Daniel Fitzgerald, Cyber Technology	Duncan Greer
16 September, Brisbane	The Smart Skies Project	Mr Steve Sliwa (CEO Insitu USA), BRT&A and Insitu Pacific Staff	Prof Rodney Walker, Reece Clothier
23 September, Brisbane	Overview of CRCSI ARCAA Powerline Following Flight Management System	Terranean Staff	Prof Rodney Walker, Dr Troy Bruggeman, Marcos Gerardo-Castro, Ryan Fechney
1 October, Gatton, QLD	Experimental Flight to Capture Overhead Colour Images of Wheat Crops for Plant Phenomics Research	High Resolution Plant Phenomics Centre	Dr.-Ing. Torsten Merz, Lennon Cork
12 October, Brisbane	The Smart Skies Project	Senior DSTO staff, BRT&A	Prof Rodney Walker, Brendan Williams (BRT&A)
13 October, Gatton, QLD	Experimental Flight to Capture Overhead Colour Images of Wheat Crops for Plant Phenomics Research	High Resolution Plant Phenomics Centre	Dr.-Ing. Torsten Merz, Lennon Cork
15 October, Sydney	Overview of progress of the sub-committee on UAS Certification and Regulation	Australian Aerospace Industry Forum	Prof Rodney Walker
17 October, Coolum, QLD	Collaborative workshop and Static Display – ARCAA and Office of Advanced Manufacturing, Queensland Dept of Employment, Economic Development & Innovation	Coolum Jet Air Show	Richard Glassock & Rhys Mudford
20-21 October, Montreal, Canada	Representing ARCAA	Global ATM Forum on Civil/ Military Cooperation organized by ICAO	Prof Rodney Walker
22-23 October, Seattle, USA	Beyond Smart Skies Workshop	Senior Boeing Staff	Prof Rodney Walker, Dr Jon Roberts, Mr David Gray
26 October, Bingen, USA	Beyond Smart Skies Workshop	Mr Steven Sliwa (Insitu CEO) and other Senior Insitu Staff	Prof Rodney Walker, Dr Jon Roberts, Mr David Gray

DATE AND LOCATION	TITLE	AUDIENCE	PRESENTER(S)
29 October, Yichang, China	Dependable Field Robotics – Applications for Computer Vision and 3D Laser Scanning	Multi Spectral Image Processing and Pattern Recognition SPIE Symposium	Dr Jonathan Roberts
2 November, Brisbane	Representing ARCAA	Buddy Doyle, Stratus Aeronautics and Universal Wing	Dennis Frousheger, Dr.-Ing. Torsten Merz, Reece Clothier
16 November, Brisbane	Meeting about 2012 ICAS Conference in Brisbane. Invited to join organising committee.	Assoc Prof Cees Bil, RMIT	Prof Rodney Walker
23-24 November, Hobart	Design Optimization using Advanced Artificial Intelligent System Coupled to Hybrid-Game Strategies	The 3rd International Workshop on Artificial Intelligence in Science and Technology (AISAT)	Dr Felipe Gonzalez
30 November, Brisbane	Visitor Presentation: " On the Time-To-Fix for Single-Frequency GNSS-Based Attitude Determination"	Dr Jason Ford, Dr Luis Meijas, Dr Troy Bruggeman, Duncan Greer	Dr Lennard Huisman and Gabriele Giorgi, Curtin University of Technology
Nov 2009 – Feb 2010, Melbourne	The Green Falcon Solar Powered UAV	Public attending the Melbourne Museum	Display arranged by Dr Felipe Gonzalez and Wesam Alsabban
2-4 December, Sydney	Optimal Mission Path Planning (MPP) for an Air Sampling Unmanned Aerial System	Australasian Conference on Robotics & Automation	Dr Felipe Gonzalez
3 December, Melbourne	Representing ARCAA	Greg Tyrrell. Chief Operating Officer at Aerosonde	Prof Rodney Walker
4 December, Hervey Bay, QLD	Representing ARCAA	Seabird Aviation	Prof Rodney Walker, Duncan Greer, Ryan Fechney
15 December, Brisbane	Overview of Aircraft Detection using Computer Vision	Tim Hughes, Team Leader, Software Solutions and Services, Airways New Zealand	Prof Rodney Walker, Dr Luis Meijas
29 December, Madrid	Path Planning for Target Tracking Using an Autonomous Helicopter	Universidad Politecnica de Madrid, Computer Vision Group	Pillar Eng

MEDIA RELEASES

* "New technology Enhances Air Travel Safety", 11 March 2009
* "Pilotless Plane Controlled by 3G Network", 16 June 2009

MEDIA ARTICLES

* Science Centric, 13 February 2009 - CSIRO Robotics Research Rated 'Coolest' Summer Job
* TMC News, March 13, 2009 - CSIRO-Boeing Partnership Celebrates 20 years; CSIRO and The Boeing Company today celebrate the 20th anniversary of their research partnership.
* Flight International, Emma Kelly, 20 March 2009, "Australian Tests Aim to Integrate UAVs Into Busy Airspace"
* ABC News, Jonathan Hall, 17 June 2009, "Qld Researchers Use Mobile Phone to Fly Pilotless Plane"
* QUT Communications Day, 18 June 2009. "QUT Flies Unmanned Plane with Telstra Next G"
* Courier Mail, 12 July 2009 – "Unmanned Aircraft to be Tested at Kingaroy"
* CASA Briefing Newsletter, August 2009 – "UAV Outback Challenge 2009"
* Boeing Velocity Magazine, September 2009 – "Student travel, Boeing style"
* US National Defence Magazine – October 2009 – "Technologies to Help Aircraft Avoid Mid-Air Collisions"
* National Defense Magazine (USA), Grace Jean, October 2009 "Collision Course"
* Australian Defence Magazine, Katherine Ziesing, October 2009 – "Swarming with Opportunities"
* Australian Defence Magazine, Vol. 17(11), November, 2009 "UAVs to the Rescue"
* ABC Local Radio 612 – 2 December 2009 – "Unmanned Aircraft for Police Chases"
* Redcliffe Aero Club Magazine "Air Chat"
* ARCAA Sod Turning April 2009
* Flight Safety Magazine, Margo Marchbank, May-June 2009 "UAS the Story Continues"
* Australian Aviation, November 20, 2009 "Solar Powered UAV to Assist in Fire Tracking"

ARCAA RESEARCH OUTCOMES INTO CURRICULUM CONTENT

Characterisation of Common Information Networks (3G, Iridium) for Aircraft telemetry and control

QUT, BEE, Engineering Systems, EN 40 Aerospace Avionics

Taught at 4th year level, BEB801 Project

Number Impacted: 20

Characterisation of Common Information Networks(3G, Iridium) for Aircraft telemetry and control

QUT, BEE, Engineering Systems, EN 40 Aerospace Avionics

Taught at 3rd year level, ENB355

Number Impacted: 24

Advanced UAV Control and Path Planning

QUT, BEE, Engineering Systems, EN 40 Aerospace Avionics

Taught at 3rd year level, ENB347

Number Impacted: 24

Tutorial on Demonstrating the Principles of Vision-Based Collision Warning Detection System, Jason Ford, Luis Meijas and John Lai – Funded by Boeing Support for Teaching

QUT, BEE, Engineering Systems, EN 40 Aerospace Avionics

Taught at 4th year level, ENB447

Number Impacted: 24

AWARDED BY	SCHEME/PROJECT	NAME
RESEARCH GRANT FUNDING - ONGOING		
Department of Employment, Economic Development & Innovation	Qld Smart Futures Fund – National and International Research Alliances Program (NIRAP) / Smart Skies Project	Prof Rodney Walker, Dr Jonathan Roberts
Boeing	Commercial Research / Smart Skies Project	Prof Rodney Walker, Dr Jonathan Roberts
Cooperative Research Centre for Spatial Information	CRC Project / Information Business Improvement Applications at ERGON Energy Project	Prof Rodney Walker
Defence Science Technology Organisation (DSTO)	Commercial Research / UAS Risk Hazard Assessment Tool Project	Prof Rodney Walker
Cooperative Research Centre for National Plant Bio-Security	CRC Project / CRC30032: Flying Spore Traps	Prof Rodney Walker, Dr Felipe Gonzalez
Queensland University of Technology	BEE External Relations Initiatives Grant / Search and Rescue UAV	Dr Felipe Gonzalez
University of Queensland, Centre of Marine Studies	Commercial Research / Marine Mammal Tracking from UAVs	Dr Luis Meijas Alvarez, Prof Rodney Walker
Department of Innovation, Industry, Science and Research (Commonwealth)	Marie Curie Actions -International Research Staff Exchange Scheme (IRSES) - Australian Academy of Science/ International Cooperation Program, for Unmanned Aerial Systems (UAS) Research and Development (ICPUAS)	Dr Luis Meijas Alvarez
Queensland University of Technology	BEE Research – Smart Systems Theme – ECR Grant / Student Support	Dr Jason Ford
Queensland University of Technology	BEE External Relations Initiatives Grant / Autopilot	Dr Felipe Gonzalez
Queensland University of Technology	BEE External Relations Initiatives Grant / UAS Australia Project	Reece Clothier,
RESEARCH GRANT FUNDING – GRANTS AWARDED IN 2009 AND COMMENCING IN 2010		
Australian Research Council (ARC)	ARC Linkage – Projects	Dr Jason Ford, Dr Luis Meijas Alvarez, Prof Peter O'Shea and Prof Rodney Walker

NEW STUDENTS

Onvaree Techakesari PhD (16/2/2009-15/2/2012)

Multiple-Model Based Target Tracking and Separation Management

Recipient of a Smart Skies Top-up.

This research investigates the use of advanced decision technology in two related air traffic management (ATM) problems: air traffic estimation and automated air traffic control in uncertain environments. This project investigates the optimisation of multi-model filters the suitable ways to combine centralised and decentralised algorithms.

Supervisors Dr Jason Ford, Dr Luis Mejias Alvarez

Aaron McFadyen PhD (20/9/09 – 31/8/13)

An Investigation into Robust Decision making for UAS Threat Detection in the Context of Sense & Avoid

The research aims to investigate the extent to which automated robust decision making for a passive 'See and Avoid' system can be performed. We are interested in exploring how difficult it is to determine collision risk and threat evaluation in such a complex dynamic environment with limited and uncertain input parameters. Pending investigation, the research hopes to contribute to increasing the autonomy of passive, uncooperative 'See and Avoid' systems in order for UAS to gain more regular unrestricted access to the national airspace.

Supervisors Dr Luis Mejias Alvarez, Professor Rodney Walker

Wesam Alsabban PhD (1/11/2009 – 31/10/2012)

Autonomous Solar Powered UAV-Aircraft and Optimal Path Planning Model and Algorithms

This research deals with unmanned aircraft systems UAS using solar energy to power the aircraft and sustain flight for long endurance. The ability for an aircraft to fly during a much extended period of time has become a key issue and a target of research, both in the domain of civilian aviation and unmanned aerial vehicles. The main challenge is to design UAVs to undertake special missions safely and efficiently using flexible programs to support the research results.

Supervisors Dr Felipe Gonzalez

CONTINUING STUDENTS

Lennon Cork PhD (16/2/2004 – 18/12/2009)

An Aircraft Dynamic Navigation Filter for Fault Tolerance in Unmanned Aircraft Systems

This research investigates the application of a complex Aircraft Dynamic Model (ADM) to aid in the navigation of an Unmanned Aircraft System (UAS). The ADM is introduced into the process and observation equations of an Unscented Kalman Filter (UKF) for an navigation system with GPS, inertial and Air Data sensors. Interacting Multiple Models (IMM) are introduced to improve the systems resistance to inertial sensor faults.

Supervisors Professor Rodney Walker, Associate Professor Duncan Campbell

Jane Hung PhD (1/3/2004 – 1/3/2010)

Energy Management and Flight Plan Optimisation Onboard an Unmanned Aerial Vehicle with Hybrid Propulsion System

Hybrid propulsion systems are used onboard UAVs to reduce the onboard fuel consumption during flight. This objective, along with others such as mission efficiency (time, distance), payload efficiency, airspace rules and weather, needs to be taken into consideration when planning a flight mission for such an UAV. This research is modelling hybrid powerplant onboard a UAV in the MATLAB® Simulink® environment and will also include multi-objective mission planning for UAVs. The two research sections will be combined and can be applied to the current ARCAA research in hybrid-powered UAV in civilian applications.

Supervisors Dr Felipe Gonzalez

Reece Clothier PhD (14/2/2005 – 4/12/2010)

Decision Support for Safety Analysis of Engineering Systems

One of the greatest challenges facing new aviation technologies is the development of safety regulations. The objective of this research is to develop the safety assessment and decision making tools necessary to support the definition of effective safety regulations. Outputs of this research are being used to support the development of civil regulations for UAS in Australia and as an input to the development of a risk assessment tool for the Defence Science and Technology Organisation.

Supervisors Professor Rodney Walker, Dr Neale Fulton

Duncan Greer PhD (29/3/2005 – 14/1/2011)

Integrity Augmentation of Aviation GPS Navigation Receiver using Low Cost Inertial Sensor Devices for General Aviation Aircraft Operations

This research is investigating means of augmenting aviation GPS with low-cost inertial devices in order to provide high integrity

navigation for general aviation operations. The outcome of this research is improved safety and efficiency of aircraft operations in all weather conditions.

Supervisors Professor Rodney Walker

Damien Dusha PhD (29/3/2005 – 14/1/2011)

Integrity Augmentation of Aviation GPS Navigation Receiver using LowCost Inertial Sensor Devices for General Aviation Aircraft Operations

This research is investigating means of augmenting aviation GPS with low-cost inertial devices in order to provide high integrity navigation for general aviation operations. The outcome of this research is improved safety and efficiency of aircraft operations in all weather conditions.

Supervisors Professor Rodney Walker

Paul Westall PhD (20/2/2006 – 1/5/2010)

Human Detection in a Maritime Search Environment using Machine Vision for UAVs

Human maritime search and rescue missions have always been a challenging task, and an element of chance is involved in the detection of survivors. Humans become fatigued and complacent after long hours of searching, thus we aim to automate this search process using machine vision. Using image processing and target tracking techniques we propose a possible system that can discriminate human survivors in open oceans. Given this search automation capability, UAVs could be used in a swarming search pattern to maximise the area covered and consequently increase the probability of survival of victims of maritime mishaps.

Supervisors Professor Peter O'Shea, Dr Stefan Hrabar, Dr Jason Ford

Pritesh Narayan PhD (20/2/2006 – 16/9/2010)

Embedding Human Cognition within Autonomous UAS Trajectory Planning

This research project is focused on the inclusion of human expert decision data within the trajectory optimisation process. It is expected that the generation of feasible trajectories which mimic aspects of the HDM's typical flight patterns, allowing for greater confidence in the onboard ADS.

Supervisors Associate Professor Duncan Campbell

John Lai PhD (24/3/2006 – 22/6/2010)

A Hidden Markov Model and Relative Entropy Rate Approach to Vision-based Dim Target Detection for UAV Sense-and-Avoid

Recipient of a Vice Chancellor Scholarship Top-up.

The research aims to develop a vision-based target detection capability that can be used by 'pilotless' aircraft to automatically identify potential collision-course threats. The candidate detection approaches under investigation have the potential to play a key role in ensuring the safe operation of unpiloted aircraft, which many consider to be the next great step forward in the evolution of aviation. Novel hidden Markov model filtering techniques and relative entropy rate concepts are exploited in the development of the target detection algorithm.

Supervisors Professor Peter O'Shea, Dr Michael Bosse, Dr Jason Ford

Pillar Eng PhD (5/3/2007 – 4/4/2011)

Trajectory Generation for a Fixed-Wing UAV Forced Landing using Motion Primitives

Recipient of a Vice Chancellor Scholarship Top-up.

This research will enable fixed-wing UAVs to autonomously plan a route and navigate along that route to a position for safe landing during an emergency caused by engine failure. The outcomes of my research will be software that can be integrated into an advanced UAV flight system to provide "Sense-and-Act" capabilities that emulate those of human pilots. This is one of the key technological research areas in the Smart Skies project.

Supervisors Dr Luis Mejias Alvarez, Professor Rodney Walker, Dr Adrian Bonchis

Steven Mills PhD (5/3/2007 – 4/3/2011)

Visual guidance for Fixed Wing Unmanned Aerial Vehicles using Feature Tracking: Application to Power Line Inspection

Recipient of a Vice Chancellor Scholarship Top-up.

This research looks at using Skid-to-Turn manoeuvres coupled with Image Based Visual Servo control for the guidance and control of fixed wing UAVs inspecting locally linear infrastructure. Conventional tracking controllers utilizing Bank-to-Turn generally overlook the impact these manoeuvres have on body fixed downward facing sensors that are effectively angled away while the aircraft turns toward them. Skid to Turn however allows heading to be corrected while maintaining wings level flight, thus making it easier to see the target. Image Based Servo Control is then used to control the position of features directly from within the image plane, thus providing an optimal view of the target being inspected.

Supervisors Dr Luis Mejias Alvarez, Dr Jason Ford

Xi Liu PhD (5/3/2007 – 1/6/2011)

Real Time Multi-Criteria Decision Making to Rank and Select Landing Sites for UAV Forced Landing

This research aims to achieve autonomous decision making for forced landing site selection, which involves extracting expert knowledge on decision preferences and priorities, mathematically modelling the decision process, and optimising to account for

differences in the unmanned aircraft compared to manned aircraft. This process must be done in a computationally efficient manner in real time as the entire system will be implemented onboard a small UAV. Automation of the forced landing process can help increase the safety and reliability of these aircraft in operation, taking steps toward demonstrating equivalent level of safety compared to manned aircraft.

Supervisors Associate Professor Duncan Campbell, Dr Luis Meijas Alvarez

Richard Glassock Masters (23/3/2007 – 1/8/2009)

Design and Modelling of Aircraft Hybrid Powerplant

This research presents a technique for determining the performance, feasibility and effectiveness of powerplant organizers on for small UAS. A Hybrid Powerplant offers the possibility of a radical improvement in the autonomy of the aircraft for various tasks without sacrificing payload range or endurance capability.

Supervisors Dr Felipe Gonzalez

Shane Degen PhD (7/1/2008 – 6/1/2012)

Reactive Vision-Based Collision Avoidance for a UAS

Recipient of a Vice Chancellor Scholarship Top-up.

This research looks at using vision-based sensor data to navigate through (avoid) a collision scenario with other dynamic targets. It uses a reactive routine so as to avoid the intruder based on characteristics observed of an intruder's behaviour in an image. The entire UAV and collision sensor are modelled in a simulator and it is shown that collisions can be avoided without knowing the exact position of the intruder.

Supervisors Dr Luis Mejias Alvarez, Dr Jason Ford

Sean Fan PhD (31/01/2008-30/1/2011)

Robust Traffic Separation Management Using Inter-Aircraft Communication

Recipient of a Vice Chancellor Scholarship Top-up.

This research is to investigate novel separation management approaches that mitigation communication issues raised by the next generation air traffic management approach.

Supervisors Dr Jason Ford, Dr Felipe Gonzalez

Zhengrong (Eric) Li PhD (28/4/2008 – 27/4/2011)

Computational Intelligence Applied to Remote Sensing Image Analysis for Vegetation Management in Power Line Corridors

This PhD research sits within the CRCSI project 6.07: Spatial Information Business Improvement Applications at Ergon Energy and aims to evaluate the use of aerial remote sensing techniques for vegetation management in power line corridors as well as automatic feature extraction from aerial remote sensing imagery. It will investigate computation intelligence techniques for improved object segmentation and feature extraction which may apply to remote sensing image analysis in this specific application.

Supervisors Dr Ross Hayward

GRADUATED STUDENTS

Paul Wu PhD

Multi-Objective Mission Flight Planning in Civil Unmanned Aerial Systems

This thesis develops a framework for automatic aircraft navigation that replicates the multi-criteria decision making capabilities of a human pilot. The proposed system finds a flight path that organiser for flight safety objectives, mission efficiency objectives and the rules of the air. This algorithm is demonstrated to find paths of equivalent cost to a high resolution benchmark algorithm but uses a third of the computation time. As a result, the framework is suitable for in-flight re-planning in response to dynamic changes in a complex aviation environment. By providing such a mission flight planning capability onboard the aircraft, it is possible to address the requirements for operating unmanned aircraft in the national airspace system.

Career Path and progress since graduating

Paul submitted his thesis in May 2009 and undertook a research role as project officer on the DSTO UAS Risk Assessment Tool Project (supervised by Reece Clothier) at ARCAA from 1 June to 12 Feb 2010. Paul graduated with a PhD in December 2009.

Troy Bruggemann PhD

Investigation of MEMS Inertial Sensors and Aircraft Dynamic Models in Global Positioning System Integrity Monitoring for Approaches with Vertical Guidance

The research made a significant contribution towards one of the challenging issues facing general aviation navigation today, which is how to improve the reliability of GPS-based vertically-guided landings. New aircraft-based augmentation approaches were proposed which fuse GPS with inertial sensors and dynamic models, and exploit this added information through special fusion techniques. Extensive studies of key navigation integrity parameters found that significant improvements could be attained with these methods, which unlike satellite or ground-based augmentation systems, have the advantage of being self-contained onboard the aircraft. Such techniques could lead to improved safety and cost savings for the general aviation sector particularly due to less risk of controlled flight into terrain occurring during a GPS vertically-guided approach. This thesis was an outcome of an ARC linkage with industry grant (industry partners Airservices Australia, and GPSat Systems Australia Ptd Ltd.

Career Path and progress since graduating

During 2009 Troy conducted research at ARCAA in the area of aircraft control for powerline inspection (CRCSI 6.07 Ergon Energy Project).

Alex Gurtner Masters

Investigation of Fisheye Lenses for Small UAV Aerial Photography

Career Path and progress since graduating

After completing his Masters, Alex returned to his native Switzerland and took a job with Verteidigung-Luftwaffe in Payerne.

VISITING STUDENTS

(September 2009 - March 2010)

Francesco Tamagnone Cosmeli

Politecnico di Torina Italy, Masters Aerospace Engineering

Contribution to ARCAA research My current research at ARCAA concerns the design of an air sampling system based on a UAV platform. Different system architectures were explored in order to obtain a versatile system usable for several applications (pollution and gas monitoring, agricultural monitoring, dust monitoring). Design of several air sampling missions was performed, by means of Horizon (ground control station software).

Principal Supervisor Dr Felipe Gonzalez

Niki Regina

Universita Di Bologna Italy, PhD

Contribution to ARCAA research The study of guidance laws is important for developing autonomous flight of UAVs. My work is focussed on the development of trajectory tracking, path following and collision avoidance.

Principal Supervisor Dr Jason Ford

Jennifer Go

Delft University, Master Aerospace Engineering

Contribution to ARCAA research UAV power busses are particularly noisy given the nature of actuators (servos), vibrations and other sensors in the aircraft. This work investigated filtering and signal conditioning strategies for UAV power systems.

Principal Supervisor Dr Luis Mejias Alvarez

VACATION STUDENTS

(November 2009 - February 2010)

Timothy Molloy

QUT B.Eng (Aerospace Avionics), Under-graduate

Contribution to ARCAA research Demonstrated the development and simulation of a 6-degree of freedom non-linear dynamic model for the Shadow UAV with accompanying guidance, control and simulation.

Principal Supervisor Dr Felipe Gonzalez

Melvin Leong Yue Yao

QUT B.Eng (Aerospace Avionics), Under-graduate

Contribution to ARCAA research This research addresses a Light Detection and Ranging (LiDAR) augmented optimal path planning at low level flight methodology for remote sensing and sampling UAVs, using LiDAR maps to avoid obstacles when planning a path from a start to a target point.

Principal Supervisor Dr Felipe Gonzalez

Armin Mehmedagic

QUT B.Eng (Aerospace Avionics), Under-graduate

Contribution to ARCAA research This research developed a ground-based wireless sensor network and data collection system for use in UAV applications.

Principal Supervisor Dr Felipe Gonzalez

Jonathan Kok

QUT B.Eng (Aerospace Avionics), Under-graduate

Contribution to ARCAA research In relation to UAV path planning, this research project demonstrates that, with the recent FPGA boards, it is possible to overcome the Evolution Algorithms' (EA) computational disadvantage by considerably improving the processing time. This permits an EA-based real-time path planner for UAVs.

Principal Supervisor Dr Felipe Gonzalez

Saad Khan

QUT B.Eng (Aerospace Avionics), Under-graduate

Contribution to ARCAA research Development of a non-linear dynamic model and simulation of ARCAA's unmanned helicopter to assist the testing of the helicopter flight control system. The simulator developed took the control outputs from the flight control system and generated simulated IMU, GPS and other sensor data.

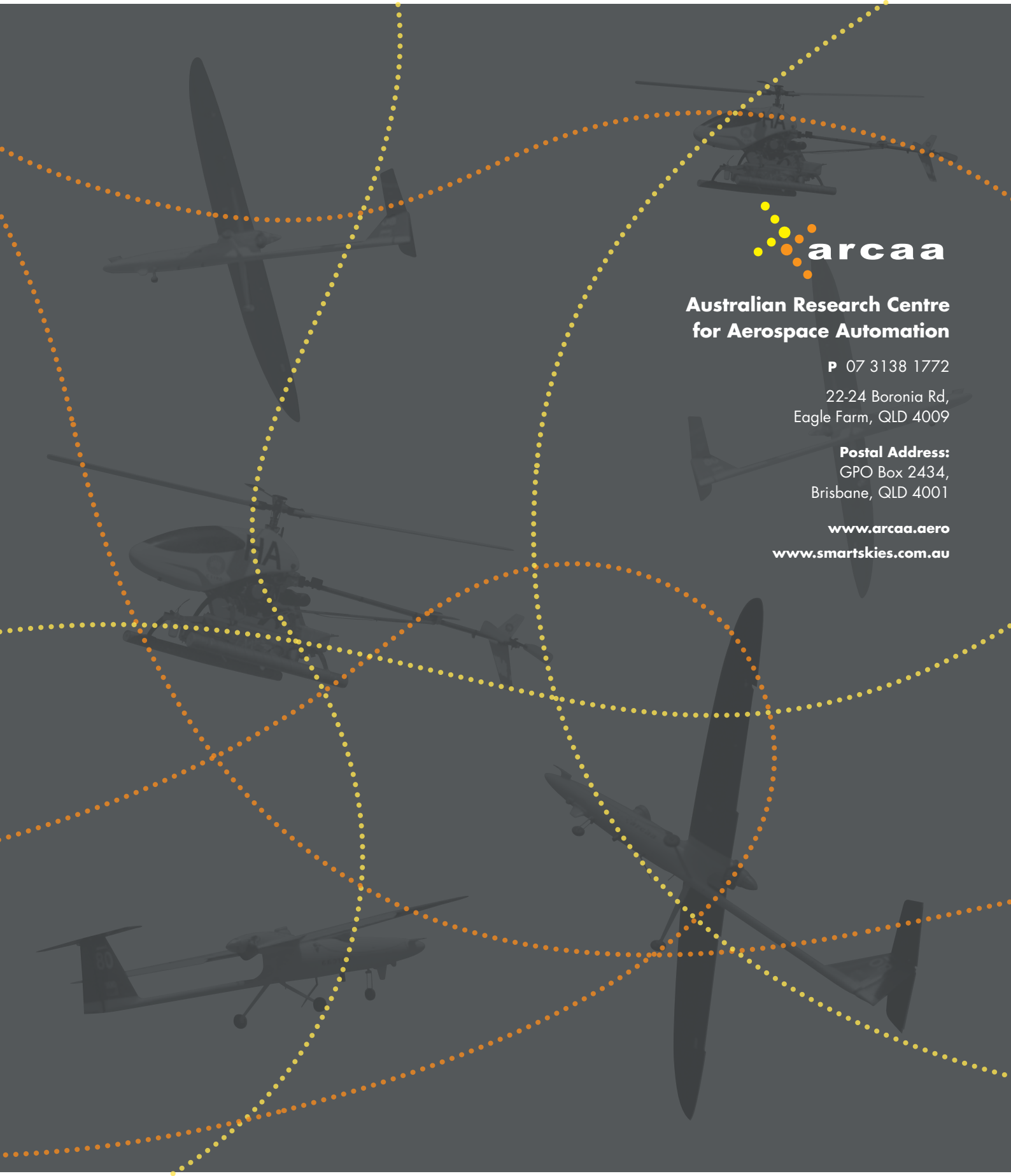
Principal Supervisor Dr. Torsten Merz

Daniel Wang

QUT B.Eng (Aerospace Avionics), Under-graduate

Contribution to ARCAA research Initial development of an automatic tracking video recording system for UAV Flight Tests. This vacation recording system provides a means of continuously recording UAV test flights without operator input to provide a data source for post flight analysis

Principal Supervisor Dr Stefan Hrabar



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