THE SMART SKIES PROJECT: ENABLING TECHNOLOGIES FOR FUTURE AIRSPACE ENVIRONMENTS

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Abstract

This paper summarises the achievements of the Smart Skies Project, a three-year, multi-award winning international project that researched, developed and extensively flight tested four enabling aviation technologies: an electro-optical mid-air collision avoidance system, a static obstacle avoidance system, a mobile ground-based air traffic surveillance system, and a global automated airspace separation management system.

The project included the development of manned and unmanned flight test aircraft, which were used to characterise the performance of the prototype systems for a range of realistic scenarios under a variety of environmental conditions. In addition to the collection of invaluable flight data, the project achieved world-firsts in the demonstration of future automated collision avoidance and separation management concepts. This paper summarises these outcomes, the overall objectives of the project, the research and the development of the prototype systems, the engineering of the flight test systems, and the results obtained from flight-testing.

1 Introduction

The integration of Unmanned Aircraft Systems (UAS) into the existing airspace system must be carefully managed to ensure the overall safety and efficiency of the airspace system is not degraded. More specifically, before UAS can be routinely operated within non-segregated airspace, it must be shown that:

1. UAS operations, at a minimum, exhibit an equivalent level of safety to that of Conventionally-Piloted Aviation (CPA) operations [1-4];
2. UAS can operate seamlessly within the airspace system [2, 3]; and
3. UAS can be operated without "adversely affecting the existing users" [4] of the airspace system (*e.g.*, impeding access to airspace).

The objective of the Smart Skies Project was to explore a number of enabling technologies that could support the safe and efficient operation of UAS within the civilian airspace system.

The Smart Skies Project was a three-year, ~AUD$9.7M research and flight test program which commenced in March 2008 [5]. Smart Skies was jointly undertaken by Boeing Research & Technology (BR&T), Boeing Research & Technology – Australia (BR&T-A) and the Australian Research Centre for Aerospace Automation (ARCAA), which is a joint-research venture between Queensland University of Technology (QUT) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) ICT Centre. The project was supported, in part, by the Queensland Government Smart State Fund and Insitu Pacific Ltd.

1.1 Project Aims and Objectives

The vision of the Smart Skies Project was the safe, efficient and routine operation of UAS in non-segregated airspace. The primary aim was to develop and demonstrate future technologies supporting the safe and efficient use of airspace by both manned and unmanned aircraft. To achieve this aim, the Smart Skies team undertook to research and develop four enabling technologies (Fig.1):

1. An automated Electro-Optical (EO) mid-air collision avoidance system that provides UAS with a "detect and avoid"[1] capability (§2);
2. An automated obstacle avoidance system that supports the safe operation of unmanned rotorcraft at low-altitudes and in unknown environments (§3);
3. A mobile ground-based air traffic surveillance system capable of providing UAS operators with information about the local air traffic environment (§4);
4. A global Automated Separation Management System (ASMS) capable of managing complex air traffic scenarios involving manned and unmanned aircraft (§5);

The final objective of the project was to demonstrate and evaluate the prototype technologies under real world conditions. The flight test capability that was developed to achieve this objective is described in §6.

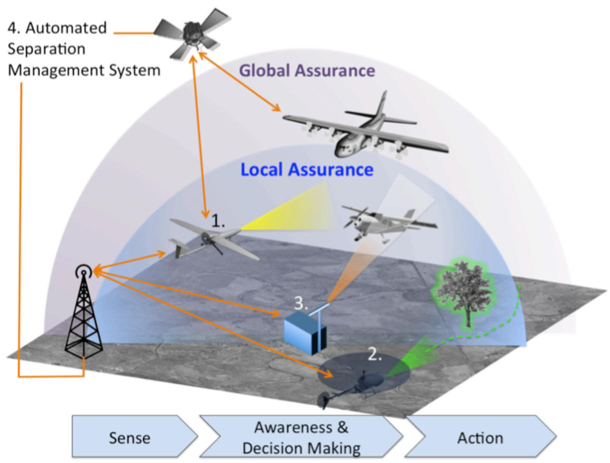

Fig. 1. Overview of Smart Skies technologies for separation management and collision avoidance

2 DETECT AND AVOID SYSTEM

The routine and seamless operation of UAS alongside other airspace users is likely to require technologies that replicate the "see-and-avoid"[6] function provided by a pilot. ICAO defines the equivalent UAS function (Detect and Avoid) as the "capability to see, sense or detect conflicting traffic or other hazards and take the appropriate action to comply with the applicable rules of flight."[1]

Smart Skies has completed preliminary investigation and flight-testing of a forward-looking EO Detect and Avoid System (DAS) capable of autonomously avoiding mid-air collisions with other aircraft whilst under Visual Meteorological Conditions (VMC).

2.1 High Level Requirements

There are a number of existing programs exploring the development of a DAS for UAS. Of the existing aircraft-based non-cooperative approaches, most have made use of high-end radar, EO, Infrared (IR) or acoustic sensors. Discussion on these and other approaches is provided in [7].

The Smart Skies Project undertook to research and develop a DAS solution particularly suited to small fixed-wing UAS. Such a solution would need to be cognisant of the size, weight, power and cost constraints typically associated with small UAS platforms. A desirable requirement was for the DAS to make use of existing cost-effective sensing and processing capabilities already on-board a typical small UAS. The initial scope was limited to day VMC and forward encounter scenarios.

2.2 The Prototype DAS

A description of the DAS is provided in [8, 9]. At a high-level, the DAS comprises the following four components: 1) Image Capture (the EO Sensor); 2) Image Stabilisation; 3) Target Detection and Tracking; and 4) Target Dynamics and Avoidance Control.

A spiral research and development program was adopted for the DAS. Over the three years of the project each of the components underwent a number of phased refinements. Angular resolution and Field Of View (FOV) were explored across a range of EO sensors and lenses. The simple image stabilisation techniques used in the early stages of the Smart Skies Project were evolved into sophisticated image-based motion and jitter compensation algorithms (see [8]) and mechanical compensation mitigation techniques (*e.g.*, the development of an aerodynamic sensor faring [Fig. 2] and anti-vibration mountings). The detection and tracking approach involved two stages: a morphological pre-processing and a temporal tracking stage. The temporal tracking component explored Viterbi and Hidden Markov Model based approaches (see [10]). Two bearing-only avoidance control laws were developed and tested. The first used a simple proportional avoidance command and the second employed an exponential control law based on the location of the target in the image plane (see [8, 11]). Each component of the DAS was refined using results obtained from the offline processing of pre-recorded flight data and from real-time testing on-board a flight test aircraft, discussed in the next section.

2.3 Flight Testing

A substantial flight test and data collection program supported the development of the DAS. This program commenced with a data collection campaign involving a Cessna 172 aircraft flying in the vicinity of a static sensor situated on top of a hill. For the second phase of data collection, the DAS was implemented on-board a small fixed wing unmanned aircraft (§6.2), which was flown in a series of head-on encounters with another small fixed wing UAS. The data collected and the results achieved from the off-line processing of the data is described in [10, 12]. Finally, data collection and real-time closed-loop flight-testing was completed using the ARCAA Airborne Systems Laboratory (ASL) flight test aircraft (§6.1). These campaigns involved a range of head on and tail closure encounter scenarios with another Cessna 172 or 182 test aircraft. A summary of the implementation and testing across the different platforms is provided in [8].

In total, data for approximately 50 different encounter scenarios was collected. These scenarios included: head on and tail closure encounters; scenarios involving small fixed-wing UAS, and General Aviation (GA) aircraft. The data collected was across a range of visual conditions including cloudy (high background clutter), smoke-haze and clear sunny days. The datasets include successful real time closed-loop tests where the DAS autonomously detected and avoided another GA aircraft. In addition to encounter scenario data, more than 20 hours of data were also collected to characterise the False Alarm Rate (FAR) performance of the DAS.

The resulting database provides an extremely valuable tool for the ongoing research and development of the DAS.

Fig. 2. Detect-and-Avoid EO sensor fitted to the wing strut of the ARCAA Airborne Systems Laboratory

2.4 Results and Research Direction

Detection performance is a complex function of the: FOV, visual conditions, characteristics of the aircraft encountered and sensor vibration. Due to the wide range of test parameters explored, it is difficult to provide a single statement of performance. However, typical results for the UAS on UAS flight testing saw detection times ranging from 8 to 10 seconds before the CPA [10].

The results from the Cessna on Cessna flight test scenarios have supported follow on research conducted as part of an Australian Research Council Linkage Project (project number LP100100302). Some of the results from the Linkage Project are published in [9, 13, 14]. From [14], using a medium FOV lens (10mm) under clear sky conditions and for encounters with a GA aircraft, the DAS typically demonstrated continuous target detection and tracking at distances of 2.2km to

Closest Point of Approach (CPA) with a FAR of less than 1.7 false alarms per hour [14]. For two general aviation aircraft each travelling at 100 knots, this equates to approximately 20 seconds before the CPA. This is above the estimated minimum of 12.5 seconds required for the recognition and reaction time of a human pilot [15]. For a smaller FOV lens (16mm), continuous detection and target tracking has been demonstrated at distances in excess of 4 NM to CPA [9] (more than 75 seconds to CPA).

The data collected from the extensive flight campaigns allows for continued research into the enhancement of the DAS. Future areas of research include the use of sensors in different spectrums, techniques for increasing the field of regard and the optimisation of the DAS for implementation on-board a small fixed-wing UAS.

2.5 Summary

In summary, Smart Skies has completed a preliminary investigation and flight-testing of the forward-looking EO DAS. This system could ultimately provide small UAS with a suitable detect and avoid capability. The DAS could also be used as a decision aid to pilots, thus improving the safety of both manned and unmanned aviation operations.

3 STATIC OBSTACLE AVOIDANCE SYSTEM

Rotorcraft unmanned aircraft have many applications distinct from those of fixed wing UAS (*e.g.*, detailed inspection of infrastructure). These applications often place them in close proximity to unknown obstacles and terrain. A highly autonomous system is required to enable such operations beyond the visual range of the UAS controller or with the UAS controller performing only supervisory control.

3.1 Research Objective

The objective was to research, develop and flight-test a prototype automated Static Obstacle Avoidance (SOA) system. The SOA system had to be suitable for use in an unknown outdoor environment and use sensors appropriate for mini unmanned helicopters in terms of weight, cost and power consumption.

The performance of the SOA system was explored in a real world environment by using it to enable the inspection of a remote piece of infrastructure. The remote inspection would be conducted Beyond the Visual Line Of Sight (BVLOS) of the aircraft controller. The system would need to be robust through intermittent communications, be capable of avoiding common obstacles such as trees and structures, and capture imagery of the inspection target.

3.2 Sensor Evaluation

The initial phase of the research program was to compare two commercially available devices that represent the state of the art in stereovision and lightweight LiDAR: the Videre-Design STH-DCSG-STOC-C stereo pair and the Hokuyo UTM-30LX scanning laser. As described in [15] a detailed evaluation including numerous flight tests was conducted of the sensors and it was found that although the stereo device fitted with 8-mm lenses provided better sensing range and larger vertical field of view than the laser, it relied on careful calibration and was adversely impacted by high contrast lighting in the outdoor environment. The wider horizontal field of view and more reliable detection of obstacles within a 20-m range meant that the laser scanner was a more suitable sensor for obstacle detection. Another outcome of the evaluation was the realisation that deliberately perturbing the helicopter's motion could greatly increase the laser scanner's field of view.

3.3 The Prototype System

Using the conclusions of the sensor evaluation and based on the ARCAA rotorcraft unmanned aircraft described in §6.3, a BVLOS inspection system was developed.

Summarising the detailed description of the inspection system provided in [16], the laser scanner was mounted vertically to give a planar field of view extending 270^{o} beneath, to the front and above the helicopter. Special flight modes utilised the flight dynamics unique to a helicopter to expand the laser's field of view. The pirouette descent mode rotated the helicopter about its yaw axis while descending to create a cylindrical field of view around the helicopter. The waggle cruise mode yawed the helicopter ±45° side to side while flying forward to sweep the laser horizontally and give a broad field of view in front of the aircraft as shown in Fig.3.

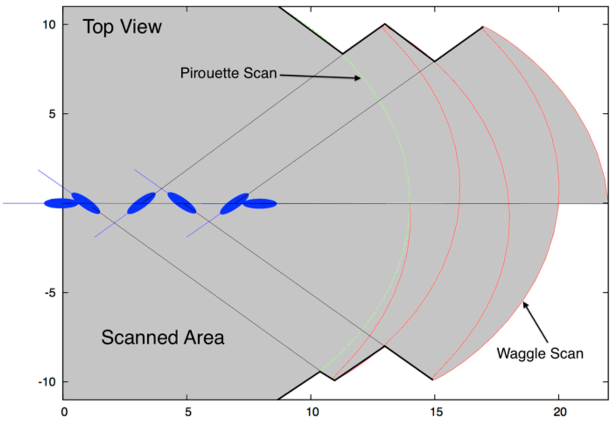

Fig. 3. Area scanned by the laser in the pirouette and waggle flight modes

A terrain following flight mode was implemented for approaching the inspection target at low altitude. The laser data from beneath the aircraft was used to determine the height above ground and the terrain slope. The helicopter was controlled to maintain a safe height above the terrain, including handling terrain discontinuities such as small trees and fences. An obstacle avoidance flight mode was developed combining reactive behaviours with a goal-oriented navigation approach to avoid the obstacles, but also arrive at the target waypoint.

The helicopter was programmed to descend using the pirouette descent flight mode, scanning for obstacles beneath and around it. Once the ground is detected, the helicopter would then fly towards the inspection waypoint in the waggle cruise mode. Fig. 3 shows the area scanned during the pirouette descent and the waggle cruise modes of flight. An avoidance waypoint is generated away from the obstacle if an obstacle is detected during the waggle cruise. The helicopter flies towards the new waypoint, and if reached continues towards the inspection waypoint, reacting away from any further obstacles in the same manner. Each new avoidance waypoint is generated based on the location of the currently detected obstacle relative to the helicopter. Initial flight tests showed that it was possible for this local planning algorithm to become trapped in concave shaped obstacle configurations. An extension of this algorithm was developed to overcome this; a full description can be found in [16].

3.4 Results and Research Direction

As a component of the final Smart Skies integrated flight trials in December 2010 the BVLOS inspection system conducted two test missions to obtain inspection images of a windmill. The windmill was 1.4 km away from the helicopter ground station and there was no safety pilot in the inspection area. Both missions were successful, with the helicopter autonomously detecting and flying around trees and arriving at the inspection waypoint to take photos of the windmill. In total more than 11 hours of autonomous flight was conducted at low altitudes in the vicinity of obstacles.

This development has shown that it is feasible to use lightweight commercial off the shelf sensors, simple perception methods and reactive behaviours to achieve autonomous obstacle avoidance on a mini unmanned helicopter.

3.5 Next Steps

The SOA system developed during the Smart Skies Project autonomously avoided the terrain below the aircraft and obstacles in front of the aircraft using the same LIDAR sensor, but using one algorithm for terrain following and another for obstacle avoidance. The next challenge is to develop a SOA system that is capable of operating in steep and complex terrain where the distinction between terrain and obstacles is not as apparent.

4 The Mobile Aircraft Tracking System

To realise the benefits of UAS for civilian applications there is a need to gain regular and routine access to non-segregated civilian airspace. To gain this access, however, there is a requirement for UAS to replicate the see-and-avoid function that is currently performed by pilots.

Adding on-board systems to a UAS to replicate the see-and-avoid function can be a complex task (Refer to §2). An alternative is to use off-board systems to perform the see-and-avoid function.

The traditional method of managing aircraft in the National Airspace System (NAS) uses ground-based primary surveillance radars (PSR). These PSRs tend to be very expensive and are typically located around busy airports. A busy airport, however, is not the ideal location for a UAS to gain access to the NAS.

An alternative is to use a low-cost and portable PSR that can support UAS operations at any location. The aircraft track information provided by the PSR could also be supplemented with information obtained from other surveillance systems, such as Automatic Dependent Surveillance – Broadcast (ADS-B), to enhance the airspace "picture" provided to the UAS pilot. This system is called the Mobile Aircraft Tracking System (MATS).

The UAS pilot uses the sensor information provided by the MATS to keep the UAS well clear of other aircraft. This ability to sense and avoid other aircraft satisfies a key requirement for flying UAS in the NAS.

4.1 Research Objective

The objective was to develop and test a cost effective, mobile and network-enabled air traffic surveillance system that provides a local capability to ensure the safe operation of UAS in civilian airspace.

The aim of the testing was to characterise the performance of the MATS and demonstrate how the system could support UAS operations in civilian airspace.

4.2 The Prototype MATS

The MATS comprises:

1) a primary surveillance radar;
2) an ADS-B receiver;
3) a VHF voice transceiver;
4) Iridium and public mobile data network modems; and
5) a server for data fusion and communications management.

The MATS was developed in conjunction with Insitu Pacific Limited and forms part of Insitu Pacific's UAS Flight Demonstration System (Fig. 4).

Fig. 4. Insitu Pacific's UAS Flight Demonstration System, which incorporates MATS.

4.3 Research, Development and Flight Test Program

An important aspect of Smart Skies Project was the ability to test the MATS using the ASL (see Section §6). The ASL represents a typical GA aircraft, which also makes it an ideal aircraft for testing the detection performance of the radar.

The ASL's on-board systems provided a capability to follow pre-determined flight paths and accurately log the aircraft's state throughout its flight. Thus, the ASL's capabilities made it possible for the MATS to make repeatable measurements of the ASL, which enabled the detection performance of the MATS to be quantified.

The variables involved in testing a radar system include range, azimuth, altitude and radar-cross section (RCS). With these variables in mind a number of simple flight plans were used to evaluate the performance of the MATS. These flight plans included circles, octagons and diamonds.

The ASL was also used to simulate intruder aircraft. These flight paths are important because they test the performance of the MATS for sense and avoid scenarios.

Some example flight trial results are presented in Fig. 5. The outer 10 NM circle is comprised of radar tracks (white lines marked with a track endpoint symbol), the ASL's "truth" data (green lines) and the received ADS-B track of the ASL (blue line). The radar tracks and "truth" data for a 6 NM octagon and a 4.3 NM diamond are also shown. Not all of the paths are symmetrical, due to operational reasons, but they do show the ability to track a manoeuvring aircraft.

Fig. 5. Example flight test results of the MATS tracking the ASL. The figure shows radar tracks (white lines), the ASL's truth data (green lines) and the received ADS-B track of the ASL (blue line). The flight trial results are from tests performed at Burrandowan, Queensland.

4.4 Results and Research Direction

Figure 5 showed an example of the flight trial results that have been used to characterise the MATS. The results of testing the MATS, at another location, have been presented in [18-20]. These results show that a typical GA aircraft can often be tracked to a range of 10-14 NM from the radar. Larger aircraft, that have a larger RCS, may be tracked at longer ranges.

The flight test results also show that the siting of the MATS is important. The local terrain can impose an azimuth dependence on the detection performance. The terrain can create shadow regions where detecting an aircraft is not possible. Terrain can also create high backscatter clutter regions, which reduce the signal to clutter ratio. These high-clutter regions are responsible for the gaps in the aircraft tracking, as shown in Figure 5.

The MATS was also connected to the Smart Skies network [19, 20]. This connectivity allowed the MATS to act as an additional data source for the AASMS (see Section §5).

The MATS has subsequently been deployed to support the ScanEagle[1] conducting marine mammal surveys in non-segregated civilian airspace [21]. These surveys were conducted approximately 23 NM from an international airport. This environment provided an opportunity to monitor and track a wide variety of aircraft and provide this information to the UAS pilot.

The results of flight-testing show that the MATS is able to assist UAS operations. The MATS provides information about the local airspace users to the UAS pilot. With this information the pilot is able to keep the UAS well clear of other aircraft – an important step for routine and regular UAS flights within the NAS.

5 Global Automated Airspace Separation Management System (ASMS)

The final enabling technology developed and flight-tested was the global Automated Separation Management System (ASMS). The ASMS is an automated system capable of providing air traffic separation services for complex air traffic management scenarios involving a mix of manned and unmanned aircraft from anywhere in the world.

5.1 Research Objective

The Smart Skies Project aimed to explore the development of an ASMS that could be used to improve the efficiency and flexibility of Air Traffic Management (ATM) for future airspace environments. The prototype Smart Skies

[1] http://www.insitu.com/scaneagle

ASMS was designed to provide an automated separation assurance service for complex airspace management scenarios. Such scenarios are characterised as involving a large number and a diverse mix of cooperative and non-cooperative airspace users (including manned and unmanned aircraft).

5.2 The Prototype ASMS

The development of the ASMS was led by BR&T in the United States. The prototype ASMS (illustrated in Fig. 6) comprises the:

1) Automated Dynamic Airspace Controller (ADAC) – monitors the state of the airspace and automatically generates separation assurance commands if a predicted (future) loss of separation is detected;
2) Common Information Network (CIN) – the communications infrastructure that connects aircraft and other sensors (*e.g.*, the MATS and weather feeds) to the ADAC;
3) Predictive Flight Management Systems (pFMS) – an advanced flight management system situated on-board aircraft that autonomously estimates the current and future state of the aircraft, manages communications with the ADAC, and manages and executes separation commands generated by the ADAC or by on-board systems such as the DAS.

The ADAC was situated in the USA and was connected to three flight test aircraft operating in Australia using satellite and public mobile data communications networks (Fig. 6.) The prototype ASMS is further described in [5, 22, 23].

5.3 Research, Development and Flight Test Results

A phased development and flight test approach was also adopted for the ASMS. The first phase of testing involved simple encounter scenarios between two fully cooperative aircraft. Progressively, more ASMS capability was added and tested. This included the ability to

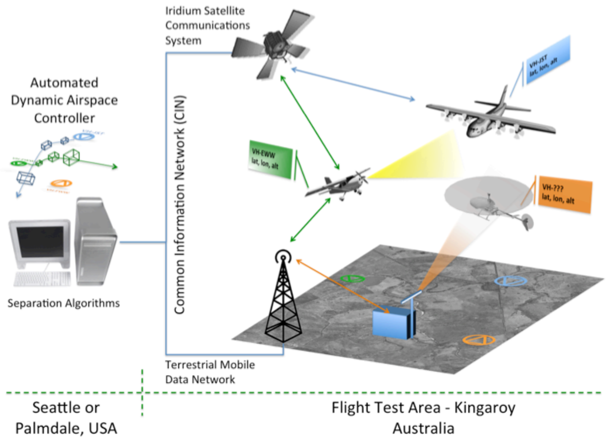

Fig. 6. Prototype ASMS

provide assurance commands in 4D (latitude, longitude, altitude and time), the capability of managing semi-cooperative aircraft, the inclusion of third party surveillance feeds on non-cooperative aircraft (*i.e.*, from the MATS), and the ability to manage aircraft with their own detect and avoid system.

Simulated real world scenarios were also used in the evaluation of the performance of the ASMS. These scenarios included a bushfire response mission, involving manned and unmanned fixed-wing and rotorcraft platforms, and operations around non-towered aerodromes. Testing and development also included scenarios where aircraft actively sort to "break" separation minima with another aircraft. The evaluation and testing culminated in scenarios involving 50 aircraft (simulated and real) all situated within a 5 NM radius of each other.

In summary, the Smart Skies Project showed how remotely located computing, commercial data links, and aircraft-based flight management systems could be used to provide separation services for complex ATM scenarios. It is believed that increased automation of ATM services will help to reduce the workload of air traffic controllers, improve airspace utilisation and maintain and improve current safety levels.

6 Flight Test Capability

A key component of the Smart Skies Project was the flight test capability developed to support the testing of the enabling technologies under real world operating conditions.

6.1 Airborne Systems Laboratory

The ARCAA Airborne Systems Laboratory (ASL) is a Cessna 172R (Fig. 7) custom modified to meet the flight test needs of the Smart Skies Project and other research programs ongoing at ARCAA.

The ASL is equipped with a 19 inch equipment rack, daylight readable cockpit display, aircraft state (attitude, latitude, longitude, height, ground speed, *etc.*) and sensor data collection system, flight management (coupled to the existing autopilot) and flexible on-board data processing. The ASL is capable of being flown autonomously (lateral control and in en-route phases only) from anywhere in the world via satellite, ground-based mobile data or LOS communications links. A detailed description of the ASL is provided in [24].

The ASL was the primary flight test aircraft, logging in excess of 250 flying hours in support of the development and evaluation of the ASMS, DAS and MATS components of the Smart Skies Project.

Fig. 7. ARCAA Airborne Systems Laboratory

6.2 Fixed-wing Unmanned Aircraft

A number of autonomous fixed-wing UAS were used as part of the Smart Skies flight test program. The most extensively used was the ARCAA Flamingo platform (Fig. 8). The Flamingo has a maximum take-off weight of approximately 20kg, a 4m wingspan and an endurance, at max weight, of approximately one hour. It was equipped with Iridium satellite, 900MHz and Next G^{TM} 3G modems, a MicroPilot 2128 autopilot and a variety of on-board computing and sensor payloads necessary to support data collection for the DAS and testing of the ASMS. By the close of the Smart Skies Project, the Flamingo had flown in excess of 70 hours of autonomous operations.

Fig. 8. ARCAA Flamingo UAS

6.3 Rotorcraft Unmanned Aircraft

The ARCAA helicopter UAS is a platform developed by ARCAA using a mix of custom and commercial off the shelf components. Based on the Vario Benzin Trainer remote control (RC) helicopter it has a main rotor diameter of 1.8m, a maximum take off weight of 12.3Kg, and is powered by a 23cc two-stroke petrol engine (Fig. 9). The flight control computers, perception sensors and navigation system are contained in a removable payload that is mounted beneath the base platform. This enables the research payload to be quickly swapped between airframes in the case of mechanical problems, or a different payload to be quickly mounted to the airframe to support new experiments. The base platform weighs 7.7 kg, which leaves a maximum of 4.6 kg for fuel and the removable payload. A full fuel load of approximately 1 kg provides endurance, including reserve, of 60 minutes. It is capable of operations BVLOS of the controller and has an operating range of approximately 5 km. A detailed description of the platform can be found in [25].

Within the Smart Skies Project the helicopter UAS was used to support the automated separation management flight trials and was the sole platform used for the static obstacle avoidance system. In one single mission the platform conducted an inspection of a windmill 1.4 km from the ground control station using the static obstacle avoidance system and interacting with the separation management system. During the flight a constant connection was maintained with the ADAC and on the return flight leg the helicopter followed an updated flight plan sent from the ADAC to avoid a simulated helicopter on an opposing flight path.

Fig. 9. ARCAA Helicopter UAS

6.4 Mobile Operations Centre

ARCAA obtained an area approval to operate UAS from a private property located approximately 25 NM east of the township of Kingaroy in Queensland. Mobile field support equipment was needed to accommodate flight test equipment and personnel under challenging environmental conditions. A custom-developed Mobile Operations Centre was commissioned (Fig. 10). The MOC provided the shelter, electrical power, communications and computing infrastructure necessary to support the safe coordination and operation of flight tests.

Fig.10. ARCAA Mobile Operations Centre

6.5 Flight Planning, Procedures and Personnel

In addition to the flight test platforms and support equipment, an essential component of the flight-test capability was the flight planning and operational procedures developed to ensure the efficient and safe execution of flight experiments. A detailed risk management process was foundational to the development and ongoing refinement of the flight test plans and operational procedures. Flight debriefs and lessons learnt reports were key to improving the efficiency of the testing. The experience and proficiency of the personnel, and the maturity of the flight-testing procedures and processes, continued to improve over the two years of active flight-testing conducted as part of the Smart Skies Project.

6.6 Summary

In summary, the ARCAA team successfully developed a cost effective flight test capability sufficient to support the flight data collection needs of the Smart Skies Project. As well as enabling real world data collection, experiences gained through the development and operation of UAS flight test capability (inclusive of the risk assessment, regulatory approval processes) have been a valuable input to national and international regulatory development initiatives for UAS.

7 Conclusions

The Smart Skies Project has made significant advancements in the development and practical flight-testing of four enabling technologies: a detect and avoid system, automated static obstacle avoidance system, a mobile aircraft tracking system and an automated global airspace management system. These technologies have the potential to improve the efficiency and safety of both manned and unmanned aircraft operations within the civilian airspace system.

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Copyright Statement

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