The Future of UAS:
Standards, Regulations, and Operational Experiences

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ABSTRACT

The outcomes of "The Future of UAS: Standards, Regulations and Operational Experiences" workshop, held on the 7 - 8 December 2006, in Brisbane, Queensland, Australia. The goal of the workshop was to identify recent international activities in the Unmanned Airborne Systems (UAS) airspace integration problem. The workshop attracted a broad cross-section of the UAS community, including: airspace and safety regulators, developers, operators, and researchers. The three themes of discussion were: progress in the development of standards and regulations; lessons learnt from recent operations; and advances in new technologies. This summarises the activities of the workshop and explores the important outcomes and trends as perceived by these authors.

NOMENCLATURE

AFD:	Australian Defence Force
ACAS:	Automated Collision Avoidance System
ACMA:	Australian Communications and Media Authority
AOPA	Aircraft Owners and Pilots Association
ARCAA:	Australian Research Centre for Aerospace Automation
ATC:	Air Traffic Control
ATM:	Air Traffic Management
ASTM:	American Society for Testing and Materials
C3:	Command, Control and Communication
CASA:	Civil Aviation Safety Authority
CAR:	Civil Aviation Regulations
CASR:	Civil Aviation Safety Regulations
CONOPS:	Concept of Operations
CNS:	Communications, Navigation, Surveillance
CRM:	Crew Resource Management
CSIRO:	Australian Commonwealth Scientific and Industrial Research Organization
DSA:	Detect Sense and Avoid
ELOS:	Equivalent Level of Safety
EASA:	European Aviation Safety Agency
EUROCAE:	European Organisation for Civil Aviation Equipment
FAA:	Federal Aviation Administration
GAT:	General Air Traffic
GCS:	Ground Control Station
HMI:	Human-Machine Interface
ICAO:	International Civil Aviation Organization
LATS:	Low Altitude Threat Simulator
LOC:	Loss of Command
LSA:	Light-Sport Aircraft
LRLS:	Long Range Lineup System
MAAA :	Model Aeronautical Association of Australia

The acronyms UAS and UAV are used interchangeably throughout this paper. However, from a formal perspective, there is a distinction.

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MASPS:	Minimum Aviation System Performance Standards
NAS:	National Airspace System
NPA:	Advance-Notice of Proposed Amendment
NPRM:	Notice of Proposed Rule Making
OAT:	Operational Air Traffic
RNP:	Required Navigation Performance
RSVM:	Reduced Separation Vertical Minima
RTCA:	Radio Technical Commission for Aeronautics
SAFD :	See & Avoid Flight Demonstration
SARPS:	Standards and Recommended Practices
SUAS:	Small UAS
SDOs:	Standards Developing Organizations
SMEs:	Small to Medium Enterprise
UAV:	Unmanned Aerial Vehicle
UAS:	Unmanned Aerial System
UMTS:	Universal Mobile Telecommunications System

INTRODUCTION

Currently one of the biggest challenges faced by the Unmanned Aerial Systems (UAS1) industry, are the restrictions in integrating operations into civilian airspace. These restrictions are generally imposed by the current regulatory environment, a lack of operational experience, and some fundamental deficiencies in UAS technology. Stakeholder collaboration and coordination is fundamental to overcoming these difficulties.

In late 2005, the Australian Research Centre for Aerospace Automation (ARCAA[1]) hosted its first *"The Future of UAS"* workshop, focusing on the *"Challenges and Applications in the Asia Pacific Region."* The workshop attracted a broad cross-section of the UAS community and the ensuing discussions identified three key issues faced by the AsiaPacific UAS industry, these were:

1) The lack of prescriptive standards and regulations governing the routine operation of UAS in the civilian airspace system.

2) The inability to obtain adequate insurance coverage for UAS operations.

3) The general lack of industry and public awareness of the potential applications for UAS.

Driven by the outcomes of the 2005 workshop, themes for the 2006 workshop explored recent developments of standards and regulations, lessons learnt from operational experiences, and advances in UAS technology. More specifically, the goals of this workshop were to:

1) *Review and comment on emerging standards* such as those for detect, sense and avoid, human machine interface (HMI), and operator training;

2) *Identify common problems* in the integration of UAS into the National Airspace System (NAS) and operations across international bodies;

3) *Understand how the requirement* for equivalent evel of safety can be (and is currently being) resolved for UAS;

4) *Understand lessons learnt* from Australian UAS trials in civil airspace (restricted and otherwise); and

5) *Raise the level of awareness* within the potential user community.

The workshop comprised a series of presentations from international experts, followed by short moderated workshops to stimulate open floor discussion on major issues. This summarises the activities of the workshop and explores the key outcomes and trends as perceived by the authors.

STANDARDS AND REGULATIONS

The standards and regulations theme contained presentations from representatives of international regulatory authorities and standards development organisations including: EUROCONTROL, CASA, ASTM F-38, EUROCAE UAV Working Group 73 (WG-73), and RTCA Special Committee 203 (SC-203). Spectrum issues for UAS were covered by the Australian Department of Defence.

EUROCONTROL – MILITARY UAS AS OAT

The first presentation of the session was from Wing Commander Mike Strong, Directorate of Civil-Military Air Traffic Management (ATM) Coordination, EUROCONTROL, and Chairman of the EUROCONTROL UAV-Operational Air Traffic (OAT) Task Force.

The objective of the UAV-OAT Task Force, and subject of the presentation, was the ongoing development of high-level and generic specifications for the use of military UAS as OAT outside of segregated airspace (operating under non-ICAO internationally agreed processes). Specifications concerning collision avoidance, provision of air services, and separation minima were presented. The principles employed by the Task Force were:

- That military UAS operating as OAT should not present a risk to other airspace users greater than

[2]ARCAA is a joint venture between the Queensland University of Technology and the Commonwealth Scientific Industrial Research Organisation (CSIRO), Information Communication and Technology (ICT) Centre.

that presented by existing manned military aircraft operating as OAT outside segregated airspace;.

- That operations involving military UAS as OAT should be transparent to air service providers and other airspace users, and
- The operation of military UAS as OAT should not deny or reduce the access which other users have to airspace.

The specifications were released for public consultation in April 2006 under the EUROCONTROL Notice of Proposed Rule-Making (ENPRM) process. At the time of the workshop, a report summarising the 273 comments and recommendations obtained over the period of public consultation was soon to be released. The amended specifications, which incorporate many of the responses received through the ENPRM consultative process were released early in 2007.

Discussion

It is important to note that the specifications defined by the Task Force do not address the issues concerning the operation of civilian UAS, or military UAS operating as General Air Traffic (GAT) under ICAO civil rules. It was also interesting that the specifications developed by the Task Force were not constrained by the capability or performance of current UAS (specifically, the current lack of a suitable sense-and-avoid technology), an issue which tends to dominate discussions in the area of UAS integration. The specifications, although intentionally non-prescriptive, are a step forward in the direction of addressing the UAS airspace integration problem.

ASTM – UNMANNED AVIATION STANDARDS

Discussion on the definition of standards pertaining to UAS airworthiness commenced with a presentation made by Laurence Newcome, representative of the ASTM International's Unmanned Aviation Standards Committee F38. The presentation provided a brief introduction to the ASTM F38 Committee, a survey of international Standards Developing Organisations (SDOs) and outlined the ASTM UAS standards roadmap.

The ASTM is a consensus standards body [1] and the objective of the F38 Committee is to "*. . . produce cost-effective consensus standards that, when applied, will enhance the safe design, manufacture, maintenance, and operation of UASs.*"

To achieve this objective the ASTM standards roadmap was established. The roadmap is a hierarchical structure of standards and is intended to be used by organisations engaged in developing or adopting standards governing UAS design, manufacture, test, training, operation, and maintenance. The roadmap also served to identify gaps and duplication in existing standards.

At the highest level, the ASTM roadmap of categorises standards into:

1) *Airworthiness Standards* – Predominantly hardware-oriented standards where the focus is on the safe design, construction, test, modification, and inspection of the individual component, aircraft, or system. Airworthiness standards are then further decomposed into standards relating to airframe, avionics, and propulsion.

2) *Operations Standards* – Standards where the focus is on the safe employment of the system within the aviation environment among other aircraft and systems. These standards are predominantly procedure- and performance-oriented and are further decomposed into standards relating to general, flight, and ground operations.

3) *Qualifications Standards* – Procedure-oriented standards focussed on the safe practices by the individuals responsible for employing the system. The qualification standards are further decomposed into crew, maintainers, and operators.

As part of the roadmap process, the comprehensive review of all existing standards revealed a number of deficiencies, including:

1) *Standards relating to unconventional takeoff and landing systems* such as catapults (pneumatic, hydraulic, bungee, etc.), and arresting gear (net, wires, and halyards).

2) *Standards relating to the security* of the command, control, and data links.

3) *Armed UASs*; specifically standards relating to the deployment, carriage, release, and safety of munitions onboard a UAS.

4) *The use of photovoltaic cells* (solar cells) and fuel cells as aviation power plants.

5) *Standards on the design and operation* of automated take-off and landing systems.

6) *The accommodation of UASs* at alternate airfields.

It was indicated that a credible transparent process is required to develop standards to address these deficiencies.

Additionally a substantial amount of testing and experience is needed to build a high degree of confidence in a set of standards. However under the current regulatory environment it is difficult to obtain the operational experience necessary for credible standards development. An expected solution to this problem is the utilisation of approved modelling and simulation tools as a means of validating standards. One such airspace modelling tool, outlined at length in the presentation, is the Massachusetts Institute of Technology/Lincoln Lab, Collision Avoidance System Safety Assessment Tool (CASSAT).

The presentation concluded by providing an overview of the Office of Secretary of Defence (OSD) See and Avoid Flight Demonstration (SAFD) program. The primary objective of this program is the development and demonstration of an autonomous collision avoidance capability on a UAS operating outside of segregated airspace. The experience gained throughout the program will be used to refine standards (ASTM 2411) for autonomous collision avoidance capabilities and to map the airworthiness certification process for collision avoidance systems. Standards development is an iterative process, and thus programs such as the OSD SAFD will have an important part in the development of credible standards for UASs.

Discussion

UAS standards development is a global problem and the issues concerning harmonisation and coordination among international parties may prove to be the ultimate obstacle to realising globally recognised standards for UAS.

The ASTM UAS standards roadmap is one tool which could potentially overcome these issues. The roadmap establishes the framework from which to construct standards, and identifies deficiencies, allowing for better coordination and allocation of resources in the refinement and development of standards. Global consensus on the structure of such a roadmap is essential to the timely and efficient development of standards and promotes a *"collaborate rather than compete"* environment.

Social-political influences will be an important factor in any regulatory process. Acknowledging this fact and embracing tools (such as roadmaps) at an early stage in the regulatory process will be key to the timely and efficient development of acceptable standards.

EUROCAE – WORKING GROUP 73 UPDATE

The European Organisation for Civil Aviation Equipment (EUROCAE) is an international association focussing on the development of standards and regulations for UAS. Subgroup Leader and Leadership Team Member for the EUROCAE UAV Working Group 73 (WG-73), Michelle Allouche, provided a presentation which outlined their progress in UAS standards development.

WG-73 was formed in May 2006 with the overall objective of developing technical materials that would support UAS airworthiness certification and operational approval criteria, enabling the safe operation of UAS in non-segregated airspace. The overarching principle governing the first phase of WG-73 activities is that UAS and manned aircraft must be treated equally within the existing Air Traffic Management (ATM) environment.

The second phase of proposed activities recognises that imposing manned aircraft equivalence on the UAS industry may result in a non-optimal solution. This phase seeks to identify new and more efficient processes for integrating UAS and manned aircraft (where UAS are not treated equivalently to manned aircraft).

The presentation provided some background on EUROCAE, the WG-73 working group, and an update on the progress and future work areas of WG-73. WG-73 activities are divided into three areas:

1) *UAV Operations* – The identification of various UAS missions within non-segregated airspace, functional and equipment requirements for these operations, their impact on other aviation activities, and the requirements for sense-and-avoid.

2) *UAV Airworthiness* – Addressing the issues concerning the definition of safety targets, airworthiness certification categories, considerations for special conditions/ restrictions on the operation of UAS, and the ongoing airworthiness of UAS systems.

3) *UAV Communications, Spectrum, Command and Control, and Security* – Addressing the issues concerning the spectrum, security, and requirements for the command, control, and telemetry links for ground and airborne systems.

Given the recent formation of EUROCAE WG-73 the presentation focussed on their aims and objectives rather than definitive specifications.

Discussion

Rather than simply focussing on the definition of standards, or the direct adoption of the existing aviation regulatory framework to UAS, the EUROCAE WG-73 has taken on a more holistic approach to the problem. WG-73 has started to address the problem from its fundamentals and is investigating important issues such as:

1) *The definition of metrics and benchmarks* describing the requirement for an Equivalent Level of Safety (ELOS);

2) *The definition of UAS certification categories,* and;

3) *The application of operational restrictions* in conjunction with prescriptive regulations.

EUROCAE WG-73 acknowledges that the solution to the effective regulation of UAS may not be in the application of the existing "off-the-shelf" regulatory frameworks. Thus it is important that organisations such EUROCAE WG-73 continue to think outside of the box and challenge the issues which bound current thinking on the regulation of UAS.

RTCA – SC203, UAS STANDARD DEVELOPMENT ACTIVITIES

Cary Spitzer from RTCA Special Committee 203 (SC-203) presented a third perspective on the UAS standards development problem. With strong participation by the Federal Aviation Administration (FAA), industry, and many alphabet organizations including the Aircraft Owners and Pilots Association (AOPA), the objective of the RTCA SC-203 is to support the need of US industry and Government to operate UAS safely in the NAS with no impact to current users. The initial focus of the Committee has been on the development of recommendations that will facilitate these operations.

RTCA Standards development is currently focussed on the definition of Minimum Aviation System Performance Standards (MASPS) for UAS in general, Command Control and Communications (C3), and Detect, Sense and Avoid (DSA) systems. The high level strategy governing the development of standards is to:

1) *Collect operational concepts* representing current and future UAS operations.

2) *To assess each concept of operation* with the objective of identifying the unique attributes of the systems and the operation.

3) *Determine the ability of the NAS* to tolerate the unique attributes and characteristics of the different UAS concepts of operation without adversely impacting safety or efficiency.

4) *Establish system level functional and performance requirements* based on tolerable UAS performance, and;

5) *Continue to decompose* these functional, safety and performance requirements to the subsystem level.

As a pre-cursor to the generation of MASPS, a UAS general guidance document was completed in March 2007 [11]. The document provides the framework for developing standards and guides the concepts of UAS operation, the operational environment and the key issues which need to be considered in the definition of MASPS. SC-203 is now concentrating on the establishment of the baseline and scope for the planned standards development activities.

Discussion

Key points raised in the presentation were the need for continued momentum in the development of technologies, policies. and regulations concerning the integration of UAS into the NAS. In addition, this momentum must come from all stakeholders in civil airspace and that domestic (United States) activities should be coordinated with international programs.

It was identified that there was some collaboration occurring between SC-203 and WG-73.

AUSTRALIAN DOD – AERONAUTICAL SPECTRUM AVAILABILITY

George Wardle, Manager of Radio Spectrum Planning, Australian Department of Defence, discussed the present availability of Aeronautical Telemetry spectrum in Australia. An allocation exists between 1435 – 1535 MHz and although priority is given to aviation users, this band is also available for non-aeronautical users through a licensing arrangement.

It was indicated that these bands are insufficient for current and future Australian requirements and are also likely reduced as competition for spectrum with other industry sectors is fierce. For example it was claimed that there are over 2 billion mobile phone users internationally compared to the few 1000 potential telemetry users in the UAS community. This was seen as a significant hurdle for the UAS industry.

Worldwide radio-frequency is managed at the treaty level through a specialised agency of the UN, the International Telecommunication Union (ITU). In 1992, the ITU reallocated some of the spectrum originally used for aeronautical telemetry to the broadcasting service. Subsequent studies found that the two users could not co-exist and consequently aeronautical telemetry suffered as a result.

Currently there are a number of new bands under consideration for reallocation to aeronautical telemetry (above 3 GHz only). All bands between 3 and 6.7 GHz for instance that have already been allocated to the mobile service are available, but not exclusively for aeronautical telemetry purposes. Other bands under consideration are 4400-4900 MHz, 5030-5091 MHz, 5091-5050 MHz, 5150-5250 MHz and 5925-6700 MHz. The first four bands require regulatory changes to implement and there is no guarantee that all will be available as these will be shared with other applications.

This situation was seen as a major impediment to UAS and in particular civil UAS. Spectrum planning at the international level occurs on a 7 year cycle with discussions next occurring in 2007. Unless a favourable outcome is obtained, there will be a 7 year wait before a dedicated UAS spectrum allocation can again be requested.

The presentation concluded that the availability of appropriate spectrum is a vital aspect of operating UAS. Properly designed links and the use of interference mitigation techniques are important to maximise safety. Wardle indicated that it is important to secure the required spectrum early in the design process as spectrum is a very limited commodity.

Discussion

Although coordination occurs at a global level, currently UAS are operating in a variety of spectrum allocations. This results in a lack of interoperability when operating UAS on an international basis. This highlights the importance of developing specific spectrum allocation for UAS aeronautical telemetry.

Given that spectrum is a finite resource the UAS community must address methods of reducing their communication requirements through increased onboard automation and intelligence. This would allow the UAS to transmit highly digested mission data, rather than all of the raw data, reducing the overall bandwidth required. However, there are numerous technical and regulatory challenges in realising highly autonomous and intelligent UAS. For example current CASA regulations require continuous real-time communications links.

The greatest competitor for spectrum is the mobile telephony industry. Perhaps the UAS industry should adopt the *"if you can't beat 'em – join 'em"* philosophy and investigate how UAS can utilise public mobile data networks. In Australia these services can currently provide downlink rates of over 3.6Mbps with a stated coverage to over 98% of the population of Australia.

SUMMARY

It is widely recognised that the absence of regulations for UAS is a significant challenge and that progress is being made towards a solution/s. However, the promulgation of ineffectual or inappropriate regulations could present an even bigger threat to the UAS industry, and despite the perceived urgency in the need for standards and regulations the industry will have to proceed with caution. Based on this statement, the following observations and comments are made:

1) *There are many issues at the foundation of the UAS regulatory problem* which are yet to be resolved. It is important that there is complete understanding and consensus on the issues such as the definition of ELOS requirements (if indeed this is an appropriate mechanism for developing requirements) which underpin the entire regulation development effort.

2) Regulators and associations concerned with the development of regulations, should *acknowledge that the most effective solution to the regulation of UAS may lie outside the bounds of existing approaches and methodologies.* UAS are a fundamentally new aviation technology, the regulation of which may require a fundamentally new approach.

3) *Diversity in approaches* helps to ensure that all potential avenues for regulatory development are explored; however, this can contribute to the problems of harmonisation and interoperability of regulations.

4) *It is important to recognise that the current airspace system was designed from the outset with a single user in mind;* manned aircraft. The airspace system has evolved and continues to evolve, however evolution should consider the future role unmanned aviation will have within the aviation environment and their relative position within the aviation industry. The current guiding principles of conformance and transparency of UAS operations are logical and valid. However, in the long term, such guiding principles may preclude the exploration of safer and more efficient airspace systems (and regulations) developed with both manned and unmanned users in mind.

5) Finally, in order to *ensure the harmonisation and uniform acceptance of standards and regulations* it is imperative that from the outset all stakeholders have an active role in development programs and associations.

Decisions made today with respect to the direction and form UAS regulations will take, will ultimately decide the future of the industry. In relation to the further development of UAS regulations and standards in Australia, it is important to identify the unique aspects of the Australian operating environment. These aspects include the airspace and terrestrial environments, the stakeholders, the potential markets, the legislative processes, and the social, cultural, and political climates. The development of regulations indigenous to Australia is unlikely and therefore careful consideration should be given in the application of international standards and regulations within the Australian context.

The current regulations adopted by CASA positions Australia as a likely leader in UAS technologies over the short term. It was felt that it would take 2-3 years before the US or Europe would have a similar level of UAS operational freedom. It is likely that the timely introduction of even more flexible UAS regulations within Australia will only come about through continued stakeholder demand.

OPERATIONAL EXPERIENCES AND AIRWORTHINESS

The second workshop theme focused on the lessons learnt from recent operational experiences, UAS training, airworthiness programs, and approvals for UAS operations.

Presentations were provided by the Australian Department of Defence (DoD), the Airworthiness Coordination and Policy Agency (ACPA), the Defence Science and Technology Organisation (DSTO), the Directorate General Technical Airworthiness (DGTA), the Royal Australian Navy (RAN), Aerosonde, BAE Systems Australia, and the Indian Centre for Air Power Studies.

DSTO – North-West Shelf Trials

Shane Dunn from the DSTO, Air Vehicles Division, discussed the North-West Shelf trials conducted in September 2006 and their associated airworthiness considerations. The purpose of the trials were to assess the surveillance potential of a UAS and a patrol boat working together, to demonstrate a component of an integrated national surveillance network. The trials assisted the Air 7000 acquisition program through the provision of operational experience in the deployment of a Mariner demonstrator UAS, and the simulated operation of a Global Hawk UAS.

The Mariner UAS, registered as a State aircraft, conducted a number of operations out of RAAF base Edinburgh, Adelaide. After a series of test flights off the coast of RAAF Edinburgh, the Mariner was flown over land to RAAF base Learmonth. This required operations in Class G airspace. There were two major challenges that needed to be addressed in these trials:

1) The UAS did not comply with see-and-avoid requirements, and;

2) The system still needs to be certified as being technically airworthy and thus presented a risk to people and property on the ground. In addition this added to the complexity of the air traffic management process.

To overcome these challenges a number of risk mitigation techniques were introduced. The measures put in place to reduce the risk of a midair collision were to:

1) Where practicable, conduct flight under IFR and operate on IFR levels.

2) Where practicable, conduct flight in controlled airspace under the oversight of ATC.

3) Where practicable, carry out activities in military restricted airspace.

4) Where practicable, conduct flying operations in VMC with navigation strobe lights activated.

5) Where practicable, conduct flying operations above FL110 (as all aircraft utilising this airspace should be radio and transponder equipped).

6) Maintain transit flight above FL200 (to avoid potential conflict with VFR traffic).

7) Establish a mission exclusion zone to ensure safe separation from typical helicopter operations between gas and oil rigs.

8) Make use of ground-based observers for operations in terminal airspace.

9) Operate in class G airspace only where traffic density could be expected to be "very low."

10) Periodically broadcast position, altitude, and intentions.

To manage the risks presented to the people and property on the ground, flights were planned to avoid the over flight of "populous" areas and to avoid offshore oil and gas infrastructure. The lack of RVSM and RNP certification resulted in complexity in ATM processes, which was overcome by:

1) Applying a 2000 foot vertical separation for flight levels above FL290; and

2) Applying 101 nmi lateral separation in OCA.

It was stated that existing airworthiness procedures and guidelines for piloted military aircraft were tailored to the trials. Using these measures, the trials were able to obtain the appropriate approvals from the Australian Defence Force and Australia's Civil Aviation Safety Authority.

Discussion

As a result of the North-West Shelf Trials, Defence, CASA, and Airservices Australia have gained valuable experience. Defence now has a broader understanding of the complexity of the risk management task in addition to an appreciation of the capabilities of UAS technologies in maritime roles. CASA and Airservices Australia also benefit through experience in the application of regulatory processes.

Despite the absence of prescriptive Airworthiness standards and DSA, the receptive and cooperative risk management philosophy in Australia still allowed Defence to conduct the trial operations. It is interesting to note that the same operations may not have been possible under FAA regulations [2]. However, to meet long-term Defence UAS capability requirements greater freedom in operations is still needed.

A number of questions were raised with respect to the precise definitions of "very low" traffic density and "populous areas." These definitions leave room for interpretation and can lead to the inconsistent risk management of UAS operations.

RAN – AUSTRALIAN KALKARA OPERATIONS

LCDR Bob Ferry (RAN) and Steve Fendley (5Dsys, Austin, TX, USA) provided a report on Kalkara UAS (an aerial target system), focusing on the lessons learnt with the RAN's Australian operations.

A summary of the primary causes of incident and failure across all 106 recorded accidents and incidents found that approximately 56% involved technical/equipment failures and 16% involved human error. Approximately 23% of incidents were due to errors in the documented design, operational and maintenance procedures.

It was observed that the number of accidents and incidents has fallen significantly since the RAN procured the first Kalkara aerial target in 1998. Increasing experience in the operation of Kalkara assisted the RAN to identify a number of technical and operational improvements in the US designed system. Some of the lessons learned included:

1) *Crew resource management, training and human machine interface* were factors prevalent in a number of incidents. These issues were addressed through improved and ongoing operator training, and the redesign of the situational awareness and control displays.

2) A number of incidents highlighted the *significance of the differences between the mission and operational requirements* of the RAN and that of the US. These differences had ramifications on technical and operational aspects of the UAS.

3) *Safety standards and procedures* need to be defined which are specific to the mission and operating environment.

4) *It is important to take into consideration other aspects involved in the risk management process* (e.g.; minimising public perception/ apprehension, and risks to the environment)

The main conclusion from the presentation was that all requirements and design change decisions will have a number of impacts across a wide number of domains. In particular, changes in the operational requirements can have significant impacts on the technical design of the system. Therefore, to ensure the safety and efficiency of operations, it is essential that all members (program, operational, user and technical) be involved in the decision-making process.

Discussion

The ADF's initial step into unmanned systems has been one of procurement as opposed to development. Subsequently, a lot can be learned from the experiences gained in the risk management of the Kalkara. These lessons are relevant to both Defence and civil/commercial UAS operations and highlight the complexity and multi-dimensionality of the risk management task. Procurement processes should place a strong emphasis on the unique safety issues involved in the acquisition of existing technologies and their application to different missions and operating environments. This will be an important consideration for upcoming ADF UAS procurements such as AIR7000 and for future civil/commercial Australian procurements.

AAI AEROSONDE – AEROSONDE OPERATIONS

Peter Bale and Rich Clifford from AAI Aerosonde Australia presented an overview of the diverse range of civil and military operations of the Aerosonde UAS. This overview detailed the operation of the Aerosonde in varying concepts of operation, including:

1) Operations in arctic, tropical, desert, and hurricane conditions.

2) Operations in segregated and non-segregated, military, and civil airspace.

3) Missions in defence, civil, and commercial applications.

4) Multi-system operations alongside unmanned underwater vehicles, human-piloted aircraft, maritime vessels, and ground assets.

Aerosonde possesses an extensive experience in operating a high technology, low risk solution for a wide range of applications. Aerosonde has flown over 1000 hours of "arctic operations" and was able to obtain a certificate of airworthiness for their 2006 hurricane demonstration project (limited to operations under the supervision of NASA). However, not having sense-and-avoid capability was an issue for their operations in Guam in November 2005.

Discussion

The presentation highlighted the flexibility and capability of UAS technologies, particularly those of smaller UAS. It also highlighted the diversity of potential markets and applications for UAS. It is interesting to note that despite the size of the Aerosonde system and the nature of some of its missions (i.e., arctic missions) the common issues of regulation, standards, certification, and see-and-avoid still presented a significant challenge. Many of the operational trials conducted in Australia might not have been possible in countries with less receptive risk management policies. These types of operations build stakeholder awareness of the capabilities and potential applications for UAS. In addition, these operations are pivotal to the progressive understanding of the risks and the effective risk management of UAS technologies.

BAE SYSTEMS AUSTRALIA – OPERATIONS AT WEST SALE

Heidi Fourie, UAV Operations Specialist at BAE Systems Australia provided an overview of current and future UAS operations at West Sale, Victoria, Australia. The presentation identified the complex challenges that needed to be overcome in order to establish West Sale as a UAS operations facility. The key challenges were:

1) The management complexities due to the operation out of non-segregated military and civil shared airspace. This required negotiation, coordination, and approvals/agreements to be made with multiple airspace stakeholders (e.g., CASA, Defence, and local airspace user and community groups).

2) The operational complexities involved in the safe flight of UAS alongside military and general aviation.

3) The sociological complexities concerning airspace stakeholders. Specifically, how to provide assurances to regulators, other airspace users, and the local community that the intended operations would not have a negative impact (e.g., safety, access to airspace, etc.).

A number of approaches were adopted to address these challenges. The first involved the definition of a phased approach for operations at West Sale which attempted to minimise the impact on stakeholders whilst, at the same time, meet the progressive operational needs of BAE Systems. The phased approach progressively expands the operational envelope (airspace, and the nature and complexity of the operation) through demonstrated experience in the safe operations.

The second and concurrent approach involved extensive consultation with all stakeholders to identify and address individual concerns with respect to UAS operations out of West Sale. This process included ongoing consultation with RAPAC, RAAF, CASA, and Airservices Australia. As a result, a number of procedural and operational processes were put in place to address the concerns identified.

The above approaches assisted BAE Systems in obtaining a Deed of Agreement with the RAAF and the issuance of an Operating Approval by CASA for continued operations at West Sale.

A number of lessons have been learnt as a result of growing experience in the operation of UAS, these include:

1) *Personnel Issues* – It is essential that all personnel have a good background knowledge of aviation, aviation practices (both military and civilian), licenses (minimum of radio), and of technologies (both UAS and other aviation technologies). It was also emphasised that this knowledge and experience would take time to acquire.

2) *Operational Issues* – Coordinating between military, civil, and air traffic service providers is a complex task. However, all stakeholders benefit from the experience.

Discussion

The philosophy adopted by BAE Systems is successful as it addresses the challenges of integrated UAS operations across a number of domains. Acceptance of routine UAS operations in shared airspace is not just about getting regulatory authorisation but is a process which must address the concerns (whether founded or not) of all stakeholders.

The phased approach allowed all stakeholders (including BAE Systems) to build confidence in the safety and integrity of the systems, procedures, and mechanisms in place before more extensive operations are undertaken.

The open and discursive approach adopted by BAE Systems has been successful in creating a safe, *"cooperate rather than compete,"* operational environment.

CENTRE FOR AIR POWER STUDIES – INDIAN UAS ACTIVITIES

Wing Commander Rajiv Goyal from the Centre for Air Power Studies, New Delhi, outlined UAS activities in the Indian Subcontinent. The presentation covered the scope of activities within India, Pakistan, and Sri Lanka and highlighted some unique civilian UAS applications specific to the region. In particular, there is the potential for UAS in the management of natural and man-made disasters (e.g., tsunamis and industrial pollution, respectively).

One of the most significant challenges has been the lack of recognition of UAS capabilities within government and regulatory bodies in the region. Currently, UAS are not defined by the Indian civil aviation regulatory authority and there is limited government support of the UAS industry (e.g., limited R&D funding).

Discussion

The presentation highlighted how, even though there are some commonalities in terms of UAS standards, each country or region has specific operational needs to be addressed. There seems to be a worldwide consensus on the need for international collaboration so as to progress the UAS industry on a global scale.

AUSTRALIAN DOD – AUSTRALIAN DEFENCE UAS ROADMAP

Peter Maguire, Director Aerospace Systems Analysis and Lead of the UAS Planning Team, DoD, provided an overview of the Australian Defence UAS Roadmap. The Australian Defence vision for UAS is that they "*. . . will provide a flexible, cost-effective means for Defence to extend integrated sovereign capability in key activities across the spectrum of operations.*" The Roadmap provides direction and guidance so as to meet this vision and defines the following implementation priorities:

1) *Ensure the successful introduction of systems/capabilities* already in service.

2) *Ensure the successful exploitation of capabilities* we introduce.

3) *Explore opportunities where UAS, technologies or new approaches to capability inputs* have demonstrated advantages.

4) *Explore and research novel opportunities* in UAS, technologies, and fundamental inputs to Defence capability.

The key challenges identified by the Roadmap include:

1) *UAS Reliability* – UAS are not as reliable as their manned counterparts so there is a need to define applicable design standards.

2) *UAS Signatures* – smaller UAS are inherently difficult for other users to acquire visually or by radar. From a mission capability perspective, this could be considered an advantage; however, from the perspective of peace-time operations alongside other airspace users, this is a disadvantage.

3) *Situational Awareness* – Other users cannot easily detect UAS, and UAS cannot easily avoid other users and the need for collision avoidance capability.

The Roadmap outlined a two track approach for UAS operations. The first is to progressively expand airspace access for current systems (Small and Tactical UAS). This will be achieved through:

1) *Development of a set of airspace management transition plans* that detail the progressive integration of UAS within the existing airspace system.

2) *Research and development in critical and enabling technologies* and associated procedures.

The second and parallel activity is to define appropriate standards that do not conflict or hinder current and future Defence operational requirements.

The role of UAS in the ADF will expand dramatically over the coming years and the roadmap will be key to addressing the issues facing Defence UAS operations. Defence acknowledges that many of the solutions will only come about through collaboration with all stakeholders.

Discussion

The development of an Australian Defence UAS Roadmap clearly indicates that a significant vision for UAS exists within Australian Defence Force. The presentation highlights the common standards problem and that collaboration is key to successful and timely UAS deployment within Australia.

ACPA – ADF AIRWORTHINESS MANAGEMENT

Squadron Leader Ken Thomas, from the ADF ACPA provided an overview of the Airworthiness Management of ADF UAS. Unlike civil/commercial UAS owners and operators, Defence has the additional responsibility of self-regulation. As a self-regulator, Defence must ensure the safety of the UAS in its intended roles whilst meeting both its needs as an operator (capability, serviceability, and availability) and as an owner (return on investment, longevity, etc.).

To achieve this, the ADF has put in place an airworthiness framework based on that used for conventional Defence aircraft. The airworthiness framework encompasses the complete management of the system and comprises two core elements:

1) *Technical Airworthiness* – The regulation of the design, production, and maintenance operations. This is achieved through the adaptation and application of existing Airworthiness management, design, and maintenance manuals/requirements.

2) Operational Airworthiness – The regulation of flying operations and the overall assessment of the risk.

The key issues concerning the regulation of UAS under the existing ADF airworthiness framework are:

1) The definition of Equivalent Levels of Safety (ELOS) for UAS-based on the levels of risk manned aircraft (of similar size or category) present to people and property on the ground and to other aircraft.

2) The definition of regulations that encompass the entire UAS and not just the air-vehicle.

3) The application of existing regulations to UAS.

4) The definition of a categorisation scheme which takes into account the wide range of UAS characteristics and operating environments.

Based on the principle of an ELOS, two airworthiness management categories of UAS were defined. The categories were defined considering the level of risks, the capability, and roles and environment of the UAS. These categories are:

1) *Category 1 UAS* – A UAS when operating in the intended roles and environment, is a system whose consequence of catastrophic failure can reasonably be expected to result in death or serious injury, or significant damage to property,

2) *Category 2 UAS* – A UAS when operating in the intended roles and environment; a system whose consequence of catastrophic failure can reasonably be expected not to result in death or serious injury or significant damage to property.

Discussion

Again, many of the challenges faced by Defence are common to those faced by civil and commercial UAS stakeholders. Defence does have a unique position in that it has the additional responsibility of self-regulation. Self-regulation does not remove Defence's regulatory (e.g., Chicago Convention, Defence Act, etc.), or societal (e.g., ethical) obligations in assuring the safe operation of UAS. However, it does provide flexibility in how Defence chooses to manage the safety of UAS.

There are a number of challenges in the adaptation and application of existing regulatory frameworks to UAS. One particular challenge is the capacity of the existing framework to accommodate the diversity in UAS design, capability, and operations whilst meeting the needs of the ADF as a UAS operator and owner.

The ADF has adopted a risk management approach by defining UAS management categories based on the level of risk. These categories facilitate flexibility in the application of regulatory processes and standards to UAS. Experiences in the application of this management approach may assist stakeholders in the development of a suitable regulatory framework for civil/commercial UAS.

DGTA – TECHNICAL AIRWORTHINESS MANAGEMENT

Mark Wade from the ADF Directorate General Technical Airworthiness (DGTA) went into further detail on the ADF's technical airworthiness program. The ADF has grown its concept of UAS airworthiness through its involvement in a number of programs including Kalkara, Guardian CL-327, Global Hawk, Mariner, and several small UAS acquisitions and leases. The DGTA published its first UAV design requirements in 1999. The design requirements were based on the configuration of the aircraft, its intended role, and operating environment. These requirements included:

1) *Basic design requirements* for every ADF UAS;

2) *Additional requirements if used near other aircraft;* and

3) *Additional requirements if used near/over populous areas.*

This airworthiness approach established the foundation for the management of technical airworthiness for recent UAS. The unique configuration, role, and operating environment of a number of UAS has helped to evolve this airworthiness framework. These UAS include the Global Hawk, Aerosonde, Skylark, ScanEagle, and Mariner UAS.

The DGTA is now using this experience in the management of future Defence UAS capabilities such as the I-View 250, and the systems selected under JP-66 and AIR7000.

Discussion

The Defence's ability to trade technical airworthiness against operational airworthiness has given flexibility in the management of Defence UAS. Such flexibility may not exist under the proposed civilian regulatory framework. Even though Civil UAS face additional airworthiness considerations, stakeholders can benefit from the maturity of the Defence's airworthiness program.

SUMMARY

A large number of UAS operations are being conducted globally despite difficulties in obtaining operational approvals. Conditions of current approvals and precautionary regulations inhibit the full exploitation of UAS capabilities.

The absence of a prescriptive regulatory process has provided UAS stakeholders (both civil/commercial and state) with greater flexibility in their proposed risk management processes to meet current operational requirements (i.e., CASR101). This has resulted in a variety of airworthiness approaches, and, in some instances, a duplication of efforts.

It is thought that through greater stakeholder collaboration and sharing of operational and regulatory experiences, that current challenges facing the industry can be overcome. The unique aspects of the Australian operational environment are likely to continue to support UAS deployments.

NEW TECHNOLOGY THEME

The new technology theme contained presentations on topics related to collision avoidance, vision-based techniques and limitations, UAS Risk Analysis and operational risk management, trajectory management, and Air-Ground trajectory synchronization, and sense-and-avoid using radar technologies.

BOEING AUSTRALIA – RADAR TRACKING OF UAS

The first presentation of this session from Michael Wilson from Advanced Unmanned Systems Boeing Australia was on the use of radars to track UAVs. The argument is that the See-and-Avoid principle serves a number of important functions in the Australian air traffic system; however, while it undoubtedly prevents many collisions, the principle is far from reliable.

Some of the limitations of the see-and-avoid function include: those of the human visual system, the varying level of demand on the pilot in performing cockpit tasks, and various physical and environmental conditions. These, and many other factors, combine to make the see-and-avoid function an uncertain method of maintaining traffic separation.

One solution proposed to address some of these issues is the use of radar onboard aircraft to remotely detect, locate, and track potential target objects within a specified region of coverage. The radar system proposed to be used onboard aircraft is similar to the low-powered marine systems commonly used to monitor bird migration or for applications in monitoring the integrity of important structures (power lines, turbines, etc.). These types of radars have a detection range of up to 6 nm with coverage of 360° in azimuth. The radar system has the potential to provide real-time automatic detection and tracking that can be displayed to the operator (or pilot).

Another solution proposed was to use the radar system as a portable ground-based air traffic detection radar. This concept would provide radar separation services only within the small operating footprint of the UAV (e.g., within CTAF-R terminal airspace). All aircraft operating within the vicinity of the UAV would be identified by the UAV ground-based radar operator and be provided a separation service via radio.

Discussion

Boeing Australia is planning to operate a number of unmanned systems over the next 10 years and will seek to overcome the challenges of *"see-and-avoid"* in the vicinity of existing airfields in segregated and non-segregated airspace.

Boeing Australia realises the importance of developing and introducing technology and operational procedures and is working closely with a number of partners to investigate the feasibility of a trial system.

The potential use and introduction of a low-cost radar, together with other see-and-avoid technologies and capabilities, will assist with the routine operation of UAS in the Australian civil airspace system.

BOEING RESEARCH AND TECHNOLOGY, EUROPE

Miguel Villaplana, from Advanced Trajectory Technologies, Boeing Research and Technology Europe (BR&TE) provided a detailed report on air-ground trajectory synchronization based on the Aircraft Intent Description Language (AIDL). BR&TE's perspective is that ATM needs to evolve toward a more strategic, trajectory-based system with increased levels of automation.

1) *Ground-based trajectory computation* (of air traffic) aids in conflict detection and resolution, arrival and departure management, and traffic flow management.

2) *Airborne trajectory computation*, including that for UAS aids aircraft guidance as well as airborne separation assurance.

There are several issues with trajectory synchronisation between the ground-based and airborne systems, these are:

1) In general, each ATM automation tool will rely on a different Trajectory Computation Infrastructure (TCIs), tailored to specific requirements. As a result, different TCIs may produce inconsistent trajectories for the same flight/situation.

2) There is a lack of consistency among airborne and ground-based trajectory predictions.

3) In order to ensure their coordinated operation, the ground-based automation tool must have consistent, synchronized views of the aircraft, so that both operate on the basis of the same trajectory.

4) Given two trajectory computation processes, consistency of the input (aircraft intent) is necessary to ensure consistency in the outputs.

5) The way of describing aircraft intent varies across TCIs: in general; each TCI has its own individual input format.

Despite these issues, commonalities exist at a conceptual level. BR&TE has developed a formal, rigorous method for describing aircraft intent that takes advantage of such commonalities and can serve as lingua franca for TCIs. The Aircraft Intent Description Language (AIDL) can support aircraft intent-based air-ground synchronization through the use of a reduced set of instructions (the AIDL alphabet), any possible aircraft operation could be formally specified in such a way that the ensuing aircraft motion is determined unambiguously.

A common aircraft intent language is seen as a key step toward the reconciliation of different trajectory computation infrastructures. The formal language structure of the AIDL captures the fundamental elements associated in the formulation of aircraft intent, providing a common standard to which any TCI can map.

BR&TE proposes the use of AIDL as a standard means to describe aircraft intent. Aircraft intent is an unambiguous description of how the aircraft is to be operated within a time-frame. At a lower level, AIDL it is the abstraction of the instructions issued by the pilot/FMS to manage the aircraft motion and a key input to the trajectory computation process.

Discussion

The proposed AIDL could serve as the basis to synchronize the views on the future UAS and other aircraft trajectory held by air and ground trajectory-based automation systems. Air-ground synchronization based on the AIDL could potentially allow the seamless integration of UAVs in a trajectory-based ATM environment – only time will tell.

CSIRO - UAS FOR INFRASTRUCTURE INSPECTION

Torsten Merz from CSIRO/ARCAA discussed the challenges of developing a mini-helicopter UAS for infrastructure inspection. Applications include the inspection of power lines, cooling towers, or to assess damage to buildings due to weather. The project focuses on improving the safety and efficiency of such inspections, providing flexible and responsive deployment, and conducting research on dependability and autonomy. The research endeavours to allow fully autonomous inspections, in the sense that a domain expert is only required to provide high-level inputs (which relaxes the requirements on the communication link).

The main challenges for the project are in addressing the dependability of the UAS mechanical, electrical and software systems, limited payload, power and flight time, and UAS autonomy. *"Dependability of a computing system is its ability to deliver service that can justifiably be trusted"* [4], and can be achieved with either fault avoidance (prevention of faults with suitable design and quality control) or fault acceptance (tolerance of faults through error detection and system recovery).

Some of the challenges in the automation process involve:

1) *Manoeuvring in an unknown environment* and avoidance of unknown obstacles,

2) *Unpredictable wind gusts, thermals, and vortices,*

3) *Limited navigational aids* (GPS may not always be available, no artificial landmarks, beacons, etc.)

4) *Forced landing and emergency flight modes.*

Some of the operational challenges include:

1) *Flight testing* of a possibly hazardous vehicle with no emergency stop,

2) *Complex deployment and operational procedures,*

3) *An uncontrollable environment,*

4) *Expense and time to rebuild after crashes*, and

5) *Airworthiness, regulations, and public acceptance.*

To address the regulatory requirements, CSIRO has adopted a progressive approach. Flight tests are currently being conducted on a small UAS over non-populous areas, below 400 feet AGL and at a distance greater than 3NM from aerodromes and outside CTRs. Current operations are also restricted to daytime, VMC conditions. Safety during an operation is managed by the UAS controller who ensures the UAS remains within visual range and maintains a safe distance from third-party people and property.

Discussion

The development of dependable UAS is a significant challenge, not only for CSIRO but the greater UAS community. The automation and operational challenges experienced by CSIRO are not unique to their application and demonstrate the lack of maturity of UAS technology. The application proposed by CSIRO is technically and operationally complex. The solutions developed to realise this complex application will have significant benefits for all UAS operations and applications.

QUT/ARCAA – DEVELOPMENT OF UAS RISK ANALYSIS TOOLS

Reece Clothier, a PhD researcher at ARCAA/QUT, provided an update on the development of risk analysis tools for UAS operations. The presentation emphasised the need for objective reasoning to support the development of effective risk management policy for UAS.

In order to develop appropriate regulations, stakeholders need an appreciation of the risks. The problem comes in that it is not possible to gain sufficient and timely knowledge of the risks through real-life operations alone (regulations are in place to prevent such hazardous events occurring). A solution to this is to utilise risk modelling and simulation tools.

The primary focus of the research is to provide an analytical appreciation of the risks presented to people and property on the ground, so as to:

1) *Support the definition of airworthiness certification categories* which take into consideration the nature of the operation and the environment over-flown;

2) *Understand the effectiveness of different operational and technology-based mitigation techniques* to manage the risks presented to people and property on the ground; and

3) *Provide inputs to and support the development of decision aid tools* such as mission planning systems.

An overview of the causal modelling and simulation framework was provided. The results obtained from the analysis of a case-study mission scenario based on the recent Mariner UAS flight trials were also presented. The analysis used geographical population data and aircraft failure models to evaluate the risk presented to individuals on the ground. The evaluation used the published flight path for the Mariner UAS on approach to RAAF Base Edinburgh and determined that the risks presented by the flight were well under the safety benchmarks currently exhibited by human-piloted aviation. The analysis was useful in identifying a number of high risk areas in the flight plan, and thus, could be used to better direct risk mitigation efforts (e.g., the development of curved approach paths).

The analysis of the case-study scenario demonstrated the effectiveness of even simple risk analysis techniques in the risk management of UAS operations. Results were also presented on the development of multi-criteria mission planning tools [5] that utilise the risk modelling and simulation environment being developed.

Discussion

The need for suitable standards and regulations for UAS has been an overwhelming theme for the workshop. It is essential that the development of regulations is an objective and risk-informed process. Such risk assessment tools could play a significant part in reducing the ambiguity in current regulations (i.e., CASR 101.025, definition of a populous area) and assist in the development of new regulations (i.e., standards for system/sub-system reliability).

QUT/ARCAA – VISION-BASED TARGET DETECTION

Ryan Carnie from QUT/ARCAA discussed the topic of electro-optic (EO) target detection for UAS and presented research on the prediction of detection performance under varying visibility conditions using atmospheric propagation models.

The goal of the research is to develop a computer-vision-based system that provides a level of situational awareness suitable for use as part of a UAS collision avoidance system. The approach uses grey-scale morphology and a track-before-detect algorithm to extract target features in a manner robust to noise, followed by a series of higher-level algorithms based on properties such as feature motion, size, and chromacity to identify genuine collision threats.

The results of field trials were presented, demonstrating the detection of a Cessna 172 target aircraft at a distance of 6.5 km (3.5 nmi). This represents a 35-40% improvement (distance-wise) on the measured performance of an alerted human observer [6]. The trials were preformed with the target aircraft amongst heavy cloud clutter. Also presented was an overview of current research focussing on the impact of varying atmospheric conditions on algorithm performance and using an understanding of atmospheric scattering to provide more effective discrimination against false alarms.

Discussion

The requirement for a non-cooperative collision avoidance capability for UAS operations is well-known throughout the industry. While other technologies, such as radar, may provide situational awareness in a wider range of operating conditions, EO sensors will likely fill an important niche due to their passive nature and close analogy to the human visual system. Understanding the effect that varying visibility conditions have on target appearance and subsequent EO detection performance will likely play an important role in developing future standards.

CAE AUSTRALIA – UAS MISSION TEAM TRAINING

Michael McGarity, CAE Australia discussed Unmanned Vehicle Systems Training and how to conduct training of a UAS Mission Team. According to McGarity, UAS crew training generally centred on the platform and this bias can lead to deficiencies in training. Training must enable UAS crews to fully exploit the capabilities of the UAS and subsequently maximise the operational and mission performance of the system in its role.

Training of UAS operators concentrates on the platform level which successfully addresses issues of platform operation but does not go beyond the operational conversion level, and informational and inter-actional complexity. In addition, most UAS training programs do not address operational tactics that are unique to UAS.

The training of UAS mission teams should consider the following aspects:

1) *Emphasising the UAS operation from a mission team perspective* and support training in all applicable roles.

2) *Emphasising the joint operation of UAS* with other aircraft and operational units, and support the development of joint tactics and doctrine.

3) *Provide training* in an immersive C2 / C4ISR environment.

Training for command staff in charge of UAS should cover:

1) *The capabilities and limitations* in the operation and performance of UAS.

2) *The use of the UAS not only as a "Sensor" but also as an "Effector"* – use of weapons by the UAS / UCAV.

3) *The integration of the UAS* with other air/surface surveillance assets (ISR / ISTAR).

4) *Mission rehearsal in a synthetic environment* to provide opportunities for operational support, such as mission planning and rehearsal.

Another aspect related to UAS training is the crew selection dilemma. The current approach is that long-time operators of the UAS have already decided on the entry requirements for a UAS operator and it makes sense to replicate what has worked successfully for existing operations. However for services new to operating the UAS, there is a dilemma in choosing the "right" type of operator(s).

CAE proposes a modular approach to UAV training, the following modules are considered:

1) *Basic training:* grounds school and UAS operations theory.

2) *Conversion training:* flight training, GCS Training Standard Procedures, Emergency Procedures, VFR Operations, IFR Operations, Instrument Rating, Simulator Check Rides, UAV Check Rides.

3) *Basic OPS Training:* relates to sensor theory, sensor training, target recognition training, EW training, threat evasion, weapons theory, military operations.

4) *Full mission training:* mission planning, sensor operations, CRM training (IP, PO, and MC), surveillance mission profiles (TUAV), surveillance mission profiles (MALE), night and weather operations.

5) *Combat mission training:* affiliation training with other platforms, systems, and units, close air support FAC training, SIGINT / COMINT mission training, net-centric warfare (NCW) training, joint / combined training and exercise participation.

Discussion

UAS are evolving rapidly in terms of their operational potential, therefore it is important to incorporate, develop, and define training strategies that can safely realise this potential. UAS "users" need to realise that the crew of the UAS are more than just "operators." With more and more complex missions being addressed by UAS, it is imperative that UAS training cover the full spectrum of UAV roles and missions.

SUMMARY

There are a number of significant challenges facing the integration of UAS into the existing airspace system, some of which have been discussed previously. It is clear that more research is needed to address many of these challenges.

It is important to acknowledge that the challenges facing UAS can be technical (e.g., developing systems, technologies, and new capabilities) and/or non-technical (e.g., regulatory, natural, airspace, social, and political) in nature. The focus of many research efforts have been on addressing the technological challenges to overcome issues such as sense-and-avoid, or insufficient system reliability. However the technical and non-technical aspects are often inseparable. It is essential that technical research address the many non-technical aspects of the problem. Failure to address such issues will present an obstacle to the practical realisation of a solution to a technical challenge.

Some of the primary issues requiring further and ongoing research include:

1) Research into the issues concerned with the human element of a UAS system, maintenance, and operation. This includes research into Human Machine Interface (HMI), Crew Resource Management (CRM), and training. Providing a better understanding of such issues can have many practical outcomes, including: the development of operator training programs, maintenance practices, and the definition of crew licensing standards.

2) Research into different UAS operational concepts and the potential impacts they have on the existing operational environment. For example, simulating the operation of UAS within different airspace environments to evaluate factors such as risk of midair collision or ATC workload. This research can potentially support the development of requirements on technical systems and provide an input to policy-making.

3) Research into the social aspects of the UAS integration problem. These aspects include

Identifying and evaluating the concerns of key stakeholders such as the public and other airspace users. Understanding these aspects will assist in the development of strategies to better manage stakeholder concerns, and, subsequently, foster a more receptive stakeholder climate.

4) Research into the key technologies which would support increased operational flexibility, predominantly those which address regulatory requirements. These can include: technologies improving system reliability (propulsion systems, etc.), sense-and-avoid, and flight termination systems. This research should also investigate the standards and procedures needed to support the implementation of such technologies.

5) Research into the technologies which support increased UAS capability, particularly in those which improve mission performance. This can include research into the miniaturisation of sensors and payloads, improving overall system efficiency, and increasing the level of automation onboard UAS to reduce the dependency on communication links and operator workload. Increasing the operational flexibility and mission capability of UAS will assist in the continuation of the industry in current and new applications.

CONCLUSION

The future of UAS workshop brought together a cross-section of the international UAS community for discussions on the critical issues of standards and regulations, operational experiences and airworthiness, and new enabling technologies. The three themes covered in the workshop have been summarised in their respective sections and discussions have been given on the presented material. The workshop fostered collaboration of key stakeholders on important issues and provided an environment for the development of solutions that will ultimately progress the UAS industry internationally and within Australia.

One fundamental observation drawn from this workshop is the "chicken and egg" relationship between the operation and regulation of UAS in the current aviation environment. That is, UAS operations are currently limited by the lack of prescriptive regulations and the development of regulations still requires the demonstration of UAS capabilities.

It took approximately 20 years from the birth of aviation before the air commerce act of 1926 was set in place. This landmark legislation was implemented at the request of the aviation industry who believed that the full commercial potential of the aeroplane could not be realised without Federal Government intervention to improve and maintain safety standards. The UAS industry now faces the difficult task of integrating a fundamentally new concept of aviation into an existing highly regulated environment – this was not the case at the birth of aviation. At that time, the aviation industry was able to rely on a progression of operational experiences to develop regulations that have been updated and further defined over the last 80 years.

The difficult task facing the UAS industry today can only be solved with the collective effort of groups, both technical and lobbyist, from around the world. The diversity of these approaches will assist in finding the optimal global solution, so long as the international efforts are collaborative and communicate in a coordinated manner.

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