ABSTRACT

This paper reviews the whole issue of UAV Airworthiness and Airspace Integration from the perspective of a manufacturer who has accumulated more than 120000 hours of in service flight experience, considering the entire fleet of IAI UAV products. It includes a brief survey of various UAV certification rule-making activities in Europe, USA and the rest of the world, considering IAI-Malat active involvement. The paper subsequently reviews the experience of current IAI-Malat products “airworthiness” and “operational” approvals. In particular, the highlights of the recent and unique B-Hunter UAV System Airworthiness Certification process successfully conducted for the Belgian MoD are presented, among other examples of IAI-Malat growing experience in European countries. Then, a summary of most significant related requirements or criteria (known or to be borne) having a major impact on UAV design is presented. At last, conclusive thoughts are presented.

INTRODUCTION

There is currently a growing demand - both in the field of military or potential civilian applications - for UAVs to be flown with less and less restrictions in terms of overflown territory or airspace zones. Appropriate solutions shall be subsequently found with regard to UAV Airworthiness and Airspace Integration issues:

- On one hand, Airworthiness certification, aiming at having a safe and reliable UAV design system and at reaching an adequate flight safety level, so that the risk to overflown population and ground properties is brought down to a level equivalent to manned aircraft equivalent category
- On the other hand, Airspace Integration, or at a broader scale Operational Certification, considering the need to operate the UAV within ever increasing portions of airspace, the risk of air collision should not be higher than be for manned aircraft equivalent category.

UAV industry is challenged to take both aspects into consideration at an early stage of the design and development, in a context of still poorly defined certification rules, despite the worldwide proliferation of draft UAV rule-making attempts.
UAV CERTIFICATION RULE-MAKING ACTIVITIES

Certification is usually defined as the “legal recognition by a certifying_authority that a product complies with applicable requirements.” This means that the following must be clearly identified when envisaging UAV airworthiness and operational certification:

• The national or international relevant law
• The official body granting the certification
• The product configuration to be certified
• The applicable technical and administrative requirements or criteria.

There is an astonishing proliferation of draft UAV rule-making activities at international level, even if, at this stage, in most of the cases, the above elements remain still vague and not formally defined for the UAV international community.

There is nevertheless a growing willingness from official bodies all over the world to tackle the issue of UAV Airworthiness Certification and Airspace Integration rules. A good indication is the recent creation of a taskforce by the European JAA, in which IAI-Malat is actively represented, in order to define a “concept” of UAV regulation till October 2003. Australia has been pioneering in recently establishing a formal UAV regulation. It has already published a CASA Part 101 [Ref. 19] covering “Unmanned Aircraft and Rocket Operations” dealing with general issues such as General Operation of UAVs, Certification of UAV controllers and Operators.

Although this international UAV rule-making process still goes in a rather “anarchic” way, one may highlight the following points:

• The general objective is to create a UAV regulation that will parallel the manned aircraft regulations in order to ensure that an UAV does not create greater safety risk to population or properties on ground and to other manned airspace users than equivalent manned aircraft “category”.
• There is an overlap – sometimes confusing - between Civil and Military UAVs in terms of applicable certification criteria. On one hand, Military and Civilian UAV airworthiness certification processes should normally remain clearly separated (different authorities, different requirements). On the other hand, such overlap seems to be inevitable with regard to Airspace Integration issues, since both civilian and military UAVs aim at using ever-increasing portions of civil airspace.
• The way to categorize the regulation as a function of UAV class or type (e.g. (weight / kinetic energy at impact together with kind of operations) is still under debate.
• It is likely that short term policies / practical guidelines will be defined and that final regulation will be established on the basis of the experience gained in using these short term policies.
The issue of Detect/See and Avoid remains a central issue governed by three interrelated aspects:

- Legal issue\(^1\) (“see and avoid” onus to UAV operator only or / and ATC controllers, when flying under controlled airspace)
- Technological constraints (in particular “non cooperative” technologies)
- Definition of the future ATM environment (e.g. ADS-B prevailing TCAS?)

Future UAV regulation shall cover the following areas:

- **Airworthiness Certification**, including
  - System Safety Objectives and Criteria
  - “JAR/FAR” Airworthiness Code specifically tailored to UAV but based upon & derived from manned aircraft requirements
  - Additional specific UAV Criteria (Communication Data Link, GCS/HMI, “Security” aspects)

- **Operational Certification**, including
  - UAV Operations within ATM environment / Airspace Integration
  - Operator qualification and training
  - Maintenance / Continued Airworthiness

**IAI-Malat Background Experience**

During the past 26 years, IAI-MALAT products have accumulated more than 130,000 flight hours of operational experience (20 customers worldwide). This experience largely supports the approach being defined in this paper with regard to Airworthiness and Airspace Integration issues.

\[^1\] See for instance current rules such as ICAO Annex 2: “It is important that vigilance for the purpose of detecting potential collisions be not relaxed onboard an aircraft in flight, regardless of the type of flight or the class of airspace in which the aircraft is operating, and while operating on the movement of an aerodrome” or FAR Part 91.113: “When weather conditions permit, regardless of whether an operation is conducted under IFR or VFR rules, vigilance shall be maintained by each person operating an aircraft so as to see and avoid other aircraft”.

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Among IAI-MALAT UAV products upon which experience is being drawn are the following products:

- **Pioneer System**, a second-generation UAV system (an advanced derivative of the first generation Scout System) is in operational use with the U.S. Navy. The Pioneer is currently marketed by Pioneer UAV Incorporated (PUI), a joint company of AAI and IAI. The US Navy and Marines successfully deployed the Pioneer during the Gulf War and later to Bosnia and Kosovo for use in peace enforcement operations.

- **Ranger System**, a third and fourth generation UAV system, specifically designed to meet European environmental conditions. ADS-95 systems have been delivered to the Swiss Army and to the Finland Army. The system is marketed jointly by MALAT and SF (the Swiss Aircraft and Systems Enterprise Corporation).

- **Searcher/ Searcher II Systems**, advanced third and fourth generation tactical UAV systems, which provide day & night real-time imagery data. The Searcher systems are in operational use with the IDF and other foreign customers.

- **Hunter System**, a third-generation multi-role short-range UAV system selected by the U.S. Army and Marines for their Short-Range requirement. The system has been deployed successfully to Macedonia providing daily 24-hour coverage of targets over Kosovo. The system flew more than 670 sorties / 3800 flight hours, operating from civilian airfields in conjunction with airplanes and rotary-wing traffic. In total, the US Hunter has accumulated more than 20000 flight hours since the beginning of the program. The system is produced jointly by IAI / MALAT and the TRW Avionics Systems Division, San Diego, California. In 1997, France has also acquired one Hunter system (the F-Hunter) that is operated as an operational demonstrator by the French Air Force. In December 1998 the Belgian Army awarded a contract to the Eagle association (a teaming of IAI with Belgian companies SONACA and THALES) for the supply of three B-Hunter UAV systems of the fourth generation. B-Hunter system incorporates new Avionics, an Advanced Ground Control station as well as a full Automatic take-off and landing system.

- **Heron system**, a family of fourth generation Medium-Altitude, Long-Endurance Strategic UAV systems in operational use with the IDF and ordered by other foreign customers.

**“Airworthiness” approvals**

“Airworthiness” approvals have been generally dealt with within the framework of the system requirements, often “hiding” design airworthiness and safety requirements. Such a process was, for instance, successfully performed for IAI-MALAT UAV systems like the US SR-Hunter, French F-Hunter and worldwide sold Searcher. The Ranger System has also gone through a qualification and certification process under the Swiss Federal Department of Defense.
The B-Hunter Certification Precedent

The B-HUNTER System represents however the most original and interesting airworthiness certification precedent. BMoD contract indeed included a special clause relating to a formal airworthiness certification process to be conducted with the military certification body.

The B-Hunter Certification Basis was made of:
- System Safety Program requirements based upon MIL STD-882C
- JAR VLA (Very Light Aircraft) tailoring
- Specific UAV Airworthiness Requirements based upon NATO guidelines (annex to AC 92D967)

Compliance demonstration with all the requirements contained in the certification basis was then conducted, based upon Engineering Design Data and Analyses, a detailed Safety Hazard Analysis - based upon an agreed Hazard Risk Assessment Matrix - as well as an Operational Support Hazard Analysis, a full Safety Assessment Report, including software criticality assessment (tailored DO-178B methodology), and equipment qualification testing. At last, Ground Tests and Flight Tests specifically related to these airworthiness requirements were performed, including system failure demonstration and Automatic Take-off and Landing capability.

A B-Hunter Airworthiness Certification Dossier was subsequently compiled, including Manufacturer’s Airworthiness Statement with relevant Type Certification Data Sheet, Airworthiness Verification Data Base and reference to all relevant manuals stating normal and abnormal procedures, airworthiness limitations and safety instructions.

These activities has led to the granting by BMoD of a Temporary Certificate of Airworthiness in March 2001 at the end of the Industrial Qualification phase, allowing the start of B-HUNTER validation flight test campaign in Belgium. Those validation tests were fully coordinated ATC coordination for the use of Belgian airspace portions and corridors, have been successfully concluded, leading to the final system delivery after customer training qualification and to the granting of the final Certificate of Airworthiness.

Operational approvals

The respective military authorities also gave operational approvals of the IAI-MALAT products mentioned above. In most cases, the reserved portions of airspace used by the UAV are under the full control of the military Air Traffic Control (ATC) Authority, which ensures the necessary coordination with the civil ATC wherever required. For instance, in the case of the F-Hunter, a step-by-step process has been applied. After an appropriate confidence level was reached, based on the high-level reliability and in-service record of the system, the F-Hunter was progressively allocated dedicated corridors to fly from one reserved portion of airspace to another one.

In the United States, besides the Hunter that has been flown under the control of military authorities, a demonstration of the IAI Firebird 2001 (civilian UAV prototype for forest fire
surveillance application and assistance to fire brigades) was successfully carried out in the State of Montana. IAI-MALAT went through the currently applicable procedure in the USA. A “Certificate of Waiver or Authorization” (FAA form 7711-1) was finally issued by the Manager of the Air Traffic Division of the FAA Northwest Mountain Region.

The MALE (Medium Altitude Long Endurance) generation

IAI Heron system operated in the IDF constitutes the basis the new generation MALE systems offered and ordered throughout the world. It takes advantage of all the experience presented above. Airworthiness and Airspace Integration aspects as per the approach presented in this paper have been considered at an early stage of the design. It benefits from the lessons learned from the experience in terms of flight safety whereas the causes of major in service events have been analyzed and converted into design safety improvements, in particular airframe designed as per tailored FAR/JAR 23, system redundancies and automation, certified engine, full Automatic Take-off and Landing capability and Ground Control station optimized in term of Human Machine Interface. The overall safety improvement trend brings this MALE system to the level of general aviation safety level.

In term of Airspace Integration, it includes all the features and safety equipment to enable Air Traffic Control communication and to minimize the risk of air collision, as identified below.

The Civil UAV European Initiative

The European Commission has accepted to share the funding of various Research and Development projects related to potential civil UAV applications. A thematic network “UAV-Net” was created, gathering some 19 European partners of the European Community States and Associated States to advance the development of UAVs for civilian purpose. This thematic network serves as a forum for information exchange, for suggesting new policies and for launching critical technology network. Two dedicated projects emanated from this network:

- “CAPECON” to identify potential civil UAV applications and define system configurations
- “USICO” to recommend practical UAV airworthiness and operational certification procedures, to review the technological aspects related to the “see/sense and avoid” issue and to validate the corresponding concepts.

IAI Engineering Divisions and Malat Divisions are actively involved in these activities that have been initiated in 2002 and shall be completed in 2004.
SUMMARY OF MOST SIGNIFICANT CRITERIA

Although, as stated above there are not yet detailed formal applicable requirements for UAV Airworthiness and Operational Certification, one can summarize the following most significant potential criteria that have major impact on UAV design and development.

AIRWORTHINESS ASPECTS

The prime golden rule is that the entire UAV system, as a whole – Air Vehicle, Ground Control Station and Communication Data Link – should be “airworthy”.

UAV Airworthiness certification and any future regulation shall address the following topics:

- System Safety Objectives and Criteria
- Tailoring of manned aircraft requirements of corresponding category and compliance (JAR/FAR)
- Additional criteria related to specific UAV features such as Communication data Link, Ground Control station and Flight Termination system.

System Safety Objectives

UAV System Safety Objectives and Assessment Criteria are based upon a certain number of basic assumptions and rules:

- The most severe event (“Catastrophic Effect”) for an UAV mishap is the impossibility to control the UAV flight, leading to an “uncontrolled” crash and subsequent fatalities severe damages on the ground.
- The “controlled” loss of UAV over an unpopulated areas would be thus of a less severe category from a safety assessment point of view.
- An Overall Safety Objective (in term of Probability Target) shall be set for the “uncontrolled UAV crash”, consistent with the risk of Catastrophic Event for equivalent manned aircraft category and possibly considering the hit probability as a mitigating factor. The rationale for quantitative safety objective used in manned aircraft certification criteria such as FAA AC23.1309-1C may be a good basis, provided the “hit on the ground” probability is accounted for, considering the population density.
- There should be an inverse relationship between the probability of a failure and its severity effects, as per a hazard assessment risk matrix considering the two above assumptions.
- In addition, basic design rules (such as fail safe concept and subsequent redundancies or back-up features) shall be applied in order to minimize the risk of uncontrolled crash and UAV loss.

Tailoring of Manned Aircraft Airworthiness Certification Code

In the absence (yet) of specific JAR/FAR code for UAVs, tailoring existing manned aircraft requirements of equivalent category seems to be the best approach in order to reach appropriate level of safety for the UAV Air Vehicle covering performance,
Tailoring means that, in agreement with the relevant “certifying” body, one should categorize – and bring the corresponding rationale for – each of these requirements e.g. in the following manner:

<table>
<thead>
<tr>
<th>Category</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>Requirement Not Applicable, as “obviously” not relevant (either to UAV applications per se or due to specific UAV configuration)</td>
</tr>
<tr>
<td>F</td>
<td>Requirement may be Fully applied as currently worded</td>
</tr>
<tr>
<td>I</td>
<td>The “Intent” of the requirement may be applied, but not as exactly worded. It is to be interpreted to render suitable to UAV applications.</td>
</tr>
<tr>
<td>A</td>
<td>Alternative criteria may be proposed, based upon a wise balance between safety and unnecessary economical burden that the requirement could bring if literally applied.</td>
</tr>
</tbody>
</table>

### Additional Airworthiness Criteria

Additional airworthiness criteria should address specific UAV aspects not necessarily covered above, such as:

- **Communication Data Link** (EMI protection, securing - encrypting & non interference from any foreign entity, failure handling - Return Home logic, ATC alerting.
- **Ground Control Station** (Human Machine Interface with the aim at minimizing the impact of potential human errors, required safety warnings and indications to be provided, failure handling, including power supply redundancy requirements, minimum crew required for safe operation)
- **Flight Management System, including flight control and navigation aspects** (fail safe principles, performance aspects)
- **Flight Termination System** (autonomous pre-programmed control, predefined alternate emergency recovery sites considering Air Vehicle gliding capability)
- **Emergency electrical power** of enough capacity to perform emergency landing.
- **Hardware & software qualification** (at system and equipment level)

Compliance demonstration with all above requirements shall be conducted, as for any other certification process, around verification means to be negotiated with the relevant certifying body (engineering analyses, inspection, laboratory, ground and flight tests). Out of this process, normal & abnormal procedures, airworthiness & safety limitations and possibly safety related maintenance tasks are to be clearly defined and compiled in the appropriate operating manuals.
AIRSPACE INTEGRATION ASPECTS

The issue of UAV Airspace Integration shall also be tackled with a global approach. The ultimate goal – even if it may have to be achieved on a step-by-step basis – is the full integration of the UAVs in the airspace and the removal of “segregating” restrictions that today impose them to fly in reserved airspace portions.

The bottom line is that, viewed from ATC, UAV should not be different from other manned aircraft sharing the same airspace.

As prerequisite conditions, before envisaging such integration, the following is to be assumed:

- UAV system has been shown / certified to be “airworthy” in line with the previous section.
- UAV is to be operated in accordance with normal, abnormal procedures and limitations resulting from this airworthiness certification process.
- Compliance with (possibly, here also, tailored) manned operational requirements is to be ensured.
- UAV operators are properly qualified
- UAV System is maintained as per appropriate maintenance procedures for continued airworthiness purpose.

The need for larger airspace portions - before full airspace integration can be achieved – may be satisfied by allocating corridors to fly from one reserved portion of airspace to another one. This allows creating - on the basis of still existing restricted areas - larger portions of airspace open to the UAVs, while minimizing the need for additional airspace.

In order to achieve full airspace integration, one will have to provide an acceptable solution for the “see/sense and avoid” issue. While this may not be yet a 100% solution, integrating the following features in the UAV do contribute - at least in the transitional context envisaged in the previous paragraph – to minimize the risk of collision and bring some “see and avoid” capability:

- IFF transponder capable of mode S (including automatic switching logic to predefined emergency codes in case of critical failure)
- Voice Relay (VHF/UHF) radio-communication, from the Ground Control Station to the ATC via the Air Vehicle.
- Anti-Collision Strobe Lights
- Forward Vision camera

Before defining and embarking on the 100% “see/sense and avoid” solution, it is of utmost importance to carefully examine the following parameters:

- The class of airspace envisaged including IFR / VFR considerations.
- The legal “onus” for the UAV operator
- The technological constraints in terms of “see/sense and avoid” equipment
All this is to take place within the context of a future Air Traffic Management environment still under gestation. The optimal solution should possibly have to combine the use of cooperative technologies (TCAS II, ADS-B) with non-cooperative technologies (optical or radar based sensors).

CONCLUSIVE THOUGHTS

As someone put it, “the trouble with the future is that it usually arrives before we are ready for it”. The future of UAV integration in the airspace is indeed about to arrive, while the regulatory framework and some of the potentially required technologies still need some maturation. A short term “confidence building” step by step approach opening the pace for the long term “full scale” integration is probably the so called “shortest long way”. IAI-Malat does propose, based on its UAV fleet considerable experience, the building blocks for such an approach, thanks to well proven airworthiness & safety design features, ATC communication capability, manufacturer’s airspace “cultural” background and system flexibility and growth potential capability for implementing future requirements and technological improvements.