

**STUDY TO ADDRESS THE DETECTION AND
RECOGNITION OF LIGHT AIRCRAFT IN THE CURRENT
AND FUTURE ATM ENVIRONMENT**

ISSUE 1.0

FINAL REPORT

This document has been produced for EUROCONTROL by Lockheed Martin STASYS Limited, The Granary, 1 Waverley Lane, Farnham, Surrey, GU9 8BB under the terms and conditions of Contract 460.

ISSUE STATUS

| Issue Number | Date of Issue |
|--------------|--------------------------------|
| 0.1 | 14 th December 2004 |
| 0.2 | 20 th December 2004 |
| 0.3 | 22 nd February 2005 |
| 0.4 | 23 rd February 2005 |
| 0.5 | 25 th February 2005 |
| 0.6 | 7th March 2005 |
| 1 | 31 March 2005 |
| 1.0 | 2 May 2005 |

RECORD OF AMENDMENTS

| Amend't Number | Date | Reason for Change | Amended by | Date Entered |
|----------------|--------|---|------------|--------------|
| 1.0 | 020505 | Minor amendments resulting from the discussion of the draft final report. Ref. email STASYS 25 April2005 | Berends | 020505 |
| | | | | |
| | | | | |
| | | | | |

QUALITY ASSURANCE

ORIGINATION

This issue was prepared for release by:



Mr David Fisher

Principal Consultant – ATM & Airports

31 March 2005

QUALITY REVIEW

This issue has been subject to a release quality review to ensure conformance with the baseline company quality requirements.

Review conducted by:



Mr Darren Roberts

Senior Consultant – ATM & Airports

31 March 2005

Release approved by:



Mr Peter Green

Business Area Manager – ATM & Airports

31 March 2005

CONTENTS

| | |
|--|------|
| REFERENCES | VIII |
| EXECUTIVE SUMMARY | XI |
| 1 INTRODUCTION | 1 |
| 2 BACKGROUND | 2 |
| 3 DEFINITION OF LIGHT AVIATION | 3 |
| 4 OPERATIONAL CONTEXT | 8 |
| 4.1 SCOPE | 8 |
| 4.2 BACKGROUND | 8 |
| 4.3 CURRENT LIGHT AVIATION OPERATIONAL REQUIREMENTS..... | 9 |
| 4.4 CURRENT PROBLEMS | 9 |
| 4.5 ATM INCIDENTS ACROSS EUROPE..... | 15 |
| 4.6 FUTURE AIRSPACE STRATEGY FOR THE ECAC STATES | 15 |
| 4.7 FUTURE LIGHT AVIATION OPERATIONAL REQUIREMENTS..... | 17 |
| 4.8 FUTURE PROBLEMS | 17 |
| 5 HAZARD SCENARIOS..... | 19 |
| 5.1 SCOPE | 19 |
| 5.2 SEPARATION ASSURANCE | 19 |
| 5.3 ATM INTEROPERABILITY | 20 |
| 6 TECHNICAL CONTEXT | 21 |
| 6.1 HISTORY..... | 21 |
| 6.2 TECHNICAL DETAILS OF SSR | 21 |
| 6.3 ASSOCIATED TECHNICAL REGULATIONS..... | 22 |
| 6.4 TECHNICAL INTEROPERABILITY ISSUES | 23 |

| | | |
|-----|---|----|
| 6.5 | HEALTH AND SAFETY | 24 |
| 6.6 | ELECTROMAGNETIC COMPATIBILITY (EMC) | 24 |
| 6.7 | POWER AVAILABILITY..... | 25 |
| 6.8 | EQUIPMENT LOGISTICS | 25 |
| 6.9 | MAINTENANCE ISSUES | 26 |
| 7 | STUDIES, TRIALS AND TECHNOLOGY DEVELOPMENTS..... | 27 |
| 8 | REGULATORY CONTEXT | 28 |
| 8.1 | GENERAL | 28 |
| 8.2 | POLICY OBJECTIVES | 28 |
| 8.3 | ICAO..... | 28 |
| 8.4 | EUROPEAN COMMUNITY | 28 |
| 8.5 | EUROCONTROL..... | 29 |
| 8.6 | OPTIONS | 30 |
| 8.7 | NEXT STEPS | 30 |
| 9 | POTENTIAL SOLUTIONS FOR THE IDENTIFIED HAZARDS..... | 32 |
| 9.1 | GENERAL SOLUTIONS..... | 32 |
| 9.2 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 1 | 34 |
| 9.3 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 2 | 35 |
| 9.4 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 3 | 36 |
| 9.5 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 4 | 36 |
| 9.6 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 5 | 37 |
| 9.7 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 6 | 37 |
| 9.8 | SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 7 | 37 |
| 9.9 | SOLUTIONS FOR ATM INTEROPERABILITY SCENARIO 1 | 38 |

| | | |
|------|---|----|
| 9.10 | SOLUTIONS FOR ATM INTEROPERABILITY SCENARIO 2 | 38 |
| 9.11 | SOLUTIONS FOR ATM INTEROPERABILITY SCENARIO 3 | 38 |
| 10 | REQUIREMENT FOR A LOW POWER LAST | 39 |
| 11 | IMPACT ASSESSMENT OF THE SSR SOLUTIONS | 40 |
| 11.1 | ECONOMIC BENEFITS | 40 |
| 11.2 | ECONOMIC COSTS..... | 40 |
| 11.3 | SOCIAL | 41 |
| 11.4 | SAFETY..... | 41 |
| 11.5 | TECHNICAL | 42 |
| 11.6 | ENVIRONMENTAL..... | 42 |
| 12 | RESULTS OF RESEARCH AND CONSULTATION | 44 |
| 13 | IMPLEMENTATION, MONITORING AND COMPLIANCE ISSUES..... | 45 |
| 14 | SUMMARY AND CONCLUSIONS | 46 |
| 15 | RECOMMENDATIONS | 51 |
| 16 | ABBREVIATIONS AND DEFINITIONS | 53 |
| 16.1 | ABBREVIATIONS..... | 53 |
| 16.2 | DEFINITIONS..... | 57 |

Annex A – Current Light Aviation Operational Requirements

Annex B – ATM Incidents Across Europe

Annex C – Studies, Trials and Technology Developments

Annex D – Results of Research and Consultation

REFERENCES

- 1 Task Requirement Sheet No: TRS/120/04.
- 2 Financial Proposal – Price Declaration AF3/2TRS.
- 3 EUROCONTROL Operational Concept Document, Volume 1 (The Vision), Edition 2.1, 12 January 2004.
- 4 EUROCONTROL Airspace Strategy for the ECAC States, Edition 1.0, 18 January 2001.
- 5 Single European Sky mandate, Justification Material for the Draft Implementing Rule on Airspace Classification in the Lower Airspace, Edition 1.0, 31 January 2005.
- 6 The Netherlands Aeronautical Information Circular Series B, 04/04, 1 April.
- 7 Overflying a Cluster of Gliders II (Final Episode)
- 8 Adelard –D/240/1705/4v1.0 15th December 2004
- 9 BEKLAS – Project final presentation 27th May 2004
- 10 Communication Research Centre Ottawa – Radar detectability of light aircraft.
- 11 DERA – Report into the trial of a Collision Avoidance System for Light Aircraft DRA/LSC1XT/LAC_AVOID REPORT Copy 5
- 12 ICAO Annex 6 Part 1
- 13 EASA Certification Documentation: CS22, 23, 27, VLA and VLR
- 14 EASA EU1592 Annex 2
- 15 FLARM – Transponders and Gliding Good or Evil?
- 16 Housard – Mid Air Collision 2nd February 1998
- 17 Marconi Electronic Systems – Low Cost Collision Warning System Feasibility Study.
- 18 NLR – Lightweight transponder – UK evaluation trials directed towards use in light aircraft and gliders.
- 19 NRPB – Exposure to Pulsed UHF Radiation Transmitted by Racal Lightweight Transponder.

- 20 UK CAA Directorate of Airspace Policy Mode S Fact Sheet Version 1.2
- 21 UK CAA Directorate of Airspace Policy Operational Requirement for a Lightweight Transponder (Draft ref 8AP/65/02/74)

Websites

www.aaib.gov.uk

www.alair.com/inspections/Aviation_Authorities.htm

www.alaska.faa.gov/capstone

www.aopa.co.uk

www.bfu.admin.ch

www.bfu.web.de

www.caa.co.uk/dap/document.asp?groupid=694

www.caa.co.uk/default.aspx?categoryid=423

www.caa.co.uk/docs/7/DAP_SSM_Mode_S_SSR_Factsheet.pdf

www.cena.fr/~sagnier/datalink/mode_s/mode_sa.htm

www.dg-flugzeugbau.de/transponder-e.html

www.easa.eu.int/certspecs_en.html

www.eurocae.org/cgi-bin/home.pl?Target=va/description/background.html&Num=1

www.filser.de

www.flarm.com/files/transponders_en.pdf

www.garmin.com/products/comparison.jsp

www.gfs.de/org

www.icao.int

www.pegasusaviation.co.uk/Quik.htm

www.rvtv.nl

www.sensis.com

www.stna.aviation-civile.gouv.fr

www.tc.gc.ca/CivilAviation/International/APEC/recommendations.htm#Air%20Traffic%20Conflict

www.vliegalseenvogel.nl

EXECUTIVE SUMMARY

State regulatory authorities are coming under increasing pressure to address how best to accommodate the recreational and sporting aviation community in the face of significant actual and forecast rises in Commercial Air Transport (CAT) activity so as to utilise the airspace more efficiently whilst maintaining or improving safety. In particular, there is a perceived urgent need to extend SSR transponder carriage by both motorised and non-motorised light aircraft in order to support the effectiveness of ACAS, as well as to enhance the effectiveness of Air Traffic Services (ATS). This is set against the background of ICAO Annex 6 Standards and Recommended Practices (SARPs) that are applicable to all international general aviation operations with aeroplanes and helicopters, which must now be equipped with a pressure-altitude reporting transponder. However, there is currently no agreed operational requirement for the regulation of extended SSR transponder carriage by light aircraft in Europe due to differences in the way airspace is currently managed by State authorities and a lack of appropriate airborne equipment, especially for gliders, balloons and microlights.

This study has attempted to take a broad view of the issues and to define and quantify the operational problems and hazards for which solutions are needed, both today and in the context of future airspace structures and requirements. A variety of stakeholders have been consulted, particularly members of the General Aviation community, and it has proven to be a highly emotive and complicated subject. The issues cross the boundaries of many different aviation domains, including those of safety, airspace management, regulation, surveillance and communications. Furthermore, due to the diversity of European airspace, individual State regulations and methods of capturing and publishing safety data, it has been extremely difficult to make a comprehensive quantitative analysis of the current risks caused by non-transponder equipped light aircraft operations in Europe.

The study has identified many potential individual hazards but they all fall into just two overall categories, namely Separation Assurance and Air Traffic Management (ATM) Interoperability. The potential solutions to manage these hazards are as varied as the risks they seek to resolve and include procedural, technological and educational components. Individually, no one possible solution addresses all the hazards identified and, in many cases, only a combination of several solutions is likely to be wholly effective. Furthermore, some of the solutions might not actually be practical or acceptable to regulators, service providers or airspace users. However, in the majority of the scenarios, extended carriage of SSR transponders on light aircraft would seem to provide mitigation for some or all of the risks. This seems to be especially the case in high traffic density airspace where there is a significant mix of IFR and VFR operations and in, particular, the potential for IFR/VFR encounters at the boundaries of Controlled Airspace.

A common application of SSR transponder carriage by all aircraft across Europe would provide the means for a 'Known' traffic environment across the board and make a significant contribution to ATM interoperability for all classes of aircraft in all categories of present and future airspace. If the forecast traffic growth figures for the 2020 timeframe come to fruition, the need for such a 'Known' traffic environment would seem to be inevitable. In particular, without such interoperability, the pressure to increase the amount of Controlled Airspace to protect CAT will be extremely vigorous. In itself, this

would have a detrimental impact on risks elsewhere, as other users would then be forced to operate, squeezed together, in decreasing volumes of uncontrolled airspace.

Nevertheless, an across the board enforcement of SSR transponder carriage would be highly controversial, potentially expensive for recreational and sporting aviators and probably not justifiable in such an overwhelming manner within several European States. Therefore, it might be best left to individual State regulatory authorities to determine the extent of the implementation of a 'Known' traffic environment based on SSR in their airspace.

The main issue that would have to be overcome for extending SSR transponder carriage to all aircraft encompasses the technical feasibility of equipping certain categories of light aircraft. Suitable equipment and international standards do not yet exist for SSR transponders to meet the needs of aircraft such as gliders, microlights and hang gliders. In particular, battery consumption in high density airspace, power output, cost and the portability of transponders are hurdles that need to be overcome. In addition, in the high traffic density airspace of many European States, only a Mode S solution would be acceptable.

It must be emphasised that SSR should not be viewed as the panacea for reducing all the risks in isolation. Improved capturing and exchange of safety data across Europe would add significantly to decision making in this area, as would a greater understanding of airspace use by light aircraft. Also, increased education in and awareness of the risk issues for each sector of the aviation community could be used to good effect. Efforts to improve the efficacy of 'See and Avoid' for VFR flights, as well as improving real-time ATM relevant information available to light aircraft pilots is well worthy of in-depth investigation.

A beneficial initial step towards addressing all the issues identified in this report would be to open up the debate throughout the pan-European aviation community. This could be accomplished through the issuing of an Advanced-EUROCONTROL Notice of Proposed Rule Making discussion paper to set out the issues and to seek widespread stakeholder views and comment.

1 INTRODUCTION

- 1.1 This study is in response to EUROCONTROL TRS 120/04, the objective of which was to determine the current and future operational requirements for the recognition and detection of individual light aviation aircraft by ATM systems and Airborne Collision Avoidance Systems (ACAS) and to assess the feasibility of equipping airframes to meet such requirements.

- 1.2 The study report is structured to define and quantify the operational problems and hazards for which solutions are needed. It then defines procedural, technical and regulatory solutions that could address these problems, both today and in the context of future airspace structures and requirements. The study then sets out the impacts of the solutions. It takes account of the ICAO Annex 6 Standards and Recommended Practices (SARPs) applicable to all international general aviation operations with aeroplanes and helicopters to be equipped with a pressure-altitude reporting transponder.

2 BACKGROUND

- 2.1 There are currently no harmonised European operational requirements concerning the regulation of extended transponder carriage requiring a standard or low-powered Light Aviation SSR Transponder (LAST). This is mainly due to the absence of an agreed operational requirement, differences in the way airspace is currently managed by State authorities and a lack of appropriate airborne equipment, especially for gliders, balloons and microlights.
- 2.2 State regulatory authorities are coming under increasing pressure to address how best to accommodate the recreational and sporting aviation community with rising Commercial Air Transport (CAT) activity in a way that utilises the airspace more efficiently whilst maintaining or improving safety.
- 2.3 Therefore, there is a perceived urgent need to extend transponder carriage by both motorised and non-motorised light aircraft in order to support the effectiveness of ACAS, as well as to improve the effectiveness of Air Traffic Services (ATS) and efficiency of airspace use.

3 DEFINITION OF LIGHT AVIATION

3.1 Sporting and light aircraft/aeroplanes have been defined using the EASA type certifying standard and the Sports Codes of the Fédération Aéronautique Internationale (FAI). The FAI is a world organisation concerned with large scale sports competitions, space activities and other performances requiring certification to stage. The FAI unites the National Air Sport Control (NAC) organisations, which administer sporting activities in their own countries. For the scope and purposes of this study, the target population of light aviation is seen as follows:

- a) **Light Aeroplanes.** This group is defined by EASA CS-23 as normal, utility, aerobatic and commuter type aeroplanes. They may seat 9 or fewer occupants, excluding the pilot, and must have a maximum certified take-off weight of 5,670kg or less. Also classified as light aeroplanes are those propeller driven twin engine aeroplanes in the commuter category that have a seating configuration of 19 or fewer occupants and a maximum certified take-off weight of 8,618Kg or less. This type is classified by the FAI as a Class C aeroplane described as a fixed wing aerodyne with a means of propulsion. This category of light aviation falls within the ICAO definition of aeroplane and requires equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- b) **Very Light Aeroplanes.** This group is defined by EASA CS-VLA as an aeroplane with a single engine (spark or compression-ignition) having no more than 2 seats, a maximum certified take-off weight of no more than 750kg and a stalling speed in landing configuration of no more than 45 kt CAS. This category is used for day VFR operations only and is not permitted for aerobatic operation. The aircraft are also classified by the FAI as a Class C aeroplane. This category of light aviation falls within the ICAO definition of aeroplane and requires equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- c) **Amateur Aircraft.** These are not classified by EASA standards (see paragraph 3.4 below) but they are defined by EASA as aeroplanes where at least 51% has been built by an amateur, or a non profit association of amateurs, for their own purposes and without any commercial objective. Amateur aircraft could fall into a number of FAI classifications depending upon their specification. Powered amateur aircraft fall within the ICAO definition of aeroplane and require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.

- d) **Gliders (motorised and non-motorised).** This aircraft group is defined by EASA CS-22 for powered & un-powered sailplanes in utility (normal soaring flight) and aerobatic categories. In this category, the sailplanes' maximum weight must not exceed 750kg and this must take into account the occupant(s)' weight plus a parachute weight of 55kg. For powered single engine sailplanes, the weight to span² ratio should not be greater than 3kg/m and the maximum weight should not exceed 850kg. For both powered and un-powered sailplanes, the occupancy should not exceed 2 persons. Gliders and motor gliders are classified by the FAI as Class D aerodynes. Powered sailplanes fall within the ICAO definition of aeroplane and require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- e) **Small Rotorcraft.** These are defined by EASA type certifying standard CS27. They are rotorcraft with a maximum weight of 3,175kg or less and nine or less occupants. The definition can also include some multi-engine rotorcraft if the design installation and performance requirements of Appendix C of CS-27 are met. A rotorcraft is also classified by the FAI as 'an aerodyne that derives the whole or a substantial part of its lift from a rotary wing system' and is a Class E aerodyne. This category of light aviation falls within the ICAO definition of helicopter and requires equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- f) **Very Light Rotorcraft.** These are defined by EASA certifying standard CS-VLR and they must have a maximum certifying take-off weight of not more than 600kg and they must be simple in design. They must carry no more than two occupants and are not to be powered by turbine and/or rocket engines. These rotorcraft types are restricted to day VFR operations. This rotorcraft type is also classified by the FAI as Class D. This category of light aviation falls within the ICAO definition of helicopter and requires equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- g) **Microlights and Ultra-light Aircraft.** These aircraft do not have any EASA certifying type standards and are therefore controlled by national regulations. They are defined as low energy aeroplanes limited by one or more of the following characteristics: stalling speed; weight to surface area ratio; maximum take-off weight; maximum empty weight; fuel quantity; number of occupants/seats. Microlights are also defined by the FAI as 'a one or two seat aeroplane with a specified maximum mass and characterised by a very low wing-loading'. Microlights fall into Class R of the FAI classifications. This category of light aviation falls within the ICAO definition of aeroplane and requires equipage with ICAO compliant SSR transponders under Annex 6 SARPs.

- h) **Hang Gliders.** Hang gliders are not classified by EASA type certifying standards but are recognised by EASA as aircraft that can take-off and land using the pilot's own muscular energy and potential energy. The FAI also recognises non-powered hand gliders as a 'glider capable of being carried, foot launched and landed solely by the use of the pilot's legs'. Non-powered hang gliders are classified as Class O by the FAI. However, powered hang gliders are classified as Class R. Powered hang gliders are hang gliders fitted with means of propulsion capable of launching it and sustaining flight. Powered hang gliders fall within the ICAO definition of aeroplane and require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- i) **Historic and Vintage Aircraft.** Aircraft in this category are sometimes referred to as 'War birds'. These aircraft are not restricted by EASA certifying standards (see Annex 2 of EU 1592 & paragraph 3.4 below) and could fall into a number of FAI classifications depending upon their specification. This category of light aviation falls within the ICAO definition of aeroplane and requires equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- j) **Para Gliders.** As for hang gliders, para gliders have no EASA certifying standards but are classified by the FAI as Class O and are defined as a hang glider with no rigid primary structure. However if the para glider is fitted with a means of propulsion capable of launching it and sustaining flight, it becomes classified as Class R. Powered para gliders fall within the ICAO definition of aeroplane and require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- k) **Gas and Hot Air Balloons.** These are not defined by EASA and do not fall within the ICAO definition of aeroplane or helicopter. Therefore, they do not require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- l) **Free Balloons.** These are defined by the FAI as Class A. A free balloon is an aerostat, supported statically in the air, with propulsion by any power source. This category does not fall within the ICAO definition of aeroplane and does not require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- m) **Airship or Dirigible.** These are recognised by the FAI as Class B aerostats, equipped with a means of propulsion and steering. This category does not fall within the ICAO definition of aeroplane and does not require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.

- n) **Motorised/non-motorised Parachutes.** Parachutes are defined by the FAI as ‘a collapsible device designed to counteract gravity using forces exerted upon it by the air’. These are classified as Class G by the FAI. This category does not fall within the ICAO definition of aeroplane and does not require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
 - o) **Model Aircraft.** Unsurprisingly, these are not included in EASA certifying standards but are recognised by the FAI as Class F aircraft having ‘limited dimensions, with or without a power source, not able to carry a human being. This category does not fall within the ICAO definition of aeroplane and does not require equipage with ICAO compliant SSR transponders under Annex 6 SARPs.
- 3.2 The FAI also has classifications for vertical take-off and landing aeroplanes, human-powered aircraft, spacecraft, tilt wing/tilt engine aeroplanes, short take-off and landing aircraft, aero spacecraft and space models. However, these are not considered relevant for the purposes of this study.
- 3.3 There is a proposal to change the existing EASA certifying classifications to establish a new set of standards between the 750kg and 5,700kg classes. This new class would potentially extend from 2,730kg to 5,700kg for single engine, non complex aeroplanes. Very light aeroplanes would continue to go up to a maximum weight of 750kg with 2 occupants and a new sporting aircraft class may well be established. There is also call for an ultra light classification for non powered aeroplanes with a maximum weight of up to 472.5 kg (450 kg plus a fixed rescue system allowance of 22.5kg) and another for aeroplanes up to 120kg maximum weight.
- 3.4 Annex 2 of EU1592 identifies those aircraft to which the EASA certifying standards stated in this document do not apply. These include aircraft with a historical relevance, aircraft designed for research/experimental purposes, amateur aircraft, aircraft designed solely for military purposes, gliders with structural mass of less than 80kg or 100kg (depending on seat numbers), unmanned aircraft with a mass less than 150kg, aircraft with a total mass less than 70kg and aircraft in paragraph (e) of Annex 2 with restricted CAS and MTOM.
- 3.5 Of the aforementioned aeroplanes and helicopters identified as requiring an ICAO Annex 10 compliant transponder to meet Annex 6 SARPs, it is believed that some or all airframes in the following categories could not currently comply due to a lack of a currently available technical solution:
- a) Very Light Aeroplanes.
 - b) Amateur Aircraft.
 - c) Very Light Rotorcraft.
 - d) Microlights and Ultralights.

- e) Powered Hang Gliders.
- f) Historic and Vintage Aircraft.
- g) Powered Para Gliders.

4 OPERATIONAL CONTEXT

4.1 SCOPE

- 4.1.1 This section links current day operational issues into the ATM 2000+ concepts and timescale of 2015-2020. It firstly establishes a view of the current user requirements of recreational and sport flying and then sets out the problems of integrating this activity with other sectors of the aviation industry. It draws heavily on consultation with the GA community, NAAs and ANSPs. The section then takes a view of ECAC airspace in 2020 and sets out user requirements in that context, before highlighting the future integration challenges. Where possible, quantitative data has been captured and included.
- 4.1.2 Using this analysis, scenarios have been described in Section 5 below, which illustrate the hazards and risks of integrating light aviation aircraft with other aviation sectors. The approach has been chosen to help identify whether or not there is currently a strong operational requirement for detecting and recognising all light aviation aircraft and whether or not this requirement will exist in the future.

4.2 BACKGROUND

- 4.2.1 In the years 2000+, European ATM must simultaneously generate extra capacity to meet the forecast increasing traffic demand, increase safety levels and reduce unit costs. Airspace users, faced with greater competition as markets are de-regulated, are calling for more flexible and cost-effective services. Unless action is taken to produce the required additional capacity, the gap between the demand for air transport and ATM capacity may well increase to such an extent that ATM-related delays, costs and effects on the environment will be completely unacceptable to passengers, freight carriers, airlines and the business jet and GA communities. Interoperability and flexibility between the diverse users of European airspace is a fundamental element for meeting the challenges of the future.
- 4.2.2 Mindful of the current public intolerance of risk, NAAs are under pressure to increase the volumes of controlled airspace (CAS) for the protection of CAT and to increase the carriage of SSR transponders to maximize the interaction with ACAS. This also forms the background to the relevant ICAO Annex 6 amendments. If a proliferation of CAS to protect CAT is to be avoided, the need for improved separation assurance measures, which would require visibility of all aircraft in a given volume of airspace, will become ever more prominent.

- 4.2.3 Germany, Austria, Switzerland and Hungary do not currently allow any IFR flights in Class G airspace below 3000ft due to safety concerns. This principally relates to the relaxed ICAO VMC minima in Class G (and Class F) in this level band. The theory is that, in the worse case scenario, IFR flights emerging from cloud could have a VFR flight in close proximity with insufficient reaction time to avoid collision. This regulation came in several years ago, long before any notion of extending mandatory SSR transponder carriage by GA VFR flights. Also, there are increasing concerns emerging from GATCO, BALPA and IFALPA about the mixing of IFR and non-SSR transponder VFR flights in unregulated airspace at whatever altitude.
- 4.2.4 SSR is now an invaluable tool in the provision of Air Traffic Services within Europe and one on which major ANSPs have become almost totally reliant. Therefore, with the increasing volume and intensity of CAT, which is forecast to double between 2004 and 2025, there is bound to be a cementing of new SSR technology inside CAS, such as the introduction of Mode S, on safety and capacity terms.
- 4.2.5 Clearly, there are two opposite ends of the spectrum for resolving these challenges and risks: either total segregation of conflicting activity or full interoperability of users based on common technological equipage. Unfortunately, the impact of either of these solutions is likely to be significant and disproportionate on differing sectors of the aviation community.

4.3 CURRENT LIGHT AVIATION OPERATIONAL REQUIREMENTS

- 4.3.1 Annex A provides a summary of the operational requirements for light aviation as captured in the course of this study.

4.4 CURRENT PROBLEMS

- 4.4.1 Some aircraft types are more at risk of causing a collision than others. For example, microlights pose a risk due to the type of flying they conduct. Approximately 58% of their flying is in Class E airspace but only 10% carry a transponder. They also fly significant distances, thereby increasing the statistical chances of meeting with another aircraft. Likewise, ballooning is often carried out in Class E airspace (36%) but only 35% of balloons are fitted with transponder equipment. Gliders pose a risk because of their great numbers in the sky at any one time. Modern gliders are also extremely hard to acquire visually when they are in 'straight and level' flight, especially from the 'head on' profile.

- 4.4.2 Unfortunately, in trying to obtain ATM incident data for the various European States, a task that has proved extremely challenging, a number of issues have become apparent. Firstly, there seems to be a lack of co-operation and harmonisation of safety activities across Europe, which makes data difficult to obtain. For example, the Director of the UK AIRPROX Board has no contacts with other similar European bodies. Some States appear to have little ATM incident data assimilated and are reluctant to publish data to third parties due to liability issues. Some information is available on the internet but each country seems to publish different information, which makes comparisons difficult. Accumulation of the same data across Europe is therefore not possible at the present time. Of most relevance to this study, there does not appear to be much ATM incident data available that identifies the airspace in which the events occurred. A summary of the incident data captured during this study is at Section 4.5 below
- 4.4.3 In many States, there appears to be a lack of co-ordination with a central AIRPROX board. Therefore, many different organisations have an input into the collection of data, which makes ownership confusing. Lastly, there is evidence of different European States emerging with different studies or reports into the problems associated with the detection and recognition of light aircraft. However, these efforts do not seem to be co-ordinated across Europe but it is understood that the EUROCONTROL Performance Review Commission is addressing this shortcoming. With greater standardisation of the ATM incident data, a clearer picture of the problems faced by GA flights could be established. With greater harmonisation of the efforts to improve the situation for light aircraft, progress in safety improvements would be more rapid. One noteworthy comment from a member of the UK AIRPROX Board was that he believed up to 75% of AIRPROXs involving light aviation in the UK could be avoided through improved information flow and education.
- 4.4.4 **Separation Assurance.** There is a perceived increasing risk of mid-air collisions involving GA aircraft outside of CAS. The current operational hazards can be broadly defined as follows:
- a) VFR GA flights sharing airspace with IFR CAT flights. The perceived collision risk is greatest in uncontrolled airspace where the mix of IFR and VFR aircraft is high. However, there is also a risk of collision in some CAS when an aircraft without a transponder is not detected by either a surveillance radar or ACAS. Modern light aeroplanes, executive jets and privately owned 'Warbirds' can operate at fast speeds and so closure rates can be considerable. The visual conspicuity of gliders, microlights and hang gliders can also be very low. There are some who view 'See and Avoid' in uncontrolled airspace to be ineffective at speeds in excess of 150 kt.
 - b) VFR GA flights sharing airspace with military aircraft on training sorties when flying in unregulated airspace. This presents a risk of collision, particularly at low-level where the 'See and Avoid' principle may not be effective at high closure rates against small

GA aircraft. This is especially the case with 'head on' profiles. Terrain cover and camouflage is also a major factor to consider for this issue and so there are differing levels of risk between States and within different portions of airspace within those States.

- c) Military and GA VFR flights sharing airspace with aeroplanes and helicopters conducting Aerial Work in unregulated airspace. These include pipeline inspection helicopters and Police Air Support Units, where the activity takes place at low-level using the 'See and Avoid' principle. Due to the perceived risk of collision, many of these special task aircraft now carry basic collision avoidance systems to supplement 'See and Avoid'. In many cases, insurance companies insist on this equipage.
- d) VFR GA flights sharing airspace with other GA aircraft in unregulated airspace. The use of Business Jets has increased and some glider pilots believe that the 'look-out' conducted by crews of these aircraft and other GA aircraft is not as good as that of military crews. Due to the ACAS II mandates and the availability of low cost TCAS I systems, Business Jets are increasingly likely to be equipped with either ACAS II or TCAS I.

4.4.5

Interaction With Collision Avoidance Systems. Collision avoidance systems are now fitted widely on all types of aircraft. However, as not all aircraft are equipped with pressure altitude reporting transponders, the full benefits of wider ACAS equipage are not currently being maximized:

- a) ACAS II Phase 2 (and Phase 3 in the future?) has reduced considerably the size and type of aircraft on which ACAS II equipage is mandatory. Although this regulation has been mainly aimed at CAT operating within the confines of CAS, it has also increased the likelihood of many ACAS II equipped aircraft operating in unregulated airspace. Moreover, there is now a greater frequency of direct routings through Class G airspace for CAT traffic that is equipped with ACAS II. This trend is expected to continue with the increased use of regional airports and the growth of low cost airlines.
- b) There have been anecdotal reports of significant numbers of ACAS II nuisance alerts being experienced by CAT when operating at the lateral and vertical edges of CAS, especially near the London TMA. This has been caused by ACAS II interaction with aircraft operating in adjacent unregulated airspace without the pressure altitude reporting being recognized. The result is a flight safety risk caused by cockpit distractions and by the risk of useful TAs being ignored.
- c) Mindful of the perceived risk of collision between military aircraft and other military or civil aircraft, at least one military authority has embarked on a procurement process to equip both combat and training aircraft with SSR-based collision warning/avoidance systems. Without widespread carriage of pressure altitude

reporting SSR transponders throughout European airspace, the benefits of this procurement will not be maximized.

- d) Although not mandated, the favourable price and availability of TCAS I systems has meant that voluntary equipage is becoming more widespread in privately owned aircraft.

4.4.6 **ATM Interoperability.** In the current climate of increasing traffic growth and diverse operational requirements of the different sectors of aviation, 'optimum' airspace design and efficient ATM are becoming increasingly more difficult to accomplish:

- a) Over the last few decades there has been increasing reliance by ANSPs on SSR data for the provision of radar services and aircraft separation/sequencing. Reliance on pressure-altitude reporting is particularly apparent. The vast majority of airfields and airports use SSR data, either from an indigenous source or from a 'feed' from an adjacent sensor. Where aircraft are not equipped with SSR transponders, interoperability is difficult to achieve efficiently and safely.
- b) Airspace design is difficult and airspace management less efficient because of the need to manage and mix 'Known' and 'Unknown' traffic environments. Furthermore, adopting FUA in the lower airspace is currently very challenging to deploy safely because it is not a 'Known' traffic environment. For example, with an 'Unknown' traffic environment, temporary airways from regional airports cannot be activated and deactivated to meet demand. Warning systems, such as those based on SSR, could be needed to assist with the safe management of situations if FUA in the lower airspace was broken. Although, there are some views that current airspace design in some States is not sufficiently cognisant of the capabilities and performance of modern CAT aircraft.
- c) In order to reduce costs and maximize profit, an increasing number of opportunities are being sought by CAT operators for more direct routings through unregulated airspace. These are typically organized during periods of low military activity, or when military ATC agencies are able to offer control services to civil aircraft. Furthermore, low cost airlines are more likely to operate from smaller airports, which might not necessarily be directly linked to the en route CAS structure. Certain portions of these flights may, therefore, take place in unregulated airspace. Typically, this will be during the critical take-off and approach phases of flight.
- d) Recent traffic growth is resulting in increased pressure on NAAs to enlarge the amount of CAS used to protect CAT. This is largely because a current lack of harmonised transponder carriage requirements reduces the interoperability between CAT and GA aircraft. This increase in CAS is having an adverse effect on

military and recreational flying and 'funnels' this activity into smaller volumes of airspace.

- e) In the UK over the last 5 years, there has been an increased use of SSR Mode A codes for conspicuity purposes at aerodromes. Airfields without SSR have been allocated conspicuity codes that they can assign to aircraft on their R/T frequencies. This indicates the agency to which they are talking to the wider ATC community and helps to facilitate better co-ordination of these aircraft with adjacent ATC units. Similarly, airfields with SSR data are also using codes to provide conspicuity on certain aircraft, such as visual circuit traffic. This increases the situational awareness of controllers. However, the procedures only work with transponder equipped aircraft and so, currently, the benefits of these arrangements are not being maximized.

4.4.7 Provision of Air Traffic Services. The provision of ATS to recreational flyers is a politically charged issue and difficult to accomplish:

- a) GA aircraft frequently require CAS crossing services, which can be difficult to manage when the aircraft is not equipped with an SSR transponder. Controller workload is increased in these situations and it is harder to integrate these aircraft into the 'Known' traffic environments around airfields.
- b) Low-level radar services (LARS) are offered by some civil and military ANSPs. Offering services to 'non-transponder equipped' aircraft increases the workload of controllers significantly.
- c) Controllers providing CAS crossing services or LARS have difficulty in detecting, identifying and maintaining the identity of aircraft with a low primary radar cross-section on some of the older legacy radars when the aircraft is not SSR equipped.
- d) Aircraft with good primary radar cross-sections are also still difficult to identify in busy airspace when they are 'non-transponder equipped'.

- 4.4.8 **Airspace Infringements.** Infringements of CAS continue to occur throughout Europe. Activity close to the boundaries of CAS, particularly large TMAs, can be significant with aircraft trying to minimise routings around it. Furthermore, with the capability of modern navigation equipment, the general trend of accurate flying in the current 'GPS for all' climate can bring light aviation VFR aircraft even closer to those boundaries. Providing mitigation against the safety consequences of infringements of Controlled Airspace (CAS) is a major requirement for NAAs and ANSPs. UK NATS believes that extensive prosecution for airspace infringements does not support safety, as it encourages people not to call up on the radio for help if they are lost. Safety is significantly improved in these circumstances if aircraft can be seen and pilots are in communication with ATC. SSR transponders help to prevent accidents when infringements occur through the enabling of safety systems. These include ATC instructions, collision avoidance systems and conflict alert tools. Airspace infringements are also easier to manage with SSR, as it presents the opportunity to provide more information for all participants.
- 4.4.9 **Renewable Energy.** In order to meet targets on the use of renewable energy, there has been a significant increase in the number of planning applications for wind energy turbine sites. This is presenting considerable difficulty for ANSPs and the aviation industry:
- a) Aircraft detection difficulties will be caused by primary radar clutter/reflections from wind turbine developments. Aircraft without SSR could be masked by this clutter.
 - b) Management and approval of planning applications will prove to be increasingly difficult as wind turbine sites proliferate. The cumulative effect of developments will become a more challenging issue and mitigation for aircraft detection will need to be addressed.
 - c) All classes of airspace are affected by wind turbine proliferation. To ensure flight safety, mitigations on how and where aircraft are handled will have to be put in place if detection cannot be assured. These measures could have an adverse effect on capacity and efficiency.
- 4.4.10 **Transition to Emerging Technology.** Some NAAs believe that there is a need to provide a migratory path from current SSR technology to future systems such as ADS-B/Data Link. Interoperability between legacy and emerging technology will need to be assured and 'backwards compatibility' between surveillance systems will be an important issue. A 'big bang' approach to implementation would not be possible due to the scale of aircraft and ground station equipment that would be required. Furthermore, continued interoperability will be particularly important where ACAS is involved.

4.5 ATM INCIDENTS ACROSS EUROPE

4.5.1 Annex B provides an indication of the ATM incidents across Europe in recent years.

4.6 FUTURE AIRSPACE STRATEGY FOR THE ECAC STATES

4.6.1 Current forecasts indicate that the level of CAT flights will at least double in the ECAC area between 2004 and 2025. Unfortunately, the existing ATM systems are unlikely to be able to meet this expected demand. In response to this, a comprehensive, 'gate-to-gate' oriented ATM Strategy for the years 2000+ was developed. One of the main areas for change highlighted in the ATM 2000+ Strategy concerns the organisation and use of airspace. This is because a major obstacle to producing more en route capacity is that, to date, effective use of European airspace has not been optimised.

4.6.2 EUROCONTROL has developed an Airspace Strategy for the ECAC States, which delivers a set of strategic objectives and actions for the provision of a harmonised framework for airspace planning for the entire ECAC airspace up to 2015 and beyond. The Strategy seeks to describe a simplified airspace organisation based on new or adapted airspace structures permitting their uniform application and leading to an optimised and harmonised organisation throughout Europe.

4.6.3 Within the Airspace Strategy document, a Traffic Environment Model is set out, which may eventually replace the current ICAO airspace classification. It refers more directly to airspace structures and attempts to further elaborate on the aforementioned airspace regimes so as to better meet user requirements. The Model refers to the following three categories of environment in accordance with the ATS level of knowledge of traffic operating within them:

- a) **Unknown Traffic Environment (U).** This is an environment within which not all traffic is known to ATS. Within this environment, continuous two-way communication and a transponder will not always be required and traffic will not always be subject to ATC clearance.
- b) **Known Traffic Environment (K).** This is an environment within which all traffic is known to ATS either with position only or with flight intentions as well. Within this environment, continuous two-way communication may be required, a transponder will always be required but not all traffic will be subject to ATC clearance.
- c) **Intended Traffic Environment (N).** This is an environment within which all traffic is known to ATS, both with position and with flight intentions. Within this environment, continuous two-way communication and a transponder will always be required and all traffic will be subject to ATC clearance.

- 4.6.4 It is planned to achieve a smooth transition from the current situation to a harmonised and simplified airspace organisation using the following steps:
- a) Harmonisation of the ICAO airspace classification of all Upper ECAC airspace above a common agreed level. This is currently referred in some States to the Upper/Lower Airspace Division Level, which is sometimes referred to as FL 'X'.
 - b) Harmonisation and simplification of the application of the ICAO airspace classification in all ECAC Airspace.
 - c) Reduction of the number of the different ICAO airspace classes to only the three categories of environment (N, K & U).
 - d) Harmonisation of the Division Level between the K and U traffic environment categories to a commonly agreed Base Level, which is sometimes referred to as FL 'Z'.
 - e) Reduction of the number of airspace categories to only two categories (N & U) by gradually moving FL X towards FL Z so that there will be no further need for the environment category K.

4.6.5 Some progress has now been made towards achieving the overall long-term aims. To all intents and purposes by the end of 2005, ECAC airspace will be a uniform Class C above FL195. However, the UK will not implement Class C until Spring 2006. The next phase is maturing rapidly, with 24 ECAC States already having widespread CAS from FL95 upwards, France with FL115 upwards and the rest with either no flight level or a base of FL195. The trend is clearly towards FL95 in the medium-long term.

4.6.6 Much of the aforementioned strategy is subject to negotiation and consultation, probably through Single European Sky Implementing Rules. It is by no means clear what the final airspace structure will be in 2020. However, any future requirements for the detection and recognition of light aviation need to be considered in the context of this Airspace Strategy. Therefore, for the purposes of this Study, the following assumptions have been made with regard to the European airspace structure that could be in place by 2020:

- a) All airspace at and above FL 95 will be CAS, with either a category N or K traffic environment.
- b) Airspace below FL 95 will generally be uncontrolled airspace, with a category U traffic environment. However, the study is mindful that it is the wish of some ANSPs and NAAs to categorize all airspace as K outside of Temporary Segregated Airspace (TSA) and Temporary Restricted Airspace (TRA) below FL 95.

- c) When IFR flights are expected below FL 95 or when visual separation is considered as safety critical for IFR flights, category N or K airspace will be established.

4.7 FUTURE LIGHT AVIATION OPERATIONAL REQUIREMENTS

4.7.1 Light Aviation is expected to grow proportionately to the economies that it serves. In the future, if General Aviation and Aerial Work operators require continued access to CAS and airports at reasonable cost, their activity is likely to be largely centred on less congested airports. Recreational and sporting aviation operating under VFR will require a legitimate right of access to European airspace and Aerial Work will need to be able to reserve airspace for particular operations. Furthermore, about 10% of Light Aviation activity will continue to be conducted under IFR, as it is today.

4.7.2 In general terms, the future operational requirements of the Light Aviation sector will be as follows:

- a) Maximum freedom of movement within all airspace regimes and environments.
- b) Operations under VFR using the 'See and Avoid' rule.
- c) The right to change flight rules from IFR to VFR, and vice versa, in the air or at least to receive special handling.
- d) Sufficient uncontrolled airspace and VFR access to CAS, free flight and dynamic routing.
- e) Sufficient contiguous airspace to permit unrestricted cross country flying.
- f) The ability to reserve airspace for particular activities.

4.7.3 UAV operators will require accommodation of their activity, based on shared use of airspace instead on segregation.

4.8 FUTURE PROBLEMS

4.8.1 Consultation with stakeholders has revealed that, although the types of hazards are expected to remain broadly similar in any future European airspace structure, the current level of risk will increase significantly as CAT levels grow and the timings of military activity change to meet training requirements. All the problems identified in Section 4.4 above will therefore remain valid in the 2015-2020 timescale.

- 4.8.2 As 80% of recreational and sporting flying activity occurs at weekends, the risk of collision between GA and military aircraft is currently reduced considerably during the working week. However, in the future it is likely that the military working week will have to be extended to facilitate more flying training for the likes of the Typhoon and JSF squadrons. In addition, the number of main operating bases will be reduced and so the airspace around the remaining ones will become busier and for longer periods than at present.
- 4.8.3 The future integration of civil and military UAVs in the European Region is also an increasingly important issue. It presents many challenges for the maintenance of safety:
- a) Future requirements for 'Sense and Avoid' functionality will almost certainly include the use of SSR as one element of a collision avoidance suite. This will be necessary to ensure interoperability with current ATM surveillance and ACAS technology. However, it will be very difficult to meet safety needs and assure the public if not all aircraft will be carrying SSR transponders.
 - b) It might not be possible to equip very small UAVs with SSR transponders that are in accordance with current ICAO Annex 10 SARPs. Therefore, the problems faced with detecting and recognising Light Aircraft may also apply to some UAVs.

5 HAZARD SCENARIOS

5.1 SCOPE

5.1.1 This section sets out the scenarios that are representative of the current and future problems detailed in Section 4 above. They capture the issues on a European wide basis and were subject to consultation at focus groups. The scenarios are categorized in accordance with the perceived overall operational requirement that the study is seeking to identify. The section distinguishes between routine day-to-day activity and special events.

5.2 SEPARATION ASSURANCE

5.2.1 **Scenario 1:** Collision risk between IFR CAT and VFR GA aircraft in the vicinity of an airport. This will typically be either as a result of an airspace infringement into the CAS surrounding the airport or from a mix of IFR and VFR traffic in the uncontrolled airspace just outside the CAS. This is a hazard about which some NAAs and ANSPs are extremely concerned and it is recognized by some sectors of the GA community. In the future ATM environment, the risks are expected to increase as the level of CAT continues to grow.

5.2.2 **Scenario 2:** Collision risk between IFR CAT and a VFR GA aircraft in the en route phase of flight. This hazard is of less concern as the vast majority of the IFR CAT en route activity is confined to CAS. Moreover, any en route activity in uncontrolled airspace takes place above FL 95. Typically, this will be a Known traffic environment either through the implementation of Class C or D airspace or, as in the UK, SSR transponders are required in Class G airspace above FL 100. However, the risks could increase with the continuing trend in the use of regional airports by low cost airlines and on the pressure for more direct routings for CAT.

5.2.3 **Scenario 3:** Collision risk between military aircraft and VFR GA aircraft. This hazard is of significant concern to many NAAs and some GA user groups across Europe. The perceived hazard is greater in the lower airspace in the en route phases of flight but significant risks are present close to military and GA airfields. In the future, the risks could increase significantly if military forces extend the working week into weekend flying to meet training capacity requirements. A marked proliferation of CAS could also force GA and military activity closer together in decreasing volumes of uncontrolled airspace.

5.2.4 **Scenario 4:** Collision risk between two VFR GA aircraft in uncontrolled airspace. This is a very real hazard in all phases of flight and, in particular, in popular flying areas. It is not anticipated that the risks will decrease in the future. Indeed, if the implementation of CAS proliferates, the risks will increase as GA activity is forced to operate in smaller areas of uncontrolled airspace.

- 5.2.5 **Scenario 5:** Collision risk created by large scale GA special events or unusual activity such as 'fly-ins', competitions and 'social meets'. Generally, these events are well planned and notified and so the risk to non-participating aircraft is lower than one might expect. However, the increasing performance and mobility of aircraft such as gliders is increasing the risk that clusters could occur routinely in areas of favourable weather conditions or informal gatherings.
- 5.2.6 **Scenario 6:** Collision risk associated with the non-detection of an aircraft masked by 'clutter' on primary radar in the vicinity of a wind turbine development. The cumulative effects of these developments are becoming an increasing concern to NAAs and ANSPs and the risks will only increase in the future as further deployments in large numbers are permitted.
- 5.2.7 **Scenario 7:** UAV operations in unsegregated and uncontrolled airspace. This is currently only a marginal problem but pressure to permit these operations on a routine basis will increase in the future. The ability to safely employ an equivalent 'See and Avoid' technique for UAVs is currently the cause of considerable debate. However, with the current SSR equipage requirements for Light Aviation in uncontrolled airspace, the current interoperability issues will be very difficult to resolve.

5.3 ATM INTEROPERABILITY

- 5.3.1 **Scenario 1:** Provision of radar services to IFR CAT aircraft in uncontrolled airspace. The lack of height and intention information on non-participating traffic makes the maintenance of separation standards extremely challenging, with resultant adverse effects on controller workload, capacity and efficiency.
- 5.3.2 **Scenario 2:** Provision of radar services for a non-SSR equipped GA aircraft in uncontrolled airspace or during a CAS crossing. This is a particular challenge because identification is potentially difficult to achieve and then maintain. Once again, there are resultant adverse effects on controller workload, capacity and efficiency.
- 5.3.3 **Scenario 3:** Implementation of FUA in the lower airspace. This is likely to become an increasingly important issue in the future as a means of integrating the increasing demands of CAT and military activity. However, the ability to activate temporary airspace at lower levels will be hampered by the lack of technical interoperability between diverse aviation sectors.

6 TECHNICAL CONTEXT

6.1 HISTORY

6.1.1 Improving the detection and recognition of light aircraft within the current ATM environment may require a technical solution. Primary radar is a tool by which controllers have maintained separation of aircraft for many years. Due to the small radar cross-section of many light and sporting aircraft, detection by this means is difficult.

6.1.2 In the 1960's, a study was conducted by the Netherlands National Physics Laboratory with RAE Farnborough and Lasham gliding club. Difficulty in maintaining aircraft separation arose from the close proximity of the Lasham Gliding Centre to the approaches at Farnborough airfield. The majority of gliders or sailplanes were constructed almost entirely of non-metallic materials and consequently were less readily detected by radar.

6.1.3 The study examined the use of a passive devices fitted to gliders to enhance the effective echoing area. Evaluation of the results and discussions with ATC authorities led to the conclusion that an operationally acceptable answer was unlikely to be found in passive devices and that attention should be drawn towards the development of a lightweight battery-powered transponder.

6.1.4 Additionally, a study carried out as far back as the 1970's by the Communication Research Centre in Ottawa came to the following conclusion: "the most obvious and most effective solution to the problem of detecting light aircraft is to require that all aircraft operating in certain airspace be fitted with SSR transponders". This is the same conclusion that many regulatory authorities are now endorsing.

6.2 TECHNICAL DETAILS OF SSR

6.2.1 Some light and sporting aircraft already carry some form of SSR transponder onboard. Currently, this is likely to be a Mode A/C transponder. This section briefly explains the differences between Mode A/C and Mode Select (Mode S) transponders, and how ACAS interacts with them.

6.2.2 In Mode A, the radar beam interrogates the transponder and the transponder replies by sending its identity code back to the controller. This enables the aircraft to be recognised. In Mode C, the transponder also sends altitude data with the Mode A identity code. This is sourced from a static pressure altimeter within the aircraft or from a separate altitude encoder. The main problem with the Mode A/C detection is interference caused by garbling and False Replies Unsynchronised In Time (FRUIT). Garbling occurs when the replies from two proximate aircraft overlap in time and, therefore, interfere with one another. FRUIT replies occur due to one aircraft replying to another interrogation in the vicinity.

6.2.3 Mode S solves most of the problems associated with Mode A/C. Mode S is based on a selective roll call procedure which consists of simultaneously interrogating single aircraft, which can be unambiguously identified using ICAO 24-bit aircraft addresses, so as to remove the problems of fruiting and garbling. Mode S Elementary Surveillance is the minimum surveillance functionality foreseen for aircraft equipped with any type of Mode S transponder. The basic functionality of the Mode S transponders provides the following:

- a) Range and azimuth measurement.
- b) Mode A and C (pressure altitude reporting) decodes.
- c) Unique ICAO 24-bit aircraft address.
- d) Automatic reporting of aircraft identification.
- e) Transponder capability report.
- f) Flight status.

6.2.4 Mode S Enhanced Surveillance provides all the functionality of Elementary Surveillance with additional data. This is not a requirement for light aircraft as most, if not all, are not fitted with the avionics to source such data.

6.2.5 Airborne Collision Avoidance Systems (ACAS) are mainly fitted to commercial aircraft and they interrogate all aircraft within their vicinity that are fitted with either Mode A/C or Mode S transponders. ACAS then computes the information in order to determine conflicting trajectories. It uses conflict resolution algorithms to avoid potential collisions and ACAS II advises the crew of required avoidance measures. Although ACAS does work with Mode A/C transponders, the performance of the system is degraded due to the problems of garbling and FRUIT. The ACAS performance is much improved with the use of Mode-S transponders. Sometimes, the Traffic Collision Avoidance System (TCAS) can be referred to rather than ACAS. TCAS is the name adopted by a particular manufacturer for their ACAS system. TCAS is often referred to instead of ACAS, as most commercial operators have installed TCAS and become familiar with its term.

6.3 ASSOCIATED TECHNICAL REGULATIONS

6.3.1 ICAO Annex 6 requires that, from 1 January 2003, all aeroplanes and helicopters shall be fitted with a pressure-altitude reporting transponder which operates in accordance with the provisions of ICAO Annex 10, Volume IV (subject to national exemptions). Annex 6 defines "Aeroplanes" as a power-driven heavier-than-air aircraft, deriving its lift in flight chiefly from aerodynamic reactions on surfaces which remain fixed under given conditions of flight. Therefore, the SARPs are not applicable to non-motorised and/or lighter-than-air aircraft such as gliders and balloons.

- 6.3.2 NAAs publish detailed transponder carriage requirements through national AICs. In general though, a few States propose to mandate Mode S Enhanced Surveillance for all IFR flights operating in densely populated airspace, such as TMAs and en route airspace, from 31 March 2005 (if above certain weight and airspeed restrictions). In other types of airspace, Mode S Elementary Surveillance will be more widely required in Europe for all categories of flights from 31 March 2008. Therefore, a significant proportion of the GA community will be required to fit Mode S Elementary surveillance by 31 March 2008.
- 6.3.3 EUROCAE has developed a set of operational performance standards for a LAST (ED-115), as proposed by WG 49. This working group envisages a version of a LAST that is compliant with the ICAO power output requirements, as currently contained in Annex 10. However, Annex 10 and MOPS do not currently support a low power variant of a transponder, which would be required by many light aircraft due to power constraints and health risks, described below.
- 6.3.4 The main problem for smaller aircraft types is the lack of availability of suitable equipment. There is currently no licensed product available that can meet user requirements and international standards. Developing such a transponder is achievable but the main issue is one of power. The unit needs to be low powered to maintain battery life for those aircraft that do not have an external power supply, and to reduce health and safety risks to the crew. However, current international regulations are such that all SSR transponders manufactured and fitted must meet ICAO SARPs power requirements to ensure correct surveillance and ACAS performance.
- 6.3.5 General aviation communities and transponder manufacturers are waiting in anticipation for the NAAs to agree upon a set of standards that are acceptable for a low power LAST. At the moment, a degree of uncertainty remains. Trials must be conducted to determine whether the EUROCAE LAST standards can be successfully adopted by all aircraft types below 5,700kg before development and licensing of products is achieved.
- 6.3.6 As part of this study, a number of avionics manufacturers were recently contacted to determine whether they had any intention of producing a Mode S LAST transponder. Becker, Dittel, Garmin, Unitel and Filser were contacted and only one company, Filser, had plans to develop and license one. This suggests that there is little momentum towards obtaining a solution for light aircraft in the near future.

6.4 TECHNICAL INTEROPERABILITY ISSUES

- 6.4.1 Technical interoperability of new technology with existing surveillance and collision avoidance systems must be assured. There could potentially be an issue with LAST transponders built with a power output which is less than that defined in the ICAO SARPs. Replies to interrogations may not be received with sufficient signal strength or in sufficient time for ACAS to operate effectively.

- 6.4.2 The normal range of ACAS systems, as defined by the SARPs, is 14nm. However, in high air traffic density scenarios, algorithms within the unit can reduce the operating power to a range of only 5nm. This is because there are only so many target trajectories that the units can successfully compute at any one time. In this scenario, there may be additional problems with low power transponders.
- 6.4.3 In cluster scenarios, where there are a number of Mode A/C altitude reporting aircraft, it may not be possible to differentiate targets successfully. Therefore, ACAS should not be used as a means of maintaining separation from Mode A/C targets in clusters. Flight trials conducted in France have confirmed this and demonstrated target confusion, garbling and track swapping in this scenario (see Annex C Section 1.1). However, if Mode S transponders are fitted to the cluster of aircraft, the ACAS performance is much improved, mainly due to it being able to differentiate between targets by use of the 24-bit ICAO addressing system.

6.5 HEALTH AND SAFETY

- 6.5.1 Health and Safety issues arise from SSR transponder power output and antenna placement. This is a major concern for very small aircraft. The current ICAO SARPs compliant transponder power output may be too powerful when the antenna is located close to the aircraft occupants. Consequently, the UK CAA has worked closely with the UK National Radiological Protection Board (NRPB) to study the effects of a 10W and a 20W transponder power output on the human body.
- 6.5.2 A study was commissioned into calculating the electrical and magnetic field strengths to find an allowable limit of power output without putting the health of the occupants at risk. The NRPB concluded that the UK prototype low power LAST output of 20W did not exceed the specific energy absorption rate (SAR) restrictions, even if worn on the body, due to the low time-averaged power output of the device. However, it was unclear whether or not the International Commission on Non-Ionizing Radiation Committee's (ICNIRP) basic restrictions on exposure to the general public would be exceeded. The NRPB considered that a 70W power output would be unacceptable on very small airframes. It is likely that the NRPB will be consulted again if a marketable LAST product is put forward by UK industry.

6.6 ELECTROMAGNETIC COMPATIBILITY (EMC)

- 6.6.1 When operating electrical equipment, such as avionics, electric and magnetic fields are generated that could interfere with the operation of surrounding equipment. Electromagnetic Compatibility (EMC) is defined as the ability of a product to operate within its intended electromagnetic environment and to accept or emit radio frequency (RF) disturbances within defined limits with the electromagnetic spectrum. Thus any new transponder would need to be EMC tested to prevent risk of interference with existing equipment.

- 6.6.2 EMC constraints may be more difficult to meet in smaller aircraft, where space for equipment is minimal, and avionics boxes and antenna are closely located. In addition, GA aircraft that are already fitted with certain radio communication and navigation equipment may not have the physical space to install another antenna for Mode S purposes without interfering with other equipment. The type of material used to construct aircraft also has an effect. For instance, carbon fibre fuselages of some gliders can act like a “Faraday’s Cage”, where the aircraft is an enclosure made of a conducting material and acts as an electromagnetic shield preventing transmission to/from the equipment within. Therefore, the antenna has to be placed outside the fuselage in a position that cannot be damaged on landing.

6.7 POWER AVAILABILITY

- 6.7.1 The availability of a power supply is another obstacle for transponder fitment. Smaller GA and sporting type aircraft such as gliders may not have the necessary power availability to support an ICAO compliant LAST transponder or even a low power LAST. The UK prototype low power LAST has been specified to operate with an external power supply or its own internal batteries.
- 6.7.2 Older transponders in motorised aeroplanes may need up to 1.5 ampere of power whilst transmitting and 0.5 amps whilst in stand-by mode. A portable battery would be strained to its limits on long endurance/distance flights. Trials are being conducted to overcome this hurdle. Filser now produces a Mode S transponder with a reasonable power consumption of 200mA and an integrated alticoder which would be suitable for gliders and alike. The UK prototype low power LAST is, therefore, being designed to provide at least 8-9 hours of battery life.
- 6.7.3 Transponder occupancy in the dense airspace of core Europe is a major consideration when transponders are operated with battery power alone. This is because when they are transmitting more regularly they use more power. There is concern that ED-115 MOPS will not meet the requirements of those light aircraft that rely on batteries to power avionics equipment for several hours at a time within high density ATM areas.

6.8 EQUIPMENT LOGISTICS

- 6.8.1 The overall weight of the transponder is also an issue. If too heavy, it could affect the flight dynamics/ballast of lighter aircraft and even alter the aircraft classification. The UK prototype low power LAST is being specified to weigh less than 1kg but 500g is the eventual aim. Filser currently produces a 700g LAST.

- 6.8.2 Space for avionics on light and sporting aircraft is very limited. Space to fit a transponder and antenna in motor gliders/gliders as well as microlights, hang gliders and para gliders is a major consideration. Filser produces a transponder that is 57 by 160 mm. Zimmermann is also developing a Mode A/C product that should fit into the aircraft instrument panel to save on space.
- 6.8.3 Display functionality and ease of use is paramount. As many recreational pilots will have little if no training in the use of the equipment, it is vital that it is installed, operated and maintained correctly. Furthermore, installation must be secure to ensure that no injury may occur on landing.

6.9 MAINTENANCE ISSUES

- 6.9.1 An exercise by Cranfield in the UK to check accuracy of GA transponders in mid-80s resulted in the discovery of an alarming amount of errors. Approximately 60% of the transponders analysed were found to have incorrect Mode C readings. A similar exercise by the FAA in the 1990s recorded similar results. Maintenance and checking of any transponders fitted to GA aircraft will be a major consideration if aircraft do not regularly work with ATC.
- 6.9.2 GA pilots would have to be educated in the maintenance requirements of transponder equipment, such as how to function check, who is licensed to service the equipment, how to fit the equipment correctly, how often maintenance is required etc. Pilots of aircraft that contain few electrical avionics boxes, such as gliders, could be unaware of maintenance regulations.

7 STUDIES, TRIALS AND TECHNOLOGY DEVELOPMENTS

- 7.1 Annex C provides details of associated studies, trials and technology developments.

8 REGULATORY CONTEXT

8.1 GENERAL

8.1.1 The EUROCONTROL regulatory process requires that rule-making must be set against a clear policy objective to ensure that regulatory material is developed to meet the strategic objectives of the Organisation. Specifically, it is essential that regulatory developments are compliant with the ICAO regulatory baseline. EUROCONTROL regulatory developments are also required to take account of the Single European Sky (SES) and support the EC in the development of the associated Implementing Rules. It is therefore important to identify appropriate policy objectives in the contexts of ICAO, EUROCONTROL and the EC.

8.2 POLICY OBJECTIVES

8.2.1 Section 6.3 describes the existing technical regulations which are applicable to the regulatory aspects of the detection of light aviation. The following paragraphs explore, in more detail, the policy objectives that would be applicable to possible regulation in this area.

8.3 ICAO

8.3.1 It has already been shown that there is a clear policy basis in ICAO Annex 6 for transponder carriage by light aviation, although it only applies to Aeroplanes and Helicopters and not Aircraft as previously defined. Extension of these SARPs on a European basis to all Aircraft should provide no problem in principle to ICAO as the initiative would be designed to enhance the implementation of existing SARPS and would not mandate a lesser requirement.

8.3.2 In respect of the technical aspects of a low power transponder variant, should a European mandate permit the implementation of a lesser requirement than the existing ICAO Annex 10 provisions, this would not provide a policy basis for European regulation. Implementation of a low power variant as a means of compliance would necessitate the amendment of Annex 10 to accommodate the new power output performance. Change proposals to ICAO Annex 10 would arise from any European regulatory project and be conducted in parallel to harmonise the implementation dates.

8.4 EUROPEAN COMMUNITY

8.4.1 The Regulation of the European Parliament and of the Council on the organisation and use of the airspace in the Single European Sky ("the airspace Regulation") states, inter alia, that:

"Airspace is a common resource for all categories of users that needs to be used flexibly by all of them, ensuring fairness and transparency whilst

taking into account security and defence needs of Member States and their commitments within international organisations.”

- 8.4.2 Annex II (Essential Requirements) of the EC Regulation of the European Parliament and of the Council on the Interoperability of the European Air Traffic Management Network (EATMN) states that:

“The surveillance network within the EATMN shall be such as to meet the requirements of accuracy, timeliness, coverage and redundancy . . .”

and that:

“Surveillance data processing systems shall accommodate the progressive availability of new sources of surveillance information in such a way as to improve the overall quality of service.”

- 8.4.3 The possibility of an Implementing Rule in this area would be subject to extensive discussion and review within the SES context and would require a separate proposal from EUROCONTROL to the Commission. The timing of this proposal should rely on a more mature assessment of the problem than provided in this study report and, therefore, should not occur until EUROCONTROL had made its own decision as to a suitable approach.

8.5 EUROCONTROL

- 8.5.1 One of the key objectives of the ATM 2000+ Strategy is:

“To provide sufficient capacity to accommodate the demand of all users in an effective and efficient manner at all times, and during typical busy hour periods without imposing significant operational, economic or environmental penalties under normal circumstances.”

- 8.5.2 The EUROCONTROL Regulatory Work Programme (RWP) 2005 (adopted by the Provisional Council) has identified a future need to address the issue of detection of light aviation as follows:

“The aim will be to develop a common regulatory approach for enhanced transponder carriage among the light aviation community, which strongly requests such a development. In a first instance, taking into account available resources, only a limited analysis of the problem will be made, to assess possible future actions. Depending of the outcome, a proposal to move the item into the core part of the RWP will be submitted to the PC, with an indication of time and efforts required.”

8.6 OPTIONS

8.6.1 Do Nothing

8.6.1.1 The do nothing option is discussed in more detail in Section (9.1.1 (a)). However, considering the lack of a harmonised approach in Europe and the possibility of a range of national approaches to the problems and issues highlighted in this report, it is likely that some form of European action will be appropriate in clarifying and harmonising the situation for light aircraft in respect of detection and transponder carriage. Indeed, the intervention of EUROCONTROL to provide clarity and harmonisation of approach in this area was sought by a large element of the operator community itself, i.e. the sports aviation flyers.

8.6.2 Non-Regulatory or Regulatory Approach

8.6.2.1 The basic principles to be adopted should be to avoid over-regulation and that a non-regulatory approach should always be sought in preference to the introduction of further regulation where this is practicable. However, where a voluntary approach would not provide the necessary level of harmonised implementation and sufficient regulatory material did not exist then consideration should be given to a regulatory approach. Experience does suggest that non-regulatory approaches to achieve a harmonised implementation of technical regulations in Europe may not always be successful. The provision of strong, clear and concise performance based regulatory material in addition to supporting material (e.g. means of compliance) is more likely to provide the necessary result.

8.6.2.2 This report has highlighted problems and associated issues in some detail and touched on some of the impacts of the introduction of provisions to enhance the detection of light aviation. However, before an approach to the problems can be identified, there would be a need for a more focussed regulatory impact assessment (RIA) which, inter alia, was able to quantify the cost, safety and environmental impacts to a level necessary to support decision-making on the type of approach. Moreover, considering the extent of the impacted parties, it would be essential to involve the stakeholder community on a much wider scale than has been possible so far. This would support the RIA development and provide early exposure of the problem and the initiatives being considered.

8.7 NEXT STEPS

8.7.1 There appears to be sufficient policy objective and evidence to support a proposal that the study is adopted as a formal regulatory project which, as a first step, would develop an RIA to the point where a decision could be made in respect of the approach to be taken. The subject already features within the EUROCONTROL Regulatory Work Programme (RWP) as a possible future project as stated above.

- 8.7.2 The outcome of this study should be used to support a proposal to the Provisional Council for the movement of the subject into the Core Part of the RWP. Movement into the Core Part does not guarantee that a rule will be developed. It means that further development of the regulatory project will take place, the outcome of which may or may not result in a regulatory approach.
- 8.7.3 As a specific next step, it is proposed that the subject and its issues are captured in an Advanced-EUROCONTROL Notice of Proposed Rule-Making (ENPRM) discussion paper. The A-ENPRM is a tool provided within the ENPRM Regulatory Process that allows EUROCONTROL to issue a discussion paper to seek widespread stakeholder comment on a particular regulatory issue. The purpose of an A-ENPRM is to seek comment on whether EUROCONTROL should proceed to initiate a rule change on a particular matter. The results of the comments received on the discussion paper may determine whether or not EUROCONTROL will proceed with a particular rule change and influence the chosen regulatory approach. A-ENPRMs do not replace ENPRMs. The A-ENPRM will also support decision-making in respect of any possible SES regulatory developments.
- 8.7.4 To provoke the necessary level of feedback, it is usual that the A-ENPRM argues and proposes a 'preferred' option and asks the stakeholders whether they would support a regulatory or non-regulatory approach.
- 8.7.5 Finally, this report makes specific recommendations that it should be left to individual States to decide how exactly transponder carriage should be applied in their airspace (TMZs, whole FIR etc). These recommendations would be taken into account within the regulatory process as part of the assessment of regulatory approach and, where considered appropriate, captured in the regulatory provisions.

9 POTENTIAL SOLUTIONS FOR THE IDENTIFIED HAZARDS

9.1 GENERAL SOLUTIONS

9.1.1 There are a wide range of potential solutions that could reduce the risks in all of the hazard scenarios identified in Section 5 above. The degree to which individual solutions are effective will vary and, in some cases, a package of individual solutions may be more appropriate. In particular, a 'layered' approach needs to be considered where measures are put in place to help aircraft avoid each other in the planning stages as well as facilitating safety mechanisms when airborne. The solutions offered below are theoretical and a number of them may not actually be practical or acceptable to NAAs, ANSPs or the user community. However, for completeness, the following range of potential options have been explained:

- a) Do nothing. Although solutions may be available that would reduce a particular risk, it may be that the impact of the solutions would be disproportionate to the level of risk that needed to be resolved. In that case, NAAs may decide that doing nothing is the most appropriate course of action. A detailed Risk Assessment, a Cost Benefit Analysis and full consultation may need to be conducted prior to implementing particular solutions.
- b) Segregation of conflicting activity either across an FIR, selectively to meet a particular need or flexibly using the FUA concept and procedures. This is an effective solution for reducing risks but the impact on some sectors of the aviation industry will be significant and potentially unacceptable.
- c) Improve the overall education and dynamic awareness and promulgation between the disparate users of airspace about each others' activity and capabilities. For example, greater use of meteorological data could be made to highlight areas where gliders are likely to be operating. This could include indications of where 'waves' have developed or suitable thermal conditions. European Aeronautical Information Data could also be improved to promulgate typical operating areas for different categories of light aviation. This would permit CAT, other light aircraft and the military to plan 'routes to avoid' high risk areas or 'hotspots' of activity on a dynamic basis. These 'routes to avoid' could be geographical or altitude or time based and should permit flying activity to be moved intelligently. Greater use of radio, data link and other 'data streams' could be implemented now and in the future to facilitate a greater information flow and tactical situational awareness of airspace users about activity, especially fast moving aircraft.
- d) Literally apply ICAO Annex 6 SSR transponder carriage to all aeroplanes and helicopters on international flights. Since 1999, all transponders carried must provide pressure altitude reporting and,

since 1 January 2003, all aeroplanes and helicopters must operate a pressure altitude transponder irrespective of airspace or VFR/IFR status. ICAO now audits State compliance with SARPs. This solution is likely to have little impact on many of the hazard scenarios identified in this study. Furthermore, there is currently no suitable technical SSR solution for some small motorised airframes.

- e) Apply ICAO Annex 6 to all aeroplanes and helicopters, even those conducting only national flights. This solution would reduce many of the risks where motorised aircraft are concerned but it would not provide mitigation for many categories of light aircraft. In particular, there is currently no suitable technical SSR solution for small motorised airframes. This solution would also not apply to aircraft such as non-motorised gliders and hang gliders
- f) Apply ICAO Annex 6 to all aircraft, whether motorised or not. This application would depend on the successful development of transponders that could be carried by very light aircraft.
- g) Implement mandatory SSR transponder carriage zones (Mode A/C and/or Mode S). These might be aligned with military low flying routes, typical off-route CAT tracks or around CAS protecting aerodromes. These zones could also be candidates for use with the FUA concept. This solution would prevent those light aircraft that cannot equip with an ICAO compliant transponder from accessing the airspace.
- h) Encourage voluntary equipage of GA aircraft with SSR transponders through providing benefits such as TIS, which provides information on other traffic to non-ACAS equipped light aircraft.
- i) Improve the effectiveness of 'See and Avoid'. Measures to increase the visual conspicuity of light aircraft could be considered, such as paint schemes and the use of LEDs along wing edges to enable associated detection systems. In the future, improved data stream distribution technology and improved processing capabilities could be considered to provide data on aircraft types and speeds that are operating nearby, so that pilots can either route to avoid or use the data to enhance visual acquisition.
- j) Implement emerging technology such as ADS-B.
- k) The provision of Air Traffic Services to VFR GA aircraft is a good way of managing different categories of flights through improved situational awareness for pilots and controllers. However, the services have to be guaranteed, funded and the use of them encouraged for the effectiveness to be maximised. It also requires light aircraft to be equipped with radio and for pilots to be trained in R/T procedures.

9.2 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 1

9.2.1 The collision risk between IFR CAT and VFR GA aircraft in the vicinity of an aerodrome could be dramatically reduced by ensuring the complete segregation of the flights. This could be accomplished using the following options:

- a) Exclusion of VFR flights from CAS. This could be implemented permanently either across the board or only in airspace where it has been shown that there is a significant risk of collision between IFR and VFR flights. A proliferation of Class A airspace could produce this effect. Alternatively, the exclusion could be based on a FUA concept of only establishing CAS temporarily at times when there is the greatest level of IFR activity and risk. These options would not reduce the risk of inadvertent airspace infringements occurring or the risk of collision once an infringement has occurred.
- b) Exclusion from CAS of only those VFR flights that are not so equipped as to be totally interoperable with the IFR aircraft and ATC operating in the airspace. This option would not totally reduce the risk of inadvertent airspace infringements occurring or the risk of collision once an infringement has occurred.
- c) Exclusion of IFR flights from uncontrolled airspace near to aerodromes in the vicinity of high levels of VFR activity. This could be implemented permanently across an FIR, selectively in the areas of highest risk, or temporarily using the FUA concept. Similar measures already exist in some European states when IFR flights are not permitted below 3,000 feet.

9.2.2 This collision risk between IFR CAT and VFR GA aircraft could also be reduced by creating a 'Known' traffic environment in the vicinity of aerodromes. This could be accomplished using the following options:

- a) Mandate carriage and operation of SSR transponders for all flights within all classes of CAS. This would ensure interoperability with current and future ATC surveillance systems and ACAS within CAS around aerodromes. This option would not totally reduce the risk of inadvertent airspace infringements occurring or the risk of collision once an infringement has occurred.
- b) Implement mandatory SSR transponder carriage zones for all flights in the uncontrolled airspace around airports. This could be implemented permanently across the board, selectively in the areas of highest risk, or temporarily using the FUA concept. The dimensions of these zones would be dependent on the activity and flight profiles of the IFR CAT operating at the particular aerodromes. This solution would de-risk potentially dangerous situations if the VFR aircraft in proximity to the aerodrome then inadvertently penetrated the CAS.

- c) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes. Baseline interoperability between all categories of aircraft would then be assured irrespective of airspace class or flight profile.
- d) With sub-paragraphs (b) and (c) above, safety and situational awareness could be further enhanced by the availability of TIS data for VFR aircraft not equipped with TCAS. Furthermore, use of the Mode S 1090 Extended Squitter functionality would facilitate the future implementation of ADS-B. When combined with multilateration techniques, these facilities could be particularly useful at lower altitudes and in other areas where surveillance radar coverage is not ideal.
- e) Guarantee the provision Air Traffic Services to VFR aircraft and encourage the use of these services in high risk airspace.

9.3 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 2

9.3.1 The collision risk between IFR CAT and a VFR GA aircraft in the en route phase of flight could be reduced as follows:

- a) Selective or total segregation in uncontrolled airspace of IFR and VFR flights that are not technically interoperable with ACAS and ATC surveillance. This could be achieved through a proliferation of CAS or through separation in height within uncontrolled airspace. Future implementation of Class C or D CAS above FL 95 will facilitate this solution in the middle airspace. This segregation principle could also be applied flexibly using FUA principles.
- b) Implement mandatory SSR Transponder carriage zones in areas of highest risk. These could be applied flexibly using the FUA concepts and procedures. For example, the UK has in effect currently applied such a zone at and above FL 100 throughout the FIR.
- c) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes. Baseline interoperability between all categories of aircraft would then be assured irrespective of airspace class or flight profile.
- d) Improve the effectiveness of 'See and Avoid' techniques and the visibility of aircraft.
- e) Improve the situational awareness of all airspace users through better promulgation, notification and information flow about activity to permit 'routes to avoid' to be planned. The availability of TIS for GA and, in the future, ADS-B for all flights could also be extremely beneficial.

- f) Guarantee the provision Air Traffic Services to VFR aircraft and encourage the use of these services in high risk airspace.

9.4 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 3

9.4.1 The collision risk between military aircraft and VFR GA aircraft could be reduced as follows:

- a) Selective or total segregation of military and GA activity. This segregation principle could also be applied flexibly using FUA principles.
- b) Improve the effectiveness of 'See and Avoid' techniques and the visibility of aircraft.
- c) Where military aircraft carry suitable collision warning or avoidance systems based on SSR technology, implement mandatory SSR Transponder carriage zones in areas of highest risk. These could be applied flexibly using the FUA concepts and procedures.
- d) Where military aircraft carry suitable collision warning or avoidance systems based on SSR technology, mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes. Interoperability would then be guaranteed in all circumstances and flight profiles.
- e) Improve the situational awareness of GA and military pilots through better promulgation, notification and information flow about activity to permit 'routes to avoid' to be planned. The availability of TIS for GA and, in the future, ADS-B for all flights could also be extremely beneficial.

9.5 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 4

9.5.1 The collision risk between two VFR GA aircraft in uncontrolled airspace could be reduced as follows:

- a) Improve the effectiveness of 'See and Avoid' techniques and the visibility of aircraft.
- b) Improve the situational awareness through better promulgation, notification and information flow about activity to permit 'routes to avoid' to be planned. The availability of TIS for GA and, in the future, ADS-B for all flights could also be extremely beneficial but widespread SSR carriage would be needed on all GA aircraft for this to be an effective solution for this scenario.
- c) Encourage voluntary equipage with technology developments such as FLARM for use between GA aircraft.

9.6 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 5

9.6.1 The collision risk created by large scale GA special events or unusual activity such as 'fly-ins' or competitions could be reduced as follows:

- a) Improved notification and access to aeronautical information.
- b) Improve the effectiveness of 'See and Avoid' techniques and the visibility of aircraft.
- c) Segregation of the activity by the use of TRAs and TSAs under the FUA principles.
- d) Encourage voluntary equipage with technology developments such as FLARM for use between GA aircraft.

9.7 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 6

9.7.1 The collision risk associated with the non-detection of an aircraft masked by 'clutter' on primary radar in the vicinity of a wind turbine development could be reduced as follows:

- a) Implement mandatory SSR Transponder carriage zones over the areas of primary radar clutter to guarantee ATC detection.
- b) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes to guarantee ATC detection.
- c) Prevent IFR flights from operating in these areas of clutter.
- d) Improve the effectiveness of primary radar coverage through the data fusion techniques of overlapping radars.

9.8 SOLUTIONS FOR SEPARATION ASSURANCE SCENARIO 7

9.8.1 The collision risk presented by UAV operations in uncontrolled airspace could be reduced as follows:

- a) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes. This would facilitate the development of an effective 'Sense and Avoid' suite for UAVs, of which SSR would be a fundamental element. This would ensure full interoperability with ATC surveillance, CWS, ACAS, TIS and ADS-B equipment.
- b) Segregation of the activity by the use of TRAs and TSAs under the FUA principles.

9.9 SOLUTIONS FOR ATM INTEROPERABILITY SCENARIO 1

9.9.1 The hazards and difficulties associated with the provision of radar services to IFR CAT aircraft in uncontrolled airspace could be improved as follows:

- a) Selective or total segregation of IFR and VFR flights that are not technically interoperable with ACAS and ATC surveillance. This could be achieved through a proliferation of CAS or through separation in height within uncontrolled airspace. This segregation principle could also be applied flexibly using FUA principles.
- b) Implement mandatory SSR transponder carriage zones for all flights. This could be implemented selectively in the areas of highest risk, or temporarily using the FUA concept. The dimensions of these zones would be dependent on the activity and flight profiles of the IFR CAT.
- c) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes to provide position, identification and height data on all non-participating aircraft.
- d) Guarantee the provision of Air Traffic Services to VFR aircraft and encourage the use of these services in high risk airspace.

9.10 SOLUTIONS FOR ATM INTEROPERABILITY SCENARIO 2

9.10.1 ATS provision of 'Crossing of CAS' services for non-transponder equipped aircraft may not be tenable in a future busy CAT environment. However, the present difficulties and risks of providing radar services for a non-SSR equipped GA aircraft in uncontrolled airspace or during a CAS crossing could be reduced as follows:

- a) Improve the visibility of aircraft with small radar cross sections to the older 'legacy' primary radars. However, this would not completely overcome the controller workload issues.
- b) Mandate the carriage and operation of SSR transponders on all aircraft in all airspace classes to provide position, identification and height data on all participating and non-participating aircraft.

9.11 SOLUTIONS FOR ATM INTEROPERABILITY SCENARIO 3

9.11.1 The implementation of FUA in the lower airspace could only really be achieved through implementing a baseline technical interoperability of all aircraft, irrespective of airspace or flight category. This would need to be based on SSR, both now and in 2020, in order to guarantee interaction with ATC surveillance, ACAS and CWS equipment.

10 REQUIREMENT FOR A LOW POWER LAST

- 10.1 Of all the solutions to the risks associated with hazard scenarios outlined in Section 5 above, the use of SSR is the only one that could be applied consistently to all but one of the scenarios. Although some individual risks could also be reduced by other measures, and particularly in a holistic layered approach of a combination of solutions, a widespread 'Known' traffic environment in all European airspace would provide a common and wholly interoperable solution to many of the individual hazards and risks. Segregation of different user categories would only continue to be needed in the busiest and most complex airspace.
- 10.2 Nevertheless, where States choose the SSR solutions to facilitate a 'Known' traffic environment in place of segregation, whether in mandatory transponder carriage zones or throughout an FIR, aircraft of all types need to be equipped with transponders in order to maximise any reduction of risk. Partial equipage of only those aircraft capable of operating an ICAO compliant transponder would result in significant risks remaining, which would have to be resolved by other means.
- 10.3 Therefore, for any of the SSR solutions to be fully effective, a suitable technical solution needs to be agreed and developed to meet the needs of those light aircraft that cannot currently equip with and operate an SSR transponder that is specified in the current ICAO Annex 10 SARPs. In particular, it will need to be low power, low cost, portable and with a long battery life. Moreover, the SSR solutions would need to be capable of operating on aircraft with very small or no cockpits, such as microlights, hang gliders and para gliders.
- 10.4 A low power LAST should only need to be designed to meet particular needs. For example, it might not be considered necessary or desirable for light aircraft to be equipped with fully ICAO compliant 70W transponders for local flying in the lower airspace. Transponders on these flights need only interact with ACAS/TCAS equipment to generate contacts at about 12-14 nm range and generate suitable RAs/TAs. They would also only need a performance to ensure radar detection for local ATC radars out to 40-60 nm. To future proof the LAST for the adoption of ADS-B, it should also provide Mode S 1090 Extended Squitter functionality.

11 IMPACT ASSESSMENT OF THE SSR SOLUTIONS

11.1 ECONOMIC BENEFITS

11.1.1 ANSPs and CAT could realise significant economic benefits through better routing and services (i.e. through cost avoidance) if all European airspace was a 'Known' traffic environment. However, these particular aviation sectors would be unwilling to fund or subsidise GA equipage to realise these benefits. This may, however, be something that the EC might consider.

11.1.2 Light Aircraft operators could gain economic benefits from access to more expeditious tracks and the associated reduced fuel costs of not having to divert around CAS.

11.1.3 Any reduction in flow capacity or less efficient routing of aircraft to provide mitigation against the effects of wind turbines on primary radars has a negative economic effect on the aviation industry. Similarly, there are negative economic effects on the renewable energy industry of aviation objections to proposed developments. Both industries would therefore gain economic benefits from a complete SSR environment in European airspace. This may provide a suitable rationale for identifying a funding line for the development of a low power LAST and for subsidising the carriage of SSR transponders by light aviation aircraft.

11.2 ECONOMIC COSTS

11.2.1 The cost of SSR transponders is a major consideration for the recreational and sporting aviation community. For example, it is debateable whether it is reasonable to expect a microlight pilot to equip with a €700 to €2,500 transponder when the airframe is only worth €4,000. Furthermore, a glider can cost from only €1,500 up to €150,000. However, the cost of a 20W LAST will be mainly driven by the size of the market and competition between a number of interested manufacturers. Currently, only one manufacturer is known to produce an ICAO compliant LAST. Potential integration of the LAST units with GPS and TIS could also make it more marketable.

11.2.2 Activities for pleasure are generally expected to cost those who participate. However, the GA sector is entitled to expect to receive reasonable benefits from any new equipage requirements. As the benefits of SSR transponder carriage are predominantly safety related, quantifying and justifying these benefits is a significant challenge. Any cost of initial purchase or increase in maintenance costs for SSR transponder carriage, through a requirement for periodic checks, needs to be considered. Notwithstanding, for GA activity based around clubs, LAST equipment could be purchased and maintained by those clubs and hired out when required for applicable flights. Alternatively, leasing transponders from a qualified depot could provide an alternative and less expensive solution.

11.2.3 The wider the implementation of SSR carriage in Europe, the larger the market would be for a low power LAST. This would reduce the cost of the equipment through economies of scale and greater competition among manufacturers. Moreover, Australia is apparently very interested in developments surrounding a low power/low cost LAST for its ADS-B proposals for GA. Therefore, there may be a wider global market for the LAST.

11.2.4 Costs for some small businesses, such as flying training schools, could increase if SSR transponders were mandated. However, there might be offsets to be made against insurance from demonstrating improved safety. Offsets from better routing or access through CAS could also be made.

11.3 SOCIAL

11.3.1 An increase in airspace infringements by GA aircraft could result in GA being denied access to certain airspace. It could also result in even more pressure to increase CAS to protect CAT. In effect, this would present a risk of recreational GA activity being 'frozen' out of particular areas of European airspace. In turn, this could move GA activity to other flying areas. The widespread implementation of SSR would provide mitigation for this potential social impact. Furthermore, the risk of GA pilots being falsely accused of airspace infringements would reduce in a 'Known' traffic environment.

11.3.2 If SSR transponder carriage became mandatory in all or parts of European airspace, there would be an increased training requirement for GA pilots to learn how to use the equipment. This could be added to PPL syllabi.

11.4 SAFETY

11.4.1 Mandatory transponder carriage zones might cause considerable difficulty for non-equipped GA aircraft if these areas included 'pinch points' between CAS where aircraft routinely transit between operating areas. Ironically, this is where the main benefit of transponder carriage could be realized; i.e. where different aviation categories are 'funnelled' together in unregulated airspace.

11.4.2 Some concern has been expressed about the impact on 'See and Avoid' lookout by cockpit distractions caused by devices such as TIS. This will need to be more fully studied and analysed.

11.4.3 If SSR transponder carriage is mandated, the impact of VFR aircraft suddenly having an unserviceable transponder in flight will need to be addressed.

11.4.4 If SSR data is consistent from an aircraft transponder, any ACAS II equipment receiving the data believes what it sees. The Mode C readout from a GA aircraft will only be checked if it is provided with a radar service from an ATS unit. Some GA aircraft may, therefore, be rarely checked. If the Mode C accuracy is not guaranteed, which is a significant risk under the current maintenance regime for GA aircraft in Europe, there might be an increased risk of an ACAS versus erroneous Mode C generated collision if transponder carriage was increased.

11.4.5 Non-radio equipped aircraft could gain safety benefits of being able to use Mode A codes on their transponders to indicate on-board distress and emergency conditions. This would allow ATC to keep other aircraft clear, provide an escort aircraft or alert and assist the emergency and rescue services.

11.5 TECHNICAL

11.5.1 The implementation of SSR Mode S technology is the only way that increased transponder carriage could be permitted in most areas of Europe. This is due to the RF pollution and detection concerns surrounding legacy Mode A/C systems.

11.5.2 ATC system capacity concerns are also overcome with Mode S, as the interrogators have over double the track capacity of Mode A/C systems. Furthermore, ATC filtering at some radars or centres would prevent an overload of data that is not required. However, filtering does not affect ACAS detection or the visibility of filtered aircraft to other ATS providers. It also does not affect the ability of the SSR transponders to interact with SSR-based safety nets.

11.5.3 If expanded SSR transponder carriage permits additional mixing of CAT with uncontrolled flights, guarantees will have to be instituted to ensure the accuracy of the altitude data provided by the uncontrolled flights. Maintenance requirements would help to overcome this issue and the LAST will ideally have built in test functionality.

11.5.4 The UK CAA is optimistic that a low power (20W) LAST could be available on the market by 2008.

11.6 ENVIRONMENTAL

11.6.1 A delay in deploying wind turbine sites because of objections by the aviation industry would have negative effect on the environment. Providing a 'Known' traffic environment based on SSR would remove a major objection that the aviation industry has on the proliferation of wind turbine sites. This would allow the aviation industry to indirectly contribute to the European efforts to reduce carbon emissions and help support renewable energy. In turn, it could allow industries like aviation, which have no choice but to rely on carbon fuels, to expand.

- 11.6.2 Any increase in CAS in Europe could move GA activity to different areas of the country. This movement would increase or change noise contours and timings. Furthermore, there could be air pollution issues of 'funnelling' GA activity into smaller areas or increasing 'track' times around CAS.
- 11.6.3 Implementing SSR in all airspace would increase the opportunity to permit 'free routing' for CAT. This is potentially environmentally beneficial, as it spreads and noise and air pollution over a larger area.

12 RESULTS OF RESEARCH AND CONSULTATION

12.1 Annex D provides details of the results of the study research and consultation.

13 IMPLEMENTATION, MONITORING AND COMPLIANCE ISSUES

- 13.1 With effect from 31 March 2008, many States in Core Europe will implement the carriage of Mode S transponders instead of Mode A/C, where the carriage of a transponder is mandatory. In addition, new aircraft issued with a first certificate of airworthiness on or after 31 March 2005 must be equipped with a Mode S transponder if they will be used in airspace where a transponder is mandatory.
- 13.2 At this point, States could be encouraged to use the 31 March 2008 Mode S implementation to enact the ICAO Annex 6 SARPs for all aeroplanes and helicopters to carry a pressure altitude reporting transponder, irrespective of airspace or whether international flight is conducted. In itself, this would go some way towards reducing the risks outlined in this study.
- 13.3 An additional implementation would then be required to mandate the carriage of Mode S transponders in high risk airspace on all other aircraft not captured in the aforementioned paragraphs. Individual States could decide whether or not to just implement appropriate mandatory carriage zones or require transponder carriage throughout an FIR, depending on the need. However, this implementation would require the definition of suitable SARPs and the development of suitable equipment. Without this, segregation from CAT might have to be implemented, as recommended in ICAO Annex 6. A target date of 31 March 2008 for this additional requirement might be achievable.
- 13.4 Advice and guidance to States from EUROCONTROL on a common basis for legislation could be provided and EUROCONTROL could assist with the definition and progression of suitable international standards for SSR transponders on light aircraft to meet the needs of the States. In addition, EUROCONTROL could develop guidance material on criteria for establishing mandatory transponder carriage zones or widespread SSR carriage throughout an FIR.
- 13.5 Compliance with equipage requirements could be monitored nationally through Aircraft Registers, certificates or airworthiness, inspections, maintenance requirements and ATC reporting. A central exemption co-ordination cell may be necessary to facilitate a realistic transition from Mode A/C to Mode S transponders on GA aircraft. However, where suitable equipment is available, segregation might need to be applied from the outset for non-transponder equipped aircraft.
- 13.6 The reliability of SSR transponders on GA aircraft will need to be assured. Therefore, the required maintenance schedules will need careful consideration. The use of built-in test equipment on transponders might also need to be considered.

14 SUMMARY AND CONCLUSIONS

- 14.1 The detection and recognition of Light Aviation aircraft is an emotive and politically charged issue.
- 14.2 Modern European airspace is complex and levels of CAT are growing phenomenally, particularly through the success of low cost airlines operating from regional airports. Many light aviation aircraft are currently not interoperable with CAT, as they cannot be detected by ACAS and applying an ATS to IFR CAT in the same airspace as these VFR aircraft without altitude information, is difficult and inefficient. There is, therefore, considerable pressure to increase the amount of CAS to protect IFR CAT aircraft.
- 14.3 The interoperability and risk of collision between light aviation and military aircraft in Europe is difficult to quantify for a variety of reasons. However, it is clear that not all participants believe that the 'See and Avoid' method of separation in scenarios involving fast jets is effective as the sole means of avoiding collisions. There is, therefore, some pressure in Europe to segregate military and GA activities, and for military aircraft to be equipped with collision warning systems.
- 14.4 The level of risk in European States varies widely due to issues such as airspace design, GA population and terrain. States have differing views of the risks and some of the scenarios highlighted in this study present a greater risk in some States than in others. In addition, some risks can be managed in different ways. In particular, a 'Do Nothing' option could apply in some States but not others. Moreover, some of the individual risks are contentious and difficult to quantify. Identifying a clear database of risks is hampered by the diversity of AIRPROX data available across the European States.
- 14.5 Notwithstanding the above, the types of hazards are generally common to all States; namely Separation Assurance and ATM Interoperability. In addition, although the types of hazards are expected to remain broadly similar in any future European airspace structure, the current level of risk associated with light aviation will increase as CAT levels grow and the timing of military activity changes to meet training requirements.

- 14.6 The main solutions that could reduce many of the individual risks revolve around segregating conflicting users, improving education and information flows between users, improving 'See and Avoid' for VFR flights, and ensuring interoperability between users. The aim of the solutions must be to achieve or improve on the current safety levels in the face of future traffic growth. Overall, the problem could best be approached using a package of measures and techniques employed at both the planning and operational level. The first aim, through planning and information flow, should be to reduce the likelihood of aircraft ever coming into serious conflict with one another. Then, where a conflict does occur, additional measures should then be in place to activate effective safety mechanisms through interoperability and assured visibility.
- 14.7 Airspace design at the planning level needs to take a holistic view of airspace use by all aviation categories, not just CAT. For example, the proliferation of CAS to protect CAT seems to increase risks in uncontrolled airspace and at the boundaries of controlled and uncontrolled airspace, as other airspace users are then funnelled into ever smaller volumes of airspace. Permanently active 'zones', even when not being used, compound this issue. In addition, improved strategic and tactical awareness and information flow for military and light aviation activity would facilitate better 'routing to avoid' techniques. Education and publicity, meteorological data, aeronautical information services, radios and data links might all be more effectively employed in this area, both now and in the future.
- 14.8 The segregation of non-interoperable activity is successful but is probably untenable for routine day-to-day VFR activity in the future unless FUA concepts can be adopted in the Lower Airspace. Greater use of segregation would almost certainly lead to a proliferation of CAS to protect CAT.
- 14.9 Where the planning levels fail to reduce the risk of light aircraft coming in to conflict with other users, the next preventative layer should be to improve the effectiveness of both visual and electronic acquisition techniques to prevent collisions. The 'See and Avoid' technique could be enhanced through increased tactical information flow and improved visual conspicuity and acquisition techniques. Electronic acquisition could be improved through the widespread carriage of SSR transponders and collision warning systems.
- 14.10 The study team has encountered widely differing opinions on the effectiveness of 'See and Avoid' in uncontrolled airspace. Some formal studies have demonstrated that 'See and Avoid' is 99% effective in avoiding collisions, whereas others, both GA and military commentators alike, are more concerned about the risks. In particular, the ability of GA pilots to safely spot low flying military aircraft operating at fast speeds is a contentious issue. The head-on profile of many modern military jets and light aircraft is extremely small and closure rates of aircraft can be phenomenal. Furthermore, the ability in all aircraft to safely 'See and Avoid' when travelling in excess of 150 kt has been questioned by a number of consultees.

- 14.11 On a planning and an operational level, it appears that there are many individual reasons why total SSR transponder carriage in European airspace could help to reduce many of the identified current and future risks for Separation Assurance and ATM Interoperability. Whether this is through facilitating better design and use of airspace or to providing guaranteed interoperability with ATC surveillance or collision avoidance and conflict alert systems. In isolation, some of these individual reasons are difficult to quantify and justify in Risk Assessments and Cost Benefit Analyses. However, cumulatively the individual reasons present an extremely convincing argument and it is illustrated clearly by the fact that SSR provides a common solution to de-risk all but one of the hazard scenarios identified in this study. SSR could provide a baseline interoperability of all airspace users at the lowest common denominator, irrespective of airspace category, as it provides a 'Known' traffic environment.
- 14.12 However, due to the differences in opinions and perceived levels of risks across Europe, it should be left to individual States to decide how and where to implement a 'Known' air traffic environment in their airspace. Some States with vast expanses of open FIR, in which VFR flying is mainly conducted, may only need to employ Transponder Mandatory Zones in areas of highest risk. Others, such as the UK, may find it more practical to implement a 'Known' environment throughout the FIRs. However, an acceptable environment first needs to be created through the development of suitable equipment and international standards to help States make the choice on implementation. Moreover, in some States any increase in transponder carriage in dense airspace could only be facilitated through the implementation of Mode S technology, both on the ground and in the air. Suitable transitional arrangements and a realistic 'targeting' of transponder carriage to meet the 'need' would have to be developed.
- 14.13 SSR transponders should be seen as an insurance box for the Light Aviation community against collisions or mistakes with airspace infringement. They also permit light aircraft to interact safely with any adjacent ATC activity, even when non-radio equipped or when not participating with that ATC activity. Transponder carriage issues are, therefore, not necessarily linked to the need for radios; although, an increased use of radio to enhance situational awareness in uncontrolled airspace is worthy of further consideration. It is also likely that light aircraft providing SSR data are more likely to receive an ATS when requested, as they have less impact on controller workload than 'non-squawking' aircraft.

- 14.14 Unfortunately, the current perceived view of SSR transponder carriage among some of the GA community is one of fear of being charged for every flight or an unfounded fear of being prosecuted more often for airspace infringements once transponders have to be carried. That said, GA representatives concede that there are some scenarios and airspace where SSR transponder carriage would be beneficial. Indeed, there are some who believe that it is essential. However, the GA community does not favour a 'blanket' implementation across Europe and it also, quite reasonably, wants to see genuine benefits accrue from any expenditure that GA operators might have to meet.
- 14.15 In any case, the widespread application of a 'Known' traffic environment based on SSR is not currently technically possible. This is because some sectors of the Light Aviation community cannot comply with ICAO Annex 10 SARPs for SSR transponders. Even when considering Annex 6 as it stands today, and for which many States have filed a difference, there is no suitable equipment for very light aeroplanes to meet Annex 6 fully for international flights. In particular, battery consumption in high density airspace, power output, cost and the portability of transponders are hurdles that need to be overcome.
- 14.16 Consequently, new international standards need to be defined and adopted. It is not considered necessary or desirable for light aircraft to be equipped with fully ICAO compliant 70W transponders for local flying in the lower airspace. Transponders on these flights need only interact with SSR based collision avoidance equipment to generate contacts at about 12-14 nm and generate suitable RAs/TAs and would not need to be detected out to the maximum extent of long-range radars. To future proof a LAST for the adoption of ADS-B, it should also provide Mode S 1090 Extended Squitter functionality.
- 14.17 Notwithstanding the aforementioned, SSR must not be viewed as the panacea for reducing the risks in isolation. For example, it has the potential to cause issues where aircraft clusters develop if its use is not properly managed. Pre-planned special events involving large numbers of light aircraft are better segregated within TSAs/TRAs or carefully managed with arrangements made for comprehensive notification and aeronautical information. However, large clusters of light aircraft can also congregate informally on a routine basis without any pre-notification. Therefore, planning for 'routes to avoid' the likely areas where clusters develop needs to be given greater prominence and the filtering of SSR responses on ATC systems needs to be considered closely. Further research into the performance of collision avoidance systems against large clusters also needs to be conducted.

- 14.18 In the future, technologies such as TIS and ADS-B could be beneficial for the aviation community as a whole. By implementing Mode S now and, in particular 1090 Extended Squitter, it could act as a stepping stone for an interoperable transition to these technologies. Data streaming could also provide greater tactical situational awareness of airborne activity in the future. However, the cockpit distractions that all these systems might present for VFR flights, operating primarily under 'See and Avoid' rules, needs to be better understood. Therefore, the greater use of oral warnings rather than visual cockpit displays in light aircraft should be further investigated.
- 14.19 EUROCONTROL could assist States in their efforts to quantify and reduce the risks outlined in this report. Improved capturing and exchange of safety data would help significantly, as would a greater understanding of airspace use by light aircraft and increased education and awareness of the risk issues for each sector of the aviation community. EUROCONTROL could also encourage the use of SSR to increase the interoperability between the diverse user groups in high risk airspace. In parallel, assistance for States is needed to define and implement international standards and MOPS to permit the carriage of SSR transponders on all aircraft through the development of a low power, portable Mode S LAST. EUROCONTROL could also have a useful role in providing a European Policy Framework within which individual States could implement appropriate parts of such an SSR carriage policy as dictated by their particular airspace needs.

15 RECOMMENDATIONS

- 15.1 EUROCONTROL should consider initiating an education and publicity campaign for the European GA community that highlights the issues and facts surrounding the benefits of increased SSR transponder carriage. Focus groups, workshops, symposia and press articles, i.e. a 'marketing campaign' are some means which have proved effective in the past.
- 15.2 EUROCONTROL should consider issuing an advance ENPRM discussion paper.
- 15.3 In order to facilitate an increased adoption of a 'routing to avoid' planning mindset in Europe, EUROCONTROL should investigate ways of improving the dynamic information flow on light aircraft activity to all airspace users. This may also require an education campaign to heighten awareness of the issues and the benefits of adopting a 'routing to avoid' planning policy.
- 15.4 Detailed research and holistic modelling of airspace use by all sectors of the aviation community, but particularly light aviation, should be conducted. This is needed to obtain a true and clear picture of the traffic volumes, geographical and height distribution of light aviation traffic as a means of providing guidance for future policy.
- 15.5 Given the diversity and difficulty in obtaining consistent safety/AIRPROX data, the EUROCONTROL Safety Domain should be invited to address this issue.
- 15.6 A full and in-depth risk assessment is needed to define those geographical areas in time and space within European uncontrolled airspace where the widespread carriage of SSR transponders would be most beneficial.
- 15.7 The implementation of 'Known' traffic environments through the carriage of Mode S SSR transponders in high risk European airspace should be encouraged.
- 15.8 It should be left to individual European States to determine the appropriate regulatory approach for SSR carriage to meet their particular airspace needs. However, EUROCONTROL should facilitate the development of a common basis for legislation to facilitate any national implementation strategies under a framework policy.
- 15.9 EUROCONTROL should develop guidance material on criteria for establishing both mandatory transponder carriage zones and widespread SSR carriage throughout an FIR.

- 15.10 EUROCONTROL should assist States with the definition and progression of suitable international standards for SSR transponders to meet the needs of light aviation aircraft. In particular, the Agency could help progress suitable MOPS and ICAO SARPs for a low power, portable LAST that can interact with collision avoidance systems at 12-14 nm and ATC radars out to a 60 nm range.
- 15.11 EC funding lines should be investigated to subsidise the carriage of SSR transponders on GA aircraft.
- 15.12 A Pan-European simulation should be conducted into the effectiveness of the 'See and Avoid' principle for separation assurance. This simulation should also consider the effects of systems such as TIS and ADS-B displays on cockpit distraction and should investigate the use and benefits of oral warnings rather than visual cockpit displays in light aircraft.
- 15.13 Detailed environmental modelling should be conducted on the impact that increased SSR carriage by light aircraft would have on 1090 MHz in Europe.
- 15.14 A study into EMC and radiation issues of LAST carriage on very light aircraft should be conducted.
- 15.15 A study and suitable modelling should be conducted into the battery power consumption of LAST equipment in high density airspace. This should also include the affect that any additional incorporated displays for traffic information and GPS data might have.
- 15.16 EUROCONTROL should consider engaging the renewable energy industry in the development of a low power LAST. A suitable organisation to approach could be the European Wind Energy Association (EWEA).

16 ABBREVIATIONS AND DEFINITIONS

16.1 ABBREVIATIONS

| | |
|--------|---|
| ACAS | Airborne Collision Avoidance System |
| ADS-B | Automatic Dependent Surveillance – Broadcast |
| AGL | Above Ground Level |
| AIC | Aeronautical Information Circular |
| AMSL | Above Mean Sea Level |
| ANSPs | Air Navigation Service Providers |
| AOPA | Aircraft Owners and Pilots Association |
| ATC | Air Traffic Control |
| ATIR | Air Traffic incident Reports |
| ATM | Air Traffic Management |
| ATS | Air Traffic Services |
| BALPA | British AirLine Pilot's Association |
| BEA | Bureau d'Enquêtes et d'Analyses (pour la sécurité de l'aviation civile) |
| BFU | German Federal Bureau of Aircraft Accidents |
| BMVBW | Bundesministerium für Verkehr, Bausund Wohnungswesen |
| BMVIT | Bundesministerium für Verkehr, Innovation & Technologie |
| CAA | Civil Aviation Authority/Administration |
| CAS | Controlled AirSpace/Calibrated AirSpeed |
| CAT | Commercial Air Transport |
| CDTI | Cockpit Display of Traffic Information |
| CIMSEL | Civil/Military SSR Environment Liaison Group |

| | |
|----------|---|
| CNS | Communications, Navigation and Surveillance |
| CWS | Collision Warning System |
| DNA-FFVV | Direction de la Navigation Aérienne – Federation Française de Vol à Voile |
| EAS | Europe Air Sports |
| EASA | European Aviation Safety Agency |
| ECAC | European Civil Aviation Conference |
| ECCAIRS | European Co-ordination Centre for Aviation Incident Reporting Systems |
| EGU | European Gliding Union |
| EMC | ElectroMagnetic Compatibility |
| ENAC | Ente Nazionale Aviazione Civile |
| ENPRM | Eurocontrol Notice of Proposed Rule Making |
| ES | Extended Squitter |
| EUROCAE | European Organisation for Civil Aviation Equipment |
| EWEA | European Wind Energy Association |
| FAI | Fédération Aéronautique Internationale |
| FIR | Flight Information Region |
| FIS-B | Flight Information Service – Broadcast |
| FL | Flight Level |
| FRUIT | False Replies Unsynchronised In Time |
| FUA | Flexible Use of Airspace |
| GA | General Aviation |
| GATCO | Guild of Air Traffic Control Officers |
| GNSS | Global Navigation Satellite System |

| | |
|--------|---|
| GPS | Global Positioning System |
| ICAO | International Civil Aviation Organisation |
| ICNIRP | International Commission on Non-Ionizing Radiation Committee's |
| IDOCAS | Intelligent Distributed Obstacle and Collision Avoidance System |
| IFALPA | International Federation of AirLine Pilots' Association |
| IFR | Instrument Flight Rules |
| IMC | Instrument Meteorological Conditions |
| LARS | Low level Radar Services |
| LAST | Light Aviation SSR Transponder |
| LED | Light Emitting Diode |
| MOD | Ministry of Defence |
| MOPS | Minimum Operating Performance Standards |
| MTOM | Maximum Take-Off Mass |
| NAA | National Aviation Authority |
| NAC | National Air sports Control |
| NATS | National Air Traffic Services |
| NLR | National Aerospace Laboratories (Netherlands) |
| NOTAM | Notice To AirMen |
| NRPB | National Radiological Protection Board |
| PPL | Private pilots' Licence |
| RA | Radio Frequency |
| RNLAF | Royal NetherLands Air Force |
| RTCA | Radio Technical Commission for Aeronautics |
| SAR | Specific energy Absorption Rate |

| | |
|-------|---|
| SARPs | Standards and Recommended Practices |
| SLV | Statens LuftfartsVæsen (Danish CAA) |
| SSR | Secondary Surveillance Radar |
| STNA | Service Technique de la Navigation Aérienne |
| TA | Traffic Advisory |
| TCAS | Traffic Collision Avoidance System |
| TESIS | Test and Evaluation Surveillance Information System |
| TIS-B | Traffic Information Service – Broadcast |
| TMA | Terminal Manoeuvring Area |
| TMZ | Transponder Mandatory Zone |
| TRA | Temporary Restricted Airspace |
| TSA | Temporary Segregated Airspace |
| UAT | Universal Access Transceiver |
| UAV | Unmanned Aerial Vehicle |
| VFR | Visual Flight Rules |
| VMC | Visual Meteorological Conditions |
| WAAS | Wide Area Augmentation System |

16.2 DEFINITIONS

- 16.2.1 Aerodyne - a heavier-than-air aircraft which derives its lift in flight mainly from aerodynamic forces.
- 16.2.2 Aeroplane – a power driven heavier-than-air aircraft, deriving its lift in flight chiefly from aerodynamic reaction on surfaces which remain fixed under given conditions of flight.
- 16.2.3 Aerostat - an aircraft lighter than air.
- 16.2.4 Aircraft – any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.
- 16.2.5 Known Traffic Environment – is an environment within which all traffic is known to ATS either with position only or with flight intentions as well.
- 16.2.6 Powered Sailplane – an aircraft equipped with one or more engines having, with engine(s) inoperative, the characteristics of a sailplane.
- 16.2.7 Transponder Mandatory Carriage Zones – Areas of airspace in which SSR transponder carriage is made mandatory.
- 16.2.8 Non complex aeroplanes - Aeroplanes with simple avionics (i.e. no Flight management computer or navigation management equipment).
- 16.2.9 PPL/IR Europe – A European organisation that provides a way of exchanging knowledge and experience about instrument flying between private pilots.
- 16.2.10 Rotorcraft – means a heavier-than-air aircraft that depends principally for its support in flight on the lift generated by one or more rotors.
- 16.2.11 Route to avoid principle – The principle of planning an aeronautical routing so as to avoid known aircraft flying practices and activity in order to reduce the risk of collision.
- 16.2.12 Sailplane - means a heavier-than-air aircraft which is supported in flight by the dynamic reaction of the air against its fixed lifting surfaces, the free flight of which does not depend on an engine.
- 16.2.13 See and avoid principle – The principle of avoiding aircraft collision by maintaining a good 'look-out'.
- 16.2.14 War birds – Vintage or historic aircraft
- 16.2.15 Wave – Wave cloud formed by the intersection of warm and cold fronts.