APPENDIX A

MODULE NO. B0-101: ACAS IMPROVEMENTS

Summary	To provide short-term improvements to existing airborne collision avoidance systems (ACAS) to reduce nuisance alerts while maintaining existing levels of safety. This will reduce trajectory deviations and increase safety in cases where there is a breakdown of separation.	
Main performance impact as per Doc 9854	KPA-04 – Efficiency, KPA-10 – Safety.	
Operating environment/ Phases of flight	En-route flight phases and approach flight phases.	
Applicability considerations	Safety and operational benefits increase with the proportion of equipped aircraft.	
Global concept component(s) as per Doc 9854	CM – conflict management.	
Global plan initiatives (GPI)	GPI-2: Reduced vertical separation minima GPI-9: Situational awareness GPI-16: Decision support systems and alerting systems	
Main dependencies	Nil	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	√
	Avionics availability	√
	Ground systems availability	N/A
	Procedures available	√
	Operations approvals	√

1. NARRATIVE

1.1 General

1.1.1 This module is dealing with the short term improvements to the performance of the existing airborne collision avoidance system (ACAS). ACAS is the last resort safety net for pilots. Although ACAS is independent from the means of separation provision, ACAS is part of the ATM system.

1.2 Baseline

1.2.1 ACAS is subject to global mandatory carriage for aeroplanes with a MTCM greater than 5.7 tons. The current version of ACAS II is 7.0.

1.3 Change brought by the module

1.3.1 This module implements several optional improvements to airborne collision avoidance system in order to minimize “nuisance alerts” while maintaining existing levels of safety.

1.3.2 The traffic alert and collision avoidance system (TCAS) version 7.1 introduces significant safety and operational benefits for ACAS operations.

1.3.3 Safety studies indicate that ACAS II reduces risk of mid-air collisions by 75% – 95% in encounters with aircraft that are equipped with either a transponder (only) or ACAS II respectively. ACAS II Standards and Recommended Practices (SARPs) are aligned with RTCA/EUROCAE MOPS. The SARPs and the MOPS have been upgraded in 2009/2010 to resolve safety issues and to improve operational performance. The RTCA DO185B and EUROCAE ED143 include these improvements also known as TCAS, v7.1.

1.3.4 The TCAS, v7.1 introduces new features namely the monitoring of own aircraft's vertical rate during a resolution advisory (RA) and a change in the RA annunciation from "Adjust Vertical Speed, Adjust" to "Level Off". It was confirmed that the new version of the CAS logic would definitely bring significant safety benefits, though only if the majority of aircraft in any given airspace are properly equipped. ICAO agreed to mandate the improved ACAS (TCAS, v7.1) for new installations as of 1/1/2014 and for all installations no later than 1/1/2017.

1.3.5 During a TCAS encounter, prompt and correct response to RAs is the key to achieve maximum safety benefits. Operational monitoring shows that pilots do not always follow their RA accurately (or do not follow at all). Roughly 20% of RAs in Europe are not followed.

1.3.6 TCAS safety and operational performance highly depends on the airspace in which it operates. Operational monitoring of TCAS shows that unnecessary RAs can occur when aircraft approach their cleared flight level separated by 1 000 ft with a high vertical rate. Roughly 50% of all RAs in Europe are issued in 1000 ft level-off geometries. AN-Conf/11 recognized the issue and requested to investigate automatic means to improve ATM compatibility.

1.3.7 In addition, two optional features can enhance ACAS performance:

a) coupling TCAS and auto-pilot/flight director to ensure accurate responses to RAs either automatically or manually thanks to flight director (APFD function); and

b) introduce a new altitude capture law to improve TCAS compatibility with ATM (TCAP function).

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT

2.1 Metrics to determine the success of the module are proposed in the *Manual on Global Performance of the Air Navigation System* (Doc 9883).

Efficiency	ACAS improvement will reduce unnecessary resolution advisory (RA) and then reduce trajectory deviations.
Safety	ACAS increases safety in the case of breakdown of separation.
Cost Benefit Analysis	TBD

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 ACAS procedures are defined in PANS-ATM, Doc 4444 and in PANS-OPS, Doc 8168. This evolution does not change procedures.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

- RTCA DO185B / EUROCAE DO143 MOPS are available for TCAS implementation.
- RTCA DO325 Annex C is being modified to accommodate the 2 functions (APFD and TCAP).

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 ACAS performance is influenced by human behaviour. ACAS is a last resort function implemented on aircraft with a flight crew of two pilots. The operational procedures (PANS-OPS and PANS-ATM) have been developed and refined for qualified flight crews. Airbus has been able to certify the APFD function, which includes human factors aspects, on A380.

5.1.2 Human factors have been taken into consideration during the development of the processes and procedures associated with this module. Where automation is to be used, the human-machine interface has been considered from both a functional and ergonomic perspective (See Section 6 for examples). The possibility of latent failures however, continues to exist and vigilance is required during all implementation activity. It is further requested that human factor issues identified during implementation, be reported to the international community through ICAO as part of any safety reporting initiative.

5.2 Training and qualification requirements

5.2.1 Training in the operational standards and procedures are required for this module and can be found in the links to the documents in Section 8 to this module. Likewise, the qualifications requirements are identified in the regulatory requirements in Section 6 which are integral to the implementation of this module. Training guidelines are described in the *Airborne Collision Avoidance System (ACAS) Manual* (Doc 9863). Recurrent training is recommended.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

- Regulatory/standardization: use current published requirements that include the material given in Section 8.4.

- Approval plans: must be in accordance with application requirements e.g. EASA NPA 2010-03 requirement of 1/3/2012 for new installations and 1/12/2015 for all installations, or ICAO mandate of 1/1/2014 for new installations and 1/1/2017 for all installations.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

7.1 Current use

7.1.1 TCAS v7.1 is already being fitted on new aircraft, e.g. Airbus A380. Operational monitoring by States and international organizations in a position to do so is recommended.

7.2 Planned or ongoing trials

7.2.1 Airbus has already developed, evaluated and certified APFD function on A380. Airbus has developed and evaluated TCAP function on A380. Certification is expected by the end of 2012.

7.2.2 SESAR project has provided evidence that the APFD and TCAP functions would bring significant operational and safety benefits in the European environment.

7.2.3 TCAP: with a theoretical 100% equipage in Europe, the likelihood of receiving an RA during a 1000 ft level-off encounter is reduced by 97% for RAs in a level-off encounter; for 50% equipage, the likelihood is reduced by 50%. It is noted that in Europe, more than half of the RAs are issued during a level-off encounter and this is a clear improvement in ATM compatibility.

7.2.4 Performance assessment in the US airspace should be conducted in 2012.

7.2.5 APFD: the results are expressed in risk ratios which is the key safety metric indicator for TCAS equipage. Risk ratio = (risk of collision with TCAS)/(risk of collision without TCAS): with a theoretical 100% equipage, the risk ratio is reduced from 33% (current situation) to 15.5%. With a 50% equipage the risk ratio is already reduced to 22%.

8. REFERENCE DOCUMENTS

8.1 Standards

- ICAO Annex 6 — *Operation of Aircraft*, Part I — *International Commercial Air Transport — Aeroplanes*
- ICAO Annex 10 — *Aeronautical Telecommunications*, Volume IV - *Surveillance Radar and Collision Avoidance Systems* (Including Amendment 85- July 2010)
- EUROCAE ED-143/RTCA DO-185B, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II (TCAS II)
- RTCA DO-325, Minimum Operational Performance Standards (MOPS) for Automatic Flight Guidance and Control Systems and Equipment. Appendix C estimated 2013

- RTCA DO185B/EUROCAE DO143 MOPS for TCAS implementation

8.2 **Procedures**

- ICAO Doc 4444, *Procedures for Air Navigation Services* - *Air Traffic Management*
- ICAO Doc Doc 8168, *Procedures for Air Navigation Services — Aircraft Operations*, Volume I — *Flight*.

8.3 **Guidance material**

- ICAO Doc 9863, *Airborne Collision Avoidance System (ACAS) Manual*

8.4 **Approval documents**

- FAA TSO-C119c.
- EASA ETSO-C119c.
- FAA AC120-55C.
- FAA AC20-151a.
- RTCA DO-185B, MOPS for TCAS II
- RTCA DO-325, Appendix C, for APFD and TCAP
- EUROCAE ED-143, MOPS for TCAS II

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APPENDIX B

MODULE NO. B0-102: INCREASED EFFECTIVENESS OF GROUND-BASED SAFETY NETS

Summary	To monitor the operational environment during airborne phases of flight to provide timely alerts on the ground of an increased risk to flight safety. In this case, short-term conflict alert, area proximity warnings and minimum safe altitude warnings are proposed. Ground-based safety nets make an essential contribution to safety and remain required as long as the operational concept remains human centred.	
Main performance impact as per Doc 9854	KPA-10 – Safety	
Operating environment/ Phases of flight	All airborne flight phases	
Applicability considerations	Benefits increase as traffic density and complexity increase. Not all ground-based safety nets are relevant for each environment. Deployment of this module should be accelerated.	
Global concept component(s) as per Doc 9854	CM – conflict management	
Global plan initiatives (GPI)	GPI-9: Situational awareness GPI-16: Decision support and alerting systems	
Main dependencies	NIL	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	Not applicable
	Avionics availability	Ready now
	Ground systems availability	Ready now
	Procedures available	Ready now
	Operations approvals	Ready now

1. NARRATIVE

1.1 General

1.1.1 This module aims to implement a baseline set of ground-based safety nets. Ground-based safety nets are intended to assist the air traffic controller in generating, in a timely manner, alerts of an increased risk to flight safety (collision, unauthorized airspace penetration and controlled flight into terrain), which may include resolution advice.

1.2 Change brought by the module

1.2.1 Ground-based safety nets are functionalities of ATM systems that have the sole purpose of monitoring the environment of operations, during airborne phases of flight, in order to provide timely alerts of an increased risk to flight safety. Ground-based safety nets make an essential contribution to safety and remain required as long as the operational concept remains human centred.

1.2.2 Ground-based safety nets have been in use since the 1980s. Provisions for ground-based safety nets were introduced in PANS-ATM, Doc 4444 in the early 2000s. In the meantime ground systems suppliers have made ground-based safety nets part of their off-the-shelf product lines.

1.2.3 This module corresponds to a baseline version of the safety nets as already implemented or being implemented in many areas.

1.3 Element 1: Short-term conflict alert (STCA)

1.3.1 This element is intended to assist the controller, in preventing collision between aircraft by generating, in a timely manner, an alert of a potential or actual infringement of separation minima. STCA must alert when the separation provision layer has been compromised but must also provide sufficient warning time to allow for corrective action, i.e. thus avoiding an airborne collision avoidance system (ACAS) resolution advisory (RA) will be generated. In some environments this necessitates the use of separation minima in STCA that are significantly lower than the separation minima used in the separation provision layer. STCA is only effective when each alert causes the controller to immediately assess the situation and if necessary take appropriate action.

1.3.2 There is presently no system compatibility between STCA (which advises of pending conflict to ATC only) and ACAS (which provides both advisory and mandatory resolution to the pilot only). However, both systems can complement each other and procedures need to be in place, that takes into account the limitations and advantages of each system.

1.4 Element 2: Area proximity warning (APW)

1.4.1 This element is intended to warn the controller, about unauthorized penetration of an airspace volume by generating, in a timely manner, an alert of a potential or actual infringement of the required spacing to that airspace volume. APW can be used to protect static, fixed airspace volumes (e.g. danger areas) but increasingly also dynamic, modular airspace volumes to enable flexible use of airspace.

1.5 Element 3: Minimum safe altitude warning (MSAW)

1.5.1 This element is intended to warn the controller, about increased risk of controlled flight into terrain accidents by generating, in a timely manner, an alert of aircraft proximity to terrain or obstacles. MSAW is only effective when each alert causes the controller to immediately assess the situation and if necessary take appropriate action.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT/METRIC TO DETERMINE SUCCESS

Safety	Significant reduction of the number of major incidents.
Cost Benefit Analysis	The business case for this element is entirely made around safety and the application of ALARP (as low as reasonably practicable) in risk management.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 The relevant PANS-ATM provisions exist. In addition they must regularly analyse the data and circumstances pertaining to each alert in order to identify and correct any shortcomings pertaining to ground-based safety nets, airspace design and ATC procedures.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 Aircraft should support cooperative surveillance using existing technology such as Mode C/S transponder or ADS-B out.

4.2 Ground systems

4.2.1 ATS units providing surveillance services must be equipped with the ground-based safety nets that are appropriate and optimized for their environment.

4.2.2 Appropriate offline tools should be available to support the analysis of every safety alerts.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 The generated alerts should normally be appropriate and timely, and the controller should understand under which circumstances interactions can occur with normal control practices or airborne safety nets. The two main issues from human performance are related to nuisance alerts which should be kept to a minimum and warning time for a genuine alert which should be high enough to support the completion of the procedure.

5.1.2 The use of ground-based safety nets will depend on the controller's trust. Trust is a result of many factors such as reliability and transparency. Neither mistrust nor complacency is desirable; training and experience is needed to develop trust at the appropriate level.

5.2 Training and qualification requirements

5.2.1 Controllers must receive specific ground-based safety nets training and be assessed as competent for the use of the relevant ground-based safety nets and recovery techniques.

6. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

6.1 Current use

6.1.1 Worldwide, most air traffic service units that provide surveillance services and that are using recent surveillance systems are already equipped with ground-based safety nets that are in principle fit for purpose. However, in many cases there is a lack of expertise, lack of tools or conflicting priorities for limited resources that cause these ground-based safety nets to not be effective.

6.2 Planned or ongoing trials

6.2.1 No general validation required.

7. REFERENCE DOCUMENTS

7.1 Standards

EUROCONTROL Specifications for STCA, APW, MSAW and APM, available at http://www.EUROCONTROL.int/safety-nets

7.2 Procedures

PANS-ATM (Doc 4444), section 15.7.2 and 15.7.4

7.3 Guidance material

EUROCONTROL Guidance Material for STCA, APW, MSAW and APM, available at http://www.EUROCONTROL.int/safety-nets

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APPENDIX C

MODULE NO. B1-102: GROUND-BASED SAFETY NETS ON APPROACH

Summary	To enhance safety by reducing the risk of controlled flight into terrain accidents on final approach through the use of approach path monitor (APM). APM warns the controller of increased risk of controlled flight into terrain during final approach. The major benefit is a significant reduction of the number of major incidents.	
Main performance impact as per Doc 9854	KPA-10 – Safety	
Operating environment/ Phases of flight	Approach	
Applicability considerations	This module will increase safety benefits during final approach particularly where terrain or obstacles represent safety hazards. Benefits increase as traffic density and complexity increase.	
Global concept component(s) as per Doc 9854	CM – conflict management	
Global plan initiatives (GPI)	GPI-9: Situational awareness GPI-16: Decision support and alerting systems	
Main dependencies	B0-102	
Global readiness checklist		Status (ready now or estimated date)
	Standards readiness	Not applicable
	Avionics availability	Ready now
	Ground systems availability	Est. 2014
	Procedures available	Est. 2014
	Operations approvals	Est. 2014

1. NARRATIVE

1.1 General

1.1.1 This module aims to significantly increase the effectiveness of ground-based safety nets.

1.2 Baseline

1.2.1 The baseline is provided by module B0-102. However, it may be possible to implement as a single package the baseline and the improvements brought by this module.

1.3 Change brought by the module

1.3.1 This module adds an approach path monitor (APM) to the safety nets provided in Module B0-102. APM warns the controller about increased risk of controlled flight into terrain accidents by generating, in a timely manner, an alert of aircraft proximity to terrain or obstacles during final approach.

1.3.2 This module proposes an optimized APM which currently keeps the number of nuisance and false alerts to an effective minimum through the use of an accurate approach path model.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT/METRIC TO DETERMINE SUCCESS

Safety	Significant reduction of the number of major incidents.
Cost Benefit Analysis	The business case for this element is entirely made around safety and the application of ALARP (as low as reasonably practicable) in risk management.

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 The relevant PANS-ATM, Doc 4444 provisions need to be reviewed and complemented.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 Aircraft should support cooperative surveillance using existing technology such as Mode C/S transponder or ADS-B out. Consideration should be extended to include all air vehicles (manned and unmanned) that will be operating within or close to the confines of controlled airspace**.**

4.2 Ground systems

4.2.1 Where appropriate a functionality providing approach path monitoring should be added to the ATS unit system. The offline safety alerts tool should be updated to cater for this new type of alerts.

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 The generated alerts should normally be appropriate and timely, and the controller should understand under which circumstances interactions can occur with normal control practices or airborne safety nets.

5.1.2 The two main issues from human performance are related to nuisance alerts which should be kept to a minimum and warning time for a genuine alert which should be high enough to support the completion of the procedure.

5.1.3 The use of ground-based safety nets will depend on the controller's trust. Trust is a result of many factors such as reliability and transparency. Neither mistrust nor complacency is desirable; training and experience is needed to develop trust at the appropriate level.

5.2 **Training and qualification requirements**

5.2.1 Controllers must receive specific ground-based safety nets training and be assessed as competent for the use of the relevant ground-based safety nets and recovery techniques.

6. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

6.1 **Planned or ongoing trials**

EUROPE: The SESAR programme is developing enhancements to ground-based safety nets such as multi-hypothesis algorithms and use of downlinked aircraft parameters. Ongoing trials of enhanced functionalities commenced in 2011.

7. REFERENCE DOCUMENTS

7.1 **Standards**

EUROCONTROL Specifications for STCA, APW, MSAW and APM, available at http://www.EUROCONTROL.int/safety-nets (to be complemented)

7.2 **Procedures**

ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*, paragraphs 15.7.2 and 15.7.4 (to be reviewed and complemented).

7.3 **Guidance material**

- EUROCONTROL Guidance Material for STCA, APW, MSAW and APM, available at http://www.EUROCONTROL.int/safety-nets (to be complemented);
- ICAO Manual for Ground-based Safety Nets (to be developed).

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APPENDIX D

MODULE NO. B2-101: NEW COLLISION AVOIDANCE SYSTEM

Summary	Implementation of airborne collision avoidance system (ACAS) adapted to trajectory-based operations with improved surveillance function supported by ADS-B and adaptive collision avoidance logic aimed at reducing nuisance alerts and minimizing deviations. The implementation of a new airborne collision warning system will enable more efficient operations and future airspace procedures while complying with safety regulations. The new system will accurately discriminate between necessary alerts and "nuisance alerts". This improved differentiation will lead to a reduction in controller workload as personnel will spend less time to responding to "nuisance alerts". This will result in a reduction in the probability of a near mid-air collision.	
Main performance impact as per Doc 9854	KPA-02 – Capacity, KPA-10 – Safety.	
Operating environment/ Phases of flight	All airspaces.	
Applicability considerations	Safety and operational benefits increase with the proportion of equipped aircraft. The safety case needs to be carefully done.	
Global concept component(s) as per Doc 9854	CM – conflict management	
Global plan initiatives (GPI)	GPI-2: Reduced vertical separation minima GPI-9: Situational awareness GPI-16: Decision support system and alerting systems	
Main dependencies	B0-101, B1-102 and B1-85	
Global readiness checklist		Status (ready now or estimated date).
	Standards readiness	Est. 2023
	Avionics availability	Est. 2023
	Infrastructure availability	N/A
	Ground automation availability	√
	Procedures available	√
	Operations approvals	√

1. NARRATIVE

1.1 General

1.1.1 The existing airborne collision avoidance system – ACAS II has been very effective in mitigating the risk of mid-air collisions. Safety studies indicate that ACAS II reduces risk of mid-air collisions by 75 – 95% in encounters with aircraft that are equipped with either a transponder (only) or ACAS II respectively. In order to achieve this high level of safety, however, the alerting criteria used by ACAS II often overlap with the horizontal and vertical separation associated with many safe and legal airspace procedures. ACAS II monitoring data from the U.S. indicate that as many as 90% of observed resolution advisories (RAs) are due to the interaction between ACAS II alerting criteria and normal ATC separation procedures (e.g. 500 feet IFR/VFR separation, visual parallel approach procedures, level-off with a high vertical rate 1,000 feet above/below IFR traffic, or VFR traffic pattern procedures). In order to achieve intended efficiencies in the future airspace, a reduction in collision avoidance alerting thresholds may be necessary in order to further reduce separation while minimizing “nuisance alerts”. Initial examination of NextGen procedures such as closely spaced parallel operations (CSPO) or use of 3 nautical mile en-route ATC separation indicate that existing ACAS performance is likely not sufficient to support these future airspace procedures. As a result, a new approach to airborne collision avoidance is necessary.

1.2 **Baseline**

1.2.1 The baseline of this module is the result of the short-term improvements to ACAS implemented with module B0-101.

1.3 **Change brought by the module**

1.3.1 Implementation of an improved airborne collision avoidance system must minimize “nuisance alerts” while maintaining existing levels of safety. Additionally, this new system must be able to more quickly adapt to changes in airspace procedures and the environment.

1.3.2 This successor system should be capable of accommodating reduced separation minima and other new airspace procedures such as 4D trajectory management or ACAS applications, as well as the particularities of new vehicles (RPAs in particular).

1.3.3 Implementation of a new airborne collision avoidance system will enable more efficient operations and future airspace procedures while complying with safety regulations. The new airborne collision avoidance systems will accurately discriminate between necessary alerts and “nuisance alerts” across the expected horizontal and vertical separation projected in future airspace procedures. Improved differentiation leads to reduction in ATC personnel workload, as ATC personnel spent exert less time to respond to “nuisance alerts”.

1.3.4 These future airspace procedures facilitate the optimized utilization of constrained airspace, while maintaining safety standards. The revision of horizontal and vertical separation enables grid-locked areas to accommodate more aircraft in all flight domains. Augmented ACAS will facilitate closely spaced parallel operations, increasing terminal and aerodrome throughput. The new ACAS will also increase en-route capacity via the implementation of 3 NM separation minima.

1.3.5 In addition, alerting criteria and procedures will be revisited for the new airborne collision avoidance system.

1.3.6 The implementation of this module depends on the on-going effort to develop a successor to the current TCAS technology.

1.4 **Other remarks**

1.4.1 The United States’ Federal Aviation Administration (FAA) has funded research and development of a new approach to airborne collision avoidance for the past three years. This new approach takes advantage of recent advances in dynamic programming and other computer science techniques to generate alerts using an off line optimization of resolution advisories. This approach uses extensive actual aircraft data to generate a highly accurate dynamic model of aircraft behaviour and sensor performance. Based on a predetermined cost function and using advance computational techniques, this approach generates an optimized table of optimal actions based on information regarding intruder state information. This approach significantly reduces logic development time and effort by focusing developmental activities on developing the optimization process and not on iterative changes to pseudo-code.

2. INTENDED PERFORMANCE OPERATIONAL IMPROVEMENT

2.1 Metrics to determine the success of the module are proposed in the *Manual on Global Performance of the Air Navigation System* (Doc 9883).

2.2 Key performance metrics include probability of a near mid-air collision (P/NMAC) and the RA alert rate.

Capacity	Reduced use of the 1030/1090 MHz spectrum
Safety	a) improve resolution advisory (RA) accuracy to support future airspace procedures, such as new separation minima, with reductions in: 1) resolution advisory rate; 2) nuisance alerts rate; and b) reduction in the probability of near mid-air collision 1) probability of near mid-air collision – P(NMAC)

3. NECESSARY PROCEDURES (AIR AND GROUND)

3.1 Necessary operational procedures for future ACAS are contained in the *Procedures for Air Navigation Services — Aircraft Operations* (Doc 8168) and the *Procedures for Air Navigation Services — Air Traffic* Management (Doc 4444). Future ACAS capabilities should support the implementation of these procedures.

4. NECESSARY SYSTEM CAPABILITY

4.1 Avionics

4.1.1 Improved algorithm and computational technique, as well as hybridization with ADS-B is needed to increase the accuracy of the RA rates and to better differentiate “nuisance” and legitimate alerts. The necessary technical issues and requirements can be found in Annex 6 — *Operation of Aircraft*, Part I — *International Commercial Air Transport — Aeroplanes*, and *Airborne Collision Avoidance System (ACAS) Manual* (Doc 9863).

5. HUMAN PERFORMANCE

5.1 Human factors considerations

5.1.1 This module is still in the research and development phase so the human factors considerations are still in the process of being identified through modelling and beta testing. Future iterations of this document will become more specific about the processes and procedures necessary to take the human factors considerations into account. There will be a particular emphasis on identifying the human-machine interface issue if there are any and providing the high risk mitigation strategies to account for them.

5.2 Training and qualification requirements

5.2.1 This module will eventually contain a number of personnel training requirements. As and when they are highlighted, they will be included in the documentation supporting this module and their importance signified. Likewise, any qualifications requirements that are recommended will become part of the regulatory needs prior to implementation of this performance improvement.

6. REGULATORY/STANDARDIZATION NEEDS AND APPROVAL PLAN (AIR AND GROUND)

- Regulatory/standardization: updates required for ACAS equipage and procedures to enable reduced collision avoidance thresholds in criteria include:
  - ICAO Annex 6 — *Operation of Aircraft,* Part I — *International Commercial Air Transport — Aeroplanes*;
  - ICAO Annex 6 — *Operation of Aircraft,* Part II — *International General Aviation — Aeroplanes*;
  - ICAO Annex 10 — *Aeronautical Telecommunications*, Volume IV — *Surveillance Radar and Collision Avoidance Systems*; and
  - ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic. Management*.
- Approval plans: to be determined.

7. IMPLEMENTATION AND DEMONSTRATION ACTIVITIES (AS KNOWN AT TIME OF WRITING)

7.1 Current use

7.1.1 ICAO Annex 6 requires ACAS II for certain categories of aircraft, depending on the maximum take-off weight (MTOW) of the aircraft. Currently TCAS II v7 is the minimum equipment specification which complies with the ACAS II Standard. Some airspace will require TCAS II, v7.1 equipment from 2015.

7.2 Planned or ongoing activities

7.2.1 When installation of new ACAS is required or recommended to operators, the cost impact on operators should be taken into consideration.

United States: ACAS trial is currently planned for 2012 to validate operational feasibility in the PBN environment.

8. REFERENCE DOCUMENTS

8.1 Standards

RTCA DO-298 *Safety Analysis of Proposed Change to TCAS RA Reversal Logic.*

8.2 Guidance material

M. J. Kochenderfer and J. P. Chryssanthacopoulos, "*Robust airborne collision avoidance through dynamic programming*," Massachusetts Institute of Technology, Lincoln Laboratory, Project Report ATC-371, 2010.

8.3 Approval documents

- ICAO Annex 6 — *Operation of Aircraft,* Part I — *International Commercial Air Transport — Aeroplanes*
- ICAO Annex 6 — *Operation of Aircraft,* Part II — *International General Aviation — Aeroplanes*
- ICAO Annex 10 — *Aeronautical Telecommunications*, Volume IV — *Surveillance Radar and Collision Avoidance Systems*
- ICAO Doc 4444, *Procedures for Air Navigation Services — Air Traffic Management*

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