

Finance and Corporate Services
Information Management

14 February 2012
FOIA reference: F0001283

Dear XXXX

I am writing in respect of your recent application of 27 February 2012, for the release of information held by the Civil Aviation Authority (CAA).

Your request:

"Kindly provide a copy of the Helios Report referenced below. Thank you.

Safety Regulation Group. CAA PAPER 2011/03 CAA 'Significant Seven' Task Force Reports.

1.1.5 Sharing Safety Information.

In 2006 the RITSG commissioned Helios to produce a report that would gather as much available information as possible on Runway Incursion prevention technologies, survey their capabilities and then rate them in order of merit against agreed criteria. The report was finalised in 2007. ... Since then the report has remained within the CAA, but recently a number of requests have been received for a copy of it. The matter was raised at the RISG meeting on 18 February 2010 and the view of the group was that the report should be shared where appropriate".

Our response:

In assessing your request in line with the provisions of the Freedom of Information Act 2000 (FOIA), we are pleased to be able to enclose the information requested.

Civil Aviation Authority

Aviation House GW Gatwick Airport South Crawley West Sussex England RH6 0YR www.caa.co.uk
Telephone 01293 768512 rick.chatfield@caa.co.uk

If you are not satisfied with how we have dealt with your request in the first instance you should approach the CAA in writing at:-

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External Response Manager
Civil Aviation Authority
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Gatwick Airport South
West Sussex
RH6 0YR

mark.stevens@caa.co.uk

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Water Lane
Wilmslow
Cheshire
SK9 5AF

www.ico.gov.uk/complaints.aspx

Should you wish to make further Freedom of Information requests, please use the e-form at <http://www.caa.co.uk/foi>.

Yours sincerely

Rick Chatfield
FoIA & EIR Case Manager

CAA INTERNAL REVIEW & COMPLAINTS PROCEDURE

- The original case to which the appeal or complaint relates is identified and the case file is made available;
- The appeal or complaint is allocated to an Appeal Manager, the appeal is acknowledged and the details of the Appeal Manager are provided to the applicant;
- The Appeal Manager reviews the case to understand the nature of the appeal or complaint, reviews the actions and decisions taken in connection with the original case and takes account of any new information that may have been received. This will typically require contact with those persons involved in the original case and consultation with the CAA Legal Department;
- The Appeal Manager concludes the review and, after consultation with those involved with the case, and with the CAA Legal Department, agrees on the course of action to be taken;
- The Appeal Manager prepares the necessary response and collates any information to be provided to the applicant;
- The response and any necessary information is sent to the applicant, together with information about further rights of appeal to the Information Commissioners Office, including full contact details.

CAA RITSG Study

Technology Assessment

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Document information

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Executive Summary

Introduction and approach

This report, produced for the UK Civil Aviation Authority (CAA) Runway Incursion Technology Sub-Group (RITSG), is an independent assessment of technologies which could contribute to a CAA objective to reduce the number of runway incursions in the UK by 5% every year. A runway incursion is defined as:

*‘Any occurrence at an aerodrome involving the **incorrect presence** of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.’*

The assessment considered only systems that were:

- a. deployable within approximately 5 years (ie before 2012);
- b. a technology (ie not a sign, marker or procedure);
- c. able to provide guidance and/or warnings to Air Traffic Controllers (ATCOs), pilots or drivers;
- d. suitable for UK operations;
- e. able to contribute to a reduction in the number of runway incursions.

The assessment identified 54 candidate technologies of which 20 were considered to most closely match the criteria above and be suitable for UK operations. These 20 systems were combined into 6 functional groups that were then assessed against 3 separate categories namely: safety performance; usability; and system complexity. This approach is represented graphically in the figure below.

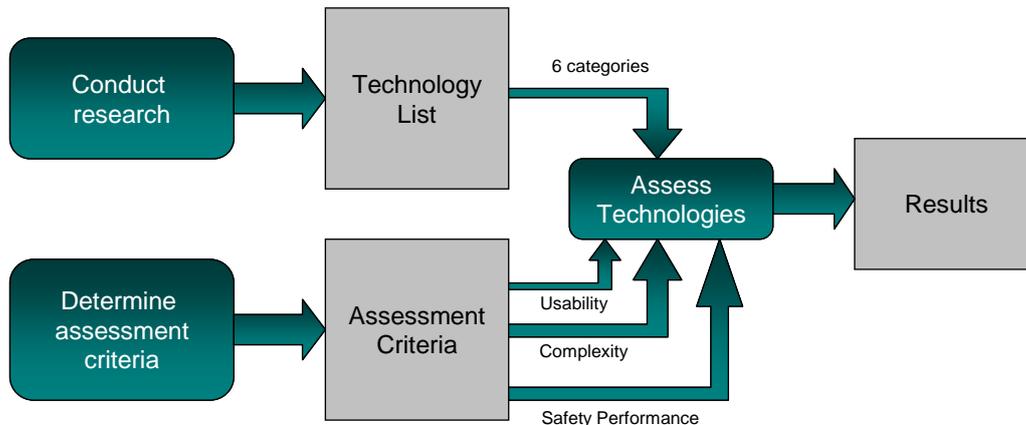


Figure A: Approach to the assessment

Grouping the 20 technologies provided two specific advantages: firstly to enable a more detailed assessment and secondly to future-proof the process by assessing system functionality rather than any manufacturers' specific implementation. The table below shows the 6 functional groups and their corresponding systems.

Group #	Description	Technology
1	Advanced surface movement guidance and control systems. Provide an enhanced level of surveillance to the controller	Ground Movement Control Park Air (RIMCAS) AMASS STREAMS Sensis ASMGCS A3000 TACSYS/CAPS
2	Surveillance system for specific regions of an airport only	CAMS RIDDS
3	Systems that reduce the risk of an erroneous clearance	EFPS enhancement
4	Systems that alert pilots/drivers to an occupied area of the airport	Ground marker RWSL ARIPS
5	Systems that provide surface navigation (but not traffic information) to the pilot	RAAS EFB
6	Systems that provide surface navigation and traffic information to the pilot/driver	PathProx RIPS ATSA-SURF TARMAC-AS ETNA

Table A: Technology categories

The 3 categories of assessment criteria, against which each of the functional groups were assessed are described as follows:

Safety performance – this category looked at evidence to answer the question “how effective is the technology likely to be at increasing runway safety?” based on causal factors that were allocated, by the CAA safety investigation and data department, to runway incursions recorded in the MOR (Mandatory Occurrence Reporting) database between 2002 and 2006.

Usability – this category incorporated 67 responses to a questionnaire sent to operational pilots and controllers to help answer the question “how user friendly is this technology to pilots or controllers?” The responses to the questionnaire were indicative rather than conclusive but nevertheless gave a useful measure of the necessary features of a runway incursion system that could not otherwise have been attained.

System complexity – this category looked at the other aspects of each technology to try and answer the important aspects of the question “how suitable is this technology for implementation”. This information typically came from manufacturer websites and was treated with caution to distinguish fact from fiction. The following four aspects were considered: cost; implementation effort; difficulty to retrofit; and likelihood of future obsolescence.

Conclusions and recommendations

Systems alerting pilots were found to be more effective at reducing incursions which is further evidence in support of the growing trend, particularly in the USA, to tackle the problem of runway incursions in the cockpit and not on the ground.

The clear winner in the safety category is the **cockpit navigation & surveillance** group, which although reliant upon a high proportion of equipped aircraft, has the potential to mitigate almost 25% of incursion causal factors. However these systems score particularly poorly in complexity due to the necessity to fit a significant proportion of aircraft with expensive avionics that may have very stringent safety requirements. On the other hand the avionics are likely to enable a significant number of other applications and capabilities that will alter the cost to benefit ratio over time and future-proof the systems.

The relative performance assessment of the systems designed for controllers may also improve in the future, because of the re-defined "runway incursion" which would increase the % of causal factors attributed to controllers.

ASMGCS-like systems are available to all aircraft now and perform well in usability and safety meaning that it is well worth considering for larger airports willing to invest in what is a fairly complex system.

A compromise between the expensive avionics requirements of the systems alerting pilots and the less effective systems that alert controllers is a system from the **Runway Occupancy** group. These systems provide the alert to the pilot without imposing expensive equipage requirements on the aircraft and they often take advantage of existing airport infrastructure. Although let down by their usability these type of systems can provide a relatively cost-effective solution for an airport.

A further cost-effective solution is a **Cockpit Navigation** system which includes a navigational display such as the EFB targeted for fast track certification in the USA. Whilst not providing any knowledge of traffic these types of systems do provide much greater situational awareness that significantly mitigate against the chance of a pilot/driver becoming disorientated and causing a runway incursion. Current activity in the US is also likely to reduce the cost and implementation effort required for EFBs.

The operational input from pilots and controllers was a valuable addition to the usability assessment and identified a number of indicative conclusions such as:

- Almost no respondents felt an alarm should be provided to the pilot without also being issued to the controller.
- Controllers were approximately 50% more tolerant of false alerts than pilots.
- There was also an almost unanimous response for any visual alert to also be supplemented with an aural element.
- Both pilots and controllers raised concerns over alerting in situations that would be considered routine - eg a pilot being alerted to a crossing runway entry point or a controller being alerted to all mobiles approaching a runway.

The technology groups scoring highest in usability exhibited properties of a low false or nuisance alerting rate, integrated displays with both visual and aural warning and took into account visibility conditions.

For a system to score well in complexity, ie be 'uncomplicated', it needed to be: inexpensive to procure, install and maintain; simple to implement (i.e. quick and not significantly affecting operations); compatible with both old and new aircraft without a major programme of retrofitting; and future-proof for the medium to long-term.

The **EFPS Enhancement** scored very well in complexity making it the least complex and most usable system. As a modular add-on to an existing and increasingly common system (EFPS) it can be implemented relatively easily and with no need for any airborne equipment.

A summary of the results of the assessment is given below.

Description (All)

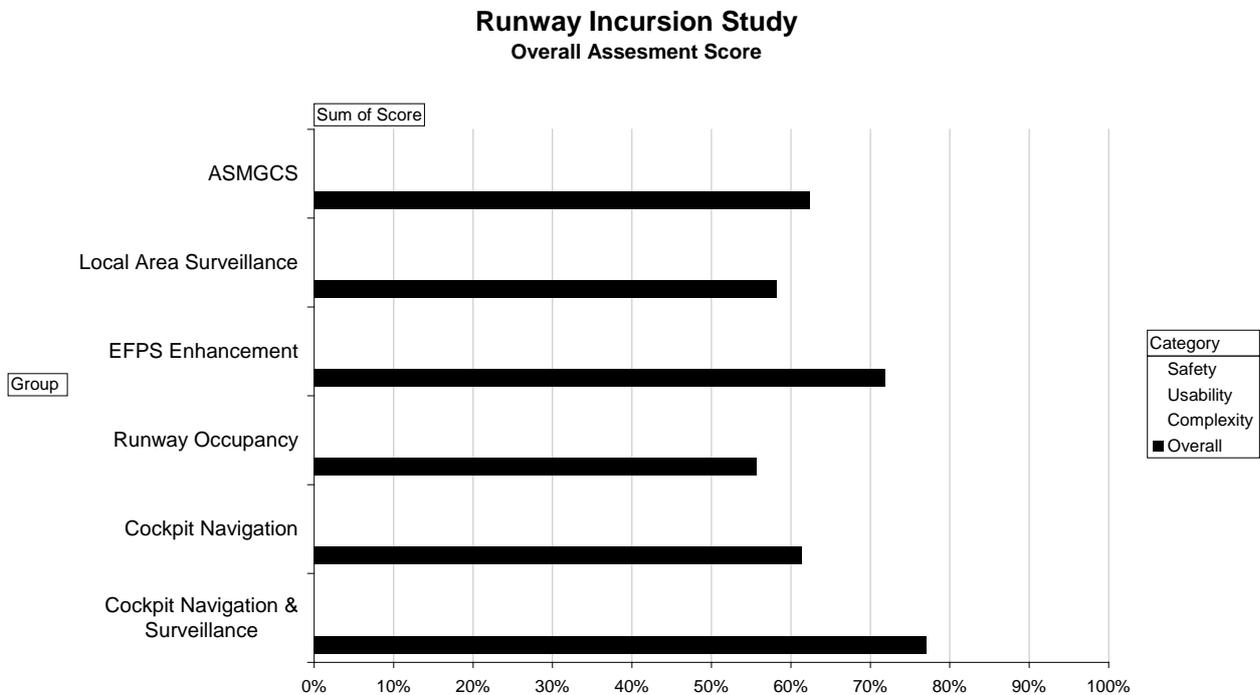


Figure B: Overall results

There does not appear to be any one 'ideal' system that is able to instantly reduce the number of runway incursions by the target 5% without compromising either usability or complexity. Furthermore a one size fits all approach can't be applied due to the sheer variety of aircraft, airports and procedures in the UK and it is likely that a combination of technologies – a so called layered approach – will be the most realistic solution in any regional implementation.

As a result of the assessment the following recommendations are made:

- Systems that alert pilots offer a greater potential for reducing the number of runway incursions than those that alert only controllers. Ideally the system would alert both.
- Systems in the Cockpit navigation & surveillance group have the potential to be the safest in the future and the long term recommendation is to support an evolution towards this type of system. In the short term insufficient work has been done on the conflict detection algorithms and the costs are too high to fit a significant proportion of aircraft with avionics that may have very stringent safety requirements. On the other hand the avionics are likely to enable a significant number of other applications and capabilities that will alter the cost to benefit ratio over time and future-proof the systems.
- The impact of the new runway incursion definition on causal factors is monitored to see how the relative safety assessment would change
- ASMGCS is available now and is well worth considering for larger airports willing to invest in what is a fairly complex but effective system.

- The EFPS Enhancement, whilst limited to fairly specific types of runway incursion, is the least complex and most usable system. As a modular add-on to an existing and increasingly common system (EFPS) it can be implemented relatively easily and with no need for any airborne equipment.
- Runway Occupancy systems provide the alert to the pilot without imposing equipage requirements on the aircraft. Although let down by their usability these type of systems can provide a relatively cost-effective solution for an airport.
- The systems in the Cockpit Navigation group provide much greater situational awareness that can significantly mitigate against the chance of a pilot/driver becoming disorientated.
- Visual alerts should also be supplemented with an aural element.
- The most usable systems should have a low false or nuisance alerting rate, integrated displays with both visual and aural warning and should take into account visibility conditions.

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1 Introduction

1.1 Purpose

This document is produced for the UK Civil Aviation Authority (CAA) Runway Incursion Technology Sub-Group (RITSG).

It is an independent review of technologies currently available or in development, which could be used to reduce the number of runway incursions at UK licensed aerodromes. A key objective of the CAA is to reduce the number of runway incursions by 5% every year.

The primary purpose of this review is to assess each technology and to provide, to the CAA, a recommendation for the most promising technology according to this assessment.

Definition of a runway incursion

In January 2007 the CAA adopted the following ICAO definition of a runway incursion:

*‘Any occurrence at an aerodrome involving the **incorrect presence** of an aircraft, vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft.’*

The distinction from the old definition is ‘incorrect presence’ which replaces ‘unauthorised or unplanned presence’ and consequently implies that incidents resulting from ATC error will now be captured as runway incursions. For example occasions when a pilot correctly follows the issued clearance, but the clearance itself is erroneous and results in an ‘incorrect presence’ on the runway, will now be defined as runway incursions.[1] This definition also encompasses situations in which an aircraft takes off (or lands) on the wrong runway.

Figure 1 shows the impact of this changed definition on the number of reported incursions from January 2007 to March 2007 (with 2004-6 for reference)

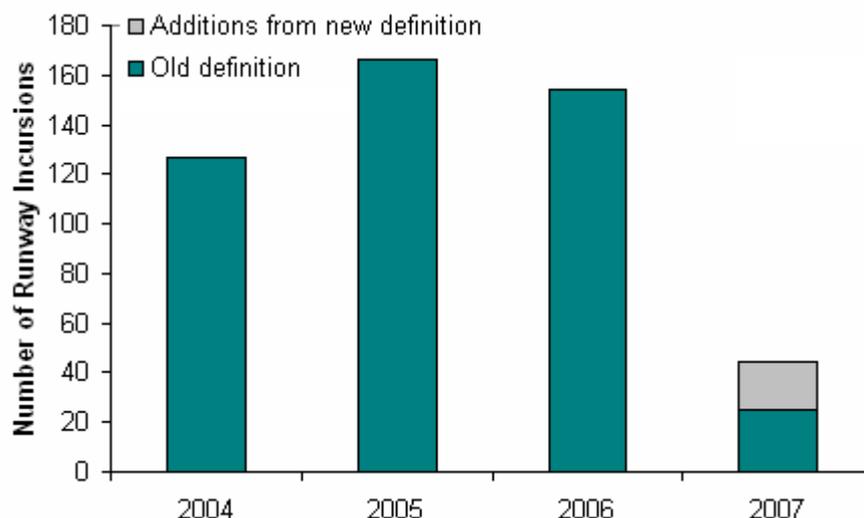


Figure 1: Impact of new runway incursion definition¹

¹ Figure courtesy of CAA

1.2 Background

In the UK there has been a significant increase in the number of reported runway incursions². In 2000 the CAA set up the Runway Incursion Steering Group (RISG) to coordinate the regional action plan to reduce runway incursions in the UK.

This group has undertaken a number of actions including enhancements to the safety gathering system, reviews of procedures and training, consideration of markings and Safety Management Systems and the development of a runway risk awareness campaign. A sub-group of the RISG is looking into the technical solutions that can reduce the problem.

The work in the UK corresponds with work at the European level, where a European Action Plan for the Prevention of Runway Incursions (EAPPRI) has been developed as a response to the growing numbers of incidents, which recent analysis reported as occurring at a frequency of twice a day in the European region. The EAPPRI sets forth 56 recommendations for those working on the manoeuvring area which can be implemented by Local Runway Safety Teams, which are now established at 91% of International airports across the European Region³.

EUROCONTROL created a snapshot of available technologies to help prevent runway incursions in 2005 which showed that there are many independent sources of alarms and alerts but that all fail to meet the ICAO requirement for an integrated system that will simultaneously advise the pilot/driver and the controller.

EUROCONTROL are also targeting specific areas of safety concern such as Air-ground communications through safety improvement initiatives which should address two of the four, mostly urgently considered, contributing factors in runway incursions⁴.

In the USA runway incursions are a top priority and have continued to decrease over the past four years. The average for 2001-2004 was 5.4 incursions per million operations which is almost one incursion per day and roughly half of that in Europe. This is still some way off their 2009 target of 0.39 per million⁵.

The NTSB (National Transportation Safety Board) are calling for "prompt action" because "the continuing occurrence of hazardous incidents show that we still have work to do."⁶ This is further supported by the NTSB most wanted⁷ list which, for some time, has been prompting the FAA to provide immediate warnings of probable collisions/incursions directly to flight crews in the cockpit.

As a result of this pressure from the NTSB, there has been a strong trend for technical solutions to runway incursions that are directed at the pilot rather than the controller - this desire looks likely to be established in Europe too. The recent announcement⁸ from the FAA that EFBs (Electronic Flight Bags) would be 'fast tracked' for certification and "need to be in the cockpit" is testament to this trend.

² CAP 763 - Aviation Safety Review, 2005

³ Runway Safety Letter - www.eurocontrol.int/runwaysafety

⁴ EUROCONTROL website: http://www.eurocontrol.int/runwaysafety/public/standard_page/Runway.html

⁵ FAA Runway Safety Report, August 2005 www.faa.gov/runwaysafety/pdf/report5.pdf

⁶ Remarks by Mark V. Rosenker, Chairman NTSB, April 2007 www.nts.gov/speeches/rosenker/mvr070416.htm

⁷ NTSB Most Wanted, www.nts.gov/recs/mostwanted/aviation_issues.htm

⁸ FAA Administrator Marion Blakey, March 23rd 2007, Source: Flight Tech Online

Training has also been targeted, particularly GA (General Aviation) pilots, through on-line websites such as the joint AOPA and Air Safety Foundation website for runway safety⁹.

At a global level ICAO are currently drafting the Runway Safety Manual which will build on the success of the EAPPRI but with an objective of reducing runway incursions worldwide.

1.3 Scope

To be considered as a candidate “runway incursion prevention technology” for this assessment study a system had to be:

- deployable within approximately 5 years (ie before 2012);
- a technology (ie not a sign, marker or procedure);
- able to provide guidance and/or warnings to Air Traffic Controllers (ATCOs), pilots or drivers;
- suitable for UK operations;
- able to contribute to a reduction in the number of runway incursions.

⁹ Runway Safety Website: http://flash.aopa.org/asf/runwaySafety/html/index/runwaySafety_expanding.htm

1.4 Approach

The approach taken in this study is detailed in each appropriate section of this report but has broadly been to first identify all available technologies, identify the criteria to measure them against and to then assess the candidates with the most potential. This is shown in Figure 2 below.

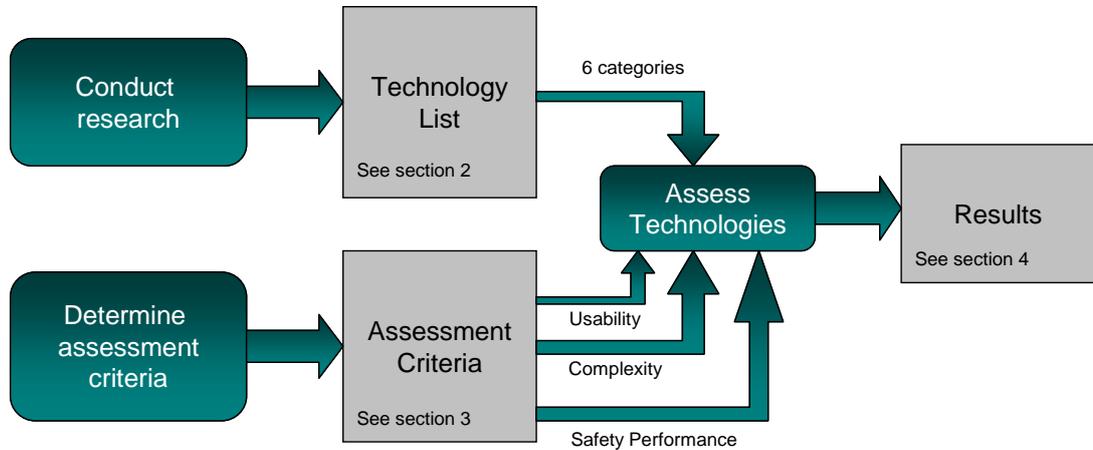


Figure 2: Approach to the assessment

The identification phase considered all technologies on the market. Based on: the expertise of Helios; conversations with manufacturers; and desk-based research; a list, showing the functionality of each technology, was compiled. This list, totalling 54 technologies, was then filtered down into a shortlist of 20 candidate technologies for assessment. This filtering took into account the scope specified above and the assessment categories identified by Helios. These 20 candidates were grouped into 6 categories before the assessment.

In assessing the technologies three categories were identified: *safety performance* determines the likely impact on the number of runway incursions based on the past trends of causal factors; *usability* judges each system against the most useful system aspects as identified by controllers and pilots; *system complexity* is the final category and considers factors such as ease of implementation and cost.

2 Technologies

This section illustrates the technologies identified by Helios and how each of them offers some form of runway incursion prevention. A shortlist of these is then compiled for the assessment described in section 3.

2.1 Available technologies

An extensive list of technologies was compiled based on information gathered from:

- Helios' expertise;
- conversations with manufacturers;
- desk-based research (websites and previous studies);

The alphabetically ordered list of 54 technologies is shown below in Table 1 and gives the manufacturer(s) and name of each technology that could be used as a means to reduce the chance of a runway incursion.

Manufacturer/Developer and name	
1.	Adacel - Voice Activated Cockpit Avionics
2.	Axis Electronics Ltd - Ground Marker
3.	CIAS Elettronica - ERMO 482X PRO
4.	CMC Electronics - CMC-2610 SureSight M-Series
5.	DLR - Taxi and Ramp Management and Control Airborne System (TARMAC-AS)
6.	ERA - Inductive Loop Sensor Subsystem (LSS) aka inductive Looop Technology (LOT)
7.	ERA - MSS
8.	ERA - PathProx
9.	ERA - SQB - Vehicle Location Transmitter AKA "SQUID"
10.	FAA - Final Approach Runway Occupancy Signal (FAROS)
11.	FAA - Surface Decision Support System (SDSS)
12.	FAA technical note - Airport Active Runway Vehicle Lighting
13.	FRL - Ground Movement Control.
14.	Galaxy Scientific Corp (uncontactable) - Airport Trak
15.	HITT - A3000 A-SMGCS systems
16.	Honeywell - Runway Awareness and Advisory System (RAAS)
17.	Jeppesen - Electronic Flight Bag (EFB)
18.	Kinetic Avionics - Surveillance Base Station (SBS) 1
19.	Kinetic Avionics - Surveillance Base Station (SBS) 2
20.	Max Vis - EVS-1000
21.	Max Vis - EVS-2500
22.	MDI Security Systems - SenseEye VMD
23.	Municipal Airports of Anchorage, Alaska - CCTV implementation project
24.	NASA - Runway Incursion Prevention System (RIPS)
25.	NASA Ames Research centre - Taxi Navigation and Situation Awareness (T-NASA)
26.	NAV Canada - Integrated Information Display Screen - Extended Computer Display System (IIDS-EXCDS).
27.	Norden Systems (Northrop Grumman) - Airport Movement Area Safety System (AMASS)
28.	Norden Systems (Northrop Grumman) - Airport Surface Detection Equipment (ASDE-3)
29.	Norden Systems, (Northrop Grumman) - Airport Surface Radar (ASR) - 9 and ASR-12
30.	Norris EO Systems - Autonomous Runway Incursion System (ARIPS)
31.	Park Air (Northrop Grumman) - Runway Incursion Monitoring and Conflict Alert System (RIMCAS) NOVA-9000
32.	Patriot Technologies - Runway Occupancy/Obstruction Warning System (ROWS)
33.	Plextek - BlightER 200
34.	Plextek - BlightER 400
35.	Qinetiq & Comsoft - Quadrant Aircraft Surveillance
36.	Runway Technologies - Runway Incursion and Debris Detection System
37.	Saarland Univerity, Centre for Integrated Systems (Germany), Voltronic electronics (Germany), Centre for Research and Technology, (Helias, Greece), FRAPort, High Tech Marketing (Austria), Advantage

Manufacturer/Developer and name	
	Technical Consulting - Intelligent Surveillance and Management functions for Airfield applications based on Low cost magnetic field detectors (ISMAEL)
38.	Sensis - Advanced Surface Movement Guidance and Control System (A-SMGCS)
39.	Sensis - Multistatic Dependent Surveillance (MDS) System
40.	Sensis - Veelo
41.	Sensis, Raytheon, ELAR and Dassault - Airport Surface Detection Equipment (ASDE X)
42.	Siemens - Simatic WinCC
43.	Stanford University & NAV 3D - Synthetic Vision Displays
44.	Thales - Mosquito Vehicle transmitters and AS-680 ground stations
45.	Thales - Surface Traffic Enhancement and Automation Support (STREAMS)
46.	Thales ATM, FAA Navigation program - Local Area Augmentation System (LAAS)
47.	Thales, Sensis, FRAport - Electronic Taxiway Navigation Array (ETNA)
48.	Thales, Sensis, FRAport - Taxi and Control System/Cooperative Area Precision Tracking System (TACSYS/CAPS)
49.	Transtech - Critical Area Management System (CAMS)
50.	Various - ADS-B APT
51.	Various - Controller Pilot Datalink Communications CPDLC
52.	Various: (L3 & Thales with Safe Route. Sensis manufacture required datalink hardware) - ATSA-SURF (CDTI)
53.	Volpe National Transportation Center - Runway Status Lights (RWSL)
54.	Volpe National Transportation Center, Northrop Grumman, Rannoch Corporation, Amber & Texas Instruments - Forward Looking Infrared (FLIR) and Infrared (IR) focal plane array technology

Table 1: Initial list of technologies

This information was organised into a spreadsheet with each row representing a technology and each column representing one of the data fields below:

- Manufacturer;
- Model;
- Description;
- Deployment (trial or operational and at which locations);
- User (Flight crew, ATCO or Vehicle driver);
- Functionality;
- HMI type (Human Machine Interface – eg visual display, aural notification etc);
- Alerting (whether alerting is part of the system or not);
- References (typically hyperlinks to related web-pages).

The completed spreadsheet is contained in annex C.

2.2 Shortlist for assessment

The full list was studied by Helios and notes were made against each technology in order to determine whether or not the system was a suitable assessment candidate (see 'initial assessment' column in annex C).

These notes formed the basis of a coarse filtering which narrowed down the candidate technologies to a short list of 20 that met the scope specified in section 1.2.

By considering each technology in a generic architecture that is comprised of position determination, processing and alerting – as shown in Figure 3 it was possible to further reduce this shortlist into 6 technology **groups**. Grouping technologies in this way provided two specific advantages – the first is that a reduced set of candidates allowed for a more thorough assessment. The second

is that the functionality is assessed rather than any manufacturers' specific implementation.

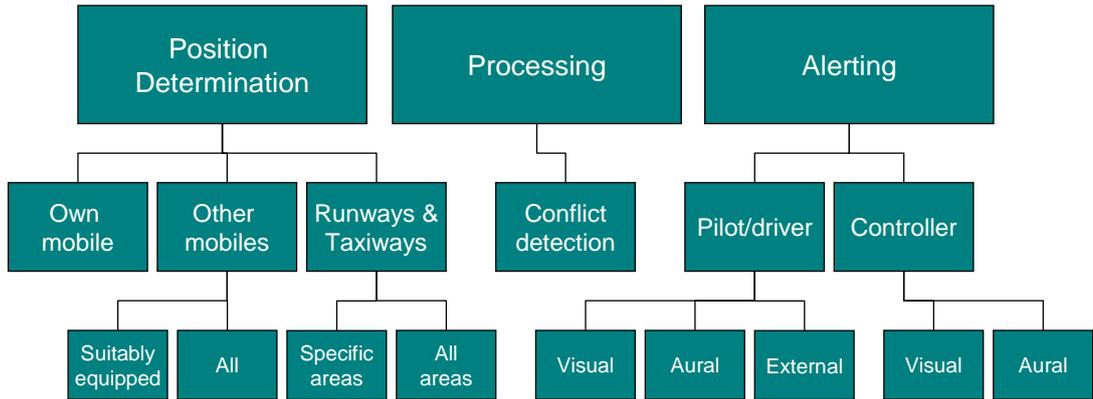


Figure 3: Generic architecture for runway incursion prevention systems

An example of how this architecture is applied, can be seen with the first group which encompasses surface movement guidance and control systems. These systems determine the position of all mobiles (ie including non-cooperative aircraft and vehicles) and all runways/taxiways (ie the full surface map). This information is processed to detect conflicts which would the controller would then be visually and aurally alerted to. This description is based on the architecture in Figure 3 which can be depicted specifically for this group with shaded boxes as shown below. The architectural elements that do not apply to this group are greyed out.

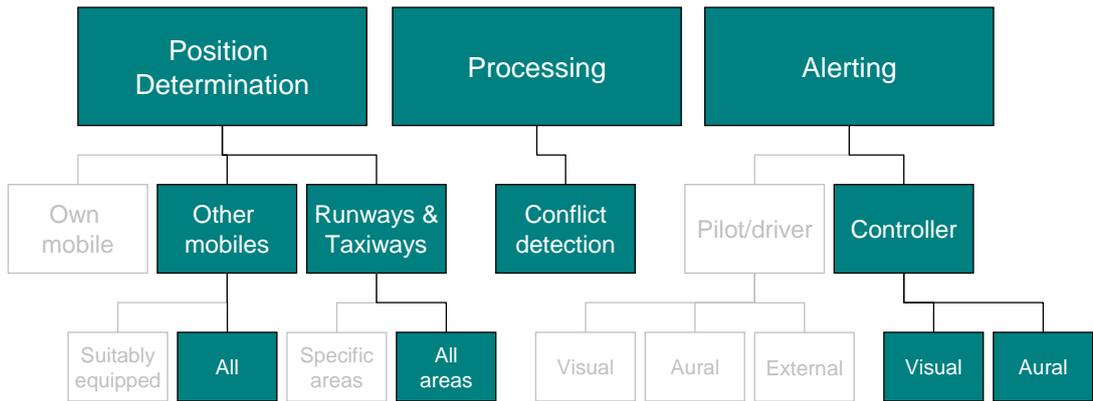


Figure 4: Generic architecture for technology group 1

Categorising each of the 20 technologies in this way lead to the 6 groups described below in Table 2.

Group #	Name	Description	Technology
1	ASMGCS	Advanced surface movement guidance and control systems. Provide an enhanced level of surveillance to the controller	Ground Movement Control Park Air (RIMCAS) AMASS STREAMS Sensis ASMGCS A3000 TACSYS/CAPS
2	Local Area Surveillance	Surveillance system for specific regions of an airport only	CAMS RIDDS
3	EFPS Enhancement	Systems that reduce the risk of an erroneous clearance	EFPS enhancement
4	Runway Occupancy	Systems that alert pilots/drivers to an occupied area of the airport	Ground marker RWSL ARIPS
5	Cockpit Navigation	Systems that provide surface navigation (but not traffic information) to the pilot	RAAS EFB
6	Cockpit navigation & surveillance	Systems that provide surface navigation and traffic information to the pilot/driver	PathProx RIPS ATSA-SURF TARMAC-AS ETNA

Table 2: Technology categories

3 Assessment

This section describes the derivation of the criteria against which each of the technology groups has been assessed. It also depicts how the assessment has been undertaken. The results of the assessment are provided in section 4.

3.1 Assessment criteria

Each of the six technology groups identified in section 2.2 was assessed in three categories:

- **Safety performance** – this category looked at evidence to answer the question “how effective is the technology likely to be at increasing runway safety?”
- **Usability** – this category incorporated the opinions of operational personnel to answer the question “how user friendly is this technology to pilots or controllers?”
- **System complexity** – this category looked at the other aspects of each technology to try and answer the important aspects of the question “how suitable is this technology for implementation” (for example cost, implementation impact etc)

A score was derived for each category, which was normalised to a % value, and these were then combined to generate an overall evaluation of each technology group relative to each other.

3.2 Safety performance

The safety performance of each system was assessed to determine how effective a technology would potentially be at reducing the chance of a runway incursion. This was a particularly important category because it would strongly link the technologies to the required reduction in the number of runway incursions.

The basis of this assessment was to consider the causal factors that were allocated, by the CAA safety investigation and data department, to runway incursions that were recorded in the MOR database between 1st January 2002 and 31st December 2006. Then to identify which of the causal factors the technology would reduce and by how much.

Each causal factor in the MOR had been attributed to one of the following entities: Aerodrome; ATC; Driver; Equipment; People; Pilot; Regulator; or Third Party. Thus a matrix could be formed from the MOR data showing the number of recorded instances when a causal factor was attributed to one of the entities above. This matrix is shown in Table 3.

During the period 1st January 2002 to 31st December 2006 there were 561 recorded runway incursions and from Table 3 it can be seen that a total of 1628 causal factors were identified for these incursions – roughly 3 causal factors per incursion. It can also be seen from this table that causal factors are attributed to pilots in more than 1 in 2 runway incursions and that pilots and drivers failing to follow a clearance is the most significant causal factor by far, accounting for 344 causal factors (21%).

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion		5				7		
Conditional Clearance		55						
CRM		1				10		
Incorrect/missed Readback		45	13			44		
Misunderstanding	1		9			25		
No R/T Available			56	1	6			
No R/T Contact		1	44			13		
Phraseology		31	4			5		
Poor ATC Coordination		3						
Poor R/T Contact			1					
Poor R/T Monitoring		3				1		
Poor signals			1					
Disorientation			6			10		
Distraction		5	5			31		
Erroneous Expectation		6	11			49		
Incorrect Clearance								
Green route left on								
Lack of situational awareness		5	4			15		
Misidentification			2			25		
Misinterpretation	1		9			26		
Misperception		1	5			13		
Overload	2					3		
Third Party			4		22			
Aircraft								
ATS Controlled Equipment	1	2		1				
Vehicles								
Failed follow Clearances			40			304		
Failed follow Instructions/Signals			30		2	13		
Failed follow Procedures	2	8	69		2	9		1
Poor Procedures	32	2	1				1	
Poor/Lack Instructions	3	12	1					
Poor Lookout/Monitoring		15	1			4		
Restricted view		4						
Confusion		3	11			36		
Ignored indications/clearances			39		2	85		
Lack of Experience/Familiarisation		1	12			34		
Lack of Understanding/Knowledge			28			8		
Complacency			2			1		
Violation			6		2			
Poor Aerodrome Security	38				1			
Poor Indicators/Signs/Lighting/Charts	21	1		6	1			
Poor/Lack of Ability/Airmanship			1			38		
Poor/Lack of Training			18			1		
Press-on-itis			12			14		
Assumption						1		
Total (as a % of 1628)	6%	13%	27%	0%	2%	51%	0%	0%

Table 3: Reference table for safety assessment

The safety performance assessment considered each technology group in-turn and involved Helios allocating a likelihood of a particular causal factor being reduced by a negligible (0%), small (25%), medium (50%) or large (75%) amount.

For each technology group, a blank replica of Table 3 was created with “s”, “m” or “l” in each appropriate cell that corresponded to a positive impact of the technology that had been recognised by Helios. The values corresponding to “s”, “m” and “l” were then multiplied by the historical data in Table 3 to provide an overall score reflecting the number of causal factors that could be prevented by each technology.

An example of this is for the causal factor “Lack of situational awareness” and the responsible entity “ATC”. Taking the first technology group (ie ASMGCS), Helios assessed that a large number of such incidents would be affected because of the additional situational awareness given to the controllers by an ASMGCS system. Given that 5 incidents had been attributed to that factor and entity in the past, it was determined that 75% (large impact) of those causes could be avoided with an ASMGCS system and thus a score of $5 * 0.75 = 3.75$ was added to the total. This example is supported by Figure 5 below.

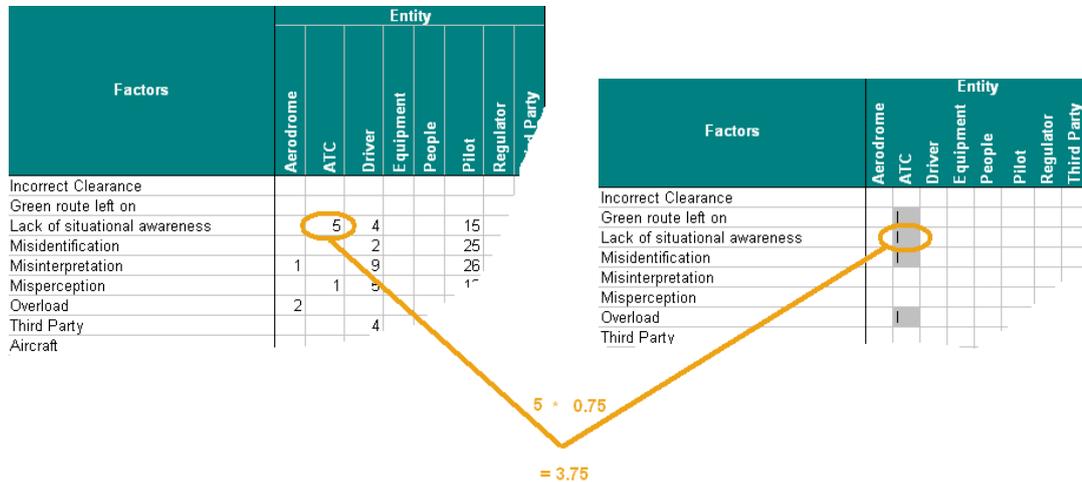


Figure 5: Safety assessment example

The tables for each of the six technology groups are shown in annex D and the results are summarised in section 4.

Assumptions

The safety performance assessment relies on the following assumptions:

- The recorded incidents are assumed to be typical of those seen at any airport – in reality runway incursion frequency is likely to vary from airport to airport. For example an airport with a tower that has a restricted view is likely to have a far higher number of causal factors attributed to poor vision than one with a very clear view.
- Causal factors from 2002-2006 are assumed to be indicative of those likely to occur in the future. However the change to the definition of a runway incursion is likely to increase the factors attributed to ATCOs (see section 1.1) and so those systems designed for controllers are likely to score better if future incident data is used.
- The assessment assumes that systems relying on co-operative surveillance are receiving the necessary inputs from the appropriate aircraft. For example a cockpit display of traffic relying on ADS-B would only have an impact on “Lack

of situational awareness” if other aircraft are visible. In reality there will be a transition to the necessary levels of equipage which would be affected by incentives or mandates (for example the ADS-B mandate in the USA).

- For the impact of the technology to be identified it assumes that there is no impact from the technology at present ie the incidents have occurred in an environment where the technology is not installed. This is likely to be the case in the vast majority of cases between 2002 and 2006.
- The causal factors are assumed to be equally likely to cause a runway incursion. Without further detailed analysis of each incident it is not possible to determine which factors are the most significant in any one incident or whether certain factors are more influential on the severity of a particular incursion.

3.3 Usability

The usability assessment category identifies the likely success of a technology based on its capacity to meet the requirements and preferences of its intended user.

To identify the requirements and preferences of the intended user, Helios developed an informal questionnaire that was distributed to a small number of operational pilots and controllers which is shown in annex F. A total of 67 responses were received, 70% of which were from controllers and the remaining 30% from pilots, as shown in Figure 6. Drivers were not asked to respond on the assumption that a system for drivers is designed in much the same way as one for pilots ie it provides a surveillance and/or navigation picture to the driver (pilot) enabling them to negotiate their vehicle (aircraft) around the airport safely.

Questionnaire response (number, %)

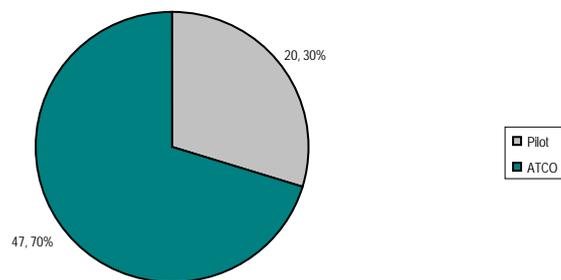


Figure 6: Questionnaire response

The responses to the questionnaire were indicative rather than conclusive but nevertheless gave a useful measure of the necessary features of a runway incursion system that could not otherwise have been attained solely by Helios. The responses to each question are shown graphically in annex F.

Whilst multiple choice answers were given by all respondents, additional comments were provided by some and these added further insight into the operational perspective.

The six technology groups split neatly into three designed for pilots and three for controllers. It was therefore decided to measure the usability of the pilot groups against the corresponding pilot responses and likewise for the controller groups. All responses were normalised to percentage values in order to ensure the assessments were comparable.

Each question in the survey relates to different usability features of a typical runway incursion prevention system, in particular those relating to alarms and false alerts. For example who should alerts be provided to? Should they be mandatory? Should they be aural? How many false alerts are acceptable? Should the alerts be multistage? etc.

The final usability score for each technology category was deduced from a combination of a capability evaluation against a usability feature and a weighting based on the user response to the corresponding question in the survey.

Usability features

The following summary, supported by annex E, indicates how each usability feature was evaluated:

- **Who should alarms be provided to?** Almost no respondents felt that an alarm should be provided to the pilot only, therefore the technology groups providing alarms to controllers only or to both pilots and controllers, scored higher. Comments included the need to avoid controller overload, and avoidance of ambiguous executive authority.
- **Should alarms provide advice or mandate a response?** Opinion was divided on mandatory alerting as, according to comments made, imposing this condition may remove vital flexibility from the system (which may in itself impinge upon the acceptable workload limits and so generate an additional hazard). This flexibility was also considered necessary to provide the ATCO with the time needed to deal with false or undetected alerts. Technology groups with mandatory alerts scored similarly to those without, due to the division of opinion.
- **What is the maximum acceptable false alert rate?** Respondent were given 3 options for this: 0 false alerts; 0.01 (1 false alert in every 100); or 0.05. Taking the average of the answers it was found that controllers were approximately 50% more tolerant of false alerts than pilots with an average maximum acceptable rate of 0.015 compared to 0.010 for the pilots. This makes sense given, for example, the implications of an alert being generated to a pilot in a highly work-intensive stage of flight such as final approach.

The average alert rate from the survey is certainly not a conclusive value however the difference between pilot and controller tolerance meant that the technology groups of controller systems scored higher than those with an equivalent alerting rate that are designed for pilots. The alerting rate for each technology group was subjectively assessed as either high, medium or low (relative to each other) based on Helios' knowledge of the systems in each group.

Comments typically related to the fact that more false alert decreases the trust placed in the system and in some cases will lead to the system being automatically switched off once a false alert threshold is reached.

- **How should the alert be transmitted?** Almost unanimously (100% of controllers and 95% of pilots) felt that a visual alarm should also include an aural element. Therefore systems including aural alerting scored higher than those without. Comments from respondents indicated that some felt aural alarms were more important than visual. Others felt that too many aural alerts made distinguishing them difficult.
- **Should multi-stage alerting be available?** Both pilots and controllers were in favour of systems that included more than one stage of alert (eg an amber warning followed by a red alert) therefore systems meeting this preference scored higher than those with just one stage of alert.
- **Should visual alerts be combined with other displays?** Approximately one third of both pilots and controllers felt that alerts should be displayed separately to existing monitors. The remaining two thirds preferred a visual alert to be combined with other display and accordingly these types of technology groups scored better.
- **Should pilots be alerted to the crossing runway entry point?** The majority (approximately 70%) of pilots felt that they should not be alerted every time they reach an entry point to a runway they need to cross. The most commonly cited reason being that it would become a distraction and reduce the impact of an alert for a real runway incursion. In the assessment, only the technology

groups for pilot systems were assessed against this usability feature and only the pilots responses were used to score each group.

- **Should controllers be alerted to all mobiles approaching a runway?** The vast majority (almost 90%) of controllers felt that controllers should not be alerted for every occasion in which an aircraft or vehicle approaches the runway because, as cited by pilots above, it would reduce the impact of an alert for a real incursion. Furthermore it would produce an almost continuous alert at the busiest airports. Only controller systems were assessed for this feature and only controller responses were used to score them.
- **Should different alerting parameters exist for day and night?** 80% of pilots and 90% of controllers felt that different parameters should not exist, and accordingly the systems that kept the parameters for alerting consistent for day and night scored better.
- **Should different alerting parameters exist for different visibility conditions?** Whilst controllers strongly favoured a “yes” answer here, pilots were marginally in favour of “no”. The technology groups for pilots therefore score highest if they do not use different alerting parameters, conversely the technology groups for controllers score highest if they do distinguish alerting parameters for different visibility conditions.

Weighting

Helios considered each of the 10 usability features described above and determined that some were more significant than others and that their scores should thus be weighted more heavily. The less significant features were weighted 25% lower and the more significant were weighted 25% more. The following table shows the weighting and response proportions that were multiplied together to create a score, per usability feature, for each technology group.

#	Usability factor	Weighting		Answer	% of responses (ATCOs)	% of responses (Pilots)
2	Who should alarms be provided to?	High	1.25	Controller	44%	11%
				Pilot/Driver	2%	0%
				Both	54%	89%
3	Should alarms provide advice or mandate a response?	Low	0.75	Advisory	55%	47%
				Mandatory	45%	53%
4	What is the maximum acceptable false alert rate?	High	1.25	High (0.05)	0.02	0.01
				Medium (0.01)	0.10	0.07
				Low (0.001)	1.00	0.65
5	How should the alert be transmitted?	Low	0.75	Visual only	0%	5%
				Visual with sound	100%	95%
6	Should multi-stage alerting be available?	Med	1	Yes	75%	68%
				No	25%	32%
7	Should visual alerts be combined with other displays?	Med	1	Separate	36%	29%
				Combined	64%	71%
8	Should pilots be alerted to the crossing runway entry point?	Med	1	Yes	N/A	21%
				No	N/A	79%
9	Should controllers be alerted to all mobiles approaching a runway?	Med	1	Yes	13%	N/A
				No	87%	N/A
10.1	Should different alerting parameters exist for day and night?	High	1.25	Yes	10%	22%
				No	90%	78%
10.2	Should different alerting parameters exist for different visibility conditions?	High	1.25	Yes	85%	44%
				No	15%	56%

Table 4: Reference table for usability assessment

3.4 System complexity

The system complexity assessment category captures other important information about each system that isn't considered by the safety or usability assessment. This information typically comes from manufacturer websites and has thus been treated with caution to distinguish fact from fiction. Despite this precaution this assessment is relatively subjective and so each system has been rated as having either of "small", "medium" or "large" impact on the following four, equally-weighted, sub-categories:

- **Cost** – a small impact was chosen where Helios considered the overall cost of procurement, installation and maintenance of a system to be relatively small (regardless of who it would be imposed upon). A large impact correspondingly denoted a large estimated overall cost.
- **Implementation effort** – where Helios concluded that a significant effort was required to implement a system, for example to dig up a runway or take an aircraft out of service for a week, then a large impact was selected.
- **Difficulty to retrofit** – if a system required avionics to be installed that a significant proportion of aircraft did not already have (nor would be likely to in the near future) then a large impact was assigned to the technology group.
- **Likelihood of future obsolescence** – this sub-category took into account the maturity of the technology group, its growth potential and the industry support for the systems contained within it. "Small" was assigned to those groups that offered the most potential for longevity.

The maximum score in this category was $4 \times 0.75 = 3.0$ where 0.75 represents large, 0.5 represents medium and small is represented by 0.25.

As with the other assessment categories, a table was used to record the results which were then normalised to a % relative to the maximum score in that category. An example of how this table was used to assess the system complexity of ASMGCS is shown below in Figure 7.

	ASMGCS
Category	
Cost	m
Implementation effort	l
Difficulty to retrofit	s
Likelihood of future obsolescence	m
Absolute score	2.00
Relative % score	
Key	
Large (l) = 0.25	
Medium (m) = 0.5	
Small (s) = 0.75	

Figure 7: Reference table for system complexity assessment

4 Results

4.1 Technology group 1 - ASMGCS

Name & Manufacturer(s)		
ASMGCS – Level 2 Advanced Surface Movement and Guidance Control System and its US equivalent: AMASS (Airport Movement Area Safety System) Includes RIMCAS (Park Air), AMASS (Norden Systems), STREAMS (Thales), A-SMGCS (Sensis), A3000 (HITT), Ground Movement Control (FRL) and TACSYS/CAPS (Thales)		
Description <i>(Refer to section 2)</i>		
Systems in this group will take surveillance information from a variety of sources to provide, to the controller, a picture of any aircraft/vehicles operating in any of the airports movement areas. Visual and aural alerts will draw the attention of the controller to any detected conflict.		
<pre> graph TD PD[Position Determination] --> OM[Own mobile] PD --> OM2[Other mobiles] PD --> RT[Runways & Taxiways] OM2 --> SE[Suitably equipped] OM2 --> All1[All] RT --> SA[Specific areas] RT --> All2[All areas] P[Processing] --> CD[Conflict detection] A[Alerting] --> PD2[Pilot/driver] A --> C[Controller] PD2 --> V1[Visual] PD2 --> A1[Aural] PD2 --> E[External] C --> V2[Visual] C --> A2[Aural] </pre>		
Safety performance <i>(Refer to section 3.2 and Annex D.1)</i>		
This technology group scores ok, eliminating an estimated 5% of runway incursion causal factors. This is mainly due to labelling aircraft on a synthetic display which gives greater situational awareness thus reducing the chance of an uncorrected missed readback, and improves the monitoring ability of the controller which also often alleviates the need to give conditional clearances. The modified CAA definition of a runway incursion also means that 5% is likely to be an underestimate given that many causal factors due to controllers were not recognised by the previous definition.		
A particular strength of this group is that it can use multiple surveillance inputs and does not require a change to aircraft equipage making it a favourable system for improving safety at a particular location.		
Comparative score (relative to best performing group):		21% Rank: 4
Usability <i>(Refer to section 3.3 and Annex E)</i>		
This group scores very well in terms of usability due to multi-stage alarms (sometimes programmable), and visual and aural alerts that typically vary with meteorological conditions.		
However they have a relatively high probability of raising false alerts typically caused by false radar reflections (which has led to these type of systems being deactivated in the past), and are usually displayed on a separate monitor rather than in combination with others.		
Unlike the other systems in this group, AMASS provides alerts that, under certain circumstances, a controller must react to (as mandated by the FAA).		
Comparative score (relative to best performing group):		99% Rank: 2

System complexity

Systems in this group are well understood and already in operation at many airports throughout the world. The architecture of such systems is usually modular and so upgrades are well catered for.

The Park Air RIMCAS is the most widely used system in the UK and aspects of the SENSIS systems are installed at the 35 busiest US airports. Many of these installations do not include the full runway incursion alerting capability that distinguishes Level 1 ASMGCS from Level 2. Where it is installed, unique target identification is often the limiting factor for an incursion prevention system that doesn't regularly false alert.

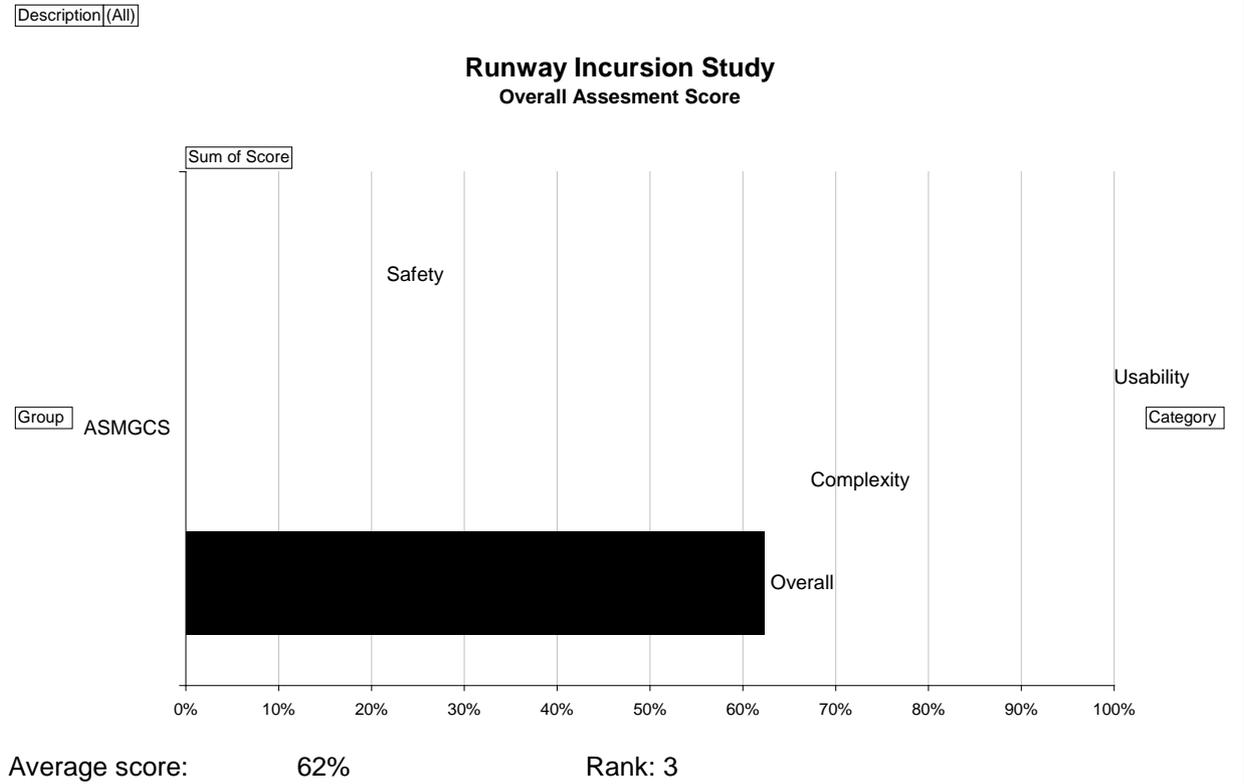
Taking inputs from multiple surveillance sources to provide a synthetic picture of traffic on an airport map means that these systems can be quite complex and require significant effort to install and implement and so are generally only suitable for busy airports.

These systems are designed to work with all aircraft and so do not impose any avionics requirements. However the system performance is improved where unique target identification is available and so Mode S and MLAT transponders are preferred.

Comparative score (relative to best performing group): Rank: 5
67%

Overall

Systems in this group score relatively poorly in safety due to only affecting the small proportion of incidents (under the previous definition of a runway incursion) where the ATCO has been a causal factor. They score well in usability, despite a high instance of false alerts, but poorly in complexity due to high procurement and implementation costs.



4.2 Technology group 2 - Local Area Surveillance

Name & Manufacturer(s)	
Local area surveillance CAMS (Transtech), Runway Incursion and Debris Detection System – RIDDS (Runway Technologies).	
Description (Refer to section 2)	
Systems in this group will take surveillance information from strategically placed sensors to provide, to the controller, an indication of any aircraft/vehicles operating in a specifically monitored area of an airport. Visual alerts will draw the attention of the controller to any detected conflict.	
<pre> graph TD PD[Position Determination] --> OM[Own mobile] PD --> OM2[Other mobiles] PD --> RT[Runways & Taxiways] OM2 --> SE[Suitably equipped] OM2 --> All1[All] OM2 --> SA1[Specific areas] RT --> SA1 RT --> All2[All areas] P[Processing] --> CD[Conflict detection] A[Alerting] --> PD2[Pilot/driver] A --> C[Controller] PD2 --> V1[Visual] PD2 --> A1[Aural] PD2 --> E[External] C --> V2[Visual] C --> A2[Aural] </pre>	
Safety performance (Refer to section 3.2 and Annex D.3)	
This technology group scores poorly in safety relative to the other groups. It is estimated that just over 2% of causal factors could be eliminated by systems in this group. With the capacity to alert only controllers (responsible for only 13% of causal factors in past CAA incidents) and only for specific parts of the runway it is unsurprising that these systems come out bottom in this assessment category.	
Comparative score (relative to best performing group):	9% Rank: 6
Usability (Refer to section 3.3 and Annex E)	
This technology group scored well in usability. The main difference between this group and the ASMGCS group is due to the preferred multi-stage alerting that is provided by ASMGCS but not this group.	
Typically employing millimetre wave radar and optical or laser beams these systems can be subject to a relatively high incidence of false alerting (particularly in LVC) and appear limited to visual alerting only. The HMI is typically stand-alone from other systems, which also counts against the group.	
Comparative score (relative to best performing group):	91% Rank: 3

System complexity

This group of systems is generally quite complex, typically using sophisticated sensors to optically identify aircraft by "reading" or "characterising" them as they pass. Installation is likely to be relatively difficult as the sensors may protrude into the obstruction free zone.

Optical/laser sensors are generally expensive to procure and maintain (as they are difficult to both align and keep aligned) but applied to a relatively small, critical area they can be a more cost effective solution for airports unable to justify an ASMGCS.

Deployment and/or endorsement of these types of systems is very limited so far, making their growth potential difficult to see. No specific avionics are required though, so retrofit is not an issue.

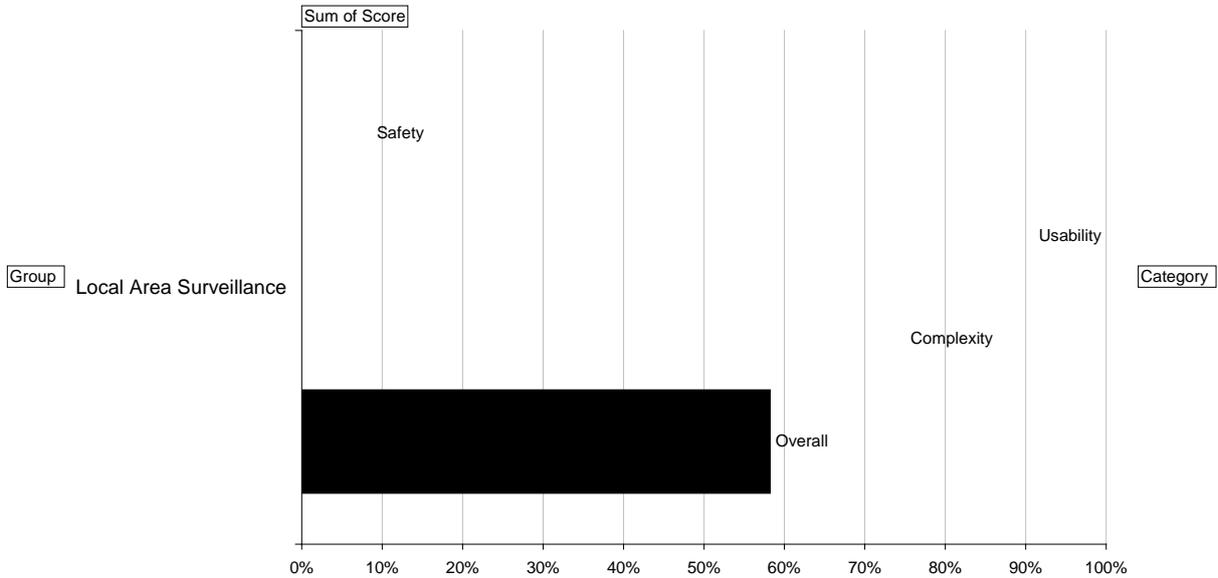
Comparative score (relative to best performing group): 75% Rank: 4

Overall

The systems are a more cost effective solution than a full ASMGCS which provide protection against incursions in critical areas of an airport. They correspondingly score well in complexity and also in usability however they only affect a small proportion of incidents where the ATCO has been a causal factor and thus score poorly in safety. Little in the way of endorsement or implementation is evident for these types of systems so far.

Description (All)

Runway Incursion Study
Overall Assesment Score



Average score: 58% Rank: 5

4.3 Technology group 3 - EFPS Enhancement

Name & Manufacturer(s)		
EFPS (Electronic Flight Progress Strip) Enhancement Electronic Flight Progress Strips (EFPS) runway incursion prevention system, (also known as the Integrated Information Display Screen - Extended Computer Display System, IIDS-EXCDS).		
Description (Refer to section 2)		
Systems in this group do not use surveillance information but they provide a safety net against controllers inadvertently issuing conflicting clearances. Visual, and potentially aural, alerts will draw the attention of the controller to stop any conflicting clearance being issued.		
<pre> graph TD PD[Position Determination] --> OM[Own mobile] PD --> OthM[Other mobiles] PD --> RT[Runways & Taxiways] OM --> SE[Suitably equipped] OM --> All1[All] OthM --> SA1[Specific areas] OthM --> All2[All areas] RT --> SA2[Specific areas] RT --> All3[All areas] P[Processing] --> CD[Conflict detection] A[Alerting] --> PDrv[Pilot/driver] A --> C[Controller] CD --> V1[Visual] CD --> A1[Aural] CD --> E1[External] PDrv --> V2[Visual] PDrv --> A2[Aural] PDrv --> E2[External] C --> V3[Visual] C --> A3[Aural] </pre>		
Safety performance (Refer to section 3.2 and Annex D.4)		
This technology group scores reasonably poorly, eliminating fewer than 4% of runway incursion causal factors. This is mainly due to the specific nature of the type and relative infrequency of the incursions it is able to prevent – namely clearing two aircraft onto the same runway. However the redefined definition of a runway incursion is likely to capture more incidents in the future that systems in this group are likely to prevent.		
Comparative score (relative to best performing group):	16%	Rank: 5
Usability (Refer to section 3.3 and Annex E)		
This technology group is the top performer in term of usability. It was highlighted by controllers that EFPS introduced an increased chance of clearing 2 aircraft/vehicles onto the same runway as it replaced traditional flight progress strips - the physical holding of which provided a barrier against such a clearance. The software is programmable but effectively forces (ie mandates) a controller to avoid placing two flight strips into the active runway 'bay' or 'window'. The chance of a false alert is thus very low and furthermore the alerting is built into an existing display.		
Comparative score (relative to best performing group):	100%	Rank: 1

System complexity

Although a relatively simple system, introducing logic into an EFPS significantly increases the necessary work to approve it. As a software system the implementation is mostly paper based and so this system scores relatively well on cost and implementation effort.

As no avionics are necessary retrofit is not an issue and the fact that EFPS is becoming the standard for the foreseeable future (installed at Luton, Gatwick, Heathrow and Stansted) means that obsolescence is unlikely too.

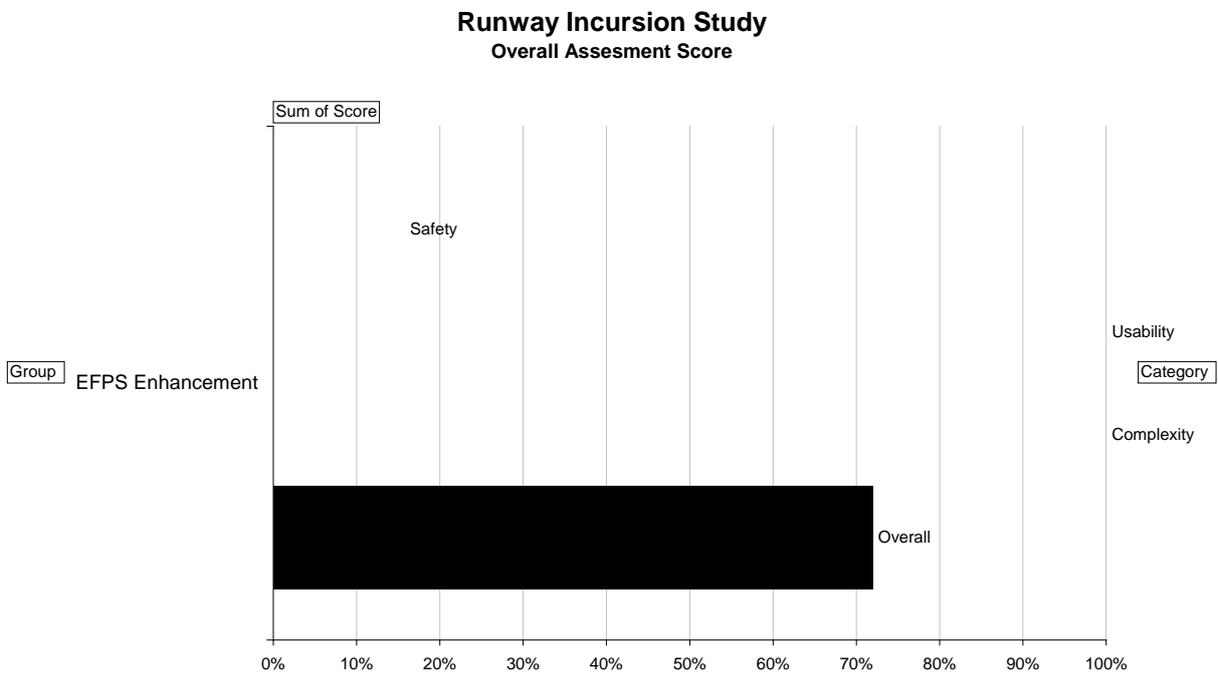
Comparative score (relative to best performing group): 100% Rank: 1

Overall

This system is designed to eliminate a specific but growing causal factor of runway incursions, which is the chance of two aircraft being given clearance onto the same runway.

Although simplistic and limited to a specific type of incursion the growing use of EFPS systems, combined with the new definition of a runway incursion is likely to see this technology becoming ever more successful in the future.

Description (All)



Average score: 72% Rank: 2

4.4 Technology group 4 - Runway Occupancy

Name & Manufacturer(s)		
Runway occupancy systems Ground Marker (Axis Electronics), RWSL (Volpe Centre), ARIPS (Norris EO Systems).		
Description (Refer to section 2)		
Systems in this group will take surveillance information from strategically placed sensors to provide, to the pilot, an indication of any aircraft/vehicle operating in a specifically monitored area of an airport. Aural alerts or external lighting will draw the attention of the pilot to any detected conflict. ¹⁰		
<pre> graph TD PD[Position Determination] --> OM[Own mobile] PD --> Oth[Other mobiles] PD --> RT[Runways & Taxiways] Oth --> SE[Suitably equipped] Oth --> All1[All] RT --> SA[Specific areas] RT --> All2[All areas] P[Processing] --> CD[Conflict detection] A[Alerting] --> PDrv[Pilot/driver] A --> C[Controller] PDrv --> V1[Visual] PDrv --> A1[Aural] PDrv --> E[External] C -.-> V2[Visual] C -.-> A2[Aural] </pre>		
Safety performance (Refer to section 3.2 and Annex D.5)		
Eliminating just over 5% of runway incursions, this technology group scores slightly better than the ASMGCS group. The main safety advantages are gained through an increased situational awareness to the pilot/driver and by an alerting mechanism to counter against incursions caused by pilot/driver distraction.		
Comparative score (relative to best performing group):	22%	Rank: 3
Usability (Refer to section 3.3 and Annex E)		
These systems score poorly in terms of usability. As with most of the systems for alerting pilots this group does not provide alerts to the controller (although it is proposed as an extension to ARIPS). They are subject to a relatively high false alerting rate based on the fact that targets are not uniquely identified (magnetic induction loops and UV lighting are used as sensors in two cases)		
Alerts tend to be limited to either lighting cues from outside of the cockpit or auditory warnings inside it. Furthermore these alerts are not combined with other systems. Pilots are typically alerted each time they approach a runway - which is considered to degrade the usability as it is thought that this will desensitise them to the warning. The systems do not modify their alerting for differing meteorological conditions.		
Comparative score (relative to best performing group):	53%	Rank: 6

¹⁰ It is proposed that a future system may also alert the controller (denoted by the dotted lines in the diagram) but this functionality has not yet been developed and is therefore excluded from the assessment of this technology group.

System complexity

Unlike other technology groups, there is noticeable difference between the systems in this group (Ground Marker, RWSL and ARIPS) despite achieving equivalent functionality, as described above. Ground marker (trialled at Bournemouth and Manchester) is the most mature of the three with ARIPS being the least developed (demonstrated August 2006).

All three systems score relatively well on estimated cost and implementation because they are mostly modifications to an existing infrastructure - lighting in the case of ARIPS and RWSL, and radio transmitters (ILS frequency) in the case of Ground Marker (although Ground Marker would also require taxiway closure for installation of magnetic induction loops that detect aircraft). The quoted cost from the manufacturer's website for ARIPS is £0.5-1.0M. Procurement and installation is quoted as 12-18 months.

Whilst ARIPS is able to monitor vehicles, both RWSL and Ground marker can't (although Ground Marker could potentially be adapted). A further disadvantage of Ground Marker is the potential obsolescence of the necessary marker's on which the cockpit alerting is based. RWSL is gaining support in the USA as a result of trials at Dallas/Fort Worth International Airport but any ICAO approval may be difficult to achieve given that the system effectively places traffic lights in front of the landing aircraft.

A number of future proposals have been proposed for these systems although they are fairly conceptual and not covered in this analysis. For example Ground Marker could be extended to include the use of SMR and approach radar to increase coverage and ARIPS may eventually provide alerts to the controllers too.

In summary, systems in this group are relatively cheap and easy to install. They will work without any significant retrofitting necessary and there is potential for them to be upgraded to protect against obsolescence.

Comparative score (relative to best performing group): 92% Rank: 2

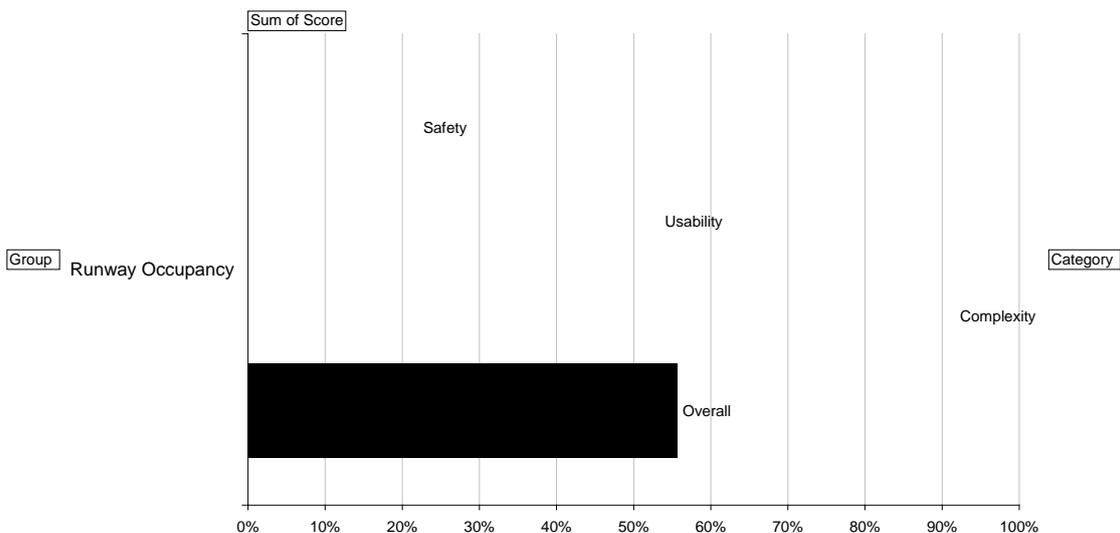
Overall

Systems in this group provide an alerting capability to the pilots without imposing a large avionics cost. Whilst the usability is generally considered to be low they do score reasonably well in safety performance and complexity (relative to other groups). In other technology groups safety performance comes at the cost of complexity because aircraft would need to be fitted with appropriate avionics and so this combination is worth noting despite the overall rank of this group compared with others.

As their deployment is relatively immature these systems may well prove in the future to be a relatively effective system for a low budget.

Description (All)

Runway Incursion Study
Overall Assesment Score



Average score: 56% Rank: 6

4.5 Technology group 5 - Cockpit Navigation

Name & Manufacturer(s)		
Surface navigation systems RAAS (Honeywell) , Class 2 EFB (Jeppesen)		
Description (Refer to section 2)		
Systems in this group provide situational awareness to the pilot/driver of their own-ship with respect to the airport surface - typically on a full airport map. This may be supplemented by aural alerts when approaching runways. No detection of conflicting aircraft/vehicle is provided.		
<pre> graph TD PD[Position Determination] --> OM[Own mobile] PD --> Oth[Other mobiles] PD --> RT[Runways & Taxiways] OM --> SE[Suitably equipped] OM --> All1[All] RT --> SA[Specific areas] RT --> All2[All areas] P[Processing] --> CD[Conflict detection] A[Alerting] --> PDrv[Pilot/driver] A --> C[Controller] PDrv --> V1[Visual] PDrv --> A1[Aural] PDrv --> E[External] C --> V2[Visual] C --> A2[Aural] </pre>		
Safety performance (Refer to section 3.2 and Annex D.6)		
Systems in this group score fairly well in safety performance mitigating just over 6% of incursion causal factors. This is due to the increased awareness and knowledge of the airport routing provided by the navigation display. This reduces the chance of a runway incursion caused, in particular, by confusion, lack of familiarisation, disorientation, lack of ability and lack of situational awareness.		
Comparative score (relative to best performing group):	26%	Rank: 2
Usability (Refer to section 3.3 and Annex E)		
Systems in this group score fairly well in this assessment category. Relying on GPS position and airport databases means that false alerts are unlikely but alerting pilots to an approaching runway every time they enter a designated area may be considered a nuisance alert. For this reason a moderate rating is assigned to the false alerting (incorporating nuisance) aspect of the assessment.		
Single stage visual alarms independent of meteorological conditions that, as with most cockpit systems, provide alerts only to the pilots count against this group.		
Comparative score (relative to best performing group):	75%	Rank: 5

System complexity

The technologies in this group require a capability on-board the aircraft/vehicle to display runway locations to the pilot/driver. In the case of the RAAS this is an extension to the EGPWS and in the case of the EFB it is an airport moving map.

A certified class 3 EFB may cost in the region of £100k but the FAA are currently fast-tracking certification of class 2 EFBs which are available for approximately £10k, making this solution a relatively cheap one. EGPWS is installed on most passenger aircraft (but not any vehicles) and should be upgradeable to include the RAAS function at a reasonable price. A portable class 2 EFB could be installed relatively quickly and with minimal down-time for an aircraft.

A significant proportion of aircraft would need to be retrofitted with appropriate avionics to benefit from these systems however their benefits are clear and they are well protected from any threat of obsolescence in the near to medium time span.

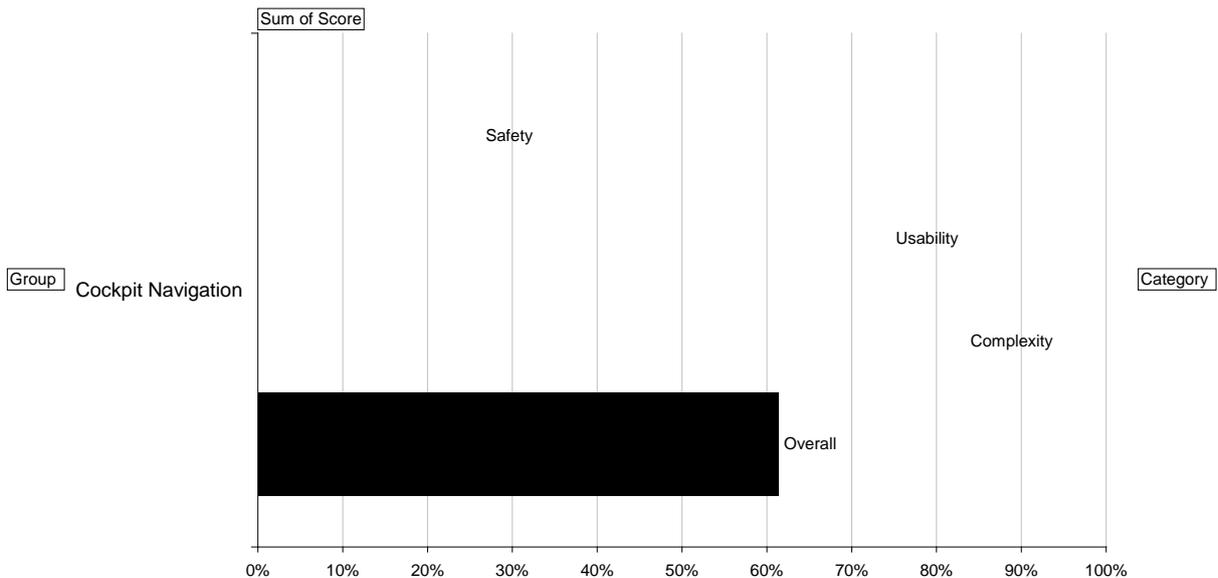
Comparative score (relative to best performing group): 83% Rank: 3

Overall

These systems provide immediate orientation of the aircraft position on the airport surface. Disorientation on the airport surface is a major contributor to runway incursions which is why this group is ranked 2nd in terms of safety performance. Although ranked low, this is a reasonably useable system and is not far behind the systems above it. As a class 2 EFB is now available cheaply this group also scores well in complexity because of the high benefit to cost ratio that it has.

Description (All)

Runway Incursion Study
Overall Assesment Score



Average score: 61% Rank: 3

4.6 Technology group 6 - Cockpit navigation & surveillance

Name & Manufacturer(s)	
Systems providing both surface navigation and information on surface traffic to the pilot/driver. Pathprox (ERA), RIPS (NASA), ATSA-SURF(L3, Thales, Sensis), TARMAC-AS (DLR), ETNA (Sensis, FRAport, Thales)	
Description (Refer to section 2)	
Systems in this group will combine surveillance information from suitably equipped aircraft/vehicles with own mobile position to provide, to the pilot/driver, a synthetic picture of cooperative aircraft/vehicles superimposed onto a full airport map. Although relatively immature, it has been assumed that visual and aural alerting is included in the system to draw the attention of the pilot/driver to any detected conflict.	
<pre> graph TD PD[Position Determination] --> OM[Own mobile] PD --> Oth[Other mobiles] PD --> RT[Runways & Taxiways] Oth --> SE[Suitably equipped] Oth --> All1[All] RT --> SA[Specific areas] RT --> All2[All areas] P[Processing] --> CD[Conflict detection] CD --> V1[Visual] CD --> A1[Aural] A[Alerting] --> PDrv[Pilot/driver] A --> C[Controller] PDrv --> Ext[External] PDrv --> V2[Visual] PDrv --> A2[Aural] C --> V3[Visual] C --> A3[Aural] </pre>	
Safety performance (Refer to section 3.2 and Annex D.7)	
Performance of systems in this group is very dependent upon the proportion of aircraft equipped but if a high proportion is assumed, then they score much higher than any other group, mitigating almost 25% of incursion causal factors. This is due to the increased awareness and knowledge of the airport routing and surrounding traffic provided by the display. This reduces the chance of a runway incursion caused, in particular, by failing to follow clearances, misunderstanding, distraction, lack of situational awareness, misidentification, confusion, lack of familiarisation and lack of ability.	
Comparative score (relative to best performing group):	100% Rank: 1
Usability (Refer to section 3.3 and Annex E)	
This system has the potential to deliver high usability by providing timely advisory multilevel alerts based on both traffic and position information to pilots/drivers. The HMI is integrated with other systems and the alarms are raised using both using both sound and visual communication.	
Alarms are raised based on surveillance derived from dependant surveillance sources (such as ADS-B), which in a mixed equipage environment means that only a partial picture will be presented to the pilot. Alerts will be raised to pilots crossing a runway, potentially becoming nuisance alerts. In addition alerts are not based upon meteorological conditions. These factors reduce the overall system usability.	
Comparative score (relative to safest group):	81% Rank: 4

System complexity

The technologies in this group require a capability on-board the aircraft/vehicle to display both traffic and runway locations to the pilot/driver.

The necessary avionics to support these systems is likely to be considerably expensive, particularly if they must be safe enough in order to base a decision to abort or continue a take off. These systems are very immature at the moment and standards are still being developed (The FAA/EUROCONTROL RFG group is still in debate as to whether alerts can be included on any cockpit surface awareness system).

The implementation effort is also likely to be significant with almost no aircraft currently able to fit this type of system without additional avionics being retro-fitted. For aircraft unable to fit an ADS-B transponder it is likely that TIS-B would be required to support the need for a full traffic picture.

However, providing a traffic picture to the pilot has many other potential uses (as defined by the RFG) which give this system a low likelihood of being made obsolete in the near-mid term.

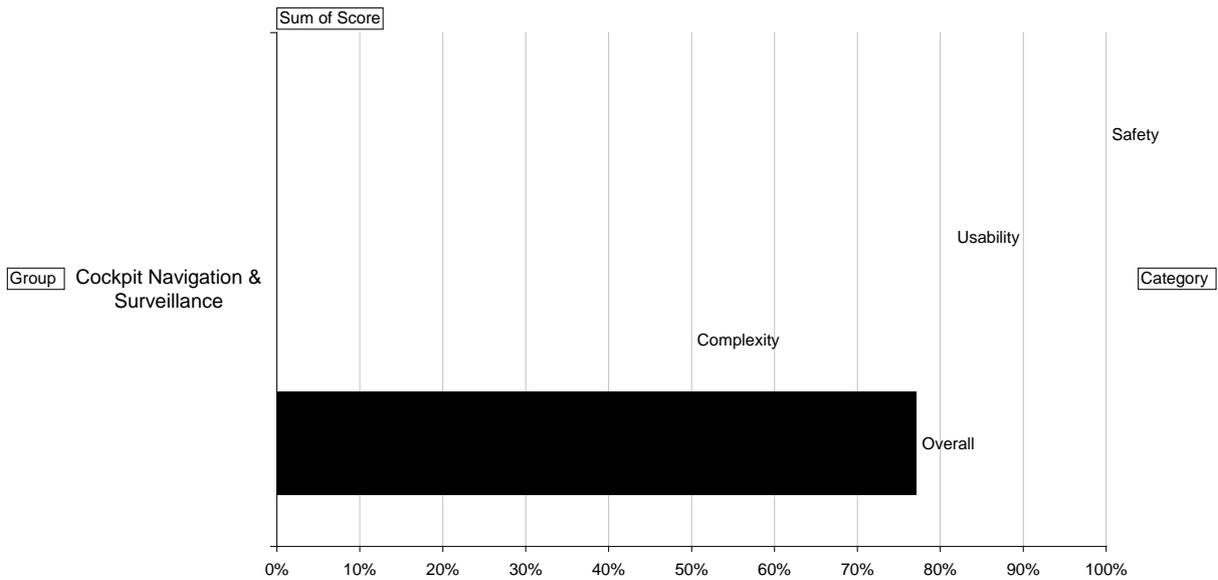
Comparative score (relative to safest group): 50% Rank: 6

Overall

Although clearly the most complex and costly to implement and not the most user-friendly this technology group provides, by some distance, the most comprehensive solution to preventing runway incursions due to the sheer range and scope of causal factors that it can reduce or eliminate.

Description (All)

Runway Incursion Study
Overall Assesment Score



Average score: 77% Rank: 1

5 Conclusions and recommendations

The conclusions are based upon the results of the assessment, summarised in Figure 8 below, and the scope of the report shown in section 1.3. They are categorised into the three areas related to safety, usability and complexity. The recommendations complete this chapter.

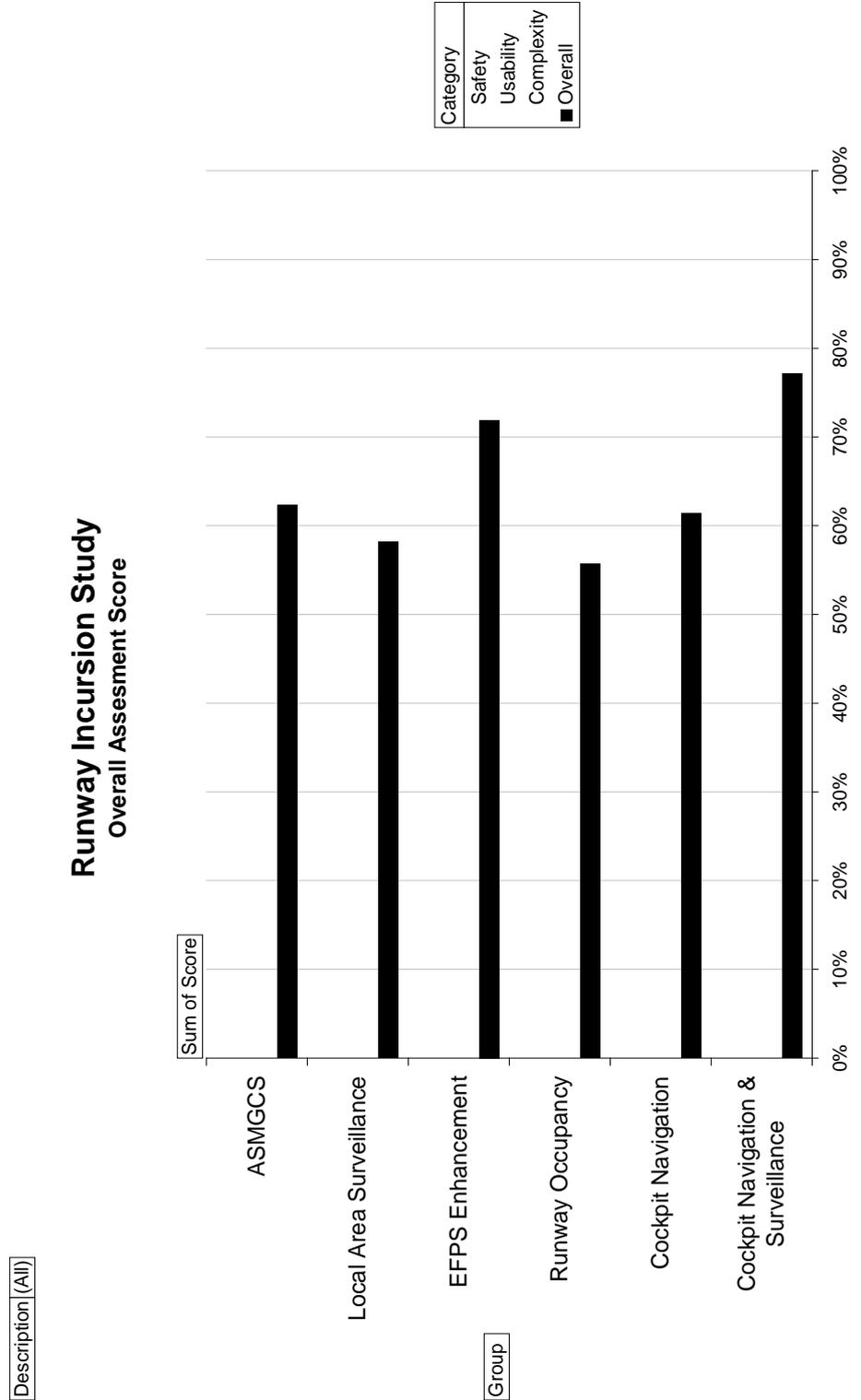


Figure 8: Overall results

The safest

Of the 3 assessment categories, it is safety performance that is arguably the most important because it indicates the degree to which the targeted 5% reduction could potentially be achieved.

The basis for the safety assessment is also supported by evidence that has been recorded in the MOR from actual incidents that have occurred in the past 4 years. This evidence shows that causal factors are attributed to pilots in more than 1 in 2 runway incursions and that pilots/drivers failing to follow a clearance is by far the most significant causal factor, accounting for 21% of causal factors.

Therefore it is unsurprising that systems alerting pilots score better in this category than those that alert controllers – in fact the top three technology groups in this category are the 3 that are designed to alert the pilot. This is further evidence in support of the growing trend, particularly in the USA (see section 1.2), to tackle the problem of runway incursions in the cockpit and not on the ground.

The clear winner in the safety category is the cockpit navigation & surveillance group, which provides a synthetic picture of the airport layout and other traffic in all weather conditions. Although reliant upon a high proportion of equipped aircraft, this type of system scores much higher than any other group, mitigating almost 25% of incursion causal factors. It must be noted though, that this assessment is based on the *potential* of the system. To achieve the 25% reduction would require a significantly higher proportion of aircraft to be equipped than is currently anticipated for 2012. Furthermore the current cost of the necessary avionics means that the many aircraft (in particular GA) may never be fitted.

The UK CAA definition of a runway incursion changed however, at the beginning of 2007 and now captures more incidents caused by controllers, which means the proportion of causal factors attributed to pilots is likely to reduce and so the relative performance of the systems designed for controllers may improve in the future.

ASMGCS-like systems are available to all aircraft now using multiple surveillance sources and not requiring any changes to aircraft equipage (although improvements are possible with Mode S transponders). Its performance in usability and safety mean that it is well worth considering for larger airports willing to invest in what is a fairly complex system.

The EFPS Enhancement seemed well supported amongst the controller community who felt that it, whilst limited to fairly specific types of runway incursion, could be a strong form of mitigation against a new risk posed by an EFPS.

For airports unwilling to invest in an ASMGCS system or EFPS there is the cheaper alternative of a system in the Local Area Surveillance group, but this alerts only controllers and only about specific parts of the runway which is why this is the lowest scoring functional group in terms of safety.

A compromise between the expensive avionics requirements of the systems alerting pilots and the less effective systems that alert controllers is a system from the Runway Occupancy group which combines the best of both. These systems provide the alert to the pilot without imposing equipage requirements on the aircraft. Although let down by their usability these type of systems can provide a relatively cost-effective solution for an airport.

A further cost-effective solution is a Cockpit Navigation system which includes a navigational display such as the EFB targeted for fast track certification in the USA. Whilst not providing any knowledge of traffic these types of systems do

provide much greater situational awareness that significantly mitigate against the chance of a pilot/driver becoming disorientated and causing a runway incursion.

The most usable

Although indicative rather than conclusive, it was felt that operational input from pilots and controllers was a valuable addition to the usability assessment. In particular it was noted that almost no survey respondents felt an alarm should be provided to the pilot without also being issued to the controller.

Another interesting point was that controllers were approximately 50% more tolerant of false alerts than pilots according to the average maximum acceptable false alert rate. There was also an almost unanimous response for any visual alert to also be supplemented with an aural element.

Finally it was noted that both pilots and controllers raised concerns over alerting in situations that would be considered routine - eg a pilot being alerted to a crossing runway entry point or a controller being alerted to all mobiles approaching a runway - on the basis that such a nuisance alarm would devalue a real alarm.

The technology groups scoring highest in usability exhibited properties of a low false or nuisance alerting rate, integrated displays with both visual and aural warning and took into account visibility conditions.

Systems not using cooperative surveillance generally score poorly here as they have a tendency to false alert for example through radar returns from tall grass or moving animals in a detection zone.

The technology group that was identified as the most usable was the EFPS Enhancement based on the fact that it has a very low false alerting probability coupled with an integrated display and flexible (programmable) alerting mechanisms.

The least complex

The complexity of the technology groups was assessed to capture the differences in cost, necessary implementation effort, difficulty to retrofit and likelihood of future obsolescence. This was done at a relatively subjective level to account for the ambiguity of information that was typically gained from the manufacturer websites.

For a system to score well in this category, ie be 'uncomplicated', it needed to be: inexpensive to procure, install and maintain; simple to implement (i.e. quick and not significantly affecting operations); compatible with both old and new aircraft without a major programme of retrofitting; and future-proof for the medium to long-term.

Systems such as those in the ASMGCS group take inputs from multiple surveillance sources and involve complex displays in the tower thus requiring significant effort to install and further effort to correctly configure before they can be used effectively. This tends to drive the cost up and limit their suitability to busy airports only. A smaller scale version of these systems is found in the Local Area Surveillance group where only part of the movement area needs to be monitored and surveillance inputs come for just a single network of sensors.

The EFPS Enhancement again scores very well in this category making it the least complex and most usable system. As a modular add-on to an existing and increasingly common system (EFPS) it can be implemented relatively easily and with no need for any airborne equipment.

In some cases systems score well in complexity through their ability to take advantage of an existing infrastructure, as is the case with systems in the Runway Occupancy group, which also has the advantage of not requiring any airborne equipment.

Current activity in the US is likely to reduce the cost and implementation effort required for EFBs, which makes Cockpit Navigation systems a relatively uncomplicated solution that as mentioned earlier can significantly reduce the chance of a runway incursion.

Systems in the Cockpit navigation & surveillance group score particularly poorly in this category due to the necessity to fit a significant proportion of aircraft with expensive avionics that may have very stringent safety requirements. On the other hand the avionics are likely to enable a significant number of other applications and capabilities that will alter the cost to benefit ratio over time and future-proof the systems.

Recommendations

Having taken a global approach to this assessment and through developing a methodology that can be applied to any system in the future, the recommendations given here can be revisited again to reflect changes to the assessment.

There does not appear to be any one 'ideal' system that is able to instantly reduce the number of runway incursions by the target 5% without compromising either usability or complexity. Furthermore a one size fits all approach can't be applied due to the sheer variety of aircraft, airports and procedures in the UK and it is likely that a combination of technologies – a so called layered approach – will be the most realistic solution in any regional implementation.

Bearing this in mind, it is recommended that:

- Systems that alert pilots offer a greater potential for reducing the number of runway incursions than those that alert only controllers. Ideally the system would alert both.
- Systems in the Cockpit navigation & surveillance group have the potential to be the safest in the future and the long term recommendation is to support an evolution towards this type of system. In the short term insufficient work has been done on the conflict detection algorithms and the costs are too high to fit a significant proportion of aircraft with avionics that may have very stringent safety requirements. On the other hand the avionics are likely to enable a significant number of other applications and capabilities that will alter the cost to benefit ratio over time and future-proof the systems.
- The impact of the new runway incursion definition on causal factors is monitored to see how the relative safety assessment would change
- ASMGCS is available now and is well worth considering for larger airports willing to invest in what is a fairly complex but effective system.
- The EFPS Enhancement, whilst limited to fairly specific types of runway incursion, is the least complex and most usable system. As a modular add-on to an existing and increasingly common system (EFPS) it can be implemented relatively easily and with no need for any airborne equipment.
- Runway Occupancy systems provide the alert to the pilot without imposing equipment requirements on the aircraft. Although let down by their usability these type of systems can provide a relatively cost-effective solution for an airport.
- The systems in the Cockpit Navigation group provide much greater situational awareness that can significantly mitigate against the chance of a pilot/driver becoming disorientated.
- Visual alerts should also be supplemented with an aural element.
- The most usable systems should have a low false or nuisance alerting rate, integrated displays with both visual and aural warning and should take into account visibility conditions.

A Abbreviations and acronyms

ADS	Automatic Dependent Surveillance
AKA	Also Known As
AMASS	Airport Movement Area Safety System
APT	Airport(s)
ARIPS	Autonomous Runway Incursion Prevention System
AS	Acquisition Squitter
ASAP	As soon as possible
ASDE	Airport Surveillance Detection Equipment
ASMGCS	Advanced Surface Movement Guidance and Control Systems
ASR	Airport Surveillance Radar (TAR)
ATC	Air Traffic Control
ATCO	Air Traffic Controller or Air Traffic Control Officer
ATM	Air Traffic Management
ATSA	Airborne Traffic Situational Awareness
ATSIN	Air Traffic Services Information Notice Number
CAA	Civil Aviation Authority
CAMS	Critical Area Management System
CAPS	Cooperative Area Precision Tracking System
CCTV	Closed Circuit TeleVision
CDTI	Cockpit Display of Traffic Information
CMC	Canadian Marconi Company Electronics
CPDLC	Controller Pilot Data Link Communications
DLR	Deutsches Zentrum für Luft und Raumfahrt (German Aerospace Centre)
EFB	Electronic Flight Bag
EFPS	Electronic Flight Progress Strips
EGPWS	Enhanced Ground Proximity Warning System
ELAR	Israeli company
EO	Norris EO Systems
ERA	ERA Surveillance Technologies
ERMO	ERMO 482X PRO Technology from CIAS Elettronica
ETNA	Electronic Taxiway Navigation Array
EVS	Enhanced Visual System
EXCDS	Extended Computer Display System
FAA	Federal Aviation Administration (US)
FAROS	Final Approach Runway Occupancy Signal
FLIR	Forward Looking Infrared
FRL	Flight Refuelling Limited
GCN	Government Computer News
GPS	Global Positioning System
HITT	HITT Group of companies of the Netherlands

COMMERCIAL-IN-CONFIDENCE

HMI	Human Machine Interface or Interaction
ICAO	International Civil Aviation Organisation
IIDS	Integrated Information Display Screen
ILS	Instrument Landing System
IR	Infrared
ISMAEL	Intelligent Surveillance and Management functions for Airfield applications based on Low cost magnetic field detectors
L3	L3 Systems Ltd
LAAS	Local Area Augmentation System
LSS	inductive Loop Sensor Subsystem
LVC	Low Visibility Conditions
MDI	MDI Security Systems Ltd
MDS	Multistatic Dependant Surveillance
MLAT	Multilateration
MOR	Mandatory Occurrence Reporting
MSS	ERA MSS Technology Model
NASA	National Aeronautics and Space Administration (US)
NAV	Navigation (Eurocontrol EATMP Domain name)
NAV3D	NAV3D Incorporated
NOVA	NOVA-9000 Controller Display Screen, Park Air
RAAS	Runway Awareness and Advisory System
RFG	Requirements Focus Group (EUROCAE Working Group)
RIDDS	Runway Incursion and Debris Detection System, Runway Technologies
RIMCAS	Runway Incursion Monitoring and Conflict Alert System
RIPS	Runway Incursion Prevention System
RITSG	Runway Incursion Technology Sub-Group
ROWS	Runway Occupancy/Obstruction Warning System
RWSL	Runway Warning Status Lights
SBS	Surveillance Base Station
SDSS	Surface Decision Support System
SENSIS	SENSIS Corporation
SMGCS	Surface Movement Ground Control Systems
SMR	Surface Movement Radar
SQB	ERA Location Technology for Vehicles
SQUID	ERA Location Technology for Vehicles
STREAMS	Surface Traffic Enhancement and Automation Support
SURF	Airport SURFace
TACSYS	Taxi and Control SYStem
TARMAC	Taxi and Ramp Management and Control
TCAS	Traffic Alert and Collision Avoidance System
TIS	Traffic Information Service

UK	United Kingdom
US/USA	United States of America
UV	Ultraviolet
VMD	SenseEye VMD Technology by MDI Security Systems

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C Initial list of technologies

C.1 Assessed

Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
1	FRL	Ground Movement Control.	Suite of integrable modular technologies that provide airport surface surveillance detection, data processing and display. Position, identification and movement vector is deduced for each target to within an accuracy of 0.2m. In Runway Incursion Boundary Monitoring (RIBM) polygon volumes defined by the runway location incursion alarms are raised as appropriate. The system can be extended to cover the lower (approach) airspace or perform debris and perimeter monitoring. Data link and radar display uses Radio Digital System (RDS) 1600 format.	High frequency radars (7 or 94 GHz), millimeter wavelength radars, SMR, approach radar, video cameras and airfield identity information database.	Deployed	Nottingham East Midlands, Farnborough, Heathrow Emergency Display Facility and Liverpool John Lennon (other airports worldwide include CAA licensed aerodromes and RAF bases).		x		Visual, Aural	Yes	An ASMGCS system with its regulatory approval unknown.
1	Park Air (Northrop Grumman)	Runway Incursion Monitoring and Conflict Alert System (RIMCAS) NOVA-9000	An integrable software module that detects incursion situations as part of a wider airport surveillance system. NOVA-9000 is an established display system. Automatic tracking (position, identification labelling and a coasting functionality) with programmable alert levels. Integrable with Park Air's NOVA-9000 ATCS A-SMGCS (a system that is operational worldwide). FAA support in the Low Cost Surface Surveillance (LCSS) project. Operable in the UK for 10 years. Two stage alerts are generated on the time interval to closest point of approach. Different alert level criteria exist to cater for low visibility and normal operations. Most widely used system in the UK.	SMR, Approach radar, Multilateration, ADS-B, D-GPS, AFTN.	Deployed	20 Airports worldwide including Stansted, Heathrow, Gatwick, Birmingham, Newcastle, Paris CdG (advanced data fusion), Seoul, Toronto, Sao Paulo, Vancouver, Linde, Malpensa, Stockholm, Frankfurt and Prague.		x		Visual	Yes	System works well for less complex airports (e.g. Newcastle) but is known to generate a large number of false alerts (e.g. Stansted where a train passing under the runway triggered an alert) at busier airports and so is often switched off by controllers. SMR based system so suffers from blind spots/reflections and requires multiple radars. FAA supported R&D scheme. FAA "Approved".
1	Norden Systems (Northrop Grumman)	Airport Movement Area Safety System (AMASS)	A software module that detects potential safety incidents. Typically based on data gleaned from primary ASDE-3 radar and multilateration systems although it can use a variety of SMR types. Uses keyhole effect on controller display. Fuses airborne approach (ASR-9/ARTS) and surface data (from ASDE-3) for both aircraft and vehicles. The system suggests runways for aircraft to land upon and its functionality includes a caution indicator for a single track violation (e.g. an incorrect direction being followed along a taxiway). The software component is written in C++ and because it only requires a Pentium III processor it can be implemented across a wide range of systems. Runway incursion prevention rules are based upon maintaining a 'key hole' shaped bubble around the target. FAA have mandated a red alert requires action by the controller.	Primary and Secondary surveillance Radar	Deployed	The 34 busiest US airports: see FAA Safety Report August 2005 for details. Trials at Atlanta, JFK, Detroit and San Francisco.		x		Visual, Aural	Yes	Enhances the surveillance data from ASDE-3 radars etc and creates a complete picture with alerting etc. Comparable to the European ASMGCS. FAA supported R&D scheme.
1	Thales	Surface Traffic Enhancement and Automation Support (STREAMS)	Extracts, tracks and fuses surveillance data from a variety of sources, detects potential conflicts and route deviations. Suggests optimal routes and guides aircraft across the airport surface. Includes conflict and conformance monitoring for runway incursion protection. A range of integrated tower automation systems can be tailored to a particular airport application using elements of STREAMS and TECOS (Terminal CO-ordination System) which offers automatic system co-ordination with the aircraft on final approach. Vehicle monitoring with ADS-B Mosquito vehicle transmitters and AS-680 ground stations. Rule based system monitors potential conflicts and aircraft conformance to a route.	SMR, airport surveillance radar (ASR), ADS-B and multilateration.	Deployed	STREAMS components installed at 18 airports worldwide, in Germany (Cologne, Stuttgart, Frankfurt, Munich), France (Lyon, Toulouse, Besel-Mulhouse, Marseilles), Italy (Milan Linate, Molan Malpensa, Bologna, Rome, Venice), Poland (Warsaw), Ukraine (Kiev-Borispol), Mexico, (Mexico City), South Korea (Jeju), Thailand (Bangkok).		x		Visual, Aural	Yes	ASMGCS system, certified to level II - attempting level IV in one location (China?)
1	Sensis	Advanced Surface Movement Guidance and Control System (A-SMGCS)	A fully integrated A-SMGCS system. Fuses and tracks surveillance data from a variety of sources to provide a surveillance picture. Flexible system can be applied as an end-to-end system, a system upgrade or an extension to an existing partial system. As standalone components of the A-SMGCS system Sensis offer the X-band PSR radar system, ADS-B/Multilateration Mode S based vehicle tracking which transmits vehicle identification and status information (The VeeLo System), Multistatic Dependent Surveillance (MDS) multilateration system, Controller Working Positions and the Multi Sensor Data Processor (MSDP) the latter of which fuses plotted data, incorporates conflict detection and alerting functionality and can be integrated with lighting and status systems.	Multiple sources including PSR, SSR, SMR, Multilateration, ADS-B (used for vehicle tracking).	Deployed	50 airports worldwide have elements of this system including Brisbane, Melbourne, Sydney, New Delhi and 35 in the US.		x		Visual, Aural	Yes	Compliant with ICAO standards (9830), Eurocae MOPS ED-126 ED-127 and MASPS ED87A
1	HITT	A3000 A-SMGCS systems	Surveillance, guidance, routing (including gate allocation) control and HMI systems for all operations on the airport surface. Functions include the provision of a logistics support tools to help improve resource management at the gate, stand management, control of airport surface lighting systems (including stop bars) and management of both arrivals and departures. Modular design produces a scalable technology solution applicable to a variety of airport sizes that change over time. Runs on standard hardware platform. Offers automatic labelling of aircraft, conflict and runway incursion alerting. Metrological and other information can also be integrated into the system. Programme participates in various research programmes.	Approach radar, SMR, multilateration, ADS-B, VDL mode 4 and induction loops. Could be adapted to use data from other sources.	Deployed	Moskou-Domodovodo, Copenhagen, Schiphol, Helsinki-Vantaa, Stockholm-Arlanda, Budapest-Ferihegy, Deutsche Flugsicherung (4 airports), Manchester, Shanghai-Pudong, Goteborg-Landvetter, Oslo-Gardemoen, Beijing Capital, Korea Gimpo, Madrid-Barajas.		x		Visual, Aural	Yes	
1	Thales, Sensis, FRApport	Taxi and Control System/Cooperative Area Precision Tracking System (TACSYS/CAPS)	Taxiway management system primarily for apron control. Provides a picture of the surrounding traffic situation to aircraft operating on the ground. Up to 400 targets can be handled simultaneously. Identity is derived from the Mode S squitter transmitted. Refreshes once per second and provides a 5 meter position accuracy for 95% of the time. The system architecture is redundant with two towers controlling Fraport (one controls the the approach and runway areas [operated by DFS] while the other tower manages taxiway and apron movements [operated by FRApport]). Commonality in the surveillance picture is shared between the two.	Multilateration (Mode A/C and Mode S), PSR, SSR, Mode S, Microwave beams, Flight Plan data and Airport database.	Deployed	Frankfurt International Airport		x		Visual		FRa port system. Good for all weather operations (low visibility conditions).

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Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
2	Transtech	Critical Area Management System (CAMS)	High resolution surveillance of critical airport surface intersections. Incursion detection and alerting occurs according to a rule based system. Visual aids help guide aircraft around taxiways. A modular system of implementation can be used to eliminate blind spots. Integrable with Transtech's "Intelligent Airport" system (managing surface traffic by controlling ramp lighting).	Millimetre Wave Sensor (Microwave) radar Clusters (75.6 GHz) and optical identification sensors to 'read' passing aircraft registration and ID the target from airport database. Data sharing with SMR and approach radar is proposed as an extension to this system.	Deployed	Frankfurt (140 other airports worldwide who use the manufacture could be swiftly upgraded), Ben Gurion. Considered by Luton.		x		Visual		Breaking a microwave beam can prove an unreliable surveillance method due to the undercarriage breaking the beam repeatedly. Similar optical sensing is an unreliable technique in LVC and has been reported as being an inefficient surveillance technique (SRG). Sensor equipment itself may present an obstruction within an obstruction free zone. Installation of multiple sensors (MWS, OIS and RDS) is expensive. It is designed for airports unable to install a full ASMGCS system. Unsure of number of regulatory endorsements although it is a FAA supported R&D scheme.
4	Axis Electronics Ltd	Ground Marker	Automatic taxi advisory system designed to orientate pilots on the airfield surface and warn them of active runway locations in their vicinity. Avionic requirements and programmable options to tailor the voice commands and/or advisories issued. Detection of approaching targets (triggering system activation) using magnetic induction loops.	75 MHz marker receiver radio transmitters (ILS frequencies) & embedded antennas at selected points alongside taxiways. Can be extended to use surveillance from approach and SMR radar.	Deployed	Concord Buchanan Field, CA. Trials at Bournemouth and Manchester	x			Aural	Yes	Enhances situational awareness of runway location but it is not effective for all runway incursion types. Cost effective system (only requires an on board radio tuned to a local frequency). Can be considered as a standalone system for less vulnerable aerodromes and a primary safety net for more advanced airports. Integrity of the control system to produce the appropriate advisories to the correct target has been questioned. Extending the system to include vehicles would require the development of new (but probably inexpensive) technology. Marker receivers are becoming increasingly non-essential equipment so the commonality of this systems functionality across types may decrease. FAA endorsement letter.
4	Volpe National Transportation Center	Runway Status Lights (RWSL)	Installed at critical airport runway intersections to provide pilots with an indication of runway occupancy. As part of the FAA's Runway Incursion Reduction Programme (RIRP) this technology is designed to improve situational awareness through the timely indication of runway usage. Runway Entrance Lights (REL) indicate when it is unsafe to cross. Conventional and Light Emitting Diode (LED) versions of RWSL are being examined. Employs radar data to detect an aircraft within a specified distance of the runway and switches on warning lights as required	SMR	Trials	San Diego International Airport, Dallas/Fort Worth International Airport.	x			Visual		Gaining support across America. FAA supported R&D scheme, and currently under assessment by them.
4	Norris EO Systems	Autonomous Runway Incursion System (ARIPS)	Instantaneous direct warning to flight crews independent of ATCO instructions. Optionally it can also provide a warning to the ATCO. Can be operated as a stand alone system or as a complement to another system. Operational concept demonstrated in August 2006. System includes both aircraft and vehicle monitoring. Technology is focused on preventing runway incursions that occur from airport intersections (taxiways and runways). Surveillance based upon a UV lighting modification to the runway lighting system. Surveillance provided by UV light is unaffected by adverse weather conditions. ARIPS is an autonomous, sensor-based system (Safety Sentry) developed with Norris's patented technology, FogEye®. It employs ultraviolet light that is not affected by fog, rain or other weather conditions detrimental to safe airport operations. ARIPS' architecture allows for a non-intrusive installation by modifying existing runway and taxiway lights without disruption to normal airfield activities. It requires no major integration with other systems, no runway or airfield construction, and runs on a power system integrated into an airport's existing power sources. ARIPS' Scalable solution for particular runway requirements. Can be integrated with the surface lighting system and the surveillance picture provided to the ATCO or ground based service personnel. Detection is autonomous from other surveillance systems.	Safety Sentry (developed fromFogEye) UV light system	In development	Trials at Ted Frances Green Airport, Providence, Rhode Island, USA	x					Sophisticated system with a 'typical' runway installation costing 0.50-1.50M pounds. May require elevated edge lights in the 'obstacle free area'. Lighting modification described would not be ICAD compliant. FAA supported R&D scheme.
2	Runway Technologies	Runway Incursion and Debris Detection System	The laser systems can operate in adverse weather conditions without suffering from degraded performance. The system is installed at the side of runways - so does not require their closure for installation - and can retract into the ground if required (e.g. for snow clearance). Additionally, at least one of the optical laser transceiver and reflector apparatus and the object characterizer apparatus include apparatus for distinguishing moving objects or other debris from stationary objects or other debris. Preferably, the object characterizer apparatus provides an output indication of the velocity vector of a plurality of moving objects or other debris. The object characterizer apparatus includes apparatus for disregarding objects or other debris whose vectors do not fit within a predetermined profile	The breaking of laser beam between ground markers.	In development			x		Visual, Aural	Yes	May also detect animals on the runway leading to the generation of false alerts.
3	NAV Canada	Electronic Flight Progress Strips (EFPS) runway incursion prevention system, AKA the Integrated Information Display Screen - Extended Computer Display System (IIDS-EXCDS).	This software package is modular, expandable and capable of controlling the airport surface lights. It is designed to create a paperless tower control operation by the control of flight strips using touch-screen technology.	SMR	Deployed	11 Candian Airports including Toronto, Montreal, Calgary and Vancouver. Stansted and Gatwick have EFPS but without the runway incursion add on.	x			Visual, Aural	Yes	A specific NAV Canada R&D scheme to enhance EFPS using a 'runway bay'.
5	Honeywell	Runway Awareness and Advisory System (RAAS)	An upgrade to existing Honeywell Mk V and Mk VII Electronic Ground Proximity Warning System (EGPWS) computers providing runway location advisories to the aircrew. Avionic requirements, product configuration/customisation database, details of 'heads up' display.	GPS position and terrain database.	Deployed	6350 runways validated worldwide (see website for database)	x			Aural		Controller does not know what the advisories given to flight crew are. The advisories depend upon how up to date the airport database is. Enhances situational awareness but is not a specific runway incursion prevention system (is not effective for all runway incursion types). Technology has both FAA TSO and EASA STC approval letters.
5	Jeppesen	Electronic Flight Bag (EFB)	Airport Moving Map (AMM) (integrated with a electronic flight planning suite) to help guide and orientate pilots on the airport surface. Integrated across various hardware platforms (flight decks and desktops). Moving Map gives real time orientation by showing the position of the aircraft on the airport surface relative to taxiways and runways. The airport map automatically loads when aircraft lands. Pilot can search and select available Airport Moving Maps (AMMs) during the flight planning process. Zoom and hold north vertical functions offered. The EFB system database supports organisations transitioning from paper to electronic based flight planning.	Geo-referenced satellite imagery, Jeppesen worldwide airport information database, GPS and Jeppesen terrain database.	Deployed	Airlines and operators worldwide including the UPS and KLM fleets	x			Visual		Could prove difficult to regulate standards in EFBs if pilots came to rely upon them. No awareness of other aircraft. No alerting is provided. Conforms to ED-B9, DO-272A, ISO 9000, DO-200A manufacturing standards. Granted "letters of acceptance" by the FAA and EASA.

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Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
6	ERA	PathProx	On board surveillance and alerting system relying on TIS-B and ADS-B supplied reports of local traffic and runway incursion algorithms to pilots and vehicle drivers. Conflict detection and alerting help to ensure a self separation service without reliance upon ATC or ground infrastructure. Initially developed by Rannoch (now ERA) as a research concept to detect over 40 different runway incursion types. Two level runway incursion alert provided directly to pilot in cockpit. This real time TCAS-like alert includes an identification of the incurring aircraft or vehicle, the associated runway, the separation distance and the time to conflict. Although resolution advice is not given an aural alert is provided, with an extension to this being a visual one upon an Airport Moving Map provided by an EFB. Prototype has been simulated and trialled.	Ownship position on an airport moving map derived from the differential correlated GPS (Global Positioning System), GNSS, LAAS (Local Area Augmentation System), MDS (Multistatic Dependant Surveillance) and the Inertial Navigation System.	In development	Trials at Ohio University Airport - Snyder Field Dallas Fort Worth	x			Visual, Aural	Yes	Alert provided directly to cockpit is valuable. Implementation timescales may put this technology out of scope. Developed as part of the NASA RIPS project.
6	NASA	Runway Incursion Prevention System (RIPS)	NASA Langley Research centre all weather system provides timely alerts to flight crews of possible runway incursions generated according to runway incursion algorithms. Cockpit display may be presented as a synthetic environment or an airport moving map (AMM). System uses the runway safety monitor (RSM) developed for NASA by Lockheed and the Pathprox system, developed for NASA by Rannoch. Alerts are generated by the Airport Movement Area Safety System (AMASS) from Northrop Grumman which are transmitted to the aircraft for display to the flight crew. First, pilots can use a color "head-down" moving map on the control panel, which graphically illustrates the runway or taxiway and warns of conflicts in either yellow (for runway traffic) or red (for runway conflict). Second, they can use a transparent head-up display, similar to that on a fighter jet, that flashes a text warning. Finally, they can hear a two-stage auditory warning.	SMR, Multilateration, Avionic GPS system, airport geographic database	In development	Trials at Reno/Tahoe International Airport, Wallops Flight Test Facility, Dallas Fort Worth	x			Visual, Aural	Yes	Essentially an enhanced pathprox system, providing a direct alert to the pilot. AMASS uplinks not recommended due to latencies involved and AMASS alerts being controller focused (Compendium) - pilots may not appreciate what the alert means - controller knows what instructions have been issued etc.
6	Various: (L3 & Thales with Safe Route. Sensis manufacture required datalink hardware)	ATSA-SURF (CDTI)	ADS-B (and perhaps TIS-B) enabled situational awareness for the pilot on final approach and on the surface. The ATSA-SURF concept is an ADS-B application. It concerns the use of a CDTI (or similar) to provide a traffic picture to aircraft on the airport surface.	ADS-B and possibly TIS-B	In development	UPS fleet currently use SafeRoute. Sensis datalink technology equipped in a wide variety of aircraft across Europe.	x			Visual		Controller does not know what flight crew picture is. Requires full equipage to be fully effective. May only provide position relative to other aircraft and not necessarily to the airport taxiways. Assumes a class II (or B) moving map. RFG will develop standards in 2008. Sensis datalink equipment and display have EASA and JAA certification readiness.
6	DLR	Taxi and Ramp Management and Control Airborne System (TARMAC-AS)	All weather on board airport guidance and navigation system using aircraft position determination. Aircraft conformance to a designated route is monitored on the ground (with warnings provided as appropriate). Display provided to pilot presents the infrastructure and traffic situation upon an airborne moving map using the existing navigation display in the cockpit (if available). Contributions from DLR. The system is flexible and modular. It can fuse data from the variety of sources available to it.	SMR, Multilateration, Avionic GPS system, airport geographic database	In development		x			Visual, Aural	Yes	Improved pilot situational awareness and alerting - the pilot can then take direct action as appropriate (so is a valuable system). Conformance monitoring supports avoiding runway incursions and taxi conflicts in low visibility. Seems as though this was initially conceived as a demonstration project but not much has happened since then. Project extended as part of ICAO A-SMGCS work.
6	Thales, Sensis, FRAport	Electronic Taxiway Navigation Array (ETNA)	Navigation and control system for vehicles operating at airports. Display presented to vehicle drivers on dashboard (SatNav style display). A wireless LAN network distributes position data of all vehicles on the airport surface. Information from the TACSYS/CAPS system delivers aircraft surveillance information to ETNA which displays it to equipped vehicles. Fleet control rooms can deliver additional information such as obstacle awareness or destination information (e.g. regarding incident sites to the fire service).	D-GPS (differential satellite navigation) position detection in addition to that provided by Veelo through the TACSYS/CAPS system.	Deployed	Frankfurt International Airport		?	x	Visual, Aural	Yes	FRA port system. Good for all weather operations (low visibility conditions). Only operational in one specific location (FRAport).

C.2 Not Assessed

Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
	Volpe National Transportation Center, Northrop Grumman, Rannoch Coporation, Amber & Texas Instruments.	Forward Looking Infrared (FLIR) and Infrared (IR) focal plane array technology	Video surveillance in all weather conditions. Comparison and analysis study of infrared camera technologies. That could aid the detection of fires, aircraft, vehicles, aircraft and humans, particularly in adverse weather conditions and fog.	IR and FLIR cameras	In development			x		Visual		Surveillance sensor - has no standalone protection against incursion. This was a study into different camera technologies but does not provide any conformance monitoring of aircraft meereley a better picture for low vis ops. FAA supported R&D scheme.
	MDI Security Systems	SenseEye VMD	Automated 3D video motion detection software using two or more cameras. Their fields of view overlaps to cover a specific 3D volume in space. By detecting movement in a volume rather than a plane the number of false alerts is lowered. Intended to be a point solution technology it allows independent verification of the target entering or leaving the runway. Automated alert functionality. System used by Eurocontrol to test pilot reaction times.	CCTV camera streaming using WAV file format.	Proposed			x		Visual		Surveillance sensor - has no standalone protection against incursion. The 3D motion detecting camera provides additional surveillance but also give another screen for the controller to monitor. While Camera technology is relatively cheap, many units are needed for an effective system. Experience has shown problems at night or in low visibility conditions. Significant development is likely to be required before it is a suitable runway incursion preventer (which suggests a low technology readiness level)
	Municipal Airports of Anchorage, Alaska	CCTV implementation project	Motion track cameras placed at noted runway incursion areas High resolution cameras automatically sense motion, zoom in, detect the target and activate an alarm in the tower. System requires wireless base station units controlled by a central server. Recorded tapes are archived for seven days.	High resolution CCTV cameras	Deployed	Merril Field, Alaska		x		Visual	Yes	This is a specific solution to a visibility problem in Alaska and provides CCTV surveillance of the blind spots from the tower. The alerting is of a detected object in a defined location. This system would not be suitable for low visibility operations. This is a specific example implementation of a CCTV based runway incursion monitoring system established to overcome location specific problems (visibility of controllers to see runway entry/exit points from the tower).
	FAA	Final Approach Runway Occupancy Signal (FAROS)	Automated safety system designed to notify pilots that the runway is occupied or otherwise unsafe for landing. When any monitored zone on the runway is occupied by a stationary or slow moving target a signal is provided to approaching pilots that the runway is occupied. When an incursion is detected the Precision Approach Path Indicators (PAPIS) flash red to provide airborne pilots with a warning. Pilot training to correctly interpret the flashing lights is essential (broadcast by TIS-B and the NOTAMS system).	Induction loops.	Trials	Long Beach Airport, USA	x			Visual	Yes	PAPI lights are not part of UK operations and therefore would need to be installed first before using them as a runway incursion prevention measure. ICAO standards require steady PAPIs and so this system would not be ICAO compliant (further hindering any possibility of this system gaining regulatory approval). It is expected that the necessary certification and approval of the procedures and lights would be difficult and that this system should not therefore be considered as a suitable UK solution. FAA supported R&D scheme.
	Stanford University & NAV 3D.	Sythetic Vision Displays	3D synthetic vision system for instrument landing and traffic awareness with Runway Incursion monitoring. A Ph.D thesis was first written on the subject of a synthetic vision display to improve awareness of pilots on final approach to local traffic and runway incursions, however only a partial surveillance picture is presented as traffic information is gleaned only from ADS-B.	ADS-B, GPS, INS and databases for Terrain and Airport environment	Proposed	Flight trials at Moffett Federal Airfield, CA	x			Visual		This synthetic display of traffic and runways is still at the R&D stage and very unlikely to achieve deployment in commercial aircraft within 5 years. It would require significant investment in avionics that looks unlikely to be forthcoming from any airline outside of the high-end business jet market. FAA supported R&D scheme.
	NASA Ames Research centre	Taxi Navigation and Situation Awareness (T-NASA)	Empirical research project for a suite of cockpit displays that provide navigation and situational awareness to pilots using a heads up display (HUD), airport moving map and 3D Audio Alerts or warnings. Aircraft route is clearly displayed to Flight Crew using a series of virtual 3D cones that the aircraft is directed down (with yellow hold bars displaying the runway status) and text information about upcoming taxiways. Other targets on the airport surface can be displayed with labels. Map shows ownership position on the labelled airport surface. Detection of targets depends upon the level of surveillance provided at a given airport for both airports and vehicles. Visual display (HUD and moving map). Aural alerts of potentially dangerous situations is presented in 3D audio so the pilot perceives the warning is coming from the relative direction of the intruding traffic	PSR, SMR, ADS-B. Multilateration and the airport database.	In development	Trialled at Chicago O Hare airport	x			Visual, Aural	Yes	Not necessarily a technology in-itself but a suite of other technologies to create an overall greater awareness in the cockpit. A very hi-tech and expensive system that is still at the research stage and therefore unlikely to achieve certification or operational deployment in the desired timeframe. Very few aircraft would support the implementation of such an advanced and costly solution. The moving map is considered as a separate solution elsewhere. FAA supported R&D scheme.
	Patriot Technologies	Runway Occupancy/Obstruction Warning System (ROWS)	Detects and Monitors surface targets on runways, hold-short areas and critical intersections. Provides runway status information to pilots on final approach via airfield surface lighting systems that warn of approaching aircraft of an occupied runway. Visual alerts to controllers provided through a surveillance monitoring service. Critical point surveillance; high resolution of crucial airport intersections. Uses technology already implemented at many airfields. System is applicable to both towered and non-towered airports and so is highly scalable. Single stage alert provided.	IDAQ data acquisition and decision support technology to monitor targets and provide real-time runway status data.		Prototype at Gulfport-Biloxi	x	x		Visual	Yes	This system would require changes to airport lighting systems and procedures and is therefore unlikely to receive approval from ICAO or UK certification authorities.
	Various	Controller Pilot Datalink Communications CPDLC	Datalink to send instructions and taxi information between the aircraft and ATC. Information is presented through text messages (increasing communication integrity) Also includes exchange of taxi plan (D-TAXI). The concept is to reduce the chance of a communications failures/breakdowns.	Controller/pilot entry	Deployed		x	x				Whilst miss-communication is a leading factor in many RIs it is unlikely that datalink will be able to replace the busy communications on the surface within the next 5 years. Furthermore CPDLC is not a technology that would directly prevent a runway incursion by providing any warning to pilots/controllers (however it may indirectly mitigate against any of those that involve a misinterpretation of any instruction, clearance or request).
	Adacel	Voice Activated Cockpit Avionics	Accurate noise tolerant voice recognition system that provides conformation of a clearance to enter the runway to all concerned parties Could be integrated into the 'voice activated cockpit' channeling enquiries about aircraft systems, FMS data entry, correlation of flight plan to local environment and interaction with an electronic flight bag. System is to be installed in the strenous conditions of the F35 Joint Strike Fighter cockpit	Driver, Pilot and ATCO voice recognition	In development	Simulations only		x		Visual, Aural		Voice activated systems are very unlikely to be mature enough for deployment in the next 5 years. In addition there are a number of barriers that such a technology must overcome including resistance from operational personnel due to the rigorous standards of communication that would be required.

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Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
	Siemens	Simatic WinCC	A HMI software tool used for process visualisation in industry applied to the airport surface. Provides a common visualisation of the airport surface through data fusion to all controllers. The tool offers automated control functionalities including the barring and releasing of taxiway junctions. Interface allows virtual observation and targeted operation of all airport lighting systems on the taxiways and runways. It can control up to 2000 dynamic objects simultaneously. Functionally includes "priority manual operation switching" which allows flexible planning of operations (eg for emergency contingencies). Tool runs on a PC with data provided to the server using an industrial Ethernet. System architecture designed to be redundant (one working position per runway plus a reserve).	Primary and Secondary surveillance Radar, SMR, ADS-B and Multilateration.	Deployed	Munich International Airport		x	x	Visual		Not a runway incursion prevention technology.
	FAA	Surface Decision Support System (SDSS)	Trajectory based management of surface operations. Tool designed to develop a fully collaborative surface environment through expanded data sharing between surface targets using common implementation and interface standards. Initiated as part of the NextGen project its development is pending a funding decision in FY09.	NASA Surface Management System (SMS)	Proposed			x		Visual	Yes	This is a surveillance sharing mechanism and has no standalone mechanism to protect against runway incursions. It is tailored for US operators and therefore not applicable to the UK, certainly not within 5 years. FAA supported R&D scheme.
	Max Vis	EVS-1000	Small, light and cost effective enhanced vision system using single infra red sensor (used in haze, smoke, snow, rain and night operations) Detects and displays immediate surrounding terrain and runways - even for cold and wet objects with minimal heat signature. Can be integrated into existing LCD video capable displays in the cockpit. Targets are not identified.	Long wave infra red sensors.	Deployed	Various lower market end aircraft. Selected by Cessna for standard type certification on citation and sovereign aircraft.	x			Visual	No	Limited use of preventing runway incursions (pilot still has to detect the situation as no alarm is raised) and equipment is very costly. Will not improve the surveillance picture from the cockpit with very restricted visibility (e.g. severe fog). FAA type certified.
	Max Vis	EVS-2500	Imagery from long and medium IR wavelength sensors better separate the background scenery from that of the runway. Short wave IR detects conventional airport lights with a good resolution in poor visibility conditions. The system fuses data imagery from this variety of sources and presents a unified picture to the pilot. Detects and displays immediate surrounding terrain and runways - even for cold and wet objects with minimal heat signature. Can be integrated into existing LCD video capable displays in the cockpit. Targets are not identified. Can be easily upgraded from EVS-2500. Currently trials being conducted with Rockwell Collins to integrate this detection into an synthetic environment vision display.	Long, medium and short wave infra red sensors.	Deployed	Various aircraft at the higher end of the market.	x			Visual	No	Limited use of preventing runway incursions (pilot still has to detect the situation as no alarm is raised) and equipment is very costly. Will not improve the surveillance picture from the cockpit with very restricted visibility (e.g. severe fog). FAA type certified.
	CMC Electronics	CMC-2610 SureSight M-Series	Infrared sensor unit with heated external window to prevent condensation obscuring surveillance and interor display facility. Can be installed in aircraft nose or fin.	Long wave infra red sensors. Two series are offered; the smaller M-series for heads down display and the L-series that can be interfaced with a HUD.	Deployed	FedEx fleet, Fitted by Gulfstream on some aircraft models.	x					Limited use of preventing runway incursions (pilot still has to detect the situation as no alarm is raised) and equipment is very costly. Detecting LED approach lights can be problematic because they emit in the visible not IR wavelength region. Will not improve the surveillance picture from the cockpit with very restricted visibility (e.g. severe fog). RTCA DO-160D compliant system.
	FAA technical note	Airport Active Runway Vehicle Lighting	Ground vehicles operating on the airport equipped with warning beacons illuminated only when the vehicle is on an active runway. Aids controller situational awareness if a vehicle is operating on or next to a runway. However the variety of colours already used for such lighting on the airport surface means not enough are available to distinguish vehicle runway occupancy to controllers. Is only applicable in good visibility conditions (particularly at night).	Vehicle drivers	Trials	Trials at Atlantic City International Airport and New Jersey	x	x	x	Visual	Yes	From trials it has been determined that the concept is not feasible from beacon colour limitations (two colours would require beacon separation which cannot be afforded on surface vehicles). Not applicable in heavy traffic conditions when airport surface is overcome with flashing lights.
	Kinetic Avionics	Surveillance Base Station (SBS) 1	Mode S/ADS-B receiver, decoder and display of local air traffic broadcasting on 1090MHz. The information received is represented on a 'virtual radar screen' using PC software. Technical specification including the software (downloadable/configurable online) and hardware (PC and USB) requirements to create a 'virtual radar screen'. Additional premium services are offered by the company including Map Mode S which allows the sharing of aircraft information within the subscribed community.	ADS-B (Mode A/C and Mode S) from aircraft	Deployed	Elstree Aerodrome		x		Visual	No	Cost effective method of surveillance but relies on ADS-B full equipment and has no specific mechanism for runway incursion prevention.
	Kinetic Avionics	Surveillance Base Station (SBS) 2	1030 MHz and 1090MHz (SSR reply and extended squitter) Mode-S and ADS-B interrogator, receiver, decoder and display of local air traffic. The information received is represented on a 'virtual radar screen' using PC software. Redundancy and maintenance package offered by manufacture. Software application (technical specification provided on website) displays a 'virtual radar screen'. Upgradable to the SBS-2RLC version which features runway lighting control using a screen interface or the SBS-2M which features multilateration.	ADS-B and interrogated transponders (Mode-S and ADS-B) from aircraft and ground units	Deployed	Integration trial at Sky guide		x		Visual	No	Cost effective method of surveillance but relies on ADS-B full equipment and has no specific mechanism for runway incursion prevention.
	Various	ADS-B APT	The concept of using ADS-B to provide surveillance of the airport surface to ATCOs This is not a technology but a concept. The concept is incorporated into other technologies even if the appropriate ADS-B standards are yet to be developed.		In development			x				ADS-B APT is one of the ADS-B applications. It is not a technology but a concept in which surface operations can be monitored by a controller using ADS-B data. The concept is not yet mature and alerting mechanisms for runway incursions are not yet developed. The main problem with ADS-B is that it relies on full equipment to be useful, this is still a long way off.
	Norden Systems (Northrop Grumman)	Airport Surface Detection Equipment (ASDE-3)	High resolution automatic airport surface monitoring and surveillance system. Can be interfaced with an automatic conflict alerting system (AMASS) module to warn controllers of potential incidents. The system resolution can detect and track persons upon the airport surface using radar video processing and target extraction software. System scans the airport surface at the rate of 1Hz and typically costs between \$6 and \$7 million per airport. Targets are tagged and have their velocity derived. A software module can provide optimal runway scheduling information. This is the prime airport sensor in the US.	Primary surveillance radar	Deployed	The 34 busiest US airports: see FAA Safety Report August 2005 for details		x		Visual	No	This is a radar system and provides no stand-alone incursion prevention. To provide any protection against runway incursions it must be installed with data fusing and monitoring software such as in the AMASS system. This system is used as a benchmark by the FAA in the "Surface Movement Guidance and Control System" Advisory Circular 120-57A.

COMMERCIAL-IN-CONFIDENCE

Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
	Sensis, Raytheon, ELAR and Dassult.	Airport Surface Detection Equipment (ASDE X)	A modular system that is capable of processing and fusing data from various sources to provide controllers with a detailed, high resolution and clear surveillance picture of the airport surface. The system is scalable and offers a more cost effective solution for smaller airports than ASDE-3. Can be interfaced with an automatic conflict alerting system (AMASS) module to warn controllers of potential incidents. Originally developed by the FAA and Volpe centre as a business like procurement project to evaluate technologies offered by 'off the shelf' manufacturers. Update rate is 1Hz and can be interfaced with ASDE-3 or induction loop technology.	Primary and Secondary surveillance Radar, SMR, ADS-B and Multilateration.	Deployed	See FAA Safety Report August 2005 for details		x		Visual	No	This is a radar system and provides no stand-alone incursion prevention. To provide any protection against runway incursions it must be installed with data fusing and monitoring software such as in the AMASS system. FAA supported R&D scheme.
	Norden Systems. (Northrop Grumman)	Airport Surface Radar (ASR) - 9 and ASR-12	Airport surface and approach radar systems. Forms part of ADSE X system. A Technology current since the late 1980's has recently undergone lifetime extension work.	Primary and Secondary surveillance Radar	Deployed	The 34 busiest US airports: see FAA Safety Report August 2005 for details		x		Visual	No	Surveillance sensor - has no standalone protection against incursion. Programme supported by the FAA.
	Qinetiq & Comsoft	Quadrant Aircraft Surveillance	Multilateration and ADS-B augmentation system Scalable system for small-medium sized airports offering more cost effective surveillance than radar. Integrable with other surveillance systems it as a 10 second update rate and is Mode S capable. The System will only detect transponder equipped aircraft or vehicles but will do so with an accuracy of 7.5m. The communications link uses either LAN, fiber optic cable or a wireless connection. Server is PC based.	ADS-B and Multilateration	Trials	Heathrow, Gatwick, Luton, Stansted Boscombe Down, Pershore		x		Visual		Surveillance sensor - has no standalone protection against incursion.
	ERA	Inductive Loop Sensor Subsystem (LSS) aka Inductive LOP Technology (LOT)	System comprises of a series of inductive loop sensors with lead in wires to a Pull Box and a detector enclosure cabinete. This detector is R/F datalinked to the LSS host computer. This component identifies the model of the target and tracks its progress across the airport surface loop system deducing the target velocity. Surveillance data can be fused with data from other surveillance systems at the central processor. Theoretically could be applied across the airport surface but is only cost effective as a point solution for blind spots/critical intersections or runways. Surveillance it provides can be used with software applications to alert controller when aircraft enters a restricted area or runway. Update rate is once per second. No noticable degradation in performance over a 5 year trial period. Replacement is labor intensive although the detector unit itself is cheap enough not to repair.	Induction loops, database linking the time varying induced current fingerprint detected with a particular aircraft or vehicle type.	Deployed	Installed in Frankfurt and as a prototype system at Long Beach Airport, CA. Trials at Greece and Dallas Fort Worth		x		Visual	No	This system is a surveillance input that provides no standalone protection against runway incursions. Combined with data fusion and monitoring software it can be used as such. Communications use ASTERIX protocol so surveillance system can be interfaced with others. Cost efficient if used as point solution (off the shelf product). Detection is reliable but must be filtered against interference from the airport lighting system. FAA supported R&D scheme.
	Plectek	BlightER 200	Short-range surface radar. Can be used as a standalone or integrated system. Low cost model offering medium range surveillance for simple open environments. Detects surface targets including people and fast moving objects. Single unit comprising Antenna, transmitter, receiver, synthesiser and signal processing. Links to a laptop, PDA or remote network. Can be battery operated in the field and has a dormant mode to save power when inactive.	SMR	In development			x		Visual	No	Surveillance sensor - has no standalone protection against incursion.
	Plectek	BlightER 400	More expensive version of the 200 model for more complex and cluttered environments. Detects surface targets including people and fast moving objects.	SMR				x		Visual	No	Surveillance sensor - has no standalone protection against incursion.
	Saarland University, Centre for Integrated Systems (Germany), Voltronic electronics (Germany), Centre for Research and Technology, (Hellas, Greece), FR Apopt, High Tech Marketing (Austria), Advantage Technical Consulting	Intelligent Surveillance and Management functions for Airfield applications based on Low cost magnetic field detectors (ISMAEL)	Project to determine use of magnetic sensors to provide passive surface surveillance when used in conjunction with other sensor systems). Algorithms are used for the identification and tracking of targets. Could present a component of an A-SMGCS solution covering blind spots, particularly at small to medium sized airports.	Magnetic induction loops.	In development	Trials at Frankfurt		x		Visual	Yes	ISMAEL is a project to develop a lower cost method of airport surveillance based on magnetic sensors. Surveillance sensor - has no standalone protection against incursion.
	Thales ATM, FAA Navigation program	Local Area Augmentation System (LAAS)	Precision navigation for final approach phase of flight. Prevents runway incursions due to inaccurate navigation aboard landing aircraft (ie by ensuring they land upon the correct runway they have been cleared onto). Accurate position data is presented to the pilot. Navigation data is uplinked to the aircraft to ensure it flies an accurate final approach route. GPS receivers in aircraft and ground reference antennas use a constellation of satellites to determine their relative positions. This data is used to obtain differential correction and integrity information for the current runway approach being assigned to the aircraft - information which is transmitted to the aircraft using a VHF datalink. The aircraft determines its own position information independently from the satellites and uses this correction data to calculate accurate corrected position estimates. VHF datalink also provides information required to perform a safe approach. Range extends to 45km from ground station.	GPS, VHF datalink, defined final approach path.	Trials	Trials at Moffett Federal Airfield, CA	x			Visual	No	Not a runway incursion prevention technology. FAA supported R&D scheme, GBAS (Ground Based Augmentation System) on which this variant is based has been recognised by ICAO.
	Sensis	Multistatic Dependent Surveillance (MDS) System	Multilateration system detects transponder equipped targets on the airport surface and in local airspace (departures and final approach). Data can be provided to decision support tools, flow management systems and controller screens. Non-rotating sensors have better reliability. Update rates are higher than radar. Requires line of sight between sensor and target - system is flexible and adaptable. Multiple sensors are needed to triangulate position. Enhances existing TMA and airport surveillance.	Multilateration (Mode A/C and Mode S), Extended squitter.	Deployed	The 34 busiest US airports		x		Visual	No	Surveillance sensor - has no standalone protection against incursion. FAA supported technology as part of the ASDE-X program.

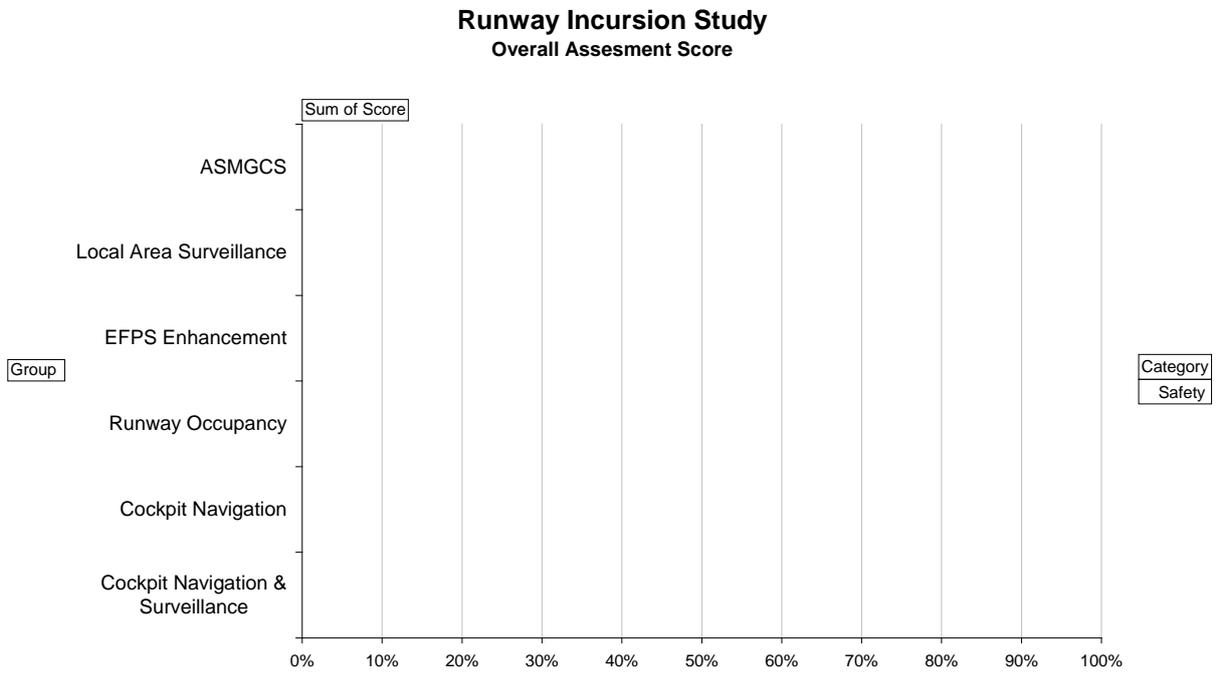
COMMERCIAL-IN-CONFIDENCE

Group	Manufacturer	Model	Description	Surveillance Source	Status	Deployment	Flight Crew	ATCO	Vehicle Drivers	HMI Type	Alerting	Initial assessment
	ERA	MSS	Multilateration system detects transponder equipped targets on the airport surface and in local airspace (departures and final approach), TMA and on the airport surface. Highly available and accurate multilateration surveillance that can flexibly grow with the airport (so prove cost effective). Can augment other systems.	Multilateration "ADS-X", extended range ADS-B (Mode A/C and Mode S), Extended squitter.	Deployed	47 US airports, 19 European (including Glasgow and Edinburgh), 2 African, 7 in Asia-Pacific, 1 in South America.		x		Visual	No	Surveillance sensor - has no standalone protection against incursion. Conformance with ICAO Annex 10 Vol IV, ED-117 (MOPS for multilateration systems), RTCA DO-260A (MOPS for extended squitter, ADS-B and TIS-B) and Eurocontrol ASTERIX standards.
	ERA	SOB - Vehicle Location Transmitter AKA 'SQUID'	Portable mode-S squitter beacon (SOB) attached to vehicles to maintain surveillance of them on the airport surface. Can be integrated into an A-SMGCS concept. Vehicles have a unique 24-bit address assigned to them. Automatic unattended surveillance in all weathers. Limited to a vehicle only system. Magnetically mounted. Can also be installed on GA aircraft or temporary surface obstructions.	Multilateration, or ADS-B unit in conjunction with a GPS receiver.	Deployed	47 US airports, 19 European (including Glasgow and Edinburgh), 2 African, 7 in Asia-Pacific, 1 in South America.	x	x	x	Visual	No	Surveillance sensor - has no standalone protection against incursion. Conformance with ICAO Annex 10 Vol IV.
	Sensis	Veelo	Portable mode-S squitter beacon (SOB) attached to vehicles to maintain surveillance of them on the airport surface. Can be integrated into an A-SMGCS concept. Mode S based Multistatic Dependent surveillance technology. In addition to the 24-bit address the vehicle can be identified by an alpha-numeric address (eg radio call signs) - configurable in the field using laptop. Permanent or temporary mounting options.	Multilateration and ADS-B.	Deployed			x	x	Visual	No	Surveillance sensor - has no standalone protection against incursion.
	Thales	Mosquito Vehicle transmitters and AS-680 ground stations	Can be integrated into Thales A-SMGCS system STREAMS. Multi-link transmitter for vehicle management providing position and identification using ADS-B mode S squitter.	ADS-B and GPS.	Deployed	Frankfurt, Madrid, Toulouse, Lyon, Seoul, Astana (Kazakhstan).		x	x	Visual		Surveillance sensor - has no standalone protection against incursion.
	CIAS Elettronica	ERMO 482X PRO	Airport traffic control and perimeter protection using x-band digital microwave barrier that cannot be blocked, shielded against or interfered with by airport surface radar. Used over range of 50, 80, 120 and 200m range. Internal processors use fuzzy logic to analyse signal and give low false alarm rates by comparing 'behaviour modes' of an intruder and a target that would generate a false alarm (average of one a year of operation) giving good target discrimination.	X-band transmitter and receiver heads operating on 16 crystal controlled modulation channels.	Proposed			x		Visual, Aural	Yes	Not a runway incursion prevention technology. Could provide perimeter security for airfield though. Meets CE, US and Canadian standards.
	Galaxy Scientific Corp	Airport Trak	Airport Vehicle tracking, control and command. Real time ground vehicle tracking system. All airport operations are controlled from a central command centre which provides a large graphical information system map of the airport. Following vehicle start up its position is automatically and continuously transmitted to the command centre.	Differential GPS and wireless communication.	Unknown				x			This is a vehicle tracking system for airport operators. It does not track aircraft and is not therefore a runway incursion prevention technology.

D Safety performance assessment

D.1 Chart

Description (All)



D.2 Technology group 1 - ASMGCS

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion	I							
Conditional Clearance	I							
CRM								
Incorrect/missed Readback	s							
Misunderstanding	m							
No R/T Available	m							
No R/T Contact	m							
Phraseology								
Poor ATC Coordination	I							
Poor R/T Contact								
Poor R/T Monitoring								
Poor signals								
Disorientation	I							
Distraction	I							
Erroneous Expectation								
Incorrect Clearance								
Green route left on	I							
Lack of situational awareness	I							
Misidentification	I							
Misinterpretation								
Misperception								
Overload	I							
Third Party								
Aircraft								
ATS Controlled Equipment	m							
Vehicles	m							
Failed follow Clearances	I							
Failed follow Instructions/Signals	I							
Failed follow Procedures								
Poor Procedures								
Poor/Lack Instructions								
Poor Lookout/Monitoring	I							
Restricted view	I							
Confusion	s							
Ignored indications/clearances	s							
Lack of Experience/Familiarisation								
Lack of Understanding/Knowledge								
Complacency								
Violation								
Poor Aerodrome Security	m							
Poor Indicators/Signs/Lighting/Charts								
Poor/Lack of Ability/Airmanship								
Poor/Lack of Training								
Press-on-itis								
Assumption								
No. of causal factors affected	82.5							
% of causal factors affected	5.07%							

D.3 Technology group 2 - Local Area Surveillance

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion	s							
Conditional Clearance	s							
CRM								
Incorrect/missed Readback								
Misunderstanding								
No R/T Available	s							
No R/T Contact	s							
Phraseology								
Poor ATC Coordination	s							
Poor R/T Contact								
Poor R/T Monitoring								
Poor signals								
Disorientation	m							
Distraction								
Erroneous Expectation								
Incorrect Clearance								
Green route left on	s							
Lack of situational awareness	m							
Misidentification	m							
Misinterpretation								
Misperception								
Overload	m							
Third Party								
Aircraft								
ATS Controlled Equipment	s							
Vehicles	s							
Failed follow Clearances	l							
Failed follow Instructions/Signals	l							
Failed follow Procedures								
Poor Procedures								
Poor/Lack Instructions								
Poor Lookout/Monitoring	l							
Restricted view	l							
Confusion	s							
Ignored indications/clearances	s							
Lack of Experience/Familiarisation								
Lack of Understanding/Knowledge								
Complacency								
Violation								
Poor Aerodrome Security	s							
Poor Indicators/Signs/Lighting/Charts								
Poor/Lack of Ability/Airmanship								
Poor/Lack of Training								
Press-on-itis								
Assumption								
No. of causal factors affected	34							
% of causal factors affected	2.09%							

D.4 Technology group 3- EFPS Enhancement

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion	m							
Conditional Clearance	m							
CRM								
Incorrect/missed Readback	s							
Misunderstanding	m							
No R/T Available								
No R/T Contact								
Phraseology								
Poor ATC Coordination	m							
Poor R/T Contact								
Poor R/T Monitoring								
Poor signals								
Disorientation	m							
Distraction	l							
Erroneous Expectation								
Incorrect Clearance	l							
Green route left on								
Lack of situational awareness	l							
Misidentification	s							
Misinterpretation								
Misperception								
Overload	l							
Third Party								
Aircraft								
ATS Controlled Equipment								
Vehicles								
Failed follow Clearances								
Failed follow Instructions/Signals								
Failed follow Procedures								
Poor Procedures								
Poor/Lack Instructions								
Poor Lookout/Monitoring	m							
Restricted view	m							
Confusion	l							
Ignored indications/clearances								
Lack of Experience/Familiarisation								
Lack of Understanding/Knowledge								
Complacency								
Violation								
Poor Aerodrome Security								
Poor Indicators/Signs/Lighting/Charts								
Poor/Lack of Ability/Airmanship								
Poor/Lack of Training								
Press-on-itis								
Assumption								
No. of causal factors affected	62							
% of causal factors affected	3.81%							

D.5 Technology group 4 - Runway Occupancy

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion								
Conditional Clearance						s		
CRM						m		
Incorrect/missed Readback								
Misunderstanding								
No R/T Available						s		
No R/T Contact						s		
Phraseology								
Poor ATC Coordination								
Poor R/T Contact								
Poor R/T Monitoring								
Poor signals								
Disorientation			l			l		
Distraction			m			l		
Erroneous Expectation								
Incorrect Clearance			s			m		
Green route left on								
Lack of situational awareness						l		
Misidentification								
Misinterpretation								
Misperception								
Overload						m		
Third Party								
Aircraft						l		
ATS Controlled Equipment								
Vehicles			m			m		
Failed follow Clearances								
Failed follow Instructions/Signals						m		
Failed follow Procedures								
Poor Procedures								
Poor/Lack Instructions								
Poor Lookout/Monitoring						l		
Restricted view						l		
Confusion						s		
Ignored indications/clearances								
Lack of Experience/Familiarisation								
Lack of Understanding/Knowledge								
Complacency								
Violation								
Poor Aerodrome Security								
Poor Indicators/Signs/Lighting/Charts						m		
Poor/Lack of Ability/Airmanship						s		
Poor/Lack of Training								
Press-on-itis								
Assumption								
No. of causal factors affected	86.75							
% of causal factors affected	5.33%							

D.6 Technology group 5 - Cockpit Navigation

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion								
Conditional Clearance						m		
CRM						l		
Incorrect/missed Readback								
Misunderstanding						s		
No R/T Available								
No R/T Contact								
Phraseology								
Poor ATC Coordination								
Poor R/T Contact								
Poor R/T Monitoring								
Poor signals								
Disorientation			l			l		
Distraction			s			s		
Erroneous Expectation								
Incorrect Clearance						s		
Green route left on								
Lack of situational awareness			m			m		
Misidentification								
Misinterpretation								
Misperception								
Overload			s			s		
Third Party								
Aircraft						m		
ATS Controlled Equipment								
Vehicles			m					
Failed follow Clearances								
Failed follow Instructions/Signals								
Failed follow Procedures								
Poor Procedures								
Poor/Lack Instructions								
Poor Lookout/Monitoring			l			l		
Restricted view			m			m		
Confusion			s			s		
Ignored indications/clearances								
Lack of Experience/Familiarisation			m			m		
Lack of Understanding/Knowledge								
Complacency								
Violation								
Poor Aerodrome Security								
Poor Indicators/Signs/Lighting/Charts			l			l		
Poor/Lack of Ability/Airmanship			m			m		
Poor/Lack of Training								
Press-on-itis								
Assumption								
No. of causal factors affected	103							
% of causal factors affected	6.33%							

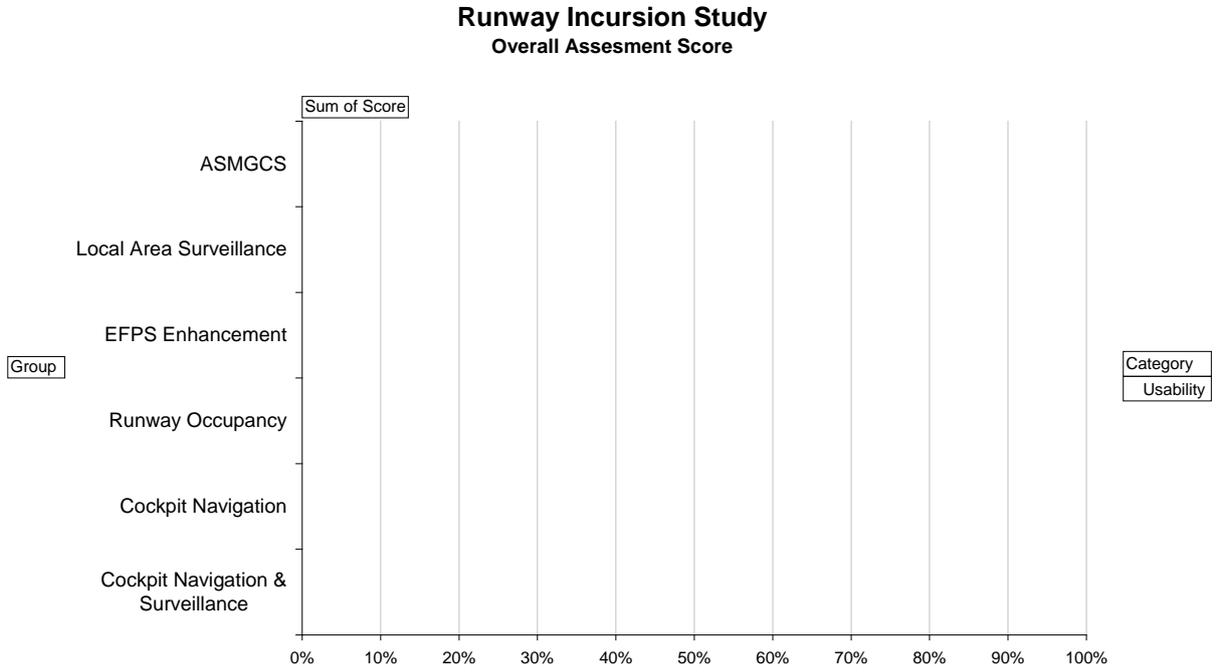
D.7 Technology group 6 - Cockpit navigation & surveillance

Factors	Entity							
	Aerodrome	ATC	Driver	Equipment	People	Pilot	Regulator	Third Party
Call-sign Confusion			l			l		
Conditional Clearance								
CRM						m		
Incorrect/missed Readback								
Misunderstanding						m		
No R/T Available						m		
No R/T Contact						m		
Phraseology								
Poor ATC Coordination								
Poor R/T Contact								
Poor R/T Monitoring								
Poor signals								
Disorientation			l			l		
Distraction			m			m		
Erroneous Expectation								
Incorrect Clearance								
Green route left on								
Lack of situational awareness			l			l		
Misidentification			l			l		
Misinterpretation								
Misperception			s			s		
Overload			m			m		
Third Party								
Aircraft						m		
ATS Controlled Equipment								
Vehicles			m					
Failed follow Clearances			m			m		
Failed follow Instructions/Signals			l			l		
Failed follow Procedures			s			s		
Poor Procedures								
Poor/Lack Instructions								
Poor Lookout/Monitoring			l			l		
Restricted view			l			l		
Confusion			m			m		
Ignored indications/clearances								
Lack of Experience/Familiarisation			m			m		
Lack of Understanding/Knowledge								
Complacency								
Violation								
Poor Aerodrome Security								
Poor Indicators/Signs/Lighting/Charts			m			m		
Poor/Lack of Ability/Airmanship			m			m		
Poor/Lack of Training								
Press-on-itis								
Assumption								
No. of causal factors affected	393.25							
% of causal factors affected	24.16%							

E Usability assessment

E.1 Chart

Description (All)



E.2 Table

#	Usability factor	Weighting		Answer	% of responses (ATCOs)	% of responses (Pilots)	ASMGS	Local Area Surveillance	EFPS Enhancement	Runway Occupancy	Cockpit Navigation	Cockpit Navigation & Surveillance
2	Who should alarms be provided to?	High	1.25	Controller	44%	11%	x	x	x			
				Pilot/Driver	2%	0%				x	x	x
				Both	54%	89%						
3	Should alarms provide advice or mandate a response?	Low	0.75	Advisory	55%	47%	x	x		x	x	x
				Mandatory	45%	53%			x			
4	What is the maximum acceptable false alert rate?	High	1.25	High (0.05)	0.02	0.01	x	x		x		
				Medium (0.01)	0.10	0.07					x	x
				Low (0.001)	1.00	0.65			x			
5	How should the alert be transmitted?	Low	0.75	Visual only	0%	5%				x		
				Visual with sound	100%	95%	x	x	x		x	x
6	Should multi-stage alerting be available?	Med	1	Yes	75%	68%	x					x
				No	25%	32%		x	x	x	x	
7	Should visual alerts be combined with other displays?	Med	1	Separate	36%	29%	x	x		x		
				Combined	64%	71%			x		x	x
8	Should pilots be alerted to the crossing runway entry point?	Med	1	Yes	N/A	21%				x	x	x
				No	N/A	79%						
9	Should controllers be alerted to all mobiles approaching a runway?	Med	1	Yes	13%	N/A						
				No	87%	N/A	x	x	x			
10.1	Should different alerting parameters exist for day and night?	High	1.25	Yes	10%	22%						
				No	90%	78%	x	x	x	x	x	x
10.2	Should different alerting parameters exist for different visibility conditions?	High	1.25	Yes	85%	44%	x	x				
				No	15%	56%			x	x	x	x
Absolute score							5.9	5.4	5.9	2.9	4.0	4.4
Maximum possible score							7.5			6.9		
% score							0.8	0.7	0.8	0.4	0.6	0.6
Relative % score							99%	91%	100%	53%	75%	81%

Annex Table 1: Usability assessment

F Questionnaire and results

F.1 Questionnaire

What makes technology useful for the prevention of Runway Incursions?

A questionnaire for operational personnel

Please take approximately 5 minutes to answer the following questions to help us identify the most important factors that make runway incursion warning systems useful for controllers and pilots/drivers.

Please answer each question and circle (or highlight electronically) the answer which applies. Additional comments and notes are welcome.

Please return responses ASAP to:

Name: James Hanson
E-mail: james.hanson@helios-tech.co.uk
Address: Helios Technology, Chamberlain House, 10-12 High Street, Bagshot, Surrey, GU19 5AE
Phone: +44 1276 452 811

1. Are you:
 - a. A Pilot
 - b. An ATCO

2. Considering the alarm in a runway incursion warning system, should the alarms provided in an event be:
 - a. Only to the controller
 - b. Only to the pilot/driver
 - c. To both

3. If you receive such alarms should they be either:
 - a. Advisory information - *i.e. pilot or controller uses own judgement to interpret the situation and to decide on the best course of action.*
 - b. Mandatory - *Depending on the situation the alarm must be reacted to in a defined manner.*

4. Roughly what level of false alerts do you consider to be the maximum acceptable:
 - a. 0
 - b. 1 in 100
 - c. 1 in 20

5. Should the alarm be:
- a. Visual with no sound
 - b. Visual with sound

6. Should there be more than one level of alert:
- a. Yes – *for example an orange visual - low aural tone when potential incursion is detected, increasing to red and loud tone when incursion of the runway strip has taken place.*
 - b. No – *only one alert regardless of the position of the detected intruder.*

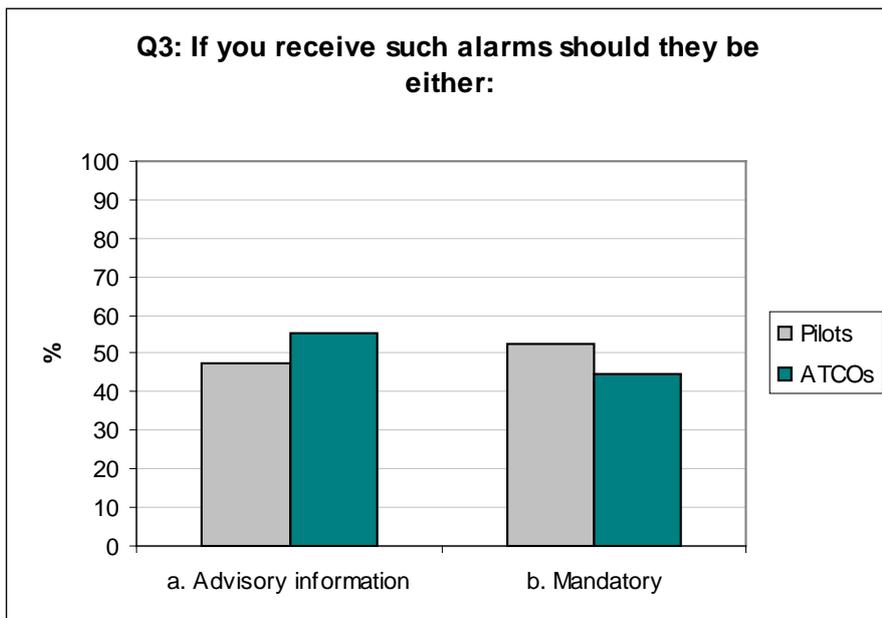
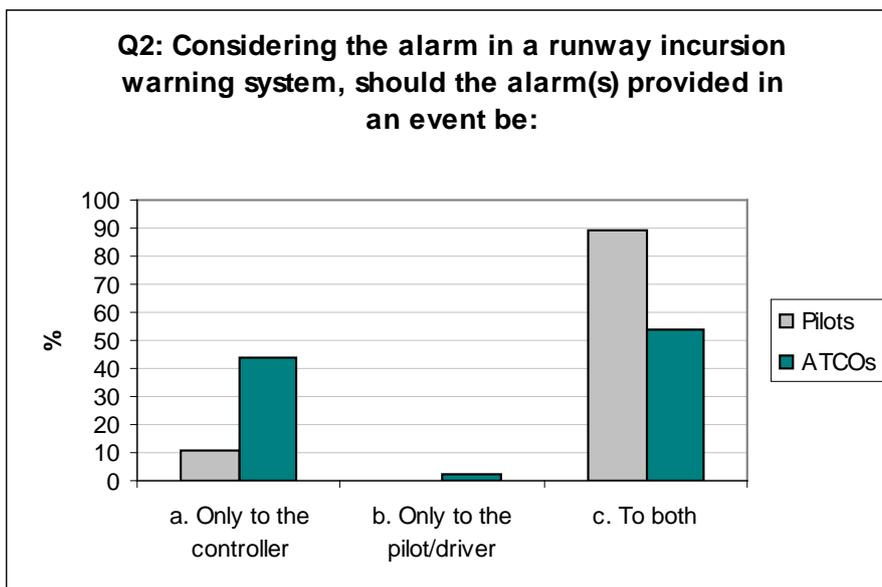
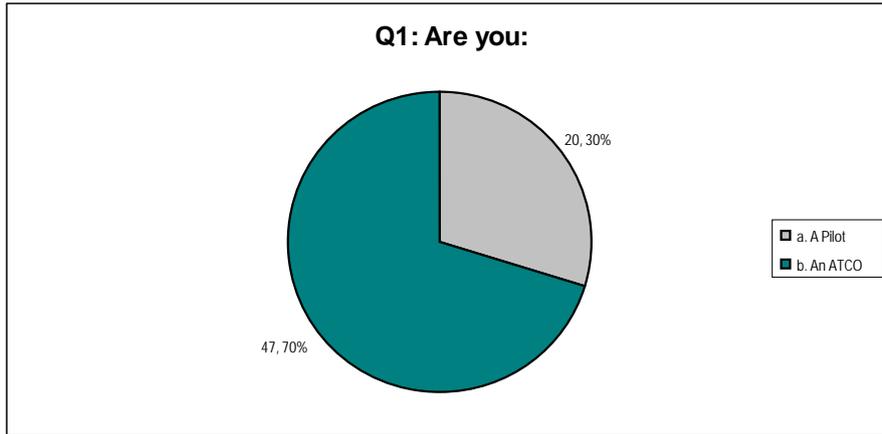
7. If displayed, should the means of showing an alert be:
- a. Separate from other displays
 - b. Combined with other displays e.g. TCAS/SMR-ATM

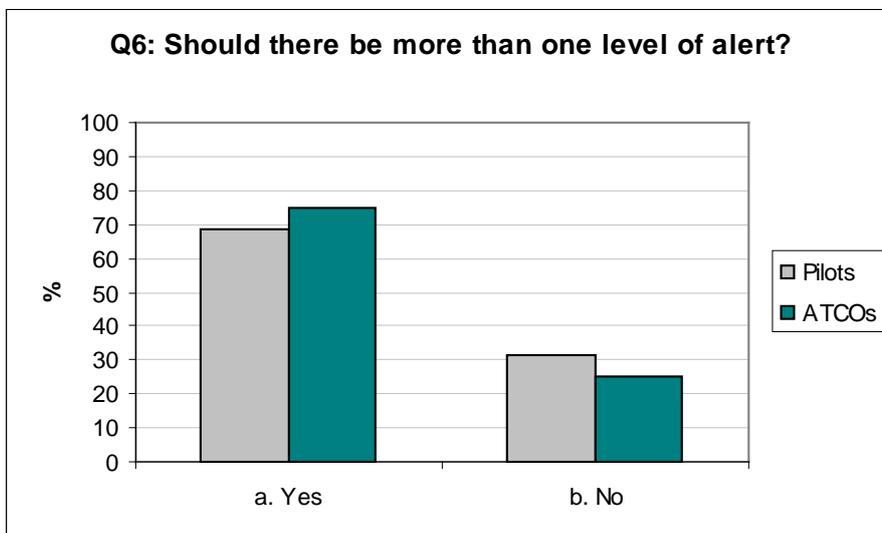
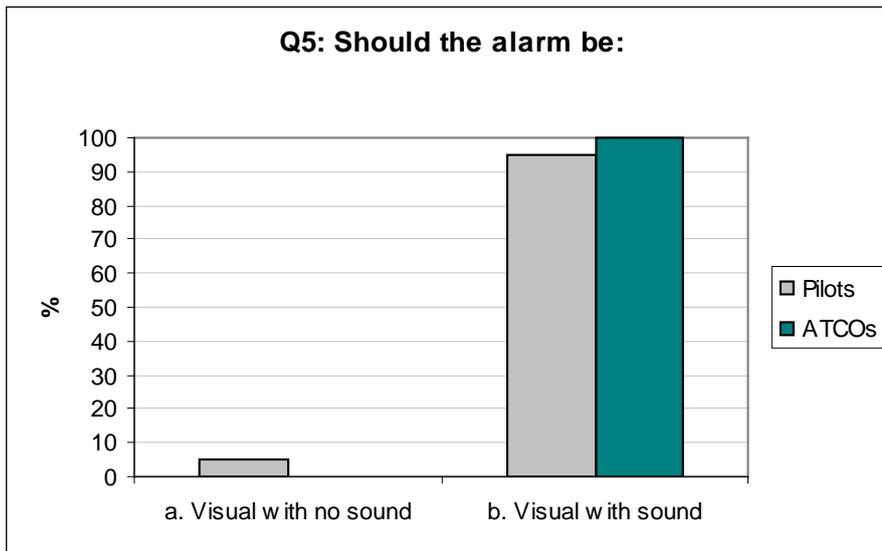
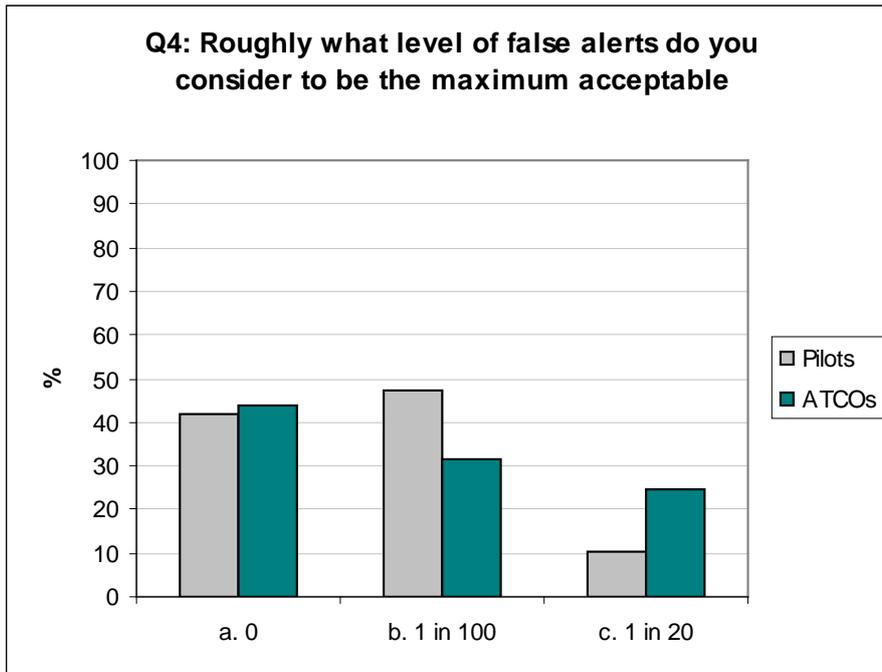
8. Should pilots be made aware of the crossing runway entry point with some form of alert, even when cleared to enter:
- a. Yes
 - b. No

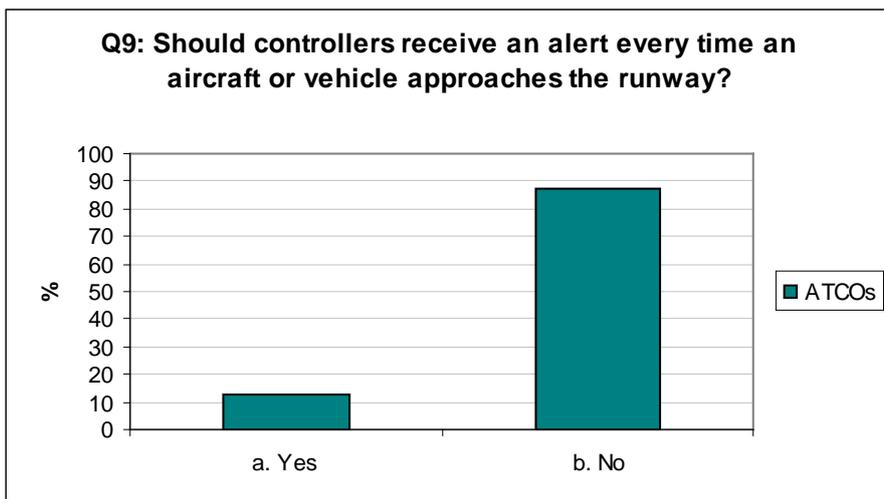
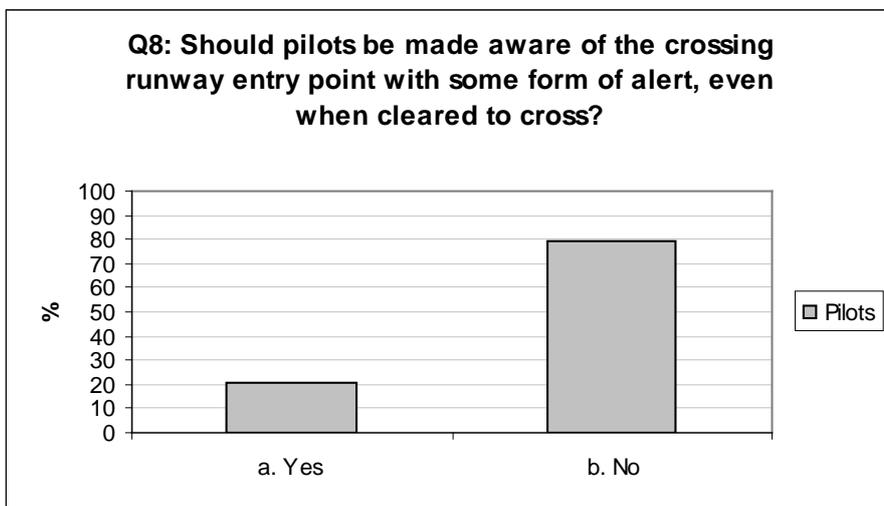
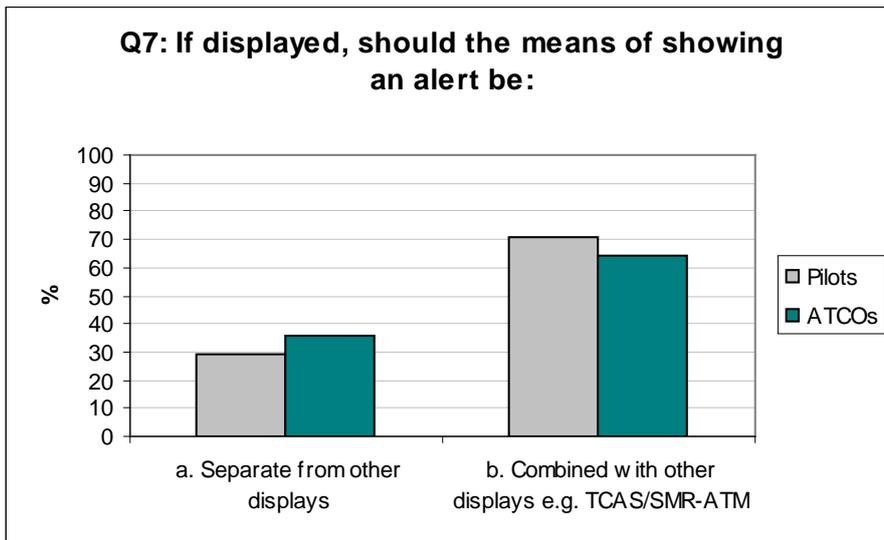
9. Should controllers receive an alert every time a aircraft or vehicle approaches the runway strip:
- a. Yes
 - b. No

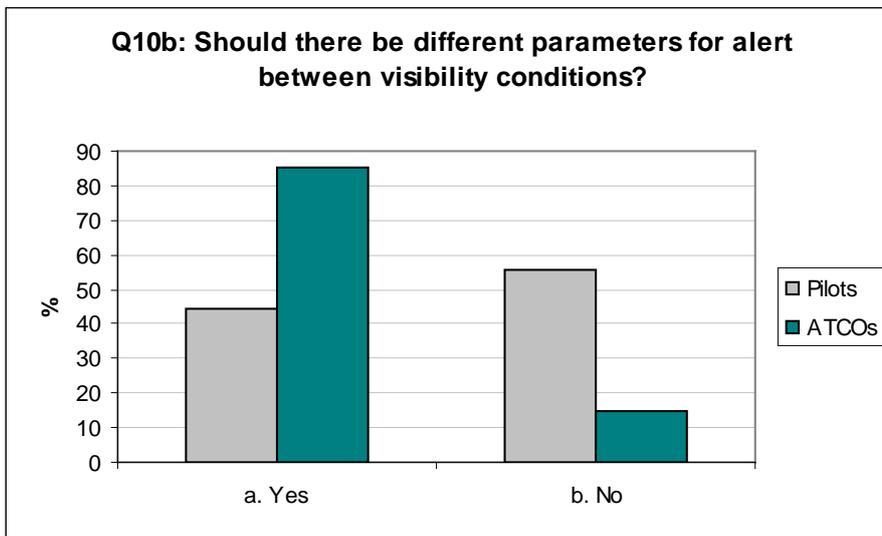
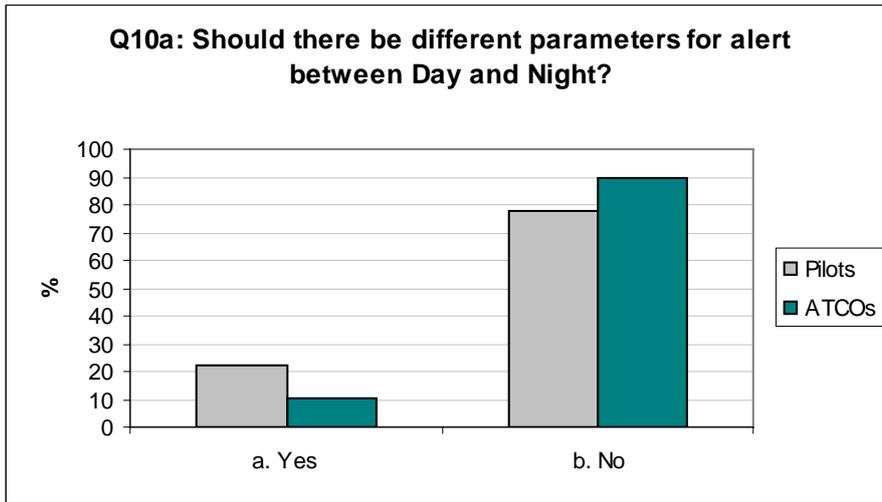
10. Should there be different parameters for alert between:
- a. Day & night – Yes / No
 - b. Visibility conditions – Yes / No

F.2 Responses





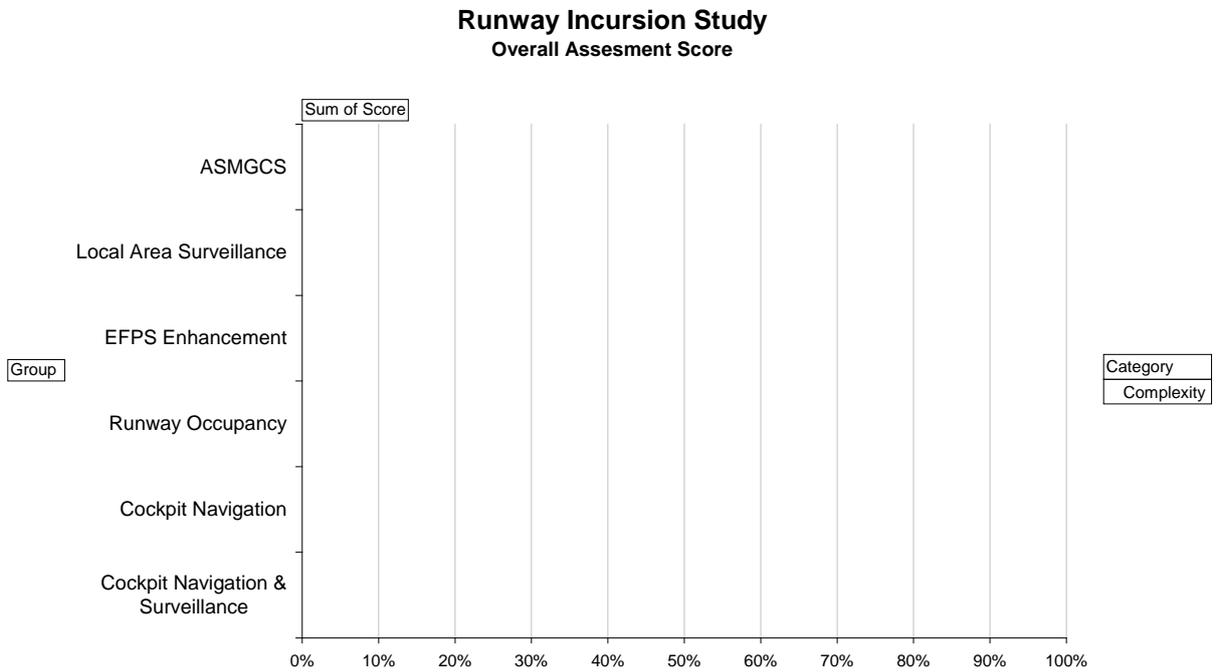




G Complexity assessment

G.1 Chart

Description (All)



G.2 Table

	ASMGCS	Local Area Surveillance	EFPS Enhancement	Runway Occupancy	Cockpit Navigation	Cockpit Navigation & Surveillance
Category						
Cost	m	s	s	s	s	l
Implementation effort	l	m	s	s	s	l
Difficulty to retrofit	s	s	s	s	l	l
Likelihood of future obsolescence	m	l	s	m	s	s
Absolute score	2.00	2.25	3.00	2.75	2.50	1.50
Relative % score	67%	75%	100%	92%	83%	50%

Key
Large (l) = 0.25
Medium (m) = 0.5
Small (s) = 0.75