Final publishable Project Summary

Title:	Intelligent Surveillance and Management Functions for Airfield Applications Based on Low Cost Magnetic Field Detectors
Acronym:	ISMAEL
Contract N°:	IST-507774
Duration:	39 months

Project Co-ordinator
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Intelligent Surveillance and Management functions for Airfield applications based on Low cost magnetic field detectors (ISMAEL, 02.2004-04.2007, co-funded under the 6th Framework Programme of the European Community, Contract N° IST-2003-507774)

ISMAEL consortium, June 2007

The Need

Increasing air travel has placed greater demands on airport capacity, and increased the pressure to maintain capacity in periods of low visibility whilst maintaining safety. This has led to the development of new concepts in surface movement surveillance, guidance and control through initiatives such as A-SMGCS and multi-lateration. However, there are still areas where these initiatives do not provide a completely satisfactory solution, for technical or economic reasons.

New technology in the field of magnetic sensors may assist in addressing these areas. Relatively cheap sensors placed in or near runways, taxiways or aprons may provide a cheaper alternative to existing radar or multi-lateration technologies for smaller airports. They may also provide an important additional source of surveillance data at larger airports, particularly in high-risk areas or where operation of the existing technologies is obstructed.

ISMAEL (Intelligent Surveillance and Management functions for Airfield applications based on Low cost magnetic field detectors, Contract N° IST-2003-507774, 02. 2004-04. 2007) is a project to determine whether these recent advances in magnetic sensors could provide a viable option for surface movement surveillance at airports, either as a stand-alone system or in combination with other technologies.

The starting point for the project was an extensive user requirements exercise, to identify the specific needs of airport operators that could be addressed by this technology, and to develop the performance, safety and other requirements needed. Potential applications of ISMAEL identified during user requirements work include Airport Surveillance, Runway Incursion Prevention and Gate Management.

Detection Principles

The key objective of ISMAEL is to develop magnetic detectors for aircraft and ground vehicle detection. Traditional magnetic field sensing is already well established as a method for vehicle detection. In these applications, magnetic fields (milli Tesla range) are generated by permanent magnets or currents in coils. Because magnetic field sources are inherently dipole in nature, they decrease with the inverse cube of distance. Therefore, the fields from these sources are localised. However, this method needs strong external magnetic sources to avoid the influence of the Earth's own magnetic field. Such strong fields are not always possible due to the limitation of manufacturing processes, difficulty of installation and maintenance of large coils in an airport environment, etc. They may also interfere with aircraft systems.

The newly developed solid-state magnetic field sensors have an inherent advantage in size and power consumption when compared with search coil, flux gate, and more complicated low-field sensing techniques (e.g. super conducting quantum interference detectors [SQUID]). The solid-state sensors exhibit a large change in resistance in response to a magnetic field. This phenomenon is known as magneto resistance (MR). Various MR materials can achieve a change of resistance up to 20%, and their sensitivity can reach the nano-Tesla range at room temperature. This gives the possibility of using magnetic sensors to detect changes in the Earth's magnetic field due to the passage Ferro-magnetic objects (e.g. vehicles and aircraft on the ground) at considerable distance.

Therefore, the main detection technique in the present project can be described as the following: As ferro-magnetic objects (e.g. components of aircraft or ground vehicles) move over the surface of an airfield, the Earth's magnetic field acts as a biasing magnet, resulting in a magnetic signature from various parts of the objects. This signature can be detected by magnetic field detectors buried underground or placed on the side of the runway or taxiway.

The key advantages of this detection method are:

- Completely non-cooperative - Requires no equipment or transponders within the aircraft or ground vehicles
- Completely passive – no possibility of interference with aircraft or airport systems
- Sensors are relatively cheap, maintenance free and small enough to be installed within existing infrastructure.
- Unaffected by weather, airport buildings reflections/shadowing, etc.
- Provides detection relative to a known fixed point.

Development of Magnetic Detector Hardware and Firmware

During the course of this project, four generations of magnetic detectors were developed and tested, the final version being the "D-series" detector. This version is based on the latest commercial sensing elements with much lower and guaranteed noise levels than earlier versions, increasing sensitivity. The detector has three identical channels for the three-dimensional detection of changes in the earth's field due to a passing ferromagnetic object. It compensates these magnetic field changes in a closed loop so that each sensing element is always working in a zero magnetic field condition. As the temperature behaviour of the sensing elements is dependent upon the field applied, the influence of temperature is nearly completely cancelled, solving a problem encountered with earlier versions of the detector.

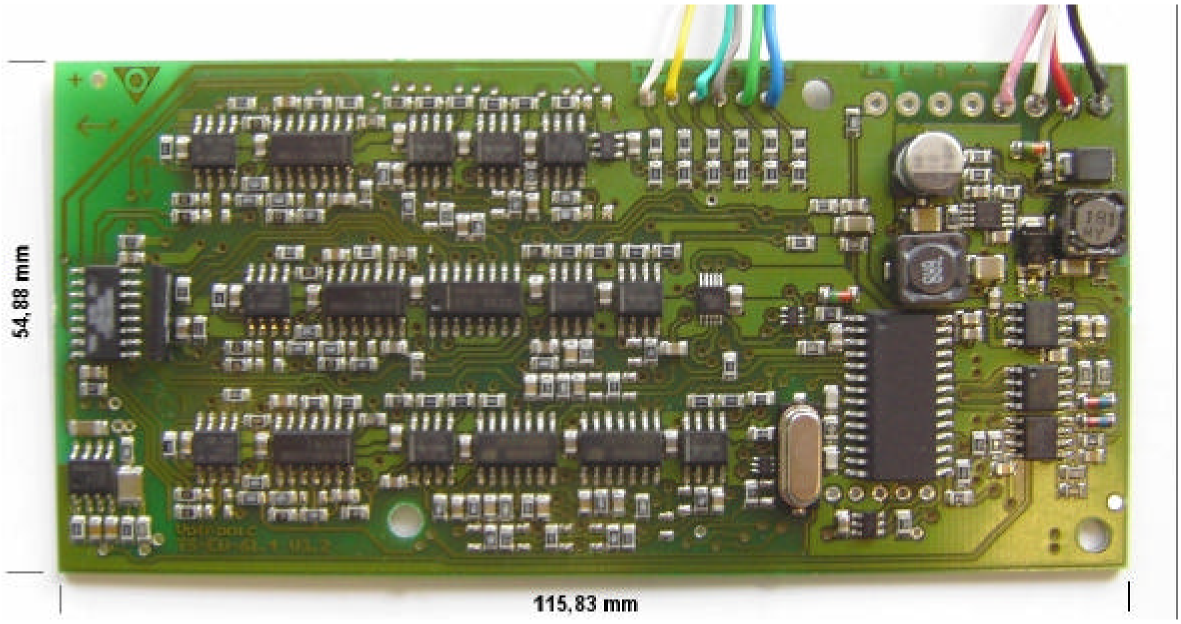

Fig.1: ISMAEL magnetic detector PCB

The detector is robust and small enough to fit within a taxiway lighting housing or similar enclosure, and requires only mW of power. Further reductions in size and cost could be achieved by using large scale integration of components.

The three-axis signal is sampled and mathematically filtered within the detector. Different techniques are used to filter out frequencies such as 16.66Hz (railroad power frequency in Germany) and 50 Hz (AGL power supplies). The low pass corner frequencies can be programmed below 100Hz. Other major on-board functions include offset subtraction; larger flipping pulses; variable gain amplification; 12 bit analogue to digital conversion; and powerful data processing, filtering and detection logic controlled by firmware.

The detector's firmware reacts to changes of the sum of the (unsigned) magnitudes of the three axes signals. When demanded, it will output the binary states "Field disturbed by amount xy", "Field not disturbed", and "Field disturbed since last polling" via RS485. Up to 127 detectors can be addressed in a single line (bus-system). Firmware can be re-programmed in the field, and it will re-boot successfully from non volatile memory in the event of a power interrupt. The firmware also controls the filtering, offset subtraction and gain setting referred to above, and provides comprehensive self-test functions. The detectors can even be used as stand-alone switching devices without using any external software or data fusion system.

The magnetic detectors have been tested both in laboratory and airport conditions. Among various parameters measured, sensitivity, signal-to-noise level and temperature stability are the most important ones for detector performance. The current detector's detection span is about +/-30 µT within the full detection range 300 µT. The potential sensitivity performance of the detector is limited by noise level and thus noise characterisation is an important measurement. A $1nT/\sqrt{Hz}$ noise level has been achieved by ISMAEL detector. The temperature dependency was a mayor drawback of earlier versions of the detectors. Through the field compensation technique, the output change of magnetic detectors is reduced to lower than 10^{-4}/K by using the flux loop configuration referred to above.
Meanwhile, sensor data fusion software (SDF) has been developed to control the magnetic detectors and process the outputs. The purpose of the SDF server is to collect data about the status of all detectors within an ISMAEL system and process this data in order to extract observations (targets, either ground vehicles or aircraft) and tracks. Observations contains information about a detector indicating the presence of a target and the time of this observation, while tracking filters this data and provides an inference about the movement of targets across the airport surface. The software can track multiple targets using multiple hypothesis tracking techniques.
The SDF server includes a graphical user interface giving a "radar-like" presentation of the tracked targets, and also outpuss observations and tracks via an Asterix encoder for use by other elements off an A-SMGCS system.

Airport Testing

During the course of the project detectors have been installed at three different airports: Saarbruecken, Frankfurt and Thessaloniki. Saarbruecken was used exclusively for detector research and development work, and results (e.g. sensing range and temperature behaviour) were used as feedback for the detector developers. The other two airports were used for airport application demonstration and system field test. The installations of detectors at three different airports show that the developed technology is flexible enough to adapt to different conditions at different types of airports.

At Frankfurt Airport all 3 potential applications (airport surveillance, runway incursion, and gate management) have been demonstrated and assessed within an appropriate measurement regime. Two different locations at the Airport were used, and have been, marked in blue in Figure 2.

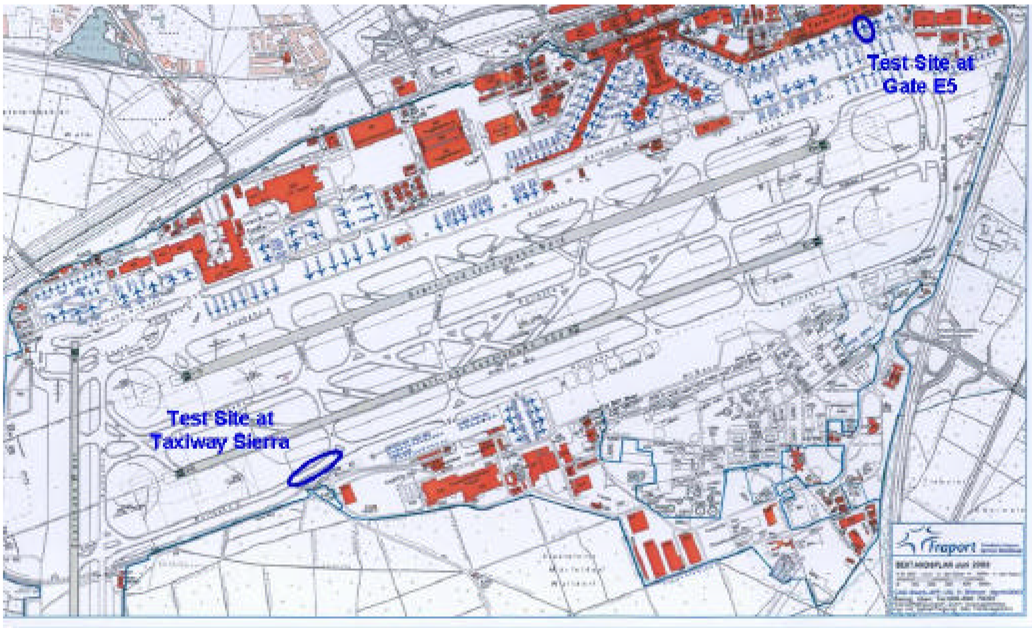

Fig.2: Detector demonstration location at Frankfurt airport

To demonstrate both of the airport surveillance and runway incursion applications, 6 detectors were installed in Taxiway Sierra (5 inside AGL housings in the centre line of taxiway and one in an AGL housing at the taxiway edge). The SDF computer was installed in an adjacent building, from where existing cable ducts ran to all the detector locations. The spacing of the sensors on the centre line is 15m and the test location covers a taxiway length of 60 metres.

The detectors were installed in August 2006 and tests were conducted up to Spring 2007. This implies that the detector hardware has been exposed fully to the winter conditions with low temperature and lots of rain and some snow. On the other hand the detectors were placed inside active AGLs and have to withstand a huge heat as well. Thus it can be seen, that the realised prototype already provides a certain amount of robustness.

Some of the key results from this test site were: mean error 5.7m, 75% less than 7.5m, 97% less than 15m. The detection rate of sensors in the centre line was 100%. A typical magnetic signature of Boeing 747 is presented in figure 3.

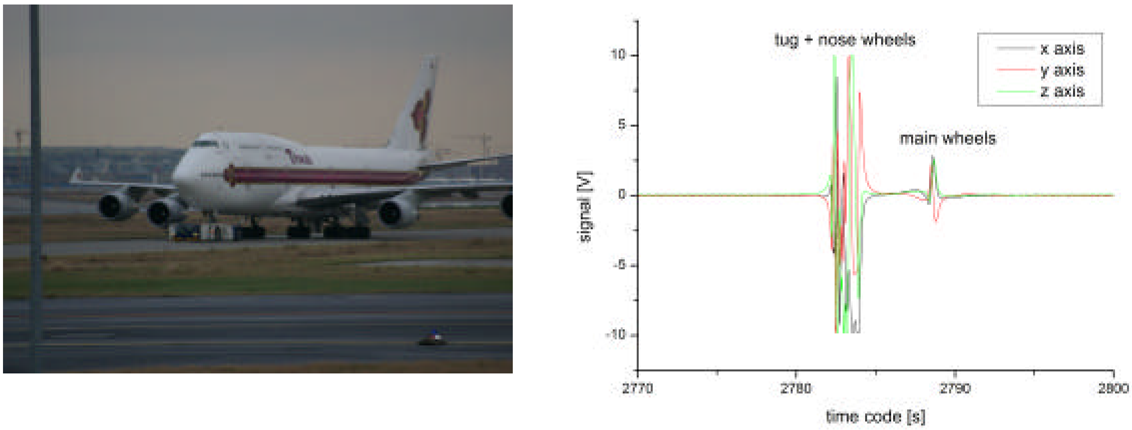

Fig.3: Magnetic signature of one Boeing 747 in taxiway Sierra guided by one tug.

To demonstrate the gate management application, three detectors were installed at gate E5. Two detectors were placed directly on the centre line of the gate and near the stop lines to capture the magnetic influence of the nose landing gear. The third detector was placed slightly away from the centre line in the likely area of a main landing gear. The test was designed so that a gate would be indicated as occupied only if all three detectors were excited. In practice raw data from each of the detectors was recorded and analysed offline to determine the status of the gate.

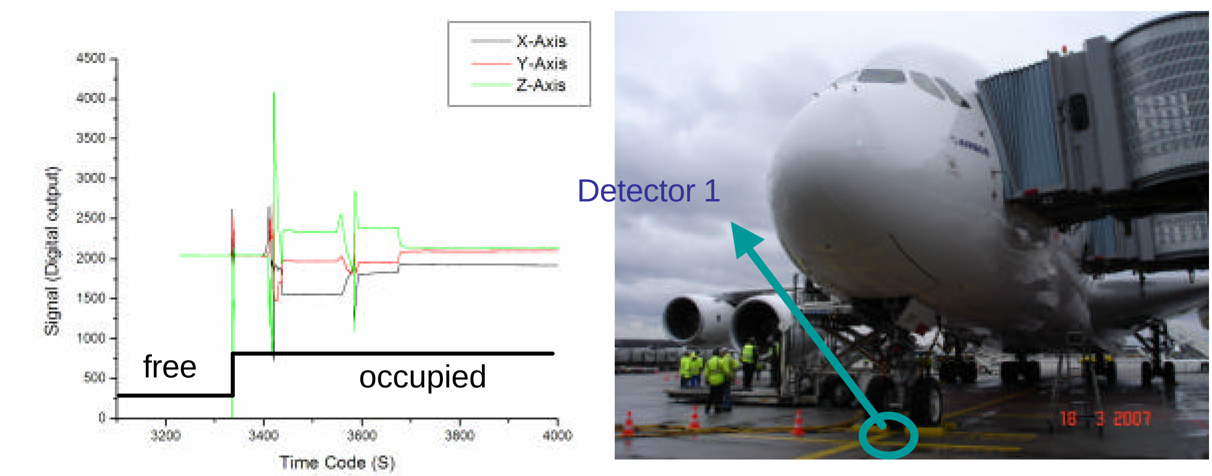

Fig. 4: Detector signals at the parking event of an A380

Figure 5 shows the layout of the detector installation at Thessaloniki airport. In total 8 detectors have been installed near the end of Taxiway Alpha which enters directly into runway 16/34. This intersection is placed at the end of this runway, which is close to the sea and 2 kilometres from the airport controller tower. This airport suffers from fog frequently during winter, so the airport controllers do need a technical solution to monitor ground traffic. The detectors have been installed with a spacing of 30m and thus cover a total distance of 210m of Taxiway Alpha.

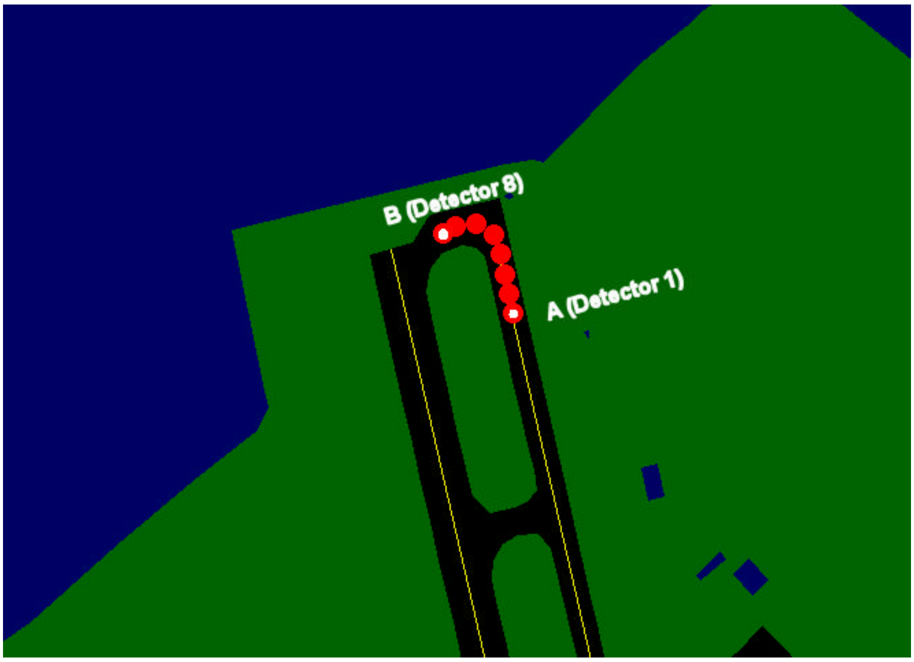

Fig.5: Layout of the Thessaloniki test site containing 8 detectors.

Every target using this route is moving from a known point A (detector 1) to a known point B (detector 8) as shown in figure 5. The logs of the SDF server are recorded and compared with the records of a GPS module (fitted in a special test vehicle to provide a comparator) and the theoretical trajectory of the target (assumed to follow the taxiway centreline, as most aircraft do follow the centreline accurately). The tests aim to examine the accuracy of position, speed and heading information contained in the target reports of the SDF.

These tests were very successful. The detectors detected vehicles and aircraft as they passed through the monitored section of taxiway. The SDF server created a continual track of position, speed and heading that was generally close to the theoretical or GPS track, and there were no false alarms. As shown below, the SDF server generated a radar-like track of the vehicle as it moved through the area.

While most vehicles and aircraft were detected correctly, in 2% of cases there was a missed detection by a single detector (i.e. a target was known to be present but was not detected). As shown in the Frankfurt tests, this rate of missed detection can be reduced to zero by reducing the spacing between sensors from 30m to 15m.

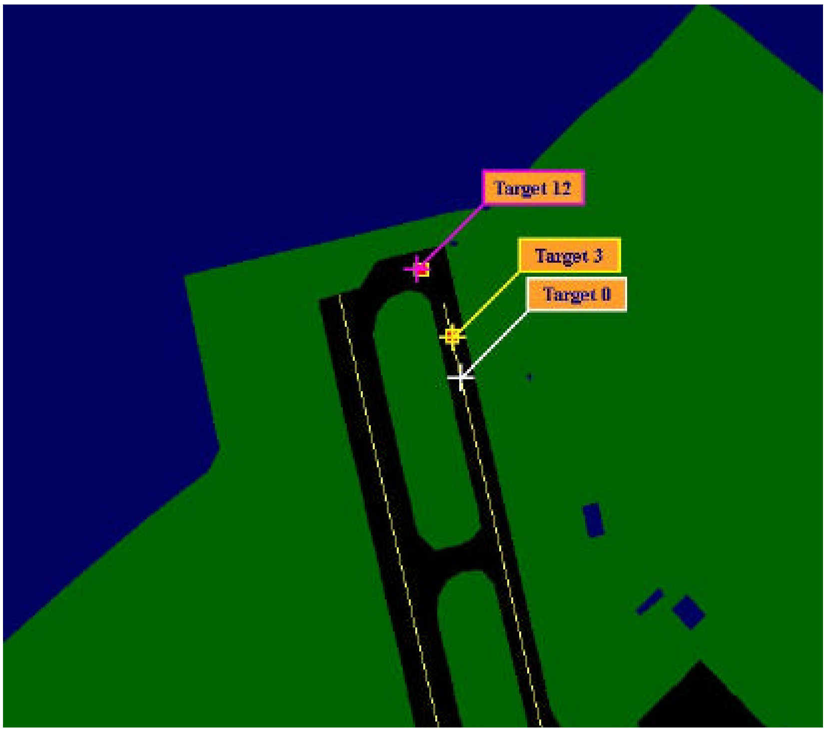

Fig.5: SDF output to system users

Potential Benefits of ISMAEL

To be acceptable to potential users the ISMAEL system must be easy to install and maintain. Therefore the concept developed in the project was to install the detectors within existing AGL fittings, either in taxiway centrelines or in stop bars. The trials demonstrated that the detectors could survive and operate successfully in active AGLs, offering considerable potential benefits in cost of installation and ease of maintenance.

ISMAEL contributes to two High Level Target Concepts defined in the 2nd Strategic Research Agenda issued by the Council for Aeronautics Research in Europe in October 2004 (ACARE 2004), namely cost efficiency and safety of the air transport system.

The benefits of the ISMAEL system perceived by (potential) users, other stakeholders and experts were assessed by survey and interviews. Potential direct safety benefits, direct efficiency benefits and indirect benefits of the ISMAEL solution were identified (table1):

Direct Safety Benefits	Direct Efficiency Benefits	Indirect benefits
Improved situational awareness	Increased airport throughput due to decreased separation requirements	Reduced environmental impact by reduction of aircraft operating times (e.g reduced taxiing times)
Decreased number of accidents	More effective ground operations due to enhanced situational awareness	Expansion of air commerce to smaller communities/ regions
Prevention of runway incursions	Reduced transportation costs due to increased efficiency	Improved regional accessibility
Improved handling of runway incursions	Increased utilization of fixed assets (e.g. runways, manoeuvring areas..)	Increased reliability of air services (increased attractiveness of air transport)
Improved surveillance and guidance in low visibility conditions	Improved surveillance and guidance in low visibility conditions (increase possible operation hours)	Increased competitiveness of European aviation industry
	Reduced costs for equipment and systems implementation compared to radar and multi-lateration	
	More efficient use of stands/ gates (accurate info about position and progress of aircraft and vehicles)	
	Increased planning and routing capacity (for ATCOs and airport operators)	

Table 1: Potential direct and indirect benefits of ISMAEL system

Perceived benefits of ISMAEL for airport surveillance: Improved surveillance, and therefore improved situational awareness, is seen as the core benefit of the ISMAEL solution. .ISMAEL can be used as a primary source of surveillance data where traditional SMR or multi-lateration are not economically feasible, or to augment these traditional sources to address difficult areas or provide a redundant source

For large airports there is an potential cost benefit with the ISMAEL solution where it is implemented to save the cost of an additional SMR antenna in an airport's overall A-SMGCS project to provide coverage of areas where existing radars do not provide good coverage. A further potential safety benefit of ISMAEL is that it provides an additional non-cooperative surveillance system relying on non-radar technology, providing dissimilar redundancy and hence enhancing safety.

For small airports which cannot afford SMR, ISMAEL might be the only non-cooperative surveillance system available for improving situational awareness. The benefits may include improved situational awareness of hidden areas, reduction in R/T communications, shortening of taxi time, improved capacity in reduced visibility and at night, and reduction of the risk of human errors.

Perceived benefits of ISMAEL for prevention of runway incursions: at larger airports ISMAEL would offer further redundancy to SMR and multi-lateration through non-cooperative surveillance for runway incursion detection. A location based system such as ISMAEL can be installed specifically to address high risk areas. The benefit compared to inductive loops or other sensors is a potential reduction in installation costs and an improvement in reliability.

For a small airport like Milano Linate (2003: 94.000 movements (AZ_Publications 2003), which has a complex layout, incurring 69.679 minutes airport delay of which 97,5% is attributed to bad weather (Eurocontrol 2006), etc.) redundancy in its non-cooperative surveillance capability would be of benefit.

Gate management support by ISMAEL is considered useful for all airports which do not utilise a fully automated gate management system, since SMR gives ambiguous results in areas (e.g. near terminal buildings) where reflections occur. However, it remains to be seen if smaller airports have these shaded areas or have gate capacity issues and hence need to know accurately when a stand is occupied. Larger airports often have existing systems for gate management and new technology (e.g. optical recognition systems) make the requirement for this application is less clear.

Parking lot indication is a completely different idea that arose during the project: Every airport attracts a lot of traffic. Parking space is scarce and car parks are important revenue sources for airports. ISMAEL might help increase customer satisfaction and asset utilization by detecting free parking lots so that cars could be directed towards them.

Exploitable Knowledge

The main **exploitable knowledge** developed lies in the Magnetic Detector and the Sensor Data Fusion (SDF) software developed. In both cases significant problems associated with the airport environment (e.g. interference and noise) have been solved. In addition, test analysis software has been developed, that might prove valuable for further research and engineering.

Dissemination

In the course of the last three years the ISMAEL consortium has carried out a large number of different **dissemination activities**, and they continue. At the start of the project the focus was on introducing ISMAEL, its basic idea, the main objectives, and the underlying magnetic detection concept. Later on the emphasis shifted towards communicating test results, technological advances, and demonstrating the achievements to a wider audience. The audience addressed included technical experts, potential users, relevant authorities, and the general public. Media deployed for dissemination activities included the project website; both reviewed and general journals and magazines; participation in conferences; the ISMAEL film; and the TV presence of the project. Contacts with potential users and other relevant stakeholders were established when gathering user requirements, and implementing the ISMAEL solution at test sites in Saarbruecken, Thessaloniki and Frankfurt. Here is one industry response: *"Sensors like the one developed in the ISMAEL project are needed to improve radar integrity in sensitive areas of the airfield."* An indication of Eurocontrol's acknowledgement of ISMAEL is the fact that the project and its website are already mentioned in a post graduate course on ASMGCS for ATCs (Dubuisson 2006). Table 2 presents the summary of ISMAEL dissemination activities:

publications	**press releases (3), brochure**	**reports in journals and magazines (21)**	**articles in reviewed journals (6)**	**advertorials (3)**
internet	**ISMAEL website**	**online publications (26)**	**Airport Safety Custer website**	**promotion and documentation of events**
TV/vídeo		**reports on TV (3)**	**online videoclip**	**ISMAEL video**
conferences		**posters (3)**	**oral presentations (11)**	**demonstrator and booth**
workshops		**clustermeetings (4)**	**public demo**	**networking session**
visits		**interviews with users**	**visits to other projects' events (2)**	**industry meeting**

Table 2: Overview of ISMAEL dissemination activities

Another important achievement was the initiation and establishment of the **European Airport Safety Cluster** together with AIRNET and SAFE-AIRPORT, two further projects funded within the scope of the "eSafety of Road and Air Transport" action line of FP6. As a result, a joint cluster web portal was put online http://www.airport-safety-cluster.com. The main focus of this platform is to increase the visibility of European research and development activities in the field of traffic safety at airports. Synergy potentials, joint activities, upcoming events, and common exploitation potentials are presented to keep interested parties informed and attract potential clustering candidates. ISMAEL also contacted other new and on-going EU projects. Meanwhile, to ensure acceptance and adoption of the ISMAEL solution by relevant user groups, compliance with existing and emerging standards in the field of airport traffic management was a major aim of the project even at this technology demonstrator stage.

For more information of ISMAEL, please visit project homepage at www.ismael-project.net or contact project coordinator Prof. Dr. Uwe Hartmann (+49 681 302 3798, u.hartmann@mx.uni-saarland.de).

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