DYNAMIC AVIONIC GROUND TRAFFIC CONTROL (DAG–TC)

By:
Douglas Tommasi Crudeli
Tommasi & Tommasi America LLC
West Joppa Road, 1106
Baltimore MD 21204
USA
rafdouglas@yahoo.it

PRESENTED FOR THE
2007 FAA WORLDWIDE AIRPORT TECHNOLOGY TRANSFER CONFERENCE
Atlantic City, New Jersey, USA

April 2007

ABSTRACT

This new system integrates several technologies for ground control activities that provide a detailed and dynamic overview of airport surface movements in real time.

In the present paper, we will introduce the conceptual framework and the practical application of the patented system which enables to identify moving vehicles and aircraft on all runways and adjacent locations in terms of both speed and characterization. As a result, the model also displays the type of aircraft detected and the class and details of ground vehicles.

The feedback is provided to the Control Tower or to the cockpit in real time by a set of dedicated software tools which leverage a continuous system of geo-referred data. The result is a clear visualization of a comprehensive, up to date overview of airport and runway operations with meaningful imagery and additional significant descriptions including aircraft make and model.

A vital aspect of the system is the ability to perform continuous controls of possible ground collision paths between all moving objects, in particular aircraft and or vehicles. The technology also has the ability to estimate collision probability and time: it immediately alerts the Control Tower and cockpits, and activates an automatic or supervised traffic light alarm system. Vehicle operators and pilots are therefore directly warned of any possible collision and helped to avoid it.

At the same time, the Control Tower is constantly and consistently updated on airport movement conditions to facilitate decision-making.

The system has been designed modularly to be scalable and to assure around the clock safety surveillance with self diagnostic elements and low maintenance.

In particular, the modularity of this system makes it easily adaptable to any geometrical configuration and airport size. The same central unit can change and/or add new modules offering flexibility for small or large airports.

The built-in auto diagnostic capabilities ensure minimal field maintenance: any failure raises a local, but non critical, alert for the whole system.

INTRODUCTION

The concepts behind the present paper were developed in order to address several safety concerns of the major surface traffic systems of airports around the globe. These concerns include the need to:

- know if something is present or moving on runways and taxiways;
- identify the type of entity (aircraft, truck, person, mammal, etc.);
- measure the speed and direction of that entity;
- identify the size and/or the model of the airplane;
- prevent collisions between aircrafts and other entities;
- prevent intrusions of any entity on runways and taxiways;
- alert the Control Tower and/or the pilot(s) to the presence of other aircraft and entities;
- provide a cost-effective solution.

There are already technologies which can perform at least some of the above-listed tasks, but they are very expensive and/or do not provide full coverage for all moving objects on the airport surface. Since only a few major airports can afford to invest so much money in safety systems, the vast majority of airports don’t have a surface safety system.

Furthermore, several ICAO protocols are already in use or planned, but only apply to a fraction of aircrafts, leaving the rest with no protection whatsoever and leaving the ATC with a significant lack of information in their Decision Support Systems.

The proposed surface traffic tracking system has been developed with scalability and flexibility in mind, in order to be adoptable by airports of any size, and without the need for collaboration by any of the possible objects of concern (aircrafts, trucks, other moving objects, people, mammals, etc.) and even with no visibility (i.e. the system works during the night and during in-clement weather like fog and rain).

0.1. GENERAL SYSTEM COMPOSITION

The system is made up of several functional units:

- Ground Detector (GD) units that measure presence and speed, placed along runways and/or taxiways and/or at a given distance;
- Ground Scanning Systems (GSS), located at critical points on run- and taxiways;
- An interconnecting network;
- Central processing Unit(s) (or CU) and Central Surveillance/control Units (CSU);
- Peripheral Visualization Units (PVU) as appropriate, within ground support facilities or on board aircraft, interconnected via one-to-one radio link or broadcast.

All the units, also GD’s and GSS’s, have a certain degree of processing power and specific data processing procedures installed.

The main processing software installed on the central processing unit(s) gathers and processes all the incoming data, integrates it with any existing information, and provides the visualization to surveillance units, where control actions can be executed by personnel (such as pilots and air traffic controllers).

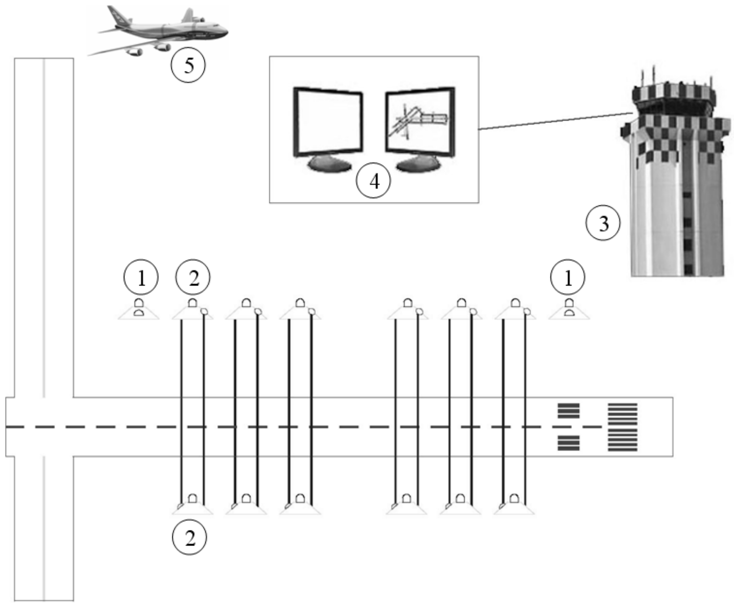


Figure A) Schematic layout. 1) GSS are located at critical sections, such as the runway beginning and end or at turns. 2) GD's give continuous coverage of runways and taxi-ways. 3) The CU is located at the ATC tower. 4) CSU's in use to display data and alarms. 5) PVU's can be used in cockpits to display the same in-formation (or part thereof) as shown on CSU's.

GROUND DETECTOR (GD)

This is one of the two active components, and it is used to detect the presence, measure the speed and identify the direction of an object passing through its optical axis.

It consists of an optical switch or distance meter that, depending on the configuration, measures a combination of the following:

- the interruption or the continuity of the optical segment;
- the distance of the interrupting object;
- the time (relative or absolute) of the interruption.
-

The component can furthermore be configured as:

- a single element (with or without a reflector);
- an active part separated from its receiver; or
- rotating/oscillating meters.

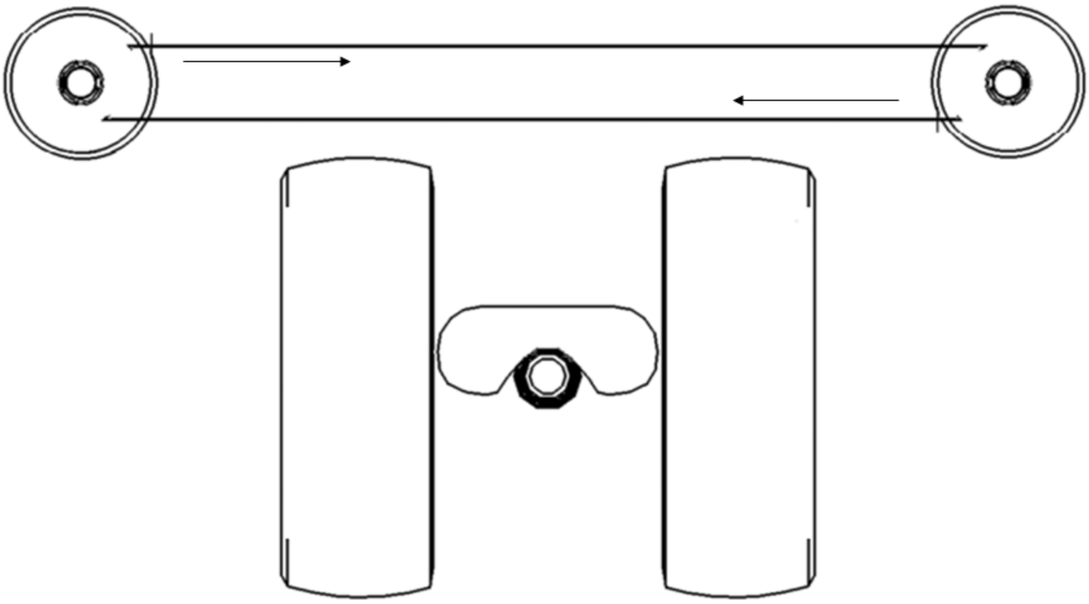
A simple GD can be used to detect the interruption of the optical segment in order to signal a crossing or intrusion, which is especially useful for avoiding impacts with mammals or other wildlife crossing the green areas around the runways. A GD can in fact be placed at various levels from the ground for the purpose of determining different types of entities.

Two or more GD's can be paired or coupled at a known distance in order to measure the speed and the direction of a moving object. GD's can be made fully modular, with one or more emitting optics and receiving optics.

In order to avoid jamming and noise deriving from other sources, the emitted signal is coded with a unique Pseudo Noise Code, which makes it far more robust and allows for a precise synchronization of interconnected units. It's also to be noted that GD's transmit data through the network only when an object is detected. They also send "alive" messages every couple of minutes to let the CU know about their status. In case of missing alive message from one or more GD's, the CU can alert the operators suggesting them to go on the spot and substitute the out of order unit. Since each GD and each GSS are georeferenced and owns a unique ID, at every moment it is possible to display a map of the status of all active units.

In the following paragraphs some typical configurations are presented.

DUAL HEAD GD FOR PRESENCE/SPEED/DIRECTION



Figre B). Scheme of a dual GD configuration. Twin GD units are used to improve reliability and ease of use. As a moving object (in this example, landing gear) enters the lines of sight, the system is activated and measures presence, speed and directions of the entity.

CLUSTERING NETWORK

Similarly to the previous configuration, a multi-head GD can provide the basis for a network, in which each node is formed by a four-head GD and mutually interconnects to other similar units. In this way area coverage is accomplished.

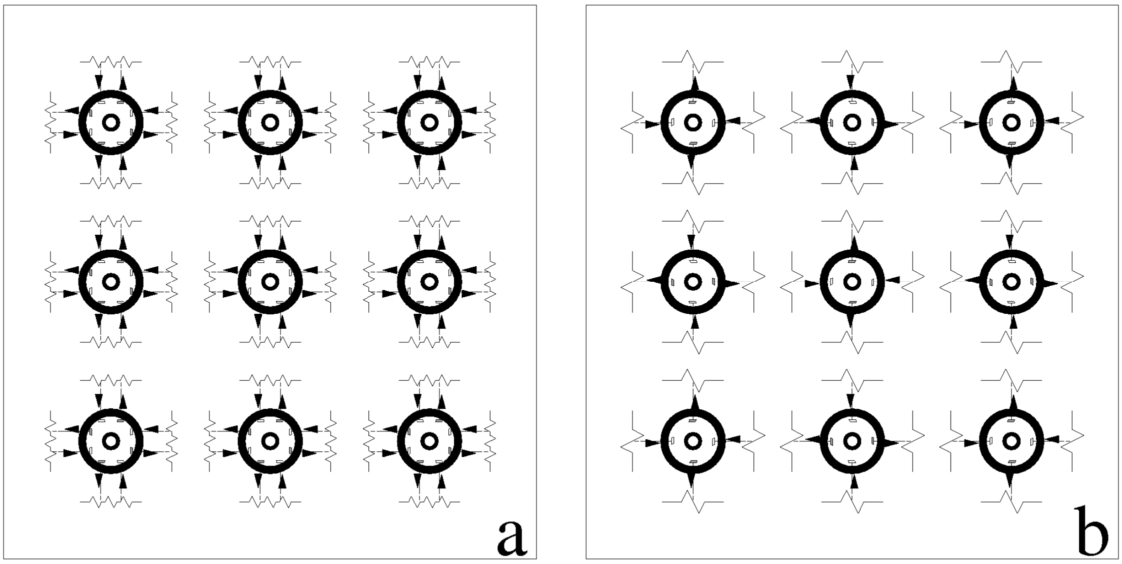


Figure C). Scheme a): GD’s with four double heads are used to build up a network: in this pattern, area coverage is provided as well as speed and direction measurement. Scheme b): GD’s with four simple heads are tiled in order to cover an area with presence detection only, useful, for example, on green areas around the airport to detect potential intrusions.

In case of multiple interconnected GD, the timing reference should be common at least to all interconnected units in order to allow for a precise computation of speed.

GD’s are provided with a network interface, which can either be cabled or wireless, in order to communicate between themselves and the Central Processing Unit, can be hosted in an independent case or in existing light cases, and are thermostatic in order to keep the same temperature even in varying climate conditions.

GROUND SCANNING SYSTEM (GSS)

The Ground Scanning System is used to determine the 2D or 3D shape of an object passing in front of it. This is accomplished with an active optical system able to measure some key points of the shape for the purpose of identifying the category of the entity (airliner, GA aircraft, truck/GSU, car, person, animal) and its model (in case of aircraft or vehicles)

The classification of the object can be achieved either with an absolute measurement (producing absolute dimensions) or with a parametrized measure (producing relative dimensions).

In the first case the category and/or the model is determined by matching the measurement with a library of absolute dimensions, while in the latter case the relative measurements are compared against a parametric database. In both cases, the database is preloaded either in the

GSS or in the CU and is structured in such a way as to minimize the processing requirements in order to deliver near real-time outputs.

GSS's are provided with a network interface, which can either be cabled or wireless, in order to communicate with the Central Processing Unit. Similarly to GD's, GSS's can be hosted in an independent case or in existing light cases and are thermostatic.

Furthermore, to comply with existing regulations, GSS's are normally off and is switched on and off by a controlling GD, which detects passing by objects, their direction and speed. In this way GSS's are only active for the minimum time required to perform the scan.

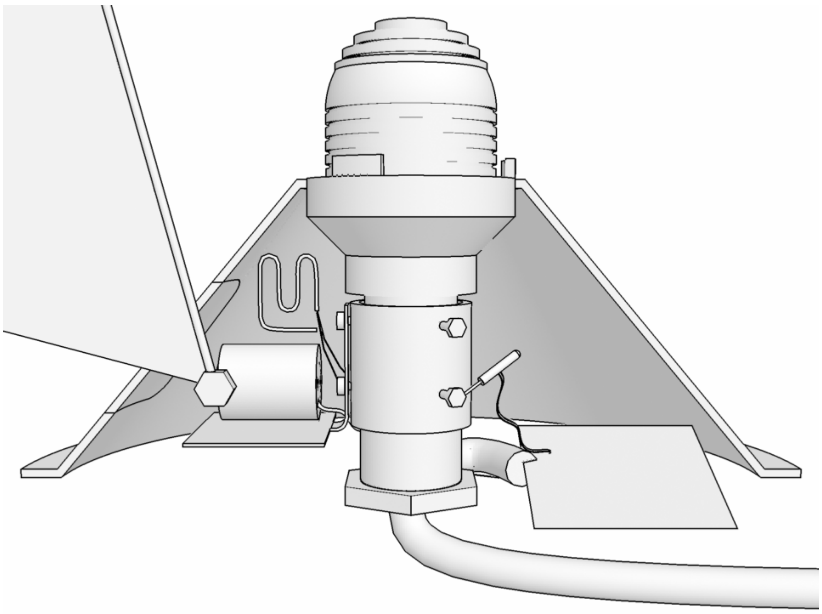


Figure D). A section plane of a GSS hosted by a light fixture. The optical scanner is on the left, and scans through a window; the electronic circuits are on the right, and a thermometer and a resistor are also included to keep the unit thermostatic.

Once the classification has taken place, the system can deliver, for displaying purposes, the 3D model of the aircraft instead of an alphanumeric tag; by dynamically inserting this 3D model on the previously loaded 3D geometry of the airport, the output is a dynamic real-time 3D model of the airport and its traffic, thus creating a full virtual representation. By streaming the dynamic information only in the form of 3D sprites to a remote unit (like a PVU), the network bandwidth is kept to a minimum, and the displayed models are immediate to understand.

CENTRAL UNIT (CU)

The Central Unit represents the main data collecting and processing facility, and is provided with one or more network interfaces, a workstation, and a software suite. This software suite is receives and process the incoming data streams from all networked GD's and GSS's, to identify:

- critical situations;
- possible collision paths;
- intrusions;
- aircraft taking the wrong runway or taxiway;
- excessive or inadequate speeds on runways during takeoff or landing;
- excessive speeds of vehicles or aircraft on taxiways.

Furthermore the CU takes charge of the production and availability of all the data required by the CSU's and by PVU's. It also actively sends critical data (for alerts and alarms) to selected CSU's and PVU's.

The CU will also be able to assume and integrate in its algorithms existing safety measures, such as real time fleet position reports, radar data output, S-mode/ASD feeds, etc.

Also collision detection takes place at the CU, and thus by means of time-space distance fields:

$$D_{Kin} : R^4_{(x,y,z,t)} \rightarrow R^2_{(dist,t)}$$

A first screening is performed in a relative distance n x n matrix (on a 1-on-1 basis), a second screening is based upon relative directions (always 1-on-1), while the actual calculation takes place only for conflicting directions.

The evaluation of the collision probability is obtained numerically (not analytical) and takes into account, for both objects:

- position/distance
- vectorial (3D) speed
- speed/position history
- speed/position variability

CENTRAL SURVEILLANCE/CONTROL UNIT (CSU)

The CSU is the human interaction interface of the system, as it provides information and receives commands from system operators. It is useful in displaying an overview of the airport area, of all the aircrafts moving on its surface, dynamic details about them, as well as information (presence, speed, heading, type) of all moving vehicles Furthermore it can alert in case of possible intrusions and follow them up, in addition to identifying critical situations, possible collision paths and their time/space details, or aircrafts taking the wrong runway or taxiway. It could even be used for pinpointing excessive or inadequate speeds on runways during takeoff or landing. As said before, the stream of data is made only of 3D sprites and some additional information about their position, speed, acceleration, status (safe or in danger) etc.

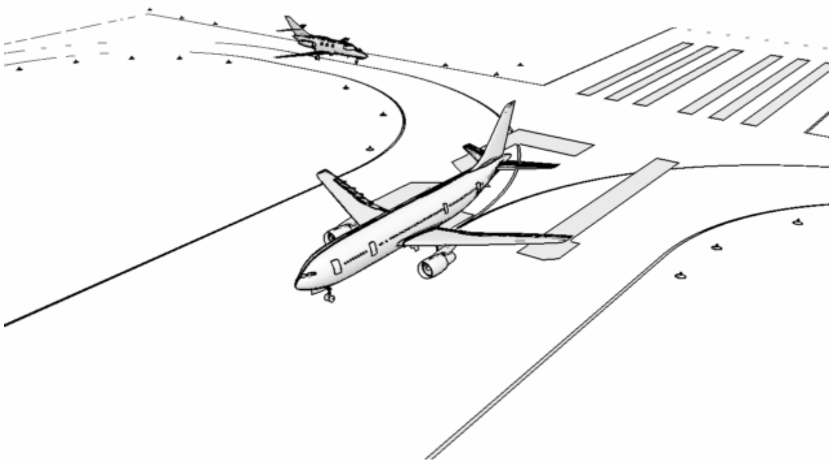


Figure E). An example of a real-time virtual 3D environment which can be displayed on CSU's and PVU's. Any point of view can be dynamically simulated.

All situations above can trigger audible and/or visual alarms, either at the CSU or on remote devices (PVU's); obviously a CSU can be interfaced to existing ATC networking, devices and protocols, in order to exchange information and to maximize the detection capabilities of potential danger situations.

By knowing the geometry of the airport surface, and with the real-time acquisition and processing (performed by the CU) through the CSU one can display the situation of the airport surface in a virtual 3D environment.

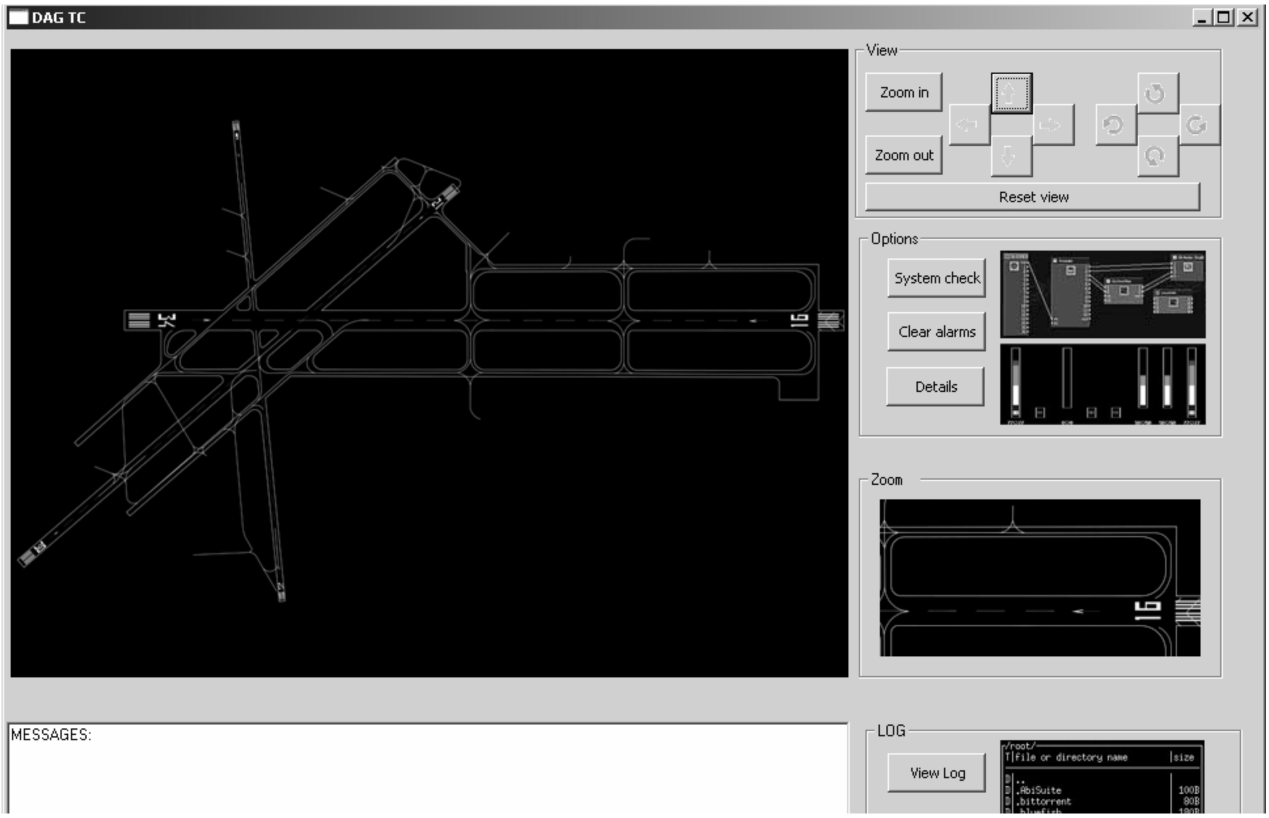


Figure F). A screenshot of the software interface representing the overview modality, in which the whole airport area is displayed. All surface movements are followed through the screen and it's possible to zoom in to a more detailed view. On another screen it's possible to fly through the 3D model constantly updated by the field data.

Also, emergency situations can be chromatically displayed. For example, a given aircraft on a colliding path can be shown in flashing red.

PERIPHERAL VISUALIZATION UNIT (PVU)

Similarly to the CSU, information relevant to a single aircraft/vehicle/GSE can be sent to (or requested by) a PVU, which is made up of a CPU, a display, and an acoustical system: it functions as an interface to convey information to the pilot/driver/field operator. PVU's can be used to visualize the whole airport area in a virtual way, in order to find out dynamic information about specific points, vehicles and aircrafts.

In particular, PVU's can be used by pilots before taking off and landing in order to visualize the actual status of the runway (also on the far end) prior to the beginning of the operation. In this way pilots can make sure that there are no other aircraft or objects on the assigned runway, no aircrafts or vehicles in colliding paths and no incursions. If this is the case, they can safely decide to go on. Otherwise, they can postpone the operation and, for example, contact the ATC or even delay the TO, or regain height instead of landing.

As an additional benefit, PVU’s can be used not only to display real-time information, but also to visualize how the situation will evolve in the next few moments, so the pilot can test, for example, if the runway will still be free from other aircraft and vehicles at the time he will be actually landing or taking off. This is of course a predictive analysis, but a fairly accurate one, since it is enforced by all the GD’s and GSS’s which are following the movements on the ground.

This can be accomplished either in a direct way (i.e. visualizing a specified predicted time frame) or in a fast-forward fashion (i.e. visualizing in ten seconds the predicted evolution of the next two minutes).

All the above operations can of course be performed also at the ATC through the use of a CSU.

The data transfer to PVU’s takes place via radio over an encrypted protocol (to prevent information sniffing by unauthorized third parties) and each PVU receives only the pertinent information (for example only the present status and predicted evolution of the runway the flight is assigned to). This achieves the minimization of the required transmission bandwidth and keeps the delivered information to the minimum required. Nevertheless a broadcast signal can include critical messages to be delivered to all aircrafts and GSU (Ground Support Units) on a public channel.

On-field operators can use PVU’s in order to locate intrusions or as a way to receive information and instructions from the ATC; similarly, GSU drivers can use PVU’s to verify their assigned paths and decide what action to take. This might prove itself to be particularly useful during emergencies, to coordinate all the vehicles.

CONCLUSION AND PROSPECTIVES

This paper presented a patented system used to continuously survey the surface of an airport by means of active elements, able to classify and follow in their movements aircrafts, vehicles and intrusions from the green. It also illustrated a way to manage such information from the ATC and on cockpits as well as some possible ways to use them in order to improve safety in the airport area.