

# Sky-Scanner: a New Paradigm for Air Traffic Management

M. Salerno, D. Rondinella, M.V. Crispino, G. Costantini, M. Carota, D. Casali

**Abstract**— Laser detection and tracking of aircrafts based systems (LIDARs, Ligh Detection And Ranging systems) are emerging as a critical design trend in development of new generation ATM (Air Traffic Management) paradigms, of which they are the main innovations. The realization of laser sensors as rotating laser range-finder arrays and their combination to versatile systems lead to major advantages for the application such as Air Traffic Control within Aerodrome Traffic Zone (ATZ), airport surveillance and ground to air laser communications, and last but not least to save cost usually at the same time with getting an improved ATC (Air Traffic Control) performance. These laser systems that today can be developed without particular difficulties are challenging classical ATM paradigms in many aspects. Nevertheless, it is commonly recognized that the effectiveness of these systems strictly relies on the capability to reliably perform a track data fusion with airport radars and to manage a new generation ATM paradigm. In particular, driving and control a data fusion between laser tracking data and radar tracking data a very high computation power is required.

The main goal of the presented project is therefore to develop a novel laser tracking technology (SKY-Scanner System) capable to detect and track of aircrafts up to at least 6 nautical miles from the ATZ barycenter, namely a facility of enabling techniques, protocols, numerical prediction tools and devices specifically designed for the analysis of the laser systems performances in ATC applications, with the final target of defining a new generation ATM paradigm based on radar and laser tracking data fusion, and ground to air laser communications. The proposed methodology is considered at the frontier of technological research but it represents the only realistic way to put solid basis for the fabrication of effective radar and lidar integrated systems for incorporation in new generation ATM paradigms.

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## I. INTRODUCTION

CONVENTIONAL methods for Air Traffic Management (ATM) that have worked until now cannot continue to cope indefinitely. As shown in [1], a new generation ATM is needed [2,3]. Several methods have recently been proposed in order to improve both security and performance [4,5].

Laser rangefinders have been effectively used in conjunction to robot and autonomous systems [6,7]; the same concept has been applied in our project for a system that will work in conjunction with radars.

The SKY-Scanner project work plan has been designed to meet this objective through the integration of different tasks addressing specific hardware (HW) and software (SW) items. The proposed technology, which is composed of four main sub-systems to be integrated:

- Montecarlo System Simulation;
- Laser Sensor Array (LSA);
- Sensor Management Computer (SMC);
- Command and Control Computer (C2C);

is completely novel, in the sense it has never been conceived to fulfill the proposed target.

Such approach has not been applied in lidar engineering.

Scientific objectives of the proposed research shall include:

- control of the tracking of aircrafts by means of a rotating cylindrical laser range-finder array;
- development of mathematical models of aircraft collision probability and optimal decision on corrective actions (DSS, Decision Support System) based on data fusion between radar data and laser tracking data;
- definition of a new generation ATM paradigm based on data fusion between radar data and laser tracking data and ground to aircraft laser communications.

Technological demonstrator is included in the validation process of the proposed methodology. The last eight months of the first year of the project will take place at the Pescara Airport (Italy) and will be dedicated to a first measurement session of aircraft positions for the definition of the basic reference performances to be exploited in the subsequent field testing session (last eight months of the project), with the employment of a test target developed and provided by ITALI Airlines.

## II. OBJECTIVES

The research, which cuts across trans-disciplinary fields, is such to provide an unequalled mean to theoretically and experimentally characterize the interaction between aircrafts and eye-safe lasers during take-off and landing operations and validate the proposed technology by means of accurate field testing measurement procedures and mathematical models, designed and developed to guarantee a deep and clear understanding of measured data as well as to guarantee a reliable definition of a new generation ATM paradigm based on data fusion between radar data and laser tracking data and ground to aircraft laser communications.

The project will introduce long-term innovation in the automatic tracking of aircraft with lidar systems, leading to major improvements in following different areas:

- lidar systems for ATC applications;
- Decision Support Systems (DSS) tools for new generation ATM paradigms;
- lidar systems for ATZ surveillance and sensible targets surveillance;
- lidar systems for transportation systems laser imaging;
- point to point laser communications;
- laser propelled aircrafts.

The project will promote breakthrough knowledge on laser tracking of aircraft, new DSS models and ATM paradigms based on data fusion between radar data and laser tracking data and ground to aircraft laser communications, such to sustain the reliable development of new perspectives in the ATM world.

The structure of the work plan is such to produce the following project milestones:

- M1 - System Requirements and First Measurement Session;
- M2 - System Design;
- M3 - Demonstrator Development;
- M4 - Demonstrator Integration;
- M5 - Field Testing.

The potential spin-off of the SKY-Scanner technology is relevant because of its major influence on many industrial applications, ranging from ATC systems to laser communication systems and laser propelled aircrafts. In the former case, a relevant impulse to the improvement of the current ATC systems is expected. To put into perspective, the estimated world market for complex lidar technologies is currently € 400 million (dominated by military applications). On the other hand, the market potential for new integrated surveillance systems as replacement for existing airport radar technology has been estimated at around € 300 billion in the world.

At a time where much of the attention of the European Air transport industry is focused on the major institutional and organizational changes occurring as part of the European Commission's Single European Sky legislation, the opportunity for the exploitation of technology continues to develop faster than ever.

An ATM system is composed by the following sub-systems (Fig. 1 e Fig. 2):

- Radar Display Processor System (RDPS);
- Flight Data Processor System (FDPS): Safety Critical Operational Features;
- ATC workstations (RADAR Display, Flight Data Display);
- AFTN Message Handling Systems
- Data recording and playback;
- Maintenance monitoring.

The RDPS is connected to the surveillance systems; its main features are the following:

- Processes radar data from multiple sources;
  - Provides composite radar picture to controllers;
- Automatic Dependent Surveillance Broadcast (ADS-B) is a new satellite based technology that allows aircraft to broadcast information such as identification, position, and altitude.

Like any system, primary radar has its disadvantages. One of these disadvantages is that primary radar also receives signals reflected from rain, ground, and trees. All these reflections make it difficult to distinguish between aircraft targets and the background clutter. Even though many special techniques have been developed to overcome these problems, primary radar is unable to distinguish one aircraft from another aircraft and in most cases surveillance radar cannot determine height to sufficient accuracy. These disadvantages, along with the increasing number of civil aircrafts, makes primary radar by itself insufficient for air traffic control purposes. Secondary Surveillance Radar (SSR) is a radio location system which measures time for an electromagnetic wave to travel to a target aircraft and back to the radar, but instead of using the passive echo reflected from a target, it uses an active transponder which is located in the target aircraft. Besides the transponder, this system is composed of the ground station, the interrogator, and the protocol used by the system to establish communication. Although a SSR system gives a position in terms of range and bearing, it is normally used in conjunction with primary radar. This is because a SSR system requires and assumes that each aircraft is carrying a working transponder. This, however, cannot at present be guaranteed, particularly in the case of general aviation aircraft.

The SSR system is designed so that a ground station can monitor an air space having a maximum radius of 200 nautical miles, and a height of some 15 km above the radar horizon.

In the radial direction the location of an aircraft must be accurate to within a few degrees so that these measurements can be correlated with the findings of the primary radar equipment. Using special codes, the identification information not only makes it possible to distinguish between different aircrafts but also facilitates the transmission of data such as aircraft altitude and identity.

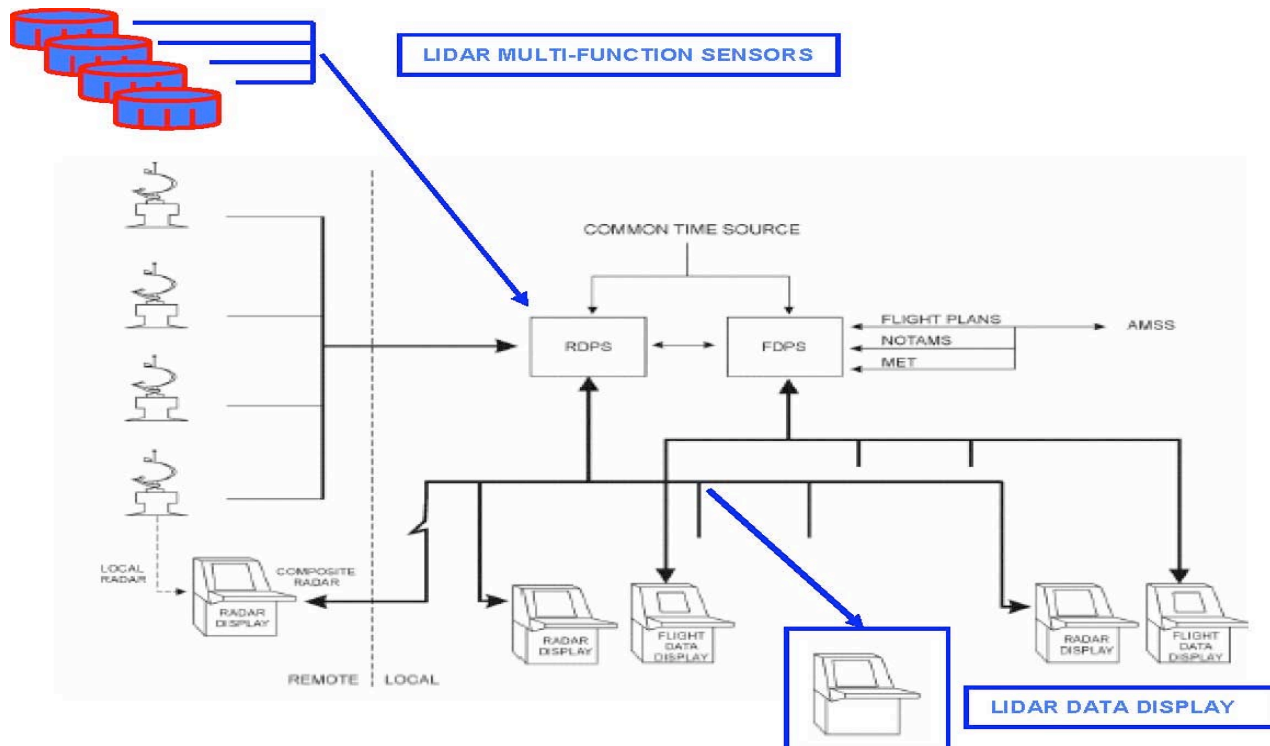


Fig. 1 Typical ATM System and Sky-Scanner Project Innovations

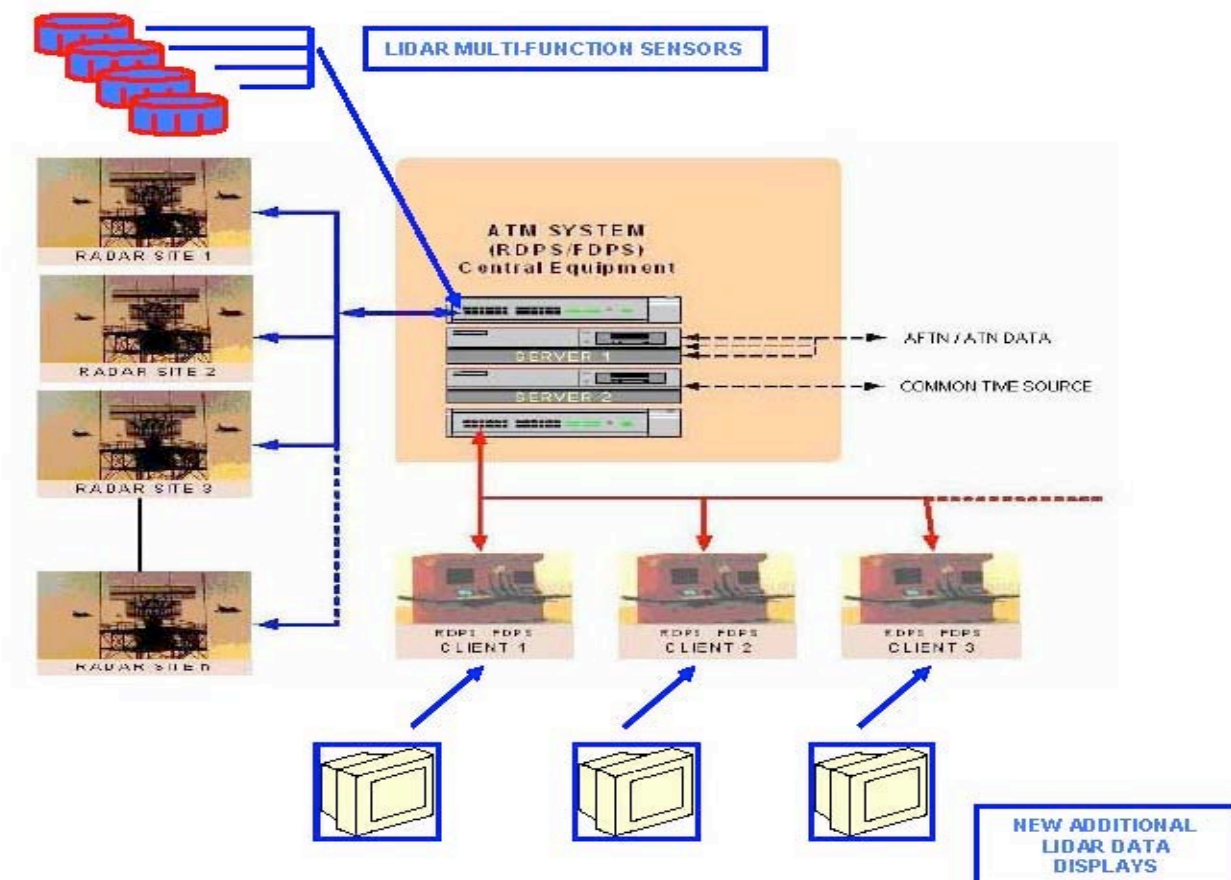


Fig. 2 ATM System Configuration and Sky-Scanner Project Innovations

Automatic Dependent Surveillance Broadcast (ADS-B) is a new satellite based technology that allows aircraft to broadcast information such as identification, position, and altitude. This broadcast information may be received and processed by other aircrafts or ground systems for use in improved situational awareness, and conflict avoidance with much more precision than before. ADS-B contains a Global Positioning Receiver (GPS) that allows an ADS-B equipped aircraft to determine its own position. The use of a GPS receiver greatly simplifies air



Fig. 3 Typical Radar display

surveillance. With this system there is no need for highly directional antennas to find bearing, and exact timing for range information. Each ADS-B equipped aircraft broadcasts its position with other relevant data, including airspeed, and whether the aircraft is turning, climbing or descending. This provides anyone with ADS-B equipment a more accurate picture of air traffic that is possible with radar alone. Furthermore, the ADS-B concept reduces considerably the current channel congestion; this is obvious since currently transponders are interrogated at a rate of almost 1000 times per second, but ADS-B only broadcasts one or two times per second.

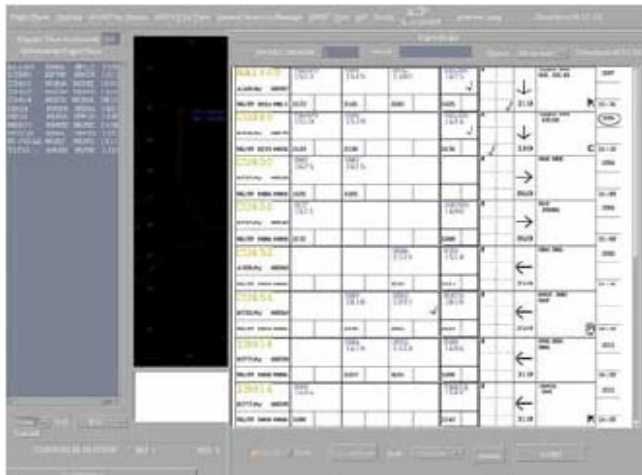


Fig. 4 Typical Flight Data Display

Even though ADS-B is a promising technology for improving traffic surveillance with better accuracy, currently it will not be implemented as a stand-alone system. For aircraft subject to TCAS II requirements, ADS-B will be implemented as an additional feature to enhance TCAS II.

Because ADS-B depends on GPS position signals, which are subject to disruption, ADS-B is not by itself reliable enough to provide critical coordinated collision avoidance or a resolution advisory (RA).

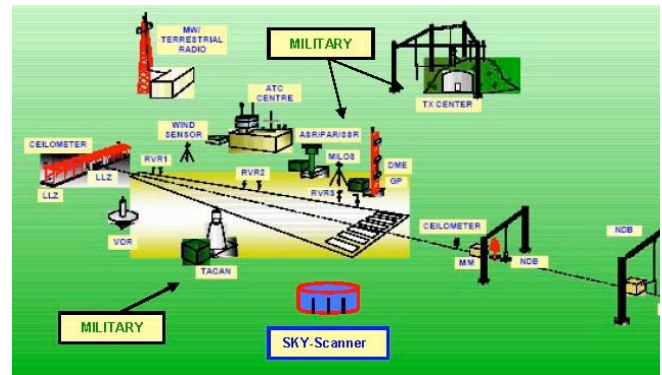


Fig. 5 Typical Civil / Military Airport

To achieve the full benefits of ADS-B, the system must be implemented on every aircraft. If one aircraft has ADS-B and the other does not, both aircraft remain "blind" to each other, thus widespread implementation of ADS-B is required before maximum traffic surveillance benefits are achieved. However, the full implementation of ADS-B remains within the political sphere, first because the use of 1090 MHz for ADS-B transmissions might cause interference with ATC and TCAS system, and secondly because the high cost to implement ADS-B is prohibitive for most of the general aviation aircraft flying today.

The FDPS main features are the following:

- ICAO-compliant flight plan data exchange;
- Automated hand-offs;
- Automated electronic and paper flight progress strips, NOTAM handling, preauthorizations;
- Aircraft/Airspace Modelling System (AAMS):
- Mathematically modeled flight path;
- Predicts estimated time at reporting points;
- Provides conflict detection.

In Fig. 4 is shown the typical Flight Data Display of the current ATM Paradigm.

The integration of LIDAR of the SKY-Scanner system with the current ATC and ATM systems is shown in Fig. 5.

In Fig. 6 is shown the laser scanning pattern referred to a hemisphere as exploration volume. The intersections of the sinusoids (32 laser range finders motions) are the angular quantas of search. In the ordinate axis is reported the elevation range of the laser beams and in the abscissa axis is reported the azimuth range of the laser beams.

In Fig. 7 the preliminary kinematic motion scheme of a single laser range finder of the SKY-Scanner system is shown. The preliminary electronic control of the kinematic motion is shown in Fig. 8.

The SKY-Scanner laser sensor motion system will be composed by the following sub-systems (Fig. 7):

- *bedplate*: electro-mechanical subsystem including clamp systems, mechanical joint rolling, driver azimuth motor and the tracking module, with control systems enclosed;



- *tracking module*: subsystem that moves the platform, the laser itself and the relative drivers and position control systems (encoders).

(Fig. 7), the only causes of vibrations are the gyroscopic effects on the motor axis, but, with appropriate specification of this component the polar

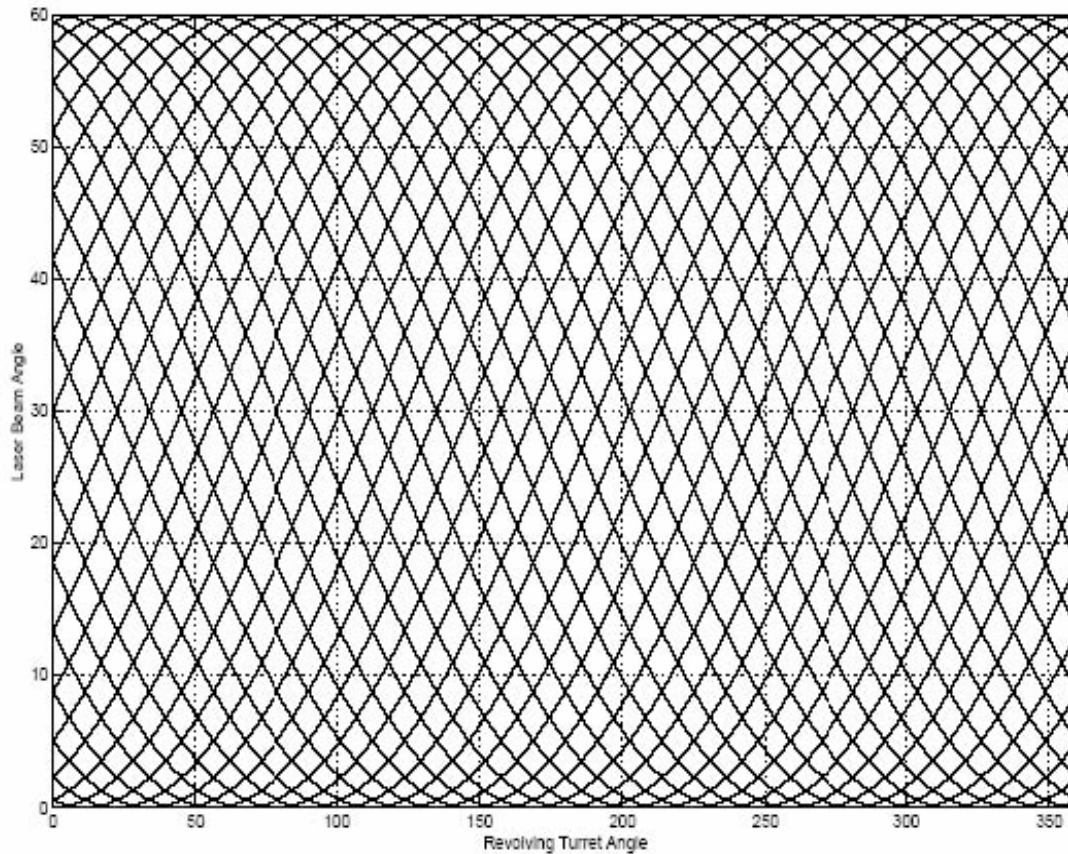


Fig. 6 Laser Scanning Pattern – Motion of the Laser Range-Finders

The advantages for this proposed electromechanical solution (Fig. 7) are:

- *zenith angles range*: the laser beam can track angular quantas from  $0^\circ$  (referring to the horizontal plane) to  $90^\circ$ , with a pointing resolution depending on encoder precision (5 axes);
- *mechanical errors on zenithal pointing*: the mechanical errors are limited by the worm gear pair couple (in opposition) (item 4 and 5). In this case the worm gear pair is coupled on the same side (for every movement) and its back-lash is low. The worm-gear pair has a low back-lash for every constant-rate wear;
- *mechanical errors on laser planarity*: the laser movement are in a plane and, as a consequence, the planarity plane is a fundamental factor for the precision scan system. With an appropriate chip-forming machining, the planarity will be guaranteed and a thrust block will be mounted on the rear of the laser plate;
- *vibrations and frictions*: reduction of the vibration transmissions and friction effects will be achieved with the use of a belt for the coupling between the pulleys. The vibrations are generated by eccentric mass (mass movements). With the proposed scheme

moments of inertia will be reduced;

- *encoders*: closed-loop control of the rotation of the electric motors;
- *gear box subsystem*: internal protection for the etching by saline atmosphere, dust, water and other.

In Fig. 8 the preliminary electronic control of the kinematic motion is shown. It is linked to FDPS (up to 1000 aircrafts displayed).

Aircraft surveillance falls into three categories: primary radar, secondary radar, and satellite based systems:

- Monopulse Secondary Radar;
- Primary Surveillance Radar (PSR) for approach/terminal;
- ADS systems.

Primary radar is based on the fact that objects reflect radio waves. Primary radars emit high power RF energy and detect the presence of an aircraft by detecting the energy reflected back by the target. Secondary radar is a combination of radar and a communication system. In contrast to primary radar, secondary radar does not use the passive echo reflected from a target, but uses an active transponder, which is located in the target aircraft.

In Fig. 1 is shown the SKY-Scanner innovation, based on the introduction of a new family of multi-function sensors with reference to the current ATM Paradigm: laser and radar data fusion at the RDPS and laser data displaying. The detailed

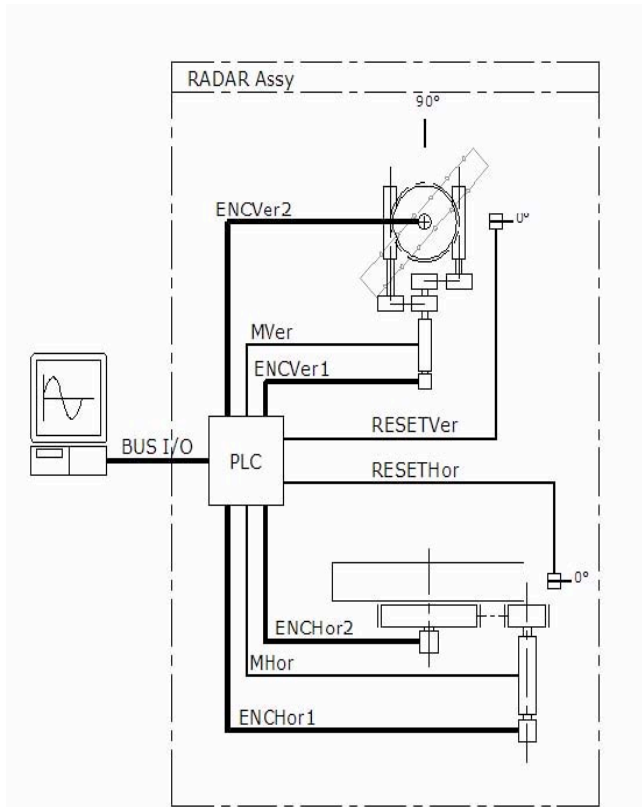


Fig. 8 Laser Sensor Electro-Mechanics – Electronic Control Scheme.

representation of the LIDAR sensor integration is shown in Fig. 2. Fig. 3 shows the typical radar display considered as reference for the LIDAR graphic data display design in the SKY-Scanner project.

Regarding the antenna bedplate the design will include:

- electric motor with encoder;
- gear box (with belt system or gear);
- encoder on the couplet axle;
- reset for the zero position angle;
- rotating joint for the connection between the mobile plate and fixed support of the bedplate antenna.

The principal focus of the design will be the control of the planarity of the azimuthal plate and the low axial oscillations referring the rotation axle. Moreover an accurate dynamic balancing of the tracking module on the mobile plate is fundamental. The system prototype (Demonstrator) of the SKY-Scanner project will be composed by one laser range finder (first level of prototype).

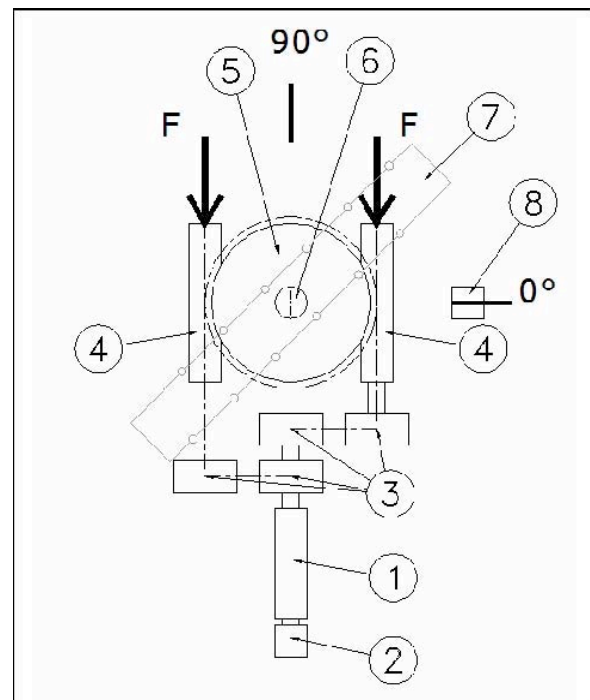
The Safety Critical Operational Features of the FDPS are:

- Short-term Conflict Alert (STCA):
  - Real-time radar-based alert;
- Medium-term Conflict Detection:
  - Mathematically models flight path;

- Strategic tool for controllers to project flight paths and view potential conflicts before they occur;
- Minimum Safe Altitude & Hazardous Airspace Warnings:
  - Provides alerts when aircraft is projected to descend below minimum safe altitudes;
  - Reduced Vertical Separation Minima (RVSM):
  - ATM support for RVSM operations.

A laser detection and ranging system based on a rotating cylindrical laser range-finder array can be a complementary solution to the current aircraft detection and tracking techniques. The system is able to perform a high precision tracking of aircraft with a maximum range of 6 NMs (Nautical Miles) from the ATZ (Aerodrome Traffic Zone) barycentre in order to contrast the classical limitations of radar systems (measurement accuracy in comparison with DGNSS and environmental pollution) and it represents a promising commitment in the field of the ATZ volume surveillance applications.

In addition, the acquisition of technological know-how in the



#### LEGEND

- 1: Electrical Motor;
- 2: Encoder for the motor position control;
- 3: Belt Pulley;
- 4: Warm Screw;
- 5: Warm Gear Pair;
- 6: Laser Encoder;
- 7: Laser Subsystem;
- 8: Horizontal Reset;
- 9: Thrust Bearing.

Fig. 7 Laser Sensor Electro-Mechanics - Kinematic Motion Scheme.

field of laser range-finder array sensors opens a new field of research and development in Europe that could lead to interesting results for ATC safety and security needs.

As an evolution of the current ATM paradigm, the SKY-Scanner project is intended to develop a demonstrator of an innovative laser range-finder array technology (SKY-Scanner system) that is able to set forth the conditions for a widespread commercialization of the system within the broad range of safety and security fields where efficient and cost-effective ATZ traffic management and surveillance is required. The SKY-Scanner Project's target consists in the development of a demonstrator of an innovative LIght Detection And Ranging (LIDAR) technology (SKY-Scanner System), that can allow detection tracking of aircrafts up to at least 6 nautical miles of distance from the ATZ (Aerodrome Traffic Zone) barycentre and that can be the base concept for the development of new ATM (Air Traffic Management) paradigms based on laser positioning and ground to air laser communications (landing

and take-off supported by laser guide).

The last eight months of the first year of the project will take place at the Pescara Airport and will be dedicated to a first measurement session of the positions of a ground target and to the definition of the basic reference performances to be exploited in the subsequent field testing session, planned for the last eight months of the third year of the project at above mentioned airport. The first measurement session targets will be composed by a flat panel with the same paint of the FAIRCHILD Metroliner SA 227 aircraft (provided by ITALI Airlines), that will be moved in different positions in the airport site, by a FAIRCHILD Metroliner SA 227 aircraft parked in the airport and by the line aircrafts parked in the airport without passengers and crew on board.

The reason of the utilization of a flat panel is due to the need of avoiding the introduction of range errors in the measure calibration related to the flexures typical of a normal aircraft panels (a solid fuselage). Then, the acquired measure data will

Table I. Scientific Goals and Related Measurable and Verifiable Form

SCIENTIFIC GOALS	MEASURABLE FORM	VERIFIABLE FORM
Control of the tracking of aircrafts by means of a rotating cylindrical laser range finders array	Measurement of the position of aircrafts: first measurement session with a planar panel as calibration target and on round aircrafts, field testing with a custom calibration target and landing and take-off aircrafts. Recording, in a statistical approach, of the tracking results given by the software alpha releases dedicated to the laser measure output data handling, carried out in laboratory (input data provided by the first measurement session), as well as during the field testing of the demonstrator.	Detection and ranging of aircrafts during the first measurement session and during the field testing.
Development of mathematical models of aircraft collision probability and optimal decision on corrective actions (DSS, Decision Support System) based on data fusion between radar data and laser tracking data fusion, and ground to air laser communications.	results given by the alpha release tool dedicated to the computation of aircraft collision probability and optimal decision on corrective actions, carried out in laboratory, as well as during the field Recording, in a statistical approach, of the testing of the demonstrator.	Theoretical improvement, not lower than 10 %, in the computation of aircraft collision probability and optimal decision current ACP and DSS models
Development of a new generation ATM paradigm based on data fusion between radar data and laser tracking data fusion, and ground to air laser communications.	Comparison of the new generation ATM requirements with the requirements of the current ATM paradigm with an accurate definition of the mutual exclusive requirements.	Algebraic representation of the different requirement domains.

form the input test set for the validation of system simulations and the validation of system software alpha releases before the field testing.

The fixed target developed by ITALI will provide a good approximation of the optical response of a FAIRCHILD Metroliner SA 227 aircraft during takeoff and landing operations and will be a calibration tool during SKY-Scanner system operation. In particular it will simulate the surface flexures of the FAIRCHILD Metroliner SA 227 airframe and the thermal behaviour of its external surfaces near the engines, during takeoff and landing maneuvers (equivalence between the thermal range of the field testing target and the thermal range of the FAIRCHILD Metroliner SA 227 surfaces near the engines).

The project's main scientific goals and the pertinent measurement and testing approaches are shown in the Table 1.

The SKY-Scanner Aircraft Collision Probability Model (ACPM) and the DSS (Decision Support System) must include the necessary input and output representations and control mechanisms. Thus the ACPM and the DSS shall encompass:

- *modelling paradigm*, that is, specific methods for solving decision problems;
- *model and data definition features*, for defining model schemas and for entering data;
- *model and data management features*, including a

specialized mechanism for maintaining, storing, retrieving, and executing models and for defining and manipulating data;

- *analytical methods and visual representations*, for exploring relationships between outcome variables and various controllable variables (including decision variables and user preferences) and/or uncontrollable variables that influence outcomes;
- *user interfaces*, either general-purpose and/or the capability to create a specialized user interface;
- *model and data interchange features*, for communicating with external programs such as databases or external user interfaces.

The project's main technical objectives and the pertinent measurement and testing approaches are shown in the following Table 2.

### III. CONCLUSION

In this paper, the project for an innovative LIDAR technology for air traffic management is presented. The research covers many areas in the field of LIDARS, Air Traffic Managements, Decision Support Systems, data fusion between radar data and laser tracking data and ground to aircraft laser communications.

Part of the work has already been accomplished: the flat

Table II. Technical Objectives and Related Measurable and Verifiable Form.

TECHNICAL OBJECTIVES	MEASURABLE FORM	VERIFIABLE FORM
Development of a demonstrator based on a rotating cylindrical laser range-finder array, and capable to detect and track aircrafts up to at least 6 nautical miles from the ATZ barycentre	Measurement of the position of aircrafts: field testing with a custom calibration target and landing and take-off aircrafts. Recording, in a statistical approach, of the tracking results given by the software alpha releases dedicated to the laser measure output data handling, carried out in laboratory during the field testing of the demonstrator	Detection Fading Probability (DFP) and Tracking Fading Probability (TFP) lower than 10% during the field testing of the demonstrator.
Development of alpha release software for the computation of the aircraft collision probability and optimal decision on corrective actions (DSS, Decision Support System) based on data fusion between radar data and laser tracking data fusion, and ground to air laser communications.	Recording, in a statistical approach, of the results given by the alpha release tool dedicated to the computation of aircraft collision probability and optimal decision on corrective actions during the field testing of the demonstrator.	Improvement of the computation results, not lower than 10 %, in the computation of aircraft collision probability and optimal decision on corrective actions in comparison to the current ACP and DSS models.
New generation ATM paradigm requirements specification based on data fusion between radar data and laser tracking data fusion, and ground to air laser communications.	Comparison of the new generation ATM requirements with the requirements of the current ATM paradigm with an accurate definition of the mutual exclusive requirements.	New generation ATM paradigm with a change in requirements not lower than 30% of the current ATM paradigm requirements.



panel for the demonstrator is ready, and the first measurement session is started.

#### ACKNOWLEDGMENT

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#### REFERENCES

- [1] S. Zerkowitz, "Is the need for a new ATM operational concept a strategic necessity?", *Aerospace and Electronic Systems Magazine, IEEE*, Volume 18, Issue 1, Jan. 2003 Pages: 10 – 12.
- [2] J. Kosecka, C. Tomlin, G. Pappas, S. Sastry, "Generation of conflict resolution manoeuvres for air traffic management", *Intelligent Robots and Systems*, 1997. IROS '97., Proceedings of the 1997 IEEE/RSJ International Conference on, Volume 3, 7-11 Sept. 1997 Pages: 1598 - 1603 vol.3.
- [3] J.W. Jackson, S.M. Green, "Control applications and challenges in air traffic management", *American Control Conference, 1998. Proceedings of the*, 1998 Volume 3, 24-26 June 1998 Pages: 1772 - 1788 vol.3.
- [4] T.J. Callantine, "Air traffic management system domain and control strategy analysis", *IEEE International Conference on Systems, Man and Cybernetics*, 10-13 Oct. 2004 Vol. 7, pages: 6268- 6273.
- [5] I.R. de Oliveira, F.S. Carvalho, J. Batista Camargo, L.M. Sato, "Multi-Agent Tools for Air Traffic Management", *11th IEEE International Conference on Computational Science and Engineering Workshops*, 2008. CSEWORKSHOPS '08. 16-18 July 2008 Pages: 355 – 360.
- [6] Lei Wang, J. Shu, T. Emura, M. Kumagai, "A 3D scanning laser rangefinder and its application to an autonomous guided vehicle" *Vehicular Technology Conference Proceedings*, 2000. VTC 2000-Spring Tokyo. 2000 IEEE 51st, Volume 1, 15-18 May 2000 Pages: 331 - 335 vol.1.
- [7] H. Lamela, E. Garcia, "A low power laser rangefinder for autonomous robot applications", *Industrial Electronics, Control, and Instrumentation, 1996., Proceedings of the 1996 IEEE IECON 22nd International Conference on*, Volume 1, 5-10 Aug. 1996 Pages: 161 - 167 vol.1
- [8] M. Salerno, D. Rondinella, M. V. Crispino, G. Costantini, M. Carota, D. Casali, "Sky-Scanner: an Innovative LIDAR Technology for Air Traffic Management", *Proceedings of the 1st WSEAS International Conference on SENSORS and SIGNALS*, Bucharest, Romania, November 7-9, 2008, Pages 46-55.