PROJECT REPORT

Final Report

UFO Deliverable: ***D6-4***

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Task and contributors

Task : **WP6100 Coordination and management of the study**

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THALES

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Abstract

This document is the Final Report for the UFO project and so concatenates the most salient technical results of the project.

Declaration by the scientific representative of the project coordinator:

Submission performed via the Participant Portal.

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Publishable Summary

The UFO project aims at ensuring aviation safety at current high standards or even better, regardless of air transport growth, through Wake-Vortex Advisory Systems improvement, in connection with SESAR P12.2.2 project. UFO research works will address a wide range of innovative technologies through studies of new Ultra-Fast Lidar/Radar Wind & EDR (Eddy Dissipation Rate for turbulence) monitoring sensors, usable for Wake-Vortex Hazards Mitigation, but also for severe Cross-Wind, Air Turbulence and Wind-Shear.

Constrained by high update rate and accuracy requirements needed for wind measurements, 2D electronic scanning antenna technology based on low cost tile have been explored for X-band radar through a development of a tile mock up as well as a new high power laser source of 1.5 micron Lidar 3D scanner with higher power.

In addition, new design tools have been developed i.e. simulators, able to couple Atmosphere models with Electromagnetic, Radar and Lidar models. In parallel, advanced Doppler signal processing algorithm was also developed and tested for 3D wind field and EDR monitoring, including the algorithm for the resources management of the different sensors. Comparison with already existing sensors as C band meteorological radar and S band ATC radar, but also ADS-B Downlink was studied.

Calibration of the ground sensors (Lidar, X band radar, C band radar with ADS-B data-link) and the simulators was achieved through a set of experimental trials in Munich and Toulouse. In Toulouse, an aircraft equipped with airborne probes will enable in situ comparison.

Coordination had been ensured with SESAR, through Eurocontrol, as associated partner, airports as End user in the UFO steering committee.

The team is composed of the main experts in Europe of the domain: 2 large companies (TSA & TR6), 4 universities (UCL, TUBS, TUD & UPMC), 1 SME (LEOSPHERE), 3 governmental research labs (DLR, ONERA & NLR) and 2 MET Offices (DWD & KNMI).

For this project we have defined 10 clear objectives which were partially addressed during the first 18 month period:

- ***S&T1**: to design an X-band Radar antenna tile with electronic scanning* ⇨ DONE.
- ***S&T2**: to develop and deploy on the field a new High Power 3D Lidar* ⇨ DONE.
- ***S&T3**: to develop/calibrate Radar/Lidar simulators for Wind/EDR* ⇨ DONE but calibration not fully done for Radar.
- ***S&T4**: to develop/test in real Doppler processing for Wind/EDR* ⇨ DONE.
- ***S&T5**: to use Lidar/Radar complementarity in wet/dry weather* ⇨ DONE but wet weather did not occur enough to fully assess.
- ***S&T6**: to develop/test new ADS-B modes for Wind/EDR downlink* ⇨ DONE.
- ***S&T7**: to upgrade/test ATC primary radar weather channel* ⇨ DONE.
- ***S&T8**: to develop/test data fusion from all sources* ⇨ DONE.
- ***S&T9**: to perform Ultra Fast Wind Monitoring proof-of-concept at 2 sites* ⇨ DONE.
- ***S&T10**: to perform a safety risk assessment and a safety case* ⇨ DONE.

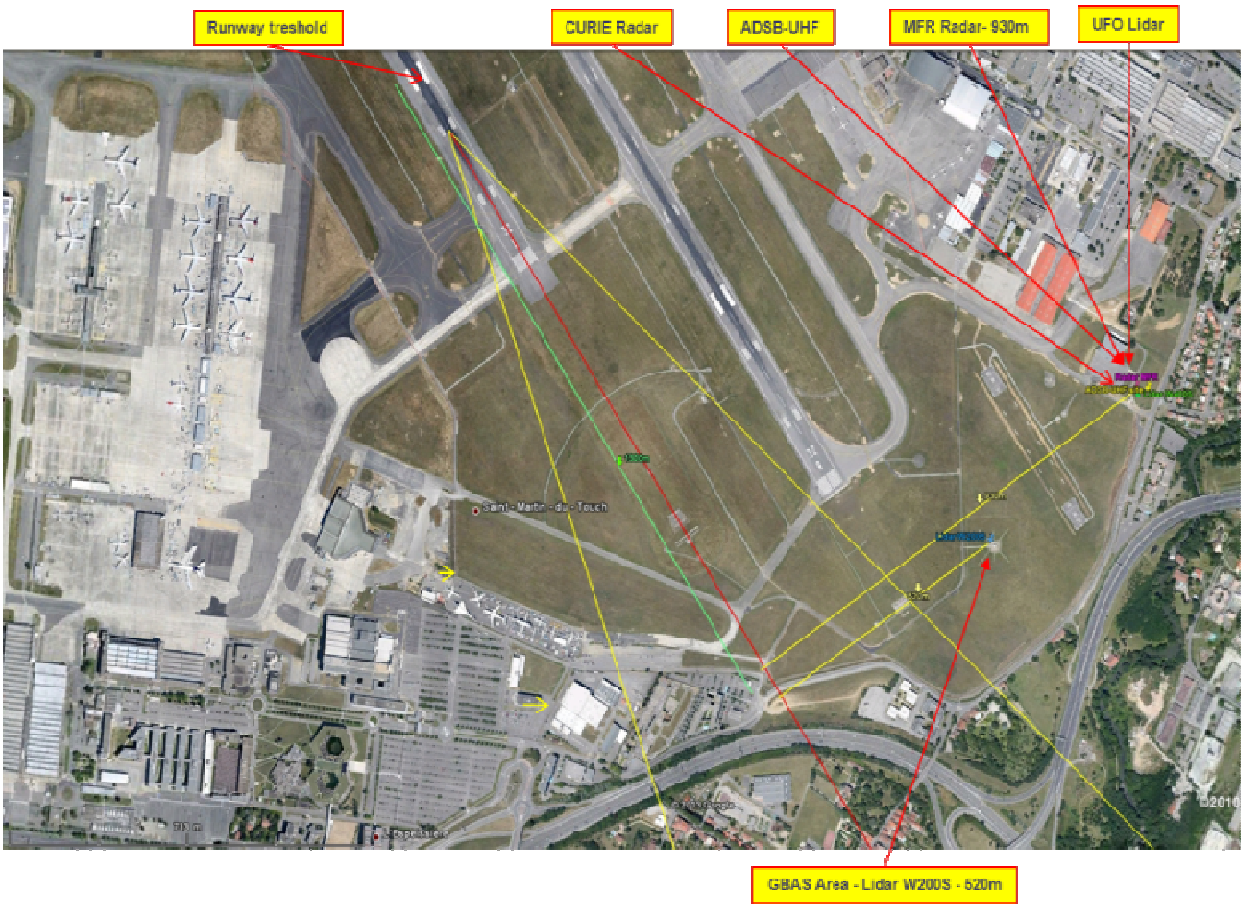


Figure: Map of the Toulouse deployment and zoom on the main installations at the airport X-Band MFR Radar, Curie Radar and Lidar Windcube.

Main achievement at the end of UFO project is that all the scientific and technological objectives were completed or nearly.

With UFO weather dependent separation (WDS) of aircraft is firmly introduced and preliminary conclusion on how it can be used are proposed.

WDS requires current (and historic) weather measurements and a forecasting algorithm to predict the atmospheric conditions for a certain point in time in the future. Based on the forecasted weather the minimum separation distance is computed. Since it is a prediction of the weather,

there is an amount of uncertainty in the prediction. For safety reasons, the uncertainty is compensated through the introduction of a safety buffer in the separation.

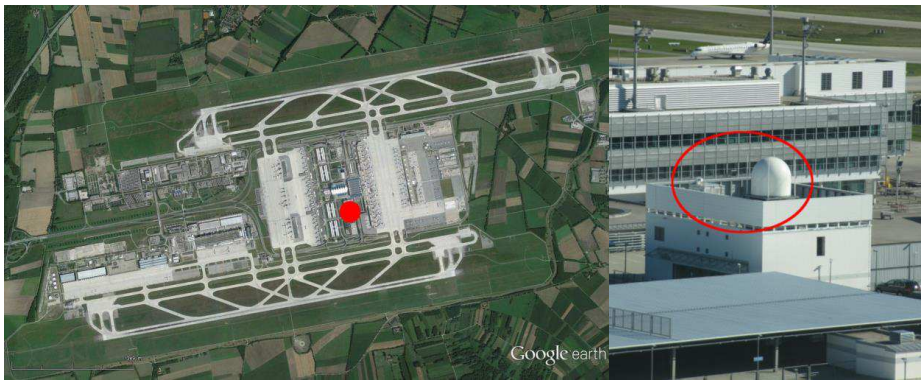
The UFO project aims to reduce this safety buffer by improving the weather measurements and the forecasting through new ground-based ultra-fast remote sensing sensors, namely X-band RADAR and LIDAR.

For the UFO system, two benefits are foreseen:

1. Reduction in the safety buffer which will reduce the delays;
2. Improved performance of the wake vortex monitoring system which reduces the probability of encountering a wake vortex.

In order to assess if it would be profitable to implement the UFO system, it would be necessary to quantify the impact in terms of expected increase in runway throughput and in terms of increased performance of the Wake Vortex Monitoring system. At this stage of the project these values are not known.

If these values are known, it is described how the benefits can be incorporated in a Cost Benefit Analysis by expressing the reduction in delay in monetary terms and by expressing the reduced accident risk as a reduction in costs arising from the accident.



Localisation of the Radar/Lidar windshear system at Munich Airport

Complete UFO team at the final meeting in Brussels

1. Introduction

The UFO project aims at ensuring aviation safety at current high standards or even better, regardless of air transport growth, through Wake-Vortex Advisory Systems improvement, in connection with SESAR P12.2.2 project. UFO research works will address a wide range of innovative technologies through studies of new Ultra-Fast Lidar/Radar Wind & EDR (Eddy Dissipation Rate for turbulence) monitoring sensors, usable for Wake-Vortex Hazards Mitigation, but also for severe Cross-Wind, Air Turbulence and Wind-Shear.

Constrained by high update rate and accuracy requirements needed for wind measurements, 2D electronic scanning antenna technology based on low cost tile will be explored for X-band radar through a development of a tile mock up as well as a new high power laser source of 1.5 micron Lidar 3D scanner with higher power.

In addition, new design tools will be developed through simulators, able to couple Atmosphere models with Electromagnetic, Radar and Lidar models. In parallel, advanced Doppler signal processing algorithm will be developed and tested for 3D wind field and EDR monitoring, including the algorithm for the resources management of the different sensors. Comparison with already existing sensors as C band meteorological radar and S band ATC radar, but also ADS-B Downlink will be studied.

Calibration of the ground sensors (Lidar, X band radar, C band radar with ADS-B data-link) and the simulators will be achieved through a set of experimental trials in Munich and Toulouse. In Toulouse, an aircraft equipped with airborne probes will enable in situ comparison.

Coordination with SESAR, through Eurocontrol, as associated partner, airports as End user in the UFO steering committee, will be favoured.

The team is composed of the main experts in Europe of the domain: 2 large companies (TSA & TR6), 4 universities (UCL, TUBS, TUD & UPMC), 1 SME (LEOSPHERE), 3 governmental research labs (DLR, ONERA & NLR) and 2 MET Offices (DWD & KNMI).

1.1. Purpose of the document

This document purpose is to provide a synthetic view of the project activities and achievements as we have reached the term of the project.

1.2. Structure of the document

This document provides a Publishable Summary of the work towards the objectives of the project, including achievements.

In §2 it propose a description of the progress including the differences between work expected to be carried out and work actually carried out.

Appendices are in the last section with lists of figures, tables, glossary and references.

2. Project technical achievements

To get a clear idea of our progress and achievements our activities are reported below per the Scientific and Technological objectives of the UFO project.

2.1. S&T1 low cost, and high power X-band Radar antenna tile

- ***S&T1****: to design architecture of elementary technological bricks for new generation low cost, light, highly reliable and high power X-band Radar antenna tile with electronic scanning capability for future airport operation.*

This objective is fully achieved as we have completed the test phase and validate the design.

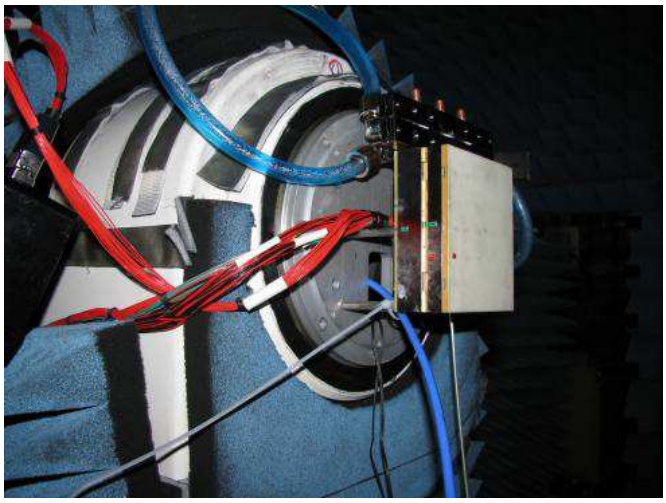


Figure 1 – Picture of the UFO X-band Tile in test

2.2. S&T2 low cost 3D Scanner wind lidar

- ***S&T2****: to design, develop, implement and test a new generation compact, low-cost 1.5 micron 3D Scanner wind lidar with high power laser source based on fiber technology.*

The new UFO Lidar was developed and tested during the measurement campaign in Toulouse held in April and May 2014. Based on the acquired data a new standard of this new prototype was designed and validated.

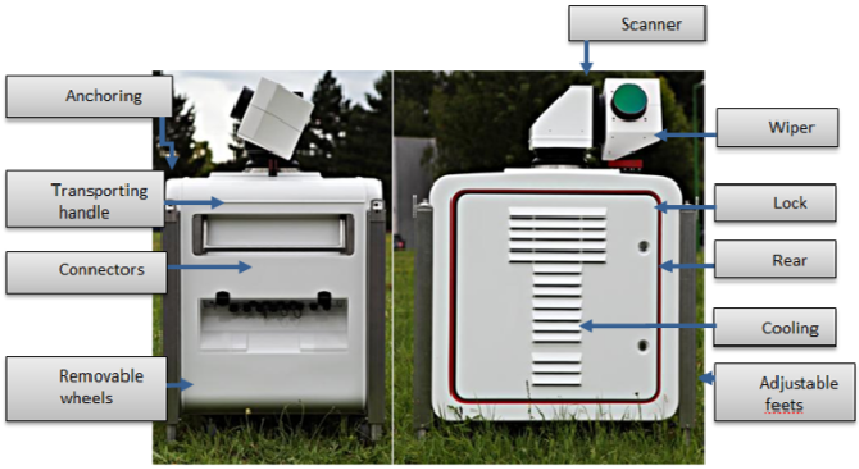


Figure 2 – Picture of the UFO Lidar with a High Power laser source (casing and mechanical were reused from an existing equipment)

2.3. S&T3 Radar and Lidar simulators

- ***S&T3****: to define, develop and calibrate Radar and Lidar simulators dedicated for Wind and EDR Retrieval Capability assessment by an accurate modelling based on a fine coupling of atmospheric model and Electromagnetic interaction.*

Objective was achieved by first the definition a standard set of Wind/EDR algorithms for both X-band E-scan Radar and Lidar. Then an original Radar simulator in X-band was developed for detection of airplane vortices using 2.5D fluid mechanics model and modified to Large Eddy Simulation (LES) for production of 3D atmospheric data evolving in time. Due to a lack of rain calibration was not fully done for Radar.
On the Lidar side on the basis of an existing Lidar Simulator was upgraded it for wind/EDR monitoring, simulation of the detection of the radial wind component, LES simulation in the presence of rain. The first model was developed by UCL is an electromagnetic simulator of the Radar Cross-Section based on Large Eddy Simulation (LES) modelling of the turbulent troposphere and is described for the two cases of interest: the clear air turbulence with stable stratification and turbulence in the presence of rain. The second model developed by TUDelft evaluates the Doppler Spectrum of the radar for the retrieval of wind fields. The user manual of the Zephyros software and the software in proper were delivered.

2.4. S&T4 processing for Wind and EDR

- ***S&T4****: to define, develop and test on real data new advanced and innovative high Doppler resolution processing for Wind and EDR retrieval.*

Algorithms were defined, implemented and tested in both X-band Radar and Lidar during the Toulouse test campaign.

2.5. S&T5 coordinated functioning of Lidar/Radar

- ***S&T5****: to study collaborative/coordinated functioning of Lidar/Radar Sensors using their complementary performances and capabilities in wet/dry weather conditions.*

With D3100 report a complete study of these complementarities was delivered. In particular an approach of the Lidar/Radar management of the available time for the various targeted measurements and functions is proposed. But rain did not occur enough to fully assess the benefit of the Radar.

2.6. S&T6 ADS-B Broadcasting modes for Wind/EDR

- ***S&T6****: to define, simulate and test new ADS-B Broadcasting modes for Wind/EDR data downlink at high update rate with error compensation.*

The system has been defined and tested in but not in flight, tests remains to be conducted.

2.7. S&T7 test on real PSR radar data new upgrade processing

- ***S&T7****: to define, develop and test on real PSR radar data new upgrade processing of ATC radar weather channel.*

During the summer 2013 an additional measurement campaign has been done in Rouen for precipitation measurements with the Thales STAR2000 S-Band radar. Data have been included in UFO project's database for further analysis and algorithms adaptation for real PSR Radar Weather Channel Processing. Further test were conducted during the Munich Airport test campaign with C-Band radar and reported in D4200-3&4.

2.8. S&T8 advanced Wind/EDR data fusion

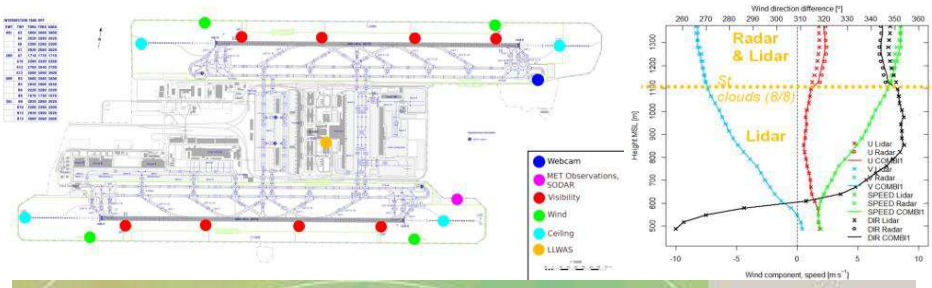
- ***S&T8**: to develop and test during trials campaigns advanced Wind/EDR data fusion from all sources in a coherent and reliable way and assimilation in weather prediction model.*

Following the Toulouse and Munich field test data analysis and conclusion were summed up in D3220 Wind/EDR data fusion report.

2.9. S&T9 proof-of-concept at two different sites

- ***S&T9**: to perform Ultra Fast Wind Monitoring proof-of-concept at two different sites (Toulouse and Munich airports).*

Toulouse field test were conducted in April and May 2014 during RP1 but most important event of this second reporting period was the Munich Airport (MUC) campaign with test of new technologies of wind measurements based on lidar, X-band radar, sodar and aircrafts (Mode-S EHS). The international airport of Munich depicts a crucial role since it is one of the biggest hubs of Europe. The focus of the measurement campaign (14 October 2014 – 3 March 2015) was to present solutions to combine all available data for precise observation of wind, wind shear, and further meteorological phenomena within all-weather situations.



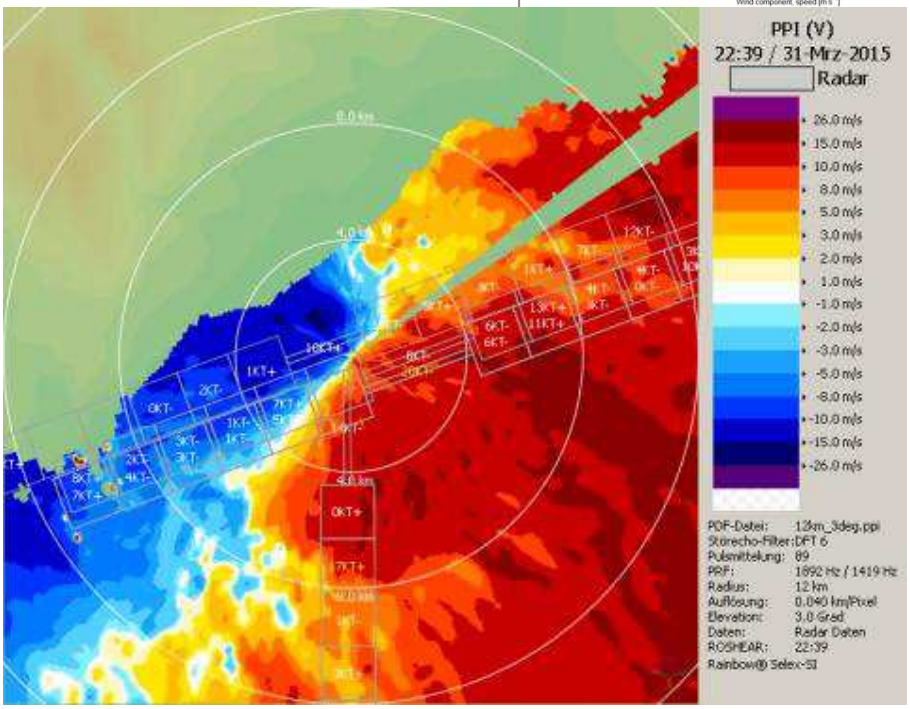


Figure 3 – Field Test in Munich: sensors deployments, sensors cross comparisons and wind shear control screen.

2.10. S&T10 Safety Case

- ***S&T10****: to perform a safety risk assessment and a safety case. Evaluation of Wake Vortex (WV) risk will involve:*
  - *the likelihood of the hazard (likelihood to encounter a vortex) and*
  - *the severity (effect of the vortex on the follower aircraft).*

These activities start with an Operational Service and Environment Definition document and continue with FHA and PSSA to complete the safety case with a Safety Benefits Analysis of X-band Radar & 3D-scanner Lidar but more broadly of fast wind measurements and their usage for ATM purposes.

2.11. Dissemination activities

We had numerous dissemination activities during the project with culmating points the organisation of the Wakenet Europe yearly events the last one was:

WAKENET WORSHOP & UFO DISSEMINATION WORKSHOP

Held in the NLR facility of Amsterdam on the 21st and 23rd of April, 2015.

With a Presentation of UFO progress and results.

Presentation of UFO Results to WAKENET members

1 Day UFO Dissemination Workshop took place on APRIL the 23rd 2015 at the same place, the day after WAKENET.

Slides available on WAKENET website: http://www.wakenet.eu/index.php?id=190

80 Attendees

Opening by EASA + 3 Invited Keynote Speakers from SESAR 11.2, WMO and DLR

3. Appendices

3.1. List of figures

3.2. Glossary

Term	*Definition*
ADS-B	*Automatic Dependent Surveillance-Broadcast*
ATC	*Air Traffic Control*
DBS	*Distance Based Separation*
EDR	*Eddy Dissipation Rate*
PPI	*Plan Position Indicator*
RHI	*Range Height Indicator*
SBS	*Stimulated Brillouin Scattering*
UFO	*UltraFast wind sensOrs for wake-vortex hazards mitigation*

3.3. References

[1] Consortium Agreement for UFO Project - TR6/SRA/RTD-319/12.

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