Project n°: 30721

NESLIE

NEw Standby Lidar Instrument (NESLIE)

Specific Targeted Research Projects (STP)

Priority 4: Aeronautics and Space

Publishable final activity report

Period covered: from T0 to T0+42

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Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
OO	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

SIGNATURE

Written by	Responsibility- Company	Date	Signature
H. Barny	NESLIE Co-ordinator	15/03/2010	
Verified by			
Approved			

CHANGE RECORDS

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1	Web site	
1	European Commission	M. Hans Joseph von den Driesch / M. Francesco Lorubbio

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1. CONTENT OF THE DOCUMENT

The NESLIE project has received funding from the European Community's Sixth Framework Programme (FP6) under grant agreement n° 30721.

The work has been carried out by the project partners:

- Thales Avionics
- Airbus France
- Dassault Aviation
- EADS IW
- IMEP
- XenICs
- CERTH
- TEEM Photonics
- NLR

The present document is the publishable final activity report of the NESLIE project.

This document contains:

- A description of the project execution
    - Project objectives
    - Contractors involved
    - Work performed and end results
    - Conclusions on project objectives achievements and results
- A presentation of the dissemination and use of the NESLIE project

2. PROJECT EXECUTION

2.1. PROJECT OBJECTIVES

The knowledge of the aircraft airspeed is necessary at every moment of the flight, including take-off and landing phases.

Current airliners airspeed measurement architecture is based on several and redundant sensor systems (total pressure sensors, static pressure sensors and temperature sensors, air pressure ducts, ADM transducers, ADR reference unit computers). Such independent airspeed "chains" are thus provided for both the Capt, and First Officer. For safety purposes, an additional "standby" channel is mandatory, the crew getting thus the capability to switch and replace its own failing system by this standby one. However, for existing aircraft air data standby architecture, primary and standby channels are composed of similar equipments with similar failure modes. In order to improve this redundancy, the study and design of new airspeed systems, implementing new technologies, is now currently expected by research labs and manufacturers.

The aim of the NESLIE project is to contribute to the development of a multi-axis laser function, able to measure True Air Speed (TAS), Angle Of Attack (AOA), and Side Slip Angle (SSA), for air data stand-by channel. The use of LIDAR based standby architecture with drastically different failure modes, compared with existing systems, will increase aircraft's safety by reducing the probability of common mode failures.

In addition, laser based air data sensors are not protruding, and then not subjected to external aggressions (hail, bird strikes, etc), then require less maintenance operations.

The objective of the NESLIE project is to design, develop and fly test a LIDAR based demonstrator able to measure the aircraft True Airspeed vector (TAS, AOA, and SSA).

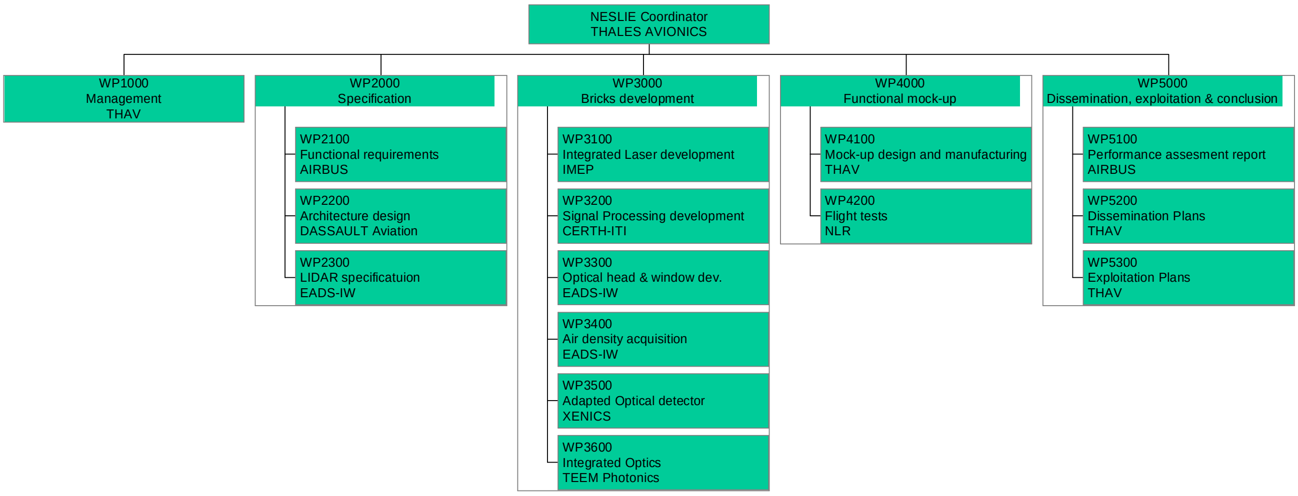
A secondary objective of NESLIE is to investigate the measurement of air density by optical means, opening the way for a fully optical Air Data System, providing all parameters necessary for the aircraft.

2.2. CONTRACTORS INVOLVED

Partner	Main contribution to NESLIE	Company type	Country
Thales Avionics	- Project coordination - Mock-up integration	Large industry	France
Airbus France	- Functional requirements - Operational impact &conclusions	Large industry	France
Dassault Aviation	ADS architecture design & performances	Large industry	France
EADS IW	- LIDAR specification - Density acquisition	Research Centre	Germany
IMEP	Integrated optics	University	France
XenICs	Optical detector	Mall & Medium Industry	Belgium
CERTH	- Signal processing - Dissemination, web site	University	Greece
TEEM Photonics	Integrated optics	Mall & Medium Industry	France
NLR	Flight testing of the mock-up	Research Centre	Netherlands

2.3. WORK BREAKDOWN STRUCTURE

There are 5 work packages in NESLIE as shown below:



The objective of the different Work Packages is described hereunder:

- WP1000 – Management

The objective of this work package is to ensure that the project objectives are met, that the work within the project is performed efficiently, and to report appropriately toward the European Commission

- WP2000 – Specifications

The purpose of this work package is to describe the architecture of the standby air data system based on a LIDAR instrument, specify the LIDAR requirements and derive theses requirements to the component level

- WP3000 – Bricks development

In the frame of this work package, the consortium develops the necessary technological bricks for the mock-up, namely:

  - Integrated laser,
  - Signal processing,
  - Optical head and window,
  - Air density measurement,
  - Adapted optical detector,
  - Integrated Optics.

The bricks will then be assembled in WP4000 to build the NESLIE mock-up.

- WP4000 – Functional mock-up

In the frame of this Work package, the consortium will manufacture a functional mock-up of the NESLIE LIDAR.
This functional mock-up will be first integrated and tested on ground. Then the mock-up will be installed and flight-tested in NLR's CESSNA Citation II research aircraft.
The NESLIE LiDAR performances will be evaluated for different operating conditions.

- WP5000 – Dissemination, exploitation & conclusion

  In this Work Package, the project will end up with a conclusion where initial specification will be compared with performance assessment. All partners will carry out the dissemination activities and the exploitation plans.

The overall NESLIE development diagram is presented hereunder

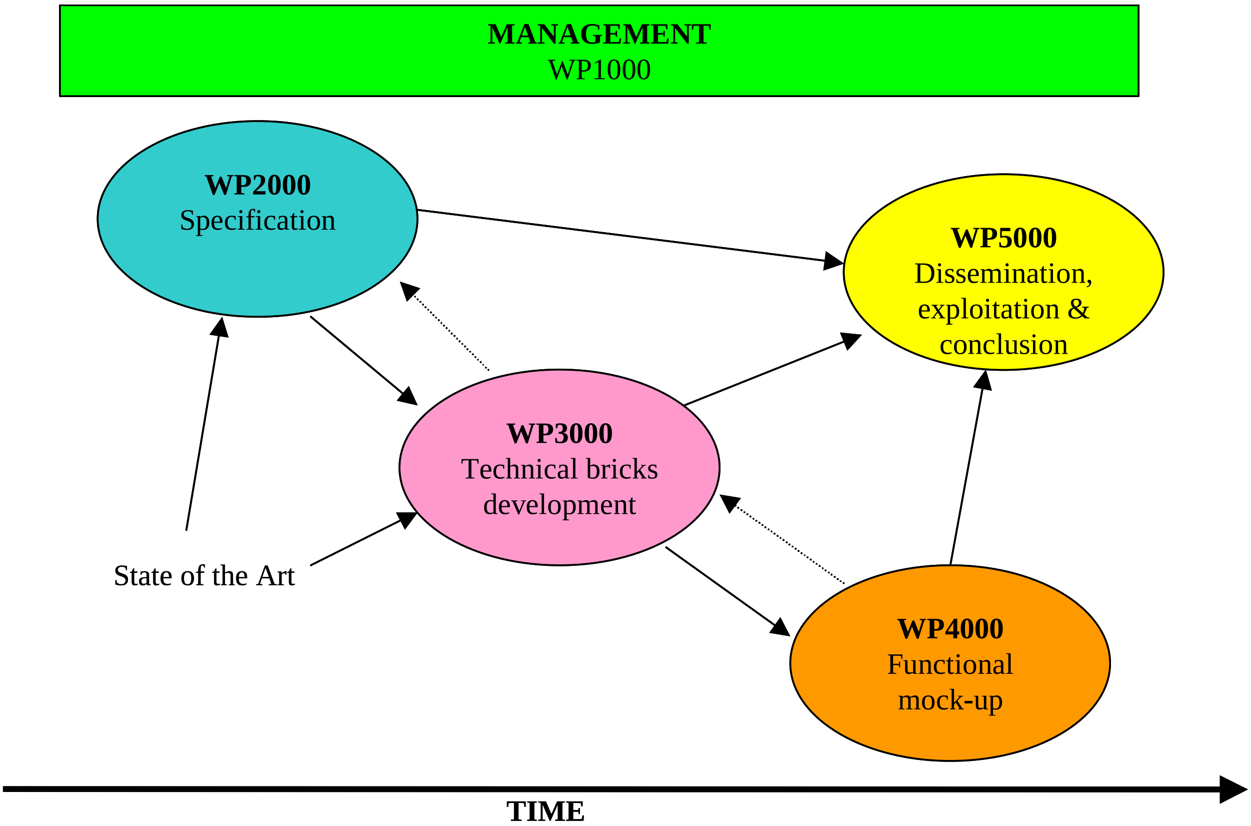


Figure 1: NESLIE development diagram

2.4. CONCLUSIONS ON PROJECT OBJECTIVES ACHIEVEMENTS AND RESULTS

2.4.1. Achievement & results of WP2000 (specification)

In WP2000, the functional and physical requirements were defined for both the mock-up to be flight tested during the NESLIE project, and for a future equipment to be implemented as part of the stand-by Air Data System.

Objective accuracies regarding the TAS, AOA and SSA have been defined according to different flight phases: cruise conditions, take-off and landing, including specific conditions such as cross wind take off and landing. Bandwidth requirements have been defined as well. In addition, the installation of such optical equipment has been analysed, taking into account the system integrity requirements.

Also in WP2000, the study of the functional architecture of the global Air data System, including an optical sensor (providing TAS, AOA and SSA) as well as conventional air data pressure and temperature sensors, was performed. Such an architecture has to provide the air data parameters that are necessary for the aircraft systems, namely the True Air Speed, the Angle Of Attack, the Side Slip Angle, the pressure altitude, the Mach number and the Computed Air Speed. This analysis was based on the overall accuracy performances of the different architectures (and compliance with standards and existing systems performances), as well as the advantages of using an optical sensor (such as the non protruding characteristics of such sensor).

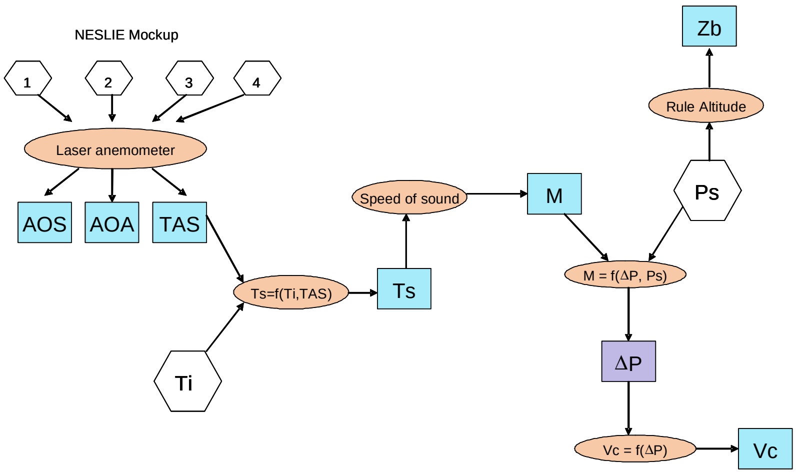


Figure 2: Air Data System architecture

Finally, an error detection analysis was performed in order to define algorithms able to detect the possible failure of one component of the Air Data System.

This Work Package also allowed the specification of the different sub-assemblies of the NESLIE mock-up, based on the overall requirements of the NESLIE flight tests experiment.

2.4.2. Achievement & results of WP3000 (Bricks development)

Laser and integrated optics (WP3100 and WP3600)

WP 3100 and WP3600 allowed the development of integrated laser and optical components such as splitters and mixers, using the glass chip technology developed by IMEP and TEEM Photonics. Several items were deeply investigated and optimised, such as laser waveguides (included Bragg grating), fibre coupling, laser passivation, and laser packaging.

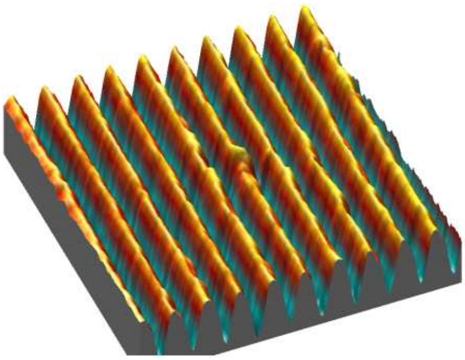


Figure 3: Bragg grating

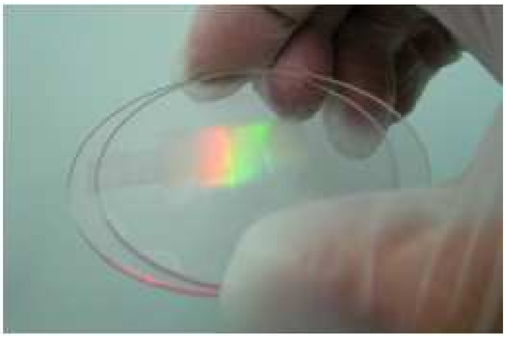


Figure 4: laser passivation

4 fully integrated laser sub-assemblies were manufactured and tested. The performance objectives were achieved:

- Laser wavelength stability
- Laser output power
- Laser linewidth
- Shot noise and Relative Intensity Noise (RIN)

The lasers and sub-assemblies were integrated in the NESLIE mock-up within the frame of WP4000.

Signal processing development (WP3200)
The signal processing development was performed within WP 3200. The signal processing development included:

- High-level Real Time Processing (RTP) including spectrum analysis of the back-scattered signal, Doppler frequency estimation and calculation of the whole True Air Speed velocity vector
- Low-level signal processing, consisting in raw signal recording (in order to allow off-line testing of alternative algorithms)

The real time signal processing development included fast signal processing (FPGA firmware development) and slow signal processing (C++ based on Linux OS). It was implemented on of the shelf components and boards in order to avoid electronic hardware development, which was out of the scope of the NESLIE project.

The signal processing development also included the interface with a Man Machine Interface laptop in order to check that the mock-up was running correctly during the flight tests.

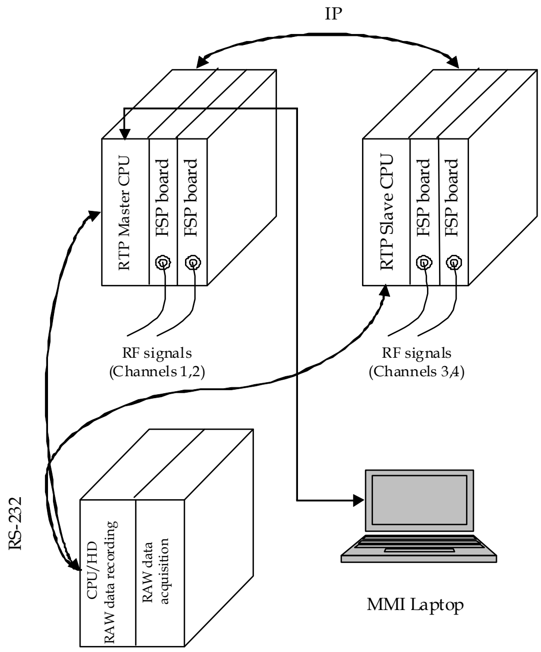


Figure 5: Signal processing architecture

Optical heads and windows (WP3300)

This Work Package included the following tasks:

- The design, manufacturing and testing of the optical heads. Those sub-assemblies allow the focalisation of the laser beam at the specified distance; they also allow to shut down the laser beam when necessary for security reasons
- The specification, purchase and test of optical components such as the power amplifier and the beam separation

Additionally antifogging and anti-moistening coatings were investigated regarding optical transparency, mechanical hardness against scratches and water roll-off angle.

The different sub-assemblies were successfully tested against their specifications. Those elements have been later integrated in the whole mock-up in the frame of Work Package 4000.

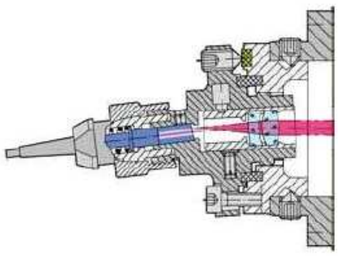


Figure 6: Optical head design

Figure 7: NESLIE mock-up optical head

Adapted optical detector (WP3500)

The objective of this Work Package was to develop a balanced optical detector suitable for the functioning of the NESLIE mock-up. This optical detector includes an optocoupler, a detector chip composed of 2 diodes, and a Trans-Impedance Amplifier.

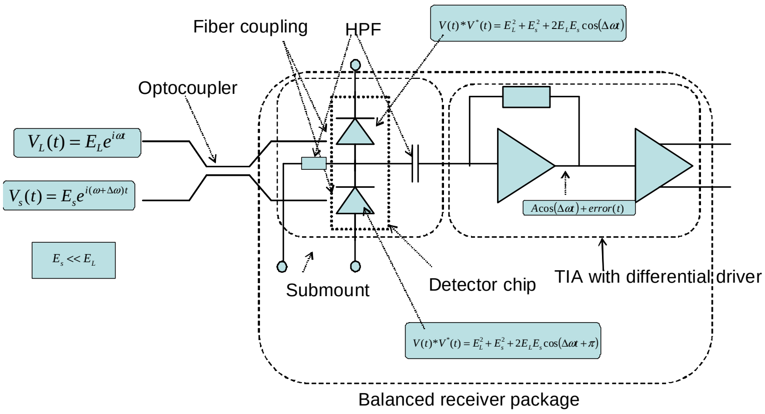


Figure 8: Balanced receiver package

During the manufacturing of the detector, several difficulties were encountered, both regarding the Front End process and the packaging and assembly process.

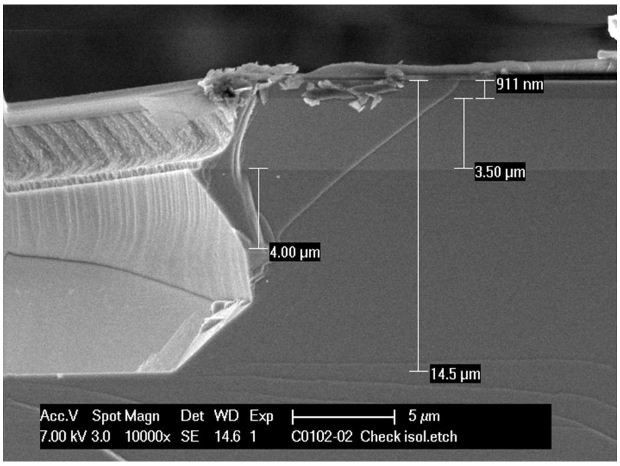


Figure 9: Diodes processing

Finally, XenICs was not able to find solutions for those difficulties and did not provide detectors in the NESLIE project time frame; commercially available detectors had to be purchased and integrated in the NESLIE mock-up.

Air density acquisition (WP3400)
The scope of this Work Package was to evaluate the possibility to measure the air density on board an aircraft by purely optical means. If possible, such technology, combined with the LIDAR based measurement of the air speed vector, would allow the use of a purely optical Air data System.

Given the very advanced characteristics of such technology, this study was purely theoretical and did not include any experimental aspect.

Several measurement principles were investigated:

- Differential absorption
- Fluorescence
- Cabannes line backscatter
- Raman line backscatter

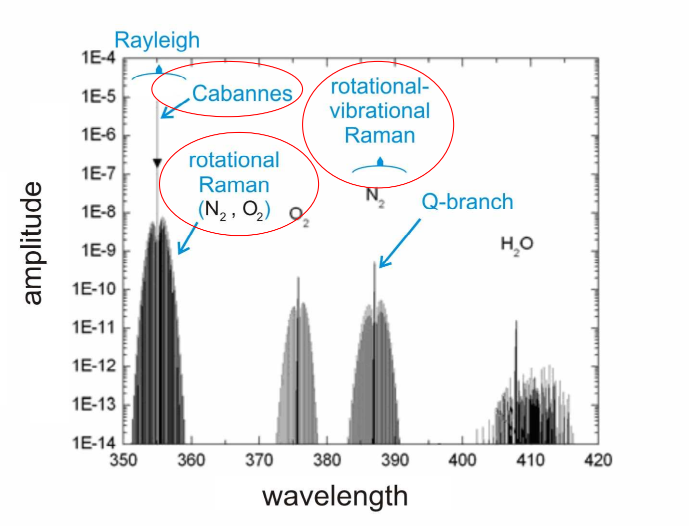


Figure 10: Cabannes and Raman backscatter lines

Finally, it was found that the use of the Raman backscattering principle is the most promising one regarding the application to air density measurement.

The main functional characteristics of such an air density measurement device were derived; expected performances comply with the objective performances with a reasonable laser power. This technology is then quite promising and will be experimentally investigated within the frame of the DANIELA FP7 project.

2.4.3. Achievement & results of WP4000 (Functional mock-up)

Mock-up assembly and testing (WP4100)
The different sub-assemblies developed within Work Package 3000 were assembled in the NESLIE Air data System mock-up suitable for the flight tests.

The NESLIE mock-up includes 4 identical channels, each channel delivering the True Air Speed along its optical axis. Then, by combining those 4 channels, the whole True Air Speed vector can be reconstructed. The 4 channels are focused on a single point outside the aircraft cabin, through a dedicated aircraft window fixed on the aircraft emergency exit.

The whole Mock up, except the optical heads, is integrated in standard 19" chassis as shown on the following figure

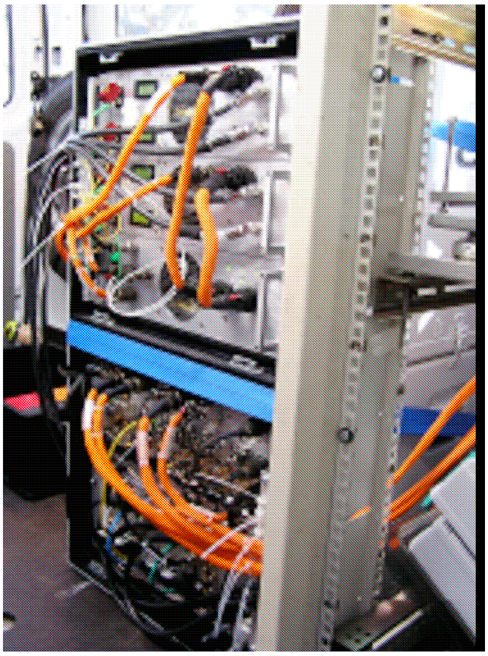


Figure 11: External view of the mock-up during ground tests

The racks contained in these chassis are:

- One power supply rack, which is powered by the aircraft (220VAC, 50Hz) and delivers the required voltages to the other racks
- Two optical racks containing two optical channel each. These racks receive their power supply from the power supply rack, communicates with the signal processing racks for laser power control and monitoring. Each channel also presents a fibre optic connector for connection to the optical head and a high frequency coaxial connector to deliver the detected signal to the signal processing racks
- Two Signal processing racks that contain numerous functions for the digitalisation of the high frequency signal, recording of raw data, fast and slow signal processing

In addition to these two rack holders, the following modules are part of the mock-up:

- A control panel that contains the main control switches and the emergency stop
- A MMI laptop used to display in real-time the computed velocities and to download the recorded data after a flight
- One optical heads module fixed to the modified aircraft window

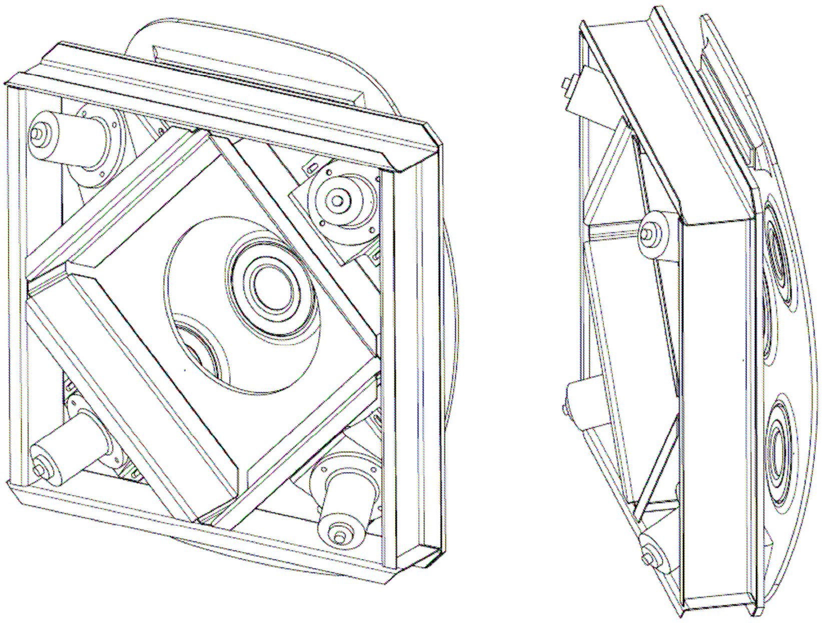


Figure 12: Optical heads module

The whole mock-up was first extensively tested in laboratory, and then was ground tested using a van.

All characteristics were found to be correct and the mock-up was then installed in the test aircraft.

Flight test (WP4200)

The flight tests objectives were:

- To evaluate the NESLIE mock-up sensitivity to different backscatter conditions, depending on altitude, meteorological and atmospheric conditions, and geographical position
- To evaluate the systems performances (with respect to accuracy and bandwidth)

During the flight tests, both data from the aircraft systems and data from the NESLIE mock-up are recorded:

- Aircraft system data
  - Inertial Reference System data (position, velocity, accelerations)
  - Air Data System data (Air Speed, temperature)
  - Nose boom data (Angle Of Attack, Side Slip Angle)
  - Reference time for the whole experiment
- NESLIE mock-up data
  - High level real time data (Air Speed vector estimate, number of detections)
  - Raw signal recording

To perform the flight tests, the NLR's Cessna Citation II research aircraft had to be modified:

- A Laser windows was designed, manufactured, certified and installed by NLR in metal plate in emergency hatch
- A nose boom equipped with AOA and SSA vanes was installed, as a reference instrument

Figure 13: NLR's aircraft with laser window and nose boom

The NESLIE mock-up was then installed on board the aircraft, including the following operations:

- Laser beams alignment (with respect to the aircraft body)
- Laser beam output power measurement
- Mock-up functional tests (on ground)
- Shakedown flight

18 test flights were performed, with a total duration of 40 hours, in March, April and May 2009. All items of the flight test matrix were covered, both for backscatter experiments and system performances evaluation.

All flight tests records, for both aircraft systems data and NESLIE mock-up data, and including also the meteorological information related to the flight, were gathered and distributed to the partners for further processing.

The analysis of the flight tests data gave the following results:

- The NESLIE mock-up was operational and provided air speed measurement for the whole flight campaign, in all altitude and atmospheric conditions. In addition, the number of detections complies with the models describing the aerosol content in the atmosphere
- The 4-measurement axis provided measurements that were in very good agreement with each other in most of the time. This demonstrates the very good performances of the mock up, independently from the local aerodynamic conditions at the mock-up measurement point
- The comparison with the aircraft system data, after some calibration operation to compensate for the local aerodynamic conditions, demonstrates the very good coherence between the NESLIE mock-up and the aircraft data. This also apply to large dynamic manoeuvres, including abrupt variations of the Angle Of Attack and the Side Slip Angle.

2.4.4. Achievement & results of WP5000 (Dissemination, exploitation and conclusions)

The analysis of the flight tests results showed clearly that the technology developed within the frame of the NESLIE project is very promising regarding its potential use for future Air Data Systems applications.

The dissemination aspects are presented in section 3.

2.4.5. Overall conclusion on project achievements

The NESLIE project objectives have been met:

- The Optical Air Data System (OADS) architecture has been specified and designed
- The technological bricks have been developed and validated (integrated laser, integrated optics, optical head and windows, real time signal processing, air density acquisition theoretical study
  Only the IR detector was not developed, but a back-up solution was defined and used, so XenICs failure had no consequence on the overall project achievements
- A LIDAR mock-up was integrated and flight tested

The flight tests results validate the Optical Air Data System concept:

- The mock-up provided measurements in all atmospheric and altitude conditions
- The analysis of the mock-up measurements show very interesting performances with respect to the specification objectives

The NESLIE project showed very promising results and represents a large progress with respect to the state of the art in Optical Air Data System.

In addition to those results, a large signal database is now available for the development of improved signal processing algorithms in the frame of the on-going DANIELA FP7 project.

3. DISSEMINATION AND USE

3.1. NESLIE WEB SITE

The NESLIE web site is available at the following address: http://www.neslie-fp6.org/

The following picture presents the NESLIE web site home page.

Figure 14: NESLIE web site home page

3.2. DISSEMINATION ACTIVITIES

Several dissemination actions were carried out during the NESLIE project. Those actions are presented in the table hereunder.

Responsible partner	Event	Title	Date
EADS	Conference ISTP 2009 (International Symposium on Atmospheric Profiling), Delft (NL)	Airborne laser system for short-range temperature and density measurements based on the Raman technique	10/2009
IMEP	SPIE conference on Integrated optics No13, San Jose CA (USA)	Development of an ion-exchanged glass integrated optics DFB laser for a LIDAR application	01/2009
CERTH - ITI	EUSIPCO-2008 - 16th European Signal Processing Conference, Lausanne (CH)	Signal processing for a laser based air data system in Commercial aircrafts	08/2008
CERTH - ITI	Recent Advances in Signal Processing, 2009, IN-TECH, Vienna, (ISBN978-953-7619-41-1)	Real-Time Signal Acquisition, High Speed Processing and Frequency Analysis in Modern Air Data Measurement Instruments	10/2009

APPENDIX A : ACRONYMS

ADS	**A**ir **D**ata **S**ystem
AOA	**A**ngle **O**f **A**ttack
CAS	**C**omputed **A**ir**S**peed
DANIELA	**D**emonstration of **AN**emometry **I**nstrum**E**nt based on **LA**ser
DP	**D**ifferential **P**ressure (Pt-PS)
FL	**F**light **L**evel
LIDAR	**LI**ght **D**etection **A**nd **R**anging
OAT	**O**ptical **A**ir **T**emperature
PS	**S**tatic **P**ressure
Pt	**T**otal **P**ressure
SAT	**S**tatic **A**ir **T**emperature
SSA	**S**ide **S**lip **A**ngle
TAS	**T**rue **A**ir **S**peed
TAT	**T**otal **A**ir **T**emperature