Grant agreement no: 338538

Project acronym: *OPTIMAL*

Project title: *OPTImised Model for Accurately measured in-flight Loads*

Instrument: *JTI CLEAN SKY*

Theme: SP1-JTI-CS-2012-03

Publishable Summary Report

Period covered: from *09 September 2013* to *01 March 2016*

Date of preparation: *15-08-2016*

Start date of project: *09 September 2013* Duration: 30 *Months*

Project coordinator name: Mr. *Dimitri Karagiannis*
Project coordinator organisation name: *INASCO*

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Project details

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Project Logo		Coordinator's Details
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Project summary

In recent years, Counter Rotating Open Rotors (CROR) have received considerable attention as the CROR concept promises a considerable reduction of fuel consumption over conventional ducted turbofan engines. Specifically for Smart Fixed Wing Aircraft CROR is expected to contribute to 20% fuel burn reduction. Despite this potential CROR engines are associated with higher noise and vibration levels and their installation pauses a challenge for the adaptation in future aircraft models.
The main objective of OPTIMAL proposal is to provide a technical solution to accurately measure all the loads encountered by a pylon which supports a Counter Rotating Open Rotor (CROR) engine in flight. The work entails the development of a methodology that will enable the assessment of flight loads on to the pylon and fuselage based on local sensor measurements. This methodology is based on an inverse Finite Element Analysis (FEA) approach where the loads at the boundaries i.e pylon-fuselage attachment can be assessed with increased accuracy and fidelity.
FEA analysis will be supported by accurate strain, temperature and acceleration measurements by an appropriate sensor network. Traditional sensors such as strain gauges and accelerometers as well as optical fiber sensors Brag Gratings will be investigated and analyzed. The two proposed sensor networks systems will be operating side by side in an effort to evaluate optical system performance and eventual feasibility for the pylon monitoring application. To this end the proposers will bring in their background knowledge and no further development of the optical measuring system is foreseen.
The proposed approach would be validated by structural testing of a scaled pylon mock-up, which will be representative of the real structure. Based on the results of these investigations, a true scale measurement system configuration would be proposed that should meet Flight Worthiness specifications of the future flying test bed.

Duration 30 months. Starting date 02 September 2013.

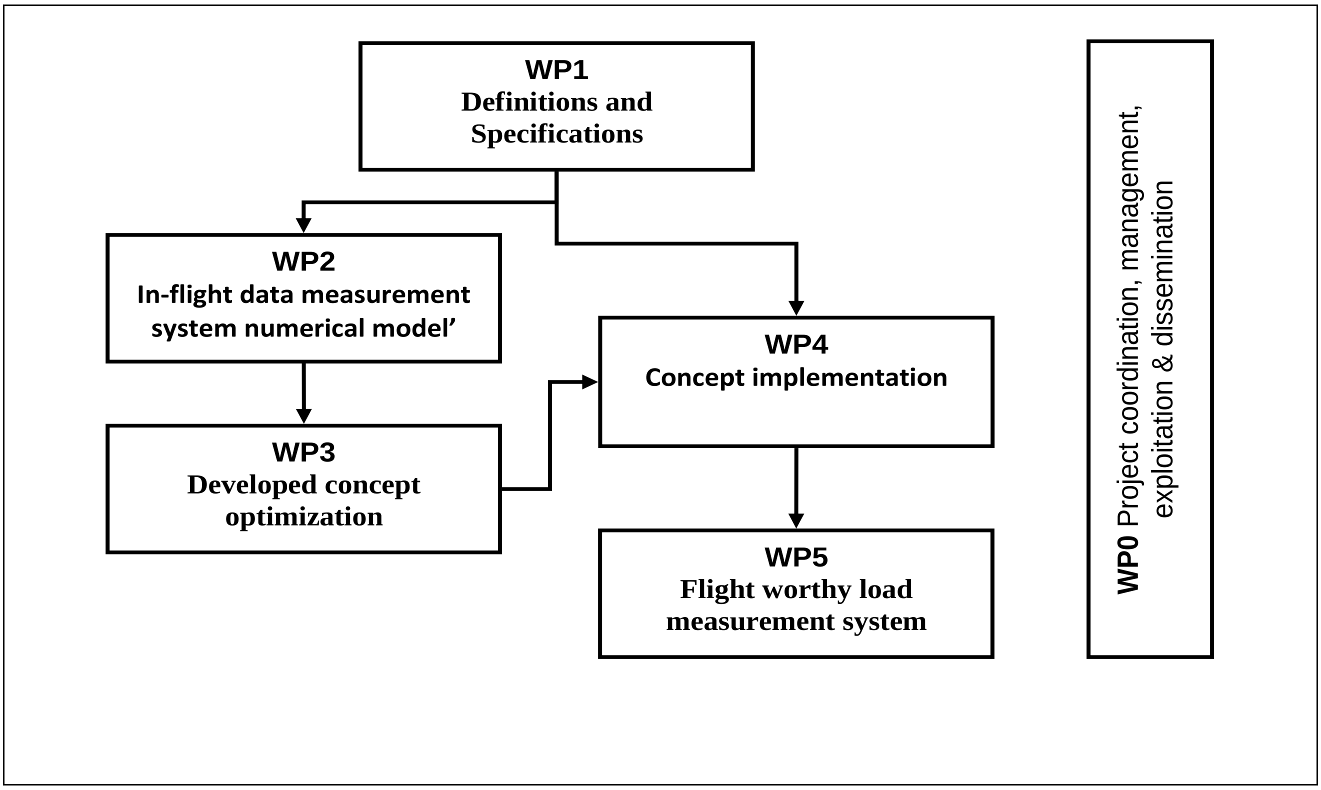
Key objectives of the project

The main objective of this topic is to provide a technical solution to accurately measure all the loads encountered by a pylon which supports a Counter Rotating Open Rotor (CROR) engine in flight. The main scientific and technical work comprises five main research objectives in agreement to the present call for proposals topic:

a) Development of a model of the proposed concept for load calculations based on measurements
b) Optimization of the load model
c) Experimental concept implementation
d) Concept update and adaptation to a flight worthy measurement system
e) Dissemination of concept principles having elements of innovation

All the procedures and actions performed in the frame of the present project will comply with the internal procedures of the SFWA partners, as far as, testing and analysis is concerned, provided that these have been available for OPTIMAL partners.

Project Workpackage interdependence



Consortium

	Partic. No.	Participant Name	Participant Short Name	Country
CO	1	Integrated Aerospace Sciences Corporation (INASCO)	INASCO	EL
CR	2	AEROTRON Research	ARES	EL

*CO = Coordinator
CR = Contractor

Work performed

The project was divided in two periods P1 from 02/09/13 to 01/03/15 and P2 from 02/03/15 to 01/03/16.
In the first period of the project, the technical work was essentially completed inWP1. There was ongoing work in WP2 to WP4. WP5 started in next reporting period. All technical specifications of the work have been set and the inverse problem solution has been formulated. The first optimisation of the concept has been performed and the CAD of the initial mock-up has been produced.
In the second period the ongoing work in all other WPs has been also completed. All technical specifications of the work have been set and the inverse problem solution has been formulated. The first optimisation of the concept has been performed and the CAD of the initial mock-up has been produced. The physical model is available and the tests have been performed. However the objective of 3% accuracy in the prediction of the loads was not achieved due to poor correlation between the measured and the computed strains. Consequently, although the inverse methodology has proven to be robust in theoretical cases that were examined it was not possible to yield the desired outcome at this stage. In order to achieve this goal the partners will continue with relevant investigations outside the OPTIMAL project and on their own expenses.

Results achieved

The main output of the reporting period was:

- A set of specifications on Pylon mock-up, sensor array configuration. Definition of Data Acquisition System (DAS) and translator software (s/w) specifications.
- Definition of mock-up test plan (test matrix, loading conditions, hardware)
- The first initial detailed numerical model has been produced and analysed.
- The inverse problem solution has been formulated
- A set of specifications on Pylon mock-up, sensor array configuration. Definition of Data Acquisition System (DAS) and translator software (s/w) specifications.
- Definition of mock-up test plan (test matrix, loading conditions, hardware)
- The first initial detailed numerical model has been produced and analysed.
- The inverse problem solution has been formulated
- Realisation of a Data Acquisition System (DAS) that can fuse information from optical (FBG) and electrical (Strain Gauge) sensors.
- Finalisation of mock-up CAD design
- Fabrication of the physical test article
- Proposal for an adapted concept on suitable for aircraft environment
- Execution of Test Matrix for Mock-up tests
- Analysis and results of the lab tests. Delivery of Pylon hardware
- Discuss of Scale up feasibility with the synthesis of the work and proposal of a way towards TRL6

Impact

The use of OPTIMAL system once validated, is expected to find applications in other structural problems where load identification is necessary and can't be directly known. Furthermore, it could be combined with Structural Health Monitoring systems in order to increase its accuracy and prediction capability in order to achieve significant reduction in maintenance downtime and cost. Eventually OPTIMAL is expected to increase reliability and safety having great importance in aeronautic transport.

Section 1. Project objectives and major achievements during the reporting period

1.1 General project objectives

The main objective of this topic is to provide a technical solution to accurately measure all the loads encountered by a pylon which supports a Counter Rotating Open Rotor (CROR) engine in flight.

The main scientific and technical work comprises five main research objectives in agreement to the present call for proposals topic:

a) Development of a model of the proposed concept for load calculations based on measurements. b) Optimization of the load model. c) Experimental concept implementation.
d) Concept update and adaptation to a flight worthy measurement system, and e) Dissemination of concept principles having elements of innovation

All the procedures and actions performed in the frame of the present project comply with the internal procedures of the SFWA partners, as far as, testing and analysis is concerned.
In order to achieve these objectives, the project has been organized into one management and five technical work packages (WP). Due to the requirements of the proposed activities all technical tasks are further broken down into tasks. This has fostered better monitoring of the activities and tractable achievements.

In order to reach those objectives the project has been divided in one management and five technical Work Packages (WP). According to the latest Amendment of the Description of Work (DoW) of 24/09/2015:

Detailed work description:

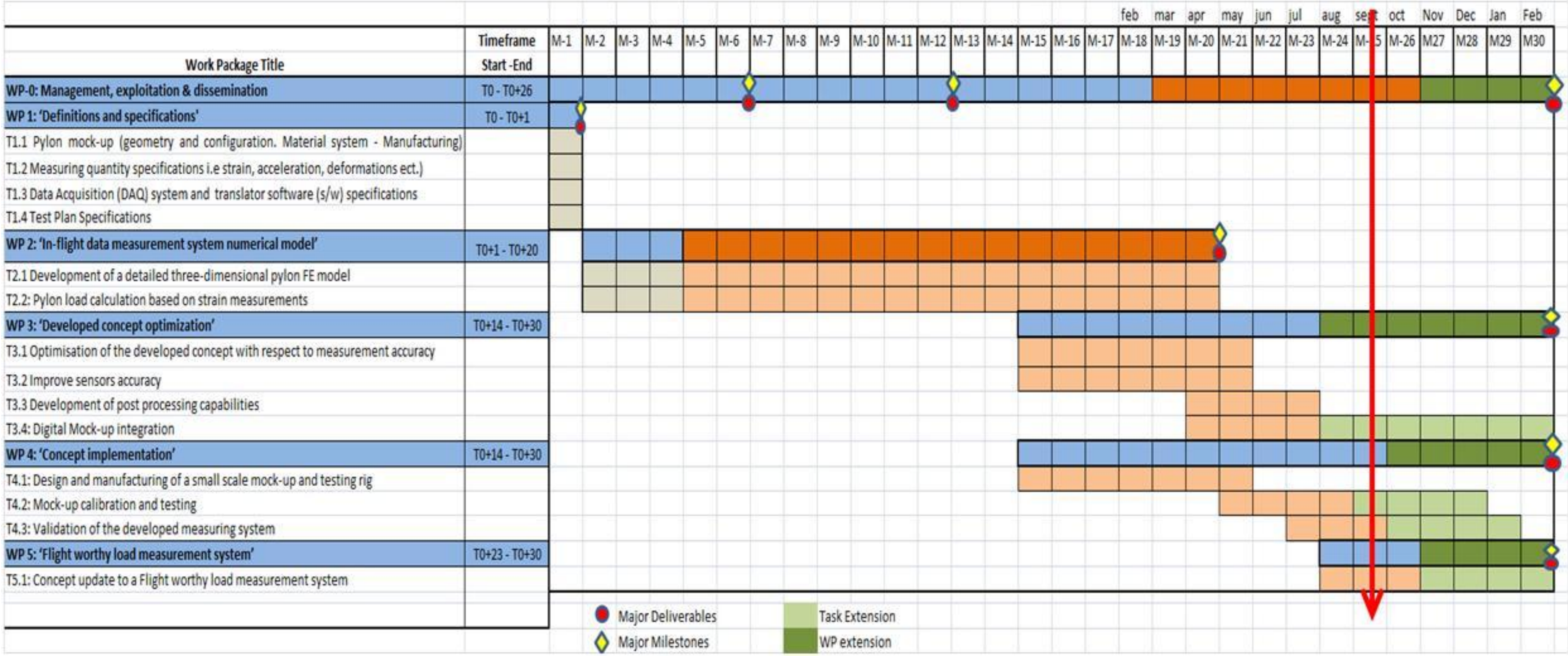


Table 1: Work package list

Work Package Title	Activity Type	Participants INASCO	Participants ARES	Leader	Timeframe Start -End	Effort per WP
WP-0: Management, exploitation & dissemination	**RTD**	**4.00**	**1.00**	INASCO	T0 - T0+30	5.00
WP 1: ‘Definitions and specifications'	**RTD**	**0.50**	**0.50**	INASCO	T0 - T0+1	1.00
T1.1 Pylon mock-up (geometry and configuration. Material system - Manufacturing) specs		0.20	0.10			
T1.2 Measuring quantity specifications i.e strain, acceleration, deformations ect.)		0.10	0.20			
T1.3 Data Acquisition (DAS) system and translator software (s/w) specifications		0.10	0.10			
T1.4 Test Plan Specifications		0.10	0.10			
WP 2: ‘In-flight data measurement system numerical model’	**RTD**	**1.00**	**4.50**	ARES	T0+1 - T0+20	5.50
T2.1 Development of a detailed three-dimensional pylon FE model		0.50	2.00			
T2.2: Pylon load calculation based on strain measurements		0.50	2.50			
WP 3: ‘Developed concept optimization’	**RTD**	**6.50**	**7.00**	ARES	T0+14 - T0+30	13.50
T3.1 Optimisation of the developed concept with respect to measurement accuracy		1.50	3.00			
T3.2 Improve sensors accuracy		1.00	2.00			
T3.3 Development of post processing capabilities		4.00				
T3.4: Digital Mock-up integration			2.00			
WP 4: ‘Concept implementation’	**RTD**	**9.00**	**2.00**	INASCO	T0+14 - T0+30	11.00
T4.1: Design and manufacturing of a small scale mock-up and testing rig		4.00				
T4.2: Mock-up calibration and testing		3.00				
T4.3: Validation of the developed measuring system		2.00	2.00			
WP 5: ‘Flight worthy load measurement system’	**RTD**	**2.00**	**0.00**	INASCO	T0+23 - T0+30	2.00
T5.1: Concept update to a Flight worthy load measurement system		2.00				
	TOTAL EFFORT	**23.00**	**15.00**			**38.00**

Table 2. Deliverables list

Deliverable 2	WP	Title	Description (if applicable)	Due date	Leading Partner	Nature 1
D0.1	WP-0	Kick-off MoM	Minutes of Meeting (MoM) of Kick-off	T0	INASCO	R
D0.2	WP-0	Activity Exploitation & Dissemination Report 1	Technical progress in WP1, WP2, WP3 and WP4	T0+16	INASCO	R
D0.3	WP-0	Activity Exploitation & Dissemination Report 2	Technical progress in WP2 to WP5	T0+30	INASCO	R
D0.4	WP-0	Final Report	Final technical report, management report, report on funding distribution between contractors.	T0+30	INASCO	R
D1.1	WP-1	Prerequisites for a measurement setup	Synthesis of the requirements provided by Topic Manager and ways to reach the objectives	T0+1	INASCO	R
D2.1	WP-2	Analytical and FEM models	Provide the models and the conclusions to fulfill the needs	T0+20	ARES	O
D3.1	WP-3	Concept Layout and System Architecture	Provide a preliminary layout of the measurement concept and the system architecture	T0+21	ARES	R
D3.2	WP3	Adapted concept on A/C	Integration of the constraints CROR FTB with Airbus Digital Mock-Up	T0+30	ARES	O
D4.1	WP-4	Test Matrix for Mock-up tests		T0+21	INASCO	R
D4.2	WP-4	Mock-up tests	Perform tests of prototypes on a relevant mock-up on ground and reporting of results	T0+28	INASCO	R/O
D4.3	WP4	Mock-up test report	Analysis and results of the lab tests. Delivery of Pylon hardware	T0+30	INASCO	R
D5.1	WP-5	Scale up feasibility	Synthesis of the work and way forward to TRL6	T0+30	INASCO	R

[1] Please indicate the nature of the deliverable using one of the following codes:
R = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other

2 Deliverable numbers in order of delivery dates. Please use the numbering convention <WP number>.<number of deliverable within that WP>. For example, deliverable 4.2 would be the second deliverable from work package 4.

Table 3. Milestones list

N°	Date[3]	WP involved	Description	Assessment criteria[4]
M0.1	T0	WP-0	Kick-off	Delivery of MoM (D0.1)
M0.2	T0+30	WP-0	Final progress status, management report	Delivery of minutes and report (D0.4)
M1.1	T0+1	WP-1	All project specifications and definitions available.	Delivery of D1.1
M2.1	T0+20	WP-2	Analytical and FEM models	Delivery of D2.1
M3.1	T0+30	WP-3	Optimised Measurement system	Delivery of D3.1&D3.2
M4.1	T0+28	WP-4	Scaled Pylon Mock-up tests available	Delivery of D4.1 & D4.2
M4.2	T0+30	WP-4	Analysis of Results and delivery of test H/W	Delivery of D4.3
M5.1	T0+30	WP-5	Flight Worthy measurement system proposal	Delivery of D5.1

1.4 Performed work, and main achievements

The work performed in the current project period followed consequently the described objectives.

In **WP1 'Definitions and Specifications'** the work was completed according to the original plan and provided useful inputs to the rest of work packages. More specifically the various project requirements are covered within the following tasks:

- T1.1 Pylon mock-up (geometry and configuration. Material system - Manufacturing) specifications (INASCO)
- T1.2 Measuring quantity specifications i.e. strain, acceleration, deformations etc. (ARES)
- T1.3 Data Acquisition System (DAS) and translator software (s/w) specifications (INASCO)
- T1.4 Test Plan Specifications (INASCO)

INASCO has been responsible for:
a) specify pylon mock-up (geometry and configuration. Material system - Manufacturing)
b) work on Data Acquisition System (DAS) and translator software (s/w) specifications
c) set up the Test Plan Specifications
ARES has been responsible to perform the following tasks: define measuring quantity specifications i.e. strain, acceleration, deformations etc.

WP 2: 'In-flight data measurement system numerical model' and its tasks deal with the accurate representation of the pylon and fuselage arrangement and its structural analysis with analytical and numerical techniques. Here the actual model has been provided by the topic manager and an initial

3 Measured in months from the project start date (month 1).
4 Show how you will confirm that the milestone has been attained. Refer to indicators if appropriate. For example: a laboratory prototype completed and running flawlessly; software released and validated by a user group; field survey complete and data quality validated.

structural analysis has been performed in order to acquire the load paths and magnitudes of the expected strains and stresses. This has been useful for the design of the scaled mock-up.

In **WP 3: 'Developed concept optimization'** the initial numerical model from WP2 has been optimized. Also the post processing capabilities have been added, in order to reach the target accuracy of the measurement concept.

In **WP 4: 'Concept implementation'** the initial the implementation of the load identification concept into a small scale mock-up has been performed and a 3D CAD model was build and is available.

Work in **WP 5: 'Flight worthy load measurement system'** entails an update of the concept to define a flight worthy measurement system configuration adapted to the Open Rotor Flight Test Demonstrator.

Finally, **WP6, includes all the management**, exploitation and dissemination activities of the present project. Here the kick off meeting activities have been reported and all management and administration aspects of the project have been followed up to the end of the last reporting period P2.

1.5 Important problems and corrective actions

The most significant problems encountered during the reporting period are described below alongside their impact in the planned project execution and the corrective measures taken by the Consortium.

1) Due to technical complexities and development difficulties for the solution of the inverse problem, it was decided together with the Topic Manager to request an extension of the time frame of the project. The concerned tasks as well as the dependant future work was rescheduled. The new time schedule is the one given in page 7. Overall a seven month extension has been given. The new grant agreement was in place on 18-03-2015.
2) In collaboration with the Topic Manager the consortium needed more time to assess and understand the results from the available test data. It was deemed necessary to examine additional load cases with a rigid mock-up support. The later is to be compared with the previous compliant support structure. The afore mentioned activities required the extension of Task 4.2 "Mock-up calibration and testing" by four months and consequently the extension affected all dependant activities in WP4 and WP5. Overall an additional four months extension was granted with a relevant extension request. The new project end date was the 1st of March 2016 and the duration of the project was 30 months instead of 26.

On technical side the project faced the following challenges:

Development of the inverse method methodology:

- The development of the inverse methodology was tedious as initially a different concept has been investigated than the one finally adopted.
- The developed method offers a simultaneous position optimization of sensor placement and a robust solution. Theoretically it achieved the desired accuracy.
- The methodology has been verified theoretically with very good results.
- Once implemented it is straight forward to predict the load from the local measurements.

It has not been possible to demonstrate required accuracy for the mockup :

- The measured strains are not correlating with the analysis (FEA).

- Together with the Topic Manager we have been investigating the cause of this but without success up to now. Many efforts have been taken:
    - Very detailed FEM
    - Repetition of the experimental campaign
    - Use of optical (FBS) sensors
    - Derivation of detailed model very close to “as build” in order to represent the structure as close as possible.
    - Use of large field optical measurement (DIC) with ARAMIS ongoing.
    - The Topic Manager proposed another approach by applying unit loads (force and torque) which is also pursued at the moment.
- The partners have put extra efforts on this issue which is outside the OPTIMAL budget.
- Since the end of the project the partners are working on their own expenses.
- The partners are willing to finalize the investigation and report to AI-F even outside of the OPTIMAL project.

Section 2. Workpackage progress of the period

2.1 WP1 Definition and Specifications

2.1.1 Progress towards objectives

All specifications and procedures are described in deliverable D1.1 "Prerequisites for a measurement setup" below in **Figure 1** a snapshot of the geometric configuration is given.

Pylon mock-up (geometry and configuration. Material system - Manufacturing) specifications – (100% Completed)

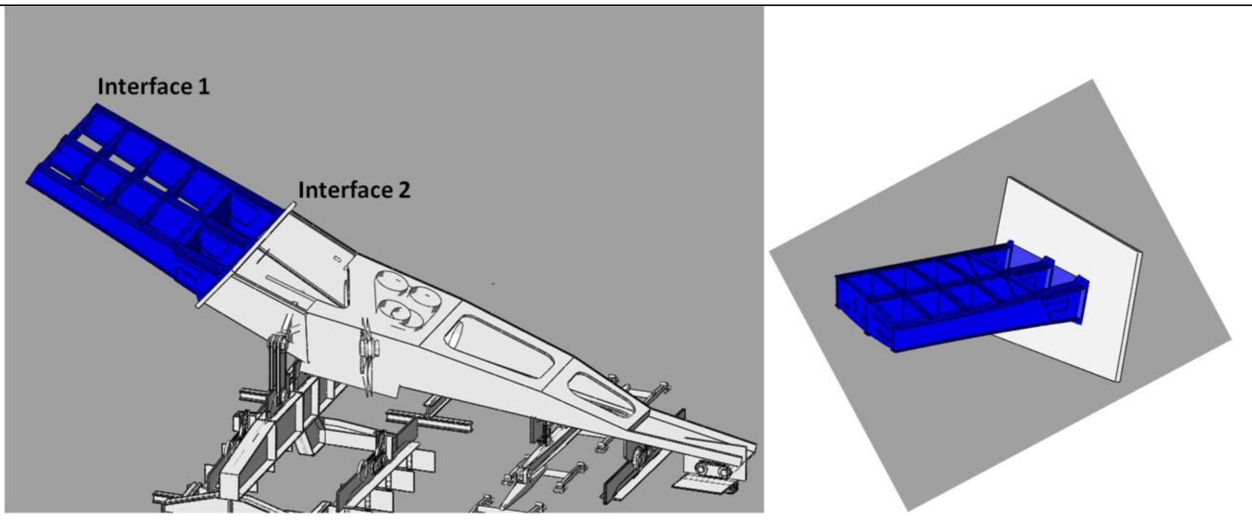


Figure 1: Simplified physical pylon model showing interfaces. Interface 1: engine to pylon and interface 2 pylon to supporting structure

Measuring quantity specifications i.e. strain, acceleration, deformations etc - (100% Completed)

All quantities to be measured have been identified. These will be mainly local strains but also temperatures, deflections and accelerations can be measured.

Data Acquisition System (DAS) and translator software (s/w) specifications - (100% Completed)

All quantities to be measured have been identified. These will be primarily local strains but temperatures as well as deflections and accelerations can be measured.

Plan Specifications - (100% Completed)

The tests will incorporate static loads representing the load conditions of the pylon.. A basic loading configuration is given in **Figure 3**.

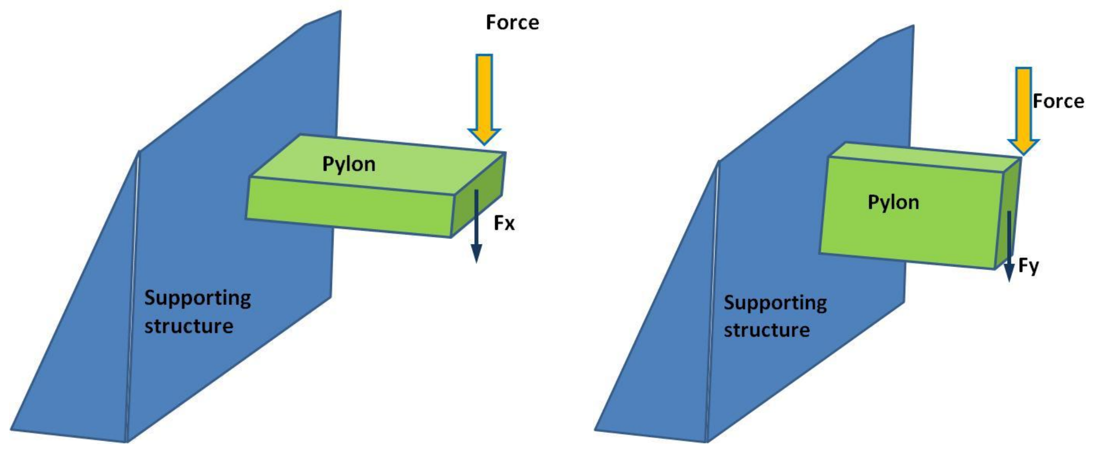


Figure 2: Simplified physical pylon model showing interfaces. Interface 1: engine to pylon and interface 2 pylon to supporting structure

2.1.2 List of deliverables and milestones

Table 2.2.4.1: Deliverables list for WP1

Deliverables of WP 1				
Code number	Date	Description	Partner	Type
D1.1	T0+1	Prerequisites for a measurement setup	INASCO	Report

Table 2.2.4.2: Milestones list for WP1

N°	Date	Description	Assessment criteria
M1.1	T0+1	All project specifications and definitions available	Delivery of D1.1

2.2 WP2 In-flight data measurement system numerical model

2.2.1 Progress towards objectives

Development of a detailed three-dimensional pylon FE model (100%)

The initial CAD model has been analysed and the load paths verified. A detailed pylon numerical model of the pylon is also available considering fixed boundary conditions at the interface with the fuselage as a first approximation.

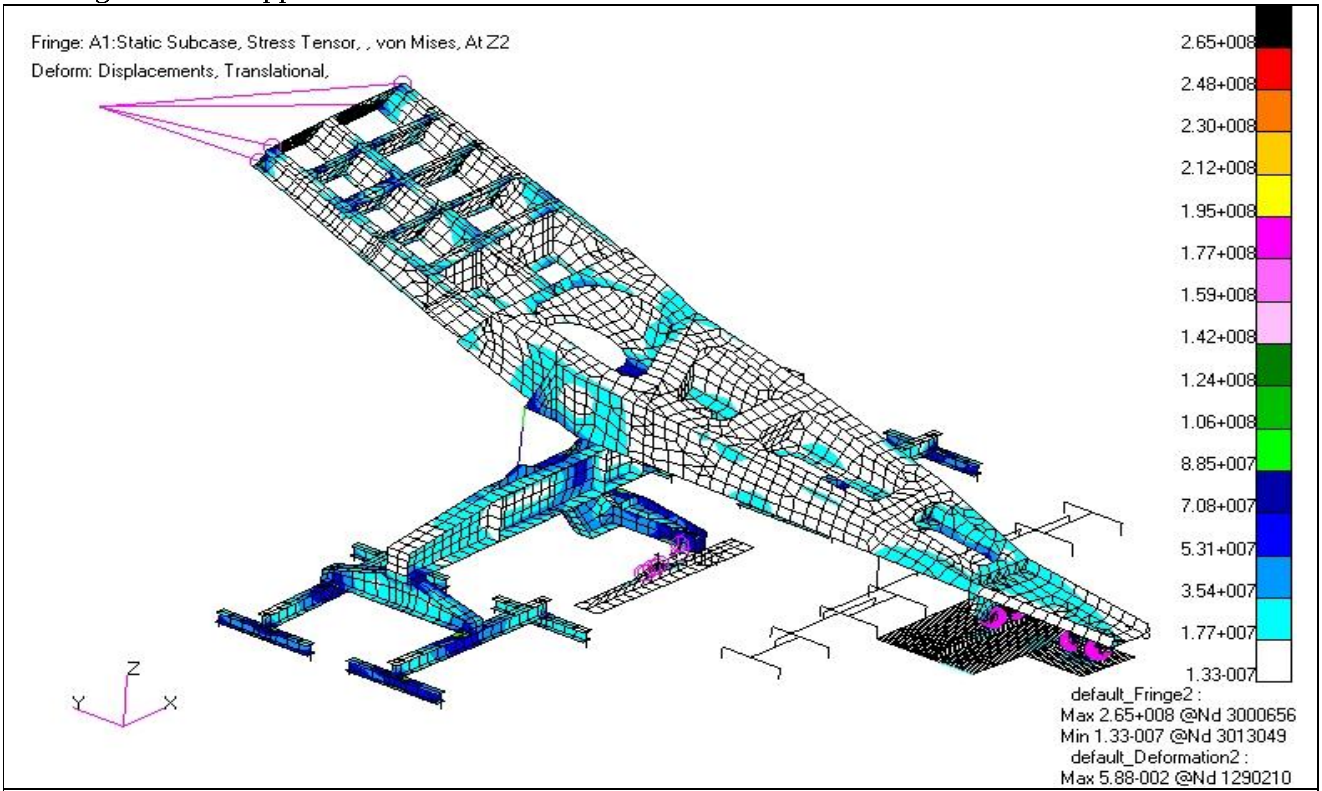


Figure 3: Max. Engine Thrust Force only load case / Overall von Mises Stress distribution.

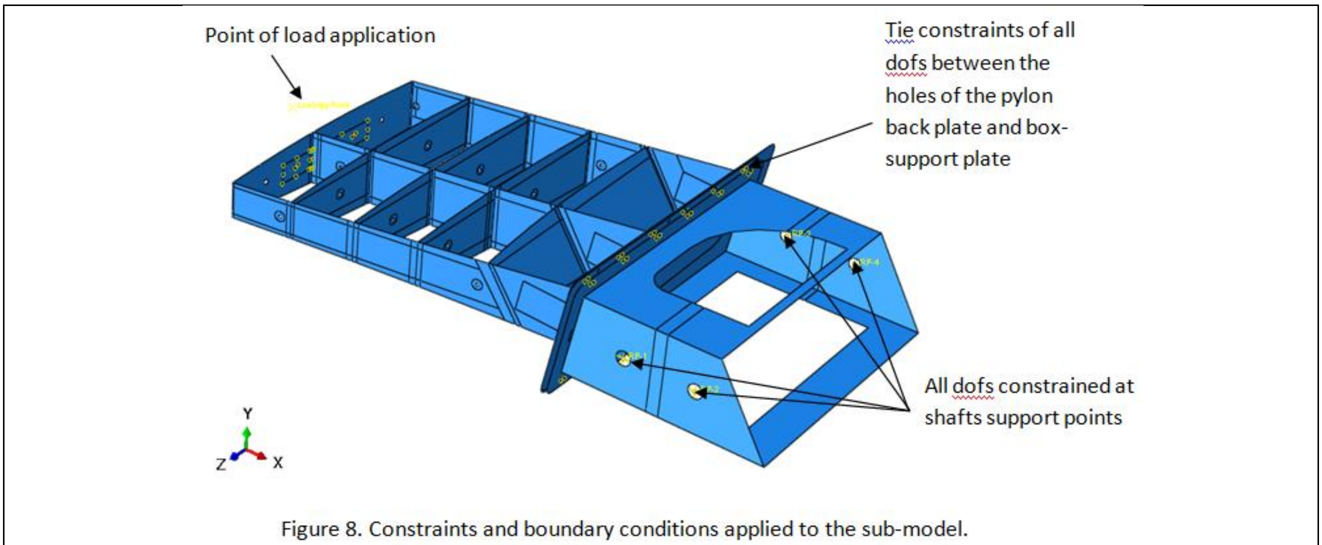


Figure 4: Pylon and support with load application and boundary condition details.

Pylon load calculation based on strain measurements (60%)

The inverse problem proved to be complex to deal with. The outlook of the procedure that was developed is shown in **Figure 5** below.

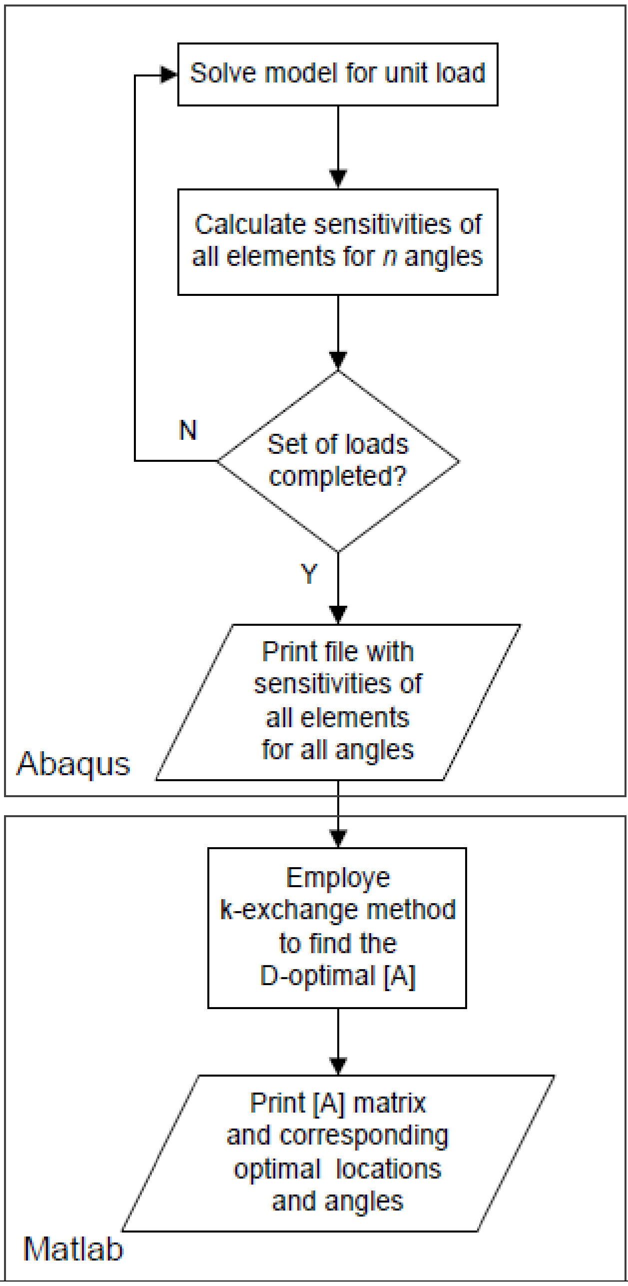


Figure 5: Implementation of the optimal sensor locations calculator and inverse method for a given number of sensor locations.

2.2.2 List of deliverables and milestones

Table 2.3.4.1: Updated Deliverables list for WP2

Code number	Date	Description	Partner	Type
D2.1	T0+20	Analytical and FEM models	ARES	Report/ Model

Table 2.3.4.2: Updated Milestones list for WP2

N°	Date	Description	Assessment criteria
M2.1	T0+20	Provide the models and the conclusions to fulfill the needs	Delivery of D2.1

2.3 WP3 Developed concept optimization

2.3.1 Progress towards objectives

<u>Development of an optimised measurement concept for the pylon structure to achieve a targeted accuracy that would include the study of low TRL - high accuracy measurement methods.</u> Task completed (100%).

The methodology has been verified on a problem from the literature. The application on the mock-up is underway.

Table 1: Optimal locations for installing single strain gauges.

Gage ID	Layer	Angle
1	Bottom	0°
2	Top	10°
3	Top	0°
4	Bottom	0°

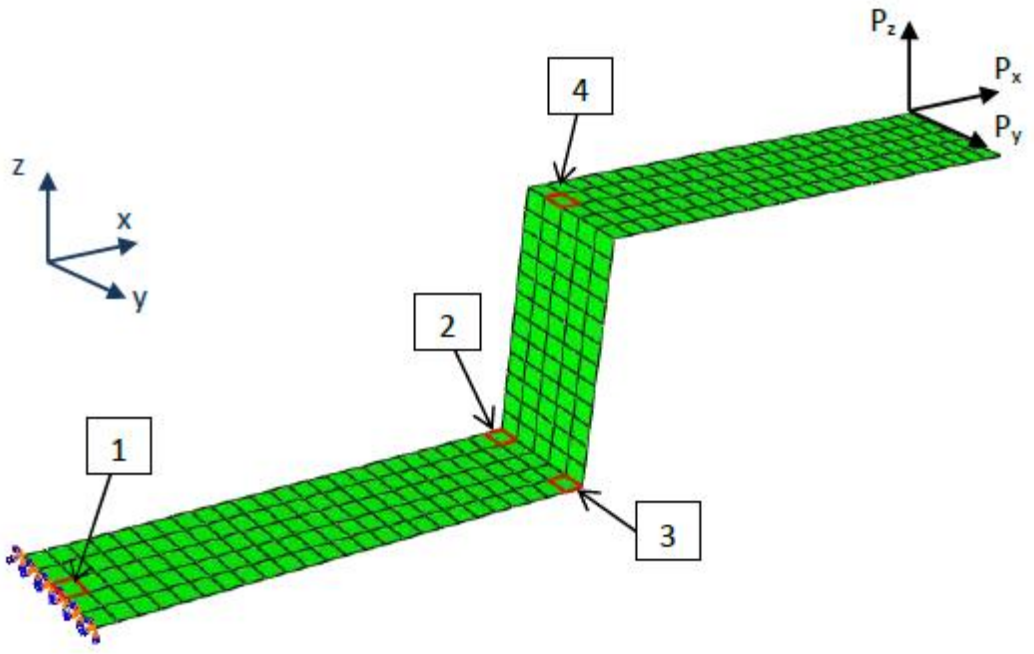


Figure 2: Cantilever geometry used for benchmarking the developed tools.

Figure 6: Verification geometry based on literature[5] to prove the efficiency of the method.

In order to reach the project objectives for increased accuracy in load prediction different strain sensing techniques apart from the basic SGs. The utilized sensors include FBG as optical fiber and embedded in glass fiber composite tab. The Data Acquisition System (DAS) has the capability to measure in real time signals from the SG and the FBG with the aspiration to combine the two different sensors in a common network in order to benefit from their distinctive characteristics.

[5] Gupta, D.K., *Inverse Methods for Load Identification Augmented By Optimal Sensor Placement and Model Order Reduction*, in *Engineering*. 2013, University of Wisconsin Milwaukee.

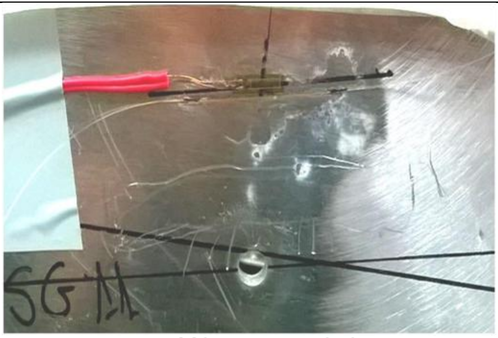


Figure 1: FBG 1 of fiber 1998A1 below SG 11.

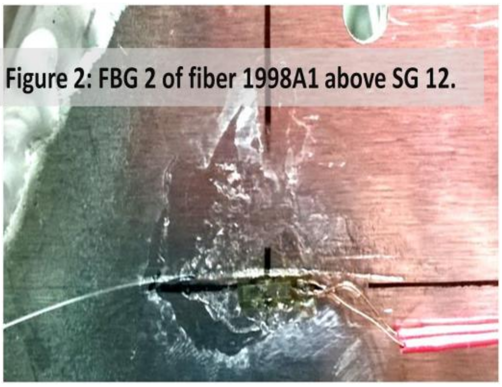


Figure 2: FBG 2 of fiber 1998A1 above SG 12.

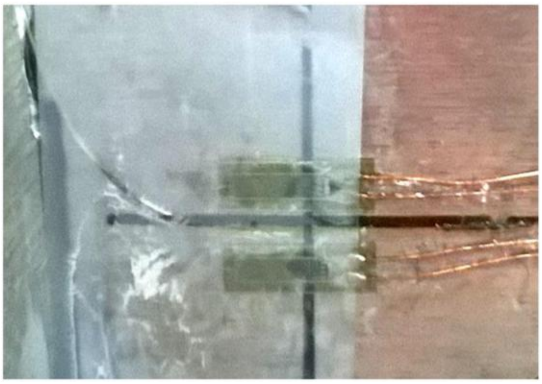


Figure 3: FBG 1 of fiber 1998A2 between SG 6 and SG 7.

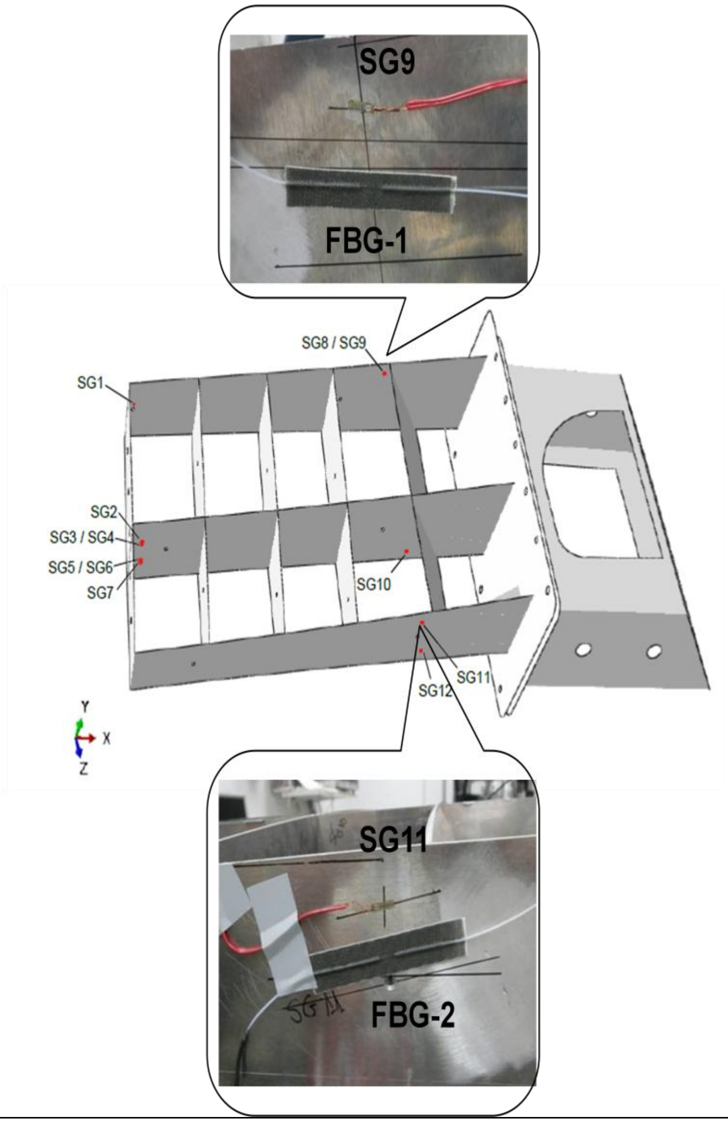


Figure 7: The different FBG types that have been used included fiber embedded tab FBS and normal fiber option shown on the left. The usability of the tabs was very much improved campared to the handling and application problems associated with the optic fiber FBG. These problems resulted in loosing many FBG sensors and eventually use only three out of twelve originally foreseen.

Further to the previously presented local strain measurements, Digital Image Correlation (DIC) sensing of large area of the component was utilised. DIC systems (operating in both 2D and 3D events) use a series of sequential digital images to determine the surface deformation and surface strain of objects. The systems identify features of an object and track the relative movement of those features throughout the sequential images. The ARAMIS DIC system uses a random speckle pattern applied to the surface of the target object to create the unique features identifiable to the system. To identify these features each image is divided into an overlapping grid of facets and each facet must be unique from its neighboring facets. To determine surface displacement of the target object each facet is tracked from one image to the next, creating a series of data points, which are mapped to create the displacement field. For 3D displacement two views (left and right) are required for each time step The specimen deformation is mapped by the changing orientation and shape of the facet. The speckle pattern on the OPTIMAL mock-up is shown in **Figure 8**.

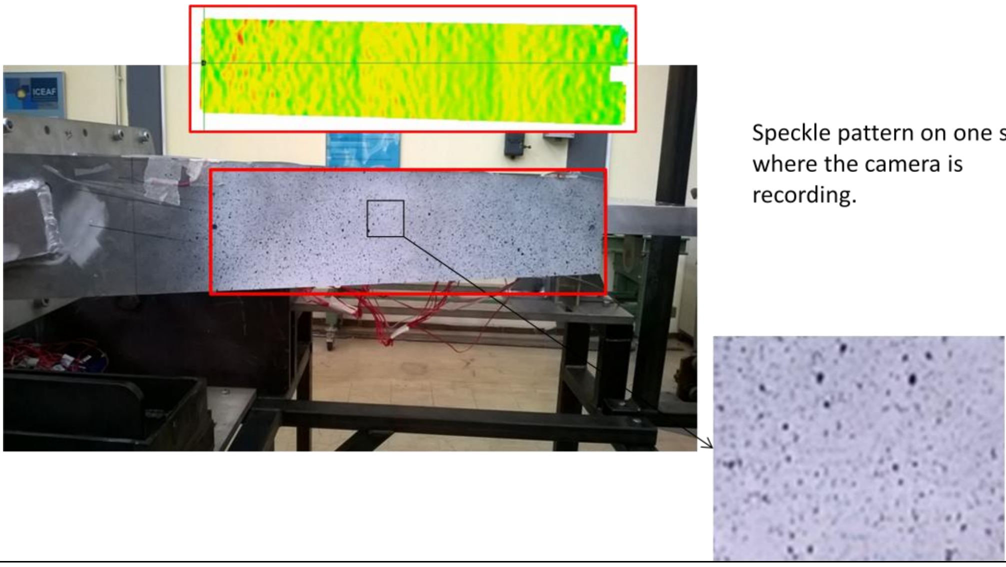


Figure 8: The speckle pattern on the side of the OPTIMAL mock-up and field photo below.

<u>Development of post processing capabilities for data acquisition.</u> Task completed (100%)

The main idea of the OPTIMAL system is to be able to make the required strain measurements and perform the load identification in real time. The load identification methodology is presented in OPTIMAL-D2.1-ARES-01-F. Once the structure is analysed the load identification is done by simple matrix calculus based on the collected Strain Gauge measurements. The Data Acquisition System (DAS) has the capability to fuse information from strain gauge and Fiber Bragg Grating sensors as well as from Linear Variable Differential Transformer (LVDT) and thermocouples. In this way it is possible to combine the different sensors in one seamless network. The measured signals and raw data are stored in data files that are accessed in real time and processed. The information is presented through the Graphical User Interface (GUI) as physical parameters (temperature, strain, time) and as calculated load components. The OPTIMAL DAS concept is shown in **Figure 9**.

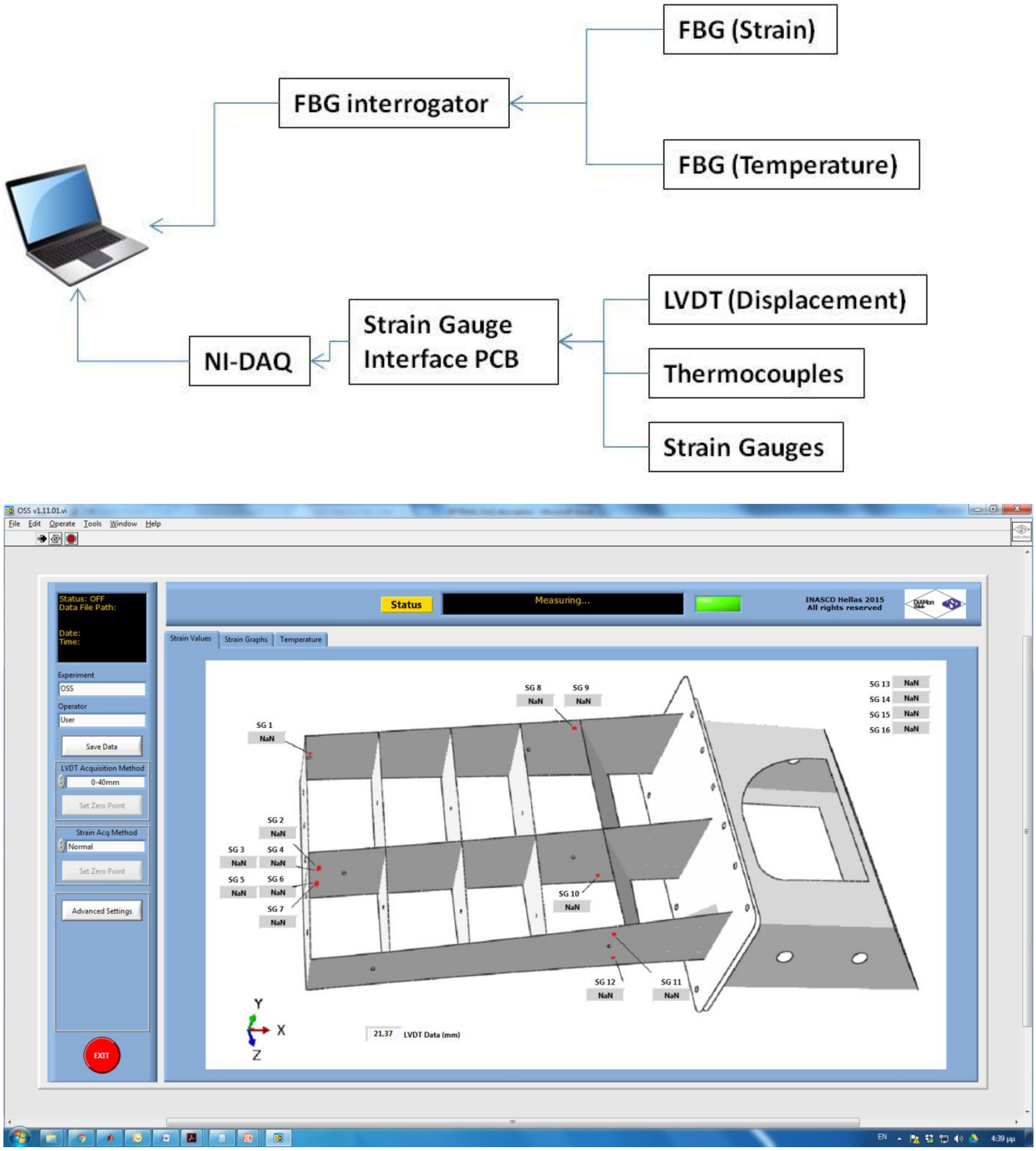


Figure 9: OPTIMAL DAS concept and real time strainindication.

2.3.2 List of deliverables and milestones

Table 2.3.4.1: Updated Deliverables list for WP3

Code number	Date	Description	Partner	Type
D3.1	T0+21	Provide a preliminary layout of the measurement concept and the system architecture	ARES	Report
D3.2	T0+30	Integration of the constraints CROR FTB with Airbus Digital Mock-Up	ARES	Other

Table 2.3.4.2: Updated Milestones list for WP3

N°	Date	Description	Assessment criteria
M3.1	T0+30	Optimized Measurement system	Delivery of D3.1 & D3.2

2.4 WP4 Concept implementation

2.4.1 Progress towards objectives

Design and manufacture of a small scale mock-up and its testing rig (100%)
The mock-up has been designed and is manufactured. In **Figure 10** The 3D CAD and the part is shown.

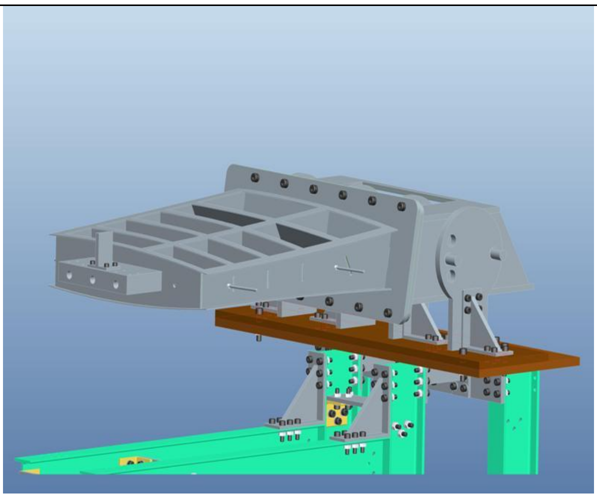
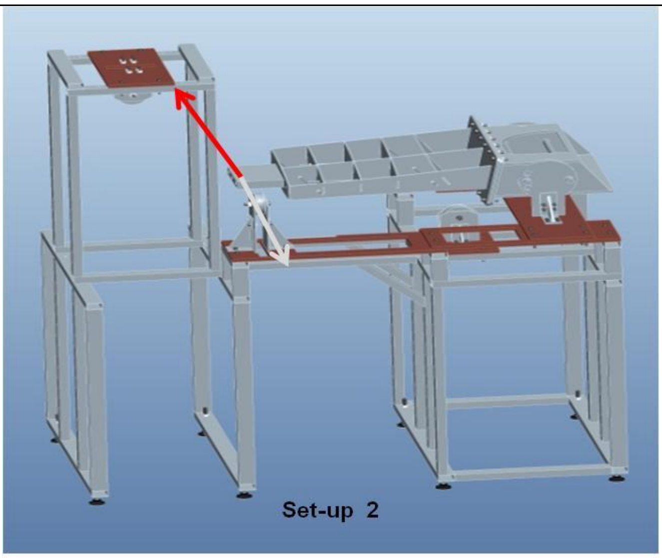



Figure 10: Pylon and support structure 3D CAD and produced hardware.

Implementation and validation of the developed measuring system into the small scale mock-up. Task completed (100%)



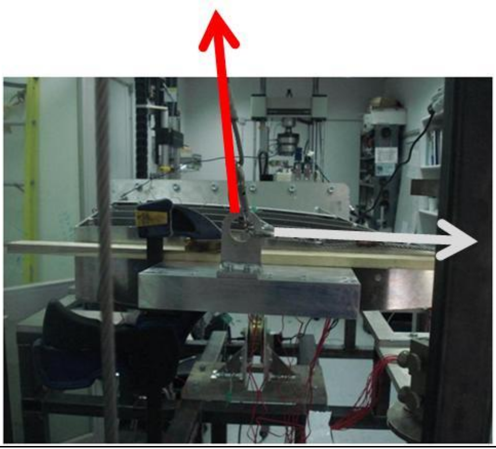


Figure 11: Mock-up set up 2 configuration shown in the left figure. The two components of load are shown with the white and red arrows. The depicted configuration is defined as load case CASE3.

Figure 11 shows set up 2 configuration. This set up utilises a different frame construction to impose the loads in a combination and outwards of the pylon. With the addition of the new frame it is possible to apply lateral load corresponding to engine thrust loading additional to an upwards acting component. The load is applied through a lug at a predefined location as shown in the right photograph of Figure 3. This configuration is defined as CASE3. A real time SG data recording is shown in **Figure 12**

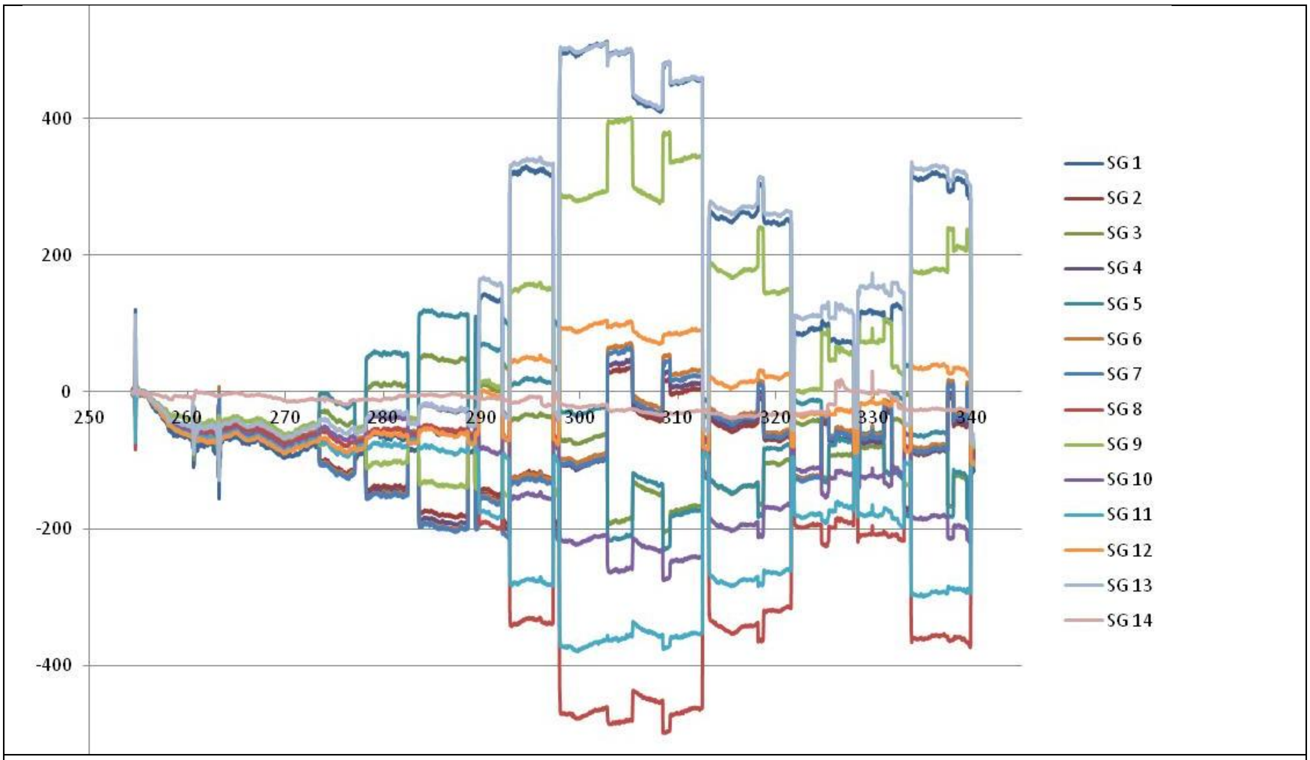


Figure 12: Real time raw data of CASE2 loading.

Model calibration. Task completed (100%)

Finally **Figure 13** shows the configuration CASE4. The set up 2 is used with two force components shown in black and red arrows. The strains and deflections presented in the following refer to a pair of applied forces with magnitude [F1, F2] which correspond to the force pair shown in **Figure 13**.

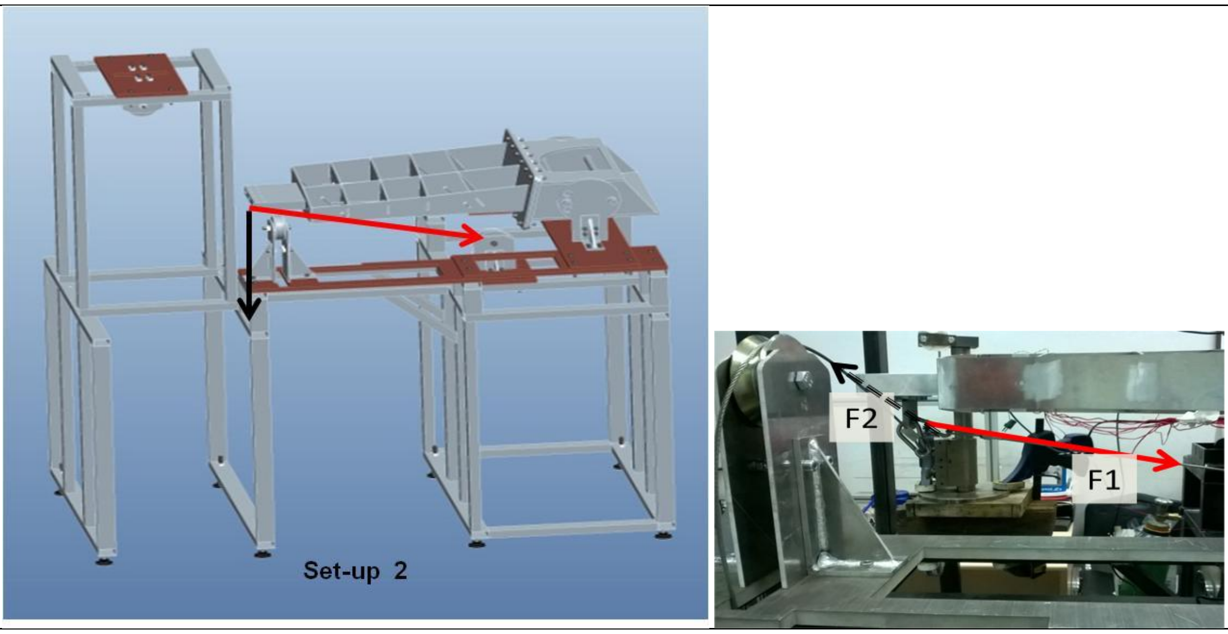
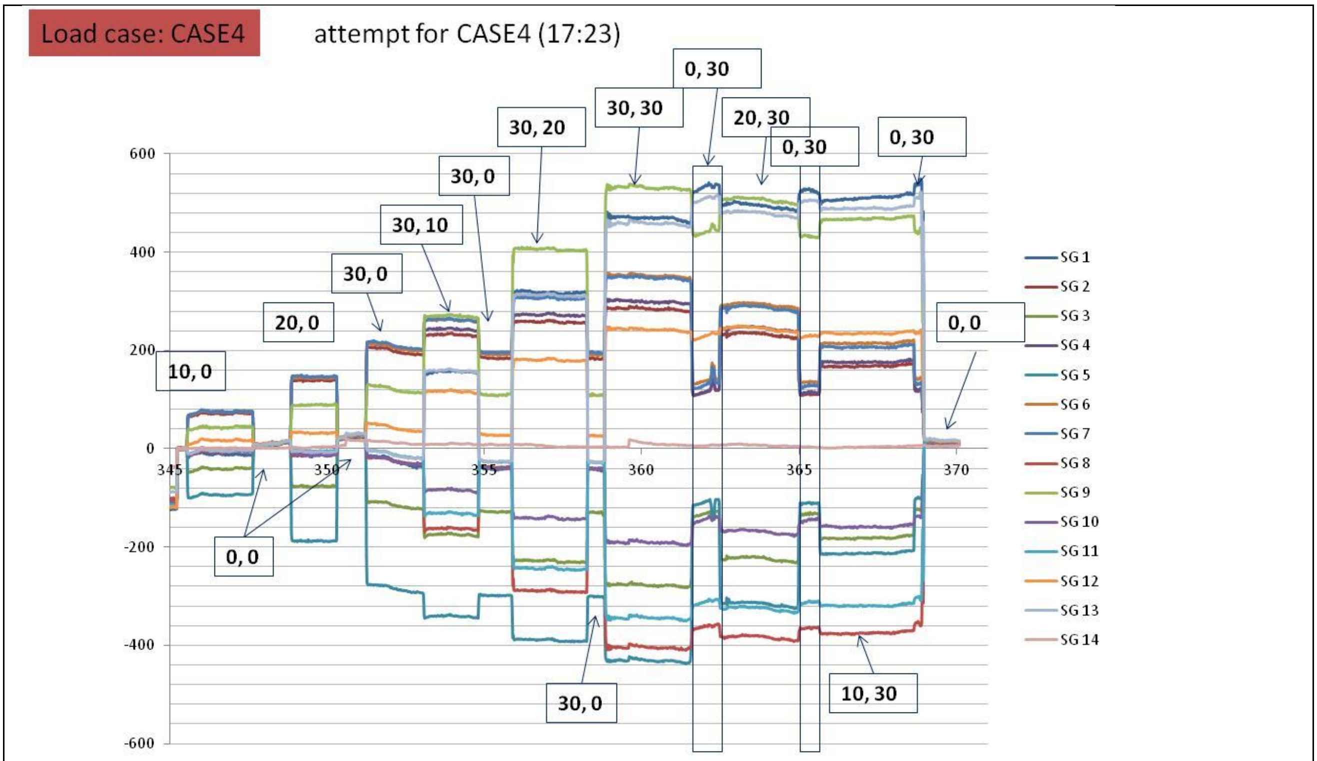


Figure 13: The depicted configuration is defined as load case CASE4. Set up 2 configuration was used shown in the left figure. The two components of load are shown with the black and red arrows.



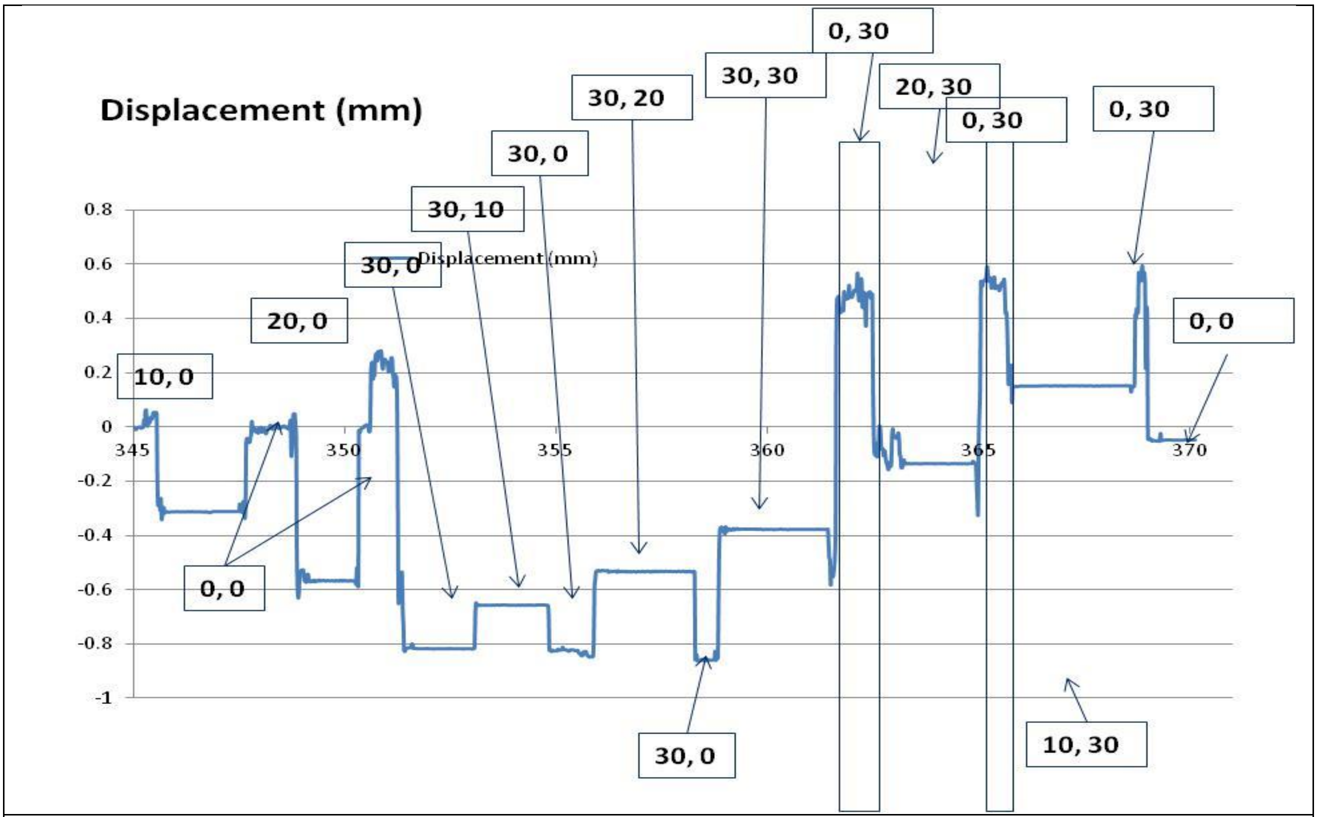


Figure 14: Real time raw data of CASE4 loading. Top: strain (microstrain) and bottom displacement at LVDT.

2.4.2 List of deliverables and milestones

Table 2.3.4.1: Updated Deliverables list for WP3

Deliverables of WP 4				
Code number	Date	Description	Partner	Type
D4.1	T0+21	Test Matrix for Mock-up tests	INASCO	Report
D4.2	T0+28	Mock-up tests	INASCO	R/O
D4.3	T0+30	Mock-up test report	INASCO	Report

Table 2.3.4.2: Updated Milestones list for WP3

WP 4: Milestones and expected result			
N°	Date	Description	Assessment criteria
M4.1	T0+28	Scaled Pylon Mock-up tests available	Delivery of D4.1 & D4.2
M4.2	T0+30	Analysis of Results and delivery of test H/W	Delivery of D4.3

2.5 WP5 Flight worthy load measurement system

2.5.1 Progress towards objectives

Work in WP5 is completed. The main idea of the OPTIMAL system is to be able to make the required strain measurements and perform the load identification in real time. The load identification methodology is presented in OPTIMAL-D2.1-ARES-01-F. Once the structure is analysed the load identification is done by simple matrix calculus based on the collected Strain Gauge measurements. The Data Acquisition System (DAS) has the capability to fuse information from strain gauge and Fiber Bragg Grating sensors as well as from Linear Variable Differential Transformer (LVDT) and thermocouples. In this way it is possible to combine the different sensors in one seamless network. The measured signals and raw data are stored in data files that are accessed in real time and processed. The information is presented through the Graphical User Interface (GUI) as physical parameters (temperature, strain, time) and as calculated load components. The OPTIMAL DAS concept is shown in **Figure 15**.

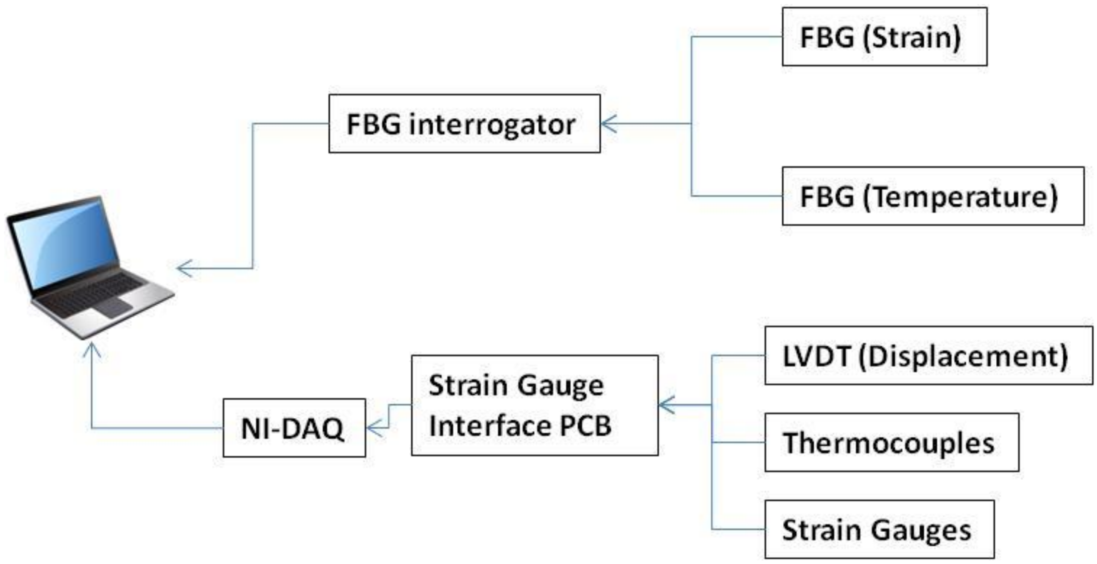


Figure 15: OPTIMAL DAS concept.

In order to propose a flight worthy scaled up measurement system the following aspects have been addressed.

Issue	SG system	FBG system
Safety during operation of operators and other equipment.	The system is safe.	The system is safe.
Weight - Volume.	SG systems are the baseline.	FBG system can significantly save weight by engraving many strain sensors in one opical fiber.
Power consumption requirements.	SG systems are the baseline.	FBG systems can significantly reduce power consumption as multiple sensors can be monitored by the same interrogator.
Electromagnetic interference.	The system is not immune o electromagnetic interference.	FBG system is immune to electromagnetic interference.
Sensor wire routing.	Through the existing structure, harness.	As with SG system. The FBG system have less lines with more sensors on them which made the routing simpler.

2.5.2 List of deliverables and milestones

Table 2.3.4.1: Updated Deliverables list for WP5

Deliverables of WP 5				
Code number	Date	Description	Partner	Type
D5.1	T0+30	Scale up feasibility	INASCO	Report

Table 2.3.4.2: Updated Milestones list for WP5

WP 5: Milestones and expected result			
N°	Date	Description	Assessment criteria
M5.1	T0+30	Flight Worthy measurement system proposal	Delivery of D5.1