HEALTH MONITORING OF AIRCRAFT

BY NONLINEAR ELASTIC WAVE SPECTROSCOPY

AERONEWS

EC SIXTH FRAMEWORK PROGRAMME
PRIORITY 4: AERONAUTICS AND SPACE
SPECIFIC TARGETED RESEARCH: AST3-CT-2003-502927
PROJECT WEBPAGE: http://www.kuleuven-kortrijk.be/aeronews/
PROJECT COORDINATOR: Prof. KOEN VAN DEN ABEELE

Final Activity Report (P1-P4)

PUBLISHABLE EXECUTIVE SUMMARY

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Project coordinator name: Koen Van Den Abeele
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Publishable executive summary

Health monitoring of aircraft by Nonlinear Elastic Wave Spectroscopy (AERONEWS)

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Web-site: http://www.kuleuven-kortrijk.be/AERONEWS/

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Zemedelske druzstvo Rpety se sidlem ve Rpetec	CR
Institute of Thermo-mechanics of the Academy of Sciences of Czech Republic	CR
Vyzkumny a zkusebni letecky ustav, a.s.	CR
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NDT Expert	FR
Fraunhofer Gesellschaft zur Förderung der angewandten Forschung e.V.	DE
Politecnico di Torino	IT
Università di Napoli “Federico II” – Dipartimento di Progettazione Aeronautica	IT
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The University of Exeter	UK
The University of Bristol	UK
The University of Nottingham	UK
Cranfield University	UK

Background and Project Objectives

Recent advances in aeronautics require the development of non-destructive evaluation (NDE) techniques that allow the quantification of *microstructural damage* in a wide variety of materials during their manufacture and life cycle, ensuring both their quality and durability. Traditional NDE techniques such as high quality linear acoustic, electromagnetic and visual inspection methods are not sufficiently sensitive to the presence and development of domains of incipient and progressive damage. For this purpose, we are proposing the development and validation of an innovative microdamage inspection system based on Nonlinear Elastic Wave Spectroscopy (NEWS).

The *primary objective* of this project is to enhance and implement new experimental and simulation tools necessary to measure, characterize, predict, quantify, and locate early stage damage in aircraft components and structures, based on the nonlinear response of the material. Nonlinear Elastic Wave Spectroscopy (NEWS) has proven to be very sensitive and effective in detecting micro-damage in materials at early stages of failure, and long before linear acoustic properties show signs of material degradation. The focus will be on the expansion of the present knowledge of the nonlinear behaviour of progressive fatigue damage in aircraft parts and structures (WP1-WP2), on the development of explicit sensor systems and advanced self-monitoring components (WP3), on the formulation of an integrated design for a testing procedure and a unique engineered monitoring system for microdamage inspection (WP4), including remote control and communication tools, and on the validation of the applicability of the system to real time in-situ inspection of a full-scale model on the ground (WP5).

Description of work

The academic capabilities and usefulness of NEWS techniques will be extended in five ways.

- Validate and certify the use of NEWS in aeronautics by extending the application of NEWS methods on materials and objects for which there is a pronounced need in aeronautics (WP1) and by formulating recommendations for the selection between different NEWS techniques with respect to materials, structures and experimental situation.
- Propose and develop the methodology for a NEWS technology-based imaging system (NEWIMAGE) through intensive NEWS modelling and enhanced numerical support for nonlinear acoustic imaging techniques of damage (localization) (WP2).
- Design smart transducer/sensing systems by developing innovative transducer-receiver systems for embedded instrumentation and advanced NDE (WP3), along with comprehensive data recording and analysis tools (WP4).
- Prepare the necessary grounds for the development of a test device measurement system by combining the NEWS ideas with advanced transducer solutions (WP3), wireless and remote communication capabilities and a user-friendly Graphic Interface (WP4) to develop an efficient, semi-automatic and reliable package for monitoring and identification of microdamage.
- Verification of the capabilities of the health monitoring system by integrating the measurement system as a portable or permanent damage diagnostic tool on selected key aircraft parts of a full scale model on the ground (WP5).

Expected Results

The development and preliminary verification of an innovative NEWS-based NDT technology and its engineering applications in aeronautics envisaged in this project, will result in an enhanced, reliable and integrated prototype measurement system and protocol for microcrack diagnostics of selected aircraft components and structures. Due to the increased sensitivity of the technology, we expect this development to result in a significant increase in aircraft and passenger safety while contributing to a substantial cost savings through a decrease in maintenance and operating times. The long term goals are the engineering of a standard measurement system based on NEWS for continuous health monitoring and early stage damage diagnosis.

Summary of the work performed in the AERONEWS project (March 1, 2004 – Feb. 29, 2008)

As a first task within the project, the partners of AERONEWS and the user group have concentrated on selecting critical parts and structures of interest to aeronautics NDT and on identifying several most common failure scenarios. This work led to an extensive database of available testing material, with representative samples ranging from steels to CFRP, honeycombs, and glass. Also, the type of damage (failure scenarios) is quite extensive, from weak bonding to single cracks, localized and extended microcracked regions, and corrosion. All suppliers have prepared an identification certificate for each sample or group of samples, stating the dimensions, composition, loading history (strength/tolerance of the material, fatigue/damage process: high cycle fatigue, low cycle fatigue, impact) and the results of (traditional) NDT experiments (x-ray, UT, etc). Along with the sample database, a list has been made for the organisation of the distribution of the samples among the partners involved with experimentation (WP1/D1-D2 + WP1/M1). The diversity of the samples provided an excellent basis for investigating a wide range of experimental techniques. The sample list and distribution schedule have been constantly updated during the project.

Following the selection and distribution of the samples, the AERONEWS activity has mostly concerned with the description and critical evaluation of NEWS techniques for quality control of basic aeronautical components (composites, layered materials and metals) and with their comparison with competing methods. At first, experimental investigations of NEWS techniques were performed on a range of simple components including various metals, polymers, welded joints, adhesive bonds, and composite laminates with various kinds of defects such as corrosion, fatigue cracks, impact damage, thermal damage, etc. (WP1/D3). The NEWS procedures that were focused on, include nonlinear ultrasonic transmission and reflection comprising higher harmonic generation of a narrowband excitation, ultrasonic wave mixing and bispectral analysis of two independent ultrasonic signals, nonlinear reverberation spectroscopy, nonlinear time reversal acoustics, high frequency multi-sine broadband excitation, contact phase modulation in bi-layered solids, frequency response function technique using arrays of actuators and sensors to determine a damage index by recognition-based neural network learning, 3^{rd} order parametric excitation profiting by the strong dispersive character of flexural waves, and phase-coded pulse sequence technique. Several of these techniques have shown sensitive signatures of the defects and have been optimized for the first implementation and testing session on real aeronautical structures during the technical workshop in Prague (May 2006).

In the second and third year the WP1 work concentrated mainly on the feasibility of the NEWS techniques by their application to thin extended structures and components of complex geometries (WP1/D4). It has provided an important feedback to the limitations and potentials of the NEWS techniques (WP1/D5 + WP1/M2) and to the objectives of WP5.

To achieve the goals of WP1 (experiments) and WP5 (application), the aeronautical partners provided several models of extended aircraft structures: a part of a fuselage, a wing lower surface test panel, and a Clevis Attachment with two and three lugs. A first special hands-on workshop (the *Prague experimental week* I) devoted to NEWS tests on the latter two samples took place at VZLU on 22nd – 26th May 2006 in the presence of 26 participants. During this workshop a preliminary attempt was made to extend the NEWS techniques originally developed for simple structures to complex structures. Each participant/partner was responsible for his/her experimental set-up and prepared and organized his/her own measurements. VZLU performed fatigue tests of the wing test panel and on the clevis attachment and provided AERONEWS participants with information regarding fatigue testing for the evaluation of their own measurements. The crack opening and closing was constantly monitored by acoustic emission (Dakel), visual inspection (VZLU), and Guided Plate mode ultrasound (VUB). In between, several partners made NEWS measurements to assess the damage. The conclusion of the first 'Prague experimental week" (described in the "Prague

experimental week activity report" which has been submitted together with the 30m intermediate report and is also part of the deliverable WP1/D4) was that, although the various techniques were not yet optimized for the use on extended and complex samples, results were overall positive and provided useful guidance as to how the technique can be improved. These conclusions have also guided the selection of the testing objects for the final validation in WP5 (WP5/D17). Besides the tests that occurred at the occasion of the Prague Experimental week, other efforts focused on the optimization of the frequency-response-function analysis for defect localization, with reference to the actuators, the sensors, and the signal processing tools. Among other samples, an MD11 part of a fuselage reinforced panel has been extensively investigated and used as "test field" for comparison of different approaches to the problem.

After the first Prague meeting it was decided to focus on a steering actuator bracket and a fork leg from a nose landing gear (chosen object for validation testing in WP5/D17). In preparation of the validation tests, the partners have been able to test an intact and a fatigued bracket, and two intact fork legs in their laboratories, and a special common experimental session has been organized at Exeter University in January 2007 with special focus on the integration of devices for the prototype development (WP4). The techniques included nonlinear wave propagation, nonlinear wave modulation, impact modulation, and nonlinear reverberation spectroscopy. The results were promising, showing both global and local signatures of damage. To prove the increased sensitivity of nonlinear techniques in NDT evaluations, an extensive monitoring experiment was planned and executed as part of WP5 in May 2007 in Prague.

In the final stages of the project, WP1 continued to operate as a support for the work that was planned in WP5 on the implementation of the NEWS techniques and the validation of the results. Part of this considered the comparison of the sensitivity of the results to traditional inspection techniques. Apart from the NEWS techniques developed as part of WP1, the consortium members provided Eddy Current testing, Rayleigh Surface Acoustic Wave inspection and Phased Array inspection. The different NEWS techniques have been constantly updated based on the experience gained within the project during the fatigue testing of the steering bracket. Most of the techniques that had been applied to single components were attempted on extended structures and complex geometries with varying degrees of success. Based on the experience of all partners using NEWS techniques, a database of the most important characteristics, requirements and limitations of the various techniques has been produced. Because of the need to deal with different component types and damages as well as to provide both global coverage and localization and in order to be able to compare the sensitivity of NEWS with traditional methods in more detail, the consortium decided that the validation testing envisaged in WP5 was going to be performed by a selection of NEWS techniques rather than just a single one as indicated in the description of work. The techniques have been grouped according to the component type under investigation (Deliverable WP1/D5 and Milestone WP1/M2).

In the domain of numerical modeling (WP2), the main goals are to provide numerical support for the experiments performed in WP1 and to develop the methodology for a NEWS technology-based imaging system (NEWIMAGE) through intensive NEWS modeling. With this aim, the AERONEWS partners involved in WP2 have modified their initial models and codes to enable the simulation of real experimental conditions by extending their nonlinear multi-scale models to two and three dimensional numerical problems.

On one hand, these codes/models were used to provide support to the development and improvement of NEWS techniques for damage diagnostics in aeronautical applications, as for example in the case of frequency modulation experiments on 2D laminate structures, 2D nonlinear Rayleigh wave propagation experiments, phase modulation analysis, nonlinear reverberation and resonance experiments, and bi-spectral analysis. Details on the results of the interaction of WP1 and WP2 in terms of modelling support for experiments can be found in the internal report WP2/D6.

On the other hand, based on the numerical modeling, two methodologies for damage localization were proposed.

- The main interest of the partners has been on the use of Time Reversed (TR) acoustics and its modification in order to exploit the potential and sensitivity of NEWS techniques. A nonlinearity based version of TR was developed and the methodology was tested by means of real and numerical experiments with interesting and encouraging results regarding damage localization. NEWS-TR can be operated in either harmonic filtering mode or using the Phase Coded Pulse Sequence filtering (also known as Pulse Inversion Method). An alternative version consists of using TR to focus energy on certain spots (surfaces) and to exploit and investigate the local nonlinear effects that way (TR-NEWS). Details can be found in WP2/D7 and WP2/D9.
- The second NEWS based imaging technique which is proposed is called MUMONRAS (Multi Mode Nonlinear Resonance Acoustic Spectroscopy). The methodology is based on the interpretation of the amplitude dependent resonance frequency shift for different resonance modes of a given object in terms of the corresponding stress field of the resonance mode. The results suggest an alternative procedure for imaging micro-scale damage with high sensitivity. The methodology and some results are also reported in the internal report WP2/D7.

Multi-dimensional extensions of NEWS based TR techniques and the development of (pseudo spectral, finite difference, and finite element) codes for parallel computing in order to meet the demands of complex 3D models have led to a number of simulations of 2D and 3D cases for wave propagation and the discrimination of damage zones in complex media with linear scatterers, such as corners, voids, and impedance barriers (WP2/D10). To focus the wave energy on the damage areas, different filtering techniques have been investigated. The sensitivity obtained in the NEWS based TR simulations in such cases tells us that it is feasible to apply the technique in real situations. As part of WP2, the simulations also concerned an optimisation study regarding the critical position of the receivers, the number/extent of receiver arrays, the robustness of the technique, the influence of experimental system noise on the treated signals, the discrimination of several sources of nonlinearity by iteration, etc. This work has supported the development of NEWIMAGE techniques for practical applications (WP2/D8).

Further developments are situated on the level of source identification and the description of arbitrary geometry objects using Finite element techniques. This was done in many cases with very good results and gain from the experimental point of view, e.g. using SSR-TRA. A refined finite element (FE) model of the steering actuator bracket has been built and successfully tested in NEWS-TR simulations. Promising results were obtained with synthetic forward-propagation data. Complementing the localization technique using NEWS based time reversal, an extension of the NEWS methods to nonlinear tomographic techniques has been proposed. This new technique is extremely appealing in terms of structural health monitoring using a sparse array device and NEWS based analysis coupled to numerical simulations. Furthermore, new interesting methods regarding signal processing have been investigated in order to improve the information retained during a filtering process. This is considered to be of high interest in real experiments, due to the easiness of the technique proposed, and from a theoretical point of view it can be exploited for the development of new NEWS-imaging techniques.

The main conclusion of this WP is that the numerical simulations have indeed supported the developments on the experimental level for NEWS based imaging techniques of micro-damage The techniques NEWS-TR and TR-NEWS with their added features such as advanced filtering have been implemented as a result in the full scale testing in WP5 after the robustness and effectiveness of the methods has been studied numerically.

The work planned in relation to the design of smart transducer/sensing systems by developing innovative transducer-receiver systems for embedded instrumentation and advanced NDE has led in

the first place to a survey on current and emerging sensor and transducer technologies and a mapping of these technologies to the specific demands of NEWS and NEWIMAGE (WP3/D11). The complete report of this survey contains an overview of NEWS techniques, contact transducers, optical and air-coupled transducers, and of the current state of the art embedded transducer possibilities. The report is a high level document for each experimentalist using NEWS and forms the basis in the currently ongoing development of excitation and sensing system(s) envisaged in the practical implementation/demonstration of the AERONEWS project.

In WP3, the main efforts were dedicated to the development of new transducers and to the adaption of existing ones according to the specific requirements of NEWS techniques. Various transducer and exciter configurations strategies have been studied in close collaboration with the techniques developed under WP1. The conclusion of this study made clear early during the project that no single transducer/sensor would be the answer for all techniques since the techniques themselves are different in nature and have different requirements. The focus was given to develop transducers/sensors for families of techniques and identify the selection criteria to allow fast identification of the appropriate device. In connection with this, the milestone M4 reports that the decision on which transducers should be used for which techniques should be taken in conjunction with milestone M2 according to the frequency-power-sensitivity demands which are summarized in two very important graphs.

The main achievements by the AERONEWS partners participating in this workpackage were (see WP3/D12 + WP3/M4 for details):

- Development of paired piezoelectric ceramic elements for selectively receiving specific harmonics of a given excitation frequency.
- Development of Cheap Optical Transducers which use lasers for excitation and detection of ultrasound.
- Experiments with dual ultrasonic sources (Low Frequency and High Frequency) using surface acoustic waves and laser excitation for the high frequency.
- Development of transducers with low higher harmonic output, i.e. extremely narrowband transducers, using piezoelectric single crystal materials such as ZnO, $LiNbO_3$, PMN-PT.
- Development of high-frequency wideband and air-coupled piezoelectric transducers (0.75MHz center frequency, planar or focused) operating in pulse-echo mode for surface vibration measurements of the sample.
- Investigation of the nonlinearity of transducers showing the influence of the spot position on the emitting surface of the transducer and the influence of the mechanical load on the second harmonic quantity generated.
- Optimization of excitation applied to the NL-TRA experiments with the application of the classical pulse inversion method and with the development of an advanced pulse inversion method.
- Investigation of piezoelectric actuators and sensors integration and testing of technologies for bonding and/or embedding of devices in fiber-glass panels using piezoelectric and Bragg Grant devices leading to the realization of “smart” components with self diagnostic features with a relative low number of actuating/sensing devices.
- Design and construction of smart surface contact transducers and systems with an integrated pre-amplifier and power amplifier to work with wide band PZT/Composite transducers for incorporation into a NEWS inspection system (developed under WP4).
- Design and testing of system concepts using SAW for specific alloy air plane components (slat

tracks) with limited available space on fully equipped slat tracks.

The constant interaction between WP3 and the other workpackages (especially WP1, WP4, and WP5) provided valuable information especially for the selection and optimization methodology related to the position, mode, and frequency content of the transducers and sensors. This was one of the main purposes for the Prague experimental week where many of the sensors/exciters developed within this workpackage were tested in the practical implementation of the different techniques under realistic conditions. The final result of this workpackage provided a methodology for sensor/transducer selection and placement together with a standardized set of sensors for NEWS techniques. This also encompassed fabricating and embedding transducers to make smart aeronautical structures for on-ground health monitoring and the use of external sensors/transducers to precise defect localization and smart NDE, taking into account feedback from all the other workpackages. Optimization of transducer and sensor requirements were conducted for the novel devices developed (for details see WP3/D13). The development of low temperature plasma deposition of piezoelectric PZT layers on thin metallic substrates (self polarization technology) has been realized. Exigent optimization of deposition procedure (composition, high purity of material constituents, and preparing conditions) resulted in manufacturing of several functional PZT patches on steel foil substrates. PZT patches allow transducer "embedding" on the surface of selected aircraft parts, especially with curved surfaces. In the very final stages of the project, the PZT sprayed patches have been applied on wing panels and on slat tracks of Airbus A320 and A380 in order to validate their possible use for on-line damage monitoring. In addition, integration of the transducers into aircraft components (embedding) was evaluated, for instance in composite plates. Many of the developed devices were used during the final trial stage of the project on the chosen test components.

The initial work in WP4 concerned the inventory of details to enable a hardware and software requirements specification to be made, based on the interaction between WP1-2 and WP3. From the analysis of excitation and sensing systems, together with current experimental tests and mathematical modeling of acoustic properties within damaged materials, a hardware and software specification for an integrated NEWS analysis system has been made (WP4/D14). The specification considered operational frequencies up to 10 MHz. Some initial prototype electronics, called ‘NBOX’, were developed during the first year of operation, following these hard- and software requirements, and were tested to evaluate the enabling technology.

The requirement identification (resulting from WP1 and 2) and the preliminary design of an advanced smart transducer package for implementation in the complete inspection system, satisfying the NEWS application demands (main objective of WP3), was taken as input in WP4 for the further development of the first prototype NEWS measurement systems. These prototypes have been used in a series of experimental tests on various aircraft components in Prague and in Exeter. The initial findings resulted in an analysis of the data flow rates required for the three principle methods of NEWS testing (harmonics, intermodulation, and time reversal NEWS). The evaluation and the review of the specifications has lead to the construction of a new type of NBOX and a continuous monitoring system, which is running in parallel with the development of the NBOX’s (see deliverable WP4/D14). Concerning the hardware improvement on the controller and communication board, the continued development of the (controller) firmware, the continued development of the new advanced (Linux 2.6) driver, and the development of the prototype of the relay switching between the analog input and output signal paths were optimized. Finally, the ARM7 micro controller based integrated system has been investigated to provide hand held monitoring and display of the data provided by the NBOX’s, as well as the use of the zigbee radio networking system.

The followed design concept has proven to be very useful as each module was used and assessed in experimental programs with design modifications and developments resulting at each stage. The

development will finally lead to commercial exploitation (WP6). The test device based upon this technology now consists of many interconnected and compatible devices developed in an iterative design process and brought together to perform a series of tests on aircraft components using most of the NEWS principles. (Details can be found in WP4/D15.) The pilot test devices were used during the experiments performed at VZLU in Prague (May-June 2007) and have been adjusted based on the results obtained during the last year. Members of the AERONEWS consortium and the user group can possibly create their own particular measuring and testing systems for specific applications from these basic modules.

Also considered within WP4 was how such NEWS systems may be configured and integrated into existing airport monitoring systems. The consortium analyzed and studied wireless airport communication systems, which include the inventory of existing wireless systems, an investigation of the user requirements and spectrum issues, and a synthesis of data link airport services. Details concerning the radio regulations and standards have been provided to see if this affects the final design. Any software being developed by the AERONEWS project with the aim of being installed in an airborne system must comply with the standard RTCA-DO 178B “Software considerations in airborne systems and equipment certification”.

The deliverable WP4/D16 has not been fully concluded as expected, that is by providing a complete remote controlled system. However the work undertaken has provided information on the technical routes to such a system and the obstacles that will prevent its immediate practical implementation. The work also provided an analysis of the bandwidths and data flow requirements of a NEWS system, this proved valuable in determining which technology to select. The investigations and demonstrations have shown that remote command instructions can be delivered over various types of radio devices and via a Local Area Network connection (LAN). The possibility of integrating NEWS systems into existing monitoring systems already implemented in aircraft has been investigated. Currently used engine monitoring systems report directly from the aircraft to the ground where specific software aids to interpret the data so that the needed maintenance actions are organised when the plane has landed. In principle, it is suggested to use the same platform for NEWS methods.

WP5 started off at month 18 with subtask WP5.1 “Choice of an appropriate site and testing object” for validation of the efficiency of the proposed NEWS system. At an early stage in the project, the decision was made to use the facilities of VZLU in Prague for the ultimate full scale tests. With respect to the test preparation and assembly task of WP5, a first test week has been organized at the VZLU facilities for conducting the preliminary experimental investigations by various AERONEWS partners of the feasibility to apply the NEWS technique on specific structural components (May 22-26 2006). For the partners the purpose of this week was to work on realistic samples that are subject to progressively increased damage. This has served as a stage in-between pure laboratory tests and the final full scale tests. Several samples were available for inspection of fatigue damage (aluminum wing like structure), impact damage (monolithic CFRP), and heat damage (monolithic CFRP). The potential NEWS procedures for damage detection considered in WP1 were identified together with their requirements on devices and transducers, their advantages and disadvantages.

After the first Prague meeting, the consortium decided to concentrate on a nose landing gear (with different structural elements such as the steering actuator bracket and the fork leg) as the final testing object (see Deliverable WP5/D17, submitted together with the 30m report). In addition, a plan was agreed containing the future steps (timing and personnel) in the WP5 activities to ensure a complete achievement of the deliverables. As part of the plan, a series of development tests were performed at individual universities and institutes on the intact and a fatigued steering actuator bracket (WP5.2, WP5.3). The second development tests were held in Exeter University, January 2007. The third measurement session dealing with an extensive monitoring of fatigue process on different structural elements of a nose landing gear, the steering actuator bracket and the fork leg, was again held in Prague (VZLU facilities) from May 28 till June 1, 2007. Ten different partners tested conventional

and NEWS based techniques on gradually fatigued components to validate the sensitivity of each technique with regards to the detection of early micro-damage. During the experimental week the fatigue loading (0-20000 cycles in steps of roughly 5000 cycles) was not enough to create noticeable micro-damage, even though AE monitoring and some of the NEWS based techniques gave an indication of incipient damage during the last stage of fatiguing. High frequency and high amplitude nonlinear techniques such as NEWS-TR and impact-modulation gave a slight indication of some damage whereas no linear technique could detect the miniature cracks. Additional fatiguing and NEWS testing have been continued over the last 6 months as part of the final validation of the techniques. The subsequent testing was performed at the individual laboratories of the partners involved in WP5. At the final stage (123000 cycles) a 2mm crack was observed near one of the corners of the sample. It was detected by eddy current, by the linear Rayleigh wave technique, and by the high frequency nonlinear techniques. This proves our initial hypothesis that the nonlinearity based techniques are more sensitive than the linear techniques. Details can be found in WP5/D18-D19.

The experimental results obtained in WP1 and WP5 gave a good foundation to analyze the possible applicability of nonlinear methods in the aeronautical industry as a tool for non destructive testing (WP5.3). As part of WP5, recommendations were specified for follow-up NEWS technology standardization and maturation in view of the implementation of the system on aircrafts. Details can be found in WP5/D20-D21.

Achievements regarding dissemination (WP6/D22) over the four years include the implementation of a dedicated web-based portal for communication and file exchange between AERONEWS partners, the organisation of more than 25 special sessions at several international conferences, the publication of about 50 scientific papers in international reviewed journals, and the advertisement of the project and project results through magazine publications, folders, brochures, and posters. Extensive details can be found in the ‘ANNEX Plan for using and disseminating the knowledge’. As a summary of the scientific work we also provided an overview of the necessary initial steps towards standardisation of the methods (WP6/D23). However, the most imperative activity in WP6 concerned the decisions for patent proposals on the technological developments that have resulted from the AERONEWS project. Three partners have initiated the submission of a patent for their developments on NBOX technology (EXETER), CHOT technology (UNOTT) and MV-2/NDT (Uni-Na).

On the management level, the main achievements have been the organisation of the 6-monthly general assembly meetings, including the kick-off meeting in Brussels, the mid-term meeting in Ghent (at 30m), which was considered to be a great success, and the final meeting (at 48m) in Toulouse. The meetings were all organized as a two days topical meeting reviewing the progress of the various workpackages and a general assembly dealing with consortium and management issues at the third day. All partners have experienced these meetings as being very fruitful and they have stimulated them in the further collaboration during the rest of the project.

Apart from these meetings, several other topical meetings have been organized. Especially the meetings in Prague were challenging since they involved also the movement of experimental equipment.

Other consortium/management tasks: In the last year of operation, the consortium agreed on a redistribution of the requested EC contribution among certain partners.

The coordinator also presented the AERONEWS project at the AERONAUTICS Days in Vienna, prepared advertisement of the project through different media (web-magazine-newspaper) and started collaboration with other EU funded projects on structural health modelling for the EU-FP7 call.

Summary of the Plan for using and disseminating the knowledge

Based on the technological development within AERONEWS in relation to the design of sensors and transducers, two patent applications are pending: one on NBOX technology (EXETER University) and one on CHOT's (University of NOTTINGHAM). These applications are in the first stages of the process.
The exploitable product fits is the domain of Ultrasonic Non destructive testing equipment. The sector(s) of application are Aeronautical & Civil engineering; Marine & Rail transport; Materials' Manufacturing; Inspection Pharmaceuticals; Food Industry. The Timetable for commercial use is 2008.
The University of Naples is currently taking the necessary preparations to apply for a patent for their development of the MV-2/NDT, a distributed DT inspection system based on MV-2 platforms and modified NDT-FRF algorithms.

Several more than 50 peer-reviewed international publications have appeared or are in press on research work performed in the four years of the project. All the publications make appropriate acknowledgement to the AERONEWS project and the FP7 program. The consortium has also been represented by its partners in more than 70 international conferences and exhibitions, giving close to 200 lectures about the NEWS applications in the field of microdamage assessment and aeronautics. In the past and over the next years, several partners have been/are responsible for the organization of about 20 special sessions on NEWS applications at international conferences. The consortium also organizes university courses for undergraduate, graduate, PhD and research students.

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Final Activity Report

PUBLISHABLE RESULTS OF THE PLAN FOR USING AND DISSEMINATING THE KNOWLEDGE

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