DOCTORATE RESEARCH PROGRAMMES ON SUSTAINABILITY / INNOVATION-RELATED TOPICS
Attachment 4

PhD PROGRAMME IN AEROSPACE SCIENCES AND ENGINEERING XXXVII CYCLE

Inter-university course in collaboration with University of Bari "Aldo Moro"

Department: Department of Mechanics, Mathematics and Management

Coordinator: Prof. Marco Donato de Tullio (marcodonato.detullio@poliba.it)

Places available:

- "Innovation" macro-area: 2 places
- "Sustainability" macro-area: 1 places

Candidates are advised that there are separate application calls for each macro-area. Candidates who intend to apply for both programmes must submit two different applications for each macro-area,

The current document includes attachments regarding specific details for research topic fields for each macro-area.

Admission Requirements

Applicants to the PhD programme in Aerospace Sciences and Engineering must hold a second level (specialized) degree as follows:

- Degree diploma awarded by an Italian university prior to Ministerial Decree 509/99;
- Specialist Degree (as per Ministerial Decree 509/99);
- Master's Degree (as per Ministerial Decree 270/04);
- Degree qualifications awarded by foreign universities officially recognised as equivalent to the above.

The Selection Board will decide upon the eligibility of qualifications as part of the assessment procedure.

Application Instructions:

Please note that the information provided in this paragraph **complements and does not substitute** that contained in arts. 2 and 3 of the Call for Applications document.

REQUIRED DOCUMENTATION

Candidates **must** upload the following documentation to their online application. **Failure to do so will result in their exclusion from the selection procedure**:

1. A **CV** following the layout of the **example** provided by Politecnico di Bari on the Politecnico website www.poliba.it in the *Ricerca/Dottorati di Ricerca* section. This file should be named "01.CV";
2. **A signed, valid identification document.** This file should be named ***"02.Documento riconoscimento". Only the following documents will be considered; failure to comply will result in exclusion from the selection process;***
   - ID cards, only if issued by an EU member state;
   - Driving licence, only if issued by an EU member state;
   - In all other cases, a fully valid passport (also non-EU citizens, including the UK);
3. **Degree qualification certification for first (Bachelor) degrees and second (specialization/Master's) degrees (or 5-year Single Cycle degrees)**. A list of all exams taken with their relative marks in both degree courses (or the Single Cycle course) should also be included,

following the example provided by Politecnico di Bari which is available from the Politecnico website in the *Ricerca/Dottorati di Ricerca* section. This file should be named "03.Titoli di laurea".

Candidates with **a degree qualification awarded by a non-Italian university** must attach the following documents to their application, prepared by the academic institute which issued them. This supersedes any form of self-declaration:

- Degree certificate or diploma showing relative final mark;
- Official transcript of exams taken during all university study programmes, showing relative results;
- Any other relevant documentation which demonstrates the equivalence of qualifications with those required in this application call (Supplementary Diploma, *Dichiarazione di Valore* (statement of value) issued locally).

These documents must be in Italian, French or English or translated into Italian or English and verified by an official Italian diplomatic or consular representative under the responsibility of the candidate. These should follow the guidelines set out in the document "*PROCEDURES FOR ENTRY, RESIDENCY AND ENROLMENT OF INTERNATIONAL STUDENTS AND THE RESPECTIVE RECOGNITION OF QUALIFICATIONS, FOR HIGHER EDUCATION COURSES IN ITALY FOR THE ACADEMIC YEAR 2021/22*" available at the link www.studiare-in-italia.it/studentistranieri;

4. **A summary / abstract of the thesis topic for specialist/Master's degree (or five-year Single Cycle degree),** stating the title and name of thesis supervisor(s) (max 3,000 characters); this file should be named "04.Abstract tesi";

5. **The candidate's thesis for specialist/Master's degree (or five-year Single Cycle degree);** for graduating students whose thesis is not yet complete (see art.2), a draft version of the thesis which has been completed up to the time of application; (N.B. *draft version* implies a version of the thesis text written by the graduating candidate up to the date of application, which, in terms of chapters and pages, allows the Selection Committee to evaluate its relative content and subject area. The abstract is uploaded as a separate file and is not accepted as a *draft version of the thesis* under any circumstances. This file should be named "05.Tesi";

6. **Research project proposal,** which must be completed in the format provided by the Politecnico di Bari; this is available at www.poliba.it/it/dottorati-di-ricerca. The proposal must include:

   - research project criteria in line with art.3 of Ministerial Decree 16061/2021 and art.5 of the call for applications document;
   - research topics in accordance with the PhD programme selected and relevant macro-area topic (Sustainability/Innovation, refer to attached macro-area details).

   Proposals are assessed purely as part of the selection procedure and are not necessarily those which candidates will develop during the programme. This file should be named "06.Proposta di Ricerca".

OPTIONAL DOCUMENTATION

7. **A self-certification declaration for any other qualification deemed suitable for evaluation** which must be signed and dated and follow the layout of the example provided by Politecnico di Bari on the Politecnico website www.poliba.it in the *Ricerca/Dottorati di Ricerca* section. In accordance with art. 46 (Statements in lieu of Certification) and art. 47 (Self-Drafted Affidavits) of Presidential Decree 445/2000 (pursuant to art. 15 of Stability Law 183/2011, candidates may not submit certificates and affidavits issued by public administrations or providers of public services for qualifications that are to be assessed. These certificates should be replaced by statements as per arts. 46 and 47 of Presidential Decree n. 445/2000). This file should be named "07. Dichiarazione altri titoli";

8. (additional, optional) **Two letters of presentation from teaching staff** who have supervised the candidate throughout their university studies. These files should be named "08.Lettere presentazione 1" , "08.Lettere presentazione 2";

9. **Language certification** demonstrating a knowledge of English which corresponds to at least B2 level. Only non-Italian citizens can attach certification which demonstrates knowledge of the Italian language. This file should be named "09.Certificazione linguistica 1" (2, 3 etc);
10. **Any publications** related to activity carried out and shown on the candidate's CV. This file should be named "10.Pubblicazione 1" (2, 3 etc);

All of the aforementioned documents must be in either Italian or English or translated into Italian or English, under the responsibility of the candidate.

In cases of large documents unavailable as electronic files or which exceed the number of MB permitted for documents, applicants may submit these separately (in paper format or as a CD or DVD-ROM), accompanied by a detailed list of contents, by 2 p.m. of the deadline date for admission applications.

Any publications submitted on paper or digital support must be sent in a closed envelope, signed along the seal, to the following address:

Magnifico Rettore del Politecnico di Bari – Direzione Gestione Risorse e Servizi Istituzionali-Settore Ricerca, Relazioni Internazionali e Post-Lauream - Ufficio Protocollo – Via Amendola 126/B, 70126 BARI (Italy)

Envelopes must display the name and surname of the candidate together with the following text: "*Concorso di Ammissione al Corso di Dottorato in…* (name of the PhD programme)". The delivery of the envelope containing publications to Politecnico di Bari - by postal service, private courier or shipping agency – is at the exclusive risk of the candidate.

Admission examination

The admission examination is based on:

1. **an assessment of qualifications held** (average exam marks, final degree mark, theses, Master's degrees, post-graduate courses, language certification, publications, etc.);

2. **an interview** to ensure a complete evaluation of the candidate and to verify the applicant's aptitude for research and willingness to undertake experience abroad, as well as areas of research interest.

The Selection Board will assess candidates' qualifications and interview with a mark out of 100 (maximum mark for qualifications 40 and interview 60). Candidates obtaining less than 10 marks for the qualification evaluation will not be admitted to the interview.

The results of the Board's assessment for qualifications and project proposals will be published on the ESSE3 portal in the private area of each candidate.

No other notification will be sent directly to candidates.

At the end of the examination procedure, the Board will carry out an overall assessment and draw up an admission rankings list on the basis of the marks obtained by candidates in each part of the examination.

The assessment criteria for qualifications will be established by each Selection Board.

SCHOLARSHIP N. 23

National Operational Programme 2014-2020
PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)
Academic Year 2021/2022 – XXXVII CYCLE

INNOVATION-BASED TOPICS (ACTION IV.4)

SCHOLARSHIP N. 23

A. Research Proposal
New generation avionics in unmanned vehicles for air mobility

a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and the formation of professional profiles as a response to the requirements of the business sector for innovation and competitiveness.

A development of research on topics of innovation, digital advancement and enabling technology while supporting the enhancement of human capital, determining factors in the progress of research and innovation in Italy.

According to the innovation plan of the European Institute of Innovation and Technology for the period 2021-2027 (L.189 / 98, 28.5.2021), the European Union aims to promote a rapid transfer of the results of research and innovation activities to the market and society. The development of intelligent systems for urban mobility, based also on the use of the vertical dimension (*Urban Air Mobility*), falls within the goals outlined for the technological development within the UE. The Urban Air Mobility, for the logistic and people transport, supports the decarbonisation process with the aim of reducing the global pollution. The change of the urban mobility paradigm towards eco-sustainable approaches, accomplishes the demands of the ecological transition. In this context, the research proposal aims at studying and designing new generation avionics systems in unmanned aircrafts for *Advanced/Urban air mobility*, which falls within the areas of interest of the Italian initiatives PNR and SNSI.

For the proposed topic, several application areas can be identified, as extra-urban monitoring for precision agriculture, road mobility control, coastal control and goods transport, being the latter the most important in terms of industrial development in Europe and potential for improving urban and metropolitan mobility.

The research proposal aims at establishing a partnership among research entities and business companies to innovate the technologies for urban and extra-urban mobility, also ensuring the technological transfer of the results towards the industrial partners involved in the project. In particular, the integration within the project of well-known national and international companies aims to increase the research impact, also representing an

added benefit for the national operational program, also in consideration of the huge socio-economic interest of the specific topic.
In addition to the valuable economic and commercial advantages related to the system prototyping, an added benefit is the high specialization of the Candidate, who, during the PhD program, will have to investigate the applications of the vehicles for Advanced/Urban air mobility. Furthermore, the Candidate will have to define the guidelines for the design of the avionics system to meet the requirements of the end user, by exploiting enabling technologies, such as micro- and nanoelectronics, photonics and wireless techniques. In collaboration with the co-proposing company, the Candidate will have to test the effectiveness of the vehicle, with careful attention paid to the cost and the entities interested in it. The partnership between university and business companies will contribute to jointly train a "talent", whose background will be useful is several regional and national economic sectors, in response to the demand for industry innovation and competitiveness in the specific sector.

b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students, with the aim of fostering innovation and exchange between the field of research and world of manufacturing and the certification of research project contributions within the sector of innovation (Law 240/2010, art. 24, section 3 and subsequent modifications and additions).

The proposed research activity aims at the study and the design of new generation avionics systems for vehicles in the Advance/Urban Air Mobility field. This research topic falls within the Subject Area "Digital Agenda, Smart Communities, Intelligent Mobility Systems", Trajectory "Urban Mobility Systems for Logistics and People" of the Italian initiative SNSI and in the subject area "Aerospace" of Italian initiative PNR 2021-2027. Currently, efforts are focused on exploiting the so-called "third dimension", that is, the air. In this scenario, as also demonstrated by the memorandum of understanding signed between the Italian Minister for Technological Innovation and Digitization and the President of ENAC in December 2019, urban air mobility represents the next generational leap, as a fertile breeding ground for the experimentation of both innovators and investors, opening up new technological, economic and industrial scenarios. Urban air mobility refers to all transport means designed for very short range (< 50 km) and low altitude (<1,500 meters from the ground) air travels, in urban and extra-urban areas.
Among the key functional elements of a vehicle, avionics systems ensure correct and safe positioning and orientation of the vehicle, also preserving the public safety. The research project focuses on the improving of the position and the orientation of vehicles, as drones, autonomous vehicles, robots, eVTOLs, etc. In addition to the standard approach based on GNSS with data augmentation, new inertial units will be investigated aiming at providing safe and sustainable mobility services. Systems based on the combination of GNSS and Inertial Navigation Systems (INSs) will be also explored, because of their huge potential. In the framework of the sustainable mobility (*automated, connected and safe mobility*), the development of systems for vehicles in the urban air mobility field satisfies the demands of an automated, connected, safe and competitive transport system. Furthermore, the development of these systems will help to support the ecological transition of the country, as desired by the REACT-EU program. A deep collaboration between the university and the company is required to meet the aforementioned goals, aiming at improving the innovation sector of the business companies. Since the envisaged research activities will allow training a professional figure in the innovation context, they fulfill the claims of the Italian Law 240/2010 and of the Italian Ministerial Decree 45/2013 for Doctorate Programs.

c. Research activity proposal, methods and contents

SCHOLARSHIP N. 23

The proposed research activity consists of three phases: identification of application scenarios and related requirements (phase #1), study and design (phase #2), testing of the proposed system (phase #3).

In the framework of the phase #1, the application scenarios of vehicles for urban air mobility will be identified, such as transport of goods, support to emergency services, transport of blood and organs, traffic or infrastructure monitoring, public safety. This activity will lead to identify the requirements for the avionics systems and any support payloads. During phase #2, the Candidate will have to analyze the avionic system solutions currently on the market and/or proposed in the literature. To estimate the vehicle position, the navigation and autonomous guidance systems include Global Navigation Satellite System (GNSS), GNSS with data augmented, GNSS/INS, Micro-Electromechanical System, Inertial Measurement Unit and Vision Based Navigation sensors.
The Candidate should assess the aforementioned technologies with reference to the required performance identified during phase #1. The requested performances could also be satisfied by innovative solutions, based on enabling technologies, (e.g. photonics), using skills developed at the Optoelectronics Laboratory of the Polytechnic University of Bari. The Lab boasts a multi-year development activity of high performance integrated photonic gyroscopes for extreme precision pointing, as demonstrated by several publications on international journals and by the international patent "*Optical Rotation sensor as well as method of manufacturing an optical rotation sensor*" and supported by several ongoing projects with companies and/or Space agencies. The application of technologies already developed by the Polytechnic could support the transfer technology process, that represents an added benefit of the proposal. During phase #3, the system prototype developed for a specific case study will be assembled and tested onboard the vehicle and the relative measurements will be analyzed to validate the results. A comparison with solutions already on the market and/or proposed in the literature will also be made to highlight the differences in terms of accuracy, safety, robustness, lightness, and repeatability of measurements. The fabrication and the characterization of the prototype in the phase #3 will allow to identify and solve problems that only the application context will be able to bring out. The reviews and the redesign of the prototype will also allow starting a first product engineering phase

B. COMPANY-BASED ACTIVITIES within the Italian territory

a. Research activity to carry out with the company

The company proposes and implements research, training and innovation projects for the development of key technologies, the creation of new professional figures, the construction of infrastructures for research and innovation purposes..
By exploiting the company's background in terms of innovative solutions in the aerospace sector, the Candidate will identify the application scenarios for the system to be designed, such as goods and passenger transport, precision agriculture, road mobility control, control of coasts and urban and extra-urban areas. This activity will be useful to define the required performance specifications, also outlining the most promising technological solutions.

b. Period of company-based study and research

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c. Measurable nature of expected results and potential impact of implemented actions with reference to the aims of the Recovery Assistance for Cohesion and the Territories of Europe

SCHOLARSHIP N. 23

programme (REACT-EU): quantifiable and measurable targets in doctoral research project in line with indicators set out in NOP reference of actions.

The current COVID-19 pandemic has also led to considerable losses in the aerospace sector, due to a redirection of European Community funds towards the "Health" macro-sector. A loss of about 4 billion euros in the sector has been estimated. The involvement in the following research program of a national company and an international company, operating in the aerospace sector, also aims to support the economy of this section, in compliance with the purposes of REACT-EU. The proposed research concerns the topic of innovation through the use of enabling technologies and the enhancement of human capital, with the aim of offering a contribution to the economy in our country. Ongoing and final results of the activities will be useful to assess the progress of the state-of-the-art in the field of the avionics systems. In particular, the goals of the three phases foreseen during the research program can be defined as follows:

• State-of-the-art of commercial and under development innovative avionics systems for Advanced/Urbain air mobility vehicles, also identifying the main application scenarios.

• Design of the avionics system. Innovative solutions will be investigated also to fulfil the application requirements.

• Manufacturing of the first prototype and testing of the technology in urban/extra-urban contexts.

These goals meet the PON benchmarks, and they are easily measurable, in accordance with the aims of the actions of REACT EU. The development of the proposed avionic system will require the merging of the know-how of the university and companies involved in the research project.

This partnership fulfils the # CO26 benchmark envisaged by Action 1.1.3 of the PON. A successful test of the device would lead to the introduction of the product in the production chain of the company, as aspired by the # 1b1 benchmark of Action 1.1.3 of the PON.

C. ACTIVITIES ABROAD

a. Research activity abroad

The foreign company involved in the research is a joint venture. It provides innovative solutions to a wide variety of military defense, civil and maritime security sectors. During the period abroad, the Candidate will have to carry out a field trial of the designed system, in urban and extra-urban contexts. This activity will focus on the validation of accuracy, reliability and safety of the developed system, such as to confirm the improvements compared to the technologies currently on the market.

SCHOLARSHIP N. 24

National Operational Programme 2014-2020
PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)
Academic Year 2021/2022 – XXXVII CYCLE

SUSTAINABILITY-BASED TOPICS (ACTION IV.5)

SCHOLARSHIP N. 24

A. RESEARCH PROPOSAL **Knowledge Representation for information fusion, inference and automatic coordination in swarms of Unmanned Aerial Vehicles for environmental monitoring and territorial control.**	
a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and overlap of knowledge and skills to promote the development of innovative products and services with reduced environmental impact, focusing on topics such as; **- protection of the ecosystem;** **- biodiversity;** **- reduction of climate change impact;** **- enhancement of sustainable development** **in order to promote green recovery and overcome the effects of the Covid-19 pandemic crisis.**	The study and research topics in the project proposal are fully consistent with the disciplinary field of the Ph.D. Course in Aerospace Engineering and Sciences, mainly concerning specialized skills and activities related to automatic control systems, complex sensor systems, data management and processing, artificial intelligence and cybersecurity. The variety of involved topics and scientific sectors denotes the strong interdisciplinary degree of the proposed Ph.D. scholarship. This allows the development of competencies and the implementation of methodologies and applications which, starting from aerospace engineering and sciences, can extend to similar areas, such as those of robotics, Smart Grids, environmental and territorial control, services related to the management and optimization of resources in a green perspective. The proposed research has a high level of innovation, thanks to the use of cutting-edge technologies based on the adoption of knowledge representation and automatic reasoning in multi-agent systems.

	Therefore, the results of the research will be able to bring scientific, social and economic benefits for the territory, by fostering the formation of skills and knowledge capable of facilitating the development of innovative services with a smaller environmental footprint and promoting the green transition.
b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students and grant funding to Sustainability-based research projects.	The proposed research is aimed at the study and application of distributed knowledge representation and automatic reasoning technologies for autonomous coordination in pervasive networks of intelligent objects. The possibility of integrating low-cost devices for data processing and transmission into heterogeneous objects allows for the simultaneous interaction of multiple devices and data stream acquisition from smart objects populating the environment. It is thus possible to identify events, classify phenomena, processes and interactions in progress, and decide on behaviors appropriate to the context. Due to the high dynamicity of data and devices in pervasive computing contexts, it is essential that individual agents are equipped with on-board inference procedures and automatic reasoning capabilities. However, there are still widely open research problems both in the optimization of traditional inference architectures and techniques for computing systems with highly limited resources, and in the management of individual agents in a distributed, coordinated, dynamic and autonomous way. The main application area of the technologies and methodologies under investigation will be the use of swarms of Unmanned Aerial Vehicles (UAVs) for innovative services such as environmental monitoring and territorial control. This kind of missions can reach levels of complexity that are difficult to manage with state-of-the-art technologies due to the size of the observation area, the required precision and the number of entities and phenomena to be identified, classified and monitored. In particular, the centralization of all data processing functionalities in a ground control station requires high bandwidth for data flows and a real-time response hardly fitting the inherent communication latencies. By applying the methodologies to be investigated in the research, it will be possible to define innovative frameworks with a limited computational load for the fusion of the data and information collected by on-board sensors, the classification of events/phenomena of interest and autonomous decision. By optimizing hardware and

	software resources, they will be executable on board of UAVs, with data interchange limited to compact high-level annotations within subsets of the aircraft swarm. This will bring benefits such as lower computational impact and greater energy autonomy. Due to these reasons, the proposed research topics are suitably framed in the National Intelligent Specialization Strategy, in relation to "Digital Agenda, Smart Communities, Intelligent Mobility Systems", within the "Embedded electronic systems, intelligent sensor networks, internet of things" development trajectory, as well as to the "Health, nutrition, quality of life" area, within the "Systems for the safety of the urban environment, environmental monitoring and the prevention of critical or risk events" trajectory.
c. Research activity proposal, methods and contents	The research proposal concerns the study, definition, optimization and application of techniques and methodologies for knowledge representation and automatic reasoning in scenarios requiring the cooperation of multiple agents – of homogeneous or heterogeneous type – for the accomplishment of a specific task. Currently, the possibility of integrating low-cost devices for data processing and transmission into heterogeneous objects opens up the opportunity to simultaneously interact with manifold devices and acquire data from smart objects populating an environment. It is thus possible to identify events, classify phenomena and processes in progress, and decide on behaviors appropriate to the context without external control. However, at the state of the art, data mining methodologies based on heuristics appear inadequate. Machine learning techniques, on the other hand, although increasingly effective, require processing and storage resources that are hardly adapted to real-time response in lightweight and pervasive computing infrastructures. A promising approach for more efficient analysis involves the annotation of objects in the physical world, collected data and the context they are immersed in by means of concise, structured and machine-understandable descriptions, based on knowledge representation languages and technologies. They can represent the input for the application of automatic inferences by intelligent agents, in order to deduce new implicit knowledge to be exploited for the pursuit of their goals. This approach can overcome the extant limitations in data interoperability as well as interpretability of results

	and models. The aim of the research is therefore to provide each agent, through the use of semantics, with greater awareness of the environment in which it operates and consequently the ability to make autonomous and coordinated decisions even in case of unforeseen events. To this end, the different frameworks, languages and tools used in knowledge representation and automatic reasoning will be analyzed. As of now, most inference engines are designed for desktop or server platforms, and are hardly adaptable to devices with highly constrained computing resources, such as Unmanned Aerial Vehicle (UAV) systems, which are the reference target for the functional and performance validation of the approaches and solutions proposed by the research. For these reasons, the proposed research will study techniques, methodologies and tools that guarantee the manipulation of knowledge bases on such devices. A further objective of the research concerns the design and implementation of new automatic inference services, which can be used in complex scenarios such as the autonomous and decentralized coordination of UAV swarms for environmental monitoring and territorial control.
B. COMPANY-BASED ACTIVITIES within the Italian territory	
a. Research activity to carry out with the company	The partner company carries out research and development activities in technologically advanced areas, such as the aerospace sector, cybersecurity and Internet of Things. In this context, the research activities to be carried out at the company concern the configuration and experimental development of a testbed, for the verification and validation of the knowledge and skills acquired during the PhD program and envisioned by the specific research proposal, within the scope of the exploitation of knowledge representation and automatic reasoning techniques for the autonomic coordination of teams of intelligent agents for environmental monitoring purposes. One of the main limitations of current multi-agent systems is that each agent has a partial view of the surrounding environment and wishes to obtain a more reliable and complete description of the context, by also considering the perspectives of the others. Approaches based on semantics can enable robust information fusion capabilities, guaranteeing each agent to automatically infer what characteristics it can offer or need in a completely decentralized and collaborative way. Therefore, the

	prototype to be developed must allow each agent to perform sensing and actuation operations, in order to: - merge information from heterogeneous sensors - produce high-level annotations of the surrounding environment - recognize conditions or events of interest - act correctly and dynamically given the current situation. A further activity may concern the management of secure information exchange and the coordination in teams of heterogeneous agents. In this perspective, it will be necessary to identify flexible and scalable mechanisms capable of guaranteeing information integrity within a collaboration framework among independent entities.
b. Period of company-based study and research	6 months
c. Measurable nature of expected results and potential impact of implemented actions with reference to the aims of the Recovery Assistance for Cohesion and the Territories of Europe programme (REACT-EU): **quantifiable and measurable targets in doctoral research project in line with indicators set out in NOP reference of actions.**	The activities outlined in the research proposal provide for the creation of new methodologies, frameworks and demonstrators based on the use of knowledge representation and automatic reasoning technologies that provide advanced services in distributed environments for decision support, monitoring and resource optimization, with particular reference to environmental protection and the efficient and effective use of computing resources. In particular, the research activity carried out at the company will lead to the creation of a prototype for the verification and experimental analysis of the proposed technologies: experimental measurements will be carried out on the developed prototype and obtained results will be analyzed in order to verify the potential of the proposed solutions. Any tangible output deriving from the research will be consolidated and disseminated through publications in scientific journals or participation in international conferences. Training opportunities for staff within the host company are also expected, so that the knowledge developed by the recipient of the Ph.D. scholarship can be acquired permanently and integrated into the company know-how and business practices. The high probability of employment at the regional, national and European level of the Ph.D. student involved in this program is therefore evident. Furthermore, the proposed research may be of interest to companies in the

	regional and national territory, through technology transfer and industrialization of developed technologies and prototypes, as well as with the training of professionals with greater skills in the proposed research areas and through the use of cutting-edge technological tools. All this comes in relation to a specific demand from companies operating in the aerospace sector, both in the Apulia Region and nationally, which are strongly interested in such scientific and technological advances. Based on these considerations, with reference to the purposes of the REACT-EU funds allocated by the European Union, it is possible to identify the correspondence of the expected results of the research with the objectives envisaged by the investments through the European Regional Development Fund (ERDF) in the "085 - Biodiversity, nature protection & green infrastructure" sector of the environment macro-area (in which Italy is the EU country with the highest allocation of ERDF resources) and in the "048 - ICT: Other types of ICT Infrastructure" sector of the digitization macro-area.
C. ACTIVITIES ABROAD	
a. Research activity abroad	Not expected.

SCHOLARSHIP N. 25

National Operational Programme 2014-2020
PhD programmes for sustainability and innovation-related subjects

Ministerial DECREE N. 1061 (10 Aug 2021)
Academic Year 2021/2022 – XXXVII CYCLE

INNOVATION-BASED TOPICS (ACTION IV.4)

SCHOLARSHIP N. 25

A. RESEARCH PROPOSAL **Development of innovative Non Destructive techniques for monitoring the structural integrity of aeronautical components**	
a. Relevance of doctorate research project in creating high added value in terms of scientific, social and economic impact on Italy, fostering appropriate research models and the formation of professional profiles as a response to the requirements of the business sector for innovation and competitiveness. **A development of research on topics of innovation, digital advancement and enabling technology while supporting the enhancement of human capital, determining factors in the progress of research and innovation in Italy.**	This research concerns the development of innovative techniques and methods of investigation and the design of components with 'embedded' and non-embedded sensors, for the 'monitoring of the state of integrity-SHM' of aircraft parts made with sustainable and circular materials. These activities will produce positive economic / environmental effects for the sector thanks to the repair of existing components which would limit their production and disposal. The added value is obtained from research, analysis, simulation and experimentation activities aimed at increasing knowledge on defects and damage mechanisms induced by the load conditions to which they are subjected. This will lead to generating a flow of know-how from the university to the company thanks to the training that will result for the group and the employees of the company concerned, on these issues. Thanks to university-based research, industrial research will cover company 'gaps' in relation to a specific problem and this will also allow us to propose a standard framework for computational modeling and testing of these materials. The analysis algorithms and test procedures will be exported to industry to create automated investigation systems. The result will be an enrichment in terms of knowledge in the industrial field thanks to the formation

	of highly specialized professional profiles constantly updated on the new test and analysis procedures in direct line with the University. It is planned to train a new professional figure of technician specialized in monitoring the structural integrity of the components. Such skills and knowledge will also be valid in other industrial fields. In the particular sector, the manufacturing industry will be able to consolidate and strengthen its competitiveness thanks to the fact that it is more versatile and sustainable. The added value is also given by the 'green' choice and the culture of monitoring, the future of the manufacturing industry, which is also pursued through the enhancement of human capital through the definition, communication and pursuit of a long-term purpose or the creation of new highly specialized professionals. This should generate a culture in which people adhere to a system of values and a positive long-term vision and strive to achieve it, contributing to the improvement of the aerospace sector and generating a positive impact on other people and industries. Finally, the implementation of these inspection techniques will significantly reduce the time and costs associated with repairs. With continuous condition monitoring, even if a defect appears, maintenance will be timely and cost-effective while ensuring the safety of airline passengers. This generally has repercussions on the entire aerospace sector as it indirectly contributes to ecological and safe air transport.
b. Adherence of doctorate research project to National Strategies of Intelligent Specialisations (SNSI) and PNR and applicability to Law 240/2010 and Ministerial Decree 45/2013 regarding PhD students, with the aim of fostering innovation and exchange between the field of research and world of manufacturing and the certification of research project contributions within the sector of innovation (Law 240/2010, art. 24, section 3 and subsequent modifications and additions).	In recent years, the culture of structural 'health' monitoring (SHM) has attracted increasing interest in assessing the state and diagnosing problems in the behaviour of components. All types of structural components, in service and not, require a certain level of integrity during their operational life to ensure performance and safety. However, exceptional, or complex degradation and stresses can cause severe component damage. Adequate monitoring of changes in structural behaviour (deformations / stresses) would allow the identification of critical states and / or local / global damage, providing useful feedback for maintenance and component design. This would allow a total exploitation of the material by foreseeing its useful life without sacrificing the safety of the product against sudden failures. Recent advances in non destructive techniques have made it possible to customize control and monitoring and to find the optimal one for each type of component. However, the still open issues that will be dealt with in this project are: • The development of innovative Non-Destructive Testing (NDT) procedures for the non-invasive assessment of

	structural conditions and related calculation methods for the intelligent identification of damage; • Damage detection and monitoring of structural integrity through the use of intelligent materials and devices; With this in mind, this project aims to develop techniques and methods of investigation with and without contact, and an innovative design of components with 'embedded and non' sensors to monitor the structural integrity of parts of the aircraft. With a view to implementing the 'green' choice, the components will be made of sustainable and circular materials such as those with a natural base or resulting from additive manufacturing processes such as 3D printing. There are 2 main aims of the project: to provide the tools to promote the use and application of such smart materials in industry and to make the production and disposal of such materials more environmentally sustainable. The potential of such research lies in the fact of promoting structures to be carbon neutral, renewable and recyclable but also promoting the culture of control and monitoring of structural integrity. The transversal nature of the research theme includes the most varied areas of engineering: naval, renewable energy, civil. The activities will be carried out with the aim of creating an integrated "eco-system" between basic and industrial research to pursue continuous innovation and an osmotic exchange of skills and knowledge between university and business thanks also to the training of the group and employees of the company involved. The outputs of the project will be essential for the aeronautical industry to produce increasingly high-performance but green products, trying to implement the transition from the linear to the circular economic paradigm.
c. Research activity proposal, methods and contents	The project aims to achieve the following Work Packages (WP): WP1: Development of experimental procedures for the study of the damage developed in composite materials stressed with static and dynamic loads. The goal will be achieved by conducting mechanical characterization tests on laboratory specimens made with sustainable and circular materials. The damage analysis will be conducted using non-destructive techniques capable of guaranteeing reliable results but in much faster times and a lower number of specimens than traditional techniques.

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	WP2: Development of non-destructive experimental procedures and techniques for the diagnostics of composite materials. The goal will be achieved by conducting non-destructive tests with thermographic techniques on specimens and components in composite material. The novelty of the survey is represented by the use of different sensors (embedded and contactless) for the complete characterization of defects in terms of size, depth and type. The aim is to reduce test times compared to traditional NDT techniques. WP3: Application and verification of procedures developed in the laboratory on components and structures on site. The verification of the objective will take place with the application of the procedures and techniques developed in the previous WPs on real components during normal operating conditions or during the stops provided for maintenance activities. Total research activity time: 36 months. Phase 1: Feasibility tests and optimization of the procedures developed with non-destructive techniques (from month 1 to month 12) - Choice of materials and production of specimens for mechanical characterization tests and production of specimens with known defects for non-destructive testing. - Test campaign with various non-destructive techniques (NDT) on the specimens made in order to optimize the set-up and test parameters. - Drafting of test procedures and software development for data analysis. Phase 2: Study of embedded sensors for continuous structural monitoring (from month 13 to month 24) - Choice of the most suitable sensors for application on the material chosen in Phase 1. - Test campaign on sample specimens in order to optimize set-up and test parameters. - Drafting of test procedures and software development for data analysis. Phase 3: Application of the procedures and software developed in Phases 1 and 2 on real components (from month 25 to month 36)

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	- Choice of components to be studied. - Application of the procedures developed in phases 1 and 2 on the selected components repeated at regular time intervals. - Application of the procedures and software developed in phases 1 and 2 on prototype components. - Drafting of a maintenance plan for the continuous control of real components.
B. COMPANY-BASED ACTIVITIES within the Italian territory	
a. Research activity to carry out with the company	The activities to be carried out at the company will be related to the following project phases: - interaction with the design department: a flow of information necessary to understand the criticalities of the component, to study the type of sensors to be used and finally to the choice of the prototype to be created will be outlined; - structural analysis, modification and integration of smart materials: this phase will be important for the design of the component and the definition of typical loads to which it is subjected; -realization of material: samples will be made operationally on which to perform the first tests and calibrate the techniques and sensors, the setups on the samples and the data analysis procedures will be defined; -assembly and prototype realization: the prototype and the inspection system will be built, the inspection setup will be defined; - traditional testing activities: testing activities will be carried out aimed at verifying procedures identified in the tests on samples.
b. Period of company-based study and research	6 months
c. Measurable nature of expected results and potential impact of implemented actions with reference to the aims of the Recovery Assistance for Cohesion and the Territories of Europe programme (REACT-EU): **quantifiable and measurable targets in doctoral research project in line**	The expected results will concern the possibility of achieving a correct exploitation of materials for the aeronautical sector thanks to the monitoring of the state of integrity and therefore of being able to effectively use the component for the estimated useful life, and then the promotion of new inspection methodologies to determine the structural state of the component. In addition, design guidelines for production processes strongly oriented towards circularity can be provided and the implementation of repair technologies and the intelligent

with indicators set out in NOP reference of actions.	recycling of end-of-life products will be considered already in the design phase. This will also allow the development of design and production processes based on end-to-end life cycle analysis by product, all in accordance with the objectives of increasing the sustainability of the production process and the industry in terms of structural components of the aircraft. The improvement of the recovery rate of materials is a quantifiable target that will make it possible to obtain as a result the greater sustainability of the production process of aeronautical components but also to disseminate in the industry new techniques for monitoring the structural health of components focused on inspection, increase the awareness and knowledge on the repair of products and in general favour the upgrade of existing components through intelligent components that monitor the state of damage and degradation. Concretely, another measurable result is the development of prototypes of non-destructive methods for structural integrity monitoring (NDT-SHM) of intelligent aeronautical components, this result will contribute to obtaining another quantifiable target given by the possibility of reducing the weight of the structures. increasing the payload. Another expected result is the dissemination of knowledge and university and company training on the use of intrinsic and non-intrinsic sensors, to monitor the structural health of the component, a subject that has a significant impact not only on the manufacturing industry but also on industries in general. related to it. In this sense, the quantifiable target is given by the possibility of increasing the useful life of products with high added value by a few years and reducing the incidence of maintenance costs by several percentage points. This project will also result in the birth of new professional figures, technicians specialized in controls with intelligent materials and this will produce significant employment effects in the manufacturing industry as well as in related industries. These activities are aimed at enhancing the technological and industrial capabilities of the local industrial fabric compared to the competition by exploiting innovation in a broad vision of sustainability that combines the reduction of environmental impact with well-being and the development of green and intelligent technologies in transport. plane of the future.
C. ACTIVITIES ABROAD	

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a. Research activity abroad	The activity to be carried out at the foreign university will be focused on the characterization of the base material and the material with sensors with the aim of characterizing them mechanically, studying the influence on the mechanical properties of the sensors and evaluating the impact of the presence of the sensors on the mechanical characteristics. in general. The characterization will take place both with traditional procedures and with rapid innovative procedures such as those based on thermography. Furthermore, the characterization tests will be assisted by experimental techniques capable of providing complementary information for the study and characterization of the damage. The tests to be performed will concern static and cyclical tests to characterize the fatigue and fracture behaviour. The objective of the collaboration is to study the fatigue behaviour and fracture mechanics and also to evaluate the behaviour of the aforementioned carved materials through the use of energy methods based on local approaches such as the one aimed at measuring the deformation energy density, and based on full-field thermographic techniques aimed at the thermoelastic analysis of stresses and the study of intrinsic dissipative sources. As for the fatigue characterization, the analyses will also be addressed from a probabilistic point of view in order to improve the statistical interpretation of the data. With regard to the mechanics of the fracture, methodologies will be studied to separate the elastic and plastic contribution to the 'J-integral' and methodologies for obtaining the plastic area at the crack apex and the energy contribution at the crack apex. The activity to be carried out will be focused on the characterization of the base material and the material with sensors with the aim of characterizing them mechanically, studying the influence on the mechanical properties of the sensors and evaluating the impact of presence of sensors on the mechanical characteristics in general. The characterization will take place both with traditional procedures and with rapid innovative procedures such as those based on thermography. Furthermore, the characterization tests will be assisted by experimental techniques capable of providing complementary information for the study and characterization of the damage. The tests to be performed will concern static and cyclical tests to characterize the fatigue and fracture behaviour. The objective of the collaboration is to study the fatigue behaviour and the mechanics of the fracture is also to evaluate the behaviour of the aforementioned carved

	materials through the use of energy methods based on local approaches such as the one aimed at measuring the deformation energy density and based on full-field thermographic techniques aimed at the thermoelastic analysis of stresses and the study of intrinsic dissipative sources. As for the fatigue characterization, the analyses will also be addressed from a probabilistic point of view in order to improve the statistical interpretation of the data. Regarding the mechanics of the fracture, methodologies will be studied to separate the elastic and plastic contribution to the 'J-integral' and methodologies for obtaining the plastic area at the crack apex and the energy contribution at the crack apex. The partner in particular the mechanical and industrial engineering department boasts great experience in characterizing the physical and mechanical properties of traditional and innovative metals (mainly aluminium, magnesium and titanium alloys) with particular attention to multiscale problems related to damage and degradation due to loads in service, of the physical and mechanical properties of additive manufacturing metals (e.g. titanium Ti6Al4V) through local approaches for the fatigue and fracture design of metallic materials to which the fundamental experience in the SEM / TEM characterization of initiation and propagation is linked of cracks in the materials. The activities can be summarized as follows: • Choice of material and design of test samples and definition of the test campaign. The choice of material derives from the activities carried out in agreement with the company; • Definition of testing and setup procedures on the material; • Testing and analysis of results. In particular, the analysis of the results will include the definition of intelligent analysis algorithms based on the automatic characterization of damage; • Testing of the component and verification of the test and analysis procedures on it.