Call: HORIZON-MSCA-2022-DN-01

(MSCA Doctoral Networks 2022)

Topic: HORIZON-MSCA-2022-DN-01-01

Type of Action: HORIZON-TMA-MSCA-DN

Proposal number: 101119959

Proposal acronym: SpecX

Type of Model Grant Agreement: HORIZON Unit Grant

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Proposal ID **101119959**

Acronym **SpecX**

1 - General information

Fields marked * are mandatory to fill.

Topic	HORIZON-MSCA-2022-DN-01-01	Type of Action	HORIZON-TMA-MSCA-DN
Call	HORIZON-MSCA-2022-DN-01	Type of Model Grant Agreement	HORIZON-AG-UN

Acronym: SpecX

Proposal title: Doctoral Network on Spectrum Analytics as a Service

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months: 48

Panel: ENG - Information Science and Engineering (ENG)

Please select up to 5 descriptors (and at least 3) that best characterise the subject of your proposal, in descending order of relevance. Note that descriptors will be used to support REA services in identifying the best qualified evaluators for your proposal.

Descriptor1: Wireless communications, communication, high frequency, mobile t

Descriptor2: Networks (communication networks, sensor networks, networks of r

Descriptor3: Internet of Things

Free keywords: *Spectrum sensing, spectrum data, measurements, analytics, infrastructure, data analysis, SDR prototyping*

Abstract *

SpecX provides the required expertise and effort to train a workforce of 10 Doctoral Candidates (DCs) in spectrum challenges at the frontier of 6G networks, (i) measuring the EM spectrum massively, dynamically and in 3D, (ii) turning the wireless data deluge challenge in new applications and innovative use of spectrum for future networks, and (iii) tackling the talent shortage in the EU's spectrum big data market. The overarching objective of SpecX is to provide high-level training to 10 DCs in large-scale spectrum measurement, analysis, and applications in future telecom infrastructure. The goal is to create a research and innovation workforce with transferable skills in radio hardware, cellular network infrastructure, edge computing, data collection, signal processing, deep learning and Artificial Intelligence, data tools to assess, improve and analyse big spectrum data and provide innovative services. This goal will be achieved by a unique combination of hands-on research training designed to provide to the DCs the needed fundamental elements to conduct the research programme, for collecting real spectrum data, analysing it, and developing innovative methods, and create insights and invent new valuable applications. Hands-on in depth-training will be strengthened with non-academic placements, as well as multidisciplinary, intersectoral, and international cooperation to maximize the employability of DCs and the impact of the project.

Remaining characters 541

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Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under any EU programme, including the current call? ○ Yes ◉ No

Please give the proposal reference or contract number.

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Declarations

Field(s) marked * are mandatory to fill.

1) We declare to have the explicit consent of all applicants on their participation and on the content of this proposal. *	☒
2) We confirm that the information contained in this proposal is correct and complete and that none of the project activities have started before the proposal was submitted (unless explicitly authorised in the call conditions).	☒
3) We declare: - to be fully compliant with the eligibility criteria set out in the call - not to be subject to any exclusion grounds under the EU Financial Regulation 2018/1046 - to have the financial and operational capacity to carry out the proposed project.	☒
4) We acknowledge that all communication will be made through the Funding & Tenders Portal electronic exchange system and that access and use of this system is subject to the Funding & Tenders Portal Terms and Conditions.	☒
5) We have read, understood and accepted the Funding & Tenders Portal Terms & Conditions and Privacy Statement that set out the conditions of use of the Portal and the scope, purposes, retention periods, etc. for the processing of personal data of all data subjects whose data we communicate for the purpose of the application, evaluation, award and subsequent management of our grant, prizes and contracts (including financial transactions and audits).	☒
6) We declare that the proposal complies with ethical principles (including the highest standards of research integrity as set out in the ALLEA European Code of Conduct for Research Integrity, as well as applicable international and national law, including the Charter of Fundamental Rights of the European Union and the European Convention on Human Rights and its Supplementary Protocols. Appropriate procedures, policies and structures are in place to foster responsible research practices, to prevent questionable research practices and research misconduct, and to handle allegations of breaches of the principles and standards in the Code of Conduct.	☒
7) We declare that the proposal has an exclusive focus on civil applications (activities intended to be used in military application or aiming to serve military purposes cannot be funded). If the project involves dual-use items in the sense of Regulation 428/2009, or other items for which authorisation is required, we confirm that we will comply with the applicable regulatory framework (e.g. obtain export/import licences before these items are used).	☒
8) We confirm that the activities proposed do not - aim at human cloning for reproductive purposes; - intend to modify the genetic heritage of human beings which could make such changes heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed), or - intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer. - lead to the destruction of human embryos (for example, for obtaining stem cells) These activities are excluded from funding.	☒
9) We confirm that for activities carried out outside the Union, the same activities would have been allowed in at least one EU Member State.	☒

The coordinator is only responsible for the information relating to their own organisation. Each applicant remains responsible for the information declared for their organisation. If the proposal is retained for EU funding, they will all be required to sign a declaration of honour.

False statements or incorrect information may lead to administrative sanctions under the EU Financial Regulation.

2 - Participants

List of participating organisations

#	Participating Organisation Legal Name	Country	Role	Action
1	FUNDACION IMDEA NETWORKS	Spain	Coordinator	
2	KATHOLIEKE UNIVERSITEIT LEUVEN	Belgium	Partner	
3	TELEFONICA INVESTIGACION Y DESARROLLO SA	Spain	Partner	
4	RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN	Germany	Partner	
5	CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LE TELECOMUNICAZIONI	Italy	Partner	
6	TECHNISCHE UNIVERSITEIT DELFT	Netherlands	Partner	
7	NEC LABORATORIES EUROPE GMBH	DE	Associated	
8	Electrosense	CH	Associated	
9	ACCELLERAN	BE	Associated	
10	UNIVERSIDAD CARLOS III DE MADRID	ES	Associated	
11	THE RESEARCH FOUNDATION OF STATE UNIVERSITY OF NEW YORK	US	Associated	
12	Saint Louis University	US	Associated	
13	ERICSSON GMBH	DE	Associated	
14	UNIVERSITA DEGLI STUDI DI TRENTO	Italy	Associated	
15	UNIVERSITA DEGLI STUDI DI ROMA TOR VERGATA	Italy	Associated	

Organisation data

PIC	Legal name
999651058	*FUNDACION IMDEA NETWORKS*

Short name: IMDEA NETWORKS

Address

Street	AVENIDA DEL MAR MEDITERRANEO 22
Town	LEGANES (MADRID)
Postcode	28918
Country	Spain
Webpage	www.networks.imdea.org

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	no		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is unknown (small- and medium-sized enterprise) for the call.

SME self-declared status	unknown
SME self-assessment	unknown
SME validation	unknown

Departments carrying out the proposed work

No department involved

Department name *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street *Please enter street name and number.*

Town *Please enter the name of the town.*

Postcode *Area code.*

Country *Please select a country*

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **IMDEA NETWORKS**

Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Dr

Gender ◯ Woman ◉ Man ◯ Non Binary

First name* **Domenico**

Last name* **Giustiniano**

E-Mail* **domenico.giustiniano@imdea.org**

Position in org. Research Associate Professor (tenured)

Department FUNDACION IMDEA NETWORKS

☒ Same as organisation name

☒ Same as proposing organisation's address

Street AVENIDA DEL MAR MEDITERRANEO 22

Town LEGANES (MADRID)

Post code 28918

Country Spain

Website https://domenico.networks.imdea.org/

Phone +34 91 481 6970

Phone 2 *+xxx xxxxxxxxx*

Other contact persons

First Name	Last Name	E-mail	Phone
Javier	Hervas	franciscojavier.hervas@imdea.org	+xxx xxxxxxxxx
Paula	de Dios	paula.dedios@imdea.org	+xxx xxxxxxxxx
Ana	Gonzalez	ana.gonzalez@imdea.org	+xxx xxxxxxxxx

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Proposal ID **101119959**

Acronym **SpecX**

Short name **IMDEA NETWORKS**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Domenico	Giustiniano	Man	Italy	domenico.giustiniano@imdea.org	Category B Senior resea	Leading	0000-0003-3136-4176	Orcid ID
Dr	Giuseppe	Santaromita	Man	Italy	giuseppe.santaromita@imdea.org	Category C Recognised	Team member	0000-0002-2285-9903	Orcid ID
Dr	Timothy	Otim	Man	Uganda	timothy.otim@imdea.org	Category C Recognised	Team member	0000-0001-8813-9186	Orcid ID
Dr	Joerg	Widmer	Man	Germany	joerg.widmer@imdea.org	Category A Top grade re	Team member	0000-0001-6667-8779	Orcid ID

Role of participating organisation in the project

Project management	☒
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☒
Prototyping and demonstration	☒
IPR management incl. technology transfer	☒
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*G. Bielsa, J. Palacios, A. Loch, D. Steinmetzer, P. Casari, J. Widmer, Accurate Ubiquitous Localization with Off-the-Shelf IEEE802.11ac Devices, In Proc. ACM Mobisys, 2021.*
Publication	*M. Rea, D. Giustiniano, "Location-aware Wireless Resource Allocation in Industrial-like Environment", IEEE Transaction on Mobile Computing, 2021.*
Publication	*S. Bartoletti, H.Wymeersch, T. Mach, O. Brunnegård, D. Giustiniano, P. Hammarberg, M. Furkan Keskin, J O. Lacruz, S.Modarres Razavi, J. Rönnblom, F. Tufvesson, J. Widmer, N. Blefari Melazzi, "Positioning and Sensing for Vehicular Safety Applications in 5G and Beyond," in IEEE Communications Magazine, vol. 59, no. 11, pp. 15-21, November 2021.*
Publication	*J. Palacios, P. Casari, H. Assasa, J. Widmer, LEAP: Location Estimation and Predictive Handover with Consumer-Grade mmWave Devices, In Proc. IEEE INFOCOM, 2019.*
Publication	*R. Calvo, H. Cordobés, F. Ricciato, D. Giustiniano, V. Lenders, Collaborative Wideband Signal Decoding using Non-coherent Receivers, In Proc. IEEE/ACM IPSN, 2019*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
ENLIGHT'EM *H2020* *GA number: 814215*	*European Training Network in Low-energy Visible Light IoT Systems. Funded by EU H2020-MSCA-ITN-2018 - Total project: 4.147k Euro, Granted for IMDEA: 735.8k Euro. 2019-2023.* *Project purpose: ENLIGHT'EM plans to design advanced lighting solutions that leverage the Internet of Things and the low baseline energy consumption of LEDs. Fifteen early-stage researchers will receive training on how to integrate low-energy VLC with the Internet of Things.* *Role: Coordinator* *Website: https://enlightem.eu/*
Flex5Gware *H2020* *GA number: 671563*	*Flexible and efficient hardware/software platforms for 5G network elements and devices. Funded by the EU under call H2020-ICT-2014-2. Granted: 251k Euro. 2015-2017* *Project purpose: The overall objective of Flex5Gware is to deliver highly reconfigurable hardware (HW) platforms together with HW-agnostic software (SW) platforms to enable a smooth transition from 4G mobile wireless systems to 5G.* *Role: Domenico Giustiniano is PI of IMDEA tasks.* *Website: https://flex5gware.eu/*
LOCUS *H2020* *GA number: 871249*	*LOCalization and analytics on-demand embedded in the 5G ecosystem, for Ubiquitous vertical applicationS. (2019-22). Funded by the EU under call H2020-ICT-2019-2. Granted: 411k Euro. 2019-2022* *Project purpose: LOCUS improves the functionality of 5G infrastructures to provide accurate/ ubiquitous location information, derive more complex features and behavioural patterns out of raw location and physical events.* *Role: Domenico Giustiniano is PI of IMDEA tasks* *Website: https://www.locus-project.e*
SOMIRO *H2020* *GA number: 101016411*	*Soft Milli-robots (2021-2023). Funded under call H2020-ICT-2018-20. Granted: 349k Euro.* *Project purpose: SOMIRO aims to build the world's first energy-autonomous swimming millirobot (less than 1 cm long), expected to have a huge impact in the field of robotics and in precision agriculture.* *Role: Domenico Giustiniano is PI of IMDEA tasks.* *Website: https://www.somiro.eu/*

RISC-6G *National call* *TSI-063000-2021-59*	*Reconfigurable Intelligent Surfaces and Low-power Technologies for Communication and Sensing in 6G Mobile Networks. Funded under a national call of Ministry of Economic Affairs and Digital Transformation, European Union NextGeneration-EU.* *Purpose: To integrate crucial new technologies into 6G to improve wireless communications, provide environmental sensing, and significantly lower the per-device energy footprint.* *Role: Domenico Giustiniano is coordinator*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	**Short description (Max 300 characters)**
MIMO Testbed	*OpenVLC based (openvlc.org) MIMO Testbed for experimentation of Visible Light Communication System*
Spectrum sensing	*IMDEA hosts different testbeds based on a large number of spectrum sensing boards from low-end devices (such as RTL-SDR controlled by raspberry boards) to higher-end systems such as Ettus and WARP.*
5TONIC	*IMDEA forms part of 5TONIC, an open research and innovation laboratory focusing on 5G and beyond technologies founded by Telefonica and IMDEA Networks based in Madrid. The objective of 5TONIC is to create a global open environment where members from industry and academia work together.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **KU Leuven**

PIC	Legal name
999991334	*KATHOLIEKE UNIVERSITEIT LEUVEN*

Short name: KU Leuven

Address

Street	OUDE MARKT 13
Town	LEUVEN
Postcode	3000
Country	Belgium
Webpage	www.kuleuven.be

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	no		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	13/01/2022 - no
SME self-assessment	unknown
SME validation	unknown

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **KU Leuven**

Departments carrying out the proposed work

Department 1

Department name: Department of Electrical Engineering ☐ not applicable

☐ Same as proposing organisation's address

Street: Kasteelpark Arenberg 10 - box 2044

Town: Leuven

Postcode: 3001

Country: Belgium

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **KU Leuven**

Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Prof.

Gender (•) Woman ( ) Man ( ) Non Binary

First name* **Sofie**

Last name* **Pollin**

E-Mail* **sofie.pollin@kuleuven.be**

Position in org. Professor

Department Department of Electrical Engineering

☐ Same as organisation name

☐ Same as proposing organisation's address

Street Kasteelpark Arenberg 10 - box 2044

Town Leuven

Post code 3001

Country Belgium

Website https://www.kuleuven.be/wieiswie/nl/person/00041938

Phone +3216321051

Phone 2 *+xxx xxxxxxxxx*

Other contact persons

First Name	Last Name	E-mail	Phone
Davy	Pissoort	davy.pissoort@kuleuven.be	+xxx xxxxxxxxx
Tim	Claeys	tim.claeys@kuleuven.be	+3250664848
Rodney	Martinez Alonso	rodney.martinezalonso@kuleuven.be	+xxx xxxxxxxxx

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **KU Leuven**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Prof	Sofie	Pollin	Woman	Belgium	sofie.pollin@kuleuven.be	Category B Senior resea	Leading	0000-0002-1470-2076	Orcid ID
Prof	Davy	Pissoort	Man	Belgium	davy.pissoort@kuleuven.be	Category A Top grade re	Team member	0000-0002-5077-4237	Orcid ID
Dr	Tim	Claeys	Man	Belgium	tim.claeys@kuleuven.be	Category C Recognised	Team member	0000-0002-7782-3553	Orcid ID
Dr	Hazem	Sallouha	Man	Belgium	hazem.sallouha@kuleuven.be	Category C Recognised	Team member	0000-0002-1288-1023	Orcid ID
Dr	Rodney	Martinez Alonso	Man	Cuba	rodney.martinezalonso@kuleuven.be	Category C Recognised	Team member	0000-0003-2529-5944	Orcid ID

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Proposal ID **101119959**

Acronym **SpecX**

Short name **KU Leuven**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☒
Prototyping and demonstration	☒
IPR management incl. technology transfer	☒
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*Claeys T., Tirmizi H., Habib H.,Vanoost D., Vandenbosch G., Pissoort D. A system's Perspective on the Use of EMI Detection and Correction Methods in Safety Critical Systems. in Proceedings of the Joint IEEE Symposium on EMC+SIPI and EMC Europe (2021)*
Publication	*Pang B., T'Jonck K., Claeys T., Pissoort D., Hallez H., Boydens J. Bluetooth Low Energy Interference Awareness Schema and Improved Channel Selectrion Algorithm for Connection Robustness . In MDPI Sensors (2021)*
Publication	*H. Sallouha, A. Chiumento and S. Pollin, "Aerial Vehicles Tracking Using Noncoherent Crowdsourced Wireless Networks," IEEE Transactions on Vehicular Technology, 2021.*
Publication	*S. Rajendran, V. Lenders, W. Meert and S. Pollin. Crowdsourced wireless spectrum anomaly detection, in IEEE Transactions on Cognitive Communications and Networking, 2019.*
Publication	*S. Rajendran, R. Calvo-Palomino, M. Fuchs, B. Bergh, H. Cordobes, D. Giustiniano, S. Pollin, V. Lenders. Electrosense: Open and Big Spectrum Data. IEEE Communications Magazine, 2018.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
EEWISE	*VLAIO Technology Transfer EMC for Emergent Wireless Systems*
H2020 MSCA-ITN Greenedge	*Design and implement machine learning based computing systems for the mobile edge that are highly energy efficient.*
H2020-ICT13 ORCA	*Experimentation facilities to promote wireless innovation in several market segments, including manufacturing, automotive industry, healthcare, ambient assistant living, public events, home automation, and utilities.*
H2020 R&I MARSAL	*Focuses on network design, virtual elastic infrastructure and network security for 5G and beyond networks.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
massive MIMO SDR	*massive MIMO SDR testbed consisting of 45 NI USRP-RIOs and has ample expertise in datadriven and deep learning.*
GPU Server facility	*GPU server facility (NVIDIA RTX 2080Ti cores)*
IoT Testbeds	*70 node BLE mesh testbed and a 36-node dense VLC testbed.*
Faraday cages	*(Semi-)Anechoic and double reverberation EMC test chambers*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

PIC	Legal name
999910824	*TELEFONICA INVESTIGACION Y DESARROLLO SA*

Short name: TID

Address

Street	RONDA DE LA COMUNICACION S/N DISTRITO C E
Town	MADRID
Postcode	28050
Country	Spain
Webpage	http://www.tid.es

Specific Legal Statuses

Legal person	yes	Academic Sector	no
Public body	no		
Non-profit	no		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	no		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	31/12/2015	- no
SME self-assessment	31/12/2015	- no
SME validation	unknown	

Departments carrying out the proposed work

Department 1

Department name: Scientific Research ☐ not applicable

☐ Same as proposing organisation's address

Street: Plaza Ernest Lluch i Martin, Nº 5

Town: Barcelona

Postcode: 08019

Country: Spain

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TID**

Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Dr

Gender ◉ Woman ○ Man ○ Non Binary

First name* **Andra**

Last name* **Lutu**

E-Mail* **andra.lutu@telefonica.com**

Position in org. Senior Researcher

Department TELEFONICA INVESTIGACION Y DESARROLLO SA

☒ Same as organisation name

☒ Same as proposing organisation's address

Street RONDA DE LA COMUNICACION S/N DISTRITO C EDIFICIO OESTE I

Town MADRID

Post code 28050

Country Spain

Website https://andralutu.com/

Phone +34664605872

Phone 2 *+xxx xxxxxxxxx*

Other contact persons

First Name	Last Name	E-mail	Phone
Javier	Garcia Rodrigo	javier.garciarodrigo@telefonica.com	+xxx xxxxxxxxx

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TID**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier	
Dr	Andra	Lutu	Woman	Romania	andra.lutu@telefonica.com	Category B Senior resea	Leading	0000-0001-7361-1257	Orcid ID	
Dr	Jose	Suarez-Varela	Man	Spain	jose.suarez-varela@telefonica.com	Category C Recognised	Team member	https://scholar.google.co.jp/citations?hl=en&user=vUByXE0AAAAJ	Other ID	Google Scholar

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TID**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☒
Prototyping and demonstration	☒
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*A. Lutu, D. Perino, M. Bagnulo, F. Bustamante (2021). Insights from Operating an IP eXchange Provider. In Proceedings of the 2021 ACM SIGCOMM 2021 Conference (SIGCOMM '21). Association for Computing Machinery, New York, NY, USA*
Publication	*D. Perino, X. Yang, J. Serra, A. Lutu, and I. Leontiadis (2020). Experience: advanced network operations in (Un)-connected remote communities. In Proceedings of the 26th Annual International Conference on Mobile Computing and Networking (MobiCom '20).*
Publication	*A. Lutu, D. Perino, M. Bagnulo, E. Frias-Martinez, and J. Khangosstar (2020). A Characterization of the COVID-19 Pandemic Impact on a Mobile Network Operator Traffic. In Proceedings of the ACM Internet Measurement Conference (IMC '20). Association for Computing Machinery, New York, NY, USA, 19–33. DOI:https://doi.org/10.1145/3419394.3423655*
Publication	*M. Fida, A. Lutu, M.K. Marina, and Ö. Alay (2017, May). ZipWeave: Towards Efficient and Reliable Measurement based Mobile Coverage Maps. In IEEE INFOCOM 2017 – IEEE Conference on Computer Communications, Atlanta, GA, 2017, pp. 1-9.*
Publication	*S. Alcalá-Marín, A. Raman, W. Wu, A. Lutu, M. Bagnulo, O. Alay, and F. Bustamante (2022). Global mobile network aggregators: taxonomy, roaming performance and optimization. In Proceedings of the 20th Annual International Conference on Mobile Systems, Applications and Services (MobiSys '22). Association for Computing Machinery, New York, NY, USA, 183–195. https://doi.org/10.1145/3498361.3538942*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
METAWIRELESS (H2020-MSCA-ITN-2020)	*Future Wireless Communication Empowered by Reconfigurable Intelligent Meta-Surfaces. The goal of this ITN is to train a new generation of researchers in the field of reconfigurable intelligent surfaces to manipulate wireless environment, and in a multidisciplinary effort involving wireless communications, physics, electromagnetic theory, and computational learning. Website: https://h2020-msca-itn-metawireless.cnit.it/*
APROPOS (H2020-MSCA-ITN-2020)	*Approximate computing for Power ad Energy Optimisation. The goal of this ITN is to tackle the challenges of future embedded and high-performance computing energy efficiency by using disruptive methodologies training a new generation of researchers on researching markets.*
DAEMON (H2020-ICT- 2018-20)	*Network intelligence for aDAptive and sElf-Learning MObile Networks. DAEMON focuses on the design of an end-to-end Network Intelligence-native architecture for beyond 5G networks that fully coordinates Network Intelligent-assisted functionalities.*
ACCORDION (H2020-ICT-2018-2020)	*Adaptive edge/cloud compute and network continuum over a heterogeneous sparse edge infrastructure to support nextgen applications – ACCORDION establishes an opportunistic approach in bringing together edge resource/infrastructures (public clouds, on-premise infrastructures, telco resources, end-devices) in pools defined in terms of latency, that can support next-generation application requirements.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Multi-site cellular testbed	*Multi-site cellular testbed equipped with both 4G and 5G capabilities and connected to commercial edge datacenter, offers a novel and unique framework for testing diverse MEC applications as well as radio core/RAN technologies and algorithms.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **RWTH AACHEN**

PIC	Legal name
999983962	*RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN*

Short name: RWTH AACHEN

Address

Street	TEMPLERGRABEN 55
Town	AACHEN
Postcode	52062
Country	Germany
Webpage	www.rwth-aachen.de

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	yes		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	17/01/2022	- no
SME self-assessment	17/01/2022	- no
SME validation	01/01/1900	- no

Proposal ID **101119959**

Acronym **SpecX**

Short name **RWTH AACHEN**

Departments carrying out the proposed work

Department 1

Department name: Mobile Communications and Computing ☐ not applicable

☐ Same as proposing organisation's address

Street: Kackertstr. 9

Town: Aachen

Postcode: 52072

Country: Germany

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **RWTH AACHEN**

Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Prof.

Gender (•) Woman ( ) Man ( ) Non Binary

First name* **Marina**

Last name* **Petrova**

E-Mail* **petrova@mcc.rwth-aachen.de**

Position in org. Professor

Department Mobile Communications and Computing

☐ Same as organisation name

☐ Same as proposing organisation's address

Street Kackertstr. 9

Town Aachen

Post code 52072

Country Germany

Website *Please enter website*

Phone +492418020900

Phone 2 *+xxx xxxxxxxxx*

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **RWTH AACHEN**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier	
Prof	Marina	Petrova	Woman		petrova@mcc.rwth-aachen.de	Category A Top grade re	Leading	0000-0003-3876-2214	Orcid ID	
Dr	Pradyumna	Kumar Bishoy	Man		pradyumna.bishoyi@mcc.rwth-aachen.de	Category C Recognised	Team member	https://scholar.google.co.in/citations?user=NKEjCocAAAAJ&hl=en	Other ID	Google Scholar

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **RWTH AACHEN**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☒
IPR management incl. technology transfer	☒
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*A. M. Voicu, L. Simić and M. Petrova, "Modelling Broadband Wireless Technology Coexistence in the Unlicensed Bands," 2021 IEEE 22nd International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2021, pp. 129-138, doi: 10.1109/WoWMoM51794.2021.00026.*
Publication	*S. Khosravi, H. Shokri-Ghadikolaei and M. Petrova, "Learning-Based Handover in Mobile Millimeter-Wave Networks," in IEEE Transactions on Cognitive Communications and Networking, vol. 7, no. 2, pp. 663-674, June 2021, doi: 10.1109/TCCN.2020.3030964.*
Publication	*P. Ren, A. Munari, M. Petrova "Performance Tradeoffs of Joint Radar-Communication Networks," IEEE Wireless Communication Letters, vol.8, no.1, February 2019, doi: 10.1109/LWC.2018.2865360.*
Publication	*B. Bojovic, E. Meshkova, N. Baldo, J. Riihijärvi, M. Petrova, "Machine Learning based Dynamic Frequency and Bandwidth Allocation in Self-Organized LTE Dense Small Cell Deployments," EURASIP Journal on Wireless Communications and Networking, 2016:183, December 2016.*
Publication	*A. M. Voicu, L. Simić, M. Petrova, "Inter-Technology Coexistence in a Spectrum Commons: A Case Study of Wi-Fi and LTE in the 5 GHz Unlicensed Band," IEEE Journal of Selected Areas in Communication, Vol. 34, No. 11, pp. 3062-3077, November 2016.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
FP7 ARAGORN	*Adaptive Reconfigurable Access and Generic interfaces for Optimisation in Radio Networks*
FP7 FARAMIR	*Flexible and spectrum-Aware Radio Access through Measurements and modelling In cognitive Radio systems*
FP7 QUASAR	*Quantitative Assessment of Secondary Spectrum Access*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
lab facility	*lab facility comprising, SDR platforms, Raspberry Pi nodes and also standard measurement equipment. MCC has extensive expertise in wireless technologies, software-defined radios and communication networks, and has rich connections and active collaborations with industry.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

PIC	Legal name
999649603	*CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LE TELECOMUNICAZIONI*

Short name: CNIT

Address

Street	VIALE G. P. USBERTI 181A
Town	PARMA
Postcode	43124
Country	Italy
Webpage	https://www.cnit.it/

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	no		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	10/01/1995 - no
SME self-assessment	unknown
SME validation	unknown

Departments carrying out the proposed work

Department 1

Department name: Research Unit at the University of Rome Tor Vergata ☐ not applicable

☐ Same as proposing organisation's address

Street: via del Politecnico 1

Town: Roma

Postcode: 00133

Country: Italy

Department 2

Department name: Research Unit at the University of Trento ☐ not applicable

☐ Same as proposing organisation's address

Street: via Sommarive 9

Town: Trento

Postcode: 38123

Country: Italy

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **CNIT**

Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Dr

Gender ◉ Woman ○ Man ○ Non Binary

First name* **Stefania**

Last name* **Bartoletti**

E-Mail* **stefania.bartoletti@uniroma2.it**

Position in org. Assistant professor

Department Research Unit at the University of Rome Tor Vergata ☐ Same as organisation name

☐ Same as proposing organisation's address

Street via del Politecnico 1

Town Rome

Post code 00133

Country Italy

Website http://netgroup.uniroma2.it/people/faculties/

Phone +39 3483407016

Phone 2 *+xxx xxxxxxxxx*

Other contact persons

First Name	Last Name	E-mail	Phone
Paolo	Casari	paolo.casari@unitn.it	+xxx xxxxxxxxx

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **CNIT**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Prof	Paolo	Casari	Man	Italy	paolo.casari@unitn.it	Category B Senior resea	Leading	0000-0002-6401-1660	Orcid ID
Prof	Stefania	Bartoletti	Woman	Italy	stefania.bartolettii@uniroma2.it	Category B Senior resea	Team member	0000-0003-1428-9776	Orcid ID

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **CNIT**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☐
Testing/validation of approaches and ideas	☒
Prototyping and demonstration	☒
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*S. Bartoletti, A. Conti and M. Z. Win, "Device-Free Counting via Wideband Signals," in IEEE Journal on Selected Areas in Communications, May 2017.*
Publication	*A. Conti, S. Mazuelas, S. Bartoletti, W. C. Lindsey and M. Z. Win, "Soft Information for Localization-of-Things," in Proceedings of the IEEE, 2019.*
Publication	*A. Shastri, N. Valecha, E. Bashirov, H. Tataria, M. Lentmeier, F. Tufvesson, M. Rossi, P. Casari, "A Review of Millimeter Wave Device-based Localization and Device-free Sensing Technologies and Applications," in IEEE Communications Surveys and Tutorials, 2022.*
Publication	*C. Fiandrino, H. Assasa, P. Casari, J. Widmer, "Scaling Millimeter-Wave Networks to Dense Deployments and Dynamic Environments," in Proceedings of the IEEE, 2019.*
Publication	*F. Granelli, R. Capraro, M. Lorandi, P. Casari, "Evaluating a Digital Twin of an IoT Resource Slice: an Emulation Study using the ELIoT Platform," in IEEE Networking Letters, 2021.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
INTEGRATE *HORIZON-MSCA-2021-DN-01* *GA: 101072924*	*JoInt wireless commuNicaTion and sEnsinG by hologRaphic surfAce TranscEivers* *The INTEGRATE project focuses on the theoretical, algorithmic, and architectural foundations of integrated communication and sensing networks, developing the first open access network-level simulator for joint communication and sensing.* *CNIT Role in the project: Coordinator*
META WIRELESS *H2020-MSCA-ITN-2020* *GA: 956256*	*Future Wireless Communications Empowered by Reconfigurable Intelligent Meta-Materials* *META WIRELESS pursues the disruptive idea of designing wireless networks by treating the environment itself as a quantity to be controlled and optimized. Precisely, the manipulation of the wireless environment can be made possible by incorporating reconfigurable intelligent surfaces.* *CNIT Role in the project: Coordinator* *Website: https://h2020-msca-itn-metawireless.eu/*
LOCUS *H2020-ICT-2018-20* *GA: 871249*	*LOCUS aims to improve the functionality of 5G infrastructures to provide accurate and ubiquitous location information, and derive more complex features and behavioural patterns out of raw location and physical events. The project will help to increase the overall value of the 5G ecosystem by making new applications possible, boosting vertical industries, and creating new business opportunities for telecommunications companies.*
B5G-OPEN *H2020-ICT-2020-2* *GA: 101016663*	*B5G-OPEN targets the design and demonstration of a novel end-to-end integrated packet-optical transport architecture based on MultiBand (MB) optical transmission and switching networks. MB expands the available capacity of optical fibres, by enabling transmission within S, E, and O bands, in addition to commercial C and/or C+L bands, which translates into a potential 10x capacity increase and low-latency for services beyond 5G.* *CNIT Role in the project: Partner* *Website: www.b5g-open.eu/*
iNGENIOUS *H2020-ICT-2020-1* *GA: 957216*	*INGENIOUS aims to design and evaluate the Next-Generation IoT (NG-IoT) solution, with emphasis on 5G and the development of Edge and Cloud computing extensions for IoT, as well as smart networking and data management solutions with AI/ML. The project embraces the 5G Infrastructure Association and Alliance for Internet of Things Innovation vision for smart manufacturing and smart mobility verticals.* *CNIT Role in the project: Partner* *Website: https://ingenious-iot.eu/*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
IoT and mmWave Testbed	*A department-scale testbed including low-power IoT radios, ultrawideband radios, and mmWave equipment for communications and sensing.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TU Delft**

PIC	Legal name
999977366	*TECHNISCHE UNIVERSITEIT DELFT*

Short name: TU Delft

Address

Street	STEVINWEG 1
Town	DELFT
Postcode	2628 CN
Country	Netherlands
Webpage	www.tudelft.nl

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	yes		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	12/01/2022	- no
SME self-assessment	12/01/2022	- no
SME validation	unknown	

Departments carrying out the proposed work

Department 1

Department name	Department of Software Technology	☐ not applicable
	☐ Same as proposing organisation's address	
Street	Van Mourik Broekmanweg 6	
Town	Delft	
Postcode	2628	
Country	Netherlands	

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TU Delft**

Main contact person

This will be the person the EU services will contact concerning this proposal (e.g. for additional information, invitation to hearings, sending of evaluation results, convocation to start grant preparation). The data in blue is read-only. Details (name, first name and e-mail) of Main Contact persons should be edited in the step "Participants" of the submission wizard.

Title Prof.

Gender ○ Woman ◉ Man ○ Non Binary

First name* **Qing**

Last name* **Wang**

E-Mail* **qing.wang@tudelft.nl**

Position in org. Assistant Professor

Department Department of Software Technology

☐ Same as organisation name

☐ Same as proposing organisation's address

Street Van Mourik Broekmanweg 6

Town Delft

Post code 2628 XE

Country Netherlands

Website *Please enter website*

Phone *+xxx xxxxxxxxx*

Phone 2 *+xxx xxxxxxxxx*

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TU Delft**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Prof	Qing	Wang	Man	China (People's	qing.wang@tudelft.nl	Category C Recognised	Leading	0000-0003-0950-1111	Orcid ID
Prof	Koen	Langendoen	Man	Netherlands	k.g.langendoen@tudelft.nl	Category A Top grade re	Team member	0000-0003-4996-3695	Orcid ID
Prof	Fernando	Kuipers	Man	Netherlands	f.a.kuipers@tudelft.nl	Category A Top grade re	Team member	0000-0002-6686-8350	Orcid ID
Prof	Guchao	Lan	Man	China (People's	g.lan@tudelft.nl	Category C Recognised	Team member	0000-0003-2190-9937	Orcid ID

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **TU Delft**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☒
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*H. Ye and Q. Wang, "SpiderWeb: Enabling Through-Screen Visible Light Communication," ACM SenSys, 2021.*
Publication	*M. Cui, Q. Wang and J. Xiong, RadioInLight, "Doubling the Data Rate of VLC Systems," ACM MobiCom, 2021.*
Publication	*S. Ghiasi, M. Zuniga and K. Langendoen, "A Principled Design for Passive Light Communication," ACM MobiCom, 2021.*
Publication	*T. Ni, G. Lan, J. Wang, Q. Zhao, and W. Xu. "Eavesdropping Mobile App Activity via Radio-frequency Energy Harvesting," USENIX Security Symposium, 2023.*
Publication	*J. Oostenbrink , F. Kuipers, "Going the Extra Mile with Disaster-Aware Network Augmentation, IEEE INFOCOM, 2021.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
H2020 MSCA-ITN ENLIGHT'EM	*Leverage the low baseline energy consumption of LEDs to deliver networked communication and demonstrate sustainable networking solutions for beyond 5G networks.*
D2S2	*Develop and use advanced miniaturized radar sensors that can operate under a wide range of difficult environmental conditions (smoke, fog, etc.) that cannot be handled by typical localization systems in operation.*
4TU.NIRICT.HaLow	*Combine the unique expertise of Dutch 4TU to enable new system-level research, ranging from the physical layer to applications, for the emerging long-range WiFi networks.*
RELYonIT	*Provide a systematic framework and toolchain to enable dependable IoT applications by taking into account all relevant environmental properties and their impact on IoT platforms and protocols.*
ERDF Do IoT Fieldlab	*Accelerate IoT innovations by facilitating groundbreaking research, by bringing the right parties together for innovation questions, and by supporting companies in the realisation of new and better products and services.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
SpiderWeb	*Testbed for through-screen visible light communication.*
LightDigit	*System for embedded AI research and sensing with visible light.*
SocialGlass	*For integration, enrichment, and sense-making of urban data.*
FedNaWi	*For robust federated learning in the Internet of Things applications.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **NEC LABORATORIES EUROPE GMBH**

PIC	Legal name
910561893	*NEC LABORATORIES EUROPE GMBH*

Short name: NEC LABORATORIES EUROPE GMBH

Address

Street	KURFURSTEN-ANLAGE 36
Town	HEIDELBERG
Postcode	69115
Country	Germany
Webpage	

Specific Legal Statuses

Legal person	yes	Academic Sector	no
Public body	no		
Non-profit	no		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	no		

SME Data

Based on the below details from the Participant Registry the organisation is unknown (small- and medium-sized enterprise) for the call.

SME self-declared status	unknown
SME self-assessment	unknown
SME validation	unknown

Proposal ID **101119959**

Acronym **SpecX**

Short name **NEC LABORATORIES EUROPE GMBH**

Departments carrying out the proposed work

Department 1

Department name 6G Networks ☐ not applicable

☒ Same as proposing organisation's address

Street KURFURSTEN-ANLAGE 36

Town HEIDELBERG

Postcode 69115

Country Germany

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **NEC LABORATORIES EUROPE GMBH**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Andrés	Garcia Saavedra	Man	Spain	andres.garcia.saavedra@neclab.eu	Category B Senior resea	Leading	0000-0003-2005-2222	Orcid ID

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **NEC LABORATORIES EUROPE GMBH**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☐
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*G. Garcia-Aviles, A. Garcia-Saavedra, M. Gramaglia, X. Costa-Perez, P. Serrano, A. Banchs. Nuberu: Reliable RAN Virtualization in Shared Platforms. In ACM MobiCom 2021.*
Publication	*EdgeBOL: Automating Energy-savings for Mobile Edge AI, J. A. Ayala-Romero, A. Garcia-Saavedra, X. Costa-Perez, G. Iosifidis. In ACM CoNEXT 2021*
Publication	*J. A. Ayala-Romero, A. Garcia-Saavedra, X. Costa-Perez, G. Iosifidis. Bayesian Online Learning for Energy-Aware Resource Orchestration in Virtualized RAN. In IEEE INFOCOM 2021.*
Publication	*J. A. Ayala-Romero, A. Garcia-Saavedra, M. Gramaglia, X. Costa-Perez, A. Banchs, J. J. Alcaraz. vrAIn: Deep Learning based Orchestration for Computing and Radio Resources in vRAN. In IEEE Transactions on Mobile Computing, 2021.*
Publication	*F. W. Murti, J. A. Ayala-Romero, A. Garcia-Saavedra, X. Costa-Perez, G. Iosifidis. Optimal Deployment Framework for Multi-Cloud Virtualized Radio Access Networks. In IEEE Transactions on Wireless Communications, 2020.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
ITN MINTS	*The project aims at technology for mmWave networking and sensing beyond 5G. This beyond 5G technology will give us even larger capacity, more diverse applications, such as very precise indoor location and radar, in addition to communication. The beyond 5G networks will however also require more antennas, and work at the so feared high mmWave frequencies (feared already for 5G).*
ITN Spotlight	*To handle the unprecedented demand for mobile data traffic, different vendors, operators and research have aimed to develop radio access technologies (RATs) that boost physical-layer link capacity, utilize millimeter wave radio, or further densify network topology.*
H2020 DAEMON	*While artificial intelligence (AI) models are commonly regarded as the cornerstone of network intelligence (NI) design, AI is not the most suitable tool for every NI task. The EU-funded DAEMON project will create a pragmatic approach to NI design. It will carry out a systematic analysis of which NI tasks are appropriately solved with AI models, providing a solid set of guidelines for the use of machine learning in network functions.*
H2020 5Growth	*We are one of the selected projects running in the framework of the 5G Public Private Partnership (5G-PPP) Phase 3, Part 3: "Advanced 5G validation trials across multiple vertical industries", co-led by the European Commission and industry, and we will explore the concrete applicability of 5G technologies to real-world use-cases across various vertical sectors.*
ITN MetaWireless	*MetaWireless puts forth the disruptive idea to design wireless networks by treating the wireless environment as an optimization variable to be adapted to maximize the network performance.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
SDR testbed	*10 USRP B210 SDR Boards*
Workstation	*Supermicro server with Intel Xeon Gold 6226R + Intel FPGA PAC N3000 + NVIDIA Tesla V100 GPU*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **Electrosense**

PIC	Legal name
897739657	*Electrosense*

Short name: Electrosense

Address

Street	Eyzälg 23
Town	Burgorf
Postcode	3400
Country	Switzerland
Webpage	https://electrosense.org

Specific Legal Statuses

Legal person	yes	Academic Sector	no
Public body	no		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	no		

SME Data

Based on the below details from the Participant Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	11/10/2019 - yes
SME self-assessment	unknown
SME validation	unknown

Departments carrying out the proposed work

No department involved

Department name *Name of the department/institute carrying out the work.* ☒ not applicable

☐ Same as proposing organisation's address

Street *Please enter street name and number.*

Town *Please enter the name of the town.*

Postcode *Area code.*

Country *Please select a country*

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **Electrosense**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Vincent	Lenders	Man	Switzerland	lenders@electrosense.org	Category A Top grade re	Leading	0000-0002-2289-3722	Orcid ID

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **Electrosense**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☐
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*V. Lenders, et al., "Electrosense+: Crowdsourcing Radio Spectrum Decoding using IoT Receivers", Elsevier Journal on Computer Networks, May 2020.*
Publication	*B. Reynders, F. Minucci, E. Perenda, H. Sallouha, R. Calvo, Y. Lizarribar, M. Fuchs, M. Schaefer, M. Engel, B. Van den Bergh, S. Pollin, D. Giustiniano, G. Bovet, and V. Lenders, "SkySense: Terrestrial and Aerial Spectrum Use Analysed Using Lightweight Sensing Technology with Weather Balloons", ACM International Conference on Mobile Systems, Applications, and Service (MobiSys), Toronto, Canada, June 2020.*
Publication	*Sreeraj Rajendran, Vincent Lenders, Wannes Meert, and Sofie Pollin, "Crowdsourced Wireless Spectrum Anomaly Detection", IEEE Transactions on Cognitive Communications and Networking (TCCN), 2019.*
Publication	*S. Rajendran, R. Calvo-Palomino, M. Fuchs, B. Van den Bergh, H. Cordobés, D. Giustiniano, S.Pollin, V. Lenders, "Electrosense: Open and Big Spectrum Data", IEEE Communications Magazine, January 2018*
Publication	*R. Calvo, D. Giustiniano, V. Lenders and A. Fakhreddine, "Crowdsourcing Spectrum Data Decoding", IEEE International Conference on Computer Communications (INFOCOM), Atlanta, USA, 2017.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
SOCRATES	*Electrosense was involved in the SOCRATES project funded by NATO Science for Peace and Security Programme the under grant G5461. Furthermore, Electrosense collaborates actively with KU Leuven and IMDEA networks in direct collaboration activities.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Several servers	*Electrosense currently owns several servers that runs 2 x 12 Core Intel Xeon Silver 4116 2.1GHz Processor. Several of the spectrum sensors deployed at users' location are also owned by Electrosense, although users have also access to the toolkit to deploy their own sensors.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **ACCELLERAN**

PIC	Legal name
942650075	*ACCELLERAN*

Short name: ACCELLERAN

Address

Street	KIEVITPLEIN 20 BUS 4.2
Town	ANTWERPEN
Postcode	2018
Country	Belgium
Webpage	www.accelleran.com

Specific Legal Statuses

Legal person	yes	Academic Sector	no
Public body	no		
Non-profit	no		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	no		

SME Data

Based on the below details from the Participant Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	27/01/2022	- yes
SME self-assessment	31/12/2017	- yes
SME validation	unknown	

Departments carrying out the proposed work

Department 1

Department name CTO Office ☐ not applicable

☐ Same as proposing organisation's address

Street QUELLINSTRAAT 49

Town ANTWERP

Postcode 2018

Country Belgium

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **ACCELLERAN**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier	
Dr	Trevor	Moore	Man	Belgium	trevor.moore@accelleran.com	Category A Top grade re	Leading	https://www.linkedin.com/in/holistic/	Other ID	Linkedin

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☐
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Software	*Enabling the full functionality of an e/gNodeB, this software package delivers an integrated software solution, including all the essential components: Layers 1, 2 and 3 of the RAN function and the necessary OAM and security features.*
Software	*The dRAX-RIC's near real-time xApp platform allows the roll-out of smart apps for management and optimization of the RAN. These apps, having access to RAN data as never before, can use this to feed to near-real time control functions, leveraging the benefits of AI and Big Data. This open platform allows third-party apps to complement the Accelleran portfolio.*
Software	*dRAX delivers on the promises of manageability and orchestration of open and disaggregated RAN.* *On top of open APIs, dRAX also provides an intuitive graphical user interface that supports the monitoring and configuration of the Open RAN elements as well as xApps onboarding.*
Software	*Accelleran's dRAX™-CU provides a fully standards-compliant, Cloud-Native implementation of the Central Unit – User Plane (CU-UP) and Central Unit – Control Plane (CU-CP) as defined by 3GPP.*
Other achievement	*Accelleran dRAX™-RIC delivers a truly Cloud-Native near real-time RAN Intelligent Controller as per O-RAN, that enables near real-time control and optimization of Open RAN 4G & 5G elements and resources under its control.* *At the basis of the dRAX™-RIC lies a framework that provides all the necessary functions for onboarding and life cycle management of xApps. It supports the deployment of containerized xApps and provides them with a number of services.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
H.2020 *Affordable5G*	*H.2020* *Affordable5G Affordable5G aims at creating a 5G network that will deliver a complete, disaggregated and affordable solution covering the needs of private and enterprise networks through technical innovation that span across all parts of the 5G network including Radio Access, Edge, 5G Core and Orchestration.*
H.2020 *5G-CLARITY 5G-CLARITY will develop and de*	*5G-CLARITY will develop and demonstrate a beyond 5G system for private networks integrating 5G, Wi-Fi, and LiFi technologies, and managed through AI based autonomic networking.* *5G-CLARITY aims to be instrumental in order to secure the leadership of Europe in the growing markets of private 5G networks, and 5G for factory automation.* *5G-CLARITY brings forward the design of a system for beyond 5G private networks that addresses the challenges in spectrum flexibility, delivery of critical serv*
H.2020 *5G-RECORDS*	*The key challenge of 5G-RECORDS is to explore the possibilities that new hardware devices and technologies may bring to the 5G ecosystem.*
H.2020 *5G-COMPLETE*	*5G-COMPLETE aims to revolutionize the 5G architecture, by efficiently combining compute and storage resource functionality over a unified ultra-high capacity converged digital/analog Fiber-Wireless (FiWi) Radio Access Network (RAN).*

H.2020 *5GCity*	*H.2020* *5GCity The ultimate goal of 5GCity was to maximize the return on investment for the whole digital market chain (users, application, cloud providers, i.e., the municipalities themselves, telecom providers, and infrastructure providers). To do so, 5GCity's main aim was to build and deploy a common, multi-tenant, open platform that extends the (centralized) cloud model to the extreme edge of the network, with a demonstration in three different cities.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	**Short description (Max 300 characters)**
dlab	*While open standards are prerequisite to delivering truly interoperable products, integrating the individual components into a working solution remains a task cut out for our experts. Providing test environments and services necessary to integrate a multi-sourced Radio Access Networs.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **UC3M**

PIC	Legal name
999899572	*UNIVERSIDAD CARLOS III DE MADRID*

Short name: UC3M

Address

Street	CALLE MADRID 126
Town	GETAFE (MADRID)
Postcode	28903
Country	Spain
Webpage	http://www.uc3m.es

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	yes		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	17/01/2022	- no
SME self-assessment	unknown	
SME validation	30/10/2008	- no

Departments carrying out the proposed work

Department 1

Department name	Departamento de Ingeniería Telemática	☐ not applicable
	☐ Same as proposing organisation's address	
Street	Avda. Universidad, 30	
Town	Leganés	
Postcode	28911	
Country	Spain	

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **UC3M**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Pablo	Serrano	Man	Spain	pablo@it.uc3m.es	Category B Senior resea	Leading	0000-0002-5176-0013	Orcid ID

Proposal ID **101119959**

Acronym **SpecX**

Short name **UC3M**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☐
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*G. Garcia-Aviles, A. Garcia-Saavedra, M. Gramaglia, X. Costa-Perez, P. Serrano, A. Banchs, Nuberu: Reliable RAN Virtualization in Shared Platforms, ACM Mobicom 2022 (accepted)*
Publication	*Francesco Gringoli, Paul Patras, Carlos Donato, Pablo Serrano, Yan Grunenberger, Performance Assessment of Open Software Platforms for 5G Prototyping, IEEE Wireless Communications Magazine, Special Issue on 5G Testing and Field Trials, Vol. 25, Issue 5, October 2018*
Publication	*Ismael Gomez-Miguelez, Andrés Garcia-Saavedra, Paul D. Sutton, Pablo Serrano, Cristina Cano, Doug J. Leith, srsLTE: An Open-Source Platform for LTE Evolution and Experimentation (Best paper award), ACM WiNTECH 2016, New York, USA, October 2016*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
METRICS	*METRICS provided the right instruments for continuous large-scale measurements, developed data analysis and privacy protection mechanisms, and designed sample applications that make effective use of the measurement infrastructure. https://cordis.europa.eu/project/rcn/109503/factsheet/en*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
5TONIC	*UC3M forms part of 5TONIC an open research and innovation laboratory focusing on 5G technologies based in Madrid. The objective of 5TONIC is to create a global open environment where members from industry and academia work together in specific research*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **SUNY**

PIC	Legal name
985856494	*THE RESEARCH FOUNDATION OF STATE UNIVERSITY OF NEW YORK*

Short name: SUNY

Address

Street	STATE STREET 35
Town	ALBANY NY
Postcode	12201
Country	United States
Webpage	http://www.rfsuny.org

Specific Legal Statuses

Legal person	yes	Academic Sector	no
Public body	no		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	no		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	16/02/1951 - no
SME self-assessment	unknown
SME validation	unknown

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **SUNY**

Departments carrying out the proposed work

Department 1

Department name: Department of Computer Science ☐ not applicable

☐ Same as proposing organisation's address

Street: 1215 Western Ave, Room 400

Town: Albany, NY

Postcode: 12222

Country: United States

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **SUNY**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier	
Dr	Mariya	Zheleva	Woman	Bulgaria	mzheleva@albany.edu	Category B Senior resea	Leading	https://www.linkedin.com/in/mariyazheleva/	Other ID	Linkedin

Proposal ID **101119959**

Acronym **SpecX**

Short name **SUNY**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☐
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*MODELESS: MODulation rEcognition with LimitEd SuperviSion. Wei Xiong, Petko Bogdanov, and Mariya Zheleva. IEEE International Conference on Sensing, Communication and Networking (IEEE SECON 2021).*
Publication	*SYMMeTRy: Exploiting Self-Similarity for Under-Determined MIMO Modulation Recognition. Wei Xiong, Lin Zhang, Maxwel McNeil, Petko Bogdanov, and Mariya Zheleva. IEEE Transactions on Mobile Computing (IEEE TMC 2021).*
Publication	*Learning the unknown: Improving modulation classification performance in unseen scenarios. Erma Perenda, Sreeraj Rajendran, Gerome Bovet, Sofie Pollin, and Mariya Zheleva. IEEE International Conference on Computer Communications (IEEE INFOCOM 2021).*
Publication	*Robust and Efficient Modulation Recognition Based on Local Sequential IQ Features. Wei Xiong, Petko Bogdanov, and Mariya Zheleva. IEEE International Conference on Computer Communications (IEEE INFOCOM 2019).*
Publication	*Enabling a Nationwide Radio Frequency Inventory Using the Spectrum Observatory. Mariya Zheleva, Ranveer Chandra, Aakanksha Chowdhery, Paul Garnett, Anoop Gupta, Ashish Kapoor, and Matt Valerio. IEEE Transactions on Mobile Computing (IEEE TMC).*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
SpectrumX	*An NSF Spectrum Innovation Center (https://www.spectrumx.org/).*
CAREER	*Automating the measurement and management of the radio spectrum for future spectrumsharing applications*
SCC	*Integrating Heterogeneous Wide-Area Networks and Advanced Data Science to Bridge the Digital Divide in Rural Emergency Preparedness and Response*
CRII: NeTS	*Next Generation Spectrum Measurement Algorithms and Infrastructures*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Software defined radios	*(2x USRP N210, 3x USRP B210, 2x RTL-SDR), two Lenovo x210 laptops, one GPSDO Kit for USRP N200/N210, multiple antennas, multiple Android-based phones, multiple embedded platforms (i.e. Raspberry Pi and Banana Pi), and one power meter from Monsoon Electronics.*
Workstation	*In addition, the lab has a 36-core Dell server with 256GB of RAM, which is currently used in research prototyping and scan analysis and is housed at the University's datacenter*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

PIC	Legal name
996981618	*Saint Louis University*

Short name: Saint Louis University

Address

Street	Grand Blvd 221
Town	Saint Louis
Postcode	63103
Country	United States
Webpage	www.slu.edu

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	no		
Non-profit	yes		
International organisation	unknown		
Secondary or Higher education establishment	unknown		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is unknown (small- and medium-sized enterprise) for the call.

SME self-declared status	unknown
SME self-assessment	unknown
SME validation	unknown

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **Saint Louis University**

Departments carrying out the proposed work

Department 1

Department name: Computer Science Department, College of Arts and Sciences, Saint

☐ not applicable

☐ Same as proposing organisation's address

Street: 3450, Lindell Blvd

Town: ST. Louis

Postcode: 63103

Country: United States

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **Saint Louis University**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Prof	Flavio	Esposito	Man	Italy	flavio.esposito@slu.edu	Category B Senior resea	Leading	0000-0002-7798-4584	Orcid ID

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **Saint Louis University**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☐
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☐
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*N. Akhtar, I. Matta, A. Raza, L. Goratti, B. Torsten, F. Esposito, "Managing Chains of Application Functions Over Multi-Technology Edge Networks", IEEE Transactions on Network and Service Management, 2021.*
Publication	*A. Sacco, F. Esposito, G. Marchetto, "An Architecture for Adaptive Data-Driven Routing Prediction at the Edge," IEEE Transactions on Network and Service Management. 2020.*
Publication	*A. Sacco, F. Esposito, G. Marchetto, "Owl: Congestion Control with Partially Invisible Networks via Reinforcement Learning", Proc. IEEE INFOCOM, 2019.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
1. US-NSF project US Ignite	*Resilient Virtual Path Management for Scalable Data-intensive Computing at Network-Edges.*
2. US-NSF project ICE-T RI	*A Knowledge-Defined Platform for Real-Time Management of Transmissions and Computations at Network Edge*
3. US-NSF project (Core: Small: Collaborative Res	*A Hybrid Elastic Edge-Cloud Application Management Architecture*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Key infrastructure	*infrastructure include a computing cluster, numerous software-defined radios of different types, and an edge cloud testbed serving 20 5G antennas that are available for multiple experiments on software-defined networking, virtualization, radio sensing and signal detection.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **ERICSSON**

PIC	Legal name
999944386	*ERICSSON GMBH*

Short name: ERICSSON

Address

Street	PRINZENALLEE 21
Town	DUSSELDORF
Postcode	40549
Country	Germany
Webpage	

Specific Legal Statuses

Legal person	yes	Academic Sector	no
Public body	no		
Non-profit	no		
International organisation	no		
Secondary or Higher education establishment	no		
Research organisation	no		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	14/09/2009 - no
SME self-assessment	unknown
SME validation	unknown

Departments carrying out the proposed work

Department 1

Department name: Ericsson Research ☐ not applicable

☐ Same as proposing organisation's address

Street: Ericsson-Allee 1

Town: Herzogenrath

Postcode: D-52134

Country: Germany

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **ERICSSON**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Andra	Voicu	Woman	Romania	andra.mihaela.voicu@ericsson.com	Category C Recognised	Leading	0000-0001-9723-3094	Orcid ID
Dr	Michael	Meyer	Man	Germany	michael.meyer@ericsson.com	Category A Top grade re	Team member		

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **ERICSSON**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☐
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☒
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☒
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*A. Palaios, P. Geuer et al., "Network under control: Multi-vehicle E2E measurements for AI-based QoS prediction," IEEE PIMRC, Sep. 2021.*
Publication	*R. Zhohov, A. Palaios, and P. Geuer, "Learning from large-scale commercial networks: challenges and knowledge extraction towards machine learning use cases", in Proc. 5G-MeMU, Aug. 2021.*
Publication	*J. Biosca Caro, J. Ansari, J. Sachs, P. de Bruin, S. Sivri, L. Grosjean, N. König, R. H. Schmitt, "Empirical study on 5G NR cochannel coexistence", MDPI Electronics, May 2022.*
Publication	*J. Ansari, C. Andersson, P. de Bruin, J. Farkas, L. Grosjean, J. Sachs, J. Torsner, B. Varga, D. Harutyunyan, N. König, and R. H. Schmitt, "Performance of 5G trials for industrial automation", MDPI Electronics, Jan.2022.*
Other achievement	*G. Wikström et al., "6G – Connecting a cyber-physical world", white paper, Feb. 2022, online available: https://www.ericsson.com/en/reports-and-papers/white-papers/a-research-outlook-towards-6g*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
5G-SMART *H2020* *GA number: 857008*	*5G for Smart Manufacturing;* *5G-SMART identified novel use cases, developed new 5G technology features, and identified viable operator business models to drive future 5G standards and technology adaption in the manufacturing ecosystem.* *In this project, EDD demonstrated, evaluated, and validated 5G systems for new manufacturing applications in 5G-enabled industry field trials.* *https://5gsmart.eu/*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Various equipment and infrastructure	*EDD has extensive experience with and access to various relevant cutting-edge equipment and infrastructure. Specifically, EDD has been using 5G private networks, URLLC testbeds based on Rel-16, state of the art SDR boards, GPU-based computation platforms, and commercial 5G equipment.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

PIC	Legal name
999841954	*UNIVERSITA DEGLI STUDI DI TRENTO*

Short name: UNITN

Address

Street	VIA CALEPINA 14
Town	TRENTO
Postcode	38122
Country	Italy
Webpage	www.unitn.it

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	yes		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	17/02/2022	- no
SME self-assessment	17/02/2022	- no
SME validation	unknown	

Departments carrying out the proposed work

Department 1

Department name: Department of Information Engineering and Computer Science ☐ not applicable

☐ Same as proposing organisation's address

Street: Via Sommarive, 9

Town: Povo

Postcode: 38123

Country: Italy

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **UNITN**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier
Dr	Paolo	Casari	Man	Italy	paolo.casari@unitn.it	Category B Senior resea	Leading	0000-0002-6401-1660	Orcid ID
Prof	Fabrizio	Granelli	Man	Italy	fabrizio.granelli@unitn.it	Category B Senior resea	Team member	0000-0002-2439-277X	Orcid ID

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **UNITN**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☒
Testing/validation of approaches and ideas	☒
Prototyping and demonstration	☐
IPR management incl. technology transfer	☒
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*J. Palacios, P. Casari, H. Assasa, J. Widmer, "LEAP: Location Estimation and Predictive Handover with Consumer-Grade mmWave Devices," Proc. IEEE INFOCOM, Paris, France, Apr. 2019*
Publication	*F. Granelli, R. Capraro, M. Lorandi, P. Casari, "Evaluating a Digital Twin of an IoT Resource Slice: an Emulation Study using the ELIoT Platform," IEEE Networking Letters, Sep. 2021*
Publication	*C. Ayimba, P. Casari, V. Mancuso, "SQLR: Short-Term Memory Q-Learning for Elastic Provisioning," IEEE Transactions on Network and Service Management, June 2021.*
Publication	*G. Bielsa, J. Palacios, A. Loch, D. Steinmetzer, P. Casari, J. Widmer, "Indoor Localization Using Commercial Off-The-Shelf 60 GHz Access Points," Proc. IEEE INFOCOM, 2018*
Publication	*T. Arzo, R. Bassoli, F. Granelli, F. H. P. Fitzek, "Multi-Agent Based Autonomic Network Management Architecture," IEEE Transactions on Network and Service Management, 2021*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
EU H2020 RECAP	*RECAP aims at making autoscaling in an edge-to-fog continuum seamless and scalable for different target applications, using a methodology that includes separation of concern, multitier optimization and machine learning to enable the fast convergence of deployment solutions*
EU H2020 MSCA-ETN MINTS	*MINTS trains future professionals and academics in all required enabling technologies, algorithms and methods to enable beyond-5G mmWave networks and applications supported by mmWave infrastructure.*
NATO SPS project DAVOSS	*This project implements a multi-layer virtualised system in which senros networks and multiple UAVs can operate together to guarantee efficient and effective borders and ports surveillance, or environmental security.*
FP7 ITN GREENET	*This ITN aimed at training ESRs in relevant issues of 4G networks, especially those emerging from a large number of foreseen devices coupled with the surge in power requirements for future emerging handsets. E.g., this includes i) reducing the energy consumption; and ii) reducing the amount of electromagnetic radiation.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Amarisoft callbox Classic	*A software-defined Release 15-compliant 5G base station and core network for testing purposes*
Software-defined radios	*Multiple software-defined radios of different brands and capabilities, to generate and receive signals of different type.*
Servers and high-end workstations	*Several servers for simulation and processing, including virtualization capabilities and clustered computing*
Drones	*Several aerial drones, including one model for the hauling of significant cargo (e.g., software.defined radios).*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? (•) Yes ( ) No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **UNITOV**

PIC	Legal name
999844864	*UNIVERSITA DEGLI STUDI DI ROMA TOR VERGATA*

Short name: UNITOV

Address

Street	VIA CRACOVIA 50
Town	ROMA
Postcode	00133
Country	Italy
Webpage	www.web.uniroma2.it

Specific Legal Statuses

Legal person	yes	Academic Sector	yes
Public body	yes		
Non-profit	yes		
International organisation	no		
Secondary or Higher education establishment	yes		
Research organisation	yes		

SME Data

Based on the below details from the Participant Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

SME self-declared status	14/12/2021	- no
SME self-assessment	unknown	
SME validation	31/12/2012	- no

Departments carrying out the proposed work

Department 1

Department name: Department of Electronic Engineering ☐ not applicable

☐ Same as proposing organisation's address

Street: via del Politecnico 1

Town: Rome

Postcode: 00133

Country: Italy

Links with other participants

Type of link	Participant

Application forms

Proposal ID **101119959**

Acronym **SpecX**

Short name **UNITOV**

Researchers involved in the proposal

Title	First Name	Last Name	Gender	Nationality	E-mail	Career Stage	Role of researcher (in the project)	Reference Identifier	Type of identifier	
Prof	Stefania	Bartoletti	Woman	Italy	stefania.bartolettii@uniroma2.it	Category B Senior resea	Leading	0000-0003-1428-9776	Orcid ID	
Prof	Giuseppe	Bianchi	Man	Italy	giuseppe.bianchi@uniroma2.it	Category A Top grade re	Team member	https://scholar.google.ch/citations?hl=en&user=JQsX7rAAAAAJ	Other ID	Google Scholar

Proposal ID **101119959**

Acronym **SpecX**

Short name **UNITOV**

Role of participating organisation in the project

Project management	☐
Communication, dissemination and engagement	☒
Provision of research and technology infrastructure	☒
Co-definition of research and market needs	☐
Civil society representative	☐
Policy maker or regulator, incl. standardisation body	☐
Research performer	☒
Technology developer	☐
Testing/validation of approaches and ideas	☐
Prototyping and demonstration	☐
IPR management incl. technology transfer	☐
Public procurer of results	☐
Private buyer of results	☐
Finance provider (public or private)	☐
Education and training	☒
Contributions from the social sciences or/and the humanities	☐
Other If yes, please specify: (Maximum number of characters allowed: 50)	☐

List of up to 5 publications, widely-used datasets, software, goods, services, or any other achievements relevant to the call content.

Type of achievement	Short description (Max 500 characters)
Publication	*S. Bartoletti, A. Conti and M. Z. Win, "Device-Free Counting via Wideband Signals," in IEEE Journal on Selected Areas in Communications, May 2017.*
Publication	*A. Conti, S. Mazuelas, S. Bartoletti, W. C. Lindsey and M. Z. Win, "Soft Information for Localizationof-Things," in Proceedings of the IEEE, 2019.*

List of up to 5 most relevant previous projects or activities, connected to the subject of this proposal.

Name of Project or Activity	Short description (Max 500 characters)
"LOCUS H2020-ICT-2018-20 GA: 871249"	*LOCUS aims to improve the functionality of 5G infrastructures to provide accurate and ubiquitous location information, and derive more complex features and behavioural patterns out of raw location and physical events. The project will help to increase the overall value of the 5G ecosystem by making new applications possible, boosting vertical industries, and creating new business opportunities for telecommunications companies.*

Description of any significant infrastructure and/or any major items of technical equipment, relevant to the proposed work.

Name of infrastructure of equipment	Short description (Max 300 characters)
Lab	*UNITV own completely independent and large lab facilities. The Electronic Department includes laboratories dedicated to Telecommunications Network, Sensors and Microsystems, Satellite Telecommunications and a Radar Laboratory.*

Gender Equality Plan

Does the organization have a Gender Equality Plan (GEP) covering the elements listed below? ○ Yes ◉ No

Minimum process-related requirements (building blocks) for a GEP

- **Publication:** formal document published on the institution's website and signed by the top management
- **Dedicated resources:** commitment of human resources and gender expertise to implement it.
- **Data collection and monitoring:** sex/gender disaggregated data on personnel (and students for establishments concerned) and annual reporting based on indicators.
- **Training:** Awareness raising/trainings on gender equality and unconscious gender biases for staff and decision-makers.
- **Content-wise, recommended areas** to be **covered** and addressed via concrete measures and targets are:
    - work-life balance and organisational culture;
    - gender balance in leadership and decision-making;
    - gender equality in recruitment and career progression;
    - integration of the gender dimension into research and teaching content;
    - measures against gender-based violence including sexual harassment.

3 - Budget

Participant number	Organisation short name	Role	Country	Country correction coefficient	Academic sector	IO	No of recruited researchers	Number of person months	Contributions for recruited researchers			Institutional contributions		Total
									Living allowance	Mobility allowance	Family allowance	Research, training and networking costs	Management and indirect costs	
1	IMDEA NETWORKS	Coordinator	ES	0.913	Yes	No	2	72	223502.40	43200	35640	115200	86400	503942.40
2	KU Leuven	Partner	BE	1	Yes	No	2	72	244800.00	43200	35640	115200	86400	525240.00
3	TID	Partner	ES	0.913	No	No	1	36	111751.20	21600	17820	57600	43200	251971.20
4	RWTH AACHEN	Partner	DE	0.983	Yes	No	1	36	120319.20	21600	17820	57600	43200	260539.20
5	CNIT	Partner	IT	0.974	Yes	No	2	72	238435.20	43200	35640	115200	86400	518875.20
6	TU Delft	Partner	NL	1.096	Yes	No	2	72	268300.80	43200	35640	115200	86400	548740.80
7	NEC LABORATORIES EUROPE GMBH	Associated	DE	0.983	No	No	0	0	0.00	0	0	0	0	0.00
8	Electrosense	Associated	CH	1.286	No	No	0	0	0.00	0	0	0	0	0.00
9	ACCELLERAN	Associated	BE	1	No	No	0	0	0.00	0	0	0	0	0.00
10	UC3M	Associated	ES	0.913	Yes	No	0	0	0.00	0	0	0	0	0.00
11	SUNY	Associated	US	1.023	No	No	0	0	0.00	0	0	0	0	0.00
12	Saint Louis University	Associated	US	1.023	Yes	No	0	0	0.00	0	0	0	0	0.00
13	ERICSSON	Associated	DE	0.983	No	No	0	0	0.00	0	0	0	0	0.00
14	UNITN	Associated	IT	0.974	Yes	No	0	0	0.00	0	0	0	0	0.00
15	UNITOV	Associated	IT	0.974	Yes	No	0	0	0.00	0	0	0	0	0.00
Total							10	360	1207108.80	216000	178200	576000	432000	2609308.80

4 - Ethics & security

Ethics Issues Table

1. Human Embryonic Stem Cells and Human Embryos			Page
Does this activity involve Human Embryonic Stem Cells (hESCs)?	○ Yes	◉ No	
Does this activity involve the use of human embryos?	○ Yes	◉ No	
2. Humans			**Page**
Does this activity involve human participants?	○ Yes	◉ No	
Does this activity involve interventions (physical also including imaging technology, behavioural treatments, etc.) on the study participants?	○ Yes	◉ No	
Does this activity involve conducting a clinical study as defined by the Clinical Trial Regulation (EU 536/2014)? (using pharmaceuticals, biologicals, radiopharmaceuticals, or advanced therapy medicinal products)	○ Yes	◉ No	
3. Human Cells / Tissues (not covered by section 1)			**Page**
Does this activity involve the use of human cells or tissues?	○ Yes	◉ No	
4. Personal Data			**Page**
Does this activity involve processing of personal data?	○ Yes	◉ No	
Does this activity involve further processing of previously collected personal data (including use of preexisting data sets or sources, merging existing data sets)?	○ Yes	◉ No	
Is it planned to export personal data from the EU to non-EU countries? Specify the type of personal data and countries involved	○ Yes	◉ No	
Is it planned to import personal data from non-EU countries into the EU or from a non-EU country to another non-EU country? Specify the type of personal data and countries involved	○ Yes	◉ No	
Does this activity involve the processing of personal data related to criminal convictions or offences?	○ Yes	◉ No	
5. Animals			**Page**
Does this activity involve animals?	○ Yes	◉ No	
6. Non-EU Countries			**Page**
Will some of the activities be carried out in non-EU countries?	○ Yes	◉ No	
In case non-UE countries are involved, do the activities undertaken in these countries raise potential ethics issues?	○ Yes	◉ No	
It is planned to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	○ Yes	◉ No	
Is it planned to import any material (other than data) from non-EU countries into the EU or from a non-EU country to another non-EU country? For data imports, see section 4.	○ Yes	◉ No	
Is it planned to export any material (other than data) from the EU to non-EU countries? For data exports, see section 4.	○ Yes	◉ No	
Does this activity involve low and/or lower middle income countries, (if yes, detail the benefit-sharing actions planned in the self-assessment)	○ Yes	◉ No	
Could the situation in the country put the individuals taking part in the activity at risk?	○ Yes	◉ No	
7. Environment, Health and Safety			**Page**

Does this activity involve the use of substances or processes that may cause harm to the environment, to animals or plants.(during the implementation of the activity or further to the use of the results, as a possible impact) ?	○ Yes	◉ No	
Does this activity deal with endangered fauna and/or flora / protected areas?	○ Yes	◉ No	
Does this activity involve the use of substances or processes that may cause harm to humans, including those performing the activity.(during the implementation of the activity or further to the use of the results, as a possible impact) ?	○ Yes	◉ No	

8. Artificial Intelligence			Page
Does this activity involve the development, deployment and/or use of Artificial Intelligence? (if yes, detail in the self-assessment whether that could raise ethical concerns related to human rights and values and detail how this will be addressed).	○ Yes	◉ No	

9. Other Ethics Issues			Page
Are there any other ethics issues that should be taken into consideration?	○ Yes	◉ No	

I confirm that I have taken into account all ethics issues above and that, if any ethics issues apply, I will complete the ethics self-assessment as described in the guidelines How to Complete your Ethics Self-Assessment ☒

Ethics Self-Assessment

Ethical dimension of the objectives, methodology and likely impact

Explain in detail the identified issues in relation to:
- objectives of the activities (e.g. study of vulnerable populations, etc.)
- methodology (e.g. clinical trials, involvement of children, protection of personal data, etc.)
- the potential impact of the activities (e.g. environmental damage, stigmatisation of particular social groups, political or financial adverse consequences, misuse, etc.)

Remaining characters 5000

Compliance with ethical principles and relevant legislations

Describe how the issue(s) identified in the ethics issues table above will be addressed in order to adhere to the ethical principles and what will be done to ensure that the activities are compliant with the EU/national legal and ethical requirements of the country or countries where the tasks are to be carried out. It is reminded that for activities performed in a non-EU countries, they should also be allowed in at least one EU Member State.

Remaining characters 5000

Security issues table

1. EU Classified Information (EUCI)[2]			Page
Does this activity involve information and/or materials requiring protection against unauthorised disclosure (EUCI)?	○ Yes	◉ No	
Does this activity involve non-EU countries?	○ Yes	◉ No	
2. Misuse			**Page**
Does this activity have the potential for misuse of results?	○ Yes	◉ No	
3. Other Security Issues			**Page**
Does this activity involve information and/or materials subject to national security restrictions? If yes, please specify: (Maximum number of characters allowed: 1000)	○ Yes	◉ No	
Are there any other security issues that should be taken into consideration? If yes, please specify: (Maximum number of characters allowed: 1000)	○ Yes	◉ No	

[2]According to the Commission Decision (EU, Euratom) 2015/444 of 13 March 2015 on the security rules for protecting EU classified information, "European Union classified information (EUCI) means any information or material designated by an EU security classification, the unauthorised disclosure of which could cause varying degrees of prejudice to the interests of the European Union or of one or more of the Member States".

[3]Classified background information is information that is already classified by a country and/or international organisation and/or the EU and is going to be used by the project. In this case, the project must have in advance the authorisation from the originator of the classified information, which is the entity (EU institution, EU Member State, third state or international organisation) under whose authority the classified information has been generated.

[4]EU classified foreground information is information (documents/deliverables/materials) planned to be generated by the project and that needs to be protected from unauthorised disclosure. The originator of the EUCI generated by the project is the European Commission.

START PAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Doctoral Networks (DN)
Call: HORIZON-MSCA-DN-2022

PART B

SpecX

Doctoral Network on
Spectrum Analytics as a Service

This proposal is to be evaluated as:

[DN]

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List of participating organisations

Consortium Member	Short Name	Academic	Non-academic	Awards Doctoral Degrees	Country	Dept./Division / Laboratory	Scientist-in-Charge	Role of Associated Partners
Beneficiaries								
1. IMDEA Networks	[IMDEA]	✓			Spain	Research Department	Domenico Giustiniano	
2. KU Leuven	[KU Leuven]	✓		✓	Belgium	Dept. of Electrical Engineering	Sofie Pollin	
3. Delft University of Technology	[TU Delft]	✓		✓	Netherlands	Department of Software Technology	Qing Wang	
4. Consorzio Nazionale Interuniversitario per le Telecomunicazioni	[CNIT]	✓			Italy	Research Department	Paolo Casari	
5. RWTH Aachen University	[RWTH]	✓		✓	Germany	Mobile Communications and Computing Group	Marina Petrova	
6. Telefonica I+D	[TID]		✓		Spain	TID Research	Andra Lutu	
Associated Partners								
1. NEC Laboratories	[NEC]		✓		Germany	NEC Laboratories Europe	Andres Garcia-Saavedra	Specialised training & hosting secondments
2. Ericsson GmbH	[Ericsson]		✓		Germany	Ericsson Research	Andra Mihaela Voicu	Specialised training & hosting secondments
3. ElectroSense	[ESense]		✓		Switzerland	Research Division	Vincent Lenders	Specialised training & hosting secondments
4. Accelleran	[ACC]		✓		Belgium	Research and Development	Trevor Moore	Specialised training & hosting secondments
5. University Carlos III of Madrid	[UC3M]	✓		✓	Spain	Department of Telematics Engineering	Pablo Serrano	Specialised training & hosting secondments
6. University of Tor Vergata	[UNITV]	✓		✓	Italy	Department of Electronic Engineering	Stefania Bartoletti	Specialised training
7. University of Trento	[UNITN]	✓		✓	Italy	Dept. of Information Engineering and Computer Science	Paolo Casari	Specialised training
8. University at Albany	[AlbanyU]	✓			USA	Department of Computer Science	Mariya Zheleva	Specialised training & Hosting secondments
9. St. Louis University	[SLU]	✓			USA	Department of Computer Science	Flavio Esposito	Hosting secondments

Data for non-academic beneficiaries:

Name	Location of research premises (city / country)	Type of R&D activities	No. of full-time employees	No. of employees in R&D	Web site	Annual turnover[1] (in Euro)	Enterprise status	SME status
Telefonica I+D	Barcelona, Spain	Research	451	256	http://www.tid.es	86.7M	Yes	No

Declarations:

Name (Institution and position)	Nature of inter-relationship
Stefania Bartoletti (CNIT; Senior Researcher)	Assistant Professor at UNITV
Paolo Casari (CNIT; Senior Researcher)	Associate Professor at UNITN

[1] Defined as the total value of sales of goods and services during the last accounting period.

List of SpecX acronyms and abbreviations

2G	Second Generation Mobile network
3G	Third Generation Mobile network
3GPP	Third Generation Partnership Project
4G	Fourth Generation mobile network
5G	Fifth Generation mobile network
6G	Sixth Generation mobile network
AI	Artificial Intelligence
AoA	Angle of Arrival
AR	Augmented Reality
BS	Base Station
CBRS	Citizens Broadband Radio Service
COST	European Cooperation in Science and Technology
COTS	Commercial Off-The-Shelf
CS	Compressive Sensing
CSI	Channel State Information
DAB	Digital Audio Broadcasting
DARPA	Defense Advanced Research Projects Agency
DC	Doctoral Candidate
DCG	Domain Coordination Group
DESCA	Development of a Simplified Consortium Agreement
DGC	Doctoral Guidance Committee
DMP	Data Management Plan
DN	Doctoral Network
DPO	Data Protection Officer
DSS	Dynamic Spectrum Sharing
EC	European Commission
ECTS	European Credit Transfer System
EM	Electro Magnetic
EMI	Electromagnetic Interference
ETN	European Training Network
EU	European Union
GC	General Coordinator
GDP	Gross Domestic Product
GDPR	General Data Protection Regulation
gNB	next generation Node B
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HR	Human Resources
HW	Hardware
ICT	Information and Communication Technology
IETF	Internet Engineering Task Force
IP	Intellectual Property
IPR	Intellectual Property Rights
IQ	In-phase and Quadrature phase
ISM	Industrial, Scientific and Medical
JU	Joint Undertaking
KPI	Key Performance Index
LICT	Leuven Centre on Information and Communication Technology
LPWAN	Low-Power Wide-Area Network
LTE	Long Term Evolution
MCAA	Marie Curie Alumni Association
MIMO	Multiple Input Multiple Output
ML	Machine Learning
MSC	Marie Skłodowska-Curie
MSCA	Marie Skłodowska-Curie Actions
MST	Management Support Team
NDA	Non-Disclosure Agreement
NWE	Network-Wide Event
OFDM	Orthogonal Frequency-Division Multiplexing
PCDP	Personal Career Development Plan
PM	Project Manager
PPP	Public-Private Partnership
PSD	Power Spectral Density
PU	Primary User
QoS	Quality of Service
RAN	Radio Access Network
RC	Recruitment Committee
R&D	Research and Development
RDF	Research Development Framework
RE	Recruitment Event
ReC	Researcher Council
REA	Research Executive Agency
RF	Radio Frequency
RRI	Responsible Research and Innovation
RTDE	Research, Test, Development and Evaluation
SAIFE	Spectrum Anomaly Detector with Interpretable FEatures
SB	Supervisory Board
SDR	Software Defined Radio
SC	Scientific Coordinator
SW	Software
TCCC	Technical Committee on Computer Communications
TDoA	Time Difference on Arrival
TRL	Technology Readiness Level
TSB	Technical Steering Board
TSC	Technical Steering Committee
TX	Transmitter
URLLC	Ultra-Reliable Low-Latency communication
VR	Virtual Reality
WIA	Wireless Infrastructure Association
WP	Work Package
WRC	Women Researchers Council

1. Excellence

1.1 *Quality and pertinence of the project's research and innovation objectives*

1.1.1 Introduction, objectives, and overview of the research programme

The value of the 5G market will enable $13.2 trillion of global economic output in 2035, and the 5G industry is investing an average of $235 billion annually to allow the continuous expansion and strengthen the 5G technology base[2,3]. Besides, the Internet of Things (IoT) industry, which is in an era of rapid proliferation, expects to have a total potential economic impact of up to $12.6 trillion a year by 2030. In such a context, the ***radio frequency part of the electromagnetic (EM) spectrum*** is a precious and limited resource, essential for wireless communications and the upkeep of economic growth. However, the exponential increase in the demand for broadband wireless communication services is stressing the availability of spectrum to accommodate new services and applications. On the other hand, the ***growth of the EU's telecommunication market is decelerating,*** and further growth critically depends on spectrum availability and its efficient usage[4]. Recently, the NSF in United States has announced a 25 million investment over five years, to build a spectrum innovation centre to "catalyse innovation and support workforce development to solve radio *spectrum challenges* that are critical to the nation"[5]. Also, in the EU, we need to build innovation potential and workforces on the interplay between spectrum and infrastructure for new growth markets. Consequently, this is the right moment to take a step forward, *sensing, monitoring, and processing spectrum* with innovative techniques and tools, and make a significant impact on the future 6G technologies market. To this end, **SpecX provides the required expertise and effort to train a workforce of 10 Doctoral Candidates (DCs) in spectrum challenges at the frontier of 6G networks**, to:

Pillar 1: Measure the EM spectrum massively, dynamically and in 3D. Although EM spectrum data collection at a massive scale faces important infrastructure, technical and research challenges. For instance, collecting 2M IQ samples per second over just 2 MHz band with crowdsourced IoT sensors would result in a data rate of 128 Mb/s to upload this data for processing in the core network. As reference, the new proposed broadband definition in US by the FCC for uplink data rate is set to 20 Mb/s. There are key technical opportunities in future 6G networks that can be exploited to tame the spectrum data deluge. Spectrum sensing benefits largely from Software Defined Radio (SDR) technology, which is reconfigurable in nature and will become a critical asset for future network deployments. Edge computing, distributed algorithms, spatial correlation, feature extraction, as well as 3D spectrum sensing, exploiting the crowd, 5G and beyond infrastructure, and Open-RAN (O-RAN) edge, all drive towards the opportunity of designing a scalable, spectrum monitoring infrastructure critically relying on edge computing and distributed big data processing.

Pillar 2: Turn the wireless data deluge challenge in new applications and innovative use of spectrum for future networks. To efficiently understand the EM Spectrum, SpecX proposes to add Artificial Intelligence (AI) capabilities and other more traditional spectrum analysis methods to create insights in spectrum use, detecting anomalies to dynamically scale and orchestrate network resources as the number of devices increase (e.g., massive IoT), localizing non-cooperative mobile transmitters to better allocate resources and 3D predictive coverage mapping by means of aerial base stations. As an example, both telecom operators and non-telecom services using the spectrum (e.g., radio-astronomy, standard frequency and time signals, radars, telemetry, aeronautical radionavigation, radio beacons, and others), could benefit from the interference and coexistence assessment by SpecX data analytics, the detection of incumbent transmitters on their bands, their emission footprints and localization, out-of-band emissions detection, opportunities for spectrum sharing and collaborative dynamic access of spectrum and achieve mission-critical wireless communication for Industry 4.0. Adding embedded AI capabilities to the radio access and edge networks relieves the communication to the core network due to the local computation and the fact that only pre-processed data, rather than raw data, are computed in the core network.

Pillar 3: Tackle the talent shortage in the EU's spectrum big data market. Dedicated skills are needed to dive into the unexplored big data spectrum, but they are missing. For example, the Wireless Infrastructure Association[6] recently reported a significant skill gap in the telecommunication market, asking for critical training on, first, RF principles and fundamentals and, second, spectrum aspects (allocation, policy, and impact of re-farming). Other critical aspects that face a skill gap are the introduction of small cells and the understanding of connectivity for the IoT. The European Commission sets ambitious goals to increase innovation and competition in the wireless domain by promoting spectrum access *flexibility* (e.g., dynamic spectrum access), but this assumes a sufficient understanding of the opportunities of the spectrum usage. From the cyber-security point of view, it is important

[2] https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/iot-value-set-to-accelerate-through-2030-where-and-how-to-capture-it
[3] https://www.qualcomm.com/content/dam/qcomm-martech/dm-assets/documents/the_ihs_5g_economy_-_2019.pdf
[4] SpectrumX, https://www.strategyand.pwc.com/media/file/Grasping-at-differentiated-straws-v2.pdf
[5] https://www.nsf.gov/news/news_summ.jsp?cntn_id=303454
[6] https://wia.org/wp-content/uploads/WIA_5G_Training-finalweb3.pdf

to monitor the spectrum and protect it from attacks whose aim is to destabilize the communications in a country and negatively impact its economic opportunities. The latter is really a countries' concern when critical communications are compromised not only for aviation or GNSS, but even for the 5G and beyond network, for instance, for ultra-low latency applications such as remote surgery and autonomous cars networks.

In short, the overarching objective of SpecX is to provide high-level training to 10 Doctoral Candidates (DCs) in large-scale spectrum measurement, analysis, and applications in future telecom infrastructure. The goal is to create a research and innovation workforce with transferable skills in radio hardware, cellular network infrastructure, edge computing, data collection, signal processing, deep learning and Artificial Intelligence, data tools to assess, improve and analyse big spectrum data and provide innovative services. This goal will be achieved by a unique combination of hands-on research training designed to provide to the DCs the needed fundamental elements to conduct the research programme, for collecting real spectrum data, analysing it, and developing innovative methods, and create insights and invent new valuable applications. Hands-on in depth-training will be strengthened with non-academic placements, as well as multidisciplinary, intersectoral, and international cooperation to maximize the employability of DCs and the impact of the project.

Integration and contribution of individual projects in the SpecX research programme. To achieve the SpecX overarching objective and implement and execute the 3 pillars of the project, we have designed 10 DCs projects. The specific science/technology (S/T) objectives (**Obj1**-**Obj10**) are summarized in **Table 1**, with each DC leading the contribution to one S/T objective of the overall project, and providing inputs to others. The output from each DC project corresponds to a component in the architecture presented in **Figure 1**, that also shows the interaction and complementarity of each DC project. SpecX is the first EU research and doctoral training program that aims to build a complete system for spectrum analytics by exploiting sensing, edge computing, machine learning and spectrum analysis for innovative spectrum use applications. The proposed conceptual architecture and network components are based on the separation between Radio Access Network (RAN)/O-RAN, edge network and core network in current 5G architectural deployments, further leveraging Service Based Architecture to virtualize the network services over the available physical resources and facilitate links between DC projects.

Table 1. SpecX specific S/T objectives (measurable and verifiable targets in **Section 3** and **Table 10**)

WP	Specific Objectives
WP1: Sensing and infrastructure	**Obj1.** To improve the embedded spectrum analysis performed in sensing devices (**Obj1a**, **DC1**), and to design a scalable embedded federated learning framework for spectrum analysis that can run on a few mobile aerial sensors or 1000s connected terrestrial sensors that all have computing constraints (**Obj1b**, **DC1 + input from DC9**). **Obj2.** To explore how spectrum sensing techniques can help edge to improve service quality, i.e., anomaly detection, orchestration (**Obj2a**, **DC2 + input from DC3**), minimize interference, and investigate how edge platforms can help spectrum sensing measurements and services, e.g., run spectrum sharing auctions/allocations across users (**Obj2b**, **DC2**). **Obj3.** To propose a sensing-based radio access architecture that is capable of identifying spectral and spatial resources at the required time scale and dynamics for 6G applications by interfacing radio access infrastructure to a spectrum-monitoring infrastructure at optimised cost and complexity (**Obj3a**, **DC3**). Compare various radio access infrastructures (O-RAN, 5G core network, Wi-Fi-based) and impact on sensing performance (**Obj3b**, **DC3 + input from DC2**).
WP2: Data Analysis	**Obj4.** To incorporate expert feedback (human-in-the-loop) to a semi-supervised learning framework to improve the state-of-the-art algorithms for anomaly detection (**Obj4a**, **DC4 + input from DC6**). To investigate solutions for adding spectrum sensing and anomaly detection in the O-RAN edge (**Obj4b**, **DC4**). **Obj5.** To build a framework for localizing transmitters at any frequency that do not collaborate for the purpose of localization, only exploiting the waveform structure of transmitters (**Obj5a**, **DC5 + input from DC9**) and perform analytics to infer pattern movements of several mobile transmitters (**Obj5b**, **DC5**). **Obj6.** To explore and design new algorithms for building efficient and reliable measurement-based mobile coverage and performance maps (accurately building real-time Radio-Environmental Maps) for 6G network performance optimizations by leveraging the data collected from the terrestrial and aerial nodes (**Obj6a**, **DC6**). Compare predictive 3D methods with real-world data (**Obj6b**, **DC6 + input from DC1**).
WP3: Network applications	**Obj7.** To investigate solutions for orchestration of network resources based on anomaly detection and spectrum sensing (**Obj7a**, **DC7 + input from DC4**). To propose scalable sensing frameworks for the massive Internet of Things (**Obj7b**, **DC7**). **Obj8.** To exploiting mobile cells to satisfy the high and dynamic demands on the wireless capacity (**Obj8a**, **DC8**). To integrate drones for sensing as well as access in converged aerial-terrestrial networks (**Obj8b**, **DC8 + input from DC6 and DC7**). **Obj9.** To develop electrosmog sensing and forecasting techniques for dense deployments, including smart cities (**Obj9a**, **DC9 + input from DC5**). To understand the fundamental limits of electrosmog sensing with embedded sensors (**Obj9b**, **DC9**). **Obj10.** To identify the possible risks and threats of using wireless connections for safety-critical applications in Industry 4.0 and develop a systematic approach on how to react on a possible anomaly in the used spectrum for a safety-critical wireless connection (**Obj10a**, **DC10 + input from DC4**). To test the approach in applications such as collaborative robots and autonomous guided vehicles and drones (**Obj10b**, **DC10 + input from DC8**).

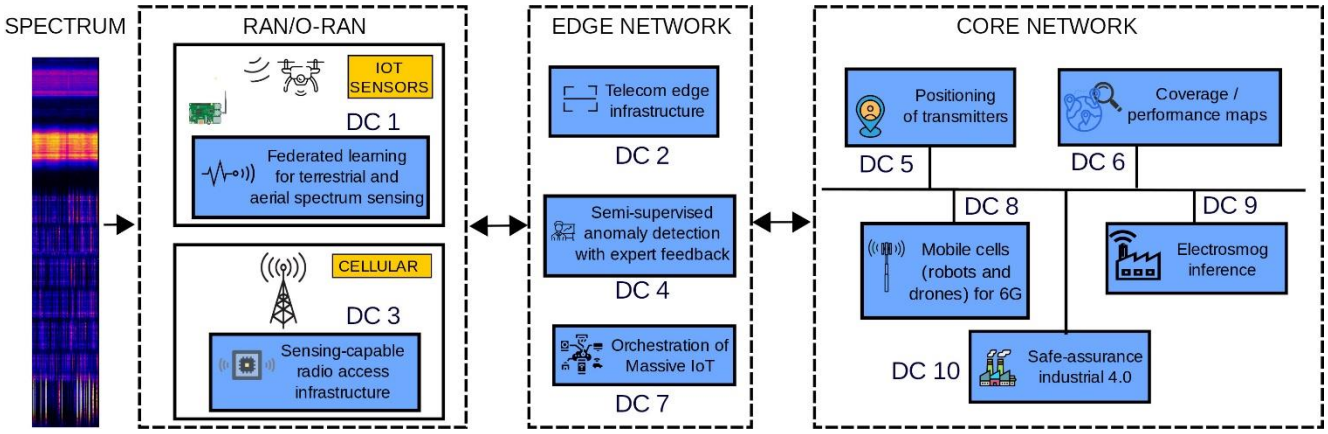

Figure 1. Overview of SpecX's research work and conceptual architecture for their inter-connections.

The architectural concept jointly addresses the fundamental challenges of spectrum sensing and infrastructure, spectrum big data analysis and the application-driven problems, and it facilitates the adoption of solutions designed by each DC. For instance, standard interfaces can be implemented to provide location of transmitters as input of electrosmog interference service. Furthermore, it guides coherent elaboration on *implementation and integration* of different types of research activities. The architecture will be reviewed, and detailed during the project execution (**D6.10-11** in **Section 3**). The project participants of SpecX (IMDEA, KU Leuven, RWTH, TU Delft and CNIT) are leading the effort of instrumenting testbed designs for spectrum sensing. This provides unique know-how, prototyping expertise, and testbed facilities to SpecX (as shown in **Figure 2**), allowing application-specific spectrum sensing to be evaluated using wireless sensed data. SpecX combines and strengthens Europe's skills and knowledge base through an intersectoral and interdisciplinary cluster of excellence: SpecX beneficiaries and associated partners are leading members of large EU initiatives, and comprise major telecommunication manufacturers (e.g., Ericsson, NEC), operators (e.g., Telefonica), hardware/system integrators (e.g., ACC), and spectrum analysis experts (ESense, as well as AlbanyU and SLU in USA).

The overall work of SpecX is organized in 6 WPs, and the 10 DC projects are organised in three research work packages: **WP1**: sensing and infrastructure, **WP2**: data analysis, and **WP3**: applications. SpecX improves physical sensing of the spectrum in WP1 and derives spectrum insights in WP2. Exploiting the know-how from WP1 and WP2, SpecX targets a range of future application areas of spectrum analytics in WP3. *Necessary S/T skills as well as soft skill to conduct the research in WP1-3* will be acquired through a dedicated program with interdisciplinary training (WP4) and entrepreneurial skills (WP5) (see **Section 1.3.1**). Individual S/T skills will further be learnt through research at host institution and secondments at both academic and non-academic partners. The coordination of the project will guarantee high employability of DCs and high impact of project outputs (WP6).

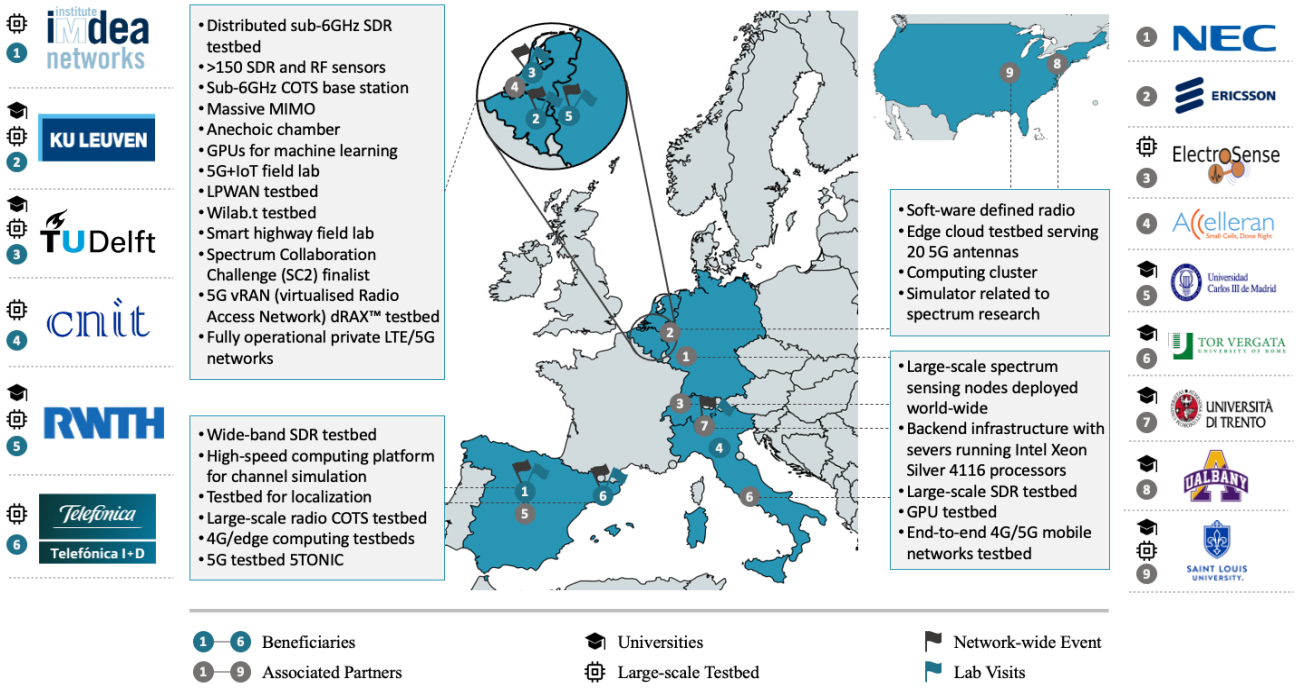

Figure 2. SpecX consortium: an overview of the six beneficiaries and eight associated partners from seven different EU countries and the USA. The infographic shows the large-scale facilities that allow network-wide measurements with a great variety of computing facilities.

1.1.2 Pertinence and innovative aspects of the research programme

Traditionally, governmental agencies and international organizations are responsible for regulating, allocating, optimising, and monitoring the usage of the radio EM spectrum. Today's spectrum measurements are mainly performed by the government and telecommunication companies which use expensive and bulky equipment scheduling very specific spectrum campaigns limited in space and time. These approaches are targeting the well-known mobile broadband application for traditional - often frequency division duplex - types of spectrum use. However, traditional ossified spectrum surveys cannot cope with the exponential increase in the number of devices and smaller cell sizes of 5G and future newer generations of wireless networks, given the number of locations that would be needed and the amount of data that would be generated to monitor all bands (licensed and unlicensed) at all locations and time. A *new spectrum monitoring paradigm is needed to sense EM waves for all bands and space locations*, and provide information beyond simple coverage for a single technology or strength maps for a single frequency band. Given the importance of spectrum, several large players or research consortia have attempted to create spectrum monitoring solutions, such as Microsoft's Spectrum Observatory[7], the CitySCape Spectrum Observatory from University of Washington or the Electrosense initiative in Europe[8] (partner of SpecX), or RadioHound[9] All these solutions, however, face spectrum data deluge, require large investments in deployments to enable a scalable spectrum monitoring density in space, time, and frequency, and fail to give spectrum data insights to stakeholders beyond coverage information.

The roll-out of 5G is starting now in the EU, reusing 4G bands with small cells or other novel 5G access technology such as Massive MIMO, and opening up also new bands in higher frequency bands such as 3.5 GHz. Each of those technologies will result in a more spatial focus of the communication: Massive MIMO, small cells or higher frequency bands. In parallel, novel use cases and types of operators emerge in the context of Industry 4.0 or other scenarios where private networks operate. To manage the coexistence of those local cells and local private networks, operators and users will critically depend on dynamic and predictive spectrum analytics rather than traditional spectrum surveys. These problems have constrained the full deployment of advanced applications. Closing these gaps in terms of spectrum availability and optimization will be essential for achieving the potential of 5G and beyond networks, and to enable new services with a high economic and societal value[10].

Related research projects: The EU has supported different spectrum-related projects where the SpecX beneficiaries were involved in, such as FARAMIR, CREW, Flex5Gware, LOCUS and ORCA, have studied the basic challenges of spectrum sensing and flexible spectrum use, often with a focus on flexible architectures and physical layer techniques. One of the two ambitious Horizon 2020 prizes was awarded in the domain of collaborative spectrum sharing, where the EU aimed to support an innovative and disruptive approach that could enable a significant increase in spectrum sharing and re-use. Other EU MSCA actions typically target network rather than spectrum data analytics. For example, the RISE action DAWN4IoE focuses on network usage and traffic to help network planning, whereas the ITN-EID ACT5G exploits network usage analytics for anticipatory networking and optimization. *SpecX complements these programs by offering a spectrum data rather than a network data point of view*. In fact, this unique vantage point makes it possible to optimize network deployments, configurations, and usage, while also enable new applications. Closer in scope to SpecX, there are also initiatives in the USA, such as DARPA Spectrum challenge and Colosseum[11]. Although instrumental to prove the feasibility of flexible spectrum use, these projects did not venture much into the analysis of spectrum use beyond radio environment or occupancy maps. More recently, SpectrumX in the USA has been awarded 25M$ to build a spectrum innovation centre to "solve radio spectrum challenges that are critical to the nation".

SpecX contains six WPs, including three research WPs (**WPs 1-3**), with clear objectives (**Obj1**-**Obj10**), milestones (**mX.Y**), deliverables (**DX.Y**) and delivery dates, as well as packages related to Training (**WP4**), Dissemination (**WP5**) and Management (**WP6**). In the following paragraphs, we provide a general overview of the S/T WPs. A more detailed S/T description is given in **Section 3**.

SpecX leverages the aforementioned initiatives in EU (where SpecX partners had an active role) and it is inspired by ongoing initiatives in USA. By pooling the resources of the leading manufacturers, network operators, spectrum use organizations and research institutions and universities, SpecX goes beyond spectrum use mapping, and targets disruptive spectrum applications relying on automated, location-aware, accurate and reliable spectrum analytics. This implies devising rich and distributed spectrum *analysis solutions* which can be tailored to the specific requirements of each use case and *implementing* them in the various testbeds available at the project

[7] http://spectrum-observatory.cloudapp.net
[8] **http://electrosense.org [Bold references are own work of the researchers of the SpecX consortium]**
[9] https://wireless.nd.edu/research/radiohound-distributed-spectrum-sensing/
[10] European Commission, "Digital Economy and Society Index (DESI)", 2022.
[11] https://www.rfglobalnet.com/doc/northeastern-to-design-the-wireless-networks-of-the-future-0001

beneficiaries. Building the sensing and localization capabilities in future cellular systems provides an unprecedented level of environmental awareness, enhanced by spectrum sensing capabilities in low-cost sensors deployed by everybody at various locations. In itself, this will pave the way towards a new line of spectrum data products and applications, as well as autonomous network control solutions to improve network resilience. The sensing analytics technology will have a tremendous socio-economic impact, as one of the spectrum analytic outcomes is the feasibility of dynamic spectrum sharing, most cost-effective sections of spectrum might be allocated to mobile communications. This will materialize through the advances in mobile network performance, capabilities, reduced cost for operators, and will enable innovation opportunities to develop new services and applications. This will further enable the creation of new spectrum access business models and eco-systems. Finally, the technology will influence society through improvements in manufacturing, transportation, communication, healthcare, and all application innovations it will enable.

Table 2 provides a detailed overview of the scientific progress beyond the state-of-the-art and the research objectives for each of the research paths explored in SpecX for overcoming the identified scientific gaps. Prior experience of SpecX's project partners presents solid foundations for fulfilling the three missions of the project (see **Section 1.1.1**) and is detailed in **Table 2**. At a high level, project partners have been at the frontier of research in the domain of modulation classification[12], anomaly detection[13], transmitter localisation[14]. It is expected that future systems will make more use of technologies that are not ground-based, such as drones used as base stations to provide temporary coverage or capacity extensions[15]. Another example is satellites providing coverage to underserved areas or emergency communications in remote areas. SpecX partners were among the first to measure LTE performance in the sky[16] or design solutions for sensing up to the stratosphere[17]. With the introduction of non-terrestrial networking, another dimension is added to the network planning and anomaly detection problems.

Table 2. State of the art and progress beyond state of the art in SpecX.

	State of the art	Progress beyond state of the art and expected innovation
Project	No spectrum analytics framework exists. Despite the scarcity and importance of the wireless spectrum, **no scalable, large scale spectrum monitoring solution exists.** Most projects focused on physical layer 2D coverage maps, whereas upper layers and feature analysis were studied much less.	**Enabling spectrum analysis for a wide range of future mobile applications (Industry 4.0, 6G, Aerial Networks, Massive Internet of Things)** by developing scalable sensing and telecom infrastructure to support application-specific requirements and leveraging the **edge computing** and **AI** paradigms.
WP1	Existing deep learning works on technology classification, and anomaly detection required **labelled dataset**[18], which is often not available or difficult to acquire. Further, training of deep learning models is executed **centrally** on powerful platforms. Modern infrastructures are equipped with dedicated machine learning processors. This concept, which involves end devices in the process, is termed as **Federated learning**[19].	Perform model training for federated technology classification and anomaly detection 1) with limited labelled data and 2) at the device level with an interplay with the edge in the learning process. Build solutions for **federated technology classification and anomaly** detection with semi-supervision from the cloud and application experts. A framework that can scale to **extreme resource constrained aerial sensors**. (**Obj1**)
	Policies for sensor data transmission have focused mainly on optimizing data collection for machine learning model training[20]. Existing edge infrastructures are agnostic with respect to spectrum sensing information in their operations, and **only rely on traditional metrics** such as the number of users, network latency, and service requirement. Also, existing **spectrum sensing infrastructures do not leverage edge** infrastructures to improve spectrum sensing information[21].	Investigate adaptive **policies for the use of edge for spectrum data processing and learning**. Design **data-driven policies** that change the **behaviour of the system** based on **spectrum usage events**. Identify and modify the **operational elements of edge infrastructures** that could benefit from the availability of spectrum sensing data to improve quality of service provided to users. **Enhance spectrum sensing techniques** by leveraging the location and computing capabilities of edge infrastructures. (**Obj2**)
	In the literature, different sensing techniques and database approaches have been proposed in the context of cognitive radio and recently in LSA and CBRS deployments[22]. However, these are **quasi-static and slow**, and cannot sustain a seamless operation across licensed and unlicensed bands for many applications in 5G and beyond network deployments[23].	Identify available spectrum resources and potential harmful interference in a **dynamic and agile fashion** across different bands. We aim at designing such functionality in the future RAN (gNBs/APs), exploring both **data-driven and predictive dynamic spectrum allocation and sharing policies**, using sensing data for timely and proactive decision making. (**Obj3**)

[12] **E. Perenda, et al. "Learning the unknown: Improving modulation classification performance in unseen scenarios."** ***IEEE INFOCOM*****, 2021.**
[13] **S. Rajendran, et al. "Crowdsourced Wireless Spectrum Anomaly Detection."** ***IEEE Trans. Cognitive Communications and Networking*****, 2020.**
[14] **H. Sallouha, et al. "Aerial Vehicles Tracking Using Noncoherent Crowdsourced Wireless Networks."** ***IEEE Trans. Vehicular Technology*****, 2021.**
[15] **Deruyck M, et al. "Designing UAV-aided emergency networks for large-scale disaster scenarios."** ***EURASIP J. Wireless Comm. & Net.*****, 2018.**
[16] **B. Bergh, et al. "LTE in the sky: trading off propagation benefits with interference costs for aerial nodes."** ***IEEE Comm. Magazine*****, 2016.**
[17] **B. Reynders, et al. "SkySense: terrestrial & aerial spectrum use analysed using lightweight sensing with weather balloons."** ***MobiSys*****, 2020.**
[18] T. O'Shea, et al. "Over-the-air deep learning based radio signal classification." *IEEE Journal of Selected Topics in Signal Processing*, 2018.
[19] K. Bonawitz, et al. "Towards federated learning at scale: System design." *Machine Learning and Systems (MLSys)*, 2019.
[20] Y. Roh, et al. "A Survey on Data Collection for Machine Learning: A Big Data - AI Integration Perspective." *IEEE TKDE*, 2021.
[21] **S. Rajendran, et al. "Electrosense: Open and Big Spectrum Data."** ***IEEE Communications Magazine*****, 2018.**
[22] R. Tehrani, et al. "Licensed spectrum sharing schemes for mobile operators: A survey and outlook." *IEEE Communications Survey and Tutorials*, 2016.
[23] M. Hoyhtya, et al. "Database-assisted spectrum prediction in 5G networks and beyond." *IEEE Circuits & Systems M*, 2019.

WP2	Existing state-of-the-art anomaly detection frameworks are not specifically optimized for the spectrum sensing domain. SAIFE already introduced a semi-supervised anomaly detection framework with interpretable features and expert feedback[24], but this scheme is still working with synthetic anomalies and has not been verified on **real application data, expert feedback and application-specific anomalies.**	**Interpretable deep learning for spectrum sensing** is, in general, not yet existing in the state-of-the-art. Design a deep learning framework that allows a large number of interpretable features (power, location, frequency, and modulation type) presented to the expert user as features of a detected anomaly. The anomaly detection framework will be **trained by expert feedback,** as well through **automated analysis of network outage events**. (Obj4)
	Existing algorithms on localising signal transmitters at any frequency make use of **expensive and bulky hardware** to accurately localize the transmitter. This limits the deployment of the systems to ad-hoc deployment in small and outdoor[25] or are affected by large positioning error[26]. Besides, there is limited effort to estimate the location of emitters completely passively (e.g. without its cooperation).	Distributed IoT and non-coherent sensors will be synchronized **not using GPS but opportunistically using signals** of the environment (LTE, DAB, Mode-S). Study TDoA-based, Doppler-based AoA-based methods that work without cooperating emitters as enablers of signal transmitter localization using non-coherent radio frequency receivers. Infer **pattern movements** with estimated position of multiple devices (Obj5)
	Cellular **coverage maps using field measurements** of signal strength currently integrates two components: (i) sampling strategy design, which involves defining a method for collecting a representative and unbiased set of measurements; and (ii) a predicting value at unobserved locations based on the collected measurements. These techniques are technology-dependent and limited in data size.	Leverage the data collected from spectrum sensing infrastructures (e.g., ESense infrastructures) and crowdsource apps and introduce **algorithms to efficiently predict mobile network performance**. Work closely with operators in SpecX to process data on the expected coverage of the radio network. Work towards building novel **anomaly detection approaches and alerting** the radio planning team about potential suboptimal configurations. (Obj6)
WP3	Future networks are inherently very flexible and resources can be allocated dynamically based on spectrum insights. Current approaches for **software-defined networking are mainly based on wired networks, and do not extend well to wireless networks**, although we have proposed a vision towards this[27]. Thinking further to the massive wireless Internet of Things, we need scalable and **specific orchestration frameworks**, e.g., as we considered for BLE[28].	Employ multi-band spectrum data to infer the status of distributed massive Internet of Things deployments, including overuse, communication issues, and anomalies. Orchestrate the deployment of status inference functions across the network, in a way to optimize computational resource usage intensity, promote fair energy consumption, and alternate optimally between spectrum sensing and spectrum usage. (Obj7)
	Emerging 5G and beyond systems are characterized by multi-tier networks, high heterogeneity, and density of devices, which are making necessary innovative spectrum sharing and interference management solutions[29]. However, there is still a general **lack of practical implementation of 3D spectrum sharing**, mainly because of over-reliance on 2D coverage planning, and the lack of predictive 3D spectrum use models[30]. Spectrum sharing in mobile networks have been limited to the self-band assigned to a certain operator for bandwidth split between services.	Design **advanced 3D spectrum access rules** to be easily programmed and executed on aerial wireless nodes, for testing in real deployment of collaborative mechanisms for increasing the level of autonomy of ground-air coexisting systems. **Exploit the movement of BSs** (mobile cells) to satisfy the high and dynamic demand on wireless capacity. Study how to provide pervasive and reliable 5G+ service **without overprovisioning** the number of fixed-location BSs (Obj8). Exploit spectrum insights from scalable lightweight anomaly detection and technology classification (Obj1) towards **dynamic 3D spectrum sharing**.
	While lack of reliable information is one of the main drivers behind the public concern regarding 5G radiation, we see few solutions for massive, large scale electrosmog measurement. For exposure analysis, state-of-the art still critically relies on **bulky and expensive measurement approaches** that can only be done by measurement experts and in limited locations[31]. Furthermore, due to the complexity of its physical layer, measuring the exposure from 5G base stations is challenging[32].	We have shown that reliable measurements are possible with cheap SDR solutions[33], and will build fundamental limits on 3D sensing with such radios. **Measures to improve reliability and to perform radiation analysis of dynamic 5G networks and beyond will be investigated** (Obj9). By exploiting scalable and lightweight (3D) technology classification (Obj1), accurate sensing with lightweight sensors enhanced with collaborative spectrum insights, will be realised. For instance, uplink/downlink radiation will be separated through technology classification.
	In current Industry 4.0, wireless connections are mainly chosen based on their energy efficiency or data speed. However, without considering external spectrum anomalies either from intended or non-intended electromagnetic interference (EMI), **the safety and dependability of the wireless connections** will be **highly uncertain.** Some knowledge about EMI resilience for safety is already available[34].	**Spectrum anomaly detection, and the response methods,** will be a crucial component of **safety-critical systems** in **industry 4.0, autonomous systems, etc.** By using spectrum anomaly detection, the safety and dependability of wireless industry 4.0 networks will drastically increase. We will use multi-protocol sensors, cognitive networks, flexible OFDM, etc., to avoid interference between the spectrum anomaly and the wireless connection. (Obj10)

[24] **S. Rajendran et al., SAIFE: Unsupervised Wireless Spectrum Anomaly Detection with Interpretable Features. *IEEE DySPAN*, 2018**
[25] J. Schmitz, et. Al. Real-time indoor localization with TDOA and distributed software defined radio: demonstration abstract. *ACM/IEEE IPSN*, 2016.
[26] M. Khaledi, et. al. "Simultaneous power-based localization of transmitters for crowdsourced spectrum monitoring." *ACM MobiCom*, 2017.
[27] **J. Santos, et al. "Breaking Down Network Slicing: Hierarchical Orchestration of End-to-End Networks." *IEEE Comm. Magazine*, 2020.**
[28] **Y. Murillo, et al. "SDN on BLE: Controlling Resource Constrained Mesh Networks." *IEEE ICC*, 2019.**
[29] E. Hossain, et al. "Evolution toward 5G multi-tier cellular wireless networks: An interference management perspective." *IEEE TWC*, 2014.
[30] M. Akhtar, et al. "Synergistic spectrum sharing in 5G HetNets: A harmonized SDN-enabled approach." *IEEE Communications Magazine*, 2016.
[31] L. Chiaraviglio, et al. "Massive Measurements of 5G Exposure in a Town: Methodology and Results." *IEEE Open Journal of the Comm. Society*, 2021.
[32] S. Adda, et al. "A Theoretical & Experimental Investigation on the Measurement of EM Field Level Radiated by 5G Base Station." *IEEE Access*, 2020.
[33] **Y. Ben-Aboud, et al. "Electro-Smog Monitoring Using Low-Cost Software-Defined Radio Dongles." *IEEE Access*, 2021.**
[34] J. Waes, et al. "Resilience of Error Correction Codes against Harsh Electromagnetic Disturbances: Fault Mechanisms." *IEEE Trans. on EMC*, 2019.

1.2 *Soundness of the proposed methodology*

1.2.1 Overall methodology

SpecX's unique approach to hands-on research and training on spectrum and telecom infrastructure challenges hinges on building up a reference spectrum analysis infrastructure in Europe that can handle the deluge of spectrum data. The research methodology of SpecX is set up in the following way: i) the DCs will be exposed to training activities covering both the domain of the WP they primarily work on and the two complementary domains, resulting in a broad knowledge base across the three domains, which is the key for cross-domain collaborations. For instance, training on crowdsourced spectrum sensing will be applied to anomaly detection framework of spectrum data; ii) All research in the project will be related to common reference architecture (see **Figure 1**) and applications (see WP3) identified and used by all domains. For instance, exploitation of existing signals as references of opportunity for data processing will avoid actively transmitting signals in the scarce spectrum resources for the purpose of localization, which will be used as output for further network analysis by other DCs; iii) Selected technology components developed during the project will be integrated in one or more proof-of concept demonstrations spanning across the three domains. The setup will be challenged by feedback from leading infrastructure vendors (Ericsson, NEC) or new players (ACC), legacy operators (Telefonica). By cooperating with the USA partners (University at Albany and St Louis University), we ensure the European reference infrastructure is also globally relevant. In what follows, we describe the innovative aspects of the methodology in each of the three technical WPs.

WP1: Sensing and infrastructure [M7-M42]

Spectrum sensing results in massive amounts of data, several orders of magnitude more than what is generated by other types of IoT sensors such as temperature and humidity. The sensors acquiring this data are the first in line to process them and obtain the relevant features for further analysis. Ideally, the big data system is perfectly scalable which means that adding more sensors, allows more compression and richer feature computation[35], which means that the total amount of data scales gracefully with network density. More practically, coordination will be achieved, through distributed methods such as federated learning where algorithms are trained across multiple decentralised edge devices (**Obj1b**), or centrally (**Obj3**), where sensors get centralized information about common transmitters. Edge computing, where more and more data is analysed in the edge instead of in the cloud, is a hot topic of investigation for big data analysis. This is especially essential for spectrum sensing, as the amount of spectrum data is simply too large (a sensor working at 10M samples/s of 8 bit generates 7 Terabit per day) to be processed in a centralised fashion. The current approach in, e.g., Electrosense[8], is centralised data gathering and processing, but this does not scale to thousands of sensors. Tools are needed that allow reducing that Terabit/day to valuable spectrum insights generated locally at the sensor itself, or at the edge for a small group of sensors. SpecX will bring computing close to the sensors, improving response time, increasing scalability, reducing the hardware cost per sensor, and saving network bandwidth between sensors and backend. In this domain, Telecom providers can play a key role for the success of this technology, as they can provide the locations for deployment of edge devices and are currently in the phase of deploying them for next-generation mobile networks. This WP will then design edge analytics infrastructure that uses Telecom infrastructure (**Obj3**), by analysing the compute resources available and the size of the data flow from the sensor to cloud. Two different Telecom infrastructures will be considered by **DCs 2-3**, one consisting of the traditional view on the RAN and core network architecture (with Ericsson) and one focusing more on a disaggregated view (O-RAN with ACC), with the goal of generating insights for improved resource sharing (**Obj2**). Furthermore, **DC1** will explore and propose solutions on how to add local machine learning acceleration on the sensor itself. Our current models will be compared against federated learning methods, and the algorithms themselves will be trained to take local computing constraints into account (**Obj1**). **DC3** will then explore the case-study of interfacing radio access nodes of a Telecom infrastructure to a spectrum-monitoring infrastructure, to access and process spectrum data in advanced cellular network deployment under a controlled cost primarily with the goal of optimizing the capabilities to identify spectral and spatial resources dynamically at the required time scale for 6G applications (**Obj3**).

WP2: Data analysis [M7-M42]

SpecX introduces data insights that can be accessed by several emerging applications, some of which are explored in WP3. First, machine learning/deep learning algorithms are a core topic in SpecX, and WP2 will provide mechanisms to process data from the infrastructure. The accuracy of machine learning algorithms incorporating human-in-the-loop for the semi-supervised learning framework developed in WP1 will be studied for anomaly detection (**Obj4**). Second, WP2 will enable the capability of localizing wireless transmitters using low-cost IoT spectrum sensors. The work will challenge past work that considered unfeasible to reliably localize transmitters

[35] **Y. Zeng et al., "Adaptive Uplink Data Compression in Spectrum Crowdsensing Systems", IEEE Dyspan 2021.**

without a wired synchronization network system on low-cost spectrum sensors and will rather uses reference wireless signals available in the air. In turn, this will enable the opportunity to infer pattern movements of mobile devices transmitting at different frequencies (licensed and unlicensed), which is not possible with today's methods (**Obj5**). The third objective of the WP2 is to increase the availability in space and frequency of a measurement-based spectrum coverage database by leveraging the data collected from the spectrum sensors (**Obj6**). In order to fulfil these objectives, **DC4** will study how machine learning algorithms in the edge can be improved in terms of accuracy by adding source knowledge based on expert feedback. **DC5** will design and implement a framework to localize signal transmissions emitted by any transmitters and extract temporal signal features computed on the edge and perform inference of location patterns. By last, **DC6** will go beyond traditional coverage maps that focus on a single spectrum band or technology and build reliable measurement-based mobile coverage maps spanning the whole spectrum using data extracted by multiple low-cost RF receivers. These real-world observations of the spectrum usage play an important role to understand the most efficient way to use the EM spectrum.

WP3: Network applications [M7-M42]

Spectrum knowledge will be the key enabler for the emerging disruptive technologies that not only demand very high QoS requirement in terms of spatial data rate (Gb/s/m^2) and latency (<5ms), but also operate in challenging environments with high 3D mobility and dynamics. This WP develops solutions to meet the requirement of four key applications: network orchestration for the massive Internet of Things, drone networks for Enhanced Mobile Broadband, reliability for Industry 4.0, and Electrosmog measurements for Smart Cities and societal awareness. Mobile broadband has been evolving from using low-frequency bands to high-frequency bands to meet with the increasing demands for wireless capacity. In the latest 5G standards, the frequency band is extended to 7.125 GHz[36]. Although 5G can provide a high data rate, it has several challenges: 1) non-line-of-sight links can significantly reduce the achieved data rate; 2) the cell radius of a 5G BS is only about 100-300 meters, which requires denser deployment than 4G. Furthermore, the cost of a 5G BS is 3 times of a 4G BS[37]. These are increasing investments in 5G infrastructure significantly. Meanwhile, the 5G spectrum license cost is exceptionally high. In addition, the demand for 5G service (such as AR/VR) changes dynamically in the time domain. This fact makes it wasteful to devote an ultra-high investment on an ultra-dense, geo- and spectrum-fixed 5G infrastructure, and extremely costly for a single operator to occupy a certain 5G frequency band in a particular area. With perfect spectrum knowledge of a particular area made available to multiple operators, BS could be instantiated dynamically and spectrum accessed by multiple operators in an optimized manner. In Industry 4.0 applications, such as collaborative robots and autonomous guided vehicles, safety is the greatest concern. The stability and dependability of a wireless connection depend strongly on the EM environment. Hence, measures need to be taken to ensure the dependability according to the intended EM environment. The spectrum knowledge can be used as a trigger to warn about the occurrence of a possible interferer and its location. Besides, realizing smart cities are demanding high-performance wireless connections and sensing where spectrum analytics plays an important role. In this WP, **DCs 7-10** will contribute to increasing the spectrum utilization efficiency in terms of Gb/s/m^2 bits/secs and resilience for 6G networks. **DC7** will optimize the management of available spectrum portions using anomaly detection for the massive Internet of Things (**Obj7**). **DC8** will exploit mobile cells to satisfy the high and dynamic demand on the wireless capacity to improve the coverage (**Obj8**). **DC9** will contribute to citizen science and smart cities by focusing on techniques to provide Electrosmog measurements and patterns using low-cost spectrum sensors (**Obj9**). **DC10** will work on securing the wireless connections in Industry 4.0. **DC10** will identify the possible risks and threats of using wireless connections for safety-critical applications in Industry 4.0, develop a systematic approach on how to react to a possible anomaly in the used spectrum for a safety-critical wireless connection, and finally, apply and test the developed approach in industry-oriented case studies (**Obj10**).

1.2.2 Integration of methods and disciplines to pursue the objectives

The SpecX method is inherently multidisciplinary in nature: knowledge of signal and data processing, machine learning, wireless hardware design but also spectrum applications will be of integrated in a new wireless infrastructure that connects the research of DCs as presented in **Figure 1**, and builds a spectrum measurement reference facility in Europe, in cooperation with vendors, operators and other players. The scope is wide, as reflected in the topics of the three technical WPs and the different topics of the DC projects, spanning from spectrum sensing hardware to edge and cloud processing architectures; and also, from large scale spectrum measurements to telecom applications; going from advanced cybersecurity technology for anomaly detection to citizen science and Electrosmog; going from signal processing to AI; going from traditional ground-based infrastructures to aerial nodes. Each DC has a primary attachment to one of the technical WPs (WP1-3) according to its main research domain, but also has secondary associations which are developed during secondments to facilitate innovative

[36] In addition, mmWave bands between 24 GHz and 40 GHz will be in 5G networks.
[37] http://www.chinadaily.com.cn/a/201908/09/WS5d4d0d24a310cf3e35564d5a.html

methodologies required when considering a complex problem from different angles. Quality of the interaction is guaranteed by at least one secondment conducted at another organization actively contributing to the secondary WP. Real data will be measured in a real infrastructure, and true interaction between all the stakeholders is mandatory to achieve the target 10 S/T objectives and the overarching goal of SpecX.

1.2.3 Gender dimension and other diversity aspects

There are no gender issues regarding the content and use cases of the research in SpecX. The main reason is that the analysed activity in the spectrum are caused by radios, and the languages used by radios are defined in standards and protocols that are gender-neutral. By ensuring diverse teams surrounding all DCs, we ensure that there is a diverse view on the technology use cases. Furthermore, when designing future applications, an inclusive team is needed to ensure that the selected applications are of interest to all individuals. Hence, to achieve the best possible results, a diverse team will be constructed, with both female and male researchers, from different parts of the world. Finally, data from each country will have different properties, that relate to the deployment of telecom infrastructure, penetration of the technology in society, and overall usage patterns. We will make sure that the opinions of all individuals are incorporated into the research agenda. All partners further implement the above inclusive approach through comprehensive gender equality plans[38], that promote equality throughout all relevant steps of the work life, from hiring to payroll equality, promotion, roles, opportunities, and decisions. Besides, as part of SpecX's plan on Responsible Research & Innovation (RRI), soft-skill training 2 will cover *gender aspects*, aiming to eliminate discrimination based on gender and diversity, while providing participants with the knowledge and skills to ensure the effective implementation of gender equality.

1.2.4 Open science practice

SpecX will systematically share knowledge and tools as early and widely as possible in the process. *Open science* best practices with the academic community, such as open peer-review, making research papers early available, or sharing code publicly or even open-source, is already practised by the consortium and will be continued. With respect to spectrum analysis, the crowd-sourced initiative of the partner organization Electrosense will be involved, and through this network, yearly workshops, datathons and other co-creation activities will be established. Note that, through Electrosense, all gathered data is already shared with the public, and a lot of existing deep learning spectrum analysis tools are already made open source in this context. Through Electrosense, data is gathered via crowdsensing, which means that everybody can participate in gathering data. The methods for data gathering are also fully publicly documented. All software to analyse the code is also open-source. Datathons will be organised, fully open, where all researchers can take part in the design of new data analysis methods, and give input to the existing data monitoring tools. From the experience we have with Electrosense, this *open way of spectrum data gathering and analysis will be further developed.* By focusing on the electrosmog monitoring application, which is of interest to the broad public, *initial experience with social science* will be developed. By liasing with initiatives in the USA (one of the partner organizations, University of Albany, is part of SpectrumX in USA), we will also consider *reproducibility of spectrum analysis*, as methods and datasets can be compared across regions. With respect to *Open Access*, we will mainly benefit from Zenodo as the main repository of the project, where *all publications will be made open immediately after publication* in the green open-access form. For selected publications, top-tier open access journals or gold open access opportunities will also be leveraged. A wealth of preprint versions of all papers will also be posted on public websites and advertised on our social media, in order to obtain early feedback from peers and interested stakeholders. Together with Zenodo, other OpenAIRE-compliant repositories will be used by different partners to comply with their internal dissemination policies (e.g., the OpenAIRE-compliant DSpace at IMDEA, https://dspace.networks.imdea.org/ and Lirias repository at KU Leuven, https://lirias.kuleuven.be).

1.2.5 Research data management and management of other research outputs

The work of SpecX will be driven by experiments, testbed prototyping, and measurements. Therefore, a large number of labelled and unlabelled datasets, such as spectrum IQ samples, spectrum statistics, will be collected. In addition, SpecX data also includes the developed algorithms. In SpecX's datasets, we will ensure that the data collected will be anonymized and processed according to General Data Protection Regulation (GDPR) requirements and European Data Protection Supervisor (EDPS) recommendations. SpecX data management plan will be consulted with IMDEA's Data Protection Officer (DPO), Maria Cumbreras, in charge of discussing and communicating all the potential ethical issues of the work and the mitigations. Additionally, the chair of the ethics committee at IMDEA Networks will contribute to the supervision of the ethical aspects of the project. SpecX's data will be stored privately on the reliable and secure clouds that are widely used at the beneficiaries, such as KU Leuven's OneDrive, TU Delft's Surfdrive, and IMDEA's Box share system, for initial processing and formats

[38] E.g., https://www.cnit.it/2021/09/28/piano-per-la-parita-di-genere-cnit-gep/

unification, following the specifications that will be detailed in **D6.4** (Data Management Plan (DMP)) and updated during the project based on needs for extensions and/or corrections. We will use **standard formats** to store the data, such as CSV and MAT, making it **interoperable** for external users. The private clouds that will be used in SpecX have a few Terabytes of storage, which is more than enough for SpecX **data size**. Subsequently, SpecX's datasets will be made open source by storing them on IEEE DataPort free service or other similar ports, and linking them on SpecX's Zenodo repository to ease their **accessibility**. Taking into consideration the IP protection that will be defined in the consortium agreement, SpecX's algorithms will be made open access on Gitlab and GitHub for **reusability** and maximize the impact of research outputs. Moreover, we will use a fixed naming and versioning convention, and further ensure the datasets are discoverable by providing Digital Object Identifiers (DOIs) to make the data generated by the project **findable** and traceable. A Creative Common License scheme is adopted to reuse the data generated in the project. DCs are trained on data management locally by each doctoral school as well as in the SpecX network-wide event, NWE (Soft-skill training 5 in **Table 3)**.

1.2.6 Artificial Intelligence (if applicable to the proposal)

DCs 1, **4**, and **7** use different artificial intelligence[39] and machine learning techniques to carry out their individual research projects. More specifically, **DC1** exploits federated learning to design a scalable computing framework for spectrum analysis with sparse aerial sensors or dense terrestrial sensors. **DC4** studies how to incorporate expert feedback into a semi-supervised learning framework in the edge for anomaly detection. **DC7** exploits various learning techniques to find the orchestration policies for computation task allocation. SpecX will devote efforts to design **robust and efficient learning techniques** for different application scenarios. For example, the global model training and inference in federated learning with exiting aggregation strategies, such as FedAvgM, are vulnerable to heterogeneous data distributions across devices, affecting the robustness of the learning. SpecX will design a novel aggregation strategy where the central server quantifies the reliability clients and appropriately selects the gradient updates from reliable clients to improve the robustness of learning models. Moreover, the superior feature extraction and classification capabilities of machine and deep learning, are built on the availability of a huge amount of labeled data to train generalized learning models. However, due to the heterogeneity in channel conditions, sensing hardware, and deployment environments, it is labor-intensive and infeasible to collect a dataset that covers all possible conditions. Thus, widely adopted one-size-fits-all solutions are inherently ill-suited for 'in the wild' spectrum sensing. This challenge applies to all the three DCs that have supervised learning involved. Therefore, in SpecX we will also develop data-efficient learning solutions that ensure robust monitoring performance and enable quick system adaptation to heterogeneous spectrum sensing conditions with little or no labeled data required for training. We will frame this challenge as the domain adaption and few-shot learning problem, and address them with the recent advances in meta-learning and transfer learning.

1.3 *Quality and innovative aspects of the training programme*

1.3.1 Overview and content structure of the doctoral training programme

Size of DN programme. SpecX provides unique system-oriented training to 10 DCs, nurturing a new generation of innovators thanks to internationally recognized researchers with broad experience in research, training, and participation in EU, national, and industry-sponsored projects. With the intensive involvement of industrial beneficiaries and associated partners (TID, NEC, Ericsson, NEC, ESense, ACC), the DCs will obtain in-depth inter-domain knowledge and skills in spectrum sensing and its key emerging applications. This interdisciplinary and intersectoral training is an essential component of each DC's PhD. The 10 DCs are distributed over six beneficiaries in five countries (**Figure 2**, Spain: IMDEA and TID; Belgium: KU Leuven; Netherlands: TU Delft; Italy: CNIT; Germany: RWTH). Additionally, nine associated partners (four companies and five universities), represent six countries (Belgium: ACC; Germany: NEC (vendor), Ericsson (vendor); Italy: UNITN and UNITV; Switzerland: ESense; Spain: UC3M; USA: AlbanyU and SLU).

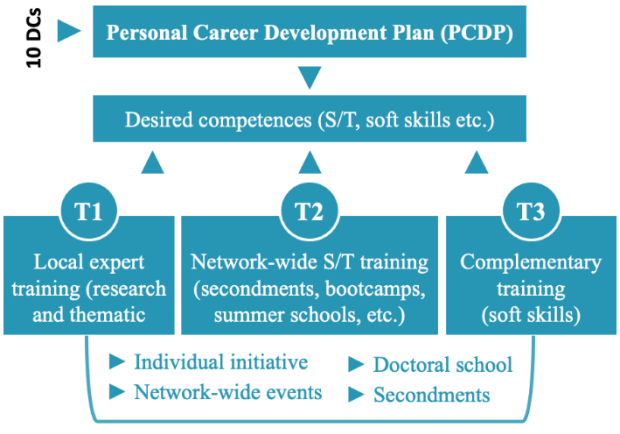

Figure 3. Schematic diagram of the training types.

A personalised training approach. The training block diagram is given in **Figure 3**. SpecX's personalised approach ensures that each DC is trained not only on SpecX's required competences, but also on her/his personal background and aspirations. The training programme consists of four elements: *(1) individual self-assessment,*

[39] https://ec.europa.eu/futurium/en/system/files/ged/ai_hleg_definition_of_ai_18_december_1.pdf

conducted after recruitment by each DC under guidance of the Doctoral Guidance Committee (DGC, incl. supervisor and co-supervisors, see **Table 13**). This identifies skills, expertise, and competences that must be developed by each DC, both for successful completion of their research project and for their future professional career; *(2) Personal Career Development Plan (PCDP)*, formulated according to each individual self-assessment. The PCDP comprises each DC's training and career needs, incl. training on transferred skills, advising and teaching, planning for publications, and conference attendance. The DGC discusses the PCDP regularly, aligns the process with each local doctoral school, and adapts it if necessary. The PCDP also serves as a reference point for the training leaders to monitor the training progress regularly; *3) tailored training programme*, developed by the DCs based on the PCDP and under the DGC's guidance. The training programme consists of: **(T1) expert training through research** in each DC's individual project and the collaborations with other DCs (cf. **Section 3.1.1**). **(T2) network-wide S/T training** (with ECTS credits) through workshops, summer school, and S/T secondments. All courses on S/T training give the DCs the needed fundamental elements to conduct the research programme. **(T3) complementary training** in generic and transferable skills, partly individual, partly through the host doctoral school, network-wide activities and secondments, following a comprehensive researcher development Framework (see **Figure 3** and **Table 5**). Finally, *(4) yearly progress assessment* of the research and training evolution, evaluated based on a proven, multi-level progress monitoring strategy (see **Table 15**).

(T1) Expert training through research (**Figure 3**). The research training has been described in **Section 1.1.1** and is discussed in detail on a per-DC basis in **Section 3.1.5** (**Table 14**). Such research training in SpecX complies with the interdisciplinary training needs for professionals working in the ICT area. All individual projects have well-defined research topics and include soft-skill training. While DCs are funded for 36 months according to the DN requirement, most of the beneficiaries come from countries where the duration of PhD studies is above 36 months, e.g., 3+/4+ years in Spain/Belgium. SpecX's beneficiaries have committed to support the DCs for the additional period, through other national/international/industrial funds (except for CNIT, because the PhD studies in Italy last for three years), such as the internal funds C2 of KU Leuven, Dutch NWO short-term funds XS, etc.

(T2) Network-wide S/T training (**Figure 3**). SpecX's advanced network-wide S/T training builds upon the specific research expertise of participating partners to stimulate an interdisciplinary training environment. SpecX plans seven *workshops* (**Table 3**). Besides, SpecX organises a *Summer School* on the "Emerging paradigms for 6G wireless networks and the enabled digital societies" (**M24**, Italy) and a dedicated *Symposium* on "Spectrum analytics as a service for future digital societies" (**M42**, Spain). Both events are organised with a strong intent to attract industry attendance and are all open to external participants.

Network-wide workshops. These workshops contribute to the training of DCs in multiple aspects: (1) DCs receive 8 S/T trainings given by experts, offering an *multidisciplinary and intersectoral training programme that provides solid foundations to the research of DCs*, including wireless networks (telecommunication), infrastructure for analytics (software/hardware), SDR prototyping (system engineering), machine learning/AI (computer science), data protection (ethics/privacy), and together with further topics such as technology integration, patenting, open-source software, economics, and policy. In addition, 12 complementary trainings on soft skills integrate smoothly into the VITAE Research Development Framework (RDF, see **Table 3** and **Table 5** for details). These soft-skills trainings are provided by the experienced Doctoral Schools of the participating organisations and by experienced researchers. (2) DCs present their work on their individual projects: this provides opportunities for the DCs to communicate their research to interdisciplinary, intersectoral, and international internal (and external) participants. (3) DCs are highly involved in the workshops' organisation, to gain organisational and logistics experience. The S/T and the soft-skills training are open to external applicants. Besides, the meetings of the Supervisory Board (SB) and the WP teams are co-located with these workshops to reduce travelling overhead and carbon footprint. The typical programme of such network-wide workshops is shown in **Table 4**.

Kick-off event/workshop. The kick-off meeting takes place in Madrid (**M8**), attended by the full consortium, including at least one representative per associated partner and all 10 DCs. The kick-off meeting will present the overarching goal of SpecX and organise a "SpecX-networking" session where DCs discuss their future visits with their secondment supervisor. The DCs will visit IMDEA's 5TONIC Lab, associated with S/T training on *"Trends in EU research for future networks"*, which provides the foundation to start their individual projects together with one-day training on "*Spectrum analytics for future wireless networks*", "*Wireless communications for the Internet of Things*", *"Prototyping and building up testbeds*" and *"Spectrum classification, from IoT to O-RAN"*.

Summer school. In **M24**, SpecX organises the summer school "*Emerging paradigms for 6G wireless networks and the digital societies*" in Trento (Italy). It consists of 15 lectures, each lasting 60 minutes, covering technical paradigms and trends from interdisciplinary ICT areas that can enable 6G wireless networks, e.g., integration of terrestrial wireless and satellite communications, ultra-dense cellular networks, reconfigurable hardware, enhanced optical wireless interfaces, networked visible light communications, intelligent networking, enablers of fully immersive user experience, etc. The invited lecturers are experts in these fields, partners of SpecX's and/or

coming from other institutions. Besides the DCs, the summer school is open to interested PhD students, postdocs, and senior researchers. All young researchers can present their work during the demo and poster sessions.

Symposium. In **M42**, SpecX organises a dedicated symposium on "*Spectrum analytics-as-a-Service for future digital societies*", where DCs will present their research results. In addition, a job fair is organised as an ideal talent/job hunting opportunity, with the participation of 5TONIC members such as Telefonica, Ericsson, NEC, and other invited companies such as IMEC and ACC.

(T3) Complementary trainings (soft skills) (**Figure 3**). SpecX puts a significant effort into nurturing the complementary skills of the DCs. A number of soft-skill training events have been planned (see **Table 3**). These trainings are designed based on the VITAE RDF, and cover all the four domains of this comprehensive framework (from domain **RDF.A1** to **RDF.D3**), rather than providing a disparate set of ad hoc trainings (see **Table 3**). The four domains are: (a) knowledge and intellectual abilities, (b) personal effectiveness, (c) research governance and organisation, and (d) engagement, influence and impact (see **Table 5**). The 12 soft-skills training are compulsory for all DCs. Besides, each DC also receives further technical and individual training during the planned secondments according to each research project. Finally, depending on needs and interests, each DC can select additional soft skill training initiatives integrated with the domains **RDF.A1-D3**. Some of these are on a per-DR basis through online courses (e.g., Coursera), others are provided through the doctoral school of the host unit. The individual training programmes of the DCs hosted by universities are embedded in the local doctoral schools (**Table 13**). Here, "individual" means that each fellow has to compose a tailored mixture of courses, complying with the DC's background and interests, and in agreement with the PCDP. The doctoral schools provide training courses to increase the DCs' scientific expertise and skills. These courses may pertain to the domain of the DC, to adjacent scientific fields (multidisciplinary research), or to research in general. All schools have accepted to mutually recognise one another's training programmes (including the ECTS credits of network-wide events).

Table 3. Main network-wide training events and contribution of partners.

	Main Training Events & Conferences	ECTS[40]	Lead	Month
1	• **SpecX kick-off meeting** in Madrid (IMDEA's auditorium), Spain, including a "SpecX-networking" session to detail all the planned secondments (1 day) • **Site Visit** to 5TONIC lab, one of Europe's foremost 5G digital innovation centres. The visit includes the **S/T training 1** on "Trends in EU research for future networks", by Prof. A. Banchs (1 day) • **S/T training 2** "Spectrum analytics future wireless networks", by Prof. S. Pollin (KUL), "Wireless Communications for the Internet of Things", by Prof. Giustiniano (IMDEA); and "Prototyping and building up testbeds", by Dr. R. Calvo (University of Ray Juan Carlos, Madrid) and "Spectrum classification, from IoT to O-RAN", Dr. V. Lenders (ESense) (1 day) • **Soft-skill training 1:** "How to come up with great research ideas", by Prof. P. Casari (**RDF.A2**) and "The art of excellent doctoral research", by Prof. J. Widmer, author of 30+ papers in top venues, e.g., MobiCom, CoNEXT, Infocom (**RDF.A1**); **S/T training** on data protection: "Privacy-oriented software development: from general concepts to horror stories", by Prof. N. Vallina, in Madrid (1 day) • **Soft-skill training 2**: "Responsible Research and Innovation (RRI), open access, ethics, scientific integrity, and gender aspects", by IMDEA R&D office (**RDF.C1**), in Madrid (1 day)	2 credits (report to be written)	IMDEA	**M8**
	• **Network-wide workshop** in Leuven (1 days) • **Site visit** to KU Leuven's WaveCore Lab and Software Defined Radio Lab, incl. a **S/T training 3**: "Privacy-enhancing technologies", by Prof. C. Diaz, an expert on privacy protection, and **Soft-skill training 3**: "Our experiences in PhD studies", by Dr. T. Claeys and Prof. Q. Wang (**RDF.B1**) (1 day) • **Mid-term meeting** between REA and SpecX consortium, incl. all beneficiaries (scientists-in-charge and all DCs), and associated partners, in Leuven (hence, close distance to Brussels) (1.5 day) • **Soft-skill training 4:** "Teamwork and interpersonal communication skills", by KU Leuven HR (**RDF.D1**), **Soft-skill training 5**: "Good research practice and data management", by Dr. A. Lutu (**RDF.C2**), and **S/T training 4** on "Dual use/export license training", by KU Leuven R&D (1 day)	2 credits (report to be written)	KU Leuven	**M13**
3	• **Network-wide Workshop** in Delft (EWI building), the Netherlands (2 days) • **Site visit** to DIoT lab, incl. **S/T training 5**: "Future challenges in wireless communication networks and 5G/IoT Field Test", by Prof. F. Kuipers and Prof. Q. Wang (TU Delft) (1 day) • **Soft-skill training 6**: "Time management & self-management for PhDs" by TU Delft HR (**RDF.B2**) (0.5 day), and **Soft-skill training 7**: "Entrepreneurship and elevator pitch with real investors", covering subjects such as creating a business plan, market research, product/market fit, fund raising, investor pitch deck, among others; by ACC, and TU Delft (two real investors will be invited for this training) (**RDF.D3**) (2 days)	2 credits (report to be written)	TU Delft	**M18**
4	• **Network-wide workshop** in Trento, Italy (1 day) • **Mid-term progress review meeting (intra-SpecX consortium)** in Trento, Italy (1 day) • **SpecX Summer School**: "Emerging paradigms for 6G wireless networks and the digital societies" with speakers from non-academic organisations (e.g., TID, Ericsson, ESense, ACC, and NEC) of the SpecX consortium as well as other invited well-known experts (Prof. S. Banerjee from Wisconsin University (USA), Dr. B. Radunovic, Microsoft), in Trento (3 days)	3 credits (report to be written)	CNIT	**M24**

[40] The ECTS credits have been agreed upon by the SpecX participating organisations. The DCs will also take other local PhD training courses to accrue enough ECTS credits for PhD graduation.

5	• **Network-wide workshop** including visit to Telefonica R&D, in Barcelona, Spain (2 days) • **Soft-skill training 8**: "Creative problem solving for researchers", by the Scientific team at Telefonica R&D (**RDF.A3**), in Barcelona (1 day) • **Soft-skill training 9**: "IPR & patent training" (**RDF.A1**) and **S/T training 6** "Open-source software", by Telefonica legal department, in Barcelona (1 day) • **Soft-skill training 10**: "Career orientation and development, and research in industrial organisation", by Telefonica HR (**RDF.B3**) and Dr. A. Lutu, in Barcelona (1 day)	2 credits (report to be written)	TID	**M30**
6	• **Network-wide workshop** in Aachen, Germany (2 days) • **S/T training 7** "Pattern Recognition and Data Analysis", by Prof. P. Patras from University of Edinburgh (also co-founder of Net AI), and **S/T training 8** "Machine learning in dynamic spectrum management and wireless networking", by Prof. M. Fiore (IMDEA), in Aachen (2 days) • **Soft-skill training 11**: "From research to impact", by R&D of RWTH Aachen (**RDF.D2**) (1 day)	2 credits (report to be written)	RWTH	**M36**
7	• **Symposium** on "Spectrum analytics as a service for future digital societies", in IMDEA, with planned job fairs, and in cooperation with 5TONIC members, in Madrid (3 days) • **Soft-skill training 12**: "Grant writing for individual fellowship after the PhD: successful stories", by invited IMDEA's Alumni (**RDF.C3**) (1 day); Closing **Network-wide workshop** with plans to maintain SpecX network, in Madrid (1 day)	3 credits (report to be written)	IMDEA	**M42**

Table 4. Typical programme for network-wide workshops (see topics detailed in **Table 3** and locations in **Figure 2**)

Day	Board/Meeting	Who?	Organisers
Mon	AM: DC presentations from WP1 and WP2 (6 DCs)	DCs + Supervisors of all DCs + Representatives industrial associated partners + MST	Host + MST
	PM: DC presentations from WP3 (4 DCs)		Host + MST
Tue	AM: TSC meeting (WP presentations by WP leaders WP1-3)	Technical Steering Committee (TSC) members	Host + MST
	PM: SB (WP presentations by WP leaders WP4-6)	SB members	Host + MST
	(PM: Recruitment Committee)	RC members	Host + MST
	(Research/Women Council + Lab visits for DCs + Guest lectures by world-leading experts + topics chosen by DCs)	DCs (obligatory)	DCs + Host
Wed -Fri	Social interaction event for DCs	DCs (obligatory) + Supervisors (optional)	Host
	S/T training + Soft-skill training	DCs (obligatory) + Supervisors (optional)	Host
	Industry/site visits	DCs (obligatory) + Supervisors (optional)	Host

An evaluation questionnaire will be distributed at the end of each training event. This will allow i) for feedback on the organisation and outcomes of each event towards improving the next one, ii) get suggestions for topics to cover in future schools (e.g. gaps between research and training), iii) to draw statistics related to the attendance outside/inside the network and the age and profile of participants.

1.3.2 Role of non-academic sector in the training programme

The five non-academic institutions of SpecX actively contribute to the training. The industrial beneficiary TID recruits one DC, provides S/T & soft-skills training, and organizes a lab visit to Telefonica facilities in Barcelona. TID also hosts secondments for other DCs, as do associated partner ESense (Switzerland), ACC (Belgium), Ericsson and NEC (Germany). TID, Ericsson, and IMDEA are part of 5TONIC lab (one of Europe's foremost 5G and beyond digital innovation centres) in Madrid, and will offer lab visit. Likewise, the industrial associated partners NEC, Ericsson, ESense, and ACC also provide industry secondments and/or complementary S/T and soft-skills training (**Table 3**). Further, each DC has at least one non-academic supervisor in her/his DGC (**Table 13** and **Section 3**). There is a strong industrial drive behind the SpecX consortium, as *the involved companies are leading vendors* (e.g., Ericsson, NEC) *or leading operators* (e.g., TID, ACC) *in the telecommunications area*. Together, they will drive, facilitate, and deploy the real-world integration of SpecX's results. The non-academic participants are strongly involved in the Summer School and the closing symposium. From the interaction with industrial partners, the DCs will learn a non-academic, problem-solving, and innovation-oriented approach to research and development, resulting in a full rounded understanding of both research and industrial impact.

Table 5. SpecX soft-skill training based on the VITAE RDF, focusing on the DCs' employability and skill development

Domain	Domain A: Knowledge and intellectual abilities			Domain B: Personal Effectiveness			Domain C: Research governance & organisation			Domain D: Engagement, influence and impact		
Description	The knowledge, intellectual abilities and techniques to do research			The personal qualities and approach to be an effective researcher			Knowledge of the professional standards and requirements to do research			The knowledge and skills to work with others to ensure the widest impact of research		
RDF Subdomain	A1. Research method	A2. Cognitive abilities	A3. Creativity	B1. Personal qualities	B2. Self-management	B3. Career development	C1. Professional conduct	C2. Research management	C3. Funding and resources	D1. Working with others	D2. Communication	D3. Engagement and impact

Soft skill Training at Network event	See NWE1& NEW5, Table 3	See NWE1, Table 3	See NWE5, Table 3	See NWE2, Table 3	See NWE3, Table 3	See NWE5, Table 3	See NWE1, Table 3	See NWE2, Table 3	See NWE7, Table 3	See NWE2, Table 3	See NWE6, Table 3	See NWE3, Table 3
Institutional organiser	IMDEA	CNIT	TID	KU Leuven	TU Delft	TID	IMDEA	TID	IMDEA	KU Leuven	RWTH	TU Delft & TID

1.4 *Quality of the supervision*

In SpecX, each DC has a dedicated supervisor and at least two co-supervisors as outlined in Table 13 as well as in Section 6. Co-supervisors complement the expertise and knowledge of the main supervisors, and will act as main supervisors during business trips and vacations of the main supervisor. During secondment, the DCs will be co-supervised by both the home and hosting institution. A core element in the supervision process is the PCDP which will be created jointly by the DC and the supervisors in the first two months of the incorporation of the DC and will be updated regularly thereafter.

1.4.1 Qualifications and supervision experience of supervisors

In line with the European Charter for Researchers, all chosen main supervisor within the SpecX consortium are experts (with an average H-index >30), have ample experience in intersectoral/interdisciplinary collaboration, and a strong track record with PhD supervision (the total number of PhDs supervised and under supervision is about 149), and commitment to offer all required support (Table 13)**.** The supervisor has a mentoring role: she/he provides a roadmap of the research, gives career advice, sharpens the entrepreneurial spirit, supports professional development and informs on the practical issues related to the individual project.

1.4.2 Quality of the joint supervision arrangements

SpecX provides joint supervision, forming the Doctoral Guidance Committee (DGC) Members (Table 13). All DCs will be supervised by: i) a Full or Associate (Research) Professor or Senior Researcher from their hiring institution, along with a second co-supervisor; ii) a local supervisor during their secondment. Industrial partners will actively contribute to DCs supervision, as each industrial partner will host at least one DC on subjects in line with both the project, and company priorities, implying that DCs' progress monitoring will include a formal industrial component throughout their PhD (Table 14). Besides, where appropriate and if allowed by the rules from each doctoral school, industrial members will be invited to serve in the PhD juries of the DCs.

2. Impact

2.1 *Contribution to structuring doctoral training at the European level and to strengthening European innovation capacity*

SpecX is fully compliant with the doctoral training structure of the EU (following the "Salzburg II Recommendations & Principles" for Innovative Doctoral Training) and it contributes to further strengthening European collaborative research. SpecX aims to be at the frontier of innovation, contributing to the strategic orientations of the Horizon Europe plan. In this context, spectrum scarcity and spectrum utilization inefficiency is a fundamental impediment toward achieving the **EU digital strategy**[41] of a post-pandemic scenario. From a technological standpoint, this project is conceived in a unique moment, when the trend towards network densification (smaller cells), the ever-increasing number of connected mobile devices (Massive IoT), and the transition towards 6G technologies will exacerbate the network operation complexity and amplify the operators' need to efficiently use the limited radio spectrum resources. The SpecX Doctoral Network aims at answering this challenge by strengthening the next generation of wireless networking systems at the EU level, thus contributing to the **Europe Mission** to make Europe fit for the digital age. SpecX's view is fully in line with the EU's target for the digital decade and 2030[42], by training highly skilled digital professionals with know-how to implement secure and performant sustainable digital infrastructures. Spectrum availability measurements, reutilization, and flexibility are also key objectives of the European Vision for the 6G Network Ecosystem[43]. Finally, SpecX contributes to the **UN's Sustainable Development Goals**, and in particular to goal 8 ("*Decent work and economic growth*", by helping preserve and optimize a strategic resource for the economy such as the EM spectrum) and goal 9 ("*Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*", as a better managed EM spectrum improves resilience against crises).

2.1.1 Meaningful contribution of the non-academic sector to the doctoral training

Secondments: There are five non-academic members within SpecX, including one beneficiary and four associated partners, which will actively contribute to the training programme. Each DC performs two secondments, of which

[41] European Commission Digital Strategy, https://ec.europa.eu/info/publications/EC-Digital-Strategy_en
[42] https://www.europarl.europa.eu/RegData/etudes/BRIE/2021/696189/EPRS_BRI(2021)696189_EN.pdft
[43] https://5g-ppp.eu/wp-content/uploads/2021/06/WhitePaper-6G-Europe.pdf

at least one is intersectoral (academia to industry and vice-versa), to broaden the DC's understanding of both the academia and the industry sectors, as well as to put each DC in contact with different working strategies and organizations at different institutions. The secondment timing is pre-agreed so as they position at the best timing for each DC's research. Additional technical and transferable skills training is performed during secondments to the non-academic sector, and adapted to the individual needs of the DC project.

Supervision and Mentoring: Each DC is supervised by a DCG composed of experienced researchers from both the academic and the industrial sector, thus ensuring supervision quality and diversity. At a high level, one DC is directly recruited by non-academic beneficiaries, while non-academic members will be co-mentoring and supervising the 10 DGCs, the industrial supervision of secondments, and the inter-sector mobility of the research training, thus largely contributing to the quality insurance of the doctoral training.

Research and Transferable Skills: SpecX offers network-wide S/T and soft-skill training through workshop-style professional development sessions with active engagement from the non-academic sector, see **Section 1.3**. The planned lab visits and co-located workshops at the facilities of the non-academic beneficiary gives the DCs a unique opportunity for direct exposure to cutting-edge technologies in telecommunication (the 5TONIC lab at TID/IMDEA). The composition of the consortium includes strong interactions with both worldwide vendors (Ericsson and NEC) and large EU operators (TID), and renowned SME (ACC, Electrosense) guarantees a public/private-sector collaboration in the research training with the acquisition of key skills needed in both sectors, including entrepreneurial skills. Per the DOC-CAREERS II Collaborative Doctoral Education report[44], SpecX puts emphasis on doctoral theses carried out with interaction between academic and non-academic sectors. Besides intersectoral employability for the DCs, and their education into the business world, this will constitute an advantage for EU research labs in industry, closing the gap with respect to doctoral education in US research labs.

2.1.2 Developing sustainable elements of doctoral programmes after the end of the DN funding

SpecX is committed towards a sustainable cooperation scheme that extends beyond the financed project duration, converting the network into a long-term and structured training programme, which involves all SpecX participants, their future PhD students, and postdocs. The elements that are sustainable include i) Training programmes at local or network-wide level; ii) Cooperation and secondment opportunities; iii) Transferable skills training offering; iv) Researchers recruitment according to the code of conduct for the recruitment of researchers. Moreover, DCs will join the Marie Curie Alumni Association (MCAA) to extend their network and interact with scientists with common research interests. Through the strong prior, ongoing and future research interactions, the creation of long-lasting training structures is fully realistic.

To achieve the above targets, the partners of SpecX will: (1) seek the creation of a workshop series co-located with a top conference on "Emerging paradigms for 6G wireless networks and the digital societies" with SpecX researchers as steering members; (2) seek the establishment of a COST action on spectrum sensing and analytics for next-generation wireless networks; (3) apply for EU and industrial funding on follow-up projects, e.g., Horizon Europe calls in the "Digital, industry and space" work programme and future calls supported by the Smart Networks and Services (SNS) Joint Undertaking; (4) formalise joint programmes among the partners, e.g., joint PhD programmes or Erasmus programmes for master student exchange.

2.2 *Credibility of the measures to enhance the career perspectives and employability of researchers and contribution to their skills development*

SpecX will unleash the potential of emerging network applications that require a new telecommunication paradigm that will be integrated into a 6G ecosystem. The DCs will become the leaders of this transition. As noted in a report from project beneficiary Telefonica[45], in the last decade, *telecom sector revenues in Europe decreased by 29%, while in the United States they have increased by 20%*. In this context, training of DCs will help the EU industry recover its leadership in wireless communication through their competitive advantage. Also, highly ranked EU universities employing the DCs will acquire talented human resources trained at and capable of cutting-edge research on a broad set of technologies, thus clearly improving their **employability**.

Boosted by the industrial, business and entrepreneurship training, the DCs will actively contribute to the start-up eco-system. These new actors created in EU will have great potential for quick take-up in new disruptive markets created for solutions that enable flexible spectrum sensing and analytics. This multi-faceted exposure of the DCs to different environments and concepts will offer them a competitive advantage over other researchers and engineers specialized in a single domain. Besides, DCs will participate in job fairs and their skills will be demanded by the knowledge-based economy. These elements are part of two network-wide events organised in collaboration with industry partners in SpecX at **M18** and **M42**.

[44] Collaborative doctoral education in Europe: Research partnership and employability for researchers - DOC-CAREERS II project, shorturl.at/ciot3

[45] European leadership in connectivity requires collaboration and consistency within the regulation, https://www.telefonica.com/en/communication-room/blog/european-leadership-in-connectivity-requires-collaboration-and-consistency-within-the-regulation/

Table 6. S/T individual skills development of DCs (refer to **Table 3** for S/T training for all DCs, and **Table 5** for Transferable skills).

DC	Primary S/T domain (at host institution)	Secondary S/T domain (during secondments)	DC	Primary S/T domain (at host institution)	Secondary S/T dmain (during secondments)
DC1	IoT, neural networks, prototyping, computation	Data analysis, network co-existence, aerial sensing	DC6	Big data, measurements, end user exp., wireless coverage	Algorithms, anomaly detection, prototyping
DC2	Edge infrastructure, physical sensing, algorithms	Measurements, anomaly detection, prototyping	DC7	Computation tasks, IoT, orchestration, ML	Optimization, analytics, anomaly detection
DC3	Algorithms, prototyping, modelling	Physical sensing, resource allocation	DC8	Aerial sensing, modelling, connectivity	Prototyping, coverage map mobile cell performance
DC4	Neural networks, algorithms, anomaly detection	Federated learning, edge computing	DC9	Algorithms, measurements, prototyping,	Physical sensing, prototyping
DC5	Algorithms, localization, prototyping, physical sensing	Modelling, IoT, measurements, analytics	DC10	Wireless applications, safety	Measurements, prototyping

Skills development. SpecX will greatly contribute to the skills developments in different domains. DCs are provided with transferable skills acquired through training, including business development in ICT and career orientation skills in both academia and industry (see **Table 5**). S/T training at consortium level is complemented by individual skill developments. In particular, as highlighted in **Table 6**, DCs will acquire knowledge in new disruptive methods and algorithms, encompassing physical communications, edge computing, big data, neural networks, and network applications of spectrum data.

2.2.1 World-class, interdisciplinary training programme

The SpecX consortium has carefully selected experts from EU institutions with a long-standing expertise in diverse research and training domains such as networked systems, wireless networking, communication system engineering, signal processing, security, etc. This guarantees the DC exposure to top-notch scientific environments and research. Each DC handles her/his own ambitious research project while being part of an interdisciplinary environment and having access to unique cutting-edge testbeds and facilities (see **Section 6**). During the network-wide workshops, additional S/T trainings and complementary soft-skills training are provided, with an emphasis on entrepreneurship skills and product-oriented innovation. The soft-skills training is integrated in the unique VITAE RDF framework, which allows to plan, promote, and support the personal, professional and career development of the SpecX researchers in 4 key domains (**RDF.A1-D3**), in view of maximising future employability (**Section 1.2.1** and **Table 5**). The training acquired at a participant's institution is formally recognised by the other participants in the context of the PhD programmes of the different doctoral schools. This mutual recognition allows the DCs to collect credits for their own doctoral programmes by performing secondments, attending network-wide workshops, conferences, and training sessions at different participant institutions.

2.2.2 Career paths in industry, academia and the public sector

The training of SpecX is specifically designed to develop and hone the skills of DCs through a comprehensive and diverse knowledge on fundamental and applied research. DCs will be supervised to achieve the high academic standards of our doctoral degree granting institutions, which have the high standing objective of publishing in top journals and conferences in their respective fields and achieve impact in the scientific community and the society. DCs will work with the final user in mind, leading to innovators that can nail down the source of the scientific breakthrough; while being always aware that, their work should benefit society and respect RRI principles. For all DCs, network-wide training and secondments will be the place where they will be encouraged to explore the tie-ins between each other's projects, enhance inter-domain research, and leverage the most recent advancements in the state of the art, further developing the objectives at the time of the proposal submission, thus acquiring both broad and deep knowledge to succeed in their careers. Associated partners (from both academia and industry) will be involved in the development of the DCs project and skills from their conception, helping to strengthen and amplify the contribution of the DCs beyond the scientific merits.

The training of SpecX DCs is inter-domain, covering the necessary communication engineering and computer science fundamentals with focus on delivering pragmatic solutions in several key industrial domains (e.g., mobile broadband, industry 4.0, massive Internet of Thing, etc.). SpecX will invest a significant effort through the training events on developing soft skills such as handling leadership roles, improving oral and writing presentation skills for different stakeholders, including real investors that will be invited during the training programme (see **Table 3**). SpecX DCs will be highly employable in various academia, industries, or public government bodies. As wireless is a basic societal need, Europe will require highly trained researchers that are both the next leaders in EU telecommunication networks and the ultimate experts to reproduce the toolkits acquired during the SpecX program in new successful yet challenging initiatives, thanks to the transferable skills of the research and training programme and the uniqueness of the challenging projects covered by each DC. Given the solid analytical training,

the topics in fundamental science covered within the network, and the publications in international top conferences and journals to present research work, all DCs will be able to pursue careers in academia and research institutes. The talented researchers of SpecX will master emerging technologies, and, furthermore, through direct and deep exposure with industry, will also acquire transferable skills to apply them in practical challenges of interest for industrial environments with shorter term cycles from research to innovation. SpecX DCs will also be a unique human resource for governmental bodies, including the European Commission and national regulators, that need expertise in new emerging sectors to forge and guide EU's policies/regulations and strategic investments.

2.3 *Suitability and quality of the measures to maximise expected outcomes and impacts, as set out in the dissemination and exploitation plan, including communication activities*

A non-exhaustive list of already identified **target groups** consists of: ***(i)*** MSCA DNs and former ETNs Networks; ***(ii)*** industry (technology developers, experts, etc.) delivering technology that benefits economy and society at large, and consortia of other EU projects which gather and share knowledge and tools for the development and use of novel solutions for digitalisation of key sectors of European economy; ***(iii)*** institutions and regulatory bodies (national & international) impacted by the potential need of redesign standards and regulations, as well as public authorities, policymakers who regulate the spectrum allocation and adopt new technologies to accelerate the transition to the digital economy; ***(iv)*** specialised media and science journalists to reach the general public; ***(v)*** general public, e.g., EU citizens, and associations who will be informed about applications that can run using spectrum analytics; ***(vi)*** private and public funding institutions for innovation and investors to bring solutions to the market; ***(vii)*** academic, research, and technology organisations actively contributing to 6G technologies.

For each target group, SpecX has set specific activities and means to reach them during the duration of the project, as described in **Table 7**, and beyond the duration of the project, with expected outcomes and long-term impacts detailed in **Table 8a, b and c**.

Table 7. Communication and dissemination target groups, activities & means to reach them and related output (as the basis for the Communication & Dissemination Plan and the Exploitation Plan).

Target groups	Main activities & means to reach them	Outputs
Internal communication (for sound project implementation)		
DN Network (beneficiaries + associated partners) & REA project officer	• DCs' PCDPs, DC progress presentations, RTDE progress reports stored on the project intranet (password-protected) • Periodic, Mid-term and Final reports, Communication & dissemination Plan, Exploitation plan, DMP, Minutes of WP and SB meetings, Financial overview reports (on Intranet) • Email (for email-hygiene all subject headings to start with [SpecX] with mailing lists depending on the target group)	Reports and presentations are assessed and monitored by (depending on report & presentation type) Supervisors, DGCs, WP leaders, S/T Coordinator, GC, MST and SB, REA Project Officer
External communication (for awareness and impact generation)		
Industry and other EU projects	• Institutional communication through bulletins and websites of all project partners, creating maximum leverage • Project website (**D6.2**) • LinkedIn "Company Page" for SpecX • Communication kit (Project flyer, presentation) at EuCNC	Project start: 1 Project flyer Regular posts: 1 Post per month in LinkedIn; 1 Post per month on Website Project End: 1 Brochure about project results + presentation Expected reach: 5K people
Policy makers, public bodies including regulatory agencies	• White paper presenting main project's achievements • Talks at events organized by national regulatory agencies (e.g., BIPT in Belgium)	3 standards to be agreed on 3 tests to be financed
Specialised media and science journalists to reach the general public	• Press releases (TechCrunch, Wired, etc) • Interviews (TV, radio, newspapers, magazines; e.g., Prof. Pollin is frequently cited in De Standaard or VRT News, with respect to 5G and spectrum issues.)	3 press releases, 5 interviews Expected reach through online newspapers: 10K people
General public	• Project website featuring blogs, news and press items, etc. • Open Days, European Researchers' Night, Science Week, Science is Wonderful, and local events such as the Arenbergfeest in Belgium • Blogs and videos shared on social media.	50 posts/news on web – Expected reach: 5K people 20 participations in events – Expected reach: 5K people 10 Videos – Expected reach: 50K 3 posts/month on social media (Twitter) – Expected reach: 15K people
Dissemination of SpecX DC research results (for maximum take-up of new knowledge and exploitation of results)		
Industry target groups and funding institutions to bring to market	• SpecX Summer School and Symposium (**D4.9-D4.10**) • Job Fair and Exhibition showing DCs' results	20 External Industry participants >6 DCs recruited by companies 1 prototype per DC, 5 patents filled

Academic, research, and technology organisation	• SpecX Summer School and Symposium (**D4.9-D4.10**) • Peer-reviewed publications at prestigious conferences and journal (MobiCom, INFOCOM, ToN, TWC, TMC, etc.) and journals (**D1.1-D3.3**); Open Access research data.	40 Peer-reviewed conference/journal/demo/poster papers (4 per DC) 150 Attendees in major conference events such as MobiCom

2.3.1 Plan for the dissemination and exploitation activities, including communication activities

SpecX pursues a fully integrated outreach (internal and external), dissemination and exploitation strategy, which is summarised in **Table 7**. The key metric is to ensure visibility and impact (the 3rd column, **Table 7**). The different components of this strategy are discussed below. They are performed by **subtask 5.1** (dissemination and outreach) and **subtask 5.2** (exploitation) of **WP5**.

Dissemination of the research results: The dissemination targets academic and industrial sectors through various channels (**Table 7**). Every DC has the opportunity to present results at the network-wide events (twice per year). All results are published in international peer-reviewed journals and conferences, after careful consideration of protecting intellectual property rights (see **Figure 4**). Following Horizon Europe's open-access policy and respecting RRI principles, the consortium ensures that all peer-reviewed publications of SpecX are deposited in the Zenodo open-access repository (https://zenodo.org). Together with Zenodo, other OpenAIRE-compliant repositories will be used by different partners to comply with their internal dissemination policies (e.g., the DSpace at IMDEA, https://dspace.networks.imdea.org/, and the repository at KU Leuven, https://lirias.kuleuven.be). Dissemination also includes publications at top conferences (e.g., ACM MobiCom, IEEE INFOCOM), where DCs present their latest findings, demos/posters, and source code/data published in repositories. For other SpecX dissemination channels, please see **Table 7**.

Exploitation of results and intellectual property: The SpecX exploitation strategy (**Figure 4**), developed and monitored through the Exploitation Plan (**D5.1-D5.5**, see **Section 3**) contains four routes, each of which is assessed per DC project. The DCs are actively involved in pursuing exploitation routes and continuously update the exploitation section in their Research, Training, Dissemination and Exploitation progress report. *For this, they are guided by their main supervisors and non-academic supervisors* (DGC, **Table 13**) and continuously trained through the SpecX entrepreneurial soft-skills training (**Table 5**). The four exploitation routes are: (**EX1**) Dedicated (bilateral, national, and EU) follow-up projects targeting a higher Technology Readiness Levels (TRL)[46], including EU EIC Pathfinder and Accelerator programs; (**EX2**) industrial implementation, e.g., TU Delft's drone-hosted mobile cells for 6G (DC8); IMDEA Electrosmog inference with low-cost spectrum sensors (DC9); patenting of breakthrough results (all DCs work on innovative projects beyond the state-of-the-art with potential for filing patents) and (**EX4**) spin-off creation, e.g., KU Leuven's federated learning for aerial and terrestrial spectrum sensors (DC1); RWTH's sensing-capable 6G radio access infrastructure (DC3). In **Table 14**, we present the possible exploitation routes per DC (cf. the last row of each DC description). *An experienced exploitation manager (Dr. J. Widmer, IMDEA) has been appointed, with the aim to work with the GC and SC to commercially exploit all breakthrough results*, irrespective of the training goals. Moreover, 5TONIC at IMDEA/TID holds a 5G start-up competition to which the consortium members are encouraged to participate. These hubs will help DCs creating disruptive business models and establishing strategies to search for investors. All consortium members have identified some background knowledge (patents, know-how, data, software, scientific studies, methods, material held prior to the project) to be contributed to the project at the proposal stage and further during the execution. In addition, the search of patents related to the research project of each DC did not reveal any relevant patent impeding the "freedom to operate" and the exploitation of SpecX's results.

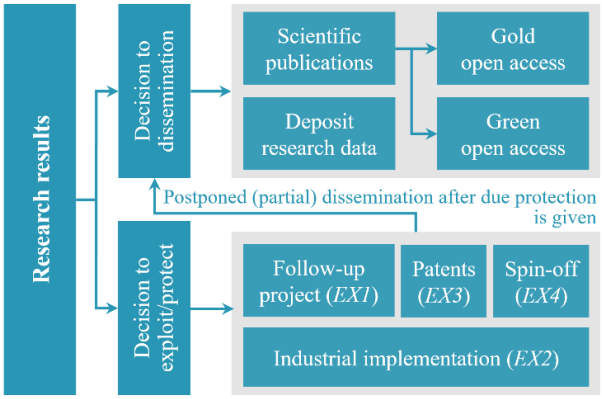

Figure 4. SpecX exploitation and dissemination strategy.

Communication activities (Table 7)

SpecX website and outreach. SpecX targets several activities to significantly increase the visibility of SpecX's output. The main public engagement activity (targeting professionals, media, and the public) is the development of SpecX website which is focused on the DCs' research, training and results in the field of spectrum analytics as a service. In the first phase of the project, the website contains short videos to introduce challenges using spectrum analytics to enable exciting futuristic applications and the way they can dramatically change people's life. As DCs produce results, short videos targeting the general public will be posted in the website to promote the main achievements. In addition to the DCs blogging on SpecX website about their research, the SpecX MST develops

[46] https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

and maintains a LinkedIn Company page. Furthermore, the consortium exploits the opportunities of Open Days at each institution to introduce SpecX to the public with presentations, demos and posters, e.g., the European Researchers' Night, Science Week, Science is Wonderful, among the UE events, as well as local events, such as ICT Days at UNITN and T3chFest at UC3M. The objective is to reach a physical and online attendance at the talk/booth between 100 and 1000 people per event (depending on the size and duration of each of them). We will reach more traditional media such as radio and TV (e.g., La 2 in Spain via IMDEA/TID and RAI in Italy via UNITN) to promote DCs' results, supported by the Communication Manager of each partner.

SpecX project videos. Before **M13**, a short video about SpecX and its 10 S/T objectives is produced together with all the 10 DCs. Then, on **M42**, a video on the results is updated by all the DCs, guided by their supervisors and the exploitation manager. SpecX consortium has ample experience with outreach using videos: for example, KUL's video clips about the project OmniDrone (www.omnidrone720.com), which totalled several thousand views; TUD will leverage their connections with national broadcasters to showcase early results and publicise security vulnerabilities for early public awareness; IMDEA has a YouTube channel for regular research updates.

2.3.2 Strategy for the management of intellectual property, foreseen protection measures

SpecX manages IPR in line with EU requirements for MSC actions (www.iprhelpdesk.eu). Introduced background knowledge owned by the beneficiaries is made freely available to the DCs as needed for their research. Foreground and side-ground knowledge in SpecX is owned by the DCs and beneficiaries that generate it. Joint ownership is regulated by the Consortium Agreement. All DCs are obliged to share their scientific articles with the consortium before submitting them for publication. The exploitation manager will i) review SpecX results to assess their exploitation potential, and ii) will coalesce SpecX's results of interest for policymakers (e.g., related to spectrum usage, or to illegal radio emission detection in protected bands) and summarize them in a brochure to be forwarded to the RF regulation authorities of the member states. This balances timely scientific dissemination with patenting and protection, possibly leading to commercialisation, follow-up projects, and the creation of spin-off companies (see **Figure 4**). Upon a decision to disseminate, SpecX makes results available to the scientific community in a gold or green open access fashion, with highlights in lay language for the general public through the network's website and social media. Protectable knowledge and early outcomes will be stored in protected non-public repositories, and access granted to each person/entity that holds rights to it. Typically, this includes all research contributors, including those that provided access and guidance to cutting-edge research facilities to experiment and prototype a new technology. The Supervisory Board supervises IPR controversy resolution based on the Consortium Agreement. The Consortium Agreement will be based on the latest version of the MCARD-HEU model template provided by DigitalEurope and will be agreed by the partners before the Grant Agreement is signed. SpecX partners have a history of joint collaborations, and also joint inventors both at EU and international level (e.g., J. Widmer, IMDEA, and P. Casari, UNITN). The corresponding knowledge and experience gained is shared as part of the DC training. Industrial partners take an active part in suggesting exploitation venues and in highlighting the commercialization potential of DC ideas. Periodic meetings (every six months, see **Table 3**) enable non-academic consortium members including associated partners to hear the progress of each DC's research, discuss the results, and scout/support exploitation possibilities.

2.4 *The magnitude and importance of the project's contribution to the expected scientific, societal and economic impacts (project's pathways towards impact)*

The advent of 6G will cause a tremendous paradigm shift in the way networks are designed, with novel transceiver designs and software network solutions that enable and drive more efficient deployment, provisioning and management of verticals. In this context, SpecX will generate consistent outcomes and impacts as described next.

2.4.1 Expected scientific impact

SpecX will allow obtaining insights from spectrum data and analytics, creating new knowledge for more efficient spectrum management and coexistence of next generation applications for both telecom and non-telecom users of the spectrum, and create the foundations for exploring new technological solutions originated from the core research WPs of SpecX. Academic, research and technology organizations working on the latest 6G technologies will be the first adopters of SpecX solutions. SpecX is aligned to Horizon Europe strategic plan 2021-24: SpecX help propel the EU's innovation capacity along with the "Digital, Industry and Space" chapter of the Horizon Europe work programme and the calls in 6G and Smart Networks supported by SNS Joint Undertaking, which will allow for cross-fertilizations with these initiatives. **Table 8a** details the main expected scientific outcomes and long-term impact, and maps them to target groups presented in **Section 2.3**.

Table 8a. Expected outcomes and long-term impacts for target groups with expected scientific impact

Target groups	Expected outcomes – Awareness and use of SpecX output - during the project and 1 year after its end	Expected long-term impacts – Consequence of people using output - years 2 to 6 after the project's end

Academic, research, and technology organisation	Talented postgraduates in core topics for 6G networks; advancement of the state of the art by each DC will generate citations and visibility. Workshop series co-located with top conference on with SpecX researchers as steering members and joint programmes among the partners.	*Scientific impact*: Achieved in the domains of novel sensing, infrastructure, data analysis and applications within academia organizations working on the latest 6G technologies. Education of new generations in the fields covered by SpecX. *Magnitude*: >10,000 researchers exploiting knowledge and data generated. *Importance*: Europe back at the forefront of 6G.
Other EU projects	Cross-fertilization with other EU projects; contribution to the Horizon Europe calls ("Digital, industry and space" work programme) and to shaping the 6G Smart Networks and Services (SNS) roadmap.	*Scientific impact:* Formation of new EU projects from the results of SpecX, providing impact both to research and economy. Preparation for early market adoption of 6G by the end of the decade. *Magnitude:* Impacting >10,000 researchers. *Importance:* New projects further develop SpecX technologies.

2.4.2 Expected economic/technological impact

SpecX outcomes after the project will contribute to boost the spectrum utilization efficiency for next generation radio technologies. European vendors and large operator will improve their competitive position through the following actions: i) the project will provide a comprehensive solution that can be applied to all verticals, with EU players that will drive the exploitation of new market sectors, ii) the strong presence of EU telecommunication stakeholders (e.g., NEC, Ericsson, TID, and ACC), combined with leading EU research institutions with a broad research portfolio in spectrum analytics, will channel real-world problems as well as current and future market needs into concrete research actions, iii) SpecX participants TID, NEC and Ericsson already contribute to telecommunication standards, including 3GPP (e.g., NEC, Ericsson) and IETF (e.g., TID and Ericsson), and SpecX will leverage the comprehensive and diverse know-how acquired by the DCs during the project, and the global reach of its key market players (the large companies of the consortium) to shape the global standards that determine how SpecX spectrum analytics will be used in future 6G networks. Economy will be fostered by SpecX results through the exploitation and communication strategy of the project, attracting funding for start-ups, and income through license fees through the interaction with potential investors and contributing to industry standards, and then indirectly influencing the economy growth via the introduction of disruptive products that will be part of the 6G ecosystem. **Table 8b** details the main economic/technological expected outcomes and long-term impact.

Table 8b. Expected outcomes and long-term impacts for target groups with expected economic/technological impact

Target groups	Expected outcomes – Awareness and use of SpecX output - during the project and 1 year after its end	Expected long-term impacts – Consequence of people using output - years 2 to 6 after the project's end
Private regulatory bodies	SpecX technologies will contribute to standards' setting, recommendations, and new regulations at European (ETSI) and international level (3GPP, ITU).	*Economic/technological impact:* will facilitate the introduction of SpecX solutions in real deployments at worldwide scale, thanks to the global reach of our industry partners. *Magnitude*: 300 policymakers working with the project's policy recommendations. *Importance*: Shaping the industry, fostering wireless services. Impacted verticals worth several € bn.
Funding institutions to bring to market	Engagement in start-up competitions (including EIT Jumpstarter). Attracting funding for start-ups; Generation of license income for filled patents; testing of advanced prototypes in realistic settings (advanced TRL).	*Economic/technological impact:* new business models/market opportunities for telecommunication infrastructure & digital economy. Startups from projects of DCs will gain market share. *Magnitude*: 2,000 entrepreneurs and innovators. *Importance*: Increasing competitiveness of EU in start-ups, closing the gap in number of tech start-ups vs US.
Industry	5G infrastructure market is projected to reach USD 47,775 million by 2027, (67.1% CAGR)[47]. Contribution to standards and research prototypes will be leveraged for generating new revenue streams.	*Economic/technological impact:* Creation of new business models towards pre-6G products (shorter term) and 6G (longer term) infrastructure. *Magnitude:* 100% of EU ICT companies (vendors and operators). *Importance:* New market segments from SpecX solutions. European companies holding critical IP; increasing growth of EU telecom providers.

2.4.3 Expected societal impact

SpecX will be a stepping stone to radically improve future wireless networks by natively embedding and extensively applying spectrum data intelligence in the whole network stack. Public regulatory bodies will receive input from SpecX already during the project duration and will be able to improve policies for spectrum regulation, and guidelines for potential improvements in the network to maximize its utilization efficiency. SpecX will inform decision making for involved actors in complex scenarios as a result of the introduction of new infrastructures and methods that comply with new regulations. The knowledge of electrosmog measurements that are collected by SpecX will provide guidelines for new policies, while objectively reporting the electromagnetic exposure. **Table 8c** details the main expected societal outcomes and long-term impact.

Table 8c. Expected outcomes and long-term impacts for target groups with expected societal impact

[47] Source: https://www.marketsandmarkets.com/Market-Reports/5g-technology-market-202955795.html

Target groups	Expected outcomes – Awareness and use of SpecX output - during the project and 1 year after its end	Expected long-term impacts – Consequence of people using output - years 2 to 6 after the project's end
Specialised media and science journalists + general public	Awareness of SpecX through the communication activities presented in **Section 2.3.3** will generate media coverage and interests of the public in emerging ICT technologies.	*Societal impact:* Adoption of new wireless technologies and applications for reliable and sustainable digitalisation of the economy. The public will be engaged by exploiting the knowledge of electrosmog measurements, so future networks can report objectively on electromagnetic field exposure. *Magnitude*: All EU citizens. *Importance*: Greater citizen wealth and involvement.
Public regulatory authorities	SpecX technologies delivered as brochures and demonstrators to RF regulation authorities, introducing proposed measurements and architectures.	*Societal impact:* Disruptive policies will be introduced by national regulators to monitor the usage of the spectrum and maximizing its utilization. *Magnitude*: All EU countries. *Importance*: Increased efficiency of public resource usage/value. Improve profit of spectrum license for many € bn.

3. Quality and Efficiency of the Implementation

3.1 *Quality and effectiveness of the work plan, assessment of risks and appropriateness of the effort assigned to work packages*

3.1.1 Work Packages (WP) list

Table 9. Work package (WP) list

WP	WP Title	Start Month	End Month	Activity Type	Lead beneficiary	DC Involvement
WP1	Sensing and infrastructure	**M7**	**M42**	Research	RWTH	DCs 1-3
WP2	Data analysis	**M7**	**M42**	Research	TU Delft	DCs 4-6
WP3	Applications	**M7**	**M42**	Research	KU Leuven	DCs 7-10
WP4	Training	**M7**	**M48**	Training	IMDEA	All DCs
WP5	Dissemination, outreach, and exploitation	**M1**	**M48**	Dissemination	IMDEA	All DCs
WP6	Management and recruitment	**M1**	**M48**	Management	IMDEA	All DCs

3.1.2 Description of Work Packages

Table 10. WPs Description (only the recruiting beneficiaries are reported, other participant involvement is shown in **Tables 4** and **13**)

WP1	**Sensing and Infrastructure**	**M7-42**	**DCs 1-3**
Lead beneficiary	**RWTH**	**Recruiting beneficiaries: KU Leuven, CNIT, RWTH**	
Objectives: To improve the performance of spectrum analysis in embedded sensing devices and design a scalable embedded federated learning framework for spectrum analysis that can run on computing-constrained sensors (**Obj1**). To explore how spectrum sensing techniques can help improve service quality and investigate how edge platforms can support spectrum sensing measurements and services (**Obj2**). To propose a sensing-based radio access architecture that can identify spectral and spatial resources at the required time scale and dynamics (**Obj3a**). To compare various radio access infrastructures and their impact on sensing performance (**Obj3b**).			
Task 1.1: IoT connectivity and federated learning hardware acceleration (KU Leuven, Obj1, DC1) **DC1** will first design the core system and federated learning accelerator. The work will investigate available platforms for deep learning acceleration, considering as requirement the capability to enable extra compression or knowledge extraction on the sensor itself at reasonable cost per device. This trade-off needs to be investigated. How much of the pipeline can run locally, what are the features that should be communicated and what should be combined in the cloud? Second, the internet connectivity and meshing strategy will be designed, studying how multiple data streams can be combined inside the network for extracting spectral knowledge.			
Task 1.2: Advance edge infrastructure for spectrum sensing (CNIT, Obj2, DC2) **DC2** explores and designs an edge infrastructure to maximize and perform the computing close to spectrum sensors improving the quality of service to the final user (anomaly detection, spectrum sharing policy, etc.) (**Obj2**). **DC2** will investigate how to integrate spectrum sensing techniques and systems with the telecom edge infrastructure and identify the elements (algorithms, applications, architecture, etc.) that can be optimized using information available from spectrum sensing. **DC2** focuses on managing the edge infrastructure to provide spectrum sensing and sharing algorithms to determine the optimal way of computing and sharing spectrum resources from an architectural point of view and therefore enhance the total capacity of the network (**Obj2**).			
Task 1.3: Sensing-based radio access architecture (RWTH, Obj3, DC3) **DC3** studies and designs new architectures and algorithms to dynamically manage spectrum resources by leveraging the 5G network infrastructure. **DC3** will interface gNB and IoT spectrum sensing nodes, investigating methods that efficiently use the transceiver design and protocol functionalities of gNBs for the problem of wideband and distributed sensing across gNBs. By keeping the cost and complexity reasonable, **DC3** will study the benefit of identifying and tracking available spectrum resources in licensed and unlicensed bands, and potential harmful interference in a dynamic and agile fashion across different bands, facilitating multi-tier access and increasing spectrum utilization in time, frequency and space. Prototypes will be implemented for performance assessment.			
Deliverables: D1.1-D1.3, D6.10-11 (Scientific) (see **Table 11**)			
Connection to other WPs: Anomaly detection, localisation, and coverage mapping (WP2); mobile cells for 6G networks and spectrum-awareness empowered wireless systems for Industry 4.0 application (WP3).			

WP2	**Data Analysis**	**M7-42**	**DCs 4-6**
Lead beneficiary	**TU Delft**	**Recruiting beneficiaries: TU Delft, IMDEA, TID**	
Objectives: To incorporate expert human-in-the-loop feedback into a semi-supervised learning framework to improve the state-of-the-art algorithms for anomaly detection and to investigate solutions for adding spectrum sensing and anomaly detection in the O-RAN edge (**Obj4**). To build a signal transmitter localization framework that does not collaborate with the target devices for the purpose of			

localization (Obj5). To design new algorithms for building efficient and reliable measurement-based mobile coverage and performance maps for 6G network performance optimizations by leveraging the data collected from the terrestrial and aerial nodes (Obj6).

Task 2.1: Scalable anomaly detection computing framework for IoT spectrum sensors (TU Delft, Obj4, DC4)
DC4 studies and proposes strategies for embedded processing on the sensor or federated learning in a local group of edge sensors with the ambition to keep as much generic spectrum anomaly detection information as possible. The main objective of the feature computation is the compression of the massive amounts of sensed data, optimized for the specific purpose of detecting anomalies, in addition to improving privacy or other non-technical characteristics of the crowd-sourced spectrum sensing framework. The generic and scalable anomaly detection framework will work over all bands but can detect band-specific anomalies.

Task 2.2: General-purpose non-cooperative signal transmitter localisation (IMDEA, Obj5, DC5)
The localization of signal transmitters typically assumes that there exists a network synchronization mechanism and that the transmitters cooperate with the localization process. **DC5** studies system-oriented algorithms that will remove these hypotheses and make use opportunistically signals of the environment (LTE, DAB, Mode-S, etc.) to provide time synchronization at the receiving network, without actively sending any signals to the intended target device, and extracting temporal features of the signals that only exploit the waveform structure of the transmitter to be localized. **DC5** will then extend the framework to infer movements of several target devices, considering impairments from the receiving network, such as frequency and bandwidth of observation.

Task 2.3: Geo-statistical analysis of spectrum data for coverage/performance maps (TID, Obj6, DC6)
DC6 explores and designs new algorithms to build efficient and reliable measurement-based mobile coverage and performance maps, by using large spectrum dataset collected by sensors of SpecX network. **DC6** creates mobile coverage and performance maps for any technologies (e.g., 4G/LTE, 5G) in different areas and times. **DC6** will also work closely with operators within the Telefonica corporation (e.g., O2 UK, Movistar Spain). By contrasting the expected radio coverage of the network with the actual experience of the end-user (from mobile apps), **DC6** will build novel anomaly detection approaches that can alert of potential suboptimal configurations.

Deliverables: D2.1-D2.3, D6.10-11 (Scientific) (see Table 11)

Connection to other WPs: ML HW acceleration, anomaly detection, edge sensing (WP1), applications-oriented deployments (WP3)

WP3	Applications	M7-42	DCs 7-10
Lead beneficiary	**KU Leuven**	**Recruiting beneficiaries: CNIT, TU Delft, IMDEA, KU Leuven**	

Objectives: To investigate solutions for the orchestration of network resources based on anomaly detection and spectrum sensing and to propose scalable sensing and access frameworks for massive Internet of Things (Obj7). To exploit mobile cells to satisfy high and dynamic demands on wireless capacity and integrate drone-based sensing and access in converged aerial-terrestrial networks (Obj8). To develop electrosmog sensing techniques for dense deployments in smart cities, and to understand the fundamental limits of sensing with embedded sensors (Obj9). To identify the possible risks/threats related to wireless connections for safety-critical applications in Industry 4.0, to develop a systematic approach on how to react to a possible anomaly in the used spectrum for a safety-critical wireless connection, and to test the approach in applications such as collaborative robots and autonomous vehicles/drones (Obj10).

Task 3.1: Orchestration and anomaly detection for massive IoT (CNIT, Obj7, DC7)
DC7 investigates how to employ radio sensing algorithms to infer the status of distributed, heterogeneous massive IoT deployments, based on the joint analysis of spectral information. **DC7** specifically focuses on algorithms for signal feature extraction, anomaly detection and signal classification. Different spectrum sensors could estimate different spectrum anomalies due to interference, etc. **DC7** evaluates orchestration policies for computation tasks that can optimize the accuracy of the anomaly and classification algorithms.

Task 3.2: Mobile cells for 6G networks (TUD, Obj8, DC8)
DC8 studies how to exploit the movement of BSs (mobile cells) to satisfy the high and dynamic demand on wireless capacity, not only in the time domain but also in the 3D spatial domain. The BSs can be relocated by robots/drones to predefined locations that have the capabilities (such as power and fiber/wireless backhaul) to host BSs, or are directly hosted by robots that can move freely on the ground, or by drones. With further information on the location of the users and coverage maps (**DC6** and **DC7**), **DC8** will study how to properly place and configure the mobile cells to satisfy the dynamic demands on wireless capacity. All in all, **DC8** studies how to provide pervasive and reliable 6G service without the need to deploy a vast number of geo-fixed BSs.

Task 3.3: Electrosmog inference and forecast (IMDEA, Obj9b, DC9)
DC9 studies innovative tools – based on IoT sensors and large-scale crowdsourcing initiatives to massively deploy a set of low-cost Electromagnetic Field (EMF) probes over the territory. **DC9** will develop reconfigurable IoT spectrum sensors with embedded software capabilities to collect EMF measurements. Innovative low-complexity algorithms that can run on embedded sensors with bandwidth smaller than the one of 5G and beyond transmitters will be designed and evaluated. Innovative techniques will be then applied by **DC9** to forecast the EMF exposure and patterns over short and medium periods of time.

Task 3.4: Spectrum-awareness empowered wireless systems for Industry 4.0 applications (KU Leuven, Obj10, DC10)
DC10 studies systematic approach, based on the spectrum anomaly detection, to ensure a dependable wireless connection which is robust and low-latency. **DC10** will develop a methodology on how the whole safety-critical wireless interconnected system should react in case an anomaly is detected. For this, **DC10** will start from the latest developments in run-time safety assurance, EMI risk management and self-adaptive systems. **DC10** and **DC8** will share knowledge and insights on achieving reliable wireless networks. The research of **DC6** will help realize the project of **DC10**. The developed methodology can be used not only in Industry 4.0 localized networks, but also in private 5G+ networks for safety-critical applications.

Deliverables: D3.1-D3.3, D6.10-11 (Scientific) (see Table 11)

Connection to other WPs: Signal feature extraction, anomaly detection and signal classification, accurate beamforming and scalable CSI estimation (WP1); Convergence of ML and edge computing (WP2).

WP4	Training	M7-48	DCs 1-10
Lead beneficiary	**IMDEA**		

Objectives: To closely follow-up on and support the training programmes of the 10 DCs.

Description: The training programme is described in details in Section 1.2. The main tasks of this WP are: to follow up on and support local expert training; to organise network-wide S/T and soft-skills training during 7 events (in cooperation with MST); to follow up with PCDP writing and updates, to be performed in particular during WP5 Consortium meetings during 7 network-wide events.

Deliverables: D4.1-4.14 (see Table 11)

WP5	Dissemination, outreach and exploitation	M1-48	DCs 1-10
Lead beneficiary	**IMDEA**		

Objectives: To expand the visibility and exploitation of spectrum analytics as a service. To coordinate dissemination of the research results to peers and general public. To exploit the research results, run for innovation competitions and develop business cases.

Task 5.1: Dissemination and outreach (IMDEA + all other beneficiaries and partners)
The SpecX consortium drafts the "dissemination and communication plan" at the beginning of the project. Then, the plan is executed, monitored, and updated when necessary, in accordance with the guidelines from the EC.
Subtask 5.1.1: Academia and industry. SpecX disseminates its achievements to the academia and industry mainly through peer-reviewed papers at top tier journals and conferences. Besides, the 10 DCs will develop demos and present them at flagship conferences to increase the visibility and impact of SpecX and its research results.
Subtask 5.1.2: Communication and public engagement. SpecX communicates to the general public the importance of spectrum sensing and analytics for future digital societies, and the contributions of SpecX in achieving a sustainable and powerful spectrum analytics service. The consortium leverages the website of SpecX, twitter, innovation competitions, and interviews to achieve this target.

Task 5.2: Exploitation (IMDEA + all other beneficiaries and partners)
The exploitation strategy is detailed in **Section 2.3.2** and **Figure 4**. It is developed at two levels: (1) Each partner exploits its own research; (2) the SpecX consortium exploits the research results as a whole unit, following the IP procedures defined in the Consortium Agreement. An exploitation plan is developed within 12 months and will be updated annually, highly involving the DCs. Funds are reserved by each beneficiary for possible patenting of the research output. Exploitation covers the four exploitation routes (cf. **Section 2.3.1**), which are actively designed for each DC topic, together with the DCs and their industrial (co-)supervisor.

Deliverables: **D5.1-5.5** (see **Table 11**)

WP6	**Management and recruitment**	**M1-48**
Lead beneficiary	**IMDEA**	

Objectives: To organise the timely recruitment of the 10 DCs. To monitor the process and support the implementation of the project. To monitor the compliance of project partners with their obligations. To collect and review reports and other deliverables and submit them to the European Commission in a timely manner. To protect personal data and assess dual use items. To organise network-wide events and meetings. To manage the experiments within the project.

Description: The structure and methodology of management is detailed in **Section 4**.

Deliverables: **D6.1-6.9** (see **Table 11**)

3.1.3 Deliverables List

Table 11. Deliverables List

Scientific Deliverables						
No.	**Title**	**WP**	**Lead benefi.**	**Type**	**Dissem.**	**Due Date**
D1.1	State of the art review with research progress on Sensing and Infrastructure	1	RWTH	PDE	CO	**M12**
D1.2	Mid-term research progress reports on Sensing and Infrastructure; overview of research activities and the status of the results	1	RWTH	PDE	CO	**M26**
D1.3	Final research progress reports on Sensing and Infrastructure; final work, tools developed, software and results available	1	RWTH	PDE	CO	**M42**
D2.1	State of the art review with research progress on Data Analysis	2	TU Delft	PDE	CO	**M12**
D2.2	Mid-term research progress reports on Data Analysis; overview of research activities and the status of the results	2	TU Delft	PDE	CO	**M26**
D2.3	Final research progress reports on Data Analysis; final work, tools developed, software and results available	2	TU Delft	PDE	CO	**M42**
D3.1	State of the art review with research progresses on Applications	3	KU Leuven	PDE	CO	**M12**
D3.2	Mid-term research progress reports on Applications; overview of research activities and the status of the results	3	KU Leuven	PDE	CO	**M26**
D3.3	Final research progress reports on Applications; final work, tools developed, software and results available	3	KU Leuven	PDE	CO	**M42**
D6.10-11	SpecX System Architectural Concept (inputs from all DCs) **(2 deliverables)**	1-3,6	IMDEA	PDE	CO	**M13, M26**
Management, Training, Recruitment and Dissemination Deliverables						
No.	**Title**	**WP**	**Lead benefi.**	**Type**	**Dissem.**	**Due Date**
D4.1-4.4	Annual report on 10 Personal Career Development Plans	4	IMDEA	R	CO	**M12,M24, M36, M48**
D4.5-4.8	Annual report on training activities, presentation of the results of past events and detailed planning of upcoming events **(4 deliverables)**	4	IMDEA	Other	CO	**M12,M24, M36, M48**
D4.9-4.10	SpecX Summer School and Symposium **(2 deliverables)**	4	IMDEA	PDE	PU	**M24,42**
D4.11-4.14	Annual report on secondments, description of the research conducted, tie-ins with the research direction of DCs at the hosting institution **(4 deliverables)**	4	Benefic.	R	CO	**M12,M24, M36, M48**
D5.1-5.4	Annual report on dissemination, communication and exploitation results, including review of strategies for target groups **(4 deliverables)**	5	IMDEA	R	CO	**M12,M24, M36, M48**
D5.5	Roadmap for exploitation and long-term impact beyond the project	5	IMDEA	R	CO	**M48**
D6.1	Consortium agreement	6	IMDEA	ADM	CO	**M2**
D6.2	Website (public part as well as internal part (protected area: intranet))	6	IMDEA	ADM	PU	**M2**
D6.3	Recruitment event	6	IMDEA	ADM	CO	**M4**
D6.4	Data Management Plan (DMP)	6	IMDEA	R	PU	**M6**

D6.5	Progress report to the REA	6	IMDEA	ADM	CO	M13
D6.6-6.8	Full reports (Periodic Report and Final Report) from the DCs (**3 deliverables**)	1-3,6	IMDEA	R	CO	M14,26,42
D6.9	Inputs for policy feedback / policy brief	6	IMDEA	ADM	CO	M48

3.1.4 Milestones List

Table 12. Milestones list (these are also indicated as "mX.Y" in the Gantt chart) (additional S/T milestones provided in DC Tables)

mX.Y	Title	WP	Lead Bene.	Due	Means of verification
m5.1	ADM	5	IMDEA	M2	Website on-line
m6.1	Recruit-ment	6		M3	20 DC candidates are preselected by core supervisors for the Recruitment Event
m6.2		6		M4	10 DCs are selected and recruited by Recruitment Committee
m4.1	PCDP	4		M8	10 Personal Career Development Plans are approved
m4.2	ADM	4		M8	10 DGCs formally established and approved by SB
m6.3		6		M13	Project check: middle-term meeting between REA and SpecX consortium
m6.4	Scien-tific	1-3, 6	Benefi.	M17	Formal doctoral school review meeting gives green light to DCs for PhD continuation
m6.5				M24	SB S/T evaluation/remediation of individual DCs based on scientific milestone at M24
m6.6		1-3,6	Benefi.	M26	White paper from revised SpecX architectural concept (D6.11)
m1.1		1	KUL	M42	DC1: Experimental feature extractions in local and telecom edge computation
m1.2			CNIT	M42	DC2: Edge computation framework for real spectrum sensing measurements
m1.3			RWTH	M42	DC3: Efficient methods using transceiver design and protocol of gNBs for spectrum sensing
m2.1		2	TU Delft	M42	DC4: Anomaly detection of multiple heterogeneous features with expert feedback
m2.2			IMDEA	M42	DC5: Localization and analytics of transmitters assuming static and moving targets
m2.3			TID	M42	DC6: Evaluation of proposed coverage map method with real world data from operator
m3.1		3	CNIT	M42	DC7: Testing of an efficient resource allocation scheme using the sensing knowledge
m3.2			TU Delft	M42	DC8: Experimental demonstration of the feasibility of mobile cells for 6G networks
m3.3			IMDEA	M42	DC9: Electrosmog framework using limited spectrum bands and real data set
m3.4			KUL	M42	DC10: Safely interconnected wireless system proved in industrial relevant environment

3.1.5 Recruitment Table per Beneficiary

Table 13. Track record of main supervisors and Doctoral Guidance Committee members per DC.

DC	Recruiting Participant	Planned start & Total Duration (month)	Doctoral Guidance Committee (DGC) Members (formal approval during 1st SB meeting)			Doctoral Schools to deliver the PhD degree
			Main academic supervisor [h-index & # PhDs supervised/ supervising] (Gender: m/f)	Academic co-supervisors (incl. extra members in DGC)	Industrial (co-) supervisors(s) in DGC	
DC1	KU Leuven	M7 & 36M	Prof. S. Pollin [h44 & 38 PhDs] (f)	Dr. R. M. Alonso [KU Leuven]	Dr. A. Voicu [Ericsson]	KU Leuven Doctoral School
DC2	CNIT	M7 & 36M	Dr. S. Bartoletti [h15 & 1 PhDs] (f)	Prof. G. Bianchi [UNITV]	Dr. T. Moore [ACC]	UNITV Doctoral School
DC3	RWTH	M7 & 36M	Prof. M. Petrova [h31 & 11 PhDs] (f)	Prof. S. Pollin [KU Leuven]	Dr. A. Voicu [Ericsson]	RTWH Doctoral School
DC4	TU Delft	M7 & 36M	Prof. K. Langendoen [h42 & 25 PhDs] (m)	Profs. G. Lan and Q. Wang [TU Delft]	Dr. T. Moore [ACC]	TU Delft Doctoral School
DC5	IMDEA	M7 & 36M	Prof. D. Giustiniano [h32 & 14 PhDs] (m)	Dr. G. Santaromita [IMDEA]	Dr. V. Lenders [ESense]	UC3M Doctoral School
DC6	TID	M7 & 36M	Dr. A. Lutu [h16 & 11 PhDs] (f)	Prof. P. Serrano [UC3M] and J. Suárez[TID]	Dr. V. Lenders [ESense]	UC3M Doctoral School
DC7	CNIT	M7 & 36M	Prof. P. Casari [h35 & 8 PhDs] (m)	Prof. F. Granelli [UNITN]	Dr. A. Saavedra [NEC]	UNITN Doctoral School
DC8	TU Delft	M7 & 36M	Prof. Q. Wang [h20 & 7 PhDs] (m)	Prof. F. Kuipers [TU Delft]	Dr. A. Saavedra [NEC]	TU Delft Doctoral School
DC9	IMDEA	M7 & 36M	Prof. J. Widmer [h52 & 15 PhDs] (m)	Dr. T. Otim and D. Giustini-ano [IMDEA]	Dr. A. Lutu [TID]	UC3M Doctoral School
DC10	KU Leuven	M7 & 36M	Prof. D. Pissoort [h17 & 24 PhDs] (m)	Dr. T. Claeys [KU Leuven]	Dr. A. Lutu [TID]	KU Leuven Doctoral School

Table 14. Individual research projects

DC1 [KU Leuven]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D1.1-D1.3, D4.11-D4.14

Project Title and WP(s): Federated learning for aerial and terrestrial spectrum sensors, WP1
Doctoral School Enrolment: KU Leuven Doctoral School

Objectives: To design a complete IoT sensing device capable of both local or connected sensing, in aerial or terrestrial settings, using hardware acceleration for machine learning at the edge. To design a scalable computing framework using federated learning, for spectrum

analysis with sparse aerial sensors or dense terrestrial sensors. These applications have computational constraints (e.g., no BS with powerful capabilities involved when considering aerial sensors). To co-optimize the deep learning on the sensors and the telecom edge, for enhanced 3D spectrum use prediction (**Obj1**).

Expected results: Complete wideband sensor design with local computing capabilities at the edge. Scalable spectrum analysis framework using federated learning, allowing local learning with central coordination applicable to sparse aerial and dense terrestrial settings.

Milestones: Wideband sensor design with local feature computation capabilities (**M24**). Federated learning design for sparse or dense settings. Trade-off analysis between local and centralised computation for prediction (**m1.1**) (**M42**).

Planned secondments: 1) Ericsson (non-academic) (4 months, M13-M16): Data analysis and modelling for coexistence of networks based on cellular technologies, with A. Voicu (Key Performance Index (KPI): joint conference paper); **2) RWTH** (4 months, M25-M28): Co-optimization of spectrum prediction with aerial and terrestrial sensors, with M. Petrova (KPI: joint journal paper)

Exploitation potential: Follow-up projects targeting higher Technology Readiness Levels (**EX1**). Prototype commercialisation (**EX4**).

DC2 [CNIT]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D1.1-D1.3, D4.11-D4.14

Project Title and WP(s): Spectrum sensing at the edge, WP1
Doctoral School Enrolment: Doctoral School of University of Rome Tor Vergata (UNIRM)

Objectives: Identification of the elements of edge infrastructures (e.g., resource allocation, anomaly detection, traffic forecast, SW/HW components) that can benefit from the availability of spectrum sensing information. Design of techniques and methods to leverage sensing information for improving the quality of service provided to users. Integration of spectrum sensing methods in edge infrastructure (**Obj2**).

Expected results: Algorithms and architectures to leverage spectrum sensing measurements in telecom edge infrastructure mechanisms (e.g., anomaly detection, user and traffic pattern prediction and orchestration). Algorithms and architectures to support and/or improve spectrum sensing measurements and mechanisms in telecom edge infrastructures.

Milestones: Identification of the elements of telecom edge infrastructures that could benefit from spectrum sensing information. Development of algorithms and architectures for modification/design of the identified elements to improve user quality of service (**M24**). Improvements of spectrum sensing mechanisms leveraging telecom edge infrastructure (**m1.2**) (**M42**).

Planned secondments: 1) ACC (non-academic) (4 months, M13-M16): O-RAN telecom measurements, with T. Moore (KPI: joint conference paper); **2) IMDEA** (4 months, M24-M27): Spectrum sensing with edge infrastructure, with J. Widmer (KPI: joint journal)

Exploitation potential: Follow-up projects targeting higher Technology Readiness Levels (**EX1**). Patents and licensing (**EX3**).

DC3 [RWTH]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D1.1-D1.3, D4.11-D4.14

Project Title and WP(s): Sensing-capable 6G radio access infrastructure, WP1
Doctoral School Enrolment: Doctoral School of RWTH Aachen University (RWTH)

Objectives: To study and identify enablers for realizing and integrating a sensing functionality in the future RAN components. Study techniques for both data-driven and predictive dynamic spectrum allocation and sharing. To identify how to integrate spectrum sensing mechanisms in telecom edge infrastructure. (**Obj3**).

Expected results: Energy efficient, low overhead and distributed sensing functionality implemented across radio network elements. Mechanisms and procedures for creating environment knowledge including spectrum and traffic patterns, and sharing the knowledge across the network. Agile resource allocation suited for variety of applications by leveraging short-term sensing and long-term spectrum information.

Milestones: Identification of sensing parameters, storing and processing of the data. Evaluating the accuracy and the complexity of the proposed sensing algorithm (**M24**). Prototyping and performance analysis of the sensing mechanism in a testbed of of-the-shelf APs or SDR-based gNBs. Design and showcasing an efficient resource allocation scheme using the sensing knowledge (**m1.3**) (**M42**).

Planned secondments: 1) KU Leuven (4 months, M12-M15): Design and evaluation of sensing algorithms, with S. Pollin (KPI: joint conference paper); **2) Ericsson (non-academic)** (4 months, M25-M28): Design of a sensing knowledge-based predictive resource allocation scheme, with A. Voicu (KPI: journal paper)

Exploitation potential: Follow-up projects targeting higher Technology Readiness Levels (**EX1**). Prototype commercialisation (**EX4**).

DC4 [TU Delft]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D2.1-D2.3, D4.11-D4.14

Project Title and WP(s): Multi-sensor and multi-band semi-supervised anomaly detection with expert feedback, WP2
Doctoral School Enrolment: TU Delft

Objectives: To improve state-of-the-art algorithms for feature extraction, anomaly detection, and classification. To study how to incorporate expert feedback into a semi-supervised learning framework and how to run the framework on embedded devices. To combine heterogeneous data streams for wideband and narrowband cooperative and non-cooperative sensors (**Obj4**).

Expected results: A strategy for combining data or compressed features from multiple sensors. A framework for creating knowledge such as anomaly detection and classification based on that fused data. A strategy for including expert feedback in the anomaly detection and classification step.

Milestones: Wideband anomaly detection and classification using uncompressed data in the RAN/O-RAN edge. Semi-supervised anomaly detection with expert feedback (**M24**). Anomaly detection using data fusion of multiple heterogeneous and compressed features on embedded devices (**m2.1**) (**M42**).

Planned secondments: 1) ACC (non-academic) (4 months, M13-M16): Algorithm design for federated anomaly detection and classification in the O-RAN edge and on embedded devices, with T. Moore (KPI: joint conference paper); **2) AlbanyU** (4 months, M21-M24): Impact of expert feedback from telecom edge on the semi-supervised learning framework, with M. Zheleva (KPI: joint journal)

Exploitation potential: Follow-up projects targeting higher Technology Readiness Levels (**EX1**).

DC5 [IMDEA]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D2.1-D2.3, D4.11-D4.14

Project Title and WP(s): Non-collaborative positioning of transmitters and patterns of movements, WP2
Doctoral School Enrolment: Doctoral School of Carlos III University of Madrid (UC3M)

Objectives: Design distributed algorithms to localise any wireless transmitter in mobile environments that does not collaborate (passive positioning). Study impact on waveform on positioning accuracy. Design of algorithms exploiting time and Doppler, working with non-coherent receivers. Extraction of analytics from multiple target users (**Obj5**).

Expected results: Algorithms to passively localize radio signal transmitters with measured time, Doppler and angle information. System evaluation of distributed localization algorithms in mobile environment with multiple users. Framework for inferring people movements from non-collaborative localization data.

Milestones: Methods for TDoA localization in embedded platforms using low-cost SDR. Methods for Doppler based localization in embedded platforms for mobile targets using low-cost SDR (**M24**). Localisation and analytics of several transmitters regardless of their band of operation assuming both static and moving targets (**m2.2**) (**M42**).

Planned secondments: 1) ESense (non-academic) (4 months, M15-M18): Design and implementation of localisation algorithms with IQ data collected from Electrosense network at different locations, with V. Lenders (KPI: joint conference paper); **2) RWTH** (4 months, M26-M29): Modelling patterns of movements with IoT receivers, with M. Petrova (KPI: joint journal paper)

Exploitation potential: Follow-up toward higher Technology Readiness Levels (**EX1**). Prototype commercialisation (**EX4**).

DC6 [TID]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D2.1-D2.3, D4.11-D4.14

Project Title and WP(s): Geo-statistical analysis of spectrum data for coverage/performance maps, WP2
Doctoral School Enrolment: UC3M

Objectives: To analyse large-scale data collected from spectrum sensing. To contrast network-side planned radio coverage with the actual experience of the end-users and build anomaly detection approaches, traffic and user patterns forecast, answer what-if questions regarding the network deployment, etc. to help radio planning teams. To design new approaches for building efficient and reliable measurement-based mobile coverage (**Obj6**).

Expected results: Data analytics approaches and estimation techniques for building efficient coverage and performance maps. Anomaly detection and predictions mechanisms approach to detect/predict deviations from the planned/expected radio coverage of real-world operators by contrasting the theoretical coverage with the end-user experience. Novel methodology for building radio coverage maps by controlling the network-side state with end-user measurements (e.g., drive tests from the operator, crowd datasets, etc.).

Milestones: Data analysis to understand the challenges for building reliable coverage maps (**M24**). Algorithm design for building radio coverage maps by controlling the network-side state with end-user measurement. Evaluation of the proposed approach using data from a real-world mobile network operator (**m2.3**) (**M42**).

Planned secondments: 1) UC3M (4 months, M14-M17): Big data analysis from spectrum sensing, with P. Serrano (KPI: joint conference paper); **2) ESense (non-academic)** (4 months, M23-M26): Algorithm for reliable mobile coverage, with V. Lenders (KPI: joint journal)

Exploitation potential: Follow-up projects targeting higher Technology Readiness Levels (**EX1**). Patents and licensing (**EX3**).

DC7 [CNIT]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D3.1-D3.3, D4.11-D4.14

Project Title WP(s): Orchestration and anomaly detection in massive IoT deployments, WP3
Doctoral School Enrolment: Doctoral School of University of Trento (UNITN)

Objectives: To employ radio sensing algorithms to infer the status of distributed, heterogeneous massive IoT deployments, based on the joint analysis of spectral information. To implement orchestration policies for computation task allocation so as to optimize the performance of status inference, also considering the architecture of future RAN infrastructure. To combine principles of network virtualization, optimization, sensor placement, and machine learning in order to achieve the above objectives (**Obj7**).

Expected results: Algorithms and architectures to collect and make sense of distributed RF spectrum sensing data in order to infer the status and orchestrate distributed and massive IoT deployments. Algorithms for management based on inference from the sensed RF data.

Milestones: Lightweight spectrum analytics algorithms for the analysis of jointly sensed RF information, including correlation studies and feature extraction (**M24**). Actuation algorithms to exploit multi-modal RF analytics for orchestration and anomaly detection of massive IoT deployments (**m3.1**) (**M42**).

Planned secondments: 1) SLU (5 months, M11-M15): Optimization and scaling of sensing computation placement algorithms for anomaly detection, with F. Esposito (KPI: joint conference paper); **2) NEC (non-academic)** (4 months, M23-M26): Design of a method to deploy, and test machine learning models in an edge-to-fog continuum for IoT resource utilization, with A. Garcia (KPI: joint journal)

Exploitation potential: Follow-up projects targeting higher Technology Readiness Levels (**EX1**). Patents and licensing (**EX3**).

DC8 [TU Delft]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D3.1-D3.3, D4.11-D4.14

Project Title and WP(s): Drone-hosted mobile cells for 6G, WP3
Doctoral School Enrolment: Doctoral School of Delft University of Technology (TU Delft)

Objectives: To propose an analytical model for the cell planning of drone-hosted mobile BSs based on user location and the coverage and interference map obtained from spectrum sensing, to achieve interference-free and pervasively high data rate for 6G networks in all possible scenarios. To study the trade-off between the physical adaptation (e.g., movement) of the BSs and the degradation of the system performance in mobile user scenarios. To study the impact of the quality of wireless backhaul on the performance of drone-hosted cells in scenarios when a fibre backhaul is not available. To experimentally demonstrate the feasibility of exploiting drone-hosted mobile cells for 6G networks (**Obj8**).

Expected results: A model on cell planning of drone-hosted mobile BSs that can achieve interference-free and pervasive line-of-sight communications in different scenarios. Insights into achievable gain versus overhead on infrastructure, especially drone movements.

Milestones: Accurate model for the cell planning of drone-hosted mobile BSs is derived. Trade-off between BS location adaptation and cell performance (**M24**). Experimental feasibility and demonstration of drone-hosted mobile cells for 6G with backhaul (**m3.2**) (**M42**).

Planned secondments: 1) KU Leuven (4 months, M13-M16): Model design of cell planning of drone-hosted mobile BS, with S. Pollin (KPI: joint conference paper); **2) NEC (non-academic)** (6 months, M27-M32): Impact of backhaul links on the mobile cell performance, with A. Saavedra (KPI: joint journal paper)

Exploitation potential: Follow-up implementation into the products of Ericsson and NEC (**EX2**).

DC9 [IMDEA]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D3.1-D3.3, D4.11-D4.14

Project Title and WP(s): Electrosmog inference, WP3
Doctoral School Enrolment: Doctoral School of Carlos III University of Madrid (UC3M)

Objectives: To measure the electromagnetic exposure using low-cost spectrum sensors. To design low-complexity algorithms that can work with IQ signals collected with sensors of bandwidth smaller than the one of the transmitters (such as 5G and beyond). To experimentally test the proposed solution on embedded devices (Obj9).

Expected results: Provide quantitative assessment of electromagnetic exposure with low-cost spectrum sensors. Design of analytics for inferring and forecasting the radio exposure. Proof of concept with prototype sensing real transmissions.

Milestones: Fundamental understanding of the limits of electromagnetic exposure measurements with embedded and software-defined spectrum sensors. Comparison of performance with respect to more traditional methods to measure the electrosmog (M24). Algorithms that fuse information from several sources to forecast the exposure (m3.3) (M42).

Planned secondments: 1) KU Leuven (4 months, M15-M18): Design of low-cost algorithms in customized hardware accelerators, with S. Pollin (KPI: joint conference paper); **2) TID (non-academic)** (4 months, M26-M29): Measurement campaign with known transmission patterns of base stations, with A. Lutu (KPI: joint journal paper)

Exploitation potential: Follow-up implementation into the products of ESense (EX2).

DC10 [KU Leuven]	PhD: Yes	Start: M7	Duration: 36M	Main deliverables: D3.1-D3.3, D4.11-D4.14

Project Title and WP(s): Safety-assurance of highly dependable interconnected systems in Industry 4.0, WP3
Doctoral School Enrolment: KU Leuven Doctoral School

Objectives: To identify the possible risks and threats of using wireless connections for safety-critical applications in industry 4.0 and drones. To develop a systematic approach on how to react on a possible anomaly in the used spectrum for a safety-critical wireless connection. To apply and test the developed approach in industry-oriented case studies (Obj10).

Expected results: Risk analysis of the use of wireless connections in Industry 4.0 and drones. Comprehensive guidance document on how to react to a detected, possibly critical interferer in order to ensure safety and low-latency. Successful application of the systematic approach in an Industry 4.0 private wireless network case study and or drones.

Milestones: White paper on the safety risks of using wireless connections within Industry 4.0. Report describing the generic methodology on how to ensure safety when a possibly critical interferer is detected (M24). Demonstration of the methodology on an Industry 4.0 wireless network case study (m3.4) (M42).

Planned secondments: 1) TU Delft (4 months, M16-M20): Safety case of a drone hosted mobile cell, with Q. Wang (KPI: joint conference paper); **2) TID (non-academic)** (4 months, M25-M28): Methodology demonstration of anomaly detection in mission and safety critical industry 4.0 cases with a. Lutu (KPI: joint journal paper)

Exploitation potential: Follow-up implementation into the products of TID (EX2).

3.1.6 Progress monitoring and evaluation of individual projects

SpecX has clearly identified main objectives (Obj1-Obj10, Table 1), deliverables (DX.Y, Table 11), milestones (mX.Y, Table 12), delivery dates (Table 11 and Table 12) and exploitation routes (EX1-EX4, Figure 4). This allows for an impartial monitoring of the project progress, both by the project management (MST, SB) and the EC. The governance structure for SpecX (cf. Section 3.2.1) allows for quality control at various levels. Moreover, reviews by an external advisory group (to be formed after the kick-off of the DN) will be used to further improve the quality control methods used by SpecX. Furthermore, SpecX uses a **two-level progress monitoring strategy** to evaluate the progress of the 10 individual projects at both the local Doctoral School beneficiary level (cf. 10 DGCs) and the DN project level. DCs will produce different reports to be monitored: (1) A PCDP as a basis for (2) the comprehensive RTDE Progress Report (word doc) that is regularly updated (in view of the DGC; TSC and SB meetings), (3) 3-monthly DC Progress Presentations (slides) which are used for the WP Meetings, (4) shorter Secondment Progress Reports, and (5) Evaluations and surveys reports each time a Secondment or training is completed, which are used for measuring the DC's training satisfaction. The RTDE report covers (1) personal info; (2) S/T progress; (3) Training progress; (4) Dissemination and outreach; (5) Exploitation. All DCs integrate a detailed PhD Work Plan in their RTDE report. SpecX also foresees a genuine involvement of the DCs in the progress monitoring. More details are presented in Table 15.

Table 15. Progress monitoring strategy *(TRN: training; C&D: Communication & Dissemination; EXP: exploitation)*

Monitoring level	Frequency	Means of reporting	Who monitors and provides feedback?	Who monitors and provides feedback?	What is monitored?			
					S/T	TRN	C&D	EXP
At beneficiary & Doctoral School level (+secondment level)	Monthly	DC progress report (word doc)	Face-to-face meeting	Main supervisor + co-supervisor(s)	✓	✓	✓	
	4 times (M16-M28-M40-M54)	DC RTDE progress report (word doc)	Face-to-face doctoral review meeting	DGC (incl. non-academic supervisor(s))		✓	✓	✓
	Every 2 weeks during secondments	Secondment progress report (word doc)	Face-to-face meeting with secondment supervisor	Secondment supervisor (non-academic ones focus on exploitation)	✓	✓		✓
	Every end of the Secondment	Secondment evaluations survey report	Online survey to be filled by each DC	DGC (incl. non-academic supervisor(s))	✓	✓	✓	✓

At DN project level	Every 5 to 6 months (in between 2 Network-Wide Events) (M10-15…39)	DC progress presentation (slides)	WP online meetings (DCs + WP Leader + S/T Coordinator)	WP leader + S/T Coordinator	✓	✓		
			WP meeting (full Network)	WP leader + S/T Coordinator + GC + feedback by other members	✓	✓		
			S/T coordinator feedback meeting (DCs + S/T Coordinator)	S/T coordinator	✓	✓		
	Each 5 to 6 months (at location of network-wide events)	DC RTDE progress report (word doc)	TSC meeting (Part 1)	Technical steering committee	✓			
			SB meeting (Part 2)	Supervisory Board		✓	✓	✓

3.1.7 Implementation Risks

The potential risks in SpecX associated with research, training, etc., are to be managed according to **Table 16**. Any unforeseen risks that manifest are reported immediately to the SB and TSC, depending on the risk. The SB or TSC then meet as soon as possible (also via teleconference) and decide on the appropriate contingency plans.

Table 16. Overview of main risk strategies – contingency plan

Risk domain	Description of risk	WP	Likelihood	Impact	Proposed mitigation scenario
Training	Envisaged experts for lectures not available	5	Medium	Low	Rely on network of SpecX participants to identify alternative speakers, adjust topics of specialised lectures. Links with other projects allow a greater pool of experts.
	Training progress of DC insufficient	5	Medium	Medium	• Short-term intervention by local supervisor and WP5 Leader based on PCDP. • WP5 team to discuss training progress and provide remedial action.
	PhD aborted when funding stops after 36M	5	Medium	Very high	SpecX beneficiaries foresee additional funding for the required time to finish the PhD in accordance with the regular PhD time in the country of origin.
S / T	Delays due to interconnections between DC projects or the inefficient collaboration among some of the DCs	1-3	Medium	Low	All DCs can start their work as soon as they are recruited. Soft-skill training on teamwork is provided during the second network-wide event to ensure smooth collaborations among the DCs. Nevertheless, there is no fundamental interdependence which impedes the progress of the individual DCs. Furthermore, exploration of cooperation opportunities is stimulated so that DCs can build further upon each other's results. IMDEA is in charge of the experiments transfers. In case there are delays in transfer of such results, solutions will be discussed in TSC meetings.
	Technical failure	1-3	Medium	Medium	The TSC meeting seek for case-by-case solutions in case of unforeseen technical failure occurring in the individual projects of the DCs.
	Spectrum sensing architecture not impactful or infeasible	1	Very low	High	Preliminary results, spectrum sensing and data analytics architectures already in place (e.g., Electrosense) show feasibility and great impact of spectrum data analysis. Agile approach will be applied to re-iterate infrastructure & algorithm design.
	Data analytics too complex or ineffective	1, 2	Low	High	Re-iterate feature extraction & learning schemes. Try advanced learning architecture & exchange more data among probes. Incorporate additional expert feedback.
	Slow S/T advancement affects applications	3	Low	High	All S/T objectives are tuned to be feasible for a typical doctoral training. Early in-network dissemination of results will identify (un)feasible approaches.
	Low S/T competence of supervisors	1-3	Very low	Very high	• Participants are thoroughly screened in the project-writing phase. Strong TSC in SpecX to support all supervisors. • Two-level quality control (two-level progress monitoring strategy (**Table 15**).
	Low S/T competence of DCs	1-3	Low	High	• High-profile recruitment methods and events planned; continuous progress monitoring (PCDP, RTDE) through DGC and SB (**Table 15**).
	Conflict Supervisor/DC	1-3	Medium	High	An ombudsperson is appointed to resolve such conflict. An anonymous feedback is in place where DCs can provide confidential comments to ombudsperson.
	Scientific misconduct	1-3	Very low	Medium	All DCs are informed on good practices and correct scientific behaviour. Evidence of scientific misconduct is reported to the SB/WP leader/coordinator and to the host institution, following the regular procedures, to ensure that appropriate actions are taken. Specific training is provided through the VITAE RDF (**Table 5**).
Exploita	IP conflicts	4	Low	High	CA with clear IPR and tech transfer guidelines; Supportive Exploitation Manager in MST; Clear screening method for publishing.
Management	Too ambitious timing for start-up	5/6	Medium	Low	Strict timing foreseen is based on achieved results in previous EU projects. The DGC continually helps tune timing for DCs and SC revises timelines at each NWE.
	Lack of sufficient applicants for DCs	6	Low	Medium	High-profile recruitment event attracting the best students. Required profiles are indicated per DC position. Additional targeted communication of vacancies, broadening research topics. Transfer of candidates from one topic to another.
	Not all DCs recruited at Recruitment Event	6	Low	Medium	IMDEA has excellent track record in effective recruitment. During RE: better to leave positions vacant (waiting for better candidates) than to recruit wrong candidates. Clear follow-up strategy: decentralised procedure to fill up vacancies.

	Participant no longer willing to cooperate	6	Low	High	Participants know each other well based on prior joint projects. Stress-tested management structure with clear demarcation of responsibilities, conflict resolution, transparent voting systems, etc. As last measure, a replacement will be sought.
	GC or WP Leader unavailable	6	Low	High	Identification of substitutes prior to the start of the project (e.g., vice GC; vice-WP Leader appointed, being a colleague from the same institute, see **Section 4**).

3.1.8 Supervisory board

The SB consists of the GC (D. Giustiniano), the SC (S. Pollin), the training chairs (A. Lutu and M. Petrova), the WP1-5 Leaders and one representative from each beneficiary. Each beneficiary has one vote in the SB. Each of the associated partners, the ReC, and the WRC also has one representative in the SB but without voting right. The GC chairs the SB. During the SB meetings, an overview of the technical quality, training, secondment, dissemination, exploitation, and reports from each DC is presented by the WP leaders, and an evaluation is conducted. Besides, it is responsible for the collection and implementation of external advices from the Advisory Board. A DC recruitment committee is assembled by the SB in **M1**. The SB meeting is organised twice a year along with the 7 network-wide events. An additional SB meeting takes place in **M48** without the network-wide workshop. The SB meeting are also organised for important decisions, and are carried out through conference calls. Decisions are preferentially made through a consensus procedure. If consensus cannot be made, decisions shall be taken by a majority of two-thirds of the votes cast. **Gender balance aspects** are taken very seriously in SpecX. Note that **3 of the 6 PIs of the beneficiaries and 4/10 of main supervisors are female.** Hence, as voting right is only for beneficiaries, genders aspects will be duly taken into account in any decision. Besides, SpecX has female SC, female training co-chairs, and the Recruitment Committee (RC) also has balanced gender.

3.1.9 Recruitment strategy

Upon acceptance, the search for suitable candidates starts by internationally publishing ads in platforms such as Euraxess, ResearchGate, LinkedIn, and mailing lists such as TCCC. The basic rule for recruiting the appropriate candidates of the DCs in SpecX is according to normal recruitment strategies, such as previous publications, motivation for research, research/education background, among others. The pre- and final selection will be made in a collective process, led by the **Recruitment Committee** formed by experts with significant prior experience in research recruitment at their groups/institutions. Each applicant can apply for up to three DC openings, in order of preference. During the pre-selection stage, up to 20 candidates will be selected based on the above strategy. Then, they are interviewed in face-to-face meetings (if in EU; the recruiting institution provides traveling and accommodation support), and by conference calls if they are outside of EU. Specifically, the RC selects the DCs following an open, transparent, impartial and equitable recruitment procedure, on the basis of: (1) their scientific skills and the relevance of their research experience; (2) the impact of the proposed training on their careers; (3) the expected benefit of research exchange between the DC's home countries, the institutions and the host of the secondments; (4) in accordance to gender equality and minority rights. The candidates are ranked and a collective decision is made, accounting the order of preference. In this way, a complementary pool of DCs can be selected. All recruitments are in line with the European Charter for Researchers, providing the overarching framework for the roles and responsibilities of both researchers and employers. The Code of Conduct for the Recruitment of Researchers ensures that the selection procedures are transparent and fair. The RC will ensure that no conflict of interest exists in or arises from the recruitment. The recruitment strategy of SpecX fully complies with the definitions of merit from the Code of Conduct. For example, merit should be not measured based only on researcher's grades, but rather based on a complete range of evaluation criteria, such as teamwork, interdisciplinary knowledge, independent thinking, soft skills and awareness of the impact of research. The RC has members of both genders and considers the promotion of equal opportunities and **gender balance** as part of the recruitment strategy. Special effort will be made to attract female researchers by aiming at **recruiting at least one third female DCs.** Among equally qualified applicants, women receive preferential consideration. All DCs are employed on full-time contracts and are enrolled as PhD candidates. DCs are assisted with settling into their new countries and research environments through the Euraxess service for relocation. The DCs are entitled to pension contributions, paid holidays, and other employment benefits as governed by the beneficiaries.

3.2 *Quality, capacity and role of each participant, including hosting arrangements and extent to which the consortium as a whole brings together the necessary expertise*

3.2.1 Appropriateness of the infrastructure and capacity of each participating organisation

SpecX brings together some of the top groups in EU that are on the very forefront of wireless systems with particular focus on cutting-edge spectrum sensing and analytics research. The details are presented in **Section 6**. Each participating organisation has facilities for supporting their specific research and training, as well as for hosting DCs. Consortium members have unique and large-scale testbeds (see **Figure 2**) and significant expertise in carrying out highly relevant and practical systems research. The facilities can be leveraged by DCs for large-

scale and realistic experiments. The SpecX consortium is created also with great care to combine complementary and multidisciplinary expertise spanning all aspects of wireless communication systems including wireless networks (telecommunications), SDR prototyping (system engineering), machine learning and deep learning (computer science), and signal processing (electronic engineering). In addition to complementary partner expertise, the SpecX programme features an extremely high innovation capacity thanks to the participation of institutions that cover the full innovation cycle from scientific discovery (academic participants) to test, manufacturing (Ericsson, NEC, and ACC), and finally consumer market (TID). In addition to these innovation partners, SpecX also links with not-for profit organisations such as Electrosense in Switzerland or large and recently established consortia such as SpectrumX in the USA, all with the ambition to strengthen the workforce and knowledge, while being exposed to the latest advancements at worldwide scale. The involvement of the members in major standardization task forces (e.g., 3GPP, IETF) further enhances the aforementioned cycle.

3.2.2 Consortium composition and exploitation of participating organisations' complementarities

SpecX consortium draws its talents from six EU member states, and is complemented by three non-EU members, with long prior experience in joint projects (e.g., IMDEA and KU Leuven have partnered with ESense since 2015). It consists of six beneficiaries (including two non-university beneficiaries) and five industry partners. SpecX's interdisciplinary and intersectoral consortium brings together unique and complementary expertise in all areas of wireless systems, with each participating organisation is fully engaged in the SpecX programme. The SpecX consortium covers the full spectrum sensing and enabled applications from fundamental research (AI-enabled multiband sensing and technology recognition, sparse sensing, etc.) to applied research (applications for mobile broadband, industry 4.0, and massive IoT). The industrial partners are carefully chosen to cover all the essential fundamental and applied research areas of spectrum sensing, e.g., international vendors (Ericsson and NEC), system provider (ACC), and leading operator (TID), while also having overlapping interests (e.g., DC6 Geostatistical analysis of spectrum data for coverage/performance maps, with involvement of both TID and ESense). The strength of the consortium is reflected by the fact that these partners are involved as coordinators or key partners in several EU or national projects that are complementary to SpecX. These projects pave the way for the high-quality training of the 10 SpecX DCs. The distinct technical expertise of the consortium is detailed in **Section 6**. Both in terms of the involved organisations and lead supervisors, SpecX includes a premier team of highly respected researchers in spectrum sensing (D. Giustiniano, IMDEA, GC; S. Pollin, KU Leuven, SC; M. Petrova, RWTH and M. Zheleva, AlbanyU), telecom edge infrastructure and intelligence (A. Lutu, TID; P. Casari, UNITN), electrosmog (J. Widmer, IMDEA), wireless networking and embedded AI (Q. Wang, TU Delft), IoT (D. Pissoort, KU Leuven), among others. In terms of guaranteed project management expertise, SpecX is coordinated by IMDEA, which has ample experience in H2020 ITNs.

3.2.3 Commitment of beneficiaries and associated partners to the programme

The six beneficiaries and nine associated partners in SpecX collaborate closely to provide intersectoral and interdisciplinary training to the 10 DCs. The training programme offered by the partners involves: (1) participation in the SB and contribution to the network-wide events, summer school, and symposium (**Table 3**), (2) hosting secondments (**Table 14**), and (3) the industrial supervision of DCs (see DGCs, **Table 13**). Hence, the DCs benefit from the integrative activities between academia and industry by obtaining a full range of trainings, ranging from advanced education to practical applications. Also, the non-academic beneficiaries and partners gain insight into emerging problems, which creates novel initiatives for academic research, and they can use the unique facilities provided by the network. The non-academic partners are exposed to bright researchers and are informed about cutting-edge results, which also allows the non-academic participants to spot potential candidates for recruitment. The Supervisory Board constitutes a prime venue to monitor the commitment of all project members and encourage synergies from research to innovation and exploitation.

3.2.4 Funding of non-associated third countries (if applicable)

No beneficiary resides in a non-associated third country. The travel cost such as flight tickets and accommodation of the associated partners in the USA participating in the NWEs will be reimbursed by beneficiaries that organise the corresponding NWEs, as it will be detailed in the Consortium Agreement. For secondments towards the US associated partners (universities AlbanyU and SLU), we will apply the same rules as for other secondments within EU or associated/third-party countries. That is, the costs of the DCs' mobility will be covered by the beneficiaries that hire the seconded DCs.

4. Network Organisation

Coordinators. *Domenico Giustiniano (IMDEA), General Coordinator (GC), with proved experience in coordination of EU, national and regional projects, is in charge of the overall supervision and management* (**Figure 1**). He links SpecX participants to the EC and executes the Grant and Consortium Agreements. The GC is responsible for monitoring the obligations of the SpecX participants. He collects, reviews, and reports the progress to the EC. With the assistance from the management support team, the GC prepares the agenda for SpecX and chairs the Supervisory Board meetings. The GC ensures the smooth running of the project based on his rich experiences on research and project management. *Sofie Pollin (KU Leuven), a well-known expert on spectrum sensing, is Scientific/Techical Coordinator (SC).* She leads the S/T training program for DCs and ensures the coherence among the research tracks. Q. Wang (TU Delft) and P. Casari (UNITN), replace the GC and the SC, respectively, during meetings in case of illness or unforeseen reasons.

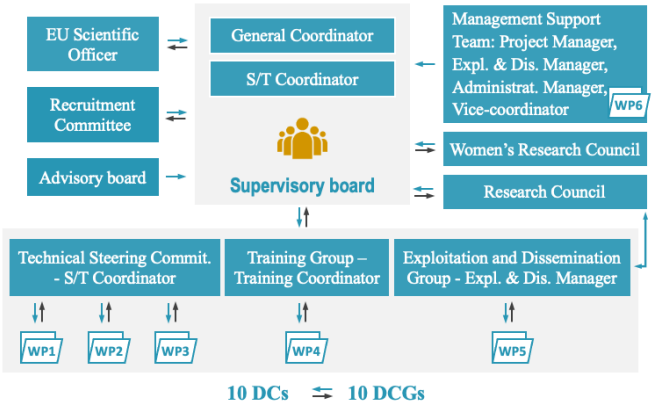

Figure 5. Schematic of the management structure.

Management Support Team (MST). The MST assists the GC for financial management, consolidation of report management, monitoring of expenses against budget allocations, and supporting the dissemination and exploitation of SpecX, e.g., project webpage and event management. The MST is staffed by an experienced project manager (J. Hervas, partially funded through the SpecX management budget), supported by the Project and Funds unit of IMDEA, and by the dissemination and exploitation manager (J. Widmer, IMDEA). The MST meets monthly to ensure the smooth execution of all tasks. IMDEA has gained top-level expertise in administrative, financial and legal management of EU projects through its several years of high-impact work and coordination, further offering professional advice about legal, technical as well as business-related issues. The GC will be advised and assisted by the above team for a number of actions, such as overall financial and administrative control, drafting and follow-up of the consortium agreement, follow-up of contractual issues, e.g. amendments to Annex-I or to the CA, managing overall legal and administrative issues, among others.

Supervisory Board (SB). The SB, the highest decision-making body, is also discussed in **Section 3.1.8**. The SB consists of the GC (D. Giustiniano), the SC (S. Pollin), the training chairs (A. Lutu and M. Petrova), the WP1-5 Leaders and one representative from each beneficiary. Each beneficiary has one vote in the SB. Each of the associated partners, the ReC, and the WRC also has one representative in the SB but without voting right. The GC chairs the SB. During the SB meetings, an overview of the technical quality, training, secondment, dissemination, exploitation, and reports from each DC is presented by the WP leaders, and an evaluation is conducted. Besides, it is responsible for the collection and implementation of external advices from the Advisory Board. A DC recruitment committee is assembled by the SB in **M1**. The SB meeting is organised twice a year along with the 7 network-wide events. An additional SB meeting takes place in **M48** without the network-wide workshop. The SB meeting are also organised for important and urgent decisions, and are carried out through conference calls. Decisions are preferentially made through a consensus procedure. If consensus cannot be made, decisions shall be taken by a majority of two-thirds (2/3) of the votes cast.

Recruitment Committee (RC). This committee involves the GC (D. Giustiniano), the SC (f, S. Pollin), and one representative from each of other beneficiaries (Q. Wang, M. Petrova (f), A. Lutu (f), P. Casari). The RC oversees the recruitment of DCs during the collective recruitment event. Besides, the RC follows up DC's training progress and career planning. The RC committee meets during network-wide events.

Researcher Council (ReC). The ReC consists of 10 DCs and meets in the workshops. It discusses issues related to project management and communicates to the SB through their representative. The quality of the overall training is discussed, and suggestions and concerns are communicated to the WP4 team and the SB. The ReC appoints a representative for the SB and **WP4**. The ReC co-plans social media and public engagement strategy.

Women Researchers Council (WRC). SpecX unites all female DCs (and additional female colleagues) in the WRC to promote cultural change in relation to gender balance in the involved organisations, and engages staff at all levels to improve the promotion of equality and diversity. The WRC appoints a representative for the SB and WP4. It interacts with organisations in ICT areas, e.g., Networking Women (n2women.comsoc.org).

WP Teams. The 4 S/T WP teams bring together the involved researchers and supervisors, and are led by one WP Leader. The WP leaders M. Petrova (RWTH; WP1), Q. Wang (TU Delft; WP2) and Davy Pissoort (KUL; WP3), and are responsible for having an overview of the S/T quality and report it to the SB. IMDEA is responsible for the training quality (WP4 leader), Dissemination and Exploitation (WP5 leader), and Management (WP6 leader). The training group includes a representative of the RC, the WRC and at least one supervisor per beneficiary. All WP teams meet on a regular basis (physical and teleconference meetings). They also meet (consecutively) during the first day of the network-wide workshops, during which DCs present their results to both WP Members and other participants (**Table 6**). This creates better interlinkage between individual WPs and DCs.

Technical Steering Committee (TSC). During the rotating workshops, the WP1-3 Leaders, the GC (supported by the MST) and the S/T Coordinator meet for an overall TSC meeting, where they check the general S/T progress and prepare for the SB meeting. The TSC is chaired by the S/T Coordinator. The S/T WP Leaders present a summary of the results obtained in their WP (building upon the results presented by the DCs during the first day of the event). The TSC takes decisions (through consensus) on WP-related S/T matters, with specific attention to the interactions of the WPs. To increase the involvement of all beneficiaries and associated partners, at least one supervisor per beneficiary and associated partner is present.

Conflict resolution. The participants will do their best to co-operate well, and will take decisions with the consent of all participants, after discussion of the facts and possible paths to follow. If there is a strong difference of opinion about the S/T work (**WPs 1-3**) or the training and dissemination/exploitation (**WPs 4-5**), or between WP Leaders and the majority of the other WP participants, the project manager organises a meeting (conference call) with the WP leaders, the S/T coordinator and the GC to develop proposals for solutions. If required, a vote is taken in the SB (2/3 majority required). SpecX uses an anonymous DC feedback mechanism to obtain (confidential) complaints, allowing swift remediation actions. Furthermore, an interpersonal communication skill is part of the soft-skill programme (see **Table 5**). Further details on the settlement of disputes will be included in the Consortium Agreement.

Project progress monitoring. We have presented the progress monitoring of individual projects in **Section 3.1.5** of Document **B1**. For completeness, we also include here some of the contents. SpecX has clearly identified the research objectives (**Table 1** in Document **B1**), deliverables (**Table 11**), milestones (**Table 12**), delivery dates (**Table 11** and **Table 12**), and exploitation routes (**Figure 4**). These details also enable the monitoring of the whole project by the MST, SB, the advisory board, as well as the EC. At each of the NWEs, the SC and each WP leader present with slides the progress of the whole project and each WP, respectively. The training chairs present the monitoring of the training activities at the consortium level, and the exploitation chairs introduce the finished/coming dissemination & outreach activities. During all these presentations, the ten DCs are also foreseen a genuine involvement in the project monitoring. Issues that affect affect the project progress will be identified, raised, and solutions will be discussed and executed by the MST and SB, with the inputs from the DCs. Effectiveness of the solutions will be assessed during the next NWEs.

Advisory Board (AB). To improve the quality control methods used by SpecX, at month **M1**, an AB will be named including world-renowned expert from the academia and industry. The AB will be tasked with providing external and independent advice on the training on a periodic basis.

5. Environmental aspects in light of the MSCA Green Charter

The SpecX project revolves around a sustainable vision from energy consumption point of view: that spectrum can be better monitored and dynamically used in future wireless networks, making it possible to dynamically optimize the usage of this limited resource. Through SpecX's training events, we will present the DCs with a unified vision that not only makes the best of the spectrum resources and jointly optimizes the spectrum analysis for different applications, but also promotes such a practice as a fundamental component towards the development of future devices. One of the training events will complement this by sensibilizing the DCs towards the minimization of the environmental impact of their research (e.g., reuse and sharing of experimental platforms, reduction of scientific paper and mail printing, minimization of traveling). The same event will specifically address the environmental impact of electronic waste and how to mitigate it through modularity and materials choice in electronics design.

In addition to the above, SpecX is committed to achieving a low carbon footprint. The number of meetings organized prudentially is 8 including kick-off and recruitment events. This balance will minimize traveling while still offering venues to form a more cohesive project team, create a sense of community, as well as participate to international conferences and workshops, when co-located. The consortium privileges meeting locations that can be reached by train or that are served by a major international hub, to reduce flight legs. Other meetings, when necessary, will be carried out using online teleconferencing/telepresence/coordination tools. IMDEA and KU Leuven will also leverage their recent and previous experience in coordinating MSCA ETNs to deploy DN management tools that minimize the use of paper and enable electronic tracking of progress, events, achievements, and milestone completion.

6. Participating Organisations

Beneficiary 1: IMDEA Networks Institute (IMDEA)	
General Description 	**IMDEA Networks** is an international research institute located in Madrid, with the objective of performing world-class research, carrying out technology transfer, and attracting talented researchers to the region of Madrid, Spain. IMDEA is funded by the Regional Government of Madrid, other public bodies, and private institutions. Its key expertise broadly lies in the areas of wireless networking, networked systems and algorithms, and Network Measurements and Analytics. IMDEA Networks offers an interdisciplinary environment encompassing about 50 staff members, including faculty staff, postdocs, PhD students, Master's students, and research interns/engineers.
Role and Commitment of key persons (including supervisors)	**Dr. Domenico Giustiniano** [m] (*General Coordinator (GC), supervisor DC5, co-supervisor DC9*) [25% FTE] is a Research Associate Professor and leader of the Pervasive Wireless Systems group. He currently performs system-level research in wireless networks, mostly focusing on large-scale spectrum sensing systems, visible light communication networks and indoor localisation systems. He holds a PhD in Telecommunication Engineering from the University of Rome Tor Vergata (2008), and Executive Education from IE Business School on Management Fundamentals and Skills for Scientists and Researchers. He is coordinator/has coordinated projects at EU level (ITN ENLIGHT'EM), national level (PinPoint5G+, MAP-6G) and regional level (TAPIR-CM, CONTACT-CM)
	Dr. Joerg Widmer [m] (*Exploitation Manager, supervisor DC9*) [20% FTE] is Research Director and Research Professor at IMDEA Networks. His research focuses on wireless networks, from mmWave communications and MAC design to mobile network architectures. He authored about 150 papers, 3 IETF RFCs, and 14 patents. He serves/served on the editorial board of IEEE TMC, TCOM and the committees of major conferences. He received an ERC Consolidator Grant, the F. W. Bessel Award of the von Humboldt Foundation, and 8 best paper awards.
	Dr. Giuseppe Santaromita [m] (*co-supervisor DC5*) [20% FTE] is a postdoctoral researcher with expertise in embedded systems and localisation.
	Dr. Timothy Otim [m] (*co-supervisor DC9*) [20% FTE] is a postdoctoral researcher with theoretical and practical expertise in signal processing, localisation, and channel modelling.
Key Research Facilities, Infrastructure and Equipment	**IMDEA Networks'** facilities include laboratory and office spaces, workstations, shared high-performance simulation servers, IT services and infrastructure support, software-radio platforms, software licenses (e.g., MATLAB), as well as full access to relevant online resources such as the IEEE and ACM digital libraries. IMDEA hosts different testbeds based on a large number of spectrum sensing boards from low-end devices (such as RTL-SDR controlled by raspberry boards) to higher-end systems such as Ettus and WARP. IMDEA forms part of 5TONIC, an open research and innovation laboratory focusing on 5G and beyond technologies founded by Telefonica and IMDEA Networks based in Madrid. The objective of 5TONIC is to create a global open environment where members from industry and academia work together in specific research and innovation projects related to 5G technologies with a view to boost technology and business innovative ventures. IMDEA brings to the project the possibility to participate in demonstration activities within 5TONIC premises, and collaborate with its associated industrial partners in joint initiatives.
Status of Research Premises	All **IMDEA Networks** facilities are solely owned by IMDEA Networks. The institute has the research space and facilities required to host all ESRs according to the project workplan.
Previous Involvement in Research and Training Programmes, including H2020 ITN	**IMDEA** has developed strong international connections over the years, leading to the participation and direction of several European, Spanish and US R&D programmes. IMDEA researchers have participated and directed projects of several European R&D programs (including mmMAGIC, Flex5Gware, ESPRIT, RACE, ACTS, 1ST, CLAM, RACUN, DAIDALOS I and II, MEDIEVAL, FLAVIA, eCOUSIN, CROWD, iJOIN), Spanish R&D programs (including PLANBA, CICYT, PASO), US R&D programs (including NSF FIND, NSF ALT, NSF CNS, NSF ANI, US ARO), and in contracts with industry and public administrations (SPS SOCRATES).
Current Involvement in Research and Training Programmes, including H2020 ITN	**Dr. Giustiniano** and **Dr. Widmer** are currently involved in following EU projects: H2020 ENLIGHT'EM, SOMIRO, MINTS, DAEMON, LOCUS. National and regional projects: TAPIR-CM, RISC-6G, MAP-6G BRAIN. Industrial: Big-locator. The full updated list is available at https://networks.imdea.org/research/projects-and-collaborations/research-projects/
Relevant Publications/datasets/ softwares/ Innovation Products/ other achievements	G. Bielsa, J. Palacios, A. Loch, D. Steinmetzer, P. Casari, **J. Widmer**, Accurate Ubiquitous Localization with Off-the-Shelf IEEE802.11ac Devices, In *Proc. ACM Mobisys*, 2021.
	M. Rea, **D. Giustiniano**, "Location-aware Wireless Resource Allocation in Industrial-like Environment", In IEEE Transaction on Mobile Computing, 2021.
	R. Calvo-Palomino, H. Cordobés de la Calle, M. Engel, M. Fuchs, P. Jain, M. Liechti, S. Rajendran, M. Schäfer, B. Van den Bergh, S. Pollin, **D. Giustiniano**, V. Lenders, Electrosense+: Crowdsourcing Radio Spectrum Decoding using IoT Receivers, In *Elsevier Computer Networks*, 2020.
	J. Palacios, P. Casari, H. Assasa, **J. Widmer**, LEAP: Location Estimation and Predictive Handover with Consumer-Grade mmWave Devices, In Proc. *IEEE INFOCOM*, 2019.
	R. Calvo, H. Cordobés, F. Ricciato, **D. Giustiniano**, V. Lenders, Collaborative Wideband Signal Decoding using Non-coherent Receivers, In Proc. *IEEE/ACM IPSN*, 2019.

Beneficiary 2: KU Leuven	
General Description 	In Horizon 2020, KU Leuven was granted 669 projects (€ 378,5 million), ranking fourth HES institution with regard to number of signed grants. KU Leuven takes up the 14th place of European HES institutions hosting ERC grants (as first legal signatories of the grant agreement, ERC annual report 2021). The over 100 ERC grants since 2007 involving KU Leuven researchers, (including affiliates with VIB and IMEC) confirm that KU Leuven is a breeding ground and attractive destination for the world's best researchers. Its success in the Horizon 2020 Marie Sklodowska Curie Actions is a manifestation of the three pillars of KU Leuven: research, education and service to society. In Horizon 2020, we were involved in 126 Innovative Training Networks, ranking us first institution of higher education with regard to number of MSCA-ITNs.
Role and Commitment of key persons (including supervisors)	**Prof. Sofie Pollin** [f] (*Scientific Coordinator (SC), Supervisor DC1*) [25% FTE] leads the Networked System Group. Her interest is the analysis of wireless systems, incl. testbed verification. She is an editor for IEEE TWC. She has rich experience with research and project management. She supervises PhD students at IMEC, acting as a bridge between innovation, and engineering solutions.
	Prof. Davy Pissoort [m] (*WP3 leader, Supervisor DC10)* [20% FTE] Full Professor in the field of Dependable Electronics and Electromagnetic Compatibility. He coordinates multiple MSCA ITN projects like SAS, PETER and AUTOBarge.
	Dr. Tim Claeys [m] (*co-supervisor DC10*) [15% FTE] is an expert in techniques to measure EM fields in the near-field and the dependability of wireless communications. He is the Scientific Coordinator of the MSCA ETN PETER project and a supervisor of multiple PhDs in the MSCA ITN ETERNITY project and MSCA DN PARASOL.
	Dr. Rodney Martinez Alonso [m] (*co-supervisor DC1*) [15% FTE] is a research associate at the Networked Systems group, WaveCore, KU Leuven. He is an expert in dynamic spectrum access technologies. He is the scientific coordinator of a VLIR-UOS project on AI-based spectrum management. He has 10+ papers published at top venues such as IEEE ToB, Elsevier CN, Appl.Science, IEEE BMSB.
Key Research Facilities, Infrastructure and Equipment	**ESAT-WaveCoRe** has large 5G and IoT test facilities. Specifically, it has a massive MIMO SDR testbed consisting of 45 NI USRP-RIOs and has ample expertise in data-driven and deep learning. The group has a GPU server facility (NVIDIA RTX 2080Ti cores). The group also has several IoT testbeds, such as a 70 node BLE mesh testbed and a 36-node dense VLC testbed. **M-group** has 30 years+ of experience in Electromagnetic Compatibility. The research facilities consist out of a full pre-compliance laboratory for EMC testing. More specifically, a unique double coupled reverberation chamber to create harsh EM environments, an anechoic chamber for EMC pre-compliance measurements and research, etc.
Status of Research Premises	KUL owns all of its facilities and is wholly independent from other beneficiaries and/or partner organisations in the consortium.
Previous Involvement in Research and Training Programmes, including H2020 ITN	**Prof. Pollin** has been the PI of the Marie Curie International Outgoing Fellowships: UC Berkeley & IMEC, 2006-2009. She was also the scientific coordinator of the H2020-ICT13 ORCA project. She was engaged in, and was PI of, several national fundamental projects and cooperations with industry. **Prof. Pissoort** has been involved in various student exchange programmes, including multiple COST-actions and TEMPUS/Erasmus+ projects. He is the coordinator of technology-transfer projects ROBUSTEL, TDD4ES, NEATH, DfX-bridge, MCS4ES, and RELIM, and coordinated MSCA ETN SAS.
Current Involvement in Research and Training Programmes, including H2020 ITN	**Prof. Pollin** is the general coordinator of the H2020 MSCA-ITN MINTS, and is currently involved in the following EU research projects: H2020 MSCA-ITN Greenedge, H2020 R&I MARSAL, H2020 R&I REINDEER, H2020 R&I HERMES. Besides, she is involved in various nationally funded projects and is cooperating with industry in bilateral projects (e.g., Nokia, Proximus, Huawei, Armasuisse). **Prof. Pissoort** is a partner and WP leader of Erasmus+ project PHYSICS. He is project coordinator of technology-transfer CORNET project EEWISE and RESSIAR-MID, partner in Flemish Innovation Stimulation Projects VIS-SmartPro and VIS-INPROVOL, and coordinator of MSCA ETN PETER and MSCA ETN AUTOBarge, while also participating in MSCA ETN Eternity and MSCA DN PARASOL.
Relevant Publications/datasets/ softwares/ Innovation Products/ other achievements	**T. Claeys**, H. Tirmizi, H. Habib,D. Vanoost, G. Vandenbosch, **D. Pissoort**. A system's Perspective on the Use of EMI Detection and Correction Methods in Safety-Critical Systems, In *IEEE Symposium on EMC+ SIPI and EMC Europe*, 2021.
	B. Pang, K. T'Jonck, **T. Claeys, D. Pissoort,** H. Hallez, J. Boydens. Bluetooth Low Energy Interference Awareness Schema and Improved Channel Selection Algorithm for Connection Robustness, In *MDPI Sensors*, 2021.
	H. Sallouha, A. Chiumento and **S. Pollin**, Aerial Vehicles Tracking Using Noncoherent Crowdsourced Wireless Networks, In *IEEE Transactions on Vehicular Technology*, 2021.
	S. Rajendran, V. Lenders, W. Meert and **S. Pollin**. Crowdsourced wireless spectrum anomaly detection, In *IEEE Transactions on Cognitive Communications and Networking*, 2019.
	S. Rajendran, R. Calvo-Palomino, M. Fuchs, B. Bergh, H. Cordobes, D. Giustiniano, **S. Pollin**, V. Lenders. Electrosense: Open and Big Spectrum Data, In *IEEE Communications Magazine*, 2018.

Beneficiary 3: Delft University of Technology (TU Delft)	
General Description 	**Delft University of Technology (TU Delft)** is the oldest and largest university of technology in the Netherlands. The university is ranked as the most prestigious institution of higher education in Netherlands (Top 50 worldwide in QS ranking 2020 and top 20 in the engineering and technology domain). The **Embedded and Networked Systems (ENS)** group, where this research will be performed, is composed of 6 faculty members and more than a dozen PhD candidates, all being active in the field of wireless communications and embedded systems. TU Delft has received the "HR Excellence in Research" Award.
Role and Commitment of key persons (including supervisors)	**Prof. Qing Wang** [m] (*Recruitment chair, WP2 leader, supervisor DC8 and co-supervisor DC4*) [25% FTE] leads wireless communication, sensing and embedded AI systems research in ENS. He is an expert on mobile networking systems, visible light communication and sensing, and embedded AI for the Internet of Things. He is a co-founder of the OpenVLC project and the Delft Embedded AI Lab. He has more than 20 papers published at top conferences, such as MobiCom, CoNEXT, SenSys, INFOOCM, etc., and top journals such as IEEE Transactions on Networking, IEEE Transactions on Wireless Communication, etc. His citation is over 3100 times.
	Prof. Koen Langendoen [m] (*supervisor of DC4*) [20% FTE] is a full professor of computer science with the EEMCS faculty of TU Delft. He holds the chair on Embedded and Networked Systems, and serves as the director of studies for the MSc on Embedded Systems. He has rich experience and an excellent track record in systems research, in particular, wireless networking protocols. He has participated as principal and co-principal investigator in numerous national (Dutch) and EU research projects, including D2S2, COMMIT, RELATE, WISEBED, CONET, and RELYonIT. Prof. Langendoen shares his expertise with industry by giving seminars and master classes at companies like Alten, CapGemini, and Nyenrode Business School.
	Prof. Fernando Kuipers [m] (*co-supervisor DC8*) [15% FTE] leads the Lab on Internet Science (LOIS) at TUD. In 2004, he obtained his Ph.D. degree cum laude, the highest possible distinction at TUD. His research addresses problems in Software-Defined Networking, Internet-of-Things, among others. His work on these subjects include distinguished papers at IEEE INFOCOM 2003, IFIP Networking 2008, ITC 2009, and EuroGP 2017. He is senior member of the IEEE, and is Vice-Chair of IFIP Working Group 6.2 on Network and Internetwork Architectures.
	Prof. Guohao Lan [m] (*co-supervisor DC4*) [15% FTE] is an Assistant Professor in the Embedded Systems Group at TU Delft. His research interests include pervasive computing, artificial intelligence of things, and machine learning. He has more than 20 papers published at top conferences, such as ACM MobiCom, SenSys, IPSN, USENIX Security, etc., and top journals such as IEEE Transactions on Mobile Computing and ACM Transactions on Sensor Networks, etc. He is a recipient of the Facebook Research Award 2021 and the 2020 ACM/IEEE IPSN Best Research Artifacts Award, among many others.
Key Research Facilities, Infrastructure and Equipment	**TU Delft** owns testbeds for visible light communication and sensing, such as sunlight for passive communication systems, SpiderWeb testbed for through-screen visible light communication, and LightDigit system for embedded AI research and sensing with visible light. **TU Delft** has developed systems for large-scale data management, including Apache Flink, the state-of-the-art stream processing system, and SocialGlass, for integration, enrichment, and sense-making of urban data. Additionally, ENS has access to a rich set of lab spaces, including an anechoic chamber, electronic and fabrication labs.
Status of Research Premises	TU Delft owns all of its facilities and is wholly independent from other beneficiaries and/or partner organisations in the consortium.
Previous Involvement in Research and Training Programmes	**Prof. Wang** had been the vice general coordinator of the H2020 MSCA-ITN MINTS. **Prof. Langendoen** had participated in D2S2, COMMIT, RELATE, WISEBED, CONET, and RELYonIT. **Dr. Kuipers** has participated in several EU Network-of-Excellence (E-Next, CONTENT, EINS) and COST (QoFIS, TMA) projects. Furthermore, he was board member of the section Telecommunication of the Royal Netherlands Society of Engineers (KIVI).
Current Involvement in Research and Training Programmes	**Prof. Wang** is currently leading the 4TU.NIRICT project on HaLow and is involved in the H2020 MSCA-ITN ENLIGHT'EM project. **Dr. Kuipers** is currently involved in (1) an EU COST action (RECODIS), (2) a joint project with the Indian Institute of Science, (3) a project with Dutch municipalities to set up a 5G field lab, and (4) three projects funded by industry (namely by SURFnet, KPN, and Cognizant). He is also executive committee member of the IEEE Benelux chapter on communications and vehicular technology.
Relevant Publications and/or Research / Innovation Product	H. Ye and **Q. Wang**, SpiderWeb: Enabling Through-Screen Visible Light Communication, In *ACM SenSys*, 2021.
	M. Cui, **Q. Wang** and J. Xiong, RadioInLight, Doubling the Data Rate of VLC Systems, In *ACM MobiCom*, 2021.
	S. Ghiasi, M. Zuniga and **K. Langendoen**, A Principled Design for Passive Light Communication, In *ACM MobiCom*, 2021.
	M. Cui, Y. Feng, **Q. Wang** and J. Xiong, Sniffing Visible Light Communication Through Walls, In *ACM MobiCom*, 2020.
	J. Oostenbrink , **F. Kuipers**, Going the Extra Mile with Disaster-Aware Network Augmentation, In *IEEE INFOCOM*, 2021.

Beneficiary 4: CNIT	
General Description 	**CNIT (National Inter-University Consortium for Telecommunications)** is a not-for-profit Consortium, bringing together 37 Italian Universities to foster research activity in the field of telecommunications, and provide facilities and clustering support to the Italian academic ICT research community. CNIT participated in hundreds of research projects, including EU coordinated projects, ERC grants and Italian nation-wide initiatives. It operates a satellite network, three national laboratories (Photonic Networks and Radar & Surveillance Systems, in Pisa, Multimedia Communications, in Naples) and 37 Research Units, one for each participating university. CNIT's contribution to this project will come from two research units: **University of Rome Tor Vergata (UNITV)** and **University of Trento (UNITN)**. These units provide specific skills and interests in the fields of wireless technologies, networking, sensing, programmable hardware, and machine learning. Such units have a large expertise in EU and NATO projects. Moreover, the involved CNIT units have a significant track of research accomplishments and top tier publications in IEEE and ACM conferences, as well as in top journals such as IEEE and ACM Transactions. In addition to scientific expertise, CNIT's team has the capability to build demonstrators and organize workshops and conferences, and is active in the editorial and technical boards of several major journals and conferences.
Role and Commitment of key persons (including supervisors)	**Prof. Stefania Bartoletti** [f] (*Supervisor DC2*) [25% FTE] is Senior Researcher at CNIT and tenure-track assistant professor at the Department of Electronic Engineering at the University of Roma Tor Vergata. Her research interests include theory and experimentation of location-aware wireless networks for multi-target tracking and physical behavior analysis. She was a researcher at the Institute of Electronics, Computer and Telecommunication Engineering (IEIIT) of the National Research Council of Italy where she co-supervised a Ph.D student in resource allocation aspects for vehicular communications.
	Prof. Paolo Casari [m] (*Supervisor DC7*) [25% FTE] is Senior Researcher at CNIT and Associate Professor at the University of Trento, Italy. He is an expert in wireless communications, sensing, localization, channel-aware protocol design and machine learning. He is currently supervising a group including one PhD student, one postdoc, and several master and bachelor students. In the past, he has led a group of up to 8 researchers, postdocs and students during his previous appointment as a Research Assistant Professor at the IMDEA Networks Institute (Madrid, Spain).
Key Research Facilities, Infrastructure and Equipment	The **University of Rome Tor Vergata** will commit the key research facilities and equipment of the Electronic Engineering Department, where the networking group (http://netgroup.uniroma2.it/) is composed of 5 faculties, plus 4 post docs, 8 PhD students and 6 researchers and software developers hired on specific activities. The Electronic Department includes laboratories dedicated to Telecommunications Network, Sensors and Microsystems, Satellite Telecommunications and a Radar Laboratory. The **University of Trento** will commit high-performance computing clusters, dedicated simulation servers, as well as several types of software-defined radios to this project. This includes a large-scale testbed including about 20 mmWave routers installed in corridors and open spaces at the university for communications, localization and wireless sensing purposes, and a commercial 5G-standalone base station and core network.
Status of Research Premises	**CNIT's** research units own completely independent and large lab facilities. UNITN recently undergone a restructuring and extension of laboratory spaces thanks to the extra funding allotted by the Italian Ministry of Education, Universities and Research under their "Departments of Excellence" initiative.
Previous Involvement in Research and Training Programmes	**Dr. Bartoletti** has been involved in a number of international, multi-year projects funded by the EU FP7 and national Italian foundations (e.g., SELECT and GRETA). She was a MSCA Global Fellow within the Horizon 2020 European Framework for a research project with the Wireless Information & Network Science Laboratory of the Massachusetts Institute of Technology (MIT) and the University of Ferrara. **Prof. Casari** has been involved in a number of international, multi-year projects funded by the EU FP7 and H2020 programs (e.g., CLAM and RECAP), the European Defense Agency, the US ARO and ONR, as well as by national Italian foundations. He was the Scientific Manager of EU H2020 RECAP and SYMBIOSIS. He also took part in a number of national Spanish projects.
Current Involvement in Research and Training Programmes	**Dr. Bartoletti** is currently the PI of the H2020 project "LOCUS" and one of the ESR supervisors in the EU H2020 MSCA ITN "Meta Wireless". **Prof. Casari** is currently the PI of the NATO SPS project "SAFE-UComm", of the University of Trento-funded project COVID-Cons, and co-PI in the EU H2020 MSCA ETN "MINTS".
Relevant Publications and/or Research / Innovation Product	**S. Bartoletti**, A. Conti and M. Z. Win, "Device-Free Counting via Wideband Signals," in *IEEE Journal on Selected Areas in Communications*, May 2017.
	A. Conti, S. Mazuelas, **S. Bartoletti**, W. C. Lindsey and M. Z. Win, "Soft Information for Localization-of-Things," in *Proceedings of the IEEE*, 2019.
	A. Shastri, **P. Casari** *et al*., "A Review of Millimeter Wave Device-based Localization and Device-free Sensing Technologies and Applications," in *IEEE Communications Surveys and Tutorials*, 2022.
	C. Fiandrino, H. Assasa, **P. Casari**, J. Widmer, "Scaling Millimeter-Wave Networks to Dense Deployments and Dynamic Environments," in *Proceedings of the IEEE*, 2019.
	F. Granelli, R. Capraro, M. Lorandi, **P. Casari**, "Evaluating a Digital Twin of an IoT Resource Slice: an Emulation Study using the ELIoT Platform," in *IEEE Networking Letters*, 2021.

Beneficiary 5: RWTH Aachen University (RWTH)	
General Description 	**RWTH Aachen University** is one of Europe's leading technical and engineering universities, as well as one of Germany's Universities of Excellence, which entails the highest quality in teaching and world-class research. It is Germany's largest technical university and home to more than 47,000 students, out of which more than 12,000 are international students from 130 countries around the world.
Role and Commitment of key persons (including supervisors)	**Prof. Marina Petrova** [f] (*Training co-chair, supervisor of DC3*) [25% FTE] is a professor at the Faculty of Electrical Engineering and Information Technologies at RWTH and the head of the Mobile Communications and Computing Group. Moreover, she is a Visiting professor at the Division of Communications Systems (COS) at KTH Royal Institute of Technology, Stockholm. In 2019 Prof. Petrova was named Wallenberg Academy Fellow and in 2020 she was awarded the SSF Future Research Leaders grant from the Swedish Foundation for Strategic Research.
	Dr. Pradyumna Kumar Bishoy [m] is a postdoctoral researcher with experience in performance modeling and analysis, resource allocation, distributed optimization and game theory
Key Research Facilities, Infrastructure and Equipment	The grop has the needed expertise and facilities to successfully carry out the DN. The group has a lab facility comprising, SDR platforms, Raspberry Pi nodes and also standard measurement equipment. MCC has extensive expertise in wireless technologies, software-defined radios and communication networks, and has rich connections and active collaborations with industry.
Status of Research Premises	The group has all the necessary facilities and infrastructure to execute this doctoral training network, including equipment and office space as well as access to high performance computing clusters. The group owns all of its facilities and is wholly independent from other beneficiaries and/or partner organisations in the consortium.
Previous Involvement in Research and Training Programmes	**Prof. Petrova** has actively participated and has taken the role of WP leader in a number of collaborative EU projects. Those include FP7 projects ARAGORN FARAMIR, QUASAR to name a few.
Current Involvement in Research and Training Programmes	**Prof. Petrova** is part of the Open6GHub, a collaborative research hub in the area of 6G communication technologies funded by the German Ministry for Education and Research (BMBF). She is also involved in a Swedish national project funded by the Swedish Foundation for Strategic Research in cooperation with Ericsson on Ultra-high reliability and resilience for cyber-physical systems. Related to *localisation and sensing for the future intelligent and Gbps networks*, she was awarded a prestigious grant from the Wallenberg Foundation in 2019.
Relevant Publications and/or Research / Innovation Product	A. M. Voicu, L. Simić and **M. Petrova**, "Modelling Broadband Wireless Technology Coexistence in the Unlicensed Bands," In *2021 IEEE 22nd International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, 2021.
	S. Khosravi, H. Shokri-Ghadikolaei and **M. Petrova**, "Learning-Based Handover in Mobile Millimeter-Wave Networks," In *IEEE Transactions on Cognitive Communications and Networking*, 2021.
	P. Ren, A. Munari, **M. Petrova,** "Performance Tradeoffs of Joint Radar-Communication Networks," In *IEEE Wireless Communication Letters*, 2019.
	B. Bojovic, E. Meshkova, N. Baldo, J. Riihijärvi, **M. Petrova**, "Machine Learning based Dynamic Frequency and Bandwidth Allocation in Self-Organised LTE Dense Small Cell Deployments," In *EURASIP Journal on Wireless Communications and Networking*, 2016.
	A. M. Voicu, L. Simić, **M. Petrova**, "Inter-Technology Coexistence in a Spectrum Commons: A Case Study of Wi-Fi and LTE in the 5 GHz Unlicensed Band," In *IEEE Journal of Selected Areas in Communication*, 2016.

Beneficiary 6: Telefonica I+D (TID)	
General Description 	**Telefónica I+D**, the research and development company of the Telefónica Group, was founded in 1988 and its mission is to contribute to the Group's competitiveness and modernity through technological innovation. With this aim, the company applies new ideas, concepts and practices in addition to developing products and advanced services. Telefónica I+D is one of the first private R&D centers in Spain as regards activity and resources and is the first company on the continent by number of European research projects in which it participates. The main asset of Telefónica I+D is its staff, which is 97% composed of university graduates from 18 nationalities. It currently collaborates with technological leaders and many organisations from 40 countries; among which figure more than 150 universities around the world.
Role and Commitment of key persons (including supervisors)	**Andra Lutu** [f] (*Training co-chair, supervisor DC6, co-supervisor DC9 and DC10*) [25% FTE] is a Researcher at Telefonica Research in Barcelona, Spain. Her main research interests lie in the areas of network measurements, traffic engineering, interdomain routing and mobile networks. After receiving her PhD at UC3M and IMDEA Networks Institute in Spain, Madrid, she worked as a Postdoc Fellow at Simula Research Laboratory, where she was a main contributor to the MONROE project, building the first open European hardware infrastructure to perform measurements in operational mobile networks. She will participate as PhD advisor.
	José Suárez-Varela [m] (*co-supervisor DC6)* is an Associate Researcher at Telefonica Research. Prior to this, he was a postdoctoral researcher at the Barcelona Neural Networking center (BNN-UPC). He holds a Ph.D. in Computer Science from the Universitat Politècnica de Catalunya (UPC) in 2020. He was co-Principal Investigator of the EU-funded project IGNNITION (H2020 NGI POINTER program), where they developed a framework for fast prototyping of Graph Neural Networks applied to communication networks (https://ignnition.org). His main research interests are in the field of AI for network control and management, traffic measurement and analysis, and cybersecurity.
Key Research Facilities, Infrastructure and Equipment	**TID** research centers in Spain with access to HW/SW resources for simulation and experiments. Pool of processing servers (i.e, cluster) with CPU, GPU and large memory capabilities. Radio testbed spanning across different sites in Spain offering a unique framework for testing diverse edge and radio applications. The testbed is composed of generic purpose server pools with virtual core networks and virtual BaseBand Unit (vBBU), hosted in the form of virtual machines or a container with open-source proprietary RAN SW/HW equipment. To provide the management and automation of the equipment, the testbed leverages a set of open source SW tools for fast prototyping, automation, and testing. Research group composed of more than 10 researchers with background on networking, machine learning and HCI. Telefonica Universitas can host events as part of the training network.
Status of Research Premises	TID owns all of its facilities and is wholly independent from other beneficiaries and/or partner organisations in the consortium.
Previous Involvement in Research and Training Programmes, including H2020 ITN	**METRICS** (ITN-607728): Measurement for Europe: Training and Research for Internet Communications Science. **PROTASIS** (RISE-690972): Restoring Trust in the cyber-space: a Systems Security Proposal. Besides these training programmes TID research team has been involved in other collaborative project as TYPES, RECRED, MPLANE.
Current Involvement in Research and Training Programmes, including H2020 ITN	**INCOGNITO** (RISE- 824015): IdeNtity verifiCatiOn with privacy-preservinG credeNtIals for anonymous access To Online services. **ENCASE** (RISE-691025): EnhaNcing seCurity And privacy in the Social wEb: a user centered approach for the protection of minors. **METAWIRELESS** (H2020-MSCA-ITN-2020): Future Wireless Communication Empowered by Reconfigurable Intelligent Meta-Surfaces. **APROPOS** (H2020-MSCA-ITN-2020) associate partners: Approximate computing for Power ad Energy Optimisation **MINTS** (H2020-MSCA-ITN-2020) associate partner: Millimiter-wave Netwroking and Sensing for Beyond 5G.Besides these training programmes TID research team is involved in other collaborative project as ACCORDION, PIMCITY, IBIDAAS, CONCORDIA, DAEMON, SPATIAL.
Relevant Publications/datasets/ softwares/ Innovation Products/ other achievements	**D. Perino**, X. Yang, J. Serra, **A. Lutu**, and I. Leontiadis, "Experience: advanced network operations in (Un)-connected remote communities," In *Proceedings of ACM MOBICOM*, 2020.
	Ö. Alay, A. **Lutu**, M. Peón-Quirós, V. Mancuso, T. Hirsch, K. Evensen, A. Hansen, S. Alfredsson, J. Karlsson, A. Brunstrom, A. S. Khatouni, M. Mellia and M. A. Marsan, "Experience, An Open Platform for Experimentation with Commercial Mobile Broadband Networks," In *Proceedings of ACM MOBICOM*, 2017.
	M. Fida, A. **Lutu**, M.K. Marina, and Ö. Alay, "ZipWeave: Towards Efficient and Reliable Measurement based Mobile Coverage Maps," In *INFOCOM – IEEE Conference on Computer Communications*, 2017.
	H. Kolamunna, Y. Hu, D. **Perino**, K. Thilakarathna, D. Makaroff, X. Guan, A. Seneviratne, "AFV: enabling application function virtualisation and scheduling in wearable networks," In *ACM UBICOMP*, 2016.
	A. Lutu, D. Perino, M. Bagnulo, F. Bustamante (2021), "Insights from Operating an IP eXchage Provider," In *Proceedings of the ACM SIGCOMM*, 2021.

Associated Partner Legal Name: NEC Laboratories Europe GmbH	
General description 	**NEC Corporation** produces tailored solutions for the core technologies and services required in a networked world, ranging from advanced semiconductor solutions, to large-scale mission-critical systems, systems integration, and broadband and mobile technologies. The NEC group employs more than 100,000 people with a multi-billion dollar sales volume worldwide. NEC began business in Europe in the early 1970s. Today, NEC has 19 affiliated companies in Europe alone. NEC Europe Ltd., which is wholly owned by NEC Corporation, was established in London in 1993. As a research unit wholly owned by NEC Europe Ltd., the **NEC Laboratories Europe GmbH (NLE)** will be involved in the SpecX project. With the focus on R&D for the next generation mobile and fixed networks, and the Future Internet, a special emphasis lies on developing and proposing solutions that meet the market needs of NEC's European customers.
Key Persons and Expertise	**Dr. Andres Garcia-Saavedra** [m] (*Secondment supervisor DC7 and DC8*) received his MSc and PhD from University Carlos III of Madrid (UC3M) in 2010 and 2013, respectively. He then joined the Hamilton Institute, Ireland, as a Research Fellow till the end of 2014 when he moved to Trinity College Dublin (TCD). Since 2015 he is working at NEC Laboratories Europe where he is currently a Principal Research Scientist.
Key Research Facilities, Infrastructure and Equipment	NEC has a 4G/5G testbed comprised of different pieces of equipment that will be upgraded as 5G equipment becomes available. The system is end-to-end, including UEs, base stations, transport/backhaul equipment, computing infrastructure, mobile core components and a hierarchical orchestration system in the control plane comprised of different NFV/SDN technologies for E2E network slicing.
Previous and current Involvement in Research and Training	**Dr. Andres Garcia Saavedra** has been PI and has been actively involved in a number of European Projects in the umbrella of H2020 5GPPP such as 5G-Crosshaul, 5G-TRANSFORMER, 5GROWTH, or DAEMON, They have participated in projects such as Spotlight, MetaWireless, or MINTS.
Relevant Publications and/or Research / Innovation Product	G. Garcia-Aviles, **A. Garcia-Saavedra**, M. Gramaglia, X. Costa-Perez, P. Serrano, A. Banchs, "Nuberu: Reliable RAN Virtualization in Shared Platforms," In *ACM MobiCom*, 2021.
	J. A. Ayala-Romero, **A. Garcia-Saavedra**, X. Costa-Perez, G. Iosifidis, "EdgeBOL: Automating Energy-savings for Mobile Edge AI," In *ACM CoNEXT*, 2021.
	J. A. Ayala-Romero, **A. Garcia-Saavedra**, X. Costa-Perez, G. Iosifidis, "Bayesian Online Learning for Energy-Aware Resource Orchestration in Virtualized RAN," In *IEEE INFOCOM*, 2021.

Associated Partner Legal Name: Ericsson GmbH	
General description ERICSSON	Ericsson enables communications service providers to capture the full value of connectivity. The company's portfolio spans Networks, Digital Services, Managed Services, and Emerging Business and is designed to help our customers go digital, increase efficiency and find new revenue streams. The Ericsson Eurolab in Herzogenrath close to Aachen is part of Ericsson GmbH in Germany and one of the main Ericsson R&D centres outside of Sweden. Ericsson Eurolab hosts a well-established wireless research team belonging to the Corporate Research. The group has been and is heavily involved in developing concepts and standards for 5G evolution and 6G.
Key Persons and Expertise	**Dr. Andra Voicu** received the PhD degree in Electrical Engineering and Information Technology from RWTH Aachen University in 2020. She is currently an Experienced Researcher at Ericsson Research, Ericsson GmbH. Her work focuses on 6G concepts for Radio Access Networks and 3GPP RAN standardization for XR services. Prior to joining Ericsson she was a postdoctoral researcher at RWTH Aachen University. She served as a TPC member for IEEE ICC Workshop on Spectrum Sharing Technology for Next Generation Communications 2021 and IEEE WiSEE 2021, 2022.
	Dr. Michael Meyer leads the Radio Network Concepts within Ericsson Research. He has a broad experience on mobile communications due to his work on 2G, 3G, 4G and 5G. His current research interests are in the areas of 5G for industry verticals, 5G evolution and 6G, and applications of machine learning and AI for wireless communications.
Key Research Facilities, Infrastructure and Equipment	Access to advanced system level simulation tools. Access to mobile communication testbed facilities.
Previous and current Involvement in Research and Training Programmes	In the past Ericsson Research was involved in various FP7 and H2020 projects. Ericsson GmbH was involved in the EU projects 5GCroCo, 5G-SMART, 5G-RECORDS.

	Currently, Ericsson Research is involved in several EU H2020 projects. Ericsson GmbH participates in the EU projects Deterministic E2E communication with 6G and SPIRIT. On national level we are engaged in AI4Mobile, 6G-ANNA, and KOMSENS-6G.
Relevant Publications and/or Research / Innovation Product	**A. Palaios**, P. Geuer *et al.*, "Network under control: Multi-vehicle E2E measurements for AI-based QoS prediction," IEEE PIMRC, Sep. 2021.
	R. Zhohov, **A. Palaios**, and P. Geuer, "Learning from large-scale commercial networks: challenges and knowledge extraction towards machine learning use cases", in Proc. 5G-MeMU, Aug. 2021.
	J. Biosca Caro, J. Ansari, J. Sachs, P. de Bruin, S. Sivri, L. Grosjean, N. König, R. H. Schmitt, "Empirical study on 5G NR cochannel coexistence", MDPI Electronics, May 2022.
	J. Ansari *et al.*, "Performance of 5G trials for industrial automation", MDPI Electronics, Jan. 2022.
	G. Wikström *et al.*, "6G – Connecting a cyber-physical world", white paper, Feb. 2022, online available: https://www.ericsson.com/en/reports-and-papers/white-papers/a-research-outlook-towards-6g

Associated Partner Legal Name: Electrosense	
General description	Electrosense (electrosense.org) is a non-profit association that has been has established in 2016 with the objective of providing a more efficient, safer and more reliable use of the electromagnetic space by improving the accessibility of spectrum data for the general public. Electrosense organises events such as workshops, datathons to can foster discussions and provide input for future development and research around Electrosense. As part of its core activities, Electrosense collects and process spectrum data for targeting verticals such as spectrum anomaly detection, spectrum monitoring and electrosmog. Following the crowdsourcing model, people contribute by sharing their data to the association and on the other hand receive processed data back.
Key Persons and Expertise	**Dr. Vincent Lenders** [m] (*Secondment supervisor DC5 and DC6*) president of the Electrosense association. Dr. Lenders earned his Ph.D degree (2006) and M.sc (2001) in electrical engineering and information technology both at ETH Zurich, Switzerland. He was also postdoctoral research faculty at Princeton University in the USA. Dr. Lenders is also the Director of the newly created Cyber-Defence Campus and of the Cyber Security and Data Science Division at armasuisse Science and Technology.
Key Research Facilities, Infrastructure and Equipment	ELECTROSENSE owns several servers that runs 2 x 12 Core Intel Xeon Silver 4116 2.1GHz Processor. Several of the spectrum sensors deployed at users' location are also owned by Electrosense, although users have also access to the toolkit to deploy their own sensors.
Previous and current Involvement in Research and Training	Electrosense was involved in the SOCRATES project funded by NATO Science for Peace and Security Programme the under grant G5461. Furthermore, Electrosense collaborates actively with KU Leuven and IMDEA networks in direct collaboration activities, as well as industry partners across Europe.
Relevant Publications and/or Research / Innovation Product	**V. Lenders**, et al., "Electrosense+: Crowdsourcing Radio Spectrum Decoding using IoT Receivers", In *Elsevier Journal on Computer Networks*, 2020.
	S. Rajendran, R. Calvo-Palomino, M. Fuchs, B. Van den Bergh, H. Cordobés, D. Giustiniano, S. Pollin, **V. Lenders**, "Electrosense: Open and Big Spectrum Data," In *IEEE Communications Magazine*, 2018.
	R. Calvo, D. Giustiniano, **V. Lenders** and A. Fakhreddine, "Crowdsourcing Spectrum Data Decoding," In *IEEE International Conference on Computer Communications*, 2017.

Associated Partner Legal Name: Accelleran	
General description	**Accelleran N.V.** is a scaleup SME based in Belgium. Accelleran is a leading provider of Open RAN software solutions for 4G/5G networks. Accelleran dRAX™ implements the key control and resource management functions of the RAN, including Service Orchestration, RIC, CU-CP, and CU-UP. Comprising proven, cloud-native and microservice-based software components, dRAX™ enables real-world deployment of multi-vendor, disaggregated Open RAN, aligned with open standards such as the O-RAN Alliance. The dRAX™ RIC offers a production-ready Open RAN development platform, enabling real-time RAN data to be leveraged to create AI-based xApps and enhanced RAN intelligence and automation. Accelleran also provides 4G/5G RAN integration services and system solutions for 5G MNOs, Neutral Host providers, Private Network owners and research facilities.
Key Persons and Expertise	**Dr. Trevor Moore** [m] (*Secondment supervisor DC4*) is CTO and co-founder of Accelleran. Trevor is the Accelleran lead in numerous H.2020 projects and will be supervising the research of the PhD student, together with members of his system group (currently a team of 4 experienced system engineers) who will be assigned for daily follow-up and mentoring.

Key Research Facilities, Infrastructure and Equipment	Accelleran labs integrate and host 5G SNPNs with 3rd party Radios (commercial RUs and SDR USRPs), 5GC (commercial and open-source) and UE/CPE (commercial units and simulator/test tools) to configure and run 4G & 5G private networks with RIC and Edge computing capabilities to develop, deploy and test applications including AI/ML algorithms for advanced research into RAN optimisation and automated operation. Accelleran owns and operates its research labs in the main Antwerp office. The labs are continually growing to integrate and validate 3GPP Rel-16 5G SNPN use-cases, in addition to existing 4G and Rel-15 5G standalone test capabilities.
Previous and current Involvement in Research and Training Programmes	Accelleran is very active in H.2020 5GPPP RIA/IA projects (such as completed 5GCity & 5G-Enhance, active 5G-Clarity, 5G-COMPLETE, Affordable5G, 5G-RECORDS, MARSAL – together with KULeuven, Unicore, FTI 5GaaS) but has not yet participated in MSCA/ITN type training programs. Accelleran participates in the Industrial Advisory Board of the Flemish FWO SBO S003921N VERI-END.com project with the University of Gent, Belgium.
Relevant Publications and/or Research / Innovation Product	Accelleran commercialises the dRAX™ 4G/5G Open RAN product line. These Cloud-Native components deliver reliable, cost-effective and scalable solutions for both and 4G and 5G networks. Accelleran was recently nominated for Deloitte's 2021 Technology Fast 50 (link).

Associated Partner Legal Name: University Carlos III of Madrid	
General description	University Carlos III of Madrid (UC3M) was founded in 1989 with the objective of providing an efficient, high quality public undergraduate and graduate education. In 2016, UC3M ranks 20 in the QS ranking of the top 50 universities world-wide under 50. The Telematics Department of UC3M is involved in education and research on broadband networks, mobile networks, advanced Internet networking and applications.
Key Persons and Expertise	**Dr. Pablo Serrano** [m] (co-*supervisor DC6*) got his Telecommunication Engineering degree and his PhD from UC3M in 2002 and 2006, respectively. He has been with the Telematics Department of UC3M since 2002, where he currently holds the position of Associate Professor. He has over 100 scientific papers in peer-reviewed international journals and conferences. **Dr. Albert Banchs** received his Telecommunications Engineering and PhD degree from the Universitat Politècnica de Catalunya. He was a visiting researcher at ICSI, Berkeley, CA, in 1997, worked for Telefonica I+D, Spain, in 1998, and for the Network Laboratories of NEC Europe Ltd., Germany. A. Banchs is the Deputy Director of IMDEA Networks and Full Professor at the Telematics Department of the Universidad Carlos III de Madrid, Spain.
Key Research Facilities, Infrastructure and Equipment	UC3M forms part of 5TONIC (https://www.5tonic.org/) an open research and innovation laboratory focusing on 5G technologies based in Madrid. The objective of 5TONIC is to create a global open environment where members from industry and academia work together.
Previous and current Involvement in Research and Training Programmes	Measurement for Europe: Training and Research for Internet Communications Science (METRICS) METRICS provided the right instruments for continuous large-scale measurements, developed data analysis and privacy protection mechanisms, and designed sample applications that make effective use of the measurement infrastructure.
Relevant Publications and/or Research / Innovation Product	G. Garcia-Aviles, A. Garcia-Saavedra, M. Gramaglia, X. Costa-Perez, **P. Serrano**, A. Banchs, "Nuberu: Reliable RAN Virtualization in Shared Platforms," In *ACM Mobicom*, 2022.
	F. Gringoli, P. Patras, C. Donato, **P. Serrano**, Yan Grunenberger, "Performance Assessment of Open Software Platforms for 5G Prototyping," In *IEEE Wireless Communications Magazine, Special Issue on 5G Testing and Field Trials*, 2018.
	I. Gomez-Miguelez, A. Garcia-Saavedra, P. D. Sutton, **P. Serrano**, C. Cano, D. J. Leith, "srsLTE: An Open-Source Platform for LTE Evolution and Experimentation," In *ACM WiNTECH*, 2016 (**Best paper award**).

Associated Partner Legal Name: UNITV	
General Description	The University of Rome Tor Vergata (**UNITV**) was founded in 1982, rapidly becoming one of the most important Italian universities. It hosts more than 40,000 students, who can choose among 120 degree programs, plus PhDs and specialization courses. Within University of Rome Tor Vergata, the Department of Electronic Engineering brings together a wide range of experts in analogue and digital electronics and in different areas of Information and Communications Technology. The Department has 52 faculties.
Role and Commitment of key persons (including supervisors)	**Dr. Stefania Bartoletti** [f] (Supervisor DC2) [25% FTE] is a tenure-track assistant professor at the Department of Electronic Engineering at UNITV. She serves on the editorial board of the IEEE Commmun. Letters. She was Chair of the TPC for the IEEE Workshop on Advances in Network Localization and Navigation (2017-2021) and of the Workshop on Synergies of Communication, Localization, and Sensing Towards 6G (2022-2023) within IEEE Globecom and ICC.

	Prof. Giuseppe Bianchi [m] (Co-supervisor DC2) [15% FTE] is Full Professor of Networking at UNITV. His research activity includes programmable network systems, wireless networks, network security, and performance modeling and is documented in about 300 peer-reviewed international journal and conference papers, with more than 20.000 citations (source: Google Scholar). He has coordinated six large scale EU projects, and has been (or still is) editor for several journals in his field, including IEEE/ACM Trans. on Networking, IEEE Trans. on Wireless Communications, IEEE Trans. on Network and Service Management, and Elsevier Computer Communications.
Key Research Facilities, Infrastructure and Equipment	**UNITV** own completely independent and large lab facilities. The Electronic Department includes laboratories dedicated to Telecommunications Network, Sensors and Microsystems, Satellite Telecommunications and a Radar Laboratory.
Previous Involvement in Research and Training Programmes	The faculties of the networking group have a large expertise in EU projects; they coordinated 11 EU projects worth 48Me, and obtained grants for their group worth about 11 Me; they have been evaluators for many EU research proposals and projects. **Dr. Bartoletti** was a Marie-Skłodowska Curie Global Fellow within H2020 and PI of the H2020 LOCUS. **Prof. Bianchi** has held coordinating positions for 6 European Projects, has chaired the PhD programme in Electronics and Telecommunications Engineering.
Relevant Publications and/or Research / Innovation Product	**S. Bartoletti**, A. Conti and M. Z. Win, "Device-Free Counting via Wideband Signals," in IEEE Journal on Selected Areas in Communications, May 2017.
	A. Conti, S. Mazuelas, **S. Bartoletti**, W. C. Lindsey and M. Z. Win, "Soft Information for Localization-of-Things," in Proceedings of the IEEE, 2019.

Associated Partner Legal Name: UNITN	
General Description 	UNITN has a long-standing history of scientific excellence and ranked 36th in "The European Teaching Ranking 2018" (1st among Italian Universities), and 5th among Italian Universities in the World University Rankings 2018. The Department of Information Engineering and Computer Science has been recently awarded excellence funding from the Italian government to develop and expand research and teaching laboratories, resulting in new freely accessible spaces for experimental activities for all students.
Key persons and expertise	**Prof. Paolo Casari [**m] (Supervisor DC7) [25% FTE] is associate professor at the Department of Information Engineering and Computer Science of UNITN. He published about 150 papers in peer-reviewed international journal and conferences. He is an IEEE Senior Member and serves on the editorial board of the IEEE Trans. on Wireless Communications and of the IEEE Trans. on Mobile Computing, besides participating to the TPC of many conferences. He received two best paper awards.
	Prof. Fabrizio Granelli [m] (Co-supervisor DC7) [15% FTE] is full professor at the Department of Information Engineering and Computer Science of UNITN, where he also served as Dean of Education from 2015 to 2017. He advised more than 80 thesis students and 8 Ph.D. students. For IEEE ComSoc, he served as a Distinguished Lecturer (2012-15 and 2021-22), as Director of Online Content (2016-17) and as Director for Educational Services (2018-19). He authored more than 200 papers.
Key Research Facilities, Infrastructure and Equipment	**UNITN** has full ownership of their facilities, including laboratories, classes, rooms, and specific wireless communication testbeds, and a department-wide testbed with software-defined and UWB radios, recently enriched with mmWave communication and localisation capabilities. These testbeds are available for the SpecX DCs to use, along with software licences to operate them (e.g., MATLAB, NI LabView).
Previous and Current Involvement in Research and Training Programmes	**Prof. Casari** was PI of the NATO SPS project ThreatDetect, and Scientific Manager of the H2020 RECAP and SYMBIOSIS projects. He participated in EU FP7 and EDA projects, is currently PI of the NATO SPS project SAFE-UComm and of the UNITN project COVID-Cons, and co-PI of the EU H2020 MSCA ETN MINTS. **Prof. Granelli** was the PI of the NATO SPS project DAVOSS, and is now the PI of the HORSE project, funded by EC in the framework of the Horizon Europe call Horizon-JU-SNS-2022.
Relevant Publications/datasets/ softwares/ Innovation Products/ other achievements	C. Fiandrino, H. Assasa, **P. Casari**, J. Widmer, "Scaling Millimeter-Wave Networks to Dense Deployments and Dynamic Environments," in *Proceedings of the IEEE*, 2019.
	S. T. Arzo, R. Bassoli, **F. Granelli**, F. H. P. Fitzek, Multi-Agent Based Autonomic Network Management Architecture," in *IEEE Transactions on Network and Service Management*, 2021.
	J. Palacios, **P. Casari**, H. Assasa, J. Widmer, "LEAP: Location Estimation and Predictive Handover with Consumer-Grade mmWave Devices," in *Proc. IEEE INFOCOM*, 2019.

Associated Partner Legal Name: University at Albany – SUNY	
General description 	The State University of New York at Albany is a public research university founded in 1844, and is part of the State University of New York (SUNY) system. The University enrolls more than 17,300 undergraduate, graduate, and professional students. The UbiNET Lab at University at Albany is a part of the Computer Science Department and is directed by Dr. Mariya Zheleva. The lab conducts research in next generation mobile wireless networks, focusing on autonomous spectrum measurement and dynamic access and resource allocation, architectures, measurement infrastructures and networked system design, integration and in-situ deployment. The lab has background in field-deployed research in rural Africa and the U.S.

Key Persons and Expertise	**Mariya Zheleva** [f] (*Secondment supervisor DC4*) is an Assistant Professor in Computer Science at University at Albany – SUNY. She graduated with her PhD in Computer Science from University of California Santa Barbara in 2014 Dr. Zheleva is the recipient of the NSF CAREER award, the Dynamic Spectrum Alliance 2019 Award for University Research on New Opportunities for Dynamic Spectrum Access and the University at Albany 2019 President's Award for Exemplary Public Engagement.
Key Research Facilities, Infrastructure and Equipment	The lab is equipped with state-of-the-art student workstations. The PI's laboratory also features a set of research equipment including software-defined radios, hosts, work stations, a power meter and commercial software-defined radio networks (such as a TVWS campus network managed by the lab).
Previous and current Involvement in Research and Training Programmes	The UbiNET Lab has so far hosted one PhD student from KU Leuven in Spring 2020 through the NGI Explorers program. This visit resulted in a paper publication and an ongoing collaboration between the UbiNET Lab and the Electrosense project at KU Leuven. The research tackled modulation recognition of wireless signals that have not been observed in training.
Relevant Publications and/or Research / Innovation Product	E. Perenda, S. Rajendran, G. Bovet, S. Pollin, **M. Zheleva**, "Learning the unknown: Improving modulation classification performance in unseen scenarios," In *IEEE INFOCOM*, 2021.
	W. Xiong, L. Zhang, M. McNeil, P. Bogdanov, **M. Zheleva**, "SYMMeTRy: Exploiting Self-Similarity for Under-Determined MIMO Modulation Recognition," In *IEEE TMC*, 2021.
	W. Xiong, P. Bogdanov, **M. Zheleva**, "Robust and Efficient Modulation Recognition Based on Local Sequential IQ Features," In *IEEE International Conference on Computer Communications IEEE INFOCOM*, 2019.

Associated Partner Legal Name: St. Louis University	
General description 	Founded in 1818, St. Louis University is the oldest university west of the Mississippi River, and maintains campuses in St. Louis, (MO, USA) and in Madrid (Spain). Students represent more than 82 foreign countries. A prime research establishment in the area, the University has been selected as a top workplace in for women by the Women's Foundation of Greater St. Louis (2020, 2021).
Key Persons and Expertise	**Prof. Flavio Esposito** [m] (*Secondment supervisor DC7*) is Associate Professor at the Department of Computer Science of SLU. He received his PhD in computer science at Boston University in 2013. His research interests include network management, network virtualisation and distributed systems. Prior to joining SLU, Flavio worked at Exegy, St.Louis and at Alcatel-Lucent, Italy. He interned at Bell Laboratories, at Raytheon BBN Technologies, and at EURECOM, France, and was a visiting researcher at the Center for Wireless Communications, Finland.
Key Research Facilities, Infrastructure and Equipment	SLU has comprehensive facilities and laboratories for the SpecX DC seconded there to conduct their research smoothly. Besides open spaces for students, key laboratory infrastructure include a computing cluster, numerous software-defined radios of different types, and an edge cloud testbed serving 20 5G antennas that are available for multiple experiments on software-defined networking, virtualisation, radio sensing and signal detection.
Previous and current Involvement in Research and Training Programmes	US-NSF project US Ignite (Collaborative Research, Focus Area 2): Resilient Virtual Path Management for Scalable Data-intensive Computing at Network-Edges. US-NSF project ICE-T RI: A Knowledge-Defined Platform for Real-Time Management of Transmissions and Computations at Network Edge. US-NSF project (Core: Small: Collaborative Research); HEECMA: A Hybrid Elastic Edge-Cloud Application Management Architecture.
Relevant Publications and/or Research / Innovation Product	N. Akhtar, I. Matta, A. Raza, L. Goratti, B. Torsten, **F. Esposito**, "Managing Chains of Application Functions Over Multi-Technology Edge Networks", In *IEEE Transactions on Network and Service Management*, 2021.
	A. Sacco, **F. Esposito**, G. Marchetto, "An Architecture for Adaptive Data-Driven Routing Prediction at the Edge," In *IEEE Transactions on Network and Service Management*, 2020.
	A. Sacco, **F. Esposito**, G. Marchetto, "Owl: Congestion Control with Partially Invisible Networks via Reinforcement Learning," In *Proc. IEEE INFOCOM*, 2019.

7. Letters of Commitment

\Orchestrating a brighter world NEC

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Website: www.neclab.eu

NEC Laboratories Europe GmbH
Kurfürsten-Anlage 36 · 69115 Heidelberg / Germany

November 14, 2022

Letter of Commitment – DN Associated Partner

I undersigned Roberto Baldessari, in my quality of General Manager Administration of NEC Laboratories Europe GmbH, confirm the intention of our organization to set up the necessary provisions to participate as associated partner in the proposal *SpecX* submitted within the call HORIZON-MSCA-2022-DN, should the proposal be funded.

On behalf of NEC Laboratories Europe GmbH, I also confirm that we intend to participate and contribute to the research, innovation and training activities as planned in this project.

In particular, NEC Laboratories Europe GmbH intends to be involved in:

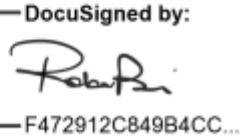
- Providing **research training** on O-RAN and Smart Surfaces during the secondments of DC7 and DC8.
- Participating in the **supervisory board** and co-supervising DC7 and DC8
- Hosting **secondments** (DC7, DC8)
- Collaborating to the **SpecX Summer School**

I hereby declare that I am entitled to represent into this process NEC Laboratories Europe GmbH.

Name: Roberto Baldessari, General Manager Administration

Date: November 14, 2022

Signature: DocuSigned by:



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ERICSSON

Unser Zeichen:
Datum: 2022-11-11
Bearbeiter: Michael Meyer

Ihr Zeichen:
Ihr Datum: 2022-11-11

Ericsson GmbH, Ericsson Allee 1, 52134 Herzogenrath

SpecX Commitment Letter

Dear Sirs,

I undersigned Michael Meyer, in my quality as the research department manager, commit to set up all necessary provisions to participate as associated partner in the proposal SpecX submitted within the call HORIZON-MSCA-2022-DN-SpecX should the proposal be funded.

On behalf of Ericsson GmbH, I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, Ericsson GmbH will be involved in

- Providing research training on analysis and modelling for coexistence of networks based on cellular technologies, and sensing-based resource allocation scheme. These actions will occur during the secondment of DC1 and DC3.
- Cooperating to the SpecX Summer School
- Participating in the supervisory board and co-supervising DC1 and DC3.
- Hosting secondments (DC1, DC3)

I hereby declare that I am entitled to commit into this process the entity I represent.

Best regards

DocuSigned by:
E6C9F579294A41B...
ppa. Jan-Peter Meyer-Kahlen

Vice President, Site Manager, Ericsson Eurolab

DocuSigned by:
B63B1DF91F1848C...
i.V. Dr. Michael Meyer

Research Manager, Ericsson Eurolab

Ericsson GmbH
Eurolab - Unternehmensbereich Forschung und Entwicklung

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Geschäftsführer · Presidents
Stefan Koetz (Vors.)
Daniel Leimbach
Bernd Mellinghaus

Aufsichtsrat · Supervisory Board
Jörgen Heilborn (Vors.)

Registrierungsnummern
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VAT: DE 811978181
WEEE: DE32508425

HORIZON-MSCA-2022-DN-SpecX

Letter of Commitment – DN Associated Partner

I undersigned Vincent Lenders, in my quality of President of Electrosense, commit to set up all necessary provisions to participate as associated partner in the proposal *SpecX* submitted within the call HORIZON-MSCA-2022-DN should the proposal be funded.
On behalf of Electrosense, I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, Electrosense will be involved in

- Providing **research training** on fundamental knowledge of sensing and communication related to the Internet of Things. These actions will occur during the secondment of DC5 and DC6.
- Delivering **S/T training** "Prototyping and building up spectrum sensing testbeds"
- Cooperating to the **SpecX Summer School**
- Participating in the **supervisory board** and co-supervising DC5 and DC6.
- Hosting **secondments** (DC5, DC6)

I hereby declare that I am entitled to commit into this process the entity I represent.

Name: Vincent Lenders

Date: 7/11/2022

Signature:

Electrosense Association
Eyzälg 23, 3400 Burgorf, Switzerland
email: vincent.lenders@electrosense.org

HORIZON-MSCA-2022-DN-SpecX

Letter of Commitment – DN Associated Partner

On headed paper of the entity

I undersigned Stan Claes, in my quality of CEO of Accelleran, commit to set up all necessary provisions to participate as associated partner in the proposal *SpecX* submitted within the call H2020-MSCA-DN-2022 should the proposal be funded.

On behalf of Acceleran, I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, Acceleran will be involved in

- Providing **research training** on localization, edge infrastructure, RAN/O-RAN and wireless communications. These actions will occur during the secondment of DC2 and DC4.
- Participating in the **supervisory board** and co-supervising **DC2** and **DC4**.
- Hosting **secondments** (DC2, DC4)
- Cooperating to **Soft skill training 7**
- Cooperating to the **SpecX Summer School**

I hereby declare that I am entitled to commit into this process the entity I represent.

Name: Stan Claes

14/11/2022,

Signature:

Doc ID: 126e8cf31569e2a18ce2f0baa1c1c85553fa510a

HORIZON-MSCA-2022-DN-SpecX

Letter of Commitment – DN Associated Partner

I undersigned Carmen Guerrero in my quality of Director of the Ph.D Program on Telematics Enginering of Universidad Carlos III de Madrid, commit to set up all necessary provisions to participate as associated partner in the proposal *SpecX* submitted within the call HORIZON-MSCA-2022-DN should the proposal be funded.

On behalf of [Universidad Carlos III de Madrid], I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, [Universidad Carlos III de Madrid] will be involved in

- **Enrolling DC5, DC6, and DC9** in the Doctoral School of the University
- Providing **research training** on wireless communication, mobile networking, execution of experiments. These actions will occur during the secondment of DC6.
- Participating in the **supervisory board** and co-supervising DC6
- Hosting **secondments** (DC6)

I hereby declare that I am entitled to commit into this process the entity I represent.

Name: Carmen Guerrero

November 7 2022

Firmado por GUERRERO LOPEZ MARIA CARMEN – ***2016** el día 07/11/2022 con un certificado emitido por AC FNMT Usuarios

Signature:

Università di Roma Tor Vergata

Dipartimento di Ingegneria Elettronica

To whom it may concern

Object: Letter of Commitment – DN Associated Partner

I undersigned Corrado Di Natale, in my quality of Coordinator of the PhD course in Electronic Engineering, commit to set up all necessary provisions to participate, as associated partner, in the proposal *SpecX* submitted within the call HORIZON-MSCA-2022-DN should the proposal be funded.

On behalf of University of Rome Tor Vergata, I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, University of Rome Tor Vergata, will participate as a component of the Italian inter-university consortium for telecommunications (CNIT), and will be involved in

- Providing research training: enroll DC2 to the doctoral program in Electronics Engineering of University of Rome Tor Vergata.
- Scientific participation to the organisation of one network-wide event and summer school in the region of Trento, Italy.
- Participating in the supervisory board.

I hereby declare that I am entitled to commit into this process the entity I represent.

Rome, 7 Nov 2022

Professor Corrado Di Natale

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UNIVERSITÀ DI TRENTO
Dipartimento di Ingegneria e Scienza dell'Informazione

HORIZON-MSCA-2022-DN-SpecX

Letter of Commitment – DN Associated Partner

I, the undersigned Prof. Elisa Ricci, in my capacity as the Director of the PhD school in Information Engineering and Computer Science of the University of Trento, commit to set up all necessary provisions to participate as associated partner in the proposal SpecX submitted within the call HORIZON-MSCA-2022-DN should the proposal be funded.

On behalf of the Department of Information Engineering and Computer Science of the University of Trento, I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, the University of Trento will participate as a component of the Italian inter-university consortium for telecommunications (CNIT), and will be involved in

- **Providing research training**: enroll DC7 in the doctoral program in Information Engineering and Computer Science of the University of Trento, Italy;
- **Co-organisation of one network-wide event and summer school** in the region of Trento, Italy;
- Participating in the **supervisory board**.

I hereby declare that I am entitled to commit into this process the entity I represent.

Name: **Elisa Ricci**, Director, PhD school in Information Engineering and Computer Science, University of Trento

Trento, 12/11/2022

Signature: 

Via Sommarive, 9 – 38123 Trento, Italy - Tel. +39 0461/283966, Fax +39 0461/283166, disi@disi.unitn.it

UNIVERSITY AT ALBANY
State University of New York

College of Engineering and Applied Sciences
Computer Science Department

HORIZON-MSCA-2022-DN-SpecX

Letter of Commitment – DN Associated Partner

I undersigned Mariya Zheleva, in my quality of Associate Professor in Computer Science at University at Albany, commit to set up all necessary provisions to participate as associated partner in the proposal *SpecX* submitted within the call HORIZON-MSCA-2022-DN should the proposal be funded.

On behalf of University at Albany, I also confirm that we will participate and contribute to the research, innovation and training activities as planned in this project. In particular, University at Albany will be involved in

- Providing **research training** on next generation wireless networking, training in research methodology, algorithm development, testbed setup and experimentation, paper writing and technical presentations. These actions will occur during the secondment of DC4
- Participating in the **supervisory board**.
- Hosting **secondments** (DC4)

I hereby declare that I am entitled to commit into this process the entity I represent.

Name: Mariya Zheleva,

11/07/2022,

Signature: 

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Flavio Esposito
Associate Professor
flavio.esposito@slu.edu

November 7, 2022

Dear Colleagues,

I undersigned Flavio Esposito, in my quality of Associate Professor of Computer Science at Saint Louis University, commit to set up all necessary provisions to participate as associated partner in the proposal SpecX submitted within the call HORIZON-MSCA-2022-DN, should the proposal be funded.

On behalf of Saint Louis University, I also confirm that we will participate and contribute to the research, innovation, and training activities as planned in this project. In particular, Saint Louis University will be involved in

- Providing research training on computer networks, network measurements, and networking data processing. These actions will occur during the secondment of DC7
- Participating in the supervisory board
- Hosting secondments (DC7)

I hereby declare that I am entitled to commit into this process the entity I represent.

With regard,

Flavio Esposito

Higher purpose. Greater good.

Appendix I: Ethics Self-Assessment

I1. Ethical dimension of the objectives, methodology and likely impact

There are no critical ethics issues related to the SpecX project, as indicated in the ethical issues checklist in Part A of the proposal. Therefore, we believe that the ethics-related risks are rather low.

Data collection and protection: While we aim to use spectrum data, we don't log personal data. As we don't transmit but only receive signals, we are also not subject to environment radiation norms. To make sure we for continuously protect personal data and protect the environment and apply export regulation and comply with ethics related to AI, we will take following actions as detailed int he next section.

Artificial Intelligence: We are working on machine learning algorithms, but the intention is to mainly use existing techniques and adapt them to the SpecX context. When using and adapting existing algorithms, there are not really ethical issues.

Misuse: Related to Dual Use, any cross-border activities will comply with all applicable international, EU and national law (in particular, the EU Export Control Regulation No 428/2009).

I2. Compliance with ethical principles and relevant legislations

Protection of personal data

Assessment: In SpecX we will collect and use data regarding spectrum use, including signal strength, noise, and so on. All the data will be stored on IMDEA data repositories or similar places. We do not collect any sensitive personal data such as health (respiration, heartbeat, etc.), and the impact of people's presence on the measured radiation patterns is only implicit. It is also not our intention to track people or get insights about crowd mobility from the gathered datasets. Nevertheless, we should ensure the data is also stored in such a way that it cannot be misused in the future.

Action: There will be specialised training on "Good research practice and data management" (A. Lutu of TID, M13) and privacy-enhancing technologies (C. Diaz of KU Leuven, M13) to make sure DCs are sufficiently aware of privacy issues when doing their research and experiments.We ensure that all data that is processed will be limited to the research activities of the DCs in SpecX. We will not create generic datasets and make them available for activity or anomaly detection beyond the targeted activities. To access the data, credentials are needed, and access will only be given after approval of a 'data license agreement'. To double-check the validity of our approach and make it concrete, we will contact the IMDEA Ethics Committee that evaluates research for ethical approval. Evaluation by this committee will, at the same time, allow an evaluation of the processing of personal data by the IMDEA Data Protection Officer (DPO).

Non-EU countries (and Dual-Use)

Assessment: As this project does not have a military finality, is not part of a sensitive call, or does not have a sensitive partner or end-user, there is no need for ethics approval by the IMDEA Ethics Committee, and by extrapolation, we also did not raise an Ethics issue in Part A. We are aware of the European regulation 428/2009 related to dual-use items for which export licenses are required. At the moment of submission, the planned secondments in Switzerland and USA do not require an agreement, but we will keep monitoring the research progress with respect to the European regulation and ensure we at all times comply with the European export regulation. The reason why there are currently no dual-use export regulation issues, is the fact that regulation 428/2009 focusing on digitally controlled radio receivers (5A001.b.5) is specifically targeting wideband (more than 1.000 channel) radio technology. The secondments to Electrosense or the USA partners are related to narrowband radio (for instance, Electrosense uses the 2 MHz RTL-SDR for sensing).

Action: We will keep track of the European regulation 428/2009 and ensure all our actions are compliant to EU law. IMDEA and KU Leuven have several years of in-house expertise to make sure that when necessary, the required authorisation/license(s) will be obtained from the national authorities. A training with the title "Dual-use/export license training" by KU Leuven is planned in M13.

Environment, health and safety

Assessment: Cellular technology is subject to environmental radiation norms for non-ionising radiation. The data collected in SpecX could help monitor the effective exposure of the environments to electromagnetic radiation caused by telecommunication systems. As there is no focus on transmitters in SpecX, there is no risk of causing excessive radiation.

Artificial Intelligence

Assessment: We are working on machine learning algorithms, but the intention is to mainly use existing techniques and adapt them to the SpecX context. When using and adapting existing algorithms, there are not really ethical issues. In our understanding, we will use data-driven methods to better understand spectrum use. While that better understanding can help to make better use of the spectrum and enable new applications, these applications will not be derived by the machine learning tools. It is the team of 10 DC that will drive the applications.

Action: By striving for a diverse team of 10 DC (gender, north/south, east/west) we hope that the applications are ethical following worldwide ethical standards. Ethics and research integrity is a mandatory training for IMDEA researchers, and it will be offered to the 10 SpecX DC during the first event with title "Responsible Research and Innovation (RRI), open access, ethics, scientific integrity, and gender bias ".

END PAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Doctoral Networks (DN)
Call: HORIZON-MSCA-DN-2022

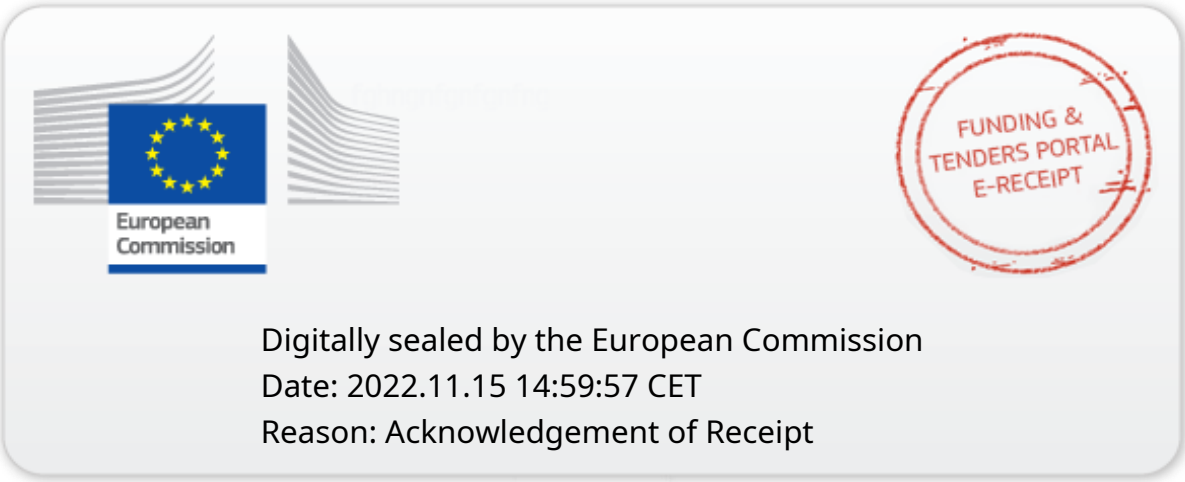
PART B

SpecX

Doctoral Network on
Spectrum Analytics as a Service

This proposal is to be evaluated as:

[DN]



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