EUROPEAN HEALTH AND DIGITAL EXECUTIVE AGENCY (HADEA)

HADEA.B – Digital, Industry and Space
B.2 – Digital

GRANT AGREEMENT

Project 101189703 — ICON

PREAMBLE

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

the **European Health and Digital Executive Agency (HADEA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and

on the other part,

1. 'the coordinator':

THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD, OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN (TCD), PIC 999845446, established in COLLEGE GREEN TRINITY COLLEGE, DUBLIN 2 D02 CX56, Ireland,

and the following other beneficiaries, if they sign their 'accession form' (see Annex 3 and Article 40):

2. **ADTRAN NETWORKS SE (ADTRAN)**, PIC 999811787, established in MAERZENQUELLE 1-3, MEININGEN 98617, Germany,

3. **FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN-NUERNBERG (FAU)**, PIC 999995408, established in SCHLOSSPLATZ 4, ERLANGEN 91054, Germany,

4. **CY.R.I.C CYPRUS RESEARCH AND INNOVATION CENTER LTD (CyRIC)**, PIC 952429809, established in AGIAS ELENIS 6 AGIAS ELENIS BUILDING 4TH FLOOR FLAT OFFICE 43, LEFKOSIA 1060, Cyprus,

5. **VYSOKE UCENI TECHNICKE V BRNE (BUT)**, PIC 999873091, established in ANTONINSKA 548/1, BRNO STRED 602 00, Czechia,

6. **VPIPHOTONICS GMBH (VPI)**, PIC 950983248, established in HALLERSTRASSE 6, BERLIN 10587, Germany,

7. **TALLINNA TEHNIKAÜLIKOOL (TALTECH)**, PIC 999842536, established in EHITAJATE TEE 5, TALLINN 19086, Estonia,

8. **Tampnet AS (Tampnet)**, PIC 878603303, established in Hinna Park Stadion blokk C Jåttåvågveien 7, Stavanger 4020, Norway,

9. **DANMARKS TEKNISKE UNIVERSITET (DTU)**, PIC 999990655, established in ANKER ENGELUNDS VEJ 101, KONGENS LYNGBY 2800, Denmark,

10. **LIGHTSENSAI LIMITED (LSAI)**, PIC 878112483, established in THE RUBICON CENTRE, ROSA AVENUE,, CORK T12 Y275, Ireland,

Unless otherwise specified, references to 'beneficiary' or 'beneficiaries' include the coordinator and affiliated entities (if any).

If only one beneficiary signs the grant agreement ('mono-beneficiary grant'), all provisions referring to the 'coordinator' or the 'beneficiaries' will be considered — mutatis mutandis — as referring to the beneficiary.

The parties referred to above have agreed to enter into the Agreement.

By signing the Agreement and the accession forms, the beneficiaries accept the grant and agree to implement the action under their own responsibility and in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

The Agreement is composed of:

Preamble

Terms and Conditions (including Data Sheet)

Annex 1 Description of the action[1]

Annex 2 Estimated budget for the action

Annex 2a Additional information on unit costs and contributions (if applicable)

Annex 3 Accession forms (if applicable)[2]

Annex 3a Declaration on joint and several liability of affiliated entities (if applicable)[3]

Annex 4 Model for the financial statements

Annex 5 Specific rules (if applicable)

[1] Template published on Portal Reference Documents.
[2] Template published on Portal Reference Documents.
[3] Template published on Portal Reference Documents.

TERMS AND CONDITIONS

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DATA SHEET

1. General data

Project summary:

Project summary
The Intent and Context-aware Optical Network (ICON) project builds the research foundation for a new generation of optical networks, in which sensing is designed as an integral part of overall system architecture. ICON will enable communication networks that offer sensing services, turning the terrestrial and subsea fibre infrastructure into a global scale sensing manifold. This will pave the way for future network evolution of services offering a wide range of sensing applications in diverse areas such as geological disturbances, global weather and oceanographic phenomena, and urban mobility. The control and management of such new sensing services will be enabled by extensible and modular ICON intelligent sensing controller that include an intent interpreter and network digital twin to preserve state information. As an integral part of future communications systems, the ICON functions and sensing devices enable transmission optimization that goes beyond today's signal monitoring. The ICON project will develop fibre sensing and controls to create context awareness of both the internal fibre system state as well as the environment encompassing it. This addition of a sensing dimension to transmission engineering in optical networks brings new tools for optimizing transmission performance and increasing availability and energy efficiency.

Keywords:

- Fiber optics and optical communications
- Optical engineering, photonics, lasers
- Sensing, Digital Twin, Machine Learning, Physical Layer, Energy Efficiency, Data Processing, OTDR, SDN

Project number: 101189703

Project name: Intent and Context-Aware Optical Networks

Project acronym: ICON

Call: HORIZON-CL4-2024-DIGITAL-EMERGING-01

Topic: HORIZON-CL4-2024-DIGITAL-EMERGING-01-54

Type of action: HORIZON Research and Innovation Actions

Granting authority: European Health and Digital Executive Agency

Grant managed through EU Funding & Tenders Portal: Yes (eGrants)

Project starting date: fixed date: 1 January 2025

Project end date: 31 December 2027

Project duration: 36 months

Consortium agreement: Yes

2. Participants

List of participants:

N°	Role	Short name	Legal name	Ctry	PIC	Total eligible costs (BEN and AE)	Max grant amount
1	COO	TCD	THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD, OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN	IE	999845446	760 227.50	760 227.50
2	BEN	ADTRAN	ADTRAN NETWORKS SE	DE	999811787	696 250.00	696 250.00

N°	Role	Short name	Legal name	Ctry	PIC	Total eligible costs (BEN and AE)	Max grant amount
3	BEN	FAU	FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN-NUERNBERG	DE	999995408	412 500.00	412 500.00
4	BEN	CyRIC	CY.R.I.C CYPRUS RESEARCH AND INNOVATION CENTER LTD	CY	952429809	426 875.00	426 875.00
5	BEN	BUT	VYSOKE UCENI TECHNICKE V BRNE	CZ	999873091	456 250.00	456 250.00
6	BEN	VPI	VPIPHOTONICS GMBH	DE	950983248	367 500.00	367 500.00
7	BEN	TALTECH	TALLINNA TEHNIKAÜLIKOOL	EE	999842536	416 775.00	416 775.00
8	BEN	Tampnet	Tampnet AS	NO	878603303	600 000.00	600 000.00
9	BEN	DTU	DANMARKS TEKNISKE UNIVERSITET	DK	999990655	443 431.25	443 431.25
10	BEN	LSAI	LIGHTSENSAI LIMITED	IE	878112483	419 375.00	419 375.00
Total						4 999 183.75	4 999 183.75

Coordinator:

– THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD, OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN (TCD)

3. Grant

Maximum grant amount, total estimated eligible costs and contributions and funding rate:

Total eligible costs (BEN and AE)	Funding rate (%)	Maximum grant amount (Annex 2)	Maximum grant amount (award decision)
4 999 183.75	100	4 999 183.75	4 999 183.75

Grant form: Budget-based

Grant mode: Action grant

Budget categories/activity types:

- A. Personnel costs
  - A.1 Employees, A.2 Natural persons under direct contract, A.3 Seconded persons
  - A.4 SME owners and natural person beneficiaries
  - A.6 Personnel unit cost
- B. Subcontracting costs
- C. Purchase costs
  - C.1 Travel and subsistence
  - C.2 Equipment
  - C.3 Other goods, works and services
- D. Other cost categories
  - D.2 Internally invoiced goods and services
- E. Indirect costs

Cost eligibility options:

- In-kind contributions eligible costs
- Parental leave

- Project-based supplementary payments
- Average personnel costs (unit cost according to usual cost accounting practices)
- Limitation for subcontracting
- Travel and subsistence:
  - Travel: Actual costs
  - Accommodation: Actual costs
  - Subsistence: Actual costs
- Equipment: depreciation only
- Indirect cost flat-rate: 25% of the eligible direct costs (categories A-D, except volunteers costs, subcontracting costs, financial support to third parties and exempted specific cost categories, if any)
- VAT: Yes
- Other ineligible costs

Budget flexibility: Yes (no flexibility cap)

4. Reporting, payments and recoveries

4.1 Continuous reporting (art 21)

Deliverables: see Funding & Tenders Portal Continuous Reporting tool

4.2 Periodic reporting and payments

Reporting and payment schedule (art 21, 22):

Reporting					Payments	
Reporting periods			Type	Deadline	Type	Deadline (time to pay)
RP No	Month from	Month to				
					Initial prefinancing	30 days from entry into force/10 days before starting date – whichever is the latest
1	1	18	Periodic report	60 days after end of reporting period	Interim payment	90 days from receiving periodic report
2	19	36	Periodic report	60 days after end of reporting period	Final payment	90 days from receiving periodic report

Prefinancing payments and guarantees:

Prefinancing payment	
Type	Amount
Prefinancing 1 (initial)	3 999 347.00

Reporting and payment modalities (art 21, 22):

Mutual Insurance Mechanism (MIM): Yes

MIM contribution: 5% of the maximum grant amount (249 959.19), retained from the initial prefinancing

Restrictions on distribution of initial prefinancing: The prefinancing may be distributed only if the minimum number of beneficiaries set out in the call condititions (if any) have acceded to the Agreement and only to beneficiaries that have acceded.

Interim payment ceiling (if any): 90% of the maximum grant amount

Exception for revenues: Yes

No-profit rule: Yes

Late payment interest: ECB + 3.5%

Bank account for payments:

IE39BOFI90139421853025

Conversion into euros: Double conversion

Reporting language: Language of the Agreement

4.3 Certificates (art 24):

Certificates on the financial statements (CFS):

Conditions:

Schedule: only at final payment, if threshold is reached

Standard threshold (beneficiary-level):

- financial statement: requested EU contribution to costs ≥ EUR 430 000.00

Special threshold for beneficiaries with a systems and process audit(see Article 24): financial statement: requested EU contribution to costs ≥ EUR 725 000.00

4.4 Recoveries (art 22)

First-line liability for recoveries:

Beneficiary termination: Beneficiary concerned

Final payment: Each beneficiary for their own debt

After final payment: Beneficiary concerned

Joint and several liability for enforced recoveries (in case of non-payment):

Individual financial responsibility: Each beneficiary is liable only for its own debts (and those of its affiliated entities, if any)

Joint and several liability of affiliated entities — n/a

5. Consequences of non-compliance, applicable law & dispute settlement forum

Suspension and termination:

Additional suspension grounds (art 31)

Additional termination grounds (art 32)

Applicable law (art 43):

Standard applicable law regime: EU law + law of Belgium

Dispute settlement forum (art 43):

Standard dispute settlement forum:

EU beneficiaries: EU General Court + EU Court of Justice (on appeal)

Non-EU beneficiaries: Courts of Brussels, Belgium (unless an international agreement provides for the enforceability of EU court judgements)

6. Other

Specific rules (Annex 5): Yes

Standard time-limits after project end:

Confidentiality (for X years after final payment): 5

Record-keeping (for X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

Reviews (up to X years after final payment): 2

Audits (up to X years after final payment): 2

Extension of findings from other grants to this grant (no later than X years after final payment): 2

Impact evaluation (up to X years after final payment): 5 (or 3 for grants of not more than EUR 60 000)

CHAPTER 1 GENERAL

ARTICLE 1 — SUBJECT OF THE AGREEMENT

This Agreement sets out the rights and obligations and terms and conditions applicable to the grant awarded for the implementation of the action set out in Chapter 2.

ARTICLE 2 — DEFINITIONS

For the purpose of this Agreement, the following definitions apply:

Actions — The project which is being funded in the context of this Agreement.

Grant — The grant awarded in the context of this Agreement.

EU grants — Grants awarded by EU institutions, bodies, offices or agencies (including EU executive agencies, EU regulatory agencies, EDA, joint undertakings, etc.).

Participants — Entities participating in the action as beneficiaries, affiliated entities, associated partners, third parties giving in-kind contributions, subcontractors or recipients of financial support to third parties.

Beneficiaries (BEN) — The signatories of this Agreement (either directly or through an accession form).

Affiliated entities (AE) — Entities affiliated to a beneficiary within the meaning of Article 187 of EU Financial Regulation 2018/1046[4] which participate in the action with similar rights and obligations as the beneficiaries (obligation to implement action tasks and right to charge costs and claim contributions).

Associated partners (AP) — Entities which participate in the action, but without the right to charge costs or claim contributions.

Purchases — Contracts for goods, works or services needed to carry out the action (e.g. equipment, consumables and supplies) but which are not part of the action tasks (see Annex 1).

Subcontracting — Contracts for goods, works or services that are part of the action tasks (see Annex 1).

In-kind contributions — In-kind contributions within the meaning of Article 2(36) of EU Financial

[4] For the definition, see Article 187 Regulation (EU, Euratom) 2018/1046 of the European Parliament and of the Council of 18 July 2018 on the financial rules applicable to the general budget of the Union, amending Regulations (EU) No 1296/2013, (EU) No 1301/2013, (EU) No 1303/2013, (EU) No 1304/2013, (EU) No 1309/2013, (EU) No 1316/2013, (EU) No 223/2014, (EU) No 283/2014, and Decision No 541/2014/EU and repealing Regulation (EU, Euratom) No 966/2012 ('EU Financial Regulation') (OJ L 193, 30.7.2018, p. 1): "**affiliated entities** [are]:
(a) entities that form a sole beneficiary [(i.e. where an entity is formed of several entities that satisfy the criteria for being awarded a grant, including where the entity is specifically established for the purpose of implementing an action to be financed by a grant)];
(b) entities that satisfy the eligibility criteria and that do not fall within one of the situations referred to in Article 136(1) and 141(1) and that have a link with the beneficiary, in particular a legal or capital link, which is neither limited to the action nor established for the sole purpose of its implementation".

Regulation 2018/1046, i.e. non-financial resources made available free of charge by third parties.

Fraud — Fraud within the meaning of Article 3 of EU Directive 2017/1371[5] and Article 1 of the Convention on the protection of the European Communities' financial interests, drawn up by the Council Act of 26 July 1995[6], as well as any other wrongful or criminal deception intended to result in financial or personal gain.

Irregularities — Any type of breach (regulatory or contractual) which could impact the EU financial interests, including irregularities within the meaning of Article 1(2) of EU Regulation 2988/95[7].

Grave professional misconduct — Any type of unacceptable or improper behaviour in exercising one's profession, especially by employees, including grave professional misconduct within the meaning of Article 136(1)(c) of EU Financial Regulation 2018/1046.

Applicable EU, international and national law — Any legal acts or other (binding or non-binding) rules and guidance in the area concerned.

Portal — EU Funding & Tenders Portal; electronic portal and exchange system managed by the European Commission and used by itself and other EU institutions, bodies, offices or agencies for the management of their funding programmes (grants, procurements, prizes, etc.).

CHAPTER 2 ACTION

ARTICLE 3 — ACTION

The grant is awarded for the action **101189703** — **ICON** ('action'), as described in Annex 1.

ARTICLE 4 — DURATION AND STARTING DATE

The duration and the starting date of the action are set out in the Data Sheet (see Point 1).

CHAPTER 3 GRANT

ARTICLE 5 — GRANT

5.1 Form of grant

The grant is an action grant[8] which takes the form of a budget-based mixed actual cost grant (i.e. a

[5] Directive (EU) 2017/1371 of the European Parliament and of the Council of 5 July 2017 on the fight against fraud to the Union's financial interests by means of criminal law (OJ L 198, 28.7.2017, p. 29).
[6] OJ C 316, 27.11.1995, p. 48.
[7] Council Regulation (EC, Euratom) No 2988/95 of 18 December 1995 on the protection of the European Communities financial interests (OJ L 312, 23.12.1995, p. 1).
[8] For the definition, see Article 180(2)(a) EU Financial Regulation 2018/1046: '**action grant**' means an EU grant to finance "an action intended to help achieve a Union policy objective".

grant based on actual costs incurred, but which may also include other forms of funding, such as unit costs or contributions, flat-rate costs or contributions, lump sum costs or contributions or financing not linked to costs).

5.2 Maximum grant amount

The maximum grant amount is set out in the Data Sheet (see Point 3) and in the estimated budget (Annex 2).

5.3 Funding rate

The funding rate for costs is 100% of the action's eligible costs.

Contributions are not subject to any funding rate.

5.4 Estimated budget, budget categories and forms of funding

The estimated budget for the action is set out in Annex 2.

It contains the estimated eligible costs and contributions for the action, broken down by participant and budget category.

Annex 2 also shows the types of costs and contributions (forms of funding)[9] to be used for each budget category.

If unit costs or contributions are used, the details on the calculation will be explained in Annex 2a.

5.5 Budget flexibility

The budget breakdown may be adjusted — without an amendment (see Article 39) — by transfers (between participants and budget categories), as long as this does not imply any substantive or important change to the description of the action in Annex 1.

However:

- changes to the budget category for volunteers (if used) always require an amendment
- changes to budget categories with lump sums costs or contributions (if used; including financing not linked to costs) always require an amendment
- changes to budget categories with higher funding rates or budget ceilings (if used) always require an amendment
- addition of amounts for subcontracts not provided for in Annex 1 either require an amendment or simplified approval in accordance with Article 6.2
- other changes require an amendment or simplified approval, if specifically provided for in Article 6.2
- flexibility caps: not applicable.

[9] See Article 125 EU Financial Regulation 2018/1046.

ARTICLE 6 — ELIGIBLE AND INELIGIBLE COSTS AND CONTRIBUTIONS

In order to be eligible, costs and contributions must meet the **eligibility** conditions set out in this Article.

6.1 General eligibility conditions

The **general eligibility conditions** are the following:

(a) for actual costs:

(i) they must be actually incurred by the beneficiary

(ii) they must be incurred in the period set out in Article 4 (with the exception of costs relating to the submission of the final periodic report, which may be incurred afterwards; see Article 21)

(iii) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(iv) they must be incurred in connection with the action as described in Annex 1 and necessary for its implementation

(v) they must be identifiable and verifiable, in particular recorded in the beneficiary's accounts in accordance with the accounting standards applicable in the country where the beneficiary is established and with the beneficiary's usual cost accounting practices

(vi) they must comply with the applicable national law on taxes, labour and social security and

(vii) they must be reasonable, justified and must comply with the principle of sound financial management, in particular regarding economy and efficiency

(b) for unit costs or contributions (if any):

(i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(ii) the units must:

- be actually used or produced by the beneficiary in the period set out in Article 4 (with the exception of units relating to the submission of the final periodic report, which may be used or produced afterwards; see Article 21)

- be necessary for the implementation of the action and

(iii) the number of units must be identifiable and verifiable, in particular supported by records and documentation (see Article 20)

(c) for flat-rate costs or contributions (if any):

(i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(ii) the costs or contributions to which the flat-rate is applied must:

- be eligible
- relate to the period set out in Article 4 (with the exception of costs or contributions relating to the submission of the final periodic report, which may be incurred afterwards; see Article 21)

(d) for lump sum costs or contributions (if any):

(i) they must be declared under one of the budget categories set out in Article 6.2 and Annex 2

(ii) the work must be properly implemented by the beneficiary in accordance with Annex 1

(iii) the deliverables/outputs must be achieved in the period set out in Article 4 (with the exception of deliverables/outputs relating to the submission of the final periodic report, which may be achieved afterwards; see Article 21)

(e) for unit, flat-rate or lump sum costs or contributions according to usual cost accounting practices (if any):

(i) they must fulfil the general eligibility conditions for the type of cost concerned

(ii) the cost accounting practices must be applied in a consistent manner, based on objective criteria, regardless of the source of funding

(f) for financing not linked to costs (if any): the results must be achieved or the conditions must be fulfilled as described in Annex 1.

In addition, for direct cost categories (e.g. personnel, travel & subsistence, subcontracting and other direct costs) only costs that are directly linked to the action implementation and can therefore be attributed to it directly are eligible. They must not include any indirect costs (i.e. costs that are only indirectly linked to the action, e.g. via cost drivers).

In-kind contributions provided by third parties free of charge may be declared as eligible direct costs by the beneficiaries which use them (under the same conditions as if they were their own, provided that they concern only direct costs and that the third parties and their in-kind contributions are set out in Annex 1 (or approved ex post in the periodic report, if their use does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants; 'simplified approval procedure').

6.2 Specific eligibility conditions for each budget category

For each budget category, the **specific eligibility conditions** are as follows:

Direct costs

A. Personnel costs

A.1 Costs for employees (or equivalent) are eligible as personnel costs if they fulfil the general eligibility conditions and are related to personnel working for the beneficiary under an employment contract (or equivalent appointing act) and assigned to the action.

They must be limited to salaries (including net payments during parental leave), social security contributions, taxes and other costs linked to the remuneration, if they arise from national law or the employment contract (or equivalent appointing act) and be calculated on the basis of the costs actually incurred, in accordance with the following method:

{daily rate for the person

multiplied by

number of day-equivalents worked on the action (rounded up or down to the nearest half-day)}.

The daily rate must be calculated as:

{annual personnel costs for the person

divided by

215}.

The number of day-equivalents declared for a person must be identifiable and verifiable (see Article 20).

The actual time spent on parental leave by a person assigned to the action may be deducted from the 215 days indicated in the above formula.

The total number of day-equivalents declared in EU grants, for a person for a year, cannot be higher than 215, minus time spent on parental leave (if any).

For personnel which receives supplementary payments for work in projects (project-based remuneration), the personnel costs must be calculated at a rate which:

- corresponds to the actual remuneration costs paid by the beneficiary for the time worked by the person in the action over the reporting period
- does not exceed the remuneration costs paid by the beneficiary for work in similar projects funded by national schemes (‘national projects reference’)
- is defined based on objective criteria allowing to determine the amount to which the person is entitled

and

- reflects the usual practice of the beneficiary to pay consistently bonuses or supplementary payments for work in projects funded by national schemes.

The national projects reference is the remuneration defined in national law, collective labour agreement or written internal rules of the beneficiary applicable to work in projects funded by national schemes.

If there is no such national law, collective labour agreement or written internal rules or if the project-based remuneration is not based on objective criteria, the national project reference will be the average

remuneration of the person in the last full calendar year covered by the reporting period, excluding remuneration paid for work in EU actions.

If the beneficiary uses average personnel costs (unit cost according to usual cost accounting practices), the personnel costs must fulfil the general eligibility conditions for such unit costs and the daily rate must be calculated:

- using the actual personnel costs recorded in the beneficiary's accounts and excluding any costs which are ineligible or already included in other budget categories; the actual personnel costs may be adjusted on the basis of budgeted or estimated elements, if they are relevant for calculating the personnel costs, reasonable and correspond to objective and verifiable information

and

- according to usual cost accounting practices which are applied in a consistent manner, based on objective criteria, regardless of the source of funding.

A.2 and **A.3 Costs for natural persons working under a direct contract** other than an employment contract and costs for **seconded persons by a third party against payment** are also eligible as personnel costs, if they are assigned to the action, fulfil the general eligibility conditions and:

(a) work under conditions similar to those of an employee (in particular regarding the way the work is organised, the tasks that are performed and the premises where they are performed) and

(b) the result of the work belongs to the beneficiary (unless agreed otherwise).

They must be calculated on the basis of a rate which corresponds to the costs actually incurred for the direct contract or secondment and must not be significantly different from those for personnel performing similar tasks under an employment contract with the beneficiary.

A.4 The work of **SME owners** for the action (i.e. owners of beneficiaries that are small and medium-sized enterprises[10] not receiving a salary) or **natural person beneficiaries** (i.e. beneficiaries that are natural persons not receiving a salary) may be declared as personnel costs, if they fulfil the general eligibility conditions and are calculated as unit costs in accordance with the method set out in Annex 2a.

A.6 For **beneficiaries with personnel unit cost**, the personnel costs under categories A.1-A.4 must be declared as unit cost and are eligible, if they fulfil the general eligibility conditions, are calculated as unit costs in accordance with the method set out in Annex 2a and comply with the conditions set out in Points A.1-A.4 for the underlying types of costs (personnel).

[10] For the definition, see Commission Recommendation 2003/361/EC: micro, small or medium-sized enterprise (SME) are enterprises

- engaged in an economic activity, irrespective of their legal form (including, in particular, self- employed persons and family businesses engaged in craft or other activities, and partnerships or associations regularly engaged in an economic activity) and

- employing fewer than 250 persons (expressed in 'annual working units' as defined in Article 5 of the Recommendation) and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million.

B. Subcontracting costs

Subcontracting costs for the action (including related duties, taxes and charges, such as non-deductible or non-refundable value added tax (VAT)) are eligible, if they are calculated on the basis of the costs actually incurred, fulfil the general eligibility conditions and are awarded using the beneficiary's usual purchasing practices — provided these ensure subcontracts with best value for money (or if appropriate the lowest price) and that there is no conflict of interests (see Article 12).

Beneficiaries that are 'contracting authorities/entities' within the meaning of the EU Directives on public procurement must also comply with the applicable national law on public procurement.

Subcontracting may cover only a limited part of the action.

The tasks to be subcontracted and the estimated cost for each subcontract must be set out in Annex 1 and the total estimated costs of subcontracting per beneficiary must be set out in Annex 2 (or may be approved ex post in the periodic report, if the use of subcontracting does not entail changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants; 'simplified approval procedure').

C. Purchase costs

Purchase costs for the action (including related duties, taxes and charges, such as non-deductible or non-refundable value added tax (VAT)) are eligible if they fulfil the general eligibility conditions and are bought using the beneficiary's usual purchasing practices — provided these ensure purchases with best value for money (or if appropriate the lowest price) and that there is no conflict of interests (see Article 12).

Beneficiaries that are 'contracting authorities/entities' within the meaning of the EU Directives on public procurement must also comply with the applicable national law on public procurement.

C.1 Travel and subsistence

Purchases for **travel, accommodation** and **subsistence** must be calculated as follows:

- travel: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel
- accommodation: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel
- subsistence: on the basis of the costs actually incurred and in line with the beneficiary's usual practices on travel .

C.2 Equipment

Purchases of **equipment, infrastructure or other assets** used for the action must be declared as depreciation costs, calculated on the basis of the costs actually incurred and written off in accordance with international accounting standards and the beneficiary's usual accounting practices.

Only the portion of the costs that corresponds to the rate of actual use for the action during the action duration can be taken into account.

Costs for **renting or leasing** equipment, infrastructure or other assets are also eligible, if they do not exceed the depreciation costs of similar equipment, infrastructure or assets and do not include any financing fees.

C.3 Other goods, works and services

Purchases of **other goods, works and services** must be calculated on the basis of the costs actually incurred.

Such goods, works and services include, for instance, consumables and supplies, promotion, dissemination, protection of results, translations, publications, certificates and financial guarantees, if required under the Agreement.

D. Other cost categories

D.2 Internally invoiced goods and services

Costs for internally invoiced goods and services directly used for the action may be declared as unit cost according to usual cost accounting practices, if and as declared eligible in the call conditions, if they fulfil the general eligibility conditions for such unit costs and the amount per unit is calculated:

- using the actual costs for the good or service recorded in the beneficiary's accounts, attributed either by direct measurement or on the basis of cost drivers, and excluding any cost which are ineligible or already included in other budget categories; the actual costs may be adjusted on the basis of budgeted or estimated elements, if they are relevant for calculating the costs, reasonable and correspond to objective and verifiable information

and

- according to usual cost accounting practices which are applied in a consistent manner, based on objective criteria, regardless of the source of funding.

'Internally invoiced goods and services' means goods or services which are provided within the beneficiary's organisation directly for the action and which the beneficiary values on the basis of its usual cost accounting practices.

This cost will not be taken into account for the indirect cost flat-rate.

Indirect costs

E. Indirect costs

Indirect costs will be reimbursed at the flat-rate of 25% of the eligible direct costs (categories A-D, except volunteers costs, subcontracting costs, financial support to third parties and exempted specific cost categories, if any).

Contributions

Not applicable

6.3 Ineligible costs and contributions

The following costs or contributions are **ineligible**:

(a) costs or contributions that do not comply with the conditions set out above (Article 6.1 and 6.2), in particular:

(i) costs related to return on capital and dividends paid by a beneficiary

(ii) debt and debt service charges

(iii) provisions for future losses or debts

(iv) interest owed

(v) currency exchange losses

(vi) bank costs charged by the beneficiary's bank for transfers from the granting authority

(vii) excessive or reckless expenditure

(viii) deductible or refundable VAT (including VAT paid by public bodies acting as public authority)

(ix) costs incurred or contributions for activities implemented during grant agreement suspension (see Article 31)

(x) in-kind contributions by third parties: not applicable

(b) costs or contributions declared under other EU grants (or grants awarded by an EU Member State, non-EU country or other body implementing the EU budget), except for the following cases:

(i) Synergy actions: not applicable

(ii) if the action grant is combined with an operating grant[11] running during the same period and the beneficiary can demonstrate that the operating grant does not cover any (direct or indirect) costs of the action grant

(c) costs or contributions for staff of a national (or regional/local) administration, for activities that are part of the administration's normal activities (i.e. not undertaken only because of the grant)

(d) costs or contributions (especially travel and subsistence) for staff or representatives of EU institutions, bodies or agencies

(e) other :

(i) country restrictions for eligible costs: not applicable

(ii) costs or contributions declared specifically ineligible in the call conditions.

6.4 Consequences of non-compliance

[11] For the definition, see Article 180(2)(b) of EU Financial Regulation 2018/1046: '**operating grant**' means an EU grant to finance "the functioning of a body which has an objective forming part of and supporting an EU policy".

If a beneficiary declares costs or contributions that are ineligible, they will be rejected (see Article 27).

This may also lead to other measures described in Chapter 5.

CHAPTER 4 GRANT IMPLEMENTATION

SECTION 1 CONSORTIUM: BENEFICIARIES, AFFILIATED ENTITIES AND OTHER PARTICIPANTS

ARTICLE 7 — BENEFICIARIES

The beneficiaries, as signatories of the Agreement, are fully responsible towards the granting authority for implementing it and for complying with all its obligations.

They must implement the Agreement to their best abilities, in good faith and in accordance with all the obligations and terms and conditions it sets out.

They must have the appropriate resources to implement the action and implement the action under their own responsibility and in accordance with Article 11. If they rely on affiliated entities or other participants (see Articles 8 and 9), they retain sole responsibility towards the granting authority and the other beneficiaries.

They are jointly responsible for the *technical* implementation of the action. If one of the beneficiaries fails to implement their part of the action, the other beneficiaries must ensure that this part is implemented by someone else (without being entitled to an increase of the maximum grant amount and subject to an amendment; see Article 39). The *financial* responsibility of each beneficiary in case of recoveries is governed by Article 22.

The beneficiaries (and their action) must remain eligible under the EU programme funding the grant for the entire duration of the action. Costs and contributions will be eligible only as long as the beneficiary and the action are eligible.

The **internal roles and responsibilities** of the beneficiaries are divided as follows:

(a) Each beneficiary must:

(i) keep information stored in the Portal Participant Register up to date (see Article 19)

(ii) inform the granting authority (and the other beneficiaries) immediately of any events or circumstances likely to affect significantly or delay the implementation of the action (see Article 19)

(iii) submit to the coordinator in good time:

- the prefinancing guarantees (if required; see Article 23)
- the financial statements and certificates on the financial statements (CFS) (if required; see Articles 21 and 24.2 and Data Sheet, Point 4.3)
- the contribution to the deliverables and technical reports (see Article 21)

- any other documents or information required by the granting authority under the Agreement

(iv) submit via the Portal data and information related to the participation of their affiliated entities.

(b) The coordinator must:

(i) monitor that the action is implemented properly (see Article 11)

(ii) act as the intermediary for all communications between the consortium and the granting authority, unless the Agreement or granting authority specifies otherwise, and in particular:

- submit the prefinancing guarantees to the granting authority (if any)

- request and review any documents or information required and verify their quality and completeness before passing them on to the granting authority

- submit the deliverables and reports to the granting authority

- inform the granting authority about the payments made to the other beneficiaries (report on the distribution of payments; if required, see Articles 22 and 32)

(iii) distribute the payments received from the granting authority to the other beneficiaries without unjustified delay (see Article 22).

The coordinator may not delegate or subcontract the above-mentioned tasks to any other beneficiary or third party (including affiliated entities).

However, coordinators which are public bodies may delegate the tasks set out in Point (b)(ii) last indent and (iii) above to entities with 'authorisation to administer' which they have created or which are controlled by or affiliated to them. In this case, the coordinator retains sole responsibility for the payments and for compliance with the obligations under the Agreement.

Moreover, coordinators which are 'sole beneficiaries'[12] (or similar, such as European research infrastructure consortia (ERICs)) may delegate the tasks set out in Point (b)(i) to (iii) above to one of their members. The coordinator retains sole responsibility for compliance with the obligations under the Agreement.

The beneficiaries must have **internal arrangements** regarding their operation and co-ordination, to ensure that the action is implemented properly.

If required by the granting authority (see Data Sheet, Point 1), these arrangements must be set out in a written **consortium agreement** between the beneficiaries, covering for instance:

- the internal organisation of the consortium

[12] For the definition, see Article 187(2) EU Financial Regulation 2018/1046: "Where several entities satisfy the criteria for being awarded a grant and together form one entity, that entity may be treated as the **sole beneficiary**, including where it is specifically established for the purpose of implementing the action financed by the grant."

- the management of access to the Portal
- different distribution keys for the payments and financial responsibilities in case of recoveries (if any)
- additional rules on rights and obligations related to background and results (see Article 16)
- settlement of internal disputes
- liability, indemnification and confidentiality arrangements between the beneficiaries.

The internal arrangements must not contain any provision contrary to this Agreement.

ARTICLE 8 — AFFILIATED ENTITIES

Not applicable

ARTICLE 9 — OTHER PARTICIPANTS INVOLVED IN THE ACTION

9.1 Associated partners

Not applicable

9.2 Third parties giving in-kind contributions to the action

Other third parties may give in-kind contributions to the action (i.e. personnel, equipment, other goods, works and services, etc. which are free-of-charge) if necessary for the implementation.

Third parties giving in-kind contributions do not implement any action tasks. They may not charge costs or contributions to the action, but the costs for the in-kind contributions are eligible and may be charged by the beneficiaries which use them, under the conditions set out in Article 6. The costs will be included in Annex 2 as part of the beneficiaries' costs.

The third parties and their in-kind contributions should be set out in Annex 1.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the third parties giving in-kind contributions.

9.3 Subcontractors

Subcontractors may participate in the action, if necessary for the implementation.

Subcontractors must implement their action tasks in accordance with Article 11. The costs for the subcontracted tasks (invoiced price from the subcontractor) are eligible and may be charged by the beneficiaries, under the conditions set out in Article 6. The costs will be included in Annex 2 as part of the beneficiaries' costs.

The beneficiaries must ensure that their contractual obligations under Articles 11 (proper implementation), 12 (conflict of interest), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping) also apply to the subcontractors.

The beneficiaries must ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the subcontractors.

9.4 Recipients of financial support to third parties

If the action includes providing financial support to third parties (e.g. grants, prizes or similar forms of support), the beneficiaries must ensure that their contractual obligations under Articles 12 (conflict of interest), 13 (confidentiality and security), 14 (ethics), 17.2 (visibility), 18 (specific rules for carrying out action), 19 (information) and 20 (record-keeping)also apply to the third parties receiving the support (recipients).

The beneficiaries must also ensure that the bodies mentioned in Article 25 (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.) can exercise their rights also towards the recipients.

ARTICLE 10 — PARTICIPANTS WITH SPECIAL STATUS

10.1 Non-EU participants

Participants which are established in a non-EU country (if any) undertake to comply with their obligations under the Agreement and:

- to respect general principles (including fundamental rights, values and ethical principles, environmental and labour standards, rules on classified information, intellectual property rights, visibility of funding and protection of personal data)
- for the submission of certificates under Article 24: to use qualified external auditors which are independent and comply with comparable standards as those set out in EU Directive 2006/43/EC[13]
- for the controls under Article 25: to allow for checks, reviews, audits and investigations (including on-the-spot checks, visits and inspections) by the bodies mentioned in that Article (e.g. granting authority, OLAF, Court of Auditors (ECA), etc.).

Special rules on dispute settlement apply (see Data Sheet, Point 5).

10.2 Participants which are international organisations

Participants which are international organisations (IOs; if any) undertake to comply with their obligations under the Agreement and:

- to respect general principles (including fundamental rights, values and ethical principles, environmental and labour standards, rules on classified information, intellectual property rights, visibility of funding and protection of personal data)
- for the submission of certificates under Article 24: to use either independent public officers or external auditors which comply with comparable standards as those set out in EU Directive 2006/43/EC

[13] Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts or similar national regulations (OJ L 157, 9.6.2006, p. 87).

- for the controls under Article 25: to allow for the checks, reviews, audits and investigations by the bodies mentioned in that Article, taking into account the specific agreements concluded by them and the EU (if any).

For such participants, nothing in the Agreement will be interpreted as a waiver of their privileges or immunities, as accorded by their constituent documents or international law.

Special rules on applicable law and dispute settlement apply (see Article 43 and Data Sheet, Point 5).

10.3 Pillar-assessed participants

Pillar-assessed participants (if any) may rely on their own systems, rules and procedures, in so far as they have been positively assessed and do not call into question the decision awarding the grant or breach the principle of equal treatment of applicants or beneficiaries.

'Pillar-assessment' means a review by the European Commission on the systems, rules and procedures which participants use for managing EU grants (in particular internal control system, accounting system, external audits, financing of third parties, rules on recovery and exclusion, information on recipients and protection of personal data; see Article 154 EU Financial Regulation 2018/1046).

Participants with a positive pillar assessment may rely on their own systems, rules and procedures, in particular for:

- record-keeping (Article 20): may be done in accordance with internal standards, rules and procedures

- currency conversion for financial statements (Article 21): may be done in accordance with usual accounting practices

- guarantees (Article 23): for public law bodies, prefinancing guarantees are not needed

- certificates (Article 24):

    - certificates on the financial statements (CFS): may be provided by their regular internal or external auditors and in accordance with their internal financial regulations and procedures

    - certificates on usual accounting practices (CoMUC): are not needed if those practices are covered by an ex-ante assessment

and use the following specific rules, for:

- recoveries (Article 22): in case of financial support to third parties, there will be no recovery if the participant has done everything possible to retrieve the undue amounts from the third party receiving the support (including legal proceedings) and non-recovery is not due to an error or negligence on its part

- checks, reviews, audits and investigations by the EU (Article 25): will be conducted taking into account the rules and procedures specifically agreed between them and the framework agreement (if any)

- impact evaluation (Article 26): will be conducted in accordance with the participant's internal rules and procedures and the framework agreement (if any)

- grant agreement suspension (Article 31): certain costs incurred during grant suspension are eligible (notably, minimum costs necessary for a possible resumption of the action and costs relating to contracts which were entered into before the pre-information letter was received and which could not reasonably be suspended, reallocated or terminated on legal grounds)

- grant agreement termination (Article 32): the final grant amount and final payment will be calculated taking into account also costs relating to contracts due for execution only after termination takes effect, if the contract was entered into before the pre-information letter was received and could not reasonably be terminated on legal grounds

- liability for damages (Article 33.2): the granting authority must be compensated for damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement only if the damage is due to an infringement of the participant's internal rules and procedures or due to a violation of third parties' rights by the participant or one of its employees or individual for whom the employees are responsible.

Participants whose pillar assessment covers procurement and granting procedures may also do purchases, subcontracting and financial support to third parties (Article 6.2) in accordance with their internal rules and procedures for purchases, subcontracting and financial support.

Participants whose pillar assessment covers data protection rules may rely on their internal standards, rules and procedures for data protection (Article 15).

The participants may however not rely on provisions which would breach the principle of equal treatment of applicants or beneficiaries or call into question the decision awarding the grant, such as in particular:

- eligibility (Article 6)

- consortium roles and set-up (Articles 7-9)

- security and ethics (Articles 13, 14)

- IPR (including background and results, access rights and rights of use), communication, dissemination and visibility (Articles 16 and 17)

- information obligation (Article 19)

- payment, reporting and amendments (Articles 21, 22 and 39)

- rejections, reductions, suspensions and terminations (Articles 27, 28, 29-32)

If the pillar assessment was subject to remedial measures, reliance on the internal systems, rules and procedures is subject to compliance with those remedial measures.

Participants whose assessment has not yet been updated to cover (the new rules on) data protection may rely on their internal systems, rules and procedures, provided that they ensure that personal data is:

- processed lawfully, fairly and in a transparent manner in relation to the data subject

- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes
- adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed
- accurate and, where necessary, kept up to date
- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the data is processed and
- processed in a manner that ensures appropriate security of the personal data.

Participants must inform the coordinator without delay of any changes to the systems, rules and procedures that were part of the pillar assessment. The coordinator must immediately inform the granting authority.

Pillar-assessed participants that have also concluded a framework agreement with the EU, may moreover — under the same conditions as those above (i.e. not call into question the decision awarding the grant or breach the principle of equal treatment of applicants or beneficiaries) — rely on the provisions set out in that framework agreement.

SECTION 2 RULES FOR CARRYING OUT THE ACTION

ARTICLE 11 — PROPER IMPLEMENTATION OF THE ACTION

11.1 Obligation to properly implement the action

The beneficiaries must implement the action as described in Annex 1 and in compliance with the provisions of the Agreement, the call conditions and all legal obligations under applicable EU, international and national law.

11.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 12 — CONFLICT OF INTERESTS

12.1 Conflict of interests

The beneficiaries must take all measures to prevent any situation where the impartial and objective implementation of the Agreement could be compromised for reasons involving family, emotional life, political or national affinity, economic interest or any other direct or indirect interest (‘conflict of interests’).

They must formally notify the granting authority without delay of any situation constituting or likely to lead to a conflict of interests and immediately take all the necessary steps to rectify this situation.

The granting authority may verify that the measures taken are appropriate and may require additional measures to be taken by a specified deadline.

12.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28) and the grant or the beneficiary may be terminated (see Article 32).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 13 — CONFIDENTIALITY AND SECURITY

13.1 Sensitive information

The parties must keep confidential any data, documents or other material (in any form) that is identified as sensitive in writing ('sensitive information') — during the implementation of the action and for at least until the time-limit set out in the Data Sheet (see Point 6).

If a beneficiary requests, the granting authority may agree to keep such information confidential for a longer period.

Unless otherwise agreed between the parties, they may use sensitive information only to implement the Agreement.

The beneficiaries may disclose sensitive information to their personnel or other participants involved in the action only if they:

(a) need to know it in order to implement the Agreement and

(b) are bound by an obligation of confidentiality.

The granting authority may disclose sensitive information to its staff and to other EU institutions and bodies.

It may moreover disclose sensitive information to third parties, if:

(a) this is necessary to implement the Agreement or safeguard the EU financial interests and

(b) the recipients of the information are bound by an obligation of confidentiality.

The confidentiality obligations no longer apply if:

(a) the disclosing party agrees to release the other party

(b) the information becomes publicly available, without breaching any confidentiality obligation

(c) the disclosure of the sensitive information is required by EU, international or national law.

Specific confidentiality rules (if any) are set out in Annex 5.

13.2 Classified information

The parties must handle classified information in accordance with the applicable EU, international or national law on classified information (in particular, Decision 2015/444[14] and its implementing rules).

Deliverables which contain classified information must be submitted according to special procedures agreed with the granting authority.

Action tasks involving classified information may be subcontracted only after explicit approval (in writing) from the granting authority.

Classified information may not be disclosed to any third party (including participants involved in the action implementation) without prior explicit written approval from the granting authority.

Specific security rules (if any) are set out in Annex 5.

13.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 14 — ETHICS AND VALUES

14.1 Ethics

The action must be carried out in line with the highest ethical standards and the applicable EU, international and national law on ethical principles.

Specific ethics rules (if any) are set out in Annex 5.

14.2 Values

The beneficiaries must commit to and ensure the respect of basic EU values (such as respect for human dignity, freedom, democracy, equality, the rule of law and human rights, including the rights of minorities).

Specific rules on values (if any) are set out in Annex 5.

14.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 15 — DATA PROTECTION

15.1 Data processing by the granting authority

[14] Commission Decision 2015/444/EC, Euratom of 13 March 2015 on the security rules for protecting EU classified information (OJ L 72, 17.3.2015, p. 53).

Any personal data under the Agreement will be processed under the responsibility of the data controller of the granting authority in accordance with and for the purposes set out in the Portal Privacy Statement.

For grants where the granting authority is the European Commission, an EU regulatory or executive agency, joint undertaking or other EU body, the processing will be subject to Regulation 2018/1725[15].

15.2 Data processing by the beneficiaries

The beneficiaries must process personal data under the Agreement in compliance with the applicable EU, international and national law on data protection (in particular, Regulation 2016/679[16]).

They must ensure that personal data is:

- processed lawfully, fairly and in a transparent manner in relation to the data subjects
- collected for specified, explicit and legitimate purposes and not further processed in a manner that is incompatible with those purposes
- adequate, relevant and limited to what is necessary in relation to the purposes for which they are processed
- accurate and, where necessary, kept up to date
- kept in a form which permits identification of data subjects for no longer than is necessary for the purposes for which the data is processed and
- processed in a manner that ensures appropriate security of the data.

The beneficiaries may grant their personnel access to personal data only if it is strictly necessary for implementing, managing and monitoring the Agreement. The beneficiaries must ensure that the personnel is under a confidentiality obligation.

The beneficiaries must inform the persons whose data are transferred to the granting authority and provide them with the Portal Privacy Statement.

15.3 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 16 — INTELLECTUAL PROPERTY RIGHTS (IPR) — BACKGROUND AND RESULTS —ACCESS RIGHTS AND RIGHTS OF USE

[15] Regulation (EU) 2018/1725 of the European Parliament and of the Council of 23 October 2018 on the protection of natural persons with regard to the processing of personal data by the Union institutions, bodies, offices and agencies and on the free movement of such data, and repealing Regulation (EC) No 45/2001 and Decision No 1247/2002/EC (OJ L 295, 21.11.2018, p. 39).

[16] Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (‘GDPR’) (OJ L 119, 4.5.2016, p. 1).

16.1 Background and access rights to background

The beneficiaries must give each other and the other participants access to the background identified as needed for implementing the action, subject to any specific rules in Annex 5.

'Background' means any data, know-how or information — whatever its form or nature (tangible or intangible), including any rights such as intellectual property rights — that is:

(a) held by the beneficiaries before they acceded to the Agreement and

(b) needed to implement the action or exploit the results.

If background is subject to rights of a third party, the beneficiary concerned must ensure that it is able to comply with its obligations under the Agreement.

16.2 Ownership of results

The granting authority does not obtain ownership of the results produced under the action.

'Results' means any tangible or intangible effect of the action, such as data, know-how or information, whatever its form or nature, whether or not it can be protected, as well as any rights attached to it, including intellectual property rights.

16.3 Rights of use of the granting authority on materials, documents and information received for policy, information, communication, dissemination and publicity purposes

The granting authority has the right to use non-sensitive information relating to the action and materials and documents received from the beneficiaries (notably summaries for publication, deliverables, as well as any other material, such as pictures or audio-visual material, in paper or electronic form) for policy, information, communication, dissemination and publicity purposes — during the action or afterwards.

The right to use the beneficiaries' materials, documents and information is granted in the form of a royalty-free, non-exclusive and irrevocable licence, which includes the following rights:

(a) **use for its own purposes** (in particular, making them available to persons working for the granting authority or any other EU service (including institutions, bodies, offices, agencies, etc.) or EU Member State institution or body; copying or reproducing them in whole or in part, in unlimited numbers; and communication through press information services)

(b) **distribution to the public** (in particular, publication as hard copies and in electronic or digital format, publication on the internet, as a downloadable or non-downloadable file, broadcasting by any channel, public display or presentation, communicating through press information services, or inclusion in widely accessible databases or indexes)

(c) **editing or redrafting** (including shortening, summarising, inserting other elements (e.g. meta-data, legends, other graphic, visual, audio or text elements), extracting parts (e.g. audio or video files), dividing into parts, use in a compilation)

(d) **translation**

(e) **storage** in paper, electronic or other form

(f) **archiving**, in line with applicable document-management rules

(g) the right to authorise **third parties** to act on its behalf or sub-license to third parties the modes of use set out in Points (b), (c), (d) and (f), if needed for the information, communication and publicity activity of the granting authority

(h) **processing**, analysing, aggregating the materials, documents and information received and **producing derivative works**.

The rights of use are granted for the whole duration of the industrial or intellectual property rights concerned.

If materials or documents are subject to moral rights or third party rights (including intellectual property rights or rights of natural persons on their image and voice), the beneficiaries must ensure that they comply with their obligations under this Agreement (in particular, by obtaining the necessary licences and authorisations from the rights holders concerned).

Where applicable, the granting authority will insert the following information:

"© – [year] – [name of the copyright owner]. All rights reserved. Licensed to the [name of granting authority] under conditions."

16.4 Specific rules on IPR, results and background

Specific rules regarding intellectual property rights, results and background (if any) are set out in Annex 5.

16.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such a breach may also lead to other measures described in Chapter 5.

ARTICLE 17 — COMMUNICATION, DISSEMINATION AND VISIBILITY

17.1 Communication — Dissemination — Promoting the action

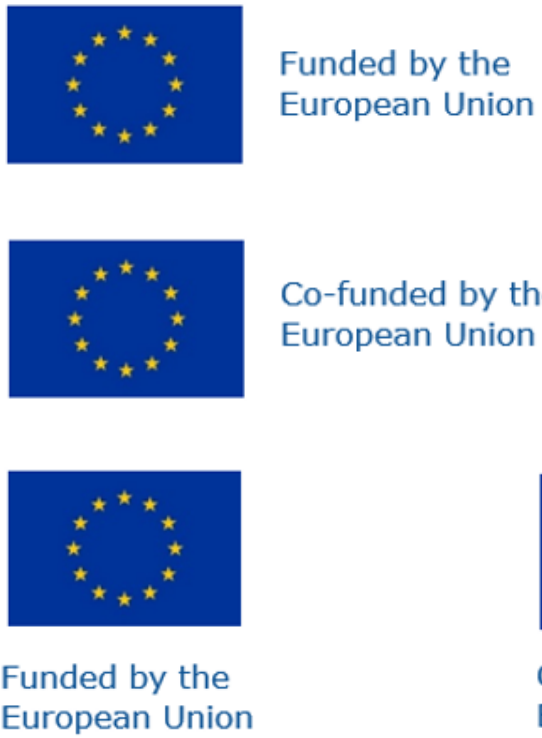
Unless otherwise agreed with the granting authority, the beneficiaries must promote the action and its results by providing targeted information to multiple audiences (including the media and the public), in accordance with Annex 1 and in a strategic, coherent and effective manner.

Before engaging in a communication or dissemination activity expected to have a major media impact, the beneficiaries must inform the granting authority.

17.2 Visibility — European flag and funding statement

Unless otherwise agreed with the granting authority, communication activities of the beneficiaries related to the action (including media relations, conferences, seminars, information material, such as brochures, leaflets, posters, presentations, etc., in electronic form, via traditional or social media, etc.), dissemination activities and any infrastructure, equipment, vehicles, supplies or major result funded

by the grant must acknowledge EU support and display the European flag (emblem) and funding statement (translated into local languages, where appropriate):



The emblem must remain distinct and separate and cannot be modified by adding other visual marks, brands or text.

Apart from the emblem, no other visual identity or logo may be used to highlight the EU support.

When displayed in association with other logos (e.g. of beneficiaries or sponsors), the emblem must be displayed at least as prominently and visibly as the other logos.

For the purposes of their obligations under this Article, the beneficiaries may use the emblem without first obtaining approval from the granting authority. This does not, however, give them the right to exclusive use. Moreover, they may not appropriate the emblem or any similar trademark or logo, either by registration or by any other means.

17.3 Quality of information — Disclaimer

Any communication or dissemination activity related to the action must use factually accurate information.

Moreover, it must indicate the following disclaimer (translated into local languages where appropriate):

> "Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or [name of the granting authority]. Neither the European Union nor the granting authority can be held responsible for them."

17.4 Specific communication, dissemination and visibility rules

Specific communication, dissemination and visibility rules (if any) are set out in Annex 5.

17.5 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 18 — SPECIFIC RULES FOR CARRYING OUT THE ACTION

18.1 Specific rules for carrying out the action

Specific rules for implementing the action (if any) are set out in Annex 5.

18.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such a breach may also lead to other measures described in Chapter 5.

SECTION 3 GRANT ADMINISTRATION

ARTICLE 19 — GENERAL INFORMATION OBLIGATIONS

19.1 Information requests

The beneficiaries must provide — during the action or afterwards and in accordance with Article 7 — any information requested in order to verify eligibility of the costs or contributions declared, proper implementation of the action and compliance with the other obligations under the Agreement.

The information provided must be accurate, precise and complete and in the format requested, including electronic format.

19.2 Participant Register data updates

The beneficiaries must keep — at all times, during the action or afterwards — their information stored in the Portal Participant Register up to date, in particular, their name, address, legal representatives, legal form and organisation type.

19.3 Information about events and circumstances which impact the action

The beneficiaries must immediately inform the granting authority (and the other beneficiaries) of any of the following:

(a) **events** which are likely to affect or delay the implementation of the action or affect the EU's financial interests, in particular:

(i) changes in their legal, financial, technical, organisational or ownership situation (including changes linked to one of the exclusion grounds listed in the declaration of honour signed before grant signature)

(ii) linked action information: not applicable

(b) **circumstances** affecting:

(i) the decision to award the grant or

(ii) compliance with requirements under the Agreement.

19.4 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 20 — RECORD-KEEPING

20.1 Keeping records and supporting documents

The beneficiaries must — at least until the time-limit set out in the Data Sheet (see Point 6) — keep records and other supporting documents to prove the proper implementation of the action in line with the accepted standards in the respective field (if any).

In addition, the beneficiaries must — for the same period — keep the following to justify the amounts declared:

(a) for actual costs: adequate records and supporting documents to prove the costs declared (such as contracts, subcontracts, invoices and accounting records); in addition, the beneficiaries' usual accounting and internal control procedures must enable direct reconciliation between the amounts declared, the amounts recorded in their accounts and the amounts stated in the supporting documents

(b) for flat-rate costs and contributions (if any): adequate records and supporting documents to prove the eligibility of the costs or contributions to which the flat-rate is applied

(c) for the following simplified costs and contributions: the beneficiaries do not need to keep specific records on the actual costs incurred, but must keep:

(i) for unit costs and contributions (if any): adequate records and supporting documents to prove the number of units declared

(ii) for lump sum costs and contributions (if any): adequate records and supporting documents to prove proper implementation of the work as described in Annex 1

(iii) for financing not linked to costs (if any): adequate records and supporting documents to prove the achievement of the results or the fulfilment of the conditions as described in Annex 1

(d) for unit, flat-rate and lump sum costs and contributions according to usual cost accounting practices (if any): the beneficiaries must keep any adequate records and supporting documents to prove that their cost accounting practices have been applied in a consistent manner, based on

objective criteria, regardless of the source of funding, and that they comply with the eligibility conditions set out in Articles 6.1 and 6.2.

Moreover, the following is needed for specific budget categories:

(e) for personnel costs: time worked for the beneficiary under the action must be supported by declarations signed monthly by the person and their supervisor, unless another reliable time-record system is in place; the granting authority may accept alternative evidence supporting the time worked for the action declared, if it considers that it offers an adequate level of assurance

(f) additional record-keeping rules: not applicable

The records and supporting documents must be made available upon request (see Article 19) or in the context of checks, reviews, audits or investigations (see Article 25).

If there are on-going checks, reviews, audits, investigations, litigation or other pursuits of claims under the Agreement (including the extension of findings; see Article 25), the beneficiaries must keep these records and other supporting documentation until the end of these procedures.

The beneficiaries must keep the original documents. Digital and digitalised documents are considered originals if they are authorised by the applicable national law. The granting authority may accept non-original documents if they offer a comparable level of assurance.

20.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs or contributions insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 27), and the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 21 — REPORTING

21.1 Continuous reporting

The beneficiaries must continuously report on the progress of the action (e.g. **deliverables, milestones, outputs/outcomes, critical risks, indicators,** etc; if any), in the Portal Continuous Reporting tool and in accordance with the timing and conditions it sets out (as agreed with the granting authority).

Standardised deliverables (e.g. progress reports not linked to payments, reports on cumulative expenditure, special reports, etc; if any) must be submitted using the templates published on the Portal.

21.2 Periodic reporting: Technical reports and financial statements

In addition, the beneficiaries must provide reports to request payments, in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2):

- for additional prefinancings (if any): an **additional prefinancing report**
- for interim payments (if any) and the final payment: a **periodic report**.

The prefinancing and periodic reports include a technical and financial part.

The technical part includes an overview of the action implementation. It must be prepared using the template available in the Portal Periodic Reporting tool.

The financial part of the additional prefinancing report includes a statement on the use of the previous prefinancing payment.

The financial part of the periodic report includes:

- the financial statements (individual and consolidated; for all beneficiaries/affiliated entities)
- the explanation on the use of resources (or detailed cost reporting table, if required)
- the certificates on the financial statements (CFS) (if required; see Article 24.2 and Data Sheet, Point 4.3).

The **financial statements** must detail the eligible costs and contributions for each budget category and, for the final payment, also the revenues for the action (see Articles 6 and 22).

All eligible costs and contributions incurred should be declared, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Amounts that are not declared in the individual financial statements will not be taken into account by the granting authority.

By signing the financial statements (directly in the Portal Periodic Reporting tool), the beneficiaries confirm that:

- the information provided is complete, reliable and true
- the costs and contributions declared are eligible (see Article 6)
- the costs and contributions can be substantiated by adequate records and supporting documents (see Article 20) that will be produced upon request (see Article 19) or in the context of checks, reviews, audits and investigations (see Article 25)
- for the final periodic report: all the revenues have been declared (if required; see Article 22).

Beneficiaries will have to submit also the financial statements of their affiliated entities (if any). In case of recoveries (see Article 22), beneficiaries will be held responsible also for the financial statements of their affiliated entities.

21.3 Currency for financial statements and conversion into euros

The financial statements must be drafted in euro.

Beneficiaries with general accounts established in a currency other than the euro must convert the costs recorded in their accounts into euro, at the average of the daily exchange rates published in the C series of the *Official Journal of the European Union* (ECB website), calculated over the corresponding reporting period.

If no daily euro exchange rate is published in the *Official Journal* for the currency in question, they must be converted at the average of the monthly accounting exchange rates published on the European Commission website (InforEuro), calculated over the corresponding reporting period.

Beneficiaries with general accounts in euro must convert costs incurred in another currency into euro according to their usual accounting practices.

21.4 Reporting language

The reporting must be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

21.5 Consequences of non-compliance

If a report submitted does not comply with this Article, the granting authority may suspend the payment deadline (see Article 29) and apply other measures described in Chapter 5.

If the coordinator breaches its reporting obligations, the granting authority may terminate the grant or the coordinator's participation (see Article 32) or apply other measures described in Chapter 5.

ARTICLE 22 — PAYMENTS AND RECOVERIES — CALCULATION OF AMOUNTS DUE

22.1 Payments and payment arrangements

Payments will be made in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2).

They will be made in euro to the bank account indicated by the coordinator (see Data Sheet, Point 4.2) and must be distributed without unjustified delay (restrictions may apply to distribution of the initial prefinancing payment; see Data Sheet, Point 4.2).

Payments to this bank account will discharge the granting authority from its payment obligation.

The cost of payment transfers will be borne as follows:

- the granting authority bears the cost of transfers charged by its bank
- the beneficiary bears the cost of transfers charged by its bank
- the party causing a repetition of a transfer bears all costs of the repeated transfer.

Payments by the granting authority will be considered to have been carried out on the date when they are debited to its account.

22.2 Recoveries

Recoveries will be made, if — at beneficiary termination, final payment or afterwards — it turns out that the granting authority has paid too much and needs to recover the amounts undue.

Each beneficiary's financial responsibility in case of recovery is in principle limited to their own debt and undue amounts of their affiliated entities.

In case of enforced recoveries (see Article 22.4), affiliated entities will be held liable for repaying debts of their beneficiaries, if required by the granting authority (see Data Sheet, Point 4.4).

22.3 Amounts due

22.3.1 Prefinancing payments

The aim of the prefinancing is to provide the beneficiaries with a float.

It remains the property of the EU until the final payment.

For **initial prefinancings** (if any), the amount due, schedule and modalities are set out in the Data Sheet (see Point 4.2).

For **additional prefinancings** (if any), the amount due, schedule and modalities are also set out in the Data Sheet (see Point 4.2). However, if the statement on the use of the previous prefinancing payment shows that less than 70% was used, the amount set out in the Data Sheet will be reduced by the difference between the 70% threshold and the amount used.

The contribution to the Mutual Insurance Mechanism will be retained from the prefinancing payments (at the rate and in accordance with the modalities set out in the Data Sheet, see Point 4.2) and transferred to the Mechanism.

Prefinancing payments (or parts of them) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

22.3.2 Amount due at beneficiary termination — Recovery

In case of beneficiary termination, the granting authority will determine the provisional amount due for the beneficiary concerned. Payments (if any) will be made with the next interim or final payment.

The **amount due** will be calculated in the following step:

Step 1 — Calculation of the total accepted EU contribution

Step 1 — Calculation of the total accepted EU contribution

The granting authority will first calculate the 'accepted EU contribution' for the beneficiary for all reporting periods, by calculating the 'maximum EU contribution to costs' (applying the funding rate to the accepted costs of the beneficiary), taking into account requests for a lower contribution to costs and CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions (if any). The resulting amount is the 'total accepted EU contribution' for the beneficiary.

The **balance** is then calculated by deducting the payments received (if any; see report on the distribution of payments in Article 32), from the total accepted EU contribution:

{total accepted EU contribution for the beneficiary

minus

{prefinancing and interim payments received (if any)}}.

If the balance is **positive**, the amount will be included in the next interim or final payment to the consortium.

If the balance is **negative**, it will be **recovered** in accordance with the following procedure:

The granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to recover, the amount due, the amount to be recovered and the reasons why and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received), it will confirm the amount to be recovered and ask this amount to be paid to the coordinator (**confirmation letter**).

If payment is not made to the coordinator by the date specified in the confirmation letter, the granting authority may call on the Mutual Insurance Mechanism to intervene, if continuation of the action is guaranteed and the conditions set out in the rules governing the Mechanism are met.

In this case, it will send a **beneficiary recovery letter**, together with a **debit note** with the terms and date for payment.

The debit note for the beneficiary will include the amount calculated for the affiliated entities which also had to end their participation (if any).

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

The amounts will later on also be taken into account for the next interim or final payment.

22.3.3 Interim payments

Interim payments reimburse the eligible costs and contributions claimed for the implementation of the action during the reporting periods (if any).

Interim payments (if any) will be made in accordance with the schedule and modalities set out the Data Sheet (see Point 4.2).

Payment is subject to the approval of the periodic report. Its approval does not imply recognition of compliance, authenticity, completeness or correctness of its content.

The **interim payment** will be calculated by the granting authority in the following steps:

Step 1 — Calculation of the total accepted EU contribution

Step 2 — Limit to the interim payment ceiling

Step 1 — Calculation of the total accepted EU contribution

The granting authority will calculate the 'accepted EU contribution' for the action for the reporting period, by first calculating the 'maximum EU contribution to costs' (applying the funding rate to the accepted costs of each beneficiary), taking into account requests for a lower contribution to costs, and CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions from beneficiary termination (if any). The resulting amount is the 'total accepted EU contribution'.

Step 2 — Limit to the interim payment ceiling

The resulting amount is then capped to ensure that the total amount of prefinancing and interim payments (if any) does not exceed the interim payment ceiling set out in the Data Sheet (see Point 4.2).

Interim payments (or parts of them) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

22.3.4 Final payment — Final grant amount — Revenues and Profit — Recovery

The final payment (payment of the balance) reimburses the remaining part of the eligible costs and contributions claimed for the implementation of the action (if any).

The final payment will be made in accordance with the schedule and modalities set out in the Data Sheet (see Point 4.2).

Payment is subject to the approval of the final periodic report. Its approval does not imply recognition of compliance, authenticity, completeness or correctness of its content.

The **final grant amount for the action** will be calculated in the following steps:

Step 1 — Calculation of the total accepted EU contribution

Step 2 — Limit to the maximum grant amount

Step 3 — Reduction due to the no-profit rule

Step 1 — Calculation of the total accepted EU contribution

The granting authority will first calculate the 'accepted EU contribution' for the action for all reporting periods, by calculating the 'maximum EU contribution to costs' (applying the funding rate to the total accepted costs of each beneficiary), taking into account requests for a lower contribution to costs, CFS threshold cappings (if any; see Article 24.5) and adding the contributions (accepted unit, flat-rate or lump sum contributions and financing not linked to costs, if any).

After that, the granting authority will take into account grant reductions (if any). The resulting amount is the 'total accepted EU contribution'.

Step 2 — Limit to the maximum grant amount

If the resulting amount is higher than the maximum grant amount set out in Article 5.2, it will be limited to the latter.

Step 3 — Reduction due to the no-profit rule

If the no-profit rule is provided for in the Data Sheet (see Point 4.2), the grant must not produce a profit (i.e. surplus of the amount obtained following Step 2 plus the action's revenues, over the eligible costs and contributions approved by the granting authority).

'Revenue' is all income generated by the action, during its duration (see Article 4), for beneficiaries that are profit legal entities (— with the exception of income generated by the exploitation of results, which are not considered as revenues).

If there is a profit, it will be deducted in proportion to the final rate of reimbursement of the eligible costs approved by the granting authority (as compared to the amount calculated following Steps 1 and 2 minus the contributions).

The **balance** (final payment) is then calculated by deducting the total amount of prefinancing and interim payments already made (if any), from the final grant amount:

{final grant amount

minus

{prefinancing and interim payments made (if any)}}.

If the balance is **positive**, it will be **paid** to the coordinator.

The amount retained for the Mutual Insurance Mechanism (see above) will be released and **paid** to the coordinator (in accordance with the rules governing the Mechanism).

The final payment (or part of it) may be offset (without the beneficiaries' consent) against amounts owed by a beneficiary to the granting authority — up to the amount due to that beneficiary.

For grants where the granting authority is the European Commission or an EU executive agency, offsetting may also be done against amounts owed to other Commission services or executive agencies.

Payments will not be made if the payment deadline or payments are suspended (see Articles 29 and 30).

If — despite the release of the Mutual Insurance Mechanism contribution — the balance is **negative**, it will be **recovered** in accordance with the following procedure:

The granting authority will send a **pre-information letter** to the coordinator:

- formally notifying the intention to recover, the final grant amount, the amount to be recovered and the reasons why

- requesting a report on the distribution of payments to the beneficiaries within 30 days of receiving notification and

- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received) and the coordinator has submitted the report on the distribution of payments, it will calculate the **share of the debt per beneficiary**, by:

(a) identifying the beneficiaries for which the amount calculated as follows is negative:

{{{total accepted EU contribution for the beneficiary

divided by

total accepted EU contribution for the action}

multiplied by

final grant amount for the action},

minus

{prefinancing and interim payments received by the beneficiary (if any)}}

and

(b) dividing the debt:

{{amount calculated according to point (a) for the beneficiary concerned

divided by

the sum of the amounts calculated according to point (a) for all the beneficiaries identified according to point (a)}

multiplied by

the amount to be recovered}.

and confirm the amount to be recovered from each beneficiary concerned (**confirmation letter**), together with **debit notes** with the terms and date for payment.

The debit notes for beneficiaries will include the amounts calculated for their affiliated entities (if any).

If the coordinator has not submitted the report on the distribution of payments, the granting authority will **recover** the full amount from the coordinator (**confirmation letter** and **debit note** with the terms and date for payment).

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

22.3.5 Audit implementation after final payment — Revised final grant amount — Recovery

If — after the final payment (in particular, after checks, reviews, audits or investigations; see Article 25) — the granting authority rejects costs or contributions (see Article 27) or reduces the grant (see Article 28), it will calculate the **revised final grant amount** for the beneficiary concerned.

The **beneficiary revised final grant amount** will be calculated in the following step:

Step 1 — Calculation of the revised total accepted EU contribution

Step 1 — Calculation of the revised total accepted EU contribution

The granting authority will first calculate the 'revised accepted EU contribution' for the beneficiary, by calculating the 'revised accepted costs' and 'revised accepted contributions'.

After that, it will take into account grant reductions (if any). The resulting 'revised total accepted EU contribution' is the beneficiary revised final grant amount.

If the revised final grant amount is lower than the beneficiary's final grant amount (i.e. its share in the final grant amount for the action), it will be **recovered** in accordance with the following procedure:

The **beneficiary final grant amount** (i.e. share in the final grant amount for the action) is calculated as follows:

{{total accepted EU contribution for the beneficiary

divided by

total accepted EU contribution for the action}

multiplied by

final grant amount for the action}.

The granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to recover, the amount to be recovered and the reasons why and
- requesting observations within 30 days of receiving notification.

If no observations are submitted (or the granting authority decides to pursue recovery despite the observations it has received), it will confirm the amount to be recovered (**confirmation letter**), together with a **debit note** with the terms and the date for payment.

Recoveries against affiliated entities (if any) will be handled through their beneficiaries.

If payment is not made by the date specified in the debit note, the granting authority will **enforce recovery** in accordance with Article 22.4.

22.4 Enforced recovery

If payment is not made by the date specified in the debit note, the amount due will be recovered:

(a) by offsetting the amount — without the coordinator or beneficiary's consent — against any amounts owed to the coordinator or beneficiary by the granting authority.

In exceptional circumstances, to safeguard the EU financial interests, the amount may be offset before the payment date specified in the debit note.

For grants where the granting authority is the European Commission or an EU executive

agency, debts may also be offset against amounts owed by other Commission services or executive agencies.

(b) financial guarantee(s): not applicable

(c) joint and several liability of beneficiaries: not applicable

(d) by holding affiliated entities jointly and severally liable (if any, see Data Sheet, Point 4.4)

(e) by taking legal action (see Article 43) or, provided that the granting authority is the European Commission or an EU executive agency, by adopting an enforceable decision under Article 299 of the Treaty on the Functioning of the EU (TFEU) and Article 100(2) of EU Financial Regulation 2018/1046.

If the Mutual Insurance Mechanism was called on by the granting authority to intervene, recovery will be continued in the name of the Mutual Insurance Mechanism. If two debit notes were sent, the second one (in the name of the Mutual Insurance Mechanism) will be considered to replace the first one (in the name of the granting authority). Where the MIM intervened, offsetting, enforceable decisions or any other of the above-mentioned forms of enforced recovery may be used mutatis mutandis.

The amount to be recovered will be increased by **late-payment interest** at the rate set out in Article 22.5, from the day following the payment date in the debit note, up to and including the date the full payment is received.

Partial payments will be first credited against expenses, charges and late-payment interest and then against the principal.

Bank charges incurred in the recovery process will be borne by the beneficiary, unless Directive 2015/2366[17] applies.

For grants where the granting authority is an EU executive agency, enforced recovery by offsetting or enforceable decision will be done by the services of the European Commission (see also Article 43).

22.5 Consequences of non-compliance

22.5.1 If the granting authority does not pay within the payment deadlines (see above), the beneficiaries are entitled to **late-payment interest** at the rate applied by the European Central Bank (ECB) for its main refinancing operations in euros (‘reference rate’), plus the rate specified in the Data Sheet (Point 4.2). The reference rate is the rate in force on the first day of the month in which the payment deadline expires, as published in the C series of the *Official Journal of the European Union*.

If the late-payment interest is lower than or equal to EUR 200, it will be paid to the coordinator only on request submitted within two months of receiving the late payment.

Late-payment interest is not due if all beneficiaries are EU Member States (including regional and local government authorities or other public bodies acting on behalf of a Member State for the purpose of this Agreement).

[17] Directive (EU) 2015/2366 of the European Parliament and of the Council of 25 November 2015 on payment services in the internal market, amending Directives 2002/65/EC, 2009/110/EC and 2013/36/EU and Regulation (EU) No 1093/2010, and repealing Directive 2007/64/EC (OJ L 337, 23.12.2015, p. 35).

If payments or the payment deadline are suspended (see Articles 29 and 30), payment will not be considered as late.

Late-payment interest covers the period running from the day following the due date for payment (see above), up to and including the date of payment.

Late-payment interest is not considered for the purposes of calculating the final grant amount.

22.5.2 If the coordinator breaches any of its obligations under this Article, the grant may be reduced (see Article 28) and the grant or the coordinator may be terminated (see Article 32).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 23 — GUARANTEES

Not applicable

ARTICLE 24 — CERTIFICATES

24.1 Operational verification report (OVR)

Not applicable

24.2 Certificate on the financial statements (CFS)

If required by the granting authority (see Data Sheet, Point 4.3), the beneficiaries must provide certificates on their financial statements (CFS), in accordance with the schedule, threshold and conditions set out in the Data Sheet.

The coordinator must submit them as part of the periodic report (see Article 21).

The certificates must be drawn up using the template published on the Portal, cover the costs declared on the basis of actual costs and costs according to usual cost accounting practices (if any), and fulfil the following conditions:

(a) be provided by a qualified approved external auditor which is independent and complies with Directive 2006/43/EC[18] (or for public bodies: by a competent independent public officer)

(b) the verification must be carried out according to the highest professional standards to ensure that the financial statements comply with the provisions under the Agreement and that the costs declared are eligible.

The certificates will not affect the granting authority's right to carry out its own checks, reviews or audits, nor preclude the European Court of Auditors (ECA), the European Public Prosecutor’s Office (EPPO) or the European Anti-Fraud Office (OLAF) from using their prerogatives for audits and investigations under the Agreement (see Article 25).

If the costs (or a part of them) were already audited by the granting authority, these costs do not need to be covered by the certificate and will not be counted for calculating the threshold (if any).

[18] Directive 2006/43/EC of the European Parliament and of the Council of 17 May 2006 on statutory audits of annual accounts and consolidated accounts or similar national regulations (OJ L 157, 9.6.2006, p. 87).

24.3 Certificate on the compliance of usual cost accounting practices (CoMUC)

Not applicable

24.4 Systems and process audit (SPA)

Beneficiaries which:

- use unit, flat rate or lump sum costs or contributions according to documented (i.e. formally approved and in writing) usual costs accounting practices (if any) or
- have formalised documentation on the systems and processes for calculating their costs and contributions (i.e. formally approved and in writing), have participated in at least 150 actions under Horizon 2020 or the Euratom Research and Training Programme (2014-2018 or 2019-2020) and participate in at least 3 ongoing actions under Horizon Europe or the Euratom Research and Training Programme (2021-2025 or 2026-2027)

may apply to the granting authority for a systems and process audit (SPA).

This audit will be carried out as follows:

Step 1 – Application by the beneficiary.

Step 2 – If the application is accepted, the granting authority will carry out the systems and process audit, complemented by an audit of transactions (on a sample of the beneficiary's Horizon Europe or the Euratom Research and Training Programme financial statements).

Step 3 – The audit result will take the form of a risk assessment classification for the beneficiary: low, medium or high.

Low-risk beneficiaries will benefit from less (or less in-depth) ex-post audits (see Article 25) and a higher threshold for submitting certificates on the financial statements (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3).

24.5 Consequences of non-compliance

If a beneficiary does not submit a certificate on the financial statements (CFS) or the certificate is rejected, the accepted EU contribution to costs will be capped to reflect the CFS threshold.

If a beneficiary breaches any of its other obligations under this Article, the granting authority may apply the measures described in Chapter 5.

ARTICLE 25 — CHECKS, REVIEWS, AUDITS AND INVESTIGATIONS — EXTENSION OF FINDINGS

25.1 Granting authority checks, reviews and audits

25.1.1 Internal checks

The granting authority may — during the action or afterwards — check the proper implementation of the action and compliance with the obligations under the Agreement, including assessing costs and contributions, deliverables and reports.

25.1.2 Project reviews

The granting authority may carry out reviews on the proper implementation of the action and compliance with the obligations under the Agreement (general project reviews or specific issues reviews).

Such project reviews may be started during the implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the coordinator or beneficiary concerned and will be considered to start on the date of the notification.

If needed, the granting authority may be assisted by independent, outside experts. If it uses outside experts, the coordinator or beneficiary concerned will be informed and have the right to object on grounds of commercial confidentiality or conflict of interest.

The coordinator or beneficiary concerned must cooperate diligently and provide — within the deadline requested — any information and data in addition to deliverables and reports already submitted (including information on the use of resources). The granting authority may request beneficiaries to provide such information to it directly. Sensitive information and documents will be treated in accordance with Article 13.

The coordinator or beneficiary concerned may be requested to participate in meetings, including with the outside experts.

For **on-the-spot visits**, the beneficiary concerned must allow access to sites and premises (including to the outside experts) and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the review findings, a **project review report** will be drawn up.

The granting authority will formally notify the project review report to the coordinator or beneficiary concerned, which has 30 days from receiving notification to make observations.

Project reviews (including project review reports) will be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

25.1.3 Audits

The granting authority may carry out audits on the proper implementation of the action and compliance with the obligations under the Agreement.

Such audits may be started during the implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the beneficiary concerned and will be considered to start on the date of the notification.

The granting authority may use its own audit service, delegate audits to a centralised service or use external audit firms. If it uses an external firm, the beneficiary concerned will be informed and have the right to object on grounds of commercial confidentiality or conflict of interest.

The beneficiary concerned must cooperate diligently and provide — within the deadline requested — any information (including complete accounts, individual salary statements or other personal data)

to verify compliance with the Agreement. Sensitive information and documents will be treated in accordance with Article 13.

For **on-the-spot** visits, the beneficiary concerned must allow access to sites and premises (including for the external audit firm) and must ensure that information requested is readily available.

Information provided must be accurate, precise and complete and in the format requested, including electronic format.

On the basis of the audit findings, a **draft audit report** will be drawn up.

The auditors will formally notify the draft audit report to the beneficiary concerned, which has 30 days from receiving notification to make observations (contradictory audit procedure).

The **final audit report** will take into account observations by the beneficiary concerned and will be formally notified to them.

Audits (including audit reports) will be in the language of the Agreement, unless otherwise agreed with the granting authority (see Data Sheet, Point 4.2).

25.2 European Commission checks, reviews and audits in grants of other granting authorities

Where the granting authority is not the European Commission, the latter has the same rights of checks, reviews and audits as the granting authority.

25.3 Access to records for assessing simplified forms of funding

The beneficiaries must give the European Commission access to their statutory records for the periodic assessment of simplified forms of funding which are used in EU programmes.

25.4 OLAF, EPPO and ECA audits and investigations

The following bodies may also carry out checks, reviews, audits and investigations — during the action or afterwards:

- the European Anti-Fraud Office (OLAF) under Regulations No 883/2013[19] and No 2185/96[20]
- the European Public Prosecutor's Office (EPPO) under Regulation 2017/1939
- the European Court of Auditors (ECA) under Article 287 of the Treaty on the Functioning of the EU (TFEU) and Article 257 of EU Financial Regulation 2018/1046.

If requested by these bodies, the beneficiary concerned must provide full, accurate and complete information in the format requested (including complete accounts, individual salary statements or

[19] Regulation (EU, Euratom) No 883/2013 of the European Parliament and of the Council of 11 September 2013 concerning investigations conducted by the European Anti-Fraud Office (OLAF) and repealing Regulation (EC) No 1073/1999 of the European Parliament and of the Council and Council Regulation (Euratom) No 1074/1999 (OJ L 248, 18/09/2013, p. 1).

[20] Council Regulation (Euratom, EC) No 2185/96 of 11 November 1996 concerning on-the-spot checks and inspections carried out by the Commission in order to protect the European Communities' financial interests against fraud and other irregularities (OJ L 292, 15/11/1996, p. 2).

other personal data, including in electronic format) and allow access to sites and premises for on-the-spot visits or inspections — as provided for under these Regulations.

To this end, the beneficiary concerned must keep all relevant information relating to the action, at least until the time-limit set out in the Data Sheet (Point 6) and, in any case, until any ongoing checks, reviews, audits, investigations, litigation or other pursuits of claims have been concluded.

25.5 Consequences of checks, reviews, audits and investigations — Extension of results of reviews, audits or investigations

25.5.1 Consequences of checks, reviews, audits and investigations in this grant

Findings in checks, reviews, audits or investigations carried out in the context of this grant may lead to rejections (see Article 27), grant reduction (see Article 28) or other measures described in Chapter 5.

Rejections or grant reductions after the final payment will lead to a revised final grant amount (see Article 22).

Findings in checks, reviews, audits or investigations during the action implementation may lead to a request for amendment (see Article 39), to change the description of the action set out in Annex 1.

Checks, reviews, audits or investigations that find systemic or recurrent errors, irregularities, fraud or breach of obligations in any EU grant may also lead to consequences in other EU grants awarded under similar conditions (‘extension to other grants’).

Moreover, findings arising from an OLAF or EPPO investigation may lead to criminal prosecution under national law.

25.5.2 Extension from other grants

Results of checks, reviews, audits or investigations in other grants may be extended to this grant, if:

(a) the beneficiary concerned is found, in other EU grants awarded under similar conditions, to have committed systemic or recurrent errors, irregularities, fraud or breach of obligations that have a material impact on this grant and

(b) those findings are formally notified to the beneficiary concerned — together with the list of grants affected by the findings — within the time-limit for audits set out in the Data Sheet (see Point 6).

The granting authority will formally notify the beneficiary concerned of the intention to extend the findings and the list of grants affected.

If the extension concerns **rejections of costs or contributions**: the notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings

(b) the request to submit revised financial statements for all grants affected

(c) the correction rate for extrapolation, established on the basis of the systemic or recurrent errors, to calculate the amounts to be rejected, if the beneficiary concerned:

(i) considers that the submission of revised financial statements is not possible or practicable or

(ii) does not submit revised financial statements.

If the extension concerns **grant reductions**: the notification will include:

(a) an invitation to submit observations on the list of grants affected by the findings and

(b) the **correction rate for extrapolation**, established on the basis of the systemic or recurrent errors and the principle of proportionality.

The beneficiary concerned has **60 days** from receiving notification to submit observations, revised financial statements or to propose a duly substantiated **alternative correction method/rate**.

On the basis of this, the granting authority will analyse the impact and decide on the implementation (i.e. start rejection or grant reduction procedures, either on the basis of the revised financial statements or the announced/alternative method/rate or a mix of those; see Articles 27 and 28).

25.6 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, costs or contributions insufficiently substantiated will be ineligible (see Article 6) and will be rejected (see Article 27), and the grant may be reduced (see Article 28).

Such breaches may also lead to other measures described in Chapter 5.

ARTICLE 26 — IMPACT EVALUATIONS

26.1 Impact evaluation

The granting authority may carry out impact evaluations of the action, measured against the objectives and indicators of the EU programme funding the grant.

Such evaluations may be started during implementation of the action and until the time-limit set out in the Data Sheet (see Point 6). They will be formally notified to the coordinator or beneficiaries and will be considered to start on the date of the notification.

If needed, the granting authority may be assisted by independent outside experts.

The coordinator or beneficiaries must provide any information relevant to evaluate the impact of the action, including information in electronic format.

26.2 Consequences of non-compliance

If a beneficiary breaches any of its obligations under this Article, the granting authority may apply the measures described in Chapter 5.

CHAPTER 5 CONSEQUENCES OF NON-COMPLIANCE

SECTION 1 REJECTIONS AND GRANT REDUCTION

ARTICLE 27 — REJECTION OF COSTS AND CONTRIBUTIONS

27.1 Conditions

The granting authority will — at beneficiary termination, interim payment, final payment or afterwards — reject any costs or contributions which are ineligible (see Article 6), in particular following checks, reviews, audits or investigations (see Article 25).

The rejection may also be based on the extension of findings from other grants to this grant (see Article 25).

Ineligible costs or contributions will be rejected.

27.2 Procedure

If the rejection does not lead to a recovery, the granting authority will formally notify the coordinator or beneficiary concerned of the rejection, the amounts and the reasons why. The coordinator or beneficiary concerned may — within 30 days of receiving notification — submit observations if it disagrees with the rejection (payment review procedure).

If the rejection leads to a recovery, the granting authority will follow the contradictory procedure with pre-information letter set out in Article 22.

27.3 Effects

If the granting authority rejects costs or contributions, it will deduct them from the costs or contributions declared and then calculate the amount due (and, if needed, make a recovery; see Article 22).

ARTICLE 28 — GRANT REDUCTION

28.1 Conditions

The granting authority may — at beneficiary termination, final payment or afterwards — reduce the grant for a beneficiary, if:

(a) the beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed:

  (i) substantial errors, irregularities or fraud or

  (ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or

(b) the beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants

awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (see Article 25).

The amount of the reduction will be calculated for each beneficiary concerned and proportionate to the seriousness and the duration of the errors, irregularities or fraud or breach of obligations, by applying an individual reduction rate to their accepted EU contribution.

28.2 Procedure

If the grant reduction does not lead to a recovery, the granting authority will formally notify the coordinator or beneficiary concerned of the reduction, the amount to be reduced and the reasons why. The coordinator or beneficiary concerned may — within 30 days of receiving notification — submit observations if it disagrees with the reduction (payment review procedure).

If the grant reduction leads to a recovery, the granting authority will follow the contradictory procedure with pre-information letter set out in Article 22.

28.3 Effects

If the granting authority reduces the grant, it will deduct the reduction and then calculate the amount due (and, if needed, make a recovery; see Article 22).

SECTION 2 SUSPENSION AND TERMINATION

ARTICLE 29 — PAYMENT DEADLINE SUSPENSION

29.1 Conditions

The granting authority may — at any moment — suspend the payment deadline if a payment cannot be processed because:

(a) the required report (see Article 21) has not been submitted or is not complete or additional information is needed

(b) there are doubts about the amount to be paid (e.g. ongoing audit extension procedure, queries about eligibility, need for a grant reduction, etc.) and additional checks, reviews, audits or investigations are necessary, or

(c) there are other issues affecting the EU financial interests.

29.2 Procedure

The granting authority will formally notify the coordinator of the suspension and the reasons why.

The suspension will **take effect** the day the notification is sent.

If the conditions for suspending the payment deadline are no longer met, the suspension will be **lifted** — and the remaining time to pay (see Data Sheet, Point 4.2) will resume.

If the suspension exceeds two months, the coordinator may request the granting authority to confirm if the suspension will continue.

If the payment deadline has been suspended due to the non-compliance of the report and the revised report is not submitted (or was submitted but is also rejected), the granting authority may also terminate the grant or the participation of the coordinator (see Article 32).

ARTICLE 30 — PAYMENT SUSPENSION

30.1 Conditions

The granting authority may — at any moment — suspend payments, in whole or in part for one or more beneficiaries, if:

(a) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed or is suspected of having committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or

(b) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant.

If payments are suspended for one or more beneficiaries, the granting authority will make partial payment(s) for the part(s) not suspended. If suspension concerns the final payment, the payment (or recovery) of the remaining amount after suspension is lifted will be considered to be the payment that closes the action.

30.2 Procedure

Before suspending payments, the granting authority will send a **pre-information letter** to the beneficiary concerned:

- formally notifying the intention to suspend payments and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the suspension (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

At the end of the suspension procedure, the granting authority will also inform the coordinator.

The suspension will **take effect** the day after the confirmation notification is sent.

If the conditions for resuming payments are met, the suspension will be **lifted**. The granting authority will formally notify the beneficiary concerned (and the coordinator) and set the suspension end date.

During the suspension, no prefinancing will be paid to the beneficiaries concerned. For interim payments, the periodic reports for all reporting periods except the last one (see Article 21) must not contain any financial statements from the beneficiary concerned (or its affiliated entities). The coordinator must include them in the next periodic report after the suspension is lifted or — if suspension is not lifted before the end of the action — in the last periodic report.

ARTICLE 31 — GRANT AGREEMENT SUSPENSION

31.1 Consortium-requested GA suspension

31.1.1 Conditions and procedure

The beneficiaries may request the suspension of the grant or any part of it, if exceptional circumstances — in particular *force majeure* (see Article 35) — make implementation impossible or excessively difficult.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the date the suspension takes effect; this date may be before the date of the submission of the amendment request and
- the expected date of resumption.

The suspension will **take effect** on the day specified in the amendment.

Once circumstances allow for implementation to resume, the coordinator must immediately request another **amendment** of the Agreement to set the suspension end date, the resumption date (one day after suspension end date), extend the duration and make other changes necessary to adapt the action to the new situation (see Article 39) — unless the grant has been terminated (see Article 32). The suspension will be **lifted** with effect from the suspension end date set out in the amendment. This date may be before the date of the submission of the amendment request.

During the suspension, no prefinancing will be paid. Costs incurred or contributions for activities implemented during grant suspension are not eligible (see Article 6.3).

31.2 EU-initiated GA suspension

31.2.1 Conditions

The granting authority may suspend the grant or any part of it, if:

(a) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed or is suspected of having committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions,

submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.), or

(b) a beneficiary (or a person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant

(c) other:

(i) linked action issues: not applicable

(ii) the action has lost its scientific or technological relevance, for EIC Accelerator actions: the action has lost its economic relevance, for challenge-based EIC Pathfinder actions and Horizon Europe Missions: the action has lost its relevance as part of the Portfolio for which it has been initially selected

31.2.2 Procedure

Before suspending the grant, the granting authority will send a **pre-information letter** to the coordinator:

- formally notifying the intention to suspend the grant and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the suspension (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

The suspension will **take effect** the day after the confirmation notification is sent (or on a later date specified in the notification).

Once the conditions for resuming implementation of the action are met, the granting authority will formally notify the coordinator a **lifting of suspension letter**, in which it will set the suspension end date and invite the coordinator to request an amendment of the Agreement to set the resumption date (one day after suspension end date), extend the duration and make other changes necessary to adapt the action to the new situation (see Article 39) — unless the grant has been terminated (see Article 32). The suspension will be **lifted** with effect from the suspension end date set out in the lifting of suspension letter. This date may be before the date on which the letter is sent.

During the suspension, no prefinancing will be paid. Costs incurred or contributions for activities implemented during suspension are not eligible (see Article 6.3).

The beneficiaries may not claim damages due to suspension by the granting authority (see Article 33).

Grant suspension does not affect the granting authority's right to terminate the grant or a beneficiary (see Article 32) or reduce the grant (see Article 28).

ARTICLE 32 — GRANT AGREEMENT OR BENEFICIARY TERMINATION

32.1 Consortium-requested GA termination

32.1.1 Conditions and procedure

The beneficiaries may request the termination of the grant.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the date the consortium ends work on the action ('end of work date') and
- the date the termination takes effect ('termination date'); this date must be after the date of the submission of the amendment request.

The termination will **take effect** on the termination date specified in the amendment.

If no reasons are given or if the granting authority considers the reasons do not justify termination, it may consider the grant terminated improperly.

32.1.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit a **periodic report** (for the open reporting period until termination).

The granting authority will calculate the final grant amount and final payment on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before the end of work date (see Article 22). Costs relating to contracts due for execution only after the end of work are not eligible.

If the granting authority does not receive the report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

Improper termination may lead to a grant reduction (see Article 28).

After termination, the beneficiaries' obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

32.2 Consortium-requested beneficiary termination

32.2.1 Conditions and procedure

The coordinator may request the termination of the participation of one or more beneficiaries, on request of the beneficiary concerned or on behalf of the other beneficiaries.

The coordinator must submit a request for **amendment** (see Article 39), with:

- the reasons why
- the opinion of the beneficiary concerned (or proof that this opinion has been requested in writing)

- the date the beneficiary ends work on the action ('end of work date')

- the date the termination takes effect ('termination date'); this date must be after the date of the submission of the amendment request.

If the termination concerns the coordinator and is done without its agreement, the amendment request must be submitted by another beneficiary (acting on behalf of the consortium).

The termination will **take effect** on the termination date specified in the amendment.

If no information is given or if the granting authority considers that the reasons do not justify termination, it may consider the beneficiary to have been terminated improperly.

32.2.2 Effects

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a **report on the distribution of payments** to the beneficiary concerned

(ii) a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, the financial statement, the explanation on the use of resources, and, if applicable, the certificate on the financial statement (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3)

(iii) a second **request for amendment** (see Article 39) with other amendments needed (e.g. reallocation of the tasks and the estimated budget of the terminated beneficiary; addition of a new beneficiary to replace the terminated beneficiary; change of coordinator, etc.).

The granting authority will calculate the amount due to the beneficiary on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before the end of work date (see Article 22). Costs relating to contracts due for execution only after the end of work are not eligible.

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 21).

If the granting authority does not receive the termination report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/ contributions if no periodic report was ever approved).

If the granting authority does not receive the report on the distribution of payments within the deadline, it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that

- the beneficiary concerned must not repay any amount to the coordinator.

If the second request for amendment is accepted by the granting authority, the Agreement is **amended** to introduce the necessary changes (see Article 39).

If the second request for amendment is rejected by the granting authority (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the grant may be terminated (see Article 32).

Improper termination may lead to a reduction of the grant (see Article 31) or grant termination (see Article 32).

After termination, the concerned beneficiary's obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

32.3 EU-initiated GA or beneficiary termination

32.3.1 Conditions

The granting authority may terminate the grant or the participation of one or more beneficiaries, if:

(a) one or more beneficiaries do not accede to the Agreement (see Article 40)

(b) a change to the action or the legal, financial, technical, organisational or ownership situation of a beneficiary is likely to substantially affect the implementation of the action or calls into question the decision to award the grant (including changes linked to one of the exclusion grounds listed in the declaration of honour)

(c) following termination of one or more beneficiaries, the necessary changes to the Agreement (and their impact on the action) would call into question the decision awarding the grant or breach the principle of equal treatment of applicants

(d) implementation of the action has become impossible or the changes necessary for its continuation would call into question the decision awarding the grant or breach the principle of equal treatment of applicants

(e) a beneficiary (or person with unlimited liability for its debts) is subject to bankruptcy proceedings or similar (including insolvency, winding-up, administration by a liquidator or court, arrangement with creditors, suspension of business activities, etc.)

(f) a beneficiary (or person with unlimited liability for its debts) is in breach of social security or tax obligations

(g) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has been found guilty of grave professional misconduct

(h) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed fraud, corruption, or is involved in a criminal organisation, money laundering, terrorism-related crimes (including terrorism financing), child labour or human trafficking

(i) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) was created under a different jurisdiction with the intent to circumvent fiscal, social or other legal obligations in the country of origin (or created another entity with this purpose)

(j) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed:

(i) substantial errors, irregularities or fraud or

(ii) serious breach of obligations under this Agreement or during its award (including improper implementation of the action, non-compliance with the call conditions, submission of false information, failure to provide required information, breach of ethics or security rules (if applicable), etc.)

(k) a beneficiary (or person having powers of representation, decision-making or control, or person essential for the award/implementation of the grant) has committed — in other EU grants awarded to it under similar conditions — systemic or recurrent errors, irregularities, fraud or serious breach of obligations that have a material impact on this grant (extension of findings from other grants to this grant; see Article 25)

(l) despite a specific request by the granting authority, a beneficiary does not request — through the coordinator — an amendment to the Agreement to end the participation of one of its affiliated entities or associated partners that is in one of the situations under points (d), (f), (e), (g), (h), (i) or (j) and to reallocate its tasks, or

(m) other:

(i) linked action issues: not applicable

(ii) the action has lost its scientific or technological relevance, for EIC Accelerator actions: the action has lost its economic relevance, for challenge-based EIC Pathfinder actions and Horizon Europe Missions: the action has lost its relevance as part of the Portfolio for which it has been initially selected

32.3.2 Procedure

Before terminating the grant or participation of one or more beneficiaries, the granting authority will send **a pre-information letter** to the coordinator or beneficiary concerned:

- formally notifying the intention to terminate and the reasons why and
- requesting observations within 30 days of receiving notification.

If the granting authority does not receive observations or decides to pursue the procedure despite the observations it has received, it will confirm the termination and the date it will take effect (**confirmation letter**). Otherwise, it will formally notify that the procedure is discontinued.

For beneficiary terminations, the granting authority will — at the end of the procedure — also inform the coordinator.

The termination will **take effect** the day after the confirmation notification is sent (or on a later date specified in the notification; ‘termination date’).

32.3.3 Effects

(a) for **GA termination**:

The coordinator must — within 60 days from when termination takes effect — submit a **periodic report** (for the last open reporting period until termination).

The granting authority will calculate the final grant amount and final payment on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before termination takes effect (see Article 22). Costs relating to contracts due for execution only after termination are not eligible.

If the grant is terminated for breach of the obligation to submit reports, the coordinator may not submit any report after termination.

If the granting authority does not receive the report within the deadline, only costs and contributions which are included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

Termination does not affect the granting authority's right to reduce the grant (see Article 28) or to impose administrative sanctions (see Article 34).

The beneficiaries may not claim damages due to termination by the granting authority (see Article 33).

After termination, the beneficiaries' obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

(b) for **beneficiary termination**:

The coordinator must — within 60 days from when termination takes effect — submit:

(i) a **report on the distribution of payments** to the beneficiary concerned

(ii) a **termination report** from the beneficiary concerned, for the open reporting period until termination, containing an overview of the progress of the work, the financial statement, the explanation on the use of resources, and, if applicable, the certificate on the financial statement (CFS; see Articles 21 and 24.2 and Data Sheet, Point 4.3)

(iii) a **request for amendment** (see Article 39) with any amendments needed (e.g. reallocation of the tasks and the estimated budget of the terminated beneficiary; addition of a new beneficiary to replace the terminated beneficiary; change of coordinator, etc.).

The granting authority will calculate the amount due to the beneficiary on the basis of the report submitted and taking into account the costs incurred and contributions for activities implemented before termination takes effect (see Article 22). Costs relating to contracts due for execution only after termination are not eligible.

The information in the termination report must also be included in the periodic report for the next reporting period (see Article 21).

If the granting authority does not receive the termination report within the deadline, only costs and contributions included in an approved periodic report will be taken into account (no costs/contributions if no periodic report was ever approved).

If the granting authority does not receive the report on the distribution of payments within the deadline, it will consider that:

- the coordinator did not distribute any payment to the beneficiary concerned and that
- the beneficiary concerned must not repay any amount to the coordinator.

If the request for amendment is accepted by the granting authority, the Agreement is **amended** to introduce the necessary changes (see Article 39).

If the request for amendment is rejected by the granting authority (because it calls into question the decision awarding the grant or breaches the principle of equal treatment of applicants), the grant may be terminated (see Article 32).

After termination, the concerned beneficiary's obligations (in particular Articles 13 (confidentiality and security), 16 (IPR), 17 (communication, dissemination and visibility), 21 (reporting), 25 (checks, reviews, audits and investigations), 26 (impact evaluation), 27 (rejections), 28 (grant reduction) and 42 (assignment of claims)) continue to apply.

SECTION 3 OTHER CONSEQUENCES: DAMAGES AND ADMINISTRATIVE SANCTIONS

ARTICLE 33 — DAMAGES

33.1 Liability of the granting authority

The granting authority cannot be held liable for any damage caused to the beneficiaries or to third parties as a consequence of the implementation of the Agreement, including for gross negligence.

The granting authority cannot be held liable for any damage caused by any of the beneficiaries or other participants involved in the action, as a consequence of the implementation of the Agreement.

33.2 Liability of the beneficiaries

The beneficiaries must compensate the granting authority for any damage it sustains as a result of the implementation of the action or because the action was not implemented in full compliance with the Agreement, provided that it was caused by gross negligence or wilful act.

The liability does not extend to indirect or consequential losses or similar damage (such as loss of profit, loss of revenue or loss of contracts), provided such damage was not caused by wilful act or by a breach of confidentiality.

ARTICLE 34 — ADMINISTRATIVE SANCTIONS AND OTHER MEASURES

Nothing in this Agreement may be construed as preventing the adoption of administrative sanctions (i.e. exclusion from EU award procedures and/or financial penalties) or other public law measures, in addition or as an alternative to the contractual measures provided under this Agreement (see,

for instance, Articles 135 to 145 EU Financial Regulation 2018/1046 and Articles 4 and 7 of Regulation 2988/95[21]).

SECTION 4 FORCE MAJEURE

ARTICLE 35 — FORCE MAJEURE

A party prevented by force majeure from fulfilling its obligations under the Agreement cannot be considered in breach of them.

'Force majeure' means any situation or event that:

- prevents either party from fulfilling their obligations under the Agreement,
- was unforeseeable, exceptional situation and beyond the parties' control,
- was not due to error or negligence on their part (or on the part of other participants involved in the action), and
- proves to be inevitable in spite of exercising all due diligence.

Any situation constituting force majeure must be formally notified to the other party without delay, stating the nature, likely duration and foreseeable effects.

The parties must immediately take all the necessary steps to limit any damage due to force majeure and do their best to resume implementation of the action as soon as possible.

CHAPTER 6 FINAL PROVISIONS

ARTICLE 36 — COMMUNICATION BETWEEN THE PARTIES

36.1 Forms and means of communication — Electronic management

EU grants are managed fully electronically through the EU Funding & Tenders Portal ('Portal').

All communications must be made electronically through the Portal, in accordance with the Portal Terms and Conditions and using the forms and templates provided there (except if explicitly instructed otherwise by the granting authority).

Communications must be made in writing and clearly identify the grant agreement (project number and acronym).

Communications must be made by persons authorised according to the Portal Terms and Conditions. For naming the authorised persons, each beneficiary must have designated — before the signature of this Agreement — a 'legal entity appointed representative (LEAR)'. The role and tasks of the LEAR are stipulated in their appointment letter (see Portal Terms and Conditions).

[21] Council Regulation (EC, Euratom) No 2988/95 of 18 December 1995 on the protection of the European Communities financial interests (OJ L 312, 23.12.1995, p. 1).

If the electronic exchange system is temporarily unavailable, instructions will be given on the Portal.

36.2 Date of communication

The sending date for communications made through the Portal will be the date and time of sending, as indicated by the time logs.

The receiving date for communications made through the Portal will be the date and time the communication is accessed, as indicated by the time logs. Formal notifications that have not been accessed within 10 days after sending, will be considered to have been accessed (see Portal Terms and Conditions).

If a communication is exceptionally made on paper (by e-mail or postal service), general principles apply (i.e. date of sending/receipt). Formal notifications by registered post with proof of delivery will be considered to have been received either on the delivery date registered by the postal service or the deadline for collection at the post office.

If the electronic exchange system is temporarily unavailable, the sending party cannot be considered in breach of its obligation to send a communication within a specified deadline.

36.3 Addresses for communication

The Portal can be accessed via the Europa website.

The address for paper communications to the granting authority (if exceptionally allowed) is the official mailing address indicated on its website.

For beneficiaries, it is the legal address specified in the Portal Participant Register.

ARTICLE 37 — INTERPRETATION OF THE AGREEMENT

The provisions in the Data Sheet take precedence over the rest of the Terms and Conditions of the Agreement.

Annex 5 takes precedence over the Terms and Conditions; the Terms and Conditions take precedence over the Annexes other than Annex 5.

Annex 2 takes precedence over Annex 1.

ARTICLE 38 — CALCULATION OF PERIODS AND DEADLINES

In accordance with Regulation No 1182/71[22], periods expressed in days, months or years are calculated from the moment the triggering event occurs.

The day during which that event occurs is not considered as falling within the period.

'Days' means calendar days, not working days.

ARTICLE 39 — AMENDMENTS

[22] Regulation (EEC, Euratom) No 1182/71 of the Council of 3 June 1971 determining the rules applicable to periods, dates and time-limits (OJ L 124, 8/6/1971, p. 1).

39.1 Conditions

The Agreement may be amended, unless the amendment entails changes to the Agreement which would call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

Amendments may be requested by any of the parties.

39.2 Procedure

The party requesting an amendment must submit a request for amendment signed directly in the Portal Amendment tool.

The coordinator submits and receives requests for amendment on behalf of the beneficiaries (see Annex 3). If a change of coordinator is requested without its agreement, the submission must be done by another beneficiary (acting on behalf of the other beneficiaries).

The request for amendment must include:

- the reasons why
- the appropriate supporting documents and
- for a change of coordinator without its agreement: the opinion of the coordinator (or proof that this opinion has been requested in writing).

The granting authority may request additional information.

If the party receiving the request agrees, it must sign the amendment in the tool within 45 days of receiving notification (or any additional information the granting authority has requested). If it does not agree, it must formally notify its disagreement within the same deadline. The deadline may be extended, if necessary for the assessment of the request. If no notification is received within the deadline, the request is considered to have been rejected.

An amendment **enters into force** on the day of the signature of the receiving party.

An amendment **takes effect** on the date of entry into force or other date specified in the amendment.

ARTICLE 40 — ACCESSION AND ADDITION OF NEW BENEFICIARIES

40.1 Accession of the beneficiaries mentioned in the Preamble

The beneficiaries which are not coordinator must accede to the grant by signing the accession form (see Annex 3) directly in the Portal Grant Preparation tool, within 30 days after the entry into force of the Agreement (see Article 44).

They will assume the rights and obligations under the Agreement with effect from the date of its entry into force (see Article 44).

If a beneficiary does not accede to the grant within the above deadline, the coordinator must — within 30 days — request an amendment (see Article 39) to terminate the beneficiary and make any changes

necessary to ensure proper implementation of the action. This does not affect the granting authority's right to terminate the grant (see Article 32).

40.2 Addition of new beneficiaries

In justified cases, the beneficiaries may request the addition of a new beneficiary.

For this purpose, the coordinator must submit a request for amendment in accordance with Article 39. It must include an accession form (see Annex 3) signed by the new beneficiary directly in the Portal Amendment tool.

New beneficiaries will assume the rights and obligations under the Agreement with effect from the date of their accession specified in the accession form (see Annex 3).

Additions are also possible in mono-beneficiary grants.

ARTICLE 41 — TRANSFER OF THE AGREEMENT

In justified cases, the beneficiary of a mono-beneficiary grant may request the transfer of the grant to a new beneficiary, provided that this would not call into question the decision awarding the grant or breach the principle of equal treatment of applicants.

The beneficiary must submit a request for **amendment** (see Article 39), with

- the reasons why
- the accession form (see Annex 3) signed by the new beneficiary directly in the Portal Amendment tool and
- additional supporting documents (if required by the granting authority).

The new beneficiary will assume the rights and obligations under the Agreement with effect from the date of accession specified in the accession form (see Annex 3).

ARTICLE 42 — ASSIGNMENTS OF CLAIMS FOR PAYMENT AGAINST THE GRANTING AUTHORITY

The beneficiaries may not assign any of their claims for payment against the granting authority to any third party, except if expressly approved in writing by the granting authority on the basis of a reasoned, written request by the coordinator (on behalf of the beneficiary concerned).

If the granting authority has not accepted the assignment or if the terms of it are not observed, the assignment will have no effect on it.

In no circumstances will an assignment release the beneficiaries from their obligations towards the granting authority.

ARTICLE 43 — APPLICABLE LAW AND SETTLEMENT OF DISPUTES

43.1 Applicable law

The Agreement is governed by the applicable EU law, supplemented if necessary by the law of Belgium.

Special rules may apply for beneficiaries which are international organisations (if any; see Data Sheet, Point 5).

43.2 Dispute settlement

If a dispute concerns the interpretation, application or validity of the Agreement, the parties must bring action before the EU General Court — or, on appeal, the EU Court of Justice — under Article 272 of the Treaty on the Functioning of the EU (TFEU).

For non-EU beneficiaries (if any), such disputes must be brought before the courts of Brussels, Belgium — unless an international agreement provides for the enforceability of EU court judgements.

For beneficiaries with arbitration as special dispute settlement forum (if any; see Data Sheet, Point 5), the dispute will — in the absence of an amicable settlement — be settled in accordance with the Rules for Arbitration published on the Portal.

If a dispute concerns administrative sanctions, offsetting or an enforceable decision under Article 299 TFEU (see Articles 22 and 34), the beneficiaries must bring action before the General Court — or, on appeal, the Court of Justice — under Article 263 TFEU.

For grants where the granting authority is an EU executive agency (see Preamble), actions against offsetting and enforceable decisions must be brought against the European Commission (not against the granting authority; see also Article 22).

ARTICLE 44 — ENTRY INTO FORCE

The Agreement will enter into force on the day of signature by the granting authority or the coordinator, depending on which is later.

SIGNATURES

For the coordinator

For the granting authority

ANNEX 1

Horizon Europe (HORIZON)

Description of the action (DoA)

Part A

Part B

Associated with document Ref. Ares(2024)7685562 - 29/10/2024

DESCRIPTION OF THE ACTION (PART A)

COVER PAGE

Part A of the Description of the Action (DoA) must be completed directly on the Portal Grant Preparation screens.

PROJECT *Grant Preparation (General Information screen) — Enter the info.*	
Project number:	101189703
Project name:	Intent and Context-Aware Optical Networks
Project acronym:	ICON
Call:	HORIZON-CL4-2024-DIGITAL-EMERGING-01
Topic:	HORIZON-CL4-2024-DIGITAL-EMERGING-01-54
Type of action:	HORIZON-RIA
Service:	HADEA/B/02
Project starting date:	fixed date: 1 January 2025
Project duration:	36 months

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PROJECT SUMMARY

Project summary

Grant Preparation (General Information screen) — Provide an overall description of your project (including context and overall objectives, planned activities and main achievements, and expected results and impacts (on target groups, change procedures, capacities, innovation etc)). This summary should give readers a clear idea of what your project is about.

Use the project summary from your proposal.

The Intent and Context-aware Optical Network (ICON) project builds the research foundation for a new generation of optical networks, in which sensing is designed as an integral part of overall system architecture. ICON will enable communication networks that offer sensing services, turning the terrestrial and subsea fibre infrastructure into a global scale sensing manifold. This will pave the way for future network evolution of services offering a wide range of sensing applications in diverse areas such as geological disturbances, global weather and oceanographic phenomena, and urban mobility. The control and management of such new sensing services will be enabled by extensible and modular ICON intelligent sensing controller that include an intent interpreter and network digital twin to preserve state information. As an integral part of future communications systems, the ICON functions and sensing devices enable transmission optimization that goes beyond today's signal monitoring. The ICON project will develop fibre sensing and controls to create context awareness of both the internal fibre system state as well as the environment encompassing it. This addition of a sensing dimension to transmission engineering in optical networks brings new tools for optimizing transmission performance and increasing availability and energy efficiency.

LIST OF PARTICIPANTS

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
1	COO	TCD	THE PROVOST, FELLOWS, FOUNDATION SCHOLARS & THE OTHER MEMBERS OF BOARD, OF THE COLLEGE OF THE HOLY & UNDIVIDED TRINITY OF QUEEN ELIZABETH NEAR DUBLIN	IE	999845446
2	BEN	ADTRAN	ADTRAN NETWORKS SE	DE	999811787
3	BEN	FAU	FRIEDRICH-ALEXANDER-UNIVERSITAET ERLANGEN-NUERNBERG	DE	999995408
4	BEN	CyRIC	CY.R.I.C CYPRUS RESEARCH AND INNOVATION CENTER LTD	CY	952429809
5	BEN	BUT	VYSOKE UCENI TECHNICKE V BRNE	CZ	999873091
6	BEN	VPI	VPIPHOTONICS GMBH	DE	950983248
7	BEN	TALTECH	TALLINNA TEHNIKAÜLIKOOL	EE	999842536
8	BEN	Tampnet	Tampnet AS	NO	878603303
9	BEN	DTU	DANMARKS TEKNISKE UNIVERSITET	DK	999990655
10	BEN	LSAI	LIGHTSENSAI LIMITED	IE	878112483

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LIST OF WORK PACKAGES

Work packages

Grant Preparation (Work Packages screen) — Enter the info.

Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
WP1	Project management	1 - TCD	23.60	1	36	D1.1 – Data Management Plan D1.2 – Project Progress Report
WP2	Use cases, physical requirements and data format for sensing systems	7 - TALTECH	40.10	2	18	D2.1 – Report on use cases and physical sensing solution specifications D2.2 – Report on data presentation and sharing format
WP3	Physical layer of ICON	2 - ADTRAN	131.00	1	36	D3.1 – Report on the implemented and intended models and simulation studies of the JC&S D3.2 – Report on the evaluated sensing technologies (experiments) D3.3 – JC&S final report models and experiments D3.4 – Report on JC&S using HCF and MCF
WP4	Data processing for efficient JC&S systems	3 - FAU	117.00	1	36	D4.1 – DSP of local sensing data and DT concept D4.2 – Machine learning algorithms and DT protype D4.3 – Cloud infrastructure and integration of signal processing in ICON system
WP5	Intelligent sensing control platform based on intent and context awareness	1 - TCD	77.90	6	33	D5.1 – Integrated ICON architectures and its interaction with the SDN network controller D5.2 – Sensing application design and performance

Work packages

Grant Preparation (Work Packages screen) — Enter the info.

Work Package No	Work Package name	Lead Beneficiary	Effort (Person-Months)	Start Month	End Month	Deliverables
						D5.3 – Performance of ICON intelligent platform
WP6	Demonstrations	5 - BUT	58.50	3	36	D6.1 – Use cases definition (for demonstrator) D6.2 – Report on technology integration and events database for ML D6.3 – Experimental demonstration results
WP7	Dissemination, exploitation, communication and standardisation activities	4 - CyRIC	40.00	1	36	D7.1 – Dissemination, Exploitation and Communication (DEC) Plan and clustering activities report, including related material (Version 1) D7.2 – DEC and clustering activities report, including related material (Version 2) D7.3 – DEC and clustering activities report, including related material (Version 3) D7.4 – IPR and patentability analysis report with Business plan (Version 1) D7.5 – IPR and patentability analysis report with Business plan (Version 2) D7.6 – Standardisation/certification activities (Version 1) D7.7 – Standardisation/certification activities (Version 2) D7.8 – Dissemination, Exploitation and Communication Plan

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Work package WP1 – Project management

Work Package Number	WP1	Lead Beneficiary	1 - TCD
Work Package Name	Project management		
Start Month	1	End Month	36

Objectives
Preparation and signing of the Consortium Agreement (CA) and Grant Agreement using the Horizon Europe Model Grant Agreement (HE MGA). Ensure the smooth running and overall good management, both scientific and administrative of the project

Description
T1.1 General project management (TCD; All) M1-M36. This task will involve the day-to-day operation of the project. As the Coordinator, TCD will have overall responsibility for the management of the project. TCD's administration and financial teams will provide the necessary support for delivering high-quality project coordination and management. This task includes the meetings and activities of the General Assembly in managing the overall project activities, including reporting to the European Commission. TCD will be responsible for organising all formal ("Plenary") meetings. The project will start with an initial ("kick-off") meeting in M1. Thereafter, plenary meetings will be held twice yearly. These formal meetings will assess the project's progress. The General Assembly will meet formally once a year. T1.2 Scientific coordination (TCD; WP Leaders) M1-M36. TCD will oversee the activities of all WPs to ensure the success of the project. TCD will work closely with all WP Leaders to ensure progress. All WPs will have regular online WP meetings to track progress, identify and address issues. The WP leaders will feed into the agenda of the meetings of the General Assembly. T.1.3 Scientific project management (TCD; All) M1-M36. TCD will coordinate activities associated with Risk Management, Data Management, and Quality Assurance. The risks identified in this proposal will form the foundation for the project "risk register". All risks will be reviewed on an ongoing basis and formally at each meeting of the General Assembly. The process will upgrade or downgrade the risks and consider any new developments for mitigating the known risks. The project will seek to identify any new or emerging risks and how to mitigate them. Any new risk will be added to the risk register, which will be developed and monitored by TCD. TCD will also develop the Data Management Plan (DMP, M6) in consultation with the partners to ensure compliance with open access and the FAIR principles. The plan will be reviewed and updated. It will describe the data collected/processed/generated, methodology/standards followed, plans for curation & preservation and planned open access to data (wherever possible), both during and after the project. Finally, the coordinator will oversee quality assurance by ensuring that all deliverables are reviewed by knowledgeable partners, who are not involved in authoring them, before approval by the General Assembly. Interim and final periodic reports will be delivered to the EC in line with the Grant Agreement. These will be accompanied by Financial Statements. TCD will lead WP1 and all WP/Task leaders will support T1.2 and T1.3.

Work package WP2 – Use cases, physical requirements and data format for sensing systems

Work Package Number	WP2	Lead Beneficiary	7 - TALTECH
Work Package Name	Use cases, physical requirements and data format for sensing systems		
Start Month	2	End Month	18

Objectives
Define the sensing use cases and their requirements, map these onto the physical sensing device specifications and performance metrics.

Define use cases involving intent-based sensing signal routing and context-aware network operation. Define the optimum form of presenting and sharing sensing data for use in multiple use cases.

Description
Task 2.1 Specifications of sensing use cases (TN; ADTN, TalTech, BUT, TCD) M2 - M16. This task will perform a study of different use cases of JC&S system, their requirements in terms of sensing parameters or events, and corresponding performance metrics. These will include range, resolution, sensitivity, but also response time, frequency of measurements, amount of data generated/required etc. Both monitoring and sensing of the telecommunication network performance as well as environmental sensing will be studied. In addition to improving network availability, focus will be placed on use cases that can deliver significant environmental impact. These will include monitoring of the cables connecting offshore wind farms, subsea CO2 storage etc. The partners will evaluate the security risks in subsea and terrestrial optical fibre networks that can lead to a downtime and increase in costs and are often caused by anchoring and fishing activity of trawlers or road excavations in the vicinity of fibre infrastructure. The second objective of T2.1 will be to evaluate the efficiency of different sensing technologies for the above-mentioned use cases and how it can be improved e.g., by sharing a single sensing unit over multiple spans or applications. Task 2.2 Physical sensing technology and demo specifications (ADTN; FAU, TCD, TN, BUT) M3 - M16. This task will map the use cases requirements from T2.1 on the physical layer specifications and the distinct sensing solutions. It will also define the expected metrics of the sensing technologies and benchmarking of the sensing systems by utilizing either SEAFOM MSP-02 recommendation or self-defined tests. This task will feed into but also take input from WP3 in the form of the performance of the physical devices developed within ICON. Task 2.3 Investigation of the standard method of presenting and sharing of the sensing data for use in telecommunication and non-telecommunication related applications. (TalTech; TCD, CyRIC) M6 - M18. This task investigates the optimum methods of presenting and sharing/storing the collected sensing data that will maximise it usability in various applications. The particular focus here will be put on facilitating the exploitation of the sensing data by the network management for a real-time network control as well as a long-term network segment availability evaluations and creation of the availability maps. In addition, the partners will also investigate the method of procuring information from other non-optical sensors (automatic information systems (AIS), weather stations etc.) to increase the reliability of the data interpretation and classification. This task will feed to WP7 standardisation efforts. Role of partners: TalTech will lead the WP2 and contribute to T 2.3 by investigating the use of the sensing data for AA. TN will contribute to the design of use-cases, evaluation of sensing technologies for use with deployed WDM subsea networks, and the presentation of sensing data and data correlated with other data sources. ADTN will evaluate different sensing technologies and specify the measurands of interest. In addition, we will contribute to the use cases for sensing in WDM networks. BUT will contribute to defining use cases and the requirements and parameters of each individual system. FAU will contribute the know how in various sensing elements, sensing methods and signal processing concepts. TCD will contribute to the use cases, particularly related to management of the optical network and OSaaS. CyRIC will contribute to the design of the use cases and the data collected for use in the cloud infrastructure.

Work package WP3 – Physical layer of ICON

Work Package Number	WP3	**Lead Beneficiary**	2 - ADTRAN
Work Package Name	Physical layer of ICON		
Start Month	1	**End Month**	36

Objectives
Develop a suit of sensing methods capable to detecting a wide range of events that can be used in networks employing subsea, terrestrial and aerial cable. Improve the performance parameters and increase the adaptability of existing sensing technologies.

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Verify the impact of the coexistence of sensing signals with the WDM communication network through simulation and experimental work.

Investigate the use of novel fibres for fibre sensing applications and verify the possibility of enhancing the backscattering coefficient using higher concentration of co-dopants in the fibre material

Description

Task 3.1 Modelling of joint communication and sensing system (VPI; FAU, DUT, ADTN) M1 - M34.
The main goal of this task is the simulation of a JC&S system. This will involve (1) development of temporal-resolved model of Rayleigh and Raman backscattering to induce different events along the fibre, (2) modelling different sensing methods to obtain insight into the limits of their sensing technologies, (3) verification of the crosstalk on the sensing and communication channel in multi-core fibres (MCF), (4) investigating the backscattering coefficient of a nested antiresonant nodeless hollow-core fibres (HCF), (5) optimising the probe signal for maximum signal to noise ratio using e.g., code sequences and pulses, (6) investigation of different nonlinearities types on the performance of the JC&S system.

Task 3.2 Development of sensing techniques for diverse infrastructure types (ADTN; FAU, TCD, LSAI, TN, BUT) M1 - M24.
In this task, the partners will work on developing the adaptable physical sensing techniques that meet the specifications and requirements described in T2.1 and T2.2. This will involve (1) improving the established sensing techniques with respect to sensitivity, range, ability to locate a change in the environmental conditions, and resolution without impacting the communication channels, (2) developing novel approaches either in reflectometry (OTDR, ET-OTDR with DFC, OFDR), tomography using optical probes or coherent transceiver-based sensing (SOP-sensing, non-disruptive probing and sounding) for JC&S, (3) establishing the detailed list of configurations and corresponding performance metrics that will be used by the intent-based, context-aware sensing controller developed in T5.1

Task 3.3 Investigation of use of novel fibre types for JC&S (FAU; ADTN, VPI, BUT, TCD) M13 - M36.
In this task, the partners will work on monitoring and sensing strategies for SMF with novel FBGs, HCF and MCF, based on the results in T3.1. This task will involve investigation of (1) novel FBGs, such as long period and phase shifted FBG, for increased temperature and strain sensitivity, (2) distributed sensing methods capable of detecting very weak sensing powers (HCF have a backscattering coefficient of -120 dB/m) or using the data signals to monitor HCF; (3) use of MCF with at least 4 cores and interrogators on both sides to improve the localization accuracy of an event occurring along the fibre, and finally (3) experimental verification of possibility to enhance the concentration of the dopant in one core to improve the signal-to-noise ratio, thus the event localization. The fibre with enhanced core will be purchased by one of the partners.

Task 3.4 Investigation of coexistence of sensing and communication signals (BUT; TCD, LSAI, ADTN, TN) M13 - M34.
In this task we will quantify the impact of including different types of sensing signals in the communication band (C-band). This will include (1) investigation of the availability of spectrum in a typical WDM network (DWDM or UDWDM), (2) study of using sensing signals outside of the EDFA amplification band (1525 - 1562 nm), (3) evaluation of the impact of WDM channels on sensing channels with respect to reach, sensitivity, crosstalk, and nonlinearities, (4) quantifying the impact of the sensing signal on the WDM data carrying channels. A detailed analysis of the available technologies of the partners will be performed by means of laboratory experiments and will deliver the final validation of the interrogator parameters defined in Task 2.2 and the developed/validated techniques in Task 3.2 which will them be used for the demonstration in WP6.

Role of partners:
ADTN will develop a multi-carrier CA-OTDR, work on SOP sensing using a coherent receiver, channel modelling and testing of coexistence of sensing and communication channels.
BUT will design adaptable systems suitable for various types of infrastructures. They will coordinate the analysis and measurement of simultaneous signal transmission within the fibre, addressing potential interference.
DTU will develop simulation models of optical fibre sensing systems employing coherent OTDR, synthesize optimum phase demodulation algorithms, explore ML for improving SNR to reach the quantum-limited value.
FAU will investigate sensing based on HCF and MCF and the FBG and Raman based distributed sensing.
TCD will work on the TE-OTDR and test the coexistence of communication and sensing.
TN will develop instrumentation for SoP measurements from dedicated, control and data signals for different use-cases and carry out coexistence tests.
VPI will develop novel models and simulation techniques addressing the envisioned fibre sensing applications and on the simulation of joint communication and sensing systems.

LSAI will extend the sensitivity range of tomographic optical sensing methods using novel waveforms and optimized receiver techniques, including DSP algorithms developed in WP4.

Work package WP4 – Data processing for efficient JC&S systems

Work Package Number	WP4	**Lead Beneficiary**	3 - FAU
Work Package Name	Data processing for efficient JC&S systems		
Start Month	1	**End Month**	36

Objectives
Develop digital signal processing (DSP) methods that are necessary to perform an optimized JC&S Investigate the volume reduction of the sensing data needed to be transmitted and stored across the network. Develop methods of correlating of network-wide information as well as data from other sources to obtain a complete picture of the network and its environment. Develop and optimise the software platform and the according infrastructure for data processing and cloud computing together with a smart user interface. Develop a context aware Digital Twin (DT) model of the sensing elements and the sensor system.

Description
Task 4.1 Signal processing of local sensing data (ADTN; LSAI, BUT, DUT, CyRIC, FAU, TN). M1 - M24 In this task, we will develop DSP algorithms and methods for local data. This will include (1) signal processing for various reflectometry concepts like CC-OTDR, ET-OTDR or probe-based tomography methods to improve performance and accuracy of the sensing system, (2) optimization of the pre-processing schemes for the extraction of relevant data from the raw signal of the sensing system and the coherent receiver, such as in-phase and quadrature components or the SOP, (3) defining the requirements for the transmitter signals of the local interrogators to enable high performance data compression for an efficient data transfer, (4) evaluation of the limiting effect of phase and intensity noise on the phase extraction in coherent receivers, the cost-effective polarization evaluation by a Stokes receiver or new concepts like event localization using wavelength dependent fibre properties in DWDM systems. Task 4.2 Processing of network-wide sensing data (CyRIC; LSAI, FAU, TCD, TN, BUT) M13 - M36. In this task, we will develop efficient algorithms for processing and correlating the pre-processed local sensing data gathered from the entire network as well as other systems. Focus will be put on minimising the environmental impact of the JC&S system by reducing the Terabyte volume of raw data gathered to a small text document, while preserving the information contained in it. This in turn will drastically reduce the amount of data that needs to be transmitted/processed/stored, leading to a further decrease in power consumption and processing time. The latter will be achieved using ML models such as model-based sampling or compression. The compressed raw data will be centrally stored in a cloud infrastructure (T4.3), which will allow to perform the classification, localization and correlation of events across the complete system, and which will interact with the intent translation layer of the intelligent sensing platform as shown in Figure 1 and developed in WP5. Task 4.3 Design, develop and optimise the cloud infrastructure and smart user interface (CyRIC; All) M10 - M36. This task will be responsible for the design, development, and deployment of the cloud infrastructure for data retrieval and processing. The platform will reside in an EU geo-located compute services setup by CyRIC, and it will be accessible from all pilot applications, software components and other external systems, such as the Network Management System. It will expose the necessary APIs to enable receiving data from the sensing elements and external sources. A common interaction layer will be designed, in the form of an API specification, to which modules should adhere for the data exchange to be feasible. Here the data presentation format, developed in T2.3, will be used. The entire system will be set up so at to ensure performance, security, robustness, accessibility, and usability. These will be achieved via security ‘enhanced’ infrastructure and highly available distributed services to ensure low latency as well as reliable and fast access. The platform will feature a sufficient processing power to accommodate the data collecting components, communication, and execution of the ML/AI and DT algorithms. At the top of the cloud platform, a smart web-accessible

user interface will be developed to allow an intuitive use of the platform without requiring in-depth knowledge of the system, to view all the collected data and results.

Task 4.4 Implement Digital Twin of the ICON (FAU; CyRIC, DUT, TCD, TN, VPI) M4 - M24.
In this task, we will develop a DT model of the JC&S system to forecast the reaction of sensing elements, the sensor fibre and the complete sensing system to various sensing events. Amongst others, the digital model will be inspired by the models developed in task 3.1. It will also implement methods for a continuous update of parameters describing the sensor characteristics depending on aging and extreme sensing events like high strain or high local temperature that may influence the sensor characteristics. Thus, the digital model will take the history of the sensing systems into account and allow for a cloud-based adaptation of the sensor model to the interrogation techniques used and the parameters to be detected. From the model, it will be possible to forward the measurement information to the network management system (NMS) and the cloud infrastructure to enhance historical view measurements through the web accessible user interface (Task 4.3). The DT will also generate immediate warnings about unexpected events as well as recommendations for actions to be taken, without requiring knowledge of significant details about the system.

Role of partners:
ADTN will work on the processing of the sensing signals with respect to CA-OTDR, extracting signals from coherent receivers and using these for sensing applications. We will work on the pre-processing of the data in the field programmable gate array to reduce the amount of data and contribute to the correlation of different sensing information to improve the accuracy of the sensing part.
BUT will work on the development of algorithms used to detect and classify events, DSP and data optimization.
CyRIC will lead the work on the network-wide data processing, the cloud platform and user interface.
DTU will explore ML including autoencoder and variational autoencoders for data reduction and selection.
FAU will work on the raw data signal processing and the development of a DT for the sensing system.
TCD will work on the network-wide data processing, interface between the sensing system and the network management system and contribute to the development of the software platform and the DT.
TN will work on methods for processing and compression of sensing-data, correlation of sensing-data with data from network monitoring and external systems to increase accuracy while minimising false detections and alarms.
VPI will contribute to the DT model based on the results of T3.1 adapted to the needs in WP4.
LSAI will develop DSP algorithms for tomographic probes and develop network wide optimization and correlation methods for optical network tomography and its joint operation with other sensing methods.

Work package WP5 – Intelligent sensing control platform based on intent and context awareness

Work Package Number	WP5	**Lead Beneficiary**	1 - TCD
Work Package Name	Intelligent sensing control platform based on intent and context awareness		
Start Month	6	**End Month**	33

Objectives
Develop the intent-based architecture with northbound and southbound interfaces to facilitate the development of sensing applications. Provide the intelligent algorithms capable of identifying the type, number and routing of sensing probes to achieve the desired sensing application intent. Build context-aware sensing to complement the intent-based sensing applications to further improve anomaly detection accuracy. Implement sensing applications interacting with the ICON intelligent platform.

Description
Task 5.1 Intent based, context-aware controller architecture (ADTN; TCD, TalTech, FAU) M6 - M33. This task will develop the control architecture to support network sensing applications, giving the ability of multiplexing different applications into the same platform. The architecture will be based on two key concepts of intent-based

operations and context-awareness. Thus, in this task, we will (1) define the component architecture, such as northbound control interfaces towards the sensing apps and southbound towards the SDN controller, (2) design the intelligent ICON control system, which will include ML analytics, context generation, and data lake architecture for storage and compression of sensing information.

Task 5.2 ICON platform intelligence (TCD; ADTN, LSAI, FAU) M13 - M31.
In this task, the intelligent algorithms for activation and routing of sensing probes to achieve the intent defined by the sensing application will be developed. This will require identifying the type of probes and their wavelength route across the network to collect the measurements required by the sensing application. The task will also take into consideration the effect that different routes will have on the measurement precision due to fibre length, type of route, noise from other WDM channels. It will also account for uncertainty about possible impairment due to lack of information, e.g., when running probes in the Optical Spectrum as a Service window.

Task 5.3 Development of sensing application operating over the ICON controller (TalTech; TCD, TN, ADTN) M12 - M30.
This task will develop applications over the intent-based control plane, according to the specifications determined in Task 2.1 and Task 2.3. We have identified three different types of the sensing applications, in which the sensing data is used to (1) support mission-critical infrastructure such as electricity grids, water and gas pipelines, off-shore wind parks, oil platforms, or CO2 storages, (2) derive infrastructure-specific failure rates, (3) for inter-disciplinary use-cases, such monitoring of the temperature, water pressure, changes in electromagnetic field (in substations, on top of the powerlines), capture lightning strikes or monitor solar winds. We expect that more applications will be identified during the project.
Role of partners:
TCD will develop ICON intelligent platform for sensing probe configuration and routing and contribute to the definition of the architecture and the development of the sensing applications.
ADTN will work the software architecture, definition of the north- and south-bound interfaces of an application agnostic sensing platform.
TalTech will work together with TCD, TN and ADTN on the availability assistant for evaluation of the network availability and resource sharing in a form of optical spectrum as a service.
TN will evaluate how the integration of sensing controller with a practical Network Operation Centre with the NMS to detect and warn against physical threats to sub-sea fibre cables and other sensing applications.
FAU will contribute to the ICON intelligent platform.
LSAI will work on probe routing for optical network tomography-based sensing and its integration into the NMS.

Work package WP6 – Demonstrations

Work Package Number	WP6	**Lead Beneficiary**	5 - BUT
Work Package Name	Demonstrations		
Start Month	3	**End Month**	36

Objectives
Definition of test scenarios and creation of the integration plan. Evaluation of sensor systems on different types of infrastructures in laboratory conditions. Demonstrations of ICON concept and technologies using the partners' field-deployed network infrastructures. Evaluation of the results and creation of strategy for infrastructure-dependent deployment of sensory systems.

Description
Task 6.1 Definition of testing activities, including final demonstrators (BUT; ADTN, TCD, TN, TalTech, FAU, CyRIC, LSAI) M3 - M9. In this task, the plan for the types of demonstration to be carried out, including the type of network and sensing techniques, will be created. The types of infrastructures available to partners (both laboratory and field-deployed) will be analysed and the possibilities of deploying suitable types of sensor systems will be proposed, using the inputs from WP2 and T3.4. The plan will serve as a precise guide for subsequent deployment and verification, as detailed in T6.2 and T6.3.

An essential part of the task will be the analysis of external support systems that could be used to aid the detection and classification of events (camera systems, piezo-based sensors, AIS information, etc.).

Task 6.2 Testbed preparation and integration of the sensing systems in the communication network (ADTN; BUT, TCD, TN, FAU, CyRIC) M9 – M30.
This task aims to detail and document the test setups for laboratory and outdoor tests selected in T6.1. In addition to the required test equipment and exact infrastructure selection and documentation, also supporting features will be pinpointed and addressed. These include power supply, cooling, management connectivity requirements and implementations, storage solutions and human resources to maintain the successful accomplishment of the testing. Based on the outputs of T6.1, laboratory test will be carried out to verify the functionality of the proposed use cases before the field trials. This will ensure optimum utilisation of the limited access to some infrastructures. In this task, the preparation of suitable systems for storing data from sensory systems and also support systems will also be carried out, using the output of Task 4.3. Finally, this task will also involve preparation of the database and the collection of the data for the ML models for automatic event classification and data reduction. Results from all experimental test will feed into this task, including those collected in T3.4.

Task 6.3 Experimental validation of the ICON solution and the final demonstration (TCD; TalTech, ADTN, BUT, TN, FAU, CyRIC, LSAI, VPI) M20 – M36.
This task covers various experimental tests that will be carried out to validate and demonstrate the ICON concept. It will require the integration of the intelligent controller with the sensing hardware and the NMS. The test detailed in T6.1 and T6.2 will be carried out here, including the year-long field trial using the TN infrastructure, to gather data for building the availability assistant and testing of ICON processing algorithms of rare events. Finally, the demonstration of the two applications of ICON, as identified in T5.3) will be performed within this task. These will include the on-site network intrusion detection and rerouting, and automated failure rate calculations for the network segments within the sensing grid.
The results T6.3 will be used to draw recommendations and lessons learnt for the ICON deployments and future improvements. These will be fed to WP7 for standardisation activities as well as dissemination and discussion with the EC, National authorities and the other projects in this area.

Role of partners:
BUT will coordinate the entire WP, participate in the definition of partial parameters of use cases, use the Brno infrastructure for selected use cases, and participate in the deployment and evaluation of measurements.
ADTN will provide/test a CA-OTDR and coherent transmission demonstrator for the field trials and demos.
TCD will work on the test and integration scenarios and will lead the testing on the OpenIreland infrastructure.
TN will work on the test and integration scenarios, lead the testing on TN subsea infrastructure for the long-duration field trials.
TalTech will lead the sensing data collection from the sensing grid, contribute to the data analyses, and use-case implementations, specific to applications investigated under Task 5.3.
DTU will deliver ML for data processing and event classification and carry out for proof-of-concept experiments.
CyRIC will contribute to the evaluation of the cloud platform, ML framework integration and data visualisation.
LSAI will provide an optical probing subsystem for the field trails and laboratory experiments.
FAU will test new fibre type- and Raman-based sensing, and the DT of the sensor system.
VPI will contribute simulative feasibility studies supporting the demonstration activities.

Work package WP7 – Dissemination, exploitation, communication and standardisation activities

Work Package Number	WP7	**Lead Beneficiary**	4 - CyRIC
Work Package Name	Dissemination, exploitation, communication and standardisation activities		
Start Month	1	**End Month**	36

Objectives
Creation and update the DC plan, communicate project results widely and through multiple channels. Implementation of clustering activities on a European scale, cooperation with European Commission and with relevant projects on the implementation of this action plan.

Coordination of knowledge/data management and IPR, development of the exploitation plan.

Interaction with standardisation bodies and certification authorities.

Description

Task 7.1 Dissemination and communication plan and activities (CyRIC; All), M1 - M36.
The dissemination, exploitation and communication plan (DEC) will be prepared at M6 by CyRIC and will be updated every 6 months. It will comprise the identification and selection of relevant audiences and the adequate communication channels for each of them, as well as the definition of the information to communicate at each stage of the project. The project will record all activities from scientific publications and public engagement activities for inclusion in the periodic reports submitted to the EC. A dissemination and communication logbook will be maintained through a web form to enable all partners to report on and review the project activities. The task also involves the production of promotional materials (brochures, leaflets, newsletters and videos) and coordination of the project presence in dissemination events, including the network of expert organisation. A project website will be setup by CyRIC before M2. The project will be represented also through X, LinkedIn and YouTube pages for easier access to larger audiences. Finally, a dedicated workshop will be organised by partners to present the project results directly to the end-users' community and other important stakeholders. The workshop will disseminate information through presentations, videos and live demonstrations of the tools. It will be held in combination with a large sector conference/event towards the end of the project.

Task 7.2 Knowledge management & distribution, innovation and IPR (CyRIC; All) M1 - M36.
Intellectual Property exploitation will be managed within this task. Any IPR conflicts or requests by the partners will be handled in collaboration with the coordinator and where applicable, also supported by the Steering Committee. All items and products of the project will be checked in relation to IPR issues by CyRIC and submitted to the attention of the Consortium. CyRIC will lead the patentability analysis, with input from the partners directly involved in the development and viable patentable results will be protected by the partners as part of this task. Furthermore, through this task, CyRIC will take care of open distribution of the results that will be publicly shared from the main outcomes of the project.

Task 7.3 Business/exploitation plan (CyRIC; ADTN, LSAI, TN, VPI), M1 - M36
Within this task, a study of the commercialization potential of each technology of the project will be performed with the support of the technology developers, making use of a set of tools, such as business canvases. The exploitation plan will propose best fit go-to-market strategies. An economic feasibility analysis will be performed to evaluate the profitability of each designed Business Model, to understand future cash flow and highlight the need for additional funding or investment. Finally, a set of sustainability activities to secure the post-project future of relevant technologies, will be planned, including investigation of further funding (digital innovation hubs in the consortium will be exploited). On a proactive level, using the exploitation planning outputs, decision makers will be approached so that they are aware of the project, its relevance and the financial needs of the business models.

Task 7.4 Standardization activities and interaction with standardization working groups (ADTN; CyRIC, TN) M1 - M36.
This task will periodically (every 6 months) review project developments from the point of view of Standards, Legal and Regulatory issues related to the project case studies, both at National and European level. Connections with regulatory bodies and standardisation working groups will be exploited to present project results to the working groups for consideration in new standards, updated regulations and for facilitating the implementation of ongoing/planned developments (e.g., contribution to the standardization in ITU-T SG15 Q6 interfaces of fibre sensing and WDM systems). The project developments will be continuously evaluated towards compliance with the latest regulations. Documentation in view of future product certification will also be collected.

Task 7.5 Networking-Synergies-Clustering and collaboration with other projects (CyRIC; All) M1-M36.
The task will realize a set of outreach activities to maximise the project's visibility and impact. Invitations and mail campaigns will be sent out more than 3 months before info-day/outreach events to maximise participation. Wide visibility and lasting synergies will be pursued by clustering and establishing relations with European/International associations, relevant projects, programmes, initiatives and networks. We will seek collaboration in a form of sharing relevant information and datasets, developing joint events and publications, but also preparing joint policy recommendations and standardisation proposals, also as part of T7.4.

Role of partners:
All partners will be involved in T7.1, 7.2 and 7.5.
ADTN, apart from the activities in which all partners are involved, will also be leading T7.4 on the standardisation activities. They will also contribute to T7.3.
CyRIC is leading the WP and T7.1, T7.2, T7.3, and T7.5. They are also contributing to T7.4.

TN, LSAI, and VPI, apart from the activities in which all partners are involved, will actively contribute to the development of a business and exploitation plan. TN will follow the progress of the standardization activity and give input through ADTN.

STAFF EFFORT

Staff effort per participant

Grant Preparation (Work packages - Effort screen) — Enter the info.

Participant	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total Person-Months
1 - TCD	9.80	4.00	14.00	6.00	25.00	14.00	5.00	77.80
2 - ADTRAN	1.00	5.00	16.00	10.00	18.00	6.00	4.00	60.00
3 - FAU	2.00	1.00	14.00	14.00	3.00	4.00	2.00	40.00
4 - CyRIC	1.00	4.00		30.00		5.00	14.00	54.00
5 - BUT	2.00	3.00	19.00	16.00		6.00	3.00	49.00
6 - VPI	1.00		28.00	3.00		1.00	3.00	36.00
7 - TALTECH	3.80	14.10			15.90	4.50	3.00	41.30
8 - Tampnet	1.00	8.00	9.00	3.00	4.00	10.00	2.00	37.00
9 - DTU	1.00	1.00	24.00	20.00	2.00	4.00	2.00	54.00
10 - LSAI	1.00		7.00	15.00	10.00	4.00	2.00	39.00
Total Person-Months	23.60	40.10	131.00	117.00	77.90	58.50	40.00	488.10

LIST OF DELIVERABLES

Deliverables

Grant Preparation (Deliverables screen) — Enter the info.

The labels used mean:

Public — fully open (⚠ automatically posted online)
Sensitive — limited under the conditions of the Grant Agreement
EU classified —RESTREINT-UE/EU-RESTRICTED, CONFIDENTIEL-UE/EU-CONFIDENTIAL, SECRET-UE/EU-SECRET under Decision 2015/444

Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D1.1	Data Management Plan	WP1	1 - TCD	DMP — Data Management Plan	PU - Public	6
D1.2	Project Progress Report	WP1	1 - TCD	R — Document, report	SEN - Sensitive	10
D2.1	Report on use cases and physical sensing solution specifications	WP2	8 - Tampnet	R — Document, report	PU - Public	12
D2.2	Report on data presentation and sharing format	WP2	7 - TALTECH	R — Document, report	PU - Public	18
D3.1	Report on the implemented and intended models and simulation studies of the JC&S	WP3	6 - VPI	R — Document, report	SEN - Sensitive	17
D3.2	Report on the evaluated sensing technologies (experiments)	WP3	2 - ADTRAN	R — Document, report	SEN - Sensitive	24
D3.3	JC&S final report models and experiments	WP3	5 - BUT	R — Document, report	SEN - Sensitive	34
D3.4	Report on JC&S using HCF and MCF	WP3	3 - FAU	R — Document, report	PU - Public	36
D4.1	DSP of local sensing data and DT concept	WP4	2 - ADTRAN	R — Document, report	SEN - Sensitive	12
D4.2	Machine learning algorithms and DT protype	WP4	3 - FAU	R — Document, report	SEN - Sensitive	24

Deliverables

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D4.3	Cloud infrastructure and integration of signal processing in ICON system	WP4	4 - CyRIC	R — Document, report	SEN - Sensitive	36
D5.1	Integrated ICON architectures and its interaction with the SDN network controller	WP5	2 - ADTRAN	R — Document, report	SEN - Sensitive	20
D5.2	Sensing application design and performance	WP5	7 - TALTECH	R — Document, report	SEN - Sensitive	30
D5.3	Performance of ICON intelligent platform	WP5	1 - TCD	R — Document, report	SEN - Sensitive	31
D6.1	Use cases definition (for demonstrator)	WP6	5 - BUT	R — Document, report	PU - Public	15
D6.2	Report on technology integration and events database for ML	WP6	2 - ADTRAN	R — Document, report	SEN - Sensitive	30
D6.3	Experimental demonstration results	WP6	1 - TCD	R — Document, report	PU - Public	36
D7.1	Dissemination, Exploitation and Communication (DEC) Plan and clustering activities report, including related material (Version 1)	WP7	4 - CyRIC	R — Document, report	PU - Public	6
D7.2	DEC and clustering activities report, including related material (Version 2)	WP7	4 - CyRIC	R — Document, report	PU - Public	24
D7.3	DEC and clustering activities report, including related material (Version 3)	WP7	4 - CyRIC	R — Document, report	PU - Public	36
D7.4	IPR and patentability analysis report with Business plan (Version 1)	WP7	4 - CyRIC	R — Document, report	SEN - Sensitive	18

Deliverables

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D7.5	IPR and patentability analysis report with Business plan (Version 2)	WP7	4 - CyRIC	R — Document, report	SEN - Sensitive	36
D7.6	Standardisation/certification activities (Version 1)	WP7	2 - ADTRAN	R — Document, report	PU - Public	20
D7.7	Standardisation/certification activities (Version 2)	WP7	2 - ADTRAN	R — Document, report	PU - Public	36
D7.8	Dissemination, Exploitation and Communication Plan	WP7	4 - CyRIC	R — Document, report	PU - Public	6

Associated with document Ref. Ares(2024)7685562 - 29/10/2024

Deliverable D1.1 – Data Management Plan

Deliverable Number	D1.1	**Lead Beneficiary**	1 - TCD
Deliverable Name	Data Management Plan		
Type	DMP — Data Management Plan	**Dissemination Level**	PU - Public
Due Date (month)	6	**Work Package No**	WP1

Description
The first version of DMP will be completed. It will be updated mid-project and at the project's end.

Deliverable D1.2 – Project Progress Report

Deliverable Number	D1.2	**Lead Beneficiary**	1 - TCD
Deliverable Name	Project Progress Report		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	10	**Work Package No**	WP1

Description
At the request of the Project Officer during the GAP (Grant Agreement Preparation) process, this Project Progress Report was included to facilitate a Technical Review in and around M10.

Deliverable D2.1 – Report on use cases and physical sensing solution specifications

Deliverable Number	D2.1	**Lead Beneficiary**	8 - Tampnet
Deliverable Name	Report on use cases and physical sensing solution specifications		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	12	**Work Package No**	WP2

Description
Final report on use cases and physical sensing solution specifications related to the outputs of T2.1 and T2.2

Deliverable D2.2 – Report on data presentation and sharing format

Deliverable Number	D2.2	**Lead Beneficiary**	7 - TALTECH
Deliverable Name	Report on data presentation and sharing format		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	18	**Work Package No**	WP2

Description
Final report on data presentation and sharing format related to the output of T2.3

Associated with document Ref. Ares(2024)7685562 - 29/10/2024

Deliverable D3.1 – Report on the implemented and intended models and simulation studies of the JC&S

Deliverable Number	D3.1	**Lead Beneficiary**	6 - VPI
Deliverable Name	Report on the implemented and intended models and simulation studies of the JC&S		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	17	**Work Package No**	WP3

Description
A report on the implemented and intended models and simulation studies of the JC&S which relates to the output of T3.1.

Deliverable D3.2 – Report on the evaluated sensing technologies (experiments)

Deliverable Number	D3.2	**Lead Beneficiary**	2 - ADTRAN
Deliverable Name	Report on the evaluated sensing technologies (experiments)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	24	**Work Package No**	WP3

Description
A report on the evaluated sensing technologies (experiments) which is related to the output of T3.2.

Deliverable D3.3 – JC&S final report models and experiments

Deliverable Number	D3.3	**Lead Beneficiary**	5 - BUT
Deliverable Name	JC&S final report models and experiments		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	34	**Work Package No**	WP3

Description
The JC&S final report models and experiments which relate to the outputs of T3.1 and T3.4.

Deliverable D3.4 – Report on JC&S using HCF and MCF

Deliverable Number	D3.4	**Lead Beneficiary**	3 - FAU
Deliverable Name	Report on JC&S using HCF and MCF		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP3

Description
A report on JC&S using HCF and MCF which relates to the output of T3.3.

Associated with document Ref. Ares(2024)7685562 - 29/10/2024

Deliverable D4.1 – DSP of local sensing data and DT concept

Deliverable Number	D4.1	Lead Beneficiary	2 - ADTRAN
Deliverable Name	DSP of local sensing data and DT concept		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	12	Work Package No	WP4

Description
A report on DSP of local sensing data and DT concept related to output of T4.1.

Deliverable D4.2 – Machine learning algorithms and DT protype

Deliverable Number	D4.2	Lead Beneficiary	3 - FAU
Deliverable Name	Machine learning algorithms and DT protype		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	24	Work Package No	WP4

Description
A report on the Machine Learning algorithms and DT protype related to the output of T4.4.

Deliverable D4.3 – Cloud infrastructure and integration of signal processing in ICON system

Deliverable Number	D4.3	Lead Beneficiary	4 - CyRIC
Deliverable Name	Cloud infrastructure and integration of signal processing in ICON system		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP4

Description
A report on the cloud infrastructure and integration of signal processing in ICON system related to T4.2.

Deliverable D5.1 – Integrated ICON architectures and its interaction with the SDN network controller

Deliverable Number	D5.1	Lead Beneficiary	2 - ADTRAN
Deliverable Name	Integrated ICON architectures and its interaction with the SDN network controller		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	20	Work Package No	WP5

Description
A report on the integrated ICON architectures and its interaction with the SDN network controller related to T5.1.

Associated with document Ref. Ares(2024)7685562 - 29/10/2024

Deliverable D5.2 – Sensing application design and performance

Deliverable Number	D5.2	Lead Beneficiary	7 - TALTECH
Deliverable Name	Sensing application design and performance		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	30	Work Package No	WP5

Description
A report on the sensing application design and performance related to T5.3

Deliverable D5.3 – Performance of ICON intelligent platform

Deliverable Number	D5.3	Lead Beneficiary	1 - TCD
Deliverable Name	Performance of ICON intelligent platform		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	31	Work Package No	WP5

Description
A report on the performance of ICON intelligent platform related to T5.2

Deliverable D6.1 – Use cases definition (for demonstrator)

Deliverable Number	D6.1	Lead Beneficiary	5 - BUT
Deliverable Name	Use cases definition (for demonstrator)		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	15	Work Package No	WP6

Description
A report on the use cases definition (for demonstrator) related to T6.1

Deliverable D6.2 – Report on technology integration and events database for ML

Deliverable Number	D6.2	Lead Beneficiary	2 - ADTRAN
Deliverable Name	Report on technology integration and events database for ML		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	30	Work Package No	WP6

Description
A report on the technology integration and events database for ML relate.d to the outputs of of T6.2 and T6.3

Deliverable D6.3 – Experimental demonstration results

Deliverable Number	D6.3	Lead Beneficiary	1 - TCD
Deliverable Name	Experimental demonstration results		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP6

Description
A report on the experimental demonstration results related to the output of T6.3

Deliverable D7.1 – Dissemination, Exploitation and Communication (DEC) Plan and clustering activities report, including related material (Version 1)

Deliverable Number	D7.1	Lead Beneficiary	4 - CyRIC
Deliverable Name	Dissemination, Exploitation and Communication (DEC) Plan and clustering activities report, including related material (Version 1)		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	6	Work Package No	WP7

Description
The Dissemination, Exploitation and Communication (DEC) Plan will be delivered together with clustering activities report, including related material v1/v2/v3 related to outputs of T7.1 and T7.5.

Deliverable D7.2 – DEC and clustering activities report, including related material (Version 2)

Deliverable Number	D7.2	Lead Beneficiary	4 - CyRIC
Deliverable Name	DEC and clustering activities report, including related material (Version 2)		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	24	Work Package No	WP7

Description
Updated version of DCP together with clustering activities report, including related material, related to outputs T7.1 and T7.5.

Deliverable D7.3 – DEC and clustering activities report, including related material (Version 3)

Deliverable Number	D7.3	Lead Beneficiary	4 - CyRIC
Deliverable Name	DEC and clustering activities report, including related material (Version 3)		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP7

Description

Final version of the DEC and clustering activities report, including related material which are related to outputs of T7.1 and T7.5.

Deliverable D7.4 – IPR and patentability analysis report with Business plan (Version 1)

Deliverable Number	D7.4	**Lead Beneficiary**	4 - CyRIC
Deliverable Name	IPR and patentability analysis report with Business plan (Version 1)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	18	**Work Package No**	WP7

Description
The first version of an IPR and patent-ability analysis report and associated Business plan related to the outputs of T7.2 and T7.3

Deliverable D7.5 – IPR and patentability analysis report with Business plan (Version 2)

Deliverable Number	D7.5	**Lead Beneficiary**	4 - CyRIC
Deliverable Name	IPR and patentability analysis report with Business plan (Version 2)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	36	**Work Package No**	WP7

Description
The second version of the IPR and patent-ability analysis report together with a Business plan related to the outputs of T7.2 and T7.3

Deliverable D7.6 – Standardisation/certification activities (Version 1)

Deliverable Number	D7.6	**Lead Beneficiary**	2 - ADTRAN
Deliverable Name	Standardisation/certification activities (Version 1)		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	20	**Work Package No**	WP7

Description
The first report on standardisation/certification activities related to the output of T7.4.

Deliverable D7.7 – Standardisation/certification activities (Version 2)

Deliverable Number	D7.7	**Lead Beneficiary**	2 - ADTRAN
Deliverable Name	Standardisation/certification activities (Version 2)		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	36	**Work Package No**	WP7

Description
The second version of the report on standardisation/certification activities related to the output of T7.4.

Deliverable D7.8 – Dissemination, Exploitation and Communication Plan

Deliverable Number	D7.8	**Lead Beneficiary**	4 - CyRIC
Deliverable Name	Dissemination, Exploitation and Communication Plan		
Type	R — Document, report	**Dissemination Level**	PU - Public
Due Date (month)	6	**Work Package No**	WP7

Description
The first draft of the Dissemination, Exploitation and Communication (DEC) Plan will be in place.

LIST OF MILESTONES

Milestones

Grant Preparation (Milestones screen) — Enter the info.

Milestone No	Milestone Name	Work Package No	Lead Beneficiary	Means of Verification	Due Date (month)
1	Specification of use cases and sensing solution	WP2	8 - Tampnet	The deliver of the report on use cases and physical sensing solution specifications (D2.1).	12
2	Sensing concepts evaluated in the lab	WP3	2 - ADTRAN	Deliverable of Task 3.2 in M24 and Deliverable of Task 4.1 in M18	24
3	JC&S evaluated by simulation and experiments	WP3	2 - ADTRAN	Deliverable of Task 3.1 and 3.4 in M34	34
4	Cloud platform v1	WP4	3 - FAU	Cloud infrastructure and v1of the platform back-end services ready, accessible by all to upload data over defined APIs.	18
5	Intelligent platform available for initial test of applications	WP5	1 - TCD	Ability to test applications defined in T5.3 on the system	26
6	Final demos specifications defined	WP6	5 - BUT	Deliverable 6.1	15
7	ICON devices, DPS and control integrated and ready for final demonstration	WP6	2 - ADTRAN	D6.2 due in M30	30
8	Final demonstrations completed	WP6	1 - TCD	Integrated JC&S testbed running, D6.3.	36

Associated with document Ref. Ares(2024)7685562 - 29/10/2024

LIST OF CRITICAL RISKS

Critical risks & risk management strategy

Grant Preparation (Critical Risks screen) — Enter the info.

Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
1	Component shortage or delayed shipping dates of fibres: (i) high, (ii) low.	WP3, WP6	The required components and fibres will be purchased as early as possible in the project to guarantee smooth lab and field tests.
2	Enhanced core of the MCF does not shows the desired SNR improvement or is out of band: (i) medium, (ii) low	WP3, WP6	Careful specification by the partners of the desired SNR improvement and centre wavelength of the enhanced spectrum. Clear discussion on the prototype with the fibre manufacturer.
3	Demonstrators damage during transport: (i) medium, (ii) low.	WP6	Safety packaging with additional padding will be used, the time-frame for the field-trials with enough margin to allow for a repair of the demonstrator or equipment.
4	Computational power of office computer insufficient for data reduction, ML and DT: (i) medium, (ii) low	WP4, WP6	Use of an additional computer (workstation) to perform these tasks
5	Test infrastructure malfunctioning/damaged/ inaccessible: (i) medium, (ii) low	WP4, WP3, WP6	Project has access to multiple infrastructures and laboratories; a replacement will be chosen from available testbeds listed in Table 1.1
6	Network operators reluctant to disclose the failure rates: (i) medium, (ii) medium	WP2	Use field-trials to gather as much information as possible to build AA, work with operators to demonstrate the advantage of AA to entice them to share information.
7	Not enough data for conclusions: (i) medium, (ii) high	WP6, WP2	We expect each of these applications to generate enough data to validate its efficacy under various conditions, such as laboratory testbeds, subsea cable testbeds, and so forth.
8	Test infrastructure does not allow the deployment of some systems (e.g. technical inconsistency, data transmission interference): (i) medium, (ii) high	WP3, WP6, WP2	Meticulous preparation and optimization of partial sensory systems, detailed knowledge of the infrastructure
9	Insufficient event knowledge database	WP4, WP6	Use of support systems and databases to classify events
10	Low/too high sensitivity of sensory systems leading to impaired detection of events. (i) medium, (ii) medium	WP3, WP2	Development and deployment of appropriate sensor systems with optimal sensitivity for the selected infrastructure, analysis of interference sources and optimization of systems.

PROJECT REVIEWS

Project Reviews

Grant Preparation (Reviews screen) — Enter the info.

Review No	**Timing** (month)	**Location**	**Comments**
RV1	9	TBC	Technical Review
RV2	19	TBC	Interim Review
RV3	36	TBC	Final Review

Proposal template Part B: technical description

ICON: INTENT AND CONTEXT-AWARE OPTICAL NETWORKS

[This document is tagged. Do not delete the tags; they are needed for processing.] #@APP-FORM-HERIAIA@#

TABLE OF HISTORY OF CHANGES	
Version 2	Changes
12.09.2014	**Annex 1 Part A**
	- *Start Date*: Fixed start date of 01/02/2025 changed to 01/01/2025 as requested. - *Work Package (WP) 7*: (i) WP7 has been renamed "Dissemination, exploitation, communication and standardisation activities" (ii) The original DCP (Dissemination and Communication plan) has been renamed DEC (Dissemination, Exploitation and Communication plan). - *Deliverables*: (i) Text of D1, DMP (Data Management Plan), updated to note need for update mid-project and at project's end. (ii) Name of Deliverables 17, 18 and 19 have been renamed to include DEC (Dissemination, Exploitation and Communication). (iii) DEC plan added as a deliverable in M6. (iv) Project Progress Report added as a deliverable in M10 [D24 (D1.2)] to facilitate a Technical Review meeting.
12.09.2024	**Annex 1 Part B**
	- *Table of History of Changes*: This table entitled "Table of History of Changes" added to Annex 1 – Part B (p.1) - *Table of Contents*: Hyperlinks added to the table of contents. - *Table 3.1h*: (i) The text of the budget justification for BEN 8 was amended to confirm that costs under "Other goods, works and services" include support for a CFS (Certificate on Financial Statements). (ii) A note has been added to the end of this section with the requested text about equipment and depreciation costs added to text. - *Ethics Self-Assessment*: The text has been amended in line with the request from HaDEA.

TABLE OF HISTORY OF CHANGES	
Version 1	**Changes**
29.07.2024	**Annex 1 Part A**
	- No changes made to proposal's Part A. - -……
29.07.2024	**Annex 1 Part B**
	- *Header*: Removed the Header from proposal's Part B - *Footer*: Removed Footer from proposal's Part B and replaced with "101189703 ICON – Part B – [Page number]" - *List of participants*: The List of participants removed from proposal's Part B (p.1). - *Table of History of Changes*: This table entitled "Table of History of Changes" added to Annex 1 – Part B (p.1) - *Table of Contents*: Table of Contents added to Annex I – Part B (p.1). - *Section 3.1*: Removed the following tables from Section 3.1 of the proposal's Part B (pp. 35-44): 3.1a List of Work Packages, [3.1b] Work Packages – Description of Work, 3.1c List of Deliverables, 3.1d List of Milestones, 3.1e Critical Risks for Implementation, and 3.1f Summary of staff effort. - *Ethics Self-Assessment*: Added the section "4. Ethics Self-assessment" to Annex 1 – Part B based on response in proposal's Part A.

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1 EXCELLENCE

1.1 Objectives and ambition #@PRJ-OBJ-PO@#

The overarching aim of this project is to create a pathway for **fibre sensing to become an integral service in optical transmission systems**, both for improving the reliability and performance of the network itself as well as enabling new functionality and sensing based services. The result will be an Intent and Context-aware Optical Network (ICON) - a new optical network built and operated using the joint communication and sensing concept (JC&S). In general, fibre sensing is undergoing a resurgence of interest due to the potential of integrating it into the communication infrastructure and leveraging this infrastructure to achieve scale and widespread applicability, a trend that is occurring in both wireless and wired/fibre systems. Through this approach, the backbone fibre networks can be turned into a massive sensor for detecting earthquakes, tsunamis and a host of geographic disturbances[1],[2]. On a metro scale, networks have also been shown to detect the flow of road traffic and transport systems[3] using both the coherent communication signals themselves and a variety of sensing probes. These methods are largely compatible with high data rate communication dense wavelength division multiplexed (DWDM) networks[4]. While promising, these early experiments remain proof of concept tests, in which the sensing technologies are a bolted-on novelty. In order to exploit these new sensing service opportunities, progress is needed in terms of the **sensor sensitivity and performance**, allowing them to find wide applicability over a range of optical transmission system configurations and deployment scenarios. Additionally, **control and management of sensing signals** will need to be compatible with optical network control and management systems, including emerging virtualized functions and software defined network controls.

Greater benefits and potential for adoption will likely require sensing that is not just an add-on service, but a key part of the operation and performance of the communication system. Fibre optic communication systems are facing challenges in continuing exponential capacity growth and adapting to new latency and timing requirements. Currently, the telecommunication sector is responsible for 3 to 4% of global CO_2 emission. Without substantial measures put in place, and with global data traffic growth continuing at an estimated 60% per year, this share could reach 14% by 2040[5],[6]. Historical Moore's law efficiency improvements are not keeping up and this largely drives energy use in optical communication systems due to their considerable digital signal processing requirements. Although optical communication is highly efficient with regard to joules per bit, it still faces difficulties with thermal

1 N. J. Lindsey et al., "Illuminating seafloor faults and ocean dynamics with dark fibre distributed acoustic sensing", Science 366, 1103-1107, 2019.

2 H. F. Martins et al., "Monitoring of Remote Seismic Events in Metropolitan Area Fibers using Distributed Acoustic Sensing (DAS) and Spatio-Temporal Signal Processing," OFC, San Diego, CA, USA, 2019.

3 G. A. Wellbrock et al., "First Field Trial of Sensing Vehicle Speed, Density, and Road Conditions by using Fiber Carrying High Speed Data," OFC 2019.

4 Z. Wang et al., "Field Trial of Coexistence and Simultaneous Switching of Real-Time Fiber Sensing and Coherent 400 GbE in a Dense Urban Environment," in Journal of Lightwave Technology, 42 (4), pp. 1304-1311, 2024.

5 www.bcg.com/press/

6 W. Briglauer, et. al., "Evaluating the effects of ICT core elements on CO2 emissions: Recent evidence from OECD countries, Telecommunications Policy, 47 (8) 2023.

density and scalability at very high capacities. Increasingly, communication system evolution is looking to novel efficiency improvements beyond the device level, such as low margin networks[7], often making use of greater availability of data from system monitoring and telemetry. Nevertheless, available data sources in optical transmission systems are limited and are often insufficient to unlock the desired benefits. JC&S has the potential to answer this limitation and usher in a new wave of network enhancements based on high value data that was not previously available.

Fibre sensing goes beyond today's optical monitors such as channel power monitors, by providing data about the optical fibre operational ***context***. Both within the fibre and external to the fibre, sensing provides data on a wide range of factors that regularly influence performance and availability. Stresses, attacks, and disruptions to the fibre, its cable and locality can **be detected and analysed**. Unexpected, service effecting perturbations such as lightning strikes, wind shear on aerial cables, and cable bridge crossings, can be **identified and managed** as opposed to being guessed at. Fibre properties and available spectrum can be thoroughly characterized prior to signal provisioning. These are key tools that can revolutionize how systems are optimized in terms of both spectral efficiency and availability.

Unlike current approaches to fibre optic JC&S, which use static sensing probes or signals specifically designed for a given application and deployed in a fixed network location, the ICON solution decouples the sensing technology from the sensing application. Instead, it enables a **flexible and dynamic** JC&S system that can be adapted to the specific applications, to obtain the required information, in a most efficient manner. ICON aims to **maximise the amount of information** that can be retrieved from the sensing data to benefit multiple uses, thus reducing or entirely eliminating the need for static probes. The ambition of the project is to **fully integrate the sensing system with the network control** to facilitate the exploitation of the sensing data in the network management. Thus, the realisation of ICON will involve developing a comprehensive suite of technologies, ranging from physical layer sensing techniques, through signal processing (including machine learning (ML), digital twin (DT) and artificial intelligence (AI) techniques) to network management mechanisms.

The proposed ICON project will develop to two key features central to integrating these new sensing capabilities into networks: **intent- and context-awareness** realised through the combination of the **physical layer sensing and the intelligent sensing control system**. In the *intent-based approach*, the ICON controller collects the intents from both the external applications and the internal system and based on their requirements, optimises sensing and network monitoring parameters. This includes choosing the type, frequency and location of the data collection that satisfies the intent efficiently, while balancing the other sensing and performance requirements of the system. Where possible, it processes data already available (e.g., gathered for another application) to retrieve the required information. The *context-awareness* on the other hand, correlates the contextual information, obtained from heterogeneous data acquired through the sensing and network monitoring systems, with information from other sources (e.g., weather reports, marine traffic or construction tracking systems) to build a comprehensive picture of network infrastructure and the surrounding environment.

The concept of ICON, illustrated using partner Tampnet's network topology, is shown in Figure 1. The network consists of both terrestrial and submarine segments, serving both wired and wireless customers. To realise ICON, the existing infrastructure, consisting of telecommunication systems with their built-in monitoring, is complemented with fibre sensing systems. In addition, the control and management of the network is expanded to include the ICON intelligent platform. Designed as a software defined networking (SDN) controller with virtualized network functions it can be flexibly integrated into existing SDN controls and other cloud services. This extensible intelligent platform interacts with both sensing application requests and the network management system (NMS) actions. These are then translated, using the intent function, to create a set of optimized operations to provision and configure the JC&S network elements. The ICON project will investigate the use of a DT, built from monitoring and sensing data collected into a data lake, and contextual information from external sources. This novel context-awareness capability will be investigated as a mechanism to improve network performance, availability, and spectral efficiency, while also enhancing the data available to external (e.g. sensing) applications and the NMS - giving network operators new insights into their network operation that is only possible with the addition of sensing capabilities.

While these ICON capabilities could be exploited for a variety of purposes, including network monitoring, monitoring of structural integrity of bridges or seismic activity etc., within this project we will concentrate on two applications (1) optimization of the network utilisation and planning, through the creation of an infrastructure-specific availability assistant (AA) and (2) ensuring infrastructure security and reliability through real-time threat detection, localisation and identification.

7 Y. Pointurier, "Design of low-margin optical networks," in Journal of Optical Communications and Networking, 9 (1), pp. A9-A17, 2017.

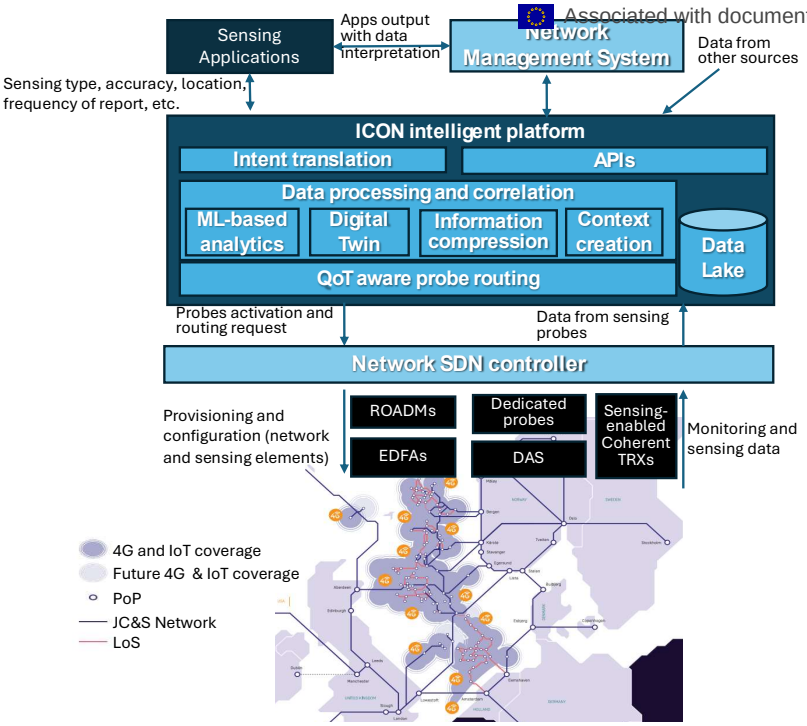

Figure 1: ICON joint communication and sensing technologies controlled through an intelligent control platform that can be integrated into or interact with terrestrial and subsea network controllers and their network management systems.

This ambitious aim of the ICON project will be achieved by:

- Development of a portfolio of **highly flexible physical layer sensing solutions** capable of detecting wide range of events (vibration, temperature, strain etc.), compatible with different network segments (access, metro, core) and delivering the required range, resolution and sensitivity for a wide range of deployment scenarios.
- Development of a **library of signal processing, context creation, and data compression algorithms** to interpret and correlate heterogenous data originating from the sensing system, both local and network-wide, as well as other sources e.g. vessel location by the automatic information system (AIS), weather and seismic data.
- Development of an **extensible set of virtualized network functions, forming an intelligent platform,** compatible with SDN control environments. This platform will include data lake and DT functions that will be used by intent and context processors and a sensing signal routing engine.
- Investigation of the operation and optimization of the ICON JC&S functions in **lab experiments and field test environments, including a year-long field trial in a production subsea network**. Effectiveness of the developed methods and their impact on the data-bearing signals will be validated in diverse network scenarios and demonstration of two ICON use cases.
- Ensuring maximum impact of the developed solutions by actively driving standardization in fields of optical communication, sensing and JC&S.

The project objectives are detailed in the tables below.

Objective 1: Physical layer joint communication and sensing
Description of objective: To fully realise the benefits offered by ICON, an array of versatile physical layer sensing solutions is required. These need to be flexible, allowing adjustment of sensing parameters (e.g., the duration and duty cycle of the Optical Time Domain Reflectometer (OTDR) signals, free spectral range (FSR) of time expanded OTDR (TE-OTDR) etc.) and enabling detection of a wide range of events in diverse environments. Thus, the project consortium will work on developing, optimising, and characterising the sensing technologies (both available and developed within the project) to build a portfolio of solutions with well-defined configurations and corresponding capabilities. This objective also includes investigation of novel fibre uses to enhance the performance of the JC&S system. Finally, as the sensing and the data signals need to coexist in the same infrastructure, the verification and characterization of crosstalk between the sensing and the communication system will be performed.
Actions: O1.1 Development of sensing solutions for diverse network infrastructures (WP3, T3.2)

O1.2 Investigation of applicability of novel fibre types for JC&S (WP3, T3.3)

O1.3 Investigation of coexistence of sensing and communication signals (WP3, T3.1 and T3.4)

Results: A portfolio of sensing technologies delivering flexibility in terms of applications and performance and achieving spatial resolution of 1 m at 50 km fibre length to 100 m for 150 km fibre length; measurement range of up to 150 km, strain detection sensitivity between 100 με and 0.1 με.

Means of verification: Sensing prototypes delivered to WP6, list of configurations of sensing devices (novel and commercially available) with corresponding performance metrics, D3.2, D3.3 and D3.4, MS2

Pertinence to the Work Programme: We will develop light-based sensors and techniques that can be integrated with the data-carrying networks. These will be used to increase the reliability and security of the optical networks and allow them to operate as a large-scale distributed sensor.

Objective 2: Effective processing and interpretation of sensing information

Description of objective: The large amount of data from the sensing system must be processed effectively to minimise the additional power consumption. This requires both processing of the local raw data at the optical interfaces and network-wide data in the cloud. Therefore, in addition to the classical correlation techniques, we will develop and implement data volume reduction methods as well as ML and DT-based methods to interpret sensing data. Interfaces will also be established to deliver the retrieved information to the network control and management and for feeding the non-telecommunication related information to other systems (earthquakes warnings etc.).

Actions: O2.1 Processing and interpretation of local sensing data (WP4, T4.1)

O2.2 Processing, volume reduction and transmission of network-wide sensing data (WP4, T4.2)

O2.3 Development of a smart cloud-based platform for processing sensing data (WP4, T4.3)

O2.4 Development of a context-aware digital twin (WP4, T4.4)

Results: Portfolio of processing algorithms for retrieving information from each physical sensing method developed within the project, cloud-based intelligent platform for JC&S data, experimentally verified DT of ICON, interfaces to network control and management and external systems. The following KPIs will be targeted: data volume reduction from TB-s to GB per week per link; correlation accuracy of the sensor information with 80% event recognition, event recognition time < 20 ms.

Means of verification: Data processing chain, including raw data processing, volume reduction, cloud-based processing and DT modelling demonstrated and verified using reference events, D4.1 to D4.3 and MS4

Pertinence to the Work Programme: Developed algorithms for sensing data interpretation will not only allow for monitoring of the performance of the optical network, but also extract event information that can be used to warn and protect infrastructure from accidental or intended damage. In addition, the focus on volume reduction and energy efficient processing will reduce the system energy consumption and environmental impact.

Objective 3: Intelligent sensing control platform based on intent to achieve context awareness

Description of objective: Creation of an efficient JC&S network requires full integration of the two systems. This needs to be done on physical and control layer. Obj.3 is aimed at developing the intelligent ICON platform for translating the sensing requirements to physical sensing configuration, managing the sensing signals across the network and exposing the obtained information to network management and external systems.

Actions: O3.1 Design intent based, context-aware controller architecture for network sensing (WP5, T5.1)

O3.2 Design of ICON intelligent platform for allocation/routing of sensing probes and data processing (WP5, T5.2)

O3.3 Development of sensing application operating over the ICON controller (WP5, T5.3)

Results: First ever fully integrated JC&S network control and management enabling intent-based sensing signal routing and context-aware network operation. Solution for multiplexing, routing and processing sensing probes that

enable the reduction of the number of sensing signals and the use of the acquired information across multiple applications. Reduced false rate alarm (with respect to each specific application on traditional sensing platforms) due to use of the intelligent sensing control platform. Increase in accuracy and balance between precision and recall (F1-score, which identifies the balance between false positives and false negatives) for the sensing applications with regards to today's respective accuracy, based on individual probes without additional context awareness.

Means of verification: the ICON sensing platform delivered to WP6, D5.1, D5.2, D5.3, MS5.

Pertinence to the Work Programme: Integration of the sensing and network controls is necessary to allow the network to act upon the sensing information acquired, which can then be exploited to improve the security and reliability of the network. It is also required to improve the efficiency of network infrastructure exploitation. Finally, the energy efficiency, stemming from the ability to multiplex sensing probes across multiple applications and the overall improvement in accuracy (thus reducing the energy required for network repairs, or loss of efficiency) is facilitated through the development of the intelligent ICON platform.

Objective 4: Demonstrate the developed technology solution to realise the JC&S system

Description of objective: The technology developed within the project will be verified and demonstrated to showcase the capabilities and benefits of the ICON solution, through a series of experiments and field trials, culminated with the final demonstration.

Actions: O4.1 Design the realistic test-bed scenarios for validation of the developed solutions to showcase the benefits of ICON technology (WP2, WP6)

O4.2 Integration of the sensing system (physical devices, signal processing, network control) with the existing testbeds (WP6, T6.2)

O4.3 Demonstration and performance evaluation of ICON through the laboratory test and field trials (WP6, T6.3)

O4.4 Collection of sensing data from a long-duration (>1 year) field-trial, for building the availability assistant and testing of ICON processing algorithms of rare events (WP6, T6.2, T6.3).

Results: An integrated communication and sensing infrastructure for verification of algorithms, sensing devices, applications developed by ICON as well as external actors. An algorithm/method of extracting, collecting and processing data to create an availability assistant.

Means of verification: The final demonstrator will incorporate the physical sensing devices, the intelligent control platform and the integration of the sensing and network control, D6.3, MS8

Pertinence to the Work Programme: This will be the ultimate verification of the effectiveness and feasibility of ICON solution to deliver the outcomes of the call i.e., enhanced security and resilience of the network, ability to use fibre as a distributed sensor.

Objective 5: Generate impact and standardization of project results

Description of objective: To ensure maximum impact of the ICON technology, the consortium will make its results available to the public by interacting with the relevant ecosystems, discussing results at scientific and industrial events with the community, and proposing standardisation of results, where appropriate. We will also present the solution to industry stakeholders to garner feedback and begin discussions with potential clients and partners.

Actions: O5.1 Communicate and dissemination of ICON results to and engagement of appropriate stakeholders (as identified in the D7.1) (WP7)

O5.2. Develop and publish ICON solution exploitation roadmap (D7.2) for key exploitable results through industry, scientific and educational exploitation routes. (WP1, WP7)

O5.3. Promote and actively drive standardization (WP7, D7.3)

Results: 3 public workshops, 20 journal publications, 40 conference publications, 3 curated datasets used in 2 hackathons, 2 PoC demonstrations, 1 final conference,1 standard recommendation.

Means of verification: D7.1, D7.2, D7.3.
Pertinence to the Work Programme: All activities support achievement of the overall outcomes of the call. Specifically, the standardisation efforts in the sensing domain would be necessary to allow an effective communication/sharing of data from different sensing devices/systems to realise a JC&S network.

1.1.1 Progress beyond the state-of-the-art

ICON goes beyond the state of the art (SotA) at multiple levels. At the level of fundamental optical devices, this project delivers ambitious and exciting **innovations in physical layer sensing** technology including the novel phase sensitive OTDR (φ-OTDR), time-expanded (TE-) OTDR, and optical network tomography (ONT). We address key challenges here such as the sensitivity, range and resolution, and focus on developing flexible technology that can be adopted to a variety of sensing applications. On the **data processing** level, we will deliver innovative solutions to not only extract the relevant information from the collected data, but to achieve it at minimum energy consumption. We will also develop advanced algorithms to reduce the amount of data that need to be transmitted and stored, to further reduce the environmental footprint of the JC&S systems. In addition, we will work on methods of correlating the network-wide information to obtain a complete picture of the network and extract further knowledge about the system and its environment, that would not be possible from observing only local data. State of the art **ML/AI and DT solutions** will be used to achieve this goal. To fully exploit of the potential of the JC&S paradigm, the sensing system needs to work in tandem with the network control and management. Thus, within ICON project, we will develop **first ever intelligent sensing platform** fully integrated into the network SDN controller. We will then demonstrate, **in field trials,** the ability of this new network to react, in real-time, to the changes in the system context, e.g., enabling the network operators to take proactive actions to prevent damage to the infrastructure. We will also show how the sensing data acquired can be used to create a pioneering **availability assistant** (AA) and how this novel JC&S controller can utilise the AA for service provisioning, protection path planning and overall improving the network efficiency and resilience.

Physical layer sensing solutions

Reflectometry

SotA: To access information on optical fibres and environmental conditions around them, OTDR is a key method[8]. It exploits either Rayleigh backscattering or Brillouin and Raman scattering mechanisms to sense the fibre environmental fluctuations. Thus, in OTDR the standard single-mode fibre itself is used as a sensor. The technique is used to characterize the spatially resolved attenuation along a fibre, by measuring the time of flight of the backscattered and reflected light of an inserted pulse. To enhance the sensitivity and the measurement range of OTDR, the coherent detection scheme can be used, which, in addition to the amplitude, enables the evaluation of the optical phase and polarization of the signal[9]. Phase is highly sensitive to small changes to the optical properties of waveguides, hence can be used to sense environmental effects that occur in the vicinity of the fibre. Such effects can be acoustic signals or vibrations, hence the name distributed acoustic sensing (DAS).

Another approach to fibre sensing is an optical frequency domain reflectometry (OFDR), which offers a relatively high resolution combined with a large dynamic range. In OFDR, a continuous wave light source, whose frequency is linearly swept with time, is separated into two signals, probe and reference. The probe signal is sent through the fibre under test (FUT) and the light backscattered from the FUT is combined with a reference signal and detected coherently. Beating of the two signals on a receiver produces a photocurrent with a constant beat frequency, which is a function of the sweep rate and the round-trip time of the probe. A tunable laser source, with a tens of nanometre wavelength sweep range, is capable of providing spatial resolution at the micrometre level. The challenge lies in obtaining a linear wavelength sweep of the laser. In addition, as the sensing range approaches the laser coherence length, phase noise increases significantly and degrades the signal-to-noise ratio (SNR). To increase the measurement range, a laser source with a narrow linewidth needs to be used, which significantly increases the cost of the system.

Recently, the use of deployed optical fibre as sensor has gained a lot of attention. In 2019, Verizon[3] demonstrated the use of an optical telecommunications network in Texas as a distributed sensor to measure vehicle speed and road conditions with a φ-OTDR. Moreover, submarine fibres have been used to detect earthquakes utilizing coherent transceivers and interferometric approaches. In such a test, to achieve the required reach and SNR at the receiver, commercial φ-OTDR systems send high-power optical pulses along the fibre. This, however, raises concerns regarding laser safety and nonlinearities that can affect telecommunication channels. As in JC&S the fibre infrastructure has a double use, the sensing technique needs to not only deliver the required sensing performance but

8 M. Barnoski and S. M. Jensen, "Fiber Waveguides: A novel Technique for Investigating attenuation characteristics," A O, 15 (9), 1976.
9 P. Lu, et al., “Distributed optical fiber sensing: Review and perspective”, Appl. Phys. Rev. 6, (041302), 2019.

achieve it without degrading the quality of the data-carrying signals. Thus, a lot of effort is being directed towards the investigation of the impact of different sensing technologies on the WDM networks. In addition, new OTDR techniques utilizing telecommunication components, that can achieve similar performance to conventional OTDR but at a reduced peak power are being vigorously pursued[10], e.g., using probe signals consisting of code sequences[11], chirped pulses[12] or multiple carriers[13] instead of individual pulses.

Beyond SotA (CA-OTDR: TRL 3 to 6; TE-OTDR TRL: 2 to 5): The partners will advance the SotA by developing two innovative φ-OTDR systems: a correlation-aided and time-expanded OTDR.

Correlation-aided OTDR (CA-OTDR) is an innovative metrology, investigated by ADTN, that uses probe signals encoded with codes having good auto-correlation properties. The use of such codes improves the spatial resolution of the reflectometry by utilizing high baud rates (up to 10 Gbit/s) and increasing the average amount of energy sent into the fibre by distributing this energy over a code sequence[14],[15]. Thus, this advanced technique is a suitable candidate for a JC&S system because of the power distribution. To obtain a cost-effective interrogator with a measurement range beyond 100 km, CA-OTDR will be paired with innovative and hybrid amplification schemes. In addition, to get rid of the fading pattern, a cost-effective multi-frequency approach will be developed. Here, the code adapted will be essentially a hybrid signal in the digital domain, enabling the generation of multi-tone optical signals.

Time-expanded OTDR (TE-OTDR) is one of the newest additions to the OTDR sensing family, which utilises a dual optical frequency comb (D-OFC), to acquire sensing information[16]. The benefits of TE-OTDR include an efficient downconversion of the optical frequencies to the radio-frequency (RF) domain[17]. As a result, the optical bandwidth of an OFC, composed of thousands of lines, can be measured from a very narrow RF comb, with compression factors typically ranging from 10^3 to 10^5. Thus, TE-OTDR delivers high-resolution (in the cm range) distributed sensor with significantly relaxed electronic requirements[18]. TCD has an extensive knowledge and experience in generating and using OFCs[19] and D-OFCs in telecommunication[20], distance measurements[21], laboratory-on-fibre[22] etc. and will leverage this expertise to develop a flexible, cost-effective TE-OTDR sensor for access and metro networks. Firstly, we will investigate the optimum technique of generating two mutually coherent OFC that deliver flexibility in terms of FSR and wavelength, maximum no. of comb lines and does not require an acusto-optic modulator or optical filtering. We will then investigate the use of spectral phase coding to minimise the peak power of the sensing signal, the use of quasi-integer ratio operation[18] to overcome the sensing range/sampling frequency limitation.

Optical Network Tomography (ONT)

SotA: Optical probing (OP) and network tomography (NT). Network tomography, in which probe signals are selectively transmitted along different paths, to infer the state of the network and its parameters, is an established methodology within data networks[23]. However, it is not used in optical networks and instead system control monitors, such as optical channel (signal power) monitors, are used where available on ROADM nodes. Optical signal monitoring, including optical performance monitoring, is useful for controlling existing optical signals and identifying various faults or impairments[24]. However, these monitors provide limited information about the physical

10 F. Azendorf, et al., "Acoustic Sensing after 50 km of Transmission Fibre using Coherent Optical Subassembly", ECOC, 2023, Scotland
11 M. Eiselt, et al., "Monitoring of Optical Networks Using Correlation-Aided Time-Domain Reflectometry with Direct and Coherent Detection", OECC, 2023.
12 E. Ip, et al., "DAS over 1,007-km Hybrid Link with 10-Tb/s DP-16QAM Co-propagation using Frequency-Diverse Chirped Pulses", OFC, 2022.
13 Y. Wakisaka, "Distortion-suppressed sampling rate enhancement in phase-OTDR vibration sensing with newly designed FDM pulse sequence for correctly monitoring various waveforms", OFC, 2020.
14 F. Azendorf, et al., "Accurate Single-Ended Measurement of Propagation Delay in Fiber Using Correlation Optical Time Domain Reflectometry", JLT, 39, (18), 2021.
15 F. Azendorf, et al., "Interrogation of 2000 Draw Tower Gratings for Quasi Distributed Sensing with Coherent-Correlation-OTDR", OSSC, 2022.
16 M. Soriano-Amat, et al." Time-expanded phase-sensitive optical time-domain reflectometry", Light Sci Appl 10, (51) 2021.
17 I. Coddington, et. al., "Dual-comb spectroscopy", Optica 3, pp. 414–426, 2016.
18 M. R. Fernández-Ruiz, et. al., "High Resolution Distributed Optical Fiber Sensing Using Time-Expanded Phase-Sensitive Reflectometry", Front. Sens., Sec. Physical Sensors, 2, 2021.
19 W. Weng, et. al., "Gain-switched semiconductor laser driven soliton microcombs", Nat. Commun, 12, 2021.
20 A. Kaszubowska-Anandarajah et. al., "Reconfigurable photonic integrated transmitter for metro-access networks," JOCN, 15 (3) 2023.
21 K. Hei, et. al, "Absolute distance measurement with gain-switched dual optical frequency comb," Opt. Express, 29 (6) pp. 8108-8116, 2021.
22 https://polarisproject.site/
23 T. He, et. al., "Network Tomography: Identifiability, Measurement Design, and Network State Inference", Cambridge University Press, 2021.
24 D. C. Kilper, et. al., "Optical Performance Monitoring," J. Lightwave Technol. 22, 294, 2004.

characteristics of the transmission media, such as noise, delay, and polarization properties of unoccupied spectrum.

General optical probing methods have been studied[25] and experiments have shown that they can be used to determine noise levels and wavelength dependent gain and loss across multiple transmission spans[26]. These sensed spectral properties were used to accurately predict the signal and noise powers of signals that were subsequently provisioned into this spectrum. They demonstrated the potential of spectrum sensing but have not been evaluated for a wider range of parameters and network configurations.

An optical communication signal can be introduced into a fibre in the form of an optical probe and the use of such coherent reference transceivers[27] is a topic of recent investigation, including tomographic longitudinal anomaly detection[28]. These probes can be used for sensing unoccupied spectral regions or channels to improve QoT estimation, enable faster provisioning, and improve anomaly detection. Coherent receivers provide a wealth of information due to the fact that they measure the full amplitude and phase of the electric field in the fibre. However, such probes are themselves signals that can interfere with other signals and change the performance of the system. This can be avoided by sampling an existing communication signal along its path (e.g. with a small optical tap) or by using non-disruptive probing methods, which can sense the entire spectrum[29]. Non-disruptive probing has been demonstrated for on-off keyed signals, but not for other advanced modulation formats with coherent receivers.

Beyond SotA (OP: TRL 4 to 5; NT: TRL 3 to 5): The ICON project will progress optical probe based sensing in several important ways: 1) probing methods will be expanded to additional fibre parameters, including polarization, 2) non-disruptive probing will be developed for use with coherent receivers and a wide range of modulation and digital signal processing techniques, 3) probing methods that re-use reflectometry based sensing (e.g. OTDRs) will be explored, lastly 4) the use of non-disruptive optical probing for fibre sensing, such as Brillouin based sensing[30], will be studied.

The other key advance that will be pursued within the ICON project is to develop optical network tomography. Building on methods developed from data network tomography, end-to-end optical probe measurements will be analysed to infer the state and internal properties of the network. A probe management system within the ICON intelligent platform will be developed to implement tomographic probe routing and diagnosis algorithms. A combination of physics- and AI-based models will be used to analyse the tomographic data. Information theoretic methods will also be exploited to optimize probe routing and localize faults[31].

Fibre types for sensing

SotA: Fibre sensing is traditionally performed in a conventional single mode fibre (SMF), using reflectometry techniques described above, or SMF with Fibre Bragg gratings (FBG) written to it[32]. FBGs are versatile sensors used for different applications. In infrastructure, it makes sense to interrogate FBG arrays or all grating fibres with short spacing between the gratings. These gratings have a reflectivity of the order of -30 dB, which makes them suitable for shorter distances. OTDR approaches can be used to interrogate them with correlation-aided approaches and use them to sense critical infrastructure with higher SNR than Rayleigh backscattering[33]. However, FBG arrays come with higher costs than single-mode fibres and only short distances can be interrogated before the probe signal is hidden by thermal noise.

The use of other types of fibre have not been till now extensively investigated for sensing applications. Multi-core fibres (MCF) were mainly used for transmission experiments in the recent years. Only a few publications mention them and their advantages for fibre sensing for obtaining information on localization [34], or which core is contracted and which is strained. In addition, these fibres were used for shape sensing to solve medical problems[35]. MCF cost is quite high when compared with SMF, and additional fibre components are needed to feed light into them. Furthermore, different cores have different group delays due to slight variations of the refractive indexes, which

25 Y. Wen, et. al., "Efficient fault-diagnosis algorithms for all-optical WDM networks with probabilistic link failures," JLT, 23 (10), pp. 3358-3371, 2005.
26 W. Mo, et. al., "Proactive and Non-Disruptive Channel Probing for Wavelength Switching in Optical Transmission" Photon. J. 9 (6), 2017.
27 D. C. Kilper, et. al. "Q-factor monitoring using FEC for fault management applications," J. Opt. Netw. 3, 651, 2004.
28 R. Hui, et. al., "Measurement of Total and Longitudinal Nonlinear Phase Shift as Well as Longitudinal Dispersion for a Fiber-Optic Link Using a Digital Coherent Transceiver," JLT, 40 (21), pp. 7020-7029, 2022.
29 W. Mo, et. al., "EDFA Wavelength Dependent Gain Spectrum Measurement Using Weak Optical Probe Sampling", PTL, 30 (2), pp.: 177-180, 2018.
30 X. Huang et al., "Temperature Online Monitoring of Submarine Cable Based on BOTDA and FOCT," CIEEC, pp. 1229-1233, China, 2019.
31 D. C. Kilper et. al., "Impact of Topology and Traffic on Physical Layer Monitoring in Transparent Networks", Invited, OW13, OFC 2009.
32 J.K. Sahota et al., "Fiber Bragg grating sensors for monitoring of physical parameters: a comprehensive review" Opt. Eng. 59 (6), 2020.
33 G. Dinardo, G. Vacca, "Fiber Bragg grating demodulation through innovative numerical procedures", Int. J. Optomechatronics, 10 (1) 2016.
34 S. Guerrier, et al., "Field Trial of High-Resolution Distributed Fiber Sensing over Multicore Fiber in Metropolitan Area with Construction Work Detection using Advanced MIMO-DAS", OFC, 2023
35 P. S. Westbrook, et al., "Multicore optical fiber grating arrays for sensing applications", ECOC, 2016, Düsseldorf

makes it difficult to find the exact location of the event[36]. In contrary, hollow core fibres (HCF) have gained high interest in various sensing applications[37,38]. Since record low attenuation and minimum latency have been reported, HCFs are also candidates for communication applications. The use of HCF in JC&S has not been reported so far, possibly due to the Backscattering coefficient of HCF being very low (of the order of -120 dB/m[39]).

Beyond SotA: (FBG: TRL 3 to 5; MCF: TRL 3 to 5; HCF TRL: 2 to 4): In the project, the partners will develop a pioneering model of MCF in a JC&S system, including the different time delays of the cores and their impact on the system. With this model, the methods of improving the localisation of the event will be developed. In addition, we will investigate the application of MCF specifically designed for JC&S. To this end, we will procure a custom-made MCF with three communications and one sensing core. The latter will have an enhanced scattering coefficient (through doping), which will improve the SNR of the interrogation techniques. The project will investigate JC&S for HCF using anti resonant fibres. The main objective is to identify a suitable technology to measure either the weakly backscattered power or to utilize technologies in transmission. Finally, novel types of FBG, such as long period and phase shifted, will be studied for increased sensitivity in SMF.

Extracting sensing information from receiver and sensing data.

The sensing data contains a significant amount of information on network performance and the environment, which needs to be skilfully and efficiently extracted. Furthermore, correlating data from the whole network and other sources, such as traffic cameras, weather stations, AIS etc., can provide further insight and knowledge for use in both telecommunication and non-telecommunication applications. Here, we review the SotA of the receiver and sensing data processing techniques and describe how ICON developed solutions will provide a paradigm shift in this field.

State of Polarization (SoP) and coherent receiver-based sensing (CRbS) and telemetry

SotA: Coherent receivers have become the dominant type of transceiver in the high-capacity transmission systems, due to their ability to employ the digital signal processing (DSP) to effectively compensate for transmission impairments, thus improve the data rates and extend the reach of optical networks. As a result, the coefficients of the adaptive digital filters of a coherent receiver contain information on the current state of the optical path e.g. SoP. Thus, if extracted, this information can be used to monitor the network performance or sense the environment in the vicinity of the fibre cable. For example, the use of SoP was demonstrated for sensing earthquakes in thousands of kilometres of long active submarine cables[40]. In[41], it was shown that the SoP changes can reveal potential availability and security threats, by detecting movements of fibre cables.

Beyond SotA: (SoP: TRL 3 to 6; CRbS: TRL 2 to 5) In this project, we will investigate several innovative techniques to extract data from coherent receivers, to enable improvements in the network resilience and efficiency, and to acquire accurate contextual information of the network. Furthermore, we will investigate how sensitivity of SoP sensing instruments can be increased and how the number of sensing systems can be reduced by simultaneous sensing of signals occurring from multiple fibres. Development of methods for automatic recognition of availability and security threat events will be performed by applying sensing data from a long-duration (>1 year) field-trial on a sub-sea infrastructure. During the field-trial, data from a minimum of four cable-sections will be collected in a database for use in machine learning and algorithm development.

Sensor (optical/non-optical) data processing and correlation of information

SotA: Data generated with typical φ-OTDR is in the order of TB/week, which requires additional storing components at the network node, increases the network energy consumption and ultimately its carbon footprint. Currently, the sensing techniques are deployed within the network to perform a specific task, detect a specific event (vibration, strain etc.). However, understanding the root cause of the event is not simple, often requiring deployment of additional sensors, which further increases the cost, complexity and power consumption of the system. Thus, new more efficient and intelligent DSP algorithms, for processing both local and network-wide data, are needed to make the JC&S a viable solution.

Local data processing. In the signal processing chain, the raw data acquired by the analogue-to-digital converter

36 F. Azendorf, et al., "Characterization of Multi-Core Fiber Group Delay with Correlation OTDR and Modulation Phase Shift Methods", OFC, 2020.
37 Ni, W. et al., "Recent Advancement of Anti-Resonant Hollow-Core Fibers for Sensing Applications", Photonics 8, (128), 2021.
38 J. Freitag et al., "Flying Particle Thermosensor in Hollow-Core Fiber Based on Fluorescence Lifetime Measurements",
39 R. Slavik, et al., "Optical time domain backscattering of antiresonant hollow core fibers", Optics Express, 2022
40 L. Costa, et. al., "Localization of Seismic Waves with Submarine Fiber Optics using Polarization-Only Measurements", Communications Engineering, 2 (86), 2023.
41 T. Dreibholz, et. al., "A Scalable Infrastructure for Continuous State of Polarisation Monitoring for Revealing Security and Vulnerability Impacts in Optical Networks," ConTEL, Graz, Steiermark/Austria, 2023.

(ADC) is processed, which consumes a lot of time and storage. Here, the main inefficiency stems from the idle time, at the interface between the acquisition and storying of the data. In most cases, the interface of the memory solid state drive (SSD) has an up to four times slower writing rate than the analogue interface. Current, ADCs with peripheral component interconnect express have rates of the order of 12.8 GB/s, while the SSD write rate is 3.3 GB/s. Consequently, the data must be pre-processed between acquiring and storing to reduce its volume. Afterwards, the data is read again on a processing machine, which evaluates the wave parameters. Subsequently, the data is stored and used by the interrogator operators to detect potential threats in their system.

Network-wide data processing. In the current coherent networks, the operators use the performance monitoring parameters of their coherent transceivers for telemetry. If such a parameter changes it is an indicator for well-trained engineers that the link is affected by a threat or natural forces[42]. In addition, subsea cables, deployed on the seafloor, are used to detect earthquakes, but without providing this information to an overall management system[43]. As a result, the two possible information streams deliver information to different, isolated receivers, missing on the opportunity to boost the available knowledge and use it for network management, event detection etc.

Beyond SotA: (Local DSP: TRL 3 to 6; Network DSP TRL: 2 to 5).

Local data processing. An average amount of data produced by the sensing system is in the order of TB/week/link. In the project, the partners will investigate what the minimum amount of raw data required to recognise an event is and develop data compression methods to achieve to reduce the data volume by three orders of magnitude (to GB/week/link). This will be done using signals from a variety of interrogators, acquired during experiment and the field-trial. In addition, we will redesign the processing chain to split the effort between the local and cloud computing resources, thus simplifying and increasing the efficiency of the processing of the sensing data. In addition, the volume reduction will also lower the required capacity of the transmission link between the local node and the cloud, further lowering the cost and energy consumption of the system.

Network-wide data processing. In ICON, context is acquired by collecting and correlating the local sensing information across the entire network in a manner described above. This data will then be used to train a novel neuronal network for event classification that will be developed within ICON. The categorised events plus their unique fingerprint will be stored in a database. On top of this database, advanced algorithms will be implemented utilizing AI to recognize the events during the operation of the network. To further enhance the even recognition and localization, to achieve the targeted value of 80% correct event classifications, these algorithms will also be trained using data from sources. Thus, the network data processing methods will be continuously optimized to obtain an effective and long-term solution.

Digital Twin for sensing systems

SotA: DT is one of the most talked-about concepts in the last few years. While the initial idea of a physical twin was proposed by NASA, the DT concept was introduced by Grieves in 2003[44]. It describes an exact digital representation of an existing physical object or process with a constant, automatic flow of information between the existing entity and the digital representation. Driven by advances in signal processing, AI, ML, big data, 5G communication and cloud computing, it is described as enabling technology for data-driven decision making, complex systems monitoring, product validation and product lifecycle management in the context of IoT or Industry4.0[45,46].

In general, the DT is a very recent technology not having reached maturity, especially in fibre optic sensing. Nevertheless, its implementation and application are increasing in several use cases such as smart cities, healthcare, automotive, smart grids and industrial. For optical communication, a DT was introduced to serve fault management, hardware configuration and transmission simulation aspects[47].

Beyond SotA: (TRL 2 to 5) A DT relies heavily on the amount and especially the quality of data that it is provided with. Often this data comes from sensors or sensor networks. However, the DT is not yet implemented for sensors itself and especially fibre sensors. A DT for each of the individual sensing elements will monitor aging behaviour of the sensors and assess data quality. In addition, a smart interworking between the single sensors is planned, to automatically detect outliers in an internal processing step leading to a dynamic calibration data set for the individual

42 K. Kaeval, et al. “Employing channel probing to derive end-of-life service margins for optical spectrum services”, JOCN, 15, (7), 2023.
43 G. Marra, et al. “Optical interferometry–based array of seafloor environmental sensors using a transoceanic submarine cable” Science, 376 (6595), 2022.
44 Uhlenkamp, J. F et al.: “Digital Twin Applications: A first systemization of their dimensions”, IEEE (ICE/ITMC) 2019.
45 Botín-Sanabria, D. M.et al.: “Digital Twin Technology Challenges and Applications: A Comprehensive Review”. Remote Sensing, 1335 2022.
46 Liu, Y. K. et al. “State-of-the-art survey on digital twin implementations”. Advances in Manufacturing, 2022.
47 Wang, D. et al.: “The role of digital twin in optical communication: fault management, hardware configuration, and transmission simulation”, IEEE Communications Magazine, 133-139, 2020.

sensor. With the sensor DT being integrated into the intelligent sensing control platform, recommendations can be given to the user about the handling and lifetime of the sensor fibre. Prolonged lifetime and better error handling will contribute to the green deal. Currently, a Digital Shadow for Fibre Bragg Gratings is under investigation[48], emphasizing the need for more digitalization in fibre optic sensing.

Integrated JC&S controller

Intelligent sensing control platform based on intent and context awareness

SotA: Fibre optic sensing technology is today widely utilized for monitoring the structural health and integrity of various infrastructures. One of the primary applications is the detection of potential fibre cable cuts caused by construction activities such as digging or marine operations[49]. Extending beyond infrastructure integrity, fibre optic sensors have found applications in external environmental monitoring, including detection of leaks in water distribution systems[50], securing oil and gas pipelines against unauthorized intrusions, traffic monitoring[51] etc. Today however these sensing applications and sensing probes are tightly linked and statically allocated. This means that each sensing application might have dedicated sensors and probes that only serve that specific purpose.

Beyond SotA: **(TRL 2 to 5).** This project goes beyond this state of the art by proposing a disaggregation of the sensing architecture, by decoupling the sensing hardware from the sensing applications. This means developing a sensing infrastructure that can dynamically adapt to a variety of sensing tasks without requiring physical alteration or re-deployment of the sensors themselves. Such a system will leverage advanced signal processing, ML algorithms, and adaptable sensor technologies, developed within ICON, to interpret the raw data from a standard set of sensors in multiple contexts, thereby providing a more versatile and cost-effective solution.

To manage this novel sensing infrastructure, the project will develop an intelligent network sensing platform (Figure 1), offering a northbound interface to the sensing applications. This will allow applications to specify their high-level requirements (i.e., their intent), including the type of sensing parameters (temperature, vibration, etc.), the geographic location or scope to be covered, and the precision or sensitivity required. The sensing platform then groups the requirements from multiple sensing applications, and decides which sensing probe need to be activated, using the optical transmission layer (fibre and ROADMs where appropriate), to dynamically configure the underlying sensing infrastructure to meet these requirements. In addition, the platform can include external information to enrich the decision making with additional contextual data (for example other sensing data marking historic trends, or information from other non-sensing sources). This optimises sensor utilization and data processing to deliver the desired outcomes. This ICON intelligent platform will be effectively a bridge between the physical sensing layer and the application layer, enabling a more agile and responsive sensing network. By abstracting the complexities of sensor configuration and data interpretation, it enables application developers and network operators to focus on the end use of the sensing data, facilitating innovation and expanding the potential use cases for fibre optic sensing technology.

Integration of sensing system with network management and its applications

SotA: Today, various sensing devices, detecting fault location and increasingly more, identifying the root cause of the fault, are used around the world to monitor the health of the fibre optical infrastructure. This it specifically important in mission-critical communications, where applications like Supervisory Control and Data Acquisition (SCADA)[52] used by the power-, gas- and water utilities require high availability to maintain transmission systems health and service consistency. These systems span from metro to long-haul and also connect off-shore wind parks, gas- and oil stations, and subsea CO_2 storage. In addition to high availability, these systems also require a minimum jitter and low variance in transmission delay between the dedicated protection paths.

From the telecommunication networks perspective, many future applications on 5G and 6G networks also require high-availability connectivity to operate reliably. For fault localization, the most commonly used device is a handheld direct-detection-based OTDR, with some models customized for continuous multi-fibre sensing with a device installed in major fibre interconnection sites, be it a telecom meet-me-in room, or a splitter box on the field.

In recent years, field-installed coherent transceivers enabling continuous collection of data from the DSP, originally installed for carrying customer data, are considered for use in making decisions on the link health. However, due to their primary purpose to transmit customer data, the coherent transceivers report only link-specific information and are static in their nature. In addition, all of the above-mentioned sensing functionalities are treated separately and in the best case, the sensing data is forwarded only to the network operation centres, responsible for the preventive and

48 Renner, E., et al.: „Implementation of a Digital Shadow for Fiber Bragg Gratings". (IEEE, NUSOD, 2021.
49 S. Bjørnstad, et. al., "A Scalable Data Collection System for Continuous State of Polarisation Monitoring", ICTON, Romania, 2023.
50 A. D'Aniello, "Detecting Background Leakages in Water Infrastructure With Fiber Optic Distributed Temperature Sensing: Insights From a Heat Transfer-Unsaturated Flow Model",. Water Resour Manage 37, pp.: 5535–5558, 2023.
51 Tekinay et al., "Applications of fiber optic sensors in traffic monitoring: a review", Innov. Infrastruct. Solut., 8, (88) 2023.
52 https://scada-international.com/what-is-scada/

operative actions during the faults.

Beyond SotA: (TRL 2 to 5) This project proposes a new approach to analyse the sensing data collected from different sensing sources, separating the analysis' outputs into three functions: operational, strategic, and user applications. The first one uses the sensing data to trigger operational processes, providing real-time and predictive information on the network performance, so that e.g. modulation formats can be optimized for maximum capacity with improved QoT estimation. The second function performs a long-term analysis, providing failure rate-based network availability calculations. Both of these functions can be presented in the form of an infrastructure-specific availability map, displaying all available performance metrics such as failure rate, availability, OSNR, GOSNR, and other. These maps provide visual information on fault probabilities and available performance margins or capacity. When the fault root causes are also known, the map allows operators to identify areas more prone to outages due to storms, digging activity, flooding, or others and make decisions to overcome the problems when planning future infrastructure or network layouts. The third function serves the user application purpose. Depending on the requirements of the end-user, it can analyse and present the sensing data as time series or selected contextual information, e.g. temperature, lightning strikes, solar wind, seismic data, etc. for use in a wide range of user applications.

With the help of these functions, operators can identify the possible threats and assess the availability penalty of each of the network segments, allowing them to make weighted decisions in adjusting their network topology and required protection paths accordingly – either manually, or through automated control plane actions. This contributes to a better understanding of the underlying infrastructure availability and encourages operators to make use of unused network resources. An operator survey conducted among 25 operators worldwide revealed, that up to 80% of operators have more than 40% of their network resources unused[53]. By developing the ICON network availability tools and integrating the intelligent sensing controller with the NMS, we will provide a path towards realisation of the above-mentioned benefits. In addition, we will explore the use of this additional network capability to encourage resource sharing mechanisms such as optical spectrum services[54]. Finally, the collected information can also help operators to select the most suitable infrastructure types for future infrastructure installations, to future-proof the networks the digital world is relying on.

1.1.2 R&I maturity and Technology Readiness Level

ICON is mid-position on the 'idea to application' spectrum. The consortium built this project on years of ongoing strategic research and innovation across multiple institutions and possesses the baseline technologies that will be disrupted and refined during ICON. The proposed **novel components, algorithms and methods** do not yet exist or are in the early stage of proof-of-concept development, but the basic technology and know-how resides within the consortium. Thus, the ICON **innovations** will be at TRL2-3 at project start. By project end, we will have validated them in the lab, and in the field-trials, and thus anticipate a TRL of 5-6. Details of TRL transition for each specific area is given in the beyond SotA descriptions above.

As discussed in sections 2.2 and 3.2, the technology has a clear route to market, via our excellent industrial consortium members, so we are confident that TRLs 8 and 9 will be achieved without undue delay, allowing for regulatory and market approval.

#@PRJ-OBJ-PO@#

1.2 Methodology #@CON-MET-CM@# #@COM-PLE-CP@#

The overall concept of ICON is to develop a fully integrated JC&S networks, which will exploit the sensing data to drastically improve the availability and reliability of the network, but also provide information to the external, non-telecommunication systems. The uniqueness of the ICON solution stems from its intent-based approach and the context-awareness. In ICON, the fixed sensing system is replaced with flexible technologies, which can be adapted to fit the requirements of a specific applications. They can be easily deployed, in a given network segment/path, and torn down, when no longer required. This intent-based operation is facilitated by the adaptable hardware solutions managed by the intelligent sensing controller. The context-awareness on the other hand, enables creation of a complete picture of the network state and the environment around it through the gathering and processing of heterogenous data, from the network and external systems. In ICON, the extraction of the contextual information is facilitated by the advanced signal processing/ML/AI algorithms and its use in the network enabled by the integration of the intelligent sensing system into the SDN network controller. Finally, a critical feature of the ICON solution is

53 K. Kaeval, „Optical Spectrum Services in Open Disaggregated Transport Networks," TalTech press (2023)

54 K. Kaeval, et. al., "Optical Networking SE, 2023. Method and apparatus for providing end-to-end optical spectrum services over multiple transparent optical network domains", U.S. Patent Application 18/075,405.

its energy efficiency achieved by the combination of the intent-based approach (reduction of the sensing probes required) and the innovative processing algorithms to reduce the volume of data needed to be transmitted and stored.

The methodology of ICON can be thus divided into 4 steps: (1) hardware solution, (2) processing and correlation of the data and establishing the cloud infrastructure for storing, processing and accessing sensing data, (3) development of the intelligent sensing platform and its integration with SDN controller, and finally, (4) validation and demonstration of ICON solution, which will include laboratory experiments, field-trials as well as final demonstration of two ICON use cases.

Hardware realisation – sensing techniques

Figure 2 illustrates the different configurations for introducing sensing signals in a ROADM (metro, long-haul, and submarine) network. The project investigates both reflective (R1, R2) and transmissive (P1, P2) sensing signals, which can be introduced or extracted at any of the red access points, depending on whether the sensing is end-to-end (E_i to E_o), unfiltered along amplified transmission path (T_i to T_o), or link by link (L_i to L_o). Note that the end-to-end signals can continue across multiple ROADM nodes. Additionally, where needed, filtering or sensing signal selection (e.g. local oscillator – LO – beating) will typically be introduced at the sensing access locations (E, T, or L). Spectrally, sensing signals can be in-band with the communication signals or out of band on the low or high frequency end. In-band monitoring must contend with or can be sensitive to amplified spontaneous emission noise due to the optical amplifiers, which may be either EDFA or Raman.

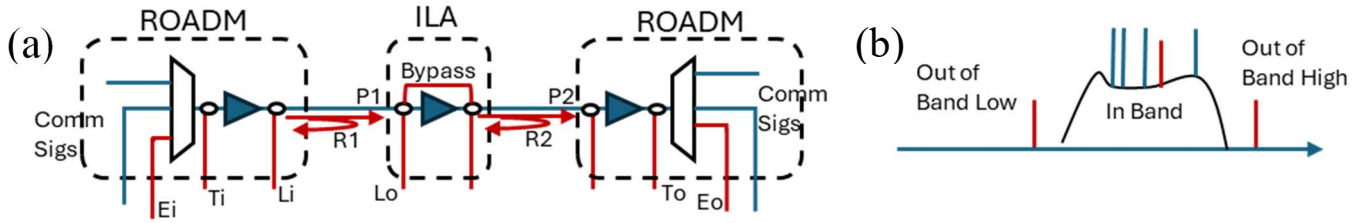

Figure 2: (a) Possible configuration for introducing sensing signals into the network: sensing signals (red) are introduced to a ROADM system either end to end (E_i to E_o), along the unfiltered and amplified transmission path (T_i to T_o), or in each fibre link (L_i to L_o). (b) Sensing signals coexist with the communication signals either in-band or out-of-band at the low or high frequency spectral regions, amplifier bypass will be considered for out-of-band signals.

Research on the optical sensing technologies will investigate the different techniques in the configurations shown in Figure 2, systematically varying the configuration parameters such as fibre lengths and types, signal types and wavelength spacing. Note that the end-to-end sensing can be realised using data-bearing or dedicated sensing signals. Of particular interest is the combination of sensing using the coherent receiver DSP together with dedicated sensing modules/signals. Introducing dedicated probes brings advantages such as greater sensitivity, ability to serve sensing-specific applications etc. However, it also constitutes an additional cost, therefore a key challenge is to realise a sensing system that is cost effective yet maximises the added functionality. This can involve combining reflective and transmissive sensing in a single unit and exploiting efficient tomographic methods on end-to-end signals.

The three sensing methods, developed within ICON, will be characterised and tested to develop a list of device configurations and corresponding capabilities. For example, for TE-OTDR, this will involve characterising the sensing range and spatial resolution as a function of FSR/FSR difference (ΔFSR) of the two OFCs, studying the use of different spectral phase coding to increase the SNR and the quasi-integer ratio operation to overcome the sensing range and/or sampling frequency limits. The impact of the laser phase noise will also be verified and used to derive the D-OFC laser linewidth specifications. These will them be fed back to T2.2 to update the hardware requirements.

In the case of CA-OTDR, hybrid amplification schemes will be evaluated to obtain a measurement range beyond 100 km. In addition, at these long ranges, laser phase noise is one of the key limiting parameters for detection of low-frequency components. Thus, it is necessary to evaluate the code length and the probing signal for higher measurement ranges. This can be a continuous signal consisting of a code or a burst created by code word and fill pattern. However, bursts lead to less energy in the fibre, requiring amplifiers with higher output power. This, however, should not exceed the laser safety class M1 (optical power < 21.3 dBm). Furthermore, the sensitivity to detect dynamic strain variations will be investigated to make sure that weak fluctuations can be measured.

For ONT, custom probe signals/patterns will be studied with both direct and coherent detection, customized for low-cost sensing using relatively low speed components. Tomography probe routing and anomaly correlation techniques will be studied to optimally map out the in-band wavelength dependent transmission characteristics (loss, noise, power, dispersion) and anomalies (power dynamics, polarization fluctuations, crosstalk). These methods will be benchmarked against full line rate coherent transceiver parameters and studied in conjunction with OTDR based monitoring. The flexible topology configuration of the OpenIreland testbed will be used to vary the number of links

and nodes (up to 1700 km and 10 nodes) and metro ROADM and PON/point to point access networks.

The characterisation of the sensing technologies will be carried out in tandem with the development of the DSP algorithms since the capabilities of the sensing methods are to the large extend determined by our ability to extract information from the acquired data. Thus, the configuration list will also include the DSP methods and their parameters for each device set-up. The complete configuration list would be then used by the ICON intelligent sensing controller to facilitate the intent-based operation, which relies on effective matching of the ICON sensing technologies with the application requirements.

Hardware realisation – speciality fibres

New fibre types as MCF and HCF are attractive for future communication application to enable an increase of capacity by space division multiplexing of to support low latency transmission, respectively. Regarding MCF, ICON will use one of the additional cores as a specific sensing channel. This core may have different doping or dimensions to increase its sensitivity towards selected environmental parameters. This is achieved e.g. by increasing the backscattering of the core material. MCF will be investigated in lab experiments to explore the potential of this concept. In a later stage, MCF sensing will be tested using the ICON hardware, where the interrogators will be placed on both ends of the fibre to jointly interrogate the communication (one or more) and the sensing core to improve the event localization.

HCF based fibre sensing up to now takes advantage of the possibility to fill the core with special gases. In the ICON project, the low backscattering from these fibres is the major challenge. We will use the developed OTDR methods and existing coherent and incoherent OFDR techniques in the lab to proof concepts to localized backscattering also for HCF. The lab tests will be supported with simulation, where possible.

In terms of the FBGs, the various types of gratings will be tested to achieve a better sensitivity in terms of strain and temperature. As the performance of the FBG-based sensor ultimately depends on the resolution of the interrogator, the performance and the capability of this sensing technique will be tested using the sensing solutions developed within ICON. Based on the results, the recommendations, in terms of application scenario and the sensing type and configuration, for the FBG-based sensing, will be drawn.

Data processing and modelling

Investigation of optical sensing methods will rely on lab-based experimental and field-trial measurements backed up by analysis and modelling. DSP methods will use digital backpropagation techniques with coherent receivers and optimized feature recovery for longitudinal anomaly detection and sensing. Custom modulation patterns for the dedicated sensing signals will be exploited to better isolate and extract features. Both classification and regression ML methods will be studied and compared against analytical methods. These methods will be used for both direct sensing data extraction and with correlation and tomographic reconstruction techniques over extended network segments. Both edgewise and run-length probing algorithms will be studied and analysed in conjunction with experimental measurements.

Local data. The local data will be acquired by ADCs and pre-processed before storing the minimum amount of data required for event classification. The processing chain will be split into two stages to improve the efficiency of the entire chain. In the first stage, the raw data will be pre-processed with advanced algorithms in the processing unit. Two approaches will be investigated during the ICON project, (1) the reduction of the data in the FPGA by evaluating the sampled signals with the ARM processor; (2) utilizing digitizer cards with high sampling rates and the internal memory of a workstation. Here, the data will be analysed before writing it to an SSD. Moreover, algorithms that analyse the differential phase along the fibre will be implemented to detect events even with low SNR. In the second stage, the compressed data will then be uploaded to the cloud, where innovative algorithms will be used to further process the data. As a result, the processing chain of local data will be simplified by reducing the sampling rate requirements of the ADC and the SSD, as well as lowering the transmission rates of the local node – cloud infrastructure link.

Network-wide and external data processing and correlation. Here, the categorized events will be stored on a data lake to improve the event recognition by implementing ML algorithms in the network infrastructure (higher levels than physical layer). To improve the event recognition, external data (e.g. from AIS) will be correlated with the local and network-wide sensing data.

Cloud-base infrastructure and smart user interface, ICON intelligent platform in Figure 1, will be the central hub for the ICON data, algorithms and systems. It will enable access to sensing information stored in the cloud and receiving data from external sources as well as execution of the ML/AI and DT algorithms. An application programming interface (API) specification will be developed, using the data presentation format designed in T2.3. The API will provide access to the intelligent platform to software components developed by ICON as well as NMSs. A smart

web-accessible interface will also be developed to provide an intuitive use of the platform without requiring in-depth knowledge of the system.

ICON Digital Twin. The developed fibre models will result in a DT of the interrogators, links and the network infrastructure that will provide valuable network state information and the system components for varying environmental conditions. It also will be used as a basis for the ML-based anomaly detection approaches. Thus, we can also test the robustness of the ML algorithms beyond the experimental data and for rare events. Additionally, in the system, we use the DT to realize a dynamic adaptation of the sensing parameters based on the intent. In this sense, extreme environmental conditions, like high strain or temperature, will be monitored and the parameters of the evaluation algorithms updated. In a further step, data of various sensors can be correlated to detect performance variation and failure at a very early stage. Sensing information from the communication channels can improve the reliability further as it opens the door for sensor supervision. The diagram of the ICON DT virtual network functions (VNF) displaying the linkage with other technologies developed by the consortium, is shown in Figure 3.

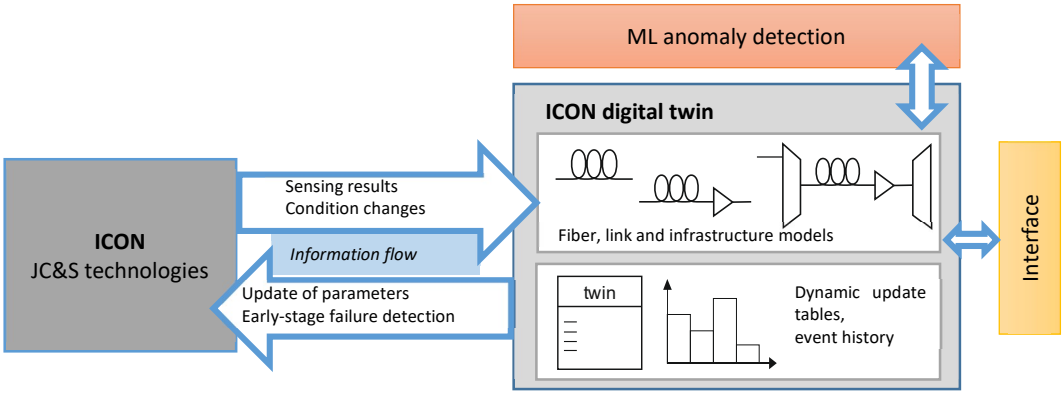

Figure 3: ICON DT concept illustration.

The DT concept of ICON will be tested first in lab experiments, and later field trial, and integrated into the ICON intelligent platform.

Intelligent sensing control platform

The intelligent sensing platform developed by ICON will enable applications to define high-level features, such as sensing parameters (i.e., temperature, mechanical stress, etc.), accuracy required (i.e., precision and reliability of the measure and whether in the time domain, space domain, frequency, etc.), location where the sensing should take place, and other use-case dependent parameters. The platform will then decide which sensor probes are required, and on which routes, to satisfy the requirements from the applications. It is important to highlight that data from sensing probes can be shared among multiple applications, thus increasing accuracy and efficiency of resources (both in terms of physical probing devices and spectrum used in the fibre).

While designing the sensing platform, we will consider the fact that different probes have distinctive features, for example in terms of sensing parameters, reach of the probe, measurement accuracy, routability across network devices (including amplifiers, wavelength switches and other filters, optical splitters, etc.). The number of probes involved will depend on type and number of probes available, overall network load, wavelength availability, restriction on possible GOSNR deterioration by the probes, effect of data channels and environmental factors on the probes' accuracy etc. In addition, by using the dynamic wavelength switching of today's ROADM-based network, some of the probes can be used dynamically to scan multiple links over time, thus increasing the information that a small number of probes can collect about the overall network state.

The sensing platform will also enable the addition of contextual information, that can enhance factors such as accuracy and timing (i.e., for raising an alarm), by considering additional factors such as environmental conditions, operational context, and historical data. An example is the use of DAS and SoP sensing, for building a contextual environment surrounding fibre cables can be used to determine whether there is potential threat to the fibre cable.

The final ICON intelligent platform (Figure 1) will be developed as containerized VNF for easy adoption by a wide range of SDN controllers, network operating systems, and cloud-based platforms. The associated APIs will be developed for compatibility with other SDN control frameworks focusing on ETSI developments such as TeraFlow[55].

Validation and demonstration of ICON concept

The validation of the ICON-developed technologies will be performed through a series of lab-based experiments and

55 https://tfs.etsi.org/

field-trials and will culminate in the two final demonstrators. The experimental tests will be carried out using the extensive infrastructure available to the ICON consortium, listed in Table 1.1. This spans from lab-based testbeds, through campus network, aerial cables to subsea network. Using this comprehensive infrastructure, a suit of tests will be performed to examine all aspects of the ICON technology, including ability to sense vibrations, static and dynamic strain, environmental changes like temperature, wind, water pressure, validating the coexistence of sensing and data signals on the same fibre etc. These tests will also be used to collect data for the DSP/ML/DT development and to test the effectiveness of these algorithms. In particular, the Elerings fibre and the TN subsea network will be used for long-term data collection that will be exploited to develop the AA and to testing processing algorithms of rare events. The experimental set-up of the year-long field-trial to be carried out on TN subsea network is shown in Figure 4.

Table 1.1: Infrastructure available to ICON project.

Type	Name	Description and relevance to ICON	Primary test scenarios
Indoor	OpenIreland testbed	Testbed features a temperature-controlled telecom site, with various types of optical communication equipment from all network layers, multiple ODF panels, 2000 km of spooled fibres, Polatis fibre switch, ROADMs, and amplifiers, which can be automatically interconnected to create various network topologies.	On-site temperature monitoring, network intrusion detection, database verification, sensing and data signal coexistence, active probe switching, cross-layer sensing, data extraction and correlation
Indoor	Tampnet lab	Laboratory with several 25 km sections of G.652.D and G.654.E fibres.	On-site vibration and temperature monitoring, pre-testing of sensing systems
Indoor	ADTN lab	Lab. with 600 km of G.652.D fibres, FSP3000 shelfs with WDM filters, amplifiers, ROADMs, coherent transceivers, climate chambers, acoustic chambers including stretcher, loudspeaker, guide pulley	On-site temperature monitoring, coexistence of signal and sensing channels, dynamic strain and static strain sensing,
Indoor	FAU lab	Fibre sensing lab with OFDR setup (incoherent and coherent), Raman sensing test bed, HCF setup, FBG writing station and climate chamber	Temperature and strain sensing for HCF, signal processing and digital twin development
Buried	OpenIreland campus	Campus infrastructure provides the access to dark fibre segments across Dublin	Vibration sensing, sensing and data signal coexistence,
Buried	ADTN field trials	4-times 8.5 km fibres buried at the depth of 0.5 m	Sensing and data signal coexistence, vibrations, temperature variation in the soil, pre-testing of sensing systems
Buried	BUT campus	Campus infrastructure with 1 – 60 km segments, each equipped with ADVA Open Line System (OLS) and 200Gbit coherent transceivers, installed in parallel with DAS and DSTS (BOTDA)	Vibration sensing, sensing and data signal coexistence, pre-testing of sensing-systems
Aerial	Elerings optical power grounding wire-based	OPWG cables spanning 2700 km across Estonia, exposed to environmental changes. Most segments feature installed DD-OTDR equipment and OLS, carrying coherent and DD transmission. The access to Elering fibres is granted through TalTech	Environmental changes: temperature, wind, lightning, EMC, solar winds, freezing, flooding, stress tolerance, sensing and data signal coexistence, long-term data collection
Subsea	Tampnet subsea	Critical infrastructure for the energy sector (oil, gas, windfarm) in Europe. The new passive subsea fibre cable with 9 landing stations along the Norwegian coast has several fibre pairs available for testing. Available segments lengths 0.6 to 700 km plus looped sections. Possibility to access fibres in cables running to oil and gas installations.	Vibration sensing, vessel and subsea activity sensing, subsea environmental changes, temperature, tides, water pressure, high-speed coherent signals interference, long-term data collection

For fibre sensing experiments, field-trials are key since generating realistic scenarios and data through experiments in lab emulations of e.g. impacts from different types of vibrations on 100 km of a buried subsea fibre cable, is challenging or even not realistic. Furthermore, identification of events like different types of vessels crossing the cable, environmental parameters like stormy weather and wave-height will need an extended observation before a

representative data from repeated events can be collected. A long-duration field-trial will therefore be performed on at least four individual sections on the approximately 700 km long NORFEST subsea fibre infrastructure along the Norwegian coast. The outcome of the field-trial will be:

1. Collection of sensing data during at least one year, building a database for algorithm development and ML techniques for automatic identification of patterns in the data. Additional context information will also be stored including work in node-rooms, trawling, vessels crossing the cables etc.
2. Comparison and correlation of data collected using different techniques installed, at least at one site using parallel fibres in the same cable section, two or more sensing systems relying on different sensing principles.

The raw-data from the most recent period (e.g. a week) will be stored locally at the sensing nodes and selected, processed clips from that data may then be uploaded to a datacentre for long-time storage. Such clips are presenting a significantly reduced dataset compared to the raw data that will be used by the Network Operation Centre for data representation in a Graphical User Interface. The latter may also show data from other data sources, like e.g. AIS. The clips of raw-data representing events, will also be used to develop algorithms and ML techniques for automatic recognition of events.

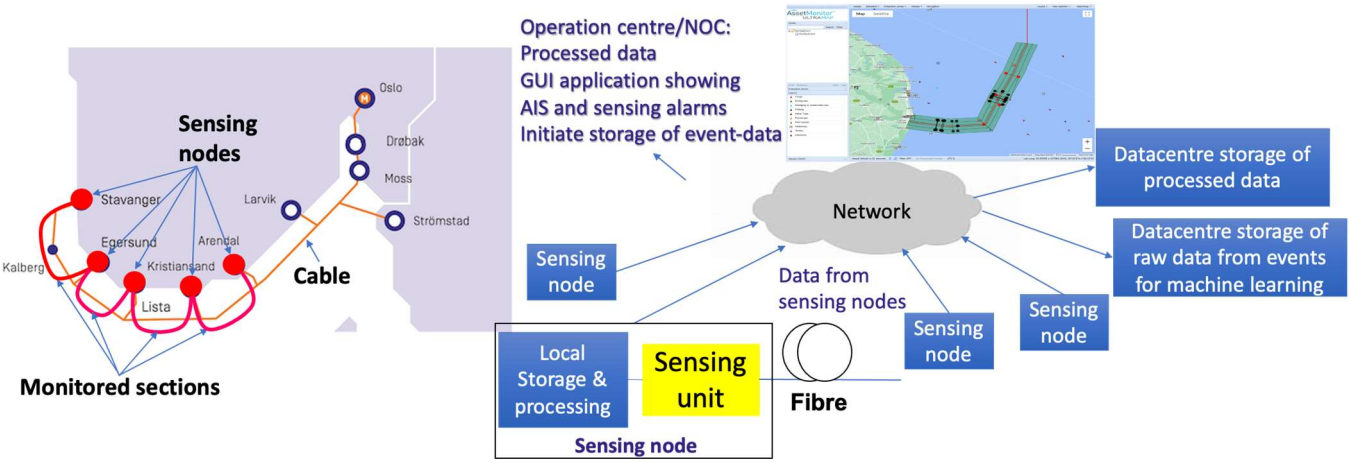

Figure 4: Experimental set-up for long-term field-trial using TN subsea network for collection and storage of data using multiple sensing-techniques.

Final demonstration of ICON technology. The two use cases that will be presented to demonstrate the potential of the ICON concept include the availability assistant and the on-site network intrusion detection.

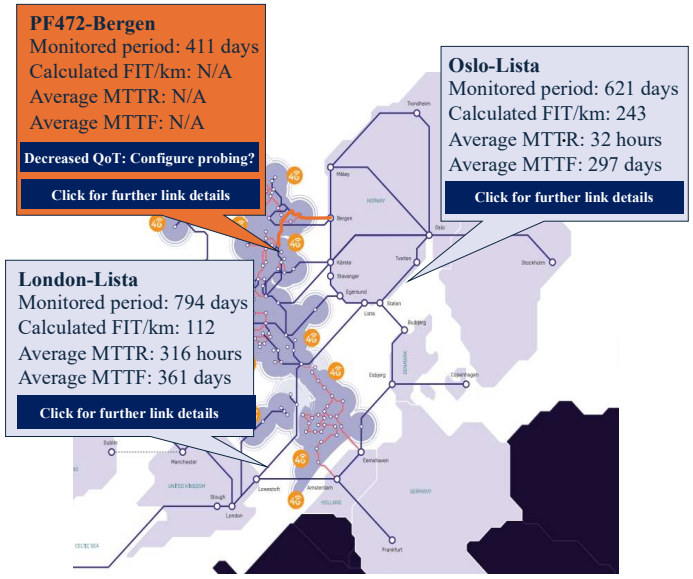

Figure 5:Availability map showing information of three links. The PF472 – Bergen path had no previous faults (FIT/km = N/A) but a degradation in QoT has been detected. The option to add sensing probes to the link is automatically provided.

Availability assistant (AA) is a database containing the information about the performance of different links within the network. The main figure of merit of the path availability is the failure rate that will be calculated using the long-term analysis from the given link using variety of sensing and monitoring techniques. The results will be presented

in a form of an infrastructure-specific availability map, displaying all available performance metrics such as failure rate, availability, OSNR, GOSNR, mean time between failure, mean time to repair, and primary fault categories of the failures in a uniform manner for all links, regardless of which sensing or monitoring method was used on the link. This map provides visual information, in which network segments the faults are more probable to occur, allowing operators to identify areas more prone to outages due to storms, digging activity, flooding, and make decisions to overcome the problems, when planning future infrastructure or network layouts. The AA will also accept inputs from other systems, providing short term information about events that could affect network availability. These might include information on planned infrastructure upgrades, which bring with them heighten threat of fibre cuts due to excavations. In response to such updates of AA, the network operator might request from the network controller deployment of an additional sensing probes on the affected path to ensure any interference with the fibre is detected in real-time and the proactive action can be taken. This intent will then be passed to the ICON intelligent sensing platform and the correct type and configuration of the sensing technology will be automatically deployed and thorn down after the works are completed and the thread no longer exists.

To demonstrate the AA, the ICON consortium will collect the sensing data from the long-term trials and where possible use the data provided by the network operators (TN, Elering) and calculate the failure rate of the network segment under monitoring, considering the length and number of failures and/or detected disruptions on the link. The initial failure rate evaluation in the project will be based on a 3-month period but will be extended to a one-year period as time passes. The output of the failure rate calculations from different monitored links will then be converted into an availability map, similar to the one shown in Figure 5, helping end-users to share optical resources and make weighted decisions in their end-to-end link availability calculations, e.g., when using optical spectrum as a service.

On-site network intrusion detection and rerouting. The final demonstrator of the ICON project will showcase the ability of the developed technology to detect interference with a fibre infrastructure, raise an alarm and perform a rerouting of the signals from the affected link to a different fibre.

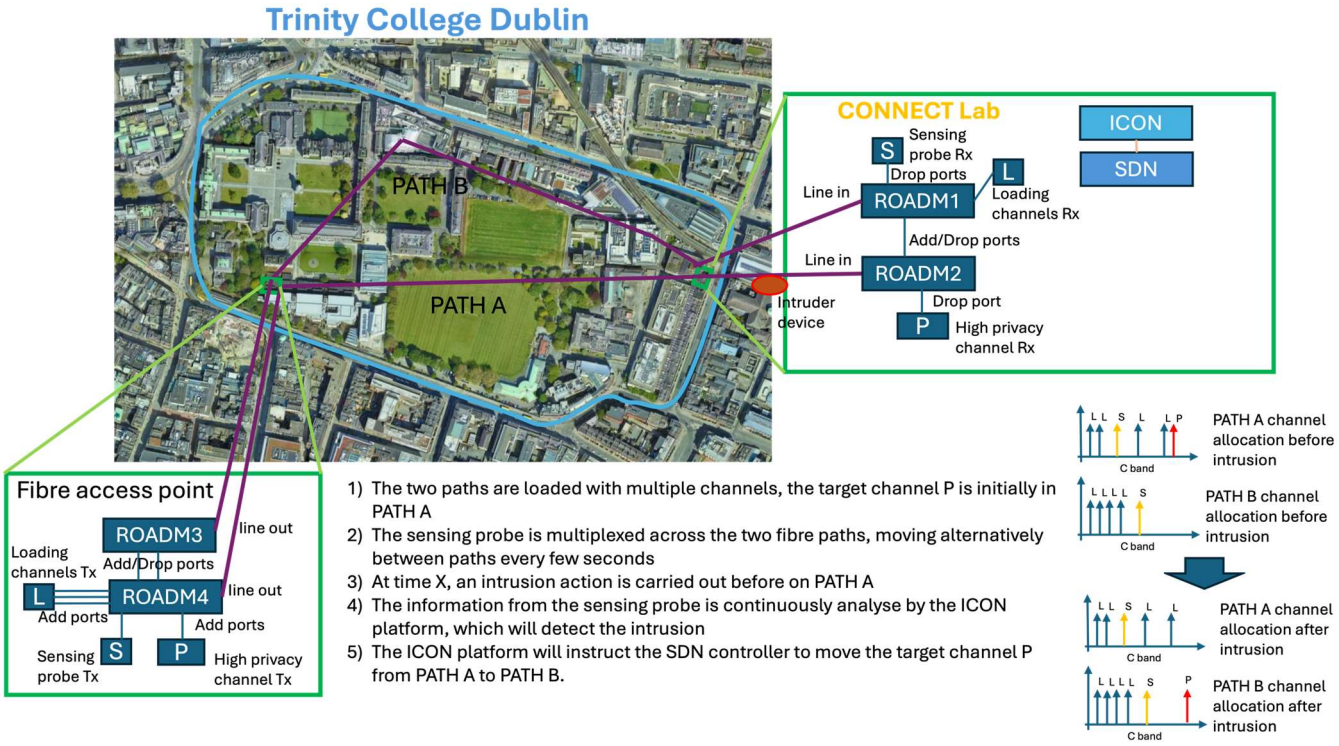

Figure 6 Setup for the demonstration showing the detection of an intrusion by the ICON platform, which instructs the SDN controller to reroute a target channel from PATH A which is under attack, to a secure PATH B.

Data from sensing devices will be used to detect possible intrusion in a given fibre. This will be carried out by sensing specific signatures linked to changes in both power and polarisation. Once the system detects the intrusion with a given confidence (e.g., between 90% and 95%, which will be established in Task 6.1), if any of the links in that fibre are labelled as having high-privacy requirement, the sensing platform will inform the SDN controller to reroute those specific links across a different route. This decision will depend on the type of sensing available and its accuracy. For example, if the sensing information can determine with sufficient confidence the presence of an intrusion, but it cannot determine its location, then the path will need to be routed over a completely disjoint path. Whether this path is available will depend on the type of assurance the operator gives to the customer, but in principle this can follow

the general rules of network protection (i.e., 1:1 vs N:M).

If the sensing information can also determine the span where the intrusion has occurred, then the rerouting only needs to bypass a specific link of the path (i.e., between two ROADMs). This shows the important trade-off between complexity of a sensing system (i.e., where ability to determine location of attack comes at the expense of system cost) versus the benefit it can provide to the overall network (i.e., enabling bypass of just one link improves fibre utilisation and thus link cost).

This demonstration will show how the sensing system, upon detection of an attack, will reroute a specific wavelength path, following the specific information provided by the sensing application. It will be carried out in the Open Ireland testbed infrastructure, where we will produce an intrusion event, which will trigger the reroute of one or more wavelength channels in a WDM metro transmission system.

Figure 6 show how the demonstration will be implemented in the CONNECT lab, using field fibre across TCD, and describes the different steps involved in sensing an intrusion and rerouting a target channel to a disjoint path.

1.2.1 National and international activities informing the proposed research.

ICON builds on expertise from significant research and innovation activities in many completed and ongoing projects whose results will feed into its programme of research and innovation activities. These are detailed in the table below together with details of existing links or, if no link exists, how a link will be established.

Project details/partners	***Relevance to ICON***
POLARIS, ***TCD*** NATO SPS G6056	Development of a high resolution, reliable, cost-effective, label-free optical laboratory-on-fibre using a gain switched D-OFC. ***Relevance:*** D-OFC and fibre sensing experience will be leveraged/build on.
ECO-eNET, ***TCD*** *SNS JU 101139133*	**TCD** is the technical lead and **ADTN** and **TalTech** are partners on the ECO-eNET project investigating a mesh edge/metro network for 6G that would include Optical Spectrum as a Service (OSaaS). This uses both analogue and digital signals, including optical fibre sensing signals. ***Relevance:*** The ECO-eNET edge network architecture would be well suited for ICON JC&S systems and thus provide a pathway for their use in future 6G networks.
SOFIN, ***CyRIC, FAU, ADTN, DTU*** *HE framework No 101093015*	**CyRIC** is coordinating the SoFiN Horizon Europe project developing a fibre optics multi-parameters sensing platform, using time and frequency reflectometry. CyRIC develops the cloud infrastructure for data storage and processing, and DTU develops new ML algorithms to extract phase data from noisy signals. ***Relevance:*** Know-how gained from the project will be exploited in ICON.
Quantifisens, ***ADTN*** *Project ID 03RU1U071D*	Development of interrogation technologies for infrastructure monitoring utilizing FBGs, ESF and SSMF to do short reach vibration sensing and supporting the work of other partners on AI. ***Relevance:*** Test setups for acoustic signal generation and dynamic strain can be used in ICON as well as different sensors.
DigiMonet, ***FAU*** *BMWi:0350066B*	Nationally funded project Digitized Optical Sensing Network for Intelligent Monitoring in Energy Production. FAU is contributing to FBG sensing with optical frequency domain reflectometry. ***Relevance:*** initial work towards cloud-based signal processing and digital twin modelling will be exploited in ICON.
Centre for Geophysical Forecasting CGF TN *Grant No. 309960*	Nationally funded research centre in Norway, focusing on sensing of geophysical events, weather and climate related parameters, whale subsea activity using fibre sensing. Also looking at Carbon capture and storage management, hydrocarbon production monitoring, geohazard monitoring and forecasting. ***Relevance:*** ICON consortium will interact with CGF team for knowledge exchange and results exploitation.
OpenIreland ***TCD***	OpenIreland is the SFI[56] funded testbed for experimental research on future telecommunication networks including optical access/metro transmission and 5G radio equipment, through licensed 5G spectrum. It is connected via dark fibre to the national research network, HEAnet, which enables experiments in a live network. ***Relevance:*** OpenIreland will be used for probing and network tomography lab experiments and dark

56 Science Foundation Ireland https://www.sfi.ie/

	fibre connections will be used for the final demonstration in a metro/campus network.
*CONNECT **TCD** 13/RC/2077_P2*	The CONNECT Centre is the SFI centre for future networks and communications. Headquartered at **TCD**, CONNECT supports over 200 researchers from 10 research institutes across Ireland. Dependable Networks is one of the research themes and OpenIreland one of flagship testbeds in CONNECT. ***Relevance:*** TCD is coordinating ICON project and hosts the CONNECT Centre.
*6G-XCEL, **TCD** SNS JU 101139194*	**TCD** is the coordinator of the 6G-XCEL SNS JU project which seeks to address the lack of coordination of AI algorithms across mobile, optical and cloud network through research on high edge network use cases that employ multi-party AI controls running over compute accelerators to coordinate control across radio and optical networks. ***Relevance:*** There is strong synergy with LightSense in the development of mechanism for processing data coming from multiple sources
HighFlySens, FAU DFG SCHM2473_4_1	National funded project developing a high spatial resolution multiple-parameter flying particle sensors in HCF. ***Relevance:*** initial work on the sensing using HCF will be leveraged.
FiberRisks MVCR VJ01010035	National project "Security risks of photonic communication networks" funded by Ministry of Interior of the Czech Republic deals with a complex analysis of security risks of optical fibre networks.
ACIMA MVCR VK01030048	National project "Anomaly detection in critical infrastructures using machine learning" under Ministry of Interior of the Czech Republic aims to design and realization of a laboratory testbed that enables from the transmission parameters of data signals (from 1 to 200 Gbit/s), detection of events such as network degradation, cable manipulation or other threats/attacks.

1.2.2 Interdisciplinarity

This project depends heavily on interdisciplinary collaboration between electrical engineering and computer science disciplines, including the unique research communities of integrated photonic communication devices, optical communication subsystems and systems, radio devices, wireless communication systems, optical network control and management, wireless network control and management, and optical and radio network architectures. As a result of this, the team has observed clear differences in the interpretation of certain concepts and practices.

1.2.3 Integration of Social Sciences and Humanities

The Work Programme does not indicate the need for the integration of social sciences and humanities in the proposed research and innovation activities. The consortium does not believe that these disciplines are relevant to the proposed research of ICON.

1.2.4 Gender Dimension

The Work Programme 2023-2024 did not identify any gender dimension for this topic. As the ICON proposal focuses on the potential of AI only within physical layers of communication networks, the consortium is confident that its proposed research programme does not raise any concerns in respect of gender dimension. However, the consortium will monitor progress of the work in respect of all gender or social dimensions throughout the project duration.

1.2.5 Open Science Practices

ICON will operate its open science practices under the principle '**as open as possible, as closed as necessary**'. The 'closed' aspect refers to the protection of the project's Foreground IP and any legitimate interests or constraints such as commercial exploitation, data protection rules, privacy, confidentiality, trade secrets, security rules. When a consortium partner is able to publish its results, these will be made available through open access publishers and open access platforms under the Creative Common International Public Licence (CC BY). The preferred open access model will be the gold model. As the consortium partner employing the main author will take the responsibility of hosting the publication, the platform chosen by each partner may vary. However, the overall approach to publications will be consistent. The approach will include sharing preprints, participating in open peer review and ensuring all project outputs will be made open access immediately through trusted repositories such as TCD's TARA or Zenodo. The consortium will also use the European Commission's **Open Research Europe** platform to enhance its open science approach. All publications will have a DOI (Digital Object Identifier) which will have metadata linking it to both the project and the author through their researcher ID such as ORCID. The various platforms have features which will enable monitoring such as the tracking of the number of reads/downloads. This will facilitate reporting

on impact and success of the approach. The consortium will adopt a consistent approach to open science practices that will be agreed in the detailed Data Management Plan which will be concluded by Month 6. The approach aims to ensure the widest possible sharing of results and outputs from the project.

1.2.6 Research Data Management and Management of Other Research Outputs

A detailed Data Management Plan (DMP) will be delivered by M6 which will describe how the ICON will seek to maximise the availability and re-use of the project's data for research purposes. This document will be iterative and evolving, subject to discussion and review at formal meeting. There will be formal reviews of the DMP in mid-project (M18) and, then again in M30 (6 months before the end).

The ICON management team aims to ensure the availability and utility of research data. The DMP will comply with the FAIR (Findable, Accessible, Interoperable, Reusable) data principles. It will describe what research data the project will generate, whether and how it will be made accessible in line with the FAIR data principles for verification and reuse, and how it will be curated and preserved. It will also summarise how the data collection, storage, protection, retention and destruction will be handled during the project execution. Anticipated elements of the DMP are summarized below.

- *Types of data/research outputs*: As the project is a Research and Innovation Action, the consortium anticipates that ICON will generate qualitative and quantitative research data (measurement and calculation data, software tools, hardware/experimental details) arising from the research programme and research dissemination activities.
- *Findability of data/research outputs*: All data will be named in a uniform way following a specific naming convention according to best practices identified. Basic metadata will be used in front-page information to facilitate the efficient recall and retrieval of information by project partners and external referees.
- *Accessibility of data/research outputs*: ICON will adopt open science practices, providing open access for all research outputs. All partners will be required to ensure that they will archive the publications on institutional repositories of at least one of the co-authors after peer-reviewed publication. The open access publication will be done following the guidelines on open access to scientific publications and research data in Horizon Europe. As data and outputs are identified, updates on the standards for metadata creation will follow the project's DMP.
- *Interoperability of data/research outputs*: Key datasets and digital assets are identified in the work program. These will be developed to be compatible with the European Open Science Cloud. While the partners may manage other internal data slightly differently in line with their organisation's principles and resources, the DMP will establish agreed standards, formats and vocabularies for data and metadata to ensure both accessibility and visibility of the project. These would include adopting standard data formats (including but not limited to) technical specifications, measurement results, file formats for the visual representation of results. As datasets are identified and collected, updates on the standards for metadata creation will be outlined in following DMP versions.
- *Reusability of data/research outputs*: All data/research outputs will be documented to support proper data interpretation via a clear and accessible data usage licence, provenance of information and meet relevant domain standards. The consortium's obligations for reusability will be addressed in the Consortium Agreement. Any research data will be licenced under the latest version of the Creative Commons Attribution International Public Licence (CC BY) or Creative Commons Public Domain Dedication (CC 0). The accessibility of data/research outputs will adhere to all legal and contractual obligations.
- Curation and storage: The details of the curation and preservation of the data will be addressed in the DMP. ICON's Project Manager, who will be based in TCD, will take on the responsibility of curation. They will be responsible for data management and quality assurance in conjunction with the General Assembly. Data management costs have been factored into all relevant partners' budgets.

The parties in the ICON consortium agree that any Background, Results, Confidential Information and/or any and all data and/or information that is provided, disclosed or otherwise made available between the Parties during the implementation of the Action and/or for any Exploitation activities ("Shared Information"), shall not include personal data as defined by Article 2, Section (a) of the Data Protection Directive (95/46/EEC) and applicable local implementing local legislation; or, as from May, 25th 2018, Article 4 of the General Data Protection Regulation. The Data Protection Directive, its implementing local legislation and the General Data Protection Regulation are hereinafter collectively referred to as the Data Protection Legislation. Accordingly, each party will ensure that all data and information contained in Shared Information is anonymised such that it is no longer personal data, prior to providing the Shared Information to such other parties. #§CON-MET-CM§# #§COM-PLE-CP§# #§REL-EVA-RE§#

2 IMPACT #@IMP-ACT-IA@#

ICON will produce innovative results that will deliver a significant contribution to improving the reliability and

security of the network, while at the same time enabling new functionality and sensing based services. ICON contributes to the Expected Outcomes anticipated in this topic as outlined here and to the wider impacts of the destination, as explored in the next section.

2.1 Project's pathways towards impact

2.1.1 Contribution to Expected Outcomes and KSOs

Expected Outcome #1: Sensors/probes to monitor the quality of the communication network and of photonic signals transported in the communication network.

ICON will develop a suite of novel flexible, adaptable and complementary sensing techniques for use with optical networks. CA-OTDR, TE-OTDR and ONT are capable of operating on a wide range of topologies to detect diverse range of events. In addition, the DSP algorithms delivered by ICON will enable extraction of information from the sensing probes as well as the photonic data signals, to facilitate a more efficient monitoring of the network performance. These will be tested using data gathered from a long-term trial (>1 year), which is a unique feature of this project. The correlation of data acquired from an entire network will further aid in ensuring the quality, security and reliability of the network. Overall, ICON will open up a new dimension in which optical networks can scale in spectral efficiency, reliability, availability, and security through the added data and functionality provided by optical sensing.

Target groups who benefit: All European network operators, network vendors and service providers, industries reliant on reliable, secure communication such as hospitals for remote surgery, finance/banking, military etc. ICON will deliver a large amount of data and new testbeds, which will benefit researchers developing new sensing methods, DSP algorithms, AI models etc.

Expected Outcome #2: Methods to use the network as large-scale distributed sensor.

The sensing techniques developed within ICON will also be applicable for extracting information about the environment in the vicinity of the fibre cable, such as strain caused by the damage to the infrastructure (e.g. a bridge or building) or temperature (e.g. due to fire). By designing fibre sensing into optical networks, entire networks will become large, distributed sensors that can be exploited for a wide range of applications including sensing seismic activity, tsunami warning, monitoring of urban transportation systems, flood monitoring and tracking, explosion detection, and intrusion detection. Furthermore, the context-awareness of ICON, facilitated by its ability to process and correlate information from the network as external sources, will improve the performance of this distributed sensor beyond what would be possible when relying on the sensing data alone.

Target groups who benefit: Diverse disciplines such as urban traffic management, geology, oil/gas/water/energy companies, law enforcement, emergency response systems will have new instruments in the form of large-scale fibre sensors to use in operation. Network operators and infrastructure providers will gain new revenue streams. Society as the advancements in warning systems for natural disasters will save lives; advancements in mobility systems will enable greater efficiency saving time and energy.

KSO A: strategic autonomy by leading the development of key digital, enabling and emerging technologies, sectors and value chains to accelerate and steer the digital and green transitions through human-centred technologies and innovations.

European sovereignty and strategic autonomy are heavily dependent on our ability to maintain control over the communication infrastructure, ensuring that it remains secure, resilient, and independent from external influences. With a rising threat to our telecommunication infrastructure, such as the fibre cables connecting Europe and Americas, it is extremely important that we are able to protect them from interference and repair quickly in case of damage. ICON delivers technology that will be able to detect and raise an alarm if the fibre cable is interfered with and pinpoint the location of the damage, to allow for quick and efficient repair.

KSO C: Making Europe the first digitally enabled circular, climate-neutral and sustainable economy through the transformation of its mobility, energy, construction and production systems.

ICON solution not only allows for the protection of telecommunication networks, but also other vital infrastructures such as electricity grids, water and gas pipelines, off-shore wind parks, oil platforms, or CO_2 storages. These often are paired with a fibre cable supporting a mission-critical communication, such as SCADA. Deploying ICON sensing technology over these cables would thus enable protection and threat detection/warning on one hand and fault location for a faster repair on the other. This is of particular importance for transport of the renewable energy, as when interrupted, to reduced supply needs to be supplemented by energy generated from coal or gas. Thus, ensuring the reliability of the energy supply is one of vital steps toward achieving climate-neutral and

sustainable European economy.

KSO D: Creating a more resilient, inclusive and democratic European society, prepared and responsive to threats and disasters, addressing inequalities and providing high-quality health care, and empowering all citizens to act in the green and digital transitions.

ICON will contribute to KSO D in two ways: firstly, it will deliver technology that can be employed to warn and responds to threats such as earthquakes or sabotage of our vital infrastructure. Secondly, by improving the quality, reliability, and security of telecommunication networks, it will facilitate deployment of a vast number of applications that will improve the lives and empower the citizens. Whether employed for common use such as keeping in touch with family and friends, remote learning, financial services, developing online business or more futuristic applications like undergoing a remote surgery, telecommunication networks need to be reliable, secure and deliver the required capacity and connection speeds. Despite the large investment in network infrastructure across Europe, there are still areas where Internet connection is realise/supported using sparse, old or prone to breakage cables, failure of which can leave significant number of citizens without the access to the Internet. ICON technology and the AA will provide tools to network operators to gain a better understanding of their infrastructure and how to operate and manage it in an efficient manner.

KSO's - target groups who benefit: By contributing to the KSOs, ICON will benefit a large variety of target groups, from business and industries, governments to current and future generation of European Citizens.

2.1.2 Scientific impacts of ICON

ICON will open a new research area that exploits sensing capabilities to scale optical networks. Diverse disciplines such as urban traffic management, geology, law enforcement, and emergency response systems will have new instruments in the form of large-scale fibre sensors to use in their research. All of these disciplines will benefit from access to new devices and apparatus that exploit the breakthrough techniques and capabilities that ICON will deliver. The project will include an extensive, long-term field-trial, which will see a large amount of sensing data collected. This will be made available to the wider research community, allowing for new methods of data processing and interpretation to be developed. Furthermore, we aim to drive the development of new standards for sensing data sharing, which will further benefit the research community working in the field.

2.1.3 Economic and technical impacts

The growth of the internet is a major driver of economic growth and technological advancement, which will benefit from the improvements to fibre networks. New sensing services over communication networks will provide new revenue streams for network operators and infrastructure providers. Better tools to respond to natural disasters or sabotage will potentially reduce the effect of disasters and save money. More efficient transportation systems will be more cost effective. While specific applications and market analysis would be premature at this point, it is clear that the technological breakthroughs provided by ICON will be key enabling technologies.

2.1.4 Societal impacts

The internet and other networks which rely on fibre optical networks will be able to handle more data with greater energy efficiency, reliability and security. Ability to prevent/locate and repair damage in the network as well as other infrastructure critical for our society, e.g. energy and water distribution systems, will ensure not only a reliable supply, but reduce the cost, waste and CO_2 emission associated with restoring the infrastructure. Ability to detect and warn against earthquakes, tsunamis etc. can save lives and reduce economic cost.

2.1.5 Scale and Significance of the Expected Outcomes and Impacts

Enhanced network reliability and availability

The context aware capabilities developed within ICON promise to transform the reliability of fibre networks and how network operators and fibre infrastructure providers manage failures. This will be an impact of major significance, which we explain here in relation to both subsea and terrestrial networks.

The Tampnet network infrastructure is representative of other reported networks and can be used as an example case (see Figure 7). Failures vary over time and location, with some links and cables prone to failures, while others continuing to operate since deployment. Within TN subsea network shown in Figure 7, there is a cable with an average failure rate of one/year, while the rest of the infrastructure have registered only one failure since deployment. These cable breaks are often caused by fishing activity and trawling, and they are very costly.

Firstly, the resulting outage can last more than seven days, secondly the repair itself is very resource demanding. The frequency of these is however low compared to other types of failures, especially in the terrestrial network, which in case of TN, consists mostly of leased fibre pairs owned by other network operators. Table 2.1 shows an overview of typical failures occurring, along with their frequency, for the complete network in Norway.

A goal with implementing fibre sensing as part of the network operation is to reduce the number of these failures through proactive actions. These might include warning field-engineers, when sensing shows abnormal patterns due to animals gnawing on cables, which in turn would allow for protective actions.

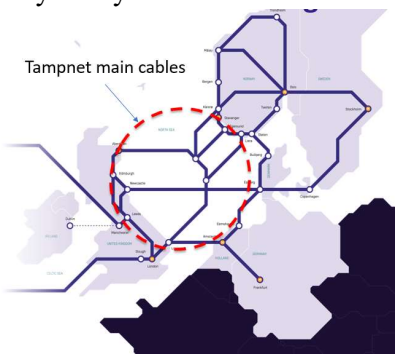

Figure 7: TN main cable location.

Table 2.1: Table showing cause and frequency of failures in TN's network in Norway.

Cause of failure	Frequency of failure, incidents/year
Digging and trawling	1
Disconnection of patch cord by field engineer	1
Gnawing by rats/mice	2
Squeezing of fibre from ice in manhole/tube or splicing box	1
Short disruption caused by field-engineer working in the network	12-24
Trees falling over aerial cables	2/3 (2 in three years)
Disruption in temporarily deployed cables (based on two cables)	6-12
Fire	2/3 (2 in three years)

Cost and environmental savings by minimizing failures, cable repair and repair-time on subsea fibre cables.

As mentioned above, repairing cable-breaks on subsea fibre cables is highly resource demanding. A vessel fit for the purpose is mobilized and in action typically between 7-10 days during the repair of a cable failure. Such vessel typically consumes thousands of litres of fuel (diesel). Table 2.2 shows figures from a repair on a TN cable with seven days duration using the vessel CS Sovereign.

Table 2.2: Cost of a 7-day repair of TN cable using CS Sovereign

Schedule	Repair Time		Average Fuel Usage [Metric Ton/day]		Total Usage	Total Emissions	Expenses
Transit + other events	Hours	Days	Transit	Dynamic position	m^3	tCO_2 equivalent	Daily (USD)
4	74	3	22	15	158	432	$50,000

From figures above it is clear that ability to avoid fibre cut and the repair would have a significant economic and environmental benefit. If fibre sensing can be used for e.g. warning and stopping vessels approaching a cable with a trawl or anchor, occurrence of fibre breaks may be reduced. If it is still not avoided, there is a gain in knowing the accurate placement of the failure, and the nearest location where the cable is exposed. It will then be possible to start picking up the cable at this point and follow it up to the failed part, saving repair-time of the vessel. Hence, additional benefits can be achieved if the fibre sensing equipment can reveal any cable that is not buried. As an example, a **one-day reduction** would lead to an approx. **432 tCO_2 equivalents and 50.000 USD**. Furthermore, cable that is not buried and protected is subject to higher risks of damage caused by subsea objects. Identifying exposed cable segments enables proactive actions for protecting the cable, both by specific monitoring of the exposed cable segments and if found adequate, rock-dump on top of the cable for protection.

European Network Impact

Today, public reporting on disruptions, failures, and outages in the telecommunication networks is not mandatory, and the data about the disruptions, failures and outages is often considered as a business-critical matter, limiting availability of data. The data reported in the literature suggests that failure rates are highly dependent on the region

of the infrastructure installation, the infrastructure type, and many other factors[57,58,59]. Amongst the sparse data on failure rates, we find information on GEANT[60] network, which in 2022, made use of approximately 30,000 km of optical fibre. Currently, it is anticipated that this length has expanded to around 50,000 km. Between June 2023 and February 2024, the network experienced 95 instances of fibre cuts, averaging roughly 10 cuts per month, that required immediate repair.

To find the estimate figure of failure rate in the European network, we would need the information on the total length of fibre across the continent. As these figures are not easily found, we extrapolate data from Estonia, which has around 3000 km of core network per 45,000 km^2. Assuming a similar infrastructure density for other terrestrial fibre networks in Europe, the total length of terrestrial fibre exceeds 400,000 km (these calculations do not include Russia). Considering an average of 2 service effecting failures per year per 1000 km[58], the total amount of infrastructure outages across Europe in a year would be roughly 800 in the core networks alone, each requiring their unique repair activities, resulting in downtimes from hours to days per damaged segment at a time.

Monitoring this entire installed fibre plant with conventional methods is not cost effective today. The ICON approach overcomes this cost barrier through the combination of efficient probing/sensing strategies, adding new sensing service revenue, and enhancing network performance in terms of spectral efficiency. In addition, intent and context aware capabilities increases the efficiency in predictive maintenance and fault localization, not only for telecom operators, but also for mission-critical facilities operators, running SCADA networks on the fibre infrastructure installed in parallel with gas, oil, and electricity lines. The fibre monitoring data from such infrastructure can prevent outages on the mission-critical infrastructure and prevent business losses, reaching hundreds of thousand euros per day (calculated based on the example of a 650 MW Estlink 2 cable outage between Estonia and Finland, considering historical pricing and transfer flow data from NordPool[61]).

Enhanced system performance and telemetry

The scale of the optical transmission performance impact is difficult to predict and will be investigated as part of the research activities in ICON. A recent study of the Microsoft US national backbone network[62] found that the capacity could potentially be increased by 70% by maximizing the spectral efficiency of the transceivers based on available margins. Improved data and visibility into the optical channel performance, afforded by the ICON technologies, would likely enable network operators to recover such available capacity more effectively and reliably. As operators look to find new ways to efficiently and cost effectively scale their networks, the available performance data provided by the ICON technologies would provide an important new tool and data source for machine learning optimization.

Large scale use of fibre for sensing applications

The use of the global communication infrastructure for sensing applications holds great promise for widespread impact in both scientific and economic areas. A 2019 paper in Science described DAS measurements on a subsea cable during a maintenance period and reported: “The observations from just a few days allowed mapping of an unknown fault system and detection of several dynamic processes in the water column above.”[1] This work was followed by a host of similar results for both subsea and terrestrial cables. The ICON project seeks to unlock this potential for entire global fibre plant and enable other yet unexplored applications such as flood and other natural disaster monitoring, explosion detection, intrusion detection, and bridge and road integrity monitoring, to name a few. The key potential for ICON is in the creation of a new global sensing capability with yet unknown applications.

2.1.6 Requirements and Potential Barriers to Desired Outcomes and Impacts

Barrier description and likelihood	Effect on the project’s impacts	Mitigation measure
Regulatory barriers. Likelihood: medium/high	Uptake of project solutions into future national and EU policy	Target relevant policymakers to persuade them of the benefits of these changes.
Lack of viable economic model/ROI for exploitation of technologies	Transition to JC&S based networks will not occur	ICON studies: different networks: campus, metro, subsea to maximize likelihood that a viable case will emerge; cost effective measures i.e., joining

57 D. Crawford, “Fiber optic cable dig-ups: Causes and cures. Network Reliability: A Report to the Nation–Compendium of Technical Papers”, National Engineering Consortium, 1993.
58 Alcoa Fujikura Ltd, 2001, “Reliability of fiber optic cable systems: buried fiber optic cable, optical groundwire cable, and all dielectric, self-supporting cable”.
59 S.D. Maesschalck, et. al., 2003. “Pan-European optical transport networks: An availability-based comparison”, Photonic Network Communications, 5, pp.203-225, 2003.
60 https://network.geant.org/
61 NordPool homepage, [available online, last accessed 15th of March 2024], https://www.nordpoolgroup.com/en/maps/#/nordic
62 M. Ghobadi, et. al., "Evaluation of elastic modulation gains in microsoft's optical backbone in North America," OFC, USA, 2016.

Likelihood: medium/high		different sensing signals into one, ICON will perform demonstrations in production networks
Financial/economic barriers Likelihood: medium	The concepts developed in that project will end with TRL 5. Consequently, there is a long way to bring these concepts into a commercialised product.	The concept investigated in the project can be adapted to the product. However, even when they are not promising for a product, the development engineer can save time by not exploring that path.
Uptake of results by end users Likelihood: medium	Full impact of ICON requires adoption of not only hardware solutions but also network level innovations	For availability maps adoption, we will perform survey amongst network operators to determine the expectations and best use for the availability maps to max. the uptake. Intelligent platform will be developed to work with SDN controller.
Lack of standard format for sensing data Likelihood: medium/high	Context awareness relies on ability to correlate data from different sources, which needs to be presented in a uniform way	We will work on developing and disseminating a standard format of sensing data
Compatibility with emerging and existing network management systems Likelihood: medium	Uptake by existing players and solutions.	We will make our solution in modular Virtual Network functions to allow for easy integration into existing and future network management systems.
End user does not see the added value of integrating the technology in the network: Likelihood: medium	Impact of ICON requires adaption from end users.	Contribute to standardisation on JC&S systems. Dissemination of whitepapers explaining the added value of JC&S for end users.

2.2 Measures to maximise impact - dissemination, exploitation and communication #@COM-DIS-VIS-CDV@#

ICON will generate a wealth of scientifically-important and commercially-promising results, as well as delivering research and innovation with significant impact for pervasive photonics and the digital transformation (as discussed above). An important aim of ICON is to **raise awareness**, through communication and dissemination, of our work and results, and to put in place the plans and framework for effective commercial and research exploitation.

Thus, our **communications plan** has three distinct aspects – a **public aspect**, which focuses on the aims and activities of the project, during its lifetime, with the overall aim of increasing public appreciation of the benefits of science to society as a whole, a **scientific research aspect**, where we communicate the project work in more detail, and stimulate the photonics and sensing research communities, and a **commercial/industry aspect**, where we raise awareness of the technologies that we are developing, and lay the groundwork for commercialisation and exploitation.

2.2.1 Public communication

Our **public communication aspect** will communicate the project mission, its value to society as a whole, and how it represents public money well spent. The target **audience** for this communication is the **media and the general public**. We also seek to communicate the excitement of the research, and to **encourage students** throughout the educational system to consider a career in science and technology. As an important side-effect, we also aim to raise the profile of the participant organisations with **funding agencies** and thus to attract future funding. **Public communication mechanisms** will include the project **website** and **social media** activities, press releases and articles in the **media**, appearances on radio and/or television, the distribution of brochures or flyers, and participation in local and national **events** such as science days, open days, school visits, workshops and conferences. In particular, we will target identified "science-friendly" journalists and publications. A "media centre" with news archive, short articles, etc. will be hosted on the project website. The ICON team has substantial expertise in such outreach activities and a proven record of accomplishment in engagement with the public, media, policymakers, and students.

Public communication **success will be measured** using metrics that apply to the mechanisms used. Website use will be tracked; numbers of attendees at events will be noted; feedback forms will be distributed to gather inputs for further communication and refinement of the message; press coverage will be noted (and linked to the website); levels of feedback (via social media, via paper forms) will be recorded; the number of events at which we are invited to attend and present will also be an important indicator of success.

2.2.2 Scientific communication

Our **scientific communication aspect** will communicate our research ideas and concepts, our activities and interim outputs, and the details of the new techniques, algorithms and control methods developed by ICON, to our fellow researchers in academia and industry. Our **key message** for this audience is that these innovations a **breakthrough technology** for JC&S, helping to make sensing an integral part of the telecommunication network. The solutions that we develop together with the data sets acquired throughout the project, will be immensely valuable for research and innovation across the wider photonics discipline. We will deliver this message via communications **channels** that are most suited to research audiences – presentations at **conferences** and **workshops**, **publications** in journals and scientific online resources, but also in meetings with peer projects from this and other photonics calls, and at events organised by Photonics21, PhotonHub Europe, European Optical Society, EPIC or the PP Annual Meeting. Impact metrics will include citations, publications, events attendees, new projects initiated, etc.

2.2.3 Commercial/industry communication

Our **commercial communications aspect** will raise awareness of our goals, interim outputs and publications among **network operators, vendors and institutions in the field of optical networking** and in sectors, where fibre sensing will have a major impact (e.g., critical infrastructure management, traffic management, sensors, geology). Our **key message** to this audience is the existence of our project and its aims, and the potential value of our expected Results to new products and market developments. Communication and awareness will stimulate the market**, drive future demand** for project results, and open doors to new strategic partnerships, particularly with companies who have an established leading position in key markets, and whose commercial offerings can be improved by deploying ICON technologies, algorithms and methods. We will reach commercial audiences via similar **channels** to the scientific/research communities, but also via trade fairs and trade shows such as SPIE, Photonics Europe, OFC, etc.

2.2.4 Dissemination

The *strategic objective of our Dissemination* activities (during and after the project) is to promote the uptake and use of the project **results**. This includes (a) paving the way to adoption of our ICON solution, thereby making sensing an integral part to of the network, and delivering commercial, economic and scientific value; (b) enabling further research in JC&S and its applications, (c) creating awareness of, and demand for, the intellectual property and innovations created by ICON.

Our specific dissemination **targets** are the photonics and optical network **research communities** and future **industry partners**: these play central roles in the long-term impact and exploitation of the project. As with Communication, our Dissemination approach is **tailored** to particular target **audiences**, with targeted **messaging** and activities, delivered by the most effective channels.

What we disseminate: By the end of the project, ICON will have developed and validated a collection of novel photonic sensing techniques, DSP algorithms, ML/AI methods for interpreting and correlating sensing data, control layer solutions and DT for sensing system and will have demonstrated their performance, flexibility, efficiency, integration and validation, through a series of experimental test in a wide range of deployment scenarios. These innovations will enable efficient and pervasive use of sensing in optical networks, delivering increase reliability and security. This combination of hardware and software solutions and know-how is the Results, which we aim to disseminate.

Who we disseminate to: The key aim of our dissemination is to inform and enthuse future users of our results - these are primarily scientific and industrial researchers, designers and product creators.

Industrial Dissemination: Specifically, our **industrial** targets include end users of the two target applications: telecommunication (network operators, network vendors Telefonica, BT, Deutsche Telekom, Ericsson, Nokia, Infinera) and sensing (owners/managers of various civil and industrial infrastructure like buildings, roads/bridges, water, gas, energy distribution systems etc.).

Scientific dissemination plans include *conferences, publications and events*.

Conferences: Attending and presenting at academic and industry **conferences** will help disseminate ICON knowledge and demonstrate key innovations.

Publications: Academic **publications** will be key for highlighting scientific and industry technology leadership. We expect to publish over sixty articles in top journals, articles, magazines, whitepapers and specifications.

Organisation of events: The consortium will organise workshops to showcase the most successful experiments, applications, services and products tested and/or originated within the context of ICON and the overall European photonics and optical networking community. They will demonstrate the value of ICON across all European optical telecommunication and sensing innovators. In addition, the project will participate in joint workshops/sessions organised by HE projects funded under the DIGITAL-EMERGING-01-54 call. Finally, the consortium will ensure presentations and exhibition booths at major events, including the annual editions of the European Conference on

Optical Communications (ECOC), Optical Fibre Conference (OFC), Optical Sensors and Sensing Congress, etc.

Dissemination & exploitation via education and training: Strong and competitive European photonic sectors require a skilled workforce. Therefore, the project partners will create an education programme to ensure the increase in knowledge and skills, related to the ICON technology, across industry and academia. This will include developing B.Eng., M.Sc. and Ph.D. projects, internships and micro credentials at the participating universities. Following the principle of research-led teaching practised at the partner organisations, ICON technology will also contribute to the creation of new courses or will be incorporated into existing (undergraduate and postgraduate) modules. Representatives from the consortium will deliver guest lectures for these modules.

In summer 2022, Trinity Careers Service launched an annual **Trinity Summer Internship Programme**, available to undergraduate and postgraduate students. As a part of this initiative, ICON partners will offer placements for the students to gain valuable industrial experience. Similar opportunities will be available in other academic partners.

The ICON technology will also be exhibited/demonstrated during **open days** and other events such as "**Science Week"** to bring the project vision to a young audience, including high-school students seeking to pursue university studies in the STEM area. The consortium will also explore ways in which the project can feed into the **Academy of Near Future**, a smart city education programme offered by CONNECT[63] centre and Dublin City Council.

Standardisation activities: The ICON partners, through their participation in the standard bodies, will ensure that our solutions are presented to the working groups for consideration in new standards, updated regulations and for facilitating the implementation of ongoing/planned developments (e.g., contribution to the standardization in ITU-T SG15 Q6 interfaces of fibre sensing and WDM systems). In addition, through project dissemination, as well as membership in organisations such as Photonics21, will work towards the creation and adoption of standards for sensing data presentation/sharing/storing and processing.

Table 2.3: ICON dissemination and communication activities

CDE tools **to maximise the visibility of ICON technology and showcase the work throughout the project**	Industry	Scientifi	Other projects	Policy Makers	Citizens
Project website: as the main communication and dissemination tools, regularly sharing project news and results. **Target:** 10,000 visits	x	x	x	x	x
Social media: X, ResearchGate and LinkedIn will be used for communication of ICON activities. Videos, demonstrating ICON technology, will be published on a YouTube channel. **Target:** average reach of 200 people/post	x	x	x	x	x
Open Access publications: in high impact journals e.g., IEEE: J. of Lightwave Technology, J. of Selected Topics in Quantum Electronics, Trans on Terahertz Science and Technology, and Elsevier Sensors and Actuators A: Physical. **Target:** 20 articles		x	x		
Conference presentations: at major conferences such as Optical Sensors and Sensing Congress, OFC, ECOC, GLOBECOM etc. **Target:** 40 presentations over the project	x	x	x		
Media releases: information on project aims, results and how they can benefit the general public will be released through non-scientific media. **Target:** 1 media release/year	x	x	x	x	x
Newsletter: ICON will share key project highlights through a GDPR-compliant mailing list and the project's website, targeting knowledge exchange with other relevant projects and the technical community. **Target:** 1 newsletter/year	x	x	x	x	x
Citizen engagement: ICON will participate in initiatives intended to foster public awareness of technology and research, such as the European Researchers' Nights and Science Week. **Target:** 1 event/year					x
Workshops: will be used to showcase the key experiments, applications and products developed by ICON and the overall European photonic community. **Target:** 3 workshops during the project	x	x	x	x	
Data sets: curated data sets will be made available to the wider research community through an open access repository on Zenodo platform. **Target:** 3 curated data sets.	x	x	x	x	
Standardisation: we will present project results to the working groups for consideration in new standards. **Target:** 1 standard recommendation.					

63 A research centre to which both TCD belong connectcentre.ie/

Public demos: ICON will demonstrate the project's outcomes and their benefit to the community by presenting results and deploying booths and demos in industry attended events (OFS, OFC & Exhibition). **Target:** 2 demos during international exhibitions	x	x	x	x	x
Training: Developing B.Eng., M.Sc. and Ph.D. projects, internships and micro credentials at the participating universities. **Target:** 4 graduates, 4 undergraduates and 2 interns trained, contribution to 2 academic courses		x			x

2.2.5 Exploitation of results and commercial impact

The core plan for the exploitation of ICON results is to commercialise project technology at the physical sensing techniques, algorithms and tools, network elements and at the system level. At the **physical sensing techniques**, the envisioned commercialisation involves the individual sensing solutions (e.g., CA-OTDR system, optical tomography) and the associated DSP for retrieving information form the data generated by them. On the **methods level,** we will exploit the AI/ML and telemetry tools, sensing system DT as well as the algorithms for data volume reduction. At the **system level**, exploitation will focus on the ICON as a whole, including the integration of the intelligent controller to the network management, the availability assistant and its utilisation to improve the network efficiency and planning. Market and research monitoring will be continuously performed by the consortium on a global scale to gain a good understanding of possible markets (size, needs, trends, rules, standards, presence of competitors, conflicting IPR) and the SOTA in relevant industrial and academic research. The outcome of this activity will be a competitiveness analysis, which will highlight existing business opportunities, guiding exploitation planning. This market monitoring and analysis will be reviewed at 6-month intervals and will be overviewed by the Innovation Management Committee and the IAB of the project.

2.2.6 Individual Exploitation Plans

ICON partners include key user, vendor, and supply chain stakeholders to translate the necessary technologies to market and realize the ICON vision in future networks. As a subsea cable operator, **TN** will seek to deploy ICON innovations in its network to both improve the availability and performance of its network and to offer new sensing services to its customers. TN will work with system vendors to incorporate the ICON technologies and evolve their systems with ICON to meet Tampnet's needs. As a system vendor, **ADTN** intends to commercialize the achieved results through their Advance Link Monitoring (ALM) product line. The novel fibre sensing techniques and network control plane architecture will enable both subsea and terrestrial network providers, as existing customer base, to make their networks more resilient and increase the availability. The ADTN research team consists of members from ADTN's Advanced Technology and Infrastructure Monitoring Product Unit. Advanced Technology contributes to fundamental research whereas the Infrastructure Monitoring Product Unit focuses on product-centric R&D. This synergy allows for the direct application of research results into novel and innovative products satisfying the JC&S use cases. **LSAI** is an early-stage start-up company commercializing a suite of AI and telemetry tools for optical networks. Following the successful completion of the project, LSAI will enhance its product offerings to provide a full suite of ICON tools and network elements. The intent will be to provide an EU based supply chain to enable system vendors and their network operator customers to transition to the ICON JC&S architecture and benefit from its advantages. **VPI** will incorporate new sensing technologies and their simulation models and DSP algorithms into their suite of optical network design tools. This will ensure that the industry and academic communities have the design tools to continue to innovate and develop further technologies within the ICON architecture.

Academic Exploitation plans

As ICON provides an architectural foundation for JC&S in optical networks, it's expected that these technologies will continue to evolve into the future and be a rich topic for further research and development. The academic partners will liaise with their Technology Transfer Offices (or equivalent) throughout the project to ensure both the protection and exploitation of their results. Each academic partner has a vibrant exploitation and innovation ecosystem supporting the movement of ideas and results from "lab to market". Each country has agencies to provide additional innovation support and the consortium will be able to avail of the support from the European Innovation Council.

2.2.7 Strategy for the Management of Intellectual Property

The consortium will conclude a Consortium Agreement (CA) before the project begins. This CA will be based on the DESCA model and will define the formal arrangements for managing all aspects of IPR. The agreement will rule access rights to the existing background IP and ownership of results (foreground IP).

A list of expected innovations (**Innovation Register**) will be drawn up at the project kick-off meeting and will be reviewed at each plenary thereafter. As new innovations are achieved, their inventors (or co-inventors) will assess for patentability and commercial potential; if such potential is identified, then no publication takes place until protection is in place. If the Result is scientifically exciting but has no direct commercialisation potential, then it may

proceed to publication without undue delay. Where the inventors from different partner organizations contributed to the invention, each of them meeting the requirements to be considered an inventor of the respective invention, there will be multiple owners of the IP. We will identify one partner to act as the representative agent of all co-owners; licenses or sales of such IP will be managed by that single entity. The revenue share for each device will be agreed prior to any commercialisation, to reflect the relative contributions of each partner, and also the ongoing efforts/investments by the 'shop-front' partner. #§COM-DIS-VIS-CDV§#

2.3 Summary

SPECIFIC NEEDS	EXPECTED RESULTS	DEC MEASURES
• Fibre cuts cause significant loss of revenue, reduce the reliability of network limiting its use for applications with high availability requirements. • Repairs of fibre cuts are often slow, costly, and contribute to CO_2 emissions. • Optical network is not used efficiently due to lack of information on the infrastructure health. Arbitrary performance margins are used to ensure required QoT. • Using optical networks as distributed sensor has significant benefits, but currently is not feasible due to large no. of sensing devices requires. • Sensing produces vast volumes of data that needs to be processed, transmitted, stored, making pervasive sensing infeasible. • Most sensing probes are fixed in terms of location and type of measurement, limiting their use to a specific application. Sensing information is not fed to network management limiting the exploitation of the obtain information.	• A suit of sensing techniques, their configuration, corresponding capabilities, and DSP algorithms. • A portfolio of algorithms and tools for correlating network-wide and external data for context awareness. • Algorithms for data volume reduction by 3 orders of magnitude. • DT model of sensing system for use with ICON • Intelligent sensing platform for controlling/ configuring sensing system that can be integrated with NMS. • First ever availability assistant demonstrated for real network scenario. • Data sets from long-term field-trial of sensing system. • Four graduate students trained	Dissemination: • Open access publications of scientific results, • Presentation of the scientific results in conferences, • Curated datasets shared on open repositories, • Technology demonstrations at international conferences, • Education and Public Engagement (EPE) program and events. Exploitation: • Commercialization of technologies by SMEs/vendor partners, • Inclusion in network requirements for future deployments by operator partner Communication: • Online communication: website, communication on social media • Printed documents distributed during • EPE events and demonstrations • Promotion video
TARGET GROUPS	**EXPECTED OUTCOMES**	**EXPECTED IMPACTS**
• Network operators, • System and components vendors, • Companies depending on reliable networks (banking, health care), • Local authorities, governments, • Critical infrastructure owners (energy, water, roads, bridges), • Researchers working in the area of sensing and JC&S, • Researchers working in other areas of science e.g. geology, seismology, oceanography.	• Commercialisation of the core ICON technology, • Incorporation of ICON solutions into standards • ICON data sets widely used by research community to advance the sensing research and development, • Acceptance of ICON-developed data format for sensing data presentation and sharing • Availability assistant incorporated into roadmaps of two network operators.	**Scientific:** Large scale fibre sensor becomes a new tool for many research areas (engineering, natural science etc.). New techniques to extract information from data leading to new discoveries. **Economic/Technological:** Improved network resources use, fewer of outages, lower repair cost, new revenue streams increase profitability of network operators. New standards drive economic and technical developments if JC&S. **Societal:** Better reliability of telecommunication networks, new applications enabled by such systems, lives and livelihoods saved due to early warning of earthquakes, improved safety of critical infrastructure, supply of energy, waste, oil etc. Greater efficiency, reduced waste contributes to Green Deal objectives and to UN-SDGs.

#§IMP-ACT-IA§#

3 QUALITY AND EFFICIENCY OF THE IMPLEMENTATION #@QUA-LIT-QL@# #@WRK-PLA-WP@#

3.1 Work plan and resources

The work plan of ICON is organised in seven Work-Packages (WPs) to ensure the general project objectives are achieved. Specific objectives are defined for each WP, as listed below, along with tasks, deliverables and milestones. The Gantt chart, shown in Figure 10, illustrates the project timeline, including the duration of individual tasks within WPs and the dates of the deliverables and milestones.

WP1 and WP7 are devoted to the project management and the dissemination, exploitation and standardisation activities respectively. The remaining WPs are where the technical work will be carried out. It will begin in M1 (WP2) with the analysis of the use cases and, from them, deriving the specifications for the ICON physical layer system. Based on the specifications, the physical layer solutions will be modelled, designed and developed in WP3. Three different types of sensing will be investigated: the CA- and TE-OTDR and the network tomography. In addition, the use of novel types of fibre for sensing applications will also be tested. Parallel, DSP algorithms for retrieving information for the sensing data, acquired both locally and across the network, will be developed and optimised in WP4. Within this WP, the cloud platform for storing and processing data and well as the ICON DT, will also be developed. The intelligent platform for controlling the sensing systems and allowing its integration into the telecommunication network management will be carried out in WP5. Outputs of WP3, WP4 and WP5 will feed to WP6, within which the experimental demonstrations and verification of the technology will be carried out. The interdependencies and flow of information between WPs are shown in Figure 8.

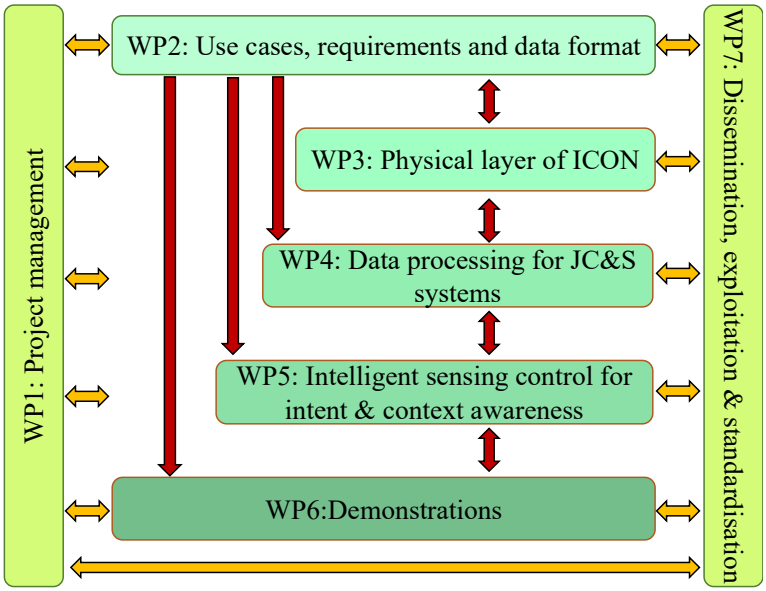

Figure 8: Interdependencies and flow of information between WPs.

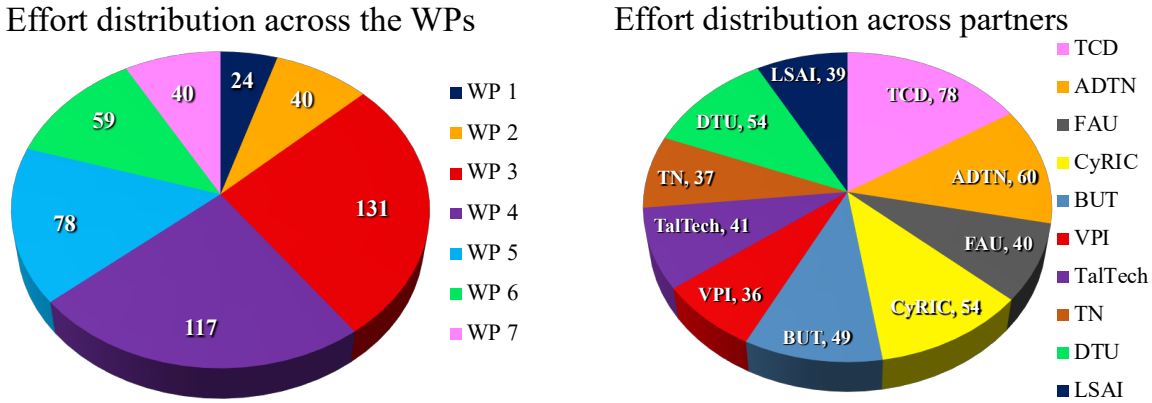

Figure 9: Effort distribution across the partners (left) and WPs (right).

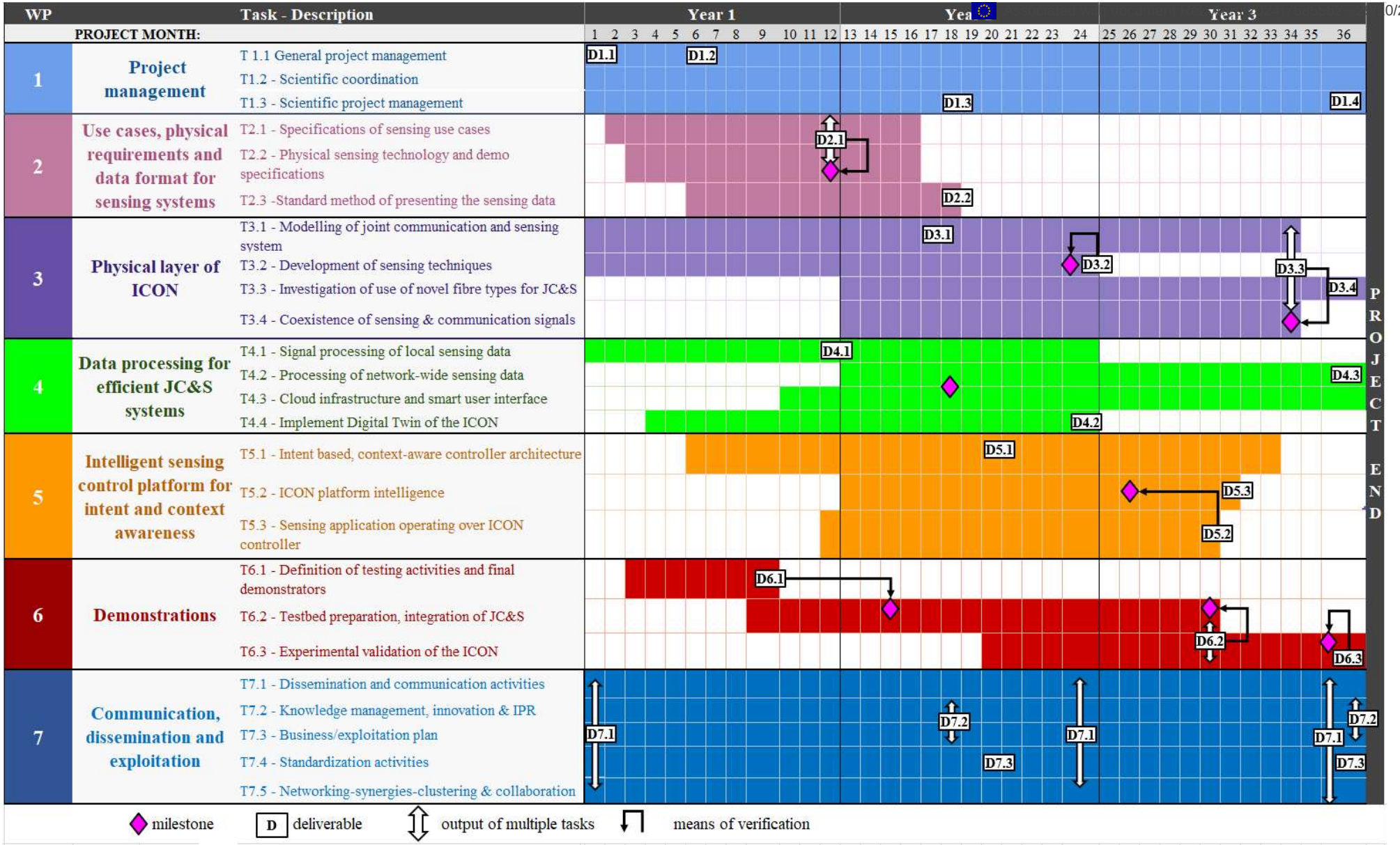

Figure 10: ICON Gantt chart.

Table 3.1g: 'Subcontracting costs' items

There are no subcontracting costs.

Table 3.1h: 'Purchase costs' items (travel and subsistence, equipment and other goods, works and services)

2 ADTN		
	Cost (€)	**Justification**
Travel and subsistence	€25,000	Travel to 3 major conferences at a cost of €12,000 (€4000/conference). The remaining €13,000 will be used for the travel to project meetings and field trials. Meiningen requires minimum 3 to 4 hours train ride to nearest major airport and in most of the cases an overnight stay at an airport hotel for early morning flights.
Equipment	€37.500	Components needed for the demonstrator, COSA €11,000, laser €8,000, power supply €2.500, main frame €2 ,000, digitizer €14,000.
Other goods, works, services	€42,000	Cost of a financial audit €10,000, consumables for the project lifetime €30,000 (€10,000/year), €2 ,000 material for the 3D printer and mechanical components.
Total	€104,500	

5 BUT		
	Cost (€)	**Justification**
Travel and subsistence	€25,000	€5,000 per year will be used for project meetings, along with relevant conference attendance. €15,000 is allocated for travel reimbursements for the preparation and deployment of use case demonstrations.
Equipment	€0	
Other goods, works, services	€60,000	€24,000 (€8,000/year) for lab consumables, €3,000 to cover auditing costs, €33,000 for testbeds preparation (optical filters, passive and active components, special fibres).
Total	€85,000	

7 TalTech		
	Cost (€)	**Justification**
Travel and subsistence	€48,000	This travel cost covers the travelling of two team members contributing to the project over the three-year project lifetime. The budget covers project meetings (kick-off, met-ups and project end meeting), as well as travels to relevant conferences, where papers are submitted. Furthermore, the travel budget includes travels to set up demonstration outside Estonia. As Tallinn airport is very small, and there are not many flights to select from, the budget for travelling from Tallinn is slightly higher than from other capitals of European countries.
Equipment	0	No equipment will be purchased from TalTech side to carry out the work in this project. The equipment to be installed on sites will be provided by other project partners.
Other goods, works and services	€3,660	1 x €2000 will be used to purchase one team laptop to carry out the project in the work. A total of €660 has been requested as lab consumables to be used over the lifetime of the project, including mainly materials to be installed at site (jumper cables, cleaning tools, etc). Further €1000 is requested to cover the fuel, keys and other consumables to reach local sites.
Total	€51,660	

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	Cost (€)	**Justification**
Travel and subsistence	€20,000	Approximately €6,600 per year will be used for travel to two project meetings and one conference, covering three project participants.
Equipment	€20,000	€19,000 will cover the cost of four State of Polarisation monitoring instruments. €1000

		will cover components and material needed during installations in field trials.
Other goods, works and services	€100,000	(1) Costs for compensation for reserving two fibre-pairs for research project field-trials purposes. It enables simultaneous test of up to three different sensing techniques on the 700 km long, 9 landings passive NORFEST subsea cable during the project period. Long duration collection of SoP data performed during the complete project period. (2) Costs for a CFS (Certificate on Financial Statements).
Total	€140,000	

Note: The ICON consortium confirm that the costs listed under the equipment costs category refer to the depreciation costs of the equipment.

Table 3.1i: 'Other costs categories' items (e.g. internally invoiced goods and services)

There are no costs under 'Other costs categories'.

Table 3.1j: 'In-kind contributions' provided by third parties

There are no in-kind contributions free of charge.

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3.2 Capacity of participants and consortium as a whole #@CON-SOR-CS@# #@PRJ-MGT-PM@#

ICON's ambitious goal of developing a JC&S system, require diverse and interdisciplinary knowledge and skills, from the physical layer solutions modelling and development, through advanced data processing methods, intelligent system control, to system integration and applications. In preparing this consortium, we recruited the **best possible partners** from the EU, each with unique and field-leading skills and resources. Each makes a **distinct** contribution and is vital to our success; importantly, they are also very **complementary**, so that the skills and resources of one partner synergise and combine effectively with the capabilities of others, to achieve aims that neither could deliver alone. In addition, the partners include representatives of all stakeholders involved in the development and exploitation of ICON, from research performing institutions, through SMEs providing software and technology solutions, system provides to network operator.

The complementarity of the competencies of the ICON partners are summarised in Table 3.1.

Table 3.1: Multidisciplinary and complementarity of competences in the ICON consortium

	TCD	ADTN	FAU	CyRIC	BUT	VPI	TalTech	TN	DTU	LSAI
Optical fibre sensing	x	x	x		x			x	x	x
Optical transmission systems	x	x	x		x	x	x	x	x	
Network telemetry and monitoring	x				x		x	x		x
Software defined networking	x	x								
DSP & simulation		x	x	x	x	x			x	x
Cloud computing	x		x	x						x
Fibre infrastructure	x	x			x		x	x		
Network management	x	x						x		

systems										
Network availability and security		**x**			**x**		**x**	**x**		**x**
Telecom applications and services	**x**	**x**			**x**			**x**		

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4. ETHICS SELF-ASSESSMENT

The ICON consortium took into account all ethics issues detailed in the *Ethics Issues Table* of the proposal's Part A and confirms that no ethics issues apply in the proposed research and innovation activities of project's work programme.

The ICON consortium will ensure that any potential ethics issues related to activities in the grant are addressed in compliance with ethical principles, the applicable international and national law, and the provisions set out in the Grant Agreement. This includes any additional ethics issues that may emerge in the course of the grant. In case any substantial new ethics issues arise, the ICON consortium will inform the granting authority.