EUROPEAN RESEARCH EXECUTIVE AGENCY (REA)

REA.C – Future Society
C.2 – Secure Society

GRANT AGREEMENT

Project 101225737 — CapCell

PREAMBLE

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

on the one part,

the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and

on the other part,

1. 'the coordinator':

UNIVERSITEIT MAASTRICHT (UM), PIC 999975911, established in MINDERBROEDERSBERG 4, MAASTRICHT 6200 MD, Netherlands,

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

2. **KATHOLIEKE UNIVERSITEIT LEUVEN (KUL)**, PIC 999991334, established in OUDE MARKT 13, LEUVEN 3000, Belgium,

3. **I3S - INSTITUTO DE INVESTIGACAO E INOVACAO EM SAUDE DA UNIVERSIDADE DO PORTO (i3S)**, PIC 892061180, established in RUA ALFREDO ALLEN 208, PORTO 4200-135, Portugal,

4. **MEDIZINISCHE UNIVERSITAT INNSBRUCK (MUI)**, PIC 999855437, established in CHRISTOPH PROBST PLATZ 1, INNSBRUCK 6020, Austria,

5. **Netherlands Forensic Institute (NFI)**, PIC 998203527, established in Laan van Ypenburg 6, The Hague 2490 AA, Netherlands,

6. **EESTI KOHTUEKSPERTIISI INSTITUUT (EFSI)**, PIC 948698801, established in TERVISE TN 20, TALINN 13419, Estonia,

7. **Politsei- ja Piirivalveamet (EPBG)**, PIC 951813471, established in Pärnu mnt 139, Tallinn 15060, Estonia,

8. **BUNDESMINISTERIUM FUR INNERES (AFCP)**, PIC 999826434, established in Herrengasse 7, WIEN 1010, Austria,

9. **COPAN ITALIA SPA (COPAN)**, PIC 951752846, established in VIA PEROTTI 10, Brescia 25125, Italy,

10. **NIMAGEN BV (NimaGen)**, PIC 875619486, established in HOGELANDSEWEG 88, NIJMEGEN 6545 AB, Netherlands,

11. **VOXDALE (Voxdale)**, PIC 880618090, established in BIJKHOEVELAAN 32 BOX C, WIJNEGEM 2110, Belgium,

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

TABLE OF CONTENTS

DATA SHEET

1. General data

Project summary:

Project summary
Sexual violence affects 1 in 10 women across Europe and has increased by 10% alone in 2021-2022. Most cases involve complex biological mixtures containing cells from the victim and perpetrator(s). Current forensic methods struggle to isolate individual DNA profiles, leaving many cases unresolved and perpetrators unprosecuted. Addressing these limitations is critical to improving evidence interpretation, ensuring justice for victims, and reducing societal impacts. CapCell aims to deliver a new approach to improve forensics and lawful evidence collection with innovative microfluidics and single-cell genomics technologies to overcome the limitations of mixed DNA evidence. Specifically, we will develop the CapCell toolkit comprised of ten easily integrated modules that capture, select, isolate, sequence and interpret individual cells of interest. We will co-create novel strategies and best practices with end-users and industry to improve evidence collection from postcoital swabs and contact traces. Recovered intact cells from male contributors will then be selected and isolated using innovative mobile microfluidic devices. By employing novel concepts, we will advance follow-up DNA sequencing assays and analysis tools to target diverse forensic biomarkers with single-cell resolution. We will align interpretation frameworks to suit single-cell DNA analysis and leverage machine learning to automate the forensic process. Eventually, CapCell will achieve its goal by validating and implementing the new toolkit (TRL5-7) in the relevant end-user environment, with the support of several forensic science institutes and police forces. To reach its ambitious objectives, CapCell brings together an experienced intersectoral consortium of 13 partners from 8 European countries, with complementary expertise in forensic genomics, biosensor technology, bioinformatics, statistics and technology prototyping. Ultimately, CapCell will contribute to a safer and healthier society across Europe.

Keywords:

- Fight against crime and terrorism
- Forensic technologies, others
- Security
- Education and training of police authorities
- Police authorities
- Forensic genetics; Human identification; DNA profiling; Sexual violence; Trace evidence, DNA mixtures; Microfluidics; Cell isolation; Single-cell genomics; Nanopore sequencing; DNA interpretation

Project number: 101225737

Project name: Innovative forensic trace investigation via microfluidics and single-cell genomics

Project acronym: CapCell

Call: HORIZON-CL3-2024-FCT-01

Topic: HORIZON-CL3-2024-FCT-01-02

Type of action: HORIZON Research and Innovation Actions

Granting authority: European Research Executive Agency

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

Project starting date: fixed date: 1 October 2025

Project end date: 30 September 2029

Project duration: 48 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	UM	UNIVERSITEIT MAASTRICHT	NL	999975911	886 762.50	886 762.50
2	BEN	KUL	KATHOLIEKE UNIVERSITEIT LEUVEN	BE	999991334	1 618 326.25	1 618 326.25
3	BEN	i3S	I3S - INSTITUTO DE INVESTIGACAO E INOVACAO EM SAUDE DA UNIVERSIDADE DO PORTO	PT	892061180	204 200.00	204 200.00
4	BEN	MUI	MEDIZINISCHE UNIVERSITAT INNSBRUCK	AT	999855437	597 383.75	597 383.75
5	BEN	NFI	Netherlands Forensic Institute	NL	998203527	446 097.50	446 097.50
6	BEN	EFSI	EESTI KOHTUEKSPERTIISI INSTITUUT	EE	948698801	190 112.50	190 112.50
7	BEN	EPBG	Politsei- ja Piirivalveamet	EE	951813471	95 048.75	95 048.75
8	BEN	AFCP	BUNDESMINISTERIUM FUR INNERES	AT	999826434	12 500.00	12 500.00
9	BEN	COPAN	COPAN ITALIA SPA	IT	951752846	153 375.00	153 375.00
10	BEN	NimaGen	NIMAGEN BV	NL	875619486	91 127.50	91 127.50
11	BEN	Voxdale	VOXDALE	BE	880618090	204 375.00	204 375.00
12	AP	accelCH	ACCELOPMENT SCHWEIZ AG	CH	998454369	0.00	0.00
13	AP (IO)	EDNAP	EDNAP European DNA Profiling Group	DK	875369905	0.00	0.00
Total						4 499 308.75	4 499 308.75

Coordinator:

– UNIVERSITEIT MAASTRICHT (UM)

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)
4 499 308.75	100	4 499 308.75	4 499 308.75

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	Interim payment	90 days from receiving periodic report
3	37	48	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)	2 399 481.36

Reporting and payment modalities (art 21, 22):

Mutual Insurance Mechanism (MIM): Yes

MIM contribution: 5% of the maximum grant amount (224 965.44), 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:

NL47INGB0657625418 INGBNL2AXXX

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 **101225737** — **CapCell** ('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 183(2)(a) EU Financial Regulation 2024/2509: '**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 2024/2509.

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 183(2)(b) EU Financial Regulation 2024/2509: '**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

The following entities which cooperate with a beneficiary will participate in the action as 'associated partners':

- **ACCELOPMENT SCHWEIZ AG (accelCH)**, PIC 998454369
- **EDNAP European DNA Profiling Group (EDNAP)**, PIC 875369905

Associated partners must implement the action tasks attributed to them in Annex 1 in accordance with Article 11. They may not charge costs or contributions to the action and the costs for their tasks are not eligible.

The tasks must be set out in Annex 1.

The beneficiaries must ensure that their contractual obligations under Articles 11 (proper implementation), 12 (conflict of interests), 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 associated partners.

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 associated partners.

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]

[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 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

- 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

[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).

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

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.

[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).

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

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):

Funded by the
European Union

Co-funded by the
European Union

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

[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).

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).

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).

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).

[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).

24.5 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 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

[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).

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

[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).

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).

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

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.

[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).

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

Rianne LETSCHERT with ECAS id nletsria signed in the Participant Portal on 11/07/2025 at 16:21:20 (transaction id SigId-16242-Fze5QQO1WzfK81TzsbTdg9iFfgJpY5KneQIVv1Bno7vzXJUZykm30cP09a7XAxEwmqDZrUk3eMYcSu07ze8d5Nv-jpJZscgsw0KIJLiW0zXzbmm-eInyHltpnZN7JFX5qS9eoZMnzw2aVtcMlK5YzaY8jD6jzvFdht1Qbzs7lCiohqZkmWBKzwQflXGV5zpRNQ8c6rqG). Timestamp by third party at 2025.07.11 16:21:24 CEST

For the granting authority

Signed by Valeria BRICOLA with ECAS id bricova as an authorised representative on 16-07-2025 08:52:53 (transaction id SigId-1984-MNjf2ZQYKtHvufg7V1E017kGEIH16WtsZawcISV9kJ1L0yxLMv34bCWiwZqJiJzvOgKyUTfT2xKNOkOujBns0K-yntOf97TTHq7M1Ew4KfYfO-eD5jFlb044dfJpJn0TzzLS9UwyN821mLFRPHmzLHWJvJj3xEiW5nOrCpuX3J1o2PZf4x87sR2dcvEIzo3pzzppTm) 2025.07.16 08:52:56 CEST

ANNEX 1

Horizon Europe (HORIZON)

Description of the action (DoA)

Part A

Part B

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:	101225737
Project name:	Innovative forensic trace investigation via microfluidics and single-cell genomics
Project acronym:	CapCell
Call:	HORIZON-CL3-2024-FCT-01
Topic:	HORIZON-CL3-2024-FCT-01-02
Type of action:	HORIZON-RIA
Service:	REA/C/02
Project starting date:	fixed date: 1 October 2025
Project duration:	48 months

TABLE OF CONTENTS

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.

Sexual violence affects 1 in 10 women across Europe and has increased by 10% alone in 2021-2022. Most cases involve complex biological mixtures containing cells from the victim and perpetrator(s). Current forensic methods struggle to isolate individual DNA profiles, leaving many cases unresolved and perpetrators unprosecuted. Addressing these limitations is critical to improving evidence interpretation, ensuring justice for victims, and reducing societal impacts.
CapCell aims to deliver a new approach to improve forensics and lawful evidence collection with innovative microfluidics and single-cell genomics technologies to overcome the limitations of mixed DNA evidence.
Specifically, we will develop the CapCell toolkit comprised of ten easily integrated modules that capture, select, isolate, sequence and interpret individual cells of interest. We will co-create novel strategies and best practices with end-users and industry to improve evidence collection from postcoital swabs and contact traces. Recovered intact cells from male contributors will then be selected and isolated using innovative mobile microfluidic devices. By employing novel concepts, we will advance follow-up DNA sequencing assays and analysis tools to target diverse forensic biomarkers with single-cell resolution. We will align interpretation frameworks to suit single-cell DNA analysis and leverage machine learning to automate the forensic process. Eventually, CapCell will achieve its goal by validating and implementing the new toolkit (TRL5-7) in the relevant end-user environment, with the support of several forensic science institutes and police forces.
To reach its ambitious objectives, CapCell brings together an experienced intersectoral consortium of 13 partners from 8 European countries, with complementary expertise in forensic genomics, biosensor technology, bioinformatics, statistics and technology prototyping. Ultimately, CapCell will contribute to a safer and healthier society across Europe.

LIST OF PARTICIPANTS

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
1	COO	UM	UNIVERSITEIT MAASTRICHT	NL	999975911
2	BEN	KUL	KATHOLIEKE UNIVERSITEIT LEUVEN	BE	999991334
3	BEN	i3S	I3S - INSTITUTO DE INVESTIGACAO E INOVACAO EM SAUDE DA UNIVERSIDADE DO PORTO	PT	892061180
4	BEN	MUI	MEDIZINISCHE UNIVERSITAT INNSBRUCK	AT	999855437
5	BEN	NFI	Netherlands Forensic Institute	NL	998203527
6	BEN	EFSI	EESTI KOHTUEKSPERTIISI INSTITUUT	EE	948698801
7	BEN	EPBG	Politsei- ja Piirivalveamet	EE	951813471
8	BEN	AFCP	BUNDESMINISTERIUM FUR INNERES	AT	999826434
9	BEN	COPAN	COPAN ITALIA SPA	IT	951752846
10	BEN	NimaGen	NIMAGEN BV	NL	875619486
11	BEN	Voxdale	VOXDALE	BE	880618090

PARTICIPANTS

Grant Preparation (Beneficiaries screen) — Enter the info.

Number	Role	Short name	Legal name	Country	PIC
12	AP	accelCH	ACCELOPMENT SCHWEIZ AG	CH	998454369
13	AP	EDNAP	EDNAP European DNA Profiling Group	DK	875369905

Associated with document Ref. Ares(2025)5511292 - 08/07/2025

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	Coordination, project and innovation management	1 - UM	44.50	1	48	D1.1 – Project implementation guidelines (PIG) D1.2 – Data management plan (DMP) D1.3 – Quality assurance (QA) and risk assessment D1.4 – Updated DMP D1.5 – Updated QU and risk assessment
WP2	End-user requirements and intact cell recovery	6 - EFSI	69.00	1	24	D2.1 – End-user needs D2.2 – Routine collection evaluation D2.3 – Improved intact cell recovery & transfer D2.4 – Novel standards for mixed sample collection
WP3	Microfluidics technology development for cell isolation	2 - KUL	110.00	1	48	D3.1 – Differential lysis protocol D3.2 – MicroLyseFX I evaluation D3.3 – MicroLyseFX II D3.4 – MicroSortFX I evaluation D3.5 – MicroSortFX II
WP4	Novel forensic sorted/single-cell sequencing assays	2 - KUL	74.00	7	42	D4.1 – Optimised assays for MicroLyseFX integration D4.2 – Novel single-cell STR/SNP assays D4.3 – Novel single-cell mitogenome assay D4.4 – Novel 1-cell-1-read STR assay
WP5	Forensic genetic data analysis and interpretation	5 - NFI	79.50	13	48	D5.1 – Fine-tuned existing tools for single-cell application

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
						D5.2 – Novel analysis tools for combinatorial indexing D5.3 – Novel analysis tools for mtDNA D5.4 – Novel analysis tools for concatemers D5.5 – Machine learning-based tools
WP6	Testing, validation and training	4 - MUI	91.00	19	48	D6.1 – User validation and implementation plan D6.2 – Implementation of interpretation guidelines for single-cell data D6.3 – Validation of single-cell analysis D6.4 – Training material D6.5 – Validation of single cell sequencing D6.6 – Demonstration of a mobile MicroLyseFX device
WP7	Communication, dissemination and exploitation	12 - accelCH	43.50	1	48	D7.1 – Project website and social media channels D7.2 – Communication and dissemination plan D7.3 – Interim impact report D7.4 – User focus groups D7.5 – Policy brief D7.6 – Roadmap for Exploitation

Work package WP1 – Coordination, project and innovation management

Work Package Number	WP1	Lead Beneficiary	1 - UM
Work Package Name	Coordination, project and innovation management		
Start Month	1	End Month	48

Objectives

The overarching goal of WP1 is to ensure efficient and effective project implementation, through these objectives:
1) Coordinate work and ensure effective project organisation and administration.
2) Ensure timely reporting, financial management and monitor the use of resources.
3) Develop a data management plan following the FAIR principles and ethical data-sharing framework.
4) Control work quality, assess potential risks and plan mitigation measures.
5) Manage the innovation and IP process and identify commercialisation opportunities.

Description

WP1 will be led by UM and co-led by accelCH

Task 1.1 Coordination, organisation and administration (Leader: UM; Participants: all; M1-48)
As the Coordinator, UM is responsible for monitoring the progress of the work and the collaboration between project partners, while accelCH will advise all partners on the correct implementation of the Horizon Europe rules throughout the project duration. During the initial months, UM will establish the organisational bodies: (a) Steering Committee (annual in-person and interim online meetings -alternating); chair: UM (AV) / members: 1 representative of each partner; quorum: 2/3; decision-making: 2/3 majority); (b) Executive Board (Bi-monthly online meetings; chair: MUI (WP); members: WP leaders and deputies; quorum: 2/3; decision-making: single majority); (c) Management Support Team (Monthly web meetings; chair: Consortium coordinator (UM) / members: Administrative Project Manager (accelCH), Innovation Manager (KUL-MeBioS), Quality & Risk Manager (UM); (d) External Advisory Board which serves as consultative body to provide an external view on project results. Communication tools, such as mailing lists and a secure cloud platform for collaboration, will be set up. accelCH will provide and maintain templates, contact lists, consortium-internal communication and project implementation guidelines, detailing guidelines for reporting, quality and risk management, beneficiary roles and responsibilities.

Task 1.2 Progress monitoring, reports & financial management (Leader: UM; Participants: accelCH; M1-48)
UM and accelCH will guide Horizon Europe technical and financial reporting, preparing and submitting the three periodic reports to the EC within 60 days of each reporting period. All reports will follow the “Guidelines on project reporting” for Horizon Europe Research and Innovation Actions. UM and accelCH will review beneficiary financial statements and organise technical review meetings with EC and WP leaders. UM will allocate EC funding (pre-financing, interim, final) to partners per payment schedule defined in the Consortium Agreement and monitor resource use to ensure alignment with the work plan. A project land-scape mapping activity will be carried out by accelCH during the project’s first consortium meeting to identify synergies with similar projects funded under HEU Pillar 2 and funding instruments (Internal Security Fund, Digital Europe Programme, European Defence Fund). The map will be monitored and updated by accelCH and identified projects will be invited to relevant activities and events planned in WP7 tasks 7.3 and 7.4 to accelerate final development and market uptake of research results.

Task 1.3 Project data management, FAIR data concept and ethics (Leader: UM; Participants: all; M1-48)
UM will oversee the different versions of the DMP and ensure that the project data is Findable, Accessible, Interoperable and Reusable, as much as possible. A first version of the DMP (D1.2) will be available in M6, while an updated version will be delivered in M24. Ethics will be considered at all stages of the data collection and technology development through an ethics-by-design methodological approach.

Task 1.4 Quality assurance and risk management (Leader: UM; Participants: accelCH, all; M1-48)
UM, with accelCH's support, will establish and enforce quality procedures for reporting, deliverables and internal and external communication, and manage risk identification and contingency planning. Three detailed quality and risk assessment reports (D1.3, M12, M30, M48) will be produced, and UM will coordinate the internal review of all deliverables and reports before submission.

Task 1.5 Innovation and IP management (Leader: KUL-MeBioS; Participants: all; M1-48)
UM, together with all partners, will set up a general IP management strategy. Together with accelCH (WP7 leader),

the Innovation Manager (Dr. Iene Rutten) will oversee the development of forensic tools, coordinating regular updates with the FIAB and other stakeholders to maximise IP protection while fostering innovation and ensuring effective implementation of WP7 exploitation activities under task 7.5. The innovation process, new IP and other relevant points will be documented by the innovation manager.

Work package WP2 – End-user requirements and intact cell recovery

Work Package Number	WP2	**Lead Beneficiary**	6 - EFSI
Work Package Name	End-user requirements and intact cell recovery		
Start Month	1	**End Month**	24

Objectives

The overarching goal of WP2 is to co-create the modular technology design based on end-user needs and innovate current biological evidence collection practices to improve intact cell recovery, through these objectives:
1) Identify end-user needs across European forensic science institutes and police forces under different jurisdictions through a mixed method approach.
2) Elucidate technological requirements and specifications for forensic implementation of microfluidics.
3) Improve forensic swab collection to suit our modular microfluidics-based single-cell analysis tools.
4) Establish novel best practices and recommendations for sample collection to maximise the yield of intact cells from mixed forensic traces.

Description

WP2 will be led by EFSI and co-led by NFI

Task 2.1 Establishment of end-user casework needs based on literature and forensic practitioners' expertise (Leader: MUI; Participants: EFSI, NFI, KUL-FBS, EPBG, AFCP, EDNAP, Advisory Board; M1-6)
MUI with partners and Advisory Board's support will establish end-users' needs in terms of forensic casework based on scientific literature and consultation with forensic practitioners. In particular, a systematic review of existing studies will be conducted to identify and describe cases and sample characteristics that have proven difficult for standard forensic DNA analysis techniques, highlighting the necessity for innovative analytical approaches. MUI will prepare and distribute a dedicated online questionnaire-based survey to collect and analyse the required information from CapCell partners. To ensure the case and sample overview reflects the most current situation, insights from a broad range of forensic institutions and police authorities outside the CapCell consortium will be gathered through expert consultation facilitated by EDNAP and through our wider network within ENFSI. Collated knowledge will be incorporated as input for technology design and development in WPs 3, 4 and 5.

Task 2.2 Evaluation of routine evidence collection strategies to assess suitability for microfluidics analysis (Leader: EFSI; Participants: MUI, NFI, KUL-FBS, KUL-MeBioS, EPBG, AFCP; M1-14)
KUL-MeBioS will define specific criteria regarding sample quantity and quality that need to be met for successful microfluidics analysis. Specifically, intact cells in suspension are preferred but it is currently unclear whether current forensic swab collection practices allow this. EFSI will develop a strategy to evaluate the presence of intact cells, cell clumps, ruptured cells, and non-cellular debris like fibres that may be recovered along with cells, as such byproducts could potentially clog the microfluidic equipment. Based on input from

Task 2.1, a selection of devices and protocols will be chosen for further evaluation. Forensic labs (KUL-FBS), institutions (MUI, NFI) and police authorities (EPBG, AFCP) will each contribute with their own sample collection tools (cotton swabs, nylon swabs and tapes) and evidence recovery strategies. Collected samples will be then sent to, assessed and compared by EFSI.

Task 2.3 Improvement of both intact cell recovery and transfer applicable to postcoital swabs and trace evidence (Leader: EFSI; Participants: COPAN, MUI, NFI, EPBG, AFCP; M1-18)
To enhance the number of intact cells available for subsequent microfluidics analysis, EFSI and COPAN will focus on optimising factors that influence intact cell recovery prior to analysis. EFSI will focus on optimising intact cell recovery from the collection devices and protocols assessed in Task 2.2. Key parameters for optimisation will include sample agitation rate, incubation time, and the choice of elution buffers. Parallel to EFSI's optimisation study, COPAN

will improve sample collection, intact cell recovery and maintenance until laboratory analysis, considering sample transport and storage as well, starting from current product portfolio and pre-commercial swabs and elution media. Upon completion of testing and optimisation by COPAN and EFSI, the novel sample collection devices and optimised protocols will be distributed to all other involved partners for further evaluation and testing.

Task 2.4 Establishment of novel best practices and recommendations for mixed biological evidence collection strategies as key prerequisite for the modular CapCell tools (Leader: NFI; Participants: MUI, EFSI, KUL-FBS, KUL-MeBioS, EPBG, AFCP, UM, EDNAP, Advisory Board; M19-24)
Based on knowledge and experience built during the previous tasks, in terms of end-user needs as well as routine and novel evidence collection protocols, NFI will draft a report with the best practices for forensic sample collection including for downstream microfluidics analysis. These standards will be based on key parameters that can affect intact cell recovery in a case-specific manner. All partners together with the Advisory Board will review and contribute to the final recommendations, which will be shared with a wider network of forensic scientists, practitioners and police authorities across Europe, with the help of EDNAP and our extended ENFSI network.

Work package WP3 – Microfluidics technology development for cell isolation

Work Package Number	WP3	**Lead Beneficiary**	2 - KUL
Work Package Name	Microfluidics technology development for cell isolation		
Start Month	1	**End Month**	48

Objectives

The overarching goal of WP3 is to develop new miniaturised microfluidic systems for isolating single male cells from relevant forensic cell mixtures towards fully automated devices, through these objectives:
1) Develop a microfluidic system for isolating single sperm cells from sperm-vaginal cell mixtures.
2) Develop a microfluidic system for isolating single male nucleated cells from male-female traces.
3) Evaluate the cell selection and isolation efficiency of both microfluidic systems to maximise compatibility with forensic-type material.
4)Integrate the microfluidic systems into standalone prototype devices according to user requirements.

Description

WP3 will be led by KUL-MeBioS and co-led by KUL-FBS

Task 3.1 MicroLyseFX module: Isolating sperm cells from postcoital swabs additionally containing vaginal cells (Leader: KUL-MeBioS; Participants: KUL-FBS, EFSI; M1-18)
Based on the in-house expertise on routinely used differential lysis procedures offered by KUL-FBS, KUL-MeBioS will leverage their extensive microfluidics expertise to design and fabricate a custom microfluidic system based on a miniaturised version. First, KUL-FBS will establish the most efficient differential lysis protocol (i.e. complete vaginal epithelial cell lysis in the shortest possible time). KUL-MeBioS will then translate this approach into a microfluidic chip with a dedicated mixing and incubation zone. Additionally, EFSI will provide input based on the findings during the evaluation of routine forensic evidence collection (WP2 Task 2.2), to enable incorporation of a filtration zone prior to cellular lysis to account for the possible non-cellular debris present. Lastly, a purification zone will be integrated post-lysis, to remove female DNA prior to downstream analysis. This will result in a first microfluidic prototype (MicroLyseFX I).

Task 3.2 MicroSortFX module: Isolating male cells from trace evidence such as touch deposits of multiple sources (Leader: KUL-MeBioS; Participants: KUL-FBS, EFSI, UM; M7-42)
KUL-MeBioS will establish and optimise a male-specific staining method (HCR-S-FISH) for enhancing the detection of male nucleated cells in trace evidence like touch deposits, but translated, for the first time, in SPCs. For SPC generation, KUL-MeBioS will leverage and extend already existing microfluidic systems in their lab. In particular, KUL-MeBioS will extend these systems to enable the preselection of droplets comprising nucleated cells followed by in-flow crosslinking and translation into SPCs. Next, this procedure will be translated into an innovative microfluidic unit. KUL-MeBioS will develop a microfluidic staining chamber for SPC storage and consecutive reagent addition. EFSI will align expectations on the number of nucleated cells expected from casework samples (WP2 Task 2.2) and similarly, KUL-FBS and UM will provide sample input requirements for downstream analysis in WP4. Also, different parameters will

be optimised to enhance the performance of on-chip staining. Subsequently, KUL-MeBioS will develop a microfluidic unit for sorting SPCs based on fluorescent signals emitted by the SPC content. This will result in a first microfluidic prototype (MicroSortFX I).

Task 3.3 Evaluation of the isolation efficiency of MicroLyseFX and MicroSortFX prototypes (Leader: KUL-MeBioS; Participants: KUL-FBS, UM; M19-46)
The MicroLyseFX prototype efficiency in isolating sperm cells will be evaluated by KUL-FBS and KUL-MeBioS using sperm cells from male donors as well as mixtures of sperm and vaginal epithelial cells from postcoital swabs of female donors in mock scenarios. Based on these findings, the microfluidic design and workflow will be further optimised by KUL-MeBioS to accommodate specific sample requirements from WP4 tools towards a goal of >85% cell isolation efficiency. The MicroSortFX prototype efficiency will also be evaluated by KUL-MeBioS and KUL-FBS using buccal (or other) cells from male donors, mixtures of female and male cells as well as deposits of buccal cells in mock scenarios. Based on these findings, the different units will be fine-tuned by KUL-MeBioS to accommodate requirements from WP4 provided by KUL-FBS and UM, ideally reaching an isolation efficiency of >65%.

Task 3.4 Development of MicroLyseFX & MicroSortFX modules towards fully integrated future products (Leader: Voxdale; Participants: KUL-MeBioS, MUI; M21-48)
To further proceed towards gradual commercial production of MicroLyseFX (with designs and prototypes including integrated microfluidics in MicroLyseFX II and integrated swab elution in MicroLyseFX III) and, to lesser extent of MicroSortFX (limited to a design for integrated microfluidics), Voxdale will leverage insights during development from KUL-MeBioS, and explore innovative design concepts through collaborative brainstorming and early prototyping. With the help of MUI, Voxdale will establish clear evaluation criteria for all proposed design concepts, considering usability, feasibility, and relevance to user needs. The selected concept will be refined through iterative development and prototyping, honing in on functionality, usability, and manufacturability.

Work package WP4 – Novel forensic sorted/single-cell sequencing assays

Work Package Number	WP4	**Lead Beneficiary**	2 - KUL
Work Package Name	Novel forensic sorted/single-cell sequencing assays		
Start Month	7	**End Month**	42

Objectives

The overarching goal of WP4 is to enable single-cell forensic DNA analysis from the Micro-LyseFX/MicroSortFX output by adjusting current detection systems and developing novel sequencing as-says, through these objectives:
1) Test enriched and single sperm cells using optimised forensic DNA profiling CE/MPS assays.
2) Create novel single-cell STR/SNP MPS assays based on in-capsule PCR and barcoding.
3) Test a pre-commercial long-range RC-PCR approach for whole-mitogenome analysis using LRS.
4) Propose a novel single-cell STR/SNP LRS strategy based on in-capsule PCR and concatemers.

Description

WP4 will be led by KUL-FBS and co-led by UM

Task 4.1 Streamlining and fine-tuning existing CE and MPS protocols for smooth integration of the MicroLyseFX output (Leader: KUL-FBS; Participants: KUL-MeBioS, UM, NimaGen; M13-24)
KUL-MeBioS will provide the isolated single or enriched sperm cell solutions obtained during the final stages of development of MicroLyseFX in WP3 Task 3.1. For downstream integration, KUL-FBS will test CE assays PowerPlex® Fusion System by Promega and the GlobalFiler™ PCR Amplification kit by Thermo Fisher Scientific. For MPS, these include the IDseek® CombiSTR™ Plus, OmniSNP™ Identity Informative SNP Kit, and Mitochondrial Full Genome kit from Nimagen. KUL-FBS and UM will optimise PCR parameters, library preparation protocols and sequencing specifications to increase sensitivity per commercial kit. For MPS, amplicons will be pooled, purified, quantified, and standard library preparation will be performed with subsequent sequencing using MiSeq FGx (KUL-FBS) and NextSeq (UM). The developed as-says will be directly used during validation in WP6 Task 6.3.

Task 4.2 Development of novel forensic STR / SNP MPS assays based on in-capsule PCR and combinatorial indexing, suited to MicroSortFX output (Leader: KUL-FBS; Participants: KUL-MeBioS, UM; M7-30)

KUL-FBS will develop a new type of multiplex PCR assay targeting both STRs and SNPs (microhaplo-types) for application within SPCs. Due to the risk of short amplicons diffusing through the pores of the SPCs, KUL-MeBioS will advise on the pore size of SPCs in combination with the amplicon length to ensure optimal amplification efficiency and amplicon retention. KUL-FBS will employ isolated single nucleated cells obtained from cell lines and enrich them through FACS using DAPI-staining to avoid dependency from WP3 Task 3.2. Successful amplicons within SPCs will subsequently be barcoded using 2 or 3 rounds of single-cell combinatorial indexing. Following SPC lysis, amplicons will be pooled, purified, quantified and library preparation will be performed with subsequent sequencing on a MiSeq FGx™. UM will contribute by sharing in-house single-cell expertise and provide sequencing support on NextSeq. Generated data will act as an input for WP5 Task 5.2 to create novel bioinformatic pipelines for data analysis. The lab method will be thoroughly tested internally before moving to validation in WP6 Task 6.4.

Task 4.3 Application of a long-range RC-PCR mtDNA LRS assay to dispensed single cells, suited to MicroSortFX output (Leader: NimaGen; Participants: MUI, KUL-FBS, UM; M25-36)
NimaGen is currently developing a new (not yet commercially available) long-range RC-PCR solution that amplifies eight long amplicons covering the whole mitogenome. KUL-FBS will use FACS to provide with single isolated epithelial cells, suspended into separate wells. Together with NimaGen, KUL-FBS will evaluate RC-PCR parameters to ensure optimal performance down to single cells. NimaGen will perform library preparation (Ligation Sequencing kit V14) for sequencing on ONT MinION and UM will support sequencing activities if required and process the data as an input for WP5 Task 5.4 to create a novel bioinformatic pipeline for data analysis. MUI will test the final protocol and compare results with available in-house MPS data, prior to validation in WP6 Task 6.4.

Task 4.4 Development of novel 1-cell-1-read STR/SNP LRS assays using in-capsule PCR and concatemer synthesis suited to the MicroSortFX output (Leader: UM; Participants: KUL-FBS; M7-42)
KUL-FBS and UM will join forces to offer a novel barcode-free strategy that takes advantage of LRS based on the principle of 1-cell-1-read concatemer synthesis of individual amplicons generated within the SPCs. UM will employ FLUX (Atrandi Biosciences) to isolate single cells inside SPCs. Next, a multiplex single-cell amplicon sequencing strategy will be employed. Employed primers will be identical to Task 4.2. UM will design and optimise additional primers if needed. After amplification and concatenation, SPCs will be dissolved, double-stranded concatemers will be purified and the final library will be assessed on Bioanalyzer. UM will perform nanopore sequencing using ONT PromethION. UM will evaluate key PCR parameters to generate complete concatemers, while KUL-FBS will employ the developed assay using SPCs generated from MicroSortFX. Generated data will be processed and act as an input for WP5 Task 5.3 to create novel bioinformatic pipelines for data analysis. The method will be thoroughly tested internally before moving to validation in WP6 Task 6.4.

Work package WP5 – Forensic genetic data analysis and interpretation

Work Package Number	WP5	**Lead Beneficiary**	5 - NFI
Work Package Name	Forensic genetic data analysis and interpretation		
Start Month	13	**End Month**	48

Objectives
The overarching goal of WP5 is to generate, optimise and validate the necessary data analysis tools and pipelines, and facilitate robust and relevant interpretation in the forensic context, through these objectives: 1) Enable single-cell profile interpretation by optimising current CE and MPS data analysis. 2) Update MPS analysis and interpretation pipelines for data based on combinatorial indexing. 3) Develop novel analysis and interpretation pipelines for LRS data including concatemers. 4) Establish machine learning tools to enable automated CE allele calling and MPS noise prediction.

Description
WP5 will be led by NFI and co-led by i3S Task 5.1 Fine-tuning of the analysis and interpretation pipelines used with routine CE and MPS data (Leader: NFI; Participants: i3S, KUL-FBS, MUI; M13-27) NFI will derive updated and fine-tuned settings and thresholds in both data analysis pipelines and statistical evaluation tools from data generated in WP4 Task 4.1 by KUL-FBS. These relate to updated stutter settings in CE-profile analysis

tools (GeneMapper or GeneMarker) as these will change when a stutter-reduced STR kit is used. i3S will perform similar tests for MPS assays. All data will be inspected including allelic balance, allele/full dropouts/dropins, problematic SNPs. mtDNA will be performed following MUI's guidelines. DNA profiles generated by single haploid cells and their effects on probabilistic genotyping need to be examined (e.g. in DNAStatistX). NFI will perform software adaptations. Effects can be tested by MUI prior to activities in WP6 Tasks 6.2 and 6.3.

Task 5.2 Update of bioinformatics and interpretation pipelines to analyse the new forensic single-cell STR/SNP data based on combinatorial indexing (Leader: i3S Participants: NFI, KUL-FBS; M13-36)
NFI will update the regions and other functions in FDSTools based on the new amplicon design parameters in WP4 Task 4.2. For data analysis of sequences obtained through combinatorial indexing, i3S will evaluate the functioning and forensic suitability of several scripts currently available in the literature, e.g. scitools, specific for single-cell data, Cutadapt for removing adapters/indexes; UMI for handling unique molecular identifier if included (previously integrated in FDSTools). I3S will integrate these bioinformatic tools within a pipeline that is integrated and user-friendly, and further adapt as data are produced by KUL-FBS in WP4 Task 4.2. Finally, NFI will internally test the integrated pipeline to further develop it to a forensic casework level, prior to validation efforts in WP6 Task 6.4.

Task 5.3 Development of novel bioinformatics and interpretation pipelines to analyse the new forensic single-cell STR/SNP concatenated data for the 1-cell-1-read approach (Leader: NFI; Participants: i3S, UM; M13-42)
Generated amplicons from various MPS systems can be ligated to create test concatenated data to provide a head start for the pipeline development. This process enables fast feedback loops between developing the lab protocol in WP4 Task 4.4, and the concept of the pipeline, which needs to filter semi-ligated products and select the targeted sequences cleaned from primer-dimers. UM will pre-process the ONT data using well-established and custom pipelines. Processed data will be tested using the novel pipeline by NFI, prior to validation in WP6 Task 6.4. NFI and i3S will extract STR and SNP data, respectively, to implement available tools to perform identification.

Task 5.4 Development of novel analysis and interpretation pipelines to analyse the new forensic single-cell mtDNA LRS data (Leader: MUI; Participants: NFI, UM, NimaGen; M25-36)
This task will run alongside WP4 Task 4.4, where NimaGen and UM will produce mtDNA data from sin-gle-dispensed male nucleated cells using RC-PCR and nanopore sequencing. Once available, UM will pre-process the ONT data using well-established and custom pipelines. Processed data will then be analysed by MUI, leveraging their mtDNA expertise. MUI will employ an adjusted pipeline based on SAM2 that implements global phylogenetic alignment from the estimated haplogroup motifs instead of commonly used local alignment and thus produces consensus reads in accordance with the human mtDNA evolution. NFI will support activities and test the novel pipeline.

Task 5.5 Establishment of novel machine learning-based algorithms to address current challenges with CE- and MPS-based allele-calling (Leader: i3S; Participants: NFI, MUI; M13-48)
NFI will develop ANNs for automated CE-STR profile analysis. The goal is to automatically discern allelic peaks from artefact peaks (pull up, stutter, or baseline noise), which is novel compared to Task 5.1. As a start, existing data will be used, followed by data generated in WP4 Task 4.1. i3S will develop machine learning-based tools that predict MPS allele-specific noise in a generalised manner (depending on features such as repeat structure, longest uninterrupted stretch). The allele-specificity is a novel feature compared to Task 5.1. These models will be sequencing platform independent. All partners will evaluate the models with in-house data using different kits and CE/MPS platforms, to provide feedback prior to implementation in WP6 Task 6.5.

Work package WP6 – Testing, validation and training

Work Package Number	WP6	**Lead Beneficiary**	4 - MUI
Work Package Name	Testing, validation and training		
Start Month	19	**End Month**	48

Objectives
The overall goal of WP6 is to validate and implement the innovative CapCell toolkit at the end-user operational environment and provide training to forensic institutes and police authorities, through these objectives: 1) Train forensic researchers and practitioners on all novel aspects of our modular CapCell tools. 2) Enable the analysis of isolated cells in the forensic context following standard procedures. 3) Test and validate the novel forensic single-cell MPS/LRS assays and data analysis tools.

Associated with document Ref. Ares(2025)5511292 - 08/07/2025

4) Demonstrate the mobile integrated MicroLyseFX device and downstream automated analysis.

Description

WP6 will be led by MUI and co-led by EPBG

Task 6.1 Training of forensic researchers and practitioners on modular CapCell tools led by technology experts (Leader: MUI; Participants: all, M19-42)
All academic, forensic and police partners will be trained to use novel CapCell technologies, downstream genotyping and data interpretation generated across WPs via online tutorials, custom-designed exercises and research visits. Experts developing each module will lead the training, with the support from MUI: KUL-MeBioS and KUL-FBS will train on MicroLyseFX and MicroSortFX concepts and prototypes as they become available. KUL-FBS, UM and MUI will train on WP4 laboratory protocols, while NFI, i3S and MUI on the novel pipelines and interpretation frameworks. Representatives from forensic institutes and police labs will be given the chance to visit KUL for live demonstration on microfluidics instrumentation and lab procedures using available samples.

Task 6.2 Implementation of novel analysis and statistical tools to interpret single-cell forensic data (TRL-7) (Leader: EPBG; Participants: KUL-FBS, i3s, MUI, NFI, EFSI, AFCP, EDNAP; M25-30)
Adjusted analysis and result interpretation pipelines generated in WP5 Task 5.1 (module 9) will be tested, implemented and validated across forensic institutes using datasets generated during training and prior development. This task will be performed and supported via virtual sessions. Tools from WP5 Task 5.1 will used by each casework lab to assess the performance of conventional CE- and MPS STR kits with established stutter ratios in the order of 10-20%. Validation of the updated CE- and MPS-profile analysis tools will be performed using existing profiles by MUI, NFI and EFSI, with support by i3S, according to ENFSIs Best Practice Manual and each lab's routine practice. EDNAP will explore an extended inter-laboratory exercise. Police labs hold an advisory role.

Task 6.3 Analysis of isolated sperm cell pools and test demonstration of adjusted forensic DNA procedures (TRL-6) (Leader: KUL-FBS; Participants: UM, MUI, NFI, EFSI, EPBG, AFCP, EDNAP, NimaGen, M31-36)
This task will build upon Task 6.2 but include also laboratory analysis by testing the fine-tuned commercial CE/MPS protocols delivered by WP4 Task 4.1 (modules 5-9). Isolated sperm cell material obtained from the MicroLyseFX device will be provided from KUL-FBS to academic and forensic laboratories (UM, MUI, NFI, EFSI). A detailed validation plan and SOPs will be drafted by KUL-FBS. Initial validation will be performed by MUI to allow for feedback to adjust procedures if needed. All validation studies will be performed using mock casework using vaginal swabs spiked with a known number of sperm cells in a coordinated plan among labs. NimaGen will provide kits, while EDNAP holds an advisory role.

Task 6.4 Testing and validation of novel MicroSort-suited single-cell forensic MPS/LRS assays (TRL-5) (Leader: MUI; Participants: UM, KUL-FBS, NFI, i3S, KUL-MeBioS; M31-48)
In this task we will perform further testing and developmental validation of the novel laboratory tools developed in WP4 Tasks 4.2-4 (modules 6-7-8), coupled with the bioinformatics pipelines developed in WP5 Tasks 5.2-4; all suited for MicroSortFX output. Our goal is to assess robustness of the assays and effectiveness of the encapsulated process. Encapsulation will take place in KUL-FBS and UM, but the portable instrument can be borrowed by MUI for testing. KUL-FBS will test the mtDNA LRS assay. UM will test both the novel MPS and mtDNA LRS assays, while MUL will test all three including the novel STR/SNP LRS assay. We will use male nucleated cells obtained from cell lines, increase complexity by testing mix-tures and employ MicroSortFX output as it becomes available. NFI and i3S will perform data analysis using the latest tools developed in WP5. NimaGen will provide kits.

Task 6.5 Operation demonstration of a mobile integrated MicroLyseFX device followed by improved and automated forensic DNA profiling (TRL-7) (Leader: Voxdale; Participants: KUL-MeBioS, MUI, KUL-FBS, UM, NFI, i3S, EFSI, EPBG, AFCP, COPAN, EDNAP; M37-48)
This task builds upon three tasks: WP3 Task 3.4, WP6 Task 6.3 and WP5 Task 5.5 and aims at a full-scale prototype field demonstration of the MicroLyseFX microfluidic device and downstream workflow (modules 1-3-5-10) for rapid and automated, machine learning-based forensic DNA profiling, fully integrated with current processes for STR/SNP/mtDNA typing in forensic and police labs. Voxdale and KUL-MeBioS will produce and ship the MicroLyseFX prototype devices to each lab for testing using realistic forensic samples such as from proficiency tests. With the support of police labs and permission of magistrates, application to real casework samples will be explored to reach the envisioned TRL. MUI will lead a coordinated inter-laboratory study among partners using preferred assays per lab further finetuned following Task 6.3 and the machine learning tools, supported by i3S. The goal is to evaluate the device's cell isolation efficiency, cost-effectiveness, user-friendliness in real forensic & operational settings, which give valuable insights for further development. EDNAP will advise activities.

Work package WP7 – Communication, dissemination and exploitation

Work Package Number	WP7	Lead Beneficiary	12 - accelCH
Work Package Name	Communication, dissemination and exploitation		
Start Month	1	End Month	48

Objectives

The overarching goal of WP7 is to raise awareness about the CapCell innovations and facilitate stakehold-er-targeted outreach and their wide-scale adoption by the forensic community, through these objectives:
1) Identify and involve relevant stakeholders in monitoring impacts of CapCell innovations.
2) Define and plan multi-channel communication measures to raise awareness, build public trust and share project results with relevant target groups.
3) Disseminate project results and innovation to relevant stakeholders.
4) Ensure efficient exploitation and define a strategy for the wide-spread uptake of CapCell results by end-users and the European forensic community.

Description

WP7 will be led by accelCH and co-led by MUI

Task 7.1 Stakeholder mapping and engagement (Leader: MUI; Co-leader: accelCH; Participants: all, M1-48)
accelCH will perform stakeholder mapping at the project's start, which will be updated continuously. MUI and accelCH will establish user focus groups in years 1 and 2, including online surveys and consultations to gather forensic casework needs to complement WP2 Task 2.1 and gather feedback from stakeholders on sample collection best practices in WP2 Task 2.4. Insights will flow into all scientific WPs (2–6), improving the innovation cycle. A Security Cluster of EU-funded projects will be formed in year 1 by MUI and accelCH, fostering synergies, knowledge exchange through working groups on relevant topic (joint communication, citizen engagement etc.). Outcomes will contribute to policy recommendations (D7.5, M36) and be presented at the final event.

Task 7.2 Target-group-oriented multi-channel communication (Leader: accelCH; Participants: all, M1-48)
With input from all partners, accelCH will develop a communication and dissemination plan (CDP, D7.2, M6) based on the stakeholder mapping (T7.1). The CDP will outline tools, channels, messages and activities to raise awareness for CapCell, build public trust, and engage stakeholders, especially end-users. Activities will be monitored, assessed, adapted as needed, and documented in the interim impact reports (D7.3). A project website (D7.1, M2) will serve as the primary information hub, featuring project details, results, news and social media links. accelCH will establish social media (LinkedIn and YouTube) accounts. Networks of partners, e.g. EDNAP, will facilitate engagement with the forensic community. accelCH will develop tailored communication materials (e.g., infographics, brochures) and create explainer videos for each CapCell module with partners` support. Press releases/ articles on CapCell's achievements will be distributed through project and partner channels to maximise outreach.

Task 7.3 Stakeholder-oriented scientific dissemination (Leader: MUI, Participants: all; M3-48)
Partners will publish project results in peer-reviewed open-access journals following publication guidelines and present results and outcomes at (inter-)national security conferences such as those organised by CERIS through oral and poster presentations. CapCell will organise Technology & Innovation sessions with relevant stakeholders including the forensic community (CERIS, ENFSI, Europol) and key industry players to discuss innovation management (WP1 Task 1.5) and technological development of CapCell, which will flow into the RfE (D7.6, M48). UM and MUI will hold a final event at the project's end to showcase CapCell results.

Task 7.4 End user (forensic institutes and police authorities) focused exploitation activities (Leader: KUL-MeBioS; Co-leader: accelCH; Participants: all, M13-48)
eLearning tools and training materials (WP6) will be made available to end-users and translated into national languages. These will be shared via Europol Innovation Lab and project channels and with the ENFSI's network to encourage broad uptake. Policy recommendations (D7.5, M36) will be freely accessible on the website and distributed through partners' networks. At the project's end, accelCH will conduct strategic grant planning, identifying relevant funding programmes for follow-up projects. Based on partner feedback, accelCH will provide a list of suitable schemes, a proposal preparation schedule, and initial support for project setup. In the final year, the RfE (D7.6, M48) will be developed by MUI with the

support of KUL's innovation manager, WP1 Task 1.5, and all partners. The RfE will define a clear strategy for short-, mid-, and long-term uptake of project outcomes by end-users, outlining responsibilities and steps for each partner.

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 - UM	18.00	3.00	3.00	36.00	12.00	12.00	6.00	90.00
2 - KUL	3.00	3.00	80.00	27.00	6.00	5.00	3.00	127.00
3 - i3S	1.00				27.50	6.00	1.00	35.50
4 - MUI	1.00	9.00	2.00	2.00	10.00	24.00	5.00	53.00
5 - NFI	1.00	9.00			24.00	6.00	1.00	41.00
6 - EFSI	1.00	21.00	1.00			10.00	1.00	34.00
7 - EPBG	2.00	3.00				9.00	2.00	16.00
8 - AFCP	2.00	3.00				9.00	4.00	18.00
9 - COPAN	0.50	14.00				1.00	0.50	16.00
10 - NimaGen	1.00			9.00		1.00	1.00	12.00
11 - Voxdale	1.00		24.00			6.00	1.00	32.00
12 - accelCH	12.00						16.00	28.00
13 - EDNAP	1.00	4.00				2.00	2.00	9.00
Total Person-Months	44.50	69.00	110.00	74.00	79.50	91.00	43.50	511.50

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	Project implementation guidelines (PIG)	WP1	1 - UM	R — Document, report	SEN - Sensitive	2
D1.2	Data management plan (DMP)	WP1	1 - UM	R — Document, report	SEN - Sensitive	6
D1.3	Quality assurance (QA) and risk assessment	WP1	1 - UM	R — Document, report	SEN - Sensitive	18
D1.4	Updated DMP	WP1	1 - UM	DMP — Data Management Plan	SEN - Sensitive	24
D1.5	Updated QU and risk assessment	WP1	1 - UM	R — Document, report	SEN - Sensitive	30
D2.1	End-user needs	WP2	4 - MUI	R — Document, report	PU - Public	6
D2.2	Routine collection evaluation	WP2	6 - EFSI	R — Document, report	PU - Public	14
D2.3	Improved intact cell recovery & transfer	WP2	6 - EFSI	R — Document, report	SEN - Sensitive	18
D2.4	Novel standards for mixed sample collection	WP2	5 - NFI	R — Document, report	PU - Public	24
D3.1	Differential lysis protocol	WP3	2 - KUL	R — Document, report	SEN - Sensitive	6
D3.2	MicroLyseFX I evaluation	WP3	2 - KUL	R — Document, report	SEN - Sensitive	20
D3.3	MicroLyseFX II	WP3	11 - Voxdale	DEM — Demonstrator, pilot, prototype	SEN - Sensitive	36
D3.4	MicroSortFX I evaluation	WP3	2 - KUL	R — Document, report	SEN - Sensitive	46

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D3.5	MicroSortFX II	WP3	11 - Voxdale	DEM — Demonstrator, pilot, prototype	SEN - Sensitive	48
D4.1	Optimised assays for MicroLyseFX integration	WP4	2 - KUL	OTHER	PU - Public	24
D4.2	Novel single-cell STR/SNP assays	WP4	2 - KUL	R — Document, report	SEN - Sensitive	30
D4.3	Novel single-cell mitogenome assay	WP4	10 - NimaGen	DEM — Demonstrator, pilot, prototype	SEN - Sensitive	36
D4.4	Novel 1-cell-1-read STR assay	WP4	1 - UM	R — Document, report	SEN - Sensitive	36
D5.1	Fine-tuned existing tools for single-cell application	WP5	5 - NFI	OTHER	SEN - Sensitive	27
D5.2	Novel analysis tools for combinatorial indexing	WP5	3 - i3S	OTHER	SEN - Sensitive	36
D5.3	Novel analysis tools for mtDNA	WP5	4 - MUI	OTHER	SEN - Sensitive	36
D5.4	Novel analysis tools for concatemers	WP5	5 - NFI	OTHER	SEN - Sensitive	42
D5.5	Machine learning-based tools	WP5	3 - i3S	OTHER	SEN - Sensitive	48
D6.1	User validation and implementation plan	WP6	4 - MUI	R — Document, report	SEN - Sensitive	24
D6.2	Implementation of interpretation guidelines for single-cell data	WP6	5 - NFI	R — Document, report	SEN - Sensitive	30
D6.3	Validation of single-cell analysis	WP6	2 - KUL	R — Document, report	SEN - Sensitive	36

Deliverables

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Deliverable No	Deliverable Name	Work Package No	Lead Beneficiary	Type	Dissemination Level	Due Date (month)
D6.4	Training material	WP6	4 - MUI	OTHER	PU - Public	42
D6.5	Validation of single cell sequencing	WP6	4 - MUI	R — Document, report	SEN - Sensitive	42
D6.6	Demonstration of a mobile MicroLyseFX device	WP6	11 - Voxdale	DEM — Demonstrator, pilot, prototype	SEN - Sensitive	48
D7.1	Project website and social media channels	WP7	12 - accelCH	DEC —Websites, patent filings, videos, etc	PU - Public	2
D7.2	Communication and dissemination plan	WP7	12 - accelCH	R — Document, report	SEN - Sensitive	6
D7.3	Interim impact report	WP7	12 - accelCH	R — Document, report	SEN - Sensitive	24
D7.4	User focus groups	WP7	4 - MUI	R — Document, report	SEN - Sensitive	24
D7.5	Policy brief	WP7	4 - MUI	R — Document, report	PU - Public	36
D7.6	Roadmap for Exploitation	WP7	2 - KUL	R — Document, report	SEN - Sensitive	48

Deliverable D1.1 – Project implementation guidelines (PIG)

Deliverable Number	D1.1	**Lead Beneficiary**	1 - UM
Deliverable Name	Project implementation guidelines (PIG)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	2	**Work Package No**	WP1

Description
Roles and responsibilities of the consortium bodies/partners, incl. quality assurance

Deliverable D1.2 – Data management plan (DMP)

Deliverable Number	D1.2	**Lead Beneficiary**	1 - UM
Deliverable Name	Data management plan (DMP)		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	6	**Work Package No**	WP1

Description
Data management strategy and key datasets, in line with the FAIR principles

Deliverable D1.3 – Quality assurance (QA) and risk assessment

Deliverable Number	D1.3	**Lead Beneficiary**	1 - UM
Deliverable Name	Quality assurance (QA) and risk assessment		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	18	**Work Package No**	WP1

Description
QA proceedings and status on technical and non-technical (un)foreseen risks

Deliverable D1.4 – Updated DMP

Deliverable Number	D1.4	**Lead Beneficiary**	1 - UM
Deliverable Name	Updated DMP		
Type	DMP — Data Management Plan	**Dissemination Level**	SEN - Sensitive
Due Date (month)	24	**Work Package No**	WP1

Description
Interim update of the DMP

Deliverable D1.5 – Updated QU and risk assessment

Deliverable Number	D1.5	Lead Beneficiary	1 - UM
Deliverable Name	Updated QU and risk assessment		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	30	Work Package No	WP1

Description
QA proceedings and status on technical and non-technical (un)foreseen risks

Deliverable D2.1 – End-user needs

Deliverable Number	D2.1	Lead Beneficiary	4 - MUI
Deliverable Name	End-user needs		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	6	Work Package No	WP2

Description
Overview of the casework requirements based on literature, questionnaires and practitioner consultation

Deliverable D2.2 – Routine collection evaluation

Deliverable Number	D2.2	Lead Beneficiary	6 - EFSI
Deliverable Name	Routine collection evaluation		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	14	Work Package No	WP2

Description
Assessment of routine sample collection strategies in terms of quantity/quality of cellular eluate

Deliverable D2.3 – Improved intact cell recovery & transfer

Deliverable Number	D2.3	Lead Beneficiary	6 - EFSI
Deliverable Name	Improved intact cell recovery & transfer		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	18	Work Package No	WP2

Description
Protocol for novel forensic sample collection to maximise intact cell recovery

Associated with document Ref. Ares(2025)5511292 - 08/07/2025

Deliverable D2.4 – Novel standards for mixed sample collection

Deliverable Number	D2.4	Lead Beneficiary	5 - NFI
Deliverable Name	Novel standards for mixed sample collection		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	24	Work Package No	WP2

Description
Best practices and recommendations to maximise intact cell recovery

Deliverable D3.1 – Differential lysis protocol

Deliverable Number	D3.1	Lead Beneficiary	2 - KUL
Deliverable Name	Differential lysis protocol		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	6	Work Package No	WP3

Description
Report on the most efficient off-chip differential lysis proto-col for postcoital swabs

Deliverable D3.2 – MicroLyseFX I evaluation

Deliverable Number	D3.2	Lead Beneficiary	2 - KUL
Deliverable Name	MicroLyseFX I evaluation		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	20	Work Package No	WP3

Description
Report on the status of MicroLyseFX development and its ability to isolate sperm cells

Deliverable D3.3 – MicroLyseFX II

Deliverable Number	D3.3	Lead Beneficiary	11 - Voxdale
Deliverable Name	MicroLyseFX II		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP3

Description
Integrated and automated microfluidic device for sample elu-tion and sperm cell isolation

Deliverable D3.4 – MicroSortFX I evaluation

Deliverable Number	D3.4	Lead Beneficiary	2 - KUL
Deliverable Name	MicroSortFX I evaluation		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	46	Work Package No	WP3

Description
Report on the status of MicroSortFX development and its ability to isolate male nucleated cells

Deliverable D3.5 – MicroSortFX II

Deliverable Number	D3.5	Lead Beneficiary	11 - Voxdale
Deliverable Name	MicroSortFX II		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	SEN - Sensitive
Due Date (month)	48	Work Package No	WP3

Description
Design for integrated and automated microfluidic device for male nucleated cell isolation

Deliverable D4.1 – Optimised assays for MicroLyseFX integration

Deliverable Number	D4.1	Lead Beneficiary	2 - KUL
Deliverable Name	Optimised assays for MicroLyseFX integration		
Type	OTHER	Dissemination Level	PU - Public
Due Date (month)	24	Work Package No	WP4

Description
Adjustments of current CE/MPS assays to allow single-cell sperm analysis

Deliverable D4.2 – Novel single-cell STR/SNP assays

Deliverable Number	D4.2	Lead Beneficiary	2 - KUL
Deliverable Name	Novel single-cell STR/SNP assays		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	30	Work Package No	WP4

Description
Report on the development and testing of the novel MPS as-says

Deliverable D4.3 – Novel single-cell mitogenome assay

Deliverable Number	D4.3	Lead Beneficiary	10 - NimaGen
Deliverable Name	Novel single-cell mitogenome assay		
Type	DEM — Demonstrator, pilot, prototype	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP4

Description
Development of a new RC-PCR assay towards a future commercial solution

Deliverable D4.4 – Novel 1-cell-1-read STR assay

Deliverable Number	D4.4	Lead Beneficiary	1 - UM
Deliverable Name	Novel 1-cell-1-read STR assay		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP4

Description
Report on the development and testing of the novel LRS assay

Deliverable D5.1 – Fine-tuned existing tools for single-cell application

Deliverable Number	D5.1	Lead Beneficiary	5 - NFI
Deliverable Name	Fine-tuned existing tools for single-cell application		
Type	OTHER	Dissemination Level	SEN - Sensitive
Due Date (month)	27	Work Package No	WP5

Description
Tools suited to single-cell CE/MPS DNA profiles, but at a casework-ready level

Deliverable D5.2 – Novel analysis tools for combinatorial indexing

Deliverable Number	D5.2	Lead Beneficiary	3 - i3S
Deliverable Name	Novel analysis tools for combinatorial indexing		
Type	OTHER	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP5

Description
Tools suited to single-cell MPS STR/SNP data

Associated with document Ref. Ares(2025)5511292 - 08/07/2025

Deliverable D5.3 – Novel analysis tools for mtDNA

Deliverable Number	D5.3	Lead Beneficiary	4 - MUI
Deliverable Name	Novel analysis tools for mtDNA		
Type	OTHER	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP5

Description
Tools suited to single-cell LRS mtDNA data

Deliverable D5.4 – Novel analysis tools for concatemers

Deliverable Number	D5.4	Lead Beneficiary	5 - NFI
Deliverable Name	Novel analysis tools for concatemers		
Type	OTHER	Dissemination Level	SEN - Sensitive
Due Date (month)	42	Work Package No	WP5

Description
Tools suited to single-cell LRS STR/SNP data

Deliverable D5.5 – Machine learning-based tools

Deliverable Number	D5.5	Lead Beneficiary	3 - i3S
Deliverable Name	Machine learning-based tools		
Type	OTHER	Dissemination Level	SEN - Sensitive
Due Date (month)	48	Work Package No	WP5

Description
Tools for automated single-cell CE allele calling and MPS noise prediction

Deliverable D6.1 – User validation and implementation plan

Deliverable Number	D6.1	Lead Beneficiary	4 - MUI
Deliverable Name	User validation and implementation plan		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	24	Work Package No	WP6

Description
Detailed plan of module choice per partner based on (newly) available infrastructure and end-user needs

Deliverable D6.2 – Implementation of interpretation guidelines for single-cell data

Deliverable Number	D6.2	Lead Beneficiary	5 - NFI
Deliverable Name	Implementation of interpretation guidelines for single-cell data		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	30	Work Package No	WP6

Description
STR, SNP and mtDNA interpretation from single cells

Deliverable D6.3 – Validation of single-cell analysis

Deliverable Number	D6.3	Lead Beneficiary	2 - KUL
Deliverable Name	Validation of single-cell analysis		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	36	Work Package No	WP6

Description
Optimised existing CE/MPS methods validated according to forensic criteria

Deliverable D6.4 – Training material

Deliverable Number	D6.4	Lead Beneficiary	4 - MUI
Deliverable Name	Training material		
Type	OTHER	Dissemination Level	PU - Public
Due Date (month)	42	Work Package No	WP6

Description
Documentation (PowerPoint presentations, flowcharts, videos and others) for training on CapCell tools

Deliverable D6.5 – Validation of single cell sequencing

Deliverable Number	D6.5	Lead Beneficiary	4 - MUI
Deliverable Name	Validation of single cell sequencing		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	42	Work Package No	WP6

Description
Novel MPS/LRS techniques for single cell sequencing in forensics

Deliverable D6.6 – Demonstration of a mobile MicroLyseFX device

Deliverable Number	D6.6	**Lead Beneficiary**	11 - Voxdale
Deliverable Name	Demonstration of a mobile MicroLyseFX device		
Type	DEM — Demonstrator, pilot, prototype	**Dissemination Level**	SEN - Sensitive
Due Date (month)	48	**Work Package No**	WP6

Description
Implementation of mobile MicroLyseFX prototype in forensic environment

Deliverable D7.1 – Project website and social media channels

Deliverable Number	D7.1	**Lead Beneficiary**	12 - accelCH
Deliverable Name	Project website and social media channels		
Type	DEC —Websites, patent filings, videos, etc	**Dissemination Level**	PU - Public
Due Date (month)	2	**Work Package No**	WP7

Description
Launch describing the project and continuously updated with project achievements

Deliverable D7.2 – Communication and dissemination plan

Deliverable Number	D7.2	**Lead Beneficiary**	12 - accelCH
Deliverable Name	Communication and dissemination plan		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	6	**Work Package No**	WP7

Description
Strategy based on stakeholder analysis, messages, tools, channels, measures, KPIs

Deliverable D7.3 – Interim impact report

Deliverable Number	D7.3	**Lead Beneficiary**	12 - accelCH
Deliverable Name	Interim impact report		
Type	R — Document, report	**Dissemination Level**	SEN - Sensitive
Due Date (month)	24	**Work Package No**	WP7

Description
Assessment of outreach activities

Deliverable D7.4 – User focus groups

Deliverable Number	D7.4	Lead Beneficiary	4 - MUI
Deliverable Name	User focus groups		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	24	Work Package No	WP7

Description
Collection of end-user needs and feedback

Deliverable D7.5 – Policy brief

Deliverable Number	D7.5	Lead Beneficiary	4 - MUI
Deliverable Name	Policy brief		
Type	R — Document, report	Dissemination Level	PU - Public
Due Date (month)	36	Work Package No	WP7

Description
Findings of the Security Cluster working groups

Deliverable D7.6 – Roadmap for Exploitation

Deliverable Number	D7.6	Lead Beneficiary	2 - KUL
Deliverable Name	Roadmap for Exploitation		
Type	R — Document, report	Dissemination Level	SEN - Sensitive
Due Date (month)	48	Work Package No	WP7

Description
Joint and individual exploitation activities

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	Consortium bodies and governance structure established	WP1	1 - UM	D1.1 submitted	2
2	End-user needs survey results	WP2	4 - MUI	D2.1 submitted	6
3	On-chip purification of sperm cells after differential lysis established	WP3	2 - KUL	Laboratory procedure has been verified to work effectively	8
4	Routine evidence collection strategies assessment complete	WP2	6 - EFSI	D2.2 submitted	14
5	Optimisation of evidence collection strategies complete	WP2	6 - EFSI	D2.3 submitted	18
6	MicroLyseFX I prototype	WP3	2 - KUL	Prototype up-and-running and ready for isolation efficiency evaluation	18
7	In-capsule PCR of STR & SNP loci	WP4	2 - KUL	Assay developed and shown to work well with good-quality DNA (i.e. from cell lines)	18
8	Validation of min. one commer-cial assay per technology (CE/MPS)	WP4	2 - KUL	D4.1 submitted	24
9	Production of in-capsule PCR amplicon concatemers	WP4	1 - UM	Good quality 1-read-1-cell sequencing data including all amplicons of interest	24
10	CE, MPS and LRS datasets for data analysis tools finetuning, development and validation.	WP5	5 - NFI	Inventory and report on the status of available data and/or feasibility of generating sufficient data within the needed time	24
11	Robust and user-friendly pipelines and probabilistic interpretation software suiting forensic standards	WP5	5 - NFI	Report on inventory whether tools like FDSTools and DNAStatistX are compatible with single-cell analysis	24

Milestones

Grant Preparation (Milestones screen) — Enter the info.

Milestone No	Milestone Name	Work Package No	Lead Beneficiary	Means of Verification	Due Date (month)
12	First round of training curricula for forensic researchers and end-users	WP6	4 - MUI	First set of training procedures available and shared with partners for execution	24
13	Establishment of in-capsule HCR-S-FISH staining	WP3	2 - KUL	Laboratory procedure has been verified to work efficiently	30
14	MicroLyseFX II prototype	WP3	11 - Voxdale	Integrated prototype ready for testing, validation and implementation by forensic labs	36
15	Validation of at least one novel MPS/LRS assay	WP4	1 - UM	Internal validation report showcasing sensitivity, accuracy and robustness	36
16	MicroSortFX I prototype	WP3	2 - KUL	Prototype up-and-running and ready for further development and future integration	42
17	Final project meeting	WP1	1 - UM	Meeting summary online and shared with partners	48

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	Difficulty in recovering enough intact male nucleated cells from contact traces (likelihood: medium / severity low)	WP3, WP2	Use of other types of trace evidence, e.g. direct contact traces, artificial mixtures of other epithelial cell types (i.e. buccal cells), white blood cells
2	Technical challenges in counting intact/ruptured	WP3, WP2	Employment of alternative manual cell counting methods like hemocytometer

Critical risks & risk management strategy

Grant Preparation (Critical Risks screen) — Enter the info.

Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
	cells/cell clumps (likelihood: medium / severity: medium)		
3	Difficulties/lack of improvement in cell recovery based on novel sample collection devices and protocols (likelihood: medium / severity: medium)	WP3, WP2	Best practices based on insights gained during the evaluation and optimisation study; evaluation of novel approaches for additional benefits, such as cost/time efficiency and user-friendliness
4	Large number of aggregated cells in recovered swab eluate remaining which clog the chips (likelihood: medium / severity: high)	WP3	Exploration of post-collection processing to reduce cellular aggregation (e.g. mixing, sonication, trypsin-treatment); use of non-aggregated white-blood cells
5	Incompatibility of lysis cocktail with purification kit for removal of female DNA (likelihood: medium / severity: medium)	WP3	Evaluation of alternative options for depletion of female DNA (silica magnetic particles) or specific retention of sperm cells (e.g. dielectrophoresis), anti-PH-20 antibody-coupled immunomagnetic beads)
6	Inability to isolate the targeted percentage of male cells (likelihood: medium / severity: high)	WP3, WP4	Redesign sample loading method and chip to minimise dead volumes and reduce sample losses
7	Inappropriate cell dimensions for encapsulation in stable SPCs (likelihood: medium / severity: medium)	WP3, WP4	Evaluation of cell lysis and adjustment of micro-fluidic designs to encapsulate and sort nuclei only; use of SPCs of smaller size and isolate cells using FACS; use of cells of smaller size (white blood cells)
8	Inefficient HCR-S-FISH staining in the SPCs (likelihood: medium / severity: medium)	WP3	Evaluation of custom polymer and porogen blends for SPC generation, including dextrans with GMA, PEGMA of different molecular weights, and solvents
9	No or inefficient DNA amplification from single sperm cells (likelihood: medium / severity: low)	WP4	Generation of mini-mixtures consisting of a limited number of sperm cells
10	Technical difficulties or delays in developing the proof of principle for in-capsule PCR (likelihood: low / severity: high)	WP4, WP5	Iterative capsule design with real-time monitoring; collaboration with technology provider; testing of alternative PCR approaches, e.g. using unique molecular identifiers or microdroplet digital PCR
11	Low efficiency of combinatorial indexing strategy (likelihood: medium / severity: medium)	WP4, WP5	Library preparation of single-enriched SPCs; extra quality control steps in the data analysis pipelines

Critical risks & risk management strategy

Grant Preparation (Critical Risks screen) — Enter the info.

Risk number	Description	Work Package No(s)	Proposed Mitigation Measures
12	Low efficiency of concatemer synthesis (likelihood: medium / severity: medium)	WP4, WP5	Optimisation of ligation conditions; use of alternative enzymes; use of smaller number of amplicons; adjust data analysis pipelines and quality control
13	Deficits in user friendliness and intuitive functionality of prototype tools and software (likelihood: medium / severity: low)	WP5, WP6	Early software versions to be tested by end-users to provide timely feedback; Involvement of end-users in prototype development and device design
14	Inability to employ real case-work samples during the MicroLyseFX device due to legal restrictions (likelihood: medium / severity: low)	WP6	Use of proficiency test samples (TrACE, GEDNAP) that resemble realistic casework material; use of mock casework samples prepared by forensic institutes based on their extensive experience

PROJECT REVIEWS

Project Reviews

Grant Preparation (Reviews screen) — Enter the info.

Review No	**Timing** (month)	**Location**	**Comments**
RV1	18	TBC / online	within two months from the end of reporting period 1 (M18)
RV2	36	TBC / online	within two months from the end of reporting period 2 (M36)
RV3	48	TBC / online	within two months from the end of reporting period 3 (M48)

Horizon Europe (HORIZON)

Description of the action (DoA)

CapCell (101225737)

Innovative forensic trace investigation via microfluidics and single-cell genomics

Part B

History of Changes

Version	Change	Page(s)
Annex 1 Part A		
V1.0	Extension of Task T2.2 for two months to M14 and change of due date of corresponding deliverable D2.2 and milestone MS4 due date to M14.	Portal
	Inclusion of WP leads and co-leads sentence in WPs 1-7. Removal of Task references in the listed objectives.	Portal
	Removal of the Innovation Reports deliverable (D1.4 in the proposal). Given that the **Innovation Radar Questionnaire** now seems to be or have become mandatory in all Horizon Europe project and virtually covers most aspects of the Innovation Report, the latter would be obsolete in our view. Since **innovation-related aspects will also be covered in the periodic reports** (WP1, Task 1.5 Innovation Management and WP7, Task 7.4 Exploitation), we would suggest removing the two Innovation Reports from the list of Deliverables.	Portal
	Inclusion of new deliverables D1.4 and D1.5, as the portal only allows for a single delivery date per deliverable and to address inconsistencies between the WP1 description and deliverables table.	Portal
	Change of D7.2 dissemination level to sensitive due to strategic content. Change of due date of deliverable D7.3 Interim assessment report to M24, as the impact, will also be reported on in the two periodic reports due after M18 and M36.	Portal
Annex 1 Part B		
V1.0	Removal of tables 2.1a, 3.1b, 3.1c, 3.1d and 3.1e and inclusion of ethics section according to GAP instructions.	-
	Update of GANTT to account for the changes made in Part A (WPs, deliverables).	35
	Inclusion of sentence stating that Table 3.1g ‘Subcontracting costs’ items is not foreseen in the project	36
	Update of table 3.1h (Table 8, Table 3.1g in proposal) to include AFCP purchase costs (travels), compiled purchase costs of KUL and correction of typo in NimaGen’s justification	36
	Inclusion of sentence stating that Table 3.1i ‘Other cost categories’ is not applicable.	37
	Inclusion of sentence stating that Table 3.1j ‘In-kind contributions’ items is not applicable.	37
	Inclusion of section 3.1.2 Affiliated Entities according to GAP instructions.	37
	Inclusion of section 3.1.3 Associated Partners, explaining the roles of the associated partners and their individual budget according to GAP instructions.	37
	Inclusion of section 5 Security, according to GAP instructions.	39

Table of Contents

External Advisory Board

Name	Position	Expertise
Prof. Michael Marciano	Professor of Practice and Director for Forensics Research, Syracuse University, USA	DNA mixture interpretation, single-cell analysis and interpretation, statistics
Prof. Gillian Tully	Professor of Practice for Forensic Science Policy and Regulation, King's College London, UK	Forensic science policy and regulation, technology validation/standardisation
Prof. Marielle Vennemann	Professor for Forensic Molecular Genetics, University of Muenster, Germany	Forensic trace analysis, reporting of evidence
Prof. Sabine Lutz-Bonengel	Professor of Forensic Molecular Biology, University Medical Centre Freiburg, Germany	Single-cell analysis, mitochondrial DNA, forensic casework
Chris Pellemans	Research & Innovation Manager, Dutch Police, The Netherlands	Forensic innovation, police investigation, forensic trace analysis, regulation

Glossary *This glossary provides definitions for key terms and concepts in a forensics context used throughout this proposal.*

Term	Description
Barcoding	Short genetic sequences attached to DNA fragments to tag cells or molecules with unique identifiers
Capillary Electrophoresis	A technique that separates DNA fragments by size using an electric field within a thin capillary tube, commonly used in DNA profiling for forensic analysis
Capsule Sort	A method that isolates and sorts cells from one or more individuals by capturing them in tiny capsules
Concatemers	Long DNA molecules formed by the sequential linking of DNA fragments, commonly used to enhance read length and achieve haplotyping resolution in sequencing applications
Differential Lysis	A forensic biology technique that separates sperm cells from vaginal epithelial cells in sexual assault evidence by selectively breaking open non-sperm cells
DNA Profiling	A forensic technique that analyses specific DNA markers to create a unique genetic profile, used for individual identification in criminal investigations and paternity testing
DNA Interpretation	The analysis and assessment of DNA profiling results to determine the origin, identity, or relationships of biological samples, often involving statistical and probabilistic evaluation
Fluorescent Staining	A technique that uses fluorescent dyes to label specific cells or DNA sequences, allowing visualisation and identification under a fluorescence microscope, e.g. fluorescence in-situ hybridisation (FISH)
Likelihood Ratio (LR)	A statistical measure used to compare the probability of evidence under two competing hypotheses, applied in forensic DNA analysis to assess DNA profile match strength
Long-read Sequencing (LRS)	A third-generation sequencing technology that produces extended read lengths, allowing for more accurate analysis of complex regions and structural variations in the genome
Massively Parallel Sequencing (MPS)	A second-generation sequencing technology that simultaneously sequences millions of DNA fragments, enabling high-throughput, high sensitivity and accuracy
Microfluidics	A technology manipulating small fluid volumes through micro-scale channels enabling rapid analysis
Mitochondrial DNA (mtDNA)	DNA located in the mitochondria, inherited maternally, and used in forensic analysis for identifying individuals, especially when nuclear DNA is limited or degraded
Postcoital Swabs	Vaginal swabs collected in sexual assault to collect biological material (sperm cells) of perpetrator(s)
Semi-Permeable Capsule (SPC)	Micro-scale container with membranes that allows selective passage of certain molecules, used to isolate and process individual cells or reactions in controlled environments
Short Tandem Repeat (STR)	Repetitive DNA sequence used for genetic profiling in forensic investigations, effective for identifying individuals in criminal cases
Single-cell Sequencing	A technology that analyses the genetic material of individual cells, providing detailed insights into cell-specific variations, especially useful in complex or mixed biological samples
Single Nucleotide Polymorphism (SNP)	Single-base DNA variation that serve as genetic markers, useful in forensic investigations for ancestry and individual identification
Trace Evidence	Small, often microscopic materials transferred during a crime, such as hair, fibers, or biological fluids, used to link suspects, victims, and crime scenes in forensic investigations.

1 Excellence

What is the urgent need? Sexual violence in Europe includes rape, sexual assault, sexual harassment and sexual exploitation. **An EU study reports that 1 in 10 women experienced sexual violence and 1 in 20 women experienced rape since the age of 15[1].** (Inter)national and European trends show that victims of sexual violence are predominantly women and girls, with an estimated 90% of rape victims being female. The EU has recorded a 10% increase in reported sexual violence offences from 2021 to 2022 (231,456 cases)[2]. In 2023, EFSI indicates that 46% of the sexual assault cases in Estonia were against minors, while KUL-FBS reports that **60% of 8,000 such cases in Belgium were dismissed by magistrates for lack of evidence, often due to the inability to produce DNA profiles from the offender(s).** Initiatives such as the European Institute for Gender Equality (EIGE) highlight that many cases struggle to progress to prosecution due to insufficient evidence and challenges in identifying perpetrators.

Use case 1 *Sexual assault >48h ago*	Use case 2 *Organised gang rape*
A woman arrives at the sexual assault reference centre and claims to have been raped via vaginal penetration and ejaculation by a male 72hrs ago.	A female student is found unconscious in the toilet of a night club. Police suspects rape, from camera evidence showing multiple suspects.
DNA results	
Genital samples are collected and confirmatory tests for the presence of prostate-specific antigen are negative. No sufficient male DNA is recovered.	The presence of semen on genital swabs is confirmed, producing a mixed DNA profile of 3 males. Mixed profiles are obtained from her clothing.
Forensic challenges	
The recovery of sufficient sperm cells after a prolonged time is extremely challenging; the current differential lysis method is not sensitive enough.	Current bulk sperm cell DNA analysis causes minor contributors to drop-out. Mixed DNA profile deconvolution of >3 males is extremely challenging.
CapCell solution	
By combining CapCell modules 1-3-5-9/10, and modules 2-4-6-7/8, we will enable the sensitive, rapid and automated DNA profiling from a single of a few number of sperms or a pool of nucleated cells, respectively; hence, enhancing the likelihood of identifying (all) male contributors to bring, them to justice.	

Figure 1. Relevant sexual assault case examples.

What are the forensic challenges? Routine forensic DNA profiling is only successful in cases where a single DNA profile recovered from human biological traces matches a suspect identified during police investigations or through (inter)national DNA database searching. However, extracting a single DNA profile is challenging and often impossible when biological traces contain cells from multiple individuals, resulting in a 'mixed' forensic DNA profile composed of inseparable DNA information. **Biological mixtures are especially frequently obtained in (sexual) assault cases** that contain vaginal and sperm cell mixtures or male/female cell mixtures of other origin (i.e. epithelial/skin). For more than a decade, the only solution to isolate the male profile(s) has been through advanced statistical interpretation that identifies the number of contributors and deconvolutes individual DNA profiles for identification. However, this often leads to an 'information gap' when **1) trace DNA contains very few cells from the perpetrator(s)** that are subsequently missed using current 'bulk' approaches**,** and **2) trace DNA contains cells from multiple contributors in highly unbalanced ratios** resulting to uninterpretable mixed profiles. This leaves thousands of sexual assault cases (examples in Figure 1) unresolved across Europe and worldwide. As a result, the impact on victims, their families and society is immense.

What is the CapCell solution? Our CapCell consortium aims to overcome the limitation of mixed DNA evidence by offering improved forensics and lawful evidence collection, analysis and interpretation. CapCell is set to increase forensic trace investigation capabilities through a new toolkit comprised of 10 modules (Figure 2) that capture, select, isolate, sequence and interpret individual cells of interest and can be easily integrated into existing forensic procedures. Focusing on postcoital swabs, we will first develop a set of modules to enable enhanced sperm cell recovery and targeted cell isolation via a novel differential lysis-based microfluidics device (MicroLyseFX), followed by tailored DNA profiling and sequencing protocols and software. **These modules will allow successful interpretation of forensic DNA evidence from a single or few sperm cells.** Then, focusing on contact traces (also collected in other types of criminal cases) we will develop a second set of modules to enable enhanced male nucleated cell recovery and targeted cell isolation via a novel fluorescence-based microfluidics device (MicroSortFX). This will be followed by novel, cutting-edge DNA sequencing assays and pipelines with single-cell resolution. **These modules will allow the successful interpretation of forensic DNA evidence comprised of multiple male individuals**. We will achieve our end-goal by validating and implementing the new CapCell toolkit in the relevant end-user environment of routine forensic DNA service, with the help of several forensic science institutes, police forces and European organisations.

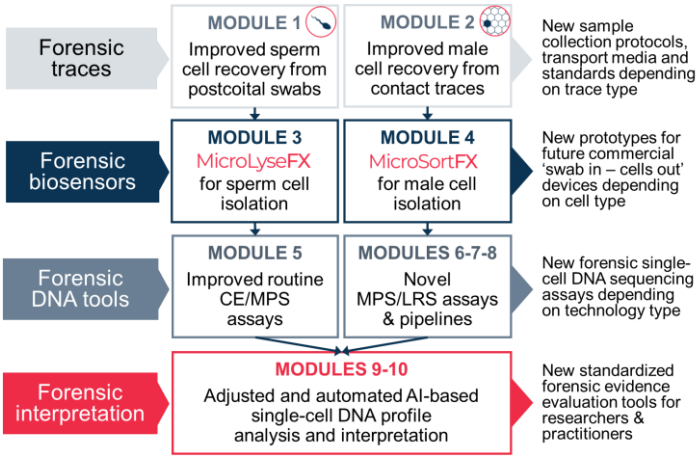

Figure 2. Modular CapCell approach.

[1] European Union Agency for Fundamental Rights (FRA), *Violence against women: an EU-wide survey – Main results*, April 2014
[2] European Commission, *Crime statistics: sexual violence crimes in the EU in 2022, a continued rise*, Eurostat Statistics Explained

Why is now the right time? CapCell capitalises on the convergence of rising forensic challenges and groundbreaking innovations, making this the ideal time to fund it. Forensic cases are becoming increasingly complex, with most DNA evidence involving mCultiple contributors. While DNA typing has become more sensitive, interpreting mixed profiles remains challenging despite advancements in statistical deconvolution. CapCell partners leverage recent, cutting-edge, ready-to-deploy technologies of the right technology readiness levels (TRLs) to address these issues. KUL's microfluidic cell isolation tools, paired with novel sequencing assays, will enable single-cell DNA analysis with unprecedented precision. Recent breakthroughs in massively parallel and long-read sequencing (MPS/LRS), supported by UM's new nanopore sequencing facility and NimaGen's pre-commercial forensic innovation, provide previously unavailable capabilities. The complementary ongoing microfluidics and single-cell research at NFI and MUI further strengthen CapCell's potential, ensuring the project is timely and poised for success.

Why is our consortium best suited? CapCell unites 13 partners from 8 European countries, combining unparalleled expertise to achieve its ambitious goals. The project is led by Assoc Prof. Athina Vidaki, a distinguished expert in forensic genetics, technology and innovation, who recently relocated to Maastricht University Medical Centre's recognised single-cell genomics/nanopore sequencing lab. She has obtained multiple awards and fellowships throughout her career, including a forensic technology-oriented 2020 NWO Demonstrator grant, a 2020 transnational epigenomics-focused Erasmus MC fellowship and a prestigious 2022 nanopore sequencing-driven Vidi grant by the Dutch Research Council's Talent Program. The consortium also features global leaders including Prof. Jeroen Lammertyn, an innovator in microfluidics with >12 patents and a spin-off company in Belgium, Prof. Titia Sijen, R&D team leader at NFI, a world-leading forensic institute, and Prof. Walther Parson, a world-renowned forensic molecular biologist with >450 publications and a wide, influential research and casework-related network. CapCell's consortium spans the entire innovation chain: forensic institutes and police forces in Austria, Estonia, and the Netherlands, leading academics in microfluidics, forensic genomics and statistics, and private-sector SMEs and industry players driving technological advances. End-user engagement is amplified through partnerships with the European DNA Profiling Group (EDNAP), ensuring the harmonisation of forensic DNA technology. With guidance from a multidisciplinary External Advisory Board and support from Europol as an observer, CapCell is uniquely equipped to revolutionise forensic single-cell DNA profiling and maximise its impact across Europe.

1.1 Objectives and ambition

Forensic DNA profiling methods have led to a paradigm shift in criminal investigations with society investing significantly in crime scene and forensic analysis resources for collected biological evidence. Driven by major research developments during the last 30 years, forensic genetic researchers have created vast knowledge on identifying and characterising various types of genetic variation, namely short tandem repeats (STRs) and single nucleotide polymorphisms (SNPs), found on both the nuclear chromosomes and mitochondrial DNA (mtDNA)[3,4,5,6,7]. Translating these efforts into casework, forensic genetic practitioners have also put significant efforts into implementing and validating the most sensitive assays based on the most variable and informative forensic biomarkers to make even the smallest amounts of DNA accessible for analysis. Altogether, the power of forensic DNA profiling in revealing the unique DNA profile of a person is demonstrated either by direct comparison of DNA profiles obtained from the crime scene to known suspects or against DNA profiles of repeat offenders in large national DNA databases.

However, despite all this progress, there are considerable limitations to the interpretation and exploitation of DNA evidence, as the current approach still relies on bulk DNA isolated from forensic traces. This results in a significant loss of information on its contributor(s), particularly when the cells of interest are scarce or present in (disproportionate) mixtures with other individuals or the victim. As a result, there is still a very large number of criminal cases across Europe, particularly sexual assault cases, that result in either recovering no or insufficient DNA belonging to the perpetrator(s), or in forensic DNA profiles that are non-interpretable as they contain mixed genetic information consisting of a huge background of the victim's cells and only a few from the perpetrator(s). **Forensic DNA profiling of the 21st century is still in urgent need of technological innovation to make the investigative process more interpretable, targeted, (time)efficient, cost-effective and, overall, more successful in catching criminals and bringing them to justice.**

[3] Butler JM (2023) *Forensic Sci Int Synerg*, 6: 100311, 10.1016/j.fsisyn.2022.100311

[4] **Parson P, Dür A (2007) *Forensic Sci Int Genetics*, 1(2): 88-92, 10.1016/j.fsigen.2007.01.018**

[5] Budowle B, Sajantila A (2024) *Nature Review Genetics*, 25: 450-1, 10.1038/s41576-024-00721-1

[6] Tillmar A, Sturk-Andreaggi K, Daniels-Higginbotham J *et al* (2021) *Genes*, 12(12): 1968, 10.3390/genes12121968

[7] Antunes J, Walichiewicz P, Forouzmand E, *et al* (2024) *Forensic Sci Int Genetics*, 71: 103055, 10.1016/j.fsigen.2024.103055

1.1.1 Specific objectives

To develop the CapCell modular tools, we have set to achieve the following seven specific objectives:

- **Objective 1 (WP1)**: Establish a project governance structure based on the simplified Consortium Agreement (DESCA) model consortium agreement, coordinate and monitor the progress of work using an established EU project management tool (accelCOCKPIT®), and manage the CapCell innovations, including newly generated knowledge and intellectual property by a dedicated Innovation Manager.
- **Objective 2 (WP2)**: Co-create novel strategies and best practices together with end-users and industry for improved evidence collection of postcoital swabs and trace samples (modules 1-2) to maximise intact cell recovery (at least 30%), tailored to casework needs as identified through literature search, surveys and consultation.
- **Objective 3 (WP3)**: Design, optimise and prototype two microfluidic cell selection and isolation systems (MicroLyseFX for sperm cell fraction and MicroSortFX for male nucleated cell fraction (modules 3-4) with a targeted efficiency of 85 % and 65%, respectively (i.e. cells in/cells out), which act as a foundation for future commercial products to enhance on-site forensic evidence processing.
- **Objective 4 (WP4)**: Incorporate the cell selection and isolation systems into existing forensic DNA profiling workflows ensuring compatibility of the output of MicroLyseFX with CE/MPS platforms (module 5) and develop and test three novel single-cell MPS/LRS sequencing assays (modules 6-7-8) for the output of MicroSortFX, that target a broad array of forensic biomarkers (STRs, SNPs, mtDNA).
- **Objective 5 (WP5)**: Develop and validate advanced data analysis techniques tailored to single-cell DNA profiles generated by different sequencing platforms (module 9), leveraging new computational methods, automated ML approaches (module 10), and suitable interpretative frameworks that align with forensic standards.
- **Objective 6 (WP6)**: Validate and implement the innovative CapCell toolkit in real-world forensic settings in collaboration with three national forensic institutes (including MUI) and two police forces by offering innovative training curricula to collect feedback for refining our prototypes, ensuring operational efficacy and end-user readiness.
- **Objective 7 (WP7)**: Foster a forensic single-cell DNA research and practitioner community by developing comprehensive targeted training programs across Europe, widely disseminating CapCell findings via workshops, online media and resources, and facilitating continuous knowledge exchange to support further collaboration and adoption of single-cell analysis in forensics.

1.1.2 Ambition and innovations

The overarching ambition of CapCell is to break through the dead-end wall of non-interpretable mixed evidentiary traces in criminal investigations by providing a timely, novel, readily applicable, modular approach that can be employed to innovate each step of the forensic DNA profiling process, to enable for the first targeted, single-cell analysis from trace evidence recovery to DNA profile interpretation (Figure 3).

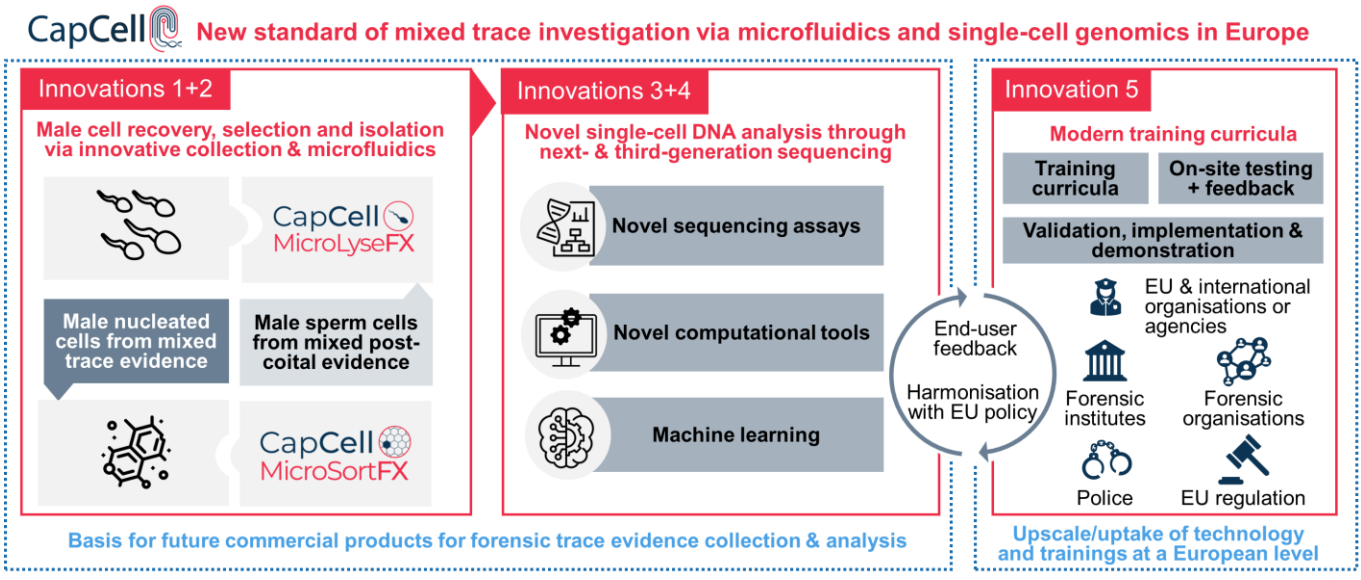

Figure 3. Future trace evidence collection and forensic analysis based on the five CapCell innovations.

Innovation 1: Novel collection devices and protocols for sexual assault evidence collection and preservation using postcoital swabs (Module 1) and trace evidence (Module 2) to suit follow-up microfluidic analysis

Challenge 1: Lack of knowledge on intact cell recovery from forensic traces using current routinely employed sample collection protocols

Every case starts at the crime scene, with officers collecting forensic, including biological, evidence that is sent to dedicated forensic labs for processing, analysis and interpretation. Notably, a variety of sample collection tools are available – particularly swabs (cotton, nylon flocked, foam, rayon) and tapes – that are used depending on the type of institute, substrate and suspected cells involved. Studies aiming to characterise which sample collection strategy generates the highest yield of DNA have revealed a very complex picture. **It is not only the type of swab but also several variables in each step of the process that matter and may affect DNA recovery**: swabbing technique, swab storage/transport, elution buffer and DNA extraction method [8]. Cotton swabs are very efficient in collecting biological material from evidence and are currently considered state-of-the-art. **Yet, particularly for sperm cells, cell recovery from cotton swabs may be as low as 20-30%**[9]. Forensic investigations focusing on intact cell recovery comparing different swabs are currently limited, particularly considering the notion that forensic evidence can be significantly degraded; hence, the recovery of intact cells is perceived as challenging. In two earlier studies, including one led by NFI, nylon flocked swabs seemed to result in higher recovery of intact cells from anticoagulant-containing whole blood and intact sperm cells from postcoital swabs, compared to cotton and dissolvable swabs[10]. **Currently, no single, standardised protocol for sample collection and processing is used by police and forensic practitioners across Europe.** This further increases variability, uncertainty and cost in DNA recovery. At the NFI and MUI, and in most routine labs across Europe, almost half of the swabs collected at the crime scene result in non-detectable or insufficient DNA for downstream processing[11].

Solution 1: Improved and standardised evidence collection strategies to maximise intact cell recovery and transfer based on end-user needs and current practices

CapCell will innovate the way sample collection of (mixed) forensic traces is performed. We will focus on mixtures of the victim and perpetrator(s) often encountered in (sexual) assault cases: male sperm and female vaginal cells as recovered from postcoital swabs (Module 1), or male and female traces as recovered from contact traces (Module 2). The efficacy of existing devices in picking up intact cellular material from the evidence and then releasing it during the separation, lysis, and DNA extraction process requires careful evaluation and testing. In CapCell, we will achieve this by a united effort of CapCell forensic institutes, the involvement of competent researchers and practitioners from EDNAP, and via a collaboration with a leading industry (COPAN) in providing sample collection devices for forensic use. **We will test newly created sample collection protocols, buffers and transport devices (currently at TRL-4)** and compare them against standard practices. Additionally, protocols currently in use by the forensic practitioners are going to be optimised to maximise their effectiveness. We will focus on optimising parameters that do not require additional equipment or costly changes. **Our experiments (towards TRL-6) will offer new insights into the recovery of intact cells from forensic traces** and clues on the applicability of the recovered cells for microfluidics analysis, relevant for the entire field of forensic genetics. Based on these innovative cell recovery modules, **we will establish new and standardised best practices and recommendations for mixed biological evidence collection**, for labs that wish to improve their current practices or are able to switch to an entirely new sampling methodology.

Innovation 2: Novel microfluidics systems for the selection and isolation of sperm cells (MicroLyseFX, Module 3) and male nucleated cells (MicroSortFX, Module 4)

Challenge 2: Inability to preselect and isolate cells of interest from forensic traces that originate from (multiple) different tissues and donors

Forensic traces recovered from (sexual) assault cases are often comprised of multiple cell types and even cell-free DNA originating from one or multiple individuals, with cells often being of low quality and quantity. Separating and specifically isolating the male fraction of such samples has been of interest for decades. **The only cell enrichment technology currently available for forensic laboratories was originally invented back in the '80s**[12] and is based on a so-called differential lysis protocol for postcoital swabs, taking advantage of the need for harsher treatment to break sperm cells open because of morphological differences. **Despite improvement efforts, its efficiency in separating sperm cells from vaginal epithelial cells is painfully low** (hence 'enrichment' and not 'isolation')[13]. In other

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biomedical fields, successful separation of cells has been achieved using manual micromanipulation[14], laser capture microdissection[16,17] or flow cytometry, more specifically fluorescence-activated cell sorting (FACS)[18,19]. **However, these techniques are difficult to adopt in the forensic context because of the lack of required sample quality and instrumentation in forensic labs**. More recently, the first microfluidics-based system has entered the forensic market, namely the DEPArray™ Nx (Menarini Silicon Biosystems). However, until now, this technology has only been demonstrated with good quality and quantity samples (i.e. 10,000 buccal cells)[20]. Additionally, it enables screening of only 6,000-10,000 single cells at once, without facilitating a preselection for nucleated cells and large investments are required for the purchase and running of this equipment (~€750 per sample). However, the main issue is the large amount of loss (40%[21]) of loaded cells in the cartridge. Consequently, due to the low number of cells allowed in the cartridge, the ratio of female to male cells needs to be high to recover sufficient cells for sequencing. In this context, alternative microfluidic systems can serve as an ideal solution for identifying and isolating individual (rare) cells[22], as they require limited reagent and sample volumes and are disposable, lowering the risk of contamination. In addition, microfluidic systems allow complex liquid manipulations to be performed on-chip in an automated manner, thus enabling operator-independent integration of complex workflows. Appreciative of these benefits, research gave rise to a broad assortment of microfluidic cell sorting, which have been extensively applied in clinical settings, yet only scarcely for analysing forensic traces[23,24], possibly because these approaches suffer from issues including limited throughput, low recovery rate of cells, and contamination of the male fraction with female DNA. **Whereas forensic single-cell analysis using droplet microfluidics has previously been explored[25] to ultimately produce single-cell DNA profiles, this methodology does not include a cell selection procedure**.

Solution 2: Development of novel miniaturised microfluidic prototype tools that can efficiently isolate male cell fractions from different forensic-type material

CapCell will develop two novel and mobile microfluidics modules, the first of their kind in forensic genetics, for the targeted isolation of the male fraction (male sperm or other nucleated cells) from forensic traces. Led by one of Europe`s leading research groups in microfluidics (KUL-MeBioS), we will benefit from their recent extensive advancements in microfluidics in other biomedical fields[26,27,28] and leverage a unique and recently established microfluidics-forensic collaboration at KUL, to enable further progress based on promising pilot data (see Methodology). More specifically, **we will further develop MicroLyseFX (currently at TRL-3), a custom microfluidics module for postcoital swabs that will further innovate the differential lysis approach,** which is already familiar and successful in forensics. Although the concept of differential lysis on-chip has been demonstrated for other applications[29], it has not yet been translated to a microfluidic device. The envisioned microfluidic chip will be simple, translating the experimental lab protocol in the micro-space by combining dedicated filtration, lysis and purification zones for the successful lysis of vaginal cells and the simultaneous isolation of the pure sperm cell fraction. Additionally, **we will develop MicroSortFX, (currently at TRL-2) a custom microfluidic module for trace evidence based on an innovative male-specific staining method which will be translated for the first time in semi-permeable capsules (SPCs)**. SPCs are microscopic spheres with a semi-permeable membrane that allows selective passage of certain molecules while restricting others.[30] These have been demonstrated to enable a range of molecular assays on encapsulated cells. Here, we will for the first time establish hybridisation chain reaction suspension fluorescence in-situ hybridisation (HCR-S-FISH) in SPCs, where male nucleated cells are fluorescently tagged, enabling their isolation in a high-throughput fashion but from low-quality samples. The microfluidic workflow will include dedicated units for generating the SPCs, staining the cells and valve-based sorting them, which will be eventually connected and integrated. Performing the staining procedure on-chip will not only facilitate automation thus reducing human errors, but is also foreseen to enable shorter incubation times, minimise reagent consumption and boost staining effectiveness compared to off-chip staining. Subsequently, we will evaluate and iterate both methods with forensic-type material based on mock scenarios (MicroLyseFX: TRL-5, MicroSortFX: TRL-4) in collaboration with KUL-FBS to ensure an efficient isolation process, taking casework needs into account. **Finally, with Voxdale, an SME**

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with expertise in product engineering and prototype development, we will take a step further towards higher TRL levels and develop the basis for integrated, automatic devices, aiming to "swab in – cells out". Driven by market needs, we will also explore the commercial exploitation of these novel devices via standard routes. Future integrated systems based on these innovative microfluidic modules will eventually accelerate suspect identification by further increasing automation, and decreasing sample loss, improving sensitivity and decreasing time-to-result.

Innovation 3: Novel forensic DNA sequencing tools suited for the microfluidics-based sorted/single-cell output based on CE (Module 5), MPS (Modules 5+6) and LRS (Modules 7+8)

Challenge 3: Incapacity of current methods to detect and/or sequence the complete DNA profile from just a single cell, or multiple DNA profiles from mixed forensic traces with single-cell resolution

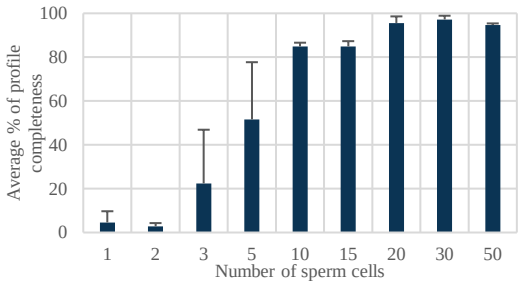

Figure 4. Mean % of STR profile completeness when analysing different numbers of isolated sperm cells using the IDseek® CombiSTR™ Plus kit from NimaGen (40 autosomal STRs and 23 Y-STRs).

Human identification in forensics is achieved through the analysis of a standard set of STR markers that are extremely variable among populations, as each of the two alleles in every individual can vary in repeat number, hence length. Forensic STR analysis has relied on standard capillary electrophoresis (CE) systems for decades[31] and we expect it to remain the primary choice of technology for most labs for the foreseeable future - at least for the generation of reference DNA profiles - due to its familiarity, low running costs and equipment investment. However, it has limited high-throughput capabilities on the number of STR loci, it is labour-intensive and time-consuming. Importantly, fragment-based STR analysis has several limitations when it comes to mixed biological evidence. **CE is limited in detecting low-level contributors with minute biological material (e.g. in postcoital swabs where male DNA is <10% of the mixture), and unable to resolve multiple contributors from mixtures (e.g. in postcoital swabs containing sperm cells from multiple contributors, or in contact traces)**, due to stutter or overlapping peaks and when peak imbalances or partial profiles are observed. In line with cutting-edge developments in human genetics, interest from the forensic community in second-generation or massively parallel sequencing (MPS) has significantly increased[32]. Integration of MPS technology into forensic casework offers many advantages: higher sample/marker throughput, increased genetic information, greater sensitivity and resolution, broader marker range, and superior data quality. Besides autosomal STRs, Y-chromosomal STRs, Y-chromosomal SNPs and mtDNA variants can be detected for lineage analysis. mtDNA is especially advantageous because of the high copy number per cell, hence offering extremely high sensitivity[33]. MPS assays are specifically appealing in highly complex and/or high-profile cases, where lots of information from a minute amount of cellular material needs to be obtained in a short period of time. Also, MPS can be advantageous for mixed profile analysis as additional sequencing variation within or surrounding STRs can be detected; but this is not always sufficient for full deconvolution. Despite MPS not yet being the standard method in forensics, there are multiple commercial kits available, even combining multiple forensic marker types and showing very high sensitivity in recent validation efforts from CapCell partners[34,35]. **Yet, current forensic MPS methods are not applicable and sensitive enough to analyse evidence with input of just a single cell.** Previously, one in four sperm cells resulted in a complete profile dropout, while a single sperm cell resulted in an average of 51% of the alleles[36]. Similarly, our pilot data analysing single sperm cells show that informative STR profiles (minimum of 50% of loci) require at least 5 sperm (haploid) cells, while with>10 cells, profiles are consistently >85% complete (Figure 4). On the other hand, despite advances in single-cell approaches in biomedicine, **when DNA from multiple cells (or individuals) is present, forensic MPS assays have not been designed to offer single-cell/read resolution in the generated data**. More recently, third-generation or long-read sequencing (LRS) technology has joined the stage as a potential sequencing platform for forensics due to its portable and real-time analysis. Particularly, nanopore sequencing requires minimal sample preparation, offers rapid, real-time data, and enables simultaneous genetic and epigenetic analysis[37]. Its compact and portable devices, such as the MinION allow for easy on-site operation, which could be crucial for guiding immediate investigative actions in the future. Additionally, nanopore sequencing combines all the general advantages of MPS in terms of sequencing capabilities. **While small-scale forensic studies have highlighted its potential**[38,39], **we still lack robust research and validation studies and available commercial nanopore sequencing kits**.

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Solution 3: Innovative experimental concepts and cutting-edge long-read sequencing technologies that allow for single-cell analysis of the generated MicroLyseFX and MicroSortFX male cell pools

CapCell will push the current state-of-the-art and develop both improved and completely new forensic DNA sequencing assays suited to single-cell analysis. First, to integrate forensic analyses of single sperm cells individually separated after pool isolation using MicroLyseFX, we will thoroughly explore possibilities to fine-tune existing CE and MPS assays used in forensic laboratories to make them more sensitive and robust when it comes to such low sample input. **KUL-FBS will lead the task to optimise several critical parameters and new chemistry currently being developed by commercial companies (TRL-4)**. This will eventually allow any forensic lab using MicroLyseFX to generate data of sufficient quality using familiar practices. Second, for integration with male cell-containing SPC pools sorted using MicroSortFX, **we will innovate forensic single-cell DNA analysis by introducing novel molecular assays to analyse STRs, SNPs and mtDNA using a diverse set of approaches,** including the first-of-its-kind application of in-capsule PCR on encapsulated human cells. We will explore the blend thereof with (1) in-capsule PCR coupled with combinatorial indexing (amplicon barcoding) for STR/SNP analysis using MPS (currently at TRL-2), (2) an upcoming (not yet commercial) forensic mtDNA assay based on reverse-complement (RC)-PCR from NimaGen using LRS (currently TRL-4), and (3) in-capsule PCR coupled with concatemer synthesis (barcode-free amplicon ligation) for STR/SNP analysis using LRS (currently at TRL-2), to also profit from advances in downstream sequencing techniques. Especially, the 1-read-1-cell concatemer approach will revolutionise the application of targeted nanopore sequencing, omitting a cell-specific library preparation and exploiting both long reads and haplotypic resolution. **All methods will be internally evaluated and validated (towards TRL-4**), before further testing in WP6. Based on these innovative modules, we will offer a new generation of forensic single-cell DNA sequencing tools specifically developed for the MicroLyseFX/MicroSortFX output, considering limitations in input cell quality/quality.

Innovation 4: Integrated single-cell DNA profile analysis (Modules 6+7+8) and interpretation (Module 9) including novel ML-based approaches for automated analysis (Module 10)

Challenge 4: Lack of casework-ready data analysis methods to analyse and interpret single-cell DNA profiles according to forensic standards

A plethora of different (open-access) algorithms and software exist to analyse genetic data generated by currently available, state-of-the-art forensic DNA methods for STRs, SNPs and mtDNA variants. A casework context requires extensive testing, high level of robustness and detailed determination of thresholds and parameter settings to have validated tools that can be implemented, accompanied by standard operating procedures/software manuals, guidelines for best practice and police for training end-users. This is exemplified by the DNAxs software suite (developed by NFI[40,41,42]) that can compare multiple DNA profiles from forensic traces against multiple reference DNA profiles (both STR and mtDNA data), calculate a weight of evidence (by the new-generation fully continuous models including peak height information), send a profile for a DNA database search (the automated pipeline is denoted the fast identification line[43,44]) and generate a report from a template. Functional testing and the use of automated unit and integration tests provide robustness to the software. For MPS-generated data, several analysis tools exist such as FDSTools (also developed by NFI[45,46]) that provide not only base calling of genetic variants but also (and unique to this software) noise correction to retrieve noise reads to the parent allele and automated naming of STR alleles[47,48]; endorsed by the International Society for Forensic Genetics (ISFG) as the preferred method for allele naming[49]. Like DNAxs, FDSTools is used on a daily basis in forensic casework, by DNA researchers and DNA experts showing the importance of have user-friendly and robust software tools. **For the analysis of single-cell profiling data, such streamlined tools and validated statistical methods are lacking.** Algorithms have been developed to look into clustering efficiency of genotyped loci obtained from single-cell replicates[50]. Subsampling of individual cells from mixtures is another strategy where a consensus of the genotypes is used to reconstructed the true diploid genotypes[51] (sperm cells have haploid genomes). Although progress has been made in this area, it is currently limited to early research stages in academic environments. **Data quality of single-cell outputs is low, with expected missing data, reduced read length and alignment quality leading to mapping quality issues, sequencing noise, higher error**

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rates and more. This can lead to lower likelihood ratios (LRs) and strength of evidence. Additionally, the proposed data analysis approaches have not yet been evaluated by forensic casework labs, nor integrated into the bioinformatics tools used in these labs. Moreover, whereas open-access and commercial software are available for basic processing of MPS- and LRS-based data, there is a need to develop computational pipelines to account for the new concepts included in this project, such as to deconvolute indexed or concatenated amplicons. **Overall, there is a need to create dedicated tools for thorough analysis and interpretation in practice.**

Solution 4: Optimised existing tools, novel computational pipelines and dedicated statistical frameworks, suitable for the analysis of single-cell CE, MPS and LRS data

CapCell will put significant effort into making the generated data as casework-ready as possible, significantly pushing the boundaries of what is currently possible in forensic practice. Particularly, the NFI team hosts an experienced team of bioinformaticians, software developers and test engineers that build and expand suitable software used by the whole forensic community. **First, we will fine-tune currently used methods (at least TRL-5) to enable analysis and interpretation of single-cell DNA profiles.** Analysing true single-cell profiles instead of DNA amounts equivalent to a single haploid or diploid cell (~3 or 6 picograms, respectively) will shed light on potential differences with diluted DNA that is commonly used in the validation of allele- and base-calling algorithms (specifically on the filtering settings and threshold) and probabilistic genotyping models. These insights will lead to improved understanding and interpretation of forensic DNA evidence. **We will employ novel ML approaches (towards TRL-5) to automate the analysis of CE-based single-cell profiles and to perform precise noise prediction in MPS-based data.** We will also gain insights into whether cell isolation using the two scenarios of cell mixtures (sperm/vaginal mixtures and trace evidence samples) result in higher LRs compared to when the mixtures are analysed as a whole. **Additionally, based on extensive experience in data analysis offered by multiple partners we will develop novel dedicated computational pipelines (towards TRL-4) to analyse the data obtained by our novel forensic single-cell approaches**. Specifically, these analysis tools will increase our understanding on the application of in-capsule PCR for forensic single-cell analysis. Since amplicon sizes may need to be enlarged, this will require software adaptation to ensure correct analysis and naming of (STR) alleles. Particularly for LRS, we will produce novel computational pipelines complying with forensic standards to enable future application of this technology in forensic settings. We will offer insights on the use of concatenated amplicons to generate single-cell haplotype**s** and how these can be successfully deconvoluted taking amplification and sequencing noise into account. **All innovative analysis modules developed in this project will be sufficiently robust and user-friendly to be used in forensic casework**.

Innovation 5: A new, validated and implemented modular CapCell toolkit in operational settings at forensic science institutes and police authorities across Europe

Challenge 5: Need for modern tools to improve forensic single-cell evidence collection, analysis and interpretation across Europe

Modern forensic genetics increasingly relies on advanced molecular genetic tools to address the complexities of evidence collection, analysis, and interpretation, especially as crime rates and complexity increases (such as in the case of sexual assaults). In Europe, there is a critical need to enhance forensic capabilities by integrating new tools into daily forensic practice via developing specialised training curricula. Particularly for mixture analysis, existing technologies based on CE are limited regarding detecting multiple (including minor) contributors due to challenges discerning minor genetic signals from artefacts and background noise. In cases where mixture profiles are obtained, **their interpretation of mixtures remains an inveterate challenge in many laboratories and cases**, despite strong efforts in developing open-source software for mixture interpretation that follows probabilistic genotyping principles, such as EuroForMix (developed under EUROFORGEN-NoE) and continuous training supplied for this software, e.g. by the ENFSI DNA WG or CEPOL. **There is an long-lasting and urgent need to provide forensic scientists with modern tools to separately detect and identify each contributor from forensic mixed traces.**

Solution 5: End-user validation and implementation of the new modular prototype tools for forensic single-cell genomics in practice via novel training curricula

Our CapCell technology will be a game changer as it promises to improve the accuracy of the results, reduce the risk of false inclusions or exclusions and enhance the reliability of forensic evidence in court. To achieve this goal, all consortium partners will first be trained to handle the diverse analytical devices to critically evaluate the performance and limitations of genotyping single cells, which will significantly increase forensic capabilities at the end-user sites. Training will include hands-on practice with instruments, data collection, and troubleshooting techniques, ensuring that personnel can conduct reliable analyses under real-world conditions. Importantly, single-cell DNA analysis generates complex data, necessitating advanced skills in bioinformatics and data interpretation. **Our harmonised approach will ensure that forensic results are comparable across European laboratories and jurisdictions**, facilitating cross-border collaboration. Standardised training also fosters mutual trust among European forensic labs,

making it easier to share expertise and resources and to work effectively on cases with transnational implications. **With our operational testing we will push the boundaries of what is customary in forensic DNA labs,** by extending current DNA methods to the latest technologies in single-cell DNA analysis based on microfluidics and long-read sequencing. Following successful end-user validation and implementation of our modular CapCell tools, **we will achieve to bring our diverse modules towards TRLs (5 to 7 depending on the module)**.

1.1.3 Innovation potential

- All modules build on state-of-the-art and **new technologies as well as recent discoveries** and findings generated by CapCell partners, for most of which a proof-of-concept is already available, while for some we aim to **achieve a target TRL of 7** at the end of the project (Figure 5).
- Modules can be **used independently but are complementary** to each other. Our risk management and contingency plan (Table 11) considers these aspects through appropriate mitigation measures that will ensure that technologies can be developed to exploit their full potential across labs with different capabilities and instruments.
- The CapCell toolkit is developed based on the most common evidence types collected during sexual assault investigations (postcoital swabs and contact traces), but may be **applicable for other similar types of traces and crimes,** further inspiring for innovation across the forensic DNA investigation landscape.
- The CapCell toolkit will be validated and implemented at three forensic institutes and two police labs included in our project, but we aim to **enable further testing and uptake across Europe**, directly through EDNAP, and indirectly through MUI who plays a leading roles in the European Network of Forensic Institutes (ENFSI).
- CapCell innovations will apply **methodological and interpretational standards** such as the standards for data processing and law enforcement under Directive (EU) 2016/670, the 2023 E-evidence regulation and directives and the Prüm framework for enhanced collaboration in law enforcement and security.
- CapCell will build on **CERIS guidelines and best practices for forensic capacity building** to address ethical and societal considerations of the developed technology. CapCell solution will align with **EU Security Policies** by supporting the implementation of the EU Security Union Strategy 2020-2025 (in particular strategic priority (iv) building a strong European security ecosystem), the **Counter-Terrorism Agenda,** the EU Strategy to Tackle Organised Crime 2021-2025 other and other relevant policies by driving the development of cutting-edge technologies for lawful evidence collection and cooperation across EU jurisdictions.
- The Europol Innovation Lab has confirmed to act as an **observer** from the project's outset to validate outcomes and advise if any project outputs should be featured in the **Europol Tool Repository**, a law enforcement-only toolbox of free software tools.

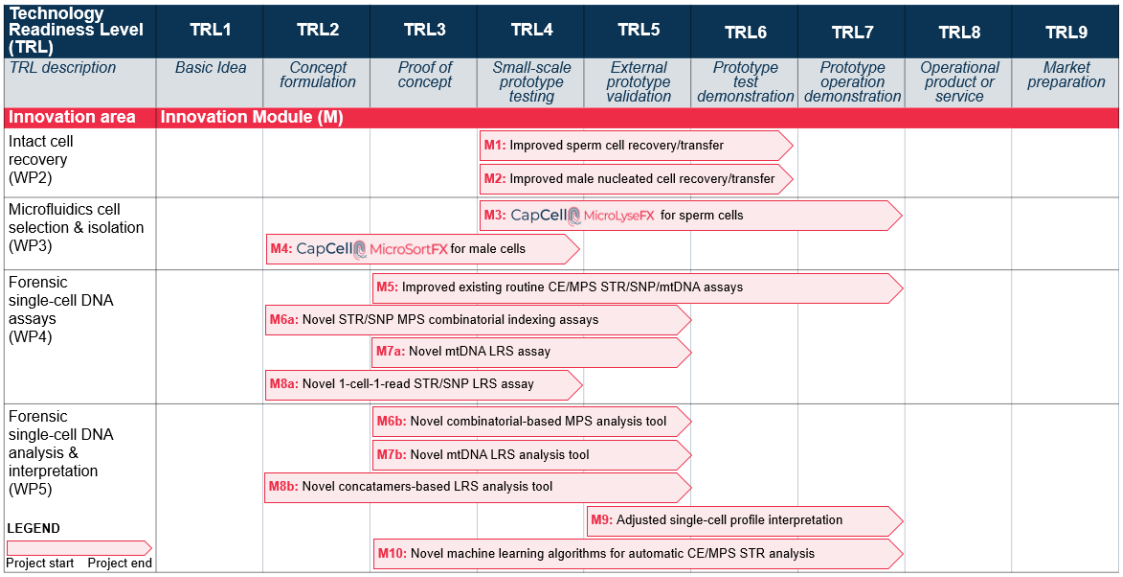


Figure 5. Technology Readiness Levels (TRLs) of the modular CapCell tools.

To fully exploit the innovation potential within this project and beyond, the newly generated knowledge and advanced tools will be evaluated for intellectual property (IP) protection within our consortium-wider innovation management framework (WP1), aiming to make the modular CapCell tools available to end-users throughout Europe.

#§PRJ-OBJ-PO§#

1.2 Methodology

1.2.1 Overall methodology

Our CapCell consortium will follow a two-tier approach to deliver the first-of-its-kind modular approach for forensic single-cell DNA profiling to address the needs of both primary users - forensic institutes and police forces - and secondary users, including technology providers from Europe`s biotechnology industry and interest groups within the forensic DNA analysis, research and technology community. **Following our multi-dimensional and inclusive approach, the CapCell toolkit will be designed and developed based on state-of-the-art and new methodologies while considering the field requirements of all relevant stakeholders.**

(1) Co-creation of the modular technology through end-user and stakeholder involvement: CapCell will involve end-users directly as project partners and indirectly through multipliers and interest groups. Particularly, the ENDAP working group of the ISFG will provide further guidance on scientific development, standardisation and best practices, data sharing and knowledge exchange. EDNAP is an Associated Partner in CapCell and will facilitate continuous feedback from the wider European forensic community, which is central to our project`s end user-focused approach. Engaging with this group, but also with ENFSI, will facilitate knowledge exchange and coordinated efforts, contributing to sustainability and future uptake by developing strategies for scaling outcomes at national and EU levels. Additionally, these partnerships will enhance our training and capacity building (WP2 / WP6) for forensic practitioners and police authorities, strengthening the European security ecosystem.

(2) Technology-driven solutions through end-user implementation and innovation management: CapCell will use open innovation to implement additional requirements from EDNAP members, promote CapCell within their European networks (ENFSI) and capture the needs of the European end-users. This approach will increase productivity and collaboration among stakeholders. The consortium's established and well-known scientific experts will ensure that the CapCell work is harmonised and disseminated across Europe to promote a standard way of working in forensic single-cell DNA profiling. More specifically, how open innovation is intended under the scope of CapCell is presented below. Intelligent DNA analysis requires a technology-based solution. Guided by our technology developers – COPAN, Voxdale, NimaGen - we will follow an agile development approach to deliver the tools developed in WPs 2, 3, 4, respectively. Agile development will enable them to iteratively develop the toolbox to ensure that a user-centred approach is implemented across the project. To strengthen the long-term sustainability of CapCell, we will assess our modular approach and tools through iterative testing and validation as real-use cases.

1.2.2 Work package-specific research methodologies

Forensic sample collection and intact cell recovery (WP2): Sexual assault cases are complex with diverse sample types and substrates (e.g. intimate samples, semen stains or touch deposits on fabric or non-porous surfaces) and potentially multiple male perpetrators. Hence, there is a need to collect insights on case characteristics that result in mixed biological evidence, and to understand what is required and can be improved in current forensic casework across Europe. CapCell will establish end-user casework needs based on a mixed approach including a scientific literature search, questionnaire-based survey and consultation with forensic practitioners. **This research will unravel the extent and type of casework across Europe including information on sample types and characteristics that result in mixed biological evidence and are in need of innovative analytical methods**. We will also document current practices, routine evidence collection protocols and experience with different methods.

(1) Improved evidence collection, recovery and preservation (Modules 1-2): EFSI, supported by several partners, will determine the readiness of material collected with current forensic practices for microfluidics. This will be achieved through evaluating the sample collection devices and protocols currently employed by police authorities and forensic practitioners, following the criteria defined by CapCell microfluidic experts at KUL-MeBioS. The selected sample collection devices and protocols will be evaluated for their effectiveness in recovering intact cells. The assessment of intact cells, cell clumps, ruptured cells, and non-cellular debris will be performed using microscopy and fluorescence imaging, including AI-based systems like Metafer (MetaSystems) and Countess 3 (Thermo Fisher Scientific). Strategies for removing unwanted byproducts (e.g., through filtration) will also be examined. The filtration systems evaluated in WP2 will complement the in-device filtration systems for microfluidics, with the former being utilised in cases of high non-cellular debris contamination. Similarly, the effect of clumping of cells following elution will be also assessed, as cell clumps might hinder single-cell migration and analysis. This assessment will direct the targeted optimisation of these protocols. There are two aspects for intact cell recovery: the number of cells collected from the evidence/surface and the number of cells retrieved from the swab/collection device; we will focus on the latter. **To enhance intact cell recovery from evidence collection strategies and establish improved experimental procedures, a series of wet-lab experiments led by EFSI will focus on maximising intact cell recovery, minimising non-cellular debris (such as swab fibres), and reducing cell clumping**. Key parameters targeted for optimisation include the selection of elution buffers as well as volume adjustments, incubation time and temperature, agitation rate and time. The final wet-lab experimental plan will be designed by incorporating feedback from end-

users on existing practices for sample collection and cell recovery, as it is expected that other factors like swabbing technique, prewetting the swab as well as the sample substrate can influence the recovery. Mock casework samples, consisting of postcoital samples containing vaginal and sperm cells in different ratios, as well as contact traces that include both male and female epithelial cells, will be collected from the donors. This range of samples aims to simulate realistic forensic scenarios and evaluate the effectiveness of the optimised protocols under study conditions.

Motivated by a recent small-scale study highlighting the promise of nylon flocked swabs in recovering intact cells[52], we will collaborate with COPAN (owner and developer of the FLOQ technology) to evaluate further and optimise current sample collection procedures, along with the maintenance of cell integrity. The sample collection methods of flocked swabs and cotton swabs are different (capillary *versus* mechanical absorption, respectively) due to their different structure and number of fibres of distinct origin. The flocked swab, with its open structure (which avoids trapping material in its core), allows for a higher sample release compared to cotton. However, the literature supporting the superior performance of flocked swabs is mainly related to total human and microbial DNA, not necessarily from intact cells. **To achieve this, multiple types of FLOQSwabs® will be tested in combination with a selection of COPAN media, potentially optimised for this application as it immediately elutes samples, hence preserving cell integrity until laboratory analysis.** These media will be tested for cell integrity under various storage conditions (e.g., time, temperature, and humidity) combined with mechanical inputs, and for cell recovery efficiency. At least two types of swabs will be used: a regular tip-sized FLOQSwabs® and an innovative divisible FLOQSwabs® introduced by COPAN, which has not yet been released to the market (TRL-5). The divisible swab allows the collected sample to be split into two sub-specimens from the same sampling site and time, creating a sample that can be analysed with novel, non-accredited workflows like microfluidics, as well as conventional laboratory analysis, or used for biobanking purposes. The assessment of cell integrity and recovery will be performed using cell count and viability assays with hemacytometer and microscopes, automated cell counter (TC20, Bio-Rad), multi-mode plate reader for real-time cell fluorescent imaging and cytometry (Spark Cyto, Tecan). Forensic institutes and police authorities will test the new devices using mock casework samples, and both the new devices and updated protocols will be compared to the ones currently in use. **Based on these results, NFI will lead the composition of novel best practices and recommendations for mixed biological evidence collection.**

Microfluidics for male cell selection and isolation (WP3): To achieve the development of microfluidic devices that can deal with the technical difficulties of forensic-type material (a few cells / high cell debris), we will develop two innovative ways to isolate cells from forensically relevant evidence types prior to forensic DNA analysis.

(1) MicroLyse FX for sperm cell selection and isolation based on differential lysis (Module 3): We aim to develop an integrated microfluidic device as a miniaturised alternative to the routine differential extraction procedure, to isolate sperm cells from vaginal swabs[53]. (Figure 6).

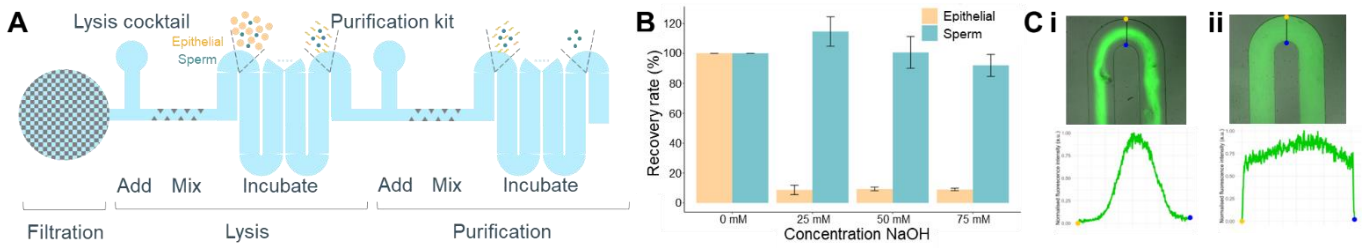


Figure 6. MicroLyseFX. A. Schematic representation of the steps, performed in MicroLyseFX. B. Preliminary results demonstrating successful differential lysis of sperm and vaginal epithelial cells using an alkaline lysis protocol with low concentrations of NaOH. C. Preliminary results demonstrating a microscopic image and resulting fluorescence profile of the combination of a fluorescently stained vaginal cell suspension with an aqueous stream in (i) the first and (ii) the fifth turn of the serpentine incubation channel in the absence of a mixing zone, demonstrating efficient mixing only occurs after the fifth turn, thereby corroborating the need for a mixing zone.

As a first step, we will check various lysis approaches to find the one that results in the most effective differential lysis in the shortest time. Here, we rely on the in-house expertise of KUL-FBS on differential lysis procedures and latest advancements in forensics applied on sexual assault cases[54]. The outcome of the different conditions for selective lysis will be analysed using FACS. In the second step, a custom microfluidic device will be designed and fabricated by KUL-MeBioS leveraging their extensive microfluidics expertise to perform the most efficient differential lysis approach in an integrated and miniaturised chip. **This chip should incorporate three crucial zones: (1) filtration, (2) lysis and (3) purification.** The filtration zone will allow the removal of debris from the eluted sample, which would otherwise clog the microfluidic channel. Hereto, we will evaluate the possibility of including a 3D-printed filtration unit at the chip inlet. The pore size of the filtration unit will depend on the expected size and count

[52] **Schulte J, Caliebe A, Marciano M *et al* (2024) *Forensic Sci Int Genetics*, 70: 103026, 10.1016/j.fsigen.2024.103026**
[53] Zelenin S, Hansson J, Ardabili S *et al* (2015) *Biotechnol Lett*, 37(4): 825-30, 10.1007/s10529-014-1734-8
[54] Hudson B, Green TD (2024) *Forensic Sci Res*, 9(2): owae022, 10.1093/fsr/owae022

of debris, as will be studied in WP2. In the lysis zone, the optimal differential lysis cocktail will first be added to the forensic sample, after which mixing of both in the shortest possible time will be optimised by including mixing structures. The mixing efficiency will be evaluated based on a model system of two coloured liquids. After mixing, an on-chip incubation step for lysis will be performed in a serpentine expansion channel where the liquid flow will be delayed to meet the optimal total incubation time. The results obtained after on-chip lysis will be analysed using FACS and compared to results obtained in bulk. Finally, to remove female DNA that is dispersed after successful lysis of the vaginal epithelial cells, a purification zone for depletion of female DNA from the mixture will be implemented on-chip. Here, reagents (TURBO DNA-free™ Kit) will first be added, followed by on-chip mixing, on-chip incubation and deactivation. **This will result in the collection of a pool of purified sperm cells, ready for subsequent individual dispensing and analysis in WP4.** Microfluidic chips will be fabricated using the soft-lithography microfabrication infrastructure at KUL-MeBioS and high-end tools in the ESAT-MICAS cleanroom, to which KUL-MeBioS has access. Requirements for future large-scale production will be taken into account throughout the design process.

(2) MicroSort FX for male nucleated cell selection and isolation based on fluorescence (Module 4):

We aim to develop a microfluidic approach for staining and sorting of single male cells from trace evidence (Figure 7). To achieve this, we will rely on the use of SPCs[55,56], in which single cells can be encapsulated and reagents can be loaded or removed by diffusion through the permeable polymer shell. To enable high-throughput detection and isolation of male cells in SPCs, we will employ a male-specific fluorescence detection method (HCR-S-FISH staining) and establish an innovative method for follow-up sorting the SPCs comprising male cells.

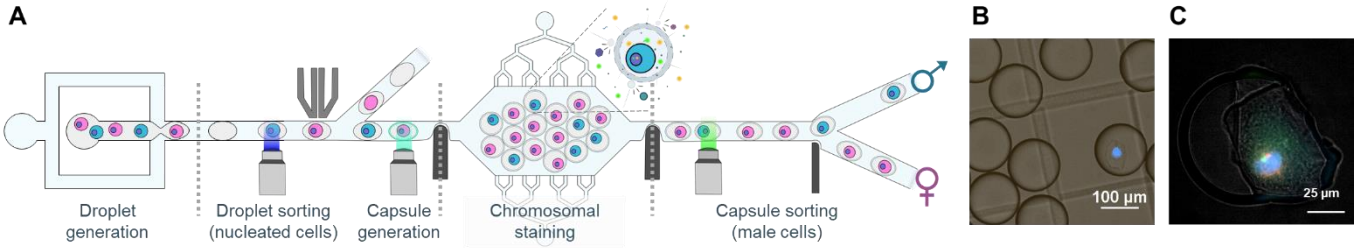


Figure 7. MicroSortFX. A. Schematic representation of the steps performed in MicroSortFX (pink: female cells; blue: male cells). B. Preliminary data demonstrating a nucleated (DAPI-stained) cell encapsulated in a water-in-oil droplet. C. Preliminary data depicting a male buccal cell, stained using the S-FISH method, displaying a green Y-chromosome-specific (Y SpectrumGreen™ probe) and orange X-chromosome-specific (X SpectrumOrange™ probe) signal in the (DAPI-stained) nucleus.

For the generation of SPCs, we will rely on a commercially available polymer blend (Atrandi Biosciences), which will be encapsulated in water-in-oil droplets together with the cells, followed by crosslinking of the polymer blend to form semipermeable shells. Hereto, we will leverage the microfluidic designs of KUL-MeBioS. Next, we will establish and optimise the procedure for HCR-S-FISH targeting male nucleated cells, based on a previously reported procedure for S-FISH. Here, we will use Tigerfish[57] to design custom X- and Y-chromosome-specific probes, the latter geared towards multiple satellite regions (e.g. DYZ1 and DYZ3), and we will combine this with HCR-based amplification, relying on previous expertise of KUL-MeBioS. **Also, we will, for the first time, translate HCR-S-FISH into SPCs in bulk, and subsequently further revolutionise this approach by translation into a microfluidic chip.** We will optimise various parameters using an experimental design to enhance the performance of the on-chip staining, which will be confirmed using fluorescence microscopy. In addition, we aim to design chambers with a range of sizes, enabling them to host tens up to thousands of SPCs, to match the expected numbers of nucleated cells from different samples, as revealed in WP2. Lastly, we will develop a microfluidic module for sorting SPCs of interest utilising valve-based sorting. **The previously developed modules will be combined into a workflow, resulting in the collection of a SPC pool with male cells, for further analysis using approaches developed in WP4.**

Effective operation (i.e. cell isolation efficiency) of the MicroLyseFX I and MicroSortFX I prototypes will be evaluated using complex sample matrices. For MicroLyseFX we will use sperm cells as well as mixtures of sperm cells with epithelial cells from vaginal swabs of female donors in mock scenarios. For MicroSortFX, we will use buccal cells from male donors, mixtures of buccal cells from male and female donors as well as deposits of buccal cells in mock scenarios. Depending on these findings and the resulting isolation efficiency, we will consider testing also other types of epithelial cells, i.e. skin cells. The effective operation of MicroLyseFX I (towards 85%) and MicroSortFX I (towards 65%) will be assessed through microscopy imaging, FACS and standard DNA protocols (i.e. direct PCR).

Lastly, we aim to proceed towards integration of the developed microfluidic platforms into dedicated devices towards future commercial products with the aim for “swab in - cells out”, leveraging the expertise of Voxdale in prototype

[55] Leonaviciene G Leonavicius K, Meskys R, Mazutis L (2020) *Lab on a Chip*, 20: 4052-62, 10.1039/D0LC00660B
[56] Leonaviciene G Mazutis L (2023) *Nucleic Acids Res*, 51(1): e2, 10.1093/nar/gkac918
[57] Aguilar R, Camplisson CK, Lin Q, Miga KH, Noble WS, Beliveau BJ (2024), *Nature Comm*, 15: 1027, 10.1038/s41467-024-45385-x

design and product development. This integration is foreseen at different levels for MicroLyseFX and MicroSortFX. **For MicroLyseFX, based on the needs and field-requirements of end-users and the European forensic market as established in WP2, Voxdale will conceptualise and develop the design of a second prototype (MicroLyseFX II), including all microfluidic modules of MicroLyseFX I in an integrated, automated device.** Next, a third prototype will be developed in which an additional swab-processing unit is integrated, building on the outcome of WP2, to enable the automated processing of samples (MicroLyseFX III). Functional prototypes will demonstrate key features and interactions, with usability testing sessions conducted to identify areas for improvement and ensure that the prototype aligns with user expectations. Finally, the designs will be prepared by Voxdale for production. This stage involves refining both housing and component designs to optimise manufacturability and performance, as well as ensuring user interface usability. Pre-production samples will be manufactured for testing and validation, and we will document all design changes and updates. Relevant data will be integrated to guarantee compliance with industry standards and facilitate a seamless transition into production. **Regarding MicroSortFX Voxdale will design a blueprint of an integrated device for future development (MicroSortFX II), targeting specific forensic needs.**

Forensic single-cell DNA profiling and sequencing (WP4): To enable profiling of the cell suspensions isolated with MicroLyseFX and MicroSortFX, we aim to revolutionise single-cell DNA analysis. We will optimise routinely used forensic DNA assays on fragment analysis (CE) and sequencing (MPS) to smoothly integrate the MicroLyseFX output (sperm cells), and develop innovative amplification and sequencing concepts, to smoothly integrate the MicroSortFX output (male nucleated cells). To offer comprehensive forensic profiling, we will analyse a diverse range of forensic genetic markers including STRs, SNPs/microhaplotypes (MHs) and mtDNA variants.

(1) Profiling of sperm cells using optimised existing CE and upcoming MPS assays (Module 5): Sperm cell suspensions from postcoital swabs as achieved in WP3 can either contain sperm cells from one individual (i.e. the perpetrator) or sperm cells from multiple donors (e.g. from the partner and perpetrator, or multiple perpetrators).

For the first scenario, sorted cell suspensions containing dozens or hundreds of cells can be analysed with current CE-based profiling, which has been the gold standard for decades. For the second scenario, which is often encountered, we aim to address the challenge of isolated sperm cell mixtures from MicroLyseFX, by dispensing the cells in individual wells of a microtiter plate using the UNO Single-Cell Dispenser (TECAN) or FACS. However, in this case CE falls short as its current sensitivity is limited, which does not allow for the successful DNA profiling of a single cell. The latter is even more challenging considering the haploid nature of sperm cells and the need of multiple cells to obtain all alleles. **CapCell will address these limitations by optimising an established commercial CE kit** - the PowerPlex® Fusion System by Promega - to increase its sensitivity and robustness with low-input samples down to single cells. For optimisation, KUL-FBS will start by fine-tuning lysis conditions, PCR conditions and cycles, reagent concentrations and solution/buffer volumes. We will also explore the added value of a targeted pre-amplification step and of employing new (not yet commercial but soon in the market) engineered polymerases currently under development by the same company (Promega). Their prototype system offers a drastic reduction in stutter artefacts, directly translating into easier profile interpretation and mixture deconvolution. On the other hand, MPS enables the sequencing of multiple DNA markers in parallel, providing greater genetic information, sensitivity and resolution than CE. Together with NimaGen, KUL-FBS and UM will test a selection of their widely accepted commercial MPS kits to make them suitable for single-cell analysis, all based on their patented and unique technology of RC-PCR. We will employ and optimise the following kits: the (pre-commercial) IDseek® CombiSTR™ Plus kit (40 autosomal STRs and 23 Y-STRs), IDseek® OmniSNP™ kit (85 high-variable human identity SNPs) and IDseek® Mitochondrial DNA Full Genome Sequencing kit. We will evaluate PCR effects as done for CE, but additionally, we will also optimise sequencing conditions using two sequencing platforms –MiSeq FGx™ (KUL-FBS) and NextSeq (UM). Importantly, for all employed kits, we will employ readily available samples at KUL-FBS and UM whose STR/SNP/mtDNA genotype is established, acting as a reference.

(2) Profiling of SPC-isolated male nucleated cells using novel MPS and LRS assays (Modules 6a-7a-8a): Isolated male nucleated cell pools from contact traces as achieved in WP3 are within SPCs. To achieve single-cell resolution, CapCell will rely on the properties of SPCs to implement innovative molecular assays, including in-capsule PCR followed by MPS/LRS. To establish these capsule-based assays while MicroSortFX is still being developed, KUL-FBS and UM will rely on the FLUX device (Atrandi Biosciences) and support from KUL-MeBioS to encapsulate individual cells in capsules, like those that will be generated in MicroSortFX. First, we will implement in-capsule PCR to amplify the DNA of the male cell pools. Whereas this was recently demonstrated for bacterial plasmid DNA[58], the lower copy number in mammalian cells compared to bacteria will render this challenging. For these experiments, we will use good-quality cells from cell lines. KUL-FBS will aim to amplify sets of well-established STRs and SNPs, starting from single PCR reactions and moving towards multiplexing. We will not only optimise amplicon length, but also amplification conditions. Amplification success will be assessed by dissolving the

[58] Leonaviciene G Leonavicius K, Meskys R, Mazutis L (2020) *Lab on a Chip*, 20: 4052-62, 10.1039/D0LC00660B

SPCs, isolating their contents and analysing PCR amplicons through standard CE to verify yield and specificity. **With single-cell in-capsule PCR established, we aim to develop several downstream experimental approaches to enable forensic DNA sequencing at a single-cell resolution level**. We do so to evaluate different experimental concepts and their suitability for forensic-type material, to develop multiple assays for the analysis of different forensic biomarkers, and also to take advantage of different instrumentation available among the CapCell partners.

First, KUL-FBS will employ combinatorial indexing[59] to develop novel forensic STR/SNP (microhaplotypes) MPS assays (Module 6a), applicable directly to isolated SPC pools. With this approach, unique barcode sequences are added to amplicons within each SPC, using two or three rounds of single-cell combinatorial indexing via transposase (Figure 8). This process will allow us to sequence multiple cells simultaneously while preserving individual cell identity. During method optimisation and in collaboration with WP5 using dedicated bioinformatic pipelines, KUL-FBS will evaluate indexing efficiency, read depth, on-target rate, allele balance, accuracy, error rates, alignment and uniform amplicon coverage. **Second, NimaGen, with the support of KUL-FBS and UM, will evaluate the possibility of applying one of their new RC-PCR-based mtDNA LRS assay (Module 7a) on single dispensed SPCs with the help of FACS[60].** This is currently only possible by using smaller SPCs so we need to evaluate whether this is feasible for the size of epithelial cell types. Following a similar approach, we will apply a pre-commercial-ready PCR protocol using our novel but well-optimised concepts by then, ensuring forward compatibility with emerging technologies for additional future forensic and clinical applications. **Third, UM with its current focus and expertise in nanopore sequencing will employ an unpublished concatemer synthesis protocol to develop novel forensic STR/SNP LRS assays (Module 8a), based on the same biomarkers used above for MPS and directly applicable to isolated SPC pools.** With this approach, we can bypass traditional library preparation by linking PCR amplicons via a T4 DNA ligation enzyme, allowing the LRS platform to read an individual cell's genotype in a single continuous read (Figure 9). After successful PCR and concatenation, SPCs will be dissolved, double-stranded concatemers will be pooled and purified. UM will also optimise the single-step library preparation and sequencing process using both various throughput sequencers (Oxford Nanopore Technologies), depending on required sequencing depth and sample multiplexing. Data analysis will be performed with WP5 partners using dedicated bioinformatics pipelines.

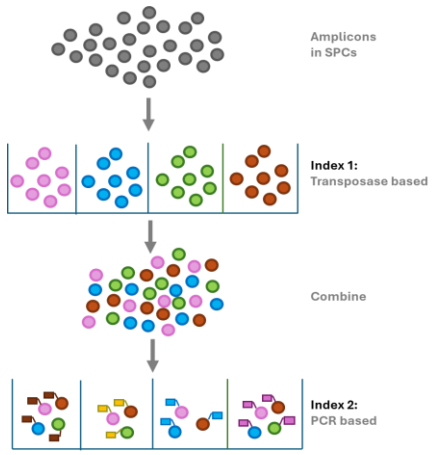


Figure 8. Combinatorial indexing.

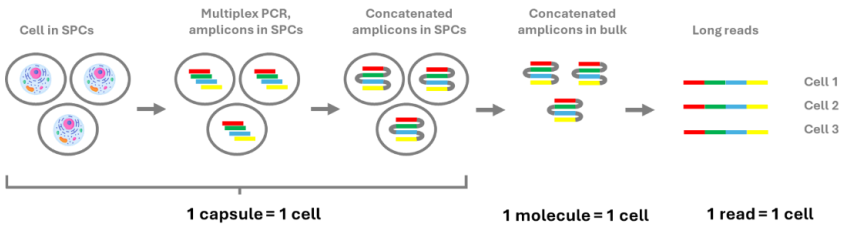


Figure 9. 1-read-1-cell principle based on concatemer synthesis.

Finally, all forensic single-cell DNA sequencing assays developed in WP4 will be thoroughly tested and evaluated having forensic criteria in mind. Using the final optimised conditions for all CE/MPS/LRS assays, we will perform internal validation using a set of suitable samples to make sure that protocols are ready for follow-up thorough validation in WP6. Additionally, to evaluate stochasticity and reproducibility, which is expected to be introduced when analysing single cells, we plan to test the number of needed technical replicates. Importantly, we will create and analyse mock cell mixtures containing relevant cell types. This will take place in collaboration with partners from WP3 so that direct testing of MicroLyseFX and MicroSortFX output is used as input for our novel assays.

Forensic single-cell DNA profile generation and interpretation (WP5): To fill the gap between experimental data and result interpretation for single-cell DNA analysis, data need to be called/analysed, true data need to be discerned from artefact/noise data and evidential weights need to be determined through probabilistic calculations.

(1) Bioinformatics analysis pipelines for the novel MPS/LRS assays (Modules 6b-7b-8b): We will perform swift bioinformatics analysis of the single-cell DNA profiling and sequencing data generated in WP4 by KUL-FBS and UM using novel experimental techniques (Modules 6a-7a-8a) suited for the MicroSortFX output, to inform on further experiments during development; thus, WP4 and WP5 have a close and interdependent connection.

Innovative lab modules 6a, 7a and 8a will deliver MPS/LRS sequencing data with combinatorial indexed, long or concatenated amplicons, respectively. These approaches require suitable adjustment of available tools used in single-

[59] Vitak SA, Torkenczy KA, Rosenkrantz JL, Fields AJ *et al* (2017) *Nat Methods*, 14(3): 302-8, 10.1038/nmeth.4154
[60] Leonaviciene G Mazutis L (2023) *Nucleic Acids Res*, 51(1): e2, 10.1093/nar/gkac918

cell DNA sequencing analysis. In overview, the bioinformatics analysis comprises three major tasks: 1) **the demultiplexing step when more than one sample is combined in one reaction** (the combinatorial indexing; here CapCell uses the major advancement of massively parallel sequencing); 2) **alignment of a pair of anchors (small pieces) of reference sequence to the reads** (which is much more efficient in terms of required computing power than aligning reads to the reference genome and it also avoids incorrect alignments with similar regions in the genome); and 3) **the extraction of genotypic data** (variants such as autosomal/Y-STRs and autosomal/mtDNA SNPs). Numerous bioinformatic tools for raw data analysis have been developed, with distinct features (to name just a few: Cell Ranger for demultiplexing, alignment, gene counting, variant calling - proprietary at 10X Genomics); GATK for variant discovery, genotyping, joint calling[61]; STRELKA for variant calling for small variants[62]; scDNAseq for quality control, normalisation, variant calling[63]). Also, different approaches exist in algorithms for variant calling as some algorithms are based in an exploratory mode and search for all variability within a target zone (e.g. HaplotypeCaller from GATK, FDSTools or STRait Razor[64]) and some will only call a certain position and ignore the remaining variability (e.g. SNP_Genotyper from Thermo Fisher Scientific). Thus, NFI and i3S will make and explore a detailed inventory including recently published tools, suitable for both MPS/LRS data. The most important feature for our envisioned data analysis is the accuracy of the data extraction, but we will also include suitability for tasks as speed and data quality control. Additionally, the alignment of data is different for targeted (RC-)PCR and concatemer strategies, not only because these represent short and long reads, but because the long concatemer reads consist of both PCR targets and amplification or sequencing noise, which requires separation. Basically, the flanks of the targets will serve as anchors that need to be recognised pair-wise (5 'and 3' anchors). The range of the amplicon needs to be established, what the orientation in the concatemer is, and how many copies are present. For simplicity, it is highly preferential to accommodate all different features in one or two tools (e.g. FDSTools, which asks for collaboration between different laboratories) as this improves user-friendliness, increases TRL and facilitates implementation in WP6.

(2) Adjusted single-cell STR/SNP/mtDNA profiling and interpretation (Module 9): Extracted single-cell DNA profiling data from WP4 need to be interpreted carefully, which carries four aspects: 1) **discerning true alleles and noise** (stutter, PCR chimera occurring from template switching, slippage on mono- or di-nucleotide stretches etc.), for which thresholds need to be set (here, a noise database needs to be generated as is custom in FDSTools which requires the analyses of a substantial number of samples for which genotyping information is known); 2) **calculating a weight of evidence based** on the results for autosomal STRs, for which various parameters (drop-in and dropout values, degradation model, and other results of data sparsity) need to be established in the probabilistic genotyping software such as DNAStatistX (the open source model central in the DNAxs statistical model extensively used at the NFI and multiple European forensic laboratories); 3) **analysing SNPs and MHs**, both of which can be used for identification purposes with an advantage of MHs for mixture analysis, for which user-friendly pipelines for extraction, analysis and prediction are needed; 4) **inference of haploid marker lineage with main focus on the mtDNA** for which full genome sequences will be derived. MUI has a long tradition in developing software to handle, analyse and interpret mtDNA data[65]. Among these is software SAM2[66,67] which implements global phylogenetic alignment from the estimated haplogroup motifs, instead of commonly used local alignment and thus produces consensus reads that are in accordance with the human mtDNA evolution[68]. Performing database searches in unaligned format is a prerequisite to avoid biased frequency estimates and harmonise the different mtDNA nomenclatures around the world. SAM2 is the only software of its kind and powers EMPOP (EDNAP mtDNA Population Database) that has evolved to a state-of-the-art resource for estimating mitotype probabilities. EMPOP is endorsed by ISFG and is used in all legislations for forensic purposes around the world. In CapCell we aim at exploiting the SAM2 algorithm to develop a pipeline that aligns mtDNA sequence raw data following phylogenetic principles. Initial haplo-grouping will be performed using mixemt[69], HaploCart[70] or HaploTracker. NUMTs will be filtered using a modified version of EMMA2[71] to further remove nuclear DNA background. Consensus sequences will then be computed based on the ranges and variants for each individual sequence using the starting position, the CIGAR string and the segment sequence. The consensus sequence will be produced by filtering the individual sequences by applying user-definable settings for minimal read depth and thresholds for mixtures (heteroplasmy), insertions and deletions. This transparent procedure allows for reconstruction of the resulting consensus and plausibility checks that are required in forensic settings. Initial experiments on MPS data have demonstrated that this algorithm leads to a higher number of recovered reads and therefore more reliable base calls than other unspecific alignment methods. This pipeline will harmonise

[61] McKenna A, Hanna, Banks E, Sivachenko A, Cibulskils K *et al* (2010) *Genome Res*, 20(9): 1297-303, 10.1101/gr.107524.110
[62] Kim S, Scheffler K, Halpern AL, Bekritsky MA *et al* (2018) *Nat Methods*, 15(8): 591-4, 10.1038/s41592-018-0051-x
[63] Gawad C, Koh W, Quake SR (2016) *Nat Rev Genet*, 17(3): 175-88, 10.1038/nrg.2015.16
[64] King JL, Woerner AE, Mandape SN, Kapema KB *et al* (2021) *Forensic Sci Int Genet*, 52: 102463, 10.1016/j.fsigen.2021.102463
[65] Rock A, Irwin J, Dur A, Parsons T, Parson W (2010) *Forensic Sci Int Gen*, 5(2): 126-32, 10.1016/j.fsigen.2010.10.006
[66] Huber N, Parson W, Dur A (2018) *Forensic Sci Int Gen*, 37: 204-214, 10.1016/j.fsigen.2018.09.001
[67] Dur A, Huber N, Parson W (2021) *Int J Mol Sci*, 22(11): 5747, 10.3390/ijms22115747
[68] Bandelt HJ, Parson W (2007) *Int J Leg Med*, 122: 11-21, 10.1007/s00414-006-0151-5
[69] Vohr SH, Gordon R, Eizenga JM, Erlich HA, *et al* (2017) *Forensic Sci Int Genet*, 30: 93-105, 10.1016/j.fsigen.2017.05.007
[70] Rubin JD, Vogel NA, Gopalakrishnan S *et al* (2023) *PLOS Comp Biology*, 19(6): e1011148. 10.1371/journal.pcbi.1011148
[71] Dur A, Huber N, Rock A, Berger C *et al* (2022) *Comp Struc BioTech J*, 20: 3630-8, 10.1016/j.csbj.2022.06.053

mtDNA analysis regardless of the instrument and provide a basis to consolidate mtDNA nomenclature to avoid errors due to ambiguous alignment.

(3) Automated single-cell DNA profile analysis and interpretation based on CE/MPS (Module 10): The analysis of CE-data is much less automated than MPS pipelines and still requires manual inspection. **Through ML - a type of artificial intelligence that deals with statistical algorithms, a huge step forward can be achieved in automation regarding multiple aspects**, such as peak height, peak shape, amplicon length, which would be beneficial not only for single-cell analysis originated from the MicroLyseFX and MicroSortFX, but also for generating fast identification with standard DNA profiling. Furthermore, **ML allows for the reduction/removal of analytical thresholds and thus, a more sensitive analysis, beneficial in case of minute amounts of DNA, such as with single cells.** Since 2020 a growing interest in the forensic community has arisen in ML algorithms for allele-calling CE and/or MPS STR profiles, which we will contribute to in CapCell. Although still in its infancy, there are already a couple of attempts to produce viable ML (artificial neural networks-ANN) algorithms to perform allele calling[72,73,74,75] reaching an overall performance of 93% (for the initial model) with a test set of a single electropherogram. Despite showing good precision rates for allele calling and baseline (96%), less efficient results were obtained for the prediction of artefacts such as stutters (68% for n-4). Recently, the established model (FaSTR DNA analysis software) was compared with traditional manual CE data genetic analysis software, reaching a 100% concordance[76]. ML algorithms for allele calling in MPS data have also been recently attempted, i.e. Fragsifier, a tool for STR calling using a random forest algorithm for the location of repetitive sequences and flanking regions. For MPS-data various types of noise occur (sequencing errors, chimaera), and allele-specific prediction of noise would be a highly useful and flexible (extendable to other sequencing platforms or kits), alternative to the current practice of generating a noise database from references samples, which is time-consuming and amplification system-specific. **However, none of these tools has been designed specifically for single-cell analysis, which we will tackle in this project.**

End user-focused implementation of the modular CapCell toolkit (WP6): CapCell aims to establish the CapCell toolkit as a practical, reliable solution for analysing complex mixed evidentiary stains in forensic casework. This WP is designed to test and validate the toolkit's performance at high TRLs, train forensic practitioners on its use, and demonstrate its applicability through real-world deployment.

(1) Training of forensic researchers and practitioners: With the support of all expert groups, MUI will focus on equipping forensic professionals with the skills to understand and operate each module of the CapCell toolkit depending on TRL. This task includes a comprehensive training program tailored to different practitioner roles, covering the toolkit's modular components from cell isolation using MicroLyseFX and MicroSortFX devices to downstream DNA sequencing and data analysis workflows. Training will be based on detailed standard operating procedures (SOPs) to ensure that trainees have a reference for the specific wet- and dry-lab tasks. The consortium has access to Moodle to organise the training material, track the process and assess the trainee's understanding. We plan to use short, focused video modules to allow trainees to learn at their own pace and revisit difficult sections as needed. Screen recording software will be used to capture step-by-step tutorials. Trainers can annotate these videos to explain each step or provide context for specific functions. If complex workflows need further visualisation, we plan to use Zoom's whiteboard functions to annotate data and collaborate in real-time, especially in virtual settings. Personal visits at the respective laboratories will allow for live demonstrations to teach lab procedures and software functions interactively. Lab work and the use of the analytical pipelines can thus be performed under supervision, providing immediate feedback on their technique. The training will be specifically tailored to small groups to encourage peer learning, discussion, and collaborative troubleshooting.

(2) Implementation (TRL-7) of MicroLyseFX at operational settings (Modules 1-3-5-9-10): For our testing, validation and implementation activities we will follow a scheme with increasing complexity of CapCell modules to allow the end-users sufficient time to grasp complex topics, validate our findings and importantly, provide feedback for the tools that can be brought back in case of the data analysis tools in WP5, or brought forward for further development after the project ends. All validation studies will be strictly performed according to ISO 17025:2017, relevant ISFG recommendations and ENFSI best practice manual and guidelines. First, starting halfway through the project, EPBG will lead the implementation of the novel analysis tools and adjusted software based on WP5 Task 5.1 (Module 9). This virtual task will allow end-users to directly test tools they are familiar with, depending on their infrastructure and kits employed (CE/MPS). Validation of the adjusted GeneMarker, GeneMapper and FDSTools software will be performed in each forensic institute and police lab, also according to each lab's individual routine practice using data generated during training. Labs will validate adjusted settings (stutter, locus

[72] Taylor D, Powers D (2016) *Forensic Sci Int Genet*, 25: 10-18, 10.1016/j.fsigen.2016.07.013
[73] Taylor D, Harrison A, Powers D (2017) *Forensic Sci Int Genet*, 30: 114-26, 10.1016/j.fsigen.2017.07.002
[74] Taylor D (2022) *Forensic Sci Int Genet*, 56: 102605, 10.1016/j.fsigen.2021.102605
[75] **Veldhuis M, Ariens S, Ypma RJF, Abeel T, Benschop CCG (2022) *Forensic Sci Int Genet*, 56: 102632, 10.1016/j.fsigen.2021.102632**
[76] Lin MH, Lee SI, Zhang X, Russell L, Kelly H, Cheng K *et al* (2021) *Forensic Sci Int Reports*, 3: 100217, 10.1016/j.fsir.2021.100217

and allelic balance, baseline noise etc.) as developed in WP5. Second, building on this task, we will add complexity by allowing the labs to additionally test and validate the laboratory process with the fine-tuned commercial CE/MPS protocols KUL-FBS will deliver in WP4 Task 4.1, coupled with the fine-tuned software tools (Modules 5-9). KUL-FBS will provide sorted/single-cell material obtained from the MicroLyseFX instrument to all end-users. The performance of MicroLyseFX output will be assessed during a technical validation by using a series of predetermined quantitative methods to assess precision (repeatability and reproducibility), measurement range, specificity, robustness as well as external quality assessment (EQA) samples from the proficiency test providers GEDNAP (German DNA Profiling) and TrACE (Trace Analysis Collaborative Exercise). The criterium for success will be the production of single male DNA-profiles. Finally, we will add extra complexity for end-users by including also the step of collecting and isolating sperm cells from forensic evidence (Module 1), prior to further automated DNA analysis based on ML (Module 10). Overall, in the final year of the project, Voxdale will lead a full-scale prototype field demonstration of the MicroLyseFX II device, to showcase its practical on-site capabilities. The first devices of MicroLyseFX II will be manufactured and sent to end-users, who will be able to apply this approach under field conditions. We will employ not only suitable samples from proficiency tests but with the support of police labs and the permission of judges, also samples from real casework, which will allow us to achieve the envisioned TRL-7. Our focus will be on assessing cell isolation efficiency, but also scalability, speed and adaptability. Through field demonstrations, CapCell aims to confirm the device's efficiency in processing samples with minimal preparation, allowing forensic teams to conduct preliminary DNA analysis directly at crime scenes. Regarding the novel automated ML models implemented in FDSTools, a concordance study will be carried out.

(2) Validation (TRL-5) of novel MicroSortFX-suited assays (Modules 2-4-6-7-8): Main technology innovator labs leading WP4 and WP5, with the support of KUL-MeBioS, will contribute to inter-laboratory exercises, validating the newly developed single-cell MPS/LRS assays to analyse STR, SNP and mtDNA biomarkers developed in WP4. In a coordinated job-sharing scheme, these partners will be working with isolated male nucleated cells to assess the robustness and accuracy of these sequencing assays and associated data analysis tools to identify individual contributors within mixtures. These samples can be artificially prepared but also include the output of our novel sample collection protocol for contact traces (Module 2) and MicroSortFX (Module 4) throughout advanced stages of method development which happens simultaneously. This external validation process will establish the assays at TRL-5, demonstrating their readiness for further development and testing in forensic applications.

1.2.3 Relevant national or international research and innovation activities

CapCell innovations will be developed in line with the EU security framework, which addresses security challenges while safeguarding fundamental rights, by leveraging the extensive experience of our partners in both European and national collaborative projects and initiatives and continuously monitor relevant projects for future collaborations.

Relevant EU initiatives: We will seek synergies with EU-funded and international research by building on the work of previous/ongoing projects (Table 1) and forming a Security Cluster (WP7). New projects and new initiatives will be monitored throughout the project through a **project landscape** (WP1) and **stakeholder mapping** (WP7).

Table 1. Examples of current and previous EU-funded projects.

Project	Project description and synergies to CapCell *(Partners involved)*	Synergies to CapCell *(WP relevance)*
FORTIFIEDx Ongoing	FORTIFIEDx aims to revolutionise point-of-care diagnostics by developing a self-powered microfluidic patch that enables biofluid sampling and on-patch analysis, targeting sexually transmitted diseases and viral haemorrhagic fevers *(KUL-MeBioS)*.	Synergies with CapCell crime scene evidence collection using microfluidics can enhance the efficiency of biological sample handling *(WP3)*.
DECIPHER Ongoing	DECIPHER aims to revolutionise the IVD POC field by developing an innovative, mass manufacturable and quantitative patch aimed at pandemic control (*KUL-MeBioS*).	CapCell can build on the expertise gathered during this project on high-throughput manufacturing techniques commonly used for microfluidic chips *(WP3)*.
PCR-4-ALL Ongoing	PCR-4-ALL aims to evaluate the impact and viability of a novel mass PCR testing method as pandemic-fighting strategy (*KUL-MeBioS*).	CapCell can build on the manufacturability assessment where adequate routes will be explored for moving the manufacturing of parts from a laboratory setting to an industrial one (*WP3 / WP6*)
VISAGE Ended	VISAGE developed tools to predict appearance, age, and ancestry from DNA traces, creating composite sketches to aid criminal investigations *(MUI, NFI)*.	CapCell can build on VISAGE's privacy-by-design and ethics framework, as well as extend its possibilities by enabling the application of VISAGE tools in mixed samples (*WP5 / WP6*).

Project	Project description and synergies to CapCell *(Partners involved)*	Synergies to CapCell *(WP relevance)*
TELEFI Ended	TELEFI mapped the use of facial recognition in criminal investigations across EU Member States and provided recommendations for harmonising practices and transnational data exchange *(EFSI, EPBG, NFI).*	CapCell can build on TELEFI's work by integrating its insights on data harmonisation and cross-border cooperation to enhance forensic evidence collection (*WP2 / WP6).*
EUROFORGEN-NOE Ended	EUROFORGEN-NoE established a European Virtual Centre for Forensic Genetic Research, aiming to advance forensic genetics while addressing privacy concerns and societal impacts via collaboration between scientists, stakeholders, and end-users *(MUI, NFI).*	CapCell can build on this to further harmonise EU evidence collection standards and enhance collaboration and synergies amongst EU end-users (*WP2 / WP6).*
DNAxs 2.0 Ended	DNAxs 2.0 is a user-friendly software developed by the Netherlands Forensic Institute that enhances case handling by quickly comparing DNA profiles and conducting statistical analyses using advanced probabilistic models *(NFI).*	CapCell can make use of the expertise of the DNAxs 2.0 software developers and their statistical knowledge (contained in the DNAStatistX module). This improves the accuracy and efficiency of mixture analysis while addressing end-user needs (*WP5 / WP6).*

Relevant national initiatives: CapCell partners are also directly connected with several key national projects on the use of microfluidics for single-cell sorting and statistical analysis in forensics and criminal investigations, including µForensiCell, MIRACLE, MabMine, FWO Hydrogel, SCORE, 10,000 mitogenomes, CIDX and several other national research initiatives.

In sum, CapCell will leverage expertise, methods and existing (inter-)national initiatives and research across disciplines to strengthen Europe's standard of evidence collection, forensic DNA analysis and the security ecosystem.

1.2.4 Interdisciplinary approach

CapCell brings together a multidisciplinary consortium of 13 partners from across Europe committed to scientific excellence in forensic genetics (Figure 10). The expertise of CapCell partners covers sample collection, microfluidics, forensic genomics, DNA sequencing, bioinformatics, statistics and technology prototyping, as well as hands-on experience in forensic casework, biological traces, human identification and technology validation/implementation. Combining academic partners (UM, KUL, i3S, MUI) with strong involvement of end-users (MUI, NFI, EFSI, EPBG, AFCP), research and innovation (R&I) technology market leaders (COPAN, NimaGen, Voxdale), a European forensic organisation (EDNAP) and an SME specialised in EU project management (accelCH) makes the CapCell consortium a unique collaborative network. Top experts from each discipline bring their specialised knowledge and methods, allowing us to approach the development and uptake of CapCell's modular technologies from a uniquely innovative perspective. This collaboration enables us to: 1) pioneer cutting-edge modules with scientific rigour, 2) design solutions that align with real-world user needs, 3) receive continuous feedback from the European community, 4) raise awareness and disseminate our findings widely, and 5) work with industry to develop prototypes, bringing our innovations closer to market and advancing Europe's competitive edge.

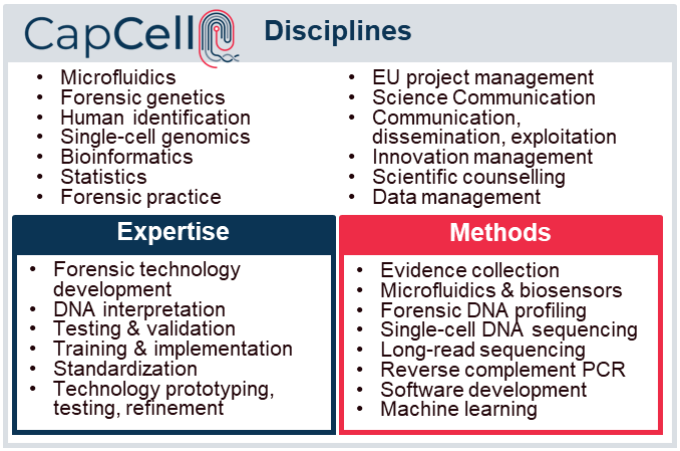


Figure 10. Diverse disciplines & expertise within CapCell.

1.2.5 Integration of social sciences and humanities

The aim of the Destination "Better protect the EU and its citizens against Crime and Terrorism" is for the benefit of all European citizens, with the call topic HORIZON-CL3-2024-FCT-01-02 focusing on new approaches and technologies for improved forensics and lawful evidence collection. Although social sciences and humanities (SSH) are not required disciplines to deliver the CapCell modules, our forensic institutes and police force partners have sociologists and psychologists in their teams to ensure appropriate communication of CapCell results, while our research and company partners have economists in their groups to assess the costs involved in the future use of the newly developed modules as part of the exploitation strategy defined in Section 2.2.2.

1.2.6 Gender dimensions

The relevance of the gender dimension in CapCell is limited due to the specific focus on evidence collection in sexual assault cases, where men are predominantly the perpetrators while women are the victims. Indeed, sexual violence and assault in the EU affect women and girls disproportionately, which reflects broader issues of gender inequality .

This is highlighted in the 2022 European report on Sexual Violence in Europe which finds that out of 215,000 sexual violence crimes registered by EU authorities in 2015, one-third of which were rapes, about 99% of those imprisoned for such crimes were men, while nine out of 10 rape victims and eight out of 10 sexual assault victims were girls and women. Furthermore, the European Union Agency for Fundamental Rights (FRA) survey reports that about 97% of individuals convicted for sexual offences are male. The primary aim of CapCell innovations is to improve the evidence collection capabilities of European police authorities and forensic communities at sexual assault crime scenes, but also beyond. To achieve this, the project will recreate realistic biological samples based on insights from sexual assault crime scenes. To maximise the impact for CapCell end-users and the European forensic community, samples must accurately reflect the reality of European cases, where most perpetrators are male, and victims are female. Given this context, there is no need to integrate a gender dimension into the research and innovation aspects of CapCell. Therefore, we consider it justified to conclude that the gender aspect is not directly relevant to our work, hence dedicated research on this is out of scope for this project.

1.2.7 Open science practices

Open science is crucial to build upon existing research, encouraging collaboration, while accelerating the innovation process and involving end-users for greater transparency in the scientific process. In line with the EU's open science policy, within the framework of CapCell mandatory and recommended open science practices will be implemented (Figure 11):

Figure 11. CapCell's open science practices.

1. **Open sharing of results:** CapCell is committed to making its results "as open as possible, and as closed as necessary." To achieve this, results will be shared via pre-print repositories (i.e. bioRxiv) for collaborative and cross-disciplinary dialogue and peer feedback. Publishing a preprint will always be aligned with the consortium IP strategy (Section 2.2.2) to avoid compromising the patent filing process.
2. **Open data sharing**: As outlined in section 1.2.7 below, a Data Management Plan (DMP) will be drafted in M6 and updated regularly during the project lifetime to expand on how the research data and results produced comply with open science practices and the FAIR (Findable, Accessible, Interoperable, and Reusable) data principles, while including justifications where access to results will be limited.
3. **Open methodology:** In CapCell, we will develop a modular approach and produce a variety of results, including publications and policy recommendations, technical training and reports, including several public deliverables. To guarantee reproducibility and enhance accessibility, results will be compliant with accepted community standards and controlled vocabularies.
4. **Open educational resources:** As part of WP6, MUI will develop training curricula to equip practitioners with the skills needed to integrate novel forensic investigation tools into operational settings. These curricula will be made freely available through the channels of our partner association (EDNAP) and relevant security organisations (Europol Innovation Lab), facilitating knowledge sharing and raising awareness among police and forensic institutes across Europe. This open-access approach will ensure widespread dissemination of these valuable resources and promote the adoption of innovative forensic techniques across Europe.
5. **Open-access publications:** Aligned with Horizon Europe's open-access policy, our consortium is committed to disseminating its research results in peer-reviewed open-access publications and depositing scientific articles in trusted repositories. It is expected that CapCell will restrict access to new technologies with potential for patent filing and possible commercial exploitation. Details will be outlined in the Consortium Agreement and the DMP.
6. **Open peer review:** To enhance the transparency and accountability of our research, the CapCell consortium members plan to engage in open-peer review practices. The consortium will utilise platforms like Open Research Europe (ORE) to facilitate this process.
7. **Citizen science:** In CapCell, stakeholder engagement and awareness raising are important measures to explain forensic DNA profiling to the public. We will involve and engage citizens via the Security Cluster's dedicated working group and multi-channel communication to bridge the gap between complex research and non-experts.

1.2.8 Research data management and management of other research outputs

Our CapCell project partners are fully committed to actively managing their data throughout the entire project lifecycle and applying general data management principles, procedures and integration practices. Research data management will be a key task in WP1, coordinating the generation of new data through the newly developed tools in WPs 2 to 4, the use case-specific data management in WP5 and the validation data from WP6. A DMP will be set up within the first six months of the project (D1.2), in consultation with the responsible person of the participating

institutions. The DMP will be updated periodically throughout the project to account for any changes in data collection, processing, or storage. Each project partner will be responsible for data management and quality assurance within their WP.

Data types: The project will generate various data types including but not limited to: data on end-user casework needs through literature reviews, questionnaires, and practitioner consultations (WP2); cell/debris recovery data during sample collection method testing and new protocols tailored for microfluidics analysis (WP2); experimental data including cell isolation efficiency from the two microfluidic approaches (WP3); blueprints and data during engineering of the microfluidic prototype and devices (WP3); CE-generated STR electropherograms and profiles (WP4); MPS-generated STR, SNP and mtDNA sequences and profiles (WP4); LRS-generated STR/SNP sequences and profiles (WP4); data analysis scripts, pipelines and adjusted software (WP5); ML algorithms for automatic analysis (WP5); STR/SNP/mtDNA data generated during training, validation and implementation activities (WP6); cell isolation efficiencies, improved genotyping protocols and DNA profiles during MicroLyseFX demonstration (WP6).

Data management principles: We will follow FAIR data management principles (Figure 12) to ensure the data's long-term usability and integration practices while adhering to national and European legislation. CapCell research data will be accessible based on the strategies outlined in Section 1.2.7, aligned with the IP strategy (Section 2.2.2), as well as strategies to protect personal or confidential information in compliance with EU's General Data Protection Regulation 2016/679 (GDPR) and other EU standards. As several tools include proprietary software and technologies, access rights and restrictions will be clearly defined in the consortium agreement (Section 2.2.2), considering IP restrictions, particularly for the collection/elution devices and the microfluidics tools.

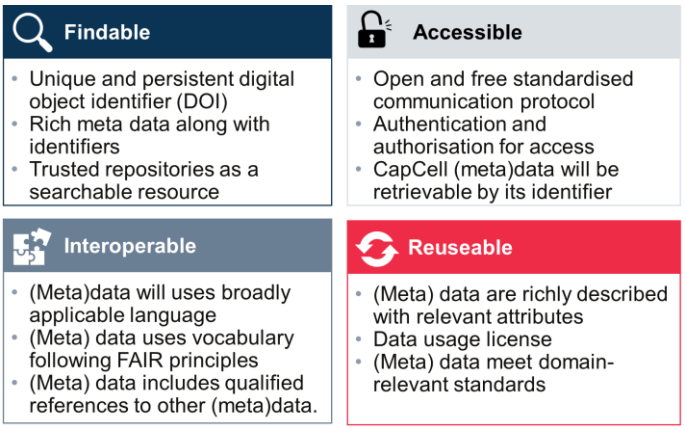


Figure 12. FAIR data management principles.

Data management procedures: During the project, data storage will be a combination of decentralised local servers and cloud services for joint research data. Data sharing between partners will be organised as follows: Police authorities and forensic institutes will share generated data during testing and evaluation of sample collection strategies as well as during validation and implementation of the novel CapCell modules, while our academic and company partners will share information on technology, analytical protocols, data analysis pipelines and DNA results with other police authorities, forensic institutes. and EDNAP.

Data security and ethics: The topic of human identification is not new and in line with what is currently performed across forensic research and casework laboratories. KUL-FBS, NFI, MUI and UM already have internal ethical approval for suitable sample collection in place, which might need to be adjusted or extended to accommodate research in CapCell. EFSI and police labs will need to obtain ethical approval from their institutes to collect samples from volunteers to be used in this study. Ethical approval requests or amendments for the planned studies from local committees will follow local procedures but will certainly include the intention of the study, the study protocol and informed consent forms. We are committed and will comply with regulations regarding the privacy of donors, both during sampling and data sharing. Finally, academic labs, forensic institutes and police authorities all have highly secure data management infrastructures already in place.

2 Impact

CapCell innovations enable **mobile and selective evidence sample collection and processing**. This produces more interpretable forensic DNA profiles usable for prosecution and enhances law enforcement's ability to identify and bring perpetrators to justice. By **involving end-users, fostering R&I and building strong partnerships with European forensic and security organisations**, the project will have a long-term impact on the EC's Security Union Strategy (2020-2025) goal of **building a strong European security ecosystem** through research, innovation, and skills development. CapCell's research will also contribute to a future-proof security environment, to tackling evolving threats and to building resilience for European societies (Figure 13). This will be achieved by contributing to the outcomes and wider impacts specified in the destination and call topic through tangible benefits for project stakeholders and the broader European community (Section 2.1). CapCell's impact will be maximised through tailored outreach measures (Section 2.2).

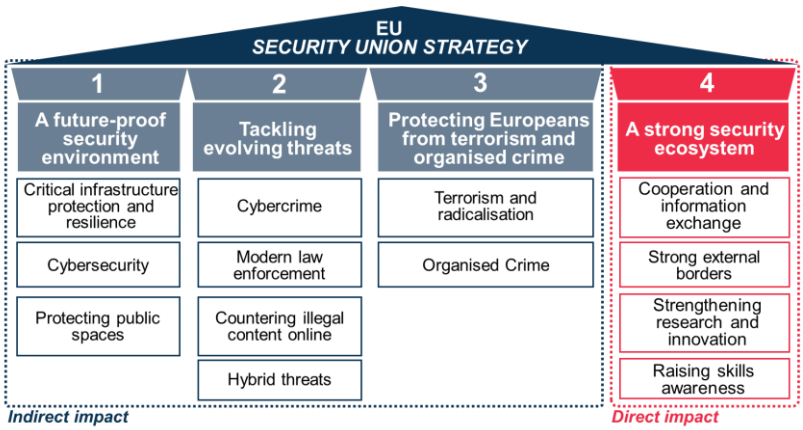


Figure 13. CapCell's (in)direct impact on the EU Security Union Strategy.

2.1 Project's pathways towards impact

CapCell's impact will unfold over the short-, medium-, and long-term (Figure 14**)**. By the project's end (short-term), our modules will reach up to TRL-7, including a prototype, and provide a basis for future commercial products. Within five years (medium-term), CapCell will modernise DNA processing and analysis in Europe, improving perpetrator identification capacities of member states. This will **foster cooperation and information exchange towards a more resilient European security ecosystem** in the long run. Fundamental rights, including privacy and data protection, will be safeguarded by **aligning with EU best practices and standards**. To maximise the project's outreach, we will involve the **broader forensic community** in our innovation process with the help of EDNAP and MUI's representative's long-standing involvement in ENFSI's DNA working group.

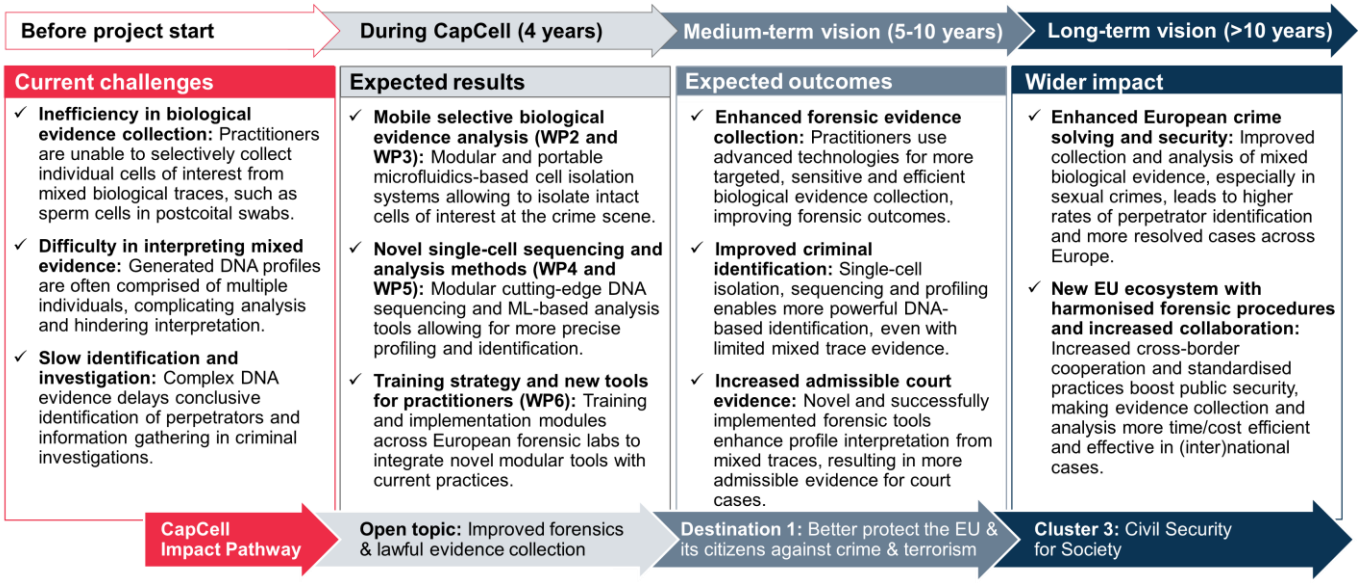


Figure 14. CapCell's short-, medium- and long-term foreseen impact.

2.1.1 Contribution of project results to outcomes and wider impacts specified in the work programme

The project has identified **six stakeholder groups** (Figure 15) that will **directly benefit from CapCell innovations,** and will be engaged in the innovation process. The sections below specify how our project results address the outcomes of the call topic (Table 2) and impacts of Destination 1 (Table 3), creating **tangible benefits for all stakeholder groups.**

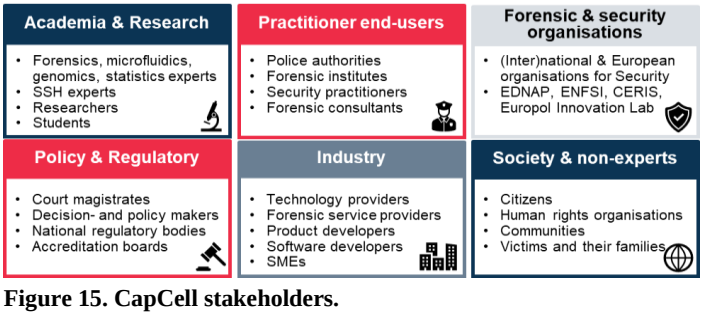


Figure 15. CapCell stakeholders.

2.1.1.1 Contribution to expected outcomes as specified in the call topic

The CapCell multidisciplinary consortium addresses the specific expected outcomes of this call, *Improved forensics and lawful evidence collection*, as described in Table 2.

Table 2: Contribution of CapCell results to the expected outcomes of the call.

CapCell's contributions to the expected outcomes of the call
Expected outcome 1: Improved European common forensic investigation capabilities, evidence collection and cross-border exchanges in the domain under consideration
CapCell will innovate forensic evidence collection, analysis and interpretation from relevant biological cell mixtures, commonly collected in sexual assault cases and other crime scenes. By being able to selectively capture and analyse cells of individual (male) contributors, the project enables identifying perpetrators and **solving cases more efficiently, increasing forensic investigation capabilities**. These tools will be adopted across Europe by including multiple forensic science institutes, police organisations and leading forensic DNA researcher/practitioner networks, facilitating smoother cross-border collaboration and exchange.
Expected outcome 2: Police Authorities and forensic institutes are provided with innovative, harmonised and modern tools and procedures for forensic applications in the investigation of the crime under consideration, in full compliance with applicable legislation on protection of personal data
CapCell will **develop, validate and implement novel standardised experimental and data analysis tools** based on **innovative and modern technologies**, designed to seamlessly integrate into current forensic DNA profiling pipelines across European forensic laboratories, complementing and enhancing existing analysis. Established partnerships with key national and European forensic institutes will serve to pilot and implement the new technologies and methods, **harmonising forensic practices across jurisdictions**. All tools and procedures will be developed **in compliance with EU data protection standards** (e.g. GDPR) and validation studies will be performed according to ISO 17025:2017 standards, ISFG recommendations and ENFSI best practice manual and guidelines.
Expected outcome 3: Forensic practitioners and Police Authorities active in crime scene investigations are provided with modern and innovative training curricula in the forensic domain under consideration.
Detailed **implementation guidelines and SOPs** will be developed in the project based on the needs and feedback of end-users (WP2), outlining the proper use of CapCell tools and procedures. **Comprehensive training curricula** (WP6) will be made available to forensic scientists across Europe through channels of partners, relevant security organisations (Europol Innovation Lab, ENFSI) and project channels. These will be translated into national languages where needed, with the goal of **equipping end-users across Europe with the same high level of expertise**.

2.1.2 Contribution to wider impacts as specified in Destination 1

CapCell will contribute to the Destination's wider impact, *Better protect the EU and its citizens against crime and terrorism*. We have outlined the impacts to which CapCell will contribute most significantly to in Table 3.

Table 3: Contribution of CapCell results to the expected impacts of the Destination.

CapCell's contributions to the wider impacts of the destination
Expected wider impact 1: Modern information analysis for Police Authorities, allowing them to efficiently fight criminals and terrorists who use novel technologies
CapCell will develop and integrate portable technologies, specifically microfluidics and nanopore sequencing, which will enable **on-site analysis capabilities** and **rapid forensic response.** These tools will better **support urgent, high-profile investigations** into sophisticated criminal and terrorist activities, enabling rapid identification to disrupt networks and prevent further incidents. CapCell's advance technologies (e.g. machine learning-driven single-cell profiling/sequencing algorithms) are **transformative for complex mixed biological evidence analysis** and **conclusive perpetrator identification.** Integrated single-cell DNA profile identification is critical for police to tackle multiple perpetrator cases or cases involving disguise and counter-surveillance tactics where minimal DNA is available. Integrating these modern tools into forensic workflows **enables police to stay ahead of criminals employing advanced technologies or strategies.**
Expected wider impact 2: Improved forensics and lawful evidence collection, increasing the capabilities to apprehend criminals and terrorists and bring them to the court
CapCell's innovative mobile microfluidics-based cell isolation systems and novel single-cell sequencing methods allow for **precise and lawful biological evidence collection and processing** in complex, multi-source samples or cases with very little available biological material. Standardising the cutting-edge CapCell toolkit across the EU, allows forensic teams to successfully gather and clearly present **evidence that is both reliable and admissible in court**. Precise generation of 'clean', interpretable DNA profiles from challenging samples produces highly reliable evidence, reducing challenges in court, supporting stronger cases, and **providing prosecutors with powerful tools to secure convictions.** Standardised interpretation frameworks will support the judicial process, help legal professionals, jurors and judges understand and better trust forensic conclusions.

Expected wider impact 3: Enhanced prevention, detection, and deterrence of societal issues related to various forms of crime, including cybercrime, and terrorism, such as violent radicalisation, domestic and sexual violence, or juvenile offenders
CapCell's advanced forensic investigation methods and tools **strengthen the ability to prevent, detect, and deter complex crimes** where DNA from multiple contributors often complicates analysis, and precise identification of suspects is essential for justice, such as **sexual violence crimes and domestic abuse.** Accurate and timely resolution of **sexual assault and rape cases** will also **prevent perpetrators from conducting follow-up serial crime** acts. Overall, improved capability to apprehend and successfully prosecute criminals will discourage perpetrators from committing crimes and **build more trust in the justice system.** CapCell's innovative solutions for on-site cell isolation and sequencing serve as the basis for the commercialisation of new products, which can help forensic and police authorities more effectively **prevent, detect and deter a wide range of crimes in the future, including in war zones.** The standardised protocols and harmonised training will **equip practitioners to handle, track and dismantle criminal networks** operating internationally.

2.1.3 Key impact pathways

Key impact pathways (KIPs) are central to Horizon Europe, ensuring R&I activities align with EU strategies and contribute to scientific, economic, and societal goals. Alongside EU KIPs, CapCell also has a specific legal-regulatory impact. The project will deliver tangible benefits across four KIPs (Figure 16), as outlined below, contributing to the wider impacts of the work programme.

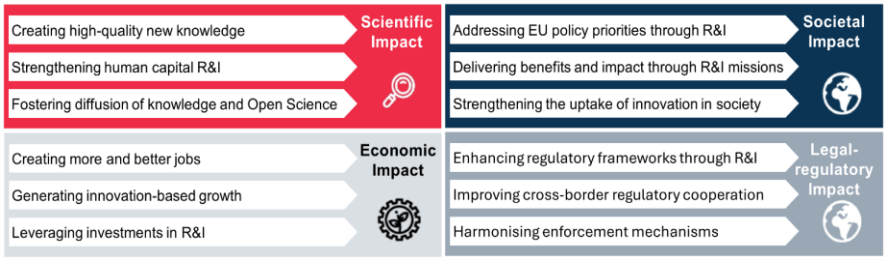


Figure 16. Key CapCell impact pathways.

Scientific impact: CapCell's improved intact cell collection and recovery protocols and standards will **significantly enhance biological evidence collection** and the capabilities of crime-scene officers to produce more (complete) DNA profiles across the EU. Our novel microfluidics prototypes will **inspire a new wave of technology development,** including for other forensically relevant cell types, other biomedical applications (e.g. cancer research) and, by extension, even for non-human cells (e.g. plant research, bacterial screening). This will **improve Europe's competitiveness and capacity for innovation** in several fields. The forensic genetic community will be able to adopt our novel concepts and technologies, including in-capsule PCR, concatemer synthesis and nanopores sequencing, and develop them further for their research investigations and other applications. The CapCell toolkit will enable end-users to determine the number of DNA contributors, assign individual profiles and improve evidence interpretation to meet court-admissible standards, thus **advancing the entire field of forensic genetics**; particularly, towards understanding direct/secondary transfer of biological material required for activity level reporting. The close collaboration with industry partners will **drive opportunities for commercialisation** and the practical adoption of CapCell technologies across diverse fields. CapCell is committed to generating high-quality, novel knowledge and **advancing human capital in R&I** by investing in dedicated training, generating reusable data for the forensic community, and interdisciplinary collaboration. Knowledge dissemination and open science practices will build a foundation for future research to expand CapCell modules into standards, methods, and tools applicable to broader crime types and beyond forensics (e.g. for medical diagnostics). This maximises long-term scientific impact and strengthens competitiveness and innovation in the wider European scientific community.

Economic impact: CapCell is expected to have a substantial economic impact by enabling more effective forensic procedures and enhancing the efficiency of judicial processes. By providing police authorities and forensic laboratories with advanced tools that streamline single-cell DNA profile analysis, CapCell will reduce the need for repeat testing and mitigate costs associated with misidentification, **helping to reduce the long-term costs associated with gender-based violence** against women (Figure 17), currently estimated at €290 billion annually in the EU[77]. The development of high-value technology will stimulate the forensic science industry, **fostering innovation-based growth through the commercialisation** of CapCell's toolkit and related technologies. This is anticipated to **create new and higher-quality employment opportunities** within academic research, forensic laboratories, and supporting industries. Through its

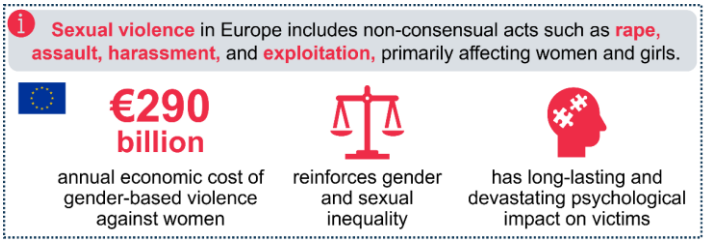


Figure 17. Economic and societal burden of sexual violence.

[77] The costs of gender-based violence in the European Union, Technical report

collaborative efforts with industry partners, the project **leverages and attracts further investment** in R&I, establishing a robust framework for continued technological advancements and sustained economic growth.

Societal impact: Improving the ability to collect and interpret individual DNA profiles from complex evidence ensures that **more perpetrators are identified and brought to justice**. This aligns with the EU's policy priorities, such as building a more resilient and equal Union, the EU Security Union strategy and the fight against organised crime. CapCell's contribution to resolving sexual assault crimes, which predominantly affect women, supports the EU's efforts to address gender-based violence (e.g. EU Directive 2024/1385) and its commitments under the Istanbul Convention (ratified by most EU Member States). CapCell's contribution to UN SDGs 5, 16, and 3 (Figure 18) underscores the project's long-term societal impact on enhanced public safety and equitable justice.

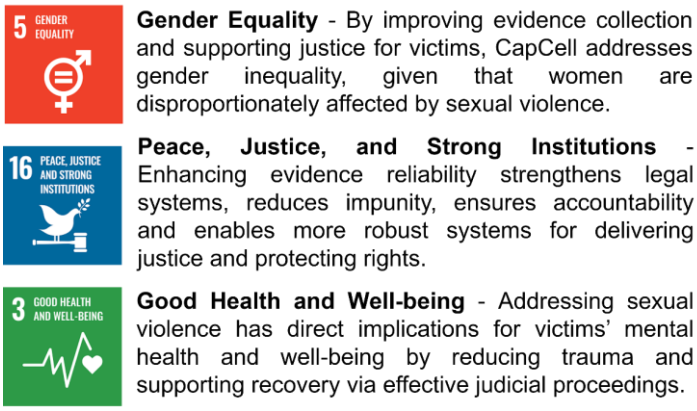


Figure 18. CapCell's contribution to the UN SDGs.

Figure 19. Sexual violence crimes in Europe.

Legal-regulatory impact: CapCell's end-user-focused approach impacts the EU's Security Union Strategy and its strategic priority of building a strong European security ecosystem. CapCell's highly modular toolkit can be plugged into existing forensic platforms and **ensures that nearly every forensic laboratory in the world can employ at least one of CapCell's modules** by choosing from integrating protocols to adopting advanced DNA profiling. This promotes access to cutting-edge tools in less and more technologically advanced regions, while cooperation with the forensic community further drives the widespread adoption of CapCell. This will create a long-lasting impact by **improving cross-border cooperation** and **driving modernisation and harmonisation** of the EU's justice system.

2.1.4 Scale and significance of the project's contributions to the expected outcomes and impacts

CapCell will achieve **tangible and significant impact** for academia, end-users, industry players, the broader forensic and regulatory community, as well as society and the general public. Its research is **transformative for forensic genetics** through unique scientific knowledge in single-cell forensics (making forensic DNA profiles single-cell-specific), significantly advancing R&I and providing opportunities for the broader research community within and beyond the forensic field. The project's 10 modules include, for the first time, mobile tools for on-site evidence collection which can significantly improve the efficiency of law enforcement procedures for all types of crime.

Key industry players in forensic sample collection and DNA sequencing (COPAN and NimaGen) will integrate CapCell knowledge into their portfolios and Voxdale, an expert SME in design and engineering, will develop a prototype for MicroLyseFX (TRL-7), **enhancing innovation and competitiveness of the European forensic technology market**. There is an urgent need for improved identification methods in the EU, where many complex crimes (e.g. sexual assault and rape) remain unsolved. CapCell's innovations are designed for widespread adoption and suited to both cutting-edge and less-advanced forensic laboratories, enabling the **modernisation of nearly any end-user's facilities**. Their widespread adoption strengthens the **prevention, detection and deterrence of a wide range of complex crimes** in Europe, including sexual crimes which predominantly affect females and contribute to the European issue of gender-based violence (Figure 19). This **benefits hundreds of thousands of victims** and **strengthens the European security ecosystem**, fostering trust and delivering widespread benefits for stakeholders.

2.1.5 Requirements and potential barriers

Potential **PESTLE (political, economic, social, technological, legal, and environmental) barriers** affecting the uptake of CapCell innovations are outlined in Figure 20. Risks may arise from political shifts, rapid technological advances, and evolving legal standards in the European security framework. These will be monitored in WP1, with **mitigation strategies proposed to enhance resilience**. Measures include engaging key stakeholders and the forensic community (including Europol Innovation Lab, CERIS, end-users, EU regulatory bodies, and the public) to monitor developments relevant to the European security landscape.

Potential barriers and evolution over time	Mitigation strategies
Political • **Data Protection:** GDPR compliance; potential for stricter future regulations. • **Law Enforcement Policies:** Varying political priorities may affect adoption. • **Funding Stability:** Political shifts could impact security funding of end-users (European and national police and forensic authorities).	• **Proactive Compliance:** Align with current/future data laws. • **Stakeholder Engagement:** Build support with EU bodies (EDNAP, Europol, CERIS). • **Diversified Funding:** Establish long-term partnerships and public-private collaborations to diversify and stabilise funding across political cycles.
Economic • **Cost:** High implementation and instrumentation costs could limit adoption. • **Market Demand:** Economic disparities between EU countries may slow adoption across regions.	• **Cost-Effective Design:** Modular, cost-efficient including portable, and scalable solutions. • **Economic Incentives:** Explore subsidies and collaborative funding models.
Social • **Public Perception:** Privacy or ethical concerns with single-cell analysis could hinder acceptance. • **End-User Adoption:** Resistance to change or due to complexity, regional cultural differences.	• **Public Education:** Build trust through widespread outreach, anonymise procedures, support discussion and clarify use. • **User-Centric Design:** Ensure ease of use, provide comprehensive training and SOPs. • **Community building:** Ongoing engagement with the forensic community and standard setting bodies
Technological • **Specialised Equipment:** Challenges with limited microfluidics expertise by forensic labs • Rapid Advances: Risk of obsolescence due to new technologies. • Interoperability: Challenges in integrating with existing systems. • Data Security: Evolving cyber threats.	• **Automate Process:** Simplify user interface and make microchips' operation accessible • **Continuous R&D:** Stay ahead of technological trends and adopt quickly. • **Standards Compliance:** Ensure compatibility with existing, routinely used systems • **Security Protocols:** Implement robust, up-to-date security measures.
Environmental • **Energy Efficiency:** Increasing focus on sustainable practices in forensic technologies. • **Laboratory waste:** Single-use microchips and reagents	• **Sustainable Design:** Optimise energy use and eco-friendly practices in development. • **Life cycle assessment:** explore strategies to reduce carbon footprint of innovation chain
Legal • **Forensic Standards:** Compliance with evolving legal standards. • **Long Validation/Approval:** Delays in adopting new concepts and technologies • **IP Disputes:** Potential for intellectual property conflicts. • **Cross-Border Complexities:** Legal differences across EU.	• **Legal Consultation:** Ensure early compliance with forensic standards. • **Regulatory Consultation:** Set-up phased validation, gain preliminary approvals • **IP Strategy:** Protect innovations, manage potential disputes. • **Harmonisation Efforts:** Advocate for unified forensic laws in the EU.

Figure 20. Potential barriers and CapCell mitigation strategies.

2.2 Measures to maximise impact – Dissemination, exploitation and communication

This section outlines CapCell's dissemination, exploitation, and communication strategy, managed under WP7 which oversees all outreach activities, including stakeholder engagement, with the involvement of all partners to ensure successful implementation. Four guiding principles have been identified to direct these efforts.

- **Stakeholder involvement and community building:** ensuring a strong end-user focus, engaging academia and research institutions for forensic expertise, and law enforcement and forensic practitioners for feedback on innovations. EDNAP will facilitate dialogue with the wider forensic community, including the ENFSI (with the support of Walther Parson (MUI), former co-chair of subgroup B of the DNA WG), while Europol will observe from the start and provide access to toolboxes for law enforcement. All partners will contribute to the ongoing dialogue with stakeholders to better meet end-user needs and strengthen the European security ecosystem.
- **EU Clustering Initiatives:** CapCell will leverage synergies with other EU-funded and international projects by building on the findings of existing initiatives (see 1.2.3) by organising cluster activities, identifying common challenges and undertaking joint communication and dissemination efforts. All partners will be involved the cluster initiatives to help maximise the project's outreach towards the European security community.
- **Cross-channel and multimedia approach:** a cross-channel and multimedia strategy will serve to effectively share information and raise awareness about the project's benefits for the European security landscape by using different tools, channels and platforms. This approach will be continuously adapted, ensuring that the impact of our outreach activities is maximised throughout the project and after its completion.
- **Open science:** In line with the EU's open science policy, CapCell will adopt both mandatory and recommended open science practices (see 1.2.7). Partners will build on Responsible Research and Innovation practices to foster public trust and drive the sustainable uptake of CapCell innovations.

2.2.1 Plan for the dissemination and exploitation including communication activities

CapCell's 'plan for dissemination and exploitation including communication activities' will be outlined in two deliverables: **1. Communication and dissemination plan (CDP, D7.2, M6)**, and **2. Roadmap for Exploitation (RfE, D7.6, M48)**. The CDP is public, while the confidential RfE focuses on the sustainable uptake and commercialisation of CapCell innovations. The following activities have been defined (Figure 21 and Table 4).

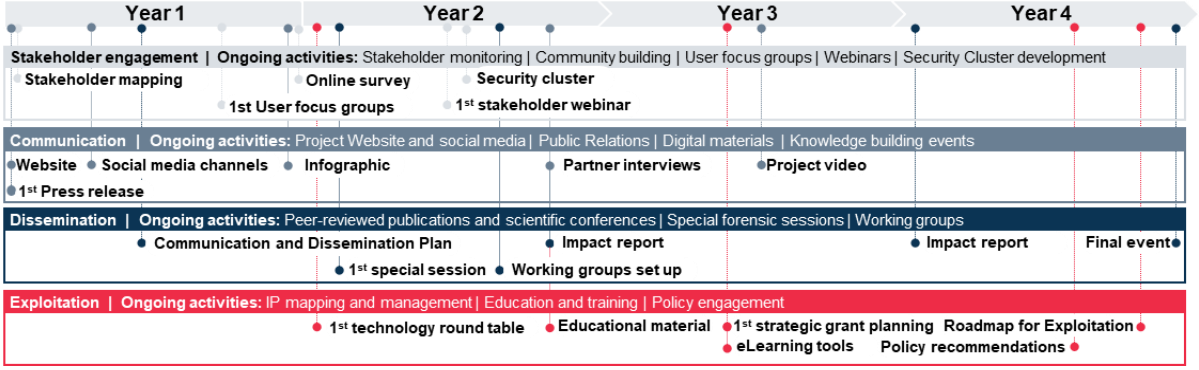


Figure 21. CapCell stakeholder involvement, communication, dissemination and exploitation activities.

Table 4. CapCell stakeholder involvement, communication, dissemination and exploitation activities.

Activity	Description	Impact | KPI*
Stakeholder involvement		
Stakeholder mapping and community building	• At the first project meeting, accelCH and MUI will organise a stakeholder mapping exercise workshop with CapCell partners to identify key stakeholders from the European forensic community. • Input will flow into the CDP and will be continuously updated. • The map will be monitored and updated and stakeholder involvement will build on Responsible Research and Innovation practices.	Stakeholder engagement and community building, knowledge transfer | *20+ stakeholders engaged*
User focus groups	• MUI and accelCH will organise **user focus groups** in years 1 and 2. • These include an **online survey** and **consultations** to complement the collection of forensic casework needs for WP2, T2.1 and gather stakeholder feedback on sample collection practices from WP2, T2.4.	Stakeholder involvement, feedback, sharing knowledge | *2-3 focus groups, 30+ participants*
Security Cluster	• MUI and accelCH will invite EU-funded initiatives identified in the project landscape (WP1, T1.2) to join the **Security Cluster**. • Cluster projects will form **working groups** on relevant topics to identify synergies, share knowledge and plan joint communication efforts. • The Cluster will jointly involve citizens, voluntary organisations and communities, and mitigate human, societal and technological risks. • Results flow into policy recommendations and the final event.	Knowledge transfer, Community building, Reduce effort duplicates, uptake of results, networking, stimulating further research | *2-3 WG, 1 recommendation*
Communication		
Project website	• The **website** set up by accelCH functions as the primary source of information on the project, consortium, project development and results. • Dedicated stakeholder areas with relevant initiatives and events include. a security cluster area as part of joint cluster efforts.	Raising awareness, building knowledge | *300 visitors/month, 1,000 impressions*
Social media	• accelCH will set up **social media channels** on LinkedIn and YouTube to distribute cross-media content and raise awareness about the project • Partners' social media channels and those of cluster projects will be leveraged to maximise outreach and impact, and reach non-experts.	Raise awareness, build knowledge, engagement, networking, | *2 posts/ month, 300 followers*
Cross-media multi-channel content	• accelCH will develop **print materials** tailored to different audiences incl. flyers, brochures, posters, roll-ups and factsheets for partners. • **Press releases and articles** on CapCell, achievements, and results, developed with partners' PR departments for publishing platforms. • UM and accelCH will develop **project videos** (partner interviews and explainer videos) showcasing the benefits of CapCell modules. • Materials will be distributed via CapCell channels, partners' channels and ISFG channels to reach the European community.	Raising awareness, providing information, building knowledge | *1 explainer video per module, 2 press releases, 100 views, 200 downloads of materials*
Dissemination		
Conference participation, peer-reviewed publications	• Partners will comply with the EU's open science policy (sec. 1.2.7). • Results published in **peer-reviewed journals** (e.g. Forensic Science International: Genetics, International Journal of Legal Medicine, Science & Justice, Lab on a Chip, ACS sensors). • Results presented at **international conferences** (e.g. biannual World Congress of the International Society for Forensic Genetics, biannual Gordon Research Conference on Forensic Analysis of Human DNA (chaired by UM in 2027), microTAS, annual ENFSI and EDNAP meetings, annual Select-Bio Lab-on-a-chip and microfluidics.	Peer scrutiny and validation of results, knowledge sharing | *Min. 10 publications. Participation at min. 15 conferences*
Technology & Innovation Sessions	• **Round tables** to share WP6 results and discuss technological developments of modules incl. innovation management (WP1, T1.5) • EDNAP will invite representatives from the forensic community (e.g. CERIS, ENFSI, Europol), R&I partners (Voxdale, COPAN, NimaGen) will leverage their networks to invite key industry players. • Results will flow into the RfE strategies.	Knowledge transfer, networking and clear feedback on CapCell standards | 1 *sessions per topic, min. 30 participants*
Final event	• UM and MUI will hold a **final event towards a new standard of forensic** mixed evidence collection, analysis and interpretation. • The consortium will invite end-users, researchers, key industry players and community stakeholders to discuss the **widespread uptake of CapCell** and future collaboration opportunities.	Knowledge sharing, industry engagement, exchange and direct feedback from expert groups | *40–70 participants*

Activity	Description	Impact | KPI
Exploitation activities		
Roadmap for Exploitation (RfE) 	• The **CapCell Innovation Manager**, with all partners, will develop a **RfE** to facilitate future commercial and non-commercial use of results. • A strategy to overcome barriers (PESTLE) and to evaluate business opportunities (SWOT) will be developed per module category. • Innovation management input (WP1, T1.5) will flow into the RfE.	Define outcomes, strategies and measures to ensure uptake of results | *3 strategies for exploitation (1 per module)*
eLearning tools, training materials 	• **Training material** from WP6 will be shared with end-users via **Europol Innovation Lab** and the **ENFSI** network (via MUI's representative with long-standing involvement in the ENFSI's DNA WG), and available for download (if public) on the CapCell website. • Materials will be translated into national languages (where possible).	Training and transfer of knowledge, facilitate future uptake | *200 views/ downloads of material*
Policy recommendation 	• Provide recommendations for best practices, guidelines and international regulations based on WP6 results. • The **policy recommendation** will be made freely available on the website, through EDNAP's network and presented at the final event.	Influence policy, uptake of CapCell as a standard | *Paper presented at final event, 2 policy briefs*
Strategic Grant Planning 	• accelCH will organise 2-3 **SGP sessions** in the final project year. • SGP will identify funding opportunities for CapCell results (e.g. EIC Transition programme for MicroSortFX).This facilitates the preparation of grant applications to exploit these outcomes effectively.	Pre-selecting relevant funding opportunities, follow-up projects | *min 2-3 consortium SGP*

* KIP: Key Performance Indicators

2.2.2 Strategy for management and intellectual property (IP)

As CapCell is expected to deliver results with high potential for future use in both the academic and industry forensics and microfluidics sector, we aim to strike a balance between protecting the IP of researchers and adhering to open science and innovation principles to ensure that our project results have the widest possible impact. Our IP strategy allows partners to support an open science philosophy while maintaining an active IP programme supported by the Technology Transfer Offices (TTO) of academic partners and legal departments of industrial partners. To facilitate the implementation of such IP strategy, the consortium has agreed to handle existing and new IP based on the new DESCA Horizon Europe Consortium Agreement:

- **Confidentiality and dissemination (publication rules)**: All information shared between partners within the project is confidential unless it was public knowledge prior to negotiations or explicitly stated otherwise by the provider. Before disseminating project results, partners must notify UM 60 days in advance of any planned publications to ensure alignment with the consortium. Objections will be considered, with valid reasons including potential harm to a partner's academic or commercial interests, IP, or confidential information of another partner.
- **Background knowledge and access rights:** The CA will formalise the access rights to all relevant background knowledge partners bring into the CapCell project including other agreements among consortium members regarding IP aspects which will be signed prior to project start. If otherwise agreed, free and non-exclusive access rights will be granted to all consortium members for CapCell purposes for the full duration of the project, excluding information restricted for confidential and ethical reasons since we are dealing with personal data and will adhere to the General Data Protection Regulation 2016/679 (GDPR) at all applicable times.
- **Foreground knowledge (ownership & protection)**: Solely generated IP will be owned by the generating partner, and jointly generated IP will be owned jointly by the partners involved in its creation. In such cases, a separate Joint Ownership and Management Agreement (JOMA) will be signed by the partners concerned. The owner(s) will decide on a protection strategy for the newly generated knowledge (i.e., foreground IP).

IP management procedure: The consortium as a whole and in particular the appointed innovation manager Dr. Iene Rutten (KUL-MeBioS) will continuously scout for IP opportunities in consultation with KUL Research & Development technology transfer office and if needed the European IP management helpdesk. A first freedom to operate (FTO) analysis has not shown major IP conflicts (e.g. search by claims keywords - forensic/crime/criminal - did not reveal patents which are dedicated to this specific field of application). accelCH has developed **accelINNO®**, a toolkit supporting active innovation management tailored to HORIZON projects, which supports project partners throughout the innovation process. It helps identify exploitable results developed in EU-funded research and innovation actions, key stakeholder requirements, IP protection options and their potential use. accelINNO® is currently already being applied in one of the Cancer Mission project GLIOMATCH and several other health-related European projects (e.g. AI-MIND and MOSAICS) and has shown to be valuable by a significant increase in the number of identified exploitable results. A preliminary overview of the foreseen Key Exploitable Results (KERs), exploitation strategy, IP strategy, owner(s) and end-user(s) can be found in Table 5.

Table 5. CapCell's foreseen Key Exploitable Results (KERs).

Partner(s)	Key Exploitable Result	Exploitation strategy	IP strategy	End-user (s)
NimaGen	IDseek® CombiSTR™ Plus	Pay per use	Not planned	Forensic institutes
NimaGen	Long range full mitogenome	Pay per use	Not planned	Forensic institutes
KUL, Voxdale	MicroLyseFX prototype	Licensing deal, spin-off	Patent filing	Police authorities; Forensic institutes
KUL, Voxdale	MicroSortFX prototype	Licensing deal, fee-for-service, spin-off	Patent filing	Forensic institutes
COPAN	New protocol for efficient collection of intact cells in forensic applications and for improved elution of such cells in a transport and preservation medium	B2B sales with international distributors (e.g., Thermo Fisher Scientific, Qiagen).	Patent filing or industrial trade secret	European police authorities; Forensic institutes; Market leaders in forensics market

Figure 22 showcases a preliminary exploitation timeline for the project's expected outcomes. The RfE is a strategic plan outlining the potential (non-)commercial uses of the outcomes of a project, and the steps needed to achieve these. It is good practice to set up the RfE before the project's start, as it ensures that objectives and outcomes align with stakeholder needs and that the project is designed to generate valuable outcomes that can be exploited effectively and efficiently. As part of WP7, we will develop an RfE (D7.6, M48) detailing the strategic approach to be made to maximise the impact of the project's outcomes even long after the project end.

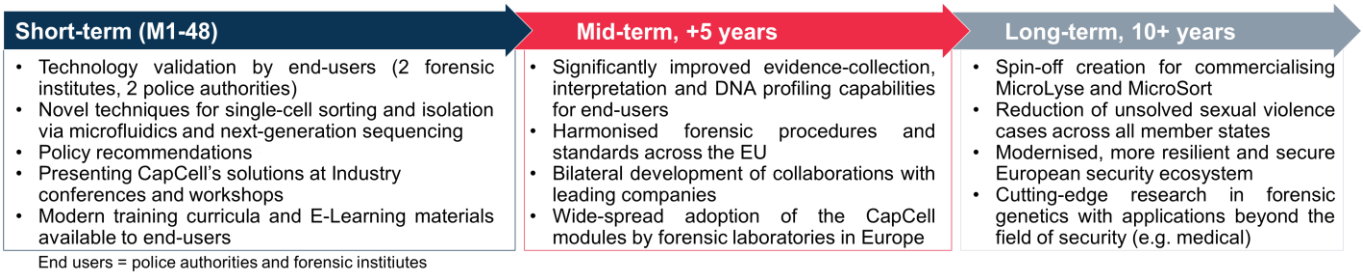


Figure 22. CapCell's exploitation timeline.

To date, there is no commercially available implemented microfluidic device that meets the specific requirements intrinsic to forensic samples. The innovative, forensically oriented CapCell platforms will overcome challenges related to low-quality samples, throughput, recovery rates and contamination. Having a mobile microfluidic device available at laboratories and eventually crime scenes significantly improves the cost-efficiency and accessibility of forensic investigations for lower-income countries which often lack this infrastructure. Also, AFCP, NimaGen and EDNAP will contribute a total of 27 PMs as in-kind contributions in staff effort, signalling strong interest from end-users and the private market for CapCell's innovations (see 3.1.2). Finally, the novel technological concepts aimed at the detection and isolation of individual low-frequency cells, can be employed to target other healthcare applications (e.g. personalised medicine, therapeutics) or advance biomedical research in areas such as cancer biology and drug development (e.g. integration with multi-omics technologies – Leuven Institute for Single Cell Omics (LISCO)). From the economic point of view, CapCell is at the interface of the following three markets: **the global forensic technology market**, with a size estimated at EUR 19.11 bio. in 2023 (CAGR of 9.5% by 2029[78]), **the forensic DNA market** with a size valued over EUR 2.37 bio. in 2022, (CAGR of 7% by 2032[79]), and, thirdly, **the global microfluidics market** is estimated to be EUR 30.85 bio. in 2024 (CAGR of 14.8% by 2029[80]). The possible exploitation avenues we foresee after the project end are:

- Further development and licensing of MicroSortFX and MicroLyseFX for forensic analysis. We plan to create novel IP, both on the general microfluidic concepts, as well as on the novel sample preparation protocols and target detection strategies. This knowledge is expected to generate direct interest from leading forensic analysis companies (e.g. Thermo Fisher Scientific, Abbott, Verogen, Qiagen) as well as leading microfluidics players (e.g. Atrandi Biosciences, Livedrop). Through **bilateral development collaborations**, we can raise the TRLs of these technologies and enter **non-exclusive licensing options** to facilitate their future commercialisation.
- Establish an **international reference centre for forensic analysis**, covering the whole chain. By offering a superior analytical platform, we expect to establish a European hotspot for forensic analysis, enabling licensing deals or carrying out fee for service contracts providing access to our technological solutions.
- **Spin-off creation** for commercialising MicroLyseFX and MicroSortFX (devices, microfluidic chips & reagent kits). SME partner Voxdale and academic partner KUL-MeBioS are well experienced in spin-off creation (e.g. FOx Biosystems a spin-off of the Biosensors group) and translating scientific advances into commercial products.

[78] Global Forensic Technologies and Services Market Insights, 2024-2030 - Rise in Gun Violence Driving Demand for Forensic Ballistics
[79] DNA Forensic Market industry analysis – GMI Insights
[80] Microfluidics market size (2024 – 2029) – Mordor Intelligence

2.3 Summary

Table 6. Impact summary table.

Specific needs	Expected results	D & E & C measures
Inefficiency in biological evidence collection: Practitioners are unable to selectively collect individual cells of interest from mixed biological traces, in particular in sexual crimes. **Difficulty in interpreting mixed evidence:** Generated DNA profiles are often comprised of DNA from multiple individuals, complicating analysis and hindering interpretation. **Slow identification and investigation:** Complex DNA evidence delays conclusive identification of perpetrators and information gathering in criminal investigations. These challenges leave **thousands of (sexual) crimes unresolved**, allowing perpetrators to evade justice and continue to commit crimes **causing significant harm to victims, their families, and society.**	**Mobile selective biological evidence analysis (WP2 and WP3):** Modular and portable intact cell collection and microfluidics-based isolation systems to specifically collect and isolate male nucleated cells of interest (sperm or other types of cells) at high speed, high sensitivity and low cost at any location. **Novel single-cell sequencing and analysis methods (WP4 and WP5):** Cutting-edge DNA sequencing and AI-based analysis tools allowing for automated and more precise DNA profiling and human identification in the forensic community. **Training strategy and new tools for practitioners (WP6):** Modern training curricula and implementation modules across European forensic labs to integrate novel modular tools with current practices. **CapCell's toolkit will provide 10 modules,** reaching up to TLR-7, which can be plugged into existing forensic platforms to modernise the European and international forensic genetic landscape.	**Communication:** CapCell will employ a variety of communication channels, including a dedicated project website, social media platforms, and digital and print materials to effectively share updates and results with stakeholders and the general public. **Dissemination:** Efforts will include publishing project findings in peer-reviewed open-access journals and presenting at international and national security conferences. Events will be held to discuss technological developments and future R&I. **Exploitation:** Activities will focus on developing eLearning tools and training materials for end-users and facilitating the widespread uptake of CapCell modules. The exploitation roadmap will develop a strategy for future commercial and non-commercial use of results. **Stakeholder involvement:** focusing on the European forensic community and on collaboration with European initiatives (Security Cluster) will maximise outreach, drive the uptake of CapCell modules and safeguard fundamental rights of citizens.
Target groups	**Outcomes**	**Impacts**
Academic & Research Practitioner End-users Forensic & Security Organisations Policy & Regulatory Stakeholders Industry Society & General Public	**Enhanced forensic evidence collection:** Practitioners use advanced technologies, including mobile devices, for more efficient and effective biological evidence collection, improving forensic outcomes. **Improved criminal identification:** Single-cell isolation, sequencing and AI-based DNA profiling enables more powerful identification, even with limited mixed trace evidence. **Increased admissible court evidence:** Novel and successfully implemented forensic tools enhance profile interpretation from mixed traces, resulting in more admissible evidence for court cases. The widespread adoption of CapCell by end-users will **modernise forensic practices** and **benefit thousands of crime victims** in Europe.	**Transformative research:** CapCell advances forensic genetics, drives innovation, and strengthens the European forensic technology market, including through applications beyond the forensics field. **Enhanced European crime-solving and security:** Improved perpetrator identification capabilities and increased case resolution boost public trust and security across Europe. **Improved EU security ecosystem:** CapCell fosters collaboration, standardised procedures, and cost-effective practices, enhancing cross-border cooperation and the competitiveness of Europe's legal system. CapCell benefits all stakeholders, **reinforcing trust in the legal system** and **driving competitiveness and innovation in Europe**.

3 Quality and efficiency of the implementation

The CapCell project is organised into 7 integrated work packages (WPs) as shown in Figure 23. WP1 handles coordination, project management, innovation, and synergy while WP7 manages communication, disseminates project results, and supports exploitation (uptake) at the end of the project.

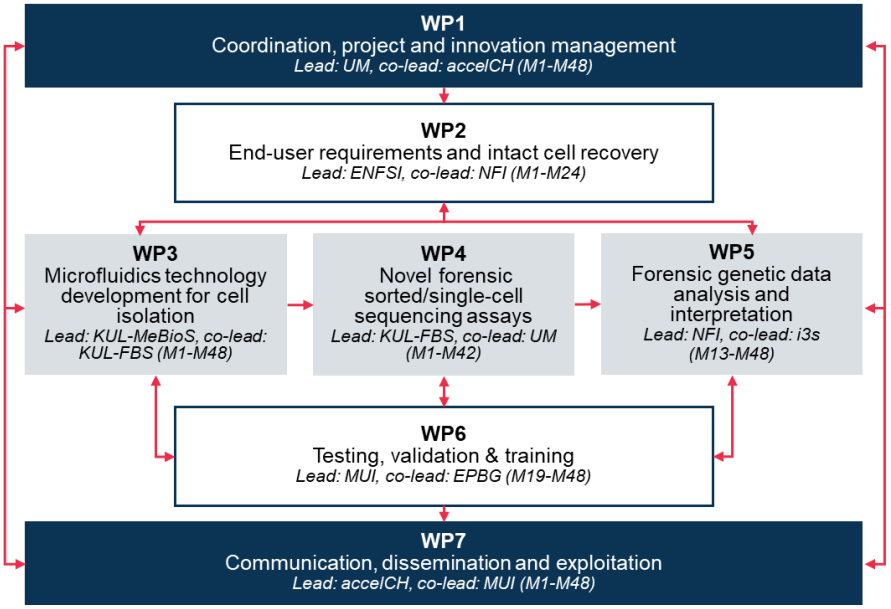


Figure 23: CapCell work plan.

While WPs 1 and 7 run throughout the project, the end-user requirement-driven WP2 and the technology-oriented research WPs 3 and 4 all start at the project's beginning. WP2 and WP3 will work and communicate closely to align the module design and development with what is possible from and for forensic traces. Particularly, WP2 will inform WP3 on the expected intact cell recovery at several time points during microfluidics development: M12 based on the evaluation of what is currently possible with routine evidence collection strategies and at M18 when improved cell collection, recovery and transfer strategies will have been developed. On the other hand, WP3 will inform WP2 early on minimum microfluidic requirements for successful cell pre-selection and isolation, particularly in terms of cell quantity and eluate quality. Best practices and recommendations for mixed biological evidence collection from WP2 will be shared at M24 and used by forensic institutes and police labs continuously while testing and validating the follow-up modules, but especially in WP6 during the demonstration of MicroLyseFX-based workflows.

WP3 and WP4 will also work and communicate closely to align the module design and development with what is possible from and for the MicroLyseFX and MicroSortFX outputs. Parallel developments of late-stages of MicroLyseFX I prototype (M13-18) and the fine-tuned laboratory tools will allow for smooth integration. This is strongly facilitated by the close proximity of the two KUL partners. Additionally, for MicroSortFX, initial inputs can be evaluated early with the novel forensic single-cell DNA assays to be developed to guide further advancement. Necessary adjustments can also take place in WP4 based on the size of SPCs and other technical requirements revealed in WP3. Additionally, as WP5 will use the technologies of WPs 3 and 4, it can start in the second project year (M13) and will provide continuous analysis to WP4 for further refinement of the CapCell modules. For this reason, the timelines of coupled wet- and dry-lab tasks are synchronised. By joining partner's expertise during these complex tasks, we enable early testing and feedback for each module. Similarly, the testing and validation of the individual modules and the integrated solution in WP6 can only start after the first results from WPs 3 to 5 are available and last until the project ends. Our goal is to start testing, validating and implementing as the different modules become available throughout the project. This is essential for the development of the adjusted, novel and AI-based data analysis tools. The timings of the different WPs, tasks and deliverables as listed in the work package descriptions (DoA, Part A) and Figure 24 allow for an iterative technology development process with several feedback loops.

3.1 Work plan and resources

CapCell GANTT

Leader (L) / Deputy (D) / Partner (P); Year 1–4; RP1 (months 1–18), RP2 (months 19–36), RP3 (months 37–48)

Task	Start	End	1 UM	2 KUL	3 I3S	4 MUI	5 NFI	6 EFSI	7 EPBG	8 AFCP	9 COPAN	10 NimaGen	11 Voxdale	12 accelCH	13 EDNAP	Milestones / Deliverables (months 1–48)
WP1 Coordination, project and innovation management	**1**	**48**	**L**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**D**	**P**	MS1, MS17
T1.1 Coordination, organisation and administration	1	48	L													D1.1
T1.2 Progress monitoring, reporting and financial management	1	48	L											P		D1.1
T1.3 Project data management, FAIR data concept and ethics	1	48	L	P	P	P	P	P	P	P	P	P	P	P	P	D1.2, D1.4
T1.4 Quality assurance and risk management	1	48	L	P	P	P	P	P	P	P	P	P	P	D	P	D1.3, D1.5
T1.5 Innovation and IP management	1	48	D	L	P	P	P	P	P	P	P	P	P	P	P	D7.6
WP2 End-user requirements and intact cell recovery	**1**	**24**	**P**	**P**		**P**	**D**	**L**	**P**	**P**	**P**				**P**	MS2, MS4, MS5
T2.1 Establish end-users casework needs	1	6		P		L	P	P	P	P					P	D2.1
T2.2 Evaluation of routine evidence collection strategies	1	14		P		P	P	L	P	P						D2.2
T2.3 Improvement of intact cell recovery and transfer	1	18				P	P	L	P	P	P					D2.3
T2.4 Establishment of novel best practices & recommendations	19	24	P	P		P	L	P	P	P					P	D2.4
WP3 Microfluidics technology development for cell sorting	**1**	**48**	**P**	**L**		**P**		**P**					**P**			MS3, MS6, MS13, MS14, MS16
T3.1 MicrolyseFX: Isolating sperm cells from postcoital swabs	1	18		L				P								D3.1, *
T3.2 MicrosortFX: Isolating male cells from touch deposits	7	42	P	L				P								*
T3.3 MicrolyseFX & MicrosortFX isolation efficiency evaluation	19	46	P	L												D3.2, D3.4
T3.4 Development of MycrolyseFX & MicrosortFX products	21	48		P		P		P					L			D3.3, D3.5
WP4 Novel forensic sorted/single-cell sequencing assays	**7**	**42**	**D**	**L**		**P**						**P**				MS7, MS8/MS9, MS15
T4.1 Existing CE and MPS protocols for integration of MicrolyseFX	13	24	P	L								P				*, D4.1
T4.2 Development of novel forensic STR / SNP MPS assays	7	30	P	L												D4.2
T4.3 Application of long-range RC-PCR mtDNA LRS assay	25	36	P	P		P						L				D4.3
T4.4 Development of novel 1-cell-1-read STR/SNP LRS assays	7	42	L	P								P				D4.4
WP5 Forensic genetic data analysis and interpretation	**13**	**48**	**P**	**P**	**D**	**P**	**L**									MS10/MS11
T5.1 Analysis and interpretation pipelines used with routine CE and MPS	13	27		P	P	P	L									D5.1
T5.2 Update of bioinformatics and interpretation pipelines	13	36		P	L		P									D5.2
T5.3 Pipelines to analyse the new forensic single-cell STR/SNP data	13	42	P		P		L									D5.4
T5.4 Pipelines to analyse the new forensic single-cell mtDNA LRS data	25	36	P			L	P									D5.3
T5.5 Novel machine learning-based algorithms	13	48			L	P	P									D5.5
WP6 Testing, validation and training	**19**	**48**	**P**	**P**	**P**	**L**	**P**	**P**	**D**	**P**	**P**	**P**	**P**		**P**	MS12
T6.1 Training of forensic researchers & practitioners on CapCell tools	19	42				L										D6.1, D6.4
T6.2 Implementation of novel analysis and statistical tools	25	30		P	P	P	P	P	L	P					P	D6.2
T6.3 Analysis of isolated sperm cell pools & test demonstration	31	36	P	L		P	P	P	P	P		P			P	D6.3
T6.4 Testing and validation of MicroSort-suited single-cell MPS/LRS	31	48	P	P	P	L	P									D6.5
T6.5 Operation demonstration of a mobile integrated MicroLyseFX	37	48	P	P	P	P	P	P	P	P	P		L		P	D6.6
WP7 Communication, dissemination and exploitation	**1**	**48**	**P**	**P**	**P**	**D**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**L**	**P**	
T7.1 Stakeholder mapping and engagement	1	48	P	P	P	L	P	P	P	P	P	P	P	D	P	D7.3
T7.2 Target-group-oriented mutli-channel communication	1	48	P	P	P	P	P	P	P	P	P	P	P	L	P	D7.1, D7.2, D7.3
T7.3 Stakeholder-oriented scientific dissemination	3	48	D	P	P	L	P	P	P	P	P	P	P	P	P	D7.2, D7.3
T7.4 End-user focused exploitation activities	13	48	P	L	P	P	P	P	P	P	P	P	P	D	P	D7.5, D7.6

Legend: Research org; Forensic institute (end-user); Police authority (end-user); Industry; Impact org — end RP1, end RP2, end RP3

Figure 24. CapCell GANTT chart (* Milestones placed at end of tasks to ensure task has been accomplished**.**)

3.1.1 Resources

The overall project costs amount to EUR 4,940,058.75 including the costs of accelCH from Switzerland but without the substantial in-kind contributions of several partners, while the **requested EU funding amounts to EUR 4,499,308.75.**

Table 7. Summary of staff effort (Table 3.1f).

#	Short name	WP1	WP2	WP3	WP4	WP5	WP6	WP7	Total PMs
1	UM	**18.0**	3.0	3.0	36.0	12.0	12.0	6.0	**90.0**
2	KUL	3.0	3.0	80.0	27.0	6.0	5.0	3.0	**127.0**
2a	*KUL-FBS*	*1.0*	*0.0*	*24.0*	***24.0***	*6.0*	*3.0*	*1.0*	***59.0***
2b	*KUL-MeBioS*	*2.0*	*3.0*	***56.0***	*3.0*	*0.0*	*2.0*	*2.0*	***68.0***
3	I3S	1.0	0.0	0.0	0.0	27.5	6.0	1.0	**35.5**
4	MUI	1.0	9.0	2.0	2.0	10.0	**24.0**	5.0	**53.0**
5	NFI	1.0	9.0	0.0	0.0	**24.0**	6.0	1.0	**41.0**
6	EFSI	1.0	**21.0**	1.0	0.0	0.0	10.0	1.0	**34.0**
7	EPBG	2.0	3.0	0.0	0.0	0.0	9.0	2.0	**16.0**
8	AFCP	2.0	3.0	0.0	0.0	0.0	9.0	4.0	**18.0**
9	COPAN	0.5	14.0	0.0	0.0	0.0	1.0	0.5	**16.0**
10	NimaGen	1.0	0.0	0.0	9.0	0.0	1.0	1.0	**12.0**
11	Voxdale	1.0	0.0	24.0	0.0	0.0	6.0	1.0	**32.0**
12	accelCH	12.0	0.0	0.0	0.0	0.0	0.0	**16.0**	**28.0**
13	EDNAP	1.0	4.0	0.0	0.0	0.0	2.0	2.0	**9.0**
	Total PM	**44.5**	**69.0**	**110.0**	**74.0**	**79.5**	**91.0**	**43.5**	**511.5**

As can be seen from Table 12, most staff effort in CapCell is foreseen in WP3 with a total of 110 PMs. WP6 follows with 91 PMs, where all partners (except accelCH) will contribute to the testing, validation and training of the CapCell outcomes. Additionally, all partners have foreseen at least 1 PM for the management (WP1) and the dissemination, communication and exploitation (WP7) of the project.

Several partners have foreseen to provide staff efforts as in-kind contributions as they have high interest in participating in the project: 18 PMs from AFCP, 10 PMs from NimaGen related to WP4 and WP6, corresponding to a contribution of at least EUR 55,000, and 9 PMs from EDNAP.

Additionally, the participation of the associated partner accelCH will be entirely funded by the Swiss State Secretariat for Education, Research, and Innovation (SERI), corresponding to a contribution of EUR 440,750. Together, these in-kind and SERI contributions leverage the total project cost well above EUR 5,200,000.

Table 3.1g 'Subcontracting costs' items – not foreseen in the project.

Table 8. 'Purchase costs' items (travel and subsistence, equipment and other goods, works and services) (Table 3.1h).

1	UM	Cost (€)	Justification
	Travel and subsistence	€ 18,400.00	4 Consortium meetings 3 attendees (EUR 12,000); 4 Conferences & workshops 2 attendees (EUR 6,400)
	Equipment	€ 28,000.00	Atrandi Biosciences FLUX instrument (EUR 20,000); ONT MinION instrument (EUR 5,000), Power laptop for data analysis (EUR 3,000)
	Other goods, works and services	€ 124,000.00	Reagents & consumables (EUR 100,000); Open Access (EUR 12,000 WP4); Audit (EUR 7,000); Data management (EUR 5,000);
	Total	**€ 170,400.00**	
2	**KUL**	**Cost (€)**	**Justification**
	Travel and subsistence	€ 42,800.00	Travels of Scientific Advisory Board members to meetings (EUR 10,000) allocated to KUL-FBS staff, 4 consortium meetings 2 attendees (EUR 6,400) allocated to KUL-FBS staff, 4 conferences & workshops of postdocs (EUR 10,000) allocated to KUL-FBS staff; Conferences & workshops 7 attendees (EUR 10,000) allocated to KUL-MeBioS staff; 4 Consortium meetings 2 attendees (EUR 6,400) allocated to KUL-MeBioS staff.
	Equipment	€ 20,000.00	Atrandi Biosciences FLUX instrument (EUR 20,000), allocated to KUL-MeBioS.
	Other goods, works and services	€ 253,250.00	Reagents, lab consumables, microfluidic materials, small lab equipment (EUR 20,000 WP3 + EUR 87,000 WP4) allocated to KUL-FBS; Cloud data storage (EUR 5,000) allocated to KUL-FBS; Reagents, lab consumables, microfluidic materials, small lab equipment CR (EUR 120,000) allocated to KUL-MeBioS; Data storage (EUR 7,750) allocated to KUL-MeBioS, Open Access (EUR 6,000) allocated to KUL-MeBioS, Audit (EUR 7,500).
	Total	€ 316,050.00	
4	**MUI**	**Cost (€)**	**Justification**
	Travels	€ 30,000.00	Travels of Scientific Advisory Board members to meetings (EUR 10,000), 4 consortium meetings 2 attendees (EUR 10,000), 4 conferences & workshops 1 attendee (EUR 5,000), research visits to Leuven (EUR 5,000)
	Other GW&S	€ 48,000.00	WP6 Reagents, chemicals and lab consumables (EUR 43,000), Audit (5,000)
	Total	**€ 78,000.00**	
6	**EFSI**	**Cost (€)**	**Justification**
	Travels	€ 10,000.00	4 Consortium meetings 2 attendees (EUR 10,000)
	Equipment	€ 8,540.00	4 year depreciation costs for Countess 3 (EUR 8,540)
	Other GW&S	€ 32,150.00	The purchase of consumables and reagents for carring out WP2 (EUR 15.860 for Task 2.2: Swabs, buffers, DNA extrcation & CE STR analysis reagents, filters.; EUR 10,800 for Task 2.3) and WP6 tasks (EUR 5.490: NA extration, quantification, CE STR analysis reagents).
	Total	**€ 50,690.00**	
7	**EPBG**	**Cost (€)**	**Justification**
	Travels	€ 10,000.00	4 Consortium meetings 2 attendees (EUR 10,000)
	Other GW&S	€ 500.00	Evidence collection kits WP6 (EUR 500)
	Total	**€ 10,500.00**	
8	**AFCP**	**Cost (€)**	**Justification**
	Travels	€ 10,000.00	4 Consortium meetings 2 attendees (EUR 10,000)
	Total	**€ 10,000.00**	
9	**COPAN**	**Cost (€)**	**Justification**
	Travels	€ 5,200.00	4 Consortium meetings 1 attendee (EUR 3,200); Conference fees (EUR 2,000)
	Other GW&S	€ 22,500.00	Chemical and cell culture reagents, biological reference samples (e.g., ATCC cell lines, commercial sperm samples, EUR 13,500); Plastic consumables (e.g., tubes, wells plate, pipette tips, hemocytometer, EUR 6,000); Swabs products (e.g., 4N6 FLOQSwabs, EUR 3,000);
	Total	**€ 27,700.00**	
10	**NimaGen**	**Cost (€)**	**Justification**
	Travels	€ 5,000.00	4 Consortium meetings 1 attendee (EUR 5,000)
	Other GW&S	€ 47,902.00	IDseek® Mitochondrial DNA Full Genome Sequencing Kit 96 rxn (6 kits WP4 EUR 9,540, 4 kits WP6 EUR 6,360); IDseek® CombiSTR™ Plus Autosomal and Y-Chromosomal STR Profiling Kit 96 rxn (3 kits WP4 EUR 6,390, 4 kits WP6 EUR 8,520) Unique Dual Index Primer Plate 96 rxn (6 kits WP4 EUR 1,668, 8 kits WP6 EUR 2,224) 2x Unique Dual Index Primer Plate 96 rxn (6 kits WP4 EUR 3,300, 4 kits WP6 EUR 2,200) IDseek® OmniSNP™ Identity Informative SNP Typing Kit 96 rxn (3 kits WP4 EUR 3,300, 4 kits WP6 EUR 4,400)
	Total	**€ 52,902.00**	

In CapCell, we foresee to organise annual in-person consortium meetings for which we budgeted on average EUR 1,250 per attendee per meeting for all beneficiaries. An Open Access budget is foreseen for the academic partners to ensure adherence to the Open Science principles. Reagents and chemicals for WP6 are centrally budgeted at MUI who will then distribute to beneficiaries as needed.

Table 3.1i 'Other costs categories' items – Not applicable.
Table 3.1j 'In-kind contributions' provided by third parties – Not applicable.

3.1.2 Affiliated Entities

Not applicable.

3.1.3 Associated Partners

CapCell includes two Associated Partners whose expertise and experience are required to achieve the project objectives.

1. **accelCH** leads WP7 and is essential for the implementation of the communication, dissemination and exploitation of CapCell and its results. Furthermore, it will support the administration of the project, working closely with the coordinator (WP1). Details of accelCH's activities are provided in the respective work package descriptions. accelCH will be funded by the Swiss Secretariat for Education, Research and Innovation (SERI) through its guarantee funding scheme, which applied to the 2024 Horizon Europe calls.

Table 9. Overview of accelCH's budget, to be funded through SERI's guarantee funding scheme.

			Estimated expenditure						
#	Short name	Country	A. Personnel costs / €	C. Purchase costs			D. Other costs categories	E. Indirect costs / € (25% * (A+C))	Total Eligible costs / € (A+B+C+D+E)
				C.1 Travel and subsistence / €	C.2 Equipment / €	C.3 Other goods, works and services / €	D.4 Virtual access to Research Infrastructure		
12	accelCH	Switzerland	€ 327,600.00	€ 20,000.00	€ -	€ 5,000.00	€ -	€ 88,150.00	€ 440,750.00

2. **EDNAP** is required to represent key stakeholders and their interests and requirements in CapCell. As a stakeholder representative, EDNAP facilitates the widespread testing and update of the CapCell innovations, allowing the consortium to collect feedback from the wider forensic communities during the development process (WPs 1-2, 6-7). EDNAP provides its efforts in kind and does not request EU funding.

3.2 Capacity of participants and consortium as a whole

CapCell's consortium brings all the required expertise and experience to successfully conduct the project. Its **multidisciplinary consortium** of 13 partners from 8 European countries features key expertise in forensic DNA profiling, including 3 forensic institutes (including MUI) and 2 police forces as end-users. Coordinated by a woman, about half of our partners` team leaders are female and our Innovation Manager contributes further to the gender balance.

Access to top-tier infrastructure: Partners' premises provide cutting-edge infrastructure designing, developing and validating the new modules. UM led by Assoc. Prof. Vidaki brings key nanopore sequencing equipment from Maastricht University Medical Centre, KUL led by Prof. Lammertyn offers key microfluidics, imaging and microfabrication infrastructure, NFI led by Prof. Sijen offers access to software used across European forensic institutes, while MUI led by Prof. Parson offers access to one of the world's most productive forensic DNA labs and to the wide network of ENFSI, where he has co-chaired the DNA working group's subgroup b for many years.

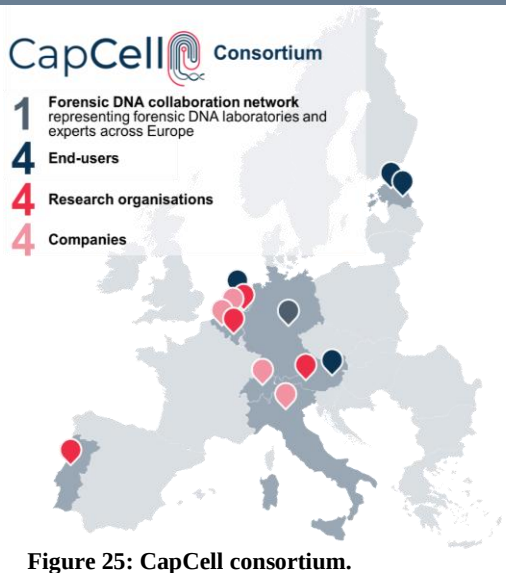


Figure 25: CapCell consortium.

Extensive expertise: Prof. Jeroen Lammertyn (WP3), an innovator and leader in microfluidics with 12 patents and an h-index of 71. Assoc. Prof. Bram Bekaert (WP4), is a DNA expert witness with strong record in forensic casework research and a h-index of 31. Prof. Titia Sijen (WP5), h-index of 53, leads a team that pioneers forensic casework analysis, contributing to several EU-funded projects. Prof. Walther Parson (WP6), a renowned figure in forensic genetics with 450+ publications and an h-index of 93, further strengthens CapCell' academic excellence. This expertise in forensics, biosensors, biomarkers and bioinformatics, combined with promising pilot data, and the involvement of end-users handling thousands of cases annually, makes CapCell scientifically robust and set for success.

Private sector involvement: Three SMEs and one industrial partner will significantly contribute to the project:

- **COPAN**, a leading industry player in microbiological sample collection and transport is a key player in the forensic sample collection market, with its dedicated product lines (4N6 FLOQSwabs®, microFLOQ®, NUCLEIC-CARD™, NAO®Basket) used by many European Police forces and forensic institutes reflecting its strong global collaborations in the field. Copan will contribute its expertise to CapCell by developing novel collection and transport devices optimised for microfluidic workflows.
- **NimaGen** introduces a disruptive approach to forensic DNA analysis using MPS, based on patented Reverse Complement PCR technology (IDseek®). This innovative system offers a closed-tube, single reaction library preparation workflow for Illumina® platforms, utilising full length paired-end sequencing facilitating the transition from classic capillary electrophoresis to MPS for STR profiling, SNP identification, and mtDNA sequencing with exceptional sensitivity, robustness, safety and simplicity. Within CapCell, NimaGen will pioneer whole mitochondrial genome sequencing from single cells.
- **Voxdale** is an expert in designing and engineering hardware products, of which a large part is medical devices. Voxdale also has a start-up studio where it launches new start-ups and spin-offs together with research institutions. The SME has significant experience in the development of diagnostics platforms with microfluidics cartridges, photonic and optic read-outs. In CapCell their expertise will be leveraged to build an integrated workflow and automation setup as a start, and later to go towards an integrated system or product.
- **accelCH**, a leading EU project management company, brings over 20 years of experience in managing and disseminating European R&I projects. It will contribute to the communication, dissemination and exploitation of CapCell results with dedicated tools. Recently, accelCH organised successful Cluster Events in areas like digital health, showcasing numerous EU-funded projects. Funding is provided by SERI.

Stakeholder involvement: We will collaborate with various stakeholder groups to develop CapCell, promoting data sharing and knowledge exchange within their extensive networks, of which our partners are already members.

- **EDNAP**, an Associated Partner, harmonises DNA typing technology for crime investigations through collaborative exercises and inter-laboratory comparisons, and has contributed to establishing European standards for STR loci, as well as advanced forensic techniques like mtDNA sequencing and SNP analysis for appearance and biogeographical ancestry estimation.
- **Expert advisory board:** Outside of the immediate consortium, CapCell has established a committed expert advisory group (shown on page 2) to assist the project in its implementation.

4 Ethics self-assessment

4.1 Ethical dimension of the objectives, methodology and likely impact

The CapCell project, aimed at advancing forensic capabilities through single-cell DNA analysis, inherently addresses ethical considerations spanning its objectives, methodology and anticipated impact.

CapCell focuses on improving forensic DNA profiling in complex cases including sexual and domestic violence, where victims are often vulnerable populations, such as women, minors, and marginalized groups. Ethical concerns arise in ensuring these individuals are not further stigmatized or harmed by forensic investigations. As the project targets cases where women and minors are predominantly victims, it recognizes the sensitivity of addressing gender-based violence and potential social stigmatization.

Single-cell DNA analysis inherently involves the collection and processing of highly sensitive genetic information, that could raise significant privacy concerns. Additionally, in principle forensic samples may indirectly reveal familial relationships, which are beyond the intended forensic scope. The methodology involves the use of biological samples, some of which could originate from cases involving minors or vulnerable individuals, such as survivors of sexual violence. Moreover, the advanced capabilities of single-cell DNA analysis could raise concerns about potential misuse, such as unauthorized surveillance, profiling, or applications beyond lawful forensic investigations. Furthermore, microfluidic devices and reagents used in CapCell may contribute to laboratory waste, raising concerns about the environmental sustainability of the methodology.

Enhanced forensic capabilities may inadvertently contribute to the stigmatization of specific groups if forensic profiling is misapplied or leads to biased practices. For example, advanced DNA profiling could disproportionately affect certain communities if misinterpreted or used without context. Also, the adoption of CapCell's advanced forensic technologies may strain smaller forensic labs with limited budgets or resources, potentially creating disparities in access and implementation across EU member states. On top, CapCell has the potential to significantly impact public trust in forensic science and law enforcement. While increased resolution of cases can bolster confidence, misuse or errors in the application of new technologies could undermine public trust.

4.2 Compliance with ethical principles and relevant legislations

The project strictly adheres to legal and ethical guidelines in forensic practice, including the ethical handling of biological evidence. Stakeholder consultation ensures alignment with EU directives such as Directive 2012/29/EU, which establishes minimum standards for victims' rights. CapCell ensures that its objectives prioritize justice for victims while avoiding approaches that may inadvertently reinforce stereotypes or biases.

The project implements robust data protection measures, adhering to GDPR requirements and forensic data-specific guidelines. Anonymization techniques are applied to all data at collection, analysis, and storage stages, ensuring personal identities remain protected. Local ethical oversight committees will approve and monitor compliance with privacy standards. Only anonymized mock casework samples will be used during testing and validation phases. These include previously consented samples, spiked mixtures, and proficiency test materials. Where real casework samples are required for operational testing, informed consent from individuals or their legal guardians is mandatory. All procedures align with ISO 17025:2017 standards to ensure ethical sample handling. CapCell restricts its technology to legitimate forensic purposes and collaborates with law enforcement agencies under strict oversight. The consortium implements strict guidelines and safeguards to prevent the misuse of the tools and methods developed. Moreover, the project explores the use of biodegradable materials and reusable components for microfluidic devices where feasible. Sustainability is integrated into all protocols, including waste management practices compliant with environmental regulations.

The project emphasizes unbiased, scientifically rigorous methods. Training programs ensure practitioners understand the importance of context in forensic interpretation and avoid reinforcing societal biases. The consortium is also committed to scalability and accessibility. Training programs and dissemination efforts are designed to ensure equitable adoption. Additionally, the project prioritizes transparency and accountability. Regular stakeholder engagement ensures alignment with societal expectations, and adherence to ENFSI and ISO standards reinforces reliability and credibility.

Overall, CapCell will integrate ethical oversight throughout its activities, also guided by multidisciplinary External Advisory Board, which among others will ensure all project phases adhere to ethical, legal and social standards.

5 Security

No security issues.

ANNEX 2

ESTIMATED BUDGET FOR THE ACTION

	Estimated eligible[1] costs (per budget category)											Estimated EU contribution[2]			
	Direct costs									Indirect costs	Total costs	EU contribution to eligible costs			Maximum grant amount[6]
	A. Personnel costs				B. Subcontracting costs	C. Purchase costs			D. Other cost categories	E. Indirect costs[3]		Funding rate %[4]	Maximum EU contribution[5]	Requested EU contribution	
	A.1 Employees (or equivalent) 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	C.1 Travel and subsistence	C.2 Equipment	C.3 Other goods, works and services	D.2 Internally invoiced goods and services	E. Indirect costs					
Forms of funding	Actual costs	Unit costs (usual accounting practices)	Unit costs[7]	Unit costs[7]	Actual costs	Actual costs	Actual costs	Actual costs	Unit costs (usual accounting practices)	Flat-rate costs[8]					
	a1	a2	a3	a5	b	c1	c2	c3	d2	e = 0,25 * (a1 + a2 + a3 + a5 + c1 + c2 + c3)	f = a+b+c+d+e	U	g = f * U%	h	m
1 - UM	539 010.00	0.00	0.00	0.00	0.00	18 400.00	28 000.00	124 000.00	0.00	177 352.50	886 762.50	100	886 762.50	886 762.50	886 762.50
2 - KUL	978 611.00	0.00	0.00	0.00	0.00	42 800.00	20 000.00	253 250.00	0.00	323 665.25	1 618 326.25	100	1 618 326.25	1 618 326.25	1 618 326.25
3 - i3S	144 305.00	0.00	0.00	0.00	0.00	10 000.00	4 055.00	5 000.00	0.00	40 840.00	204 200.00	100	204 200.00	204 200.00	204 200.00
4 - MUI	399 907.00	0.00	0.00	0.00	0.00	30 000.00	0.00	48 000.00	0.00	119 476.75	597 383.75	100	597 383.75	597 383.75	597 383.75
5 - NFI	341 878.00	0.00	0.00	0.00	0.00	10 000.00	0.00	5 000.00	0.00	89 219.50	446 097.50	100	446 097.50	446 097.50	446 097.50
6 - EFSI	101 400.00	0.00	0.00	0.00	0.00	10 000.00	8 540.00	32 150.00	0.00	38 022.50	190 112.50	100	190 112.50	190 112.50	190 112.50
7 - EPBG	65 539.00	0.00	0.00	0.00	0.00	10 000.00	0.00	500.00	0.00	19 009.75	95 048.75	100	95 048.75	95 048.75	95 048.75
8 - AFCP	0.00	0.00	0.00	0.00	0.00	10 000.00	0.00	0.00	0.00	2 500.00	12 500.00	100	12 500.00	12 500.00	12 500.00
9 - COPAN	95 000.00	0.00	0.00	0.00	0.00	5 200.00	0.00	22 500.00	0.00	30 675.00	153 375.00	100	153 375.00	153 375.00	153 375.00
10 - NimaGen	20 000.00	0.00	0.00	0.00	0.00	5 000.00	0.00	47 902.00	0.00	18 225.50	91 127.50	100	91 127.50	91 127.50	91 127.50
11 - Voxdale	150 500.00	0.00	0.00	0.00	0.00	10 000.00	0.00	3 000.00	0.00	40 875.00	204 375.00	100	204 375.00	204 375.00	204 375.00
12 - accelCH															
13 - EDNAP															
Total consortium	2 836 150.00	0.00	0.00	0.00	0.00	161 400.00	60 595.00	541 302.00	0.00	899 861.75	4 499 308.75		4 499 308.75	4 499 308.75	4 499 308.75

[1] See Article 6 for the eligibility conditions. All amounts must be expressed in EUR (see Article 21 for the conversion rules).
[2] The consortium remains free to decide on a different internal distribution of the EU funding (via the consortium agreement; see Article 7).
[3] Indirect costs already covered by an operating grant (received under any EU funding programme) are ineligible (see Article 6.3). Therefore, a beneficiary/affiliated entity that receives an operating grant during the action duration cannot declare indirect costs for the year(s)/reporting period(s) covered by the operating grant, unless they can demonstrate that the operating grant does not cover any costs of the action. This requires specific accounting tools. Please immediately contact us via the EU Funding & Tenders Portal for details.
[4] See Data Sheet for the funding rate(s).
[5] This is the theoretical amount of the EU contribution to costs, if the reimbursement rate is applied to all the budgeted costs. This theoretical amount is then capped by the 'maximum grant amount'.
[6] The 'maximum grant amount' is the maximum grant amount decided by the EU. It normally corresponds to the requested grant, but may be lower.
[7] See Annex 2a 'Additional information on the estimated budget' for the details (units, cost per unit).
[8] See Data Sheet for the flat-rate.

ANNEX 2a

ADDITIONAL INFORMATION ON UNIT COSTS AND CONTRIBUTIONS

SME owners/natural person beneficiaries without salary

See Additional information on unit costs and contributions (Annex 2a and 2b)

HE and Euratom personnel unit cost

See Additional information on unit costs and contributions (Annex 2a and 2b)

HE and Euratom Research Infrastructure actions

See Additional information on unit costs and contributions (Annex 2a and 2b)

Euratom staff mobility costs

See Additional information on unit costs and contributions (Annex 2a and 2b)

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

KATHOLIEKE UNIVERSITEIT LEUVEN (KUL), PIC 999991334, established in OUDE MARKT 13, LEUVEN 3000, Belgium,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Elke LAMMERTYN with ECAS id nlammeel signed in the Participant Portal on 17/07/2025 at 16:12:11 (transaction id SigId-7239-KdFlCd89aRAl5II0hWveEAjtPZSGe5Pf2ctvdzrLPo2n8sDYO9DE1yzJueHQ76yIrhjaEAzcmi6gyFv5PUhykUG-rS0vSrmBGYChFko3rL5i90-XNsRCfwJzRc1v3hSHVv5mtzuy8zI00RUgGcsKpOhzczzQizkQXvwZ4kQ4PYjSNGg5PewIqW41vcDiLds2E5W31WC). Timestamp by third party at 2025.07.17 16:12:18 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

I3S - INSTITUTO DE INVESTIGACAO E INOVACAO EM SAUDE DA UNIVERSIDADE DO PORTO (i3S), PIC 892061180, established in RUA ALFREDO ALLEN 208, PORTO 4200-135, Portugal,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Claudio SUNKEL with ECAS id nsunkecl signed in the Participant Portal on 17/07/2025 at 12:34:39 (transaction id SigId-4211-d8SRjNJ0JY1zzp67oo5s37WziANw0y3gTgXtRF83Us6QgxvKWUlFuxDV6TefIdqmoXEEa3FMBzwlS1FAReOD6wq-rS0vSrmBGYChFko3rL5i90-0zd3S4zh4G9CupY3EFy4UzKe76qwPolLMGTWTBAAPsXScRzadQ0mhiH4zzojHe5ezKNxzNrCFjQUlmDnV0fOUMI9). Timestamp by third party at 2025.07.17 12:34:45 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

MEDIZINISCHE UNIVERSITAT INNSBRUCK (MUI), PIC 999855437, established in CHRISTOPH PROBST PLATZ 1, INNSBRUCK 6020, Austria,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Wolfram RIENECK with ECAS id nrienewo signed in the Participant Portal on 16/07/2025 at 12:34:43 (transaction id SigId-5054-kqkcKeQ24BvGzU2378cAI10ygu6zjg1AIyXJtTgIfQWGrhfzvMXpkJyp5ry4UmxTu1YzsEKhY0X4hKUhLqKqAUq-yntOf97TTHq7M1Ew4KfYfO-1iFWuegjr5IKrzUa4dAAlCF1Q65UxNJyY7K01PFc1y0yPPK5E4lB48O06MzvIzJrBwv76UfNOseaAzy0czU71j1). Timestamp by third party at 2025.07.16 12:34:49 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

Netherlands Forensic Institute (NFI), PIC 998203527, established in Laan van Ypenburg 6, The Hague 2490 AA, Netherlands,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Annemieke de Vries with ECAS id n002pq7g signed in the Participant Portal on 16/07/2025 at 17:32:42 (transaction id SigId-9025-zabG0a6VLEXzshfQAwvAUFvW7zYdmNKMiVU2pwKq040Vih7mALWI1D6ZyS0wTSS1uA7qGXnELY0Ry6gy392hGlm-yntOf97TTHq7M1Ew4KfYfO-BaNEolrhqVA3XJIpEazifhgCAtnyhYPBQbE81VFG1AGcLYLzZsQ61fnzcMpgT3Ue1Jw0PHE98WLNQ71RcXUjFoG). Timestamp by third party at 2025.07.16 17:32:55 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

EESTI KOHTUEKSPERTIISI INSTITUUT (EFSI), PIC 948698801, established in TERVISE TN 20, TALINN 13419, Estonia,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Ivar Prits with ECAS id n004923w signed in the Participant Portal on 04/08/2025 at 16:02:19 (transaction id SigId-21411-bqmOPoH3QJh7J3NkY95zVTfHy1aQkBd3BtA8Z5yD3eLNne5rD1du9ccVOaQI85azVDQLTMazpKOQen273mRzzt6-jpJZscgsw0KyS5CZsW4nI8-GiM87zzbcM8VMZLRCdQCsR4yWA6eEQD3EAxHzcORLVGSozzY61Nm2zvw2T55kmPGjXuFPhYRebaRp7bhcIEbSrKG). Timestamp by third party at 2025.08.04 16:02:24 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

Politsei- ja Piirivalveamet (EPBG), PIC 951813471, established in Pärnu mnt 139, Tallinn 15060, Estonia,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Kristi MÄE with ECAS id nmaekris signed in the Participant Portal on 11/08/2025 at 09:37:14 (transaction id SigId-54745-mAKhx39B9dxbcAU2DLqEwMbMBh1OKcl1t5LiWi13oqdkBcAIiM8SJzxzzGASQZSLaQeiIRx6YpVQNczzMzgpsczu-jpJZscgsw0KyS5CZsW4nI8-LYXIrI0OfccjEx9wbZd2ExvDyjjzNhrdTxMNmcF8juOW4EbyLvbRzpg1EnFCyyDYAgkq1NrpjVp55hCNK70vD0). Timestamp by third party at 2025.08.11 09:37:19 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

BUNDESMINISTERIUM FUR INNERES (AFCP), PIC 999826434, established in Herrengasse 7, WIEN 1010, Austria,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Reinhard SCHMID with ECAS id nschrinh signed in the Participant Portal on 28/07/2025 at 10:44:36 (transaction id SigId-10620-b5siwf BSgert8cTXkTrIm5vPEModOUFLMLzlhkc8gBdU9aMgPg34CR8MJfu7 R3mpDzycp0sCAhfxSTedG4zlD2m-jpJZscgsw0KJT7k9L9Lj3e-zXPGSE QAaKpbFmx9HvqudwGanRU9gMEfuW8Ef2ngBkzzlGhDqbivwCDL6b iH1cEq8VzL5zQ0zw4v8zpKzTqXrEVU). Timestamp by third party at 2025.07.28 10:44:41 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

COPAN ITALIA SPA (COPAN), PIC 951752846, established in VIA PEROTTI 10, Brescia 25125, Italy,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Stefania Triva with ECAS id n00igbrf signed in the Participant Portal on 17/07/2025 at 13:35:26 (transaction id SigId-4928-c427ZMD03B1FtlPESFijphuZuQVbeYmlYqhRTY0uu8nHksZaD7zhfDOxiwRbvG24bZzjNebGYVSMzcpCuNT4Zjm-rS0vSrmBGYChFko3rL5i90-gedKjT5E4tezLvgxKCxQIZatF1zunvx1zJM9MEnHuFpjVNtoZg1ftxLfzcUIIzvm6g01rSgoAzILU4EEnCkjQ5KG). Timestamp by third party at 2025.07.17 13:35:30 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

NIMAGEN BV (NimaGen), PIC 875619486, established in HOGELANDSEWEG 88, NIJMEGEN 6545 AB, Netherlands,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Rudolf van der Steen with ECAS id n00hc7af signed in the Participant Portal on 16/07/2025 at 13:40:23 (transaction id SigId-5835-pnegGjmtFkAKUWlgewdzirygYKT2qdlRzULLdpKplH7JNLDzKTZ0t0TrMelzZrBpmXXiA214Gh93KDR0xKPHn8a-yntOf97TTHq7M1Ew4KfYfO-IikxGQS0nF20AYwP8H4St3zl39HcNK1ZwubdZgjpRrzHP6jtU1kYC1FMpzh1DaUR7pc34HszUb6DSJW7zKJzpyim). Timestamp by third party at 2025.07.16 13:40:29 CEST

ANNEX 3

ACCESSION FORM FOR BENEFICIARIES

VOXDALE (Voxdale), PIC 880618090, established in BIJKHOEVELAAN 32 BOX C, WIJNEGEM 2110, Belgium,

hereby agrees

to become beneficiary

in Agreement No 101225737 — CapCell ('the Agreement')

between UNIVERSITEIT MAASTRICHT (UM) **and** the **European Research Executive Agency (REA)** ('EU executive agency' or 'granting authority'), under the powers delegated by the European Commission ('European Commission'),

and mandates

the coordinator to submit and sign in its name and on its behalf any **amendments** to the Agreement, in accordance with Article 39.

By signing this accession form, the beneficiary accepts the grant and agrees to implement it in accordance with the Agreement, with all the obligations and terms and conditions it sets out.

SIGNATURE

For the beneficiary

Tim Dieryckx with ECAS id n0045yfm signed in the Participant Portal on 28/07/2025 at 10:08:55 (transaction id SigId-10108-cXt6WgsycsZ98zpAoN5gCXovNXsY4Uzzk2ifSC2k1QEKQtJy4VN0TexlEzOQKrgi77QxPWB0KPlzP1fewUP6t5n-jpJZscgsw0KJT7k9L9Lj3e-Fqs9yRsneV5rxAIzfXo6x6tf7IojiIXogpgFF2FVF3Fak9ZFvroMiIajJCpAd7AN5V0YzJmrswOCpwzWzYCDqAO). Timestamp by third party at 2025.07.28 10:09:01 CEST

FINANCIAL STATEMENT FOR [PARTICIPANT NAME] FOR REPORTING PERIOD [NUMBER]

	Eligible[1] costs (per budget category)																	EU contribution[2]				Revenues
	Direct costs															Indirect costs	Total costs	EU contribution to eligible costs			Total requested EU contribution	Income generated by the action
	A. Personnel costs				B. Subcontracting costs	C. Purchase costs			D. Other cost categories							E. Indirect costs[2]		Funding rate %[3]	Maximum EU contribution[4]	Requested EU contribution		
	A.1 Employees (or equivalent) 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	C.1 Travel and subsistence	C.2 Equipment	C.3 Other goods, works and services	[D.1 Financial support to third parties]	D.2 Internally invoiced goods and services	[D.3 Transnational access to research infrastructure unit costs]	[D.4 Virtual access to research infrastructure unit costs]	*[OPTION for HE PCP/PPI:* D.5 PCP/PPI procurement costs*]*	*[OPTION for Euratom Programme Cofund Actions:* D.6 Euratom Cofund staff mobility costs*]*	*[OPTION for HE ERC Grants:* D.7 ERC additional funding*]*	*[OPTION for HE ERC Grants:* D.8 ERC additional funding (subcontracting, FSTP and internally invoiced goods and services)*]*	E. Indirect costs						
Forms of funding	Actual costs	Unit costs (usual accounting practices)	Unit costs[5]	Unit costs[5]	Actual costs	Actual costs	Actual costs	Actual costs	[Actual costs]	Unit costs (usual accounting practices)	[Unit costs[5]]	[Unit costs[5]]	[Actual costs]	[Unit costs[5]]	[Actual costs]	[Actual costs]	Flat-rate costs[6]						
	a1	a2	a3	a5	b	c1	c2	c3	[d1a]	d2	[d3]	[d4]	[d5]	[d6]	[d7]	[d8]	e = 0,25 * (a1 + a2 + a3 + a5 ~~+ b~~ + c1 + c2 + c3 ~~+ d1a + d2 + d3 + d4 + d5~~~~[~~ + d6~~]~~ [+ d7] ~~[+ d8]~~)	f = a+b+c+d+e	U	g = f*U%	h	m	n
XX – [short name beneficiary/affiliated entity]																						

The beneficiary/affiliated entity hereby confirms 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 documentation that will be produced upon request or in the context of checks, reviews, audits and investigations (see Articles 19, 20 and 25).

For the last reporting period: that all the revenues have been declared (see Article 22).

ⓘ Please declare all eligible costs and contributions, even if they exceed the amounts indicated in the estimated budget (see Annex 2). Only amounts that were declared in your individual financial statements can be taken into account lateron, in order to replace costs/contributions that are found to be ineligible.

[1] See Article 6 for the eligibility conditions. All amounts must be expressed in EUR (see Article 21 for the conversion rules).

[2] If you have also received an EU operating grant during this reporting period, you cannot claim indirect costs - unless you can demonstrate that the operating grant does not cover any costs of the action. This requires specific accounting tools. Please contact us immediately via the Funding & Tenders Portal for details.

[3] See Data Sheet for the reimbursement rate(s).

[4] This is the *theoretical* amount of EU contribution to costs that the system calculates automatically (by multiplying the reimbursement rates by the costs declared). The amount you request (in the column 'requested EU contribution') may be less.

[5] See Annex 2a 'Additional information on the estimated budget' for the details (units, cost per unit).

[6] See Data Sheet for the flat-rate.

ANNEX 5

SPECIFIC RULES

CONFIDENTIALITY AND SECURITY (— ARTICLE 13)

Sensitive information with security recommendation

Sensitive information with a security recommendation must comply with the additional requirements imposed by the granting authority.

Before starting the action tasks concerned, the beneficiaries must have obtained all approvals or other mandatory documents needed for implementing the task. The documents must be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they must be submitted together with an English summary.

For requirements restricting disclosure or dissemination, the information must be handled in accordance with the recommendation and may be disclosed or disseminated only after written approval from the granting authority.

EU classified information

If EU classified information is used or generated by the action, it must be treated in accordance with the security classification guide (SCG) and security aspect letter (SAL) set out in Annex 1 and Decision 2015/444[1] and its implementing rules — until it is declassified.

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

Action tasks involving EU classified information may be subcontracted only with prior explicit written approval from the granting authority and only to entities established in an EU Member State or in a non-EU country with a security of information agreement with the EU (or an administrative arrangement with the Commission).

EU 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.

ETHICS (— ARTICLE 14)

Ethics and research integrity

The beneficiaries must carry out the action in compliance with:

- ethical principles (including the highest standards of research integrity)

[1] 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).

and

- applicable EU, international and national law, including the EU Charter of Fundamental Rights and the European Convention for the Protection of Human Rights and Fundamental Freedoms and its Supplementary Protocols.

No funding can be granted, within or outside the EU, for activities that are prohibited in all Member States. No funding can be granted in a Member State for an activity which is forbidden in that Member State.

The beneficiaries must pay particular attention to the principle of proportionality, the right to privacy, the right to the protection of personal data, the right to the physical and mental integrity of persons, the right to non-discrimination, the need to ensure protection of the environment and high levels of human health protection.

The beneficiaries must ensure that the activities under the action have an exclusive focus on civil applications.

The beneficiaries must ensure that the activities under the action do not:

- aim at human cloning for reproductive purposes
- intend to modify the genetic heritage of human beings which could make such modifications heritable (with the exception of research relating to cancer treatment of the gonads, which may be financed)
- intend to create human embryos solely for the purpose of research or for the purpose of stem cell procurement, including by means of somatic cell nuclear transfer, or
- lead to the destruction of human embryos (for example, for obtaining stem cells).

Activities involving research on human embryos or human embryonic stem cells may be carried out only if:

- they are set out in Annex 1 or
- the coordinator has obtained explicit approval (in writing) from the granting authority.

In addition, the beneficiaries must respect the fundamental principle of research integrity — as set out in the European Code of Conduct for Research Integrity[2].

This implies compliance with the following principles:

- reliability in ensuring the quality of research reflected in the design, the methodology, the analysis and the use of resources
- honesty in developing, undertaking, reviewing, reporting and communicating research in a transparent, fair and unbiased way
- respect for colleagues, research participants, society, ecosystems, cultural heritage and the environment

[2] European Code of Conduct for Research Integrity of ALLEA (All European Academies).

- accountability for the research from idea to publication, for its management and organisation, for training, supervision and mentoring, and for its wider impacts

and means that beneficiaries must ensure that persons carrying out research tasks follow the good research practices including ensuring, where possible, openness, reproducibility and traceability and refrain from the research integrity violations described in the Code.

Activities raising ethical issues must comply with the additional requirements formulated by the ethics panels (including after checks, reviews or audits; see Article 25).

Before starting an action task raising ethical issues, the beneficiaries must have obtained all approvals or other mandatory documents needed for implementing the task, notably from any (national or local) ethics committee or other bodies such as data protection authorities.

The documents must be kept on file and be submitted upon request by the coordinator to the granting authority. If they are not in English, they must be submitted together with an English summary, which shows that the documents cover the action tasks in question and includes the conclusions of the committee or authority concerned (if any).

VALUES (— ARTICLE 14)

Gender mainstreaming

The beneficiaries must take all measures to promote equal opportunities between men and women in the implementation of the action and, where applicable, in line with the gender equality plan. They must aim, to the extent possible, for a gender balance at all levels of personnel assigned to the action, including at supervisory and managerial level.

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

Definitions

Access rights — Rights to use results or background.

Dissemination — The public disclosure of the results by appropriate means, other than resulting from protecting or exploiting the results, including by scientific publications in any medium.

Exploit(ation) — The use of results in further research and innovation activities other than those covered by the action concerned, including among other things, commercial exploitation such as developing, creating, manufacturing and marketing a product or process, creating and providing a service, or in standardisation activities.

Fair and reasonable conditions — Appropriate conditions, including possible financial terms or royalty-free conditions, taking into account the specific circumstances of the request for access, for example the actual or potential value of the results or background to which access is requested and/or the scope, duration or other characteristics of the exploitation envisaged.

FAIR principles — ‘findability’, ‘accessibility’, ‘interoperability’ and ‘reusability’.

Open access — Online access to research outputs provided free of charge to the end-user.

Open science — An approach to the scientific process based on open cooperative work, tools and diffusing knowledge.

Research data management — The process within the research lifecycle that includes the organisation, storage, preservation, security, quality assurance, allocation of persistent identifiers (PIDs) and rules and procedures for sharing of data including licensing.

Research outputs — Results to which access can be given in the form of scientific publications, data or other engineered results and processes such as software, algorithms, protocols, models, workflows and electronic notebooks.

Scope of the obligations

For this section, references to ‘beneficiary’ or ‘beneficiaries’ do not include affiliated entities (if any).

Agreement on background — Background free from restrictions

The beneficiaries must identify in a written agreement the background as needed for implementing the action or for exploiting its results.

Where the call conditions restrict control due to strategic interests reasons, background that is subject to control or other restrictions by a country (or entity from a country) which is not one of the eligible countries or target countries set out in the call conditions and that impact the exploitation of the results (i.e. would make the exploitation of the results subject to control or restrictions) must not be used and must be explicitly excluded in the agreement on background — unless otherwise agreed with the granting authority.

Results free from restrictions

Where the call conditions restrict control due to strategic interests reasons, the beneficiaries must ensure that the results of the action are not subject to control or other restrictions by a country (or entity from a country) which is not one of the eligible countries or target countries set out in the call conditions — unless otherwise agreed with the granting authority.

Ownership of results

Results are owned by the beneficiaries that generate them.

However, two or more beneficiaries own results jointly if:

- they have jointly generated them and
- it is not possible to:
    - establish the respective contribution of each beneficiary, or
    - separate them for the purpose of applying for, obtaining or maintaining their protection.

The joint owners must agree — in writing — on the allocation and terms of exercise of their joint ownership (‘joint ownership agreement’), to ensure compliance with their obligations under this Agreement.

Unless otherwise agreed in the joint ownership agreement or consortium agreement, each joint owner may grant non-exclusive licences to third parties to exploit the jointly-owned results (without any right to sub-license), if the other joint owners are given:

- at least 45 days advance notice and
- fair and reasonable compensation.

The joint owners may agree — in writing — to apply another regime than joint ownership.

If third parties (including employees and other personnel) may claim rights to the results, the beneficiary concerned must ensure that those rights can be exercised in a manner compatible with its obligations under the Agreement.

The beneficiaries must indicate the owner(s) of the results (results ownership list) in the final periodic report.

Protection of results

Beneficiaries which have received funding under the grant must adequately protect their results — for an appropriate period and with appropriate territorial coverage — if protection is possible and justified, taking into account all relevant considerations, including the prospects for commercial exploitation, the legitimate interests of the other beneficiaries and any other legitimate interests.

Exploitation of results

Beneficiaries which have received funding under the grant must — up to four years after the end of the action (see Data Sheet, Point 1) — use their best efforts to exploit their results directly or to have them exploited indirectly by another entity, in particular through transfer or licensing.

If, despite a beneficiary's best efforts, the results are not exploited within one year after the end of the action, the beneficiaries must (unless otherwise agreed in writing with the granting authority) use the Horizon Results Platform to find interested parties to exploit the results.

If results are incorporated in a standard, the beneficiaries must (unless otherwise agreed with the granting authority or unless it is impossible) ask the standardisation body to include the funding statement (see Article 17) in (information related to) the standard.

Additional exploitation obligations

Where the call conditions impose additional exploitation obligations (including obligations linked to the restriction of participation or control due to strategic assets, interests, autonomy or security reasons), the beneficiaries must comply with them — up to four years after the end of the action (see Data Sheet, Point 1).

Where the call conditions impose additional exploitation obligations in case of a public emergency, the beneficiaries must (if requested by the granting authority) grant for a limited period of time specified in the request, non-exclusive licences — under fair and reasonable conditions — to their results to legal entities that need the results to address the public emergency and commit to rapidly and broadly exploit the resulting products and services at fair and reasonable conditions. This provision applies up to four years after the end of the action (see Data Sheet, Point 1).

Additional information obligation relating to standards

Where the call conditions impose additional information obligations relating to possible standardisation, the beneficiaries must — up to four years after the end of the action (see Data Sheet, Point 1) — inform the granting authority, if the results could reasonably be expected to contribute to European or international standards.

Transfer and licensing of results

Transfer of ownership

The beneficiaries may transfer ownership of their results, provided this does not affect compliance with their obligations under the Agreement.

The beneficiaries must ensure that their obligations under the Agreement regarding their results are passed on to the new owner and that this new owner has the obligation to pass them on in any subsequent transfer.

Moreover, they must inform the other beneficiaries with access rights of the transfer at least 45 days in advance (or less if agreed in writing), unless agreed otherwise in writing for specifically identified third parties including affiliated entities or unless impossible under the applicable law. This notification must include sufficient information on the new owner to enable the beneficiaries concerned to assess the effects on their access rights. The beneficiaries may object within 30 days of receiving notification (or less if agreed in writing), if they can show that the transfer would adversely affect their access rights. In this case, the transfer may not take place until agreement has been reached between the beneficiaries concerned.

Granting licences

The beneficiaries may grant licences to their results (or otherwise give the right to exploit them), including on an exclusive basis, provided this does not affect compliance with their obligations.

Exclusive licences for results may be granted only if all the other beneficiaries concerned have waived their access rights.

Granting authority right to object to transfers or licensing — Horizon Europe actions

Where the call conditions in Horizon Europe actions provide for the right to object to transfers or licensing, the granting authority may — up to four years after the end of the action (see Data Sheet, Point 1) — object to a transfer of ownership or the exclusive licensing of results, if:

- the beneficiaries which generated the results have received funding under the grant
- it is to a legal entity established in a non-EU country not associated with Horizon Europe, and
- the granting authority considers that the transfer or licence is not in line with EU interests.

Beneficiaries that intend to transfer ownership or grant an exclusive licence must formally notify the granting authority before the intended transfer or licensing takes place and:

- identify the specific results concerned
- describe in detail the new owner or licensee and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or licence on EU interests, in particular regarding competitiveness as well as consistency with ethical principles and security considerations.

The granting authority may request additional information.

If the granting authority decides to object to a transfer or exclusive licence, it must formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information it has requested).

No transfer or licensing may take place in the following cases:

- pending the granting authority decision, within the period set out above
- if the granting authority objects
- until the conditions are complied with, if the granting authority objection comes with conditions.

A beneficiary may formally notify a request to waive the right to object regarding intended transfers or grants to a specifically identified third party, if measures safeguarding EU interests are in place. If the granting authority agrees, it will formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information requested).

Granting authority right to object to transfers or licensing — Euratom actions

Where the call conditions in Euratom actions provide for the right to object to transfers or licensing, the granting authority may — up to four years after the end of the action (see Data Sheet, Point 1) — object to a transfer of ownership or the exclusive or non-exclusive licensing of results, if:

- the beneficiaries which generated the results have received funding under the grant
- it is to a legal entity established in a non-EU country not associated to the Euratom Research and Training Programme 2021-2025 and
- the granting authority considers that the transfer or licence is not in line with the EU interests.

Beneficiaries that intend to transfer ownership or grant a licence must formally notify the granting authority before the intended transfer or licensing takes place and:

- identify the specific results concerned
- describe in detail the results, the new owner or licensee and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or licence on EU interests, in particular regarding competitiveness as well as consistency with ethical principles and security considerations (including the defence interests of the EU Member States under Article 24 of the Euratom Treaty).

The granting authority may request additional information.

If the granting authority decides to object to a transfer or licence, it will formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information requested).

No transfer or licensing may take place in the following cases:

- pending the granting authority decision, within the period set out above
- if the granting authority objects
- until the conditions are complied with, if the granting authority objection comes with conditions.

A beneficiary may formally notify a request to waive the right to object regarding intended transfers or grants to a specifically identified third party, if measures safeguarding EU interests are in place. If the granting authority agrees, it will formally notify the beneficiary concerned within 60 days of receiving notification (or any additional information requested).

Limitations to transfers and licensing due to strategic assets, interests, autonomy or security reasons of the EU and its Member States

Where the call conditions restrict participation or control due to strategic assets, interests, autonomy or security reasons, the beneficiaries may not transfer ownership of their results or grant licences to third parties which are established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) — unless they have requested and received prior approval by the granting authority.

The request must:

- identify the specific results concerned
- describe in detail the new owner or licensee and the planned or potential exploitation of the results, and
- include a reasoned assessment of the likely impact of the transfer or license on the strategic assets, interests, autonomy or security of the EU and its Member States.

The granting authority may request additional information.

Access rights to results and background

Exercise of access rights — Waiving of access rights — No sub-licensing

Requests to exercise access rights and the waiver of access rights must be in writing.

Unless agreed otherwise in writing with the beneficiary granting access, access rights do not include the right to sub-license.

If a beneficiary is no longer involved in the action, this does not affect its obligations to grant access.

If a beneficiary defaults on its obligations, the beneficiaries may agree that that beneficiary no longer has access rights.

Access rights for implementing the action

The beneficiaries must grant each other access — on a royalty-free basis — to background needed to implement their own tasks under the action, unless the beneficiary that holds the background has — before acceding to the Agreement —:

- informed the other beneficiaries that access to its background is subject to restrictions, or
- agreed with the other beneficiaries that access would not be on a royalty-free basis.

The beneficiaries must grant each other access — on a royalty-free basis — to results needed for implementing their own tasks under the action.

Access rights for exploiting the results

The beneficiaries must grant each other access — under fair and reasonable conditions — to results needed for exploiting their results.

The beneficiaries must grant each other access — under fair and reasonable conditions — to background needed for exploiting their results, unless the beneficiary that holds the background has — before acceding to the Agreement — informed the other beneficiaries that access to its background is subject to restrictions.

Requests for access must be made — unless agreed otherwise in writing — up to one year after the end of the action (see Data Sheet, Point 1).

Access rights for entities under the same control

Unless agreed otherwise in writing by the beneficiaries, access to results and, subject to the restrictions referred to above (if any), background must also be granted — under fair and reasonable conditions — to entities that:

- are established in an EU Member State or Horizon Europe associated country
- are under the direct or indirect control of another beneficiary, or under the same direct or indirect control as that beneficiary, or directly or indirectly controlling that beneficiary and
- need the access to exploit the results of that beneficiary.

Unless agreed otherwise in writing, such requests for access must be made by the entity directly to the beneficiary concerned.

Requests for access must be made — unless agreed otherwise in writing — up to one year after the end of the action (see Data Sheet, Point 1).

Access rights for the granting authority, EU institutions, bodies, offices or agencies and national authorities to results for policy purposes — Horizon Europe actions

In Horizon Europe actions, the beneficiaries which have received funding under the grant must grant access to their results — on a royalty-free basis — to the granting authority, EU institutions, bodies, offices or agencies for developing, implementing and monitoring EU policies or programmes. Such access rights do not extend to beneficiaries' background.

Such access rights are limited to non-commercial and non-competitive use.

For actions under the cluster 'Civil Security for Society', such access rights also extend to national authorities of EU Member States for developing, implementing and monitoring their policies or programmes in this area. In this case, access is subject to a bilateral agreement to define specific conditions ensuring that:

- the access rights will be used only for the intended purpose and
- appropriate confidentiality obligations are in place.

Moreover, the requesting national authority or EU institution, body, office or agency (including the granting authority) must inform all other national authorities of such a request.

Access rights for the granting authority, Euratom institutions, funding bodies or the Joint Undertaking Fusion for Energy — Euratom actions

In Euratom actions, the beneficiaries which have received funding under the grant must grant access to their results — on a royalty-free basis — to the granting authority, Euratom institutions, funding bodies or the Joint Undertaking Fusion for Energy for developing, implementing and monitoring Euratom policies and programmes or for compliance with obligations assumed through international cooperation with non-EU countries and international organisations.

Such access rights include the right to authorise third parties to use the results in public procurement and the right to sub-license and are limited to non-commercial and non-competitive use.

Additional access rights

Where the call conditions impose additional access rights, the beneficiaries must comply with them.

COMMUNICATION, DISSEMINATION, OPEN SCIENCE AND VISIBILITY (— ARTICLE 17)

Dissemination

Dissemination of results

The beneficiaries must disseminate their results as soon as feasible, in a publicly available format, subject to any restrictions due to the protection of intellectual property, security rules or legitimate interests.

A beneficiary that intends to disseminate its results must give at least 15 days advance notice to the other beneficiaries (unless agreed otherwise), together with sufficient information on the results it will disseminate.

Any other beneficiary may object within (unless agreed otherwise) 15 days of receiving notification, if it can show that its legitimate interests in relation to the results or background would be significantly harmed. In such cases, the results may not be disseminated unless appropriate steps are taken to safeguard those interests.

Additional dissemination obligations

Where the call conditions impose additional dissemination obligations, the beneficiaries must also comply with those.

Open Science

Open science: open access to scientific publications

The beneficiaries must ensure open access to peer-reviewed scientific publications relating to their results. In particular, they must ensure that:

- at the latest at the time of publication, a machine-readable electronic copy of the published version or the final peer-reviewed manuscript accepted for publication, is deposited in a trusted repository for scientific publications

- immediate open access is provided to the deposited publication via the repository, under the latest available version of the Creative Commons Attribution International Public Licence (CC BY) or a licence with equivalent rights; for monographs and other long-text formats, the licence may exclude commercial uses and derivative works (e.g. CC BY-NC, CC BY-ND) and

- information is given via the repository about any research output or any other tools and instruments needed to validate the conclusions of the scientific publication.

Beneficiaries (or authors) must retain sufficient intellectual property rights to comply with the open access requirements.

Metadata of deposited publications must be open under a Creative Common Public Domain Dedication (CC 0) or equivalent, in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: publication (author(s), title, date of publication, publication venue); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the publication, the authors involved in the action and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for any research output or any other tools and instruments needed to validate the conclusions of the publication.

Only publication fees in full open access venues for scientific publications are eligible for reimbursement.

Open science: research data management

The beneficiaries must manage the digital research data generated in the action ('data') responsibly, in line with the FAIR principles and by taking all of the following actions:

- establish a data management plan ('DMP') (and regularly update it)

- as soon as possible and within the deadlines set out in the DMP, deposit the data in a trusted repository; if required in the call conditions, this repository must be federated in the EOSC in compliance with EOSC requirements

- as soon as possible and within the deadlines set out in the DMP, ensure open access — via the repository — to the deposited data, under the latest available version of the Creative Commons Attribution International Public License (CC BY) or Creative Commons Public Domain Dedication (CC 0) or a licence/dedication with equivalent rights, following the principle 'as open as possible as closed as necessary', unless providing open access would in particular:

    - be against the beneficiary's legitimate interests, including regarding commercial exploitation, or

- be contrary to any other constraints, in particular the EU competitive interests or the beneficiary's obligations under this Agreement; if open access is not provided (to some or all data), this must be justified in the DMP

- provide information via the repository about any research output or any other tools and instruments needed to re-use or validate the data.

Metadata of deposited data must be open under a Creative Common Public Domain Dedication (CC 0) or equivalent (to the extent legitimate interests or constraints are safeguarded), in line with the FAIR principles (in particular machine-actionable) and provide information at least about the following: datasets (description, date of deposit, author(s) and embargo); Horizon Europe or Euratom funding; grant project name, acronym and number; licensing terms; persistent identifiers for the dataset, the authors involved in the action, and, if possible, for their organisations and the grant. Where applicable, the metadata must include persistent identifiers for related publications and other research outputs.

Open science: additional practices

Where the call conditions impose additional obligations regarding open science practices, the beneficiaries must also comply with those.

Where the call conditions impose additional obligations regarding the validation of scientific publications, the beneficiaries must provide (digital or physical) access to data or other results needed for validation of the conclusions of scientific publications, to the extent that their legitimate interests or constraints are safeguarded (and unless they already provided (open) access at publication).

Where the call conditions impose additional open science obligations in case of a public emergency, the beneficiaries must (if requested by the granting authority) immediately deposit any research output in a trusted repository and provide open access to it under a CC BY licence, a Public Domain Dedication (CC 0) or equivalent. As an exception, if the access would be against the beneficiaries' legitimate interests, the beneficiaries must grant non-exclusive licenses — under fair and reasonable conditions — to legal entities that need the research output to address the public emergency and commit to rapidly and broadly exploit the resulting products and services at fair and reasonable conditions. This provision applies up to four years after the end of the action (see Data Sheet, Point 1).

Plan for the exploitation and dissemination of results including communication activities

Unless excluded by the call conditions, the beneficiaries must provide and regularly update a plan for the exploitation and dissemination of results including communication activities.

SPECIFIC RULES FOR CARRYING OUT THE ACTION (— ARTICLE 18)

Implementation in case of restrictions due to strategic assets, interests, autonomy or security of the EU and its Member States

Where the call conditions restrict participation or control due to strategic assets, interests, autonomy or security, the beneficiaries must ensure that none of the entities that participate as affiliated entities, associated partners, third parties giving in-kind contributions, subcontractors or recipients of financial support to third parties are established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) — unless otherwise agreed with the granting authority.

The beneficiaries must moreover ensure that any cooperation with entities established in countries which are not eligible countries or target countries set out in the call conditions (or, if applicable, are controlled by such countries or entities from such countries) does not affect the strategic assets, interests, autonomy or security of the EU and its Member States.

Recruitment and working conditions for researchers

The beneficiaries must take all measures to implement the principles set out in Annex II to the Council Recommendation on a European framework to attract and retain research, innovation and entrepreneurial talents in Europe[3] ('the European Charter for Researchers'), in particular regarding:

- working conditions
- transparent recruitment processes based on merit, and
- career development.

The beneficiaries must ensure that researchers and all participants involved in the action are aware of them.

Specific rules for access to research infrastructure activities

Definitions

Research Infrastructures — Facilities that provide resources and services for the research communities to conduct research and foster innovation in their fields. This definition includes the associated human resources, and it covers major equipment or sets of instruments; knowledge-related facilities such as collections, archives or scientific data infrastructures; computing systems, communication networks, and any other infrastructure, of a unique nature and open to external users, essential to achieve excellence in research and innovation. Where relevant, they may be used beyond research, for example for education or public services, and they may be 'single-sited', 'virtual' or 'distributed'[4]:

When implementing access to research infrastructure activities, the beneficiaries must respect the following conditions:

- for transnational access:
  - access which must be provided:

    The access must be free of charge, transnational access to research infrastructure or installations for selected user-groups.

    The access must include the logistical, technological and scientific support and the specific training that is usually provided to external researchers using the

[3] Council Recommendation C/2023/1640 of 18 December 2023 on a European framework to attract and retain research, innovation and entrepreneurial talents in Europe, Annex II (OJ C, C/2023/1640, 29.12.2023).

[4] See Article 2(1) of the Horizon Europe Framework Programme Regulation 2021/695.

infrastructure. Transnational access can be either in person (hands-on), provided to selected users that visit the installation to make use of it, or remote, through the provision to selected user-groups of remote scientific services (e.g. provision of reference materials or samples, remote access to a high-performance computing facility).

- categories of users that may have access:

  Transnational access must be provided to selected user-groups, i.e. teams of one or more researchers (users).

  The majority of the users must work in a country other than the country(ies) where the installation is located (unless access is provided by an international organisation, the Joint Research Centre (JRC), an ERIC or similar legal entity).

  Only user groups that are allowed to disseminate the results they have generated under the action may benefit from the access (unless the users are working for SMEs).

  Access for user groups with a majority of users not working in a EU Member State or Horizon Europe associated country is limited to 20% of the total amount of units of access provided under the grant (unless a higher percentage is foreseen in Annex 1).

- procedure and criteria for selecting user groups:

  The user groups must request access by submitting (in writing) a description of the work that they wish to carry out and the names, nationalities and home institutions of the users.

  The user groups must be selected by (one or more) selection panels set up by the consortium.

  The selection panels must be composed of international experts in the field, at least half of them independent from the consortium (unless otherwise specified in Annex 1).

  The selection panels must assess all proposals received and recommend a short-list of the user groups that should benefit from access.

  The selection panels must base their selection on scientific merit, taking into account that priority should be given to user groups composed of users who:

    - have not previously used the installation and
    - are working in countries where no equivalent research infrastructure exist.

  It will apply the principles of transparency, fairness and impartiality.

  Where the call conditions impose additional rules for the selection of user groups, the beneficiaries must also comply with those.

- other conditions:

The beneficiaries must request written approval from the granting authority for the selection of user groups requiring visits to the installations exceeding 3 months (unless such visits are foreseen in Annex 1).

In addition, the beneficiaries must:

- advertise widely, including on a their websites, the access offered under the Agreement
- promote equal opportunities in advertising the access and take into account the gender dimension when defining the support provided to users
- ensure that users comply with the terms and conditions of the Agreement
- ensure that its obligations under Articles 12, 13, 17 and 33 also apply to the users
- keep records of the names, nationalities, and home institutions of users, as well as the nature and quantity of access provided to them

- for virtual access:
  - access which must be provided:

    The access must be free of charge, virtual access to research infrastructure or installations.

    'Virtual access' means open and free access through communication networks to digital resources and services needed for research, without selecting the users to whom access is provided.

    The access must include the support that is usually provided to external users.

    Where allowed by the call conditions, beneficiaries may in justified cases define objective eligibility criteria (e.g. affiliation to a research or academic institution) for specific users.

  - other conditions:

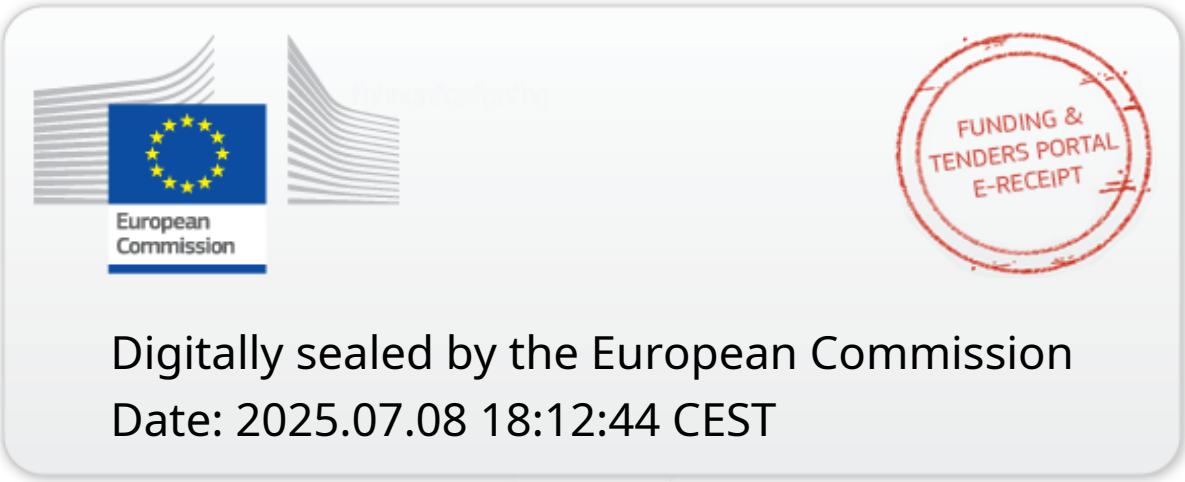
    The beneficiaries must have the virtual access services assessed periodically by a board composed of international experts in the field, at least half of whom must be independent from the consortium (unless otherwise specified in Annex 1). For this purpose, information and statistics on the users and the nature and quantity of the access provided, must be made available to the board.

    The beneficiaries must advertise widely, including on a dedicated website, the access offered under the grant and the eligibility criteria, if any.

Where the call conditions impose additional traceability[5] obligations, information on the traceability of the users and the nature and quantity of access must be provided by the beneficiaries.

These obligations apply regardless of the form of funding or budget categories used to declare the costs (unit costs or actual costs or a combination of the two).

[5] According to the definition given in ISO 9000, i.e.: “Traceability is the ability to trace the history, application, use and location of an item or its characteristics through recorded identification data.” The users can be traced, for example, by authentication and/or by authorization or by other means that allows for analysis of the type of users and the nature and quantity of access provided.



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