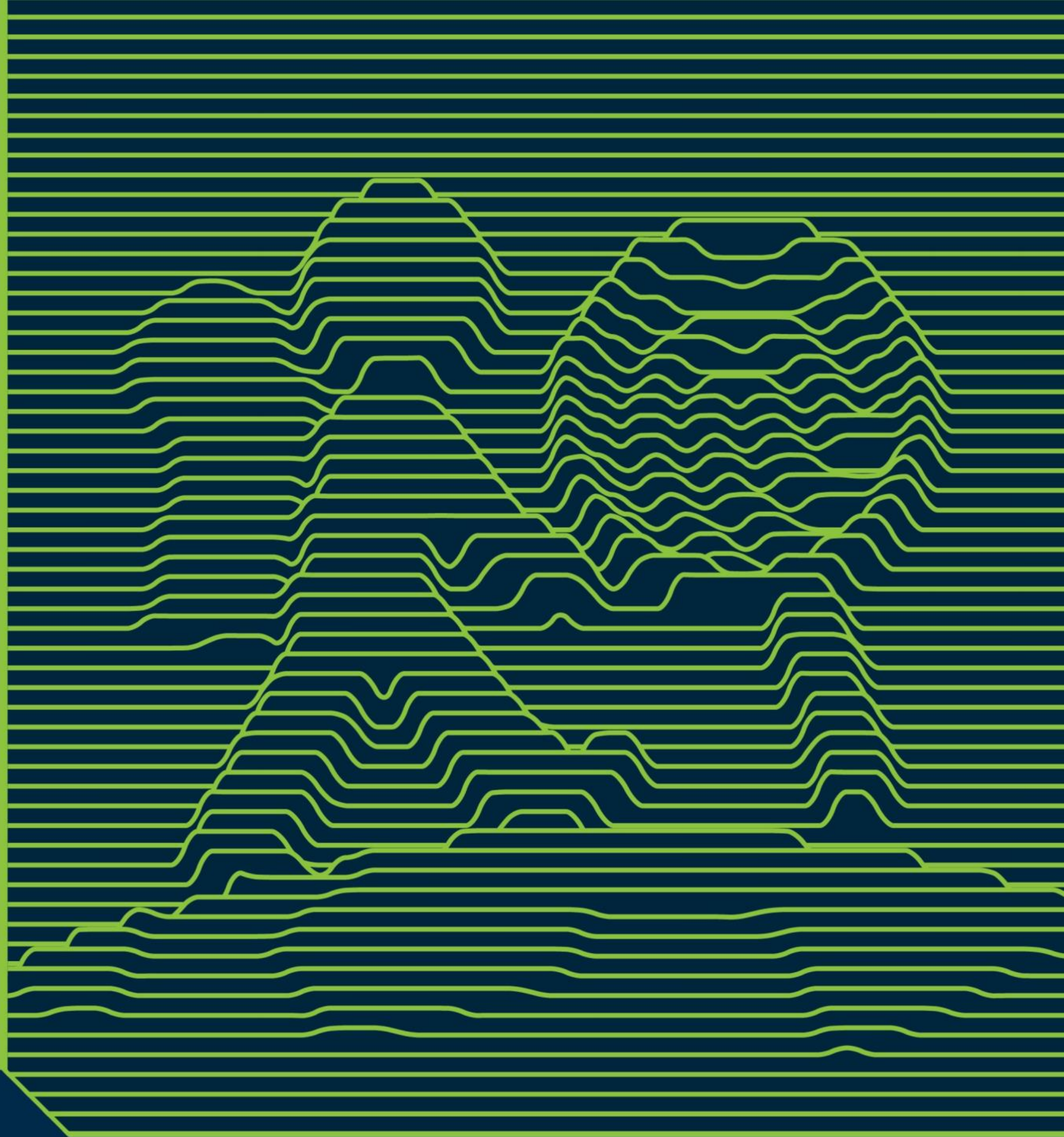
Technology Foresight on Biometrics for the Future of Travel



BORDER SECURITY OBSERVATORY
RESEARCH AND INNOVATION UNIT

FRONTEX

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EUROPEAN BORDER AND COAST GUARD AGENCY

Project Overview

Project Overview

Research Team

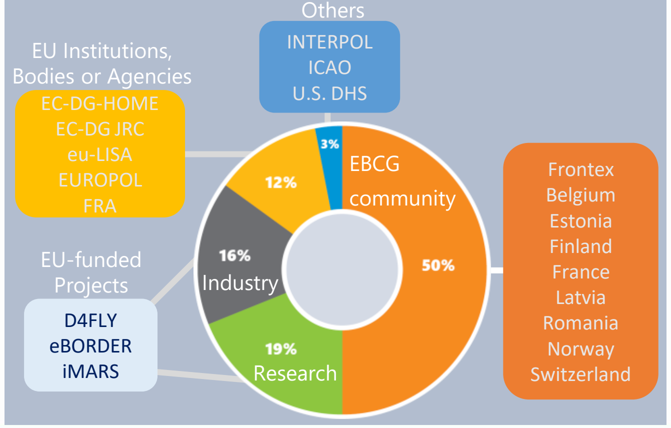
Steinbeis 2i
Germany

4CF
Poland

Erre Quadro
Italy

Institute of Optoelectronics
Military University of Technology
Poland

>40 **Stakeholders actively involved**
(strong focus on EU and EBCG)



2021

JANUARY
Kickoff Meeting

APRIL
1st Technology Foresight Workshop on Scenario Building

MAY
Delphi Survey

JUNE
2nd Technology Foresight Workshop on Roadmapping

SEPTEMBER
Final Project Meeting

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Motivation

Growing mobility of individuals and need for **Seamless Border Checks** pushing towards implementing:

- Digital Identity Management Solutions
- No-Gate physical solutions for seamless border checks at BCPs

COVID-19 pandemic

- need for technological solutions compatible with policies and measures typically taken in case of pandemics

Biometric Technologies

Border checks will have to transform to:

- Effectively safeguard EU's external borders
- Improve border crossing experience (seamless & contactless travel)

Biometrics is key enabler for **automated recognition of individuals** at BCPs

Use of biometrics in large-scale IT systems is a major priority for the EU

Foresight for pre-acting rather than re-acting

Objectives

Research study

Research study on the future opportunities that biometric technologies could provide to the European Border and Coast Guard (EBCG) community

- Identify specific research and innovation activities
- Knowledge on how to maximize future benefits of biometric technologies

Desired outputs

- **TF Methodology and Supporting Tools**
- **Taxonomy of biometric technologies**
- **Research Study**

Methodological Framework

STAGES		PHASES	STEPS
		1. ANALYSIS OF RESEARCH CONTEXT	Identification of Needs
EXPLORATION Identify the right things	**DISCOVER** (Expansion of options)	**2. INSIGHT HUNT**	State-of-the-Art Review Clustering of Technologies Identification of Stakeholders Building Scenarios for the Future
	DEFINE (Narrowing options down)	**3. FILTERING RESULTS**	Filtering by Key Strategic Factors Filtering by Other Relevant Factors Filtering by Future Scenarios
UNDERSTANDING Understand things right	**DEVELOP** (Expansion of understanding)	**4. DEEP ANALYSIS**	Modelling the Roadmaps
	DELIVER (Actionable insights)	**5. MAPPING CAPABILITIES**	Capability Readiness Analysis

METHODS

- Matrixes of needs & functional requirements
- Desk research
- Patentometric & bibliometric analyses
- Delphi Survey
- 4CF Matrix
- Rip Van Winkle Method
- Futures Wheel
- Forecasting/Backcasting
- Scenario Analysis
- Weighted Criteria Matrix
- Workshops

TOOLS

- 4CF HalnyX
- Miro Board
- Domain Terminology Extractor
- Smart Ranker
- Weighted Clusterer

1. Analysis of Research Context

Identification of Needs

Analysis of Frontex needs for key functions of biometric technologies

Aim

- Needs analysis to specify the field and scope of the research and to set the goals for the study
- Tailor the Technology Foresight Methodology to Frontex needs

4 “must-haves” for biometric technologies identified for reference in later phases of the project

- Seamlessness
- Compliancy with fundamental EU values and regulations
- Applicability within pandemic-specific restrictions
- Low vulnerability to adversary attacks

2. Insight Hunt

State-of-the art Review

Taxonomies

2.
INSIGHT HUNT

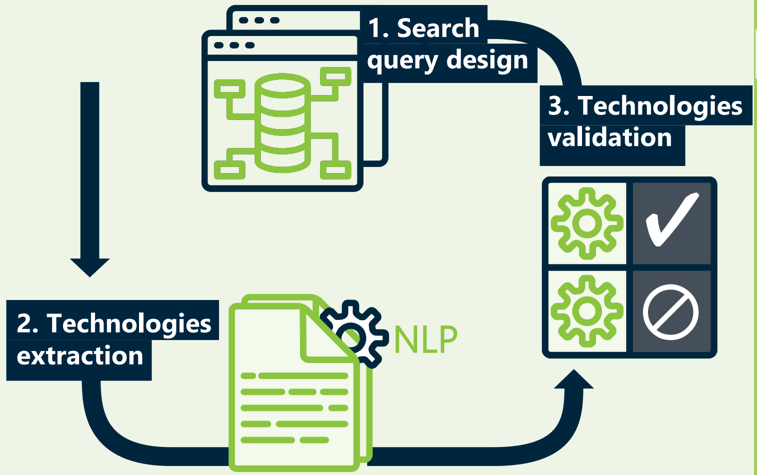
Aim

- Establish a common systematic understanding of the biometrics domain
- Create reference documents which could enable future R&I activities

Output

- Taxonomy of biometric technologies
- Taxonomy of biometrics-enabled technological systems

- **Highly iterative** process based on the extraction of terminology from patents and scientific literature
- **Automatic tools** (embedding NLP) for analysis of massive technical and scientific documentation



Three-level Taxonomy
of Biometric Technologies

- 57 biometric technologies
  - 5 biomolecular
  - 39 morphological
  - 13 behavioural

Two-level Taxonomy
of Biometrics-Enabled Technological Systems

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State-of-the art Review

Taxonomies

1	BIOMOLECULAR BIOMETRICS	
2	MORPHOLOGICAL BIOMETRICS	
3	BEHAVIOURAL BIOMETRICS	

BIOMETRICS TECHNOLOGIES

- 1.1 DNA biometrics
- 1.2. Other biomolecular biometrics
- 2.1. Face recognition
- 2.2. Friction ridge recognition
- 2.3. Iris recognition
- 2.4. Vascular pattern recognition
- 2.5. Physiological signals biometrics
- 2.6. Hand geometry recognition
- 2.7. Other minor morphological biometrics
- 3.1. Keystroke recognition
- 3.2. Gait recognition
- 3.3. Handwriting recognition
- 3.4. Speaker recognition
- 3.5. Other minor behavioural biometrics

BIOMETRICS-ENABLED TECHNOLOGICAL SYSTEMS

1. Self-service systems
2. Identity document readers and verification sub-systems
3. Full-body scanning systems
4. Systems based on personal devices
5. Movable systems
6. Large-scale IT systems
7. Virtual traveller identity schemes

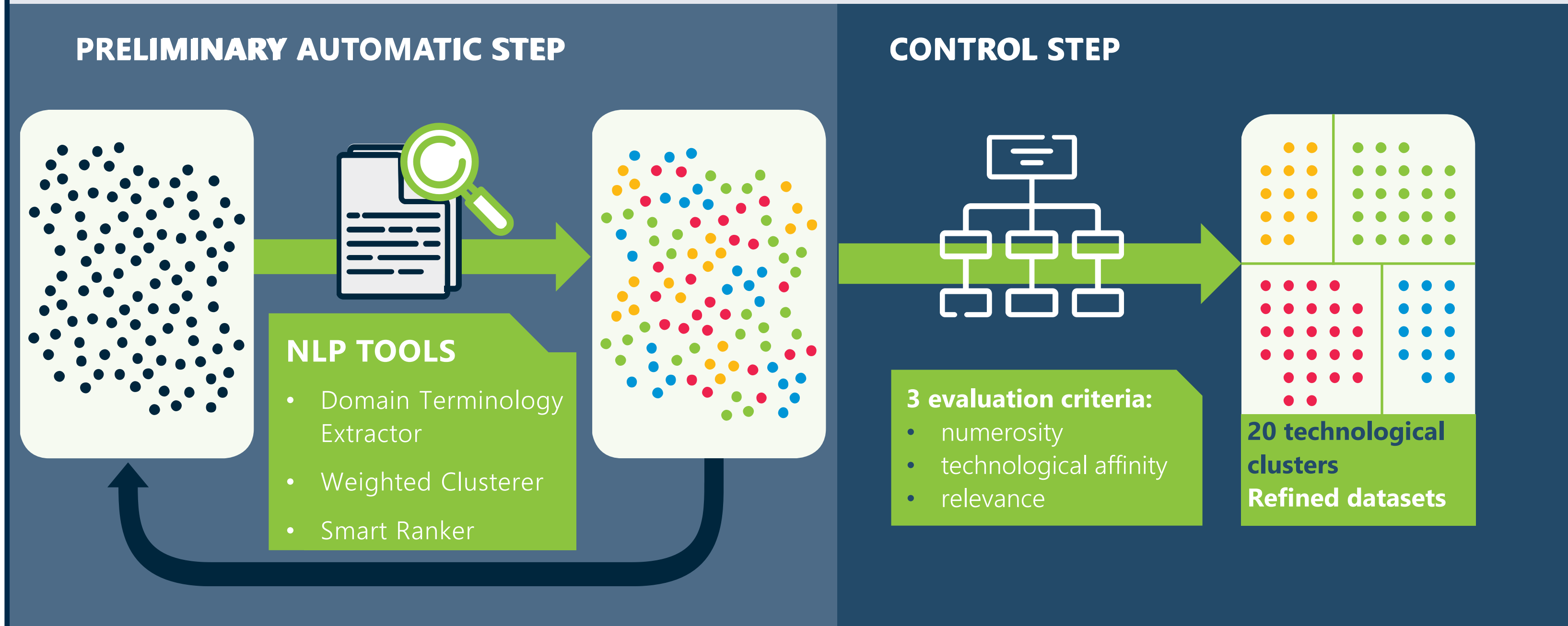
Clustering of Technologies

Identification of Technological Clusters

2.
INSIGHT HUNT

Aim

- Group the large set of biometric technologies into **clusters** to assure the usability of the taxonomy in the different phases of the Tech Foresight
- Create homogeneous datasets of patents and scientific publications suitable to conduct patentometric and bibliometric analyses



Clustering of Technologies

Identification of Technological Clusters

1. DNA biometrics
2. Infrared face recognition
3. 2D face recognition in the visible spectrum
4. 3D face recognition
5. Infrared friction ridge recognition
6. 3D friction ridge recognition
7. Contactless friction ridge recognition
8. Contact-based friction ridge recognition
9. Iris recognition in the NIR spectrum
10. Iris recognition in the visible spectrum
11. Iris recognition at a distance
12. Eye vein recognition
13. Hand vein recognition
14. Heart signal recognition
15. Hand geometry recognition
16. Periocular recognition
17. Keystroke recognition
18. Gait recognition
19. Handwriting recognition
20. Speaker recognition

Clustering of Technologies

Patentometric and bibliometric analyses of Clusters

Aim

- **Analyse the lifecycle** of 20 Biometric Technological Clusters to gather information about their evolution
- **Theory of Technology Lifecycle applied**
- Datasets of patent families and scientific publications were used to **study technological evolution**

Proprietary patent database
(based on EPO's Database)

OpenAIRE database
(scientific publications)

CORDIS database of EU-funded projects

DATA ANALYSIS

Technological life-cycle assessment

Geographical distribution of R&D, manufacturing and commercial activities

Most prolific R&D entities

Clustering of Technologies

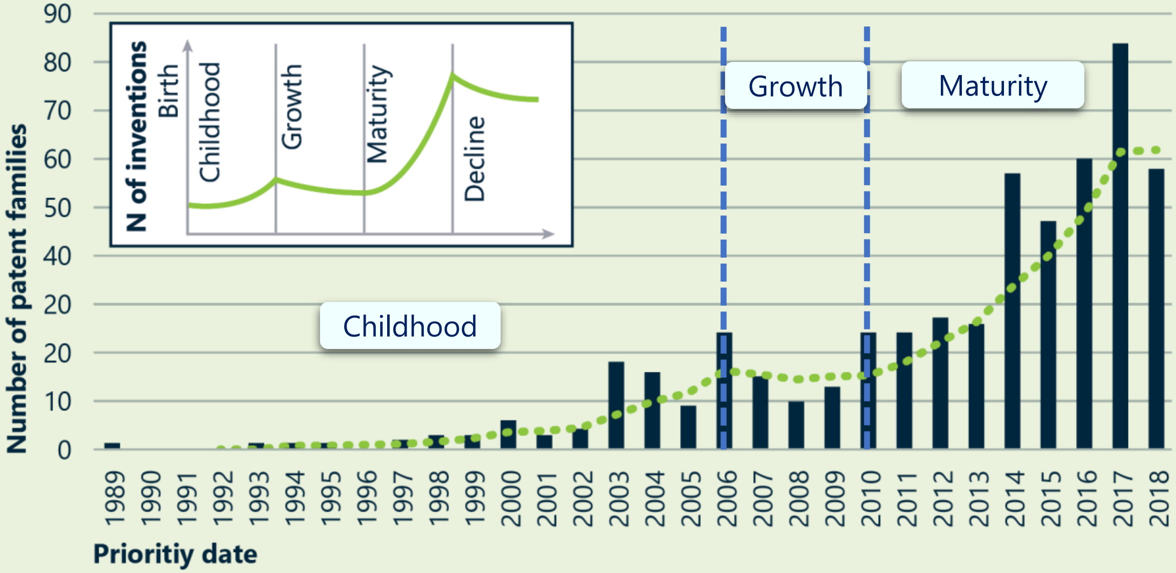
Patentometric and bibliometric analyses of Clusters

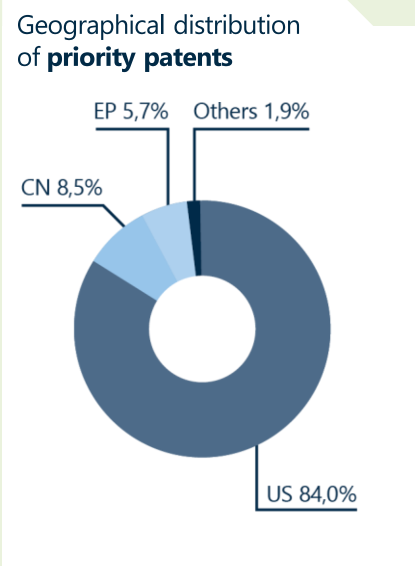
#	Technological clusters	No. Patent families	No. Patents	No. Papers	State in technology lifecycle	Concentration of inventive activity (%)	Concentration of publishing activity (%)	Concentration of editorial activity (%)
20.	**Speaker recognition**	**1,760**	7,468	848	Maturity	34.7	6.4	67.9
8.	**Contact-based friction ridge recognition**	**1,758**	8,599	158	Maturity	24.1	60	100
3.	**2D face recognition in the visible spectrum**	**1,437**	5,012	580	Maturity	20.7	8.8	68.8
19.	**Handwriting recognition**	**1,273**	6,347	821	Maturity	18.2	15.5	77.7
12.	**Eye vein recognition**	**1,048**	5,117	544	Maturity	18.4	12.1	60.7
2.	**Infrared face recognition**	**1,047**	5,111	151	Maturity	27.9	24.2	81.6
7.	**Contactless friction ridge recognition**	**811**	3,974	25	Maturity	19.5	40.4	84
9.	**Iris recognition in the NIR spectrum**	**650**	3,068	30	Maturity	30	56.7	100
4.	**3D face recognition**	**561**	2,545	269	Maturity	27.9	18.6	74.7
13.	**Hand vein recognition**	**532**	1,958	457	Maturity	42.2	17.7	77.2
1.	**DNA biometrics**	**473**	2,556	168	Maturity – minor relevance	19.6	23.4	58.9
15.	**Hand geometry recognition**	**428**	2,349	186	Maturity – minor relevance	36.9	21	71
17.	**Keystroke recognition**	**378**	1,482	129	Maturity – minor relevance	28.8	65.9	79.8
14.	**Heart signals recognition**	**267**	1,207	134	Growth	30.1	32.1	76.9
11.	**Iris recognition at a distance**	**259**	1,285	77	Growth	46.7	39	84.4
10.	**Iris recognition in the visible spectrum**	**222**	1,212	40	Growth	37.4	47.7	100
5.	**Infrared friction ridge recognition**	**195**	843	66	Growth	34.2	36.4	84.8
6.	**3D friction ridge recognition**	**120**	571	41	Growth	54.9	126.8	100
18.	**Gait recognition**	**32**	163	67	Childhood	68.7	73.1	100
16.	**Periocular recognition**	**27**	197	38	Childhood	88.8	84.2	100

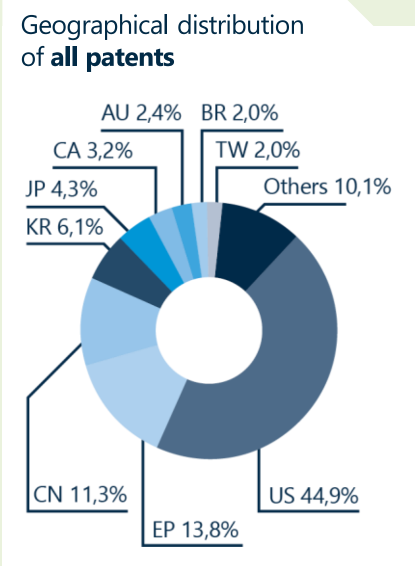
Clustering of Technologies

Patentometric and bibliometric analyses on Clusters

3D face recognition







Assignee	Number of patent families	% of the total
Microsoft	21	3.8
Amazon Technologies	19	3.4
Google	18	3.2
Apple	13	2.3

Publisher	Number of scientific publications	% of the total
IEEE	87	32.3
Springer	34	12.6
Elsevier	25	9.3

Building Scenarios for the Future

Scenarios for the future of travel, border checks and biometrics in 2040

2.
INSIGHT HUNT

Aim

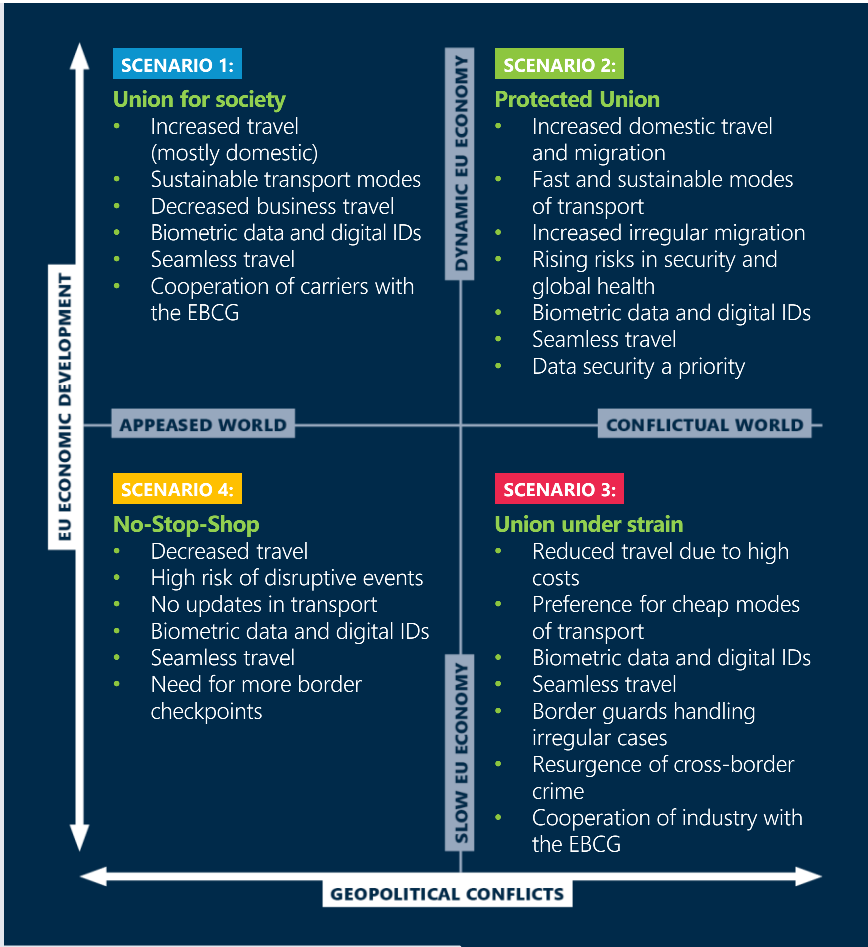
- Reframing visions of the future in order to challenge them
- Assessing how alternative futures might influence the evolution of biometrics.

Choice of scenarios

- Based on JRC's study "*The Future of Customs in the EU 2040: A foresight project for EU policy*"[1]
- Adapted to incorporate aspects relevant to the travel and border check context

Use of scenarios

- Roadmapping
- Mapping capabilities



[1] Ghiran A., Hakami A., Bontoux L., Scapolo, F. The Future of Customs in the EU 2040: A foresight project for EU policy, EUR 30463 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-26299-2, doi:10.2760/29195, JRC121859.

3. Filtering Results

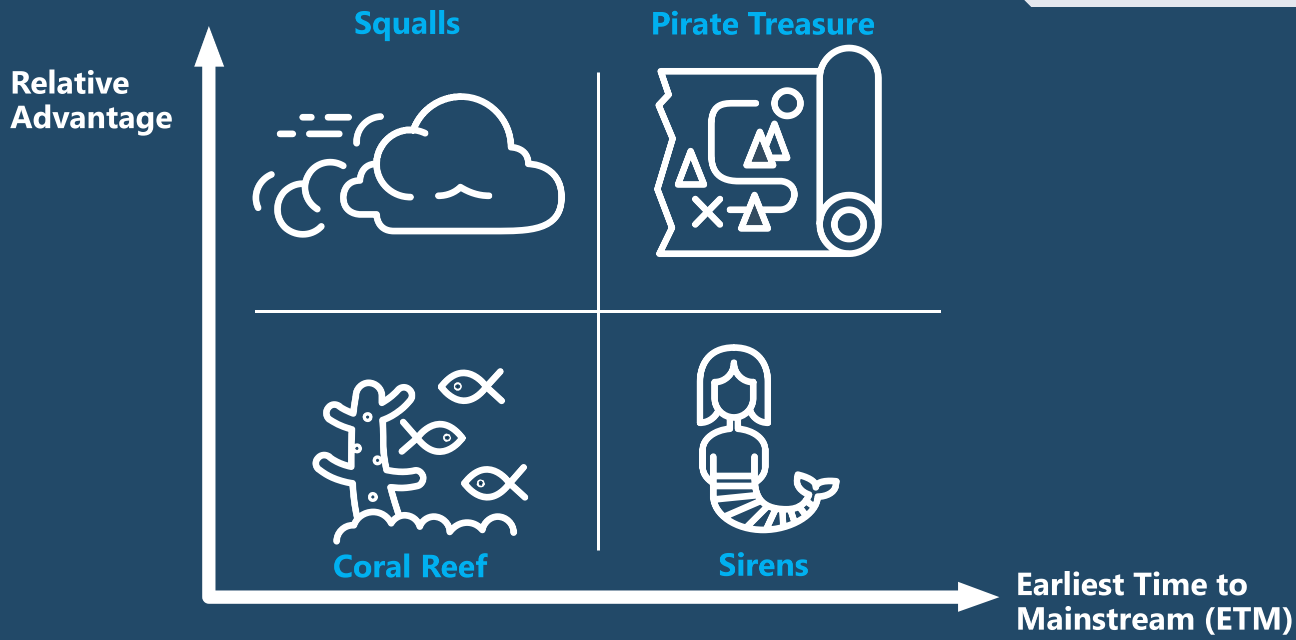
Filtering by Key Strategic Factors

Prioritisation of biometric technologies – The Delphi Survey

Aim

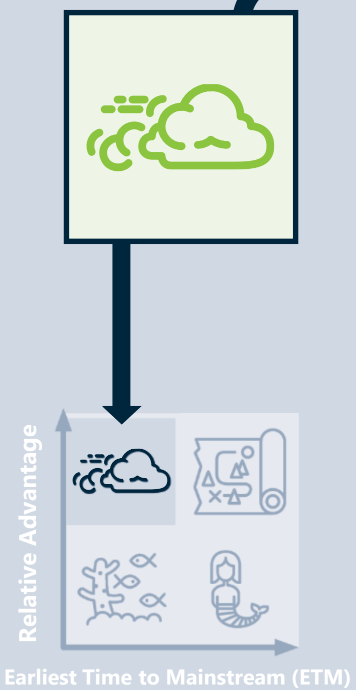
- Select the Key biometric Technological Clusters – KTCs
- Quantitative assessment of the 20 Technological Clusters using 2 metrics: **Relative Advantage** and **Earliest Time to Mainstream** by a **real-time Delphi**
    - Collect experts' opinions
    - Stimulate consensus-oriented structured discussions
    - Exploit collective intelligence, not only statistical distribution of answers

FILTERING RESULTS
3.



Filtering by Key Strategic Factors

Prioritisation of biometric technologies – The Delphi Survey



#	Technological clusters	Delphi Assessment Composite Metric p=RA-ETM/2	Relative Advantage Average	Relative Advantage St Dev	Relative Advantage Number of assessments	Earliest Time to Mainstream Average	Earliest Time to Mainstream St Dev	Earliest Time to Mainstream Number of assessments
3.	2D face recognition in the visible spectrum	3.52	5.17	2.27	30.00	3.30	2.50	31.00
2.	2D infrared face recognition	3.45	5.86	1.96	29.00	4.80	2.30	31.00
4.	3D face recognition	3.44	6.81	1.51	32.00	6.70	3.50	32.00
9.	Iris recognition in the near-Infrared spectrum	3.07	6.48	1.79	27.00	6.80	3.40	27.00
8.	Contact-based friction ridge recognition	3.00	4.04	1.99	28.00	2.10	1.50	26.00
10.	Iris recognition in the visible spectrum	1.49	5.18	2.12	28.00	7.40	3.30	27.00
11.	Iris recognition at a distance	1.09	7.11	2.57	27.00	12.00	4.50	28.00
7.	Contactless friction ridge recognition	0.84	5.38	2.19	29.00	9.10	3.30	28.00
16.	Periocular scanning	0.44	5.11	2.15	27.00	9.30	2.60	27.00
5.	Infrared friction ridge recognition	0.41	3.73	1.93	30.00	6.70	3.40	29.00
20.	Speaker recognition	-0.07	3.79	2.18	28.00	7.70	4.10	28.00
13.	Hand vein recognition	-0.41	4.52	2.27	29.00	9.90	4.00	29.00
18.	Gait recognition	-0.56	4.52	1.89	27.00	10.10	3.90	27.00
6.	3D friction ridge recognition	-0.98	4.34	2.28	29.00	10.60	3.60	28.00
15.	Hand geometry recognition	-1.87	2.74	1.84	27.00	9.20	4.20	28.00
12.	Eye vein scanning	-2.34	4.25	2.20	28.00	13.20	3.80	28.00
1.	DNA scanning	-2.56	5.19	3.16	31.00	15.50	3.90	30.00
19.	Handwriting recognition	-2.70	1.63	1.47	27.00	8.70	5.00	27.00
17.	Keystroke dynamics	-4.02	1.00	0.72	27.00	10.00	5.50	27.00
14.	Heart signals recognition	-6.38	1.11	0.77	28.00	15.00	3.40	28.00

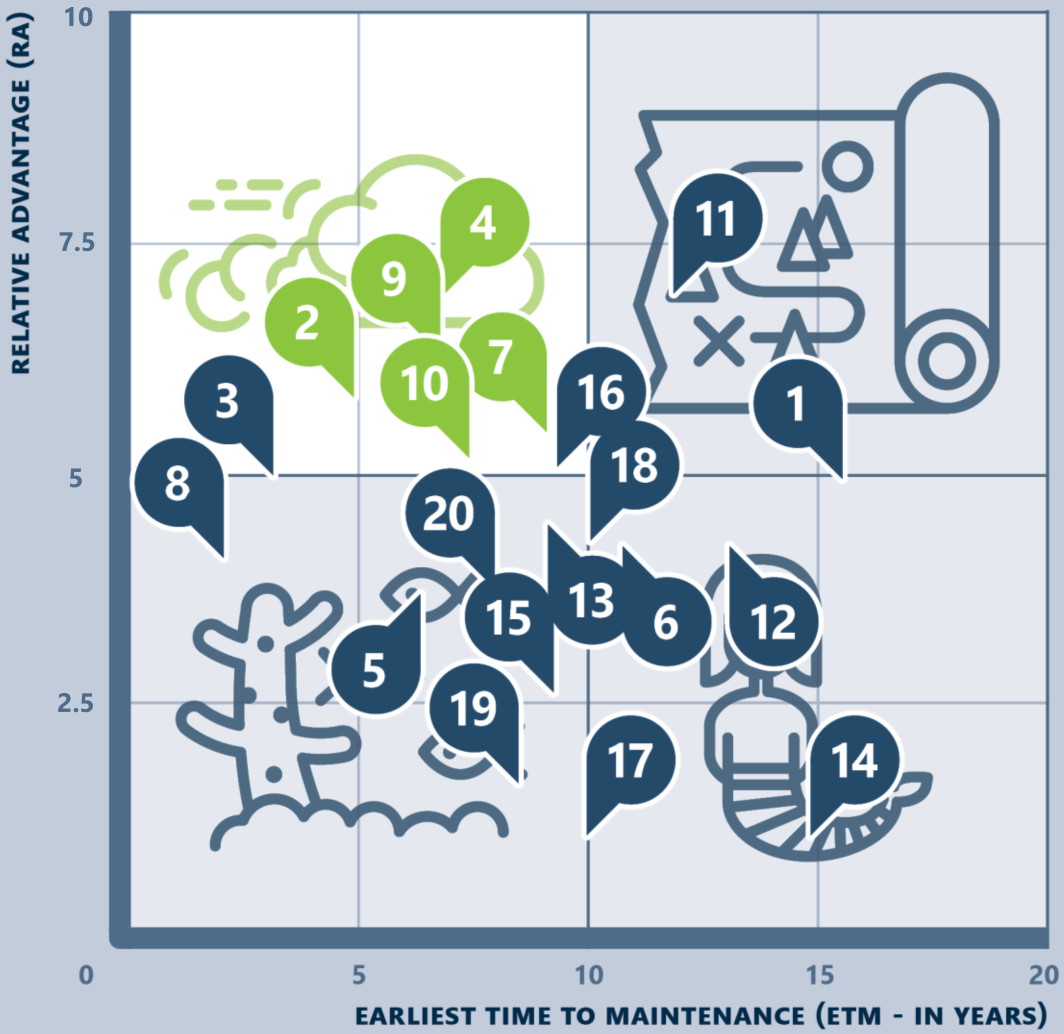
Filtering by Other Relevant Factors

ADDITIONAL CHECKS FOR

- redundancy
- vulnerability to adversary attacks
- "must-haves" from the needs analysis

FINAL SELECTION OF 5 KTC

- **2.** Infrared face recognition
- **4.** 3D face recognition
- **7.** Contactless friction ridge recognition
- **9.** Iris recognition in the NIR spectrum
- **10.** Iris recognition in the visible spectrum



4. Deep Analysis

Roadmaps of key biometric technological clusters

4.
DEEP ANALYSIS

Aim

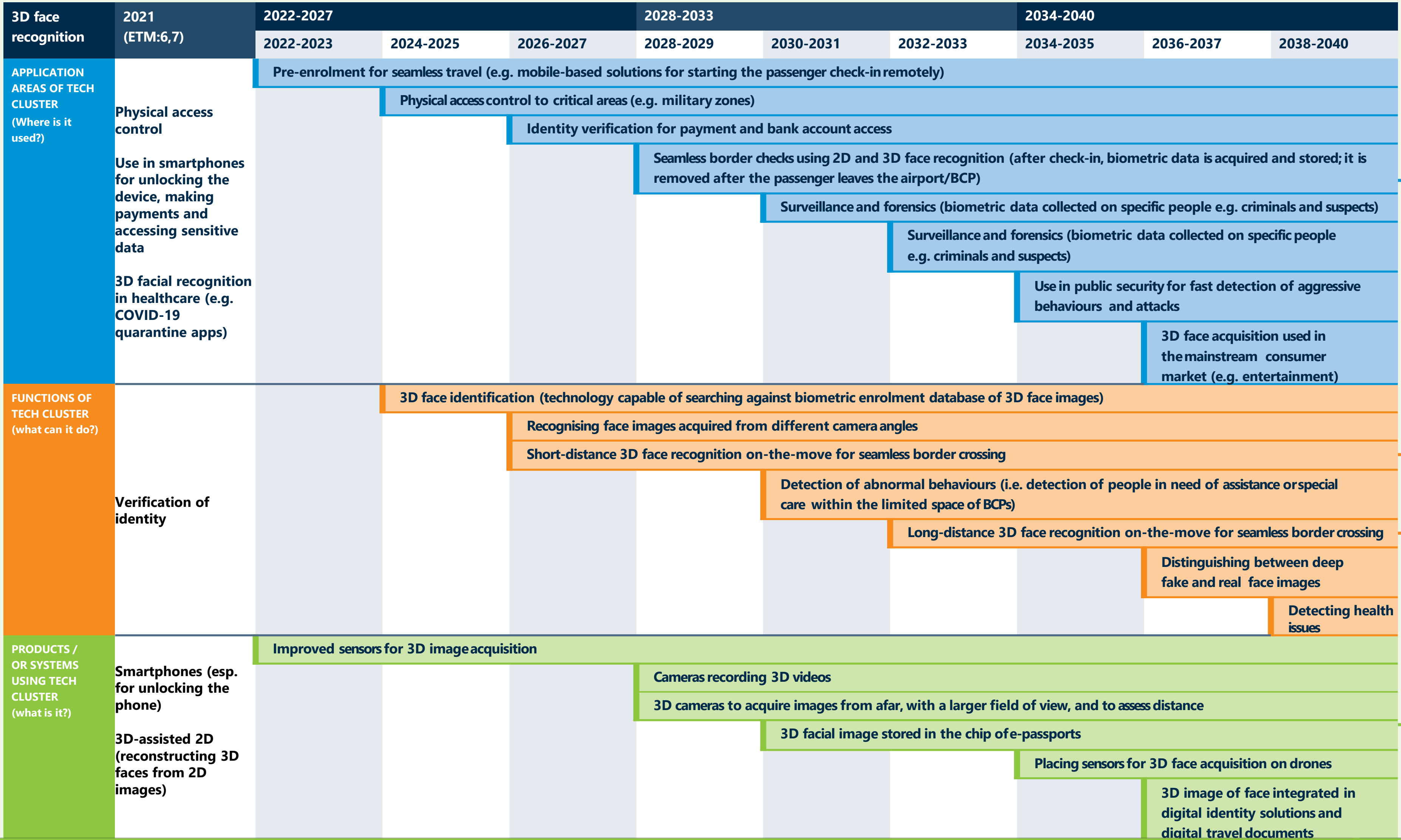
- In-depth analysis of the key technological clusters
- Envisage potential future developments in terms of:
  - Applications
  - Functions
  - Products and systems

Outcomes (for each KTC)

- Visual technology roadmap chart
- List of expected key opportunities and challenges in the today-2040 timeframe
- Comparative analysis to study how the of the hypothetical scenarios might influence the developments envisaged in the roadmaps

Roadmaps of key biometric technological clusters

Visual technology roadmap charts – 3D face recognition



EXAMPLE DEVELOPMENTS

2028 – 2040
Seamless border checks using 2D and 3D face recognition (after check-in, biometric data is acquired and stored; it is removed after the passenger leaves the airport/BCP)

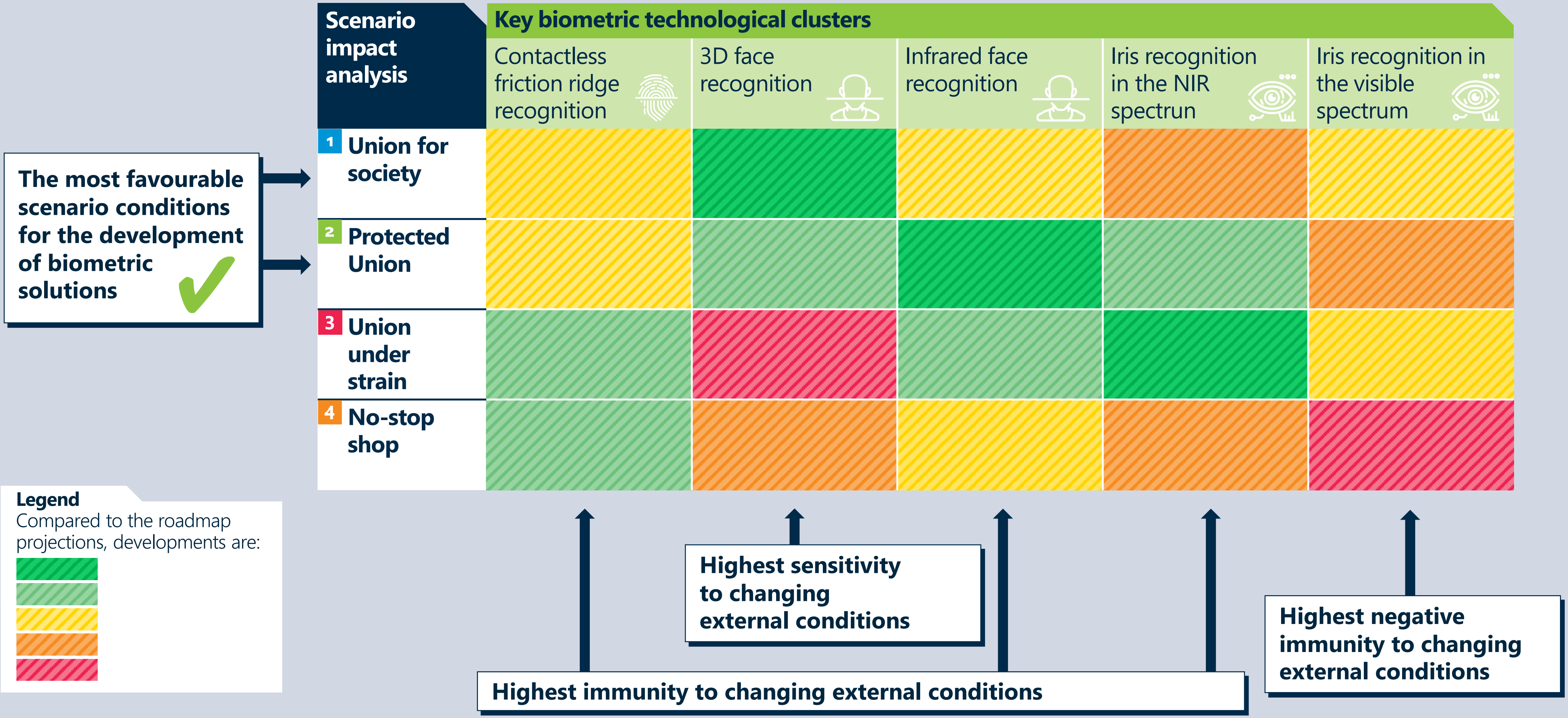
2026 – 2040
Short-distance 3D face recognition on-the-move for seamless border crossing

2032 – 2040
Long-distance 3D face recognition on-the-move for seamless border crossing

2030 – 2040
3D facial image stored in the chip of e-passports

Roadmaps of key biometric technological clusters

Cross-cluster comparison of scenario impact – 3D face recognition



5. Mapping Capabilities

Capability Readiness Analysis

Aim

- Explore existing EU capability landscape
- Identify capability gaps and opportunities across the various timeframes and scenarios

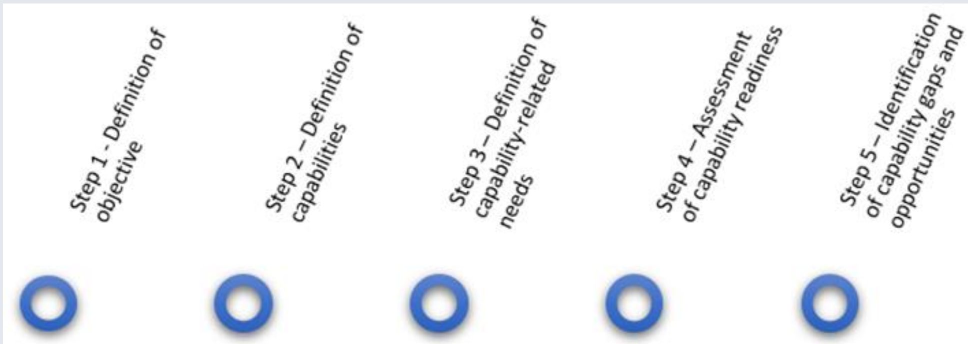
Outcomes (for each KTC)

- Capability readiness heatmaps

MAPPING CAPABILITIES

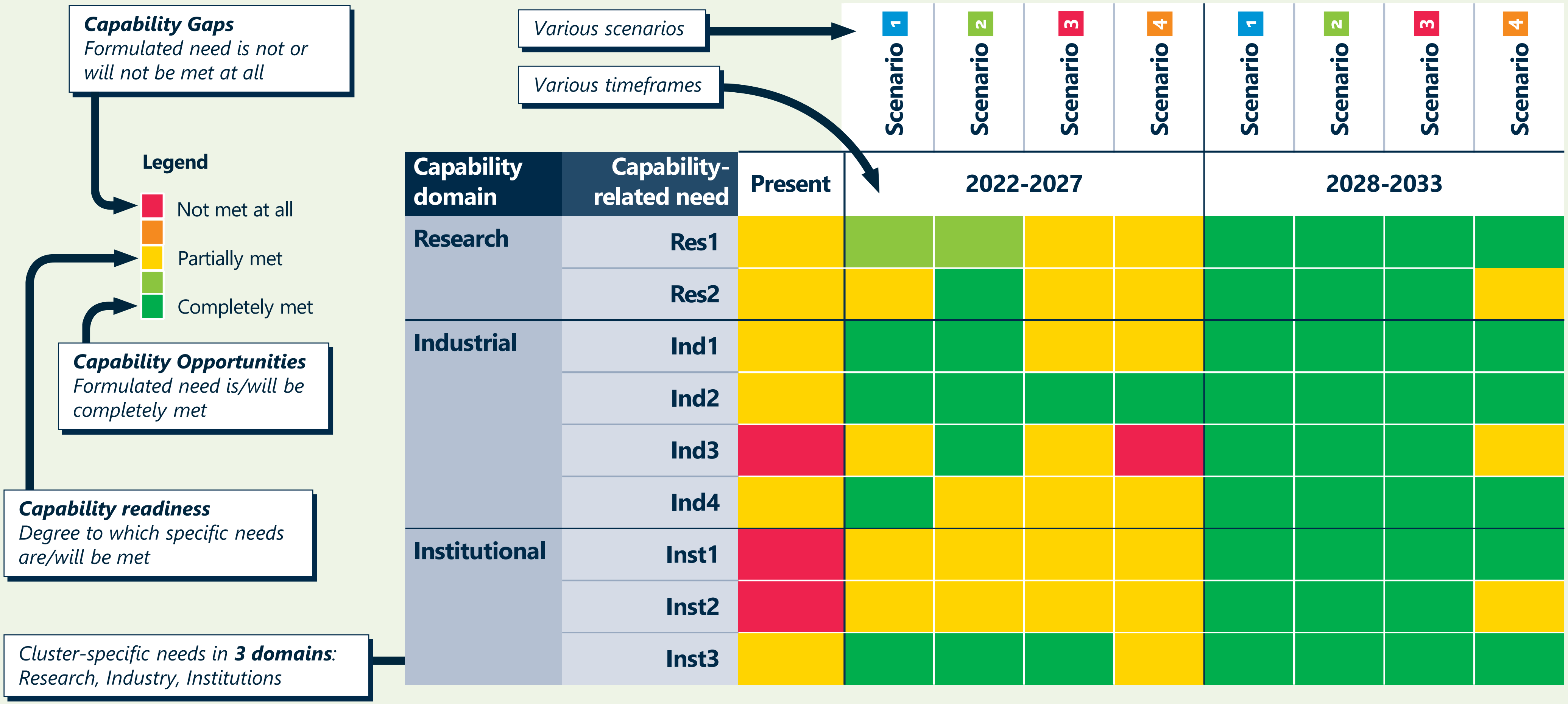
5.

METHODOLOGY



Capability Readiness Analysis

Heatmaps – 3D face recognition



Conclusions

Main Outcomes

Each of the phases of this complex Research Study produced its own set of future-oriented insights with the intention of supporting the EBCG community in decision-making processes that:

exploit opportunities

mitigate associated threats

result in the implementation of new biometrics-enabled technological solutions

5 Key Technological Clusters

Infrared Face Recognition

3D Face Recognition

Contactless Friction Ridge Recognition

Iris Recognition in the NIR Spectrum

Iris Recognition in the Visible Spectrum

Main Outcomes

Technology Foresight Manual describing the TF Process, the Methods and the Tools

Taxonomy of Biometric Technologies and Biometrics-Enabled Technological Systems

Analyses conducted over the patents, scientific literature and EU-funded projects

Set of scenarios for the future of travel and border checks

Prioritisation Matrix of biometric technological clusters

Set of roadmaps developed for the key biometric technological clusters

Heatmaps reflecting capability readiness for the key biometric technological clusters

Project Newsletters

APPLICATION

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NEWSLETTER #1 - METHODOLOGY

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NEWSLETTER #2 – SCENARIO ANALYSIS

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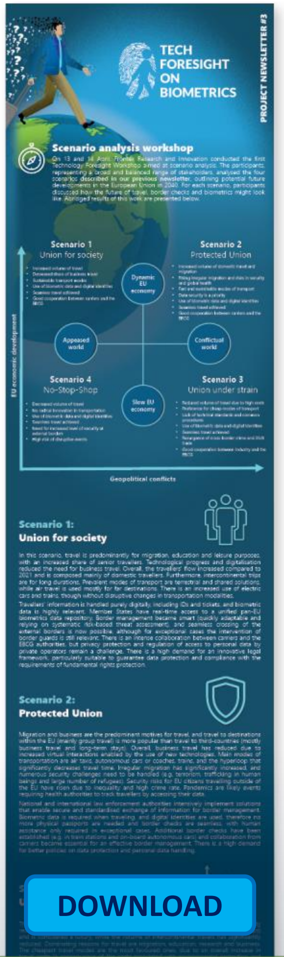
NEWSLETTER #3 – SCENARIO ADAPTATION



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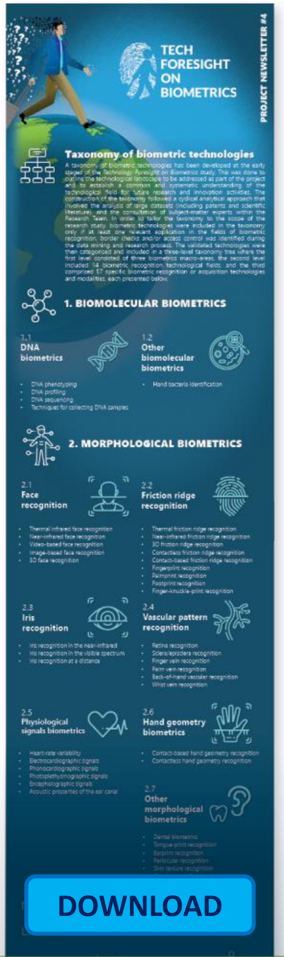
NEWSLETTER #4 – TAXONOMY



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NEWSLETTER #5 – 4CF MATRIX

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NEWSLETTER #6 – RESEARCH STUDY

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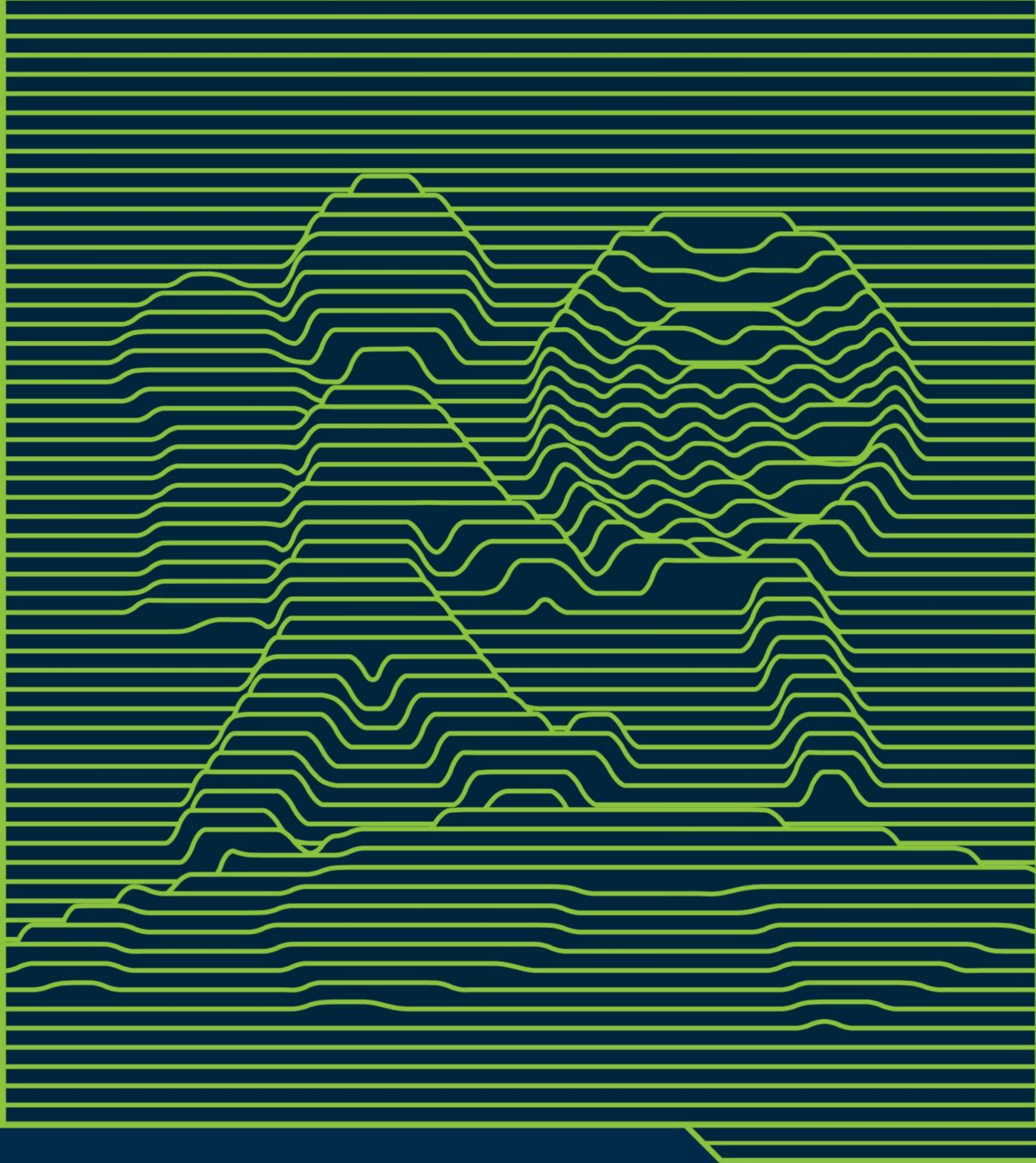

If you have any questions regarding this research study please contact Frontex Research and Innovation at **research@frontex.europa.eu**