INFRASTAR

Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

Mid-Term Review Meeting

Odile ABRAHAM (project coordinator)

Hakim FERRIA (project manager)

IFSTTAR

French institute of science and technology for transport, development and networks

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 676139

Overview

- Scientific
  - Context, objectives, main results, network synergy
- Training
  - Programme, complementary skills, secondments, open training events
- Networking
  - Interaction, dissemination, outreach activities
- Management
  - Recruitment, management, budget

Context

Civil infrastructures are the basis of socio-economic wealth for modern societies.

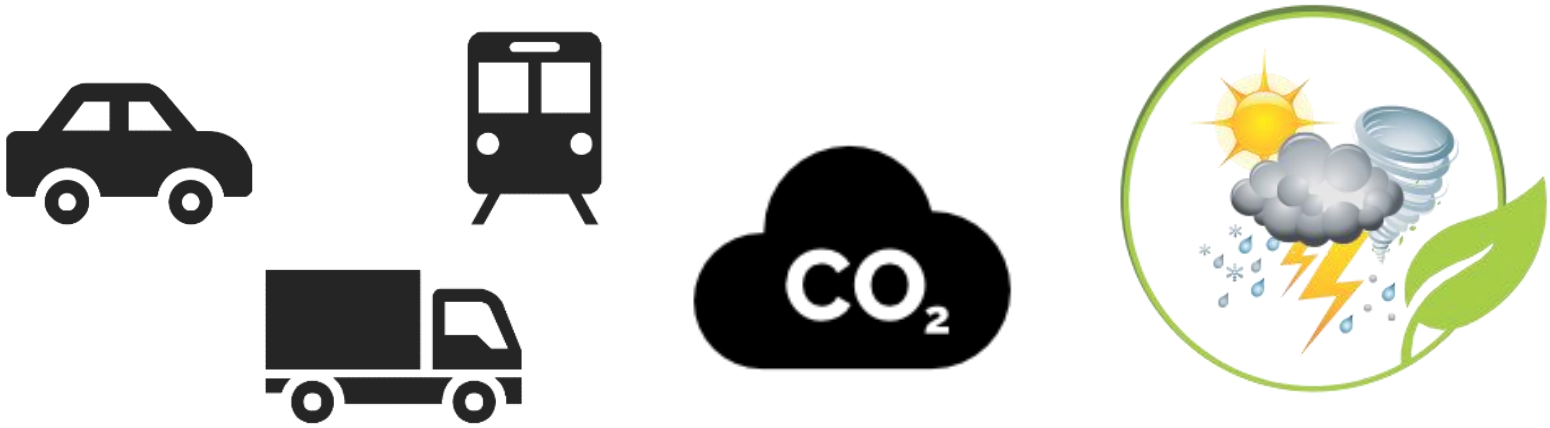
Context

Civil infrastructures are the basis of socio-economic wealth for modern societies.

Concrete is the most used material in volume in the world

Context

- Traffic increase
- Climate change
- CO2 emission
- Increasing demand for housing, water, energy, mobility



Context

Civil infrastructures are the basis of socio-economic wealth for modern societies.

FATIGUE ↔ CONCRETE

Limitations:

#1 Concrete structures are subjected to fatigue.

#2 Current technological means to measure fatigue are outdated, imprecise, and inappropriate.

#3 There is a lack of theoretical and practical developments of probabilistic methods.

Objectives

- 3 major challenges:
  - To develop new relevant auscultation and monitoring systems.
  - To reduce and optimize the safety margin encountered in wind turbine and bridge design in the assessment of remaining strength.
  - To optimize design and life cycle costs.

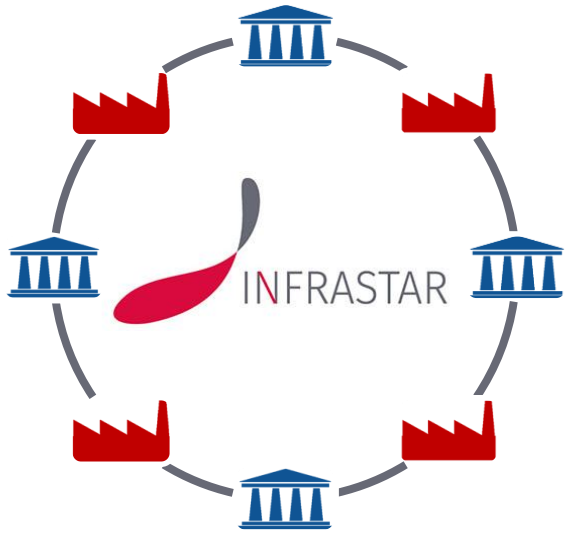
Develop knowledge, expertise and skills for optimal and reliable management of structures.

Strategy

Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

- 3 scientific Work Packages
  - WP1: Monitoring and auscultation
  - WP2: Structural and action models
  - WP3: Reliability approaches for decision-making
- WP4: Recruitment and training policy
- WP5: Management, dissemination, outreach and business opportunities

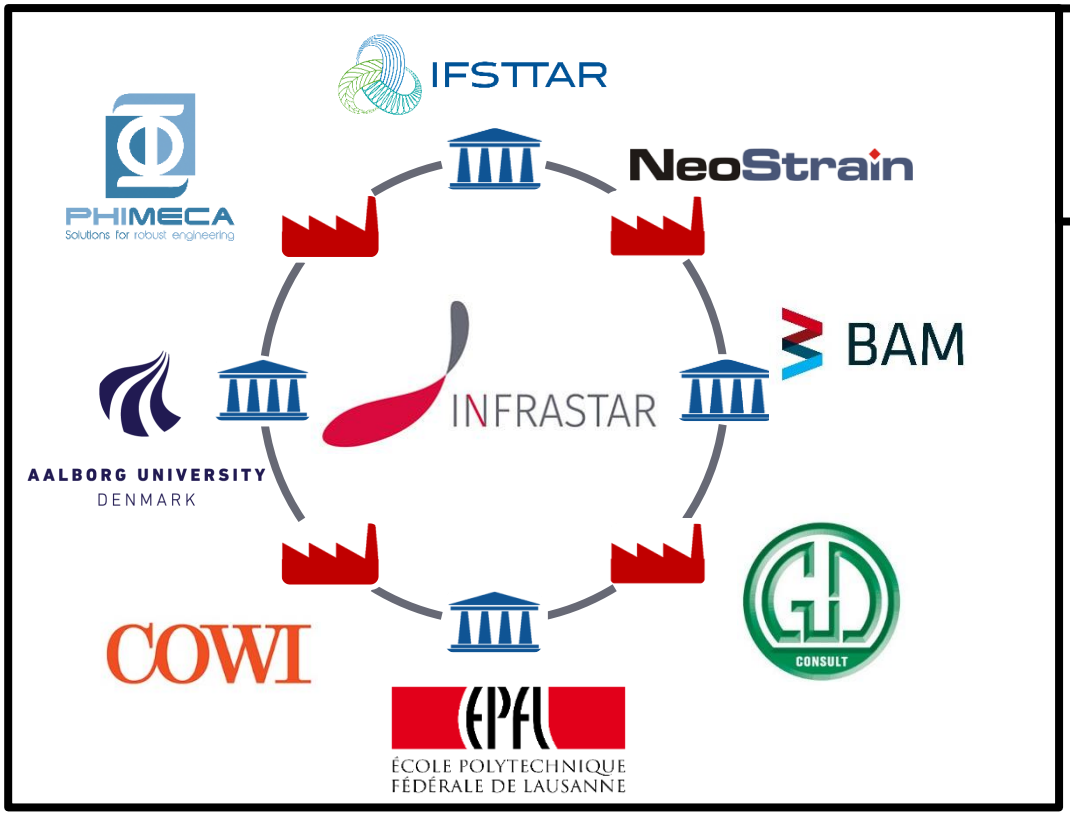
The network



8 beneficiaries

- **4 academic institutions**
- **4 industries**

The network



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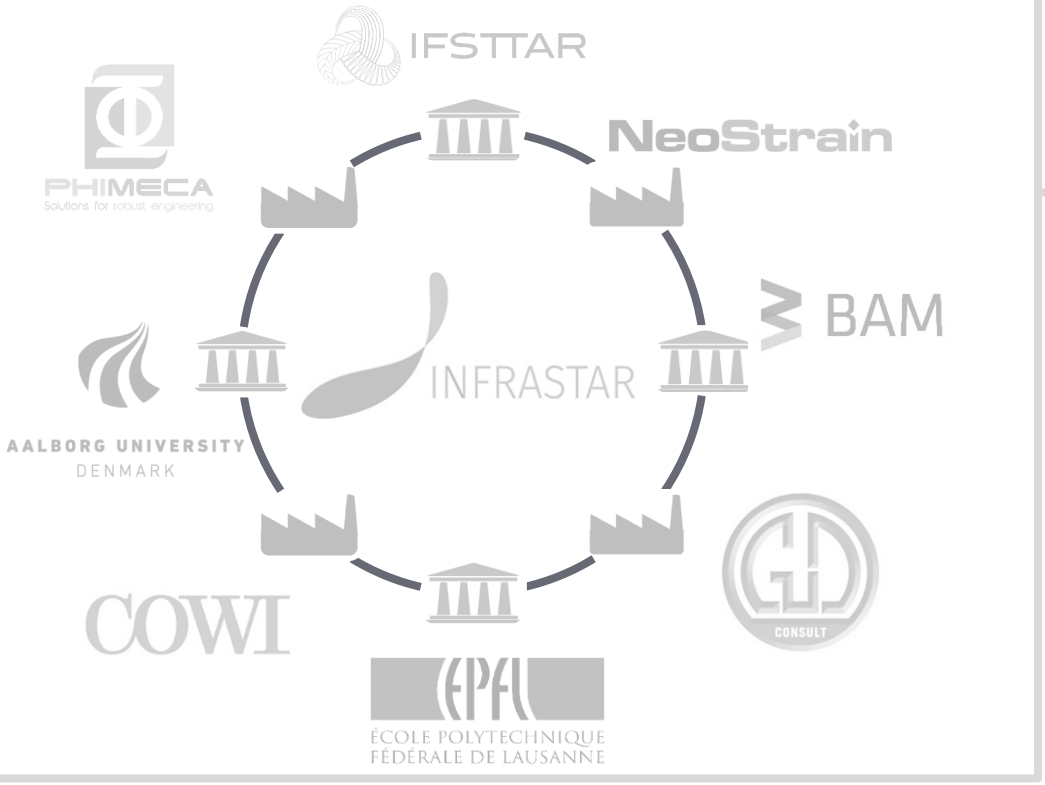
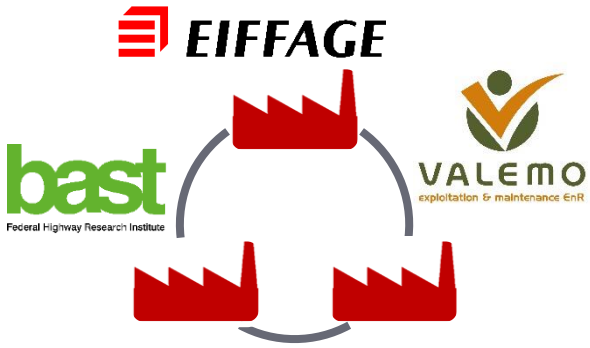


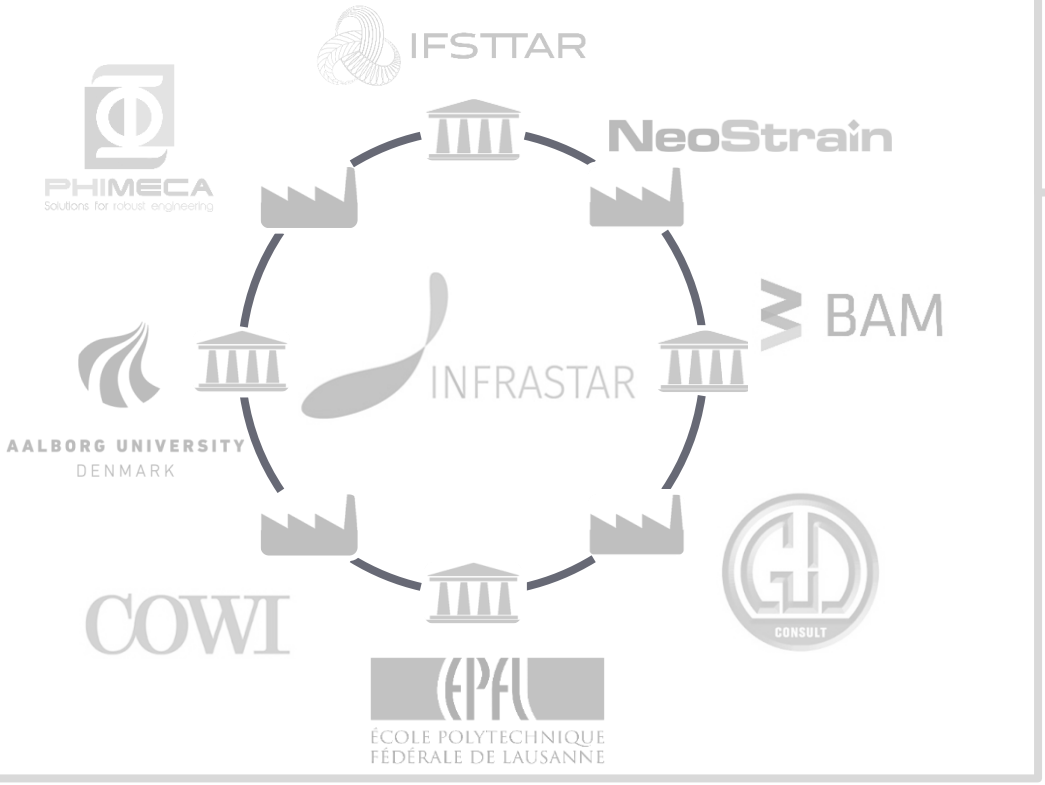
8 beneficiaries

- 4 academic institutions
- 4 industries

3 partner organisations



The network



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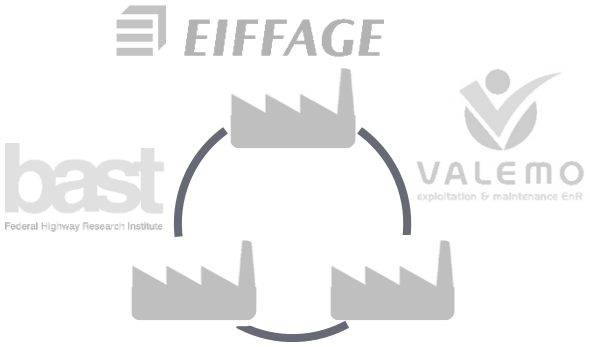

1 advisory board with 7 members

TNO innovation for life · DNV·GL · University of Surrey · TOTAL · Politechnika Wrocławska · DB · BAM

ESRs of WP1

ESR1 Xin Wang
@
BAM

ESRs of WP1

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@
BAM

ESR2 Antoine Bassil
@
IFSTTAR

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ESR3 Joyraj Chakraborty
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NeoStrain

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NeoStrain

ESR2 Antoine Bassil
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IFSTTAR

ESR4 Imane Bayane
@
EPFL
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

ESRs of WP2

ESR5 Bartek Sawicki

@

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ESRs of WP2

ESR5 Bartek Sawicki

@

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

ESR6 Mariia Nesterova

@

IFSTTAR

ESRs of WP2

ESR5 Bartek Sawicki

@

ESR6 Mariia Nesterova

@

ESR7 Gianluca Zorzi

@

ESRs of WP2

ESR5 Bartek Sawicki
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ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

ESR7 Gianluca Zorzi
@
CONSULT

ESR6 Mariia Nesterova
@
IFSTTAR

ESR8 Joey Velarde
@
COWI

ESRs of WP3

ESR9 Amol Mankar

@

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DENMARK

ESRs of WP3

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ESR10 Morteza Ahmadivala

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PHIMECA
Solutions for robust engineering

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ESR10 Morteza Ahmadivala
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ESR10 Morteza Ahmadivala
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PHIMECA
Solutions for robust engineering

ESR 12 Lijia Long
@
BAM

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WP1
Monitoring and auscultation

To smarten the structures.

Embedded ultrasonics

Fibre Optics

NDT parameters ↔ fatigue

Data fusion

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WP1
Monitoring and auscultation

What was done? What are the results?

- State of the art
- Throughout review of Non Destructive Testing for **fatigue damage assessment**
- Practical **hands-on** on Non Destructive Evaluation methods (extra skills)
- **Joint implementation** of Fibre Optics and Embedded ultrasonic sensors in several meter size test specimen specially designed
- **Processing** of data, **sharing** of data (BLEIB specimen, Crêt de l'Anneau)
- Modelling of **Fibre Optics coating transfer function**
- **Crack monitoring and sizing**

WP2
Structural and action models

To improve structural and fatigue loading models.

Reinforced Concrete and UHPFRC

Extreme Actions (traffic, wind)

Soil cyclic behaviour

Ground Base Foundation WT

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COWI

WP2
Structural and action models

What was done? What are the results?

- State of the art
- **Structures** : Bridge, WT foundation, soil, Reinforced concrete and UHPFRC
- **Actions** : Wind, traffic, waves
- **Data** collection (monitoring), data extrapolation
- Fatigue **resistance** models (from literature data)
- Fatigue **loading** models (including case studies)

WP3
Reliability approaches for decision-making

To improve the risk assessment for decision-making.

- **Reliability Analysis**
- **Maintenance Optimisation**
- **Risk Analysis**
- **Value of Information**

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What was done? What are the results?

- State of the art
- **Probabilistic framework** for **reliability assessment**
- **Statistical analyses and stochastic models** (based on data from literature) for fatigue of concrete and fatigue of steel rebars
- Stochastic models for action effects (1st attempt on Crêt de l'Anneau viaduct)
- **Time variant reliability problems** (Surrogate models, Bayesian approach)
- Bayesian decision theory
- Risk based approaches (1st implementation on icing event in wind turbine)
- Value of Information (1st implementation on a truss bridge girder)

WP1 WP2 WP3
Next scientific steps

For each ESR: to make a personal **contribution to knowledge**

For each of them in **INFRASTAR**: to benefit of a **multi-disciplinarity** breeding ground to **amplify** their contribution

→ How: the **shared objects**

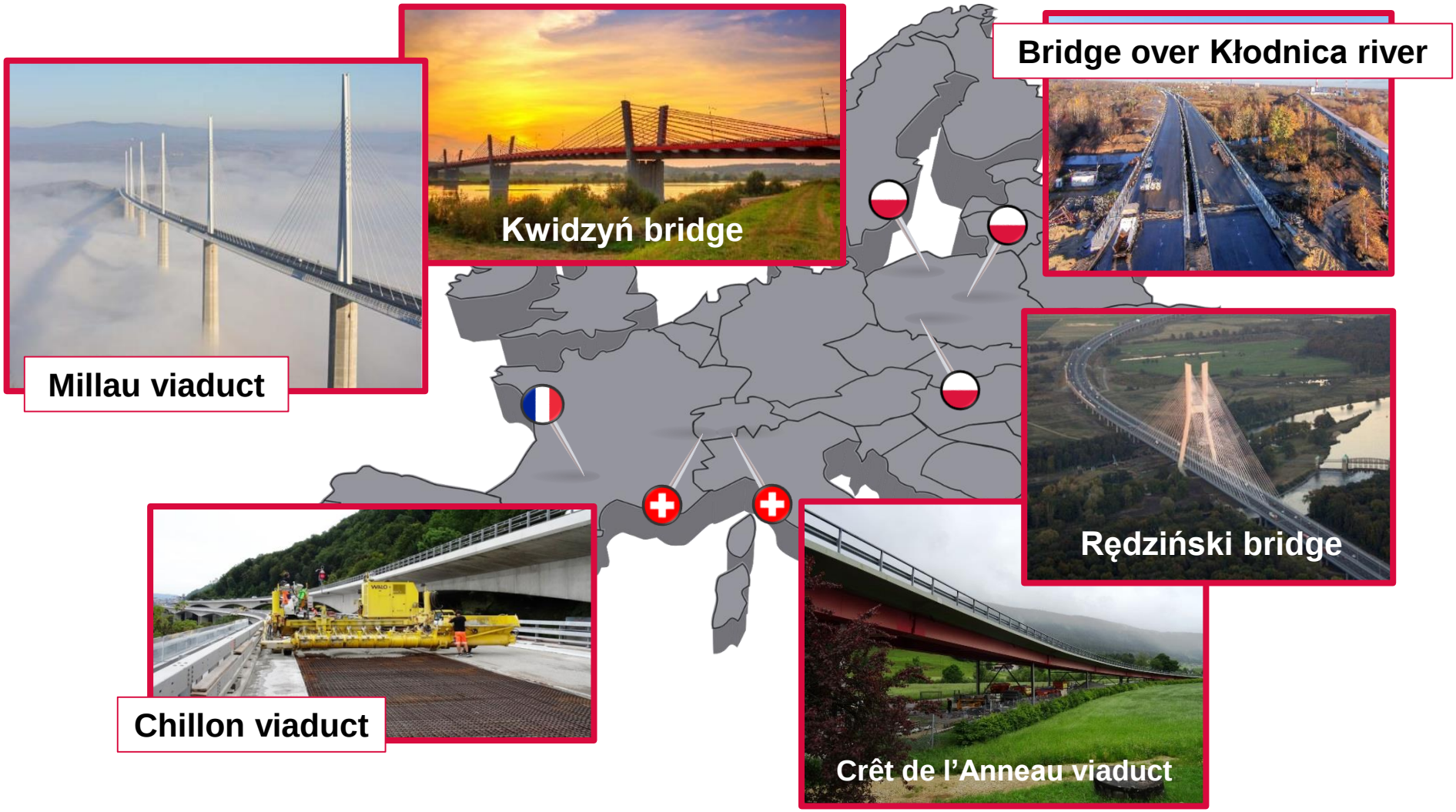
Co-operation

Shared objects

- Aims:
  - To promote collaboration between WPs
  - To boost ESRs collaboration
  - To exemplify the inter-sectoral approach

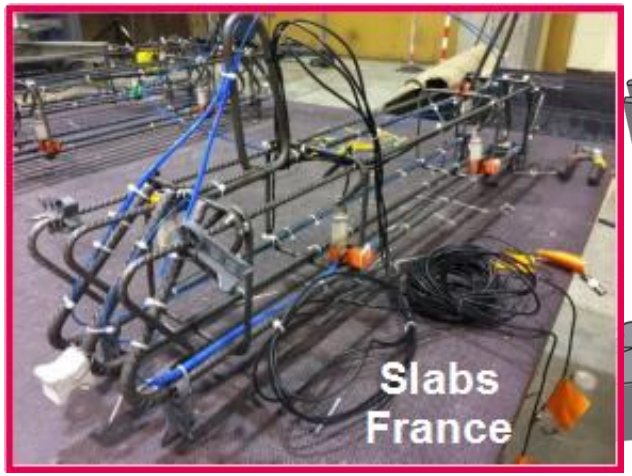
- Nature:
  - On site structures
  - Reduced scale lab specimen
  - Models
  - Data sets
  - etc

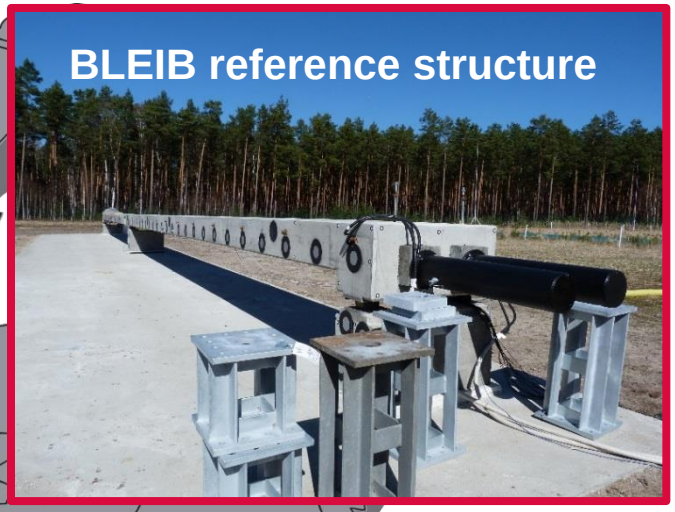
Shared objects / Bridges



Shared objects / Wind Turbines

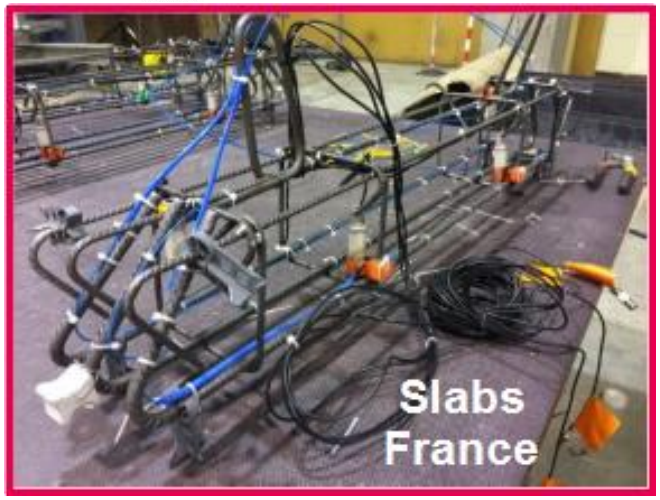
Shared objects / Lab specimen

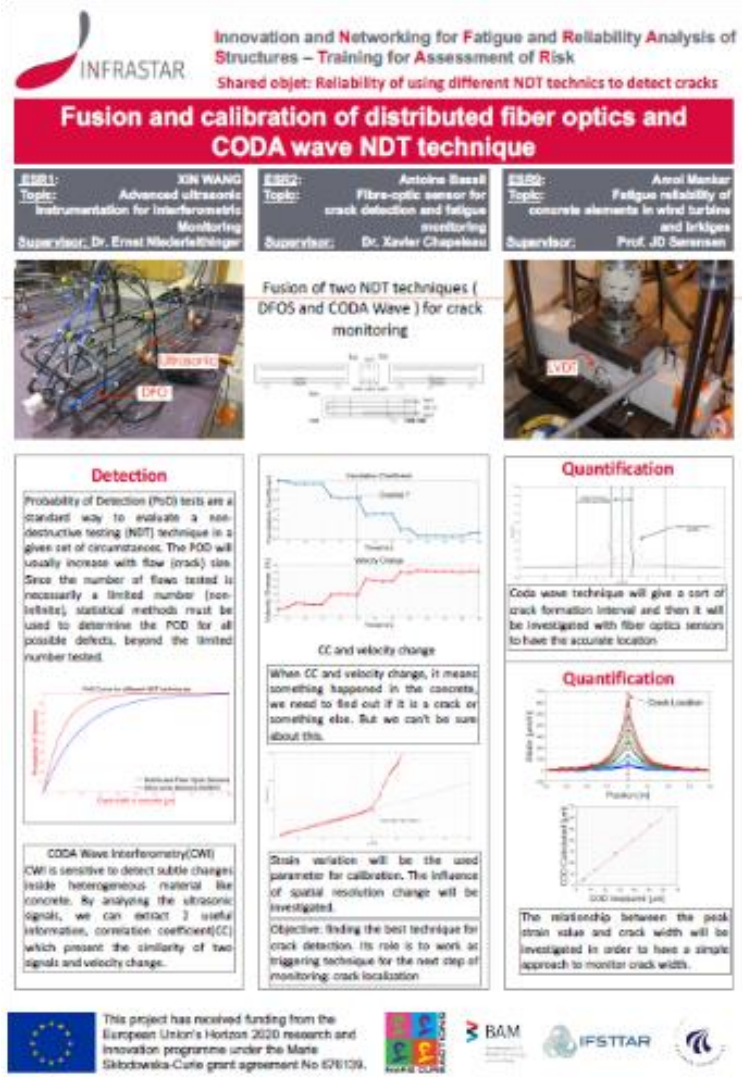




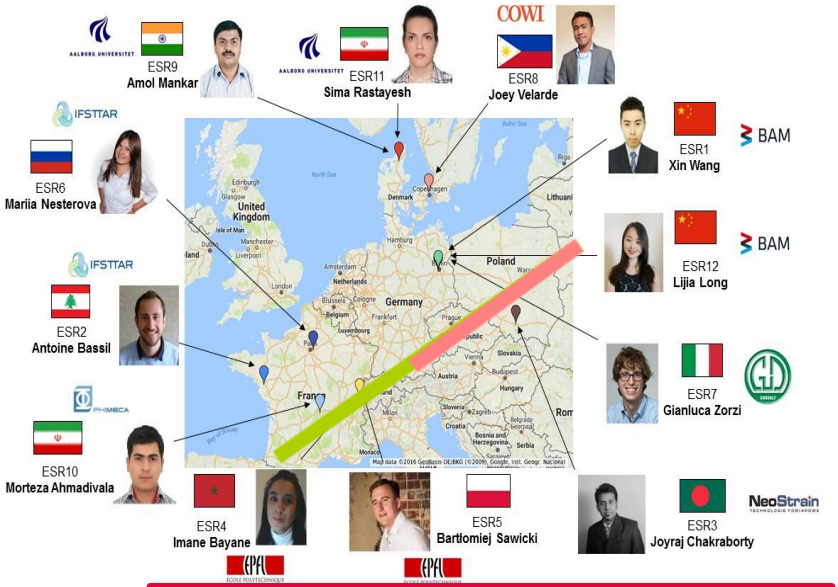
Co-operation

Co-operation: Ex. 1





Co-operation: Ex. 2



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QUANTIFICATION THE VALUE OF SHM INFORMATION ON Crêt de l'anneau VIADUCT

Imane Bayane [1], Lijia Long[2,3], Sebastian Thöns[2,3], Eugen Brühwiler [1]

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2. Dept. 7.0: Safety of Structures, Federal Institute for Materials Research and Testing (BAM), 12205 Berlin, Germany, lijia.long@bam.de
3. Dept. of Civil Engineering, Technical University of Denmark, 2800 Lyngby, Denmark, sebt@byg.dtu.dk

1. MOTIVATION

Crêt de l'anneau viaduct is a mixed concrete and steel road viaduct located in Switzerland.
After 60-year of service life, it is supposed to be under fatigue problems through probabilistic reliability analysis, which requires repairing or closing the viaduct.

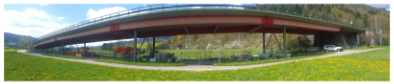

Figure 1 Panoramic view of Crêt de l'anneau viaduct

➡ In order to make best decision, Structural Health Monitoring (SHM) is implemented for one year to investigate the fatigue behavior.

2. STRUCTURAL PROBABILISTIC MODEL

Crêt de l'anneau is a road mixed concrete steel viaduct
The viaduct is made up of 8 articulated spans over 200m length.
The bridge is modeled as series system.

Figure 2 Plan view of Crêt de l'anneau

Consider both limit states of concrete and rebar.

3. SHM INFORMATION

Figure 3 SHM strategy

Sensor location: in the mid span 2 and span 4
10 strain gages, 6 thermocouples, 1 humidity sensor
Monitoring period: 30/07/2016 (strain gage)

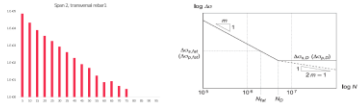

Figure 4 Fatigue evaluation using rain flow algorithm (left) and S-N curve (right)

4. QUANTIFICATION OF VOI

Conditional value of information analysis
Calculating posterior and prior utilities
Considering structural reliability behavior, decision scenarios and the benefits and cost

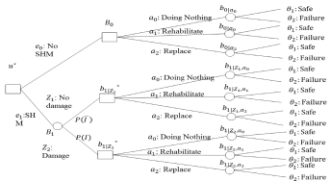

Figure 3 Illustration of decision tree and quantification of Value of Information

5. CONCLUSON

The results show that there is no fatigue problem in the viaduct. Through quantification the value of SHM information on Crêt de l'anneau Viaduct, it is founded that the money and time can be saved, the risk of the bridge can be reduced and that the viaduct can be operated for longer time.
Quantification the value of acoustic emission will be done as a future work.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 676139.

ITN Innovative Training Networks

Co-operation: Ex. 3

Millau viaduct

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Innovation and Networking for Fatigue and Reliability Analysis of Structures – Training for Assessment of Risk

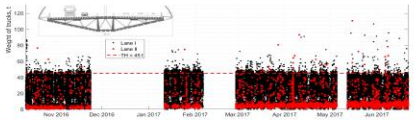
Reliability and Risk Analysis Based on Weight In Motion Data in Case of a Traffic

IFSTTAR
Mariia NESTEROVA
ESR6 – IFSTTAR, Paris, FRANCE
Supervisor: Franziska SCHMIDT

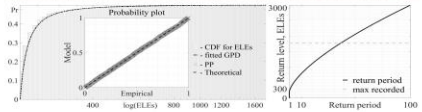
Sima Rastayesh
ESR12 – AAU, Aalborg, Denmark
Supervisor: John Dalsgaard Sørensen

Extreme Value Analysis of the traffic actions on the bridge

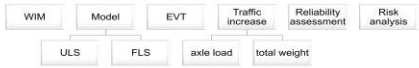
The recordings were made by WIM system installed under the first span of the viaduct between October 2016 and July 2017. Monitoring was done with certain gaps during winter and spring holidays, with the total period of 6 months.



The Extreme Value Theory analysis is applied to the data represented by weights of vehicles passing the bridge, in order to evaluate return periods for the level of actions. The Peaks Over Threshold approach is used that includes fitting the extreme vehicles to the Generalized Pareto Distribution.



Taking into account a few very heavy trucks passed the bridge, the bending moment for the 6-meters element of the span of Millau is obtained from each vehicle axle. Obtained values of return period for both ULS and FLS show no damage during operational life of the bridge, according to the initial design.

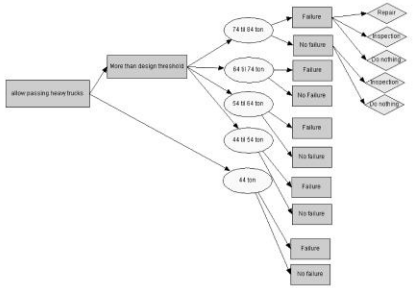


Therefore, the increase of traffic in axle and total weight is estimated, with following reliability indexes. This information provides the basis for decision tree for the risk analysis.

Maximum weight of trucks to be allowed to pass the bridge

The question in our context is should very heavy trucks be allowed to pass a our bridge or not? This question can be answered using a reliability analysis and comparison with the target reliability level from bridges; The question can also be answered based on a risk analysis where the consequences are modelled. Further, a proof loading could be used to obtain more information on the load bearing capacity and thus be included in the risk analysis.
The bridge that is chosen as case study is the highest bridge in the world. So the risk assessment of this bridge is an eminent issue for its owners. In the European country, the maximum weight of a track that could pass in a bridge is forty tons which the design of the bridge is based on that. But the records of the weight of trucks as shown in the first graph, shows there are some trucks that are even around 120 tons. So, the question is that what would be the effect of these trucks. What would be the consequence here in our structure?

In order to solve this extreme load decision problem, the decision tree will be used based on Bayesian approach.



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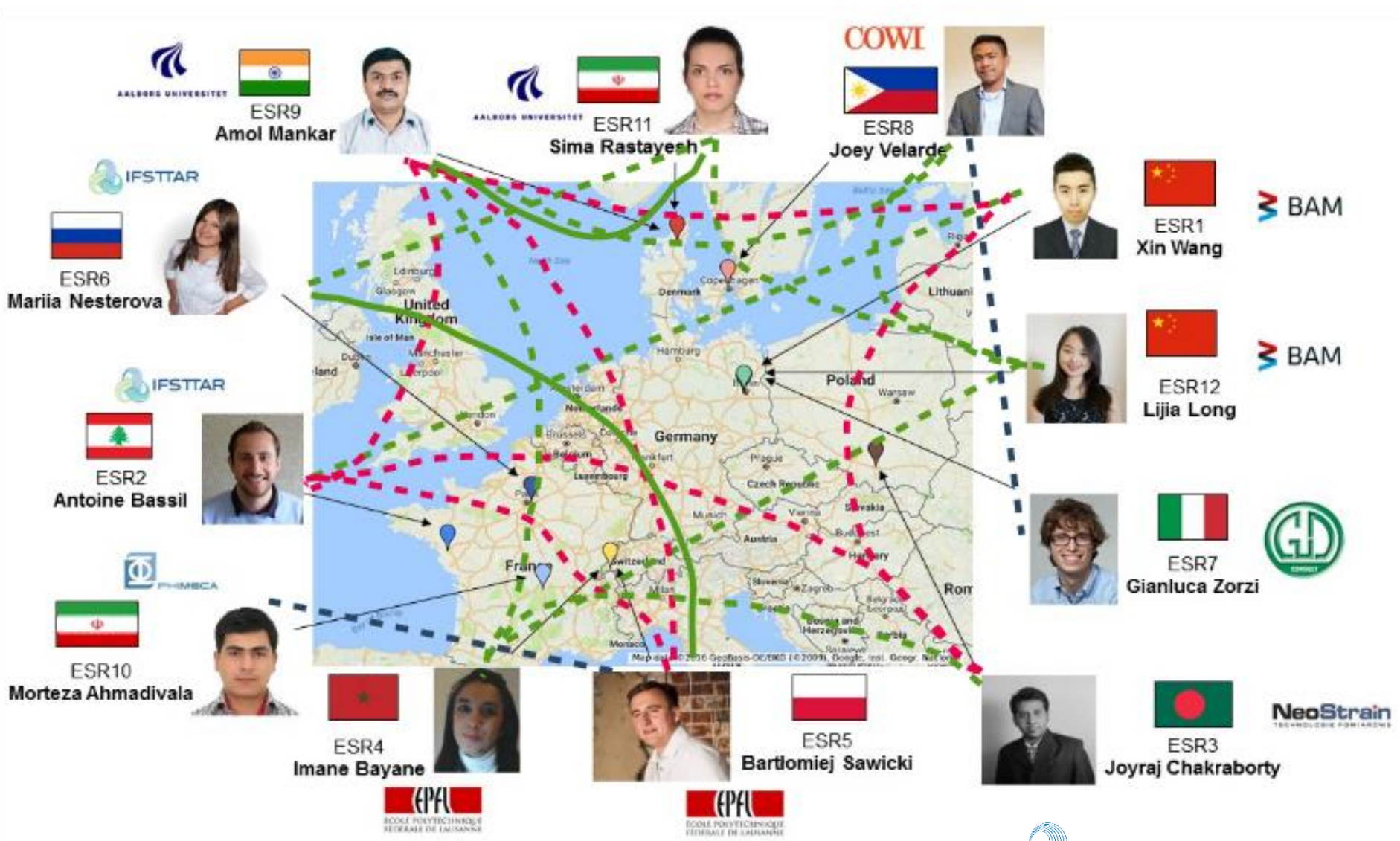

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Training programme

To enhance employability of ESRs.

To provide individual, collective training courses and complementary skills.

To expose them to different cultural, scientific and organisational environment.

To help them to understand the scope of their work in an industrial context.

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Training Weeks

Secondments

Implementation days

Training programme

To enhance employability of ESRs.

Three training weeks:

- Scientific lectures (43 hours).
- Lecturers from academia and industries.
- Technical visits (8 hours).
- Teamworks on shared objects (5 hours).
- Presentation/discussion (60’ / ESR).

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Training programme

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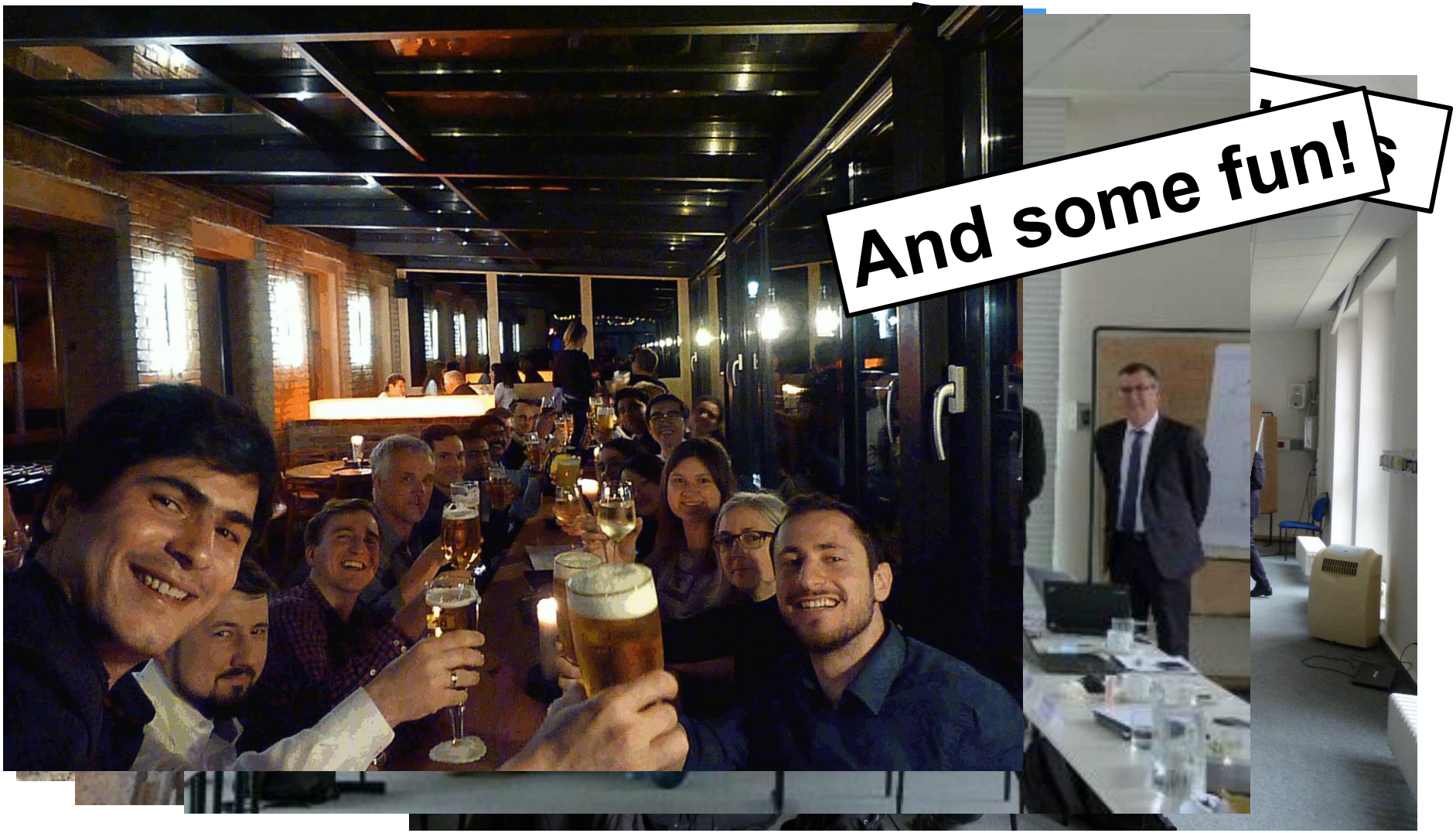

Complementary skills

- Ethics in research
- Open access, open data
- Teamwork
- Career development
- Entrepreneurship
- Intellectual property

Personal Career Development Plan

Secondments

To experience different organisations, environment and cultures.

34 months performed	33 months remaining

- Mobility (country and/or sector).
- Partnership of academic and non-academic institutions.
- Joint supervision.
- Secondment agreement, work programme.

Open training events

- Winter school @ IFSTTAR
  - March 2019
  - Advanced and practical courses
  - Poster session

- Final workshop in Brussels
  - February 2020
  - Towards the industries
  - Widely open

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Interaction with private sector

To boost networking opportunities.

- ImpDay#01 @ bast Federal Highway Research Institute ☑
- ImpDay#02 @ EIFFAGE ☐ **Save the date:** Friday 12 October 2018
- ImpDay#03 @ COWI ☐ **Save the date:** June 2019

Interaction with private sector

VALEMO
exploitation & maintenance EnR

Dissemination

Communication to the scientific community.

2016

2017

2018

2019

2020

Dissemination

Communication to the scientific community.

3 conference papers

2016

2017

2018

2019

2020

Dissemination

Communication to the scientific community.

13 conference papers

2016

2017

2018

2019

2020

1 poster

3 journal papers

Dissemination

Communication to the scientific community.

22 conference papers

2016

2017

2018

2019

2020

15 journal papers

Outreach activities

Communication to the public.

- Blog
- Three minutes thesis
- Fête de la science
- PhD days
- Videos

Outreach activities

Communication to the public.

- Blog
- Three minutes thesis
- Fête de la science
- PhD days
- Videos

12 blogs
78 posts since June 2017

Outreach activities

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- Blo
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- Videos

Outreach activities

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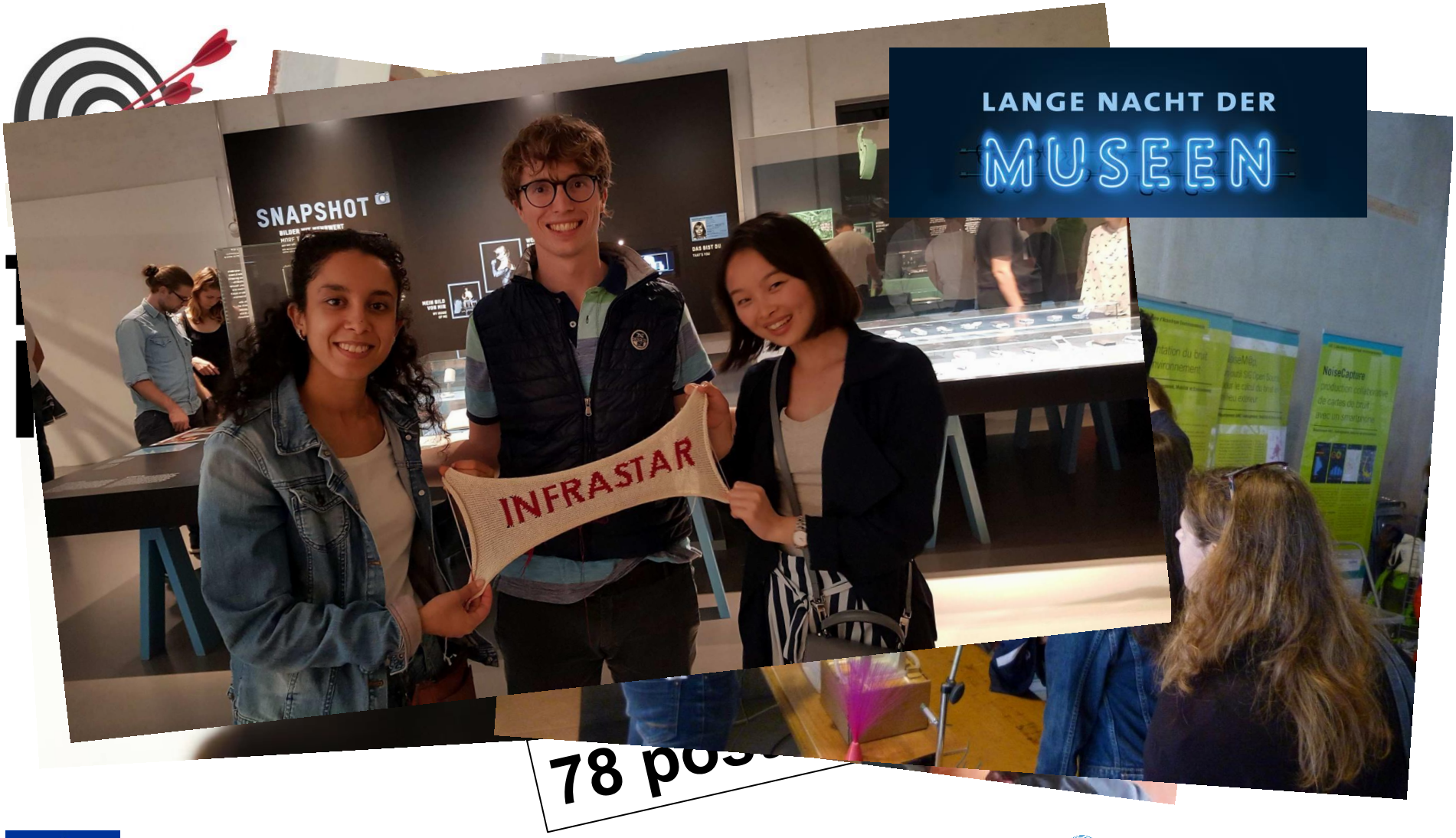

Outreach activities

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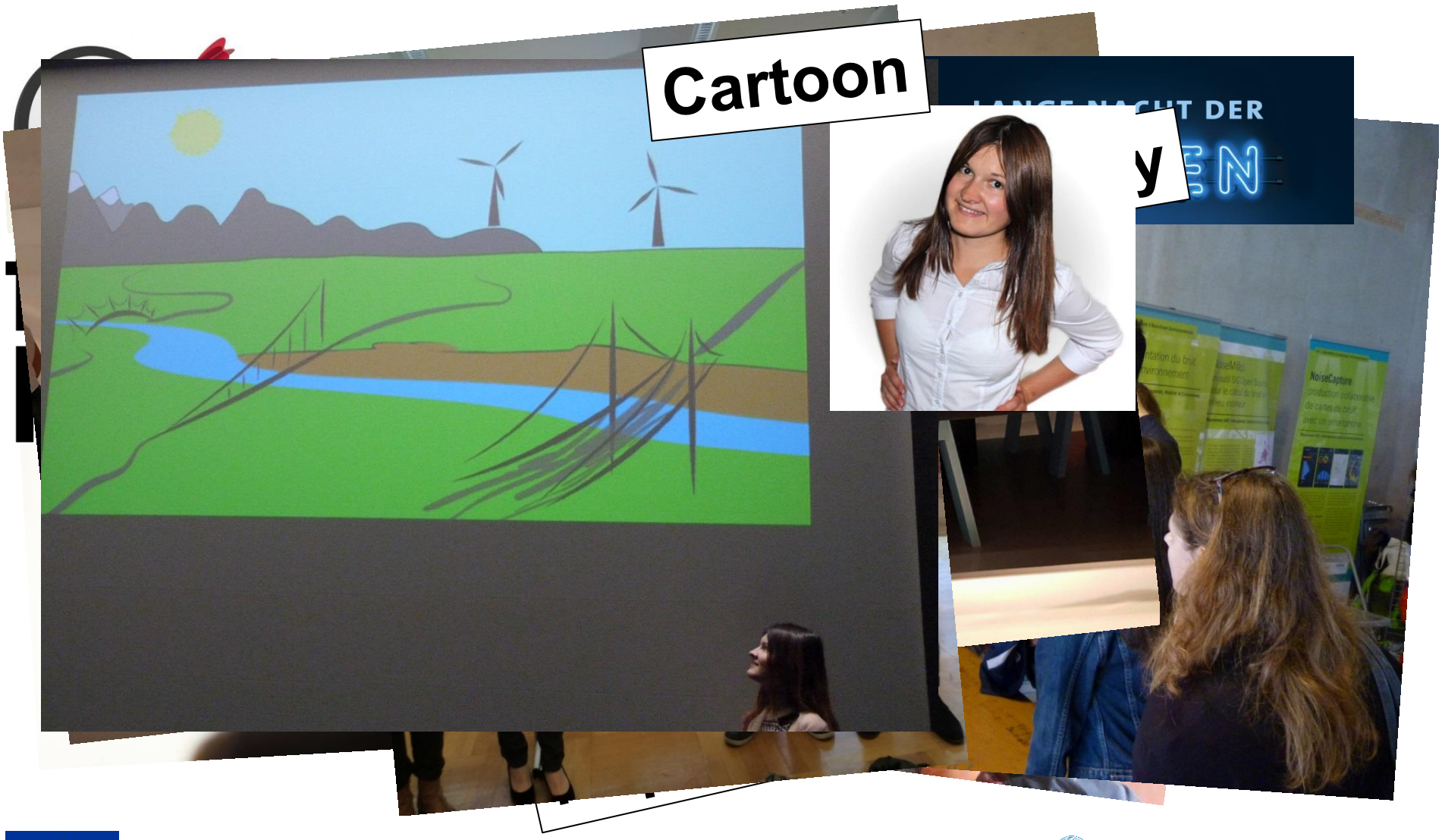

Outreach activities

Communication

- Website ☑
- Templates, logo ☑
- Social networks: ☑
  - Facebook (230 posts, 90)
  - Twitter (260 posts, 108 followers)
- Blog 78 posts ☑
- Videos ☑
- Newsletter (2 issues), brochure, etc. ☑

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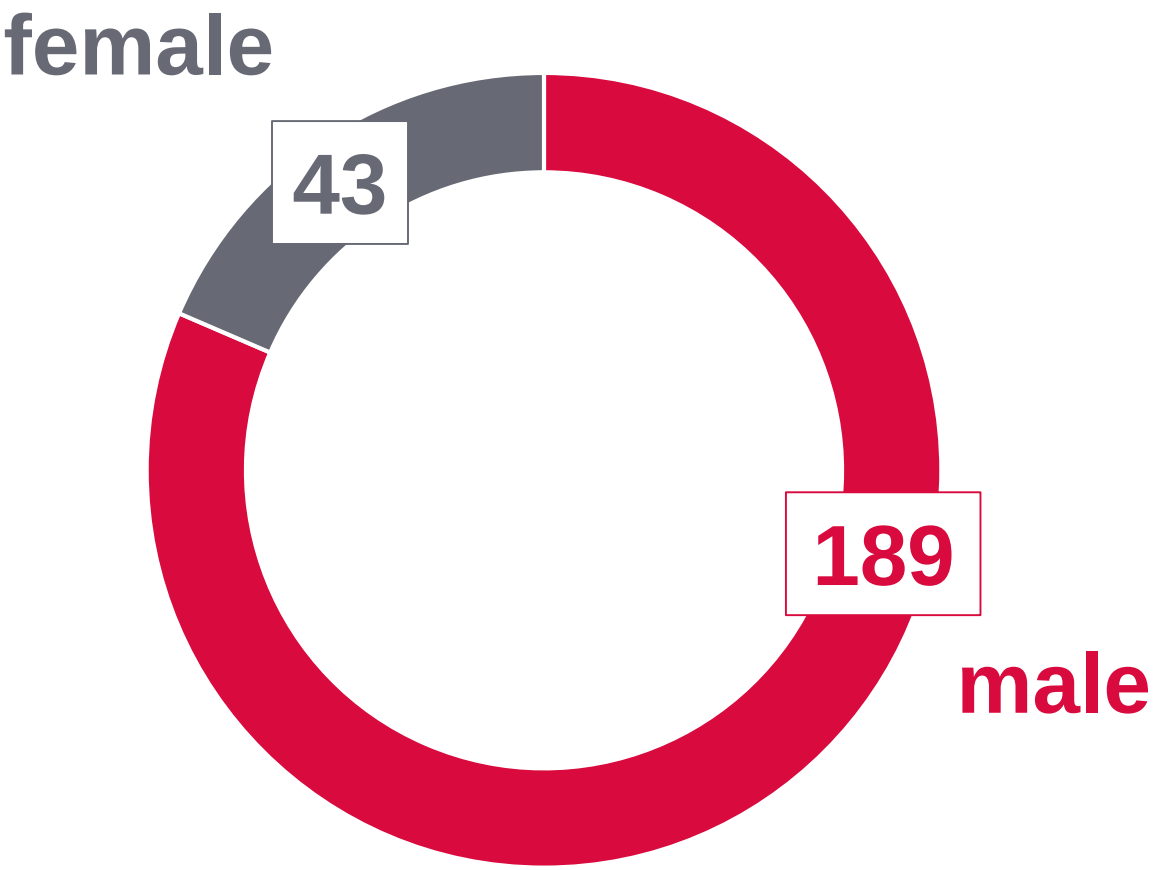
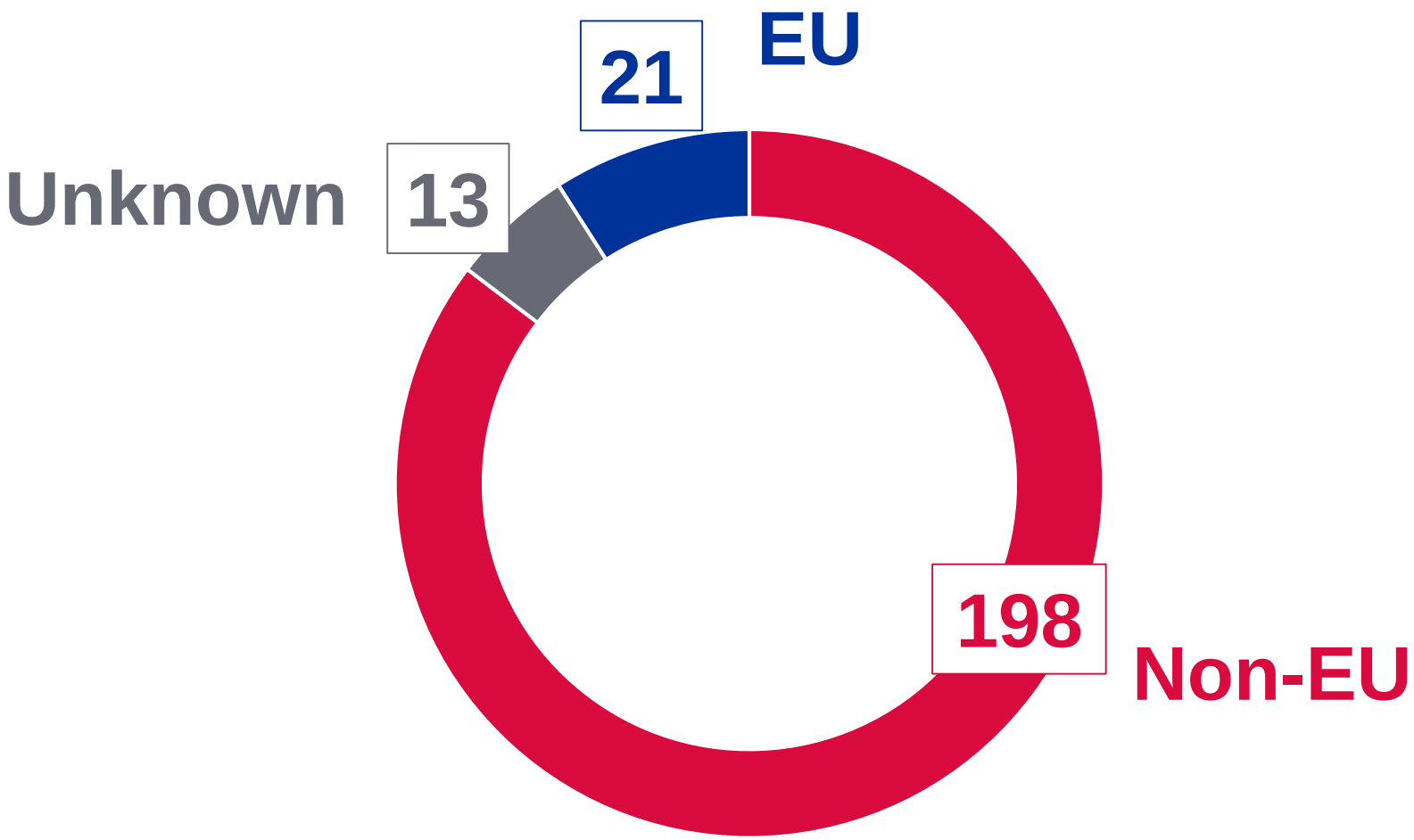
Recruitment

Open, transparent, impartial, equitable and merit-based

Recruitment

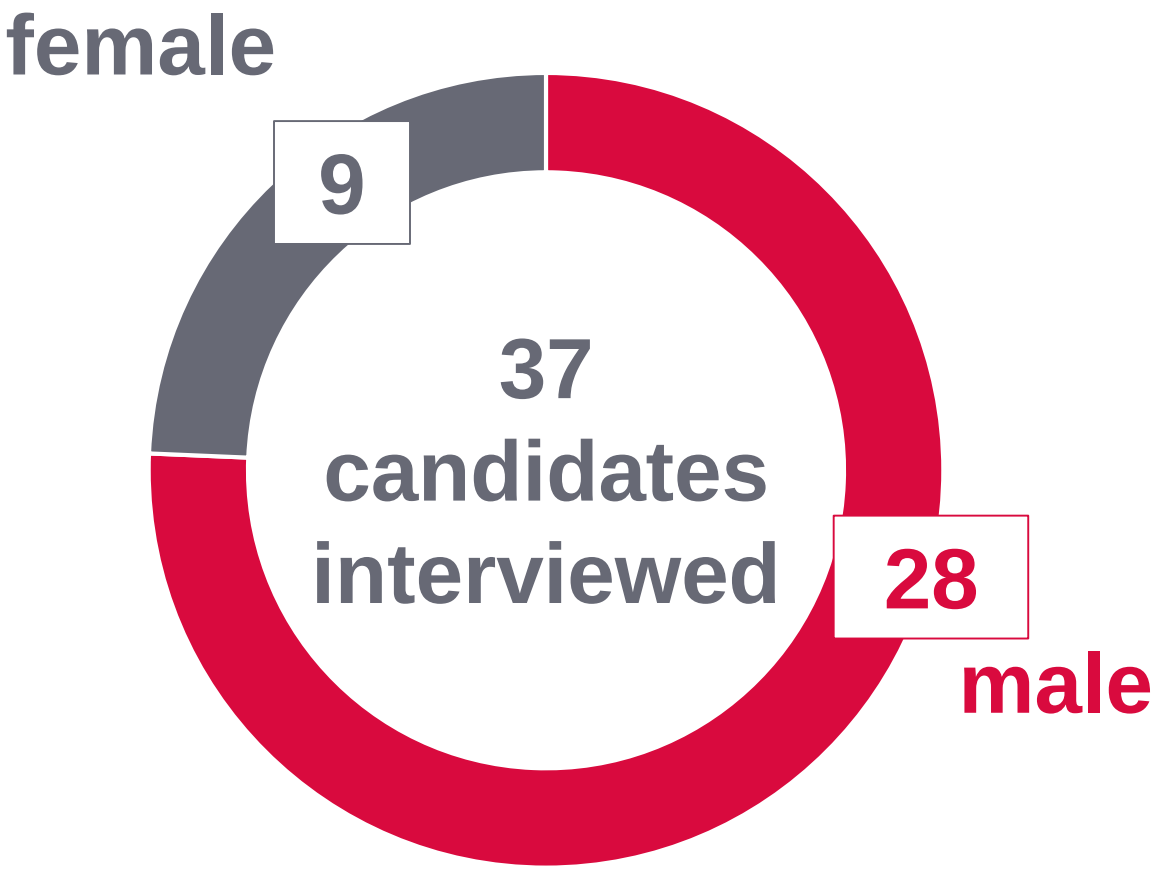


Recruitment

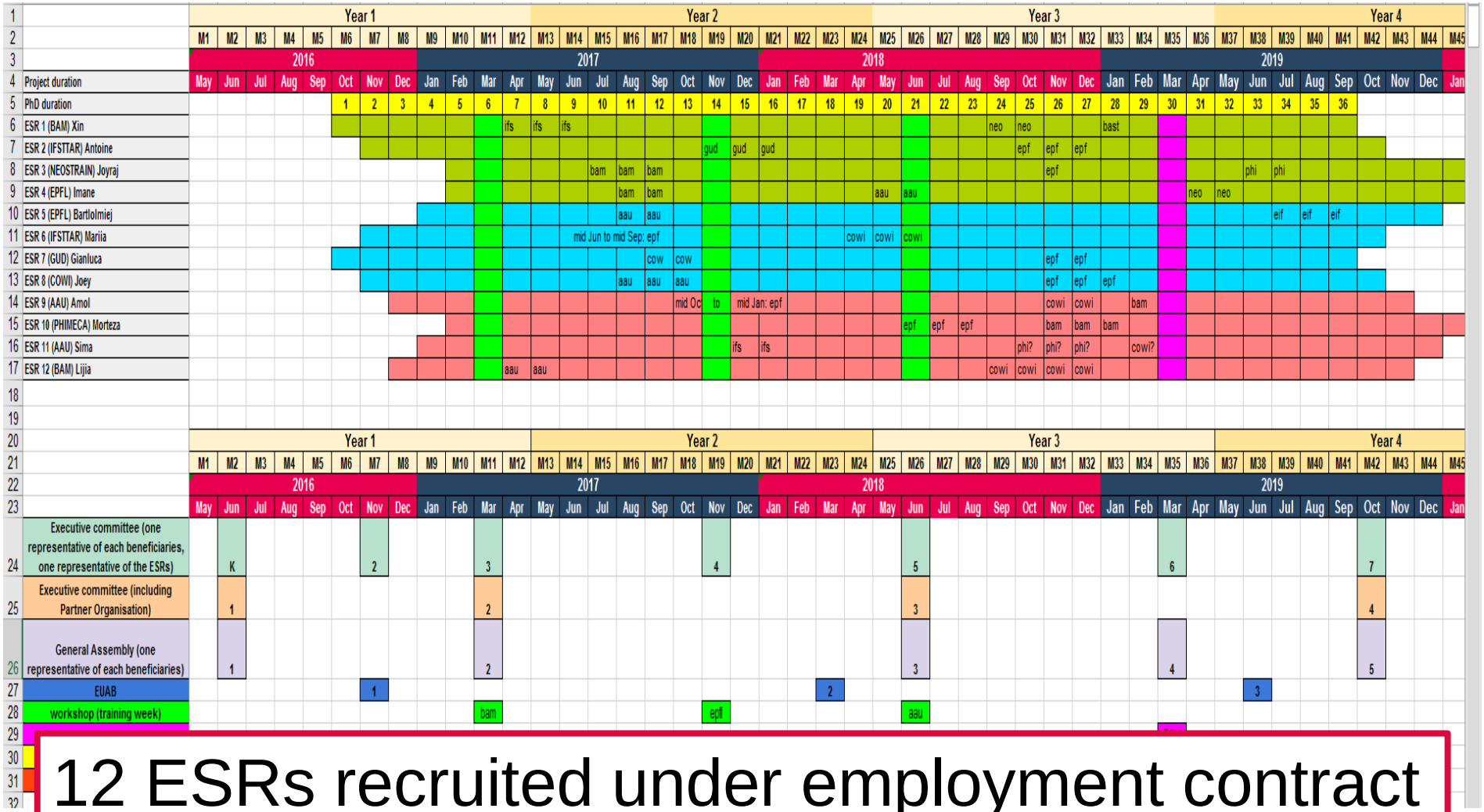


Recruitment

Recruitment



Recruitment



12 ESRs recruited under employment contract

Management

Beneficiaries

IFSTTAR

BAM

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

AALBORG UNIVERSITY DENMARK

PHIMECA
Solutions for robust engineering

COWI

NeoStrain

CONSULT

12 ESRs

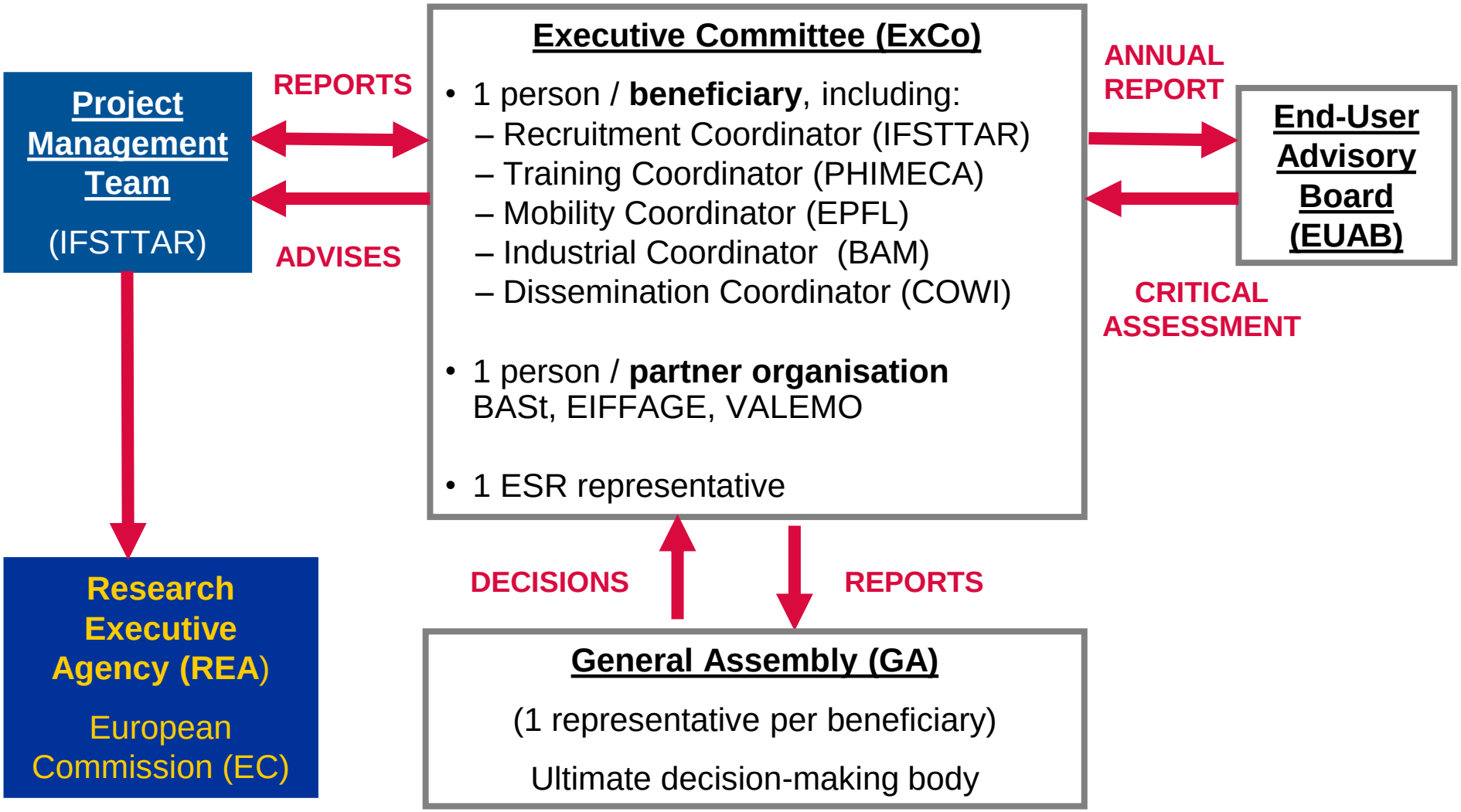
Partner organisations

bast
Federal Highway Research Institute

EIFFAGE

VALEMO
exploitation & maintenance EnR

Management


Project Management Team
(IFSTTAR)
REPORTS
ADVISES
Executive Committee (ExCo)
• 1 person / beneficiary, including:
– Recruitment Coordinator (IFSTTAR)
– Training Coordinator (PHIMECA)
– Mobility Coordinator (EPFL)
– Industrial Coordinator (BAM)
– Dissemination Coordinator (COWI)
• 1 person / partner organisation
BASt, EIFFAGE, VALEMO
• 1 ESR representative
ANNUAL REPORT
CRITICAL ASSESSMENT
End-User Advisory Board (EUAB)
Research Executive Agency (REA)
European Commission (EC)
DECISIONS
REPORTS
General Assembly (GA)
(1 representative per beneficiary)
Ultimate decision-making body

Management

Project Management Team

(IFSTTAR)

REPORTS

ADVISES

Executiv

- 1 person / **be**
  - Recruitmer
  - Training Cc
  - Mobility Co
  - Industrial C
  - Disseminat

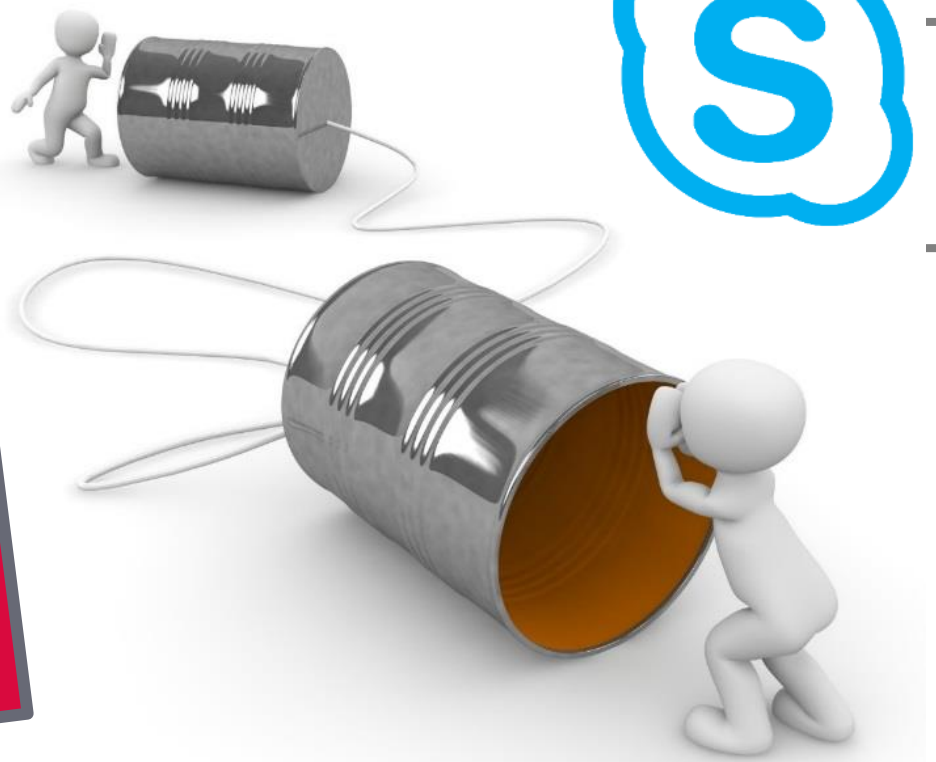
- 5 ExCo
- 4 GA
- 18 consortium ConfCalls
- 22 specific ConfCalls
- ESRs meetings

Gener

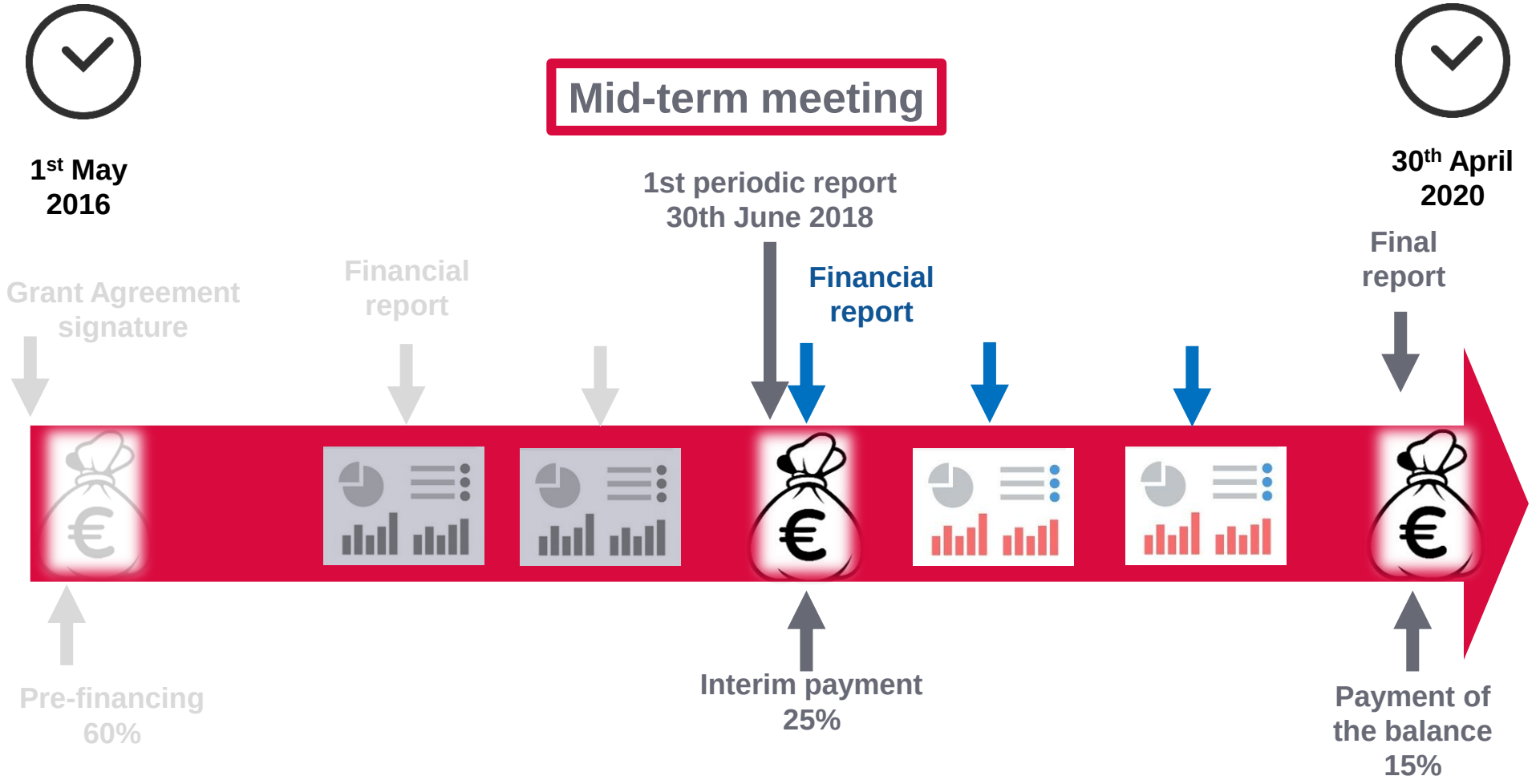
(1 represe

Ultimate decision-making body

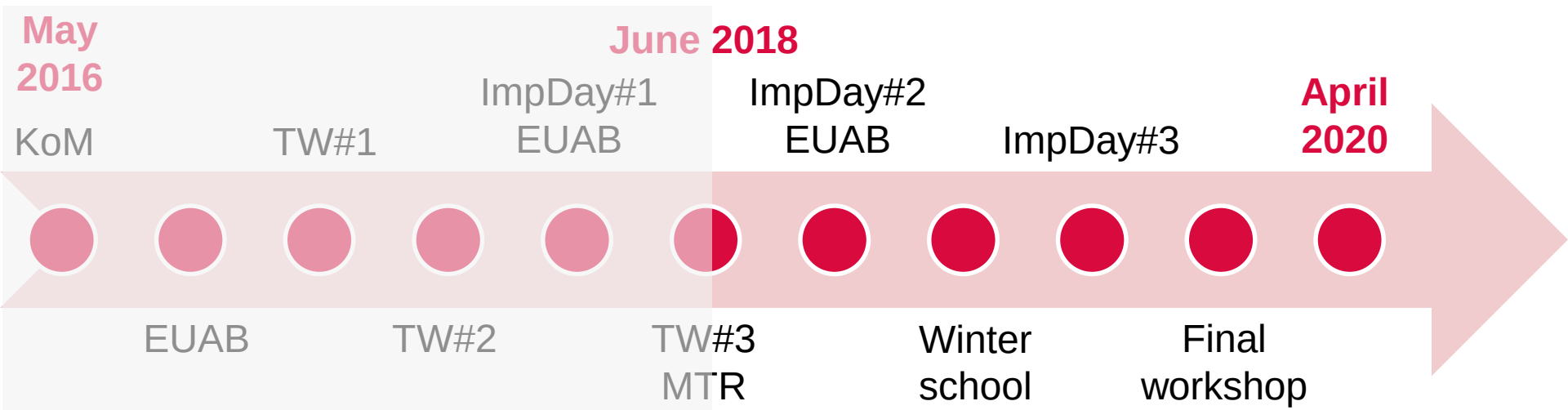
European Commission (EC)



Budget


1st May 2016
Mid-term meeting
30th April 2020
1st periodic report 30th June 2018
Grant Agreement signature
Financial report
Financial report
Final report
Pre-financing 60%
Interim payment 25%
Payment of the balance 15%

Next steps



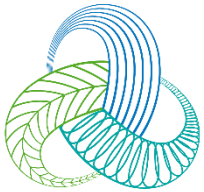
Deliverables submitted:

- ☑ 1 Project and 1 ESR handbook
- ☑ 1 recruitment report
- ☑ 3 State of the arts
- ☑ 2 training activity reports
- ☑ 1 implementation-day report
- ☑ 2 EUAB reports
- ☑ Website, newsletter, diss. material
- ☑ Draft periodic report

To be submitted:

- ☐ First periodic report
- ☐ 1 training activity report
- ☐ 2 implementation-day reports
- ☐ 2 EUAB reports
- ☐ Peer-reviewed papers
- ☐ 12 scientific reports
- ☐ 1 outreach activity report
- ☐ 1 dissemination plan
- ☐ Final report

Thank you for your attention



IFSTTAR

French institute of science and technology for transport, development and networks

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Stay tuned **http://infrastar.eu**

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