



EuroNanoLab: a distributed nanofabrication infrastructure for advanced research

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EuroNanoLab coordinator

Workshop on « **Research and Technology Infrastructures for the European Nanotechnology Ecosystem** »

EuroNanoForum, May 4th, 2021 – 13:30-15:30 (UTC+1)

Preparing the future of Micro and Nanofabrication

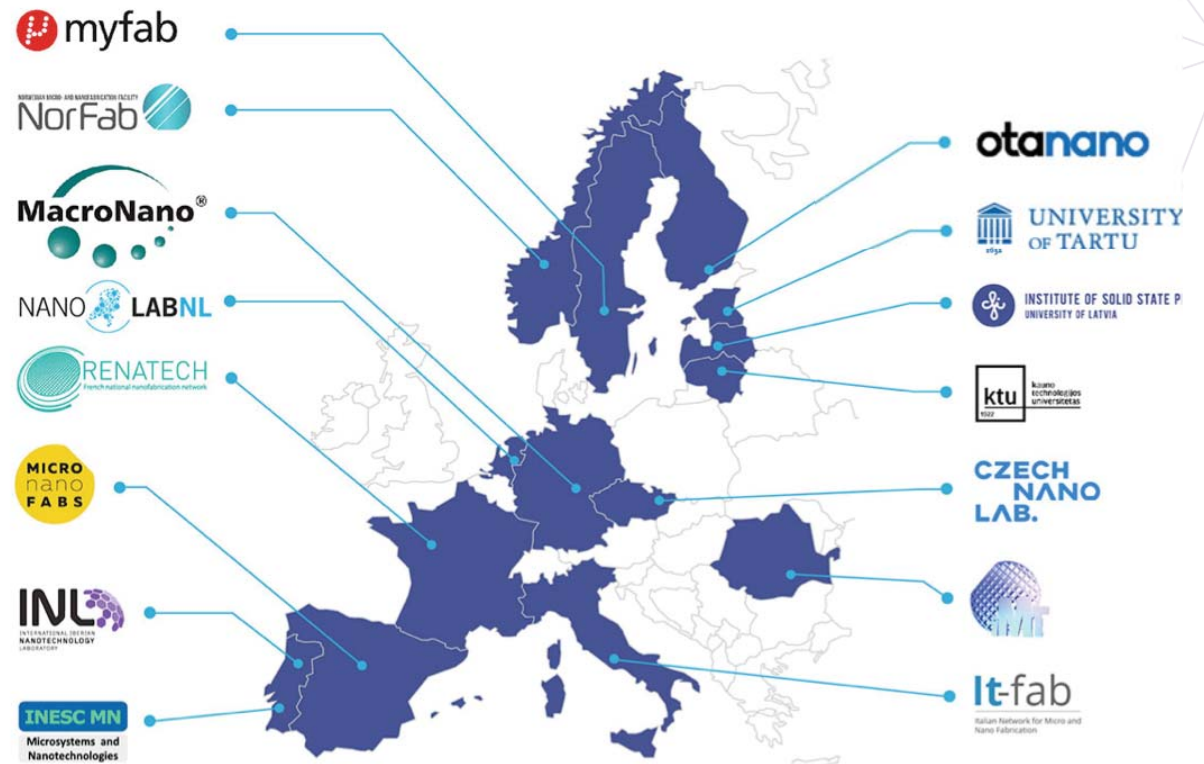
<http://euronanolab.eu>

EuroNanoLab's goal: allowing scientists to dream smaller & faster

EuroNanoLab is an open-access nanofabrication distributed RI comprising European Nanolabs

Dedicated to basic research

Which - by joining forces - aims at providing a better nanofabrication support to cleanroom's scientific users.

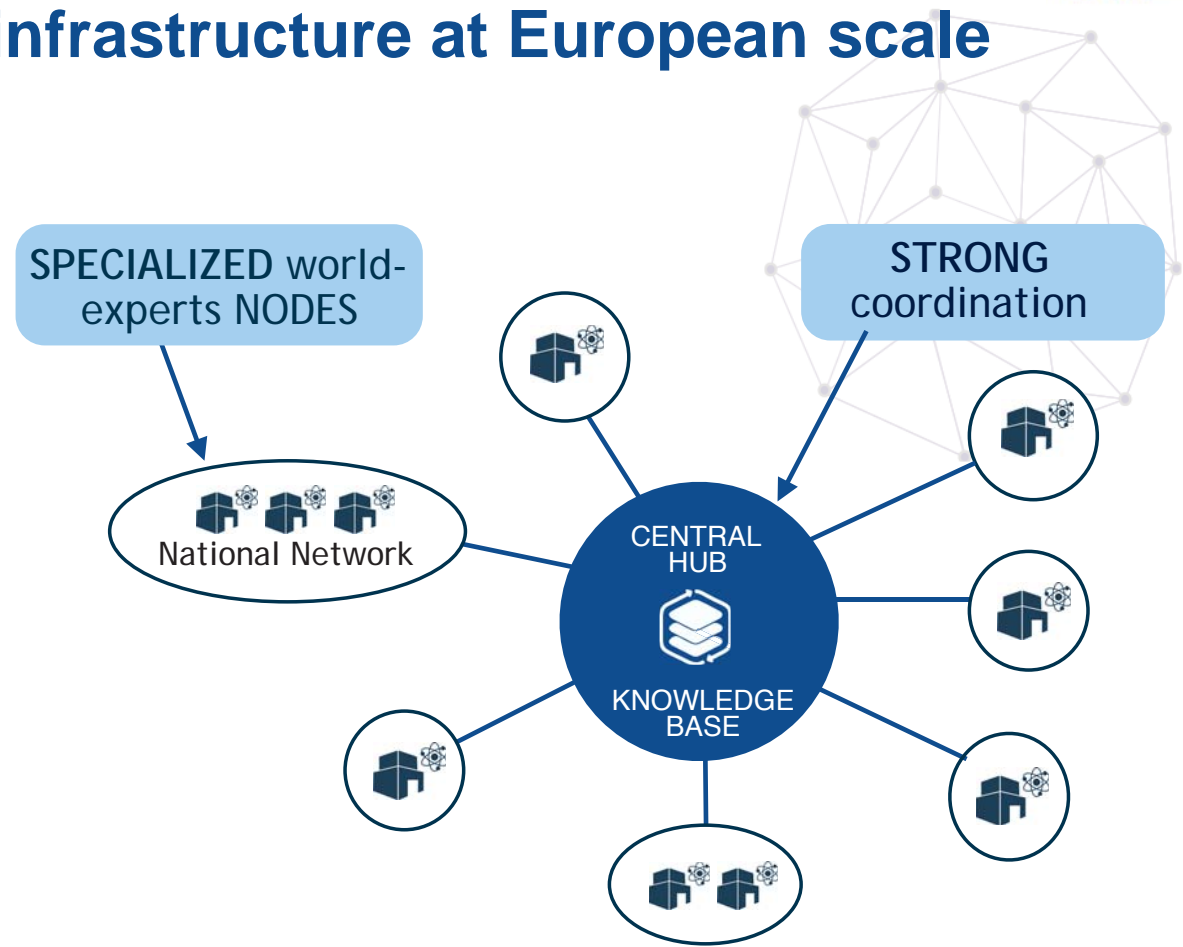


EuroNanoLab: 44 Nanolabs in 14 countries

EuroNanoLab's figures: an infrastructure at European scale

| | |
|---|--------|
| Users number* | 6 096 |
| Avg. hours / user / yr | 202 |
| ERC projects using ENL cleanrooms | 131 |
| Companies using ENL cleanrooms* | 751 |
| Cleanroom size (m ²) | 34 333 |
| Staff number | 703 |
| Operation cost (M€/ yr) | 104 |
| Equipment value (M€) | 1 035 |
| International peer reviewed papers / yr | 2 596 |

* ENL's users are either academic users or company users who also need to make proofs of concepts



EuroNanoLab: the target organisation





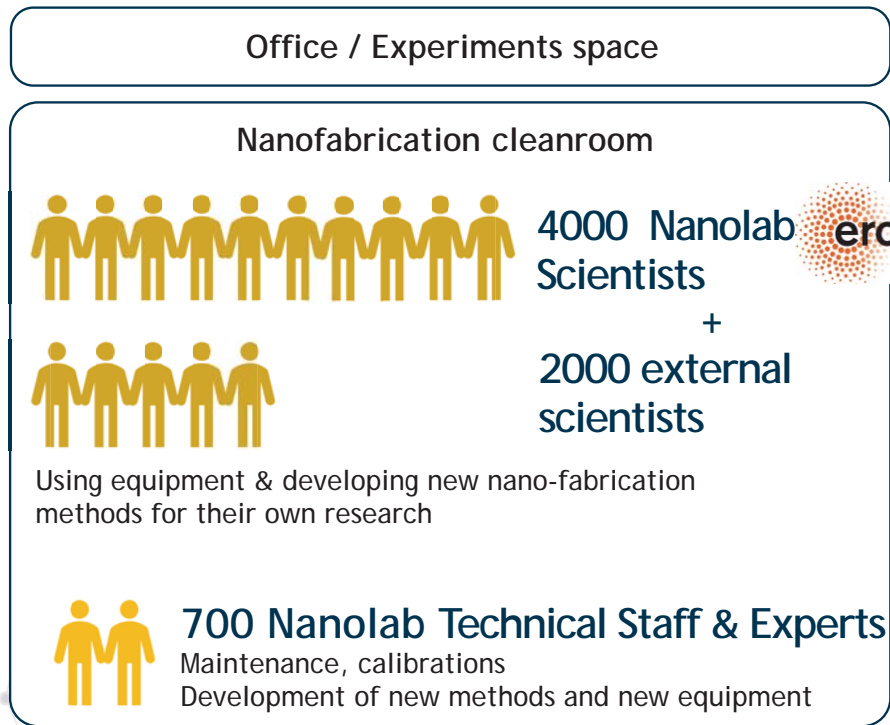
EuroNanoLab members



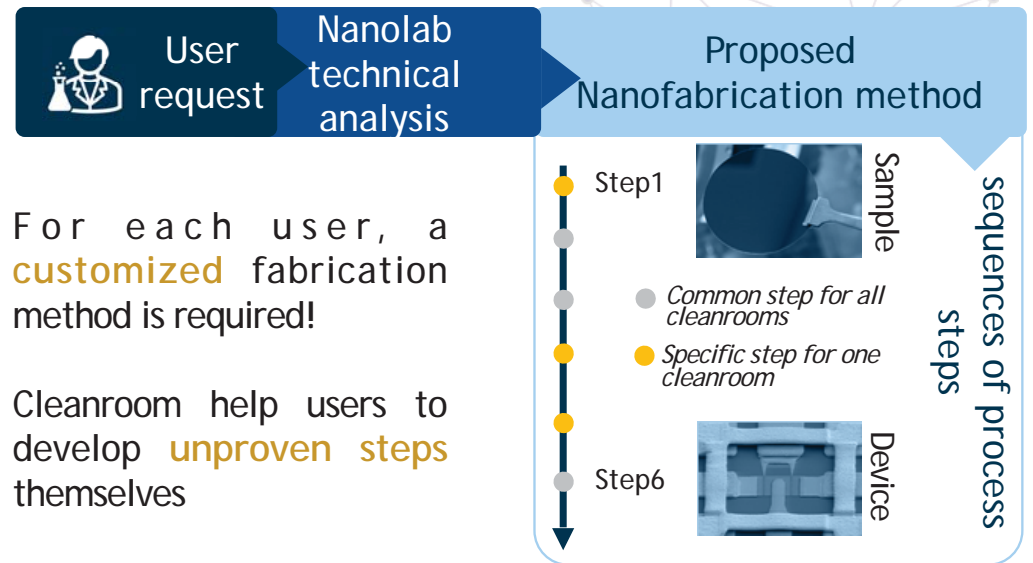
Who are the NANOLABS (partners of EuroNanoLab)?

ENL partners are **academic research labs** (Nanolabs) offering **external open-access** to their cleanroom.

NANOLAB



EXPERTISE of Nanolabs: Nanofabrication methods



- For each user, a **customized** fabrication method is required!
- Cleanroom help users to develop **unproven steps** themselves

More than 60% of user requests cannot be readily fulfilled (due to unproven process steps) → Too often, users limit their ambitions only to available technologies

erc Scientific excellence: 131 ERC projects for ~ 400 users

EuroNanoLab scientific excellence **strategy** and **vision**

The prioritized Scientific Fields identified are the ones that are the most interlinked with nanofabrication technologies, and therefore will have the major benefits from the development of new nanofabrication methods



Scientific Council
composed by 5 Scientific Committees

Quantum
Technologies

2D Materials

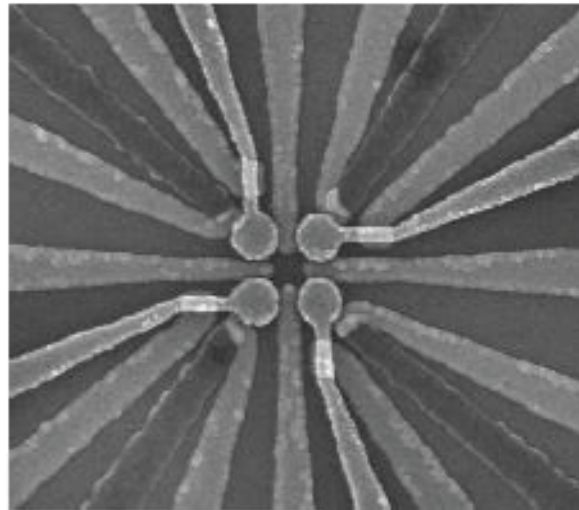
Neuromorphic
Computing

Nanobio
technology

Astronomy, space
exploration &
environment
monitoring

ENL achievements: research results with high-potential

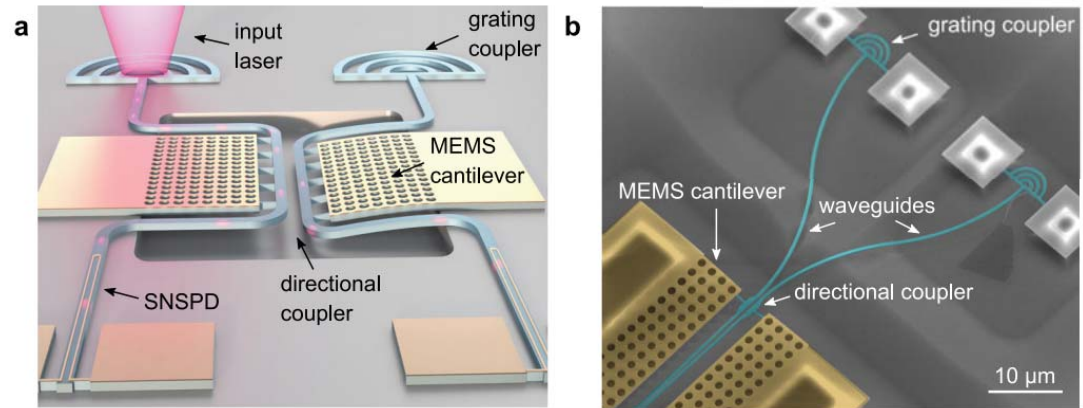
WORLD BREAKTHROUGH IN SEMICONDUCTOR QUANTUM TECHNOLOGIES (2021)



Hendrickx, N.W. *et al.* A four-qubit germanium quantum processor. *Nature* **591**, 580–585 (2021)
 QuTech, Delft, The Netherlands

First Quantum processor with four entangled Ge qubits using scalable semiconductor technologies

INTEGRATED QUANTUM PHOTONICS PLATFORM (2021)

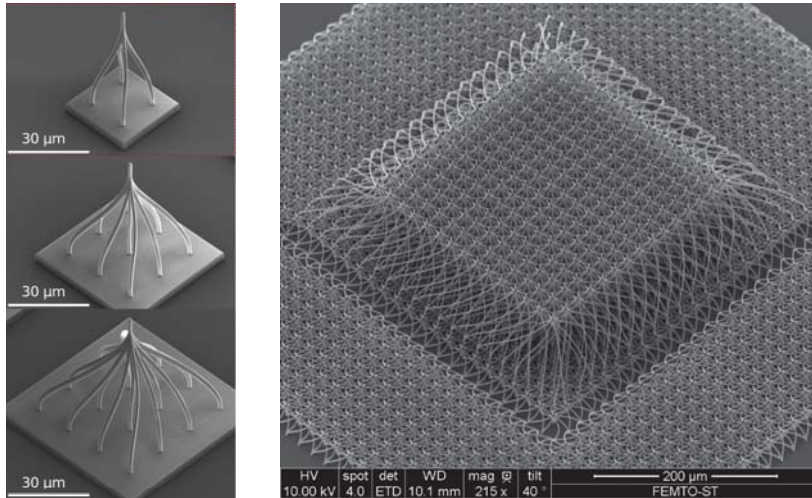


Samuel Gyger, *et al.*, Reconfigurable photonics with on-chip single-photon detectors. *Nature Communications* **12**, Article number: 1408 (2021)
 Myfab - KTH, Sweden

Integrated quantum photonics platform to experiment quantum logics for large-scale quantum photonics applications. Low heat dissipating integrated photonic circuits are interfaced with heat sensitive superconducting single-photon detectors on the same chip.

ENL achievements: research results with high-potential

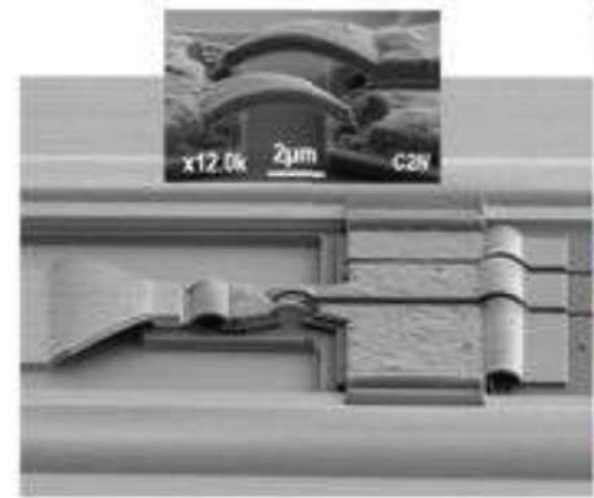
DENSE OPTICAL INTERCONNECT FOR NEUROMORPHIC COMPUTING (2020)



Moughames, et al., Opt. Mater. Express 10, 2952 (2020)
FEMTO-ST, Besançon, France

Massive optical interconnects for neuromorphic computing (15x15 inputs, each connected to 81 outputs of the 23x23 output layer, through 1.2 μm polymer core/air cladding waveguides)

RECORD THz-WAVE RECEIVER FOR SPACE EXPLORATION (2022)



A. Maestrini et al., 43rd IRMMW-THz Nagoya (2018).
C2N, Palaiseau, France

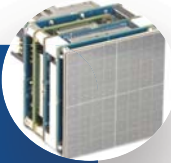
The most sensitive 1.2 THz radiation receiver in the world for the ESA JUICE project (JUper ICy moons Explorer) to be launched in 2022

Integration in the European research infrastructures landscape

ASTROPARTICLE PHYSICS & ENVIRONMENT

New type of detector

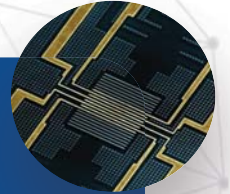
- Users: SKA, ELT, CTA, ACTRIS
- EuroNanoLab: development & fabrication



SPINTRONICS

New material for magnetic memories

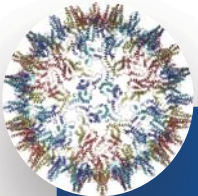
- Users: PRACE, XFEL, EMFL
- EuroNanoLab: Material synthesis, device design/fabrication



STRUCTURAL BIOLOGY

Separator to isolate a virus

- Users: INSTRUMENT, ESRF
- EuroNanoLab: nanostructuring, microfluidic chip design & fabrication



MULTIDISCIPLINARY RESEARCH

(medicine, materials science, electronics)

Biodevices for physiological systems

- Users: INFRAFRONTIER, EuroBioImaging
- EuroNanoLab: Biodevice design & fabrication



EuroNanoLab is working with three partners to map existing and missing technology capabilities in Europe





**EuroNanoLab's project for the future:
join forces to build an efficient nanofabrication system**

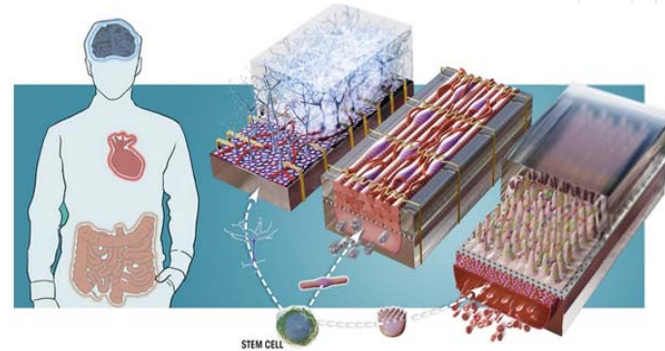


New research challenges: making more complex Nanosystems

Increasingly COMPLEX NANOSYSTEMS are needed through efforts on:
NEW MATERIALS, INTEGRATION & CONNECTIVITY

- Individual cleanrooms can no more face these technology challenge alone
- Joining forces is necessary to ensure Europe's sovereignty on Nanofabrication for research

Organs-on-chips: complex systems to understand the complexity of living organisms

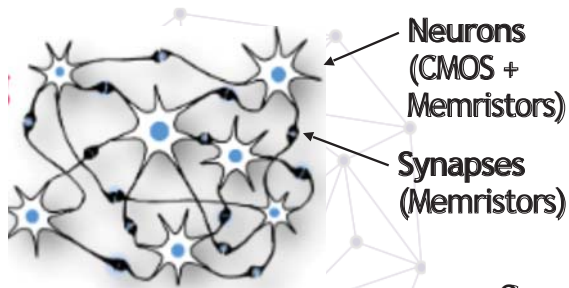


- Complex 3D networks
- Integrating many pumps, sensors & electrical interconnects

Image: Netherlands Organ-on-Chip initiative

More accurate in-vitro drug testing

Neuromorphic computing (AI): complex systems mimicking our own brain



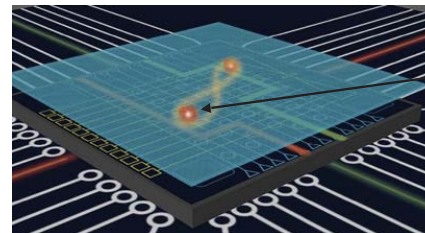
Neurons (CMOS + Memristors)
 Synapses (Memristors)

- Memristors: materials, design, fabrication?
- Upscaling and connectivity!

Image: J. Grollier, erc grant bioSPINspired

Current computer: 100 W/cm²
 Human brain: 20 Watt in total!

Quantum technologies: complex systems for high-complexity computations



Entangled qubits

- Quantum coherence
- Uncommon materials
- Clean interfaces
- Entanglement upscaling limit?

Image: Ryoichi Ishihara, EEMCS & QuTech

Solving ultra-high complexity problems

EuroNanoLab commitment: provision of unproven technologies

EuroNanoLab's vision: a new nanofabrication system involving different cleanrooms **when necessary**

Requirements of our users:

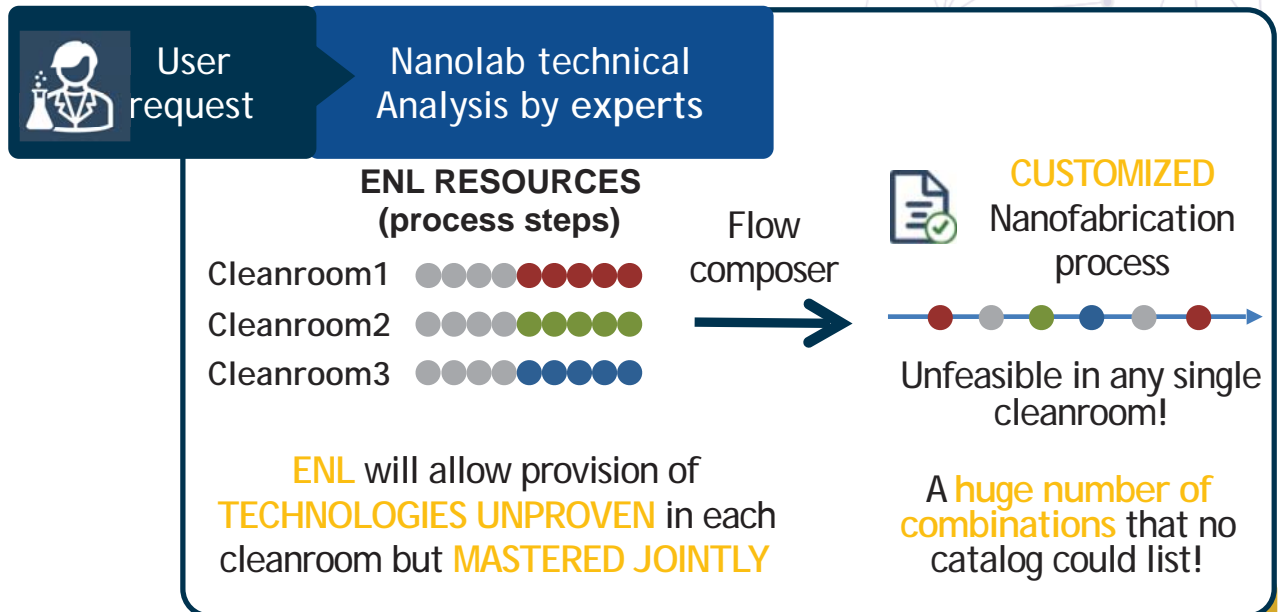
- Out-of-the-blue projects
 - Uncommon materials & topologies
 - Tough specifications
 - Increasingly complex devices
- Low time-to-result

60% of user's requests need unproven technologies

EuroNanoLab's mission:

Provide to its users,

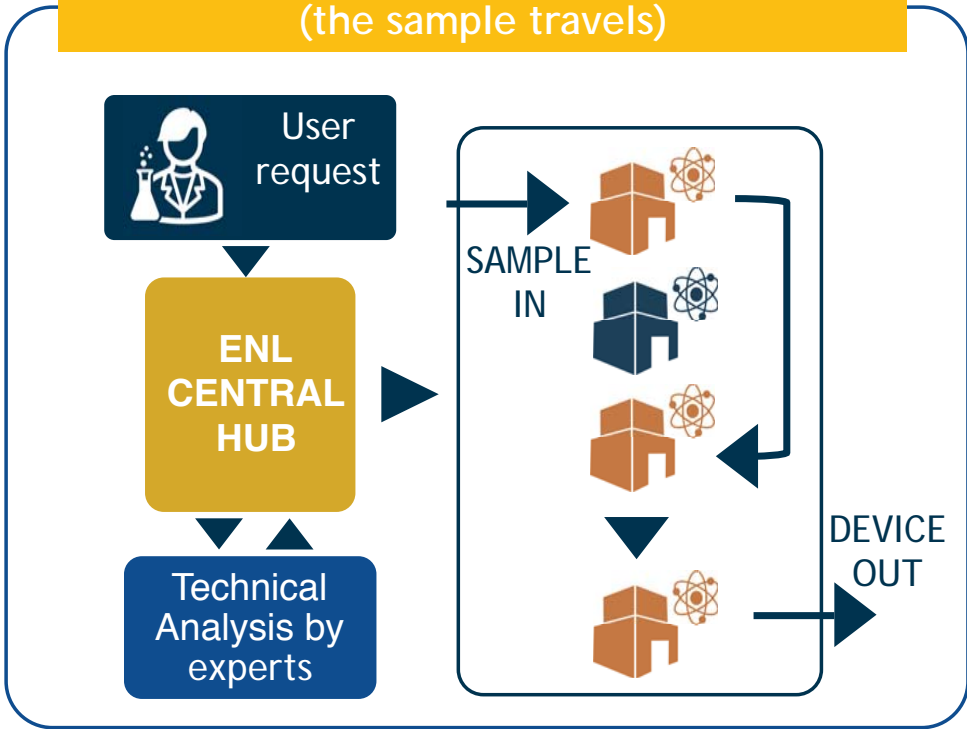
- everywhere in Europe,
- as fast as possible,
- for present & future needs the most appropriate technology



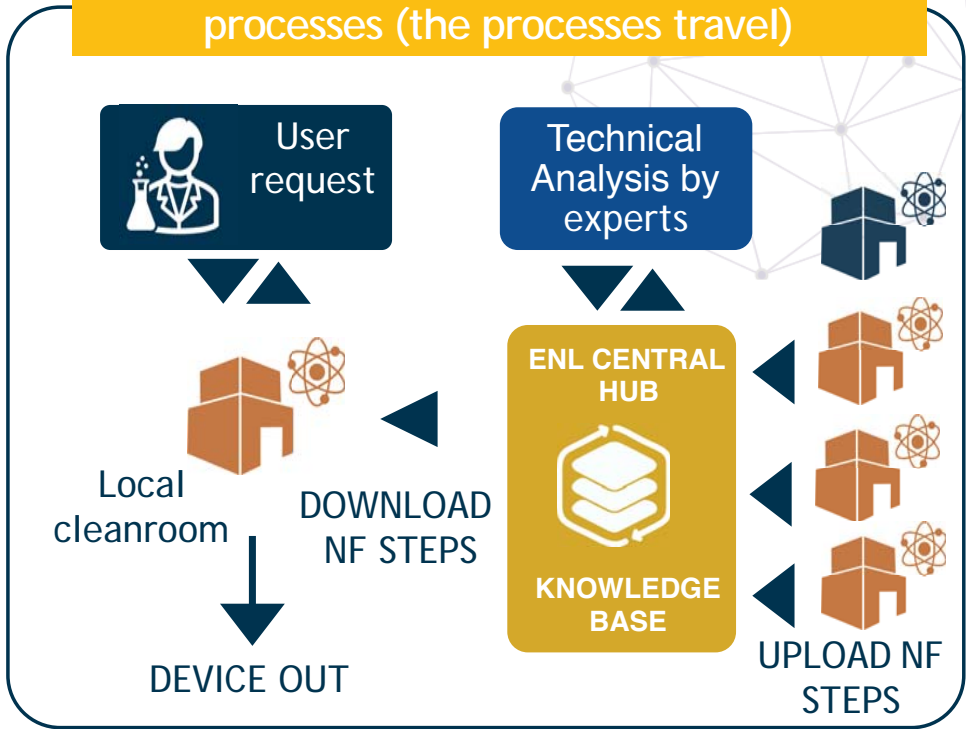
An innovative nanofabrication system more able to satisfy users demands (and unique worldwide) to revolutionize Europe's nanofabrication capabilities

EuroNanoLab's nanofabrication concept: **implementation**

Processes involving several cleanrooms
(the sample travels)



Future goal: import remote nanofabrication
processes (the processes travel)



- To achieve the project, process **interoperability, reproducibility & portability** is necessary →
- **SHARING OF KNOWLEDGE** between nodes is mandatory

- **Integration & harmonization of the nodes**
- **Joint knowledge base with common standards** (nomenclatures, representation of processes, etc.)
- **Joint development of nanofabrication methods**

Access modes to EuroNanoLab cleanrooms

General principles

- All nodes already provide 100% open-access to the whole cleanroom
- External users have the same rights as internal ones
- Any kind of project will be accepted - at least under market driven access - as long as there is no oversubscription

Excellence-based access

- Projects funded by national/international research grants
- Technology development excellent projects selected by EuroNanoLab are free for the user
- In case of oversubscription, excellence-based projects are prioritized



EuroNanoLab e-infrastructure

Main outputs of EuroNanoLab activities

- new nanofabrication methods that have a limited demand of storage and computational resources, almost stable in time
- “physical objects” (wafers or pieces of wafers, prototypes, devices)



e-infrastructure

Main objective is to ensure **DATA QUALITY** more than **DATA QUANTITY**

- define metadata structure and data management policy
- setup Central Hub access portal and users service



EuroNanoLab implementation network
« **GO NANOFAB** »



EUROPEAN OPEN SCIENCE CLOUD

CENTRAL

LOCAL



EuroNanoLab
CENTRAL HUB

Access portal
service

Process
data

e-learning
data

Scientific
results

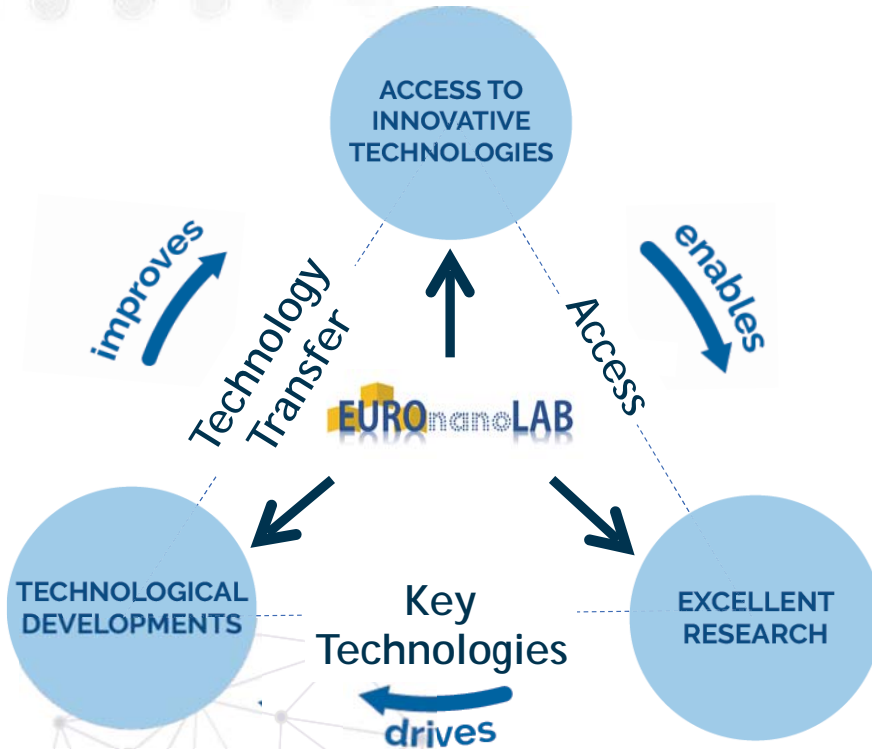
LIMS
system

Computation
resources



EuroNanoLab
Single Nodes

EuroNanoLab within the value chain of innovation



EuroNanoLab strengthens the Virtuous Circle of Innovation

Innovation ecosystems:

- More than 700 high-tech companies/yr access to EuroNanoLab nodes (startups, spin-offs, SMEs, corporates)
- 13% of ENL nodes' budget is coming from industry
- 10% of ENL's PhDs belongs to Industrial / Innovative PhD programs linked to Regional specialisations

Examples of RIS3 / EuroNanoLab Node alignment:



Strata



Electronic Coast[®] Norway



**THANK YOU
FOR YOUR ATTENTION**

Preparing the future of Micro and Nanofabrication

<http://euronanolab.eu>