Quantum Sensing

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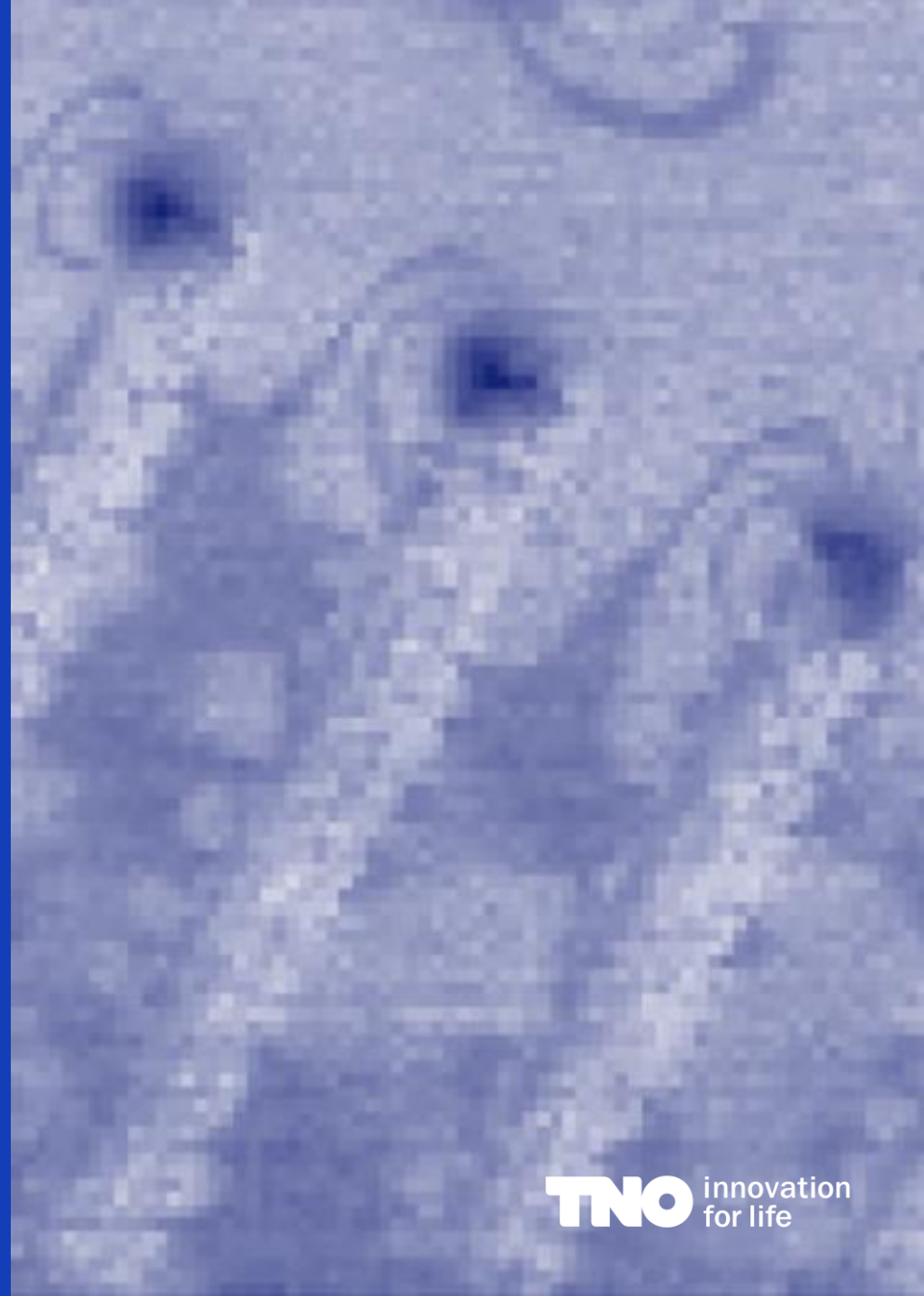
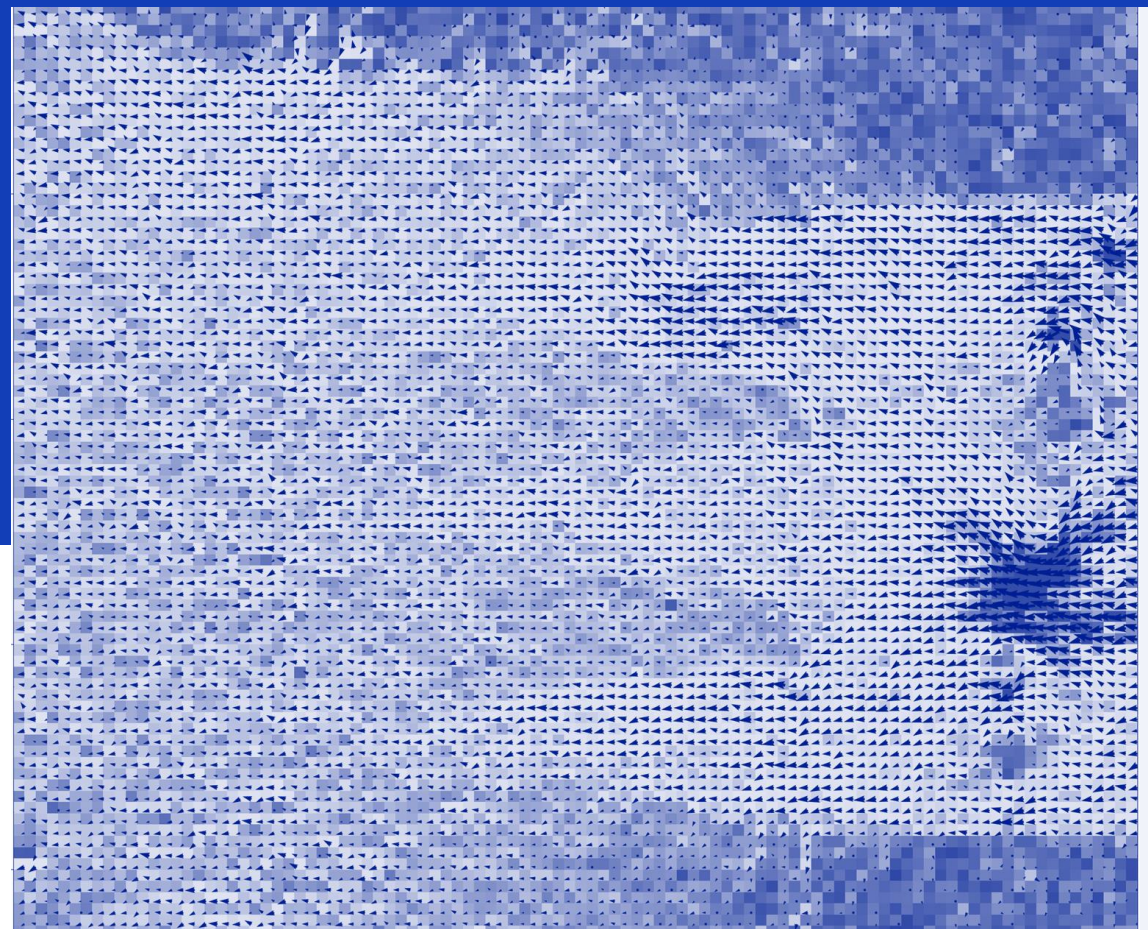
SID - April 17st, 2024



TNO innovation for life

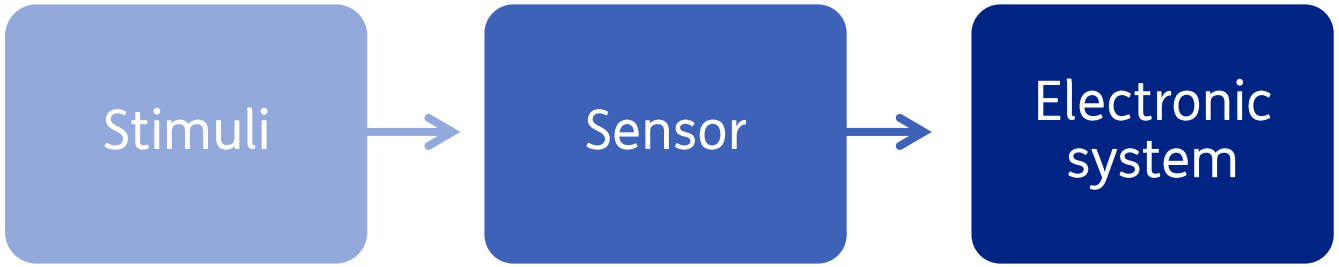
Agenda



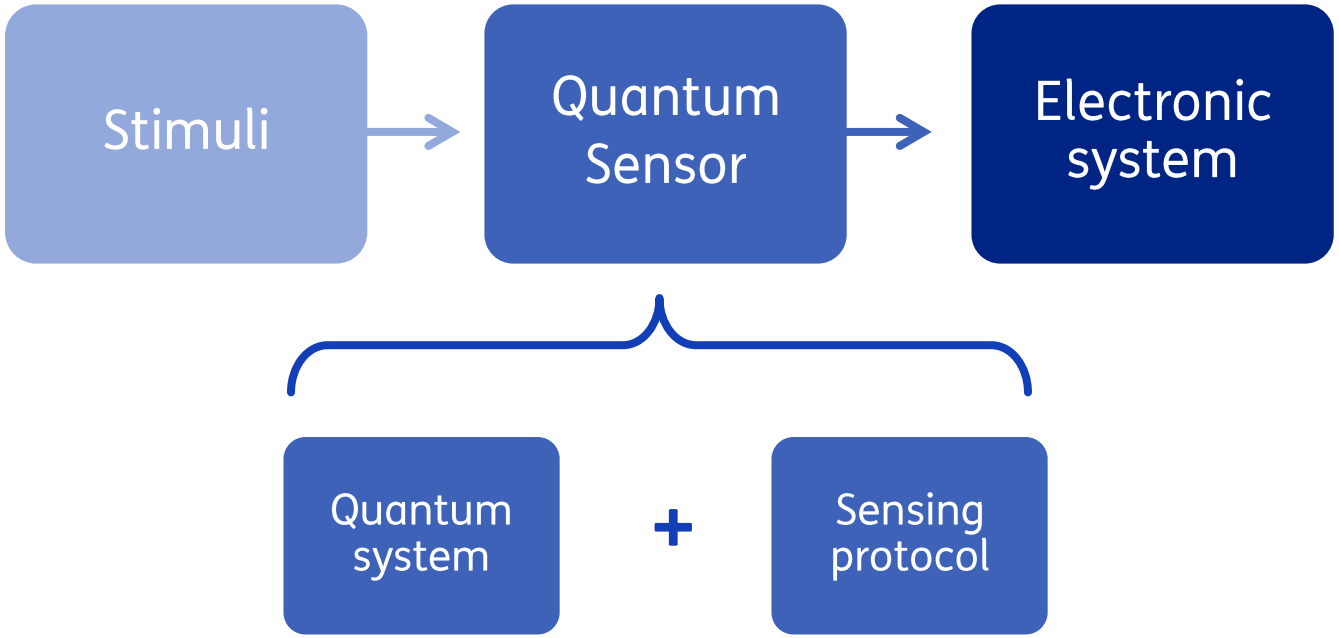
1. Quantum Sensing in eight slides
2. TNO Quantum Sensing Program
3. Dutch National Quantum Sensing Program

1. Quantum Sensing in eight slides

Sensors translate stimuli into electrical signals



Carefully controlled quantum systems can mediate this translation



Many quantum systems are useful for sensing

	Gas				Solid-state								
Systems	Neutral atoms		Other atomic states		Solid-state spins				Superconducting circuits			Other sensors	
	Atomic vapor	Cold cloud	Trapped ions	Rydberg atoms	NMR Sensor	Donors in Si	Quantum dots	NV centers	SQUID	Flux qubit	Charge qubit	Optome-chanics	Interfero-meters

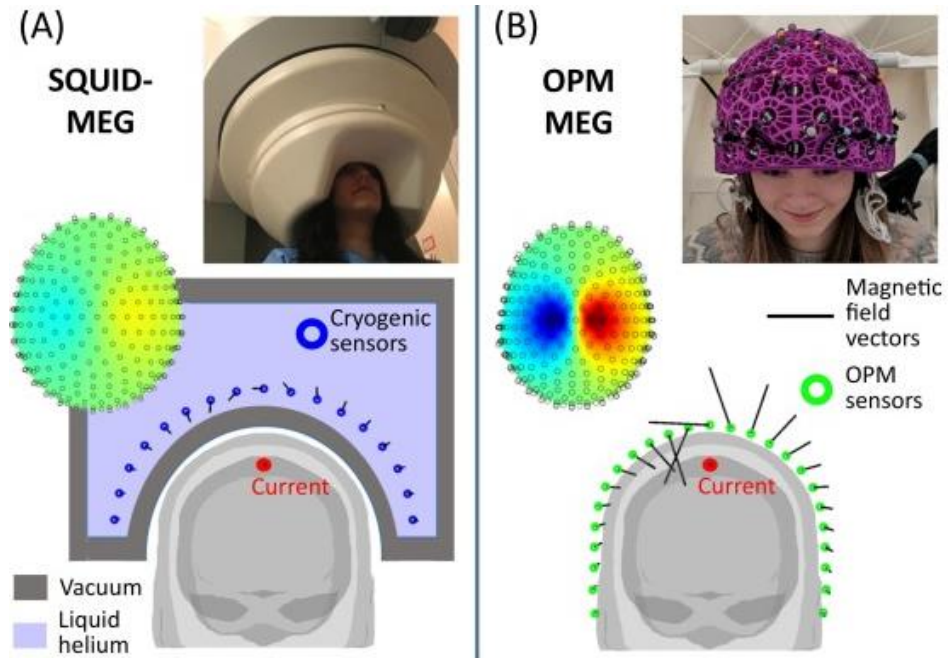
You can find many Quantum Sensors in the wild

Example 1: Atomic Gravimeter

Advantages with respect to classical gravimeters:

- Absolute measurements
- Similar accuracy
- Similar stability
- Portable and low power consumption
- Continuous operation (years)
- Lower price (~100 k€)

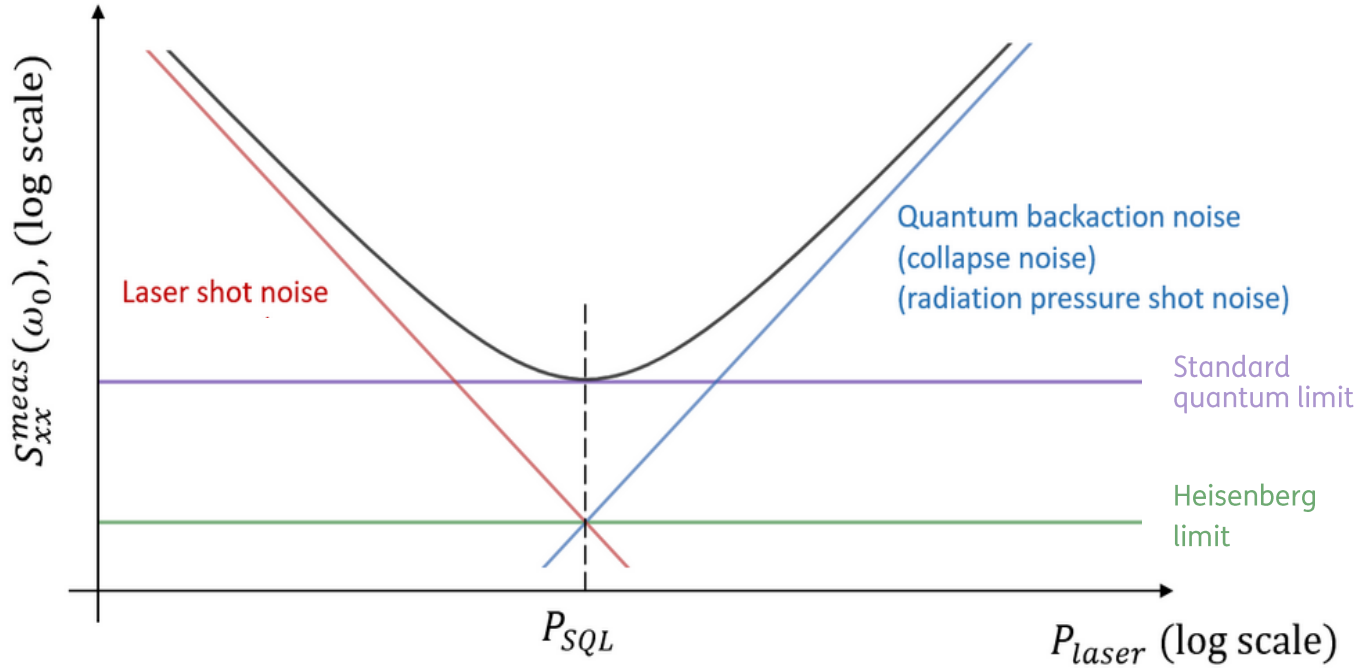
Example 2: Optically Pumped Magnetometers OPMs



Quantum sensors exhibit performances beyond what is classically possible

Some of the sensors have

- Higher spatial resolution
- Higher dynamical range
- Lower SWAPC

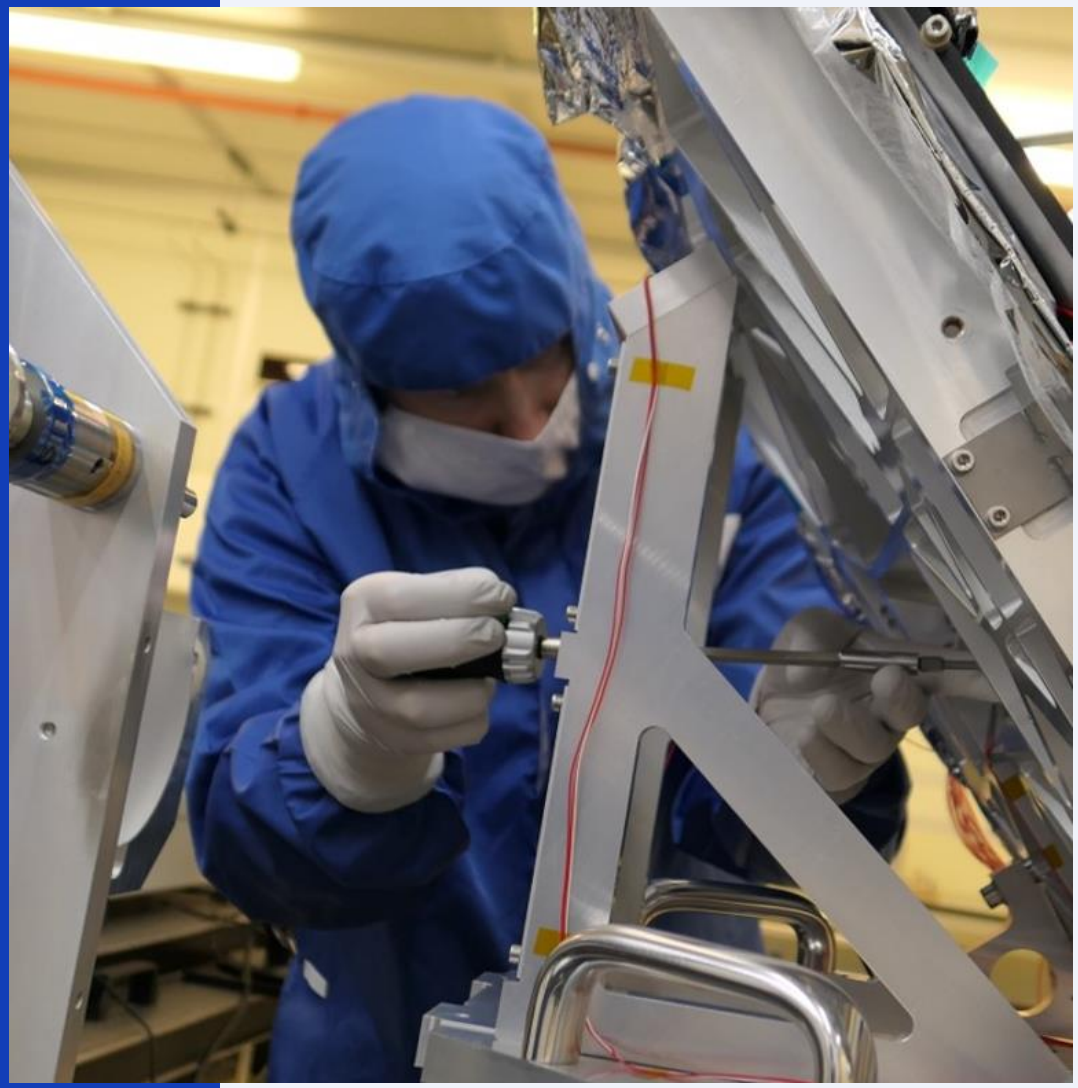


Continuous force and displacement measurement below the standard quantum limit.
David Mason, et al. Nature Physics 15, 745 (2019)

Quantum Sensing

2. TNO Quantum Sensing Program

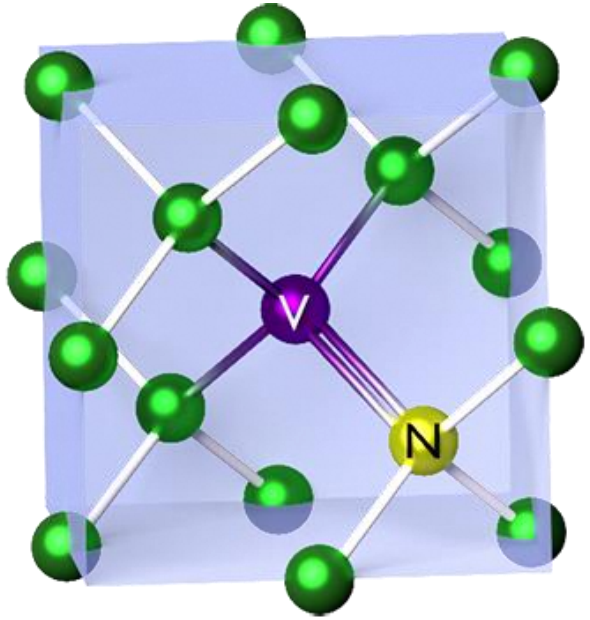
We use TNO's technology and know-how to accelerate the industrialization of quantum sensors



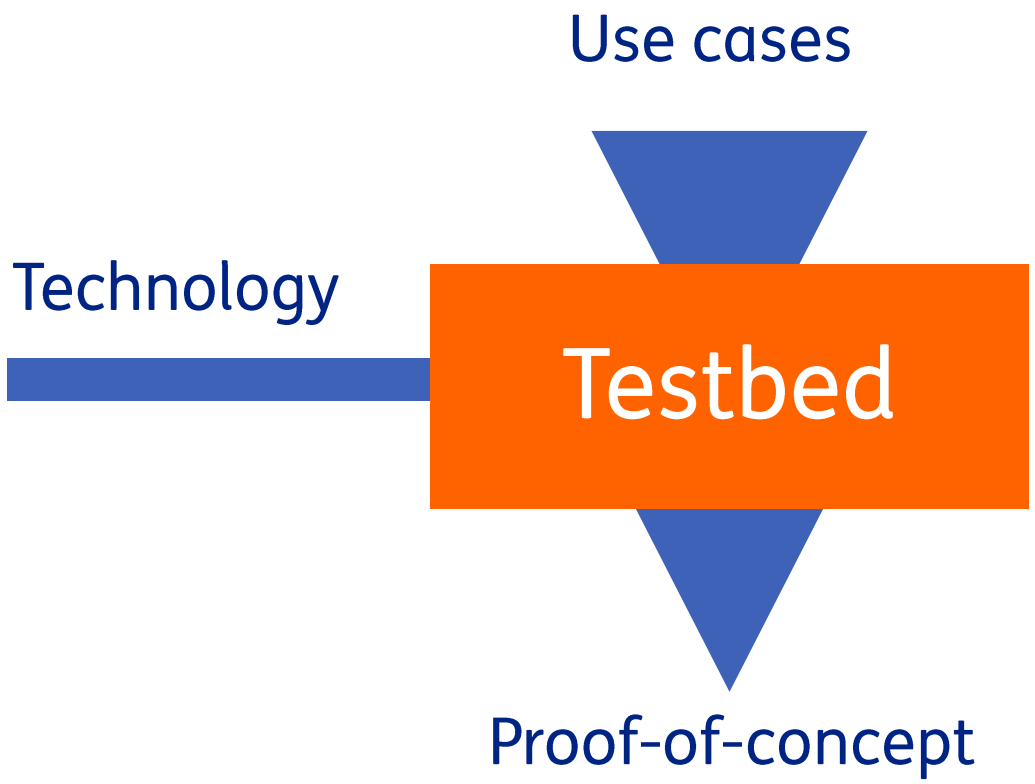
NV-center based Quantum Sensors

	Gas				Solid-state								
Systems	Neutral atoms		Other atomic states		Solid-state spins				Superconducting circuits			Other sensors	
Physical quantities	Atomic vapor	Cold cloud	Trapped ions	Rydberg atoms	NMR Sensor	Donors in Si	Quantum dots	NV centers	SQUID	Flux qubit	Charge qubit	Optome-chanics	Interfero-meters
Magnetic field	■	■			■	■	■	■	■	■		■	
Electric field			■	■			■	■			■		
Acceleration		■										■	
Rotation	■	■	■					■					
Displacement													■
Time/Freq.	■	■	■										
Force			■										
Mass												■	
Pressure								■				■	
Temperature							■	■					

■ > TRL 4 technology validated in lab ■ > TRL 7 demonstration in operational environment



Testbed Facility



Use cases

Instrument benchmark

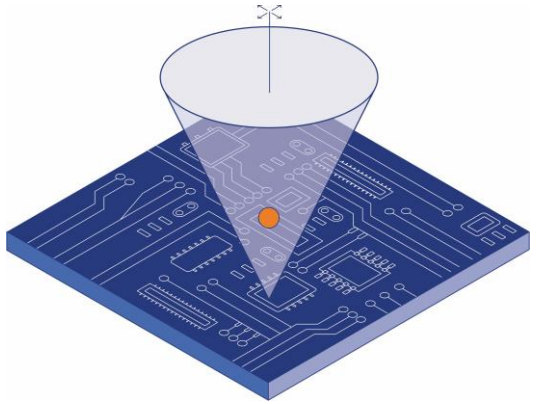
Component benchmark

Sample measurements

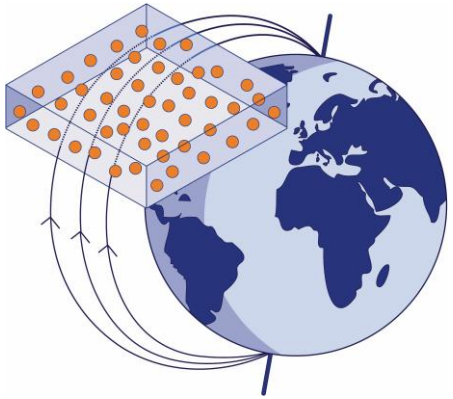
? Feasibility studies

Testbed Facility's Diamond technology

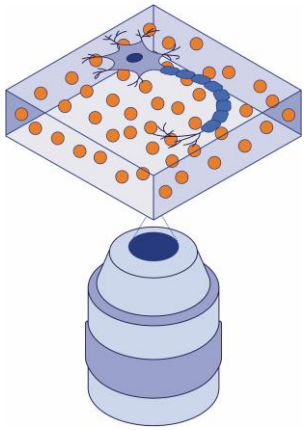
Scanning probe microscopes



Compact magnetometers



Wide field microscopes

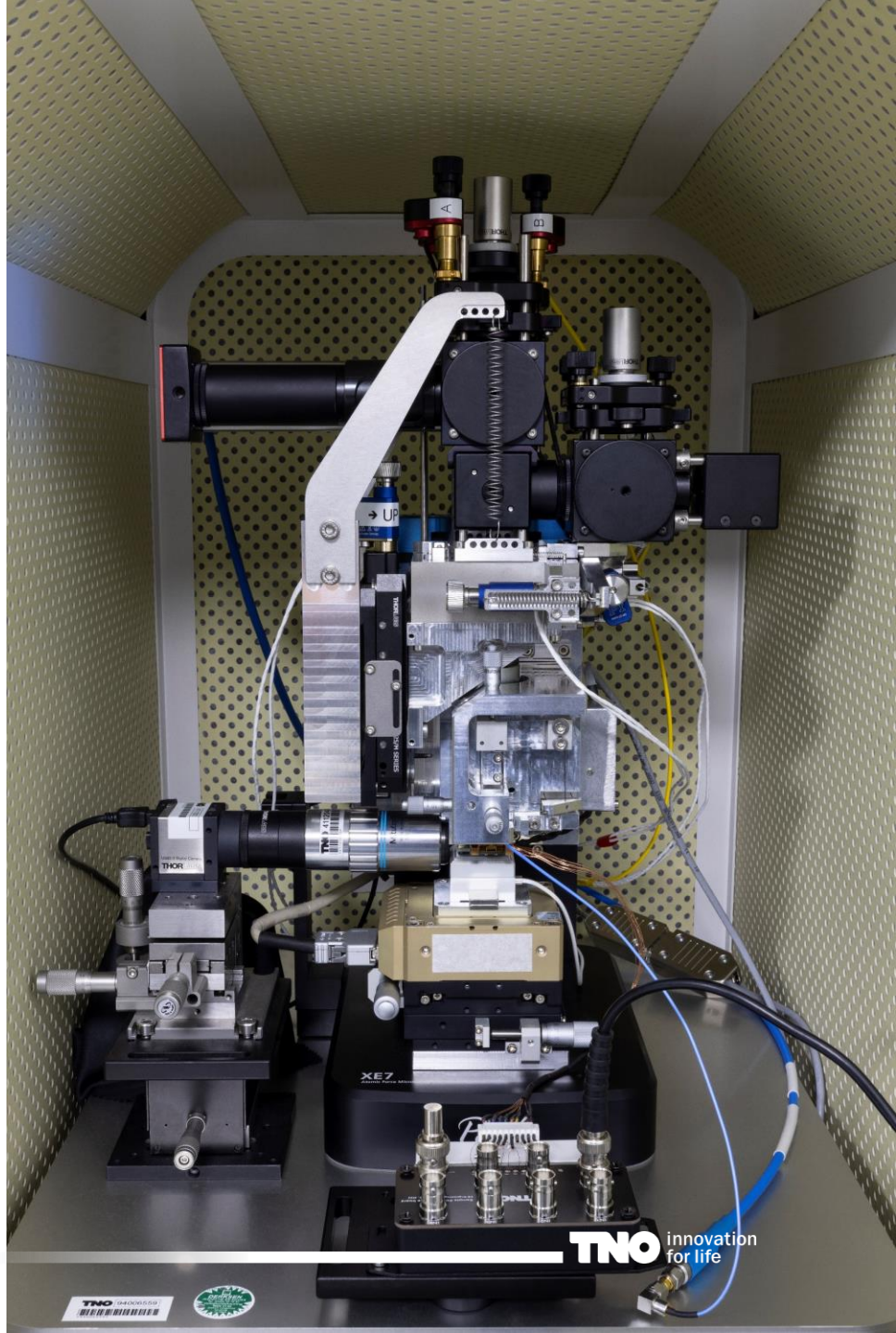


Quantum Scanning Probe Microscopes

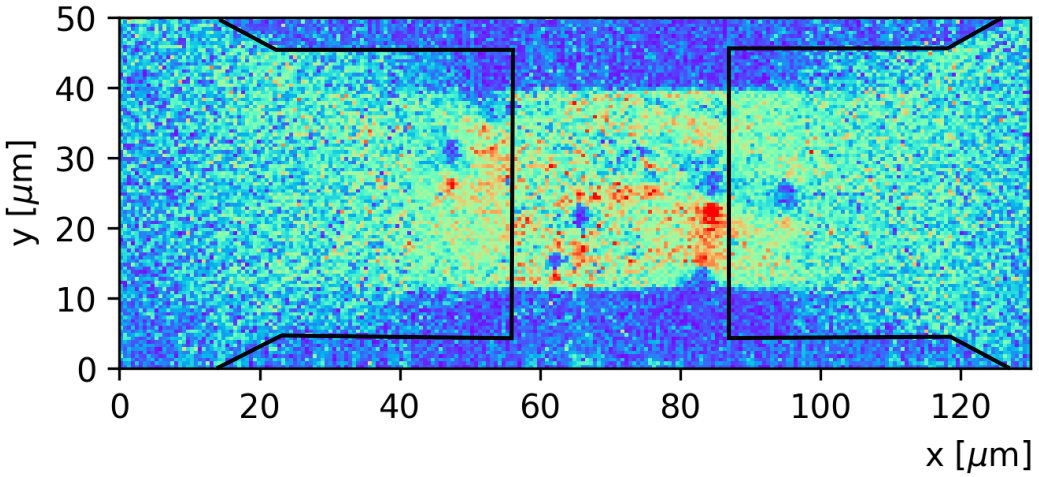
Non-destructive high-resolution measurement of magnetic fields, currents and temperatures.

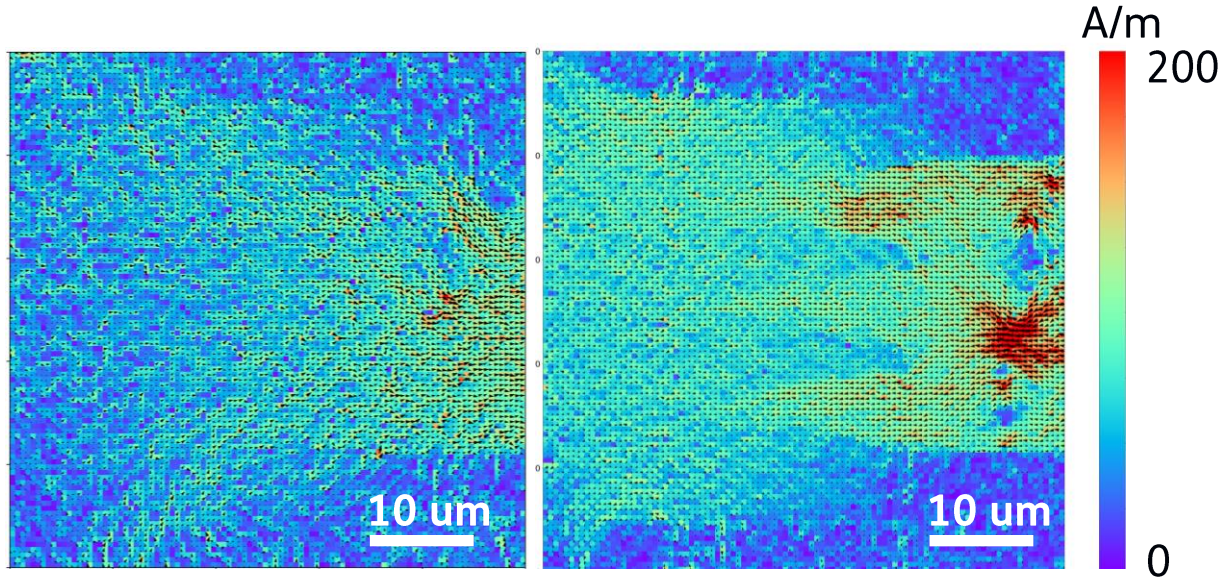
Features

- Resolution $< 50\ \mathrm{nm}$
- Sensitivity $\sim 5\ \frac{\mu\mathrm{T}}{\sqrt{\mathrm{Hz}}}$
- Target speed: 100 pixels per second



Use case example: Current Mapping in Graphene





Rectangular contact Triangular contact

In Collaboration with

ANL Applied Nanolayers

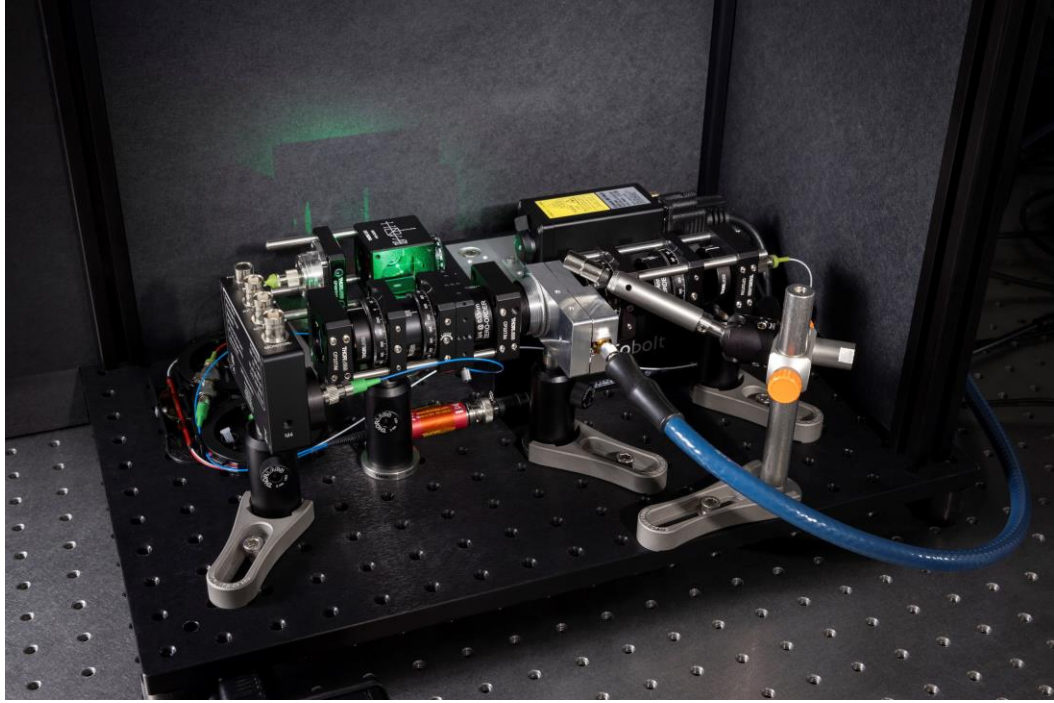
TU Delft

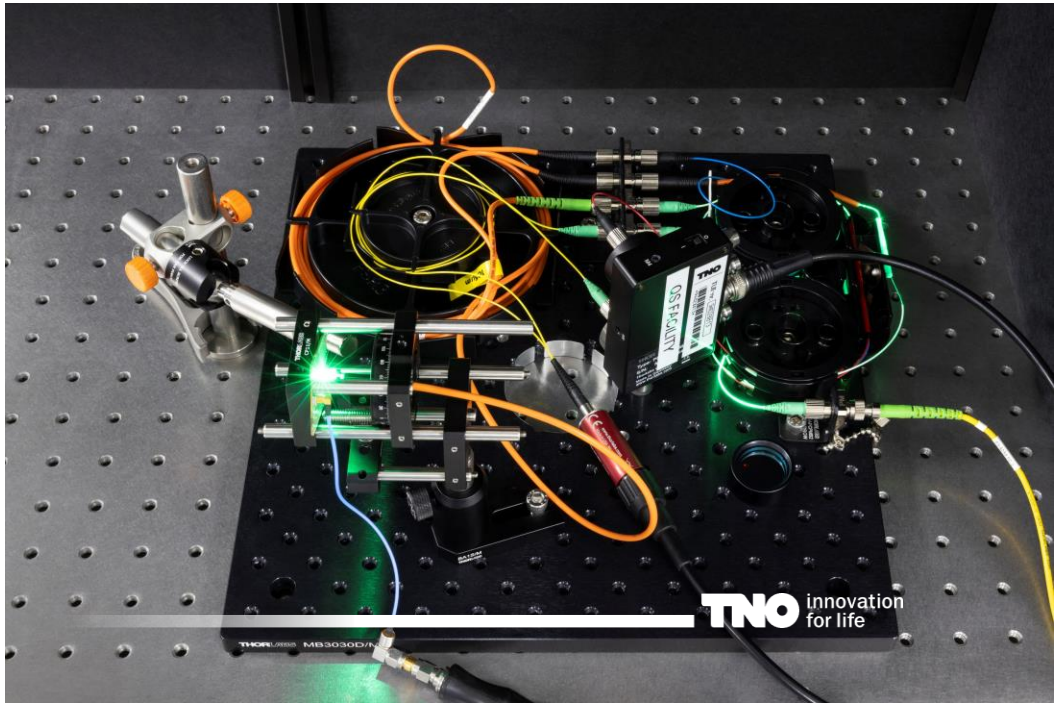
Compact Vectorial Magnetometers

High-sensitivity measurement of vectorial magnetic fields, with compact instruments.

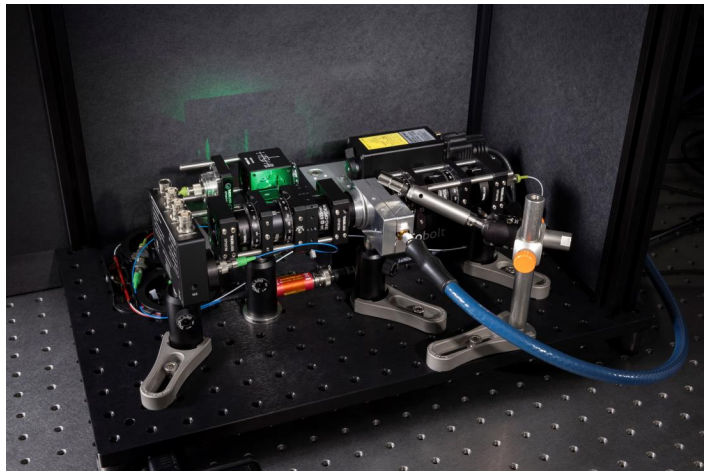
Features

- Resolution $\sim 3\ \mathrm{mm}$
- Sensitivity $\sim 1\ \frac{\mathrm{nT}}{\sqrt{\mathrm{Hz}}}$
- Free-space, PICs and Fiber based solutions





Use case example: GPS-free navigation



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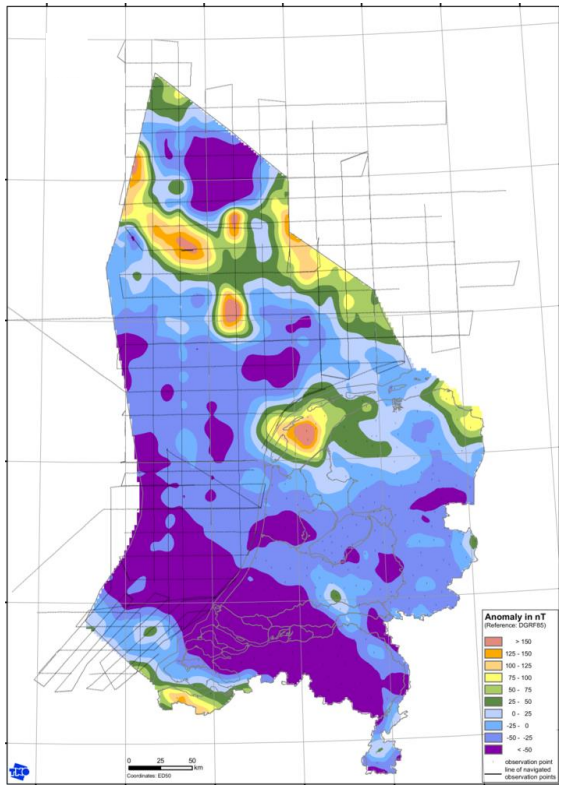

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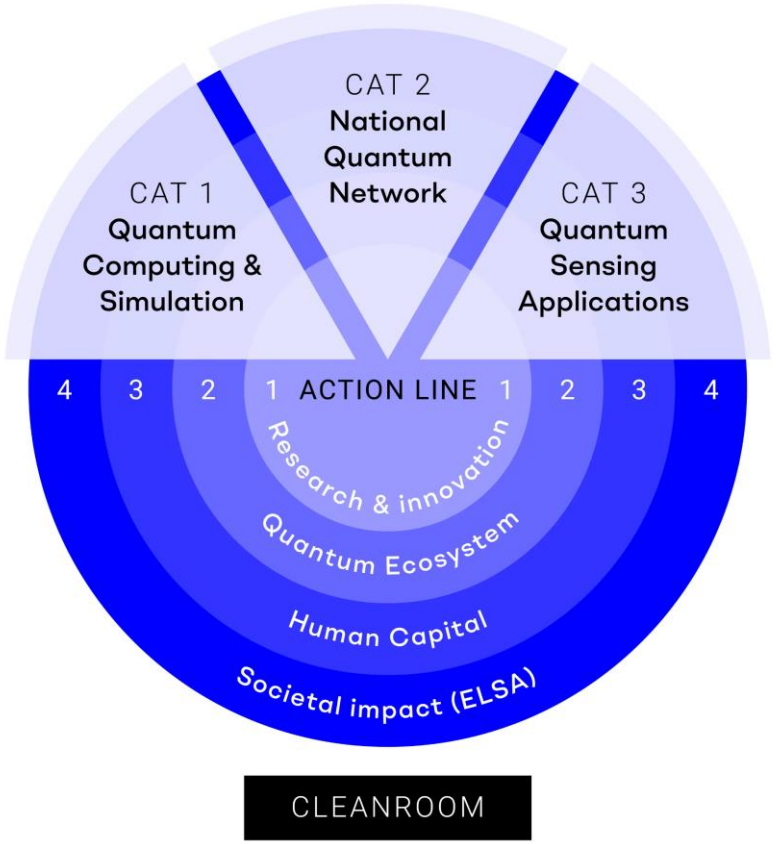
GPS-free navigation

3. Dutch Quantum Sensing Program – CAT3

Quantum Delta NL

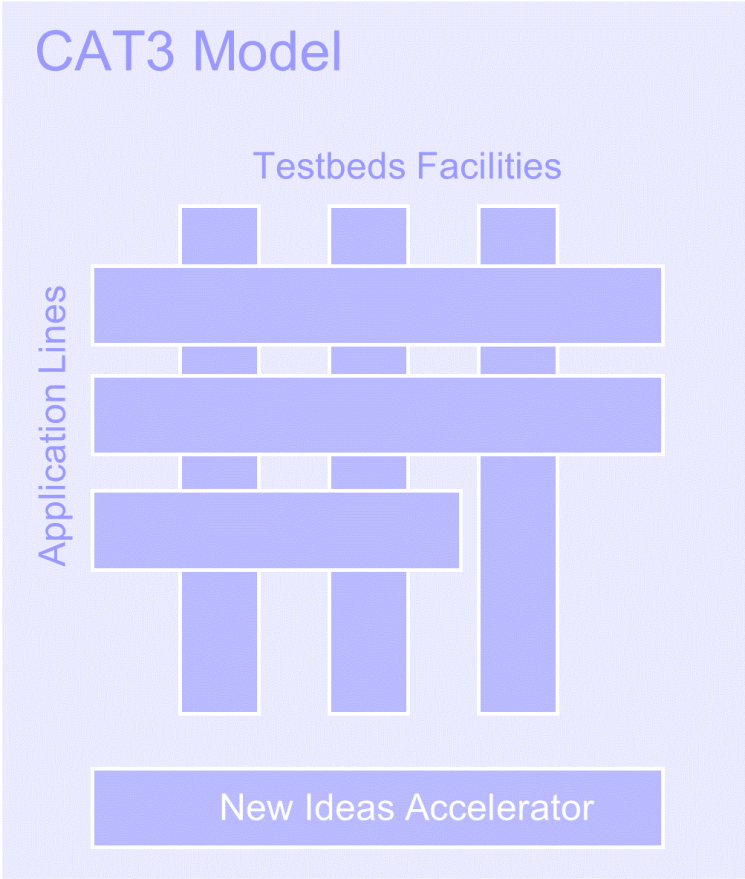


Quantum Delta NL is a program by the Ministry of Economic Affairs to create **significant societal impact** through advancements in Quantum Technologies.

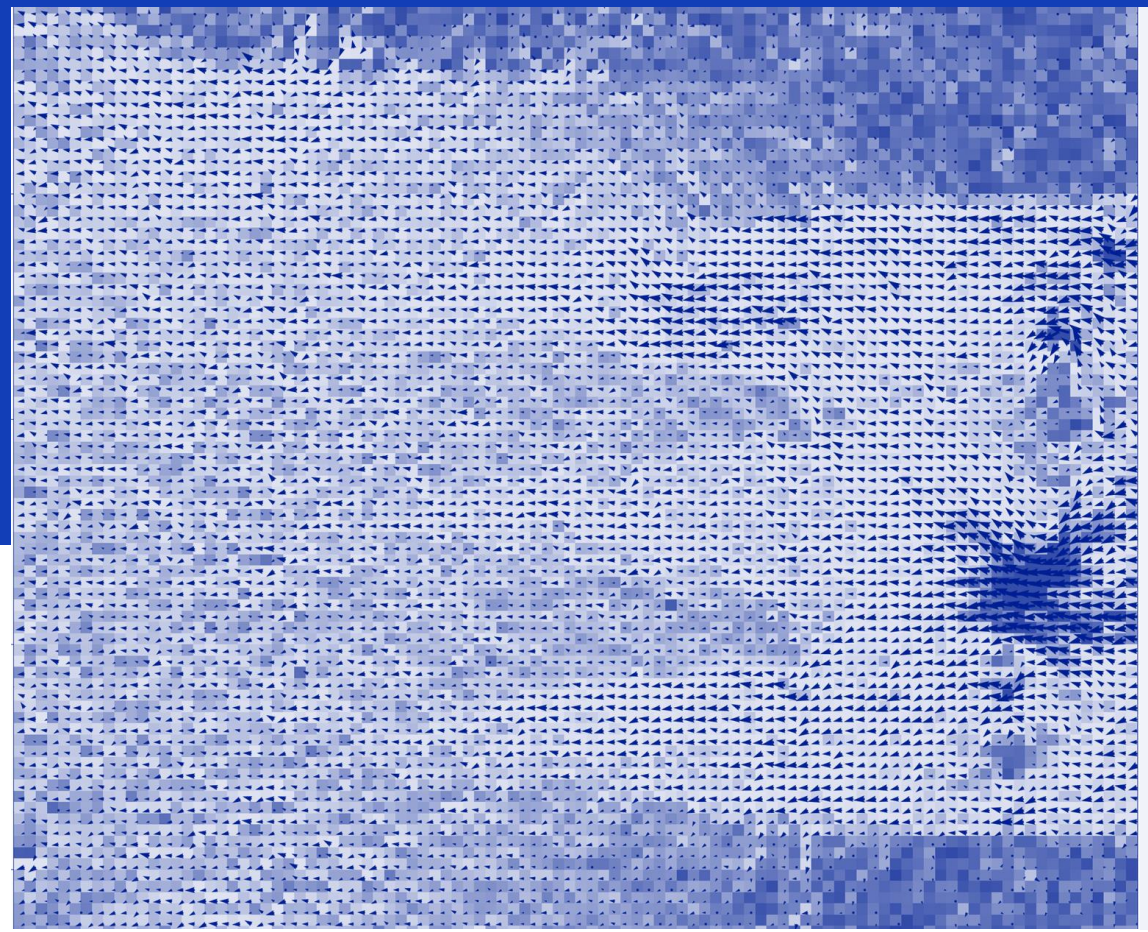
CAT-3: Quantum Sensing Applications

Our goal is to accelerate the industrialization of Quantum Sensors by

- Establishing open access Testbed Facilities based on different technologies
- Developing use cases within Application Lines with industrial/end-user partners
- Strengthening the ecosystem by supporting New Ideas



Agenda



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Thanks for your attention