Tomographic Research of Underground and large STructures with Muographic Expertise (TRUST-ME)

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LSBB Laboratoire Souterrain à Bas Bruit
Low Noise Inter-Disciplinary Underground Science & Technology

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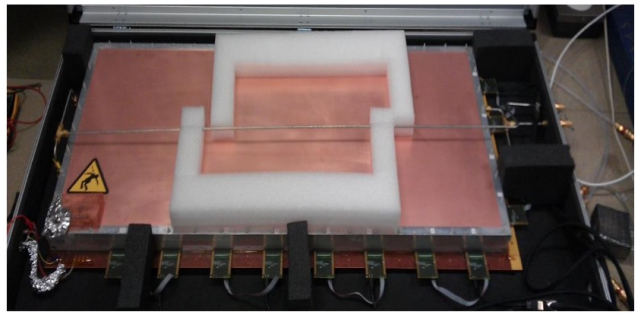
AVIGNON UNIVERSITÉ

Clément Risso | Ignacio Lázaro Roche

TRUST-ME Project overview (Former T2DM2)

- T2DM2 detector validated in field conditions (2018)
  - Supported and developed by LSBB
  - New kind of muon detector (MUST²)
  - Technology and method patented in 2015
- Project duration: 2 years
  - April 2022 – April 2024
- Staff:
  - Ignacio Lázaro-Roche: research engineer, project leader
  - Clément Risso: software engineer
- TRUST-ME: major electronics update and application-oriented software tools
  - Aimed targets: dams and groundwater reservoirs

MUST² detector (2018)



Ignacio Lázaro Roche

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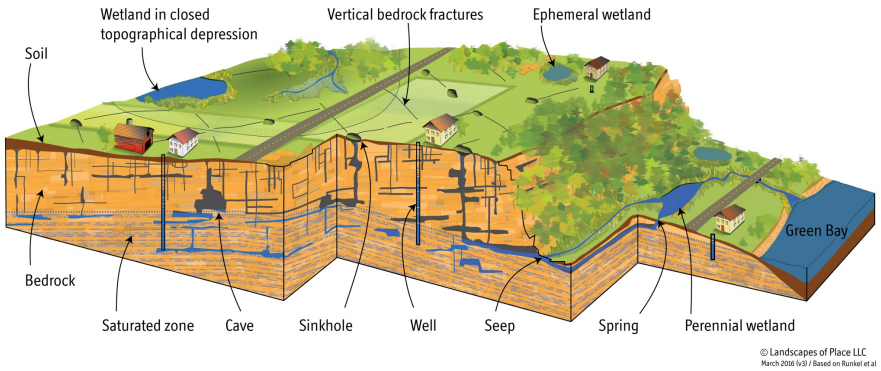
Targeted applications

- Sustainable management of water resources
  - Climate change, demographic growth cause increasing need for water
  - 25% of world population depends on groundwater from karstic reservoirs
- Surveillance of large infrastructures
  - Many dams have reached the end of their lifespan
  - 200 dam failures between 2000 and 2009
  - Existing monitoring techniques are limited



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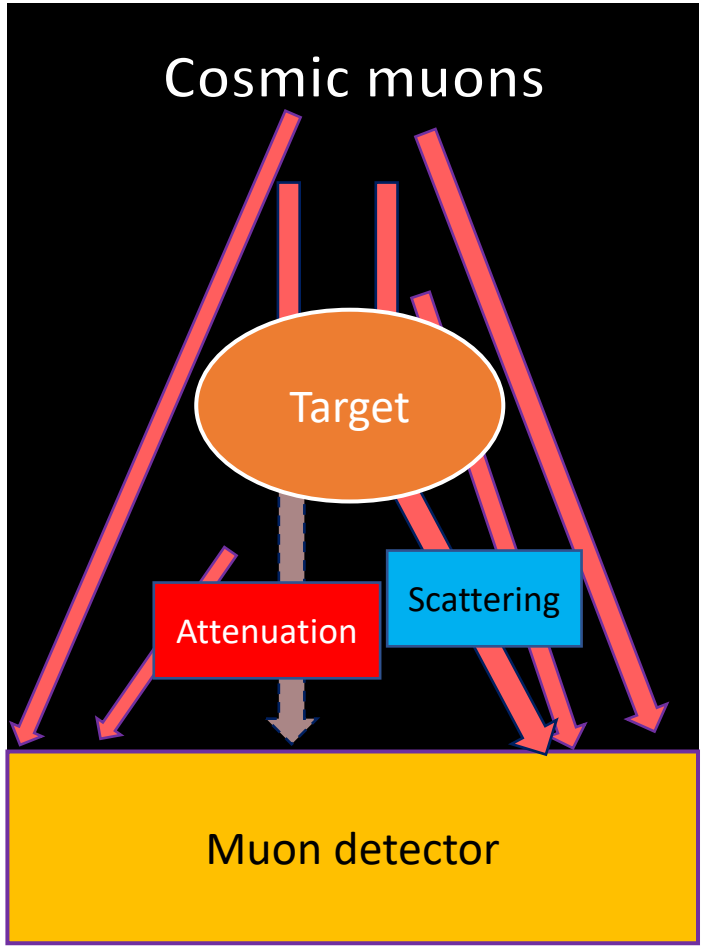
Broken dam in Vega de Tero, Spain (1959)

www.nytimes.com

The Three Gorges Dam faces problems involving pollution and geological disaster prevention. Reuters

Muography principle

- Muons are **naturally generated** in cosmic showers
  - Undergo absorption and scattering along their path
  - Interactions ∝ path length and density
- Muography **gives us information** about target
  - Density mapping
  - Overburden
  - Evolution of density (from long-term acquisition)
- **Transmission** muography uses absorption
  - Muons cross hundreds of m before being completely attenuated
- **Scattering** muography based on trajectories
  - High angular resolution, better positioning



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Why develop a new technology?

		Muon trajectory reconstruction	Muon timestamp	Ang. res. analogue to geophysics tech.	Wide field of view	Portability
Visual detectors	Film nuclear emulsion	✓	✗	✓	✓	✓
	Cherenkov telescopes	✓	✓	✓	✗	✗
Scintillator	Hodoscopes	✓	✓	✓	✗	✗
Gaseous detectors	GRPCs	✓	✓	✓	✗	✗
	Micropatterns in multilayer	✓	✓	✓	✗	✓
	TRUST-ME	✓	✓	✓	✓	✓

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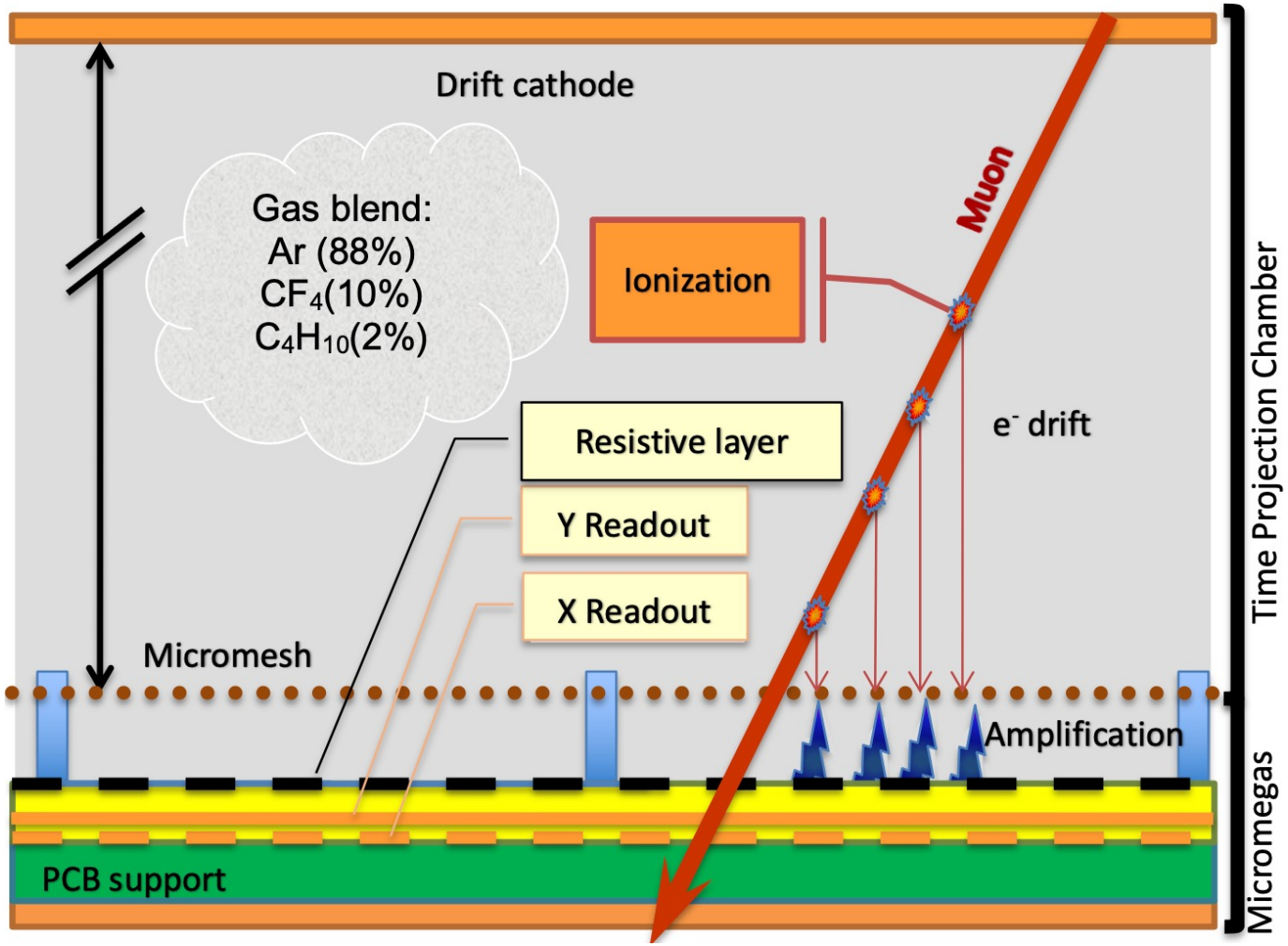
Functioning principle

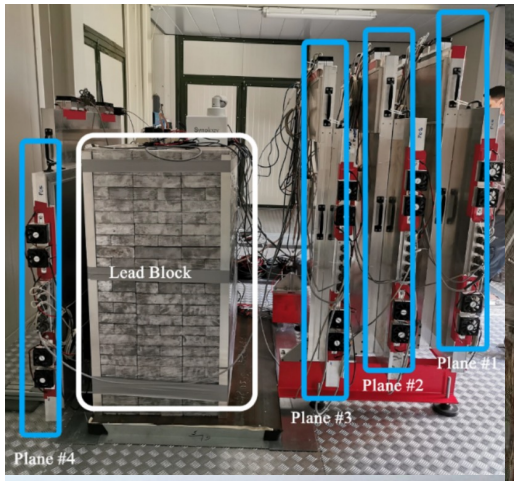
- μ enters conversion & drift chamber
- Gas ionizes ⟶ e^- drifts to readout plane
- Charges amplified after the micromesh
- Signal induced in readout tracks
- Data acquisition trigger can be customized

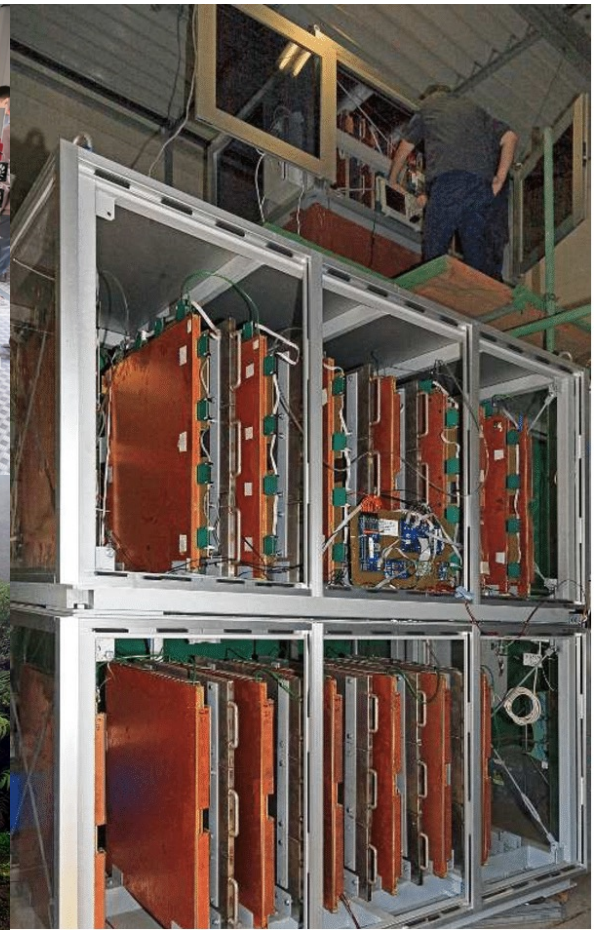


Ignacio Lazaro-Roche

How does it look?

Other technologies

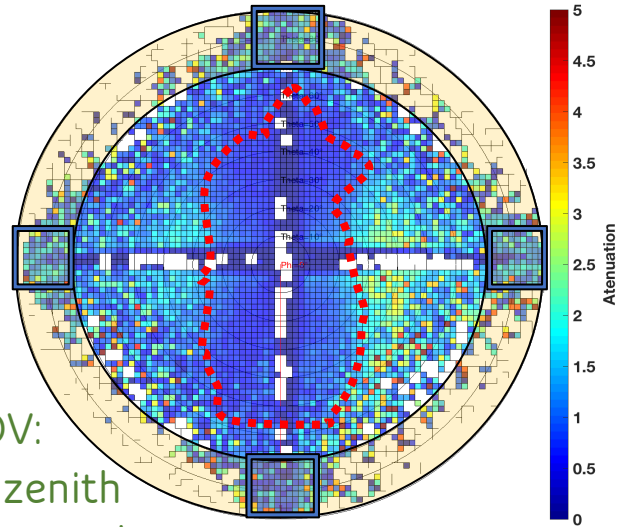




MUST^2

Compact & light (~25kg)

Sturdy



FOV:
160° zenith
360° azimuth

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Capabilities and applications

- Remote density mapping for underground and large structures
  - Existence of cavities, dense areas and discontinuities
    - Gravity movements, deposits, faults, pre-fracture tensile areas…
- Monitoring of density evolution
  - Characterization of dynamic / non-modellable systems
    - Variations either periodical (day/night, summer/winter…) or punctual (construction work, rain, floods…)
- Provides additional data
  - Muography can be associated with well-established geophysics techniques
    - Increases reliability and range of techniques such as gravimetry, electrical resistivity etc.
- Sometimes the only option available

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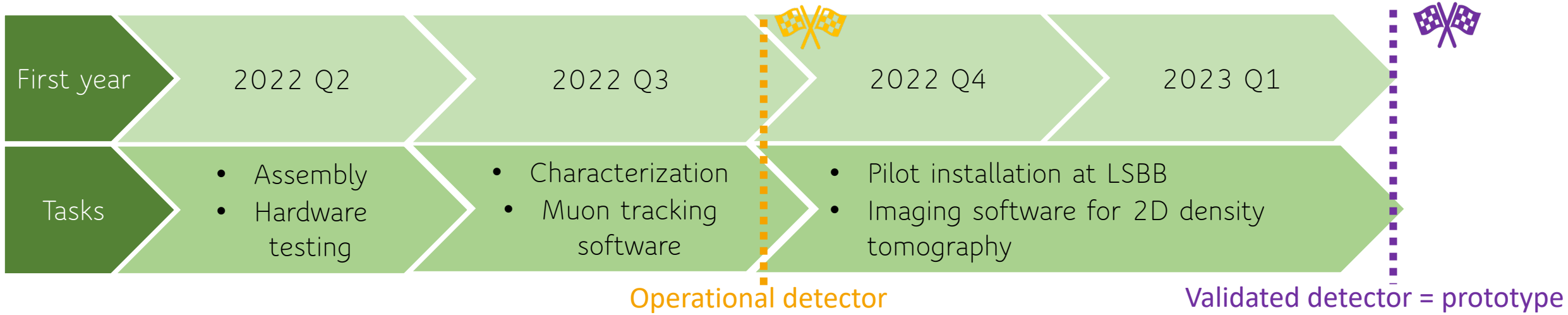
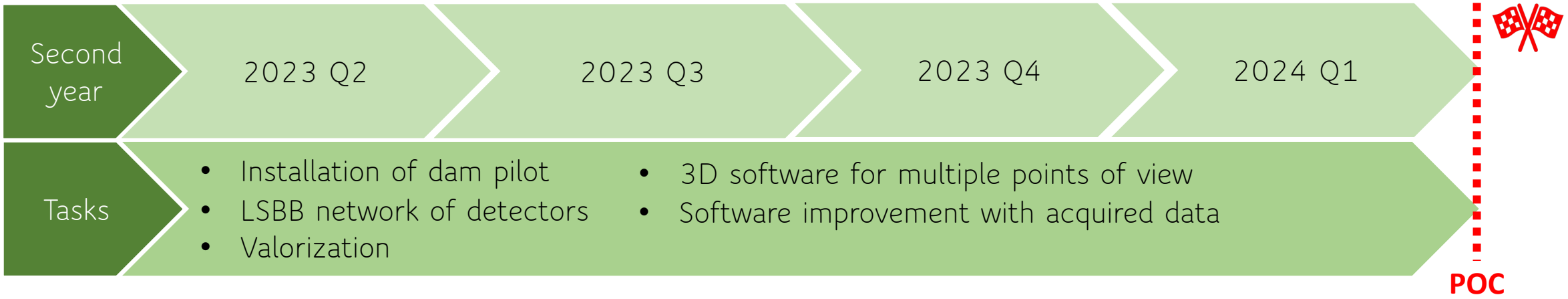
New features after the upgrade

Characteristics	Previous version	TRUST-ME version	
Data analysis from multiple point of views	No	**Yes**	4D tomography possible
Electronics can be bought from market	No	**Yes**	Key point for commercialization
Need for auxiliary detectors	Yes	**No**	Less costly and bulky
Auto-triggering from muon	No	**Yes**	Programmable and exportable
Automatic deletion of void data	No	**Yes**	Less data traffic, improved storage
Numeric amplification gain	Fixed	**Yes**	Programmable, better signal/noise
Gain variation with temperature	Yes	**No**	Constant performance
Time resolution	25 ns	**1 ns**	Improved angular resolution
Sampling frequency	7 kHz	**4 MHz**	Beam measures

Project roadmap & challenges





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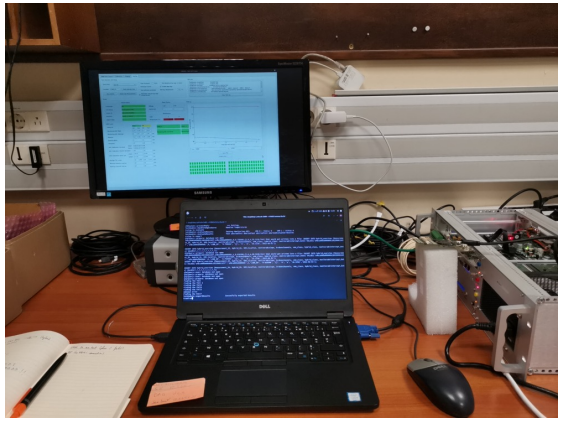
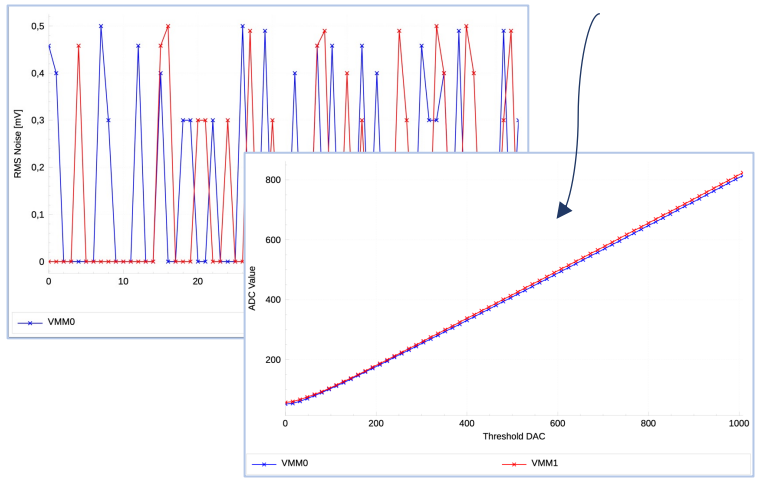
Ongoing work

Assembly of heatsinks on acquisition cards (x160…)

Setup of an underground *clean room* for detector assembly

-New floor and ceiling
-Laminar flow hood (EN 61010)
-2 electronics workbenches
-Gas management





Chip flashing, hardware and performance testing of hybrids

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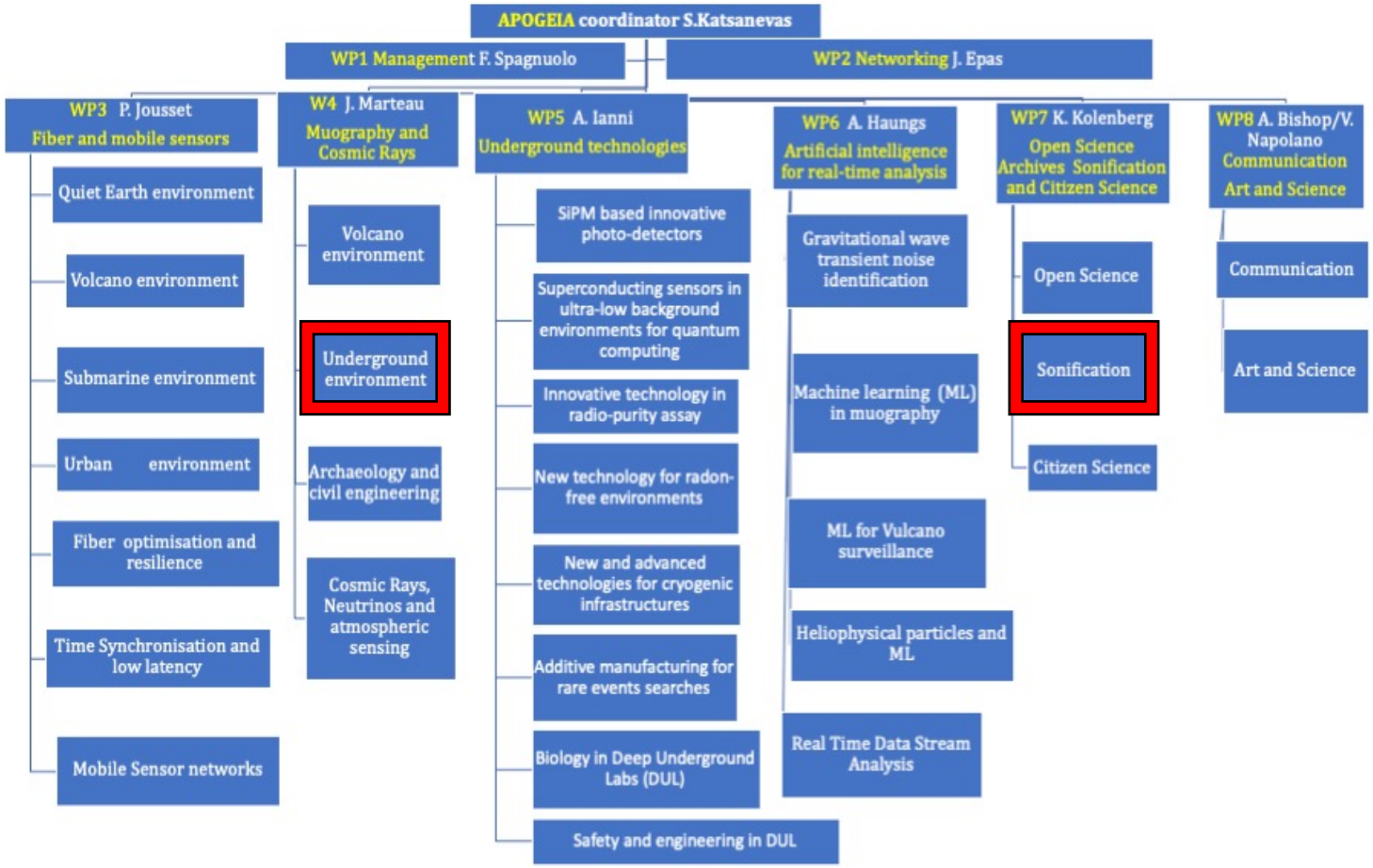
APOGEIA - LSBB contribution



WP4.

- Benchmarking site for critical-zone muographic measurements.
- Multi- technique/technology/scale experiment

WP7.

- Data from Muographic acquisition will be sonificated

A convenient location

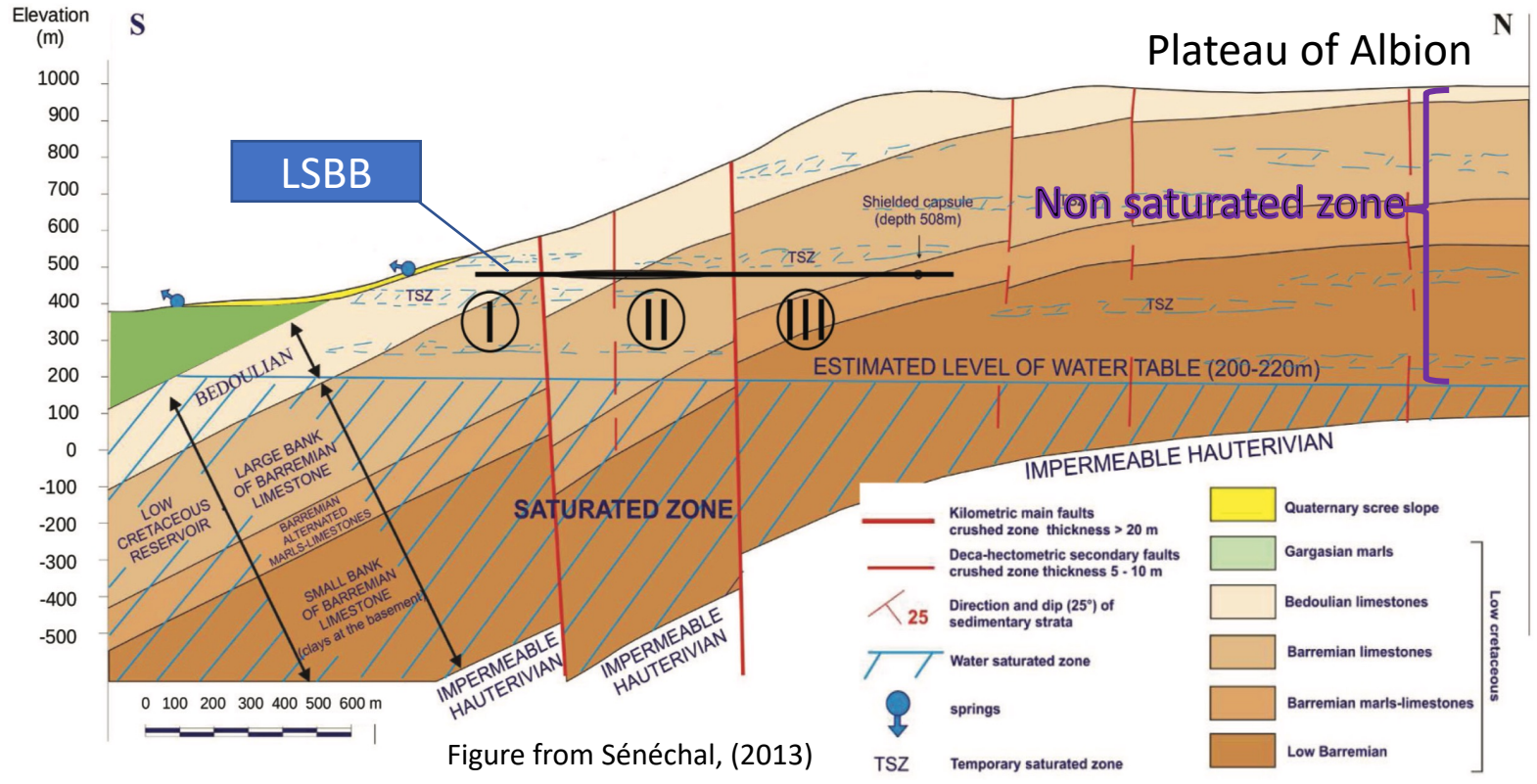
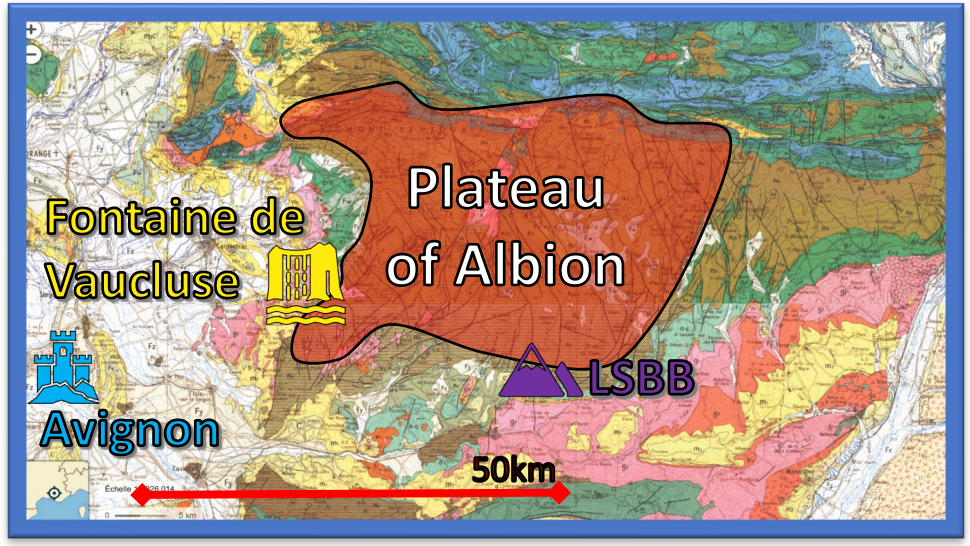


Figure from Sénéchal, (2013)



Experimental site: carbonate reservoir

- 140 years of flow measurements at FdV water catchment
- 17 years of hydrochemical simultaneous measurements at both LSBB and FdV
- Easy and « random » access to LSBB flows in the unsaturated area of the karstic aquifer and within the saturated zone (boreholes)

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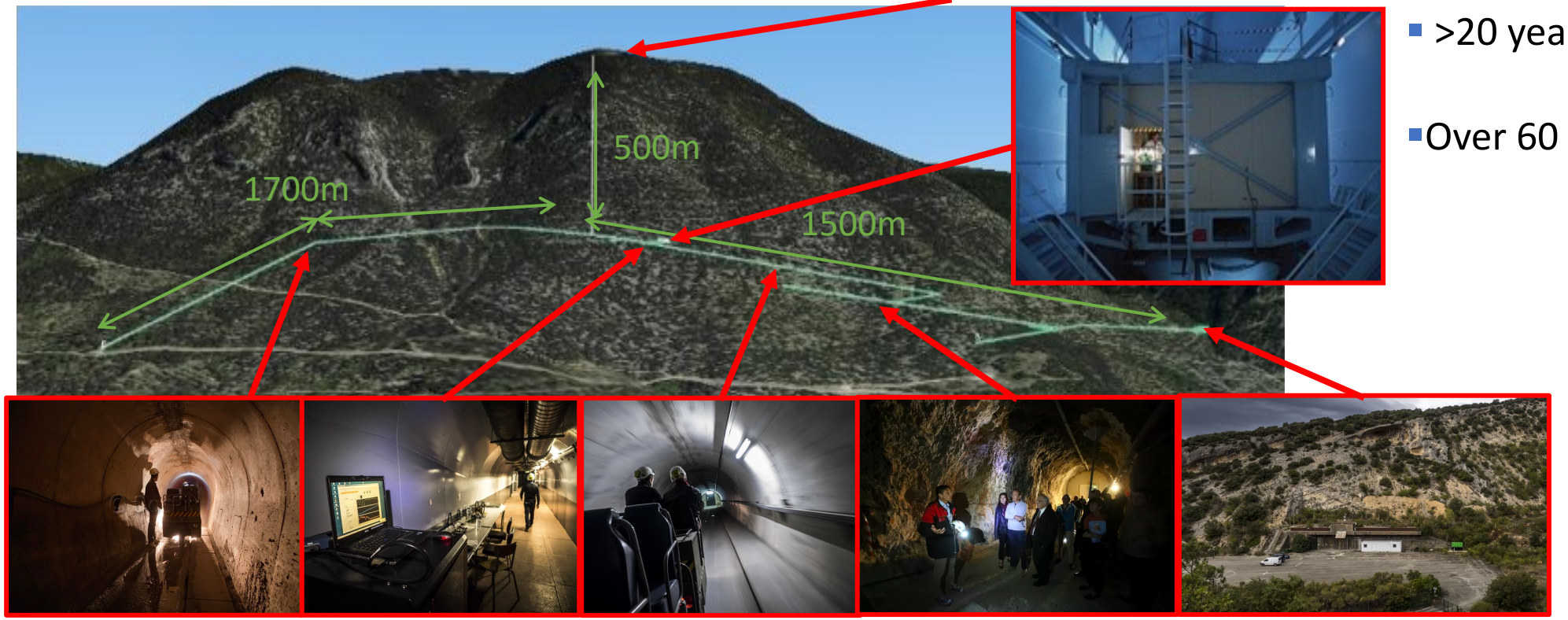
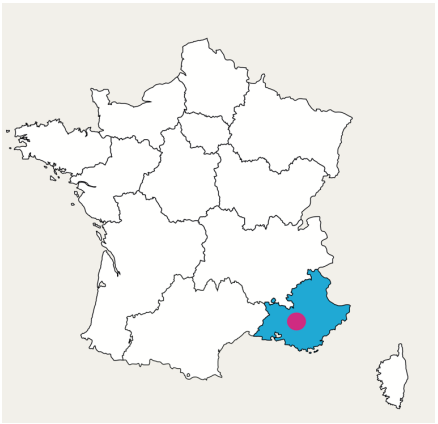
Well-known, versatile environment

- Underground **and** surface unique facilities
  - 4.3km of galleries
  - 53 ha of surface



- Permanent network of detectors
- Periodical campaigns
- >20 years of environmental data
- Over 60 PhD thesis



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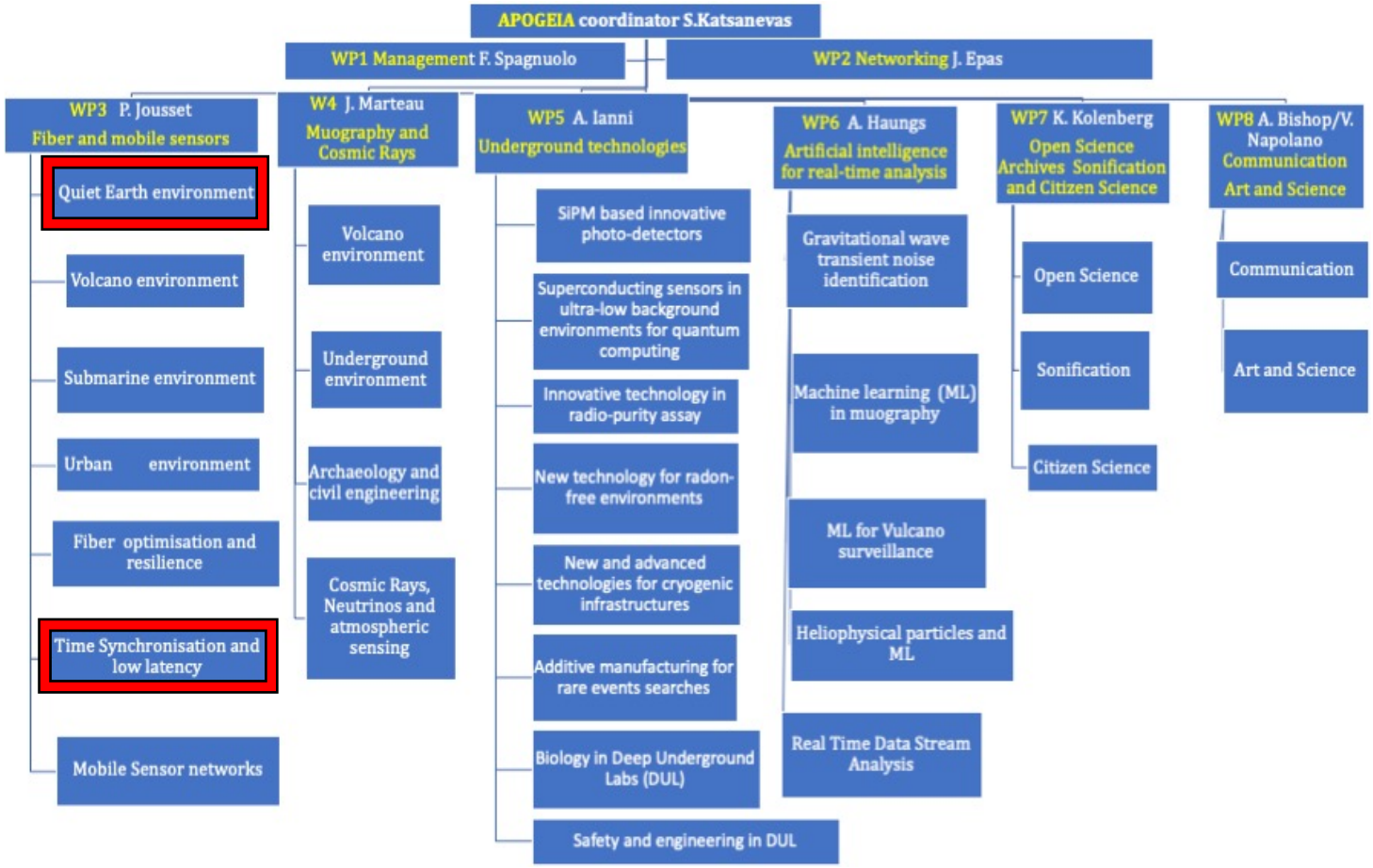
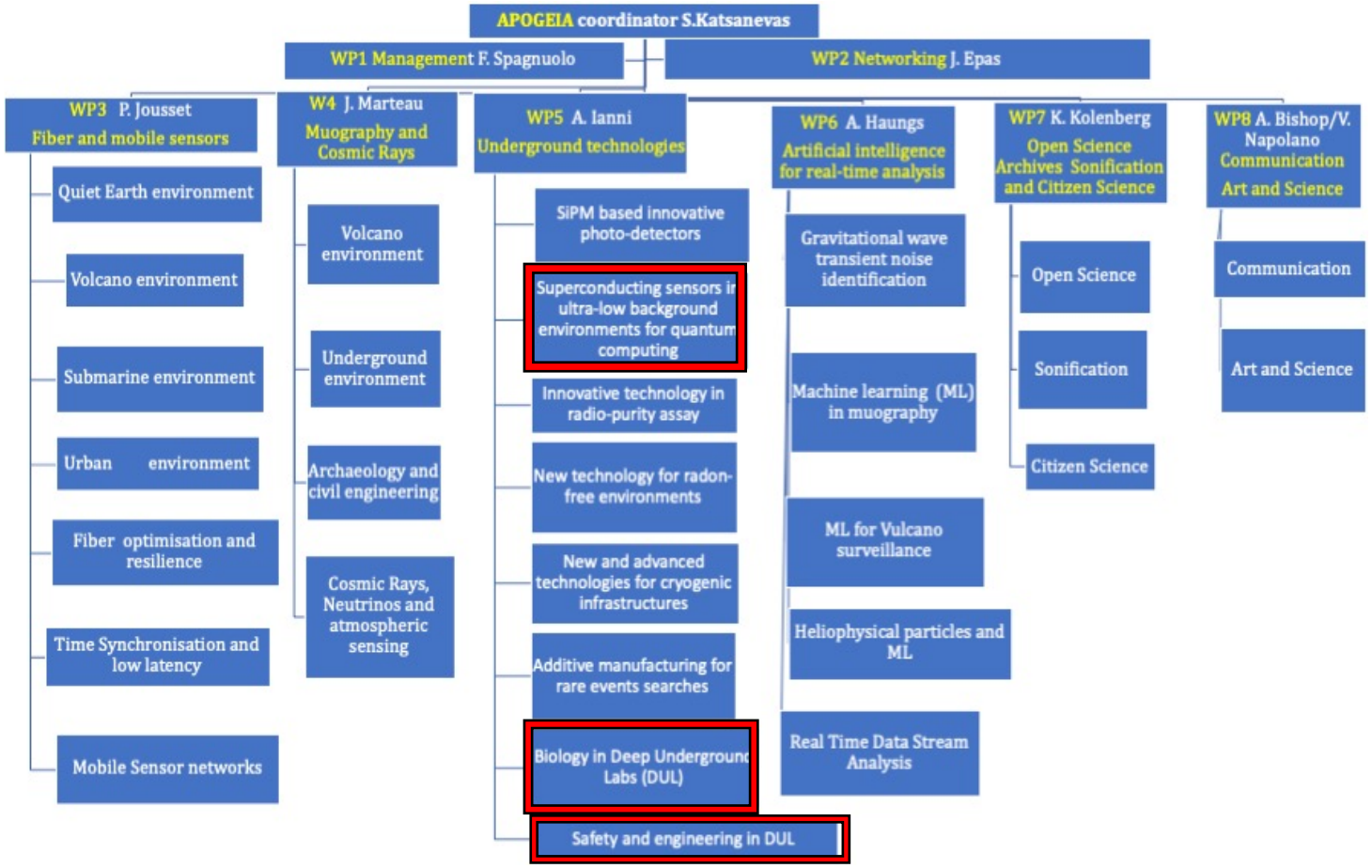


WP3.

- Test site to assess the capability of various optic fiber instrumentation (interrogators) in quiet environments in order to reach the ultimate performance of OF technologies
- Perform and benchmark DAS (acoustic), DSS (strain) and DTS (temperature) continuous measurements of the ground noise
- Characterize the ground noise in quiet environments
- Network Synchronisation and time/frequency distribution

APOGEIA - LSBB contribution



WP5.

- The LSBB is equipped with two superconducting gravimeters, vertical to each other, and separated by 520 meters of rock.
- This unique configuration makes it possible to measure mass fluctuations with twice the sensitivity of a single gravimeter and provides sensitivity to lateral variations.
- Strong synergies with muographic measurements
- Characterization of microbiological material in karstic environment for water quality control
- Part of the European network for improving UL safety solutions.

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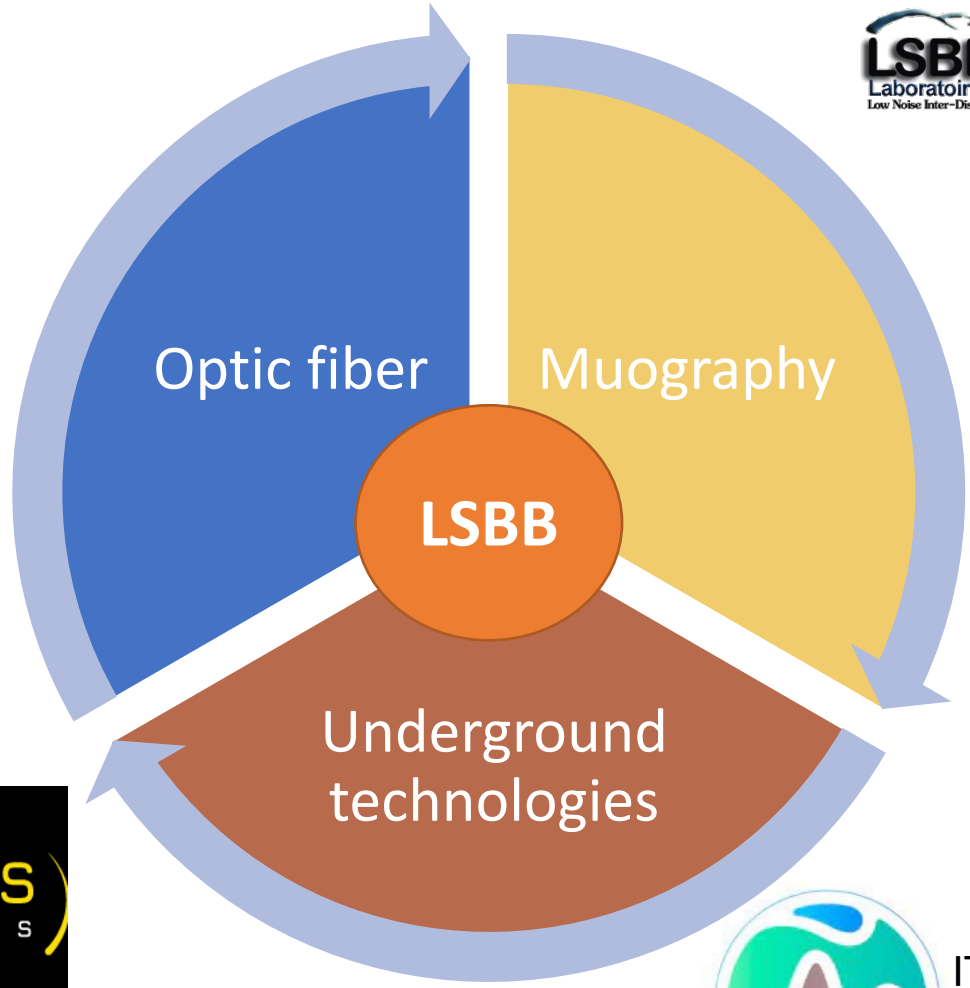

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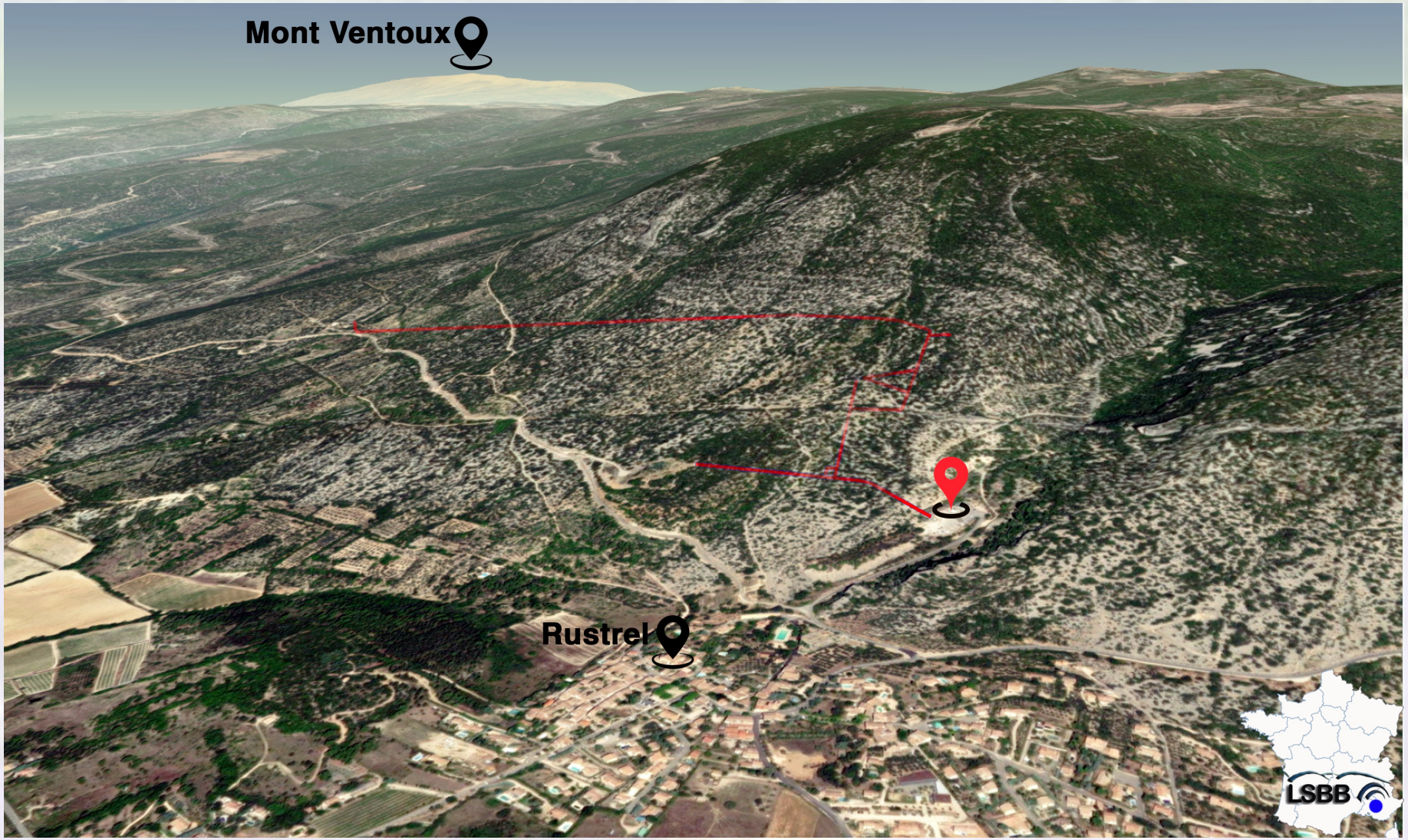
Thank you for your attention



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