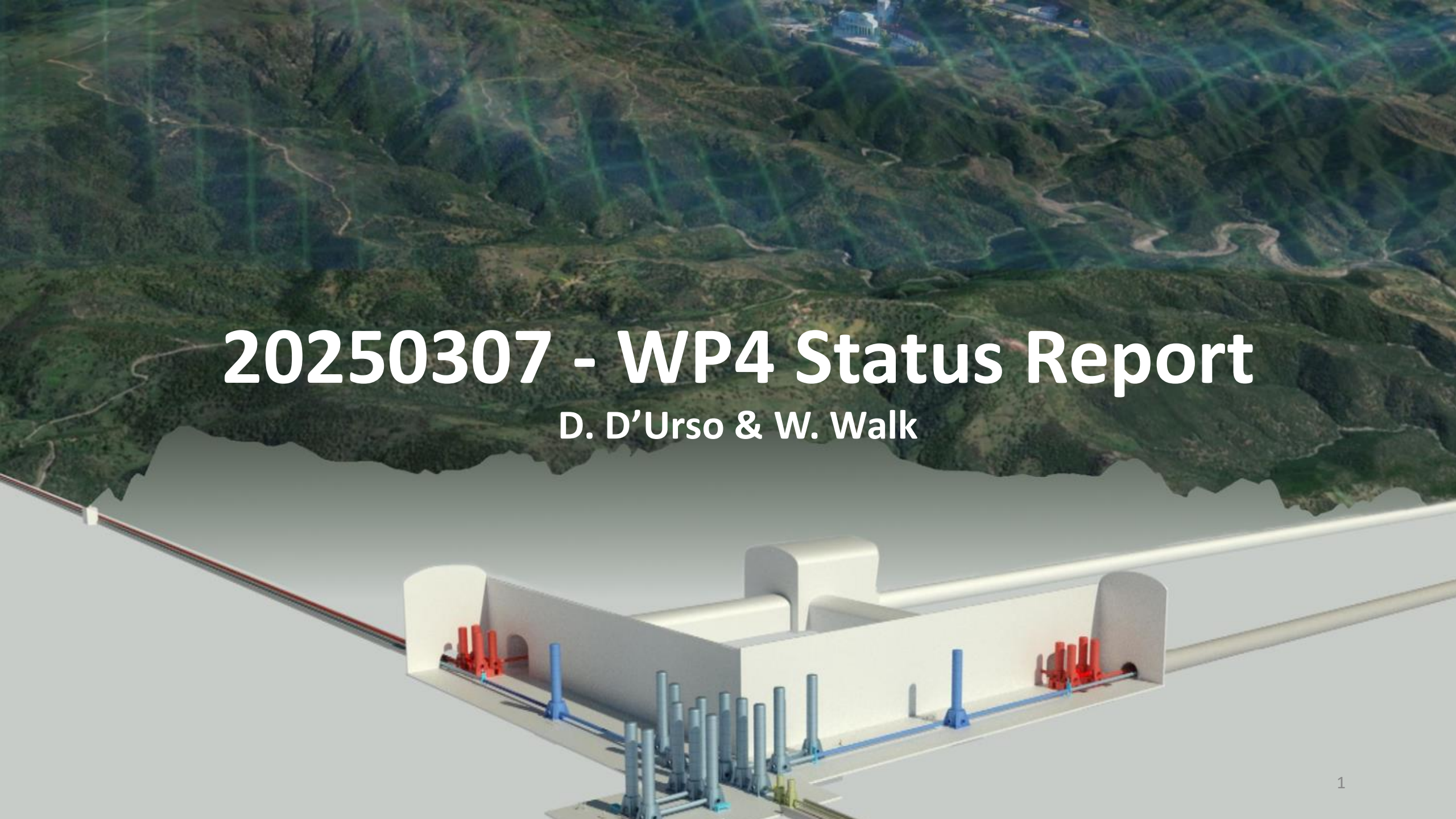
20250307 - WP4 Status Report

D. D’Urso & W. Walk



Current Status

- Activities at Sites
- SCB Organigram
- Paper on geological and geo-technical investingations
- WP4 status
- Evaluation of site dependent detector performance

The Sardinian Candidate Site

Action lines

- Geological studies
  - ❑ understanding and characterization of local geology
- Site monitoring
  - ❑ identification and quantification of local source impact
  - ❑ implication for site preservation quality
- Civil and environmental engineering
  - ❑ geotechnical investigation
  - ❑ optimal placement and environmental sustainability of the underground and surface infrastructures
- Socio-economic impact

PERMANENT ARRAY since 2021

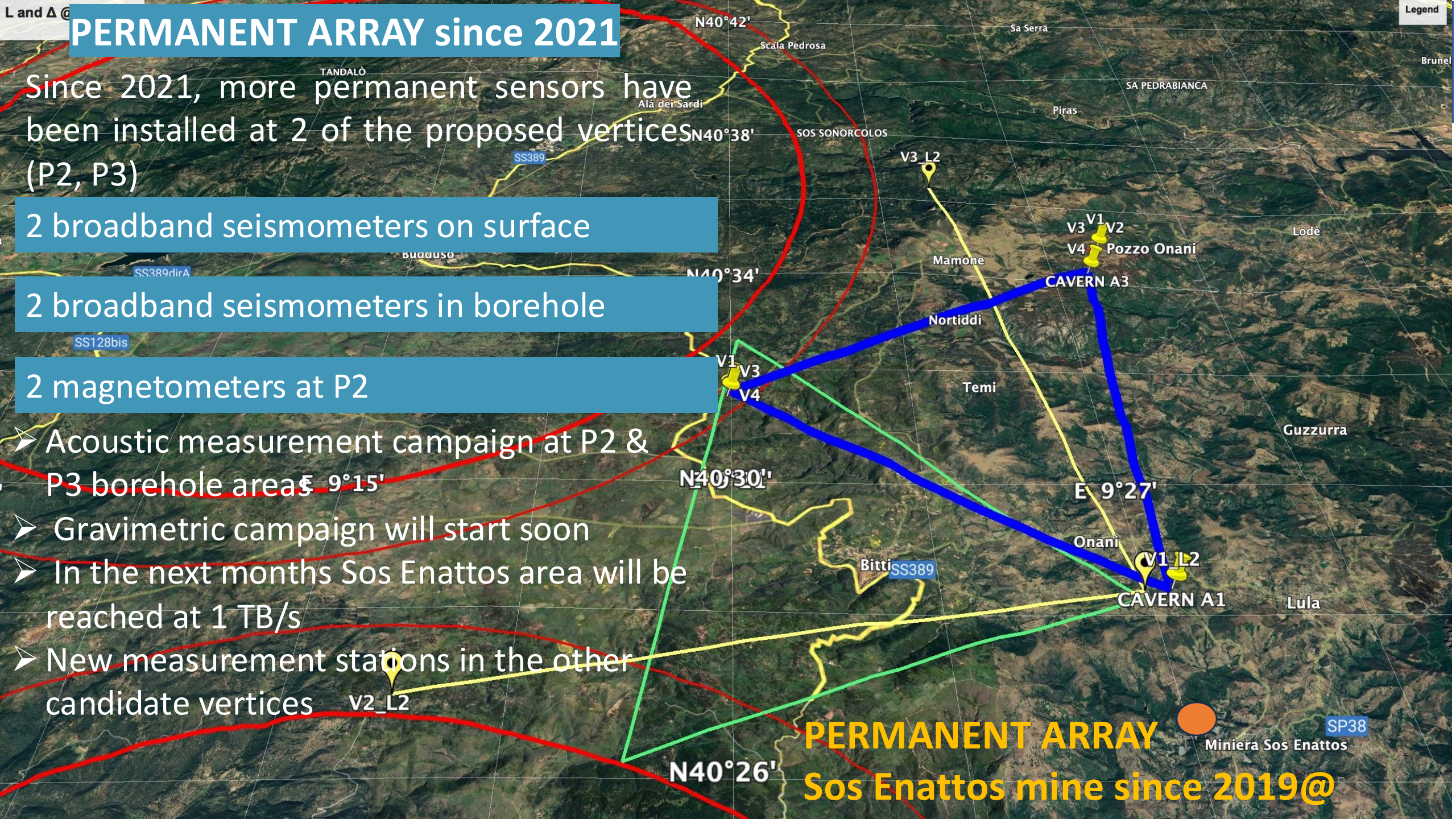
Since 2021, more permanent sensors have been installed at 2 of the proposed vertices (P2, P3)

2 broadband seismometers on surface

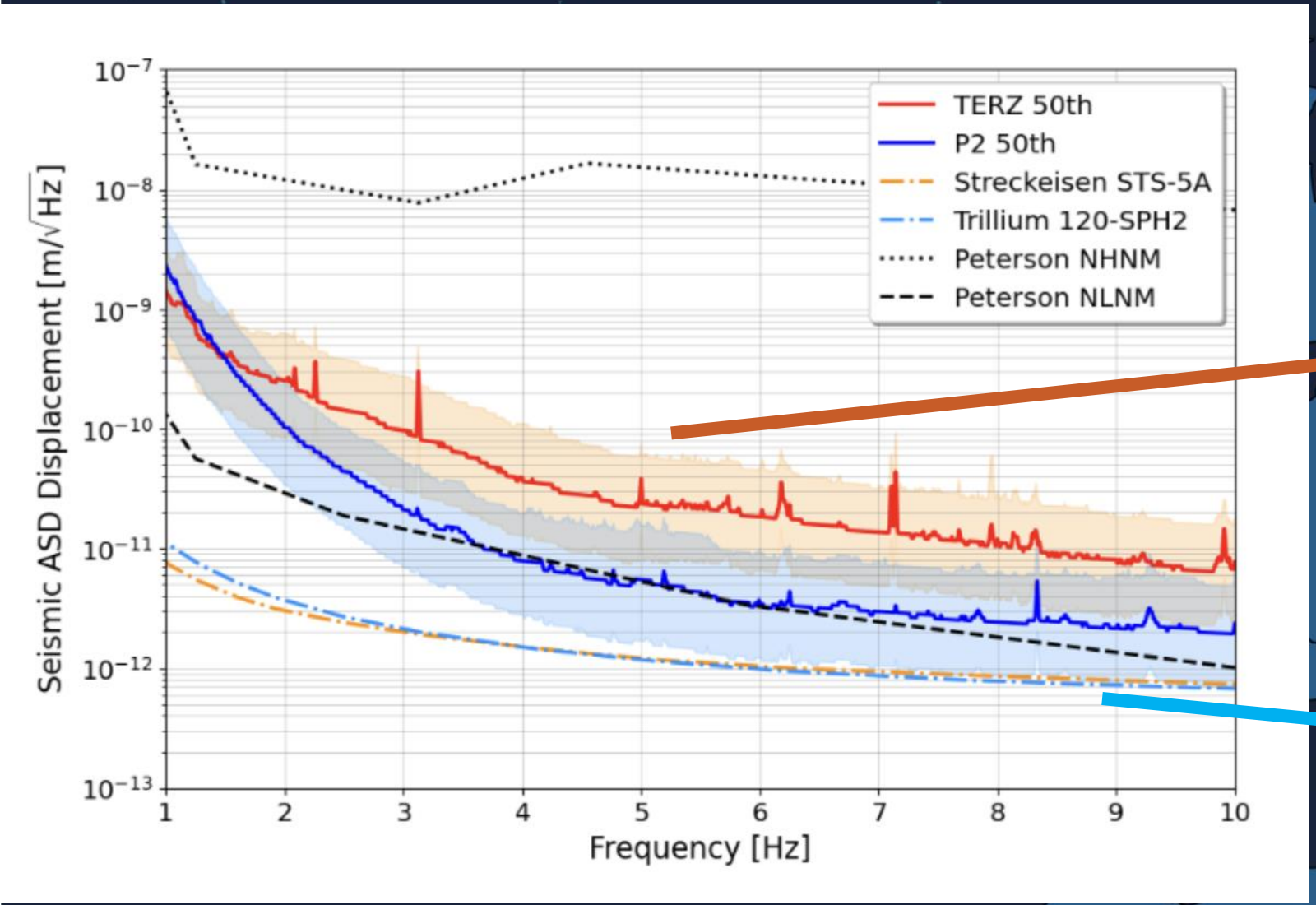
2 broadband seismometers in borehole

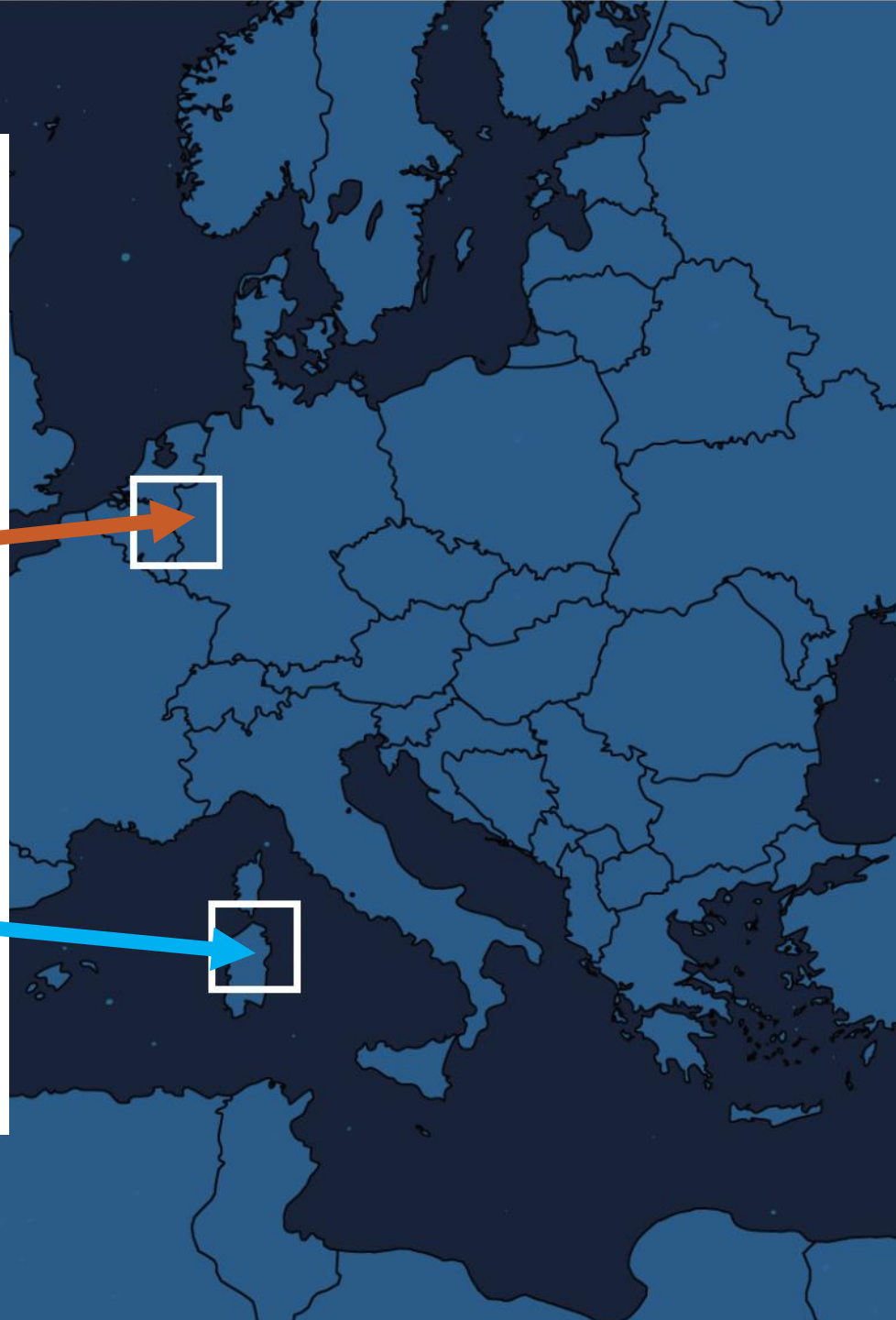
2 magnetometers at P2

- Acoustic measurement campaign at P2 & P3 borehole areas
- Gravimetric campaign will start soon
- In the next months Sos Enattos area will be reached at 1 TB/s
- New measurement stations in the other candidate vertices



Sardinia vs EMR





Seismic noise / frequency

Effect on ET Sensitivity

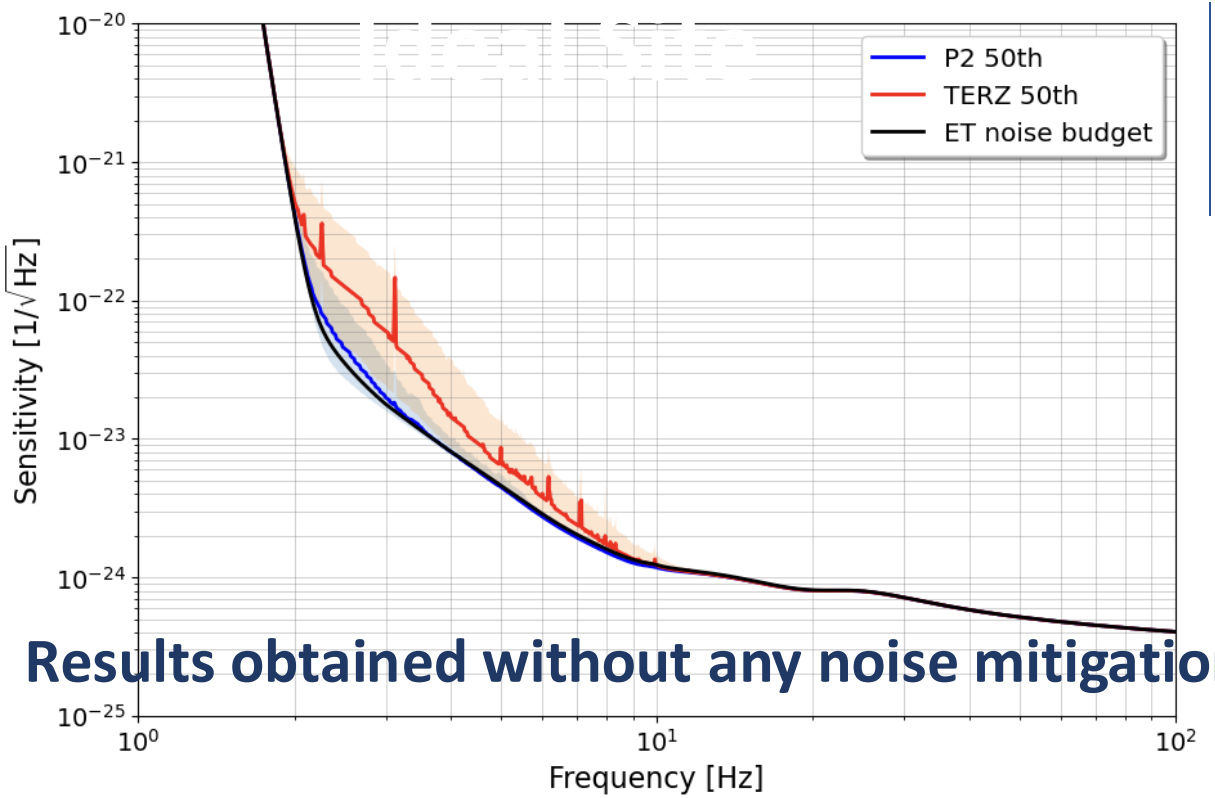
F. Badaracco, J. Harms, Class. Quant. Grav. 36 (2019) 14, 145006
assuming:

- Contribution only from body waves
- 1/3 of the seismic noise coming from compressional waves
- Spherical or cubic cave
- Uncorrelated NN on the ITF Test Masses

$$\tilde{h}_{NN} = \frac{4\pi}{3} G\rho_0 \frac{2\sqrt{2}}{L} \frac{1}{(2\pi f)^2} \tilde{x}$$

- $\tilde{x}$: ASD of NN
- $\frac{1}{(2\pi f)^2}$: ASD of Seismic Displacement

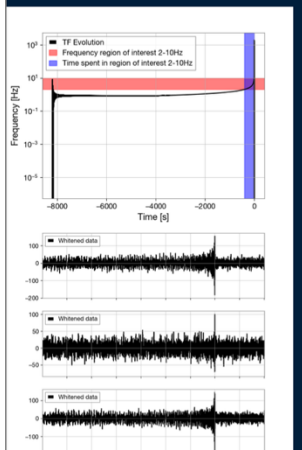
Manuscript approved by ETC internal referees, available at https://arxiv.org/abs/2503.02166



Results obtained without any noise mitigatio

GW150914-like event at cosmological distance

M1 = 35 M_sun
M2 = 30 M_sun
D = 4000 Mpc (z = 1)



T 2 Hz - 10 Hz	T 2 Hz - to merger	Design SNR 2 Hz-10 Hz
400 s	403 s	41

P2 10%	P2 50%	P2 90%
43 (+5%)	42 (+2%)	40 (-3%)

TERZ 10%	TERZ 50%	TERZ 90%
42 (+2%)	37 (-10%)	27 (-35%)

In current generation detectors, similar signals last few hundred milliseconds from 20 Hz to merger

GW170817-like event at cosmological distance

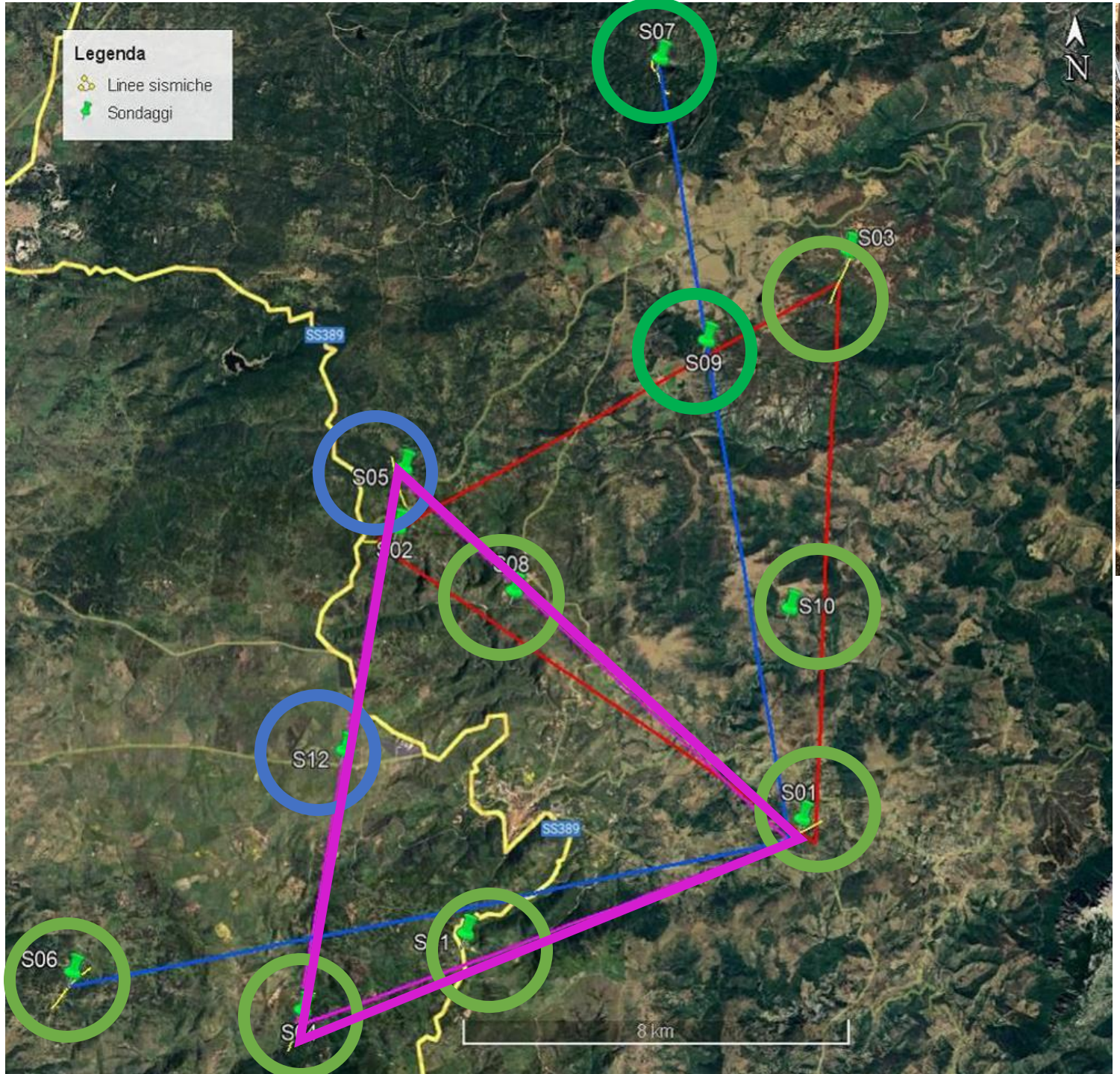
M1 = 1.4 M_sun
M2 = 1.4 M_sun
D = 1000 Mpc (z = 0.2)

T 2 Hz - 10 Hz	T 2 Hz - to merger	Design SNR 2 Hz-10 Hz
20 h	-	18.2

P2 10%	P2 50%	P2 90%
19.3 (+6%)	19 (+4%)	17.7 (-3%)

TERZ 10%	TERZ 50%	TERZ 90%
18.6 (+2%)	15.7 (-24%)	11 (-39%)

SNR fractions with respect to design are compatible with the previous cases.



New Drilling Campaign started in July ‘24

- 12 boreholes completed: **S01, S03, S04, S06, S07, S08, S10**
- **on going: S05, S12**
- **Chosen the best triangle**

ETIC Project: Current Activities

- Conceptual Design of underground infrastructure for both geometries
- Conceptual Design of surface infrastructure
- Local permits, authorization and nulla osta. Meeting with relevant Institutions
  - ✓ safety
  - ✓ environmental impact
  - ✓ …

Activities and Timing

- Data for noise studies already available, studies on going.

- Company deadline **Q3 2025**
  - Technical Studies for Subsurface Assessment and Risk Analysis
  - Design and Construction Feasibility Assessment
  - Cost and Time Estimation
  - Environmental Impact Assessment, Permits, and Noise Mitigation Measures
  - Safety and Security Plan
  - Technical Infrastructure (Underground and Surface)

ET Italian Community

- https://www.einstein-telescope.it
- Contacts:

Matteo Serra, ET Italy communication, matteo.serra@ca.infn.it, Gloria Nobile gloria.nobile@ca.infn.it

MUR Ministero dell'Università e della Ricerca

REGIONE AUTÒNOMA DE SARDIGNA
REGIONE AUTONOMA DELLA SARDEGNA

INFN Istituto Nazionale di Fisica Nucleare

nei progetti Etic, ETpp/Infra-Dev, Sar-Grav, Terabit

Agenzia Spaziale Italiana — nel progetto Etic

CINECA — nel progetto Terabit

EGO European Gravitational Observatory — nel progetto ETpp/Infra-Dev

Consortium GARR THE ITALIAN EDUCATION & RESEARCH NETWORK — nel progetto Terabit

GSSI GRAN SASSO SCIENCE INSTITUTE CENTER FOR ADVANCED STUDIES Istituto Nazionale di Fisica Nucleare — nel progetto Etic

INAF ISTITUTO NAZIONALE DI ASTROFISICA — nel progetto Etic

ISTITUTO NAZIONALE DI GEOFISICA E VULCANOLOGIA — nei progetti Meet/Faber, Sar-Grav

OGS Istituto Nazionale di Oceanografia e di Geofisica Sperimentale — nel progetto Terabit

ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA — nel progetto Etic

UNIVERSITÀ DEGLI STUDI DI CAGLIARI — nei progetti Etic, Sar-Grav

Università degli Studi della Campania Luigi Vanvitelli — nel progetto Etic

Università di Genova — nel progetto Etic

UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II — nel progetto Etic

UNIVERSITÀ DEGLI STUDI DI PADOVA — nel progetto Etic

UNIVERSITÀ DEGLI STUDI DI PERUGIA — nel progetto Etic

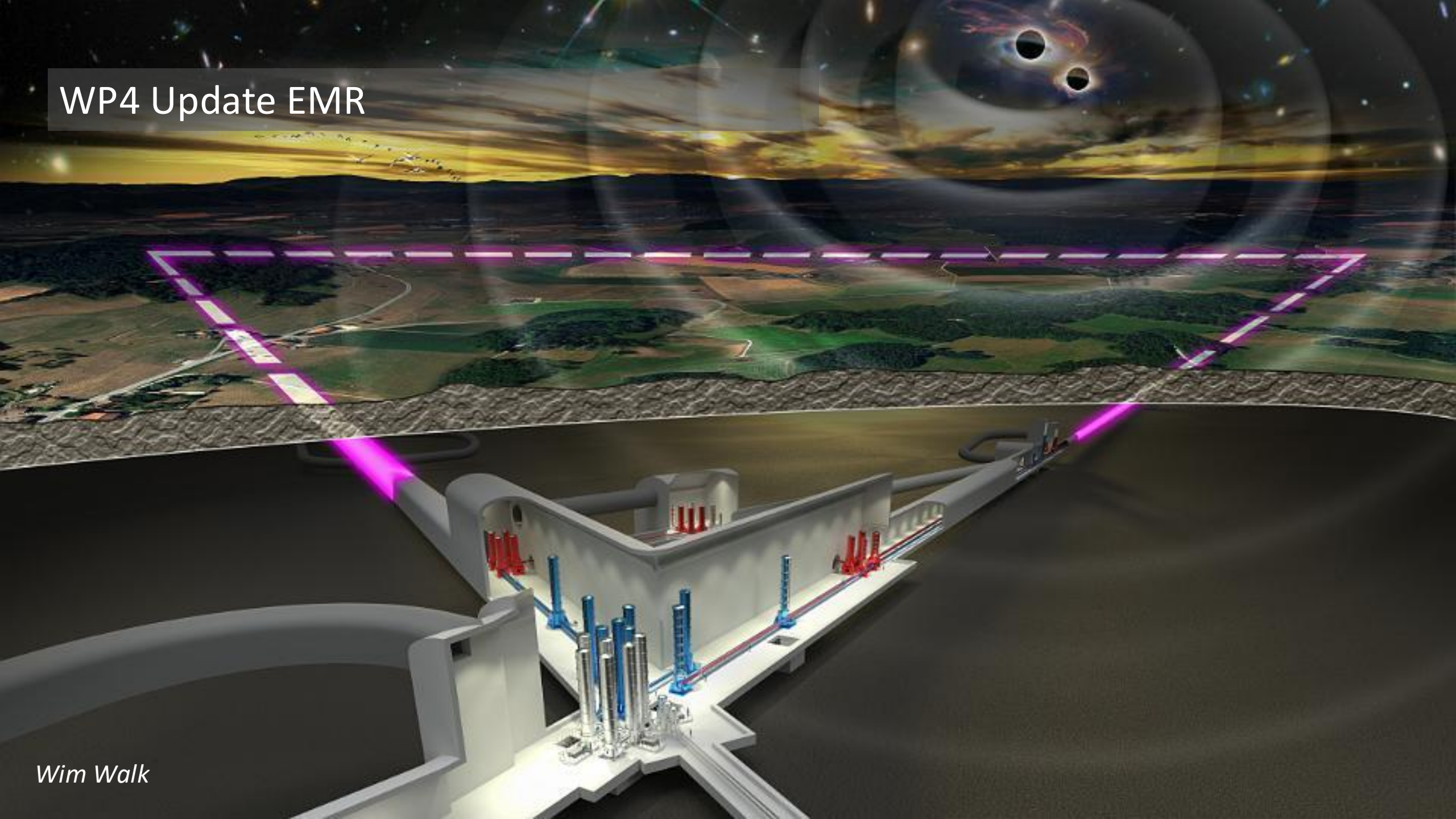
UNIVERSITÀ DI PISA — nel progetto Etic

SAPIENZA UNIVERSITÀ DI ROMA — nel progetto Etic

TOR VERGATA UNIVERSITÀ DEGLI STUDI DI ROMA — nel progetto Etic

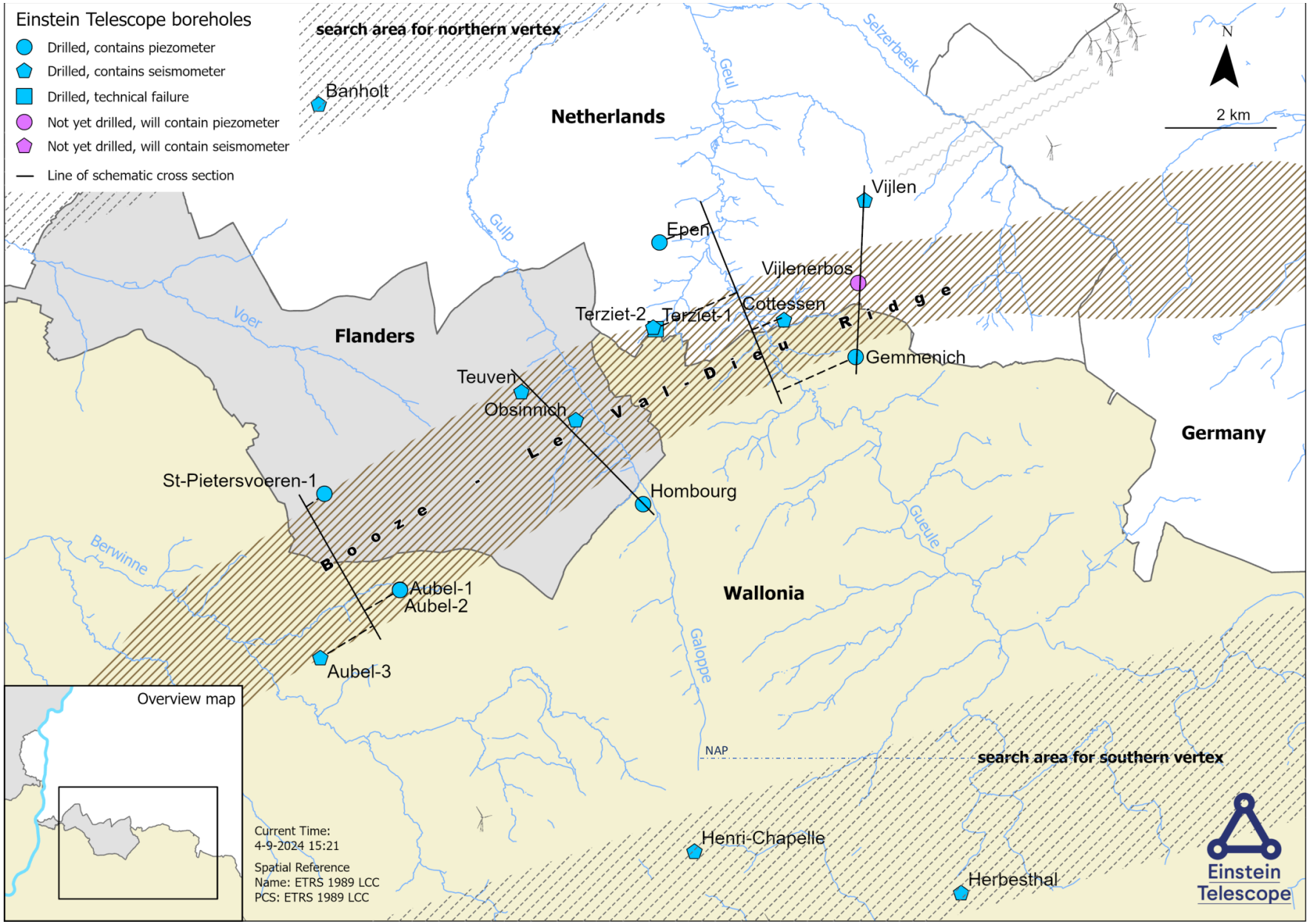
UNISS UNIVERSITÀ DEGLI STUDI DI SASSARI — nel progetto Sar-Grav

WP4 Update EMR



Wim Walk

Map of completed boreholes



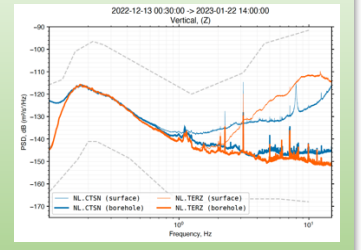
11 new boreholes in 2024

- Flanders: 3 locations in Voeren
- Wallonia: 5 locations: Plombières (2), Aubel, Welkenraedt and Lontzen
- Dutch Limburg: 3 locations in Vijlen (2) and Epen
- Extremely low impact on Environment
- Communication

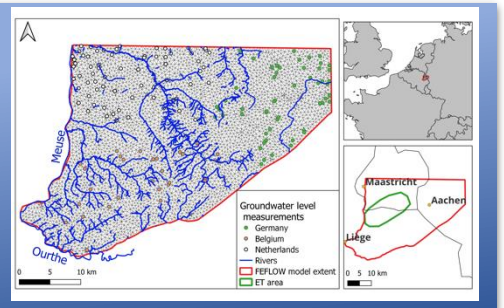
Current Status:

- 11 new boreholes completed 300-400m deep
- Total of 16 boreholes being evaluated

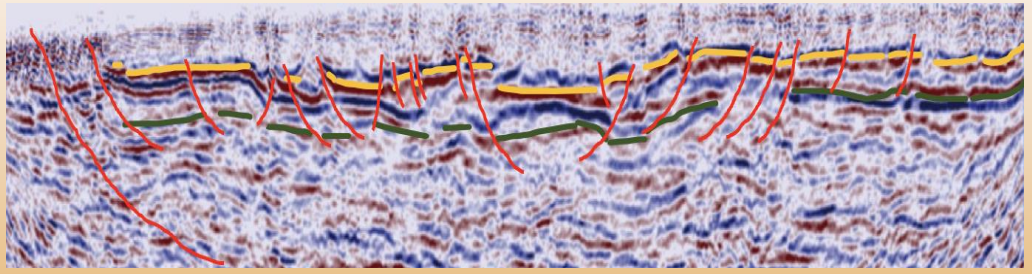
- Noise measurements at surface ongoing and subsurface starting in 10 borehole network



- 3D Subsurface Hydro-geological model being constructed
  First significant versio ready Q3



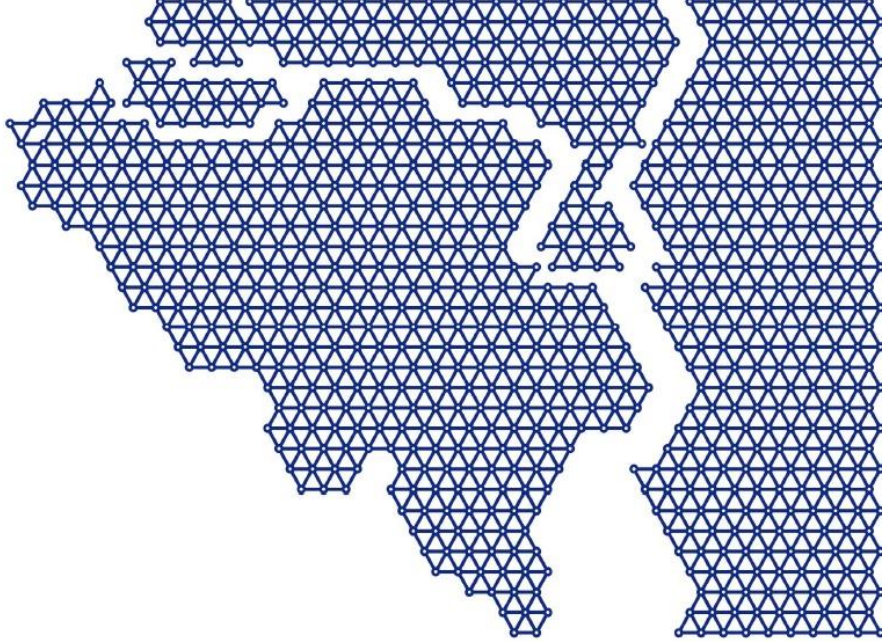
- 100 km seismic being shot NOW



Document – Deliverable

Update Socio-Economic Impact Study

Ready



Einstein Telescope

ETPP-WP4 Socio-economic impact update report of the EMR Project Office

Einstein Telescope

ET-EMR Project Office
Version 1.0

17 February 2025

EINSTEIN TELESCOPE

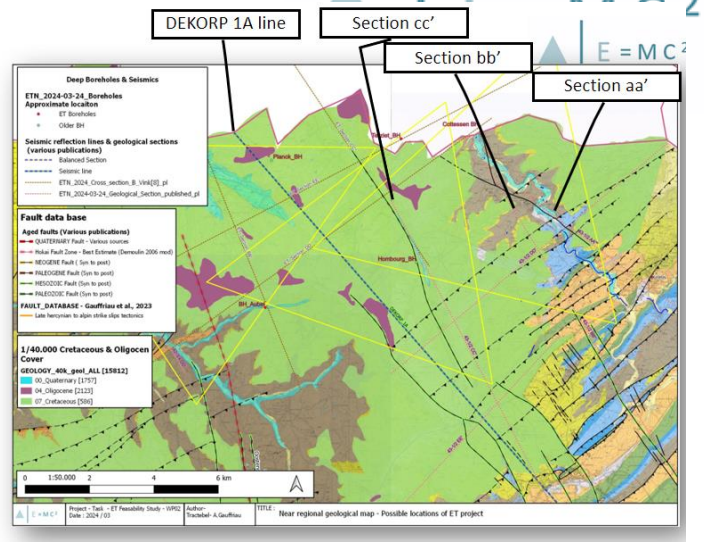
Civil Engineering EMR

Einstein Telescope

Conceptual geological model

Geological map.

DEKORP 1A seismic line and 1:25000 geological cross sections are shown on the map.



- Review of the geological and geotechnical data
- Facilities and Infrastructure
- Developing alternative construction scenarios
- Estimating building cost most likely triangle construction scenario


laminated black CLAYSTONE

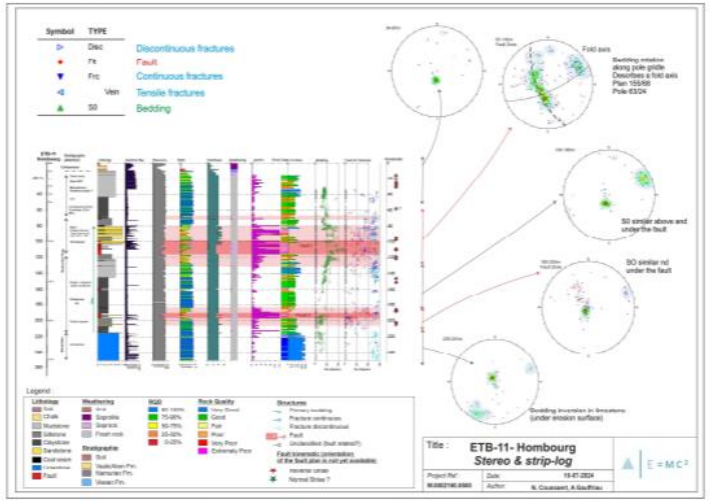
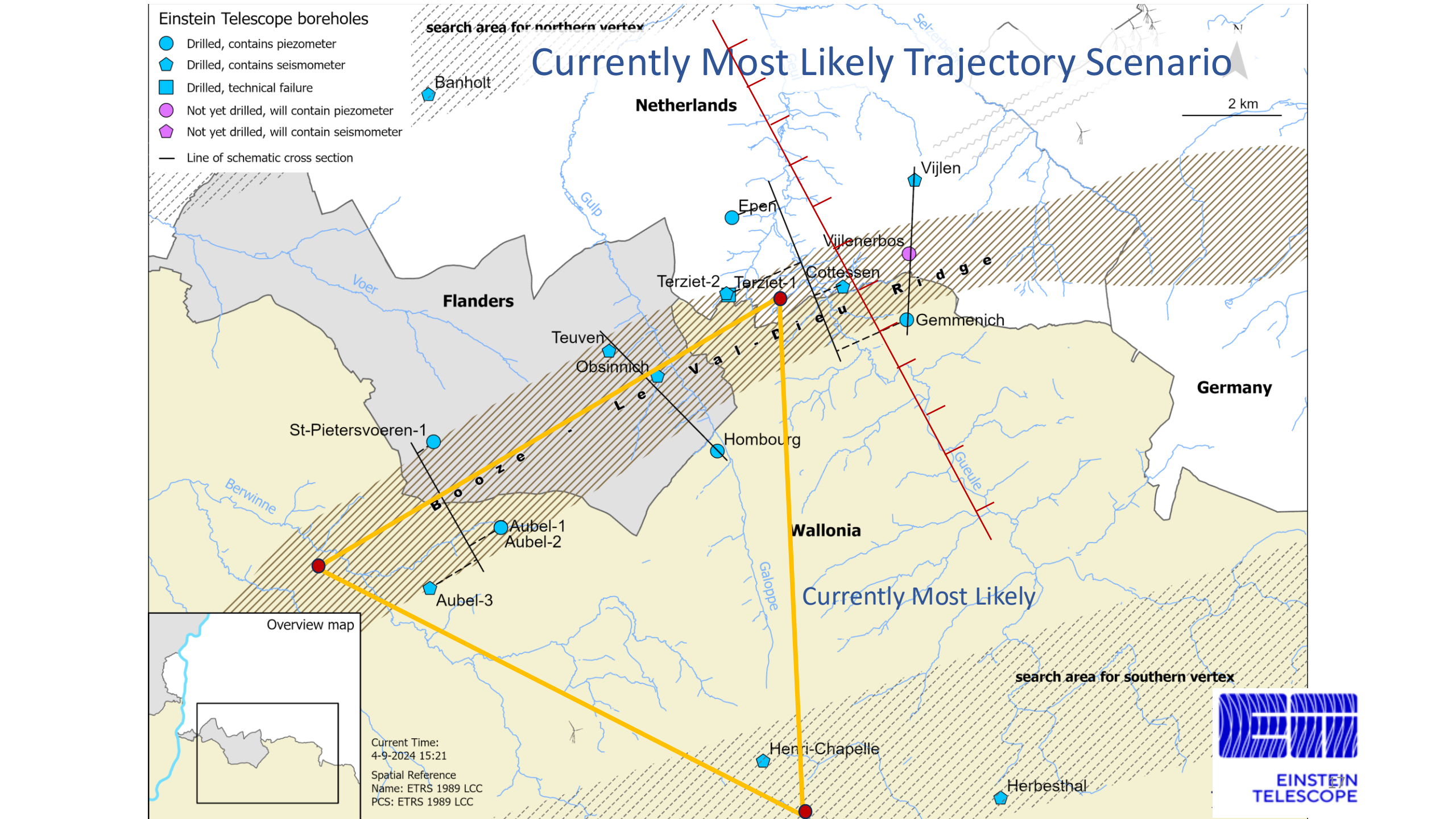


Figure 5 : Structural patterns of each tectonic domains toward depth


Einstein Telescope boreholes
Drilled, contains piezometer
Drilled, contains seismometer
Drilled, technical failure
Not yet drilled, will contain piezometer
Not yet drilled, will contain seismometer
Line of schematic cross section
search area for northern vertex
Currently Most Likely Trajectory Scenario
2 km
Banholt
Netherlands
Vijlen
Epen
Gulp
Vijlenerbos
Cottessen
Terziet-2
Terziet-1
Ridge
Voer
Flanders
Gemmenich
Teuven
Obsinnich
Val-Dieu
Germany
St-Pietersvoeren-1
Hombourg
Booze - Le
Berwinne
Gueule
Aubel-1
Aubel-2
Wallonia
Galoppe
Aubel-3
Currently Most Likely
Overview map
search area for southern vertex
Current Time:
4-9-2024 15:21
Spatial Reference
Name: ETRS 1989 LCC
PCS: ETRS 1989 LCC
Henri-Chapelle
Herbesthal
EINSTEIN TELESCOPE

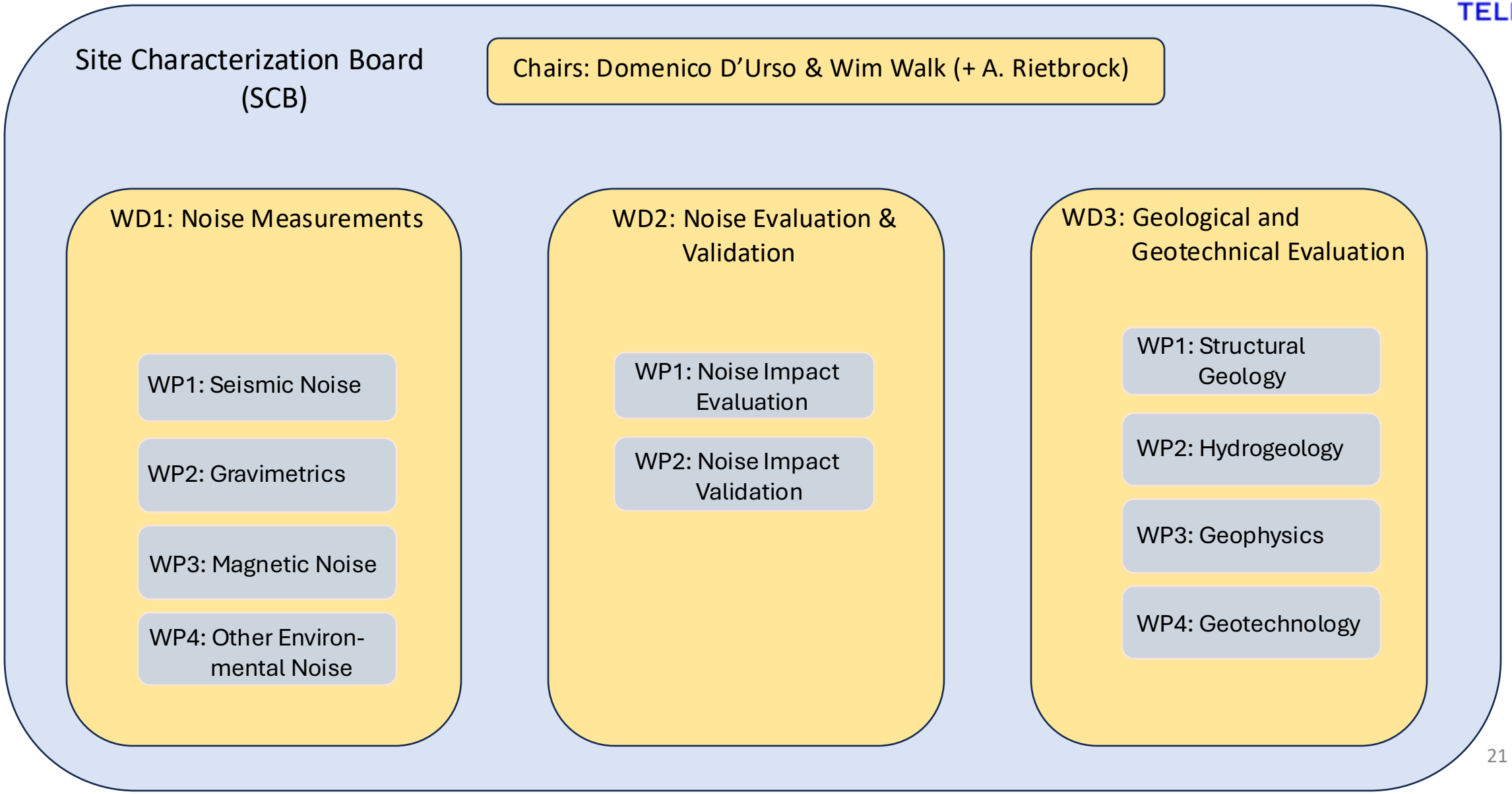
Useful links

- Wiki page
- Mailing list: et-spb@et-gw.eu (subscribe)
- Site data Web Services
- Einstein Telescope @ Sardinia https://www.einstein-telescope.it/en/home-en/
- Einstein Telescope @ EMR https://www.einsteintelescope.nl/en/

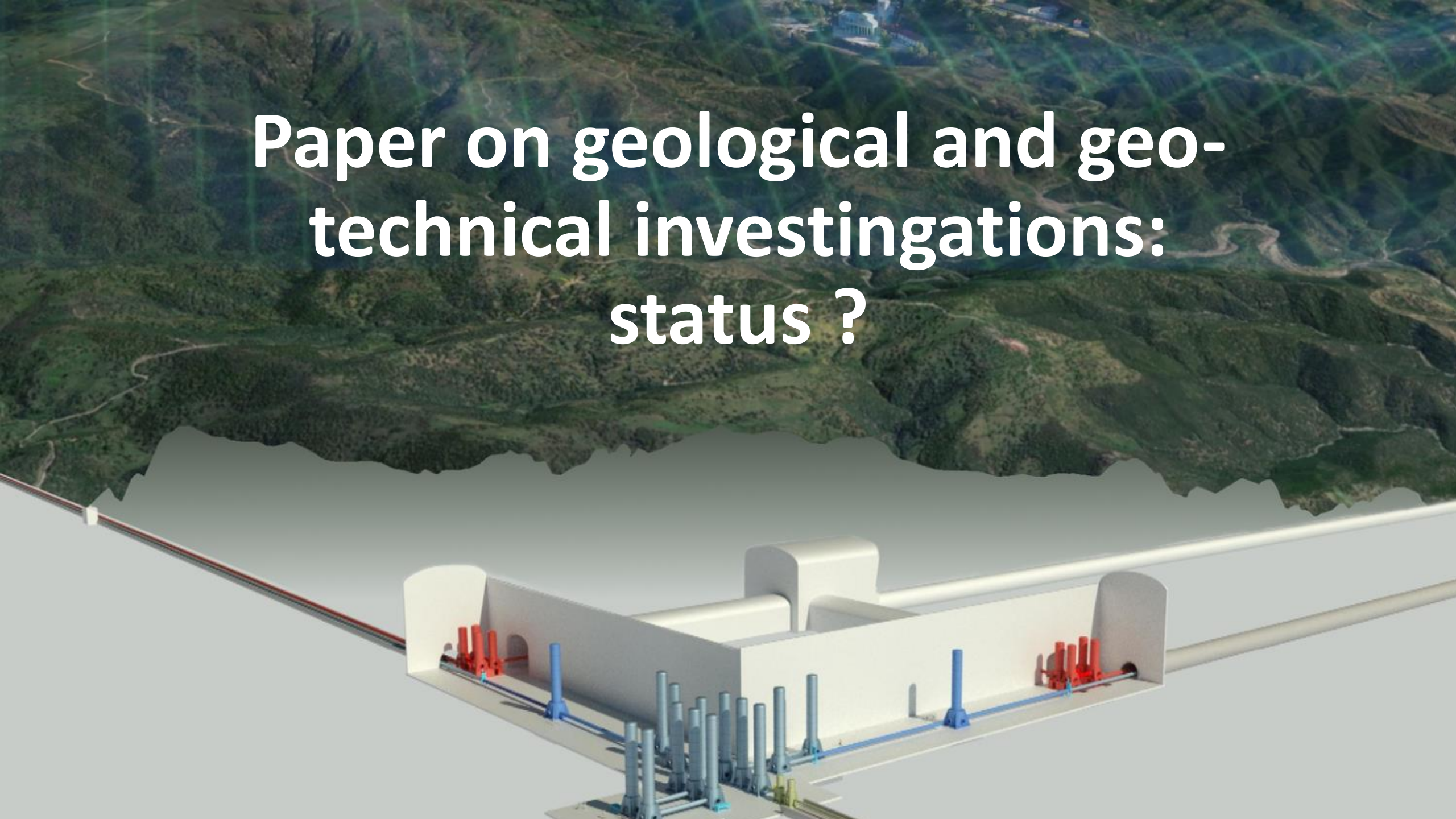
The Lausitz Candidate Site

SCB Organigram

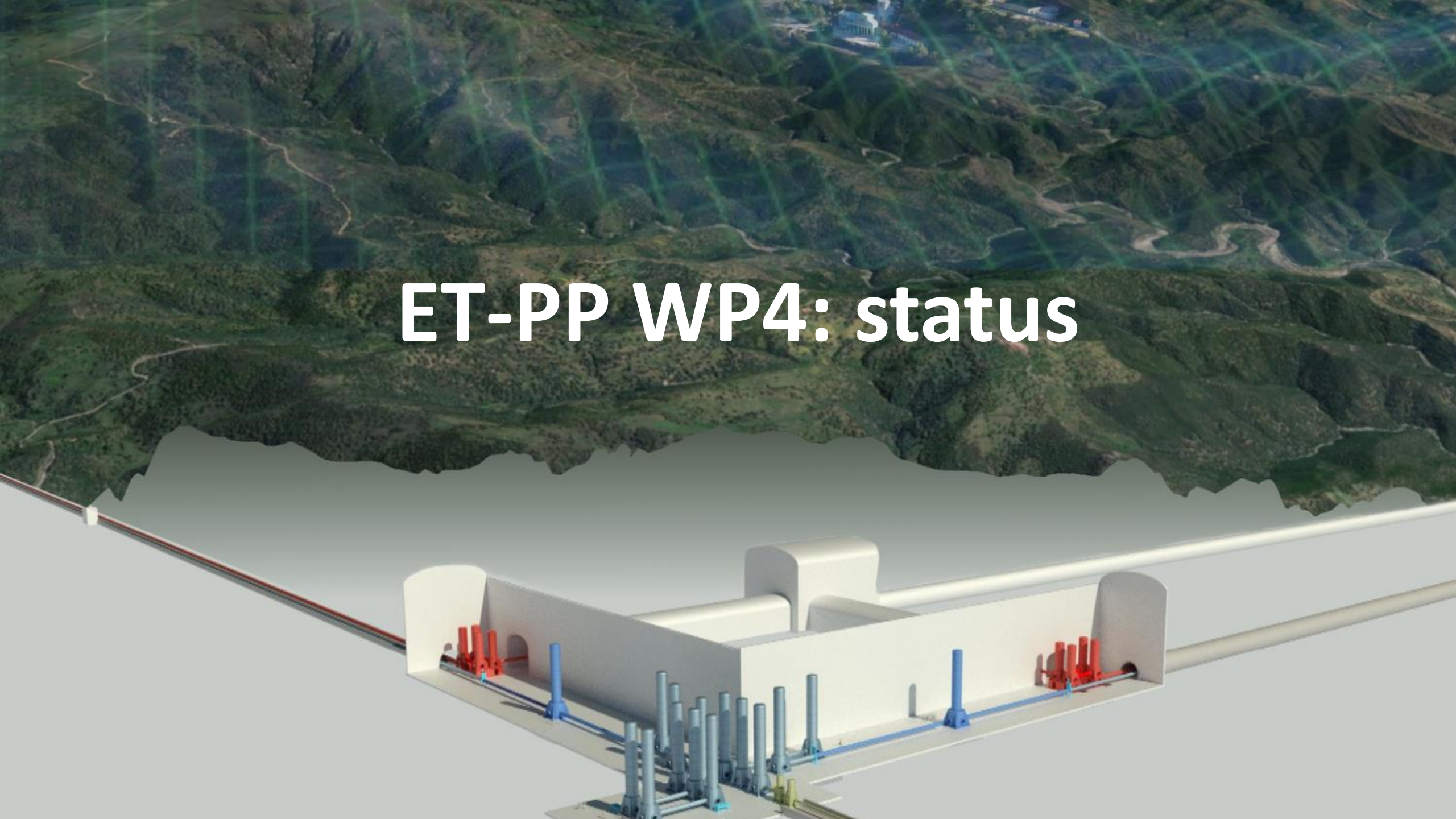
The SCB Structure



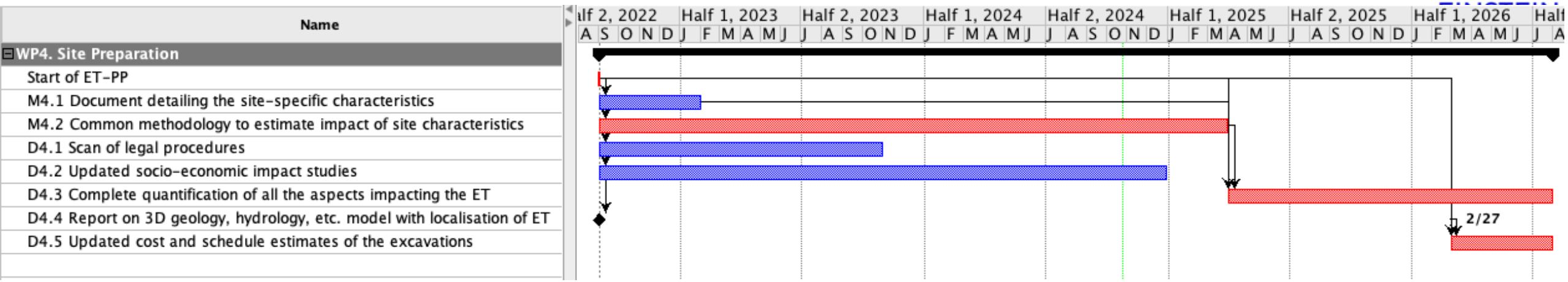
Paper on geological and geo-technical investingations: status ?



ET-PP WP4: status



WP 4: Deliverables and milestones



Code	Name	Expected date
M2 (M4.1)	Document detailing the site-specific characteristics that impact ET sensitivity and its duty cycle	M6/Feb23 M25/Oct24
M3 (M4.2)	Common methodology to estimate impact of site characteristics	M32/March25

Code	Name	Expected date
4.1	Scan of legal procedures	M18/Oct.23
4.2	Updated socio-economic impact studies	M27/Dec24
4.3	Complete quantification of all the aspects impacting the ET performance for each site	M47/Jul26
4.4	Report on 3D geology, hydrology, etc. model with localization of the ET infrastructure	M42/Feb26
4.5	Updated cost and schedule estimates of the excavations	M47/Jul26

WP 4: Deliverables and milestones

Milestones:

M2-M6: Document detailing the site-specific characteristics that impact ET sensitivity and its duty cycle

M3-M32: Common methodology to estimate impact of site characteristics on ET sensitivity and operation and, if required, a scheme to compensate it

Deliverables:

D4.1- M18: Scan of legal procedures, permitting and land acquisitions

D4.2 – M27: Updated socio-economic impact studies. Scan of accessibility, quality of life etc.

D4.3 – M47: Complete quantification of all the aspects impacting the ET performance for each site

D4.4 – M42: Report on 3D geology, hydrology, etc. model with localisation of the ET infrastructure

D4.5 - M47: Updated cost and schedule estimates of the excavations, including, if necessary: instrumentation for Newtonian Noise cancellation; costs of debris removal; costs of land acquisition, permitting, etc.

M4.2 – Milestone M3

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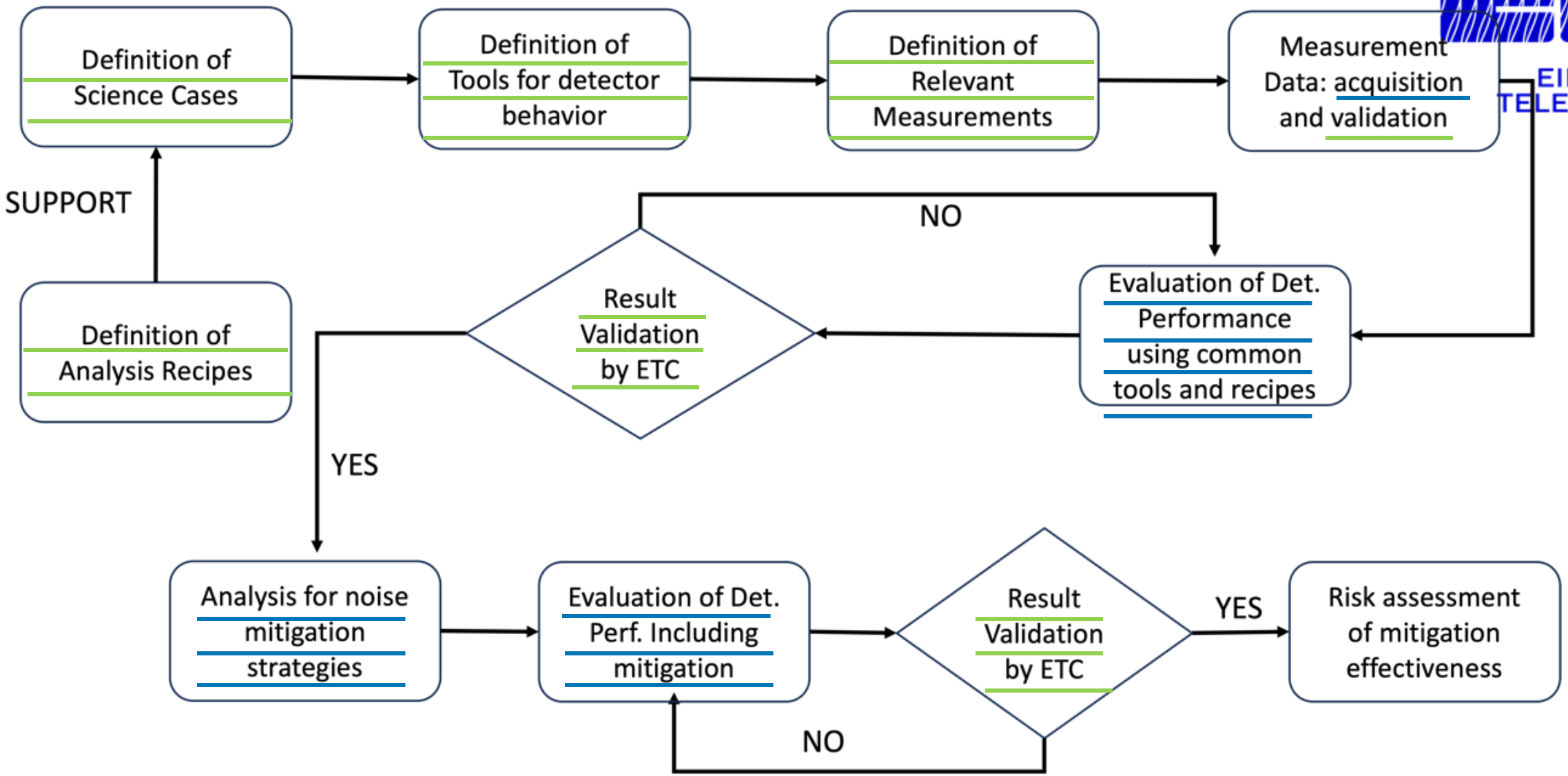
- **ET-PP M04.02:** "Common methodology to estimate impact of site characteristics on ET sensitivity and operation, and if required, a scheme to compensate it"

The document describes the process that will be followed to quantify the impact of the site on ET performance (deliverable D4.3)

- ❑ methodology scheme
- ❑ Definition of science target
- ❑ definition of tools
- ❑ possible scientific benchmark
- ❑ definition of a Validation procedure
- ❑ milestones


Definition of Science Cases
Definition of Tools for detector behavior
Definition of Relevant Measurements
Measurement Data: acquisition and validation
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SUPPORT
Definition of Analysis Recipes
Result Validation by ETC
NO
Evaluation of Det. Performance using common tools and recipes
YES
Analysis for noise mitigation strategies
Evaluation of Det. Perf. Including mitigation
Result Validation by ETC
YES
Risk assessment of mitigation effectiveness
NO
ETC
LT

M4.2 – Milestone M3

- The estimation of impact of local noise on ET performance, considering the implementation of possible mitigation strategies as well, requires the involvement of the ET Collaboration and the local teams
- Milestones
  - ❑ Update of ET Science Case (Feb 25)
  - ❑ Identification of analysis tools
  - ❑ Identification of tools to reproduce detector behavior
  - ❑ Definition of a validation procedure
    - ✓ Validation team (ETC)
    - ✓ International review board
  - ❑ Data availability (Feb. 26)
- The deliverable D4.3 is expected by July 2026.

Table of Contents

M4.2 – Milestone M3

- Physics Cases, tools and recipes, figure of merits based on D6.1 (Updated ET Science Case)
- Estimation of detector sensitivity - NN
  - description of the analytical approach
  - possibility to use more sophisticated tools available in the future

"Models of NN may become more and more complex as they incorporate an increasing amount of site-specific information like topography, geology, and observed or modeled inhomogeneities of seismic fields. Model predictions can be affected by systematic and significant numerical errors, and one needs to develop methods to constrain and validate simulation results (e.g. an analytical benchmark"

"As already said, NN models may become more and more complex considering an increasing amount of site-specific information. The here presented analytical solution is the first and the basic approach that can be followed. In the future, we may use more sophisticated tools, if available and approved by the ETC, taking into account a much more detailed 3D model of the area. "

M4.2 – Milestone M3

- Validation:
  - Internal Validation (ETC process);
  - External Validation. ETC and ET Organization should appoint an international board of experts. The board may be composed by experts in cosmology, multi-messenger astronomy, in gravitational wave detector and data analysis, geophysicist and seismic noise measurements.
- Next step: Formal Approval by ETC – EB

D4.2

- A refine of previous socio-economic impact
- Update is being worked by individual local teams
- Document will be composed by two distinguished parts, one for each candidate site
- Expected an updated version at the end of ET-PP to account the final “ET configuration” (localization, geometry, subsurface geology, geo-technical understanding, ...)

Evaluation of site dependent detector performance

Time to move

- ET-PP deliverable expected by July 26

"Complete quantification of all the aspects impacting the ET performance for each site"

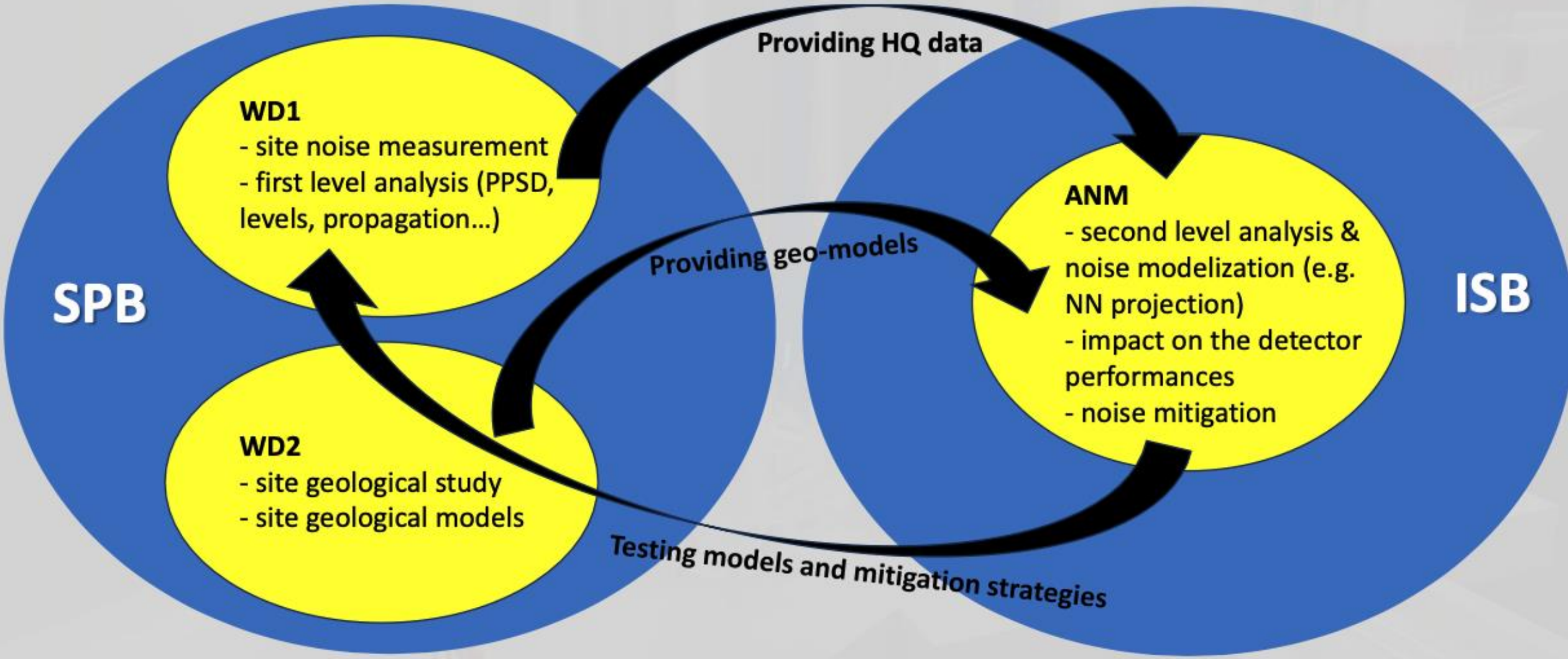
- SCB/WP4 should steer a process involving OSB, ISB and Local Teams
- OSB-ISB are already supporting the Task Force

1. Appoint Local Team Reference guys
2. Meeting with ISB-OSB chairs
3. Formation of a devoted working group

We need to harry up!

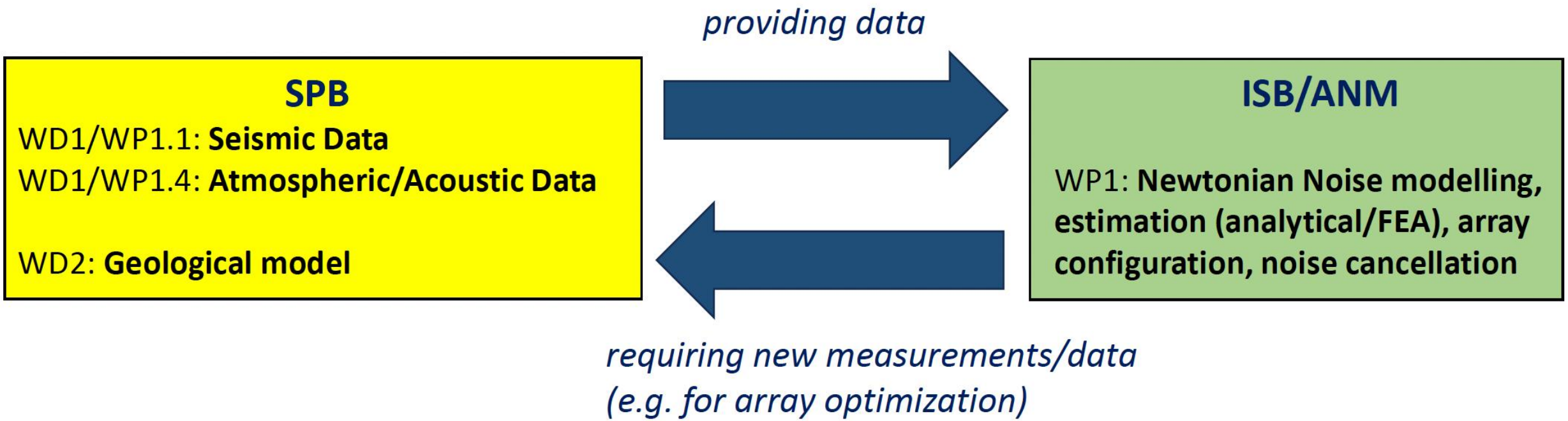
ISB/ANM & SPB

The noise analysis is a synergic effort between SPB and ISB/ANM. Modelization and evaluation of the impact on the detector are tasks of ANM WPs.



ISB/ANM & SPB

- **Noise quantification and mitigation** must be evaluated within the dedicated WPs in the ISB-Active Noise Mitigation division, e.g.:
  - **Newtonian Noise** modelling, quantification, cancellation are duties of the NNC WP of ISB/ANM, providing the required data is a duty of SPB/WD1:



ISB/ANM & SPB

- **Noise quantification and mitigation** must be evaluated within the dedicated WPs in the ISB-Active Noise Mitigation division, e.g.:
  - **Magnetic noise:** MN (natural and anthropic at the site) quantification is a duty of SPB/WD1, instrumental MN, overall impact on the detectors and mitigation strategies are duties of the MN WP of ISB/ANM