

What has been achieved so far towards measurements standards



ET TECHNOLOGY (MAIN) CHALLENGES



Challenging engineering

New technology in cryo-cooling

New technology in optics

New laser technology

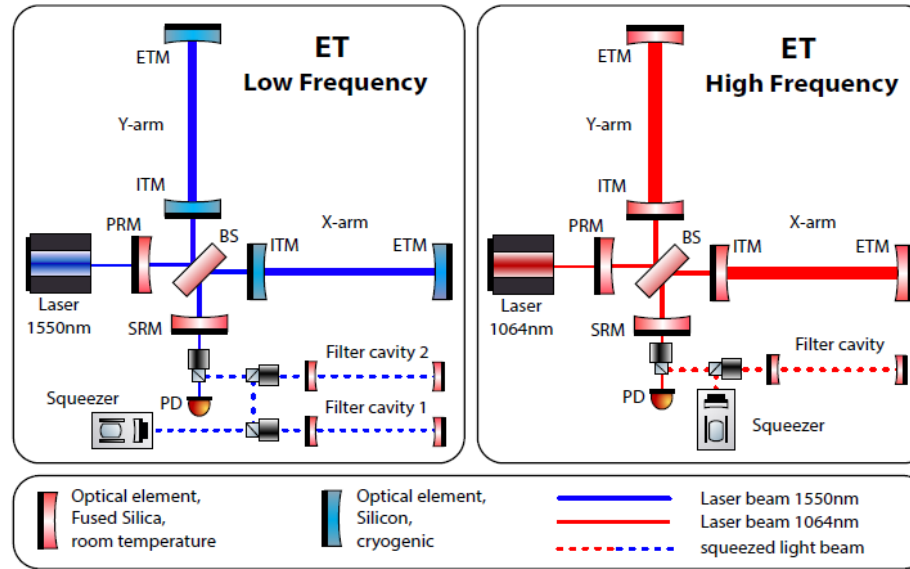
High precision mechanics and low noise controls

High quality opto-electronics and new controls

- The multi-interferometer approach asks for **two parallel technology developments**

• ET-LF

- Underground
- Cryogenics
- Silicon (Sapphire) test masses
- Large test masses
- New coatings
- New laser wavelength
- Seismic suspensions
- Frequency dependent squeezing



• ET-HF

- High power laser
- Large test masses
- New coatings
- Thermal compensation
- Frequency dependent squeezing

Evolved laser technology

Evolved technology in optics

Highly innovative adaptive optics

High quality opto-electronics and new controls

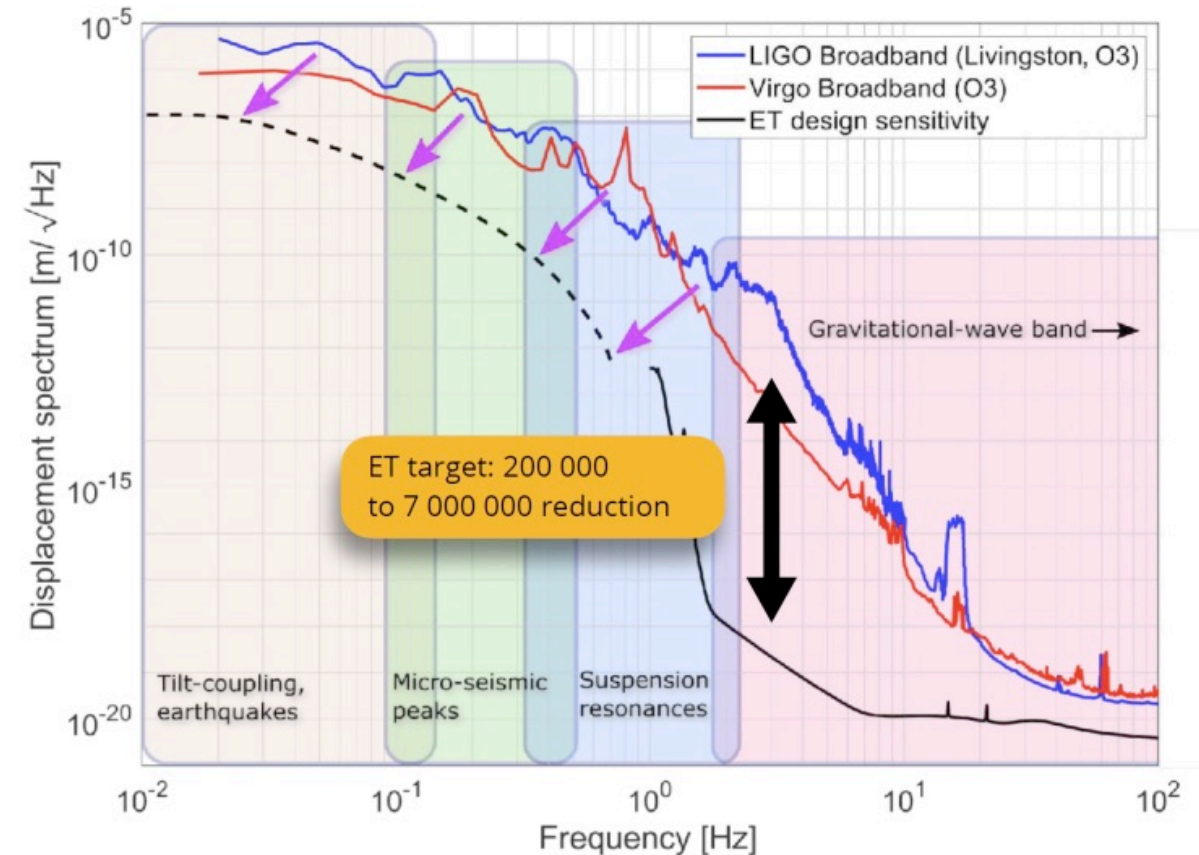
Focus at low frequencies

➤ LF noise is given by

- ❑ Microseism motion
- ❑ Newtonian noise
- ❑ Thermal noise
- ❑ Upconversion of residual motion into the detection band
- ❑ Control noise

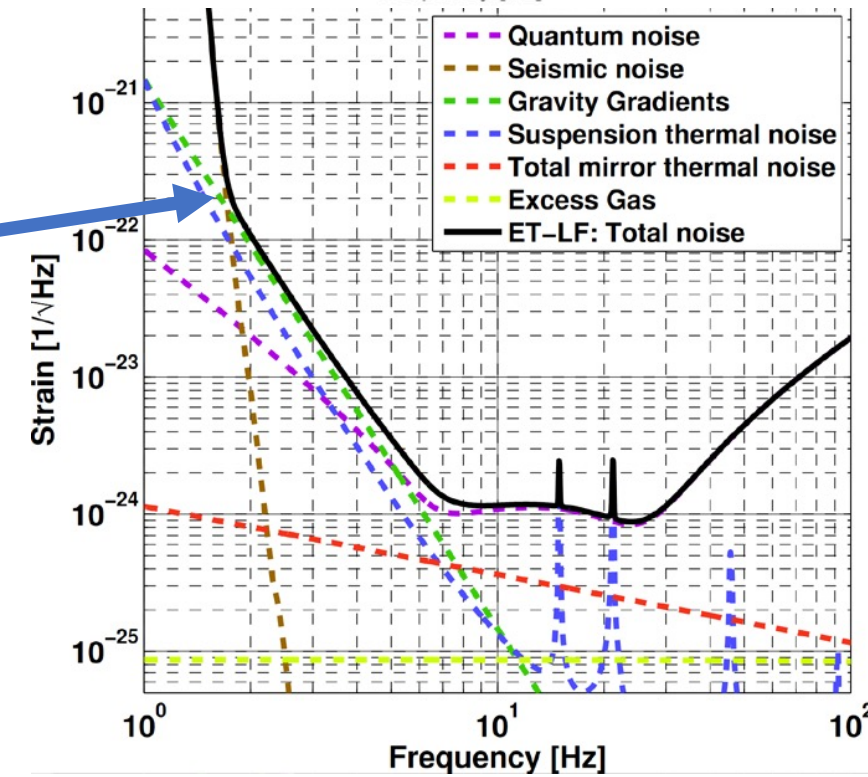
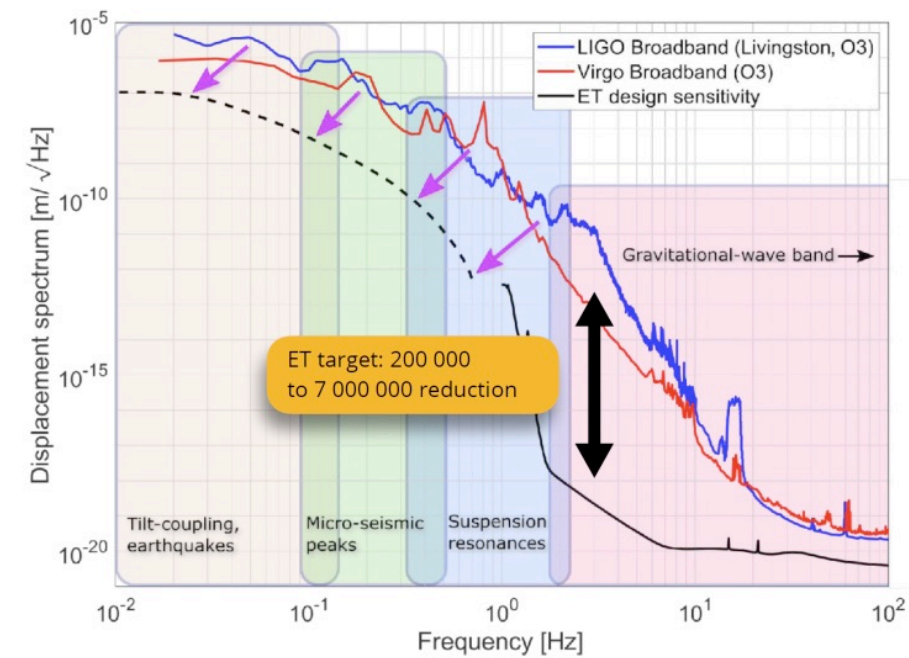
➤ Newtonian noise crossing:

$2 \times 10^{-22} \text{ Hz}^{-1/2}$ at 1.8 Hz (AdV: 3.2 Hz)



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Site Characterization in the ET

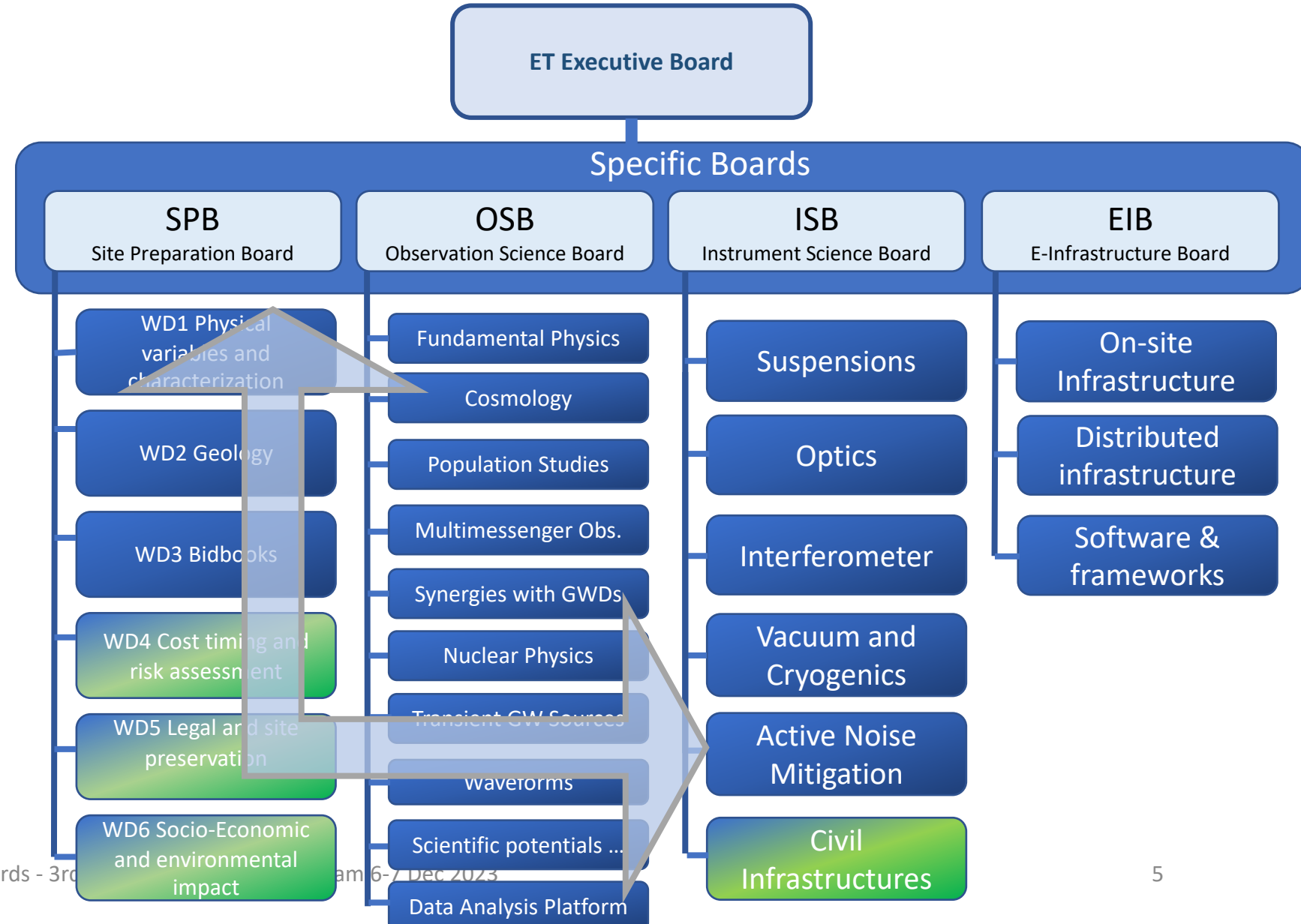
➤ **Site Characterization** coordinated in the framework of the **ET Collaboration: Site Preparation Board (SPB)**.

➤ Strong interaction with the Active Noise Mitigation division in the Instrument Science Board (ISB).

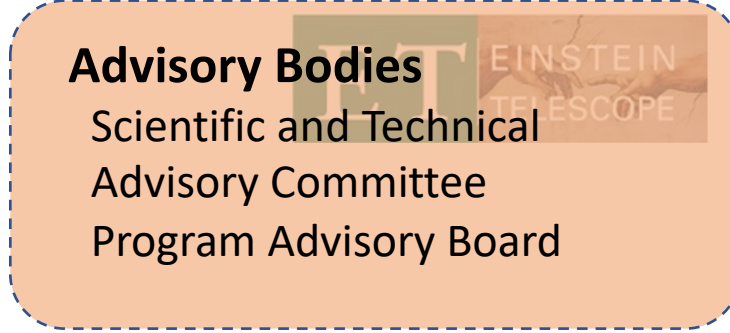
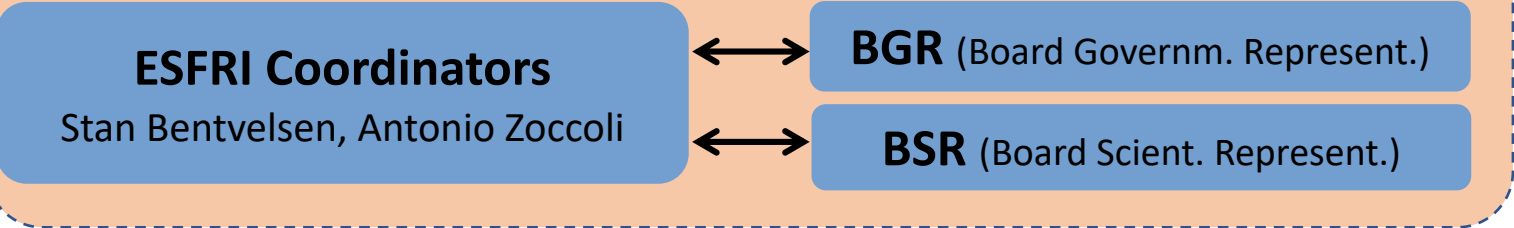
ET-LF



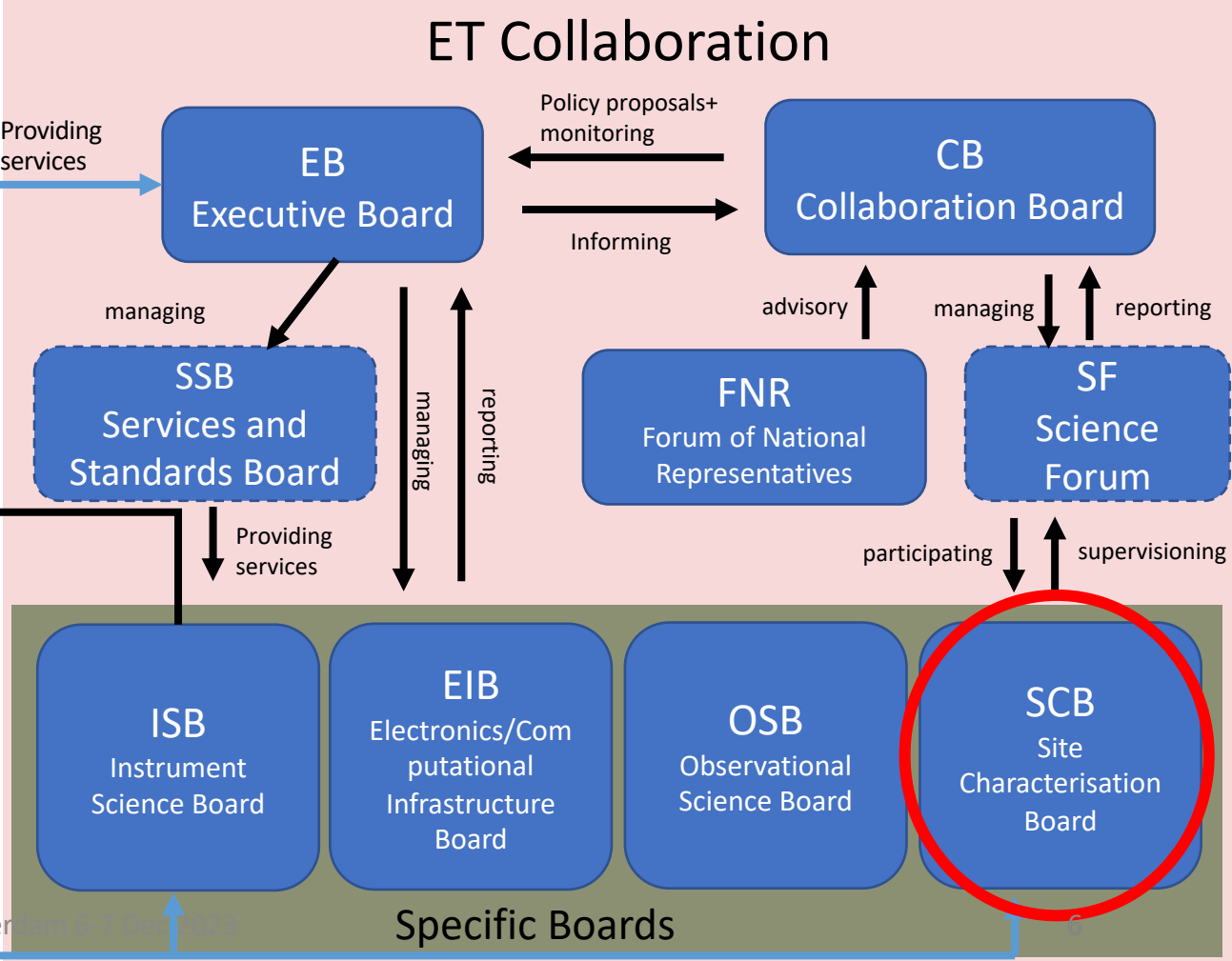
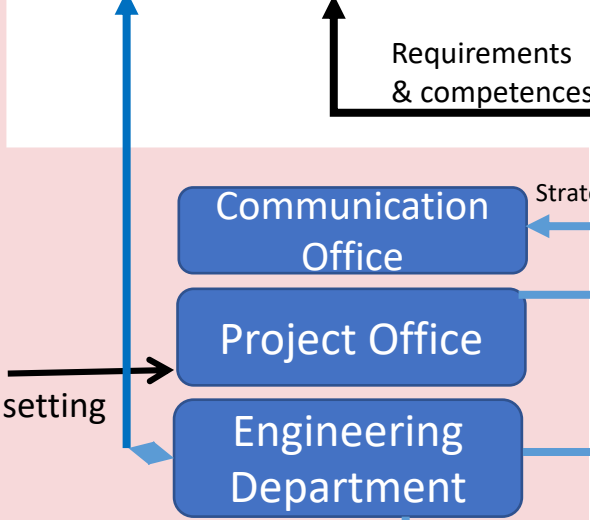
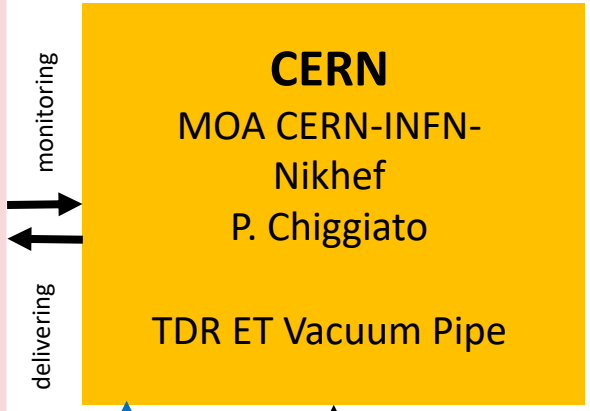
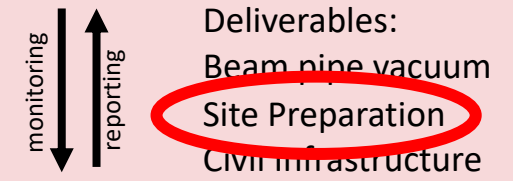
understanding of environmental noise effects and reliable mitigation systems



Proto-council



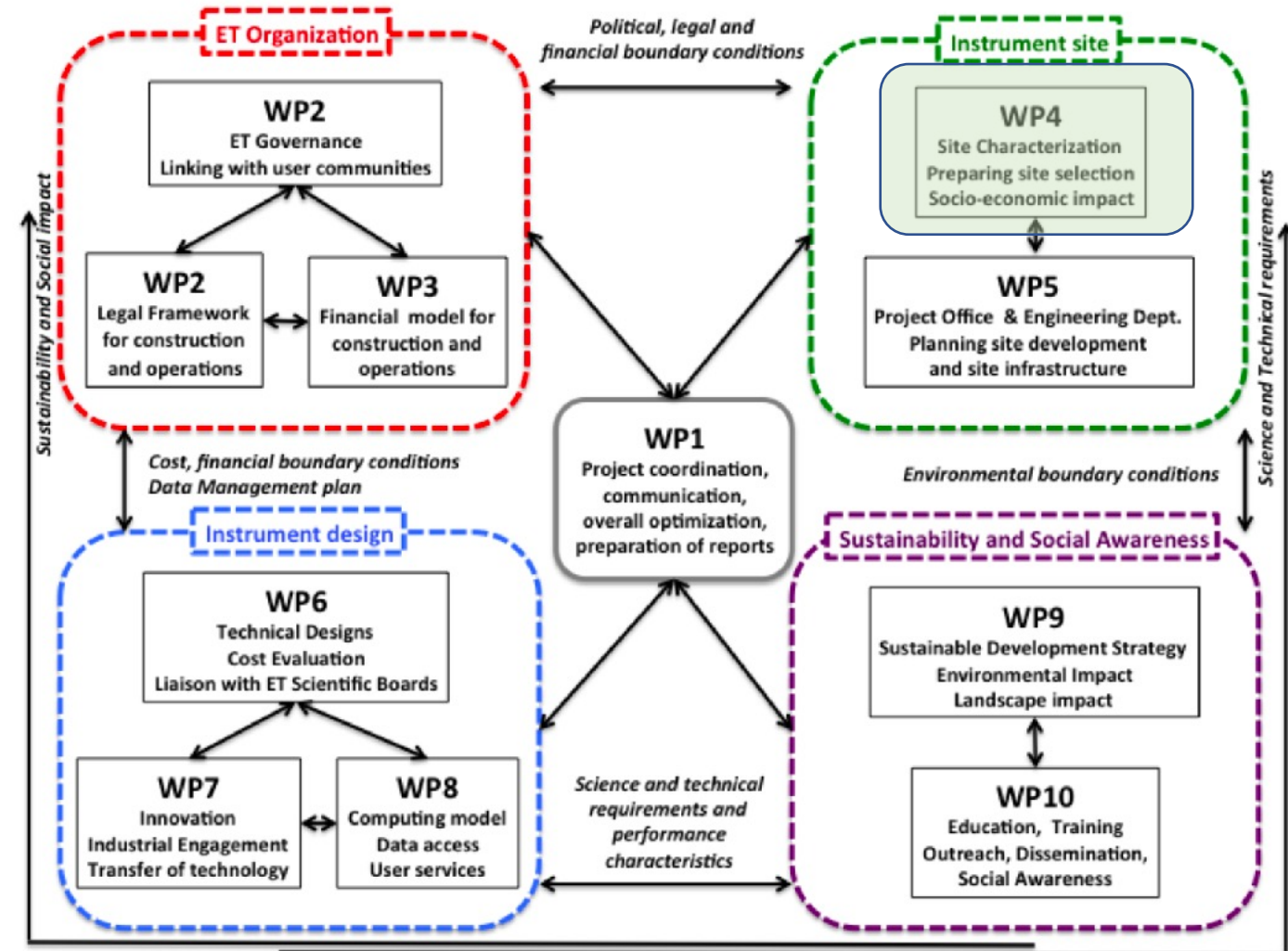
Policy & monitoring



INFRADEV: ET-PREPARATORY PHASE



- ET governance
- Legal framework
- Financial Model
- WP4: Site characterization
- Project Office & engineering
- Technical design
- Innovation
- Computing Model
- Sustainability Strategy and Environmental impact
- Outreach



SPB Documents already produced



- **M1.1: physical variables:**
ET-0012A-23, discussed and finalized at the II SPB Workshop (Jan 2023)
<https://apps.et-gw.eu/tds/?content=3&r=18113>
- **M1.2: measurements recommendations and standards:**
ET-0013A-23, discussed and finalized at the II SPB Workshop (Jan 2023)
<https://apps.et-gw.eu/tds/?content=3&r=18114>
- **M1.3: data format standards and analysis tools**
ET-0270A-23, <https://apps.et-gw.eu/tds/?content=3&r=18398>
- **ET-PP M04.01:** “*Site-specific Characteristics impacting ET sensitivity and duty cycle*” (manly based on previous documents) ET-0252A-23, <https://apps.et-gw.eu/tds/?content=3&r=18379>

- Long term (at surface and in boreholes at depth) and short term seismic measurements (passive or active surveys)
- Host teams should provide these useful studies to assess how the ET duty cycle can be affected by ambient disturbances:
 - ❑ Correlations between the seasonal variations of the microseismic peak and the storm surge or wave heights in the surrounding oceans.
 - ❑ Effects of regional and local seismicity, both for natural (earthquakes) or anthropogenic events (quarry blasts). a catalogue of events should be provided, including the peak ground acceleration (PGA) or peak ground velocity (PGV).
 - ❑ effects of the teleseismic phase arrivals (during the O3 observation run at Virgo the 65% of control losses due to earthquakes were caused by teleseismic phases)
 - ❑ a statistical study of the resilience of the detector to the above-mentioned disturbances should be done by taking into account the ET design sensitivity and one (or more) particular target.

➤ Long term:

- Broadband measurements should last at least two years. Three-component
- 10th, 50th and 90th percentile of the acceleration proper spectral density (PSD) has to be assessed in the 10^{-2} - 20 Hz band. The PSD should be calculated following the McNamara & Buland method with a 1800 s window and 50% (900 s) overlap.
- Underground borehole installation should be always paired with a surface-level installation
- significant transient events (either of natural or anthropic origin) should be collected in a catalogue for the observation time. The host teams should also provide a historical log of seismic events

- short term (several weeks) (information about the body to surface wave content of the seismic noise and the propagation characteristics like the surface-wave dispersion and its propagation direction):
 - arrays of broadband and/or short-period seismometers
 - measurements at least in the areas surrounding the proposed corners of the ET infrastructure.
 - spectral noise distribution maps in four frequency bands: [0.5-2 Hz], [2-4 Hz], [4-10 Hz], [10-20 Hz].
- Seismometers have to be chosen according to the ambient seismic-noise spectrum and should achieve a signal-to-noise ratio better than 10 between 3 and 10 Hz.
 - if local natural background noise approaches the Peterson's low noise model (NLNM), the requirement could be relaxed to a factor 7
- Host teams should provide:
 - an estimation of the surface wave dispersion curve
 - the characterization of seismic sources
 - study of local sources
- Active seismic surveys based on reflection/refraction seismology should be performed in the areas covered by the seismic arrays, possibly complementing the seismometer array with lines of geophones providing information about subsurface structures.

M1.1: gravimetry & geodynamics studies



- Physical quantities to be monitored
 - ❑ the local and instantaneous gravity variations
 - ❑ gravity anomalies in the area of interest
 - ❑ the strain, strain-rates and tilt variations measured on the Earth surface and eventually below the surface
- The regional surface deformations can be monitored by means of GNSS and InSAR techniques

Indication for measurements listed in the SPB documents

M1.1: magnetic noise



- EM noise can directly couple with magnetic actuators placed on the suspended mirror, or also along the suspension chain (significant at low frequency) and/or can induce currents on electronic equipment, cables, and connectors, potentially affecting critical signals used for the interferometer control and producing, in this way, an indirect disturbance on the detector output (most effective at higher frequencies)
 - ❑ Schumann Resonances (at 8, 14, 20, 26, 32 Hz) may directly limit the sensitivity of ET by acting as a local EM disturbance, but can also have an impact on search for stochastic gravitational waves, based on correlation between far detectors
 - ❑ EM noise due to atmospheric electric discharges
 - ❑ power lines
- Measurements: at least 2 magnetic field probes with very high sensitivity in the ELF band (intrinsic noise levels as low as 10^{-4} nT/Hz^{1/2} at 1 Hz)

Indication for measurements listed in the SPB documents

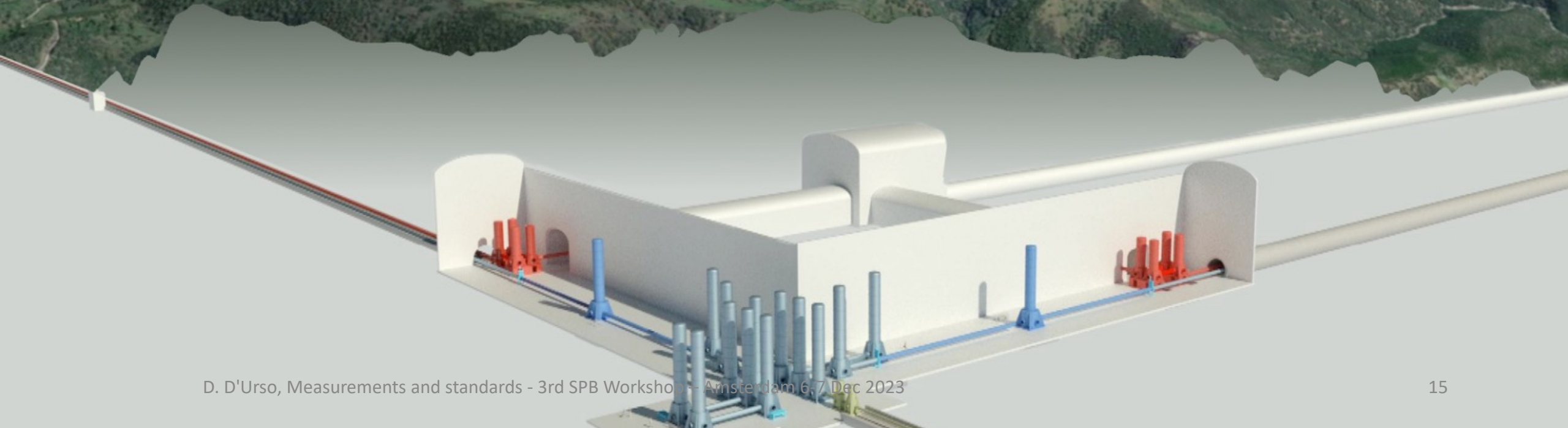
M1.1: other env noise



- The noise will most likely be determined by the noise in the cavities and therefore it is impossible to measure it before the actual construction. We can measure the current acoustic and barometric noise on the surface at the locations of the end stations of ET
 - ❑ infrasound noise on the ground (frequency range 0.1Hz to 30Hz)
 - ❑ micro barometric noise - this is the low frequency extension of the infrasonic noise with frequency down to microhertz
 - ❑ weather at sites: temperature, wind, pressure, precipitation, humidity.

Indication for measurements listed in the SPB documents

WP4 Milestones and Deliverables



WP4 Milestones & Deliverables



Milestone name – Date (in months)/Lead Institution

➤ **M4.1 – M3/UW** : *Document detailing the site-specific characteristics that impact ET sensitivity and its duty cycle => **REPORT*** **DELIVERED**

➤ **M4.2 – M10/UW** : *Common methodology to estimate impact of site characteristics on ET sensitivity and operation and, if required, a scheme to compensate it => **REPORT***

(months from ET-PP start date, Sept. 1st)

- Discussion with ISB on WDs and WPs
- Common working group is going to be set up and thematic meetings will be organized to eliminate differences between the different approaches.
- **Dedicated Workshop** including related WPs from ISB –
- A document will be prepared to report a standardization on measurement methodologies and agreements on common tools to be used for noise estimation

WP4 Deliverables



Deliverable name – Date (in months)/Lead Institution

- **D4.1- M10/Nikhef:** *Scan of legal procedures, permitting and land acquisitions, i.e. the steps to be taken prior to starting excavations*

- **D4.2 - M15/INFN:** *Updated socio-economic impact studies. Scan of accessibility, quality of life etc.*

Delayed to Dec. 31st 2023

- **D4.3 - M28/UW:** *Complete quantification of all the aspects impacting the ET performance for each site*

- **D4.4 - M30/INFN:** *Report on 3D geology, hydrology, etc. model with localisation of the ET infrastructure*

- **D4.5 - M42/Nikhef:** *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.*

(months from ET-PP start date, Sept. 1st)

Open Issues for the SPB Workshop: Bidbook Scientific content



- **Common Template for scientific aspects!**
- Standards and best practices for site noise measurement and evaluation have been set. Host teams have to provide needed information. Timeline ?
- Evaluation of site characteristics on ET performances
- Site noise mitigation
- Scientific Risk assessment

Open Issues for the SPB Workshop: Strategy and document validation



- Host teams are working hard trying to collect all the information to produce their “bidbook”
- Host teams are already producing outputs
- Missing the definition of a quality procedure in the site selection process
- Missing validation and approval procedure (tomorrow session)

- Site characterization crucial to achieve the expected sensitivity at low frequencies
- SPB/SCB documents containing relevant site characteristics, standards and measurement procedures already available
- This Workshop has been set to discuss the status of noise understanding towards a definition of a common methodology
- ET geometry is still under discussion. As set by the ET Collaboration, Site Characterization have to take into account both possibilities
- Open issues for discussions:
 - Bidbook Scientific template (measurement content is already set)
 - definition of a quality procedure (document validation and approval)