



Preparatory Phase for the Einstein Telescope Gravitational Wave
Observatory

Milestone 2

Document detailing the site-specific characteristics that
impact ET sensitivity and its duty cycle.

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EXECUTIVE SUMMARY

This document, M4.1 “Site-specific Characteristics impacting ET sensitivity and duty cycle”, is a milestone of the ET-PP Project, which is funded by the European Commission Framework Programme Horizon Europe Coordination and Support action under grant agreement 101079696.

The report will describe the site characteristics that may have an impact on the Einstein Telescope infrastructure. Environment may play an important role affecting cost, lifetime and detector performances therefore on detector sensitivity and duty cycle.

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Introduction

In this document we define the site characteristics that may have an impact on the Einstein Telescope (ET). The environment of modern fundamental physics experiments assumes an increasingly important role with great impact on infrastructure, cost, and science.

In particular, the environment has a crucial role in a third-generation gravitational wave (GW) observatory like ET. Site conditions (e.g. geological and geodynamical features, ground water) have an effect on the construction feasibility, costs and lifetime of the infrastructure and, at the same time, may impact detector performance (e.g. underground water flow may produce Newtonian Noise) while environmental noises (e.g. seismic motion) have a direct impact on the detectors sensitivity and duty cycle. See (Amann, F. et al., 2020) and (Naticchioni, et al., 2023) for a more complete review. See (Naticchioni, et al., SPB-WD1-M1.2) for a wide discussion about the standards and the procedures for the ET site characterization.

The document is divided into two sections, one related to physical variables and the second one to the geological and geo-technique aspects.

Site characteristics – Physical Variables

In this section, we discuss the set of physical variables that have an impact on ET's performance and operations. The following is an incomplete list of such variables that are widely discussed in (Amann, F. et al., 2020) and (Naticchioni, et al., 2023).

- Seismic field. Properties of the local wavefield in terms of frequency, amplitude and type of dominant waves and assess its time variability, possibly identifying the seismic sources. Useful studies to assess how the ET duty cycle can be affected by ambient disturbances are the following (Naticchioni, et al., 2023):
 - 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 events and anthropogenic.
 - Effects of the teleseismic phase.
 - Statistical study of the resilience of the detector to the above-mentioned disturbances.
- Geodetic site characterization:
 - Local and instantaneous gravity variations.

- Gravity anomalies in the area.
 - Strain, strain-rates and tilt variations measured on the Earth surface and eventually below the surface.
- Magnetic noise. Electromagnetic (EM) fields could act as a disturbance for any electronic equipment and for magnetic or charged materials. For this reason, they represent a significant source of noise for ET. EM noise can directly couple with magnetic actuators placed on the suspended mirror, or also along the suspension chain; secondly, it 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.
 - Natural EM noise.
 - Artificial EM sources
- Other environmental noises.
 - 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; weather at sites (temperature, wind, pressure, precipitation, humidity).

Site characteristics – geological, geophysical and geotechnical information

There are many challenges related to the construction of a deep (~ 300 m) and long (more than 30 km of total tunnel length and experimental halls) infrastructure such as the ET and most of them are related to the difficulty to the knowledge of the geological conditions (structures, faults, lithology, fractures, alteration, ...) at depths over large scales. Some of those aspects may affect the performance of the infrastructure as well. The expected list of characteristics includes:

- Sub-surface geology. We can have variations of seismic amplitude at small scales due to filtering, damping, and amplification. A detailed understanding of the geology leading to site effects would be required for models of seismic terrestrial gravity noise.
- Groundwater flow. A water handling system is required if water cannot be kept out of the tunnel. If such a system employs pumps, they might be a significant source of infrastructure noise affecting the GW detector. Water flow as part of a drainage system inside tunnels might potentially act as a main source of gravity noise.
- Rock quality and geomechanical parameters. Rock geomechanical parameters will govern the seismic noise propagation and attenuation from the surface to the instruments, including rock-infrastructure interactions.

References

(Amann, F. et al., 2020)
(Naticchioni, et al., 2023)
(Naticchioni, et al., SPB-WD1-M1.2)