



Einstein Telescope ESFRI Roadmap proposal

Michele Punturo on behalf of the ET steering committee

ET Project: Preparation of the ESFRI proposal

- The last year has been an intense period for ET because of the preparation of the ESFRI Proposal
 - Preparing the ESFRI documentation
 - A team of about 20 persons (wide ET steering committee) from all the EU countries involved in GW worked regularly with weekly (sometimes daily) meetings to prepare:
 - The ESFRI questionnaire
 - A renewed science case document
 - A renewed conceptual design report
 - 3 socio-economic impact documents
 - A cost book
 - An updated planning of the project
 - Several ancillary documents
 - ...
 - Final submission deadline ~~05/05/2020~~ 09/09/2020 due to COVID-19 emergency



Einstein Telescope (ET)

Proposal Submission
Questionnaire

ET steering committee

- The ET steering committee born at the 2018 ET symposium as group of delegates of the GW community (country-balanced) having the duty to form the ET collaboration structure and the ET ESFRI proposal
- The second activity required to grow-up the committee inserting new competences
- The committee is meeting every week (at least) in order to accomplish the target of the ESFRI roadmap proposal submission

01-Family Name	02-First_Name	03-Institution
Bagnasco	Stefano	INFN
Barsuglia	Matteo	CNRS
Branchesi	Marica	INFN
Brocato	Enzo	INAF
Bruno	Giacomo	Uclouvain
Bulik	Tomas	Astrouw
Carpinelli	Massimo	INFN
Chirstensen	Nelson	CNRS
Danzmann	Karsten	AEI
Deidda	Luca	UniSS
Fafone	Viviana	INFN
Flaminio	Raffaele	CNRS
Freise	Andreas	VU-Amsterdam
Gemme	Gianluca	INFN
Grado	Aniello	INFN
Harms	Jan	INFN
Hild	Stefan	Maastricht
Katsanevas	Stavros	EGO
Levai	Peter	Wigner
Linde	Frank	Nikhef
Losurdo	Giovanni	INFN
Lueck	Harald	AEI
Maggiore	Michele	Uni-Geneva
Martinez	Mario	IFAE
Meer	Rob	Nikhef
Paoli	Andrea	EGO
Punturo	Michele	INFN
Reitze	Dave	LIGO
Ricci	Fulvio	INFN
Rowan	Sheila	Glasgow
Shoemaker	David	LIGO
Stahl	Achim	Aachen
van den Brand	Jo	Nikhef
Van Remortel	Nick	Uantwerpen



ESFRI questionnaire

- It contains the answers to the ESFRI questions, based on the ET conceptual design report, on the ancillary documents, on the studies of the ET steering committee, on external consultancies and on the preliminary studies realised by the GWIC 3G
- Let see some of these inputs in the following slides

ET science case

- Original work in the ET conceptual design ([ET-0106C-10](#))
- Further developments in the scientific literature originated by the ET design study
- Recent update by the GWIC*-3G** subcommittee:
 - [The Next-Generation Global Gravitational-Wave Observatory: New Astrophysics with the Farthest, Oldest, and Most Violent Events in the Universe](#)
- ET observatory science reaches detailed in the study for the ESFRI proposal, published version in [M. Maggiore et al, Science case for the Einstein telescope, Journal of Cosmology and Astroparticle Physics, 24 March 2020.](#)
 - Focus on low frequency characteristics of ET and triangular shape

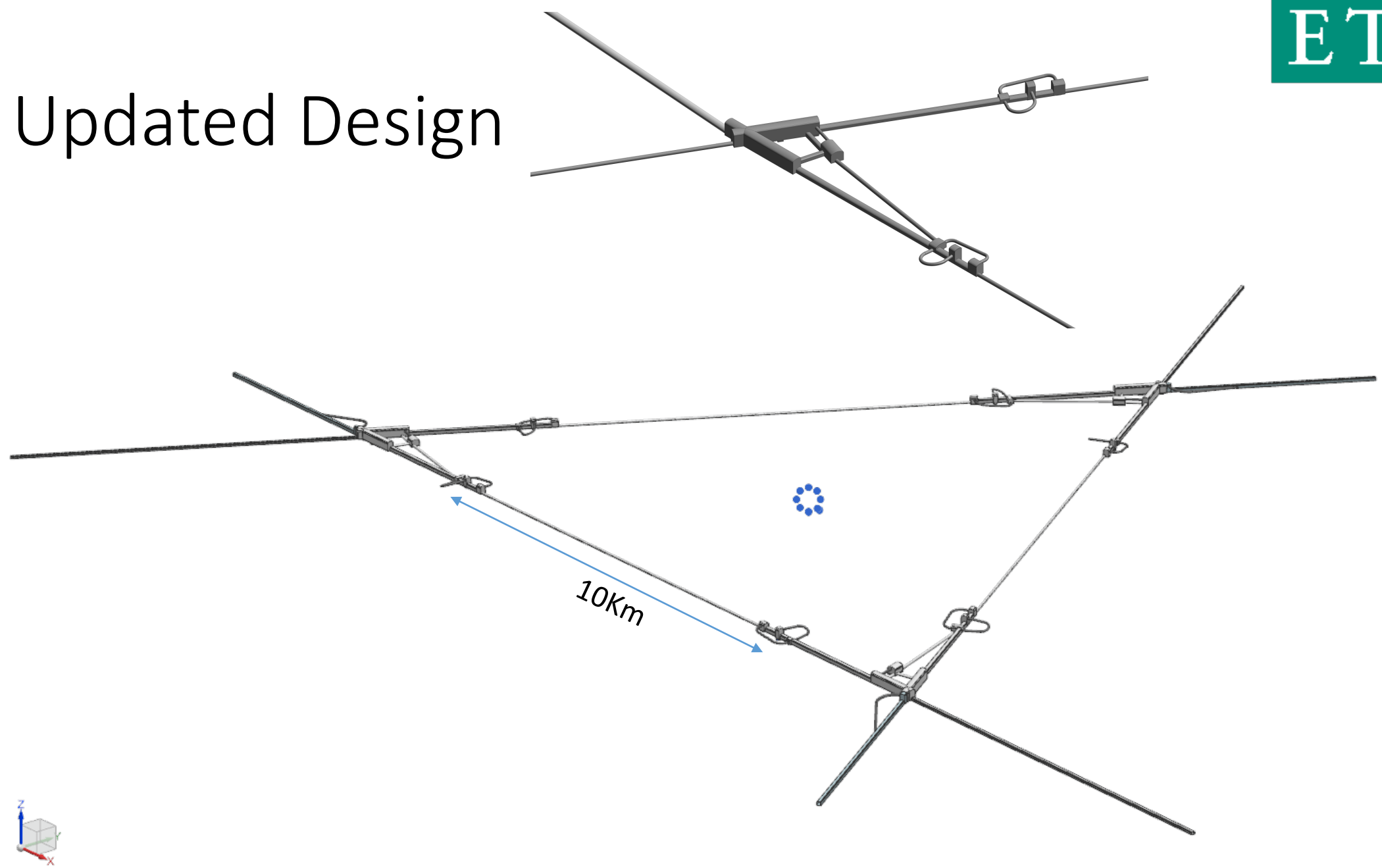
*GWIC - Gravitational Wave International Committee (<https://gwic.ligo.org/about.html>) is a committee of delegates of GW experiments and communities. was formed in 1997 to facilitate international collaboration and cooperation in the construction, operation and use of the major gravitational wave detection facilities world-wide. It is associated with the International Union of Pure and Applied Physics as its Working Group WG.11. Through this association, GWIC is connected with the International Society on General Relativity and Gravitation (IUPAP's Affiliated Commission AC.2), its Commission C19 (Astrophysics), and another Working Group, the AstroParticle Physics International Committee (APPIC)

**GWIC-3G (<https://gwic.ligo.org/3Gsubcomm/>) The GWIC Committee on Third Generation Ground-based Detectors is charged with examining the path to the development of a network of future ground-based gravitational-wave (GW) observatories

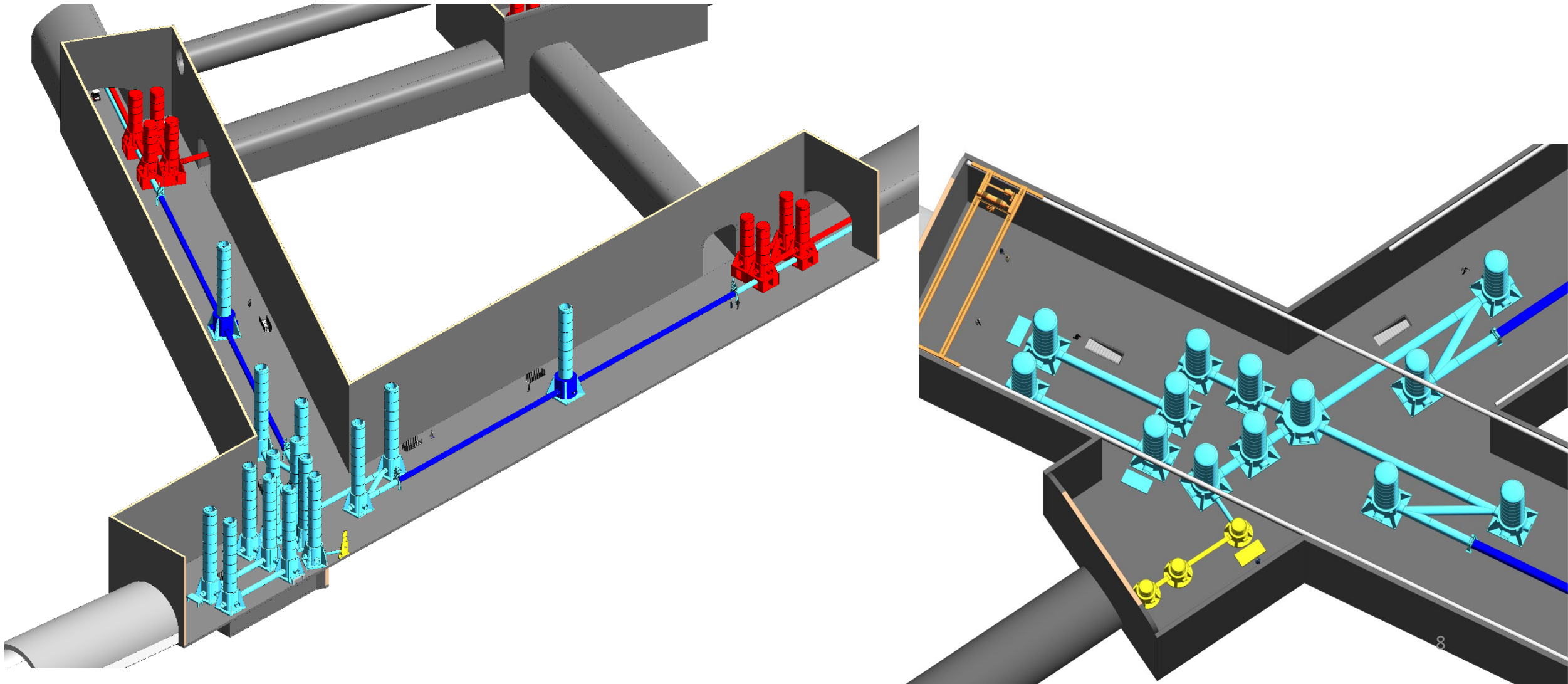
Updated Design

- The conceptual design report of ET has been released in 2011 with a first cost evaluation
- Although the CDR is still a solid reference document, we needed an updated design of the infrastructure in order to have a more reliable cost evaluation
 - No time before the submission to elaborate a full TDR, but an updated design of the infrastructure has been iteratively elaborated:
 - In 2018 thanks to the interaction with the SWS Engineering company (who is realising the Brenner Tunnel)
 - In 2019-2020 interacting with the Implenia company (who is realising the LHC-High Luminosity civil works)

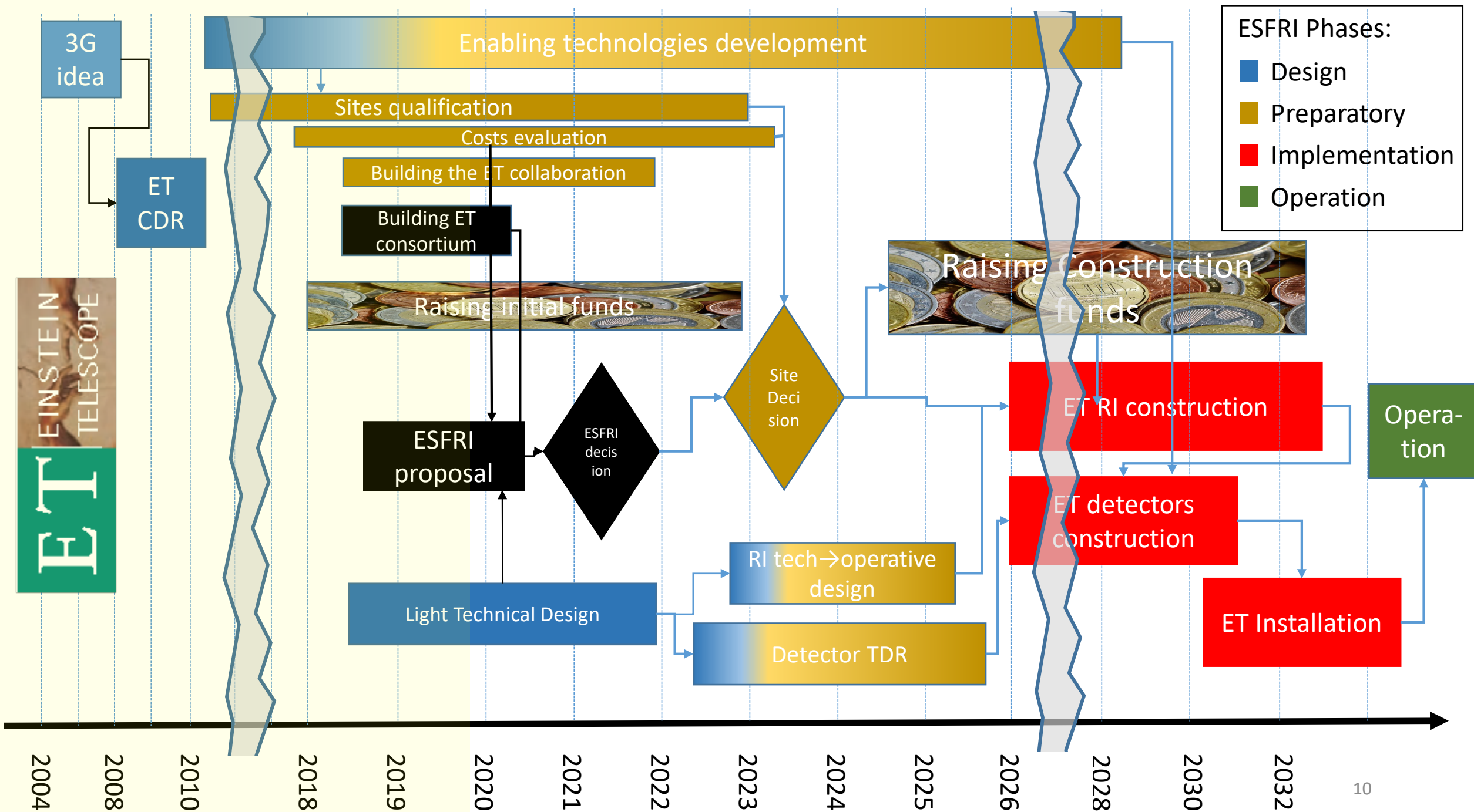
Updated Design



Updated Design



ET roadmap and gantt diagram



ID	Modalità attività	Nome attività	Durata
1	→	Design phase	892 g
2	→	Underground RI design	890 g
3	→	Pilot civil engineering study	261 g
4	→	in house 2D design of the site	600 g
5	→	Pre-preliminary design by external company	230 g
6	→	Environmental impact certification	60 g
7	→	Surface RI Design	523 g
8	→	Detector Preliminary design	784 g
9	→	Detector preliminary design Delivering	0 g
10	→	Design phase Cost evaluation	892 g
11	→	Preparation phase	1819 g
12	→	Site candidatures	992 g
13	→	Site qualification	883 g
14	→	Detailed Geological studies at the two sites	806 g
15	→	Seismic, acoustic, magnetic measurements in the first verte	784 g
16	→	Boreholes excavation at the other 2 corners	300 g
17	→	Boreholes seismic measurements	300 g
18	→		
19	→	Site customisation of the design	429 g
20	→	Preliminary customisation activities	261 g
21	→	Final customisation and design delivering	60 g
22	→	Site dependent cost evaluation and funding schemes for each	160 g
23	→	Site dependent socio-economic study	892 g
24	→	Updated socio-economic impact study for each site	586 g
25	→	Finalising socio-economic impact study	60 g
26	→	Candidature document package writing	30 g
27	→	Site bid document delivering	0 g
28	→	Site comparison	180 g
29	→	Site Decision	0 g
30	→	Preliminary funds raising	1045 g
31	→	RI Technical design completion	520 g

S2

3/07



Draft

g=days

32	→	RI TDR delivering	0 g
33	→	Governance	984 g
34	→	Governance studies	827 g
35	→	Governance definition	30 g
36	→	ET Legal Body	0 g
37	→	Land acquisition	600 g
38	→	Detector Design Completion	935 g
39	→	Detector TDR	0 g
40	→	Implementation phase	2626 g
41	→	Excavation	1565 g
42	→	Direction of the civil works	2112 g
43	→	Services underground (ventilation ...)	1044 g
44	→	Civil works in Surface	1566 g
45	→	Detector components production	1458 g
46	→	ET installation	806 g
47	→	ET pre-commissioning	632 g
48	→	ET commissioning	230 g
49	→	Detector Tecnology Development (R&D)	2610 g

11

ET cost book



- The evaluation of the ET costs is an iterative process:
 - CDR
 - ESFRI evaluation based on the above mentioned studies
 - The interaction with the external companies resulted on two evaluations matching within an approx. 15% error on the infrastructure excavation (contingency)
 - Site dependent evaluations (2023)
 - TDR based after the selection of the site (2025)
- Annexed to the ESFRI proposal, we submit an ET cost book

Phase	Euro M€	Committed	Year	Comment
Total investment	1912	2,8%	2008-2035	
Design	5	100%	2008-2021	The design cost consists mainly of the conceptual design funded by the EC in FP7. Specific technical design activities will be completed in the preparation phase.
Preparation	171	25%	2018-2026	The preparation cost includes the preliminary, definitive, operative designs needed to launch the call for tender for the realisation of the infrastructure. It includes also development costs.
Implementation	1736	0%	2026-2035	Implementation will start with the beginning of the excavation works. The implementation cost will depend upon the selected site. Here a conservative evaluation is presented.
Average annual operation	37	0%	2033-2080	The scientific operation is expected to start in 2035, but operation costs will occur from 2033. This estimate of the ET operations cost includes –apart from the cost related to the running of the ET RI– also the expenses for maintenance, consumables, local administrative- & support staff, local computing facilities, etc. It does not include the costs for remote computing facilities.
Termination	40	0%	2081-2085	The estimated termination cost is based on one year of running costs and on the cost for securing the underground infrastructure.

Socio-Economic Impact

*TO measures the increase of the volume of economic activity induced by the project.

**VA measures the new value generated by the project, i.e. its contribution to the GDP, net of the duplication effects due to the production of intermediate goods and services along the supply chain.

- Three socio-economic impact studies (hundreds page in total) have been elaborated for the two sites
 - Support by academic economists or external companies
 - Their essence has been merged in the four pages attached to the ESFRI proposal
 - Main numbers:
 - Implementation phase:
 - 1€ invested in ET generates 3.6€ of Total Output (TO*) or between 1.4 and 1.55 of Value Added (VA**)
 - Total Output of 6100M€ or 2400-2600M€ VA
 - Estimated overall employment effect of about 34,000 py over the construction period (about 1,500 construction site workers and the remaining 32,500 are jobs created along ET supply-chain).
 - Around 50% of this budget is location bound for it will be used for the development of the site and other low-tech expenses.
 - The remaining 50% is an approximation for the high-tech expected investments for development in science, technology and innovation.

Socio-Economic Impact

- The annual cost of ET has been evaluated in 37M€ using as input the annual cost of EGO/Virgo, the annual cost of LNGS, merging them with some weights elaborated by a team of GW experts and the result has been compared with the annual cost of KAGRA*
 - These costs relate to the employees' wages and the provision of goods and services other than labor, including IT equipment, software maintenance, consumables, security, electricity, etc.
- The annual TO being 133 M€, the VA outcome ranging between 52 and 57 M€ and overall estimated employment of about 883 py of which 163 is the ET staff and 720 are jobs created along ET supply-chain.

*KAGRA is the Japanese GW detector, online at the very end of the last LIGO-Virgo observational run O3, implementing in reduced scale some of the technical solutions indicated for ET: Underground infrastructure, Cryogenic operation. It can be considered a precursor of ET; there is a LoI between ET and KAGRA acting as agreement for collaborations in technology development

Governments

- The submission of an ESFRI proposal is done by Governments, through their ESFRI delegates
- The Research ministries have to write an Expression of (political) Support (EoS) letter
 - At least three national governments are needed and one is identified as leader, formally submitting the proposal
 - (At least) The leader country must also submit an Expression of (financial) Commitment (EoC)
- Italy is candidate to submit the ET-ESFRI proposal as leading country
 - We have already the EoS written in a way that it seems valid also for EoC
 - Internally, we have also an official letter of the local government of Sardinia that express its commitment in case the site is selected in Sardinia
- The Netherlands participates as perspective member country and we have the Dutch government EoS
- We are going to have the Belgian government EoS, national funding agency FWO signed
 - France and Spain seems positively aiming to provide the EoS
 - Germany in stand-by, because they have to insert ET in the national roadmap before the ESFRI roadmap
 - Project submitted in Poland, but no final decision achieved (discussion on the role of Polish institutions)
 - Still no feedback from Hungary and UK
 - Involvement of Switzerland needs still to mature

ET Consortium

- Few core institutions prepared a Lol playing the role of RPO/RFO agreement
 - According the ESFRI jargon they are composing the ET consortium
 - Agencies (30*) that currently signed and sent back the Lol, becoming founding agencies, are:

*CNRS proposed the project for the ESFRI roadmap and the process of evaluation is on going at the Ministry of research. Feedback expected at end of June

Country	Institution Name	Acronym
Italy	Istituto Nazionale di Fisica Nucleare	INFN
Italy	Istituto Nazionale di AstroFisica	INAF
Italy	Istituto Nazionale di Geofisica e Vulcanologia	INGV
Italy	Università degli Studi di Sassari	UniSS
Italy	Università degli Studi di Cagliari	UniCa
Netherlands	NWO-I / Nikhef	NWO-I
Netherlands	Maastricht University	UM
Germany	MPI for Gravitational Physics	AEI
Germany	Leibniz Universitaet Hannover	LUH
Germany	RWTH Aachen University	RWTH
Germany	University of Hamburg	UHH
United Kingdom	University of Glasgow	UoG
United Kingdom	University of Birmingham	UoB
United Kingdom	University of Portsmouth	UoP
United Kingdom	Cardiff University	CU
United Kingdom	Universit y od Strathclyde	US
Poland	University of Warsaw	UW
Poland	Copernicus Astronomical Center	CAMK
Poland	Institute of Mathematics	IMPAN
Poland	National Centre for Nuclear Research	NCBJ
Spain	Institut de Física d'Altes Energies	IFAE
Spain	Universitat de les Illes Balears	UIB
Spain	Universitat de València	UVEG
Belgium	Vrije Universiteit Brussel	VUB
Belgium	Fonds Wetenschappelijk onderzoek	FWO
Switzerland	Universite' de Geneve	UniGe
Spain	Institut de Ciències del Cosmos, Universitat de Barcelona	ICCUB
Spain	Institut of Space Sciences	ICE-CSIC
	Instituto de Estructura de la Materia, Agencia Estatal Consejo Superior de Investigaciones Científicas	IEM-CSIC
Spain	Agencia Estatal Consejo Superior de Investigaciones Científicas	CSIC



MOU ET-CERN

- Agreement between ET and CERN on technological developments and governance
 - Involving initially INFN and Nikhef, but intended for all the funding agencies and institutions supporting ET
 - First focus on
 - civil engineering;
 - safety;
 - vacuum technology;
 - cryogenics.

Collaboration Agreement KN4657/DG/EinsteinTelescope

Between

The European Organization for Nuclear Research
("CERN")

And

the Lead Institutes of the Einstein Telescope
Collaboration:

The Italian National Institute for Nuclear Physics
("INFN")

and

The Dutch National Institute for Subatomic Physics
("Nikhef"),

(hereinafter "Party" and collectively "Parties")

Concerning

Collaboration on the design of future gravitational wave
detection experiments

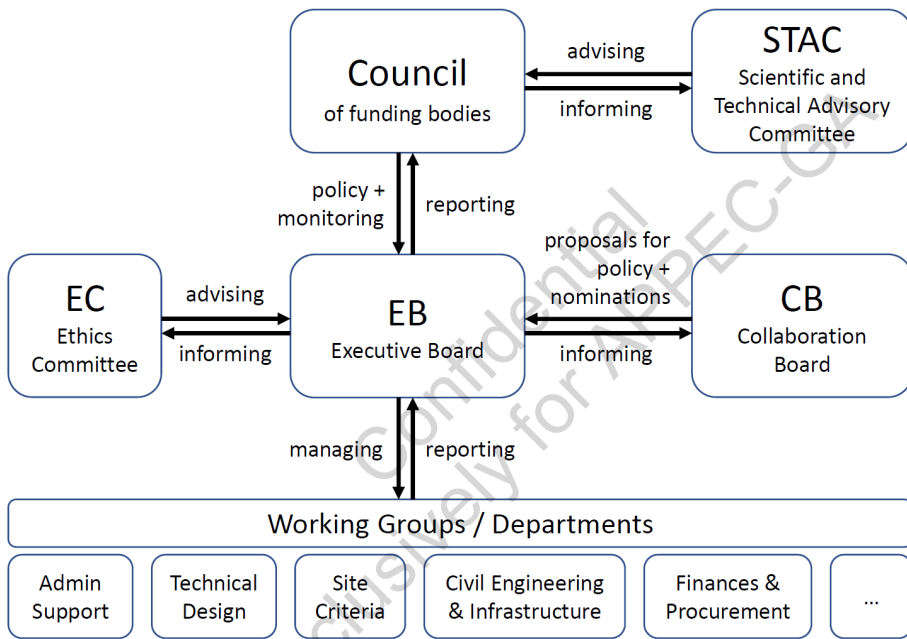
2019

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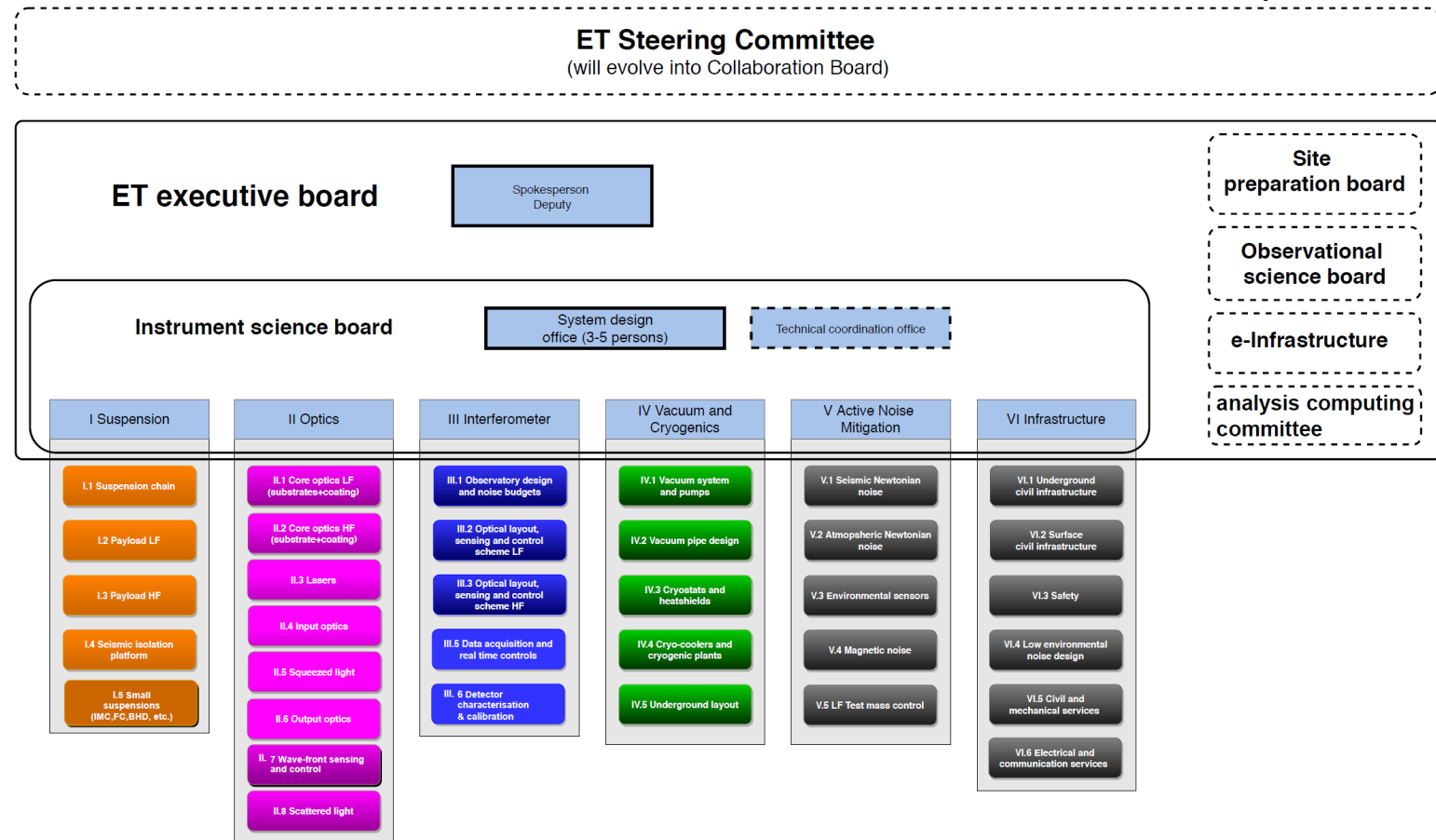
ET Governance

- ET Governance drafted in the ET ESFRI proposal
 - Still very preliminary

As suggested by the Lol institutions:



Under construction by ET-SC:



Euregio Meuse-Rhine

Einstein Telescope



New technologies: *ETpathfinder R&D lab*

Interreg 
Vlaanderen-Nederland
Europees Fonds voor Regionale Ontwikkeling

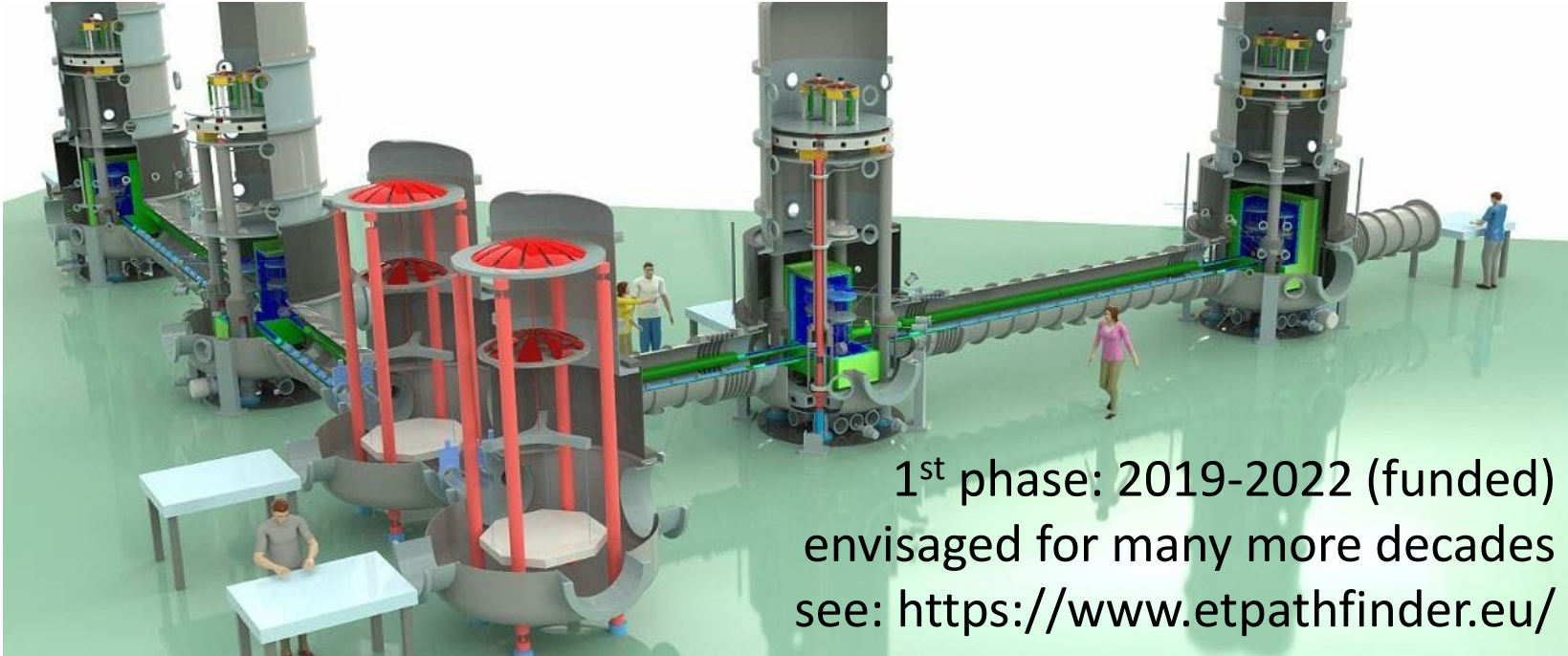


R&D Field Lab ETpathfinder

Stichting Nederlandse Wetenschappelijk Onderzoek Instututen (Nikhef) en een consortium van Nederlandse en Vlaamse universiteiten staan in voor de ontwikkeling van de ET Pathfinder, een R & D-faciliteit waar nieuwe technologieën tot stand kunnen komen voor state-of-the-art zwaartekracht-detectoren waarmee naar het heelal geluisterd kan worden. Met ETpathfinder kunnen noodzakelijke testen worden gedaan die daarna op grote schaal worden uitgevoerd in de uiteindelijk geplande Europese Einstein-telescoop.

www.grensregio.eu

14,5 M€ grant
(investment only!)
open to all



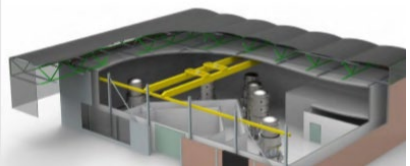
1st phase: 2019-2022 (funded)
envisaged for many more decades
see: <https://www.etpathfinder.eu/>



ETpathfinder DESIGN REPORT

The ETpathfinder Team*

*Mihel, Maastricht University, University of Antwerp, Ghent University, Katholieke Universiteit Leuven, Université Catholique de Louvain, Hasselt University, Vrije Universiteit Brussel, Fraunhofer Institute for Laser Technology, RWTH Aachen, University of Twente, Eindhoven University of Technology, Liege Universit , VITO, INO.



Focus:

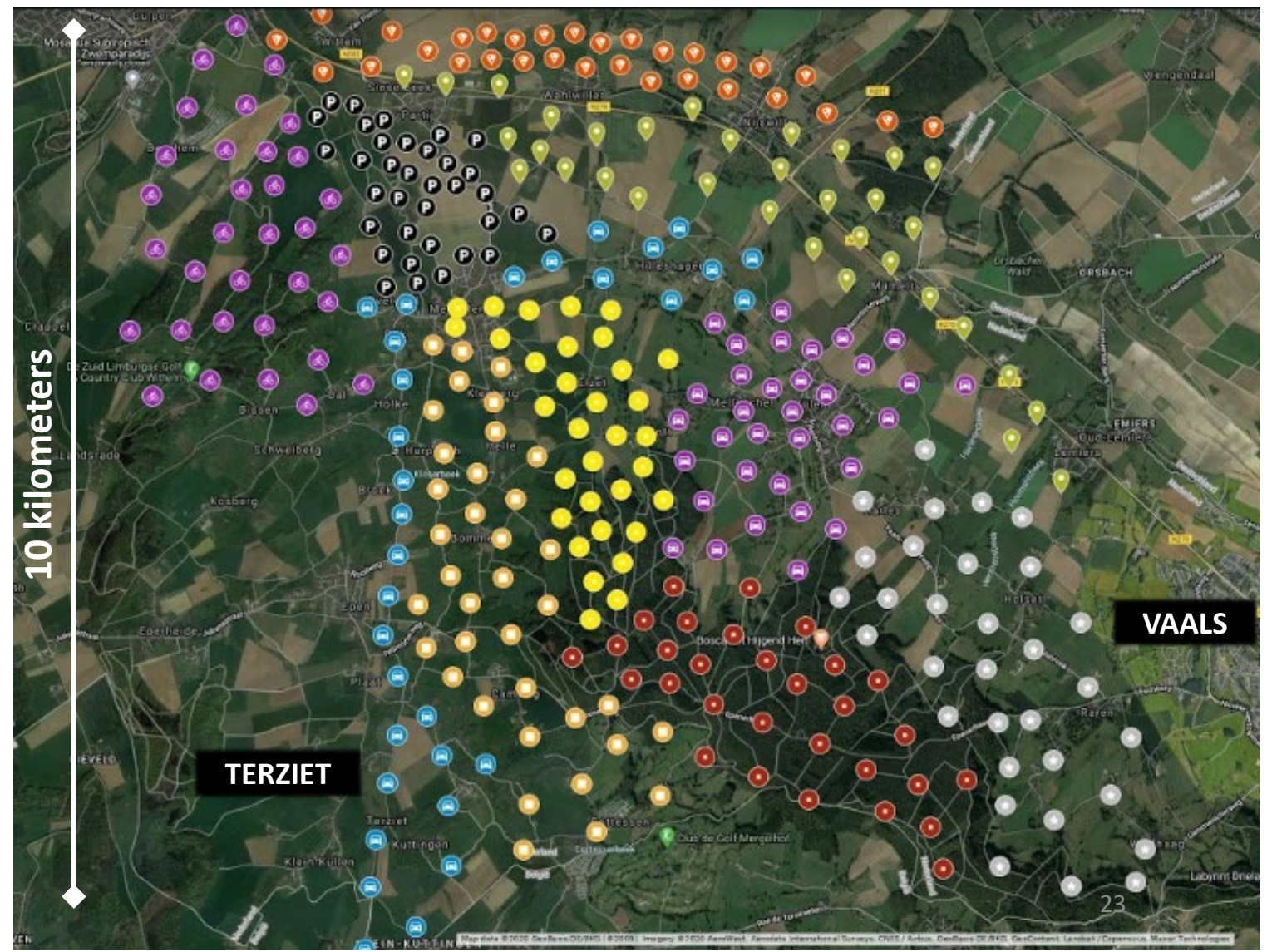
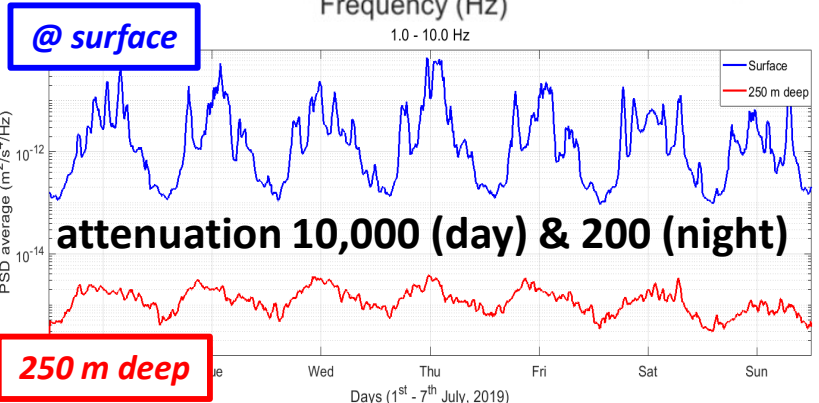
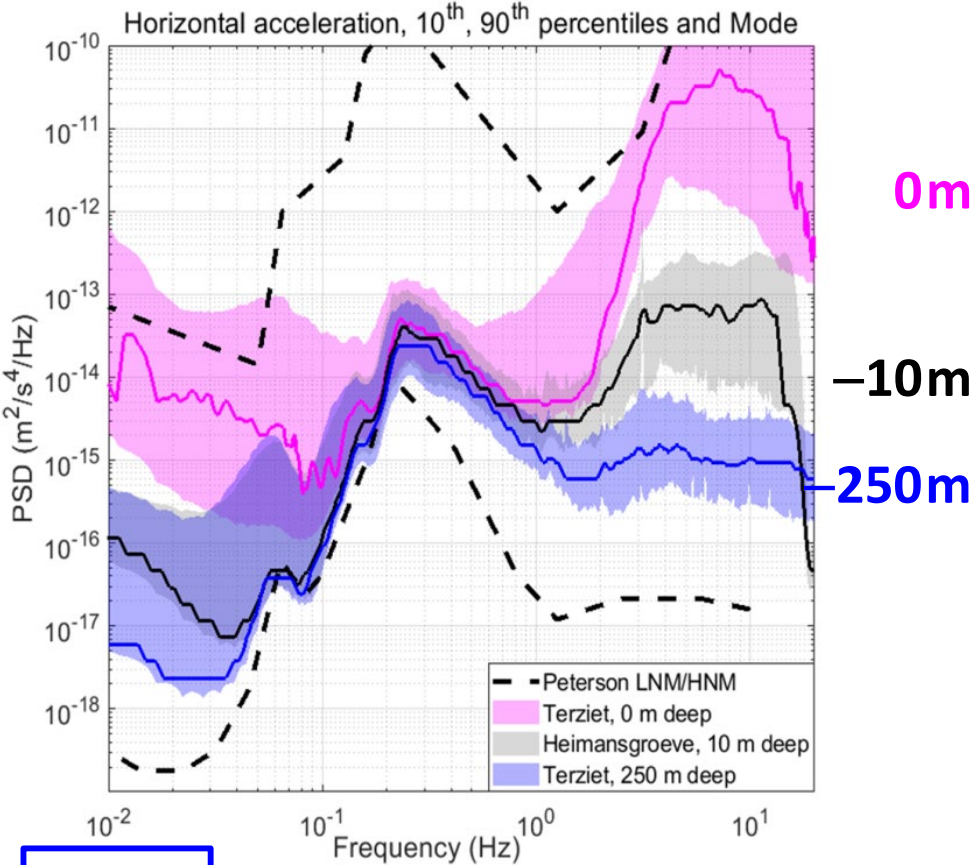
- *cryogenic silicon mirrors*
- *controls*

Projectleader:

S. Hild, Maastricht University

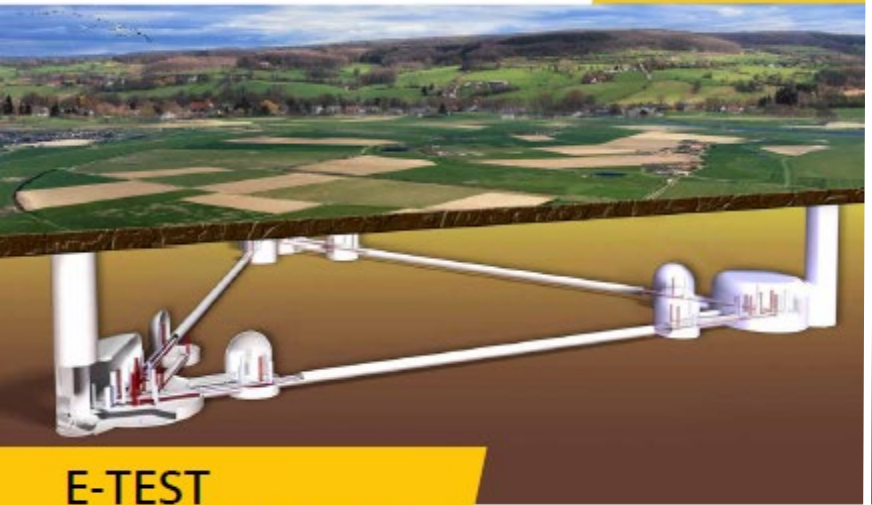
Euregio site: *seismic studies, E-TEST*

ongoing/next steps: seismic campaigns & . . .



Euregio site: *seismic studies, E-TEST*

ongoing/next steps: seismic campaigns & . . .



E-TEST

The Einstein Telescope will open a new window on the Universe through the observation of gravitational waves. Its infrastructure will be buried 300 meter below the surface to reduce human-, wind- and ground-induced vibrations and movements. The Interreg project E-TEST is a very important step of the Einstein Telescope, as it will be a proof of concept, both on the prototype side and on the geological side. E-TEST will build a prototype – a large suspended mirror at cryogenic temperature (10 Kelvin) – to validate the telescope's technology. E-TEST will also run an underground study to map and model the geology of the Euregio Meuse-Rhine. This will allow to define the optimal design and location of the future Einstein Telescope. This project is a major scientific breakthrough but will also have a significant economic impact on SMEs in the Euregio Meuse-Rhine.

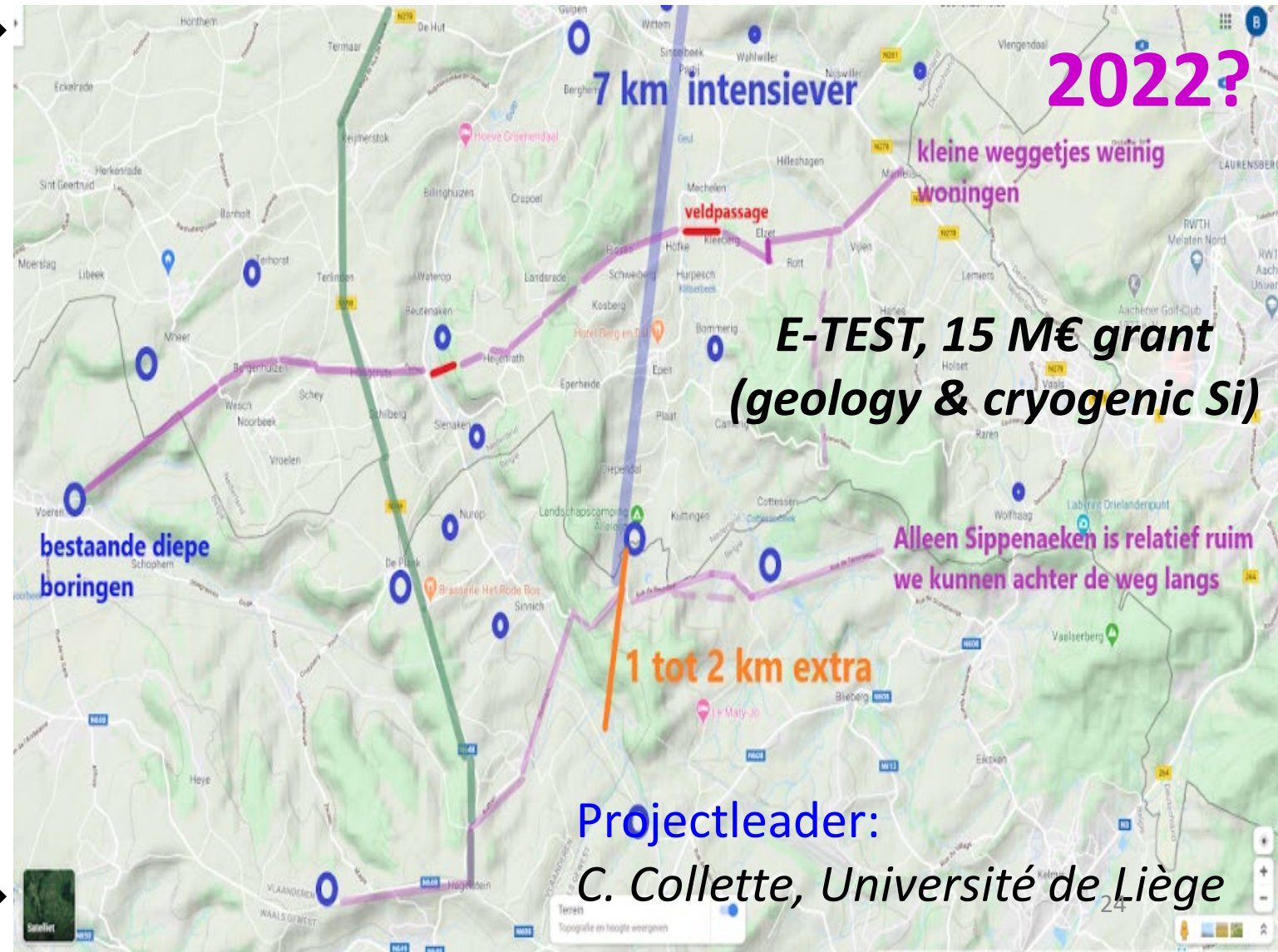
www.interregemr.eu

At Interreg Euregio Meuse-Rhine, we fund projects where partners work together across borders. In 2014-2020, we invest EUR 96 million from the European Regional Development Fund in our region.

We are a collaboration between 13 regions from Belgium, Germany and The Netherlands. Together, we develop shared solutions to common challenges. This gives Interreg its own, distinct spirit of cooperation: across regions and across borders.

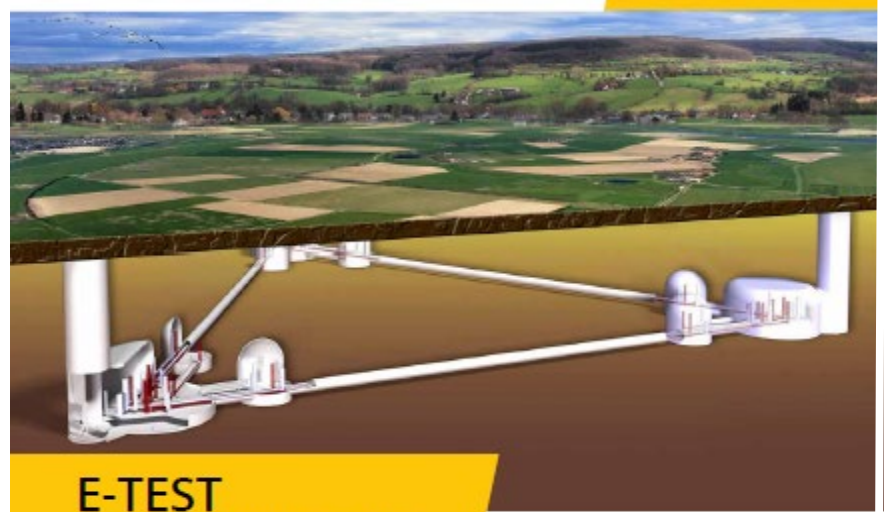


10 kilometers



Euregio site: *seismic studies, E-TEST*

ongoing/next steps: seismic campaigns & bore holes



E-TEST

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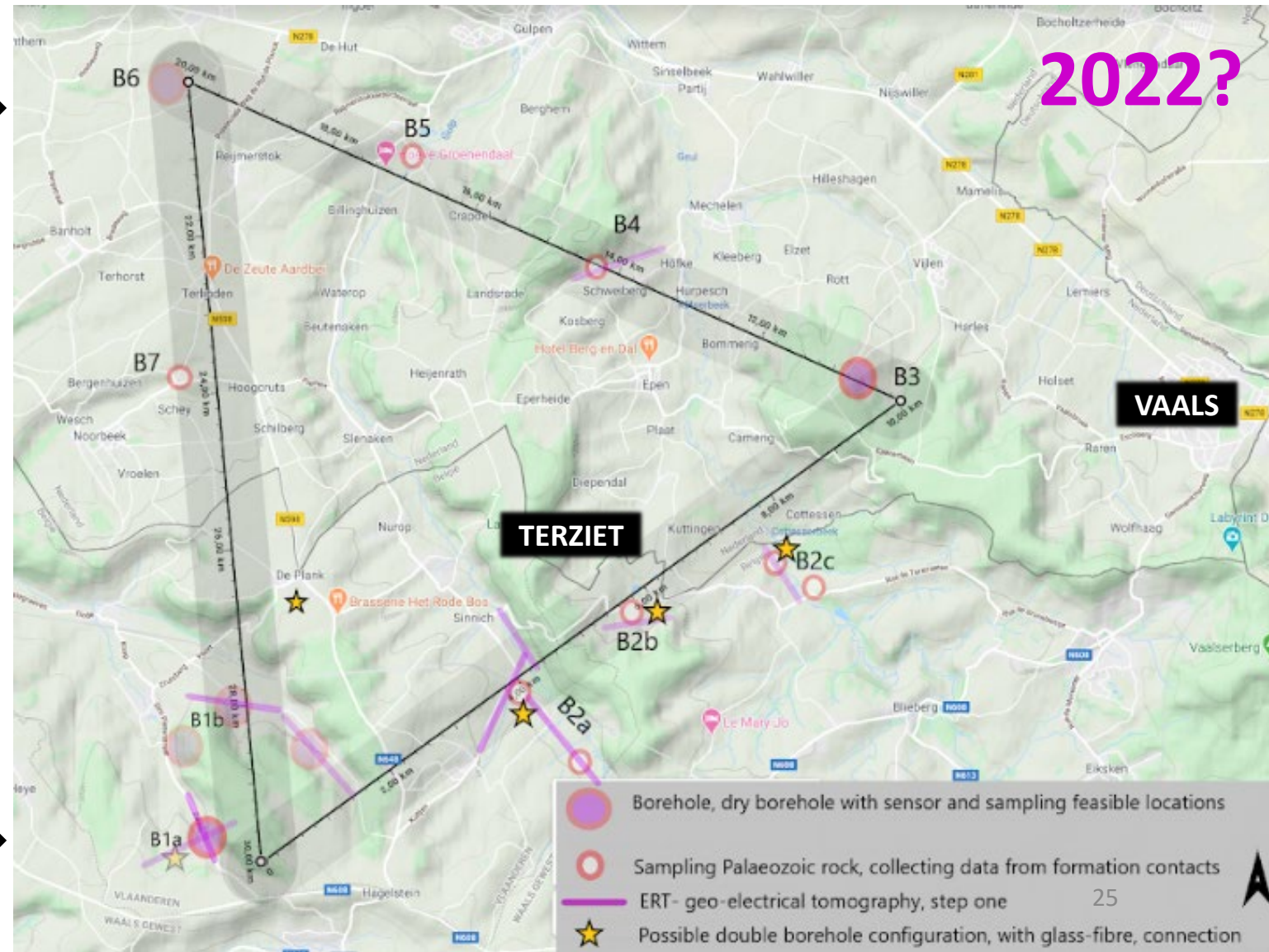
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10 kilometers





Sardegna – Sos Enattos Einstein Telescope

Update June 2020



Italian candidature or the site in Sardinia

- Site identified during the ET design study
- Strong interest of the Italian government (and of the local government, see later):
 - Special investment of 17M€ (11M€ already transferred to INFN)
 - It is an initiative impacting on the whole GW research strategy in Italy

Attività di ricerca a valenza Internazionale		
Descrizione sintetica	2019	2018
É in corso di perfezionamento un Protocollo di intesa tra il MIUR, la Regione Autonoma della Sardegna, l'INFN e l'Università di Sassari con l'obiettivo di consentire l'attuazione di tutte le opere necessarie a sostenere la candidatura italiana del sito di Sos Enattos in Sardegna ad ospitare l'infrastruttura europea Einstein Telescope (l'interferometro di terza generazione per lo studio delle onde gravitazionali). Il finanziamento, inizia nel 2018 approfittando anche della congiuntura positiva creatasi con la fine della contribuzione alla costruzione XFEL. Come descritto nel citato protocollo di intesa, i fondi serviranno sia alla qualificazione del sito minerario che alla prova delle tecnologie di terza generazione che verranno provate nell'interferometro esistente.	5.500.000	5.500.000

- Additional 1M€ investment for site qualification by MUR (PRIN)

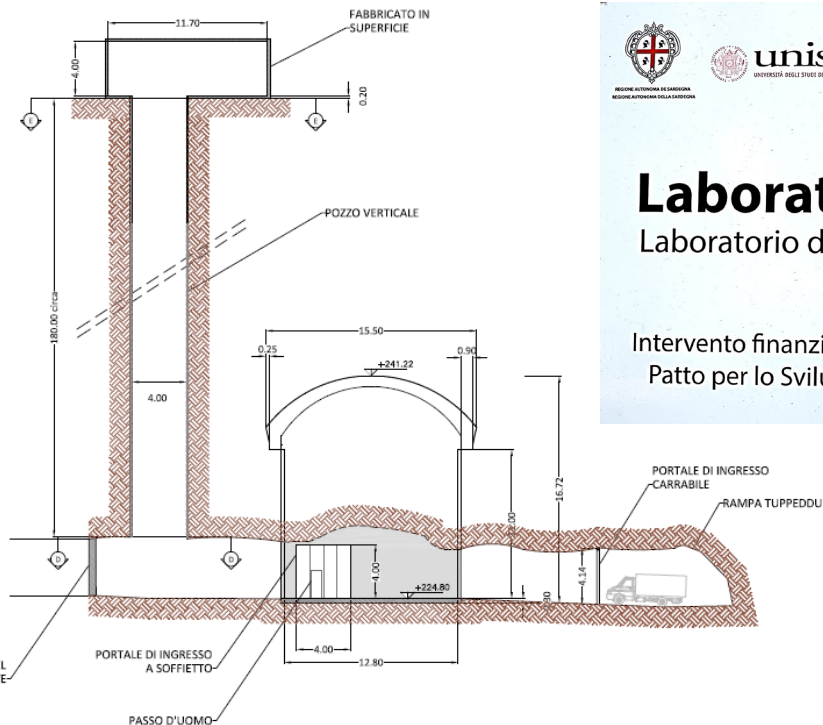
Sar-Grav Laboratory in Sos Enattos

Funded by Regione Sardegna (4M€)

- ❑ A 200m² **surface Laboratory** with annexed control room;
- ❑ 120m² **underground Laboratory** under construction

Focus:

Low seismic noise experiments (e.g. Archimedes O(600k€)) Cryogenic Payloads, low frequency and Cryogenic sensors development



Laboratorio Sar-Grav

Laboratorio di Fisica della Gravitazione

Intervento finanziato con risorse FSC 2014-2020
Patto per lo Sviluppo della Regione Sardegna



ET – Sos Enattos site (Sardinia) characterisation

Collaboration between several Italian institutions:

- INFN (sezioni di Roma1, Roma3, Napoli, LNS, Perugia, Cagliari, Pisa);
- INGV;
- Universities of Sassari, Roma-Sapienza, Napoli-Federico II, Cagliari; GSSI;

Future collaborations operative/possible after COVID-19 lock-down

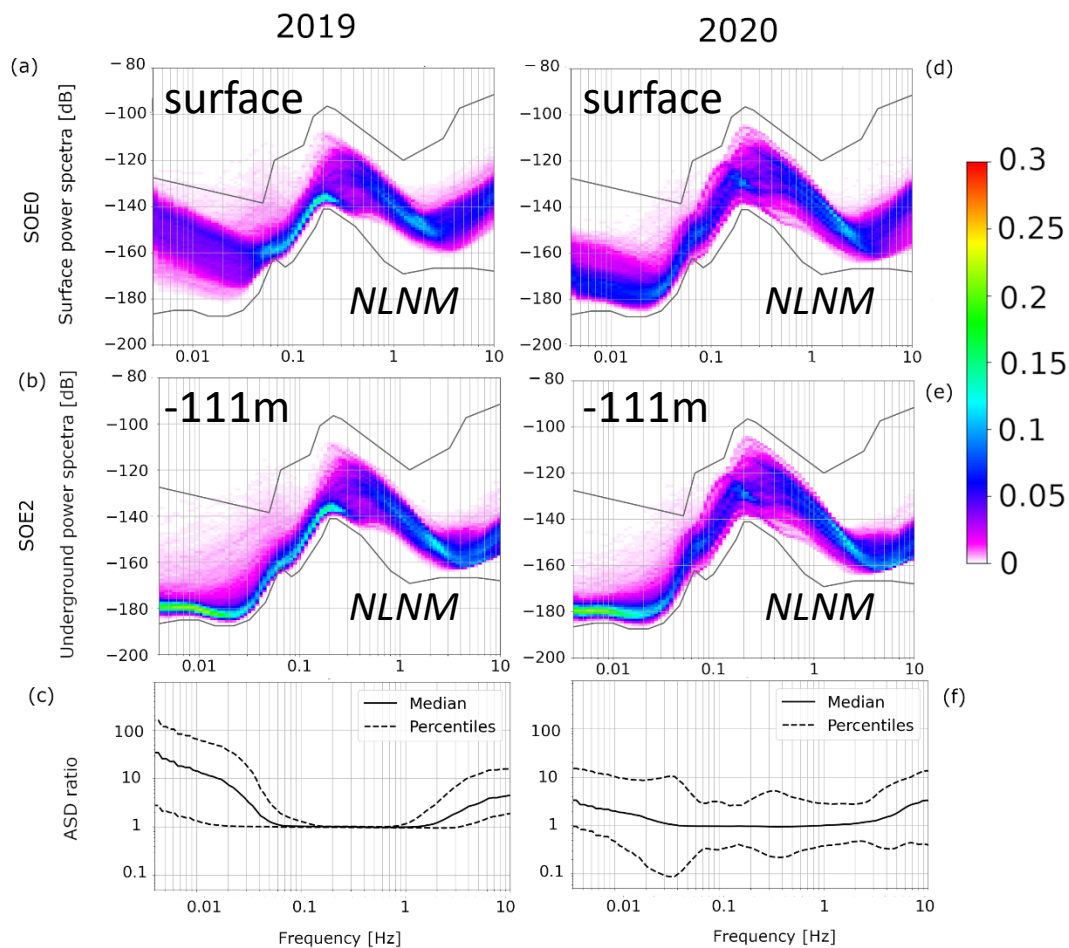
- the Polgraw group (Poland) already contributed to qualify the Sardinian site and it has plans for sensor array deployment
- French geophysics institutions will participate to the site characterisation;
- Possible deployment of sensors from KIT (Germany)
- Interest from Spanish groups
- Characterisation activities included into the *APOGEIA* proposal for the call H2020-INFRAIA 2018-2020, with the possible participation of other European institutions.

Site characterisation ongoing at the Sos Enattos former mine (*Lula corner*), *Bitti corner*, *Onani corner*:

- Seismic noise evaluation (ground level and underground);
- Seismic array measurements (sources identification, Newtonian noise modelling);
- Environmental noise at the site (local/global magnetic noise, acoustic noise...);
- Local weather monitoring;
- Geological survey along the proposed site (at corners and along the ET “triangle”);

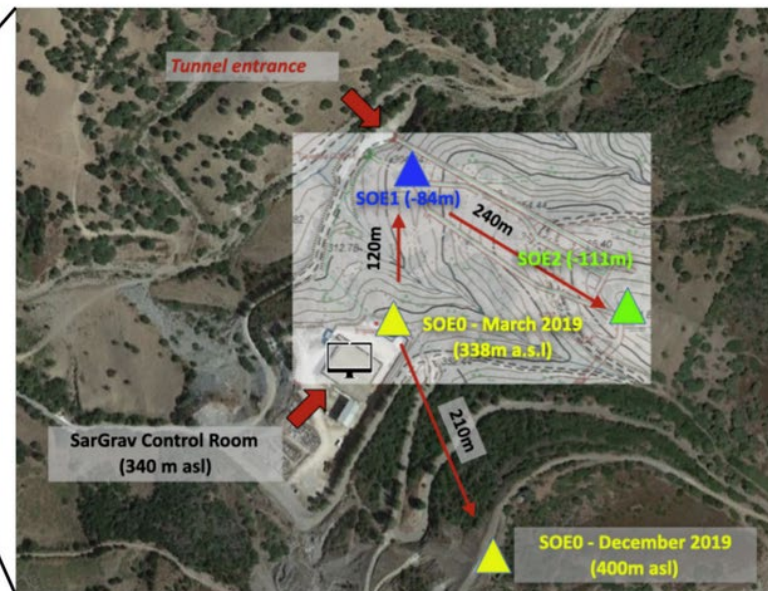
- *ET Italia site activities coordinator: Domenico d’Urso (Uniss)*
- *ET Italia site characterisation coordinator: Luca Naticchioni (INFN)*

Sardinia: Seismic & environmental studies

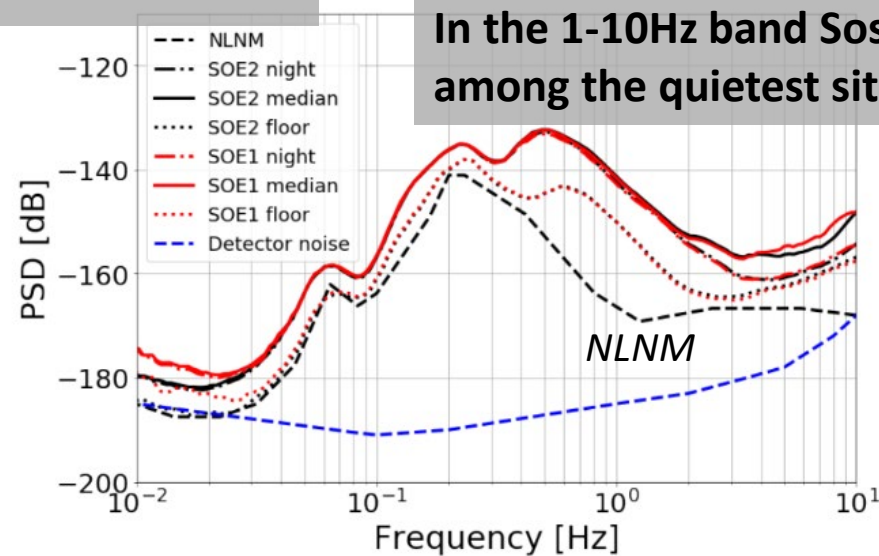


Probability

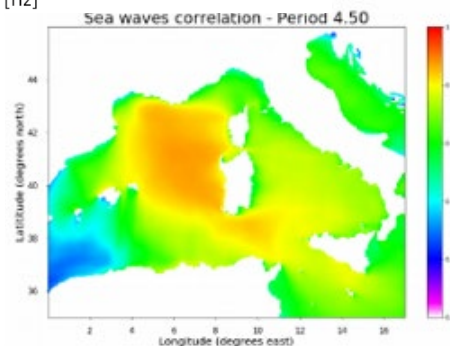
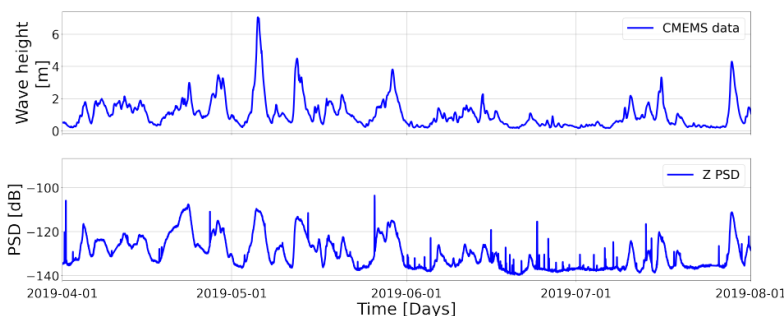
Low anthropic noise, no significant amplification effects



In the 1-10Hz band Sos Enattos is among the quietest sites in the world



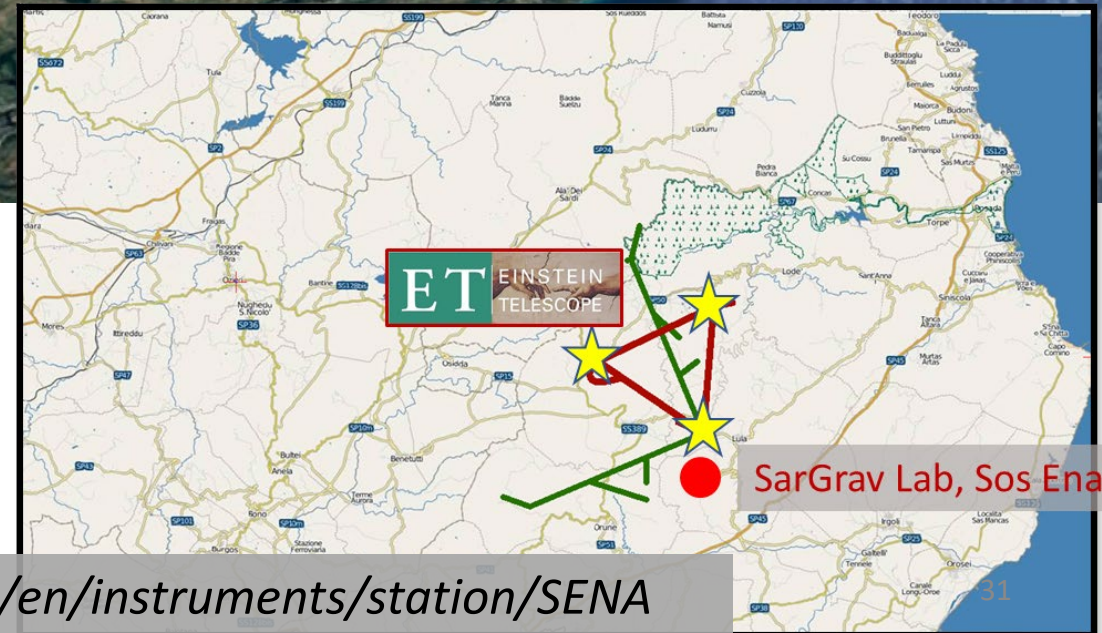
Microseisms correlation with NW 4.5s Med Sea waves



Sardinia: Seismic & environmental studies

What's next

- ❑ Two 250m-deep boreholes at the corners 10km far from Sos Enattos for borehole broadband seismometer installations in 2021 → expected improvement in data quality;
- ❑ Short-Period seismometer (~70) array for source localization and Newtonian noise modelling;
- ❑ Active seismic surveys at the corners and geological surveys along the “triangle”;
- ❑ Magnetic and acoustic noise measurements.



Sos Enattos seismic data public access: <http://cnt.rm.ingv.it/en/instruments/station/SENA>

SWOT analysis ET project

Helpful

Harmful

Internal

Strengths:

- Monumental Science Potential (ET & 3G science books)
- Uniqueness of the project in Europe (pan-European)
- Minimal ESFRI requirements accomplished
- A large fraction of the technologies are either available or pioneered by AdV+: synergies
- Planning better defined after ET-SC intense work
- Two sites candidate: Initial preparatory phase funding assured in some of the corresponding countries

Weaknesses:

- Human resources with the right skills currently limited by the intense AdV+/aLIGO activities: conflicts under discussion
- Size of the ET community needs to grow
- Technical design report still to be produced: cost estimation still to be consolidated
- Lack of civil engineering support/competences
- Two sites candidate: competition & de-focusing
- Official involvement of other EU governments still pending

External

Opportunities:

- Echoes of the GW discoveries
- Lifetime of AdV+/aLIGO and realisation timeline of ET matches: it is possible to deliver science without “holes”
- Timeline matches with LISA
- 3G plans also in US
- Strong interest of the neighbouring scientific communities (Astronomers, Nuclear physicists, ..)
- Potential interest of the HEPP community (and CERN) to exploit synergies

Threats:

- Delays (including COVID) could reduce timeliness
- Selection of the site could reduce the interest of some of the governments
- 3G plans also in US

Conclusions

- ET ESFRI proposal is (almost) ready to be submitted
 - Formal ESFRI requirements are substantially satisfied, but we need to increase the number of governments supporting ET:
 - How can APPEC further help?
 - Documentation is ready
- Site qualification is progressing, despite the COVID-19 problems
 - An acceleration is expected in the next months
 - More countries to be involved
- Internal organisation progressing
 - Need to create the management bodies
 - Need to create the ET collaboration