Preliminary considerations about the Geodesy and Metrology for the Einstein Telescope

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PRELIMINARY CONSIDERATIONS ABOUT THE GEODESY AND METROLOGY FOR THE EINSTEIN TELESCOPE*

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INTRODUCTION

One of the items of the Technical Design for the infrastructures of the 3rd generation of GW detector, the Einstein Telescope (ET), will be the geodesy and the metrology associated to the realization of such challenging infrastructure research facility.

These preliminary considerations are related to the ET Conceptual Design [1], which is based on 3 nested interferometers with triangular shape.

Since the discussion about the ET optical scheme is still ongoing, these preliminary evaluations shall be revised once decided the final configuration, in order to have the best possible evaluation of the needed overall budget. This note represents therefore the starting point for including this important engineering activity in the WBS of the future ET Technical Design Study.

ET is the 3rd generation of GW detectors and its Conceptual Design has been elaborated in the years 2008-2011. It consists of 3 nested detectors arranged in an equilateral triangular shape of 10 km side.

The main features and infrastructure facilities are:

- From 100m to 200m depth underground (hopefully > 200m);
- Xylophone scheme up to 6 folded interferometers;
- 3 interferometers for Low frequency – 3 for High frequency;
- LF interferometer → cryogenic test masses;
- HF interferometer → high power laser;
- 3 underground corner caverns (Ø 65m, H 30m) and 6 satellite caverns (Ø 30m, H 30m);
- Tunnel inner Ø 5.5÷6.0m; double tunnel (300m) linking corner and satellite caverns;
- Surface facilities and vertical shafts (in relation to the site location).

This paper describes the preliminary estimate in terms of quantities and cost required to implement a unique Reference System Network and manage the relevant survey engineering activities, needed for the alignment and the monitoring over the years of each different part of the scientific apparatus.

The estimate shall be revised along with the realization of the Technical Design that will finalize the mechanics, the optics and all the vacuum components, through the different phases of the installation actually described in the Conceptual Design. Also the needed accuracy in the alignment procedure for each different component shall be determined with particular attention performing cost-benefit analysis, in order to optimize the process and the final design of the reference network.

This preliminary evaluation is based on the experience gained during the alignment activities developed for Virgo and Advanced Virgo over the years, as well on the latest evolution of the techniques and of the measurement instruments. It also takes advantage of the geodesy studies and metrology techniques already applied in comparable installations for scientific research, such as those of the EN-ACE-SU Group of CERN in charge of the alignment of the particle physics accelerators, with which there is an ongoing collaboration.

The implementation of a unique reference system (ETRS - Einstein Telescope Reference System) is essential for a correct and integrated approach of the Technical Design towards the realization of ET. This is a fundamental point, in order to have, since the very beginning of the designing phase, a shared reference system easily viable during all the different alignment phases.

ESTABILISHMENT OF THE EINSTEIN TELESCOPE REFERENCE SYSTEM

According to the ET Conceptual Design configuration, the ETRF will consist of both a surface network and an underground network. There will be transfer networks along the vertical shafts, needed to link the two parts of the facility and realizing a unique congruent reference system.

The surface network will include an external network optimized for GNSS survey (Fig.1), made of 15 main reference points (stable foundation pillars), and possibly other additional 15, thickened in the corner areas. This infrastructure will be a reliable GNSS network for the initial framework and for the subsequent monitoring over years of the whole ET surface area.

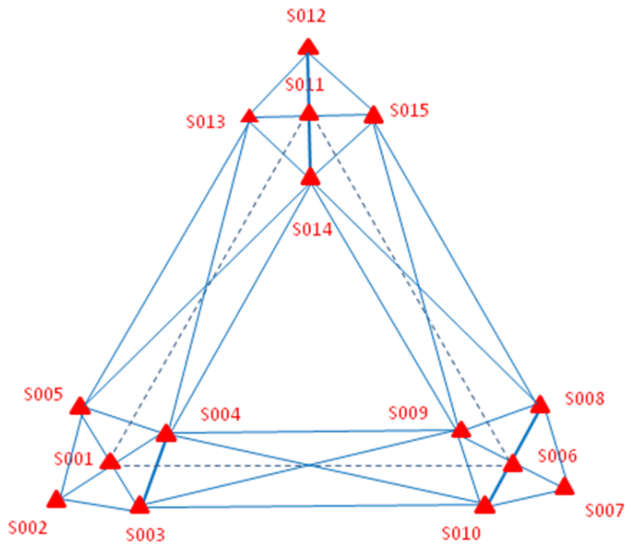

Figure 1: Possible layout of the GNSS network.

A Total Station (TS) network located inside the surface buildings will complete the surface network. As preliminary indication, in this phase we can consider a reference point every 100 m^2 for this part of the facility, being its main purpose the link between the GNSS network and the underground network.

The transfer of the surface network to underground will be a very challenging step of the framework of the whole network. The preliminary evaluation of this item is based on large CERN experience (Fig. 2) starting from early PS/SPS tunnels (years '60-'70) to the LEP/LHC tunnel (years '80 to years 2000), as well for other projects, as more recently CNGS [2]. For this item, it has been considered the installation of 6 main reference points for each shaft.

Figure 2: Adapted Taylor-Hobson sphere and forced centring plate above the CERN ECA4 shaft

The overall underground network will be formed of both the reference networks placed in the corner and satellite caverns and the networks placed along the 3x10 km tunnels. The reference system networks will be divided in main and auxiliary points, and designed for 3D, height or planimetric surveys, according to the accuracy needed for the alignment of the different components or for the monitoring over-years purposes.

The following Table 1 summarizes the configuration of the ETRS network considered in this preliminary study.

At this stage, the cost estimation for the realization of the network facility is not really significant, being the layout not clearly defined. However, a very rough estimation can be equally considered, based on previous experiences and applications. The overall estimated cost is of di order of 1100÷1200 k€ (without VAT), including the purchasing of the metrology tools for materializing the points and the installation cost.

Table 1: ETRN configuration

Reference Network		Distribution parameter	Tot. pts nr.
GNSS	main	1/1000÷2000m	15
	auxiliary (op.)	1/2500÷3000m	15
Surface Buildings		1/100 m^2	96
Shafts		(3+3)/shaft	18
Corner Caverns	hall	1/100 m^2	99
	towers	4/tower	204
Satellite Caverns	hall	1/100 m^2	42
	towers	4/tower	96
Tunnels	main/height	1/25m	1236
	main/planim.	2/25m	2472
	auxiliary/planim.	2/25m	2472

PURCHASING OF THE INSTRUMENTS AND SOFTWARE

The preliminary evaluation for the provisioning of the needed measuring instruments and the associated software is based on latest metrology techniques and types of measuring instruments, available on the market. Discussions and experiences have been exchanges in the recent conference held in Grenoble IWAA 2016 [3].

Table 2a,b reports the instruments and the different types of software considered in this estimate.

Table 2a: List of instruments for ET survey engineering activities. VAT not included in the cost

Nr.	Instrument type	Unit cost [€]	Tot cost [k€]
2	Digital Levels	8000	16.00
2	Laser Trackers	120000	240.00
1	Laser Scanner	100000	100.00
2	Sets of reflectors	10000	20.00
10	Sets of accessories for reflectors	2000	20.00
10	Set of tripods, tools, etc.	1000	10.00

Table 2b: List of software licences for ET survey engineering activities. VAT not included in the cost

Nr.	Software type	Unit cost [€]	Tot cost [k€]
5	GNSS post processing	4000	20.00
5	Alignment	4000	20.00
5	TS post processing/adjustment	2000	10.00
5	Data archiving	2000	10.00

The overall estimated cost is of the order of 400 k€ for the instruments, including accessories, and of 60 k€ for the software (all costs without VAT).

MANPOWER FOR ET SURVEY ENGINEERING ACTIVITIES

The preliminary evaluation of manpower needs for the implementation and the management of the survey engineering activities is reported in the following Table 3. The evaluation considers the activities spread over a period of 10 years (Fig.3). The total estimated FTEs are 16.575.

Table 3: List of manpower needs for ET survey engineering activities. Period: Tech. Design start Y=0.

Task	Qualification	Nr.	Phase	Duration	FTE/y	From	To
Network design	survey engineer	1	Tech. Des.	2y	0.25	Y1	Y3
	CAD technician	1	Tech. Des.	2y	0.25	Y1	Y3
Fiducialization design	mechanical engineer	1	Tech. Des.	2.5y	0.50	Y0.5	Y3
	survey engineer	1	Tech. Des.	2.5y	0.25	Y0.5	Y3
Instrument training	survey engineer	1	Tech. Des.	3m	1.00	Y3.25	Y3.5
	survey technician	3	Tech. Des.	3m	1.00	Y3.25	Y3.5
Site selection - GNSS survey	survey engineer	1	ET constr.	3m	1.00	Y3.5	Y3.75
	survey technician	3	ET constr.	3m	1.00	Y3.5	Y3.75
Superv. of network pts installation	survey technician	3	ET constr.	3y	0.10	Y4	Y7
Network survey	survey engineer	1	ET constr.	3y	0.40	Y4.5	Y7.5
	survey technician	3	ET constr.	3y	0.40	Y4.5	Y7.5
Interferometers alignment	survey engineer	1	ET constr.	3y	0.50	Y7	Y10
	survey technician	3	ET constr.	3y	0.50	Y7	Y10

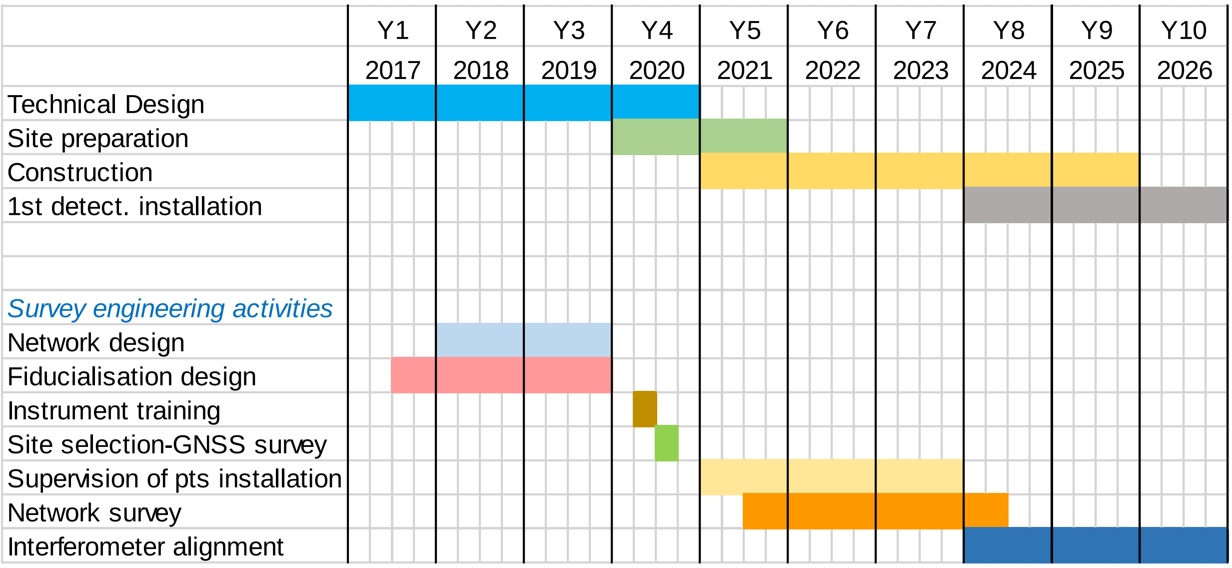

Figure 3: Preliminary timeline of the survey engineering activities in relation to the expected ET overall timeline.

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