ETO Task force for ET detector layout - 19th weekly meeting

F. Sorrentino

Comments by review committee

- Chapter 1, page 2, The_ET_Baseline_Detector_Layout.pdf
  - What is the definition of “acceptable costing”?
    - @Fiodor: our reference is the preliminary costing for the ESFRI proposal, but we cannot estimate the absolute cost at this stage. We interpreted the mandate as the need to produce a layout for which:
      - minor cost reduction can be only achieved by substantial increase in technical Risk
      - major cost reduction can be only achieved by descoping the scientific performance
    - We added an explanation in the revision of Chapter 1.

Comments by review committee

- Chapter 2.2, page 6, The_ET_Baseline_Detector_Layout.pdf
  - The system decomposition in four branches and the nodes described in this chapter should be present in the TAB.1/TAB.7. With the given material, it has been impossible to understand the completeness of the model and its coherence and consistency. A simplified diagram of the Level 3 would help
    - @Romano

Comments by review committee

- Chapter 2.4, page 8, The_ET_Baseline_Detector_Layout.pdf
  - In the System decomposition (figure 4), it seems to be missing the infrastructure layout
    - @Romano

Comments by review committee

- Chapter 3,1, page 11, The_ET_Baseline_Detector_Layout.pdf
  - Many terms are here qualitatively defined ... are they quantitatively defined elsewhere?
    - @Anna/Antonio: We have altered the text for clarity and added numbers where possible. At the end we added references to the documents where a more exhaustive and quantitative analysis is provided.

The overall optical layout is developed by adhering to a set of optical constraints aimed at maximizing detector performance in terms of sensitivity and controllability. For ET-LF, we prioritize minimizing the number of optics, in order to minimize the number of suspensions and reduce suspension and related control noises. For ET-HF, the circulating power in the interferometer is high and the optics are subject to thermal deformation. Key among these constraints is maintaining a not too small beam size on optical surfaces to mitigate thermal noise contributions. Additionally, an appropriate accumulation of the Gouy phase is required to ensure the stability of all optical cavities. Minimization of optical losses, essential for preserving the sensitivity curve, has also guided the layout. To this end, the angles of incidence have been optimized, and a collimated beam has been implemented at the beam splitter for the ET-HF detectors in both 2L and triangular configurations. This requirement has been relaxed for ET-LF, where the lower circul
without significantly compromising performance.

The overall optical layout has been developed by adhering to a set of optical constraints aimed at maximizing detector performance in terms of sensitivity and controllability. For ET-LF, we prioritize minimizing the number of optics, in order to minimize the number of suspensions and reduce suspension and related control noises. For ET-HF, the circulating power in the interferometer is relatively high (up to 3 MW in the arms) and the optics are subject to thermal deformation. A key constraint is maintaining a sufficiently large beam size on optical surfaces in order to reduce power density, thereby mitigating thermal noise contributions. Additionally, an appropriate accumulation of the Gouy phase ($\sim 20°$) is required to ensure the stability of all optical cavities. Minimization of optical losses, essential for preserving the sensitivity curve, has also guided the layout. To this end, the angles of incidence have been optimized to compensate astigmatism, and a collimated beam has been implemented at the beam splitter for the ET-HF detectors in both 2L and triangular configurations. This requirement has been relaxed for ET-LF, where the lower circulating power (up to 18 kW in the arms) allows for a less stringent collimation condition. More details are provided in [4] and [6].

Comments by review committee

- Chapter 3.6.1, The_ET_Baseline_Detector_Layout.pdf
- Not clear what the TAB.3/9A is.
  - @Anna/Antonio: We have altered the text for clarity:

TAB.3/9A: **general**
This lists global/general geometric requirements and assumptions used throughout the design process, which cannot be assigned to a single optic or group of co-located optics (as in TAB.3/9B and C).

and provided a similar sentence in the corresponding Supporting Document text (sec.3.7).
This table is intended to capture more global and generalised requirements that cannot be assigned directly to a single optic, or functional group of small optics, as provided in TAB.3/9B and TAB3/9C. Its scope is currently limited to geometrical considerations (e.g. the opening angle of the arms, which defines the L vs triangle geometry). In the longer-term, we envision this expanding to also capture system-wide requirements connecting parameters of the optical configuration e.g. to the sensitivity curve, active controls, and so on, providing a more complete flow of requirements.

Comments by review committee

- Chapter 4.2.2, page 25, The_ET_Baseline_Detector_Layout.pdf
  - It would be useful to have an idea of the weight (%) of the large impact vs the small/medium impact
    - @Romano

Comments by review committee

- Chapter 4.3, page 26, The_ET_Baseline_Detector_Layout.pdf
  - Not clear what is the outcome…and what is the difference/improvements has been achieved wrt 2024 baseline
    - @Romano

Comments by review committee

- Chapter 5.1.4, page 30, The_ET_Baseline_Detector_Layout.pdf
  - The new layout reduces/optimises the number of towers and interconnecting vacuum pipes (and I guess, vacuum systems needed to reach and maintain vacuum)…why this is not considered in the analysis as a cost reduction?
    - @Max - cost analysis was limited to infrastructure across this study

Comments by review committee

- Chapter 5.2.1, page 33, The_ET_Baseline_Detector_Layout.pdf
  - Comparison with 2024 reference – quantify the “smaller”.
    - @Max

Comments by review committee

- Chapter 6.1.3, page 43, The_ET_Baseline_Detector_Layout.pdf
  - Volumetric Breakdown of the Layout(s) – the statement that “it is nearly the triple” is not correct as you would have to multiply the L for 2.
    - @Jonathan - The volumes are for a single L, and thus the numbers are to be multiplied if constructed in 2 locations. ~1.5x when compared to the total volume of the caverns+tunnels for 2L.

Comments by review committee

- Chapter 6.1.3, page 43, The_ET_Baseline_Detector_Layout.pdf
  - The sentence “(not accounting for the access “is incomplete/truncated…..
    - @Jonathan - the sentence was indeed incomplete. The text has been corrected.
    - In absolute terms, the Triangle layout requires a larger excavation volume in all categories. But when considering the L configuration is to be built in 2 locations, the total volume (not yet accounting for the access, any additional infrastructure needed on the surface, and additional surface-to-subsurface connections needed) would be roughly similar.

Comments by review committee

- Chapter 7.2.2, page 52, The_ET_Baseline_Detector_Layout.pdf
  - Design Structure Matrix (DSM) Interdependency Study – what is the result?
    - @Ghada

Comments by review committee

- Chapter 8.1, page 59, The_ET_Baseline_Detector_Layout.pdf
  - Noise budget for baseline configuration, comparison with 2024 reference – DEFINE MINOR and why you did not go in a further optimisation.
    - @Mikhail/Valeria - the sentence containing “minor” is removed, it carried no significance at this point. We did not do any optimization on the noise budget, as the main objective of the task force was to preserve the science case (and thus have little to no modification to the sensitivity). The optimization of the parameters from the perspective of the science case is a separate activity that would be appropriate to carry out as a follow-up to the current work. No further modification is made to the document based on this comment.

Comments by review committee

- Chapter 1, page 2, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - The study logic makes reference to a reference infrastructure layout. Which one?
    - @Fiodor - this is given by the combination of technical infrastructure as described in section 6, including scaffoldings, clean rooms, cryogenic infrastructure, technical rooms, and the civil infrastructure described in section 7, including main tunnels and caverns. This is a simplified model for the ET infrastructure, and does not account for important elements in the technical infrastructure (e.g. ventilation, dewatering) as well as in the civil infrastructure (e.g. access, technical shafts, safety rooms). Reference infrastructure corresponds to the reference 2024 detector layout. We extended the text in Chapter 1 in the revised version to better explain this point.

Comments by review committee

- Chapter 1, page 3, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - After the sentence, “This allowed to identify the main cost drivers and the most critical parameters for civil infrastructure costing…..” A table should be provided to list which one they are
    - @Fiodor - the coarse list of main cost drivers is shown in tables 7 and 8 of the main document (The_ET_Baseline_Detector_Layout.pdf), while a detailed list of functional volumes is given in tables 30 and 31 of the supporting document (Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf). We added references to tables in the text of Chapter 1 in the revised version.

Comments by review committee

- Chapter 1, page 3, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - There is a mention to a “simplified risk analysis” but there is no reference to it. Do we need to consider it referencing to the “Full Risk Study.xlsx”?
    - @Fiodor - yes, indeed the risk register has to be considered as the result of a simplified risk analysis, which is far from including all relevant technical risks in the ET project, and only addresses risk items whose severity differs among the different configurations under study in the present work. We included a reference to the risk register (Full Risk Study.xlsx) in the text of Chapter 1 in the revised versio

Comments by review committee

- Chapter 3.3.5, page 38, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - There are risks identified that are not listed in the “Full Risk Study.xlsx”.
    - @Marco/Giacomo/Ghada - List of risk evinced in the chapter 3.5.5
    - FC2Mirrors, not tunable finesse 2L line 5 Filter cavity finesse can be mistuned with respect the ITF configuration
      - Risks associated to periscope are highlighted in line 6 and 7 for 2L

Comments by review committee

- Chapter 4.4, page 78, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - It would be useful understand the net contributions (thermal noise limitations vs noise generated by the cryosystems) of each feature of the cryosystems (i.e (1) payload cooling, cryopumps limitation of the payload heat load, to the each There are risks identified that are not listed in the “Full Risk Study.xlsx”.
    - @Steffen/Fulvio/Ettore - ==========Fulvio/Steffen==========
    - The compatibility of the baseline cryogenic payload design with the ET total noise curve has been demonstrated in DOI 10.1103/PhysRevD.108.123009. In particular, we stress a main conclusion concerning the cryo-payload configuration: the soft links necessary to cool down the payload cannot be connected to the marionette directly. Rather, the cooling interface must be integrated in the stage above, i.e., the platform.
      - Concerning the helium cryostat and the crypumps, coupled to it, we note:
      - A conceptual study on a low-noise thermal shield around the cryogenic payload is published in DOI 10.1088/1757-899X/1301/1/012013;
    - The cryopumps are cooled by single-phase helium flow and are located enough far from the test mass. A more detailed study will be carried out once the thermo-mechanical design is further advanced.
    - Apart from the KAGRA data, technical noise figures for an ET cryogenic system are not yet available. On the other hand, R&D activities are flourishing in various laboratories of the ET collaboration. Here we cite just three of them:
      - the Amaldi Research Center in ome where a cryostat that can host a full side cryo payload of ET as conceived in DOI 10.1088/1757-899X/1301/1/012013, is under construction. It includes a new system to reduce the radiation thermal input without using standard Multi-Layer-Insulation.
    - The ERC ADG project GRAVITHELIUM is the R&D activity of the laboratory of Karlsruhe Institute of Technology (KIT), started in October 2024. The KIT group investigates the technical noise isolation of a He-II based payload cooling system, as well as the inherent noise behavior of a superfluid liquid column in a cryogenic marionette suspension.
      - At the Centre Spatial de Liege (CSL) of the Liege university the CSl group tested a new compact isolator system to supende a large silicon mirror (100 kg), cooled at 25-40 K in a cryostat (Classical and Quantum Gravity. doi:10.1088/1361-6382/ace230).
    - To have a full scenario of these activities we should cite the efforts focused on the material sytudy at low temperature, carried on by the groups more involved in ethanol activity of the ET suspension division. to the suspension division F

Comments by review committee

- Chapter 4.4.7 and 4.4.8, page 87, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - Missing text
    - @Henk Jan - the two mentioned sections have been removed in the revised version. The cryogenic infrastructure options are already described as “Alternative cooling strategies”, formerly as 4.4.5 and now moved to section 6. While cyopumps option technology is considered irrelevant.

Comments by review committee

- Chapter 5.2, page 94, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - The strategy for the vacuum system for the pipes interconnecting the towers still lacks of details and might have an impact on the space required if the cryogenic solution is retained
    - @(Patrick/)Julien/Antonio P. - The pumping strategy for the towers has been defined by ISB Vac&Cryo group and is only briefly described here. In particular, the mentioned cryogenic pumps are foreseen at a few selected positions on the connecting links between the towers. These cryogenic pumps will be smaller than the main ones, i.e. the cryotraps positioned at the extremities of the beampipes.
    - The ISB Vac&Cryo group is currently optimizing their size and positions with respect to the characteristics of the towers. Their external diameter will be slightly larger than the linking pipe itself, with limited clearance required around the links for maintenance. In any case, the impact on the volume and the civil infrastructure will be limited, as these units are relatively compact compared to various other components, such as the towers chambers or the cryotraps.

Comments by review committee

- Chapter 6.1.2, page 99, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - The noise impact of the operation in rest mode for clean room is not described. This could be a limiting factor in the cleanroom strategy and the surface/volume requirements for the infrastructure layout
    - @(Max/)Julien - During “Rest Mode”, cleanrooms operate with reduced intake air flow, meaning less air is moved through the volume, which reduces the noise generated. The Air Handler Unit (or similar machinery) achieves this by reducing its motor fan velocity, which is easily implementable.
    - The Noise Mitigation group within ISB will calculate the exact noise levels at a later stage. Current experience from Virgo regarding HVAC system noise evaluation can be provided while these studies are underway.

Comments by review committee

- Chapter 6.1.4, page 106, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - The requirements for the HVAC system are not defined hence we consider that you have taken sufficient margins to consider the volume occupied by the ventilation system. Please confirm what are these margins. In addition, the requirements on the HVAC also largely depends on site conditions (air quality, humidity of the under ground, etc.). Have you taken these variables into consideration?
    - @Max/Patrick

Comments by review committee

- Chapter 6.1.2, page 99, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - Is the requirement for ISO9 applicable minimum requirement for the all underground?
    - @Max/Patrick

Comments by review committee

- Chapter 6.2, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - Confusing unstructured analysis. An introduction to the objectives and a summary table of the options analysed with the corresponding solutions/conclusions would help. In addition, there is no link with the final baseline presented in the Figure 58
    - @Max

Comments by review committee

- Chapter 7.3, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - It is understood that the estimation has been “based solely on estimated minimal excavated volumes”. This implies that the estimated cost d not take into consideration the ground conditions of the two/three proposed sites (which could have been communicated by the local sites). Does this mean that you have taken the upper conservative bound in the estimations (I.e. the worst case)?
    - @Jonathan/Maria - The 'worst-case scenario' (upper conservative bound) was not necessarily used. A standard or average unit cost for excavation was employed, based on benchmarks from similar projects. This approach allows for establishing a neutral reference estimate. The detailed cost analysis, which will include the impact of the specific geological conditions of each site, will be conducted in a later and more advanced phase of the project by the local teams, once the baseline layout has been defined and more in-depth geotechnical studies are available

Comments by review committee

- Chapter 7.5, page 135, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - A good number of technical requirements have been presented in the previous chapters but not contextualised here. For example, the ISO9 requirements, the Noise room space, etc.
    - @Jonathan

Comments by review committee

- Chapter 7.5, page 137, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - The whole observation of the drainage pipes and their implications for the civil engineering layout are not well described and it would help a drawing to understand what the actual proposed design is. The consideration on water flow and minimum distance of 100m from the arm pipe and the 20m/s speed seems wrong. Can you please check.
    - @Fiodor - the arguments here are meant to provide technical requirements rather than to propose technical solutions. A proper design of dewatering piping will be up to the engineering studies by local teams. Anyway, we included a simplified drawing in the revised version of the document. The argument to limit the maximum speed of drainage water is from a simplified numerical computation by one of the major experts of Newtonian Noise in the ETC Instrument Science Board. The outcome of the computation provides a NN noise spectrum for a given geometry and a given speed of the water flow. It turns out that the resulting NN is roughly proportional to water speed, and inversely prportional to the minimum distance of the water ducts from the LF TM.

Comments by review committee

- Chapter 7.5, page 137, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - Considering the requirements of ISO9, a good part of the Lining and finishing requirements can be derived
    - @Jonathan

Comments by review committee

- Chapter 9.3, page 160, Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf
  - There is an extensive presentation of the derivation of the scientific requirements on the main design parameters. However, it would be useful having a table summarizing which one they are and, more importantly, what are the conclusions of the TF on this analysis
    - @Ulyana/Francesco

Comments by review committee

- TAB.4, there are no tolerances defined like for the other requirements
  - @Max

Comments by review committee

- In general, the documents still contain some typos and missing references (for example, page 85 Supporting_Document_for_The_ET_Baseline_Detector_Layout.pdf)
  - @all

Figure ?? shows some startpoints of tracks from the surfaces outside the liquid-nitrogen (LN2) cooled shield (the warm environment), inside the inner part of the LN2 shield, inside the neon-cooled shield (35K), inside the hydrogen-cooled shield (15K). The payload (mirror, marionette, cold filter, reaction mass) is cooled to 8K, as is the coldest cryotrap.

Additional comments from draft report

- Mandate compliance
  a. Consider adding an executive summary (few pages) to help clarify what are the key scientific objectives and the corresponding key design parameters, in tabular form, and how these changed relative to the previous baseline.
  b. Continue to update and refine the 2025 baseline documentation while tracking the project risks introduced by the changes in baseline. This documentation will serve as the starting point for further work within a well-structured project organization, which can subsequently carry out further optimization of the ET design

Additional comments from draft report

- Mandate compliance: the executive summary should include at a minimum
  a. What are the achievements with respect to the 2024 baseline?
  b. What are the key design parameters?
  c. What are the key cost drivers?
  d. What are the key cost savings?
  e. What are the key risks?
  f. What are the main outstanding issues that remain to be solved?

Author list and external contributors

- We will include some names outside of the task force team as “external contributors” in the author’s list:
  - Alessandro Agapito, Biswajit Banerjee, Nicolò Cibrario, Andrea Cozzumbo, Francesco Crescimbeni, Alessio Ludovico De Santis, Michele Mancarella, Benedetta Mestichelli, Niccolò Muttoni, Lavinia Paiella, Simona Procacci, Ippocratis Saltas, Filippo Santoliquido, Manuel Arca Sedda, Pawan Tiwari, Cristiano Ugolini, Li Yufeng: for science case computations
  - Angèlique Lartaux: for filter cavity RoC and design
  - Martina De Laurentis and Eleonora Polini: for clipping loss computation in filter cavity pipes
  - Matteo Leonardi: for squeezing global optical design
  - Sumin Lee: for Zeemax simulation on mode matching telescopes to FC
  - Jean-Pierre Zendri and Aymeric van De Walle: for support in requirement computation for filter cavity and periscope mirrors
  - Paola Puppo and Fabian Pena Arellano: for support vertical thermal noise computation
  - Any more?

Consistency checks & missing information

- All sections
  - please check broken references
  - fix text highlighted in red
  - adjust language for text imported from other documents (e.g. “we believe”, “we expect”, …)
  - fix missing text

Feedback by ETC on Gitlab

- In the text in Section 8.1, references to Figs. 19 and 20 seem to be swapped

Final steps and follow up

- Apply changes to documents and complete answers to reviewer's comments within Friday 27/6
  - delivery on Friday 27/6 evening
  - together with release of review committee's report
- With the final delivery, Task Force mandate is concluded: thank you all for your extremely valuable contribution to this remarkable result!
- However…
  - local teams will likely need some interface providing clarifications on the use of task force output documents
  - we will keep the GitLab repository to track possible question by local teams and to provide corresponding answers
  - we will **contact task force team members if needed** to work out clarification requests
  - this is a temporary procedure: over the coming months ETO will have to arrange a coordination structure among the various ET stakeholders to work in the long term
    - input on that from all parties will be required, please stay tuned…