ETO Task force for ET detector layout - third weekly meeting

F. Sorrentino

Preliminary brainstorming

- Some suggestions from GitLab issue
- Some topics from previous discussions (M. Korobko):
    - LF could be in a tuned configuration as an "initial" version of the detector: this will allow to have only 1 filter cavity.
    - Can two FCs of the same detector be in two different arms? If we can guide light through, this would mean only 1 FC per arm and it could fit into the main arm.
    - FC cavity length considerations: et/isb/interferometer/et-optical-layout-10km-triangle#59
- Detector length (M. Korobko)
    - Can we reduce the detector length? Especially this goes for the L-shape with 15km, but also going e.g. 10 → 8km might not be very dramatic wrt sensitivity loss. If we have to tradeoff 5km FCs, this might still be beneficial (i.e. reducing the length but getting 5km FCs).
    - For HF, if we want to maintain detector bandwidth, improvement in sensitivity scales as $\sqrt{L}$, so going 10km → 15km is "just" factor 1.2 sensitivity increase (in practice a bit more, since different noises scale differently). For LF, going 10km → 15km is even less pronounced (for the current level of noises), since it impacts the optical spring in a non-trivial way.

Preliminary brainstorming

- Cryogenics (N. Holland)
  - Are there compelling reasons, for example loss introduced by water adsorbed on ET-LF cryogenic test masses, to investigate wavelengths other than 1550 nm for ET-LF?
    - I know that there are attractive reasons, for example established telecommunications technologies, for considering 1550 nm but are there more compelling reasons that might draw us to other wavelengths?
  - Is it worth considering an "initial" version of ET-LF without cryogenic test-masses, and then upgrading once this technology is stably demonstrated at KAGRA/a multi-meter prototype? Almost certainly this would compromise the lowest frequency performance in this "initial" version.
    - Even IF such an approach was taken there would likely need to be some installation, appropriate pumping for at least the LF arms seems most probable, of the "final version" technical infrastructure from the beginning

Preliminary brainstorming

- Upgradability risk (N. Holland)
  - Thus far, and as it must be for the majority of the task force, the discussion has focused on the "initial" layout for ET. However the infrastructure is intended to last for 50 years, and accommodate technology upgrades. There appear to be at least three ways upgrades can be implemented.
    1. Technological upgrades within the existing infrastructure.
    2. Infrastructure expansion with existing technology.
    3. Simultaneous technological upgrades and infrastructure expansion.
  - Thus far upgradability concerns seem to focus on principally on item 1, above. At a minimum it seems prudent to also assess the risks associated with infrastructure expansion. There are a few reasons for this:
    1. Some types of infrastructure expansion may be simpler/cheaper than others. E.g. Enlarging a mode cleaner end cavern is (probably) far simpler and cheaper than enlarging the vertex cavern.
    2. The "initial" layout/design may already preclude some types of infrastructure expansion. E.g. The layout of the vertex caverns, set by the optical layout, may prevent expansion of these caverns in the direction between the LF and HF vertices, due to geological stability.
  - Consideration of infrastructure upgradability risks may alter the risk calculation for purely technological solutions. For example the risk penalty associate with an otherwise riskier technological solution may be de-weighted because "equivalent" infrastructure upgrades are precluded.

Preliminary brainstorming

- Reducing IMC tunnel length by going from triangle to bowtie configuration (M. Majoor)
    - The current IMCs in the optical layout are all considered triangle configuration. For a single vertex, this is 550m of tunneling (150m for LF and 300m + 100m for HF). By changing from triangle to bow tie configuration, the length of these tunnels can be halved. This reduces 275m tunneling per vertex, resulting in 550m for 2L and 825m for triangle reducing (hopefully) costs.
- Comments (S. Steinlechner)
    - As an additional comment, it seems feasible to align at least the ET-LF IMCs parallel with the orientation of the arms, i.e. drilling past the vertex a bit more, in case this saves significant cost because one doesn't have to start another tunnel at a new location in a new direction.

Preliminary brainstorming

- Geometry-independent
  - optical layout
    - Number of core/auxiliary optical elements to reduce the amount of cavern excavation
      - Likely achieved by merging secondary optical elements within the same tower
        - Seismic isolation requirements?
    - IMC folding (triangle -> bowtie) to reduce IMC tunnel length
  - design of instrument elements
    - reduced footprint of LF TM cryostat
    - reduced height for LF TM towers
      - folded IP
      - active platform
    - reduced height of HF core optics towers (sticking to HF requirements)
- Geometry-dependent
  - Optical layout
    - position of filter cavities and mode cleaner cavities (in main tunnel, in same tunnel, etc.); to reduce the amount of tunnel excavation
    - Reduce tunnel length? I.e. shorter or folded cavities? E.g. for main arms
  - design of instrument elements
    - vacuum tank access (lower vs lateral)
  - structure of caverns, e.g. stacked caverns to reduce amount of cavern excavation

Preliminary brainstorming - next steps

- Keep adding suggestions on GitLab issue
- Combine ideas to identify a few global configurations to be studied during in-person meetings
- In particular, determine:
  - needs for additional preliminary design work (either on optical layout, suspension, cryogenics, vacuum)
  - rough identification of impact on civil infrastructure
  - rough identification of impact on performance

Work breakdown structure

- Parallel discussions with expert groups during last week
  - to establish the work plan, in particular for preparatory activities to identify and analyze configuration options, as well as
  - to establish a coherent requirements tree connecting
    - design choices with the top-level performance requirements
    - to the impact on civil infrastructure costing.
- The WBS is being refined with respect to
  - the time needed
  - the logical predecessors
  - the people in charge for each task
- Excel table under finalisation
- Main use will be to
  - align the timing of different interconnected task
  - Make sure preparatory activities are carried out in time before in-person meetings

Work breakdown structure

- Preliminary system decomposition
  - applied to main critical technologies (suspensions, cryogenics, vacuum) + optical layout
  - Involving noise budget & science case tools
- Connection to top-level scientific requirements
  - computation of impact of design choices on sensitivity curve for various parameters (GWINC)
  - coarse estimation of the corresponding impact on science case vs design parameter(s) via simplified metrics
- Connection to civil engineering costing
  - compute detector layout envelope vs design option/parameter
  - coarse destination of the corresponding impact on civil infrastructure costing vs design parameter(s) via simplified criteria

Schedule of in-person workshops

- Some feedback after last weekly meeting against the choice of 10-12/2 for the first in-person meeting
    - new poll done, pointing to the week after
- Considering the availability of core team members, the best date for the first in-person meeting in Pisa will be **from February 18 to February 20**.
    - please note it in your agenda
    - we’ll circulate details on the organisation in the following weeks
- Best choice for the second workshop in Amsterdam is from March 18 to March 20
    - we’ll confirm the date ASAP

Sparse topics

- Next steps
  - Main WBS (sub)tasks to become (sub)sections on the shared Overleaf document
  - People in charge of tasks can start editing the sections to describe background information on technologies and optical layout
    - work plan organisation
    - system decomposition for requirements management
  - risk analysis meetings to be organised during the following weeks
  - proposed topics for next weekly meeting:
    - configuration brainstorming continued
    - preliminary criteria and tools for civil infrastructure cost breakdown
    - preliminary criteria and tools for performance risk evaluation
    - structure of in-person meetings
    - criteria for flexibility evaluation