Overview of the ET design and next steps on the ET roadmap

Michele Punturo

INFN Perugia

ET-0008A-17

Short history of the 3G and ET idea

- 2004: ILIAS - the Virgo and GEO communities participate to a I3 project funded in FP6 together to the underground lab laboratories
  - A fraction of a networking activity (N5-WP3), chaired by H. Lueck and M. Punturo, is devoted to the future “research infrastructures” for GW
  - First idea for a Design study, submitted but failed because of an unclear vision
- 2005: ESF funded an Exploratory workshop in Perugia titled “Toward 3G GW detectors”
  - We focused the concept of a 3G observatory and we agreed how to submit a proposal
- 2007: we submitted to EC a successful proposal for the conceptual design study a 3G observatory: Einstein Telescope

… Short history of the 3G and ET idea

- 2008-2011 ET design study realisation (funded by European Commission)
- 2011 ET Conceptual Design Report delivering
- 2012-2016:
  - Minor support from institutions (ASPERA R&D, national funds, …) waiting for detection

The present

- The GW detection(s) stimulated new activities on 3G
- Funding agencies are (too) slowly and progressively (and hopefully) understanding the importance of giving a future of this sector
- Activities are restarted/started among two directions:
  - Bottom-up
  - Top-down

Bottom-up activities

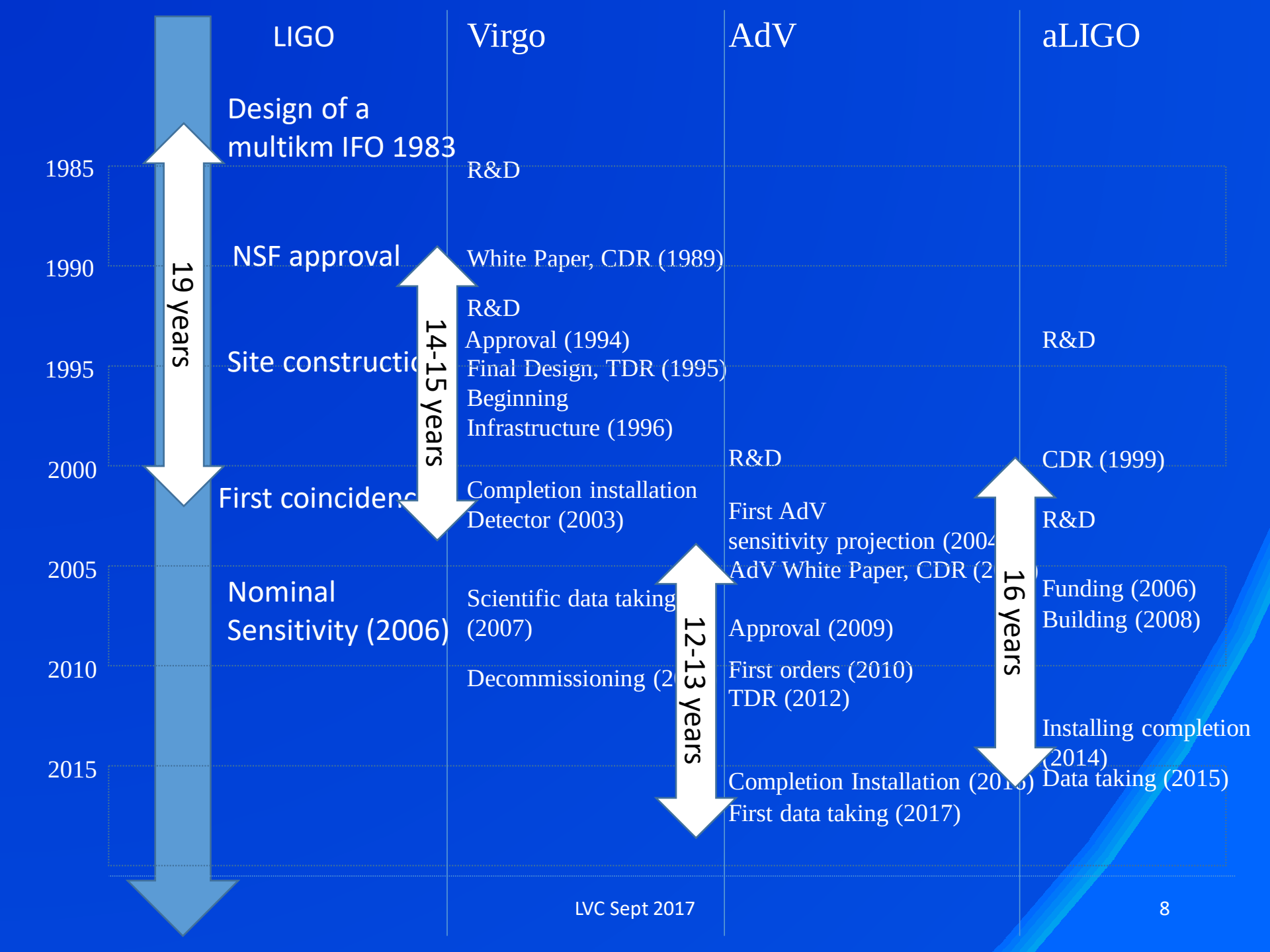
- Three initiatives in Europe, approximately related to the site investigations performed during the ET Design Study phase
  - ET in Hungary
    - Site identified, small underground lab realised, accurate seismic measurement performed and progressing
    - National academia support
  - ET in The Netherlands
    - Site identified, accurate seismic studies funded and ongoing
    - Strong political support at local and national level
    - Some level of involvement of Germany and Belgium
  - ET in Italy/Sardinia
    - Site identified, Seismic measurements performed in a pre-existing infrastructure
    - Underground laboratory recently funded by the regional government, strong interest of the local academia

Top-down

- Two main top-down actions relative to 3G:
  - GWIC 3G committee
    - Scientist initiative
    - Regular meetings every 15 days
    - Global vision:
      - Science case for a global 3G network
      - Definition of the common enabling technologies
      - Coordination of R&D activities
      - Preparation of the governance of a future network of GW
  - GWAC
    - Funding agencies initiative coordinated by NSF
    - Meetings every O(year)

The future

- To have ET operative in the first years of 2030 decade
- Is it too early or too late?
  - GW detector realisation requires a long process (~15 years between CDR and first operations)


LIGO
Virgo
AdV
aLIGO
Design of a multikm IFO 1983
1985
R&D
1990
NSF approval
White Paper, CDR (1989)
19 years
14-15 years
R&D
Approval (1994)
1995
Site constructi
Final Design, TDR (1995)
Beginning Infrastructure (1996)
R&D
2000
CDR (1999)
First coincidenc
Completion installation Detector (2003)
First AdV sensitivity projection (200
R&D
2005
AdV White Paper, CDR (2
Nominal Sensitivity (2006)
Scientific data taking (2007)
Funding (2006)
Building (2008)
Approval (2009)
12-13 years
16 years
2010
Decommissioning (2
First orders (2010)
TDR (2012)
Installing completion (2014)
2015
Completion Installation (201
Data taking (2015)
First data taking (2017)

ET time?

- FCC (Future Circular Collider) discussed during LIGO/Virgo-CERN meeting
  - 80-100km long tunnel close to LHC
  - Expected Excavation time 7 years
  - ET excavation cannot be too shorter

Why we are here?

- Global effort (GWIC):
  - Scientific potential of a 3G network justifying the investment
  - A panorama of the enabling technologies and a coordinated R&D effort at the global level
  - Agreed and shared roadmap toward 3G
- ET specific effort:
  - A preliminary version of the ET - TDR to be submitted to the appropriate roadmapping organisations, possibly either integrated or in parallel with Cosmic Explorer
    - ESFRI in Europe (2019)
    - Decadal survey in USA?

Next steps

- Next steps in 3G evolution needs still to be defined also thanks/within the 3G GWIC sub-committee
- My personal vision:
  - End 2018:
    - 3G network science case
    - Revised ET CDR with TDR elements
      - Better cost estimation
    - General agreement in GWIC+GWAC/APPEC on the strategy to be pursued
  - 2019: submission of the ET project to the ESFRI roadmap with:
    - A very short ET site candidate list* and a global strategy where ET is the (first) observatory of the network
  - 2022: Site selected, funding strategy defined
  - 2025: Begin of the excavation works

*ET sites list (still personal view)

- ET MUST be a pan-European initiative, possibly inserted in a global strategy
  - If we repeat the errors of the past in GW research (separation of the Virgo and GEO efforts), we will repeat also the same difficulties
- We should present to ESFRI a very short list of sites (1-3) with a clear list of countries supporting these candidates and a defined decision mechanism and timing. The role of each country obviously will change according to the selected site, but there should not be renunciations.

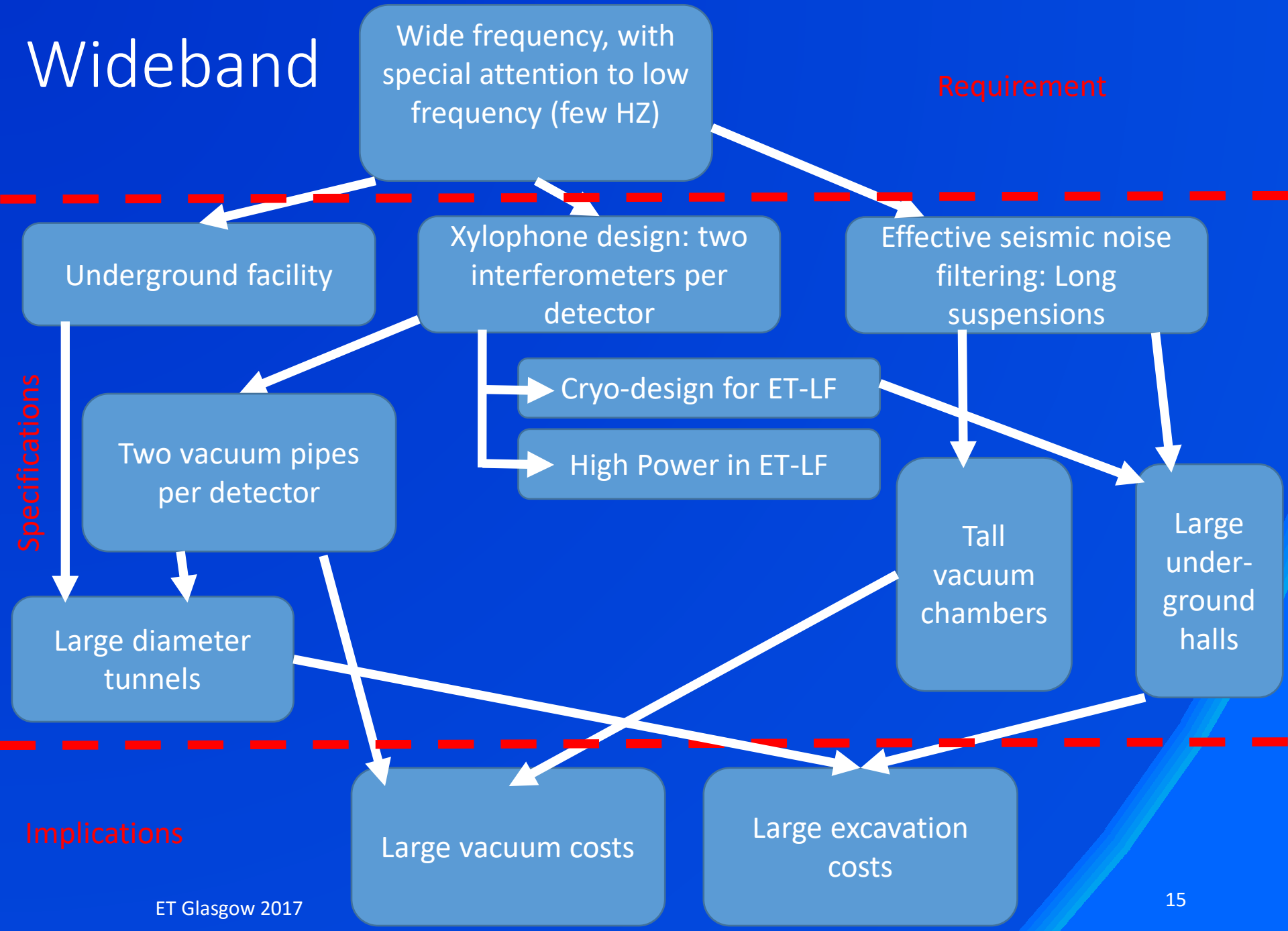
Discussion points

- If we agree that we are here to initiate a path of update of the CDR in order to have a (draft and partial) TDR hopefully at the end of 2018, we should identify what are the elements to be discussed
- In the following slides I try to give my (partial) view of the points that need urgently a review
- Let start from the infrastructure

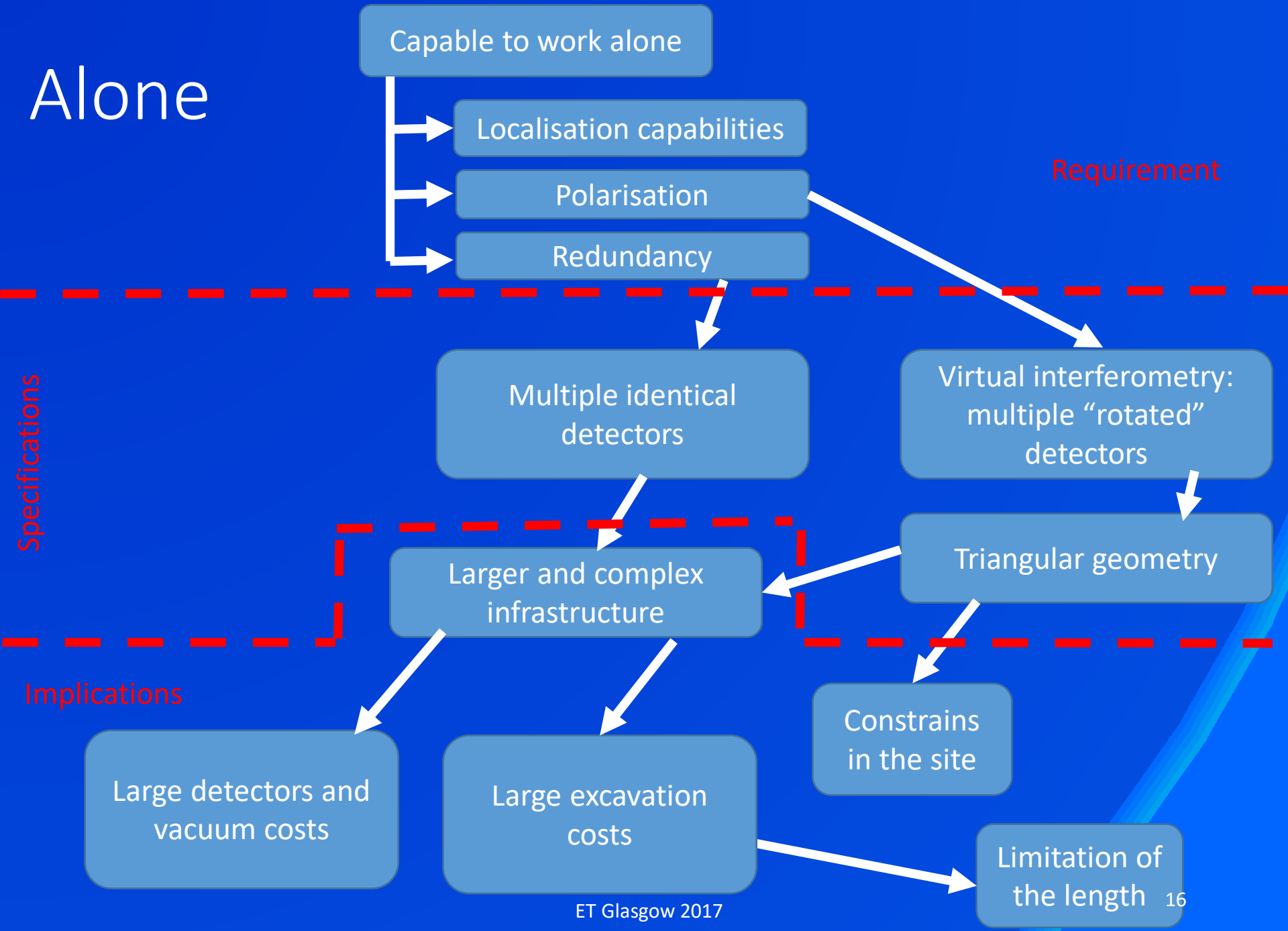
The 3G idea of ET

- To realise a 3G new GW observatory
  - 3G: Factor 10 better than advanced (2G) detectors
  - New:
    - We need a new infrastructures because
      - Current infrastructures will limit the sensitivity of future upgrades
      - In 2030 current infrastructures will be obsolete
  - Observatory:
    - Wide frequency, with special attention to low frequency (few HZ)
      - Stellar mass Black Holes
    - Capable to work alone
      - Localization capability
      - Polarisations
      - High duty cycle: redundancy
    - 50-years lifetime of the infrastructure
      - Capable to host the upgrades of the hosted detectors

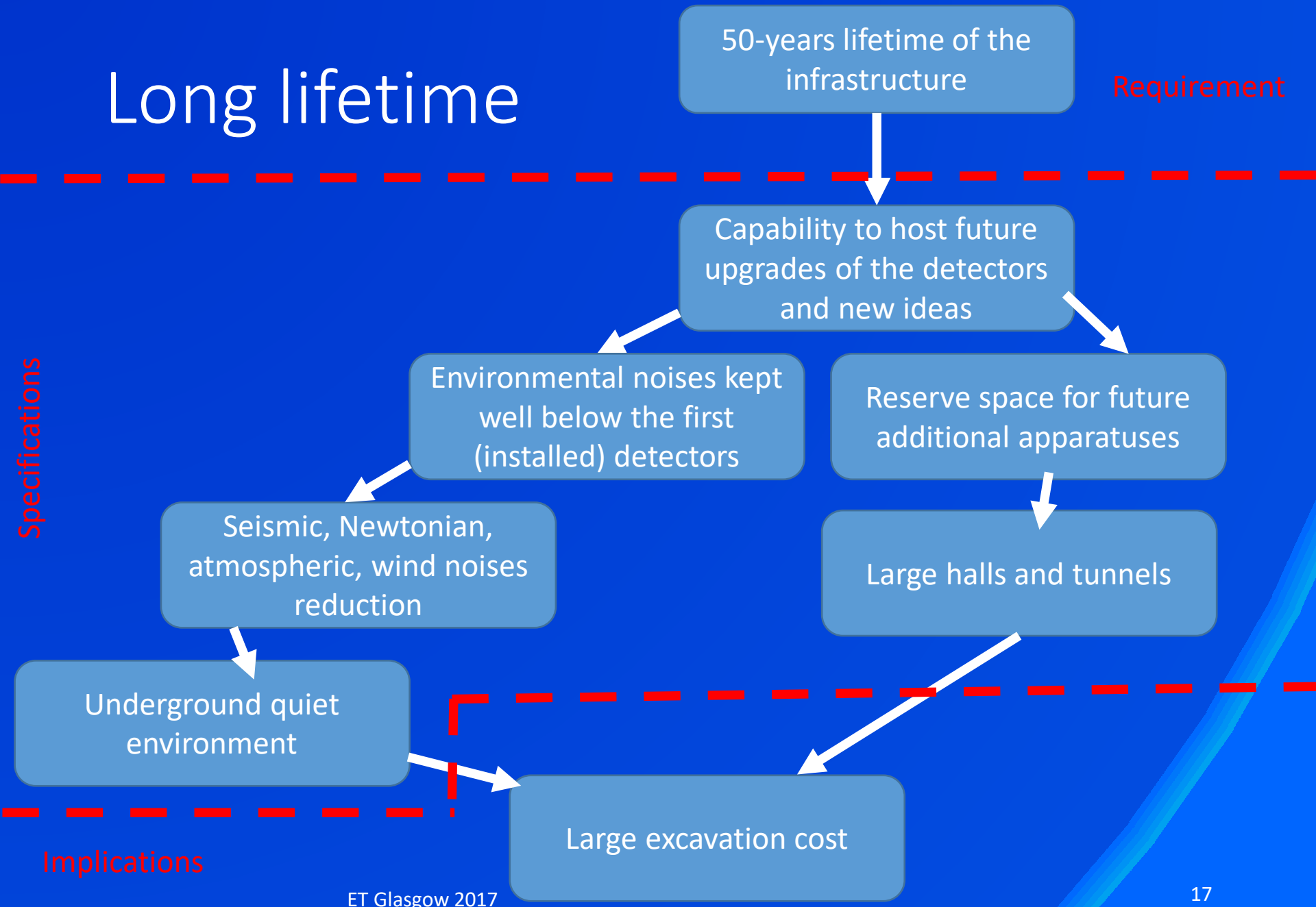
Wideband


Wide frequency, with special attention to low frequency (few HZ)
Requirement
Underground facility
Xylophone design: two interferometers per detector
Effective seismic noise filtering: Long suspensions
Specifications
Cryo-design for ET-LF
High Power in ET-LF
Two vacuum pipes per detector
Tall vacuum chambers
Large under-ground halls
Large diameter tunnels
Implications
Large vacuum costs
Large excavation costs

Alone


Capable to work alone
Localisation capabilities
Polarisation
Redundancy
Requirement
Specifications
Multiple identical detectors
Virtual interferometry: multiple “rotated” detectors
Triangular geometry
Larger and complex infrastructure
Implications
Large detectors and vacuum costs
Large excavation costs
Constrains in the site
Limitation of the length

Long lifetime



Questions

- Is it possible to mitigate the “implications”, preserving the requirements?
  - We need new ideas/solutions
  - For example, is Xylophone design still “a must”?
- Are the requirements still valid?
  - 3G network makes ET pointing capabilities not necessary
  - Stability of the current AdV detectors, multi-observatory strategy make redundancy not mandatory
- To measure polarisations is a key component:
  - How much it must be concentrated in a single observatory is related to the global network composition and to the level of integration of the 3G project
    - Preserving it could be a risk reduction element

Few elements of discussion on ET technologies

(partial and incomplete view)

Low Frequency (1)

- ET-LF design of the seismic filtering system is based on the Virgo SA experience
  - Quite successful in terms of performances
  - Long lasting experience on this solution (with some issue, like blade fragility)
- But a 17m tall tower impacts on the requirements of the experimental halls and vacuum chambers
  - We should compare LIGO experience in terms of “compactness”

Low Frequency (2)

- Newtonian noise subtraction
  - In the ET Design Study, sensitivity curve has been computed without using Newtonian Noise subtraction
  - CE more recently introduced a factor 10 subtraction
  - What is achievable under ground?
- Is it worth to update the ET-D sensitivity curve?

Low frequency (3)

- Cryogenic payload:
  - Where we are about suspension material and design?
  - Silicon suspension wires technology is still an option?
  - What we learn from Sapphire suspensions in KAGRA?
  - Is 10K operating temperature still the solution?
  - What we lose/gain going to 110K adopting Voyager design?

Test masses

- What is the current understanding of the thermal noise and absorption quality of the Silicon test masses?
- What is effective geometry we can purchase?
- What happens if we update the specifications in the design study?

Coatings

- How much are we progressed in understanding the coatings at low temperature with respect to the ET design study?
  - New ideas on coatings (nano-layers, crystalline, …)

Optical Design

- The design based on Michelson interferometers with Fabry-Perot cavities demonstrated its validity
- Do we have solid reasons to believe that the evolution of this design will encounter a show stopper?
  - Do we need a revolution?
  - What is the eventual impact on the infrastructure?
  - What is the impact of the required squeezing technologies (filter cavities, …)?
  - Are LG higher modes still a possible technology?

High frequency

- Are 3MWatt still realistic in the ET-HF cavities?
- Should ET-HF be underground?
  - Could we have two different locations for ET-HF and ET-LF?
- What is the technology for ET HP laser?

Conclusions

- This is the first ET design update workshop:
  - No conclusions are available
- My hope is to arrive, at the end of this week, with a series of teams that identify a set of urgent updates of the ET design study and will work on it in the next months
- Currently we have no financial support, but contacts with the funding agencies are in progress to improve the situation.