

EINSTEIN
TELESCOPE

Geometry Comparison Report and the cost estimate. How to link with COMPASS?

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ET cost estimate: context

- In the past the only cost estimate was given in the ESFRI document (TDS ET0000A-20). This, even though it was an excellent practice (and the only possible) at the time, suffers of incompleteness of the systems architecture and from the fault of an integration plan, the cost being surely underestimated. Cost around 2000 Meuros.
- Now we have:
 - 1) HC preparing the bid with CI and TI estimated provided by engineering companies. The boundaries for Technical Infrastructures are still to be defined. **At present, in the GCR we ARE NOT taking into account Civil and Technical infrastructures**
 - 2) In the framework of the Geometry comparison report (GCR) the BGR ask ETO to provide a cost estimate based on site independent elements. Therefore, ETO is providing estimates for the detector and other cost drivers interfaces systems (Cryogenics, Clean Rooms, Scaffoldings, Boreholes) in the framework of the Geometry comparison report. Attention, the GCR is supposed to be site independent (to make it more difficult...☺)

For point 1 I have no details...I can introduce point 2

The Cost Estimate

- Main problem : ET is not a project
- There is no functional OBS -> No responsibilities structures -> No WP, No WBS, No Schedule, no coherent integration plan....
- At present ET is represented by a set of organizational structures which operate in different contexts but always seek to replace the project structure...
- Is this means that we cannot do anything? NO, it only means that particular attention must be paid to the **involvement and roles** of the various stakeholders, **the context of the activities** and their **boundary conditions (initial assumptions)**.

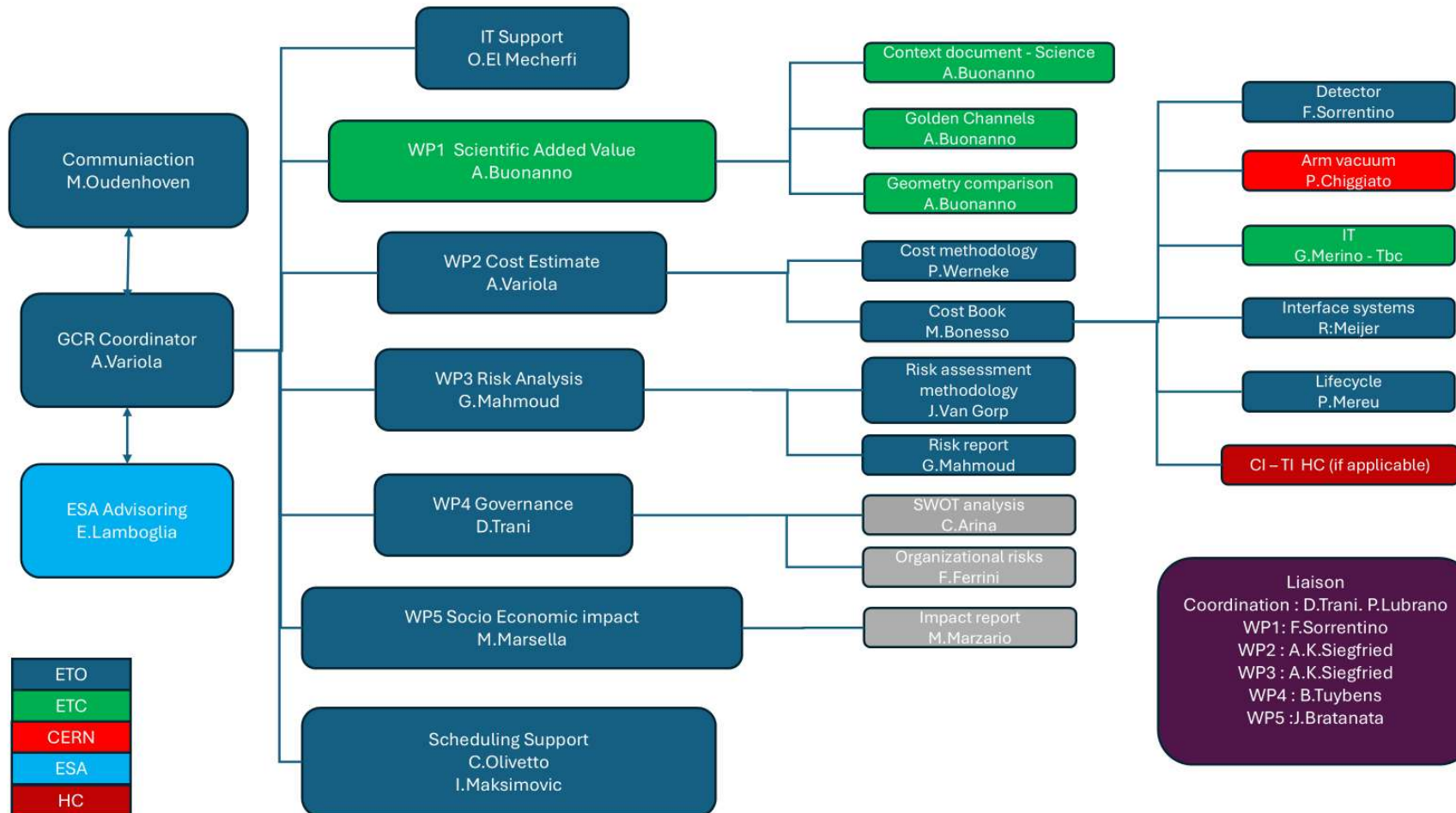
The Geometry Comparison Report

ETO is asked to provide, for end September 2026, a report on the geometry comparison, considering site independent drivers. This report is based on five main topics:

- 1) The scientific added value
- 2) The cost estimate
- 3) The risks assessment
- 4) The governance
- 5) The socio-economic impact

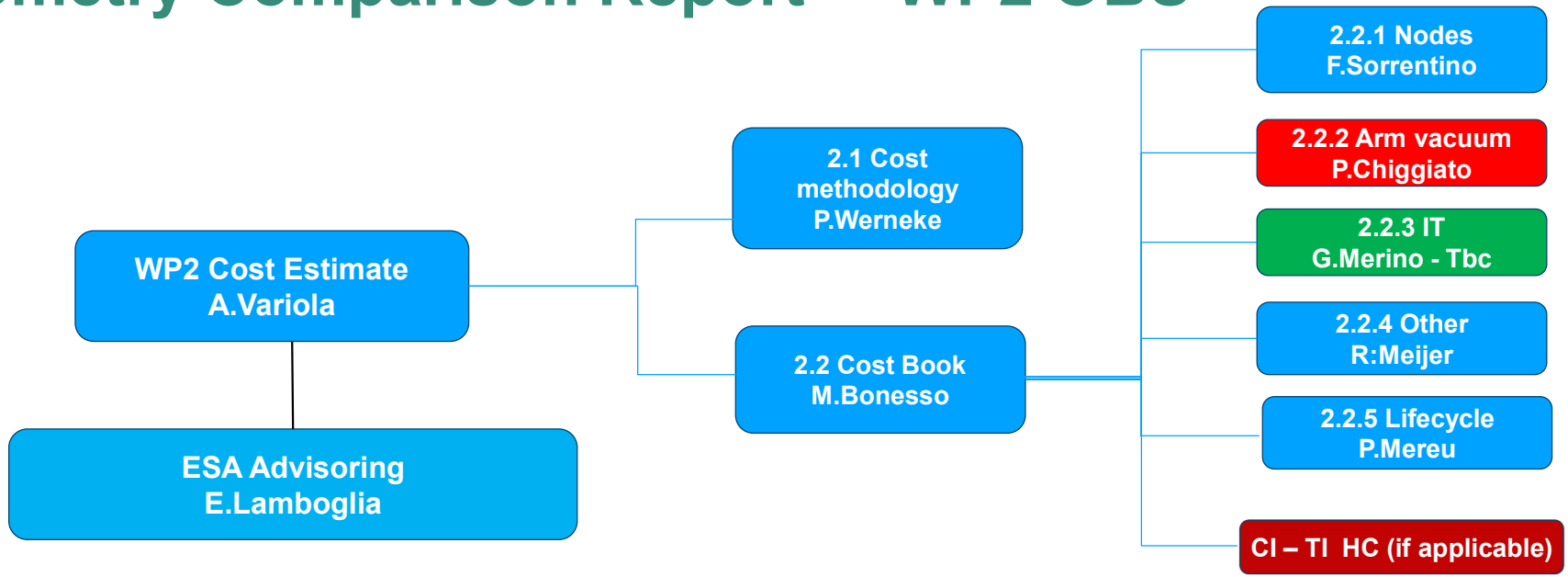
To be managed as a **project**.

GCR - OBS



- ETO
- ETC
- CERN
- ESA
- HC

Geometry Comparison Report – WP2 OBS



ETO
ETC
CERN
ESA
HC

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Civil and technical infrastructure and Compass

- As said, at present we have not access to this information, but a dynamical context can change things.
- Engineering is in the hand of competent companies that are collaborating with HC, thanks to established contracts. But these started when a defined context for the bid do not exist. Now SSCWG will provide this context, and the work of HC and companies will have to adapt resulting in a self consistent exercise.
- At the end it should be possible to integrate the two efforts in a coherent one, but we do not know when, and if this is applicable to Compass.
- But this is an occasion so we must be prepared to take this opportunity but not promising nothing, since the time schedule cannot fit with our timeline.

The GCR Cost Estimate. Main assumptions

- **Costing site independent** – the goal is to have a **comparison** between the cost for the triangle and the 2L **independently from the site dependent factors**.

ASSUMPTIONS:

- Design maturity level, no project structure (WBS), short timeframe -> hardware cost drivers. **Methodology to be adapted**
- **GCR will not take into account safety cost** (if not integrated), missing a safety plan.
- **YES Integration costs when possible, where defined**. **Attention**, site independent so integration hardware in Euro, manpower in FTE, lifecycle in units (kw..)
- **Costing based on PBS**, What PBS? Vacuum Arm -> CERN. Detector -> task force use the integrated system PBS (next slides) This will allow to easier the possible estimation of the integration efforts and to assure the completeness of the items' lists.
- Lifecycle costs have also been requested. -> commissioning and operation. **Dismantling is not included** for many reasons.
- For the PBS we identified as **cost drivers : Nodes, Arm Vacuum, IT, Others (tbd), Lifecycle associated costs**.
- At present GCR is **not supposed to provide any quotation about civil and technical infrastructures** that are in the Host Consortia attribution. A communication channel has been opened.
- **It is not a design to cost or trade off analysis**: cost is not a constraint or an optimization parameter. We will work with the 'dummy list' of elements

WP2 Tasks

Cost Estimate by task

2.2 to provide a first cost book release for both configurations. This will take into account: PBS based, Design maturity, Project management context. Supposed to set a coherent context and templates for data acquisition and analysis.

2.2.1 to provide the cost estimates for the ET detector based on nodes -> definition from the integrated system PBS. PBS breakdown has to be finalized up to the 'tender' Tier. BOM to be developed to provide number of elements in the two configurations

2.2.2 to produce a cost estimate for the arm vacuum. Considered in the costing exercise performed by CERN, under the ETO – CERN collaboration contract. Mature design with bottom-up approach, to be translated in the task 2.2 defined format. First definition of Arm/detector interfaces provided (see slide..)

2.2.3 to provide the cost estimate for the IT Infrastructures. A revision of the existing PBS is ongoing for this cost exercise. Due to the dynamical aspect of IT it is possible that sometimes scenarios will be considered.

2.2.4 to assess any other cost driver 'hidden' in the attribution or in the interfaces : cryogenics / clean rooms / scaffolding / seismic network....Cost estimate will be so taken into account.

2.2.5 to provide of POSSIBLE list of Lifecycle items to be estimate and their costs (site independent so Euro, FTE, kW..) The lifecycle will be defined by: procurement, commissioning and operation, so here OPEX

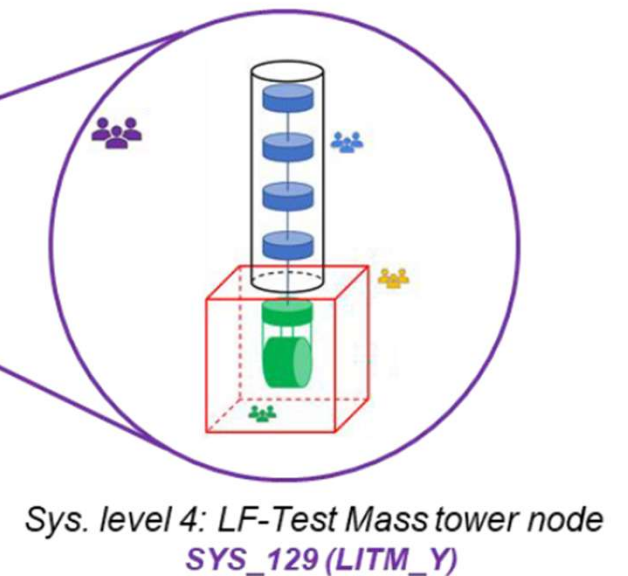
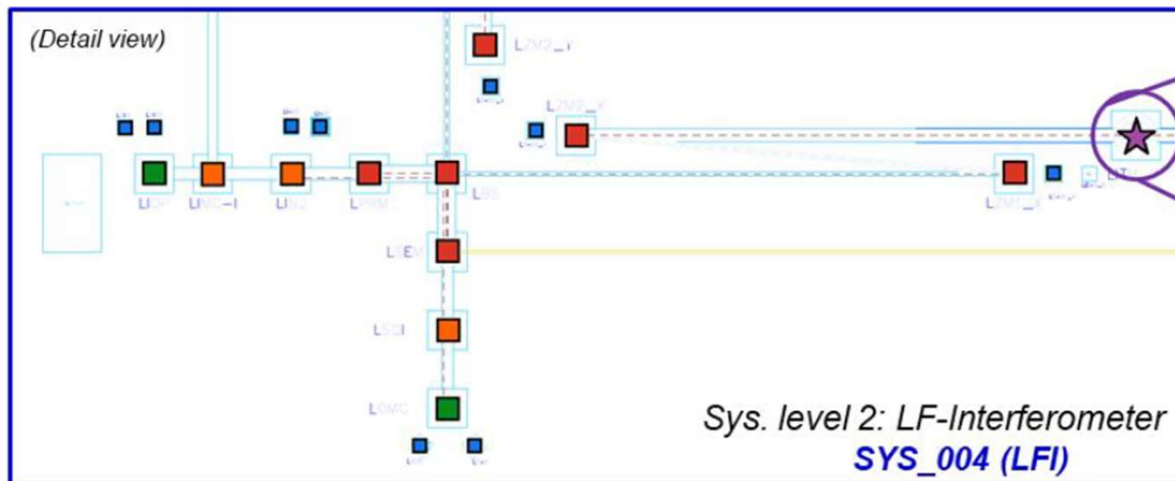
Interfaces 2.2.1 – 2.2.2

CERN will take care of all hardware in between the two gate valves at the entrance of the 15 (10) km pipes, i.e. including pumps, baffles etc.

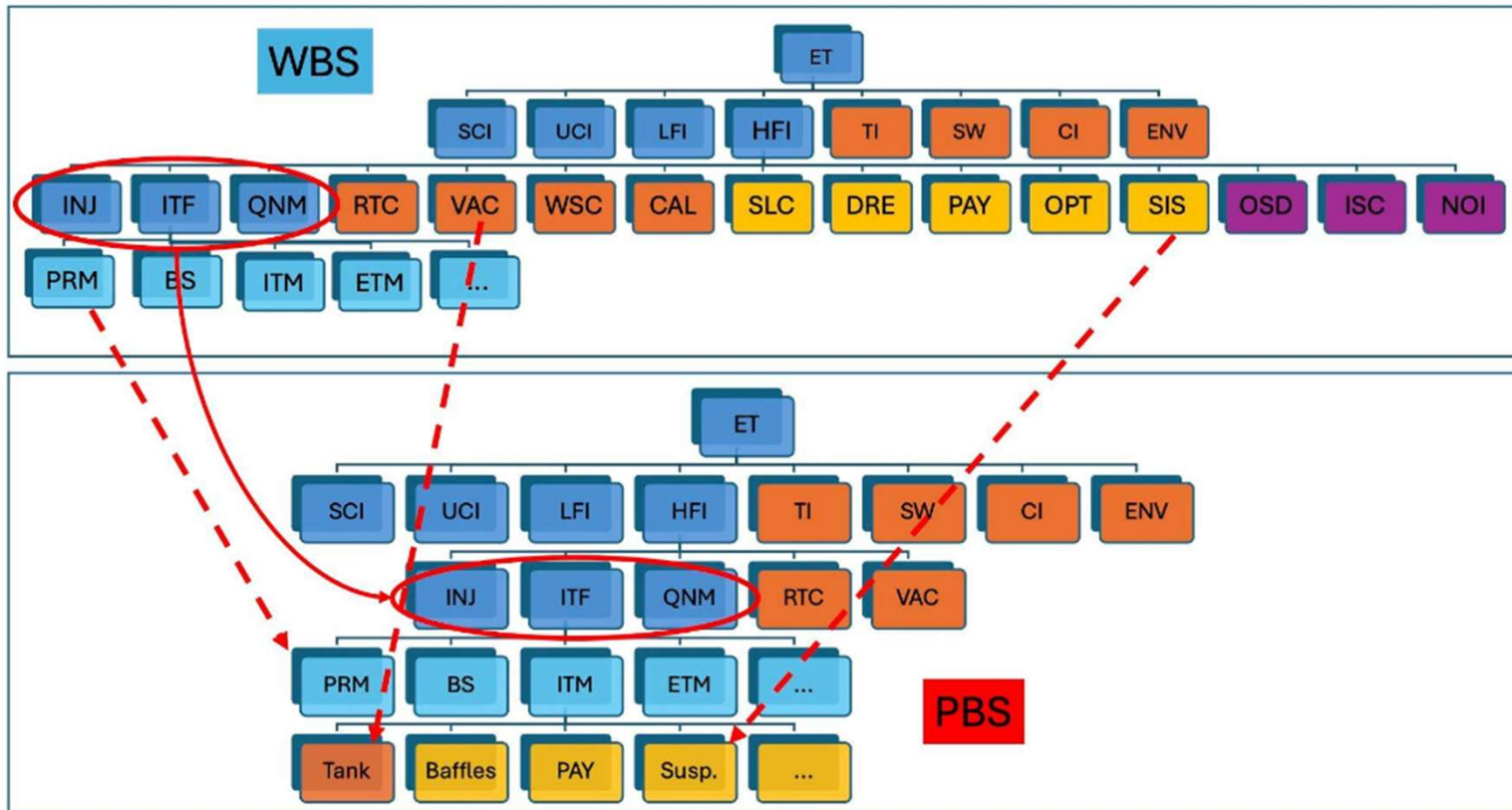
- arm vacuum task will also include the mechanical structure to support the pipes;
- arm vacuum task will also estimate the necessary integration work for pipes installation;
- arm vacuum task will also estimate the electrical energy requirements for pipes bake-out;
- strong interconnections -> arm vacuum task will also include the cost of all filter cavity pipes; nodes task team will provide functional requirements for filter cavity pipes;
- arm vacuum task will not estimate the cost for cabling; however they will provide the number and type of needed connections; a cost estimate can be inferred by applying the methods developed within the nodes task for cabling;
- some equipment items will be common to nodes task, e.g. baffles, pumps, valves; common items will be eventually compared, and the final cost estimate will be homogenized.

2.2.1 PBS methodology

- High-level system captured in breakdown levels 1-3
- *Nodes* (ex. integrated towers) captured at 4th breakdown level
- Integrated-system breakdown stops at level 4
- Tower subsystems (>lv. 4) in PBS1.0



2.2.1 – detector - Mapping functions from (virtual WBS) to PBS



- WSC: Wavefront Sensing & Control
 - CAL: Calibration
 - SLC: Stray Light Control
 - DRE: Detectors & Readout Electronics
 - OPT: Optics
 - SIS: Seismic Isolation System
 - OSD: Optical Simulation & Design
 - ISC: Interferometer Sensing & Control
 - NOI: Noise Budget
-
- SCI: Surface Civil Infrastructure
 - UCL: Underground Civil Infrastructure
 - LFI: Low Frequency Instrument
 - HFI: High Frequency Instrument
 - INJ: Laser & Injection system
 - ITF: Interferometer
 - PRM: Power Recycling Mirror Tower
 - BS: Beam Splitter Tower
 - ITM: Input Test Mass Tower
 - PAY: Payload
 - ETM: Terminal Test Mass Tower
 - QNM: Quantum Noise Mitigation system
 - RTC: Real-Time Control system
 - VAC: distributed Vacuum systems
 - TI: Technical Infrastructure
 - SW: Software & Data handling
 - CI: Computing Infrastructure
 - ENV: Environmental Monitoring

Task. 2.2.5, starting considerations

- Reference:
 1. GUIDELINES ON COST ESTIMATION OF RESEARCH INFRASTRUCTURES StR-ESFRI - Support to Reinforce the European Strategy Forum on Research Infrastructures – by CSIL – the Centre for Industrial Studies.
 2. ESA Cost Engineering Handbook – Tailored version for ESA/ETO
 3. Einstein Telescope PBS (ET wiki).

- Identification of the costs to be included in the LifeCycle (OPEX, or is there something more?):
 - a. Utilities (electricity, water, ...);
 - b. Consumables (technical gases, fuels,);
 - c. Replacement parts (is scheduled/ordinary maintenance cost part of LC or Design costs?);
 - d. Extraordinary maintenance (manpower and parts) ? ;
 - e. Experiment personnel (FTEs);
 - f. Services (on-call technical staff, safety, guards, canteen, foyer, reception, library,).

- Question 1: Is bake-out to be included in LC? Or is Bake-Out part of the last part of the commissioning phase of ET?
- Question 2: Where the costs should be taken from?

Methodology

Reference and main methodologies

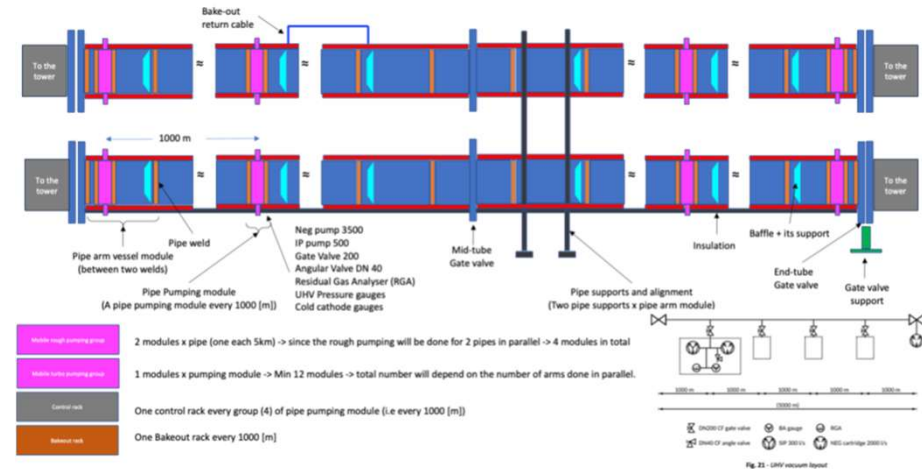
- Reference ESA engineering handbook (E.Lamboglia advisor). Other standards have been consulted .
- Four cost estimate methods : analogy, expert judgment, parametric, bottom up. These must be tuned with the maturity level of the design and to the data availability.
- Methodologies can be updated if we are able to increase the level of details of the system architecture and of the elements engineering.

CERN Method(s) used for the preliminary cost estimates

- A class estimate has been provided and adapted to the maturity of the equipment.
- Multiple estimation methods have been used and adapted to the case:
 - Expert judgment and engineering bottom-up estimate for First-Of-A-Kind equipment.
 - Cost benchmarking and parametric scaling factors for similar existing equipment.
 - Off-the-shelf equipment (vendor quotes or catalogue prices) and well-known market rates.
- Preliminary sanity checks have been included in the models:
 - Benchmarking against similar projects (LIGO, VIRGO, KAGRA)
 - Top-Down vs Bottom-Up comparison
 - Unit Cost Verification (€/kg for stainless steel, €/m for vacuum pipes)

CERN Method(s) used for the preliminary cost estimates

- From the baseline scope, a PBS has been created that includes all the components.
- From the technical design, the properties and the quantities have been derived (i.e. km of tubes, number of UHV pumps, km of cables, etc.).
- With the above, a cost model has been developed that include an estimate for each PBS line and grouped in FIVE main headings:
 - Vacuum pipe
 - Filter Cavities
 - Pipe Bake-out system
 - Pipe vacuum system
 - Vacuum monitoring and control



Estimate datas available

- 1) System decomposition in three level.
- 2) The last level must be 'ready for costing' - TENDER LEVEL
- 3) Name of the component/system estimated
- 4) # for both triangle and 2L (BOM)
- 5) TRL (<https://horizoneuropencppportal.eu/sites/default/files/2022-12/trl-assessment-tool-guide-final.pdf>)
- 6) AACE maturity level. AACE International Recommended Practice No. 18R-97:
COST ESTIMATE CLASSIFICATION SYSTEM – AS APPLIED IN ENGINEERING, PROCUREMENT,
AND CONSTRUCTION FOR THE PROCESS INDUSTRIES
(<https://aheinc.ca/wp-content/uploads/2018/12/AACE-Cost-Estimate-Classification-System.pdf>)

7) Unit Price

8) Methodology applied (Should be coherent with Maturity level)

9) Cost driving requirements (if possible)

10) Integration costs :

a) If they are included in the offer in euro

b) If hardware needed for integration, in euro

c) Additive manpower for integration in FTE

d) Power in kWh

A document for cost requirements

Tower Type 3

Real Time Control (RTC)

Vacuum (VAC)

Wavefront Sensing and Control (WSC)

Calibration (CAL)

Stray Light Control (SLC)

Detection and Readout Electronics (DRE)

Payload (PAY)

Optics (OPT)

Seismic isolation System (SIS)

Cabling (CAB)

Data Acquisition (DAQ)

Real Timing computing (RTPC)

Tank

Pumps

Hardware (HWS)

Ring Heater (RH)

CO2 Projectors (CO2)

Photon Calibrator (PCAL)

Newtonian Calibrator (NCAL)

Active Baffles

Passive Baffles

Photodetectors (PD)

Electronics (ELE)

Core

Auxiliary

Core

Auxiliary

Mechanics (MEC)

Electronics (ELE)

Example : Breakdown from PBS

Example: equipment ready for costing

- Laser system. If procured in high tech companies (Thales, Amplitude ...) on specification (tender/procurement) the breakdown stop at that Tier .
- If custom design the laser should be broke down in its components like optics, amplifiers, electronics, controls etc etc
- Fous on find, with the chosen methodology, where we are able to provide the most accurate possible cost estimate (no stop for laziness 😊)

Example : ACE matrix

For maturity, consider the second and the third column

ESTIMATE CLASS	Primary Characteristic	Secondary Characteristic			
	LEVEL OF PROJECT DEFINITION Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges [a]	PREPARATION EFFORT Typical degree of effort relative to least cost index of 1 [b]
Class 5	0% to 2%	Concept Screening	Capacity Factored, Parametric Models, Judgment, or Analogy	L: -20% to -50% H: +30% to +100%	1
Class 4	1% to 15%	Study or Feasibility	Equipment Factored or Parametric Models	L: -15% to -30% H: +20% to +50%	2 to 4
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-Detailed Unit Costs with Assembly Level Line Items	L: -10% to -20% H: +10% to +30%	3 to 10
Class 2	30% to 70%	Control or Bid/ Tender	Detailed Unit Cost with Forced Detailed Take-Off	L: -5% to -15% H: +5% to +20%	4 to 20
Class 1	50% to 100%	Check Estimate or Bid/Tender	Detailed Unit Cost with Detailed Take-Off	L: -3% to -10% H: +3% to +15%	5 to 100

Analogy

Analogy
Expert judgment
Parametric (data available)

Bottom up

Notes: [a] The state of process technology and availability of applicable reference cost data affect the range markedly. The +/- value represents typical percentage variation of actual costs from the cost estimate after application of contingency (typically at a 50% level of confidence) for given scope.
[b] If the range index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%. Estimate preparation effort is highly dependent upon the size of the project and the quality of estimating data and tools.

Figure 1. – Cost Estimate Classification Matrix for Process Industries

Summary

At the end of this exercise what we have?

- 1) A well-defined detector PBS based on integrated systems
 - 2) A reviewed version of the IT PBS
 - 3) A WBS skeleton proposal for Detector, IT, CI and TI...still work to be done
 - 4) An underestimate cost estimate for the detector, IT, Interfaces, lifecycle
 - 5) HC will have costs for CI and TI (when final version?). Release Bid constrained
 - 6) We will not anyway have a project structure
-
- With this what we can do in COMPASS?

COMPASS: Two scenarios

- 1) Restart the whole process to have a rigorous (standard) cost estimate based on a WBS
- 2) Further develop the integrated system PBS, defining also the interfaces and maintain the present cost estimate methodology. WBS will be harmonized later

PBS based

Minimize the underestimation!!!

- 1) FORGET THE SITE INDIPENDENT CONSTRAINT!!!! (real added value for COMPASS)
- 2) Maintain (at least) the present structure for work.
- 3) Add to the configuration team an interface manager. Interfaces have to be defined.
- 4) Study integration procedures. These will be included in the system costs. This needs at least two profiles of integrators.
- 5) Analysis if integration procedures are extended to lower level than the nodes.
- 6) Follow up of the design maturity, to provide parametric or bottom-up based estimates.
- 7) Improve the scenario for IT infrastructures
- 8) Integrate a risk response process for contingencies.
- 9) Define a true validation plan for lifecycle (need expert physicist)
- 10) Include safety costs, at least fix a scenario for this (as interfaces)
- 11) Refine analysis for cost estimate accuracy

This will produce a reliable result, but out of standards

WBS based

Restart the process, follow the standards!!!!

- 1) FORGET THE SITE INDIPENDENT CONSTRAINT (real added value for COMPASS)
- 2) Define WP and OBS from the first 3 Tiers of the PBS
- 3) Define responsible for the studies
- 4) Select the WBS lifecycle (Hybrid?)
- 5) Select the WBS type (deliverable oriented?)
- 6) Shape the WBS starting from PBS
- 7) Integrate the HW cost estimate done in GCR in the WBS costing
- 8) Evaluate integration cost
- 9) Define a scenario for IT WBS
- 10) Provide a Validation plan for the lifecycle
- 11) Introduce a risk response for contingencies

PBS based, pros and cons

- Pros:

- 1) We start from some/a lot of work done with attention paid to quality
- 2) The organizational structure exists, needs to be maintained
- 3) A PBS based cost estimate can be expanded later in a WBS based one
- 4) At present we have not organizational structure, PBS will be focused on HW and its integration
- 5) Does not need to have any preliminary decision (lifecycle, WBS type)

- Cons

- 1) Not including some integration aspects (only possible with WP and scheduling). Underestimate
- 2) Not including the part of Organizational and Project effort. Underestimate
- 3) Maturity and Accuracy based on interpretation of models, not always fitting with scientific projects. No standards -> accuracy models to be adapted
- 4) No information on 'how' we want to spend (in kind, mass production...)
- 5) Need integrators and interfaces management

WBS based, pros and cons

- Pros:
 - 1) Rigorous methodology. Easy to evaluate accuracy
 - 2) Allow the full integration of all the aspects, contingencies, lifecycle, mass production, safety
 - 3) Provides reliable estimates, standards can be applied. Easy to implement parametric evaluation
 - 4) Pillar for the future work, when ET will be structured
 - 5) Generate also a first version of the master and detailed schedule
 - 6) Budget plan will allow starting the approach on how to implement EVM

- Cons
 - 1) Need new organization, manpower with **COMMITMENT** from different stakeholders, resources allocated
 - 2) Need to have any preliminary decision (lifecycle, WBS type)
 - 3) Need a long initial phase of definition, before to approach the cost estimate
 - 4) Need some validation procedures, so the definition of Hierarchical lines. Virtual project context
 - 5) Pros linked also to other PM activities (schedule, resources, risks....). Also, these need commitment from stakeholders
 - 6) Stakeholders must be managed

The real difference

- The WBS approach will allow to rely on standards to assess the accuracy of the cost estimate...but need a structural approach (a risk)
- The PBS one is a patchwork of different methodologies, so we can rely on our perception (and on reviews) that this method have a good reliability...this need to maintain (or to slightly increase) the present effort (not negligible).

Concluding...How to proceed?

- We have to start to discuss what model we want to apply...and decide, we have 8 months to be ready!
- Whatever decision needs a rapid feedback to stakeholders to engage the possible resources, to be ready to start with a good plan. This must be coherent with the present context!
- We must be operative, so free to manage activities and resources across the different organizational bodies.
- We cannot proceed haphazardly. These are the only possible scenarios, and the course of action must be discussed and APPROVED by ETO.
- We have to work as a single body, respecting organizational structures, involved stakeholders, existing processes and procedures and carefully considering the work already done.