EINSTEIN TELESCOPE

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Toward a harmonized and agile Risk management approach (aligned with MBSE)

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When were Risk Studies performed in ET by the ETO PO ?

Phase	Risk-Related Activity
2024 – 2025	- **ETO PO General Risk Campaign (starting June 2024)** : First General structured, collaborative risk campaign across **technical groups** (All ISB Subsystems : Interferometer Group , Optics Group, Suspension Group , Vacuum and cryogenics Group, ANM Group; and Engineering Department) - **It Delivers the First Full Risk Register for ET** - **TRL Assessments**
2025	- **Continuing with the ETO PO General Risk Campaign** : Review , other Stakeholders - **ETO Taskforce :** • **TRL assessments** • **Comparative risk studies** between different Configurations of 2L and Triangle Geometries • Flexibility (**DSM**) and Penalty of change (**trade-off analysis between designs and cost impact evaluation**) studies
Now	• Reviewing Risk Register + Taking actions ; Also learning lessons • Cross-cutting risk integration (identifying, analyzing, and managing risks that affect multiple **subsystems, teams, or domains simultaneously**) • Integrating, Risks into MBSE (Jama and 3DX) • Final Risk Management Plan with Lesson learned + Risk Report and Risk Registers

Outcome of the ETO PO General Risk Campaign

- **More than 200 risks** **(mostly technical)** identified and assessed across major subsystems (Interferometer, Active Noise Mitigation (ANM), Vacuum & Cryogenics, Optics, Suspension, Engineering Department)
- Risk identification was **strongly collaborated with technical and scientific teams**, ensuring ownership and technical accuracy.
- Moving from Assessing risks only to transforming **risk mitigations into real design enabler**.

Example on a Technical Risk from the ETO PO General Campaign and its impact on trade off

Factor	Value
Severity	5 /5
Likelihood	5/5
Overall Risk	High

Risk Description:

A risk that the required specifications for the ET-LF test mass (TM) substrates may not be met.

ET-LF lack of substrate availability in suitable dimensions (actually 45 cm diameter) and with suitable optical properties.

Cause:

The test mass substrates must possess **both large dimensions** **and** **exceptional optical characteristics,** including **low optical absorption and low birefringence**.

*At present, materials that meet these criteria (silicon and sapphire) are not available at the required **size** and **quality.***

Birefringence is a particularly significant challenge for sapphire.

Impact:

If the necessary substrates cannot be procured, the **ET-LF detector may not be constructed according to its current design.**

This would compromise its ability to meet scientific objectives, potentially requiring reductions in beam size and TM mass.

Suggested Mitigations :

- Continue parallel R&D efforts into both silicon and sapphire substrates ?!!!! ➔ **We may move start building/ highlighting PROJECT Requirements such as ET labs for developing R&D for ET**
- Investigate the viability of other materials designs.
- Conduct trade-off studies to assess the feasibility of tolerating higher optical absorption levels ?!!!! ➔ **Scope**
- Explore alternative optical layouts that are compatible with smaller mirror sizes ➔ **Configuration**

Impacts analysis - trade off : example on a cost variation scenario

Example :

If we suggest reducing the diameter of LF TM from 45 cm to 35 cm (to give more time for developing R&D) then the arm length will be maximum 10 KM

→ we can't construct a 2L configuration for ET with 15 KM armlength (we will be able to construct 10 KM 2L Configuration instead) and the triangle ET Configuration of 10 KM armlength won't be not affected.

Example on the cost change :

- **Cost Impact : Cost difference of possible 24,98 % reduction of the excavated volumes with respect to the 2025 2L Configuration (15 KM) one.**
- **The triangle cost remains unchanged.**

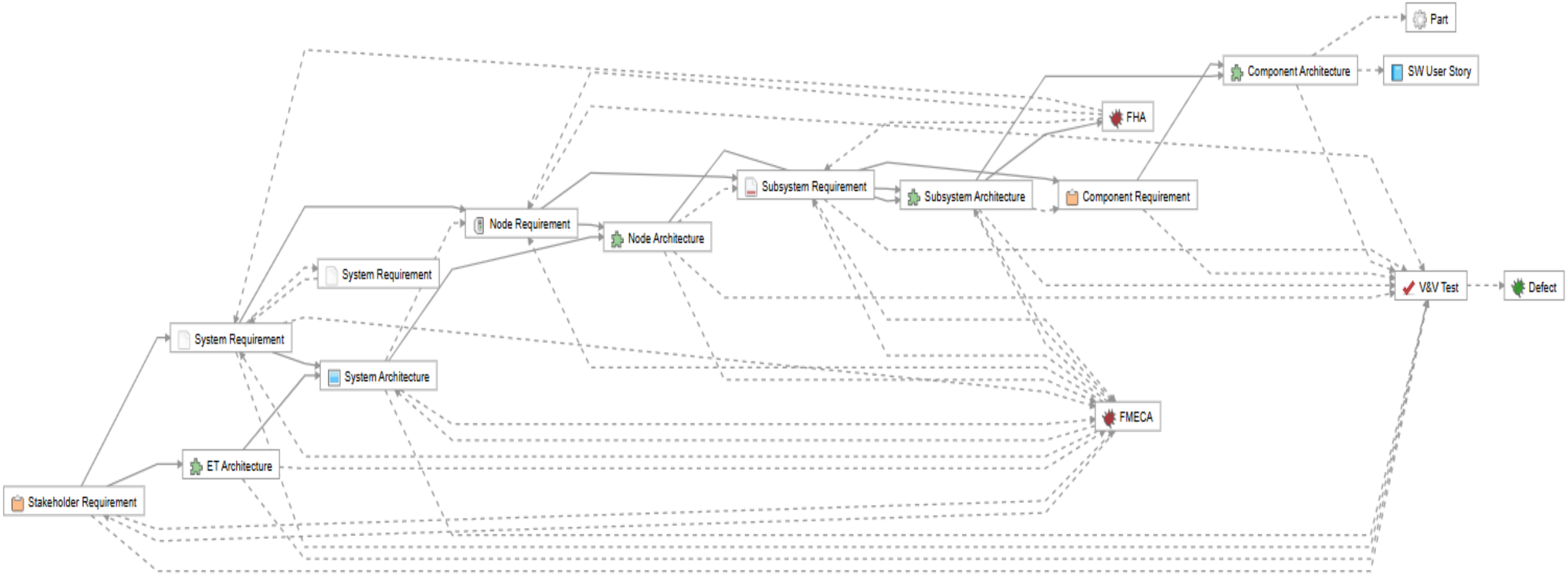
The trade off should take into account the impact of the length reduction on the scientific scope, also on the upgradability.

Rik Analysis using Excel Sheets

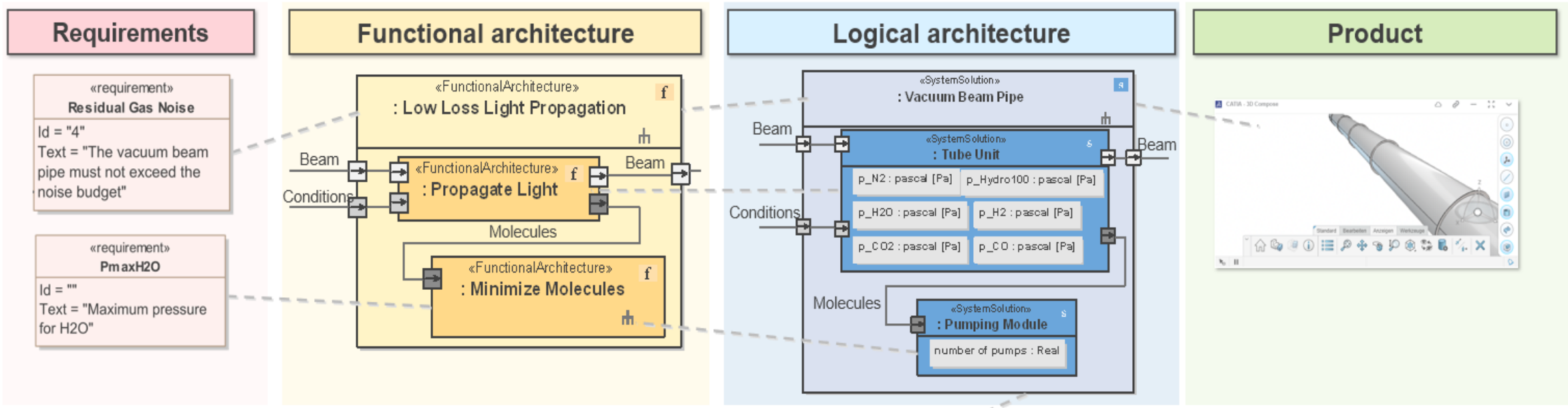
1st pass	Configuration	Risk ID	ID Nb	Group	WP	Product	Date	Risk Title	Risk Domain	Risk Cause	Risk Impact	Suggested mitigation	Severity before mitigation (Triangle)	Likelihood before mitigation (Triangle)	Criticality (Triangle)	Severity before mitigation (L Shape)	Likelihood before mitigation (L Shape)	Criticality (L Shape)	Comments	Risk Escalation Level	Risk Ownership (in collaboration with)	Risk Ownership WP	Residual Severity (Triangle)	Residual Likelihood (Triangle)	Residual Criticality (Triangle)	Residual Severity (L Shape)	Residual Likelihood (L Shape)	Residual Criticality (L Shape)
	<I	R.Op.Sc.	1	Optics	Input Output Optics		18.1.2025	Limited progress on 100 design	Schedule	Insufficient person power	Delay in design by at least a year	Increase FTE commitments to 100 from 0.1 FTE to several FTE. Have two co-chairs of the group, with at least one of them with significant FTE commitment.	4	5	20			•		Escalated to Management	ETO				•			•
	<I	R.Op.Tc.	1	Optics	Input Output Optics		18.1.2025	Constraints on ratio between cavities length	Technical		No coordination between Optics and Interferometer division	Define the interferometer control strategy, adjust the lengths of the different cavities to fit that strategy, and adjust the position of the covers by few tens of meters to respect the needed relations.	5	4	20			•	Length of the arm cavity, of the power recycling cavity and signal recycling cavity, and length of the second (or only) input mode cleaner have integer relation. The lengths need to be multiple of each other (or half multiple depending in some cases). This is needed so the radio-frequency fields have the right resonant or anti-resonant conditions.	Escalated to Management					•			•
	<I	R.Op.Tc.	2	Optics	Core Optics			ET-LF lack of substrate availability in suitable dimensions and with suitable optical properties	Technical	Test mass substrates with large dimensions, low optical absorption and low birefringence are required. Currently large enough and pure enough silicon/sapphire is not available. Birefringence is an issue for sapphire.	Scope risk - ET-LF could not be constructed in its current design (reduced beam size, test-mass mass).	Continued R&D of silicon and sapphire in parallel. Trade-off studies of the effect of accepting higher substrate optical absorption. Investigate modified optical layouts compatible with smaller mirror sizes. Investigate composite test mass designs.	5	5	25			•	TRL (International Collaboration .. CE)	Escalated to Project Steering Committee					•			•
	<I	R.Op.Tc.	3	Optics	Core Optics			ET-LF & ET-HF thermal noise/optical absorption non-compliance	Technical	Failure to meet coating thermal noise target or optical absorption target.	Reduced sensitivity (coating thermal noise), increased heat load (absorption)	R&D on coating materials and coating design (more human power maybe / Budget)	3	4	12			•	A lack of time to invest more in ET / They have the needed experience , they don't have enough time / Experienced people in Coating for the mirrors are needed (2 engineers / scientists are enough , if more it's better) / the fact that there's no funding from ET makes it hard to hire "experienced" people for this matter	Team-Managed					•			•
	<I	R.Op.Tc.	4	Optics	Core Optics			ET-LF & ET-HF coating uniformity/defect non-compliance	Technical	Potential issues with upscaling coatings to larger diameters (uniformity / point defects). Delay in developing new mirror production facility (two mirrors at once).	increased heat load (absorption), increased scattering (defects), increased arm mismatch	R&D on upscaling coating deposition (more human power maybe / Budget) (Hight confidence to guaranty the Results)	3	4	12			•	A lack of time to invest more in ET / They have the needed experience , they don't have enough time / Experienced people in Coating for the mirrors are needed (2 engineers / scientists are enough , if more it's better) / the fact that there's no	Team-Managed					•			•
	<I	R.Op.Tc.	5	Optics	Core Optics			Ice formation in ET-LF	Technical	Growth of ice layers on test mass surface due to cryopumping of water vapour from interferometer arms.	Increased optical absorption and thermal noise. Altered mirror reflectivity	Better vacuum. Design of better baffles etc. R&D of systems to remove ice e.g. heating mirror periodically / CO2 laser ablation of ice layer.	3	3	9			•		Inter-Group Collaboration					•			•
	<I	R.Op.Tc.	6	Optics	Core Optics			Damage of a Test-Mass/Beamsplitter	Technical	Damage during the installation of the suspensions or the transfer to the tower. Failure of the coating	Shutdown for >2 years for the inteferometer and extra cost.	Spare parts ready on the shelf.	4	2	8			•	Such a damage occured in the past in Virgo because of the break of a viewport.	Inter-Group Collaboration					•			•
	<I	R.Op.Sc.	2	Optics	Core Optics			Too long delivery time for the Test-Mass/Beamsplitter	Schedule	Blank manufacturing Polishing Coating	Delay	Start the supply in the early steps of the construction. Update regularly the lead time from vendors.	3	3	9			•	Polishing companies have currently lead times of 2 years for a couple of	Team-Managed					•			•
	<I	R.Op.F	1	Optics	Core Optics			Increase of the price for the TM/BS	Financial	Blank production is an energy consuming process Polishing	Huge increase of the total cost for the supply of		4	4	16			•	The price of Energy is increasing with the years / we don't have enough	Escalated to Management					•			•

Parameters | Risk Register | Dashboards | Optics Risk Register | Optics Parameters | V&C Parameters | V&C Risk Register | Quantitative Risk Assessment ...

Rik Analysis within MBSE (JAMA)



Risk Analysis within MBSE



Title	Type of Risk	Impact	Probability	Rating	Severity	Affected Items	Risk Rating Goal	Action Plan	Abatement Plan
Handling of Hea...	Security	4	3	12	3-High	Vacuum Beam Pipe	2	Avoid	Provide regul...
Confined Space ...	Security	4	3	12	3-High	Vacuum Beam Pipe	3	Control	Implement stri...
Vacuum Leaks	Technical	3	3	9	2-Medium	Vacuum Beam Pipe	3	Avoid	Rigorous testi...
Fire Hazards	Security	4	3	12	3-High	Vacuum Beam Pipe	3	Control	Implement the...

Risk Analysis within MBSE

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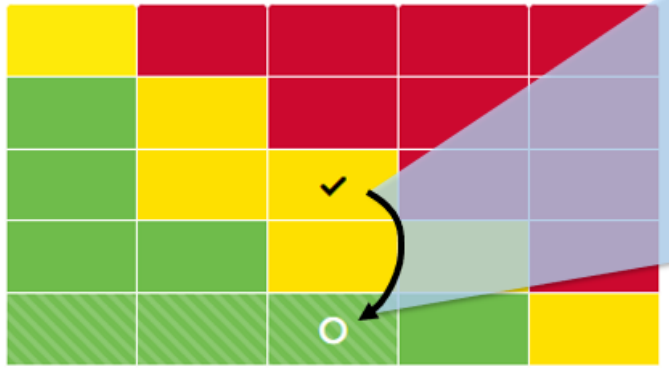
Vacuum Leaks

Risk Cause:
- Manufacturing defects
- Leaky joints and valves
- Failure in seals
- Thermal expansion

Risk Impact:
- Reduced vacuum quality
- System contamination

Risk Assessment: Medium



Abatement Plan:

E.g. Rigorous testing and quality assurance during assembly

Lessons Learned

- Shorter assessment cycles = more agility and faster decisions.
- Effective communication/documentation is key for alignment.
- Continuous stakeholder feedback strengthens buy-in and outcomes.
- MBSE integration enhances traceability and long-term learning.

Conclusion

Our Last Risk Activities :

- Enabled direct engagement with stakeholders to identify, assess, and mitigate project risks.
- Provided our first full experience, teaching valuable lessons.
- We now have data-driven insights to guide risk actions and decisions.
- Future campaigns will emphasize broader stakeholder involvement, ensuring diverse and comprehensive risk perspectives.
- A more adapted and tailored risk management plan (RMP) aligned with project-specific and stakeholder needs

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Thank You !