

Collaborative Design and R&D Directions for Next-Generation Gravitational-Wave Observatories

This document, prepared by Lisa Barsotti (MIT), Matteo Barsuglia (APC), Jan Harms (GSSI), summarizes the community discussion held during the GWADW 2026 workshop in Elba on May 17-23, 2026 and outlines a vision for strengthening collaborative design and R&D between ET and CE.

The slides prepared to guide the discussion and summarize feedback are available on the GWADW 2026 website:

https://agenda.infn.it/event/48986/contributions/298009/attachments/150687/230702/GWADW_CollabR&D-Closing.pdf

Introduction

The Einstein Telescope (ET) and Cosmic Explorer (CE) represent the next generation of gravitational-wave observatories. Together, they will define the future global gravitational-wave network and enable transformational advances in astrophysics, cosmology, and fundamental physics. Given the scale, complexity, and cost of these facilities, the community increasingly recognizes that a coordinated approach to detector design and technology development is essential.

Over the past several years, ET and CE collaborators have developed a number of successful collaborative activities. Examples include coordinated vacuum system design efforts, participation in common working groups (i.e, stray light mitigation), and the **neXt-Generation Collaborative Design (XGCD)** meetings hosted by Jan Harms and Lisa Barsotti, launched in 2024. These activities have provided valuable forums for sharing lessons learned, discussing technical approaches, and identifying common challenges. Notably, these collaborations developed largely from the bottom up, driven by practical necessity and common technical goals rather than by a formally structured coordination mechanism.

However, the rapid maturation of both projects, with fast progress in many areas, coupled with the logistic challenges in maintaining a close collaboration, raise an important question: is informal and ad-hoc collaboration sufficient to meet the needs of next-generation detector development?

As part of these conversations, another important question emerged: shouldn't the LVK, soon International Gravitational-Wave Network (IGWN), be the forum already created to strengthen collaborations?

Overall Objective

A recurring theme throughout the discussion was that collaboration should extend beyond periodic exchanges of information. Participants expressed a strong desire to build a more integrated framework that allows the global detector community to leverage its expertise efficiently and avoid unnecessary duplication of effort.

The scale of next-generation observatories makes it impractical for each project to independently develop every technology, tool, and subsystem. Success therefore means identifying areas where common solutions can be developed and shared. Potential examples include simulation frameworks, system engineering tools, real-time control architectures, detector modeling software, and selected subsystem designs.

Collaboration can also reduce technical risk. Joint development efforts allow design concepts to be tested by a broader community, improve confidence in critical decisions, and help identify potential shortcomings earlier in the design process. Shared R&D can also reduce overall costs by pooling expertise, infrastructure, and prototype development efforts.

More broadly, participants emphasized the importance of revitalizing the global gravitational-wave instrumentation community, and strengthening collaborations with groups which currently are not at the forefront of ET and CE design.

Key Open Questions for Detector Design

The discussion highlighted several important technical challenges that remain common to both ET and CE, and that motivate the need for a coordinated R&D effort. Many questions concern the validation of novel optical configurations and technologies that have not previously been implemented in operating gravitational-wave detectors. Examples include the performance of telescope systems positioned after the beam splitter, the implications of using different optical angles of incidence on the beam-splitter (rather than the standard 45 degrees), and strategies for simultaneously achieving high circulating power and high levels of quantum squeezing.

Infrastructure planning also emerged as an important topic. Because next-generation facilities are expected to operate for decades, design decisions made today must preserve flexibility for future upgrades and technological evolution. Furthermore, environmental sustainability and constructive engagement with local communities are becoming increasingly important considerations for large-scale research infrastructures, providing another area in which the ET and CE can benefit from sharing experiences and best practices.

Other areas that emerged during GWADW which would benefit from further discussion include a shared vision for the worldwide prototype facilities, pathways toward 10 dB

squeezing performance, Newtonian noise mitigation, advanced simulation tools, and the application of artificial intelligence to detector operations and design, just to name a few.

Participants noted that the community would benefit from maintaining a living list of critical open questions and prioritizing collaborative efforts around those topics.

Evolving the ET–CE Collaboration

The community discussed several options for strengthening collaboration beyond the current XGCD format.

One possibility is to continue the existing model while increasing the frequency and scope of discussions. Another is to establish stronger collaborations around specific technical areas where common interests are particularly strong, such as optical modeling, suspension systems, real-time controls, and systems engineering.

Participants also proposed organizing dedicated workshops, technical symposia, summer schools, and visiting-scientist programs to foster deeper connections among students, postdoctoral researchers, engineers, and senior scientists. Such activities would help build a shared technical culture while facilitating knowledge transfer across institutions and generations.

Several participants advocated for expanding access to technical documentation and encouraging joint technical notes and publications. Shared documentation can improve transparency, reduce duplication of effort, and accelerate progress on common challenges.

More formal organizational structures were also discussed. While no specific model was endorsed, there was broad agreement that the growing maturity of ET and CE warrants consideration of mechanisms that support sustained coordination and collaborative decision-making.

ET-CE and IGWN

An additional concern raised during the discussion was that next-generation detector activities currently sit somewhat outside the framework of the International Gravitational-Wave Network (IGWN).

While the primary purpose of IGWN is to address organizational issues for the network of current gravitational-wave detectors, we would like to raise the concern that by strengthening the ET-CE collaboration outside IGWN will likely amplify the separation between IGWN and next-generation detectors.

Finding solutions to simple practical problems like where to post the slides, how to share simulation data and even which meetings to attend (either on zoom or in person) are just some examples of how strengthening the ET-CE collaboration will de-facto create separate structures to the ones that the LVK/IGWN has already created.

Conclusions and Recommended Actions

The discussion revealed strong consensus that collaborative design between ET and CE should evolve beyond occasional exchanges toward a more structured and strategic partnership. The principal motivations are clear: reducing technical risk, lowering development costs, accelerating progress on critical design challenges, and maximizing the effectiveness of the worldwide gravitational-wave instrumentation community.

Several concrete actions emerged from the discussion. These include:

- revitalizing the XGCD effort,
- expanding joint working groups,
- increasing access to shared documentation,
- promoting collaborative technical publications,
- establishing training opportunities such as summer schools,
- developing mechanisms that support researcher exchanges.

We would like to bring this document forward to the ET and CE leadership to shape a path forward that can start and sustain these activities.

We also recommend the ET, CE and IGWN leadership to have a conversation around these topics, as there could be unintended negative consequences in strengthening ET and CE collaborations outside IGWN.

We would welcome the opportunity to discuss these topics jointly with the ET and CE leadership and to contribute to identifying approaches for advancing in these efforts.

As ET and CE move from conceptual design toward implementation, continued investment in collaborative R&D will be essential. The success of next-generation gravitational-wave observatories will depend not only on technological innovation, but also on the ability of the international community to work together toward common goals.