Cosmic Explorer Project Status

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Abstract. NSF's LIGO, with Virgo and KAGRA, were designed to succeed in launching the new epoch of gravitational-wave astronomy, on a 'best effort' basis. The next generation of terrestrial observatories, exemplified here by Cosmic Explorer, can take a more structured approach to observatory and initial instrument design. For CE, priorities are to enable an initial reach some 10x greater for neutron-star coalescence while managing cost and risk. The US National Science Foundation is supporting both design and experimental activities, complemented by work in the UK, Germany, Australia, and Canada.

1. Introduction

NSF's LIGO gravitational wave (GW) detectors [1] launched the epoch of observation of gravitational waves in 2015 [2]. Since that initial detection, a rich harvest of signals from binary black holes and neutron stars captured in the final moments around coalescence has provided unique insights into general relativity, nuclear physics, multi-messenger astronomy, and populations of compact objects.

The sensitivity of LIGO and the other current GW detectors Virgo [3] and KAGRA [4] is sufficient to see e.g., nearby binary sources, to a redshift z of order 1. We can learn a great deal from probing further, both to increase accessible populations and to see the evolution of binary systems over the lifetime of the universe, as well as seeking other sources of GWs. Technology is now in hand to build detectors which can see all of the binary systems coalescing in the range of frequencies accessible to terrestrial interferometric GW detectors.

We give, on behalf of the Project, a very brief introduction here to Cosmic Explorer [5], the US vision for a next-generation terrestrial GW Observatory and the work underway to develop the Conceptual Design.

2. Cosmic Explorer Overview

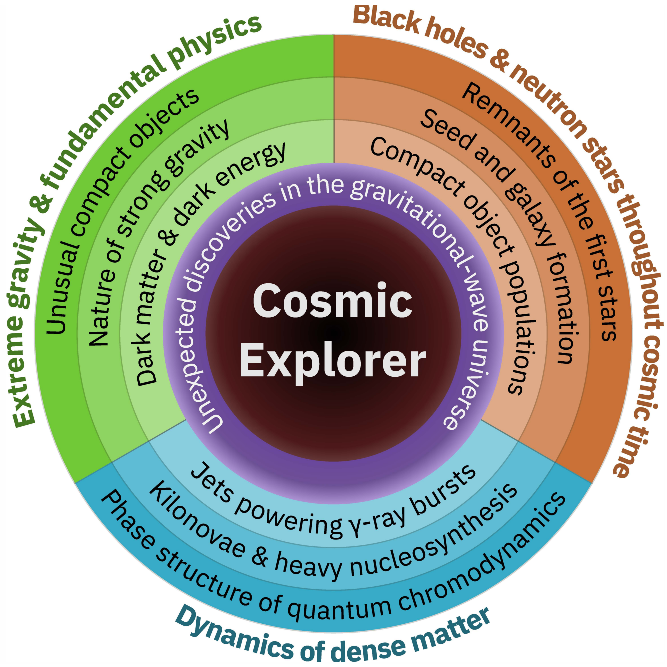
Cosmic Explorer (CE) is planned to take the form of two L-shaped surface facilities—one with 40 km arms and another with 20 km arms—operating at 1064 nm and room temperature. With an anticipated sensitivity roughly ten times greater than today's observatories, CE will be a key element of the future global gravitational-wave network, working in concert with the Einstein Telescope (ET), LIGO-India, and the multi-messenger astronomy (MMA) community.

Building on the foundation of LIGO, CE represents an evolutionary step forward in detector design and scientific reach. The concept includes a LIGO-like observatory and an initial detector, with the potential for future upgrades. Work toward this vision, supported by the National Science Foundation (NSF), includes R&D in vacuum technology, site evaluation and responsible siting, optical design and mode sensing/control, and the systems engineering and project management necessary to realize such a large-scale scientific facility.

The path forward for CE is defined by NSF processes [6], which will shape both the funding trajectory and the overall project timeline. Together, these steps are laying the groundwork for Cosmic Explorer to become a transformative observatory for the 21st century.

Figure 1 is a graphical representation of the wide range of observational science possible with CE. For a discussion, please see [7, 8, 9].

Figure 1. Graphical illustration of the science goals for CE.



3. From LIGO to Cosmic Explorer: An Evolutionary Step Forward

The LIGO program—first with Initial LIGO and then with Advanced LIGO—established a highly successful paradigm for combining observatory and instrument design. Cosmic Explorer (CE) carries this legacy forward as an evolutionary step, shaped by lessons learned and guided by ambitious astrophysics goals.

In LIGO, both the observatory and detectors were pushed to the technological frontier. CE, by contrast, benefits from a more mature foundation. Its design allows greater freedom to optimize around astrophysical objectives, enabling a true science-driven flowdown from discovery goals to technical implementation.

The CE observatory configuration itself is considered low-risk, following the proven LIGO model but scaled up to the required dimensions. While the construction will demand a major capital investment, the core design principles remain familiar and robust. Similarly, the initial detector is conceived as a low-risk system, ensuring high confidence in rapid success once operations begin.

CE's envisioned 50-year lifetime provides the opportunity to incorporate revolutionary technologies—quantum measurement, artificial intelligence, cryogenics, and beyond—through future detector upgrades. This long horizon will ensure that Cosmic Explorer not only realizes today's science goals but continues to advance gravitational-wave astronomy for decades to come.

An important step forward for this generation of observatories is the ability to drive the design by the science. To that end, CE is pursuing a Science Traceability Matrix (STM) approach [10], enabling a structured approach, moving from the Observational Science goals, through measurement requirements, and leading to instrument technology requirements. Ultimately also the data products – and the access model – will need to be developed.

4. Observatory Design Status

Cosmic Explorer (CE) employs arms ten times longer than LIGO with a 40 km baseline, plus an additional 20 km facility optimized for binary neutron star observations, to achieve a tenfold boost in sensitivity. Built as a surface-based observatory, CE makes a deliberate tradeoff:

sacrificing some low-frequency performance due to Newtonian noise, but gaining enormous scientific reach, moderating cost, and maximizing flexibility for future upgrades.

The observatory's vacuum system is now under active study, with significant support from the National Science Foundation. CE is also building international connections, with collaborations underway with CERN and with the Einstein Telescope (ET) community.

Suitable sites for CE must meet quite a number of technical requirements, such as seismic stability, minimal repositioning of earth, access, and cost [11]. Beyond the technical design, CE's success depends on careful consideration of geographical and sociological factors. In particular, the host community needs to be collaboratively engaged and welcoming. The papers by Key [12], Bristol [13], and Datrier [14] from this meeting will cover this central element of CE in detail.

5. Instrument design status

LIGO is serving as a prototype for Cosmic Explorer (CE), providing both the technical foundation and the operational experience needed to conceive a much larger-scale observatory. In particular, the A# upgrade to LIGO is directly relevant to CE, advancing technologies that will transition naturally into the design of the next-generation facility.

The current, NSF-funded Conceptual Design activities for CE are focused on a broad range of critical subsystems. These include optical and interferometer design, thermal compensation, stray light mitigation, and the development of improved optical coatings. Work is also advancing on high-power lasers and squeezed-light sources, as well as vibration isolation systems, suspension design, and strategies to mitigate gravity-gradient noise. Complementing these hardware efforts is the design of a robust digital architecture, which will support precision control, data acquisition, and analysis.

Together, these activities represent the foundation of CE's technical roadmap, ensuring that the observatory will build upon LIGO's proven paradigm while scaling up to deliver transformational astrophysical reach.

Figure 2 demonstrates the anticipated evolution of sensitivity from the current LIGO detectors, through A#, and to CE (and ET). For a discussion, please see [15].

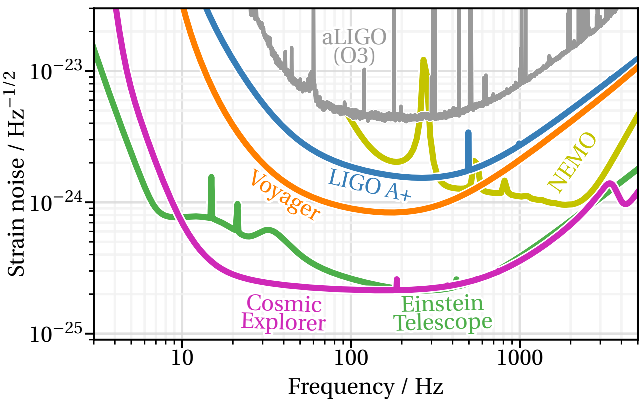


Figure 2. Strain sensitivity progression, LIGO to CE. (cite Horizon Study)

6. The path forward

The NSF convened a Blue Ribbon Panel in 2023 that determined that CE was the best option for a US next-generation GW detector[16]. A variety of networks were evaluated, all of which would enable the remarkable science possible with CE while adding determination of position in the sky and polarization.

The CE team continues maturing the design, following the NSF guidance for new facilities. If all goes well, we will have a rich harvest of GW and Multi-Messenger Astrophysics data in the 2030's.

Acknowledgments

This talk is a top-level summary of work by by the CE Project and the CE Consortium [17]; the author thanks them all for their contributions.

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Submissions close on August 31, 2025 at 23:59 **maybe UK time**

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