Cosmic Explorer Observatory Conceptual Design

Joey Shapiro Key, Rae Jing Han, Shawon Riffat Ara, for the Cosmic Explorer Project

University of Washington Bothell, Bothell Washington 98021, USA

E-mail: joeykey@uw.edu

Abstract. The Cosmic Explorer observatory will detect gravitational waves as a next-generation ground-based facility to begin operations in the 2030s. During the design phase, the project is investing in evaluation to understand the impacts on the local region and the field of gravitational wave astrophysics. Cosmic Explorer prioritizes mutually beneficial relationships with local and Indigenous communities, building these relationships as an essential component for identification of potential locations for the observatory. Members of the Cosmic Explorer Consortium contribute to scientific gains and form a community for collaboration, training, and education. As a large scientific facility, Cosmic Explorer will expand the reach of observational gravitational-wave astronomy while impacting the people who interface with the project.

1. Introduction

The Cosmic Explorer Horizon Study [1] established the concept for a next-generation gravitational wave observatory in the United States. The development of Cosmic Explorer provides a unique opportunity to create and implement best practices for building observatories in partnership with local and Indigenous communities with an emphasis on recruiting and facilitating participation and collaboration. Accompanying articles summarize the current Cosmic Explorer project status [2] and site evaluation progress [3, 4].

2. Cosmic Explorer Observatory

Cosmic Explorer (CE) is planned to take the form of one or two L-shaped surface facilities with up to 40 km arms and an anticipated sensitivity roughly ten times greater than current observatories [5]. 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 the National Science Foundation (NSF) Laser Interferometer Gravitational-wave Observatory (LIGO) [6], 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. The NSF provides support for research and development and project management necessary to realize such a large-scale scientific facility.

3. Cosmic Explorer Conceptual Design

The conceptual design for the Cosmic Explorer observatory is part of the Major Facility design process as defined by the NSF Research Infrastructure Guide [7]. This phase establishes the Cosmic Explorer Project Office, including systems engineering and management structures to

develop the initial Project Execution Plan and the initial Design and Development Plan for Cosmic Explorer. Conceptual design work includes development of the science traceability matrix [8], the initial facility infrastructure concept, and the initial detector reference design for Cosmic Explorer.

Cosmic Explorer is shaping the field of gravitational-wave astrophysics and directly impacts the future of many early career researchers. The project coordinates scientific development and contributes to recruiting, training, mentoring, and networking of students and professionals. The Indigenous and Place-Based Partnerships and Responsible Siting (IPP-RS) work provides opportunities for local and Indigenous communities at potential Cosmic Explorer sites [9].

The Cosmic Explorer Horizon Study established a baseline for the observational science goals and technologies needed to realize Cosmic Explorer. The NSF Research Infrastructure Guide [7] documents the Major Facility Life Cycle including the Conceptual Design phase and requires the development of a Project Execution Plan, which plays an important role in the project and organization definition and goals.

Work toward the CE Conceptual Design and CE-related research is distributed among CE Project and CE Consortium contributors. Development of our understanding of the scientific potential of gravitational-wave observation is ongoing and worldwide, and work on the CE science traceability matrix elucidates the connection between scientific goals and top-level observatory design parameters. The observatory concept including reference designs and requirements for facilities, detectors, and computing infrastructure are developed in collaboration with vacuum systems research and development, suspension design, stray light and local-gravity noise mitigation, interferometer optical design, and digital control and astrophysical analysis architecture. Collaboration with IPP-RS ensures integration with the CE observatory concept.

4. Cosmic Explorer Consortium

The Cosmic Explorer Consortium [10] provides an open and efficient opportunity for members of the international physics and astronomy communities to contribute to the conceptualization of Cosmic Explorer, its design, and its future use. Participation in the Cosmic Explorer Consortium provides access to a mailing list that can be used to communicate with other consortium members and access to a document center to share documents related to Cosmic Explorer. Membership in the Cosmic Explorer Consortium is open to all who are interested, does not carry any obligations, and may overlap with membership in other collaborations (e.g., the LIGO Scientific Collaboration, Virgo, KAGRA, or OzGrav). Members are encouraged to collaborate with each other, as well as scientists outside the Cosmic Explorer Consortium, on projects related to Cosmic Explorer.

Cosmic Explorer Consortium objectives include:

- Bringing together the scientific, technical, individual, interpersonal, cultural, and systems expertise needed for the development and effective use of Cosmic Explorer.
- Facilitating the contribution of talents and perspectives from across the astronomy and physics community to Cosmic Explorer's science and technology.
- Supporting equitable participation in creating, and equitable access in using, the knowledge, infrastructure, and innovations that result from Cosmic Explorer.
- Working to ensure responsible and fair allocation of necessary and available Consortium resources across people, processes, and priorities.

5. Cosmic Explorer Project

The Cosmic Explorer Project Office provides leadership and coordination for Cosmic Explorer-related activities. The conceptual design advances the project to solidify engineering and design contracts and prepare the Project Execution Plan for the NSF Conceptual Design Review. CE

Conceptual Design activities are currently focused on a range of critical subsystems for hardware as well as digital architecture that 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.

6. Cosmic Explorer Evaluation and Consulting

The University of Washington Center for Evaluation & Research for STEM Equity (CERSE) serves as the internal evaluator for Cosmic Explorer. CERSE is an externally funded, interdisciplinary research center providing research, program evaluation, and consulting that leverages their social science skills and knowledge to contribute to science and engineering projects. CERSE's program evaluation and research offer evidence-based insights toward reimagining systems and improving policies and practices to support sustainable, equitable futures for all.

Cosmic Explorer evaluation focuses on two main communities of interest. The CE Project includes all faculty, staff, graduate students, and postdocs who are funded (or expect to be funded) to engage in Cosmic Explorer related activities. The CE Consortium is a larger group defined by an email list subscription, which is open to any members of the broader scientific community who are interested in the CE efforts. A key component of the CE conceptual design is the CE Personnel and Organizational Development (POD) Committee, which engages in a variety of activities to support equitable outcomes within CE and in the field of gravitational wave research more broadly. As members of the CE POD Committee, CERSE staff collaborate with the Director of POD and other members of the Committee to provide both formative and summative evaluation as well as developmental consulting to inform and strengthen CE efforts.

Formative evaluation supports project improvement and effective strategies for reaching intended outcomes and goals. Summative evaluation assesses the extent to which desired project outcomes have been achieved and assesses overall project impact. Project consulting supports CE strategic planning and organizational developmental processes. The evaluation focus areas are inclusiveness and sense of belonging, mentorship, professional development and career advancement, organizational communication and shared vision, structure, intellectual community, and IPP-RS.

The evaluation team collects and analyzes data from surveys of Project and Consortium members and interviews with Project members. Regular evaluation reports offer recommendations on strategic planning and organizational development, addressing evaluation questions and including findings regarding the broader infrastructure and operations efforts, focusing on themes that emerge across the data sources.

Key recommendations from the evaluation activities include:

- Cultivate commitment to equitable communication and collaboration
- Prioritize in-person engagement opportunities to build relationships and trust
- Create intentional support for new and/or early career Project members
- Provide structures, training, and resources to enable effective mentorship
- Increase role clarity and provide opportunities for role-related skill development
- Strengthen communication horizontally (across working groups) and vertically (from Project leaders)
- Keep operational goals realistic and flexible, in alignment with staffing and organizational capacities

The CE leadership team, Project, and Consortium members discuss recommendations and plans to address key elements to support overall sucess for Cosmic Explorer.

Acknowledgments
The National Science Foundation supports the Cosmic Explorer conceptual design with contributions from members of the CE Project and the CE Consortium [10].

References

[1] Evans M, Adhikari R X, Afle C, Ballmer S W, Biscoveanu S, Borhanian S, Brown D A, Chen Y, Eisenstein R, Gruson A, Gupta A, Hall E D, Huxford R, Kamai B, Kashyap R, Kissel J S, Kuns K, Landry P, Lenon A, Lovelace G, McCuller L, Ng K K Y, Nitz A H, Read J, Sathyaprakash B S, Shoemaker D H, Slagmolen B J J, Smith J R, Srivastava V, Sun L, Vitale S and Weiss R 2021 *arXiv e-prints* arXiv:2109.09882 (*Preprint* 2109.09882)

[2] Shoemaker D 2025 Cosmic Explorer Project Status J. Phys.: Conf. Series, submitted; https://dcc.cosmicexplorer.org/CE-P2500001

[3] Bristol W 2025 An Interdisciplinary Site Suitability Analysis for Cosmic Explorer J. Phys.: Conf. Series, submitted

[4] Datrier L 2025 Site Evaluation and Identification for Cosmic Explorer J. Phys.: Conf. Series, submitted; https://dcc.cosmicexplorer.org/CE-P2500002/public

[5] Evans M, Corsi A, Afle C, Ananyeva A, Arun K G, Ballmer S, Bandopadhyay A, Barsotti L, Baryakhtar M, Berger E, Berti E, Biscoveanu S, Borhanian S, Broekgaarden F, Brown D A, Cahillane C, Campbell L, Chen H Y, Daniel K J, Dhani A, Driggers J C, Effler A, Eisenstein R, Fairhurst S, Feicht J, Fritschel P, Fulda P, Gupta I, Hall E D, Hammond G, Hannuksela O A, Hansen H, Haster C J, Kacanja K, Kamai B, Kashyap R, Key J S, Khadkikar S, Kontos A, Kuns K, Landry M, Landry P, Lantz B, Li T G F, Lovelace G, Mandic V, Mansell G L, Martynov D, McCuller L, Miller A L, Nitz A H, Owen B J, Palomba C, Read J, Phurailatpam H, Reddy S, Richardson J, Rollins J, Romano J D, Sathyaprakash B S, Schofield R, Shoemaker D H, Sigg D, Singh D, Slagmolen B, Sledge P, Smith J, Soares-Santos M, Strunk A, Sun L, Tanner D, van Son L A C, Vitale S, Willke B, Yamamoto H and Zucker M 2023 Cosmic Explorer: A Submission to the NSF MPSAC ngGW Subcommittee (*Preprint* 2306.13745) URL https://arxiv.org/abs/2306.13745

[6] Aasi J *et al.* (LIGO Scientific Collaboration) 2015 *Class. Quant. Grav.* **32** 074001 (*Preprint* 1411.4547)

[7] NSF 2025 Research Infrastructure Guide https://nsf-gov-resources.nsf.gov/files/Research-Infrastructure-Guide-January-2025.pdf?VersionId=U9Twwu5MTzJsPoyCqhYqxH8L7d7r7uUs

[8] Weiss J, Smythe W and Lu W 2005 Science traceability *2005 IEEE Aerospace Conference* pp 292–299

[9] Daniel K J, Smith J R, Ballmer S, Bristol W, Driggers J C, Effler A, Evans M, Hoover J, Kuns K, Landry M, Lovelace G, Lukinbeal C, Mandic V, Pham K, Read J, Russell J B, Schiettekatte F, Schofield R M S, Scholz C A, Shoemaker D H, Sledge P and Strunk A 2025 *Review of Scientific Instruments* **96** 014502 ISSN 0034-6748 (*Preprint* https://pubs.aip.org/aip/rsi/article-pdf/doi/10.1063/5.0242016/20339208/014502_1_5.0242016.pdf) URL https://doi.org/10.1063/5.0242016

[10] Consortium 2025 Cosmic Explorer Consortium https://cosmicexplorer.org/consortium.html