Cosmic Explorer Status

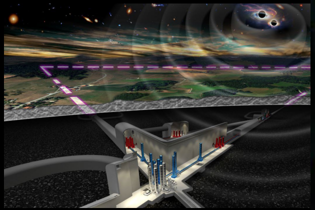
Matthew Evans
for the CE Project

Artists: Edward Anaya, Virginia Kitchen, and Angela Nguyen (Cal State Fullerton)

High-Level View

Cosmic Explorer is the US concept for a next-gen gravitational-wave observatory

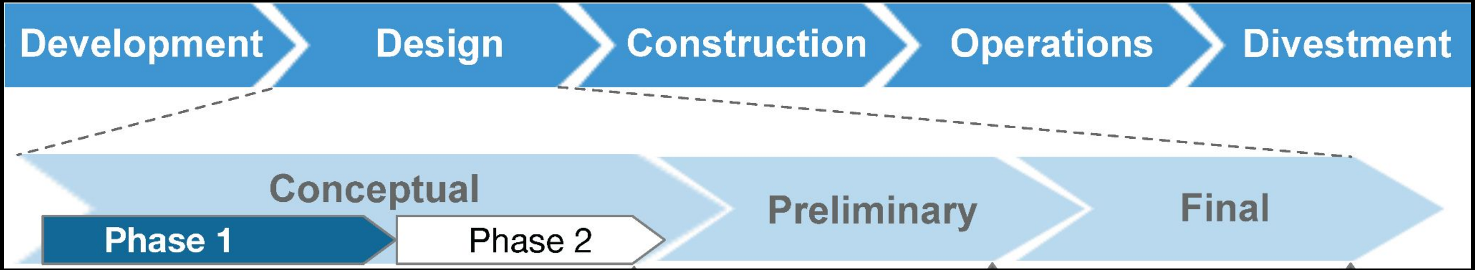
- 40 km and 20 km L-shaped surface observatories
- 1064 nm @ room temperature
- roughly 10x sensitivity of today's observatories
- will operate as part of a global network with ET, LISA, and others



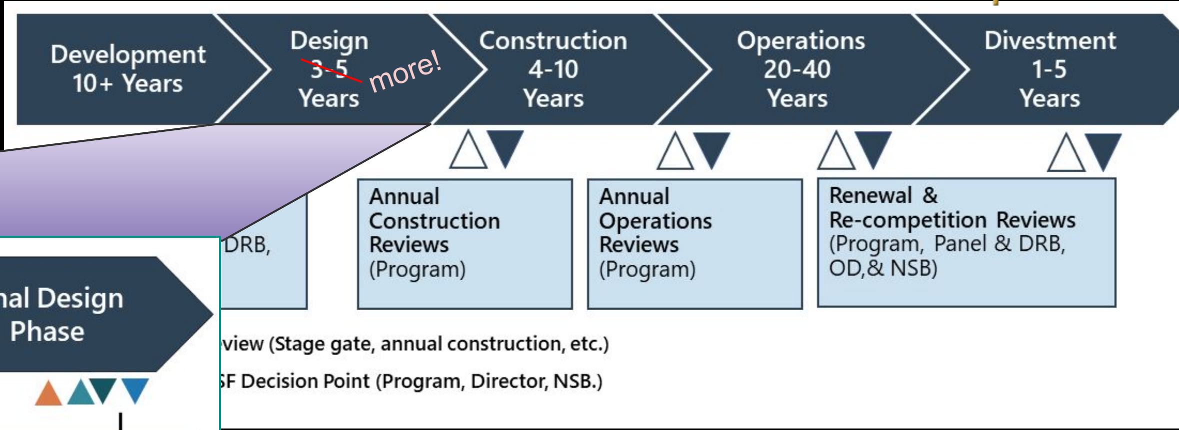
CE is envisioned as an NSF-led Project

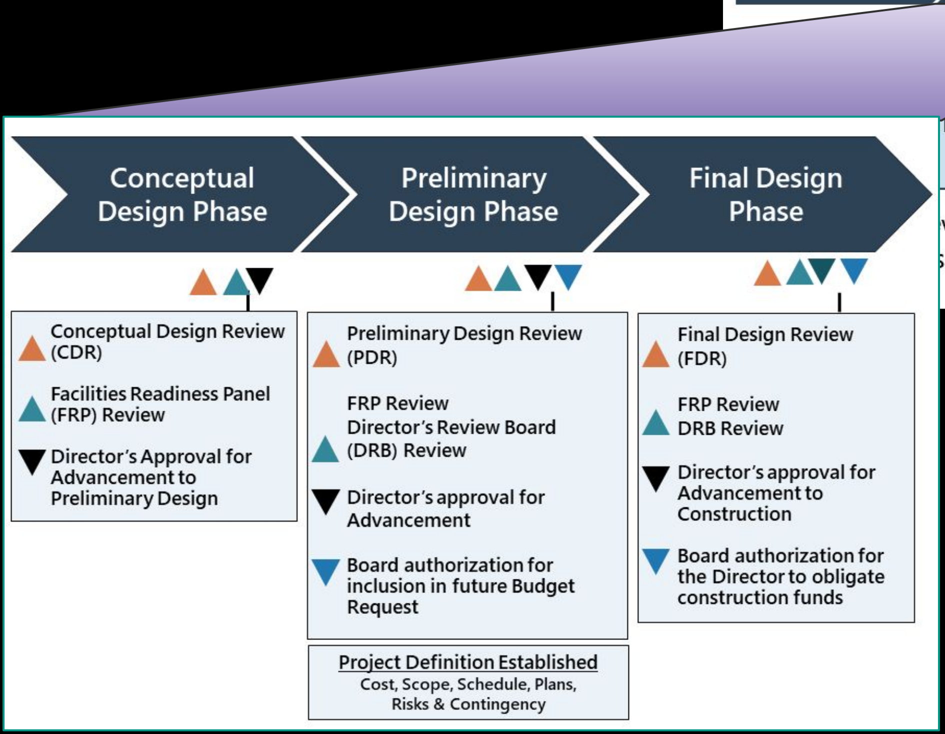
- Several coordinated grants by the NSF to work on aspects of CE conceptual design, including: vacuum technology research, site evaluation and responsible siting, detector optical design, mode sensing and control, project core

NSF processes define the possible CE funding path and project timeline



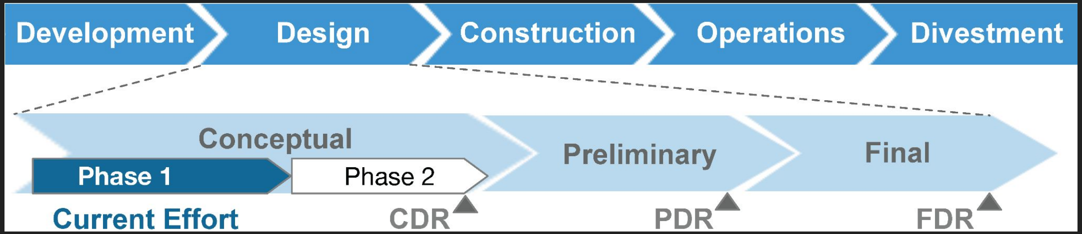
NSF Major Facility Project Life Cycle - (from RIG)



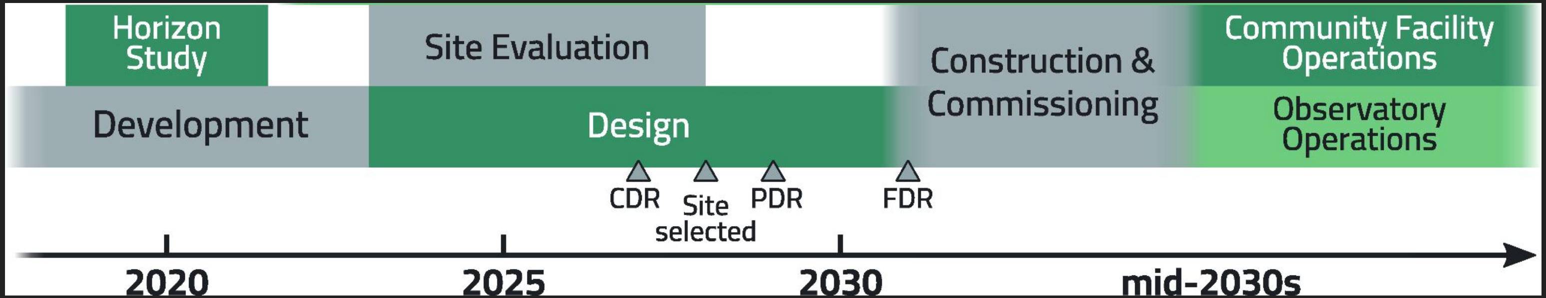


Terminology from NSF infrastructure lifecycle, documented in the Research Infrastructure Guide (RIG)
https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf21107

Cosmic Explorer Timeline



- Project progress
  - Conceptual Design (3+years)
  - Preliminary Design ~$75M (2-3 years)
  - Final Design ~$100M (2 years)
  - Construction ~$1-2B (5 years)
  - Operations ~$60M / year (50 years?)
  - Decommissioning/Divestment



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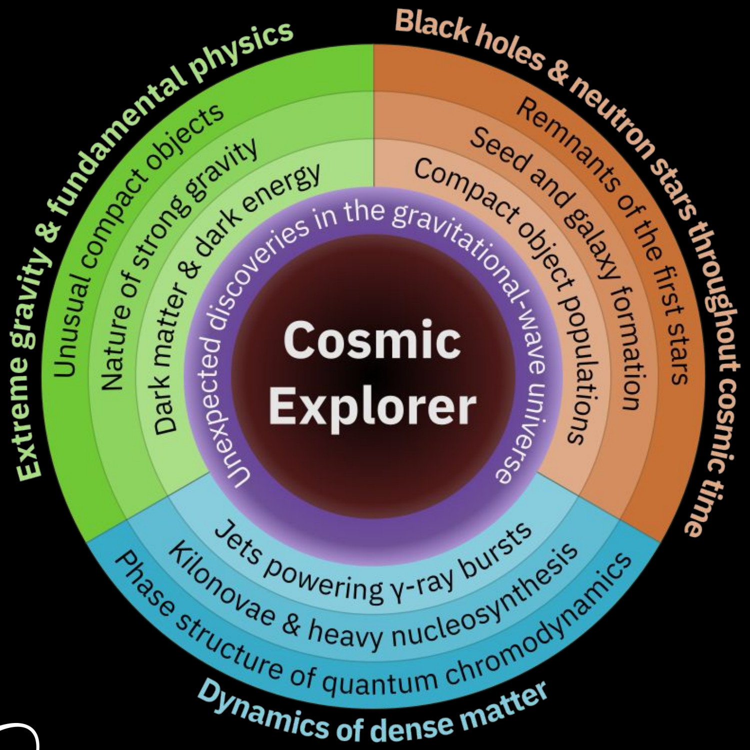
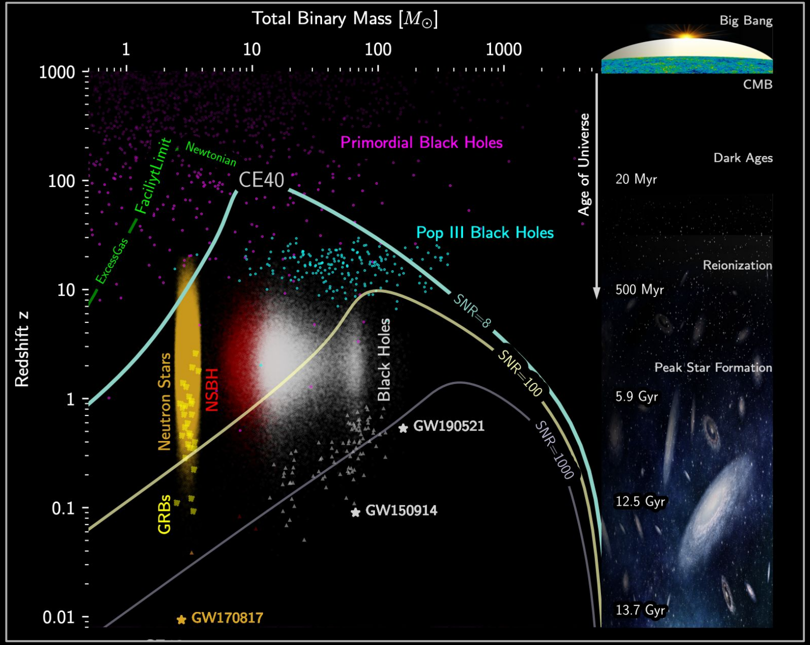
A Horizon Study for Cosmic Explorer: Science, Observatories, and Community



https://arxiv.org/abs/2109.09882

Cosmic Explorer: A Submission to the NSF MPSAC ngGW Subcommittee



https://arxiv.org/abs/2306.13745

<u>ngGW comm's recommendations in a nutshell</u>

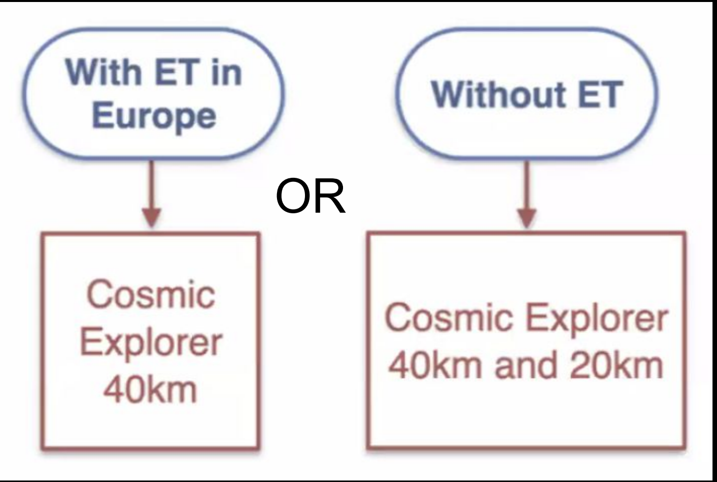
The NSF Mathematical and Physical Sciences Advisory Committee (MPSAC), at the request of the MPS Assistant Director, established (in January 2023) the Next Generation Gravitational-Wave (ngGW) Detector Concept Subcommittee.

In March 2024, ngGW cast recommendations under **two major scenarios**:

- **With ET** in Europe → **CE40 only** recommended
- **Without ET** in Europe → **CE40+CE20** recommended
- *All recommendations include CE!*

What does this mean for CE?

- Design work will continue for CE 40km + 20km
- We are working with NSF solicit a full design proposal for CE (i.e., to complete the Major Facility design, as described in the NSF Research Infrastructure Guide)



credit : Kalogera et al.

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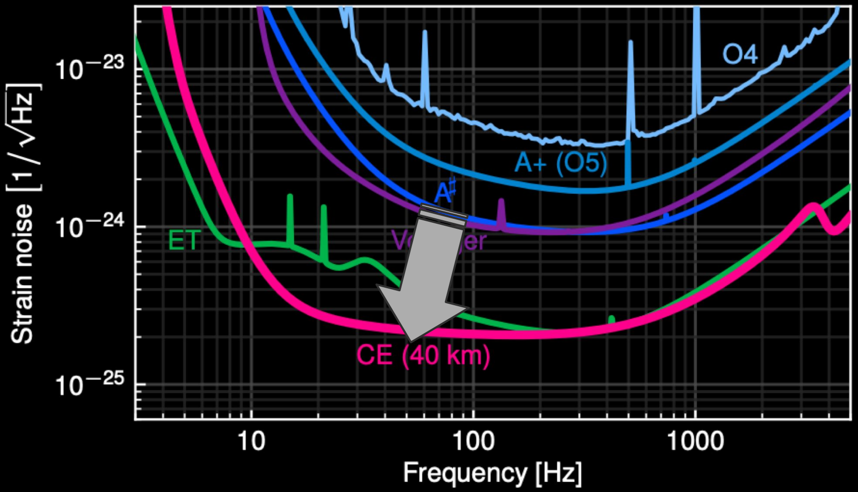
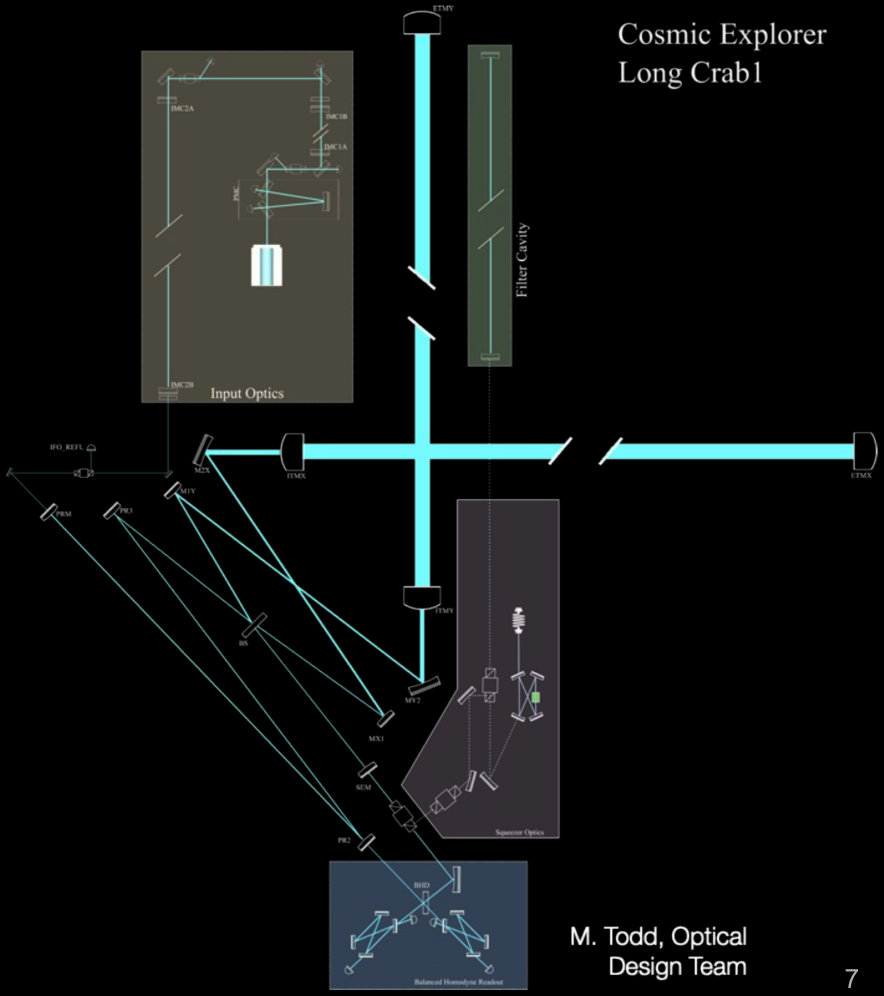
NSF MPSAC ngGW report

What are we doing now?

- We are working to grow CE project, look for a home for CE, and develop the CE design… and understand how it can be adapted to do the best science!
  “Science Traceability”



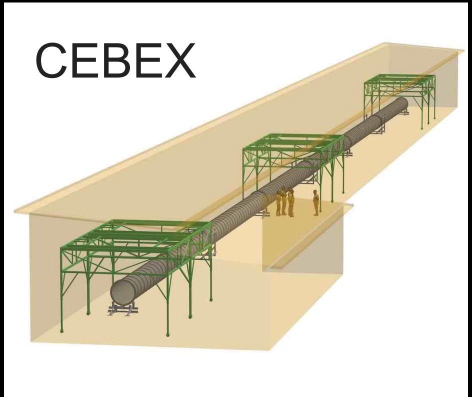


M. Todd, Optical Design Team

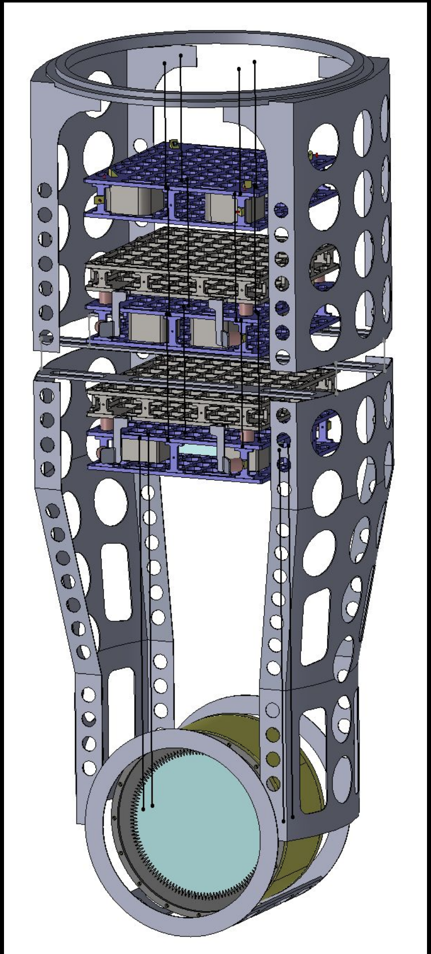
CE Activity

Many efforts ongoing:

- Project and Design Execution Plans
- Science Traceability Matrix
- Site evaluation: completed national search, visiting regions, developing relationships
- Improved observatory costing
- Stray light mitigation
- Optical design and thermal compensation
- Vibration isolation and suspension design
- Lasers and squeezers
- CE Beamtube Experiment (CEBEX)
- Gravity gradient noise mitigation
- Improved optical coatings
- …



CE SUS



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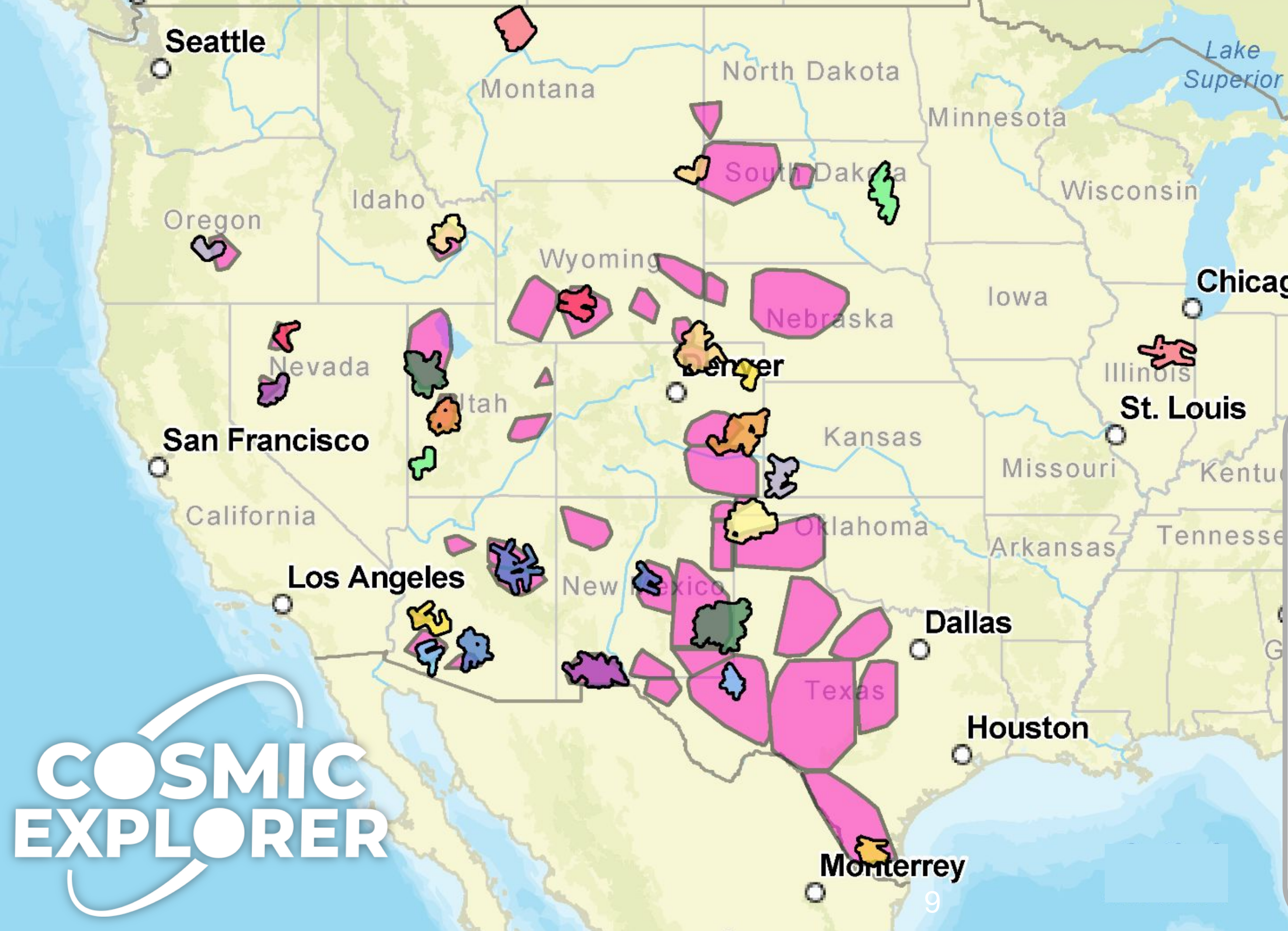
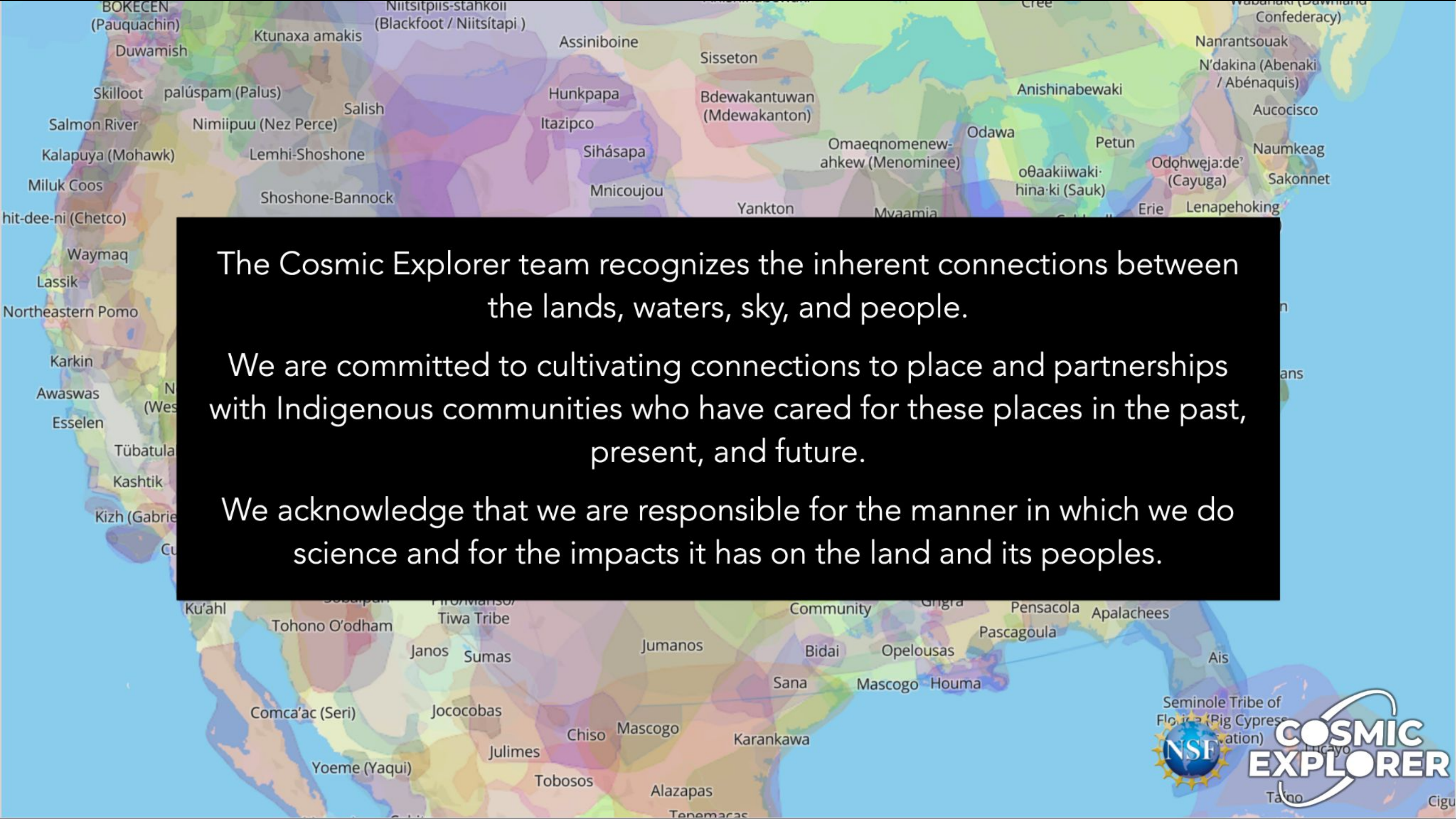
CE Location Search



The example layouts shown here are based solely on high-level data. No decision has been made on Cosmic Explorer locations at this time. Observatory locations and configurations will be co-developed in consultation with local and Indigenous communities. Any future decision to build will follow established protocols, including NEPA and NHPA processes, and will involve representatives from all relevant federal agencies, the National Science Foundation, local governments, Native Nations, and ancestral stewards.



The Cosmic Explorer team recognizes the inherent connections between the lands, waters, sky, and people.

We are committed to cultivating connections to place and partnerships with Indigenous communities who have cared for these places in the past, present, and future.

We acknowledge that we are responsible for the manner in which we do science and for the impacts it has on the land and its peoples.

More on this…

- Jenne and Josh will lead a round-table discussion about CE observatory open questions in today's parallel session

- Josh will talk about the CE location search on Thursday in the morning plenary

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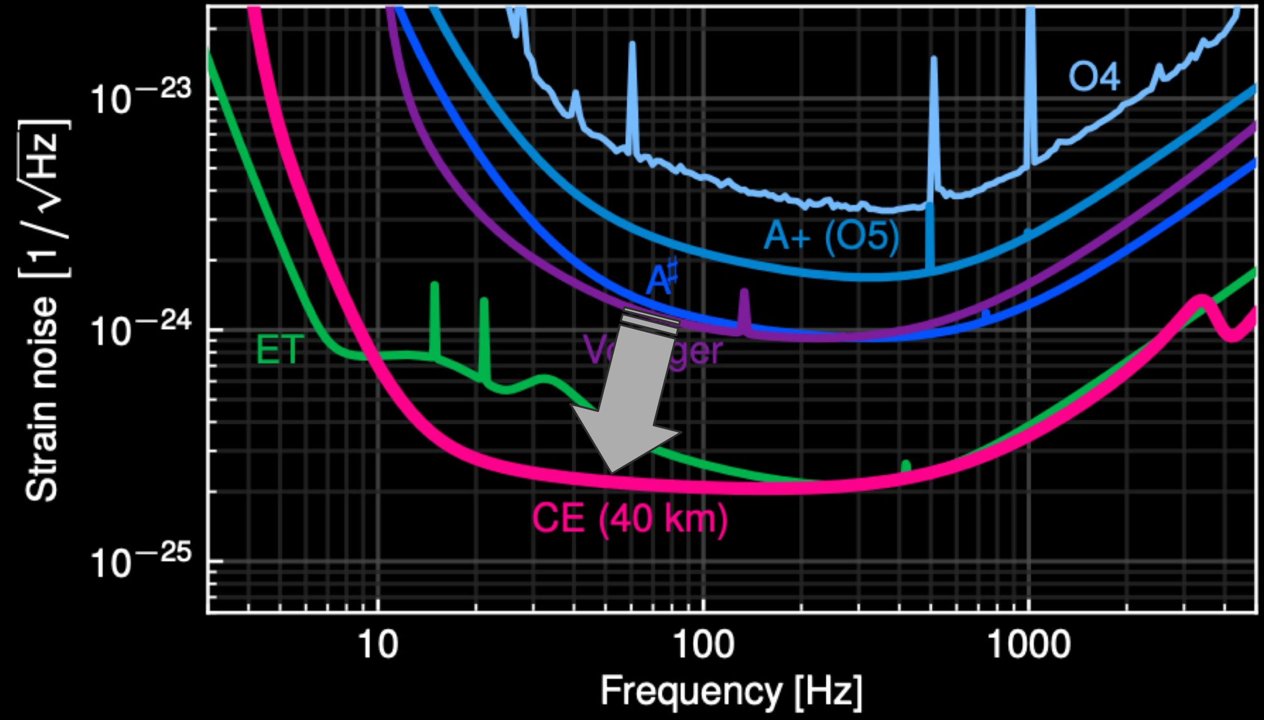
Sensitivity evolution from LIGO to A♯ and Cosmic Explorer



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A♯ as a pathfinder for Cosmic Explorer

LIGO A♯	Cosmic Explorer
4 km long arms	40 km and maybe 20 km long arms
1.5 MW arm power	1.5 MW arm power
10 dB frequency dependent SQZ	10 dB frequency dependent SQZ
100 kg fused silica test mass	440 kg fused silica test mass
Redesigned QUADs, 160 cm total length, 400 kg total mass, 1.6 GPa fiber stress	Nominally QUADs, 4 m total length, ~2000 kg total mass, 1.6 GPa fiber stress
2× reduction in CTN over A+ coating goal	A+ coating goal
Improved seismic isolation	Improved seismic isolation
2× suppression of Rayleigh wave Newtonian noise	10× suppression of Rayleigh wave Newtonian noise

Technical overlap between A# and Cosmic Explorer

The next slide has a table of A# and Cosmic Explorer R&D topics.

For each topic, a colored circle captures additional R&D effort required to validate the Cosmic Explorer design, on top of the R&D in support of A# (“differential" R&D, expressed by Δ).

- green circle: CE R&D is focused on adapting A# solutions
- yellow circle: A# solutions might not be sufficient
- red circle: A# solutions are known to be insufficient or not applicable

For Example:

		A♯ R&D	CE R&D	Δ
Core Optics	Substrates (§4.1.1)	production and polishing of fused silica optics 45 cm ∅, 100 kg	further scaling, toroidal mirrors for corner, polishing of strong lens in ITMs	🟡
	Coatings (§4.1.2)	amorphous coatings: materials better than A+ coatings and scaling	amorphous coatings: further scaling required	🟢
		crystalline coatings: birefringence tests and scaling	crystalline coatings for future upgrades: further size scaling required	🔴

Technical overlap between A# and Cosmic Explorer

		A$^\sharp$ R&D	CE R&D	Δ
Core Optics	Substrates (§4.1.1)	production and polishing of fused silica optics 45 cm ∅, 100 kg	further scaling, toroidal mirrors for corner, polishing of strong lens in ITMs	🟡
Core Optics	Coatings (§4.1.2)	amorphous coatings: materials better than A+ coatings and scaling	amorphous coatings: further scaling required	🟢
Core Optics	Coatings (§4.1.2)	crystalline coatings: birefringence tests and scaling	crystalline coatings for future upgrades: further size scaling required	🔴
Vibration Control	Suspensions (§4.2.1)	improved controllability, high stress fibers, test mass actuation, full scale prototype	design optimization, long high stress fibers, test mass actuation, full scale prototype	🟡
Vibration Control	Active Vibration Isolation (§4.2.2)	improved sensors and global control strategies	scaling up of A$^\sharp$ design	🟢
Lasers & Input	Lasers (§4.3.1)	high power laser, beam quality	integration of A$^\sharp$ design	🟢
Lasers & Input	Input Optics (§4.3.2)	mitigation of laser noise couplings (intensity, frequency, beam jitter)	mitigation of laser noise couplings with double mode-cleaners	🟡
Readout & Quantum	Readout (§4.4.1)	optimization of Balanced Homodyne	adaptation of A$^\sharp$ design	🟢
Readout & Quantum	Squeezing (§4.4.2)	loss, mode mismatch and phase noise reduction, robustness	adaptation of A$^\sharp$ design, reduction of SEC loss, study of HOM in band	🟡

		A$^\sharp$ R&D	CE R&D	Δ
Sensing & Control	Length & Angle (§4.5.1)	control noise reduction, optimal hierarchical control	adaptation of A$^\sharp$ design, lock acquisition for 40 km arms	🟡
Sensing & Control	Mode (§4.5.2)	improved sensors and actuators, evaluation of BS thermal lensing	adaptation of A$^\sharp$ design elements, study of low AOI on BS	🟡
Sensing & Control	Parametric Instab. (§4.5.3)	improved modeling and dampers	adaptation of A$^\sharp$ design	🟢
Facility & Interface	Vacuum system (§5.2)	maintenance of existing infrastructure	large scale sector test of new system	🔴
Facility & Interface	Newtonian Noise (§5.1.2)	modeling and demonstration of subtraction techniques	adaptation of A$^\sharp$ design, facility design optimization	🟡
Facility & Interface	Stray Light (§5.3)	incremental improvements, material research	beam tube baffling strategy, analysis of corner layouts, detection strategy	🔴
Facility & Interface	Environment (§5.1.1)	incremental improvements	building isolation, beam tube isolation, HVAC redesign	🔴
Facility & Interface	Electronics (§4.5.4)	advanced prototypes	exploration of modern low-noise electronics designs	🟡
Computing & Data	Digital I/O (§4.6.1)	incremental improvements	architecture re-design with modern technology	🟡
Computing & Data	Calibration (§4.6.2)	incremental improvements	fast and accurate low latency calibration techniques	🟢
Computing & Data	Data Analysis, Transfer and Storage (§4.6.3)	incremental improvements	integrated architecture for low-latency analysis of ~ 1000 daily events	🟡

neXt-Generation Collaborative Design (XGCD)

- ET-CE technical discussion on topics of common interest
- Several topics discussed so far: Optical Design, Straylight mitigation discussed, Lasers and Laser Noise couplings, Seismic Isolation and Sensors, Suspension design, …
- Next topic to be decided soon – talk to Lisa Barsotti

NeXt Generation Collaborative Design

https://indico.gssi.it/e/xgcd

Monday Apr 22, 2024, 11:00 AM → 12:40 PM US/Eastern

Jan Harms (Gran Sasso Science Institute), Lisa Barsotti (MIT)

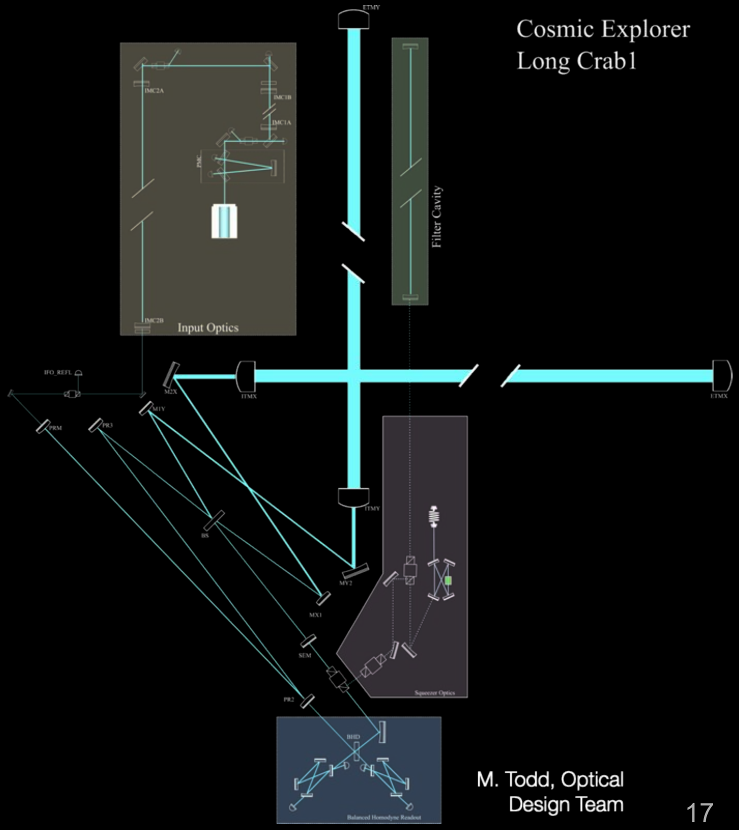
Description The goal of this series of online meetings is to provide a forum for regular discussions between the teams that work on common design aspects of next-generation gravitational-wave detectors Einstein Telescope and Cosmic Explorer.

The plan is to have a meeting each 2-3 months and start with topics that are more urgent, i.e., that have a strong impact on the detector infrastructure including optical layout, stray-light noise, Newtonian noise, ...

More on this…

- Lisa will lead a round-table discussion about STM feedback to the CE design in today’s parallel session

- Stefan will talk about the CE detector design and instrument R&D on Thursday in the morning plenary



Cosmic Explorer
Long Crab1

M. Todd, Optical Design Team

Funded areas of conceptual design work

NSF funded several proposals in Fall 2023; 3 year proposals

- Site Search and Indigenous Place-based Partnerships $4.5M
- Core Project $2.9M
- Interferometer Optical Design $0.9M
- Stray Light Control $0.6M
- Mode Sensing and Control $0.5M

And there are some important efforts that have been funded since:

- Vacuum R&D, prototyping and design $15M+
- Digital Architecture $1.0M
- Newtonian Noise $0.9M
- UK STFC funding (supporting CE and ET) – Instrument and Observational Science

What next?
Secure funding for advancing the CE design (several awards end in Summer 2026)

Our baseline until we are told otherwise by the NSF:

- Awardees funded in summer CY23 (FY23, CD phase 1) will put in proposals for renewal in **fall 2025**, for FY26 funding starting in the summer of CY26 (CD phase 2).
  - Based on the expectation that the CDR happens in the spring of CY28.
- If all goes well, the PD phase will start in the summer of CY28. To make this possible:
  - NSF will solicit proposals for PD and FD in early CY27
  - with proposals due in the summer of CY27
  - and funding allocated in FY28

CY25	CY26	CY27	CY28	CY29	CY30	CY31	CY32
			CDR		PDR		FDR

How can you get involved?

- Join the CE Consortium!
  https://cosmicexplorer.org/consortium.html

- Participate in the CE Science Calls (~monthly)
  https://cosmicexplorer.org/sciencecalls.html

- Join the CE Project… the next round of proposals is in the works!

The Message

- We're looking forward to stability at the NSF
  - And a path for CE to continue as a NSF major facility project
- Technology development for A# synergistically aligned with Cosmic Explorer needs – several joint efforts ongoing
- We are collaborating with ET on multiple topics (Vacuum, optical design, … XGCD!)
- Thank you for attending this PAX/CE Symposium – Looking forward to gather feedback, comments and suggestions from this community