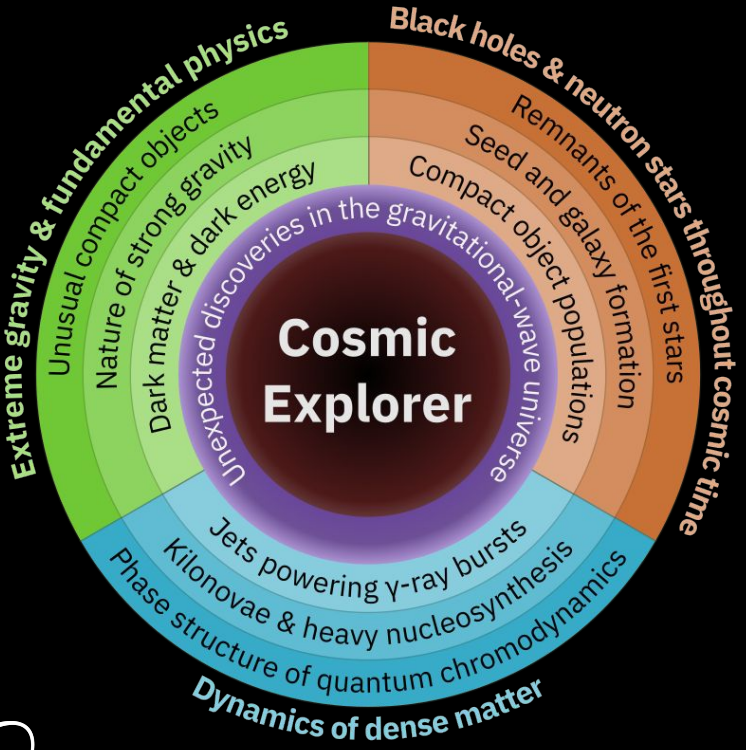
Cosmic Explorer Status

Matthew Evans
for the CE Project

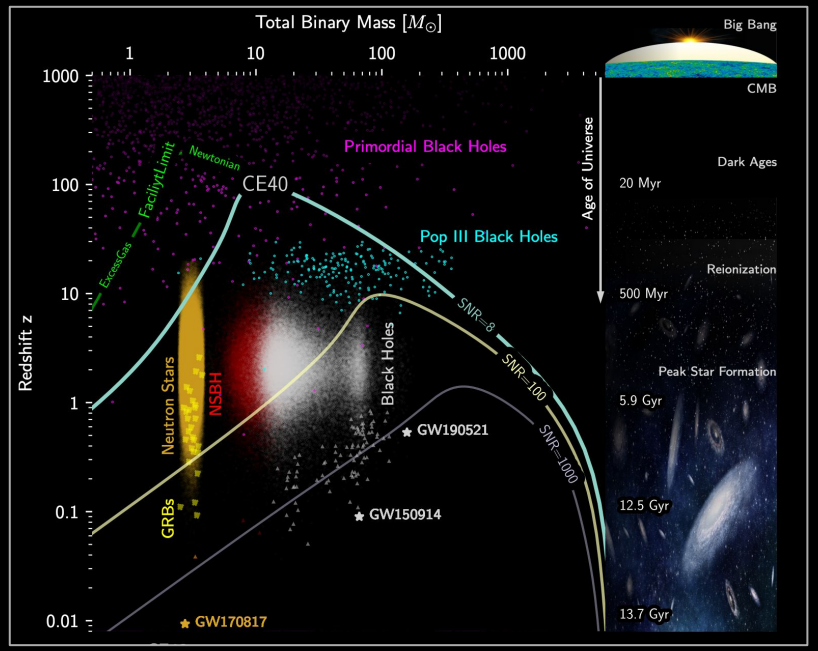
Artist's concept of Cosmic Explorer by
Andrew Jenkins, Cal State Fullerton

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

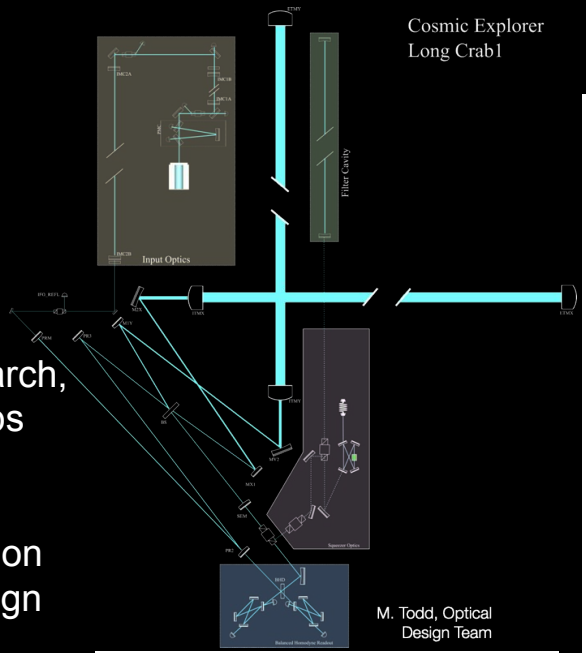


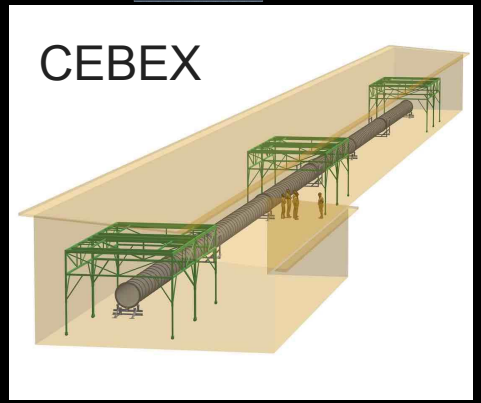
https://arxiv.org/abs/2306.13745

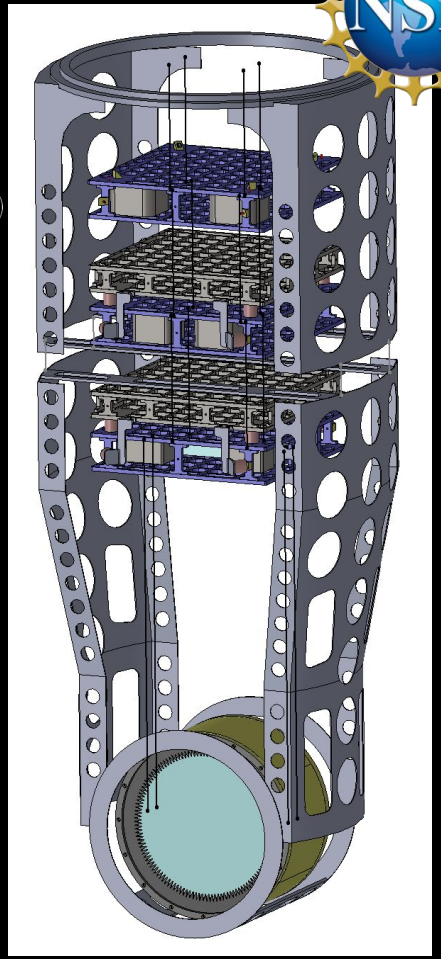
CE Activity

Many efforts ongoing:

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



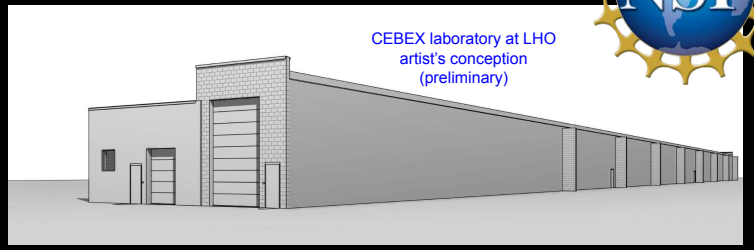


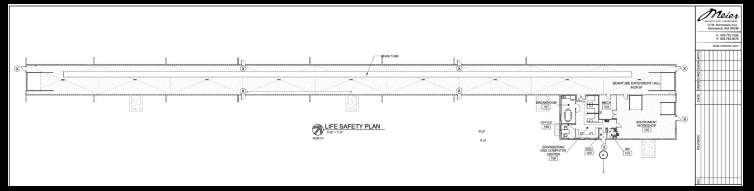


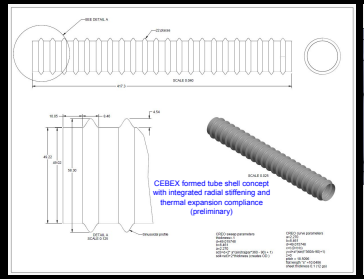
Cosmic Explorer Beamtube EXperiment (CEBEX)

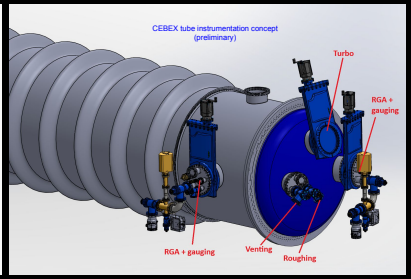
Courtesy of Mike Zucker

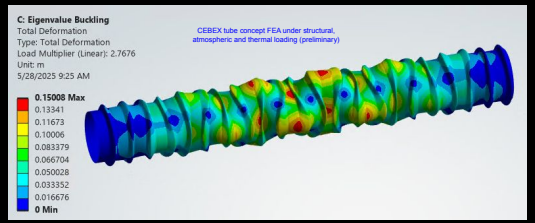
- NSF mission: qualify **scalable, fast, low-cost** UHV beamtubes for CE
  - Material, surface science, fabrication, welding, assembly, leaktest, bakeout, instrumentation
  - Generate **CE reference design and cost book**
  - **120m l. x 1.24m ∅ prototype beamtube platform** (possibly multiple design variants)
  - **New 11,400 ft^2 (1,063 m^2) lab facility** near LIGO Hanford Y midstation
  - Complementary collaboration with **ET Pilot Sector** program, now in progress at **CERN**
- CEBEX laboratory facility
  - Architectural and engineering design is over 50% complete
  - Selecting builder in October, **target occupancy by summer '26**
- Prototype tube design
  - Baseline RFI circulated to industrial fabricators:
    - Corrugation-stiffened 304L, ~ 2mm wall; inspired by GEO600 and CERN designs
    - Flared radial flange or formed socket field joints
    - I^{2}R sector bakeout (similar to LIGO and Virgo)
    - **Targeting fabricator selection by late winter**
  - Options/variants under parallel study
    - Discrete stiffeners & expansion joints (like LIGO and Virgo)
    - Alternative UHV construction materials
      - Ferritic SS (CERN)
      - Carbon steel (LIGO Lab)
    - Sleeved or butt-welded field joints
    - Traveling induction bake with ultra-dry viscous flow scrubbing
- CEBEX team is growing!
  - Tube engineering: Coyne, Franco, Iudintseva, Lazzarini, Sanchez
  - Civil & facility engineering: Gately, Guidry, McCarthy
  - PM: Richards, Hill, Hansen
  - Co-PI's: Csizmazia, Feicht, Zucker*









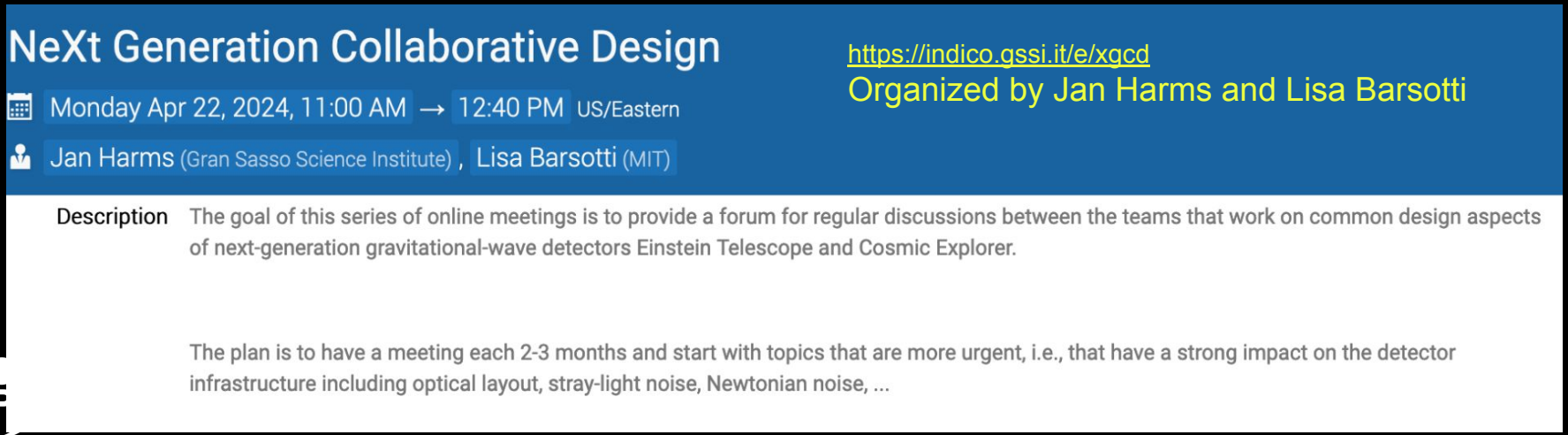


*contact zucker@caltech.edu for info

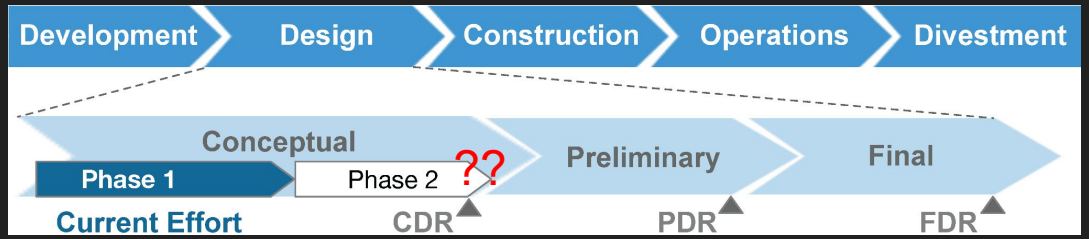
Workshop at LHO in one week

neXt-Generation Collaborative Design (XGCD)

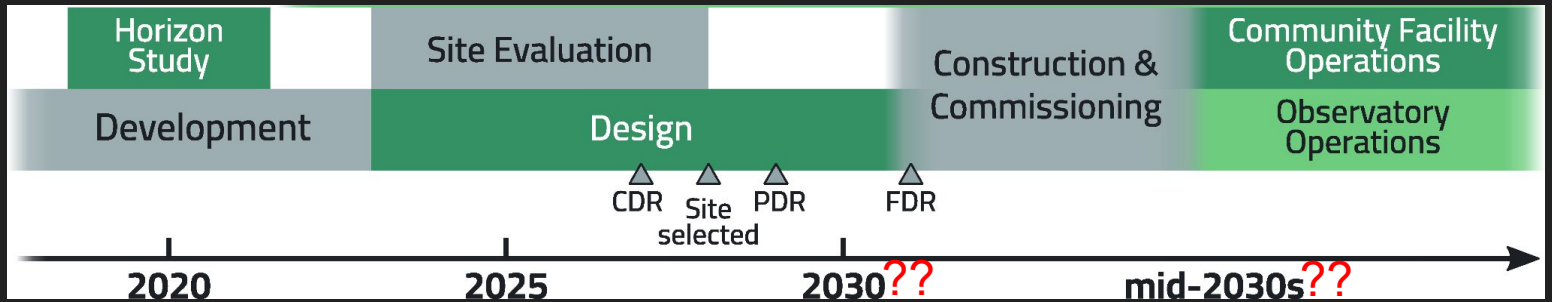
- ET-CE technical discussion on topics of common interest
- Several topics discussed so far: Optical Design, Straylight mitigation, Lasers and Laser Noise couplings, Seismic Isolation and Sensors, Suspension design, …
- Next topic: **Squeezing (October 20, 11am ET)**



Cosmic Explorer Timeline



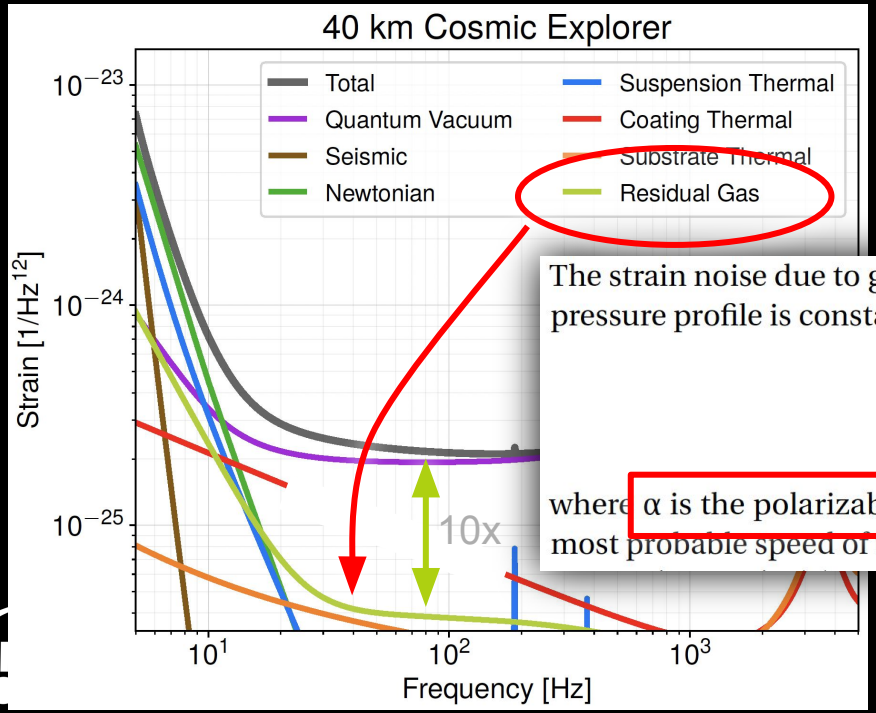
- Project progress
  - Conceptual Design (3+years)
  - Preliminary Design ~$75M (2-3 years)
  - Final Design ~$100M (2 years)
  - Construction ~$1-2B (5 years)
  - Operations ~$60M / year (50 years?)
  - Decommissioning/Divestment



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

CE Vacuum Requirements - Motivations

This is from a detector point of view… I know nothing about vacuum systems!



from CE-T2300008 (by Kevin Kuns)

The strain noise due to gas scattering in one arm for one molecular species, assuming the pressure profile is constant along the beamtube, is [3]

$$S_h = \frac{(4\pi\alpha)^2\rho}{v_0 L^2}\int_0^L \frac{e^{-\omega w(z)/v_0}}{w(z)}dz \equiv \zeta P \qquad (1)$$

where α is the polarizability, $\rho = P/kT$ is the number density, and $v_0 = \sqrt{2kT/m}$ is the most probable speed of the molecule. The integrand can be approximated …

CE Vacuum Requirements - Numbers!

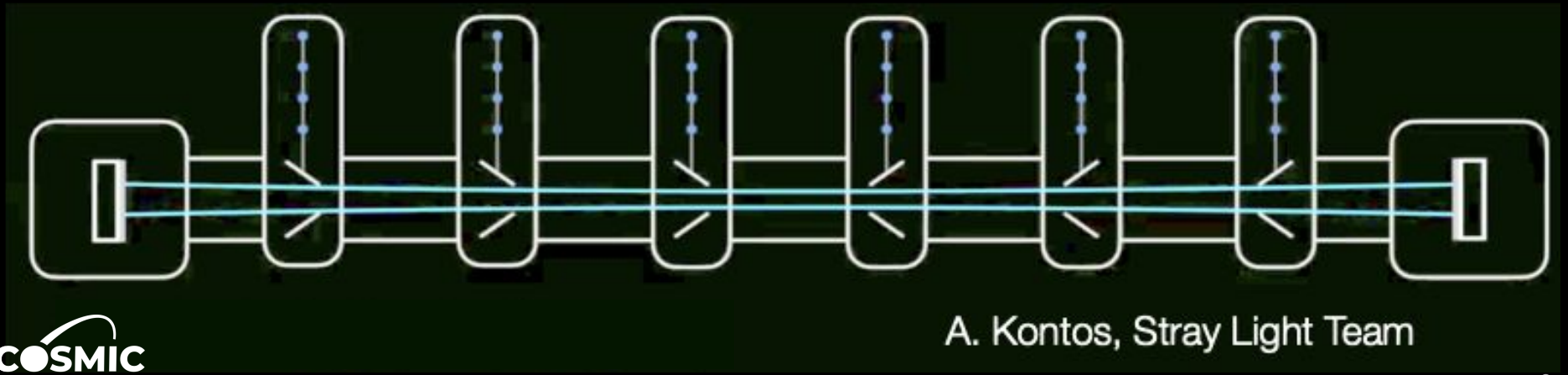
Species	Beamtubes Req / torr	Beamtubes Goal / torr	Chambers Req / torr	Chambers Goal / torr
He	1.3×10^{-9}	3.4×10^{-10}	8.8×10^{-10}	7.9×10^{-11}
H_2	3.3×10^{-10}	8.3×10^{-11}	3.1×10^{-9}	2.8×10^{-10}
Ne	1.8×10^{-10}	4.5×10^{-11}	3.9×10^{-10}	3.5×10^{-11}
H_2O	3.0×10^{-11}	7.6×10^{-12}	1.0×10^{-9}	9.4×10^{-11}
O_2	2.1×10^{-11}	5.3×10^{-12}	7.8×10^{-10}	7.0×10^{-11}
N_2	1.9×10^{-11}	4.7×10^{-12}	8.3×10^{-10}	7.5×10^{-11}
Ar	6.7×10^{-12}	1.7×10^{-12}	2.8×10^{-10}	2.5×10^{-11}
CO	5.8×10^{-12}	1.4×10^{-12}	3.3×10^{-10}	3.0×10^{-11}
CH_4	4.8×10^{-12}	1.2×10^{-12}	4.4×10^{-10}	4.0×10^{-11}
CO_2	2.8×10^{-12}	6.9×10^{-13}	2.7×10^{-10}	2.4×10^{-11}
Xe	6.3×10^{-13}	1.6×10^{-13}	1.5×10^{-10}	1.4×10^{-11}
100 u H_nC_m	8.9×10^{-14}	2.2×10^{-14}	1.8×10^{-10}	1.6×10^{-11}
200 u H_nC_m	1.7×10^{-14}	4.2×10^{-15}	1.2×10^{-10}	1.1×10^{-11}
300 u H_nC_m	6.2×10^{-15}	1.5×10^{-15}	1.0×10^{-10}	9.2×10^{-12}
400 u H_nC_m	3.1×10^{-15}	7.6×10^{-16}	8.8×10^{-11}	7.9×10^{-12}
500 u H_nC_m	1.7×10^{-15}	4.3×10^{-16}	7.9×10^{-11}	7.1×10^{-12}
600 u H_nC_m	1.1×10^{-15}	2.8×10^{-16}	7.2×10^{-11}	6.5×10^{-12}

from CE-T2300008 (by Kevin Kuns)

Species	Mass / kg	Polarizability / m^3	$\alpha/\alpha_{H_2}(m/m_{H_2})^{1/4}$
He	6.64×10^{-27}	2.08×10^{-31}	0.31
Ne	3.35×10^{-26}	3.81×10^{-31}	0.86
H_2	3.35×10^{-27}	7.87×10^{-31}	1.00
H_2O	2.99×10^{-26}	1.50×10^{-30}	3.29
O_2	5.31×10^{-26}	1.56×10^{-30}	3.96
N_2	4.65×10^{-26}	1.71×10^{-30}	4.19
Ar	6.63×10^{-26}	1.66×10^{-30}	4.45
CO	4.64×10^{-26}	1.95×10^{-30}	4.78
CH_4	2.66×10^{-26}	2.45×10^{-30}	5.23
CO_2	7.31×10^{-26}	2.51×10^{-30}	6.89
Xe	2.18×10^{-25}	4.01×10^{-30}	14.47
100 u H_nC_m	1.66×10^{-25}	1.14×10^{-29}	38.43
200 u H_nC_m	3.32×10^{-25}	2.21×10^{-29}	88.60
300 u H_nC_m	4.98×10^{-25}	3.29×10^{-29}	145.97
400 u H_nC_m	6.64×10^{-25}	4.36×10^{-29}	207.87
500 u H_nC_m	8.30×10^{-25}	5.49×10^{-29}	276.76
600 u H_nC_m	9.96×10^{-25}	6.54×10^{-29}	345.07

Stray light in the Tubes

One clear implication of having a very long, very thin, hole in the air is that a few photons might go astray and bounce off the walls. Others will have a lot to say about this, so I'll move on…



Facility Implications

What are all these little buildings?

Why so many roads?

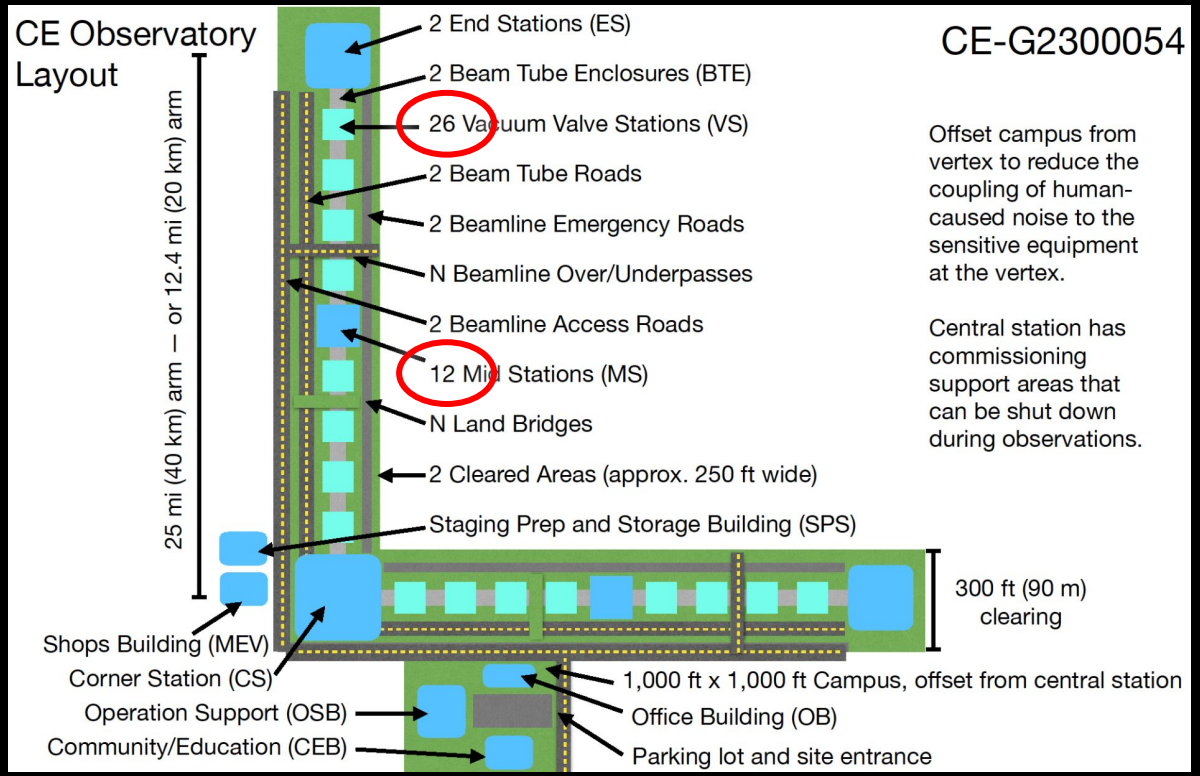
Facility Implications

Pump ports every 250m?
300+ access points (with power? enlarged enclosure?).

Valves every 2km?
38 buildings to support them!

A few suspended baffles?
More/bigger buildings.

Parallel installation teams?
80km of roads (how wide?).

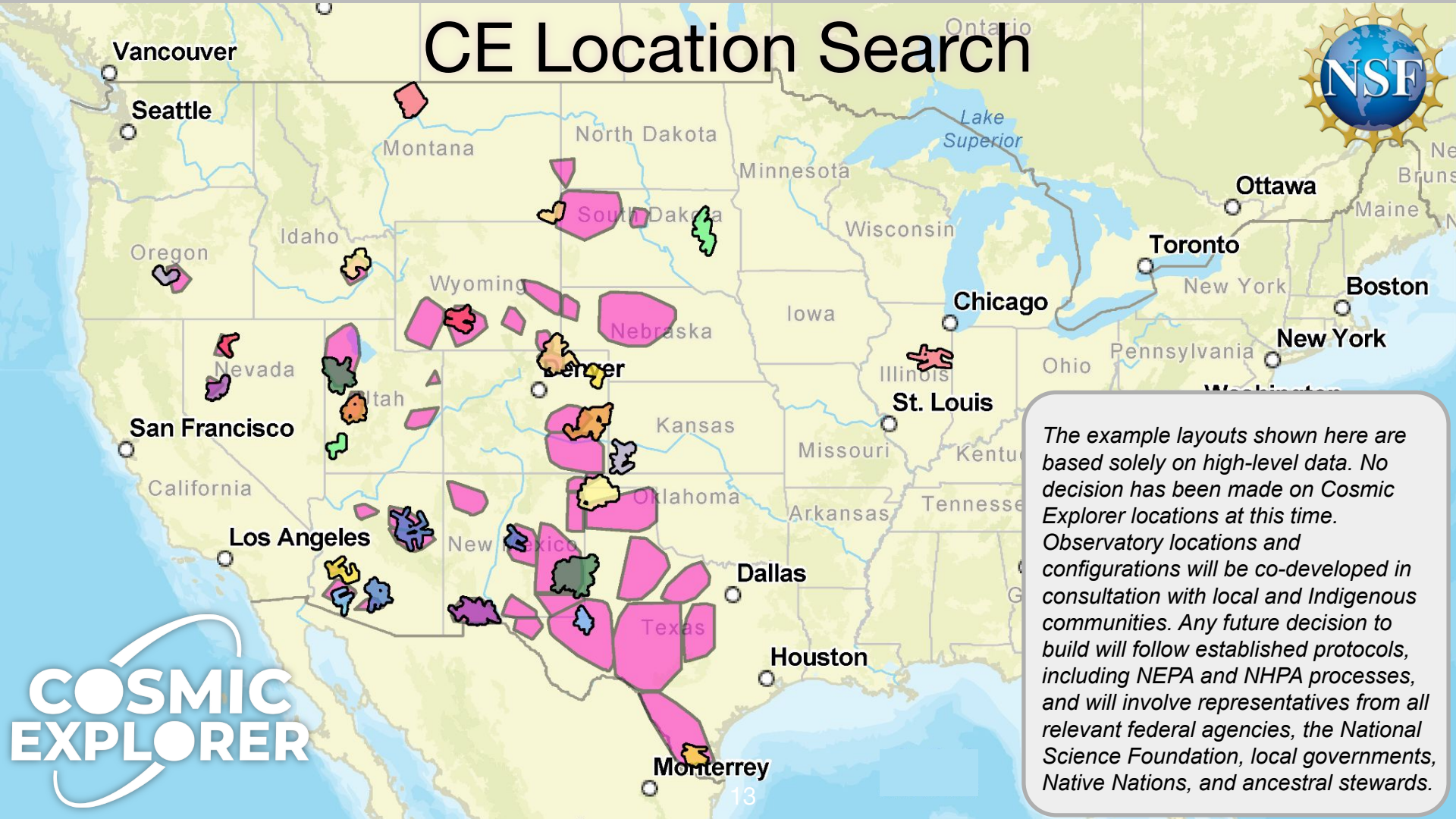


The Message

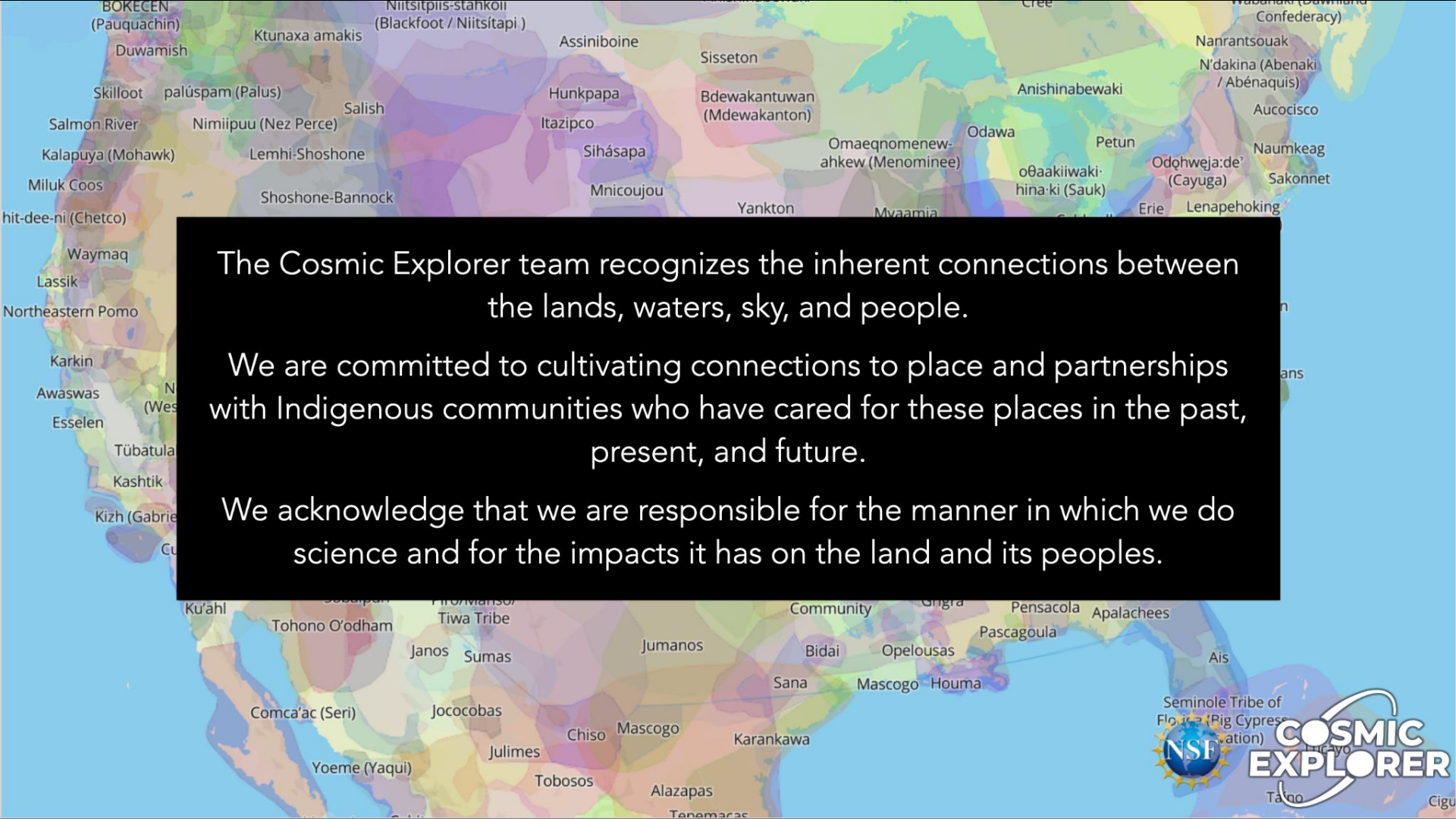
- We're looking forward to stability at the NSF
  - And a path for CE to continue as a NSF major facility project
- We are collaborating with ET on multiple topics (Vacuum, optical design, … XGCD!)
- The CE vacuum system is roughly one third of the observatory cost… so, **several hundred million** dollars!

- Thank you for attending - I'm happy to take questions!

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.
NSF
COSMIC EXPLORER