Dawn-V Workshop

“Time constraints and opportunities across the globe”

LIGO planning

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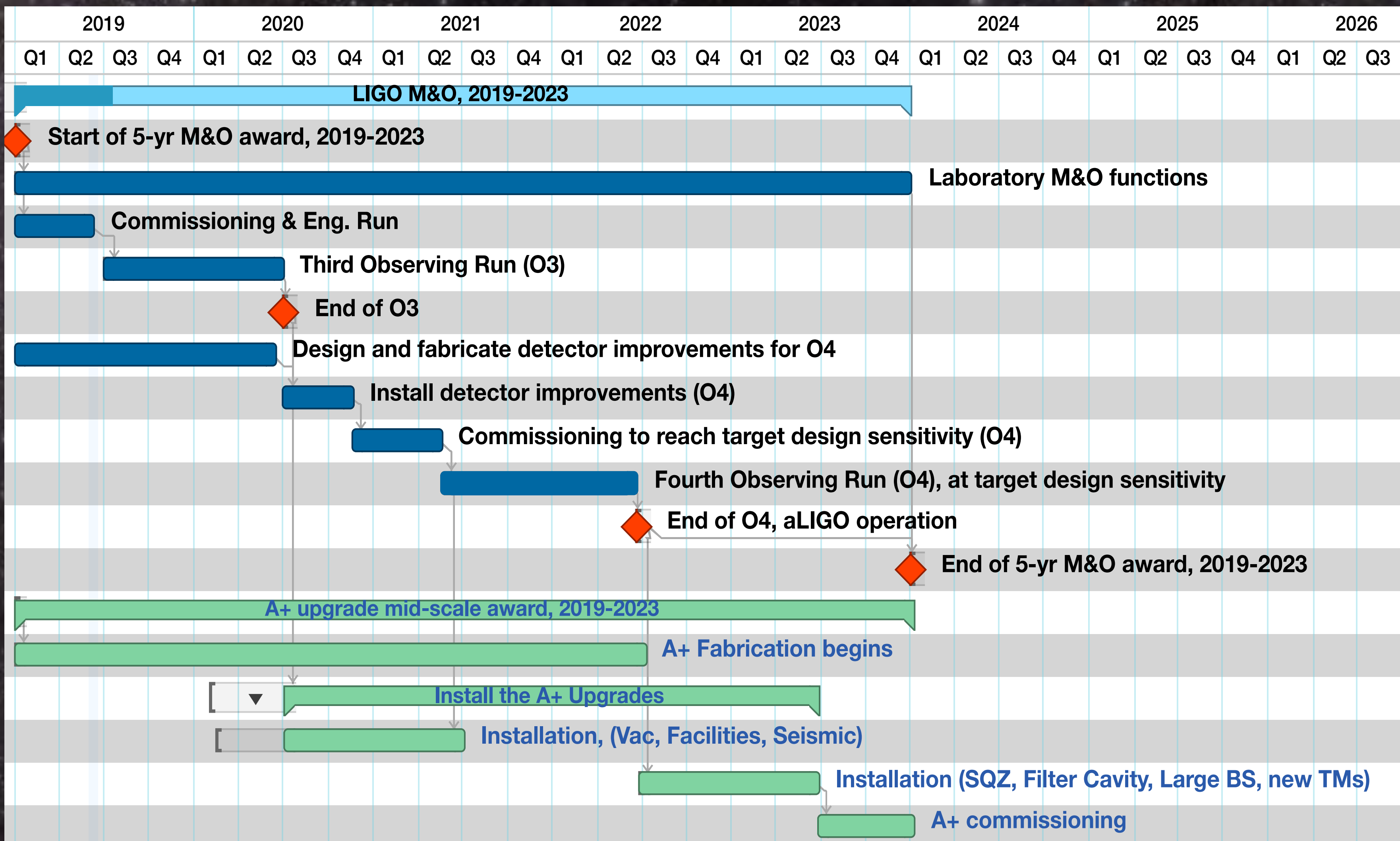
EGO, Cascina, Italy

NGC 4993 + GW170817
Credit: ESO/A.J. Levan, N.R. Tanvir


Today through ~ 2026
LIGO-G1900969-v1

Five Year Plan for Observational Runs, Commissioning, and Upgrades 2019-2023

*As of April 2019**



** May be revised as O3 continues, in consultation with Virgo, KAGRA*

LIGO-G1900969-v1

A+ in a nutshell*

- A now-FUNDED incremental upgrade to aLIGO that leverages existing technology and infrastructure, with minimal new investment and moderate risk
  - UK, Australia are partners, following successful aLIGO model
  - Incremental cost: *a small fraction of aLIGO investment*
- Plan: start commission by 2023, observations thereafter
- Target: factor of 1.7† increase in range over aLIGO
  =>About a factor of 5 greater CCB event rate
- "Scientific breakeven" within 1/2 year of observation after installation/commissioning shut down
- Stepping stone to future 3G detector technologies
- Link to future GW astrophysics, cosmology, nuclear physics

† BBH 20/20 $M_\odot$: 1.64x
† BNS 1.4/1.4 $M_\odot$: 1.85x

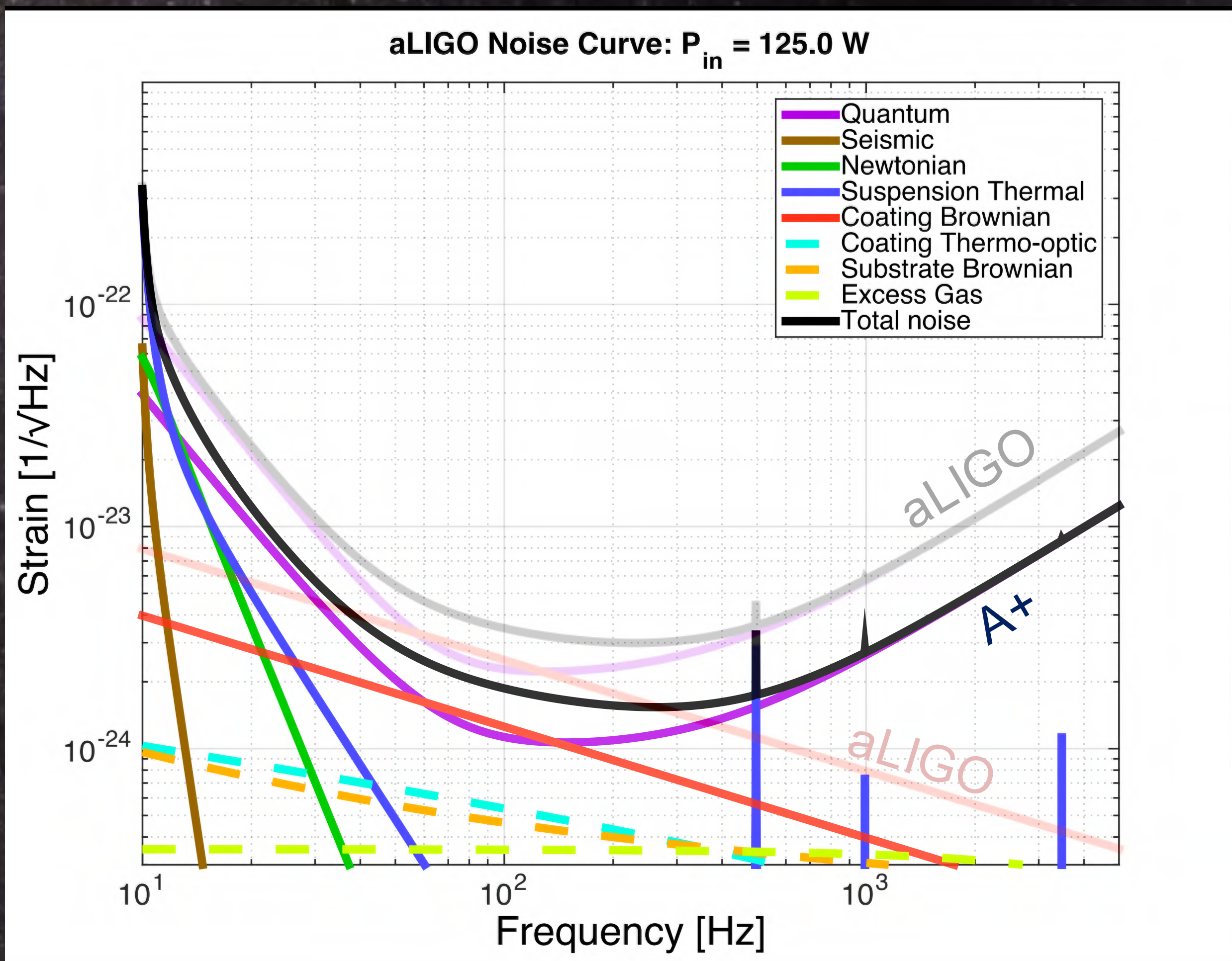
* Updated, from M. Zucker presentation GWADW17, LIGO-G1700825

Planning within LIGO Laboratory Coordinated with the LIGO Scientific Collaboration

- Key technology upgrades
  - Frequency dependent squeezing (300 m filter cavity)
  - Lower loss coatings
    - Target: 4X lower loss – 2x better strain
    - Coordinated effort between Laboratory and principal LSC groups with coatings experience
      - Working with groups outside the LSC with expertise in high-temperature deposition, low-rate deposition,
  - Balanced homodyne readout for lower noise, better scatter immunity, reduced losses, better phase tuning, greater readout dynamic range

Sensitivity target for A+

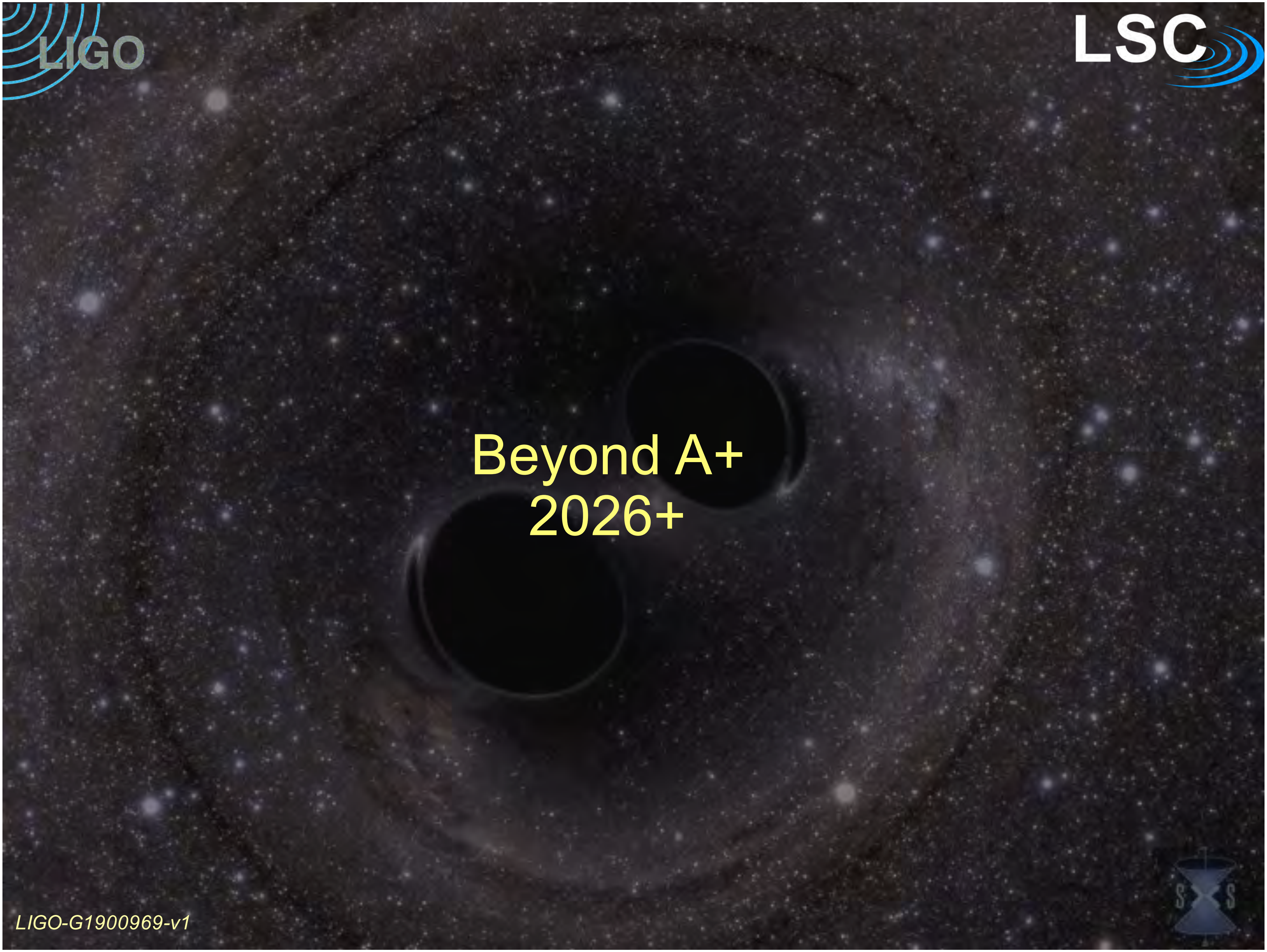
- A+ vs. aLIGO sensitivities



Laser Power: 125.00 Watt
SRM Detuning: 0.00 degree
SRM transmission: 0.3500
ITM transmission: 0.0140
PRM transmission: 0.0300
Finesse: 446.41
Power Recycling Factor: 40.54
Arm power: 710.81 kW
Power on beam splitter: 5.07 kW
Thermal load on ITM: 0.385 W
Thermal load on BS: 0.051 W
BNS range: 354.06 Mpc (comoving)
BNS horizon: 814.04 Mpc (comoving)
BNS reach: 510.28 Mpc (comoving)
BBH range: 2.24 Gpc (comoving, z = 0.6)
BBH horizon: 5395.58 Mpc (comoving, z = 2.
BBH reach: 3700.64 Mpc (comoving, z = 1.1
Stochastic Omega: 6.78e-10

Planning within LIGO Laboratory Coordinated with the LIGO Scientific Collaboration

- Near term: LIGO-India (2025)
  - New "green-field" facility being built by the Government of India
  - The facility should be better than the LIGO sites seismically
  - Long-term resource for the global network
  - Baseline plan: a 3rd Advanced LIGO interferometer
    - L-I is taking A+ impacts on the facility design into account, e.g., ensuring that a filter cavity can be accommodated with minimal impact in the future.
    - L-I has acknowledged that by the time it comes on line the US A+ detectors will have better performance than the baseline Advanced LIGO design the US is providing.
    - The intent is to introduce the same upgrades at the time of installation. There are plans to augment the L-I budget baseline for these modifications.


LIGO
LSC
Beyond A+
2026+
LIGO-G1900969-v1

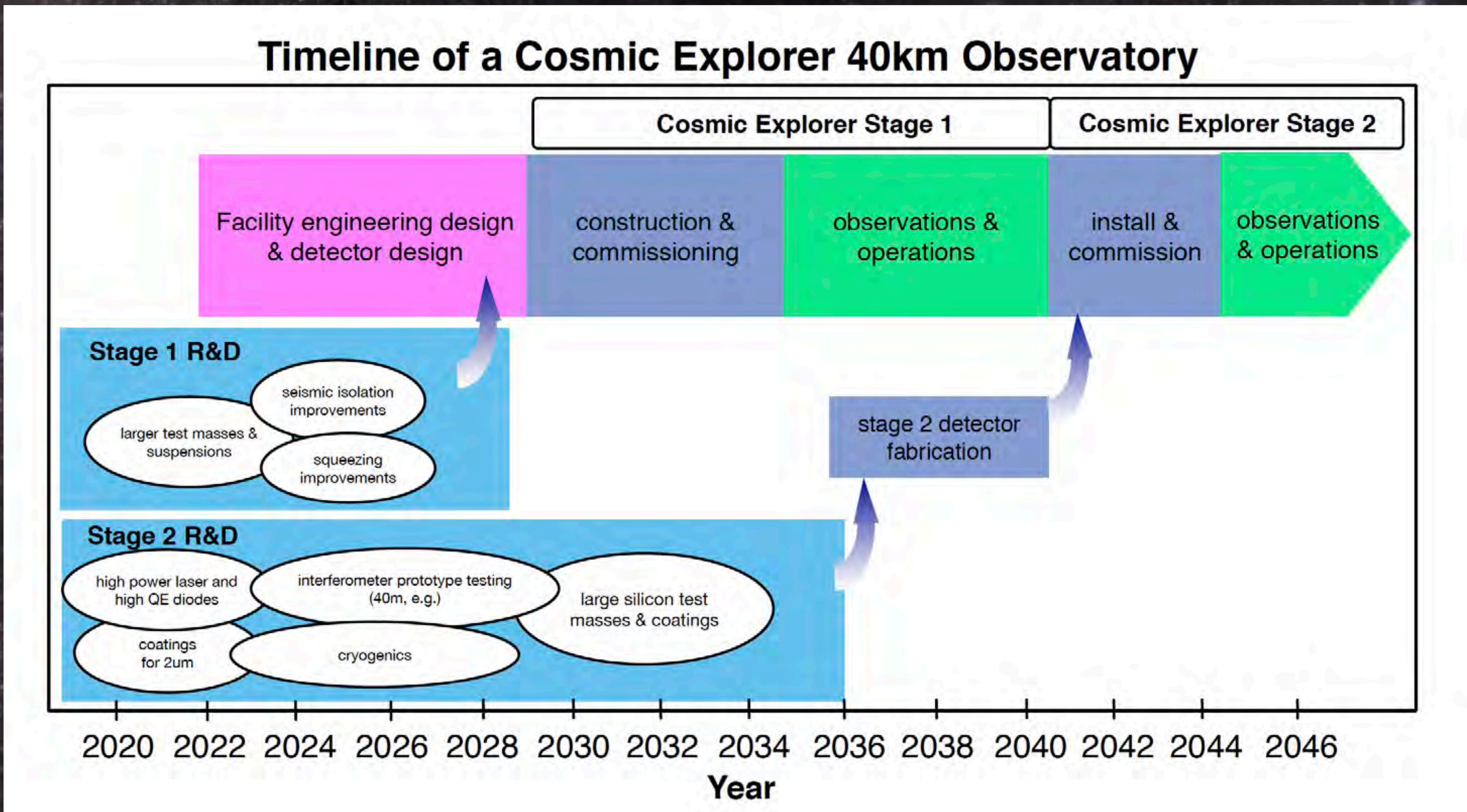
US 2020 Decadal Survey + 3 US 3G

- Charge to committee asks it to take into account the new era of multi-messenger astronomy as it assesses programs, priorities
- LIGO is not specifically part of the charge
  - The concept, costs for a 3G US detector are not sufficiently mature for it to be included in this survey
  - Cadence of the surveys requires R&D planning inputs for this 2020 Survey
  - The GW community has submitted a number of white papers to the committee laying out what is needed during the next decade in order to enable a US 3G detector construction late in the next decade

US 2020 Decadal Survey + 3 US 3G

- GWIC: "Gravitational-Wave Astronomy in the 2020s and Beyond: A view across the gravitational wave spectrum"
  - + a number science case WPs
- LSC: "Gravitational wave astronomy with LIGO and similar detectors in the next decade"
- *LIGO Laboratory: "The US Program in Ground-Based Gravitational Wave Science: Contribution from the LIGO Laboratory"*

The US Program in Ground-Based Gravitational Wave Science: Contribution from the LIGO Laboratory



The US Program in Ground-Based Gravitational Wave Science: Contribution from the LIGO Laboratory (2)

- Long lead time scale suggests a 2-phase approach to 3G CE
  - Follows the successful 2-phase Initial/Advanced LIGO model proposed to NSF in 1989
- Phase 1: use A+ technology and scale up to 40km arms
  - Focus and major costs would be on infrastructure
  - Use “conventional” technologies that will have been commissioned and in use for 1+ decades
- Phase 2: Voyager technology development will target an upgrade
- A mostly quantum-limited detector that can be further enhanced with higher power, squeezing, or more advanced quantum noise techniques

Voyager technologies

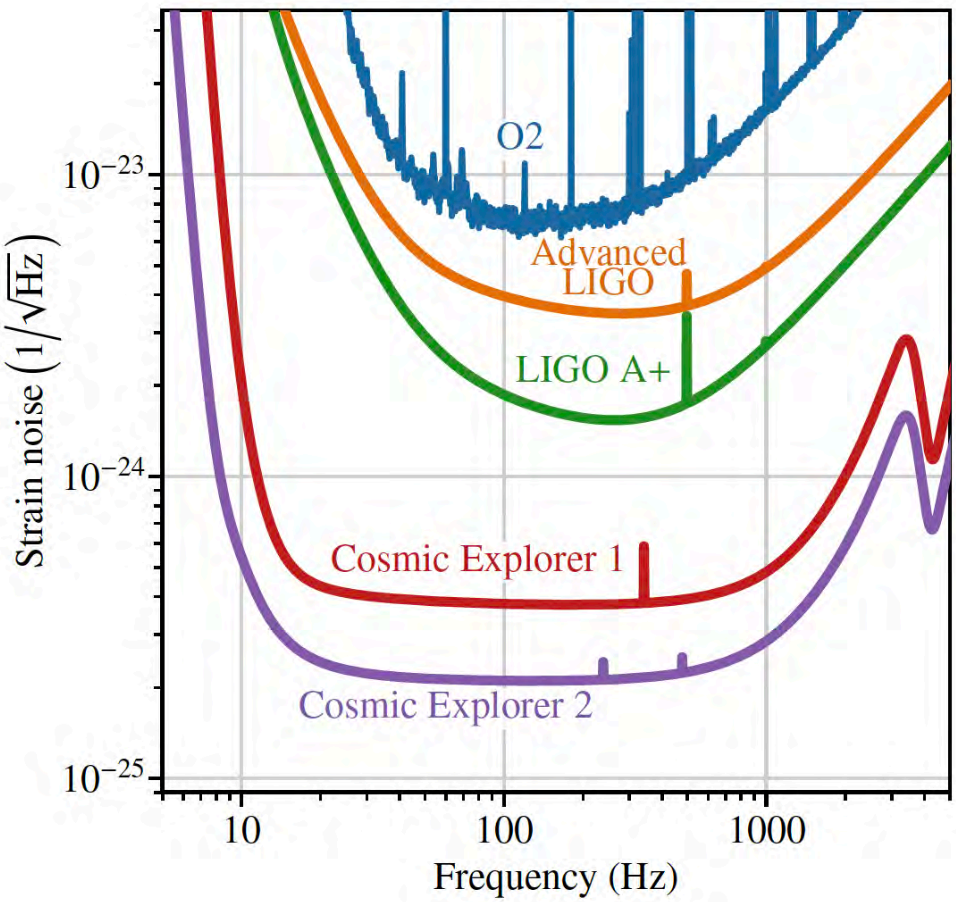
Sub-Systems

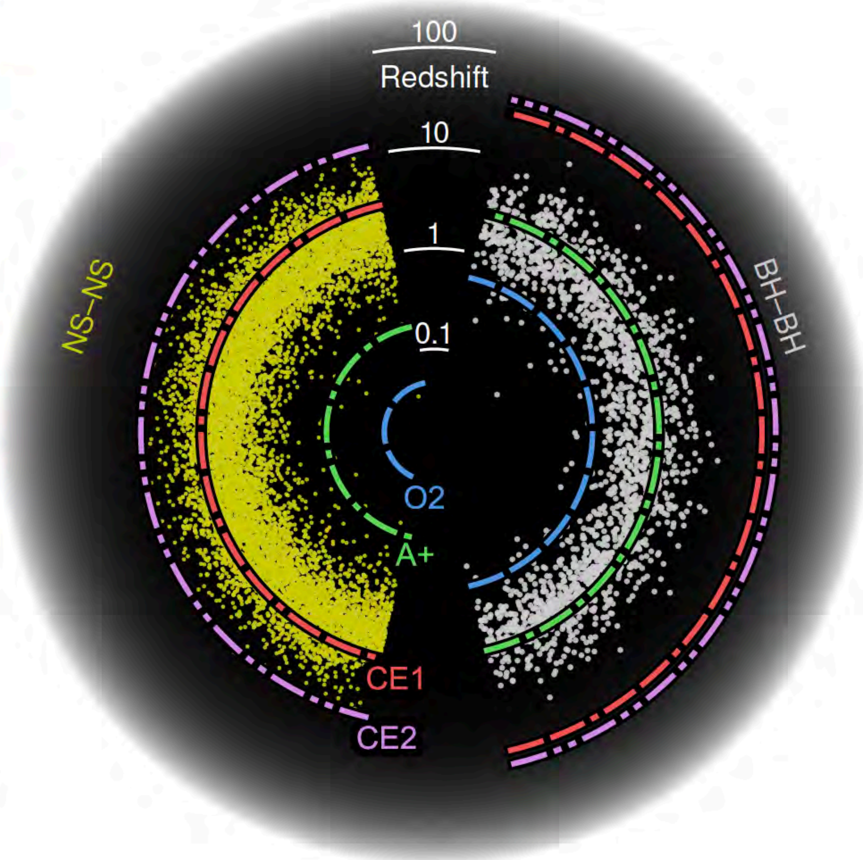
- Silicon Mirrors: **200 kg, 45 cm dia.,** mCZ process
- **Coatings**: α-Si/SiO_2 (α-Si: ~lossless thin film)
- **Cryogenics**: 123 K (zero CTE), radiative (non-contact) cooling
- Lasers (2000 nm): P~ 180 W, P_{ARM} ~ 2800 kW
- Wavefront Compensation: thermally adjustable lenses only (no actuation of test mass)
- Photodiode Quantum Efficiency: 80 -> 99% for 2 micron

Draft Whitepaper: https://dcc.ligo.org/LIGO-T1400226

From A. Adhikari, NSF review Nov 2017

CE: A phased approach





2020 Astro Decadal Survey (2)

- LIGO Laboratory is developing a second white paper to the Decadal Survey's call for Activity, Project, or State of the Profession Consideration (APC)
- Elements will include:
  - An engineering study for the design and construction of a 40km arm length L-shaped interferometric gravitational-wave detector
  - Identifying candidate construction sites and provide realistic costs.
  - Identifying detector technologies and designs for a phased approach for the 3rd generation detectors
  - Outlining a program of laboratory research and prototyping to adapt existing detector components and designs to the longer arms (Phase 1)
  - Developing capability to test larger heavier test masses and suspension systems and to develop the technologies involving cryogenics, new materials for test masses and different wavelength lasers and optical components (Phase 2)
  - A program for forging an international collaboration for the construction and operation of a unified 3rd generation network of gravitational-wave detectors.

Closing comments

- LIGO Laboratory is leading a collaboration study funded by NSF to conceptualize a 40 km detector
  - Preparatory to a full engineering & prototyping phase (ref: previous slide)
- The big questions:
  - Will LIGO be operating in essentially an A+ configuration from 2025 to 2035 (maybe with incremental improvements)?
  - Given the current state of detector R&D, when will LIGO be in a position to carry out an upgrade beyond A+?
  - Will there be resources to do a Voyager upgrade to (one or both) the existing sites to further increase detector sensitivity before CE is online?
- Push ahead to get a CE-class observatory built as fast as possible while getting an R&D effort in place to develop Voyager technologies?