National Science Foundation
Directorate for Mathematical & Physical Sciences

MEMORANDUM

DATE: November 22, 2022

TO: Cornelia Lang, MPSAC Chair

FROM: Sean L. Jones, MPS Assistant Director

SUBJECT: Request from MPS to create an MPSAC Subcommittee to review and evaluate concepts for the Next Generation Gravitational Wave Detector facility

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The Assistant Director of the Mathematical and Physical Sciences Directorate requests that the Mathematical and Physical Sciences Advisory Committee (MPSAC) establish a Next Generation Gravitational Wave (GW) Detector Concept Subcommittee (NextGenGW SC) to assess and recommend a set of concepts for new GW observatories in the U.S., including an articulation of the corresponding scientific opportunities. The overarching goal is to identify configurations that can operate at approximately an order of magnitude greater than the sensitivity of LIGO A+ by the mid-2030s. While the outcome of this subcommittee will be to recommend an optimal NextGenGW concept, the expectation is that as that concept matures into an MREFC-scale detection network, the findings of this subcommittee will inform future deliberations of the existing MPSAC Subcommittee on Facilities and Major Research Infrastructure.

Background

NSF's Laser Interferometric Gravitational-Wave Observatory (**LIGO**), the first Major Research Equipment and Facilities Construction (**MREFC**) project, has been a flagship detector for NSF for more than two decades. LIGO's first direct detection of GW in 2015 made NSF the world leader in the nascent field of GW science, a discipline often called "a new window" on the Universe. This new window has led to the explosion of a related field known as Multi-Messenger Astrophysics (**MMA**), which includes not just GW detectors, but any other astronomical/astrophysical work related to phenomena that emit more than one *messenger* (i.e., EM radiation, particles, and GWs). Thanks to LIGO, NSF is the only agency in the world that supports research in all three types of messengers. LIGO discoveries have led to a number of awards for the LIGO Scientific Community members, including the 2016 Special Breakthrough Prize in Fundamental Physics, the 2016 Shaw Prize in Astronomy, the 2016 Kavli Prize in Astrophysics, the Gruber Prize in Cosmology, the 2017 Nobel Prize in Physics, the AAS Bruno Rossi Prize, 2019 New Horizons in Physics Prizes, 2020 Breakthrough Prizes for contributions to Multi-Messenger Astrophysics, and the 2020 Australian Prime Minister's Prize for Science.

However, LIGO was initially designed with a life span of about 20 years, although it is being incrementally extended through additional, and ever increasing, investments to refurbish or

replace critical elements. The scientific community is preparing the groundwork for the design, construction, and eventual operation of the next-generation GW detector. The National Academy of Sciences (**NAS**) Astro Decadal Survey 2020 "*Pathways to Discovery in Astronomy and Astrophysics for the 2020s*" describes it as a central component of the future of astronomy and astrophysics:

"*Gravitational wave astrophysics is one of the most exciting frontiers in science. One of the survey's key priorities is the opening of new windows on the dynamic universe, with gravitational wave detection at the forefront. The continued growth in sensitivity of current-generation facilities, such as LIGO, through phased upgrades and planning the next-generation observatory, such as Cosmic Explorer, is essential. This will require investment in technology development now. The survey committee strongly endorses gravitational wave observations as central to many crucial science objectives*."

Consideration of the NextGenGW detection network is, over and above its potential to foster the progress of science, also a direct response to the Astro2020 recommendation. The formation of the subcommittee is the first step in this direction. The subcommittee will also provide a platform for community input, which will be essential in shaping the advice provided by the MPSAC.

The next-generation U.S. GW detector network will operate as part of an international network that is expected to include the European observatory known as the *Einstein Telescope*. The Einstein Telescope entered the European Strategic Forum on Research Infrastructure (ESFRI) roadmap in 2021 and is planned to reach a sensitivity 10 times that of the current LIGO A+ upgrade. A comparable increase in sensitivityof a future U.S.-based detection network will ensure the U.S. makes a leading and meaningful contribution to the global network, further extending the global discovery reach.

Charge

The NextGenGW subcommittee is asked to assess and recommend configurations for a U.S. GW detection network that can operate at a sensitivity approximately an order of magnitude greater than that of LIGO A+ by the middle of the next decade. The subcommittee will take input from the scientific community by any means deemed appropriate, such as requesting white papers, holding information seminars or town hall meetings, etc.

Specifically, the subcommittee is asked to deliver:

- An overview of the potential astrophysical scientific outcomes of the next generation of the U.S. GW detection network with prescribed sensitivity, and with connections to other scientific areas.
- A survey of the highest priority detector concepts that could be nodes of the GW detection network, considering for each one the potential for scientific discovery, technical readiness by the end of the decade, technical risk, R&D requirements, construction cost, and maintenance and operations costs for the first ten years. The

network nodes to be considered will include new facilities as well as potential upgrades to the current LIGO sites.

- Based on this survey, a recommended list of GW detection network configurations that will deliver a detector with sensitivity an order of magnitude greater than the LIGO A+ design. The prioritization will optimize the potential scientific impact, consistent with the level of resources needed to plan, construct, and operate it. The committee will consider projected MREFC funding levels as well as available support for operations. The recommendation will take into account the international global GW network the U.S. detector is expected to complement.

The subcommittee will provide a preliminary report to the MPSAC by October 2023, and a final report by January 2024 for consideration. In accordance with Federal Advisory Committee Act (FACA) rules, the reports will be discussed and approved by the MPSAC before formal transmittal to NSF.

We appreciate your effort in establishing this subcommittee. Its deliberations and recommendations will inform NSF on a prioritized list of U.S. GW network configurations and contribute to NSF planning activities. The formation of the subcommittee does not imply any commitment by NSF to specific funding or project status.

We look forward to working with you on this important endeavor.