



LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
LIGO Laboratory / LIGO Scientific Collaboration

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The LIGO Laboratory Charter (2019 – 2023)		
LIGO Laboratory Directors		

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Table of Contents

1	Objectives	4
1.1	Scientific Objectives.....	4
1.2	Technical Objectives	4
1.3	Broader societal impacts.....	5
2	Facility Description	5
3	Mission and Responsibilities	6
4	National Science Foundation Cooperative Agreement	7
5	Institutional Roles and Responsibilities	7
5.1	NSF.....	7
5.2	Caltech.....	8
5.3	MIT.....	9
5.4	Oversight Committee.....	9
5.5	Executive Director and Deputy Director.....	9
6	Organization of the LIGO Laboratory	10
6.1	LIGO Laboratory Directorate.....	11
6.2	LIGO Scientific Collaboration	11
6.3	Other Scientific Collaborations	12
6.4	LIGO Program Advisory Committee	12
6.5	LIGO Visitors Program	12
6.6	Education and Public Outreach Program	13
7	LIGO Laboratory Groups.....	13
7.1	Hanford & Livingston Observatories	13
7.2	MIT LIGO Laboratory	14
7.3	Business Office.....	14
7.4	Laboratory Engineering Groups	14
7.5	CIT Science Group - GW Astrophysics and Detector Science Subgroups.....	15
7.6	Laboratory Computing Group	16
8	LIGO Laboratory Projects	16
8.1	Advanced LIGO Plus ‘A+’ Project	16
8.1	Detector commissioning.....	16
8.2	LIGO Detector Developments.....	16
8.3	Campus-based Research Facilities – 40m interferometer (CIT), LASTI (MIT).....	17
8.4	LIGO-India	17
8.5	Gravitational-Wave Open Science Center (GWOSC)	17
9	LIGO Directorate Functions	17
9.1	Oversight of Education and Outreach	17
9.2	Cybersecurity.....	17
9.3	The Laboratory Chief Engineer.....	18
9.4	The Laboratory Chief Detector Scientist.....	18
9.5	The Executive Committee	18
9.6	The Staffing Committee	18
9.7	The Operations Management Team (OMT).....	18
9.8	The Diversity Committee	18

9.9	Environment, Safety and Health Protection	19
9.10	Laboratory R&D Coordinator	19
9.11	Laboratory Change Control Board	19
9.12	Laboratory External Committees	20
10	Governmental Code Requirements	20
11	Procurements and Subcontracts	20
11.1	Policy	20
11.2	Responsibilities.....	20
11.3	Approach	21
12	Reporting and Reviews	21
12.1	Annual Report	21
12.2	Annual Work Plan (AWP).....	21
12.3	Acquisition Plan	21
12.4	Quarterly Reports	21
12.5	Credit Draws.....	22
12.6	NSF Site Visits/Panel Reviews	22
13	Workshops.....	22
14	Technical Reports	22
	References	23
	Figure 1. Overall LIGO Organization.....	24
	Figure 2. LIGO Laboratory Organization (as of Oct 1, 2018).....	25

1 Objectives

1.1 Scientific Objectives

The scientific objectives of LIGO include research in the fundamental physics of gravitation as well as in astronomy and astrophysics. The first detections of gravitational waves by LIGO in 2015 have opened the field of gravitational-wave physics and astronomy. Possible future advances in gravitational physics include:

- further detections of gravitational waves;
- tests of General Relativity in the strong field and high velocity limit;
- direct measurement of the polarization and propagation speed of gravitational waves;
- direct observation of the dynamics of black holes; and
- constraining the neutron-star equation of state.

Possible observations in astronomy and astrophysics that may not be measurable by other methods include:

- the final moments of coalescing extragalactic binary neutron star systems, which serve as the design benchmark for the sensitivity and spectral coverage of LIGO;
- coalescing black-hole/black-hole and black-hole/neutron-star binary systems;
- the inner dynamics of stellar collapse;
- the internal and surface dynamics of neutron stars;
- the dynamics of the primordial universe at the earliest stages of cosmic evolution; and
- an inventory of the gravitational-wave sources distributed throughout the universe.

It is highly likely, as has been the experience when other branches of observational astrophysics have been opened, that LIGO will discover previously unobserved classes of sources. The LIGO facilities are designed to accommodate a succession of detectors with enhanced sensitivity and adjustable spectral response to retain flexibility in the exploratory phase of the science, and to optimize scientific returns once gravitational waves have been detected.

Advances in the experimental science related to gravitational-wave detection have already brought about advances in the physics of precision measurement, and have significant potential to bring about still further advances in the field, specifically:

- new forms of laser interferometry, with new levels of precision
- using quantum states of light to exceed the Standard Quantum Limit in interferometric sensing
- unprecedented stability of short-term frequency references
- understanding of, and the means to reduce, the influence of thermal noise in precision measurement

1.2 Technical Objectives

The LIGO Observatory infrastructure is designed to provide an environment for detectors of increasing sensitivity and versatility. The LIGO Laboratory operates observatories at Hanford, Washington and Livingston, Louisiana. In the initial LIGO operations era (2002-2010), two interferometers of 4 km and 2 km arm lengths were operated at Hanford, and a single 4 km interferometer at Livingston. During the Advanced LIGO operations era, which began in 2015, one 4 km Advanced LIGO interferometer each is operated at Livingston and Hanford. A third interferometer will be situated in India, remote from the continental U.S., to provide a triad of km-scale interferometers separated by intercontinental baselines.

Advanced LIGO is designed to be sensitive to binary neutron star mergers to an average distance of 172 Mpc once it achieves design sensitivity. During the 2019-2023 period, the LIGO Laboratory will undertake a series

of observing runs with Advanced LIGO to conduct searches for gravitational waves. Between observing runs, LIGO scientists and engineers will commission the LIGO interferometers to reach their design sensitivity.

An important element of the LIGO mission is to support the development of improved interferometric detectors of gravitational waves through campus activities of the Laboratory and the greater LIGO Scientific Collaboration (LSC), and to accommodate and exploit those improved instruments at the observatories. Specifically in the 2019-2023 period, a mid-scale upgrade project, Advanced LIGO Plus ('A+') will commence to push Advanced LIGO's sensitivity beyond its original design goals.

1.3 Broader societal impacts

1.3.1 Education and Public Outreach

LIGO Laboratory operates Education and Public Outreach (EPO) programs, primarily based at the Hanford and Livingston Observatories, which are situated in rural areas having large underserved populations. Together, the two sites either host or provide contact in classroom settings to tens of thousands of individuals who might not otherwise be exposed to the importance of science and critical thinking. Professional development programs provide training and coaching to K-12 teachers to improve the quality of STEM education. The EPO teams actively engage in partnerships with organizations representing minority professionals to provide internship, training, and other educational opportunities to students who are considering STEM careers. LIGO Laboratory EPO is a critical component of the LSC EPO group, enabling LIGO outreach to engage a worldwide audience. In addition to our LSC EPO connections, critical to these efforts are long-established collaborations and partnerships with education-focused institutions in the observatories' local communities.

1.3.2 Undergraduate Education

Through the Laboratory visitors program and the CIT/MIT summer undergraduate internship programs, LIGO typically hosts students during the summer and smaller numbers during the school year who are afforded an opportunity to work with Laboratory scientists and engineers on ongoing research projects. The hands-on opportunities we provide these students, who are the next generation of scientists and engineers, are often career determining for them.

1.3.3 Technology development

LIGO Laboratory routinely works with industry to develop or improve the various technologies that make LIGO possible. Examples of these technologies includes:

- Low noise analog and digital electronics, and real-time software for the control of our instruments
- Novel computing techniques needed in data analysis
- Low loss (both optical and mechanical) optical coatings and massive optics; many of the issues we face are common to other precision measurement applications, such as light frequency standards
- Active, very quiet, seismic isolation techniques

2 Facility Description

The major LIGO facilities consist of vacuum systems at two widely separated sites: Hanford, Washington, and Livingston, Louisiana. The vacuum systems, in the shape of an "L" with 4 km arms, enclose laser interferometer beams. The beams originate from and are detected at the vertex of the "L" (corner station) and are reflected from the ends of the "L" (end stations). The system comprising two interferometers operates in coincidence as a single gravitational-wave detector.

The vacuum system consists of two major subsystems: the beam tubes running along the arms of the “L”, and the vacuum chambers and associated manifolds within the corner stations and end stations. The vacuum chambers contain the test masses (end points of the interferometer) and their associated seismic isolation systems, the interferometer optics, the optics for beam injection and extraction from the interferometer, and the electro-optic and mechanical instrumentation to maintain interferometer alignment and detect the measured gravitational-wave signal.

The beam tubes are protected by concrete enclosures, which provide environmental protection and serve to reduce interferometer noise from scattered light due to wind-driven and acoustically excited motions of the tubes. The enclosures also provide thermal protection to mitigate diurnal temperature excursions.

The buildings at both sites are designed to accommodate full exploitation of LIGO by improved and/or multiple detector phases of LIGO. In addition to the vacuum chambers and pumps, the corner station houses the facility and interferometer control systems, the laser power and cooling systems, the facility computer systems, office space for staff and visitors, staging areas, equipment receiving areas, and small electronic and mechanical shops. Additional buildings located near the corner station house additional office and laboratory space, data archiving and analysis computing, large equipment assembly areas, and education/public outreach demonstrations and classrooms. The mid-station and end-station buildings are smaller, containing only vacuum chambers, pumps, and equipment receiving and staging areas.

In addition to the large remote facilities, both Caltech and MIT host on-campus research facilities that support the Laboratory’s overall mission and objectives. Caltech has a 40 m (1% scale) interferometer that is dedicated to research on various aspects of interferometry critical to making the 4-km instruments operate. In the past this has included the first demonstration (by LIGO) of signal and power recycled suspended Fabry-Perot interferometry, proof-of-concept demonstration of squeezing for km-scale instruments, development of novel control and acquisition schemes that were needed to allow the full scale instruments to operate, etc.

MIT has a 15 m LIGO Advanced Systems Test Interferometer (LASTI) that employs full-scale vacuum vessels identical to those at the two observatories. This has enabled us to prototype, test, and improve on a number of seismic isolation subsystems and suspensions that were then deployed at the observatories. The MIT facility also has dedicated infrastructure to investigate and develop quantum squeezing of light for use in LIGO.

3 Mission and Responsibilities

The program and mission of the LIGO Laboratory are to:

- Observe gravitational wave sources;
- Operate the LIGO Observatories and campus facilities to support the national and international scientific community;
- Exercise stewardship of the observatory detectors, buildings, grounds and equipment, intended for continuous scientific use over the next several decades;
- Exercise stewardship over data produced by the Advanced LIGO detector;
- Develop instrument science and technology for advanced detectors that approach and exploit the facility limits on interferometer performance and lead to new observatories;
- Support the development of LIGO-India in partnership with the Institute for Plasma Physics, the Inter-University Centre for Astronomy and Astrophysics, the Raja Ramanna Centre for Advanced Technology, and the Department of Atomic Energy Division of Construction Services and Estate Management from India.
- Support scientific education and public outreach related to gravitational wave astronomy.

To achieve these goals, LIGO Laboratory will:

- Provide necessary support, personnel, and equipment for the two Observatories – Hanford LIGO Observatory (LHO) at Hanford, WA, and the Livingston LIGO Observatory (LLO) at Livingston, LA
- Develop and maintain appropriate and effective cooperative relationships and partnerships in the communities that host our observatories
- Perform necessary research and development required to support the activities at LHO and LLO
- Perform opportunistic improvements of the LIGO interferometers
- Operate the LIGO interferometers for science data taking
- Manage, distribute, and curate LIGO scientific data for use by the LSC
- Regularly release LIGO data to the broader scientific community as provided for in the LIGO Data Management Plan
- Process and analyze the science data and publish the results in participation with the LIGO Scientific Collaboration
- Provide infrastructure and research support for members of the LIGO Scientific Collaboration participating in the LIGO scientific research program
- Define interferometer upgrades and carry out a research and development program to underpin future upgrade proposals, in conjunction with the LIGO Scientific Collaboration
- Coordinate with collaborating Indian institutions to deploy the third Advanced LIGO interferometer at a facility to be provided by the Government of India
- Provide support and guidance for research and development programs carried out at LSC institutions related LIGO program as described in the LSC development White Papers
- Support the development of, and coordinated observation by, the international network of gravitational wave detectors
- Continue to develop and expand an outreach program to interpret LIGO to the public and provide educational opportunities for young people
- Address new industrial technologies and applications stimulated by the requirements of gravitational wave observation

4 National Science Foundation Cooperative Agreement

The LIGO Laboratory operates under a Cooperative Agreement between the US National Science Foundation (NSF) and the California Institute of Technology (Caltech). In turn, Caltech maintains a subaward with MIT to cover MIT's role in joint operation of LIGO Laboratory with Caltech. The Agreement defines the obligations of Caltech and MIT in carrying out the mission of the Laboratory. This Charter is incorporated by reference in the Cooperative Agreement in the governance of the LIGO Laboratory.

5 Institutional Roles and Responsibilities

The LIGO Laboratory reporting and oversight is defined in the organizational hierarchy shown in Figure 1 at the end of this document. The major roles and functions of these entities are discussed below.

5.1 NSF

NSF is responsible for providing funding, general oversight, monitoring, and evaluation to help ensure Laboratory performance in accordance with approved work plans. The terms and conditions for LIGO Operations and Maintenance and the A+ Upgrade Project Upgrade are set forth in the Cooperative Agreements

(CA) PHY- 1764464 and PHY-1834382 between the NSF and Caltech.^{1,2} NSF will strive to obtain funding consistent with the Target Funding Levels set forth in the Cooperative Support Agreement. The actual funding available for LIGO operations will be negotiated with the Laboratory on the basis of the Annual LIGO Work Plan that, upon approval by NSF, will constitute the official operating plan for the year. Within the framework of the annual operating plan, NSF will undertake to provide the funding in a timely fashion and to provide the necessary document reviews and approvals as indicated in the Work Plan.

5.1.1 NSF Program Manager

Within the NSF, the LIGO Program Manager is responsible for scientific, technical, cost and schedule review, and agency guidance. Review of progress and programmatic review of annual work plans is the responsibility of the LIGO Program Manager. Direct communication between the LIGO Program Manager and the LIGO Directorate is the method by which this review and guidance will be accomplished. Performance of work under the Cooperative Agreement is subject to the general guidance and oversight by the NSF Program Manager for LIGO.

5.1.2 NSF Division of Acquisition and Cooperative Support

The NSF Division of Acquisition and Cooperative Support is responsible for Cooperative Agreement matters between the NSF and Caltech. Formal communications related to contracts and the NSF Division of Acquisition and Cooperative Support and the Caltech Office of Sponsored Research will accomplish required approvals. Annual funding increments and contractual obligations flow from the NSF Division of Acquisition and Cooperative Support, National Science Foundation (NSF), to Caltech under the Cooperative Agreement. Major procurements involving substantive subcontracts are approved or concurred with by the NSF Division of Acquisition and Cooperative Support in accordance with the terms and conditions of the Cooperative Agreement. The NSF Division of Acquisition and Cooperative Support will generally pre-approve such subcontracts based on information submitted by Caltech/LIGO as part of the annual work plan and the recognition that the Caltech Procurement System has been fully validated for purchases under federal grants and contracts through the NSF Business Systems Review (BSR) process. In those cases where the NSF Division of Acquisition and Cooperative Support requires additional information to approve a subcontract, NSF will inform Caltech/LIGO so as to allow the needed additional information to be provided in a timely manner.

5.2 Caltech

Caltech is held accountable, as the awardee, for the performance of the LIGO Laboratory, as described in the LIGO Annual Work Plan, as well as the relevant CAs. Caltech is responsible for staffing the Laboratory, providing institutional support, and ensuring adequate oversight of the execution and performance of the program. In turn Caltech ensures seamless joint operations with MIT through a subaward to the latter. Caltech's Office of Sponsored Research is responsible for matters between Caltech and NSF that pertain to the administration of the terms and conditions of the Cooperative Agreement and will accomplish this through formal communications with the NSF Division of Acquisition and Cooperative Support. Legal review and matters related to real property and property management are the responsibility of the Caltech Legal Counsel reporting to the President and the Caltech Vice President for Business and Finance, respectively.

¹ Cooperative Support Agreement 2019-2023 - The Operation and Maintenance of LIGO, between the National Science Foundation, Washington, D.C. 20550, and the California Institute of Technology, Pasadena, CA 91125.

² “The A+ Upgrade to Advanced” LIGO PHY-1834382 between the National Science Foundation, Washington, D.C. 20550, and the California Institute of Technology, Pasadena, CA 91125.

5.2.1 *Caltech Reporting*

Like other research programs in physics at Caltech, LIGO activities are part of the Division of Physics, Mathematics and Astronomy (PMA) through which academic appointments and educational matters are administered. The LIGO Laboratory Executive Director reports to the PMA Division Chair. The Division also provides administrative and logistical support to LIGO and oversight of the Caltech effort on LIGO.

5.3 MIT

The LIGO Laboratory encompasses a joint effort of Caltech and MIT. The MIT roles and responsibilities are defined through a Memorandum of Understanding³ and subaward from Caltech; the MIT subaward is subject to NSF approval. MIT administration shares responsibility with Caltech administration for oversight of the execution and performance of the LIGO program through representatives on the LIGO Oversight Committee. The MIT administration is also responsible for oversight, staffing and support of the MIT LIGO Group and for ensuring that it successfully meets its institutional commitments. It is the policy of the LIGO Laboratory to fully integrate MIT's participation in its operations with minimal institutional boundaries.

5.3.1 *MIT Reporting*

At MIT, academic appointments and educational aspects of LIGO are administered through the Department of Physics; research activities are supported through the Kavli Institute for Astrophysics & Space Research. The Department of Physics and the Kavli Institute for Astrophysics & Space Research provide oversight of the MIT effort on LIGO. They report to the President of MIT through the Dean of Science.

5.4 Oversight Committee

The presidents of Caltech and MIT have established a LIGO Oversight Committee, chaired by a member appointed by the Caltech President. It is composed of three members each from Caltech and MIT appointed by their respective presidents, one appointee each from several other LSC institutions that are major stakeholders in LIGO, two elected representatives from the LSC who serve as non-voting "technical advisors", two appointed external non-voting representatives from the theoretical astrophysics community and the observational astronomy community, and an NSF representative as an observer. The past LSC Spokesperson also serves as a non-voting member. The Oversight Committee reports to the presidents through the Chair of Physics, Mathematics and Astronomy at Caltech, and the Dean of Science at MIT. It provides review of LIGO program status and progress as required. The Oversight Committee functions under a formal written charge LIGO-M040409.

5.5 Executive Director and Deputy Director

The LIGO Laboratory Executive Director is appointed by the Caltech President in consultation with the MIT President and with the approval of NSF. The Director performs his/her responsibilities in close association with the LIGO Laboratory Deputy Director, who is appointed by the Director with the approval of the Presidents and the NSF. The LIGO Laboratory Executive Director, in association with the Deputy Director, reports progress on a periodic basis to the LIGO Oversight Committee.

5.5.1 *Reappointment and Performance Review of the Executive Director*

The Caltech Chair of the Division of Physics, Mathematics and Astronomy nominates the Executive Director. The nomination is reviewed by the Caltech Provost and forwarded to the Caltech President. The Caltech

³ Memorandum Of Understanding between the California Institute Of Technology (Caltech) and the Massachusetts Institute Of Technology (MIT) on the Laser Interferometer Gravitational Wave Observatory (LIGO), LIGO M010338.

President, in consultation with the MIT President, appoints the Executive Director as described above. The appointment is made in writing and the appointment letter states the term of the appointment, up to five years in duration.

Caltech reviews the performance of the LIGO Executive Director at the conclusion of the Director's term or at any other earlier time deemed appropriate by the Division Chair. Following the review, the Division Chair may nominate the Executive Director for continuation or reappointment, or may nominate a new Executive Director.

5.5.2 Associate Directors

The Associate Director for LIGO MIT is nominated by the MIT Dean of Science. The nomination is subject to the approval of the LIGO Lab Executive Director, and sent to the MIT President for appointment. The appointment is made in writing with a stated duration of up to five years. At the end of the appointment period, or at any earlier time deemed appropriate by the MIT Dean of Science, the Dean may nominate the Associate Director for MIT for continuation or reappointment, or may nominate a new Associate Director for MIT.

The Associate Director for Observatory Operations is appointed by the LIGO Lab Executive Director.

6 Organization of the LIGO Laboratory

The LIGO Laboratory is composed of four geographically distinct sites working together as a single integrated entity to carry out the Laboratory's mission. The two observatories are committed to commissioning and efficient operation of the interferometers, maintaining the facilities' infrastructure, and conducting education and public outreach programs. The Caltech and MIT campuses provide mission-critical scientific, engineering, and business functions to operate the Observatories and the Laboratory as a whole. The campus-based program for the LIGO Laboratory maintains systems and sustaining engineering and strong R&D efforts and laboratories to maintain, evolve, and improve the detectors, and plays a leading role in data distribution, curation, analysis, science, and education of the next generation of gravitational-wave scientists.

The primary organizational and management structures of the LIGO Laboratory were established during the construction of Initial LIGO. LIGO Laboratory has adopted a matrix organization for flexibility and to optimize the use of its human resources as it addresses the needs of the Laboratory across the four sites. The Laboratory functions as one "organic whole" composed of multiple sites.

The matrix system takes account of the needs of the Laboratory while respecting the need to manage and supervise personnel in such a way that promotes career opportunities, provides a fair and transparent process of employee evaluation, and limits the number of concurrent assignments for any employee to a reasonable level.

Within this matrix system each employee will be a member of one of the LIGO Laboratory groups. An employee may have operational assignments within this or to another operations group, to one or more project assignments, or a mixture of both.

LIGO Laboratory ensures effective use of its human resources by implementing common infrastructure at all sites whenever appropriate. This applies, for example, to administrative and technical services across all Laboratory sites, including but not limited to, business, general computing, engineering, R&D, data and computing, and cybersecurity functions.

The LIGO Laboratory organization is illustrated in

Figure 2 at the end of the document. Detailed discussion of the Laboratory groups, project, and special organizational functions are found in Sections 8-10 of this document.

When determined to be in the best interests of LIGO, members of the LIGO Scientific Collaboration from outside LIGO Laboratory may be given responsibility for some aspects of LIGO Laboratory activities through the mechanism of a Caltech appointment as a Visiting Associate in LIGO.

6.1 LIGO Laboratory Directorate

The LIGO Laboratory Directorate consists of the Executive Director, the Deputy Director, the Associate Director (AD) for Observatory Operations, and the Associate Director (AD) for MIT. The Spokesperson of the LIGO Scientific Collaboration also serves as a member of the LIGO Laboratory Directorate for matters pertaining to the LSC. Although the Executive Director and the Deputy Director have different well-defined primary responsibilities, the overall Laboratory direction is fully shared by the Executive Director and the Deputy Director and either can speak for the Laboratory. The Executive Director, the Deputy Director, the Associate Director for Observatory Operations, and the Associate Director for MIT are fully informed on all major decisions and will be mutually involved in the decision making as appropriate.

The Executive Director has overall responsibility for the LIGO Laboratory. The Executive Director's primary responsibility is to ensure the development and implementation of the LIGO Laboratory program in a timely and cost effective manner with the goal of carrying out a program of gravitational wave astronomy. The Deputy Director is primarily responsible for executing the LIGO program. The Associate Director for Observatory Operations is primarily responsible for overseeing the LIGO Hanford and Livingston Observatories, and serves as the LIGO-India Coordinator and liaison to the LIGO-India Project. The Associate Director for MIT is primarily responsible for representing MIT's institutional interests in the direction of the LIGO Laboratory. Together, the Deputy Director and the Associate Director for MIT organize and manage the Laboratory team composed of Caltech and MIT staff.

The Executive Director is the principal point of contact for communication and interaction with NSF, through its LIGO Program Manager. The Executive Director is also responsible for maintaining interactions and collaboration with the scientific community (both national and international). The LSC Spokesperson, as a member of the Directorate is responsible for working with the Executive Director, the Deputy Director, the AD for Observatory Operations, and the AD for MIT to ensure that the efforts of the LSC and LIGO Laboratory are well aligned and that overlapping functions of the LSC and LIGO Laboratory are carried out in a well integrated manner.

6.2 LIGO Scientific Collaboration

The LIGO Scientific Collaboration (LSC) carries out the LIGO instrumental and analysis research and development program, data analysis, and the publication of scientific results, and it enables participation by collaborating groups in appropriate LIGO activities. The LSC maintains its own governmental structure (governed by its Charter and Bylaws) while its activities are integrated with those of LIGO Laboratory. Scientists and engineers from the LIGO Laboratory are members of the LIGO Scientific Collaboration, and participate in the full range of its activities.

The LSC reports to the NSF through the LIGO Directorate by virtue of the fact that the Spokesperson is a member. The LSC regularly reports to NSF on matters of mutual importance and interest to the Laboratory through the annual Laboratory operations review. The LSC produces annual white papers (work plans) on R&D and data analysis, computing, and EPO; these plans are approved by the Spokesperson and the LSC Executive Committee.

The LIGO Executive Director and Deputy Director are ex officio members of all planning and evaluative bodies of the LSC. Representatives of the LSC serve as technical advisors to the LIGO Oversight Committee. Representatives of key LSC stakeholder institutions serve as members of the LIGO Oversight Committee.

To support the Laboratory in its operation of the Observatories, the LSC offers guidance on issues involving scientific tradeoffs in operations:

- a) Optimizing the scientific returns in the operation of the LIGO Laboratory facilities;
- b) The relative distribution of observing and development time at LSC gravitational wave detectors;
- c) Prioritizing improvements in the LIGO facilities;
- d) The timing and readiness of major instrumentation changes in the long baseline system;
- e) Human resources to support common tasks needed for science data qualification and production.

The LSC is expected to contribute to the complete range of tasks associated with meeting LIGO's goals. Specific responsibilities are agreed to in the Memoranda of Understanding between groups and the LIGO Laboratory; the objective is that LSC members both inside and outside the LIGO Laboratory will share fairly in these efforts. All Memoranda of Understanding between member groups and the LIGO Laboratory are co-signed by the LSC Spokesperson.

Collaborative work specifically between the LIGO Laboratory and any member group of the LIGO Scientific Collaboration is defined in a separate Memorandum of Understanding (MOU) between the Laboratory and the responsible institution. Specific tasks will be included in Attachments to these MOUs with defined deliverables and periods of performance.

6.3 Other Scientific Collaborations

As the field of experimental gravitational wave research develops, it may become appropriate to form additional and independent scientific collaborations. These collaborations will also be governed by MOUs and Attachments.

6.4 LIGO Program Advisory Committee

The LIGO Program Advisory Committee (PAC) is a principal source of advice to LIGO Directorate on scientific policy, technical choices, support of the scientific community, and organizational matters. It will review both Laboratory and LSC programs based on a charge provided by the LIGO Directorate.

The Committee meets at least twice per year, providing a written report after each meeting. Reports may contain specific recommendations on matters discussed in the meeting. This advice will be considered by the Directorate in making decisions.

NSF shall be informed of all meetings of the PAC, and will be provided with copies of any materials prepared by the Laboratory and LSC for presentation to the PAC as deemed appropriate by the LIGO Directorate.

The Committee members are appointed by the Directorate for an initial term of three years, with new members appointed with staggered terms to ensure continuity and renewal of the Committee. The PAC chair is also appointed by the Directorate.

6.5 LIGO Visitors Program

The LIGO Laboratory operates a Visitors Program that provides research opportunities for scientific visitors to the campuses and Observatory sites, and allows Laboratory staff to visit other research groups and sites. Supported visits are expected to be of significant duration (one month or longer) and are proposed as research

projects to the Laboratory Directorate for review and subsequent support. Shorter-term and targeted or informal visits may also take place.

6.6 Education and Public Outreach Program

LIGO shares its exciting research mission through education and outreach programs that involve learners of all ages in explorations of physics, astronomy, mathematics, and scientific inquiry. In addition to educating undergraduate and graduate students through traditional science research experiences, LIGO offers informal science education opportunities to K-12 students through Observatory field trips and classroom visits by Observatory outreach staff. LIGO provides informal education experiences for preschoolers, students, and adults through public science activities at the Observatory sites and in the surrounding communities. In these communities, LIGO maintains a focus on reaching groups that are typically underrepresented in science. In concert with other NSF education initiatives, LIGO outreach coordinators participate in the development of educational materials that communicate the elements of LIGO's science framework to teachers and students on a national level. LIGO's flagship science education program is the LIGO Science Education Center (SEC) operated through the partnerships between LIGO, Southern University Baton Rouge, the San Francisco Exploratorium, and the Baton Rouge Area Foundation, together with other local collaborating educational entities, and with the support of the NSF. The SEC is located on the grounds of the Livingston, Louisiana Observatory, and provides hands-on science experiences for students and the public through exhibits produced by the Exploratorium. Extensive pre- and in-service teacher training and professional development occurs at the SEC.

7 LIGO Laboratory Groups

Each LIGO Laboratory group reports to the Directorate and is led by a Group Leader and, as needed, a Deputy Group Leader appointed by the Directorate (see

Figure 2 at the end of the document). These positions serve as line management for the respective group. Each group is represented on the Laboratory Executive Committee. Staff assignment to an operational group represents that individual's principal assignment. Through a matrix management system, scientific and technical staff are able to participate significantly in activities of other operational groups and projects within LIGO Laboratory. While each group has a primary function and funding allocation, there may be substantial overlap in the activities of groups commensurate with the requirements of scientific research and the Laboratory's mission.

7.1 Hanford & Livingston Observatories

The Hanford Observatory and the Livingston Observatory are organized as separate operational groups within the LIGO Laboratory. Each observatory is responsible for the effective operation of the facilities and scientific programs at the respective Observatory site. A scientist who serves as the Head of the Observatory leads each Observatory and reports to the AD for Observatory Operations. In addition, each observatory includes an Observatory (Operations) Manager who is responsible for the technical and operational effectiveness of the observatory facilities and staff. The Observatory Manager or a designate serves as the lead Environment, Safety and Health Officer for the Observatory site, reporting to the Head and, in this capacity, directly to the LIGO Laboratory Deputy Director. The staff at each Observatory is structured to support operations, maintenance, and the scientific program. Staff numbers are sufficient to assure adequate local human resources for all normal operations including scientific and technical expertise at the site. Each Observatory will work with LIGO staff from the Caltech and MIT groups in executing enhancements, upgrades and new capabilities, and in carrying out the scientific program. Staff members from this group who are members of the LIGO Scientific Collaboration may also participate in analysis of LIGO astrophysics data consistent with their other responsibilities.

Much of LIGO Laboratory's Education and Public Outreach (EPO) program is based at the LIGO Hanford and Livingston Observatories. The LIGO Livingston Observatory hosts the LIGO Science and Education Center (SEC) which houses classrooms and exhibits designed by the Exploratorium. Programs at both Observatories emphasize K-12 informal science education and teacher professional development programs.

7.2 MIT LIGO Laboratory

The MIT LIGO Laboratory Group is represented in the Directorate by the AD for MIT and participates in the LIGO Laboratory program across the full spectrum of Laboratory activities. Its members interact closely and seamlessly with the CIT and Observatory groups to carry out the overall LIGO mission. The functions and activities of this group include Management, Administration, Detector Support, Test Facilities, Data Analysis/Computing, and Advanced Detector R&D. Staff members from this group who are members of the LIGO Scientific Collaboration also participate in analysis of LIGO astrophysics data consistent with their other responsibilities.

7.3 Business Office

The Business Office has administrative responsibility for the Laboratory's administrative functions across all sites.

The Business Office is responsible for program planning support, for business operations including budgeting, funds management, cost accounting, procurement, property management, personnel actions and effort reporting, for document and records management, and for management of Laboratory Policies and Procedures. With direction from the Directorate, the Business Office prepares Laboratory Proposals and Operations Annual and Quarterly Reports for the NSF and coordinates all formal communications with the NSF through the Caltech Office of Sponsored Research. The Business Office provides administrative support for the Observatory sites, collaborative matters, and administrative assistant and secretarial support to the LIGO Laboratory.

For internal LIGO Operations reporting and management, budgets are established at the beginning of each fiscal year with the approval of the Directorate based on the Annual Work Plan submitted to the NSF, the funding level approved by the NSF, and any guidance provided by the NSF. These budgets are established for each Work Breakdown Structure (WBS) element and cost category. Budgets are distributed to the responsible account managers and constitute authorization to commit funds. Monthly reports track actual costs against budgets and enable corrective action if required.

7.4 Laboratory Engineering Groups

All aspects of engineering are organized in an engineering group under the Laboratory Chief Engineer. The campus groups are augmented by substantial engineering capabilities resident at the two observatories. All engineering activities are matrixed across the four sites. Staff members from this group who are members of the LIGO Scientific Collaboration also participate in analysis of LIGO astrophysics data consistent with their other responsibilities

7.4.1 Optics and Mechanics

The CIT Optics and Mechanics Group, with the groups at MIT, LLO, and LHO, is responsible for engineering design and analysis and design drafting for LIGO scientific programs, facilities, and research and development tasks. Members of this group team with LIGO staff and collaborators as needed to support all activities requiring mechanical and optical engineering. This group provides technical configuration management and quality assurance and adheres to the Laboratory's engineering standards and practices.

7.4.2 Controls and Data Systems (Hardware & Software) Groups

The Controls and Data Systems Group is responsible for digital electronics and controls engineering, and analog electronics design for LIGO scientific programs, facilities, and research and development tasks. Members of this group coordinate with LIGO staff at the other sites and with collaborators to support all activities involving electronics and controls. This group adheres to the Laboratory's engineering practices and standards.

7.4.3 Systems Engineering

The Laboratory systems engineering group oversees all aspects of Laboratory engineering processes and standards. The group undertakes systems-level analyses, hazard analyses, and trade studies. The Technical Review Board, under systems engineering, evaluates any major configurational changes to the interferometers. The substantial vacuum system infrastructure, operated and maintained by observatory staff, is under configuration control and reviewed as needed by the Vacuum Review Board that is also under systems engineering.

7.5 CIT Science Group - GW Astrophysics and Detector Science Subgroups

The CIT Science Group is made up of two subgroups—The CIT GW Astrophysics subgroup, and the CIT Detector Science (or Experimental Physics) Group.

7.5.1 GW Astrophysics

The CIT GW Astrophysics subgroup participates actively in the analysis of astrophysics data and publication of results from LIGO. This group is responsible for supporting modeling of sources and algorithm development, and for initiating new approaches to the analysis of LIGO data. Data analysis by members of this subgroup is undertaken as part of the LSC the data analysis efforts. The MIT group's data analysis activities are coordinated with CIT's efforts.

7.5.2 CIT Detector Science

The CIT Detector Science subgroup, together with the MIT Detector Science subgroup, is responsible for ensuring and improving the performance of the LIGO detector systems used in gravitational wave research. To this end, it:

- conducts advanced R&D related to Advanced LIGO to develop techniques for risk reduction;
- conducts advanced R&D aimed at longer term/future improvements of LIGO's gravitational wave detection capabilities;
- solves problems and devises future improvements;
- provides scientific leadership in specifying and introducing detector improvements and upgrades in association with the staff at the Observatory sites; and
- Models the physics of the interferometers.

Members of the CIT Detector Science subgroup participate in advanced R&D in coordination with the LSC and contribute to R&D activities within LIGO Laboratory Projects. Staff members from this subgroup who are members of the LIGO Scientific Collaboration may also participate in analysis of LIGO astrophysics data consistent with their other responsibilities.

The subgroups that constitute the CIT and MIT Detector Group interact closely, meet often, and work together on problems of mutual interest.

7.6 Laboratory Computing Group

The Laboratory Computing Group, with membership at the four LIGO Laboratory sites, is responsible for the hardware and software systems used by LIGO for data analysis. This group works closely with the data analysis groups of the LSC and, together with collaboration-level organizations, carries the primary responsibility for software standards and software engineering used in LIGO data preparation, distribution, curation, and analysis. Systems that provide general computing to the Laboratory staff are also implemented and supported in this group. The group supports computational technology in support of extraction of astrophysical information. Staff members from this group who are members of the LIGO Scientific Collaboration also participate in analysis of LIGO astrophysics data consistent with their other responsibilities.

8 LIGO Laboratory Projects

LIGO Laboratory Projects (as of the date of this document) include focused activities of finite duration such as major R&D projects for interferometer enhancements, as well as campus-based research facilities (LASTI, 40-meter Interferometer, and other campus facilities supporting the Laboratory). Additional LIGO Laboratory projects may be initiated by the Directorate as needed in order to meet the mission of the Laboratory. A process of internally reviewed proposals is used to help set priorities and address needs. The list of projects is dynamic, with projects dropping off upon completion or termination and others being added as they start up. At the time of this writing the following activities fall under its scope.

8.1 Advanced LIGO Plus ‘A+’ Project

A+ is a mid-scale upgrade of the Advanced LIGO interferometers designed to improve their sensitivities by factors of 1.5 (binary black hole mergers) to 1.9 (binary neutron star mergers), by reducing the noise floor across the interferometers’ bandwidths by implementing of frequency-dependent squeezing, improved test mass mirror coatings with lower Brownian thermal noise, and other improvements. A+ is collaborative international effort with contributions from the United Kingdom (funded by the Science and Technology Facilities Council) and Australia (funded by the Australian Research Council).

8.1 Detector commissioning

Detector commissioning is responsible for bringing the instruments at the observatories to target sensitivity for each LIGO observing run, and ultimately to the design sensitivity. This effort is matrixed across the four Laboratory sites.

8.2 LIGO Detector Developments

The LIGO Developments Program implements near-term detector improvements required to enable the instruments to achieve their full design potential, both in sensitivity and reliability. As R&D projects move beyond proof-of-concept and prototyping, their full-scale implementation at the observatories is carried out under this activity as a ‘projectized’ effort.

Detector commissioning is responsible for bringing the instruments at the observatories to target sensitivity for each LIGO observing run, and ultimately to the design sensitivity. This effort is matrixed across the four Laboratory sites.

Taken together, these activities see specific detector improvements through from their initial conceptualization, design, fabrication, installation and finally commissioning. To provide a coherent “projectized” approach to the entire process, the Detector Project Manager (DPM) will work closely with the engineering and commissioning teams. The DPM reports to the LIGO Laboratory Directorate and is responsible for oversight of these efforts, tracking and reporting their progress to the Directorate, providing

regular updates of their status to NSF, and replanning when unforeseen developments take place that dictate changes in the plan.

8.3 Campus-based Research Facilities – 40m interferometer (CIT), LASTI (MIT)

LIGO's campus-based research facilities provide special test and research facilities at MIT and Caltech. These include the MIT test interferometer (LASTI), the Caltech 40-meter test interferometer, and other smaller facilities and supporting infrastructure such as ancillary facilities used for optics, laser and noise research, metrology, and materials research. The group managing each facility is responsible for its readiness and availability and for supporting the research and test activities carried out by LIGO Laboratory and collaborating investigators who use the facility. Their responsibilities include calibration, documenting procedures, and training investigators.

8.4 LIGO-India

The Government of India (GOI) has approved the LIGO-India project that will install the third Advanced LIGO interferometer in a new green-field observatory facility in India, to be constructed by the GOI. LIGO's role in this effort is to advise our Indian colleagues on all aspects of site selection, site infrastructure, design, and eventual implementation. In addition, the Laboratory provides technical training and on-the-job experience opportunities at the two U.S. sites for Indian colleagues as they ramp up their project.

8.5 Gravitational-Wave Open Science Center (GWOSC)

The GWOSC is responsible for preparing LIGO (and Virgo) data for broader distribution to the larger research community outside the LSC. Data curation and distribution is undertaken by the GWOSC in collaboration with a number of LSC scientists outside the Laboratory. Data releases are organized and approved by the LSC, while the GWOSC implements these releases, providing software tools for outside researchers to explore and download the data.

9 LIGO Directorate Functions

The LIGO Directorate oversees and has reporting to it a number of other Laboratory-wide functions, roles, and activities. Functions and roles are discussed below.

9.1 Oversight of Education and Outreach

The Executive Director is responsible for Directorate oversight of the Laboratory's Education and Outreach activities. The Executive Director assures that these activities are appropriate, effective, and consistent with the mission of the Laboratory and the NSF.

9.2 Cybersecurity

The Laboratory Cyber Security program is based on a layered approach that ensures that the most significant assets are fully protected and secure, while allowing the flexible access to information required to enable the widely distributed LSC to effectively analyze LIGO data. The Laboratory's most stringent requirement applies to the Observatory Security Critical Systems, which comprises the interferometers and data archives. This ensures that interferometer operation and control can take place in a secure environment and that the integrity of archived data is protected.

9.3 The Laboratory Chief Engineer

The Laboratory Chief Engineer is responsible for ensuring that the Laboratory's engineering standards and practices are followed in all appropriate Laboratory activities. These roles, along with the review boards, were discussed under the Engineering Group's System Engineering role.

9.4 The Laboratory Chief Detector Scientist

The Chief Detector Scientist oversees all aspect of commissioning and coordinates observatory activities with site commissioning leaders. In addition, the Chief Detector Scientist coordinates with the Chief Engineer on all aspects of detector development and enhancement.

9.5 The Executive Committee

The Executive Committee is the principal management body used by the Laboratory Directorate to review Laboratory program execution and status, and to develop the basis for management decisions. The Executive Committee meets regularly and will be chaired by the Executive Director, in association with the Deputy Director. It will consist of the managers of each of the LIGO Laboratory functional groups, a number of senior LIGO Laboratory scientists, and all LIGO professorial faculty members at Caltech and MIT.

9.6 The Staffing Committee

The Staffing Committee is responsible for evaluating applicants and making hiring decisions for LIGO Laboratory professional staff positions (excepting professorial appointments at CIT and MIT) as well as for approving applications for the LIGO Laboratory Visitor Program. The Staffing Committee will meet monthly and be chaired by the Executive Director, in association with the Deputy Director. It will consist of the managers of each of the LIGO Laboratory functional groups and all LIGO professorial faculty members at Caltech and MIT.

9.7 The Operations Management Team (OMT)

This team comprises senior management involved in engineering, detector science and commissioning, business, and observatory management. The team is responsible for overseeing day-to-day operations of the observatories and other mission-critical operations activities. The team also interfaces with the collaboration observing run planning committee, and handles routine Laboratory decisions related to scientific data-taking runs. The OMT is chaired by the Associate Director for Observatory Operations and co-chaired by the Associate Director for MIT.

9.8 The Diversity Committee

LIGO Laboratory is committed to expanding the participation of all citizens in science and engineering at all levels of the educational process, and to providing opportunities for professional scientists to participate in LIGO's cutting edge research. The LIGO Laboratory Workforce Diversity Plan (M1400272) guides the Laboratory's actions in this area. Much of LIGO's public outreach activities emphasize diversity, and the Laboratory itself is alert and proactive in providing opportunities for underrepresented minorities and women to join the staff and to thrive professionally. In addition, the Laboratory's efforts in this regard are coordinated and interact synergistically with the LSC's diversity efforts.

In order to identify additional approaches and mechanisms to improve the diversity of the Laboratory's staff, the positions of LIGO Laboratory Diversity Officers have been created. The Diversity Officers are appointed by and report to the Laboratory Directorate and co-chair the Laboratory Diversity Committee.

The Laboratory Diversity committee is made up of Laboratory staff members and a few knowledgeable outsiders. The committee advises the Laboratory Directorate about actions that can be taken to move the

Laboratory forward towards the goal of providing opportunities for underrepresented minorities and women to join the Laboratory staff and to thrive professionally.

9.9 Environment, Safety and Health Protection

The LIGO Laboratory Safety Officer is responsible for the Laboratory's ES&H program and reports to the Directorate. The LIGO Laboratory Deputy Director is responsible for ES&H programs throughout LIGO for both the Operations and any Projects underway. At each Observatory site, the Observatory Manager serves as the primary manager responsible for ES&H programs and in this capacity directly reports to the Deputy Director.

Caltech has an established Environmental, Health and Safety Office, responsible for the Institute's overall safety and health program, and LIGO management will implement the applicable health and safety program elements as outlined in the Caltech Safety Manual. The Caltech Safety Office policies will be applicable to the Observatory sites, supplemented by additional policies developed by LIGO staff in consultation with the Caltech Safety Office. For work performed at MIT, the safety and health protection measures adopted by MIT will similarly apply.

Contractors and visitors to the LIGO operational sites will be informed of ES&H rules and procedures applicable to the specific area. Hosts will be responsible for the safety of visitors.

9.10 Laboratory R&D Coordinator

R&D across the entire laboratory is overseen and coordinated by the Detector Research and Detector Development Coordinator, who is responsible for arranging for the review of new R&D projects proposed by Laboratory staff, tracking R&D progress, The R&D Coordinator reports to the Directorate on a regular basis, especially if issues arise regarding priorities and resource allocation. The R&D Coordinator is also responsible for identifying when mature R&D projects are ready to move into actual implementation on the observatory interferometers.

9.11 Laboratory Change Control Board

Changes in the LIGO Operations budget baseline are initiated through a documented request submitted by the cognizant account manager to the Business Manager, who chairs the Change Control Board. Requests are required for all cumulative budget changes within a subsystem account that exceed \$50,000. The cognizant manager initiates the request, and if the need for a change control action is not certain, the burden on the cognizant manager shall be that a documented request will be made.

For the Operations activities of the LIGO Laboratory, the Business Manager logs each received Change Request and schedules meetings of the LIGO Change Control Board (CCB) to conduct reviews of open Change Requests. The Laboratory CCB consists of the following individuals:

- The LIGO Deputy Director (signs for the Directorate);
- The Observatory Heads;
- The ADs for both Observatory and MIT Operations;
- The leaders of CIT Detector Science Group, the Laboratory Computing Group, CDS, CIT Astrophysics and Analysis Groups
- The Laboratory Chief Engineer;
- The Laboratory Chief Detector Scientist;
- The Business Manager (chair).

The Business Manager is responsible for preparing the agenda and meeting minutes. The CCB reviews each request and makes recommendations to LIGO Executive Director. The Business Manager issues a written

notice of each decision, maintains a log of the status of all Change Requests, and retains a file of all approved Change Requests in the LIGO Document Control Center (DCC).

All change request activity and budgetary realignments are tracked and reported to the NSF in accordance with the reporting requirements identified in the Cooperative Agreement and this Laboratory Charter.

9.12 Laboratory External Committees

The primary standing committee is the LIGO Program Advisory Committee (PAC), which was described earlier in Section 6. Other committees may be convened on an *ad hoc* basis to advise the Directorate on issues that may arise. Past examples included the Advanced LIGO Program Advisory Panel (PAP), the LIGO Astronomy and Astrophysics Advisory Panel (LAAAP), the LIGO Academic Advisory Committee (LAAC, now a formal committee of the LSC). Strategic planning committees are constituted whenever major Laboratory decisions have to be made.

10 Governmental Code Requirements

The LIGO Laboratory, including its contractors, will comply with applicable US Federal Codes, laws and regulations, industrial codes, and state rules, regulations and codes. The Business Office, together with the Deputy Director, will be responsible for clarifying compliance requirements and the resolution of safety issues.

11 Procurements and Subcontracts

11.1 Policy

LIGO procurements occur at both Caltech (including the Caltech-managed Observatory sites) and MIT, and are processed according to the procedures established by the Purchasing Department at the host institution and approved by the Office of Naval Research under OMB requirements.

All LIGO facilities- and equipment-procurements will be processed and administered by the Caltech or MIT Purchasing Department depending upon the institution originating the procurement, assisted by the LIGO Laboratory staff.

Major procurements involving substantive subcontracts (those exceeding \$250k in direct costs) must be approved or concurred with by the NSF Division of Acquisition and Cooperative Support, in accordance with the terms and conditions of the Cooperative Agreement. The NSF Division of Acquisition and Cooperative Support will generally pre-approve such subcontracts based on information submitted by Caltech/LIGO as part of the yearly work plan and the recognition that the Caltech Procurement System has been fully validated for purchases under federal grants and contracts. In those cases where the NSF Division of Acquisition and Cooperative Support requires additional information to approve a subcontract, NSF will inform Caltech/LIGO so as to allow the needed additional to be provided in a timely manner.

LIGO Laboratory staff performs subcontract technical and programmatic management. All procurements and subcontracts will be subject to the terms and conditions of the Cooperative Agreement and the requirements of land sale and lease documents pertaining to the LIGO Observatory sites.

11.2 Responsibilities

The LIGO Deputy Director is responsible for ensuring that all aspects of LIGO facilities and equipment procurement are managed and planned successfully. An acquisition plan, developed annually along with the Annual Work Plan, will support the procurement approach for major procurements. The Deputy Director, in

association with the Executive Director, shall approve all major subcontracts. The Business Office is responsible for preparing, facilitating and administering the documentation associated with major LIGO procurements. The cognizant technical Task Leaders will initiate subcontracts and procurements. Working closely with the Business Office, the Task Leaders will be responsible for assuring that all procured components, items, services, and construction are produced and delivered as required to support LIGO Laboratory objectives. The Task Leaders will also provide technical direction and oversight of these contracts and procurements.

11.3 Approach

Procurement policies and procedures, embodied in the Caltech Purchasing Policy and Procedure Manual, will be utilized for all facilities and equipment procurement actions originating at Caltech (including the Caltech-managed Observatory sites). This manual establishes compliance with the NSF Cooperative Agreements. All major procurements that require NSF concurrence will be identified and scheduled in the annual Work Plan. Similarly, LIGO Laboratory procurements originating at MIT may be placed using corresponding policies and procedures at MIT. Both Caltech and MIT have procurement systems approved by the Office of Naval Research under OMB requirements.

12 Reporting and Reviews

12.1 Annual Report

The LIGO Laboratory through the Caltech Office of Sponsored Research will submit an Annual Report to the NSF by October 1 containing a summary of overall progress during the past year, including results to date, and a comparison of actual accomplishments with the proposed goals of the currently approved Work Plan; an indication of any current problems or favorable or unusual developments and any other pertinent information.

12.2 Annual Work Plan (AWP)

The Annual Work Plan is organized by Laboratory group and WBS level, and includes the funding requested for the upcoming one-year period beginning October 1. The AWP will summarize the proposed goals for R&D, science, and collaborative programs for the program year for which funds are sought. Proposed staffing levels, significant staffing changes, an organization chart, and an explanation of changes in the LIGO organization will be presented. A preliminary AWP will be submitted to NSF annually by July 1, with the final plan due by September 1.

12.3 Acquisition Plan

The annual acquisition plan will include all major planned procurements in excess of the current level that requires NSF approval, including the proposed date of submission to NSF and the type of procurement. The acquisition plan will be included in the Annual Work Plan.

12.4 Quarterly Reports

Reports in the form of presentations to NSF personnel will be submitted quarterly to NSF as a way of reporting progress toward accomplishing the goals of the Annual Work Plan, including expenditures against operations budgets. Reports will be delivered soon after the end of the quarter for the first three quarters of the fiscal year.

12.5 Credit Draws

The Caltech Office of Financial Services submits to NSF on a weekly basis a letter of credit draw request that includes all NSF sponsored grants at Caltech with unreimbursed costs, including LIGO. The draw identifies cash disbursements made since the last NSF draw and the available balance for the LIGO Laboratory and other NSF awards.

Caltech will submit for approval by NSF all collaborative Memoranda of Understanding.

12.6 NSF Site Visits/Panel Reviews

The NSF will conduct periodic site visits to review LIGO activities, including both LIGO Laboratory Operations and Maintenance and the A+ Upgrade Project.

The NSF will convene Panels to conduct periodic reviews of the LIGO Laboratory, covering technical and management issues. NSF shall provide the Laboratory with a copy of the charge to the Panel prior to the review with adequate time to agree on the agenda and to prepare the necessary presentation material.

13 Workshops

The LIGO Laboratory will sponsor or participate in workshops on specific topics relevant to the development of gravitational-wave interferometers. The frequency of such workshops and the topics they address will be determined in consultation with interested outside scientists, such as the LIGO Scientific Collaboration and the other international groups pursuing laser interferometer gravitational-wave detection.

14 Technical Reports

To enhance the participation of the general scientific community in gravitational wave research, the LIGO Laboratory will publish research results in refereed journals, and will make unpublished internal technical reports available to the NSF and to the general scientific community on request. Further, the Laboratory provides the infrastructure and support for posting and distributing the LSC's research results.

References

UNDER DEVELOPMENT Cooperative Support Agreement 2019-2023 - The Operation and Maintenance of LIGO, between the National Science Foundation, Washington, D.C. 20550, and the California Institute of Technology, Pasadena, CA 91125.

“The A+ Upgrade to Advanced” LIGO PHY-1834382 between the National Science Foundation, Washington, D.C. 20550, and the California Institute of Technology, Pasadena, CA 91125.

Memorandum Of Understanding between the California Institute Of Technology (Caltech) and the Massachusetts Institute Of Technology (MIT) on the Laser Interferometer Gravitational Wave Observatory (LIGO), LIGO M010338, current version

<http://www.ligo.caltech.edu/>

<http://www.ligo.org>

Figure 1. Overall LIGO Organization

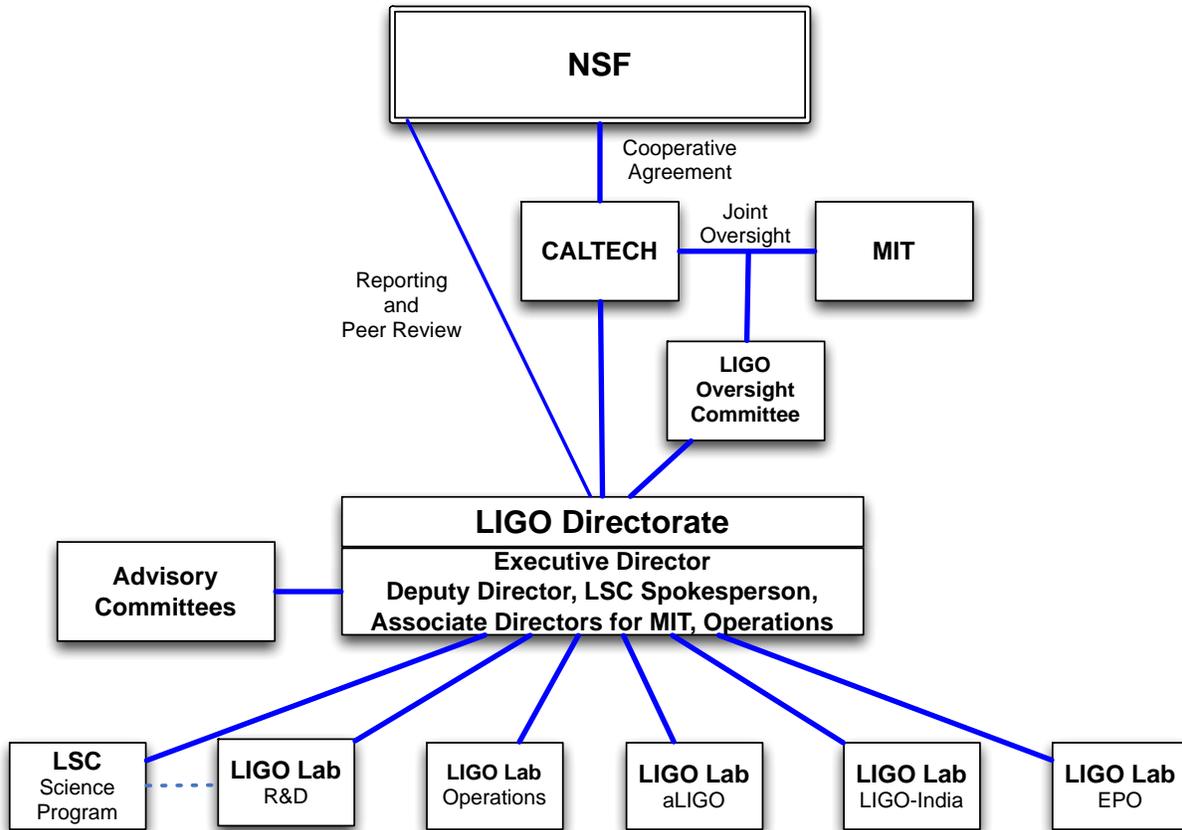


Figure 2. LIGO Laboratory Organization (as of Oct 1, 2018)

