LIGO SCIENTIFIC COLLABORATION
VIRGO COLLABORATION
KAGRA COLLABORATION

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The LSC-Virgo-KAGRA Operations White Paper (2024 edition)

The LSC-Virgo-KAGRA Operations Working Groups

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Instructions

This LaTeX template provides a standard framework for documenting the work plans for each division of the Collaboration. Various class, style and macro files are located in the tools subdirectory. In general, any necessary changes to these files should be backported to the template repository so that the modifications can be made available to all of the white paper projects.

There are a number of macros near the top of `WP-template.tex` that will allow you to define the long name of the division, the division acronym, the white paper year, and the document control numbers for LIGO, Virgo and KAGRA.

The Executive Summary provides an overview of the division's work. Each working group should describe the mission of the group and the rationale behind the group's priorities (we strongly recommend keeping this to 2 pages max). The file `ES-template.tex` provides a sample format; each division should decide on a standard format for the working group summaries within their division. The target audience for this section is outside the Collaboration.

Each subsequent section of the white paper documents a set of Collaboration Projects scoped to the working group(s) in the section name, as shown in `AP-template.tex`. A Collaboration Project delivers a product for the Collaboration, e.g. data, software, designs, hardware, publications, services, ... To map this to the language of a work breakdown structure (WBS), as used by some working groups, each project is a level-1 element which is broken down into a complete list of level-2 elements (or **activities**) representing intermediate deliverables of the project. Each level-2 element may be further broken down into a list of level-3 elements (or **tasks**); we strongly recommend including task-level items if a complete list is available at the time of writing.

The file `AP-template.tex` shows how to organize the information about each project. The following LaTeX commands and environments allow standardized information entry for projects:

Command `\WPproject{Name}{yyyy-mm-dd}{yyyy-mm-dd}`: A `WPproject` is a level-1 WBS element. It takes three arguments: the project name, the project start date (in the format yyyy-mm-dd), and the estimated project due date (in the format yyyy-mm-dd). If the dates are not known, please use TBD.

Environment `\begin{WPactivity}[f]{Name} ...\end{WPactivity`: A `WPactivity` is a level-2 element of the WBS for the project. It has one optional argument that takes either `t` to indicate the activity is `\InfraOpsTrue` or `f` to indicate the activity `\InfraOpsFalse`. The default is `f`. The first required argument is the name of the activity.

Environment `\begin{WPtask} ...\end{WPtask}`: A `WPtask` is a level-3 element of the WBS for the project. Tasks inherit their InfraOps classification from their parent `WPactivity`.

Each `\WPactivity` is automatically added to a list of activities that is included at the end of the white paper. The same is true for each `\WPtask`. A script is provided to parse this information into a csv-file for ingestion into the LSC MOU system.

Required personpower estimates should be added to the central internal spreadsheet

`https://docs.google.com/spreadsheets/d/194HOAAE0-Ps6mC3aMVRq4XtcL_mf5CU7RNjauoRYI3E`

once the projects, activities, and tasks are defined.

Overview and Executive Summary

The Collaboration program committee reviews and establishes the goals of the Collaboration on an annual basis. The LSC Program is documented in LIGO-M2300188. Each Division of the Collaboration identifies the work needed to achieve the Collaboration's goals and documents them in a white paper. This is the white paper for the Operations [OPS] Division.

The successful operation of the LIGO, Virgo, and KAGRA detectors and key infrastructure are critical to enabling gravitational-wave astronomy. Gravitational wave detections are made possible by optimized instrument sensitivity and uptime, well-characterized noise, accurately calibrated data, and robust computational infrastructure that supports not only the detectors but also the data analysis pipelines used to identify and characterize gravitational wave signals. These activities are undertaken by the LIGO Laboratory in collaboration with the broader LIGO Scientific Collaboration (LSC), by the Virgo Collaboration in collaboration with EGO, and with the KAGRA Collaboration.

The LSC Operations Division exists to organize and manage all LSC activities related to, and necessary for, detector operation (see Section 5 of LSC bylaws: LIGO-M050172). It comprises the Detector Characterization, Calibration, Low Latency, Computing and Software, and Open Data Working Groups and the Support of Observatories and Run Planning Committees.

The Virgo and KAGRA Collaborations are active participants both in co-chairing and membership in all the aforementioned Working Groups. The Virgo and KAGRA collaborations are represented on the Joint Run Planning Committee, which is charged with the strategic planning of engineering and observing runs. The Support of Observatories committee is unique to the LSC.

The LIGO, Virgo, and KAGRA **Commissioning** teams work toward optimizing the sensitivity and uptime of the global detector network. The LSC, Virgo, and KAGRA **Detector Characterization (DetChar)** groups interface with the detector commissioning teams and work to improve GW signal searches by identifying and mitigating noise sources that limit sensitivity to astrophysical signals. The LSC, Virgo, and KAGRA **Calibration** teams produce fast and reliable calibration of detector data. The LSC, Virgo, and KAGRA **Computing and Software** teams support the joint LSC-Virgo-KAGRA computing infrastructure and software. The LSC, Virgo, and KAGRA **Low Latency** teams provide rapid notification of Gravitational Wave candidate events to the wider observing community. The LSC, Virgo, and KAGRA **Open Data** teams curate the observation data for public release. The LSC **Support of Observatories** committee coordinates LSC contributions to the Observatories including the LSC Fellows program.

This *LSC-Virgo-KAGRA Operations White Paper* describes the planned activities for these efforts, in the context of the LIGO Scientific Collaboration 2023 Program.

Further details on the planned activities in collaboration between the DetChar and Calibration groups and the four LSC-Virgo-KAGRA data analysis working groups (Burst, Compact Binary Coalescence, Continuous Waves, and Stochastic Gravitational-Wave Background) can be found in the *LSC-Virgo-KAGRA Observational Science White Paper*, LIGO-T2300406. The data analysis working groups also undertake tasks related to the Operations of the LIGO-Virgo-KAGRA observatories, described therein.

This Operations White Paper also complements the *LSC Instrument Science White Paper*, LIGO-T2300411, which covers the Advanced Interferometer Configurations Working Group (AIC) including Newtonian Noise and Interferometer Simulations, the Quantum Noise Working Group (QNWG), the Lasers and Auxiliary Optics Working Group (LAWG), the Optics Working Group (OWG), the Suspensions and Seismic Isolation Working Group (SWG), and the Control Systems Working Group (CSWG).

The LIGO Laboratory operates and maintains the LIGO Hanford and Livingston observatories through a Cooperative Agreement with the US National Science Foundation. The LIGO Laboratory makes major contributions to the LIGO Scientific Collaboration, including responsibility for delivering calibrated, well-characterized gravitational strain data at a target sensitivity during designated observing runs. The broader LSC, jointly with the Virgo and KAGRA Collaborations, is in turn charged with producing astrophysical results, including low latency GW candidate alerts. The **LIGO Laboratory Operations** include activities which are deeply collaborative with the LSC (e.g., Calibration, Detector Characterization, Low-Latency public alerts), those with some participation from the LSC (e.g., Commissioning), and others which are largely internal to the LIGO Lab (e.g., maintenance of the vacuum equipment).

EGO operates and maintains the Virgo detector, whose various systems are developed, installed, steered and upgraded jointly by the Virgo Collaboration and EGO. The instrument is funded by CNRS (France), INFN (Italy) and NIKHEF (The Netherlands), through the the EGO Consortium.

OPS-0.1 LIGO Observatory Operations

On January 16, 2024 there will be an approximately two month break in the O4 run to perform some repairs and upgrades to the detectors. LIGO Observatory Operations will focus on planning and executing activities during the break and then revert to supporting the O4b run.

The priorities of the LIGO Observatories is to:

- Plan and execute the repairs, upgrades and maintenance of the detectors during the O4 break.
- Support the stable running of the detectors during O4b.

OPS-0.2 LIGO Upgrades - A+

The mission of the "A+ detector" project is to provide a major upgrade to the Advanced LIGO detectors. The project began in 2019 and is expected to continue through the end of 2024. Several upgrades were already completed prior to O4; the balance will be completed before O5.

OPS-0.3 Virgo Observatory Operations

The mission of the working group is....

OPS-0.4 Virgo Upgrades - AdV+ Phase II

The mission of the ...

OPS-0.5 KAGRA Observatory Operations

The mission of the working group is....

OPS-0.6 KAGRA Upgrades

The mission of the ...

OPS-0.7 LIGO Aundha Observatory Operations

The LIGO-India project is preparing an expression of interest for identifying contractors who are capable of construction both the civil and vacuum infrastructure at the Aundha site. The goal is to have construction begin in 2024. In paralell the initial "pathfinder" shipment of some detector components to the Testing & Training facility at the Raja Ramanna Centre for Advanced Technoogy (RRCAT) in Indore will be executed.

The priorities of the LIGO-India project is to:

- Begin construction of the observatory infrastructure at the Aundha site.
- Begin construction of the vacuum components of the Aundha detector.
- Define and document the interfaces between LIGO Aundha Observatory (LAO) subsystems.
- Complete the installation and begin using the 10m prototype at RRCAT.
- Build a PSL table, for use in LAO, using components shipped from the USA.
- Comission training facilities for future staff at the LAO site.
- Begin shipment of detector components from LIGO Hanford to India.
- Upgrade components of the stored Aundha detector to the same level as current Livingston and Hanford detectors.
- Procure and assemble detector components that are not available in storage.
- Construct a fiber pulling and fiber welding facility at RRCAT and train LIGO-India personnel in their use.

OPS-0.8 Detector Characterization mission summary

Sensitivity to gravitational-wave signals is limited by noise from the instruments and their environment. Robust detection of signals, the vetting of candidate signals, and the accuracy of parameter estimation are *crucially* dependent on the quality of the data searched and the collaboration's knowledge of the instruments and their environment. The LIGO, Virgo and KAGRA Detector Characterization groups are focused on working together with the astrophysical search groups and the detector groups to (i) deliver the data quality information necessary to avoid bad data, veto false positives, and allow candidate follow-up for gravitational-wave searches and (ii) characterize the Advanced gravitational-wave detectors to help to identify data quality issues that can be addressed in the instruments to improve future instrument and search performance. This focus leads to three core activities: 1) preparing for future observing runs, 2) supporting the upgrade and commissioning of the detectors during commissioning breaks and 3) delivering data quality information and vetting candidate gravitational-wave events during and after observing runs.

In preparing for O4 [1], the highest priorities are improving the incorporation of data quality information into the low latency searches, further automating candidate event validation, conducting pre-O4 analysis of noise sources that most affected the astrophysical analyses, and developing key tools to improve the performance of the detectors and the astrophysical searches. The highest priorities in preparing for future observing runs are improved automation of existing key tools and monitors of known data quality features, as well as maintaining and extending the software infrastructure required to provide needed data quality information to online and offline searches. Another high priority is curating data quality information for public data releases.

In support of the O3–O4 commissioning break, the highest priority is conducting on-site and off-site investigations of interferometer and environment behavior to support the upgrade and commissioning efforts. This includes the development of critical tools for commissioning and an early characterization of each sub-system, including a coherent system of monitoring web pages.

During O4, the highest priorities are to provide data quality information to the gravitational-wave searches to reduce the impact of artifacts in the data, validate the quality of the data around the time of candidate events, investigate instrumental noise which most impacts astrophysical searches, maintain key tools which allow us to monitor and investigate detector performance, and provide support to the sites.

In parallel, there are a number of key longer-term research and development tasks, including the development of improved methods to uncover the coupling paths and the sources of the noise transients which most impact the searches, and to implement automated noise characterization tools.

To accomplish these priorities, the DetChar groups require enough personpower from the Collaborations, including code developers to support and build key software infrastructure.

More details can be found in Section OPS-8. The present document updates the 2022 Ops. Div. white paper [2].

Working group priorities

The priorities of the working group are:

1. **Highest Priority**
    - **Priority A:** The working group will... [Section **??**]
    - **Priority B:** The working group will... [Section **??**]
2. **High Priority**
    - **Priority A:** The working group will... [Section **??**]
    - **Priority B:** The working group will... [Section **??**]

Methods for Advancing Frontiers of...

The two main levels of longer term R&D activities of the working group comprise:

1. **Essential**
    - **Item A:** The group will...
    - **Item B:** The group will...
2. **Exploratory**
    - **Item C:** The group will...

OPS-0.9 Calibration mission summary

The mission of the LIGO, Virgo, and KAGRA calibration groups is to provide reliable and timely calibrated strain data for all detectors as well as quantified uncertainty estimates.

The raw optical power variations at the gravitational-wave readout ports of the detectors are calibrated into dimensionless strain on the detectors before use with astrophysical analyses [3, 4]. The process for doing so requires detailed modeling of the feedback control system and the interferometric, opto-mechanical response of the detectors [5]. Some model parameters vary slowly with time throughout operation of the interferometer which must be monitored and, when possible, corrected [6]. All detectors continue to use photon calibrator systems [7, 8, 9, 10] for their primary absolute displacement fiducial reference to develop each static detector model, measure parametric time dependence, and validate any strain data stream once constructed. Virgo plans to employ a secondary reference of gravitational (Newtonian) systems to enhance and compliment the primary systems [9, 11, 12].

Strain is produced in near real-time (low-latency) using methods such as those described in [3, 4]. For the purposes of this white paper, the following language will be adopted: The calibrated strain data contains a quantifiable systematic error due to imperfections in the calibration models. This systematic error is quantified to a certain of level of confidence and can therefore be quoted with, for example, a 68% confidence interval that represents a probabilistic range of the true systematic error. The combination of the systematic error and its corresponding confidence interval will be called the "total calibration uncertainty." Historically, the level of systematic error in the strain data was occasionally, directly confirmed across the detectors' sensitive frequency region, and continuously monitored at select frequencies with the photon calibrator systems. In doing so, the systematic error was confirmed to be within acceptable limits at snapshots in time, but the total calibration uncertainty at all times was not measured in low-latency. During the course of O4, the calibration groups aim to produce low-latency calibration strain data as the main product and will investigate methods for producing much lower latency ($\sim$hours rather than weeks-to-months) estimates of the total calibration uncertainty associated with the low-latency calibrated data. If necessary, the data will also be re-calibrated offline, with models updated and informed by careful analysis of all measurements taken throughout the observational period [13]. Such data sets have reduced systematic error and well-quantified total calibration uncertainty but at the sacrifice of weeks-to-months of latency.

The tasks critical to the infrastructure and operations of the detector calibration groups include:

- Maintain global network of absolute displacement fiducial references, including photon calibrator (PCAL) and gravitational-field / Newtonian calibrator (GCAL/NCAL) systems.
- Upkeep of precision models of the detector response (low-latency and offline DARM models) during O4, including regular characterization of the detectors.
- Maintain and retain extensibility of the DARM loop model software used for workflow from calibration measurements to uncertainty estimation, including software improvement to speed up production of systematic error and uncertainty estimates. Continue efforts toward common software whenever feasible in collaboration across LIGO, Virgo, and KAGRA.
- Maintain and operate the low- and high-latency $h(t)$ data production software, including upkeep of the filters based on the DARM loop model to match the detector changes.
- Maintain and operate the production of a calibration state vector to be released along with $h(t)$ data that indicates the fidelity of the calibrated data.
- Develop and deploy real-time monitoring for the low-latency $h(t)$ data production.

- Develop and deploy infrastructure for low-latency total calibration uncertainty estimation.
- Continued coordination with observational science groups to facilitate mock astrophysical and detector noise signals injected in the DARM control loop (aka “hardware injections”).
- Maintain the calibration software tools used for reviewing and diagnosing calibration issues.
- Develop, maintain, and deploy methods for removing (or “cleaning”) known noise sources from the strain data.
- Continually maintain documentation of methods and results, review final calibration products and software, and publish calibration results.
- Stream-line and automate (wherever possible) the process of calibrating each interferometer.
- Improve the low-latency calibration software in accuracy, efficiency, and latency.

The tasks that the calibration groups will be working towards with longer term R&D include:

- Improve DARM loop models and methods for characterizing the DARM loop systematic error.
- Understand the impact of total calibration uncertainty on astrophysical results including detection and astrophysical parameter estimation.
- Improve the understanding of the detectors response above 1 kHz.
- Continue efforts towards simultaneously reducing systematic error and latency in $h(t)$ production.
- Improve the hardware used as the absolute calibration reference.

OPS-0.10 Low Latency mission summary

The mission of the working group is the prompt identification and dissemination of gravitational-wave detections within the transient astronomy community during real-time analysis of the interferometers’ data. The group provides the integration of multiple tasks, from the astrophysical searches that identify event candidates to the issuing of astronomical alerts.

In the fourth observing run (O4) the LIGO-Virgo-Kagra Collaborations have successfully provided open public alerts (OPA) to the transient observing communities through the General Coordinates Network (GCN) and the Scalable Cyberinfrastructure to support Multi-Messenger Astrophysics (SCiMMA) project. The group also provided the infrastructure for identifying coincidence of gravitational-wave triggers with gamma-ray bursts and neutrino events, and sharing them with the community in real-time. It maintains the Public Alerts User Guide[1], which provides the broader community information on how to receive and interpret the real-time gravitational-wave information.

Looking towards O4b, the group will be making incremental changes in the low-latency infrastructure that will (a) improve the stability of the existing alert pipeline, (b) improve the efficiency of alert generation, (c) offer the ability to include more detectors (i.e., KAGRA), and (d) provide refinements of our data-products.

[1] https://emfollow.docs.ligo.org/

Working group priorities

The priorities of the working group are:

1. **Highest Priority**
    - **Priority A:** The working group will increase reliability and automation throughout the entire alert pipeline, including through monitoring. [Section OPS-10.1]
    - **Priority B:** The group will continue to document the alert products and the broader ecosystem within the User Guide. [Section OPS-10.2]
    - **Priority C:** The working group will interface and work with the Burst, CBC and DetChar groups in carrying out comprehensive tests of the end-to-end pipeline(s) using replay, simulated and engineering data (e.g. MDCs). [Section OPS-10.3]
2. **High Priority**
    - **Priority A:** The working group will continue to maintain and improve external coincidence software, RAVEN. [Section OPS-10.4]
    - **Priority B:** The working group will continue to maintain and improve GraceDB. [Section OPS-10.6]
    - **Priority C:** The group will continue to review the alert system and broader ecosystem. [Section OPS-10.7]
    - **Priority D:** The working group will finish integration of parameter estimation pipelines, including rapidpe and bilby. [Section **??**]

Methods for Advancing Frontiers of...

The two main levels of longer term R&D activities of the working group comprise:

1. **Essential**
    - **Item A:** The working group will interface and work with the CBC and Burst groups to improve, refine and communicate data products. [Section OPS-10.8]
2. **Exploratory**
    - **Item C:** The group will explore serverside implementation of the superevent manager alongside GraceDB.

OPS-0.11 Computing and Software mission summary

The mission of the working group is to support the scientific work of the collaborations through the operation and suppport of cyberinfrastructure and hardware resources for scientific data analysis, robust security and identity and access management, and other collaboration services that allow our large scientific organizations to function effectively. It seeks to identify and manage new computational technologies that may increase the effectiveness of the rest of the scientific mission of the collaborations, or enable the same science with fewer resources or greater robustness.

Because so much of the work of the collaborations involve computing and software, it may not be obvious which activities are within the scope of this group. To best reflect the expertise of the working group and the natural organizational structure of the other working groups, the scope of the Computing and Software working group excludes software development in other working groups, general computing of collaboration institutions (including the interferometers), interferometer control and data acquisition systems up to and including the data concentrator, control room software and services, the calibration pipelines, and the data cleaning pipeline. For most of these excluded areas, the infrastructure tools and services on which they depend may be considered in-scope. There are also special considerations for the operation of computing centers that provide computing resources: the amount of effort that is in-scope for this working group is that *fraction* of the actual person-power required that equals the fraction of the total computing service units provided that are made available for general collaboration use *and* prioritized by the chairs of the Observational Science division.

Working group priorities

The priorities of the working group do not break down cleanly into a subset of certain projects, but are organized as follows:

1. **Highest Priority**
    - **Priority A:** The working group will provide infrastructure and services to support low-latency science, as identified in specific activities under data analysis services and data handling services. [Sections OPS-11.2 and OPS-11.3]
    - **Priority B:** The working group will coordinate information security and as needed respond to security incidents. [Section OPS-11.6]
2. **High Priority**
    - **Priority A:** The working group will support high latency data analysis through the operation of computing clusters, and the infrastructure and services that provide data access and workflow submission. These are a subset of the activities in the data analysis services, data handling services, and computing systems projects. [Sections OPS-11.2, OPS-11.3, and OPS-11.8]
    - **Priority B:** The working group will operate, support, and maintain collaboration services to facilitate the functioning of the collaborations. [Sections OPS-11.1 andOPS-11.4]

Methods for Advancing Frontiers of...

The two main levels of longer term R&D activities of the working group comprise:

1. **Essential**
    - **Item A:** The group will investigate improved methods for data distribution and access, both for low-latency data analysis and high latency offline analysis.

- **Item B:** The group will migrate toward and support improved federated identity and access management.

2. **Exploratory**

- **Item C:** The group will, through consultation with identified high-priority data analysis pipelines, faciltate improving the hardware performance of critical pipelines, and migrate those pipelines to run with optimal performance on suitable hardware accelerators.

OPS-0.12 Open Data mission summary

The mission of the Open Data working group is to prepare, host, and document releases of public instrument data from the LVK collaboration, as described in the LIGO Data Management Plan. In addition, we support public releases of analysis results and other LVK data products.

Working group priorities

The priorities of the working group are:

1. **Highest Priority**

- **Public Data Preparation:** The working group will prepare the O4a data release. [Section OPS-12.1]

- **GWOSC Webserver Development:** The working group will develop and maintain the GWOSC webserver [Section OPS-12.2]

2. **High Priority**

- **Display Community Catalogs:** The working group will display catalogs developped using public data in the Event Portal. [Section OPS-12.3]

- **Create Desktop App:** The working group explore creating a desktop application for viewing GW data files. [Section OPS-12.4]

- **Open Data Workshop:** The working group will organize an Open Data Workshop [Section OPS-12.5]

OPS-0.13 Timing Diagnostics and Development mission summary

The mission of the working group is....

Working group priorities

The priorities of the working group are:

1. **Highest Priority**

- **Priority A:** The working group will... [Section **??**]
- **Priority B:** The working group will... [Section **??**]

2. **High Priority**
   - **Priority A:** The working group will... [Section **??**]
   - **Priority B:** The working group will... [Section **??**]

Methods for Advancing Frontiers of...

The two main levels of longer term R&D activities of the working group comprise:

1. **Essential**
   - **Item A:** The group will...
   - **Item B:** The group will...
2. **Exploratory**
   - **Item C:** The group will...

OPS-0.14 Joint Run Planning mission summary

The mission of the working group is to facilitate the coordination of the run planning among the active observatories, currently KAGRA, Virgo, and LIGO.

Working group priorities

The priorities of the working group are:

1. **Highest Priority**
   - **Priority A:** The working group will facilitate information exchange between the LIGO, Virgo, and KAGRA Collaborations to help establish and coordinate the run plans [Section **??**]
   - **Priority B:** The working group will maintain the LVK-published timeline for runs and any other key communication artefacts used to communicate with the observing community [Section **??**]
2. **High Priority**
   - **Priority A:** The working group will support the Rapid Response Teams for Virgo, KAGRA, and LIGO [Section **??**]
   - **Priority B:** [Section **??**]

Methods for Advancing Frontiers of...

The two main levels of longer term R&D activities of the working group comprise:

1. **Essential**
   - **Item A:** The group will not pursue research – this is not relevant for JRPC
   - **Item B:** The group will...
2. **Exploratory**
   - **Item C:** The group will...

OPS-0.15 Support of Observatories mission summary

The mission of the working group is....

Working group priorities

The priorities of the working group are:

1. **Highest Priority**
   - **Priority A:** The working group will... [Section **??**]
   - **Priority B:** The working group will... [Section **??**]
2. **High Priority**
   - **Priority A:** The working group will... [Section **??**]
   - **Priority B:** The working group will... [Section **??**]

Methods for Advancing Frontiers of...

The two main levels of longer term R&D activities of the working group comprise:

1. **Essential**
   - **Item A:** The group will...
   - **Item B:** The group will...
2. **Exploratory**
   - **Item C:** The group will...

OPS-1 LIGO Observatory Operations

There are many detector-related activities at the LIGO Hanford and Livingston observatories to support Observatory Scientific Operations:

- The Commissioning team is charged with bringing the detector configuration to a state that is appropriate to meet the upcoming run goals, and to document and transfer operating knowledge to the Detector Engineering group and operators. This activity is detailed below.
- The Detector Engineering group monitors, characterizes, maintains, and repairs working detector configurations. Their goal is high-quality reliable uptime during runs. The Detector Engineering Group leaders manage Engineering Runs at the observatories, setting day-to-day priorities, scheduling work, approving interruptions, and tracking progress. The Detector Engineering Group leaders also chair the daily (or similar cadence) Engineering Run Management meetings and closely coordinate with the LSC Operations Division during the run up to an observing run.
- The Detection Coordinators work for the best science outcome and lead Observational Runs at the observatories. Together with the LSC chair of the RPC they closely plan and monitor run readiness and performance.
- The Computing, Electronics, Facilities and Vacuum teams support operations both directly and indirectly related to the detectors. In general, these groups give priority to the operational phase currently underway, be it commissioning, running, or key preparations for these. During runs these groups' activities will be carried out in close consultation with Run Management. As they also support high-priority non-run-related activities, such as the safe stewardship of Vacuum Equipment and infrastructure, cyber-security patching, and employee safety, not all of their work can be effectively overseen by Run Management.
- The LIGO Laboratory Systems group is central to the planning of all activities related to the detectors including vacuum refurbishment efforts. Typical activities that will be undertaken over the next year will focus on particulate control, stray light control, test mass point absorber R&D, improved automation of detector operation, vacuum system recovery, and the extensive modifications and installations needed for the A+ upgrade.
- The LIGO Laboratory Control and Data Systems (CDS) group maintains and updates the CDS suite of software used in real-time control and data acquisition systems deployed to the LIGO sites and R&D facilities. This includes introducing updates to the software suite based primarily on changes in software packages not developed in-house and computer technologies (software improvement) and providing general support in the area of electronics design, fabrication, test and maintenance (electronics improvements).

OPS-1.1 ALTS.COMM: Advanced LIGO Commissioning

Start date: 2024-01-01
Estimated due date: 2025-01-01

Personnel applied to H1 and L1 detectors during dedicated commissioning periods in order to bring the detectors to their target design sensitivity and uptime levels. Performance improvement tasks include characterization and documentation of detector behavior, diagnosis and mitigation of noise sources, tuning and optimizing control systems, and integration of new detector components (Lab WBS ALTS.COMM).

ACTIVITY OPS-1.1-A-**INFRAOPS**: ALTS.COMM: ADVANCED LIGO COMMISSIONING

OPS-1.2 ALTS.DI: Detector Improvements

Start date: 2024-01-01
Estimated due date: 2025-01-01

Covers labor for LIGO Lab managed observatory detector system improvements, in the fabrication phase. The scope includes detector system, subsystem, and technology fabrication and implementation. This includes all activities after the Final Design Review (FDR) up to commissioning efforts (Lab WBS ALTS.DI).

ACTIVITY OPS-1.2-A-**INFRAOPS**: ALTS.DI: DETECTOR IMPROVEMENTS

OPS-1.3 ADTR.GEN: LIGO Lab Operations

Start date: 2024-01-01
Estimated due date: 2025-01-01

The sum of LSC-relevant LIGO Lab Operations activity at the four LIGO Laboratory sites not reflected in Commissioning and Detector Improvements. This includes Detection Coordination, Site Computing, Electronics, Facilities and Vacuum activities, Laboratory Control and Data Systems (CDS), and Systems Engineering (Lab WBS LOPS.CDS, LOPS.CTRL, LOPS.DASC, LOPS.DOM, LOPS.FAC, LOPS.GCT).

ACTIVITY OPS-1.3-A-**INFRAOPS**: ADTR.GEN: LIGO LAB OPERATIONS

OPS-2 LIGO A+ Upgrade

The "A+ detector" project is a major upgrade to the existing Advanced LIGO detectors, which began in 2019 and expected to continue through to late 2025. Design, procurement and installation for A+ is well underway, led by the LIGO Lab with UK and Australian hardware contributions, as well as support by other members of the LSC.

Upgrades Completed before the O4 Run

A number of A+ Project deliverable elements have been fast-tracked for installation prior to the O4 run. These fast-tracked (accelerated development) elements of the A+ Project include a high-transmission Faraday isolator in the output optics section, adaptive wavefront control for improved mode-matching to the output mode cleaner and frequency-dependent squeezing. With concurrent detector improvements (including mitigation of point absorbers and higher laser power), the BNS range for O4 could be as high as 192 Mpc; This would effectively triple the O3 event detection rate.

In order to accomplish this A+ scope for O4 a number of vacuum system and facility modifications had to be accomplished. Facility construction of a Filter Cavity End Station (FCES) and Filter Cavity Enclosure (FCE) has been completed at both observatories. The filter cavity has been successfully locked at both LIGO sites, an important milestone for pre-O4 preparations

The FDS components (seismic isolation, suspensions, electronics, photodetectors, scattered light baffling, etc.) have all been installed at both observatories and are being commissioned at Hanford and read for commissioning at Livingston. The high-transmission (low loss) Faraday isolators have been installed as have the adaptive wavefront control elements (both thermally and piezo-actuated).

Future Upgrades

The full A+ expected BNS design range of 325 MPc is not expected until the O5 run with the addition of lower thermal noise coatings on the test mass optics, a larger beamsplitter and suspension and the addition of a Balanced Homodyne Detection (BHD) readout system.

OPS-2.1 LIGO A+ Project

Start date: 2019-10-01
Estimated due date: 2025-09-30

Activities connected to the A+ Upgrade. Note that costs for A+ have their own WBS assignments. In general LIGO Lab efforts on the upgrade are billed to detector improvements.

ACTIVITY OPS-2.1-A-**INFRAOPS**: ALTS:DI.APLUS DETECTOR IMPROVEMENTS - A+

Effort on the A+ project including project management, systems engineering, vacuum, control & data systems, facility modifications, core optics, suspensions, seismic isolation and interferometer sensing and control.

OPS-3 Virgo Observatory Operations

OPS-3.1 Virgo Observatory Operations

Start date: 2023-10-01
Estimated due date: 2025-01-01

ACTIVITY OPS-3.1-A-**INFRAOPS**: OPERATIONS OF THE VIRGO OBSERVATORY

All operations of the Virgo Observatory.

OPS-4 AdV+: Phase II Upgrade

OPS-4.1 AdV+: Phase II Project

Start date: 2023-10-01
Estimated due date: 2025-01-01

ACTIVITY OPS-4.1-A-**INFRAOPS**: ADV+ PHASE II UPGRADES

AdV+ Phase II Upgrades

OPS-5 KAGRA Observatory Operations

OPS-5.1 KAGRA Observatory Operations

Start date: 2023-10-01
Estimated due date: 2025-01-01

ACTIVITY OPS-5.1-A-**INFRAOPS**: OPERATIONS OF THE KAGRA OBSERVATORY

All operations of the KAGRA Observatory.

OPS-6 KAGRA Upgrades

OPS-6.1 KAGRA Upgrade

Start date: 2023-10-01
Estimated due date: 2025-01-01

ACTIVITY OPS-6.1-A-**INFRAOPS**: KAGRA UPGRADES

Upgrades to the KAGRA Observatory.

OPS-7 LIGO Aundha Observatory Operations

OPS-7.1 LIGO Aundha Observatory Facility Construction

Start date: 2023-10-01
Estimated due date: 2025-01-01

Activities related to the construction of the LIGO Aundha Observatory in the Hingoli district of Maharashtra state in India.

Motivation and goals

The LIGO Aundha Observatory will provide a third LIGO interferometer to participate in observations as part of the international network.

Finalize the design for the LIGO Aundha Observatory. Identify a contractor to perform the civil and vacuum construction of the facility according to design requirements and adhering to a schedule provided by project management. Work with the chosen contractor to build the Observatory.

Expected products and/or outcomes

The end result will be the addition to the international gravitational-wave network of another kilometer-scale interferometer; the LIGO Aundha Observatory

ACTIVITY OPS-7.1-A-**INFRAOPS**: CIVIL CONSTRUCTION OF LIGO AUNDHA OBSERVATORY

Acquisition of the Aundha site. Construction of buildings, roads and other infrastructure to house the 4km interferometer. Provision of power and water to the site.

Activity OPS-7.1-B-**InfraOps**: LIGO Aundha Vacuum Construction

Build or purchase the vacuum components needed for the LIGO Aundha interferometer. This includes the two 4km long vacuum tubes, chambers to house detector components, Cryopumps and Gate Valves. Construction and testing of prototype chambers, cryopumps and beam tube segments is also part of this activity.

Activity OPS-7.1-C-**InfraOps**: Interfaces between LAO Subsystems

Activities related to finalizing interfaces between different subsystems and preparing reference documents.

OPS-7.2 LIGO Aundha Testing and Training

Start date: 2023-01-01
Estimated due date: 2025-01-01
Testing and training activities related to LIGO India.

Motivation and goals

The Aundha detector will utilize components currently in storage at the LIGO Hanford Observatory and will leverage these assemblies, the expertise gained from operating the current LIGO observatories, and improvements and upgrades to build a state of the art interferometer. The goal is to build a team in India with the expertise requires to test detector components prior to installation and to commission and operate the Aundha Observatory.

Expected products and/or outcomes

The end result will be a group of local experts capable of playing lead roles in the installation, commissioning, and operation of the Aundha detector.

Activity OPS-7.2-A-**InfraOps**: LIGO India 10m Prototype

Installation and operation of a 10m prototype at the Testing and Training (T&T) facility in the Raja Ramanna Center for Advanced Technology (RRCAT). This prototype will be used to train LIGO India scientists and engineers on LIGO control systems and the principles of interferometer operation.

Activity OPS-7.2-B-**InfraOps**: LIGO India Pre-Stabilized Laser

Use components shipped from LIGO Hanford in order to build and test a 35 W Laser at the RRCAT T&T facility.

Activity OPS-7.2-C-**InfraOps**: Commissioning LIGO India Training Facilities

A Training Program for LIGO-India aimed at generating the needed personpower for Commissioning and Operation of the observatory in the future. This training program requires development of several stand-alone training modules, addressing each of the major subsystems of aLIGO, aimed at training students, postdocs, project personnel, as well as scientists and engineers at different institutions, who wish to take up projects in this area. This is envisioned as a structured, multi-level training program starting at the conceptual (Instrument-Science) level, leading up to imparting various aLIGO-specific detector technology skills at higher levels. These modules may also be used for teacher training, Master's level course-work and for seeding undergrad student labs at various institutions of higher education.

OPS-7.3 LIGO Aundha Detector: Shipping, Upgrades and Construction

Start date: 2024-01-01
Estimated due date: 2025-01-01

Shipping the detector components currently stored at Hanford to India, upgrading components where appropriate and constructing new components where needed.

Motivation and goals

The Aundha detector will primarily utilize components currently in storage at the LIGO Hanford Observatory. A careful inventory of components will need to be made and each assembly or component parts will need to be inspected and carefully packed for shipment. Items received in India will need to be tracked in our inventory and inspected to ensure that they have survived the shipping process intact.

Many of these components will need to be upgraded to match the current state-of-the-art LIGO interferometers. Additionally, there will be a need to build some new assemblies, such as extra HAM Isolation platforms, in order to bring the Aundha detector to a similar level of performance as the Livingston and Hanford detectors.

Expected products and/or outcomes

The end result will be a carefully inventoried set of detector components received from the LIGO laboratory in the US. These components will be upgraded as needed to benefit from the experience gained in the operation of the US based LIGO detectors. New assemblies will be constructed as required.

ACTIVITY OPS-7.3-A-**INFRAOPS**: DETECTOR SHIPPING FROM LIGO HANFORD TO INDIA

Inventory, prepare, pack and ship detector components for use in the LIGO Aundha interferometer.

ACTIVITY OPS-7.3-B-**INFRAOPS**: DETECTOR UPGRADES FOR LAO

Upgrade components of the LIGO-India detector in order to benefit from lessons learned during the operation of the current LIGO detectors and from advances in technology.

ACTIVITY OPS-7.3-C-**INFRAOPS**: DETECTOR CONSTRUCTION AND AUGMENTATION FOR LAO

The current LIGO detectors contain components that were added after the LIGO-India detector was put into storage. Most notable of these are the squeezer and extra seismic isolation tables. This task covers the procurement, assembly, testing and installation of detector components that are not available from storage.

ACTIVITY OPS-7.3-D-**INFRAOPS**: LIGO INDIA SUSPENSION WORK

Train LIGO India personnel in fiber pulling and fiber welding and in the installation of test mass optics into the suspension. Construct a fiber pulling lab and a fiber welding set up at RRCAT.

OPS-7.4 LIGO Aundha Observatory Services

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Construction, operation and planning of the LIGO Aundha Observatory demands a sizeable amount of management efforts. Also, during the initial phases of the observatory all the major efforts may not be foreseen and, hence, not included in the white paper.

ACTIVITY OPS-7.4-A-**INFRAOPS**: LIGO AUNDHA OBSERVATORY SERVICES

Management tasks and essential services for the LIGO Aundha Observatory that are not captured by more specific tasks listed in the white paper.

ACTIVITY OPS-7.4-B-**OTHER**: LONG TERM ACTIVITIES FOR THE LIGO AUNDHA OBSERVATORY

Long term activities related to LIGO Aundha Observatory, which may not be considered critical, but important to carry out, e.g., for academic interests, and do not fall under specific tasks listed elsewhere in the white paper.

OPS-8 Detector Characterization

The following sections outline the priorities for detector characterization work in 2023 in terms of tasks necessary during the fourth LIGO-Virgo-KAGRA observing run or tasks required for **future observing runs** beyond O4.

OPS-8.0.1 LIGO DetChar Roles

There are many active roles within the LIGO detector characterization group, and often some people have more than just one role. There are two appointed DetChar chairs at present who oversee and steer the entire group. Working alongside them is a small committee who lead the low latency data quality, instrument characterization, DetChar-specific computing, and event validation efforts. This committee is structured by the DetChar co-chairs, and members are appointed by the DetChar co-chairs. There are five liaisons between search groups and DetChar. The data quality shift coordinator oversees the staffing of the data quality shifts and serves as a point of contact for data quality shift mentors. The safety studies coordinator coordinates with the Hardware Injection team to perform regular DetChar Hardware Injections, oversees the analysis of these safety studies and maintains the channel list. The review chair of the LIGO DetChar group manages the review of critical DetChar code and coordinates code configuration control with other working groups for observing runs. A small group of people also oversee, maintain and develop the key software required by the DetChar group.

OPS-8.1 Monitoring known or new DQ issues

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.1-A-**INFRAOPS**: MONITORING KNOWN OR NEW DQ ISSUES IN THE LIGO INTERFEROMETERS

TASK OPS-8.1-A(i)-**INFRAOPS**: INVESTIGATION OF WORST OFFENDER NOISE SOURCES

These are known to include:

- Scattering
- Blip glitches
- Anomalous environmental coupling (e.g., thunderstorms, periscope motion, beam clipping)
- Spectral Artifacts
- *See LIGO DCC P2000495 for more information on the noise sources most prevalent in O3.*

TASK OPS-8.1-A(ii)-**INFRAOPS**: MONITORING AND STUDIES TO CHARACTERIZE SPECTRAL ARTIFACTS (LINES OR COMBS) THAT IMPACT SEARCHES FOR PERSISTENT GRAVITATIONAL WAVE SIGNALS

TASK OPS-8.1-A(iii)-**INFRAOPS**: MAINTENANCE AND CHARACTERIZATION OF THE PHYSICAL ENVIRONMENT MONITOR (PEM) SENSORS

This includes evaluating the environmental couplings of the interferometers.

TASK OPS-8.1-A(iv)-**INFRAOPS**: MEASURING AND MONITORING THE LEVEL OF MAGNETIC COUPLING AT THE LIGO OBSERVATORIES

ACTIVITY OPS-8.1-B-**INFRAOPS**: MONITORING KNOWN OR NEW DQ ISSUES IN THE VIRGO INTERFEROMETER

TASK OPS-8.1-B(i)-**INFRAOPS**: INVESTIGATION OF GLITCHES IN VIRGO: RATE, CLASSIFICATION, SEARCH FOR THEIR ORIGIN, AND HELP TO MITIGAT/FIX THEM

TASK OPS-8.1-B(ii)-**INFRAOPS**: SUPPORT THE REINFORCE E.U. PROJECT TO DEVELOP AN INTERACTIVE GLITCH WEB CATALOG AN A CITIZEN SCIENCE PROJECT TO CLASSIFY GLITCHES

TASK OPS-8.1-B(iii)-**INFRAOPS**: DEPLOYING AN IMPROVED BNS RANGE DROP MONITOR

TASK OPS-8.1-B(iv)-**INFRAOPS**: MONITORING AND STUDIES TO CHARACTERIZE SPECTRAL ARTIFACTS (LINES OR COMBS) THAT IMPACT SEARCHES FOR PERSISTENT GRAVITATIONAL WAVE SIGNALS

ACTIVITY OPS-8.1-C-**INFRAOPS**: MONITORING KNOWN OR NEW DQ ISSUES IN THE KAGRA INTERFEROMETER

TASK OPS-8.1-C(i)-**INFRAOPS**: INVESTIGATION REASONS FOR LOCK LOSSES

TASK OPS-8.1-C(ii)-**INFRAOPS**: MAINTENANCE AND CHARACTERIZATION OF THE PHYSICAL ENVIRONMENT MONITOR (PEM) SENSORS

This includes monitoring the environment inside and outside the experimental area, performing vibration and hammering tests, and perfomring acoustic and magnetic injections.

ACTIVITY OPS-8.1-D-**INFRAOPS**: LIGO DATA QUALITY SHIFTS

TASK OPS-8.1-D(i)-**INFRAOPS**: CONTRIBUTING TO CONDUCTING OR MENTORING LIGO DQ SHIFTS

Data quality shifts will be the primary means of ensuring full coverage of h(t) data quality analysis for both detectors during the next observing run, including limiting factors to interferometer performance such as weather or earthquakes. Data quality shifters must invest first in training, and a qualified mentor must be identified for new volunteers.

ACTIVITY OPS-8.1-E-**INFRAOPS**: MONITORING KNOWN OR NEW DQ ISSUES THAT ARE CORRELATED BETWEEN DETECTORS

TASK OPS-8.1-E(i)-**INFRAOPS**: PERFORM STUDIES OF INSTRUMENTAL AND ENVIRONMENTAL CORRELATIONS BETWEEN DETECTORS, PARTICULARLY CORRELATED MAGNETIC NOISE.

ACTIVITY OPS-8.1-F-**INFRAOPS**: INVESTIGATION OF DQ ISSUES THAT IMPACT SEARCH BACKGROUNDS

TASK OPS-8.1-F(i)-**INFRAOPS**: STUDYING HOW INSTRUMENTAL ARTIFACTS AFFECT THE SENSITIVITY OF A SPECIFIC SEARCH OR SEARCH METHOD.

The standardized metric for assessing the impact of DQ information on a particular search will be search volume-time (VT), measured by the effect on the background of each search and on recoverability of signals. Population model assumptions in these studies should be clearly documented.

TASK OPS-8.1-F(ii)-**INFRAOPS**: DEVELOPING SEARCH-SPECIFIC TECHNIQUES FOR NOISE MITIGATION.

This includes:

- Contributions to developing / incorporating low-latency DQ information into the online searches.
- Estimating the contribution of the correlated magnetic noise to the measurement of $\Omega_{\rm gw}$ in stochastic searches, and using parameter estimation formalism to separate this contribution from the true stochastic background contributions
- Exploring possibilities of removing the correlated magnetic noise that impacts stochastic searches from the strain data.
- Studying alternatives for delta sigma cut and Median PSD estimation instead of mean PSD estimation in stochastic searches.

TASK OPS-8.1-F(iii)-**INFRAOPS**: INVESTIGATING THE LOUDEST BACKGROUND OUTLIERS FOR A SPECIFIC SEARCH OR SEARCH METHOD

TASK OPS-8.1-F(iv)-**INFRAOPS**: CALIBRATION UNCERTAINTY ASSESSMENT FOR STOCHASTIC SEARCHES

OPS-8.2 DQ products for the astrophysical searches

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.2-A-**INFRAOPS**: GENERATION OF OFFLINE LIGO DQ PRODUCTS

TASK OPS-8.2-A(i)-**INFRAOPS**: DEVELOPING, TESTING, AND DOCUMENTING OFFLINE DQ FLAGS

TASK OPS-8.2-A(ii)-**INFRAOPS**: SUPPORT FOR ADDITIONAL OFFLINE DQ PRODUCTS SUCH AS IDQ TIMESERIES

TASK OPS-8.2-A(iii)-**INFRAOPS**: PRODUCING LISTS OF LINE ARTIFACTS THAT IMPACT SEARCHES FOR PERSISTENT GRAVITATIONAL WAVE SIGNALS

TASK OPS-8.2-A(iv)-**INFRAOPS**: PRODUCING LISTS OF INSTRUMENTAL CORRELATIONS BETWEEN DETECTORS, INCLUDING INFORMATION ON TIME EVOLUTION

TASK OPS-8.2-A(v)-**INFRAOPS**: MEASURING CORRELATED MAGNETIC NOISE THAT IMPACTS SEARCHES FOR THE STOCHASTIC GRAVITATIONAL-WAVE BACKGROUND

TASK OPS-8.2-A(vi)-**INFRAOPS**: REVIEW OF OFFLINE DQ PRODUCTS

TASK OPS-8.2-A(vii)-**INFRAOPS**: DEVELOP AND PRODUCE GATED H(T) FRAMES WITH LOUD SHORT-DURATION GLITCHES SUBTRACTED FOR USE BY SEARCHES FOR PERSISTENT GRAVITATIONAL WAVE SIGNALS (CW AND STOCHASTIC)

TASK OPS-8.2-A(viii)-**INFRAOPS**: STUDY THE IMPACT OF NON-LINEAR NOISE SUBTRACTION AND GATED H(T) ON STOCHASTIC SEARCHES, AND ADOPT WHERE NECESSARY

ACTIVITY OPS-8.2-B-**INFRAOPS**: GENERATION OF ONLINE LIGO DQ PRODUCTS

TASK OPS-8.2-B(i)-**INFRAOPS**: SUPPORT OF ONLINE DQ PRODUCTS

This includes development and maintenance of a git repository with configuration files and products delivered with low latency h(t) frames: state information, data quality flags, iDQ timeseries, and veto definitions

TASK OPS-8.2-B(ii)-**INFRAOPS**: REVIEW OF ONLINE DQ PRODUCTS

ACTIVITY OPS-8.2-C-**INFRAOPS**: GENERATION OF OFFLINE VIRGO DQ PRODUCTS

TASK OPS-8.2-C(i)-**INFRAOPS**: DEVELOPING, TESTING, AND DOCUMENTING OFFLINE DQ FLAGS AND VETOES

TASK OPS-8.2-C(ii)-**INFRAOPS**: PRODUCING AND REVIEWING LISTS OF LINE ARTIFACTS THAT IMPACT SEARCHES FOR PERSISTENT GRAVITATIONAL WAVE SIGNALS

TASK OPS-8.2-C(iii)-**INFRAOPS**: FULL AUTOMATION (AND LATENCY REDUCTION) OF THE PRODUCTION OF OFFLINE DQ FLAGS AND VETOES

ACTIVITY OPS-8.2-D-**INFRAOPS**: GENERATION OF ONLINE VIRGO DQ PRODUCTS

TASK OPS-8.2-D(i)-**INFRAOPS**: REDUCE LATENCY OF ONLINE FLAGS AND VETOES PRODUCTION

ACTIVITY OPS-8.2-E-**INFRAOPS**: GENERATION OF OFFLINE KAGRA DQ PRODUCTS

TASK OPS-8.2-E(i)-**INFRAOPS**: PROVIDING SEGMENT INFORMATION USING AUXILIARY CHANNELS

TASK OPS-8.2-E(ii)-**INFRAOPS**: PROVIDING CAT1 DQ FLAGS FOR EACH SEARCH GROUP

TASK OPS-8.2-E(iii)-**INFRAOPS**: PROVIDING CAT2/3/4 DQ FLAGS FOR EACH SEARCH GROUP

TASK OPS-8.2-E(iv)-**INFRAOPS**: PRODUCING AND REVIEWING LISTS OF LINE ARTIFACTS THAT IMPACT SEARCHES FOR PERSISTENT GRAVITATIONAL WAVE SIGNALS

ACTIVITY OPS-8.2-F-**INFRAOPS**: GENERATION OF ONLINE KAGRA DQ PRODUCTS

TASK OPS-8.2-F(i)-**INFRAOPS**: PROVIDING THE ONLINE DQ STATE VECTOR

TASK OPS-8.2-F(ii)-**INFRAOPS**: PROVIDING OBSERVATION MODE DQ SEGMENTS WITH SHORTER CADENCE THAN THE O3GK RUN

ACTIVITY OPS-8.2-G-**INFRAOPS**: GENERATION OF VETO DEFINER FILES FOR ASTROPHYSICAL SEARCHES

TASK OPS-8.2-G(i)-**INFRAOPS**: PRODUCING AND REVIEWING OFFLINE VETO DEFINER FILES, WHICH DEFINE THE DQ FLAGS THAT ARE USED TO VETO DATA FOR EACH INDIVIDUAL ASTROPHYSICAL SEARCH

OPS-8.3 Vetting and data mitigation for GW signal candidates

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.3-A-**INFRAOPS**: DETCHAR VETTING OF TRANSIENT GW CANDIDATES

TASK OPS-8.3-A(i)-**INFRAOPS**: CONTRIBUTING TO CONDUCTING OR MENTORING GW EVENT CANDIDATE VALIDATION

Using the automatically generated Data Quality Report (DQR) [14] to vet the data quality around gravitational wave event candidates, including evaluating environmental couplings

TASK OPS-8.3-A(ii)-**INFRAOPS**: FIELD A DETCHAR RAPID RESPONSE TEAM TO VET THE DATA QUALITY FOR LOW-LATENCY GRAVITATIONAL WAVE CANDIDATE EVENTS

ACTIVITY OPS-8.3-B-**INFRAOPS**: SUPPORT OF THE IGWN DATA QUALITY REPORT

TASK OPS-8.3-B(i)-**INFRAOPS**: DEVELOPMENT, MAINTENANCE AND REVIEW OF TASKS FOR THE IGWN DQR

The end goal is full automation (note, work related to the IGWN DQR codebase is listed in **??**)

TASK OPS-8.3-B(ii)-**INFRAOPS**: PRODUCE TRAINING MATERIAL TO EVALUATE THE IGWN DQR FOR GW EVENT VALIDATION

ACTIVITY OPS-8.3-C-**INFRAOPS**: SUPPORT OF THE VIRGO DATA QUALITY REPORT

TASK OPS-8.3-C(i)-**INFRAOPS**: DEVELOPMENT, MAINTENANCE AND REVIEW OF TASKS FOR THE VIRGO DQR

ACTIVITY OPS-8.3-D-**INFRAOPS**: DETCHAR VETTING OF PERSISTENT GW CANDIDATES

TASK OPS-8.3-D(i)-**INFRAOPS**: SUPPORT VALIDATION OF CW CANDIDATES, INCLUDING DEVELOPMENT AND STUDIES TO ADDRESS DETCHAR-RELATED ITEMS IN THE PROTOCOL FOR ESTABLISHING CONFIDENCE IN A CW CANDIDATE [15]

TASK OPS-8.3-D(ii)-**INFRAOPS**: SUPPORT VALIDATION OF STOCHASTIC GW CANDIDATES, INCLUDING DETCHAR-RELATED ITEMS IN THE STOCHASTIC DETECTION CHECKLIST [16]

ACTIVITY OPS-8.3-E-**INFRAOPS**: DATA MITIGATION FOR GW CANDIDATES

TASK OPS-8.3-E(i)-**INFRAOPS**: PRODUCE, TEST AND REVIEW GLITCH MITIGATED FRAMES FOR PARAMATER ESTIMATION ANALYSES

For reference, the O3a data mitigation review document is at [17] and the O3b data mitigation status is at [18]

TASK OPS-8.3-E(ii)-**INFRAOPS**: DEVELOPMENT AND AUTOMATION OF DATA MITIGATION PROCESS

OPS-8.4 Commissioning support

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.4-A-**INFRAOPS**: LIGO DETCHAR SUPPORT OF COMMISSIONING

TASK OPS-8.4-A(i)-**INFRAOPS**: TRACKING ISSUES THAT AFFECT INTERFEROMETER UPTIME, SUCH AS SEISMIC MOTION

TASK OPS-8.4-A(ii)-**INFRAOPS**: INVESTIGATING NOISE SOURCES THAT LIMIT DETECTOR SENSITIVITY

For example, hour-scale correlations between h(t) and auxiliary channels or jumps in detector binary neutron star range.

TASK OPS-8.4-A(iii)-**INFRAOPS**: INTERFACING WITH COMMISSIONERS AND INSTRUMENT EXPERTS TO PROPAGATE INSTRUMENT CHANGES AND DEVELOPMENTS TO DETECTOR CHARACTERIZATION INVESTIGATIONS AND MONITORING.

TASK OPS-8.4-A(iv)-**INFRAOPS**: MONITORING AND USING THE FAULT REPORTING SYSTEM (FRS) AND THE ELECTRONIC LOGS (ALOGS) TO COMMUNICATE RESULTS AND REQUEST TESTS.

TASK OPS-8.4-A(v)-**INFRAOPS**: PERFORMING INVESTIGATIONS AS PROMPTED BY COMMISSIONERS, INCLUDING REQUESTING ADDITIONAL INFORMATION OR SUGGESTING FOLLOW-UP TESTS WHEN NEEDED AND REPORTING RESULTS ON THE ALOGS.

TASK OPS-8.4-A(vi)-**INFRAOPS**: MENTORING AND TRAINING SCIENTISTS IN THE DETECTOR CHARACTERIZATION GROUP TO PERFORM INSTRUMENTAL INVESTIGATIONS

TASK OPS-8.4-A(vii)-**INFRAOPS**: MENTORING AND TRAINING SCIENTISTS PARTICIPATING IN THE LSC FELLOWS PROGRAM

This task supports LSC scientists working at the site to improve the detector data.

TASK OPS-8.4-A(viii)-**INFRAOPS**: REPORTING TO COMMISSIONERS AND INSTRUMENT EXPERTS ABOUT NOISE FEATURES THAT HAVE THE LARGEST IMPACTS ON SPECIFIC ASTORPHYSICAL ANLYSES.

ACTIVITY OPS-8.4-B-**INFRAOPS**: VIRGO DETCHAR SUPPORT OF COMMISSIONING

TASK OPS-8.4-B(i)-**INFRAOPS**: DEPLOY LOCK LOSS MONITOR

ACTIVITY OPS-8.4-C-**INFRAOPS**: KAGRA DETCHAR SUPPORT OF COMMISSIONING

TASK OPS-8.4-C(i)-**INFRAOPS**: PROVIDING TOOLS AND INFORMATION TO COMMISSIONERS.

This includes:

- Summary pages [19]
- Bruco [20]
- Fscan [21]
- Pastavi; WEB base data plot tool [22]
- Noise budgetter; python base noise budget management tool [23]

OPS-8.5 Support of key DetChar tools

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Types of work covered in this section:

- Support of key tools, including upgrade work such as python 3 compatibility, as well as user feedback and documentation for key infrastructure. Development standards for DetChar codebase:
  - Code is open source
  - Code is hosted on github.com or git.ligo.org to enable a github-flow-style development cycle
  - Code includes web-accessible documentation
  - Code has been through review
  - Code includes unit testing
  - Code includes clear and complete installation instructions
  - Code configuration files are available and up to date
  - Python is recommended for development to maximize compatibility with existing tools, reducing duplication-of-effort and redundancy
- Automation of key tools in LIGO DetChar
- Integration of key tools to be cross-compatible
  - Wherever possible, all tools in common use (i.e. excluding those in the early stages of development) should share a well-maintained, well-documented, and accessible codebase.
  - Wherever possible, all tools should be developed for use at all IGWN computing sites
  - All triggers and data products will be stored in appropriate common data formats [24] and will be discoverable with common tools (see key tools listed in Section Op-3.1-E). For instance, any data product should be accessible in a single function call on a site cluster.
  - Improve documentation and support of key tools: All DetChar tools in common use should be fully and centrally documented, accessible on the IGWN clusters (or easy to install), and well supported by responsive experts.

Expected products and/or outcomes

Required inputs

This list relies on software dependencies maintained by the LIGO Laboratory (e.g., the Guardian [25],), the LSC Computing and Software Committee (e.g., GWpy [26], the segment database [27, 28, 29], the channel information system [30], low-latency data distribution), the LSC Remote Access group (e.g., NDS2), and the Virgo and KAGRA Collaborations (e.g., Omicron, NoEMi). While those software elements are not in the scope of DetChar, continued maintenance of the software, adaptation for use on LIGO data, and operations on LIGO data are of the highest priority to enable IGWN science.

ACTIVITY OPS-8.5-A-**INFRAOPS**: REVIEW OF KEY DETCHAR TOOLS, PARTICULARLY THOSE USED TO GENERATE VETOES

ACTIVITY OPS-8.5-B-**INFRAOPS**: GWSUMM SUMMARY PAGES: MAINTENANCE, OPERATION, AND DEVELOPMENT

The summary pages [31] are an invaluable set of webpages containing key plots that describe the state and behavior of the IGWN detectors and their environment. This is a fundamentally necessary service.

This activity includes:

- maintenance of GWSumm [32] which is used to generate the summary pages
- providing summary pages
- improving the contents of summary pages

ACTIVITY OPS-8.5-C-**INFRAOPS**: DATA MONITORING TOOL (DMT): MAINTENANCE, OPERATION, AND DEVELOPMENT

The Data Monitoring Tool (DMT) [33] includes the low-latency DMT DQ vector infrastructure. This is a fundamentally necessary service.

ACTIVITY OPS-8.5-D-**INFRAOPS**: OMICRON: MAINTENANCE, OPERATION, AND DEVELOPMENT

Omicron triggers [34] identify transient noise triggers, including in low latency, delivered with very high reliability. This is a fundamentally necessary service.

ACTIVITY OPS-8.5-E-**INFRAOPS**: TOOLS FOR SAFETY INFORMATION AND STUDIES: MAINTENANCE, OPERATION, AND DEVELOPMENT

Safety information and studies [35] [36] [37] flag auxiliary channels that witness the gravitational wave strain readout, such that a passing gravitational wave might also induce a response in an *unsafe* auxiliary channel in addition to h(t). Accurate and up-to-date safety information is necessary for interpretation of any tools that correlate auxiliary channels with h(t) to model or infer noise couplings. This is a fundamentally necessary service.

ACTIVITY OPS-8.5-F-**INFRAOPS**: IDQ: MAINTENANCE, OPERATION, AND DEVELOPMENT

Maintenance, operation, and development of iDQ [38]

ACTIVITY OPS-8.5-G-**INFRAOPS**: SNAX TOOLKIT: MAINTENANCE, OPERATION, AND DEVELOPMENT

Maintenance, operation, and development of SNAX toolkit [39]

ACTIVITY OPS-8.5-H-**INFRAOPS**: GW-DETCHAR: MAINTENANCE, OPERATION, AND DEVELOPMENT
GW-DetChar [40] contains Omega scans, LASSO, automated monitoring of scattering, ADC/DAC overflows and software saturations.

ACTIVITY OPS-8.5-I-**INFRAOPS**: STOCHMON: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of Stochmon [41]

ACTIVITY OPS-8.5-J-**INFRAOPS**: STAMP-PEM: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of STAMP-PEM [42]

ACTIVITY OPS-8.5-K-**INFRAOPS**: HVETO: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of [43]

ACTIVITY OPS-8.5-L-**INFRAOPS**: UPV: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of UPV [44]

ACTIVITY OPS-8.5-M-**INFRAOPS**: LIGODV WEB: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of ligoDV web [45]

ACTIVITY OPS-8.5-N-**INFRAOPS**: POINTY POISSON: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of Pointy Poisson [46], [47]

ACTIVITY OPS-8.5-O-**INFRAOPS**: VET: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of VET [48]

ACTIVITY OPS-8.5-P-**INFRAOPS**: OFFLINE NOISE SUBTRACTION CODE: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of offline noise subtraction code, for example [49], [50], and [51]).

ACTIVITY OPS-8.5-Q-**INFRAOPS**: SUITE OF DETCHAR REMOTE ACCESS TOOLS: MAINTENANCE, OPERATION, AND DEVELOPMENT
Includes remote MEDM and EPICS [52], remote DataViewer [53].

ACTIVITY OPS-8.5-R-**INFRAOPS**: LIGOCAM: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of [54]

ACTIVITY OPS-8.5-S-**INFRAOPS**: FSCANS AND DEPENDENT TOOLS: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of the Fscan spectral monitor [55] and dependent tools

ACTIVITY OPS-8.5-T-**INFRAOPS**: DETCHAR COHERENCE TOOL: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of the coherence tool [56]

ACTIVITY OPS-8.5-U-**INFRAOPS**: MONITORING TOOL FOR CW HARDWARE INJECTIONS: MAINTENANCE, OPERATION, AND DEVELOPMENT
Maintenance, operation, and development of the CW hardware injection monitoring tool [56]

ACTIVITY OPS-8.5-V-**INFRAOPS**: INDEPENDENT COMPONENT ANALYSIS; MULTI-CHANNEL CORRELATION ANALYSIS: MAINTENANCE, OPERATION, AND DEVELOPMENT

Preparing Independent Component Analysis, Multi-channel correlation analysis [57] for providing veto information for search groups.

ACTIVITY OPS-8.5-W-**INFRAOPS**: ADAPT DETCHAR COMPUTING ECOSYSTEM TO NEW STORAGE ARCHITECTURE AT EGO

ACTIVITY OPS-8.5-X-**INFRAOPS**: MAINTAINING KEY TOOLS IN VIRGO DETCHAR

TASK OPS-8.5-X(i)-**INFRAOPS**: MIGRATING SOFTWARE FROM THE VIRGO SVN SYSTEM TO THE IGWN GITLAB

OPS-8.6 Interfacing with other groups in the operations and observational science divisions

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.6-A-**INFRAOPS**: INTERFACING BETWEEN DETCHAR AND THE SEARCH GROUPS, CALIBRATION, AND COMPUTING TEAMS

TASK OPS-8.6-A(i)-**INFRAOPS**: INTERFACING WITH SEARCH GROUPS

DQ liaisons identified by each pipeline should identify and report sensitivities in the pipelines to data defects.

TASK OPS-8.6-A(ii)-**INFRAOPS**: INTERFACING WITH THE CALIBRATION, COMPUTING, AND LOW-LATENCY TEAMS.

TASK OPS-8.6-A(iii)-**INFRAOPS**: ASSIST THE CALIBRATION GROUP WITH INVESTIGATING AND TESTING WHICH AUXILIARY CHANNELS ARE NEEDED TO PRODUCE BROADBAND NOISE SUBTRACTED FRAMES, IF NEEDED BY THE COLLABORATION

OPS-8.7 Machine learning for detector characterization

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.7-A-**INFRAOPS**: MACHINE LEARNING FOR DETCHAR INVESTIGATIONS OF THE LIGO INTERFEROMETERS

TASK OPS-8.7-A(i)-**INFRAOPS**: GRAVITY SPY [58] MACHINE-LEARNING CLASSIFICATION, REGRESSION, AND DATA MINING TO IDENTIFY INSTRUMENTAL CAUSES OF GLITCH CLASSES, AND WORKING WITH GRAVITY SPY CITIZEN SCIENTISTS TO IDENTIFY NEW GLITCH CLASSES AND TO IMPROVE THE QUALITY OF THE TRAINING SET FOR THE MACHINE-LEARNING ALGORITHM.

TASK OPS-8.7-A(ii)-**INFRAOPS**: MACHINE LEARNING [59] CLASSIFICATION, REGRESSION AND DATA MINING STUDIES TARGETING KNOWN NOISE SOURCES, E.G., SCATTERING.

ACTIVITY OPS-8.7-B-**OTHER**: PREDICT LIGO DETECTOR PERFORMANCE BASED ON INSTRUMENT STATE USING MACHINE LEARNING

TASK OPS-8.7-B(i)-**OTHER**: LOCK LOSS PREDICTION.

TASK OPS-8.7-B(ii)-**OTHER**: PREDICTION OF NOISE CHARACTERISTICS OR OTHER DETECTOR PERFORMANCE METRICS.

ACTIVITY OPS-8.7-C-**OTHER**: MACHINE LEARNING FOR DETCHAR INVESTIGATIONS OF THE VIRGO INTERFEROMETERS

OPS-8.8 Organization of planning and development for current and future observing runs

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.8-A-**INFRAOPS**: ORGANIZATION OF PLANNING AND DEVELOPMENT IN LIGO DETCHAR FOR THE CURRENT AND FUTURE OBSERVING RUNS

TASK OPS-8.8-A(i)-**INFRAOPS**: CONTRIBUTIONS TO DESIGN AND EVALUATION OF THE COHERENT PLAN FOR DQ PRODUCTS AND DETCHAR SERVICES FOR CURRENT AND FUTURE OBSERVING RUNS.

TASK OPS-8.8-A(ii)-**INFRAOPS**: CONTRIBUTIONS TO ORGANIZATION AND UPKEEP OF THE LIGO DETCHAR WORKPLAN AND REQUIREMENTS DOCUMENT.

ACTIVITY OPS-8.8-B-**INFRAOPS**: ORGANIZATION OF PLANNING AND DEVELOPMENT IN VIRGO DETCHAR FOR THE CURRENT AND FUTURE OBSERVING RUNS

TASK OPS-8.8-B(i)-**INFRAOPS**: DEFINITION OF A NEW DETCHAR GROUP ORGANIZATION, TARGETING DATA-TAKING PERIODS: FACTORY-LIKE AND OPERATIONS-ORIENTED

TASK OPS-8.8-B(ii)-**INFRAOPS**: DEFINITION OF A NEW DETCHAR SHIFT ORGANIZATION EMBEDDED IN THE GLOBAL VIRGO SERVICE TASK FRAMEWORK

TASK OPS-8.8-B(iii)-**INFRAOPS**: CONSTRUCTION OF A CORE TEAM OF DETCHAR EXPERTS, ACTIVE IN THE LAST PERIOD BEFORE O4 AND DURING THE WHOLE RUN

TASK OPS-8.8-B(iv)-**INFRAOPS**: ADDRESSING PERSONPOWER ISSUES THAT HAVE LIMITED THE NUMBER OF TASKS THE VIRGO DETCHAR GROUP COULD FOCUS ON DURING O3

OPS-8.9 Characterization of interferometer and auxiliary channels for O4 and future observing runs

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.9-A-**INFRAOPS**: CHARACTERIZATION OF THE LIGO INTERFEROMETERS AND AUXILIARY CHANNELS DURING A+ INSTALLATION AND FOR FUTURE OBSERVING RUNS

TASK OPS-8.9-A(i)-**INFRAOPS**: DOCUMENTATION OF PLANNED OR NEWLY INSTALLED INTERFEROMETER SUBSYSTEMS AND ENVIRONMENTAL MONITORS.

TASK OPS-8.9-A(ii)-**INFRAOPS**: MAINTENANCE OF LISTS OF AUXILIARY CHANNELS USEFUL FOR DETCHAR STUDIES TO INCLUDE NEW SUBSYSTEMS AND ENVIRONMENTAL MONITORS.

TASK OPS-8.9-A(iii)-**INFRAOPS**: MAINTENANCE OF SUMMARY PAGE CONTENT TO INCLUDE NEW SUBSYSTEMS AND ENVIRONMENTAL MONITORS.

TASK OPS-8.9-A(iv)-**INFRAOPS**: SIGNAL FIDELITY STUDIES OF NEWLY INSTALLED AUXILIARY CHANNELS.

TASK OPS-8.9-A(v)-**INFRAOPS**: AUXILIARY CHANNEL SAFETY STUDIES FOR NEW SUBSYSTEMS AND ENVIRONMENTAL MONITORS.

TASK OPS-8.9-A(vi)-**INFRAOPS**: DEVELOPMENT AND IMPROVEMENT OF PEM SENSORS AND SENSOR CHARACTERIZATION FOR A+ AND FUTURE OBSERVING RUNS, E.G., MAGNETOMETERS TO MONITOR SCHUMANN RESONANCES IN THE EARTH'S ELECTROMAGNETIC FIELD.

ACTIVITY OPS-8.9-B-**INFRAOPS**: CHARACTERIZATION OF THE VIRGO INTERFEROMETER AND AUXILIARY CHANNELS DURING ADV+ INSTALLATION AND FOR FUTURE OBSERVING RUNS

TASK OPS-8.9-B(i)-**INFRAOPS**: DEVELOP A NEW TOOL TO MANAGE, REFERENCE AND PROVIDE ACCESS TO THE NUMEROUS LISTS OF CHANNELS THAT ARE NEEDED AND USED BY VARIOUS SOFTWARES.

TASK OPS-8.9-B(ii)-**INFRAOPS**: DEPLOY POINTY POISSON FRAMEWORK FOR REGULAR VIRGO CHANNEL SAFETY STUDIES BEFORE AND DURING O4.

ACTIVITY OPS-8.9-C-**INFRAOPS**: CHARACTERIZATION OF THE KAGRA INTERFEROMETER AND AUXILIARY CHANNELS DURING KAGRA INSTALLATION AND FOR FUTURE OBSERVING RUNS

TASK OPS-8.9-C(i)-**INFRAOPS**: AUXILIARY CHANNEL SAFETY STUDIES FOR NEW SUBSYSTEMS AND ENVIRONMENTAL MONITORS

OPS-8.10 Research and development of methods for noise identification/mitigation

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.10-A-**INFRAOPS**: IMPROVE MONITORS OF KNOWN DQ FEATURES IN THE LIGO INTERFEROMETERS

TASK OPS-8.10-A(i)-**INFRAOPS**: IMPROVING MONITORING AND REPORTING OF DIGITAL AND ANALOG OVERFLOWS, REACHING SOFTWARE LIMITS, AND OTHER KINDS OF SATURATIONS; MONITORING AND REPORTING OF REAL-TIME DATA HANDLING ERRORS (TIMING, DROPPED DATA, ETC.).

TASK OPS-8.10-A(ii)-**INFRAOPS**: IMPROVING MONITORS FOR EXCESS MIRROR MOTION LEADING TO SCATTERED LIGHT.

TASK OPS-8.10-A(iii)-**INFRAOPS**: SCHUMANN RESONANCE STUDIES.

TASK OPS-8.10-A(iv)-**INFRAOPS**: DEVELOP TOOL TO QUERY STOCHASTIC MONITORS TO FIND WHICH AUXILIARY CHANNELS ARE COHERENT WITH THE GRAVITATIONAL WAVE STRAIN DATA AT A GIVEN FREQUENCY.

TASK OPS-8.10-A(v)-**INFRAOPS**: OPTIC SUSPENSION RESONANCE 'VIOLIN MODE' MONITORING

ACTIVITY OPS-8.10-B-**INFRAOPS**: IMPROVE MONITORS OF KNOWN DQ FEATURES IN THE VIRGO INTERFEROMETER

ACTIVITY OPS-8.10-C-**INFRAOPS**: IMPROVE MONITORS OF KNOWN DQ FEATURES IN THE KAGRA INTERFEROMETER

TASK OPS-8.10-C(i)-**INFRAOPS**: IMPROVING THE ICA ALGORITHM

TASK OPS-8.10-C(ii)-**INFRAOPS**: AUTOMATING VETO ANALYSIS AND VETO SEGMENT PRODUCTION

TASK OPS-8.10-C(iii)-**INFRAOPS**: DEVELOPING AUXILIARY CHANNEL CORRELATION SEARCH PIPELINES

TASK OPS-8.10-C(iv)-**INFRAOPS**: DEVELOPING AND APPLYING METHODS TO REMOVE NONLINEARY COUPLED NON-GAUSSIAN NOISES THROUGH INDEPENDENT COMPONENT ANALYSES

TASK OPS-8.10-C(v)-**INFRAOPS**: AUTOMATING GLITCH TRIGGER GENERATION

ACTIVITY OPS-8.10-D-**OTHER**: RESEARCH AND DEVELOPMENT OF USING KNOWN METHODS FOR NOISE IDENTIFICATION/MITIGATION ON DIFFERENT INTERFEROMETERS

TASK OPS-8.10-D(i)-**OTHER**: INVESTIGATING THE USE OF IDQ AT VIRGO DURING O4

ACTIVITY OPS-8.10-E-**OTHER**: RESEARCH AND DEVELOPMENT OF NEW METHODS FOR NOISE IDENTIFICATION/MITIGATION

TASK OPS-8.10-E(i)-**OTHER**: RESEARCH AND DEVELOPMENT OF NEW METHODS FOR NOISE IDENTIFICATION/MITIGATION

Any new methods are to be tested and validated on recent LIGO-Virgo-KAGRA data in a performance test outlined by the DetChar group.

OPS-8.11 Curation of detector charactization information for interal and public use

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.11-A-**INFRAOPS**: CURATION OF DETECTOR CHARACTERIZATION INFORMATION FOR INTERNAL USE

TASK OPS-8.11-A(i)-**INFRAOPS**: CURATION, DOCUMENTATION, AND REVIEW OF DOCUMENTATION FOR KEY TOOLS.

TASK OPS-8.11-A(ii)-**INFRAOPS**: CURATION, DOCUMENTATION, AND REVIEW OF DOCUMENTATION FOR CONFIGURATION FILES USED IN DETECTOR CHARACTERIZATION ANALYSES.

ACTIVITY OPS-8.11-B-**INFRAOPS**: CURATION OF DQ INFORMATION FOR PUBLIC DATA RELEASES THROUGH GWOSC

TASK OPS-8.11-B(i)-**INFRAOPS**: CURATION, DOCUMENTATION, AND REVIEW OF DQ VETOES FOR RELEASE BY THE GW OPEN SCIENCE CENTER (GWOSC) [60].

TASK OPS-8.11-B(ii)-**INFRAOPS**: DEVELOPMENT AND DOCUMENTATION OF THE "DETECTOR STATUS" PUBLIC SUMMARY PAGES HOSTED BY THE GWOSC [31].

OPS-8.12 Quantify the impact of transient noise on parameter estimation

Start date: 2024-01-01
Estimated due date: 2025-01-01

Motivation and goals

Expected products and/or outcomes

Required inputs

ACTIVITY OPS-8.12-A-**OTHER**: QUANTIFY THE IMPACT OF TRANSIENT NOISE ON PARAMETER ESTIMATION FOR TRANSIENT GW EVENTS

TASK OPS-8.12-A(i)-**OTHER**: TEST THE EFFECTS OF TRANSIENT NOISE ON RECOVERED SOURCE PROPERTIES

TASK OPS-8.12-A(ii)-**OTHER**: DEVELOP AND TEST METHODS TO RECONSTRUCT AND REMOVE FROM H(T) ISOLATED GLITCHES AND OTHER NOISE TYPES

OPS-9 Calibration

Throughout O4, it is imperative that each LIGO, KAGRA, and Virgo calibration group remain active in preparation and operation tasks for O4. To do so, the groups must maintain an active role in the Observational Science, Instrument Science, and Operations divisions. The following plans discuss the activities the Calibration groups in each collaboration will perform in support of Operations. Please see interrelated sections in the parallel white papers for plans better suited therein.

OPS-9.1 LIGO Calibration Operations

Start date: 2023-12-01
Estimated due date: 2025-01-01

ACTIVITY OPS-9.1-A-**INFRAOPS**: LIGO CALIBRATION HARDWARE MAINTENANCE

18 FTE months

A rigorous upkeep and monitoring schedule of all absolute displacement fiducial references must be maintained in order to retain accuracy and precision sufficient for characterization of the detector DARM loops.

TASK OPS-9.1-A(i)-**INFRAOPS**: MAINTENANCE AND MONITORING OF PHOTON CALIBRATORS

18 FTE months

Continue the maintenance schedule and monitoring of the photon calibrator systems, including but not limited to: continued interaction with NIST, PTB and other observatory projects in propagating the calibration of transfer standards (TSA and TSB) to reference power standards (Gold standards) maintained by each project, and generalizing the practice of comparing results from NIST, PTB, LIGO, Virgo and KAGRA, following the O4 global calibration scheme described in LIGO-P2100484 and LIGO-P2300412. This involves shipping the transfer standards between LHO (LIGO), LAPP (Virgo), Toyama Univ. (KAGRA), PTB (Braunschweig, Germany) and NIST (Boulder, CO) both before and during the O4 run. LHO also calibrates Working standards for both LHO and LLO that are used to calibrate the Pcal power sensors at the end stations. Periodic responsivity ratio measurements made in both LHO Pcal lab and at the interferometer end stations are required. Shipments and periodic re-calibration of LLO Working standard are also required.

ACTIVITY OPS-9.1-B-**INFRAOPS**: LIGO DETECTOR MODELING FOR CALIBRATION

24 FTE months

The current LIGO calibration pipeline encodes a model of the detector response in order to calculate the strain from the DARM error and control signals. This model needs to be maintained and kept up-to-date as the interferometer evolves and changes.

TASK OPS-9.1-B(i)-**INFRAOPS**: DARM LOOP MODEL MEASUREMENTS AND UPDATES

12 FTE months

Many measurements inform a carefully constructed model of the DARM control loop in order to achieve precise and accurate calibration. As the detectors are changed during the course of O4 or commissioned during the commissioning break, each calibration group will revisit all model parameters, remeasure if necessary, and update them to reflect the changes and upgrades to the detectors. In addition, any large-scale infrastructure changes that are required of the model, which are needed as a result of the upgrades leading into O4, must also be done in a timely fashion.

TASK OPS-9.1-B(ii)-**INFRAOPS**: DARM LOOP MODELING SOFTWARE MAINTENANCE

12 FTE months

The DARM loop model and systematic error budgeting software is a `Python`-based project called `pyDARM` that was successfully deployed and used initially in O3 [13]. `pyDARM` is now a publicly available package on common Python repositories PyPI and conda-forge (will eventually get into IGWN). Work is ongoing to streamline and automate the workflow from (1) measurement analysis, to (2) model development, to (3) installation of that model in to the low-latency and offline pipelines that produce h(t), and finally to (4) systematic error assessment and uncertainty estimation.

ACTIVITY OPS-9.1-C-**INFRAOPS**: LIGO CALIBRATION MEASUREMENTS

14 FTE months

Regular calibration measurements need to be taken throughout the observing run to keep the calibration pipeline up-to-date.

TASK OPS-9.1-C(i)-**INFRAOPS**: REGULAR MEASUREMENTS THROUGHOUT OBSERVING RUN

8 FTE months

Transfer functions of the sensing and actuation function are obtained through swept sine measurements. The photon calibrator is used to obtain these measurements.

TASK OPS-9.1-C(ii)-**INFRAOPS**: MEASUREMENTS FOR FREQUENT CALIBRATION SYSTEMATIC ERROR ESTIMATES

6 FTE months

We will investigate and deploy new methods for performing regular and faster calibration measurements that allow for more frequent characterization of the calibration systematic error.

ACTIVITY OPS-9.1-D-**INFRAOPS**: LIGO STRAIN PRODUCTION SOFTWARE AND INFRASTRUCTURE

15 FTE months

The LIGO calibration pipeline currently consists of two components: a front end, real-time process that does most of the calibration calculation, plus a downstream `gstlal`-based process that provides corrections for time variation and other issues. Both of these software components need to be maintained.

TASK OPS-9.1-D(i)-**INFRAOPS**: MAINTAIN CALIBRATION PRODUCTION PIPELINE PROGRAMS AND SOFTWARE

5 FTE months

The pipeline programs that actually generates the calibrated strain channel, both the front end component and the `gstlal` component that runs downstream in the DMT system, need to be maintained. Both software of the pipeline components also needs to be maintained to retain compatibility with their surrounding computational environments which are necessarily constantly evolving.

TASK OPS-9.1-D(ii)-**INFRAOPS**: UPDATE SOFTWARE TO BE CONSISTENT WITH DARM MODEL AS NEEDED

3 FTE months

Changes in DARM model parameters and/or infrastructure will be propagated to the respective pipelines with minimal introduction of systematic error in an extensible and robust fashion. This includes the most current and accurate ways to track time-dependence and communicate live calibration fidelity through the calibration state vector.

TASK OPS-9.1-D(iii)-**INFRAOPS**: CLEANING OF STRAIN DATA

4 FTE months

Certain noise sources, such as calibration lines and power mains lines, are known and can be removed from the strain data. The calibration groups needs to coordinate with Detector Characterization and other groups to develop, maintain, and deploy the necessary noise-cleaning methods for strain data in O4.

TASK OPS-9.1-D(iv)-**INFRAOPS**: OFFLINE STRAIN DATA REGENERATION

3 FTE months

If for some reason the strain production is inadequate for any period of time, it will have to be regenerated to produce a "C01" version of the strain channel during the period of inadequacy. The software, scripts, and environment needed to run the offline regeneration need to be maintained, and regeneration process itself needs to be managed.

ACTIVITY OPS-9.1-E-**INFRAOPS**: LIGO CALIBRATION MONITORING

8 FTE months

Development and maintenance of services that provide on-going monitoring of the LIGO Calibration pipeline.

TASK OPS-9.1-E(i)-**INFRAOPS**: SUMMARY PAGE MAINTENANCE AND COORDINATION

4 FTE months

Detector monitoring web interfaces, a.k.a. "summary pages," based on the `gwpy` and `gwsumm` software packages, have been used as the primary monitoring tool for calibration outside of the control rooms. These pages need constant maintenance and upgrades to keep up with any changes and evolving checks on the calibration. The LIGO calibration group will interface with the Computing and Software working group to keep this tool up-to-date with needed calibration monitoring checks.

TASK OPS-9.1-E(ii)-**INFRAOPS**: REAL-TIME MONITORING TOOLS

4 FTE months

In addition to working with the software development teams to maintain the general summary pages, the LIGO calibration group is also developing/maintaining/improving real-time monitoring tools for the computational status of each detector's low-latency calibration pipeline to assist in operational status tracking.

ACTIVITY OPS-9.1-F-**INFRAOPS**: LIGO HARDWARE INJECTIONS

3 FTE months

The photon calibrator system remains the best tool for creating DARM actuation in each detector, whether this be for verification of the data produced by each calibration group, for testing of astrophysical search pipelines, or for understanding the cross-coupling of the detectors' network of auxiliary loops and sensors. LIGO plans to continue the interactive relationship with each appropriate consumer group in order to facilitate these activities.

TASK OPS-9.1-F(i)-**INFRAOPS**: FACILITATION OF HARDWARE INJECTIONS

3 FTE months

Several artificial, simulated continuous signals are added via the photon calibrator hardware injection to the detector data stream. These signals are coherent between detectors in order to simulate a real continuous signal. They serve as known fiducial reference signals, acting as invaluable tools aiding validation of detector calibration and data cleaning procedures.

ACTIVITY OPS-9.1-G-**INFRAOPS**: LIGO CALIBRATION REVIEW AND DOCUMENTATION

15 FTE months

The calibration process and products need to be documented and reviewed, and the final calibrated strain products need to be validated for release.

TASK OPS-9.1-G(i)-**INFRAOPS**: CALIBRATION REVIEW

12 FTE months

All calibrated data, the generation and monitoring processes there-in, systematic error budgets, and uncertainty must be reviewed. The review process involves creating quantitative summary statistics of the data throughout a given observational time period, which is done using various software packages. Creating and documenting each of these statistics, reviewing the code that generated the model, data and statistics, investigating any anomalies or peculiarities that arise from this review, ensuring the results are reproducible, and fixing any issues that are identified in the process are all essential parts of the review. The review process is necessary but time consuming. The calibration group plans to participate in any reviews held, and improve the efficiency and speed of creating the quantitative summary statistics of the data, which should assist in speeding up certain aspects of the review process that are limited by computation time.

TASK OPS-9.1-G(ii)-**INFRAOPS**: DOCUMENTATION OF CALIBRATION PROCESSES

3 FTE months

On going efforts to record calibration efforts and procedures in the electronic logs, software repositories, technical notes, drawings, and graphical presentations document control centers, wiki pages, and peer-reviewed articles. The LIGO calibration group results are posted and documented in the LIGO Document Control Center, in the form of a related-document tree, whose trunk is [61]. Additional, organizational content may be found on the ligo.org wiki page [62].

ACTIVITY OPS-9.1-H-**INFRAOPS**: LIGO CALIBRATION PIPELINE IMPROVEMENTS

42 FTE months

Continuing development is needed to improve the calibration process and pipeline, to make it e.g. more robust against behavioral changes of the detectors, more accurate, to simplify the pipeline and the process, to make it more efficient, manageable, and maintainable, improve automation, etc.

TASK OPS-9.1-H(i)-**INFRAOPS**: IMPROVED AUTOMATION OF CALIBRATION MEASUREMENTS

6 FTE months

The LIGO calibration group will continue to upgrade the current systems for automating calibration measurements, such as swept sine measurements, during the course of O4.

TASK OPS-9.1-H(ii)-**INFRAOPS**: IMPROVED AUTOMATION OF CALIBRATION MODEL UPDATES

6 FTE months

After measurements are taken, the calibration model and filters often need to be updated based on the most recent measurements. This will allow the calibration to remain more constantly accurate.

TASK OPS-9.1-H(iii)-**INFRAOPS**: FRONT-END CALIBRATION PIPELINE IMPROVEMENTS

6 FTE months

We would like to move as much of the calibration pipeline processing as possible into the front end, to achieve the lowest latency possible, and simplify the overall pipeline. Some post-processing will likely still be required due to the causal limitations of the real-time system. To achieve these goals the following may be required:

- implementing FIR filtering routines to improve frequency-dependent systematic error incurred with the current systems IIR filters.
- continuing development and verification of the near-real-time data product that is corrected for detector response time dependence.

TASK OPS-9.1-H(iv)-**INFRAOPS**: LOW-LATENCY CALIBRATION PIPELINE IMPROVEMENTS

6 FTE months

The downstream `gstlal`-based component of the calibration pipeline could be improved in various ways, by e.g.:

- implementing approximation free methods for calculating time-varying calibration factors that will result in better accuracy.
- improving the computational speed and resource consumption of the pipeline.
- reducing the overall latency of the pipeline.
- implementing real-time monitoring into the pipeline.

TASK OPS-9.1-H(v)-**INFRAOPS**: IMPROVE CALIBRATION ERROR AND UNCERTAINTY ESTIMATION
12 FTE months
We need to reduce the time it take to produce an estimation of the total calibration uncertainty on the C00 data. This will require new methodology that could include more frequent measurements of the detector response as well as new low-latency infrastructure for constructing a calibration uncertainty estimate from these measurements.

TASK OPS-9.1-H(vi)-**INFRAOPS**: EARLY-WARNING CALIBRATED STRAIN PRODUCTION
6 FTE months
LIGO will modify the existing strain production methods as needed to produce an extremely low-latency calibrated strain data stream that is at least valid in the frequency range needed for early-warning transient searches. The LIGO calibration group will explore methods for modifying existing filters and filtering techniques to create an early-warning calibrated data stream.

ACTIVITY OPS-9.1-I-**OTHER**: LIGO LONG TERM CALIBRATION IMPROVEMENT PROJECTS
26 FTE months
Various projects should be pursued to improve the calibration process over the long term.

TASK OPS-9.1-I(i)-**OTHER**: DETECTOR MODELING IMPROVEMENTS
3 FTE months
Models of the detectors response function need to be improved as the detector evolves, to maintain accuracy of the calibration.

TASK OPS-9.1-I(ii)-**OTHER**: ERROR AND UNCERTAINTY MODELING IMPROVEMENTS
3 FTE months
Research into ways to improve or overhaul how the calibration error and uncertainty are estimated.

TASK OPS-9.1-I(iii)-**OTHER**: MODIFY DARM LOOP TO MINIMIZE SYSTEMATIC ERROR
2 FTE months
Work in concert with the detector commissioning groups to modify the design of the loops to minimize contributions of systematic error and to reduce now-known, controllable, systematic error in the DARM via refinement of the interaction between other detector control loops.

TASK OPS-9.1-I(iv)-**OTHER**: CALIBRATION ABOVE 1 KHZ
3 FTE months
Verifying the accuracy of models for the calibration above 1 kHz is challenging due to the difficulty in collecting precision measurements at high frequencies where the detector noise is high and actuator strength is low. Work is ongoing to develop and implement methods for accurately modeling the detector response at high frequencies and to more accurately determine the uncertainty in this frequency range. See further discussion in the Instrument Science White Paper.

TASK OPS-9.1-I(v)-**OTHER**: FIX SOURCES OF KNOWN SYSTEMATIC ERRORS
3 FTE months
Maintaining precise and accurate calibrated data relies on understanding any systematic errors

present in the overall scale of the calibration and resolving these errors where possible is standard part of each calibration group's effort. Depending on the results of the above mentioned understanding of the integration of calibration systematic error and uncertainty within astrophysical analysis (including those for which low systematic error above 1 kHz is important), efforts to reduce the systematic error beyond existing levels of will be appropriately matched with the needs.

TASK OPS-9.1-I(vi)-**OTHER**: COMPENSATE FOR KNOWN SYSTEMATIC ERRORS
3 FTE months
Additionally, if the systematic error is quantified, the calibration groups will develop and implement methods to correct for this systematic error in the strain data, therefore eliminating it to within the level of confidence it was measured. This is unique from eliminating the source of the systematic error. New methods for calibrating the data by frequent, direct measurement of the detector response function will also be explored and developed in parallel to the current calibration methods during O4.

TASK OPS-9.1-I(vii)-**OTHER**: UPGRADES TO PHOTON CALIBRATOR SYSTEMS
6 FTE months
Pcal systems have demonstrated the ability to generate fiducial displacements with accuracy better than 0.3%. The Pcal power standards, however, have exhibited unexplained variations in their responsivity which require further investigation. LHO Pcal responsivity ratio measurement system suffers from discontinued LabView support for DAQ modules. Virgo (LAPP) has demonstrated improved results using python code running on a realtime computing platform. Similar upgrade should be implemented for the LHO system. Most Pcal power sensors were upgraded for the O4 run, but not the receiver-side sensors at the end stations. They should be upgraded with revised transimpedance amplifier boards that include AD590 temperature sensors and spacers to reduce responsivity temperature dependence. Update analysis codes and procedures to be compatible with the ongoing O4 global calibration scheme and changes to improve efficiency of routine measurements.

TASK OPS-9.1-I(viii)-**OTHER**: INCORPORATE CALIBRATION ERROR AND UNCERTAINTY WITH ASTROPHYSICAL RESULTS
3 FTE months
The LIGO, Virgo and KAGRA groups are partnering with astrophysical analysis groups to understand the impact of systematic error and uncertainty in calibration on astrophysical results. Feedback from studies will inform how (and/or whether) to proceed in improving the existing levels of systematic error and uncertainty. See more discussion in this year's Observational Science White Paper.

OPS-9.2 Virgo Calibration Operations

Start date: 2023-12-01
Estimated due date: 2025-01-01

ACTIVITY OPS-9.2-A-**INFRAOPS**: VIRGO CALIBRATION HARDWARE MAINTENANCE

TASK OPS-9.2-A(i)-**INFRAOPS**: MAINTENANCE OF PHOTON CALIBRATORS
Monitor and maintain the two Virgo photon calibrators, as well as perform regular re-calibration bringing the Virgo Working Standard to the end-station photon calibrators. Continue the practice of comparing transfer standards to all four detectors and NIST and PTB. This means shipping of

transfer standards between Virgo and other sites during O4, and may reveal systematic effects on their cross-calibration.

TASK OPS-9.2-A(ii)-**INFRAOPS**: MAINTENANCE AND STUDY OF NEWTONIAN CALIBRATORS
Monitor and maintain the Virgo Newtonian calibrators, study the possible noise coupling with the detector. Compare the Newtonian calibration with the photon calibration.

ACTIVITY OPS-9.2-B-**OTHER**: VIRGO CALIBRATION MEASUREMENTS
Regular calibration measurements need to be taken throughout the observing run to keep the calibration pipeline up-to-date.

TASK OPS-9.2-B(i)-**OTHER**: REGULAR MEASUREMENTS THROUGHOUT OBSERVING RUN
Weekly automatized measurements are planned to extract the transfer functions of the sensing and actuation, and as well as to measure interferometer optical response and to weekly-monitor the bias and error of the h(t) reconstructed strain.

TASK OPS-9.2-B(ii)-**OTHER**: PERMANENT MEASUREMENTS THROUGHOUT OBSERVING RUN
Permanent injection of about 10 sine signals in the detector are used to monitor the bias and error of the h(t) reconstructed strain.

ACTIVITY OPS-9.2-C-**OTHER**: VIRGO STRAIN PRODUCTION SOFTWARE AND INFRASTRUCTURE
The Virgo reconstruction pipeline include the reconstruction of the raw calibrated h(t) time series, corrected for the modeled slow time variations, the correction of an estimated bias, the subtraction of calibration lines and the linear subtraction of some wide-band noise.

TASK OPS-9.2-C(i)-**OTHER**: MAINTAIN CALIBRATION PRODUCTION PIPELINE PROGRAMS AND SOFTWARE
The pipeline program that generates the calibrated strain channel needs to be maintained.

TASK OPS-9.2-C(ii)-**OTHER**: UPDATE SOFTWARE CONFIGURATION TO BE CONSISTENT WITH CALIBRATION MODELS AS NEEDED
Changes in the calibration models will be propagated to the reconstruction pipeline, in general only in its configuration, and if needed in the code itself.

TASK OPS-9.2-C(iii)-**OTHER**: CLEANING OF STRAIN DATA
The calibration lines and some known wide-band noise with linear coupling to h(t) can be removed from the strain data. The list of noise to be removed must be kept up-to-date during the observing run and the efficiency of the noise subtraction must be monitored.

TASK OPS-9.2-C(iv)-**OTHER**: LOW-LATENCY STRAIN DATA PRODUCTION
The strain data is produced online with latency of about 10 s, along with a preliminary estimate of its bias and uncertainties U00 storeds in the same frame files.

TASK OPS-9.2-C(v)-**OTHER**: OFFLINE ESTIMATION OF STRAIN DATA UNCERTAINTIES
The bias and uncertainties on the h(t) strain data will be estimated from permanent lines and some weekly measurements. A new set of frame files will be produced offline, including the initial online strain data, along with updated frequency-dependent uncertainty estimates UO1. Only the Analysis Ready periods will be available in these frames.

TASK OPS-9.2-C(vi)-**OTHER**: OFFLINE STRAIN DATA REGENERATION
If for some reason the strain production is inadequate for any period of time, it will have to be regenerated to produce a C01 version of the strain channel during the period of inadequacy, along with its associated uncertainty. The software, scripts, and environment needed to run the offline regeneration need to be maintained, and regeneration process itself needs to be managed.

ACTIVITY OPS-9.2-D-**OTHER**: VIRGO CALIBRATION MONITORING

Development and maintenance of services that provide on-going monitoring of the Virgo Calibration pipeline.

TASK OPS-9.2-D(i)-**OTHER**: SUMMARY PAGE MAINTENANCE AND COORDINATION

Detector monitoring web interfaces, i.e. Detector Monitoring System (DMS) and VIrgo Monitoring (VIM), are used as the primary monitoring tool for calibration inside and outside of the control room. These pages need constant maintenance and upgrades to keep up with any changes and evolving checks on the calibration.

ACTIVITY OPS-9.2-E-**OTHER**: VIRGO HARDWARE INJECTIONS

The calibrated electromagnetic actuators remains the reference for creating DARM actuation in the Virgo detector for understanding the cross-coupling of the detector network of auxiliary loops and sensors, or for simulating astrophysical signals in the detector. A series of softwares are used to inject these signals either in Virgo only, either coherently with the LIGO detectors to simulate a real continuous signal. They have to be maintained and monitored.

ACTIVITY OPS-9.2-F-**OTHER**: VIRGO CALIBRATION REVIEW AND DOCUMENTATION

The calibration process and products need to be documented and reviewed, and the final calibrated strain products need to be validated for release.

ACTIVITY OPS-9.2-G-**OTHER**: VIRGO CALIBRATION PIPELINE IMPROVEMENTS

Continuing development is needed to improve the calibration process and pipeline, to make it e.g. more robust against behavioral changes of the detectors, more accurate, to simplify the pipeline and the process, to make it more efficient, manageable, and maintainable, improve automation, etc.

TASK OPS-9.2-G(i)-**OTHER**: IMPROVED AUTOMATION OF CALIBRATION MEASUREMENTS AND ANALYSIS

The Virgo calibration group will continue to upgrade the current systems for automating calibration measurements and their analysis during the course of O4.

TASK OPS-9.2-G(ii)-**OTHER**: LOW-LATENCY CALIBRATION ERROR ESTIMATION

The method to estimate the total calibration uncertainty on the low-latency calibrated data is still to be completed and fully validated.

ACTIVITY OPS-9.2-H-**OTHER**: VIRGO LONG TERM CALIBRATION IMPROVEMENTS PROJECTS

TASK OPS-9.2-H(i)-**OTHER**: UPGRADES TO PHOTON CALIBRATOR SYSTEMS

Upgrades of the photon calibrator systems are planned when the larger mirrors will be installed in the Virgo detector. They are described in the Technical Design Report of AdV+-phase2.

TASK OPS-9.2-H(ii)-**OTHER**: UPGRADES TO NEWTONIAN CALIBRATOR SYSTEMS

Upgrades of the NE Newtonian calibrator systems and addition of a system at the WE end-station are planned. They are described in the Technical Design Report of AdV+-phase2.

TASK OPS-9.2-H(iii)-**OTHER**: UPGRADES TO PHOTODIODE OUPTUT CALIBRATION SYSTEM

Systems to monitor and calibrate the output photodiodes (frequency-dependent response and timing) are planned to be added. Plans are described in the Technical Design Report of AdV+-phase2.

TASK OPS-9.2-H(iv)-**OTHER**: USE OF SCATTERED LIGTH FROM END-STATIONS TO CHECK STRAIN DATA RECONSTRUCTION

Addition of scattering vibrating element on the optical benches in transmission of the ETM to test a method using scattered light to cross-check strain data reconstruction level.

TASK OPS-9.2-H(v)-**OTHER**: EARLY WARNING CALIBRATED STRAIN PRODUCTION

Virgo will explore methods to produce extremely low-latency calibration strain data stream useful for early-warning transient searches.

OPS-9.3 KAGRA Calibration Operations

Start date: 2023-12-01
Estimated due date: 2025-01-01

ACTIVITY OPS-9.3-A-**OTHER**: KAGRA CALIBRATION HARDWARE MAINTENANCE

5 FTE months

Maintain hardware to maintain the calibration of KAGRA in O4.

TASK OPS-9.3-A(i)-**OTHER**: MAINTENANCE OF PHOTON CALIBRATORS

5 FTE months

KAGRA will work with LIGO and Virgo to maintain KAGRA's photon calibrator system, including but not limited to: continuously perform absolute calibration of each photon calibrator system using the power standard.

ACTIVITY OPS-9.3-B-**OTHER**: KAGRA DETECTOR MODELING FOR CALIBRATION

3 FTE months

The current KAGRA calibration pipeline encodes a model of the detector response in order to calculate the strain from the DARM error and control signals. This model needs to be maintained and kept up-to-date as the interferometer evolves and changes.

TASK OPS-9.3-B(i)-**OTHER**: DARM LOOP MODEL MEASUREMENTS AND UPDATES

3 FTE months

Many measurements inform a carefully constructed model of the DARM control loop in order to achieve precise and accurate calibration. As the detectors are changed during the course of O4 or commissioned during the commissioning break, each calibration group will revisit all model parameters, remeasure if necessary, and update them to reflect the changes and upgrades to the detectors. In addition, any large-scale infrastructure changes that are required of the model, which are needed as a result of the upgrades leading into O4, must also be done in a timely fashion.

ACTIVITY OPS-9.3-C-**OTHER**: KAGRA CALIBRATION MEASUREMENTS

1 FTE months

Regular calibration measurements need to be taken throughout the observing run to keep the calibration pipeline up-to-date.

TASK OPS-9.3-C(i)-**OTHER**: REGULAR MEASUREMENTS THROUGHOUT OBSERVING RUN

1 FTE months

Transfer functions of the sensing and actuation function are obtained through swept sine measurements. The photon calibrator is used to obtain these measurements.

ACTIVITY OPS-9.3-D-**OTHER**: KAGRA STRAIN PRODUCTION SOFTWARE AND INFRASTRUCTURE

6 FTE months

KAGRA's calibration pipeline currently consists of two main parts: one is a real-time process and the other is a process intended for offline generation. Both of these software components need to be maintained. KAGRA also plans to make its product generation structure more like LIGO: the low latency pipeline makes the main product.

TASK OPS-9.3-D(i)-**OTHER**: MAINTAIN CALIBRATION PRODUCTION PIPELINE PROGRAMS AND SOFTWARE

2 FTE months

The pipeline programs that actually generates the calibrated strain channel need to be maintained. The pipeline components also needs to be maintained to retain com- patibility with their surrounding computational environments which are necessarily constantly evolving.

TASK OPS-9.3-D(ii)-**OTHER**: UPDATE SOFTWARE TO BE CONSISTENT WITH DARM MODEL AS NEEDED

3 FTE months

Changes in DARM model parameters and/or infrastructure will be propagated to the respective pipelines with minimal introduction of systematic error in an extensible and robust fashion. This includes the most current and accurate ways to track time-dependence and communicate live calibration fidelity through the calibration state vector.

TASK OPS-9.3-D(iii)-**OTHER**: DARM LOOP MODELING SOFTWARE UPDATE

1 FTE months

KAGRA will imitate the LIGO and Virgo pipelines and start (re)building the low latency pipeline in order to make it the main product generation pipeline.

ACTIVITY OPS-9.3-E-**OTHER**: KAGRA CALIBRATION REVIEW AND DOCUMENTATION

3 FTE months

The calibration process and products need to be documented and reviewed, and the final calibrated strain products need to be validated for release.

TASK OPS-9.3-E(i)-**OTHER**: CALIBRATION REVIEW

2 FTE months

All calibrated data, the generation and monitoring processes there-in, systematic error budgets, and uncertainty must be reviewed. The review process involves creating quantitative summary statistics of the data throughout a given observational time period, which is done using various software packages. Creating and documenting each of these statistics, reviewing the code that generated the model, data and statistics, investigating any anomalies or peculiarities that arise from this review, ensuring the results are reproducible, and fixing any issues that are identified in the process are all essential parts of the review. The review process is necessary but time consuming. The calibration group plans to participate in any reviews held, and improve the efficiency and speed of creating the quantitative summary statistics of the data, which should assist in speeding up certain aspects of the review process that are limited by computation time.

TASK OPS-9.3-E(ii)-**OTHER**: DOCUMENTATION OF CALIBRATION PROCESSES

1 FTE months

On going efforts to record calibration efforts and procedures in the electronic logs, software repositories, technical notes, drawings, and graphical presentations document control centers, wiki pages, and peer-reviewed articles. The KAGRA calibration group results are posted and documented in the JGW Document Server or the KAGRA DAC wiki system.

ACTIVITY OPS-9.3-F-**OTHER**: KAGRA IMPROVE ABSOLUTE REFERENCE HARDWARE

4 FTE months

TASK OPS-9.3-F(i)-**OTHER**: UPGRADES TO PHOTON CALIBRATOR SYSTEMS

3 FTE months

KAGRA has the newest PCal system, which includes a 20 W laser, dual-AOM actuation, and steering mirrors for spot-position control. Improvements to reduce laser power noise and beam quality are planned.

TASK OPS-9.3-F(ii)-**OTHER**: AUTOMATION OF POWER SENSOR CALIBRATION
1 FTE months
KAGRA will make an automatic power sensor calibration system at Pcal lab by referring to the system at LIGO.

ACTIVITY OPS-9.3-G-**OTHER**: KAGRA LONG TERM CALIBRATION IMPROVEMENT PROJECTS
6 FTE months

TASK OPS-9.3-G(i)-**OTHER**: DEVELOPMENT OF NEWTONIAN CALIBRATORS
6 FTE months
KAGRA will continue to develop an improved Newtonian calibrator system, with the goal of real-world technical testing at O5.

OPS-10 Low Latency

OPS-10.1 Low Latency system architecture

Start date: 2023-10-01
Estimated due date: 2025-01-01

The low-latency system has supported many discoveries over the past three observing runs, during the course of which the architecture and tooling has gone through three distinct phases of evolution, of which the latest is GWCelery. We now have a mature understanding of the requirements from both internal and external stakeholders, and should be progressing toward a durable architecture and software stack that will serve the community through the rest of O4.

Motivation and goals

The unifying constant across observing runs is that we wish to have a simple and reliable system for annotating and orchestrating LIGO/Virgo/KAGRA alerts, built from widely used open source components. Its responsibilities include:

- Merging related candidates from multiple online LVK transient searches
- Correlating LVK events with transient events in the electromagnetic spectrum as well as in neutrinos
- Launching automated follow-up analyses including data quality checks, rapid sky localization, automated parameter estimation, source classification, and source properties inference
- Generating and sending machine-readable alerts
- Sending updated alerts after awaiting human input
- Automatically composing templates for any human-readable prose (e.g. “Circulars”)

Expected products and/or outcomes

The realization, maintenance and operation of the O4 alert system is the highest priority task for the low-latency group in this White Paper cycle.

The key aspects of the O4 system include the following:

- ability to provide two mechanisms/platforms for the distribution of the alerts; one based on the GCN protocol and overall approach as in O3 and a new one that will be based on *kafka* streams,
- target a few-seconds ($\sim 15s$) intrinsic latency of the system, including ability to send preliminary alerts with only basic information like the type and significance of the event (i.e., without the complete event payload),
- incorporate under the same infrastructure MoU-based analyses and resulting events that will require public or private alert-issuing,
- maintain multiple development and testing computing environments for deployment of production code,
- retain GWcelery as the main workflow manager but rework few key services like the event aggregator and GCN alert sender.

Required inputs

The alert system is the intersection of many pieces of critical infrastructure, including searches and data quality information.

ACTIVITY OPS-10.1-A-**INFRAOPS**: IMPROVE DEPLOYMENT AND TESTING METHODS FOR THE LOW-LATENCY INFRASTRUCTURE

Facilitate prototyping, testing, review and deployment of the low-latency computing software and hardware infrastructure via multiple and flexible environments where these can be undertaken. As part of that, we will streamline the review and overall protocol for deployment of the low-latency-specific software infrastructure.

TASK OPS-10.1-A(i)-**INFRAOPS**: LOW-LATENCY TRIGGER MOCK EVENT GENERATOR IMPROVEMENTS

Maintain improve and develop the system that replays gravitational-wave pipeline triggers and uploads them. Ensure that the system allows easy testing and performing stress-test the low-latency infrastructure without having the need to operate the search pipelines.

TASK OPS-10.1-A(ii)-**INFRAOPS**: LOAD TESTING FOR THE LOW-LATENCY INFRASTRUCTURE

Continue regular load testing to debug out of memory errors and other related issues.

TASK OPS-10.1-A(iii)-**INFRAOPS**: DEPLOYMENT OF THE LOW-LATENCY INFRASTRUCTURE

Consider improvements to the deployment workflow, to simplify the introduction of bug fixes.

TASK OPS-10.1-A(iv)-**INFRAOPS**: PERFORMANCE AND ERROR TRACKING FOR THE LOW-LATENCY INFRASTRUCTURE

Maintain use of error tracking software such as Sentry and time-series monitoring such as Prometheus.

ACTIVITY OPS-10.1-B-**INFRAOPS**: FEATURE DEVELOPMENT FOR THE LOW-LATENCY INFRASTRUCTURE

While the system is relatively mature, there are a number of broad goals for O4b.

TASK OPS-10.1-B(i)-**INFRAOPS**: REDUCE LATENCY OF THE LOW-LATENCY INFRASTRUCTURE
Benchmark and reduce latency throughout the entire alert pipeline.

TASK OPS-10.1-B(ii)-**INFRAOPS**: INCORPORATING EXTRA DETECTORS IN THE LOW-LATENCY INFRASTRUCTURE
Test integration of detectors not present in O4a, i.e. Virgo and KAGRA, within the alert framework.

OPS-10.2 Low Latency system documentation

Start date: 2023-10-01
Estimated due date: 2025-01-01

The Public Alerts User Guide[2] provides the broader community information on how to receive and interpret the real-time gravitational-wave information. The guide and its update is presented regularly at the OpenLVK-EM telecons, monthly meetings between gravitational-wave and the interested community.

Motivation and goals

LIGO/Virgo/Kagra is as a major international astronomy facility and a public scientific resource, **similar** to astrophysics space missions like the Fermi Gamma-Ray Space Telescope, the Neil Gehrels Swift Observatory, or the James Webb Space Telescope; or analogous to major ground-based observatories like Gemini Observatory, W. M. Keck Observatory, or the European Southern Observatory. Facilities in this class are expected to provide high quality and up to date public documentation for scientists. Documentation generally includes observing capabilities, operations plans, explanation of data flow, description of data products and data formats, sample code, and tables of sensitivity and sensitivity calculators.

Since O3 and continuing through O4, the low latency group has curated the User Guide, soliciting and collecting contributions from other LIGO/Virgo/Kagra working groups, and making timely updates. For example, it documents data products, including providing guidance and explanation on usage of the various products.

Expected products and/or outcomes

We provide documentation of the alert content (public information delivered and science properties of the alert such as FARs, p(astro), EM-Bright numbers, etc.).

Required inputs

ACTIVITY OPS-10.2-A-**INFRAOPS**: REGULAR PUBLIC ALERTS USER GUIDE UPDATES AND RELEASES
Maintenance of the User Guide requires editors to review PRs for correctness, conciseness, and grammar; and one or two maintainers to tend to the Sphinx configuration and the CI/CD pipeline.

TASK OPS-10.2-A(i)-**INFRAOPS**: RELEASE USER GUIDE MONTHLY
Desire to release the User Guide once per month

[2] `https://emfollow.docs.ligo.org/`

OPS-10.3 Data replays and mock data challenges

Start date: 2023-10-01
Estimated due date: 2025-01-01

The low latency group has provided a data replay and injection set of O3 data useful for performance and acceptance testing. This should continue in some form for O4b.

Motivation and goals

Given that pipelines will continue to need to update and new pipelines potentially introduced, the data replay will serve an important role.

Expected products and/or outcomes

The technical and scientific exploitation of the data replay and associated injection sets will continue to be important in O4b.

Required inputs

The data replay and injection set requires support from both search pipelines as well as computing staff.

ACTIVITY OPS-10.3-A-**INFRAOPS**: DATA REPLAYS FOR LOW-LATENCY ALERT SYSTEM TESTING
Finalize and carry out search, annotation, alert-triggering and pipeline testing in a continual form using O3 replay data, simulated data as well as engineering data as soon as they become available. These data replays form a key piece of the the acceptance testing for search and annotation pipelines.

TASK OPS-10.3-A(i)-**INFRAOPS**: MAINTAIN CURRENT DATA REPLAY AND ASSOCIATED INJECTION SETS FOR LOW-LATENCY ALERT SYSTEM TESTING
Maintain use of the existing system, including downstream analyses.

TASK OPS-10.3-A(ii)-**INFRAOPS**: INTEGRATING NEW SEARCHES INTO THE LOW-LATENCY ALERT SYSTEM
The working group will test integration of searches not present in O4a, i.e. Subsolar Mass (SSM), within the alert framework.

TASK OPS-10.3-A(iii)-**INFRAOPS**: LATENCY TRACKING FOR THE LOW-LATENCY ALERT SYSTEM
Profile latency of all tasks and implications to the target global latency of <10 s for regular, non-merger, alerts as well as pre-merger ones.

OPS-10.4 External Coincidences

Start date: 2023-10-01
Estimated due date: 2025-01-01

RAVEN is module within gwcelery that looks for coincidences with external events (gamma-ray bursts, neutrino bursts), assigns a joint significance, and potentially sends out alerts if significant.

Motivation and goals

With the alert system for RAVEN working consistently as expected, there is still work to improve this system and address the remaining known shortcomings.

Expected products and/or outcomes

RAVEN should be able to report on all coincidences that pass publishing conditions, and we should improve the current methods for including sky map info into the joint FAR due to known biases. Before the end of O4, an offline search script should be available to analyze the run and to be used for future speculative searches.

Required inputs

RAVEN relies on search results from both CBC and Burst pipelines, as well as external triggers.

ACTIVITY OPS-10.4-A-**INFRAOPS**: IMPROVED JOINT FAR FOR EXTERNAL COINCIDENCES
Improvements to the sky map overlap/joint FAR method: distance, occultation, correct bias.

ACTIVITY OPS-10.4-B-**INFRAOPS**: OFFLINE SEARCHES WITHIN THE EXTERNAL COINCIDENCES
Create an offline search script, covering events from an entire observing run or more.

ACTIVITY OPS-10.4-C-**INFRAOPS**: INCLUDING MULTIPLE EXTERNAL COINCIDENCES
The current design for sending RAVEN alerts (i.e. GW alerts with additional info regarding an external event) is to only include info on a single coincidence/external event.

OPS-10.5 Parameter estimation

Start date: 2023-10-01
Estimated due date: 2025-01-01

During O4, significant event candidates are followed up by automated parameter estimation analyses performed with the Bilby and RapidPE-RIFT pipelines. They explore broader parameter space than the other low-latency inference pipelines such as Bayestar, and provide more accurate estimates on source location, classification, and properties to update their initial estimates.

Motivation and goals

In order to provide improved inference results stably throughout O4, we need to maintain infrastructures in GWCelery, Bilby, and RapidPE-RIFT that are relevant for automated parameter estimation. While their results have been sent out more or less smoothly for event candidates in O4, their data products and the procedure to send them out can be improved.

Expected products and/or outcomes

Bilby provides estimates on source location and properties. RapidPE-RIFT provides estimates on source classification.

Required inputs

Automated parameter estimation relies on search results from CBC pipelines to determine its analysis configurations.

ACTIVITY OPS-10.5-A-**INFRAOPS**: MAINTAIN AND IMPROVE AUTOMATED BILBY ANALYSIS

Maintain and improve automated Bilby analysis. Potential improvements include enabling Bilby to update source classification and automating procedure to send out Bilby results.

ACTIVITY OPS-10.5-B-**INFRAOPS**: MAINTAIN AND IMPROVE AUTOMATED RAPIDPE-RIFT ANALYSIS

Maintain and improve automated RapidPE-RIFT analysis. Potential improvements include enabling RapidPE-RIFT to update source location and properties, and automating procedure to send out RapidPE-RIFT results.

OPS-10.6 GraceDB and igwn-alert

Start date: 2023-10-01
Estimated due date: 2025-01-01

The Gravitational-Wave Candidate Event Database (GraceDB) is the central location that houses analyses for transient searches. State changes in GraceDB (which may take the form of new event uploads/annotations, new superevent uploads/annotations, log/file updates, etc.) are communicated to outside parties by the igwn alert system.

Motivation and goals

At its core, GraceDB is, architecturally, a standard Web/API application. A MySQL (MariaDB) backend is powered by a Django web framework. External requests are served by Apache acting as a reverse-proxy for a Gunicorn-based WSGI HTTP server. Files are stored on an NFS filesystem. Low-latency analyses stream data from the detectors and upload "candidate events" to GraceDB via a representational state transfer (REST) API. igwn-alert is an alert data stream based on kafka and leverage SCiMMA infrastructure for data delivery. Client-side tools maintained by LSCSoft allow users to listen and respond to igwn-alert messages. igwn-alert messagesare machine-readable JSON-formatted so as to be read by automated follow-up processes. igwn-alert listeners act on notifications from GraceDB and are used to launch follow-up analyses (*e.g.,* Superevent creation, parameter estimation, sky localization, etc.). Results from follow-up analyses are then uploaded and stored in GraceDB.

Expected products and/or outcomes

GraceDB and igwn-alert are the orchestrator and source-of-truth for external observers and follow-up processes.

ACTIVITY OPS-10.6-A-**INFRAOPS**: MAINTAIN AND OPERATE CLOUD DEPLOYMENT FOR GRACEDB

All four GraceDB tiers (Production, Playground, Test, Dev) currently reside in a highly-available (HA) configuration in Amazon Web Services' (AWS) us-west-2 region. In 2024, the cloud deployment will be maintained and operated in order to ensure the performance, stability, and security of the user experience. This includes, but it is not limited to: (i) Scaling and partitioning of EC2 compute nodes, (ii) Regular security patching of EC2 compute nodes and docker containers, and (iii) Regular updates of GraceDB's core software packages, including Python, Django, and PostgresQL

ACTIVITY OPS-10.6-B-**INFRAOPS**: EXPLORE ALTERNATE DEPLOYMENT STRATEGIES FOR GRACEDB

GraceDB has been running in a Docker Swarm configuration since O3b. With Docker Swarm running out of mainstream support in favor of various flavors of Kubernetes (K8S, K3S, EKS). Leverage expertise and experience at Caltech and Cascina to deploy and test new deployment strategies for O4b.

ACTIVITY OPS-10.6-C-**INFRAOPS**: STREAMLINE AND DEVELOP API EXPERIENCE FOR GRACEDB

Reduce API call latencies through a multistrategy approach: 1) reduce the latency of existing API calls through a combination of database optimization and asynchronous request-response-alert cycles, 2) combining low-level user functions into targeted high-level specialized calls, 3) moving targeted user request functions server-side.

OPS-10.7 Low Latency system review

Start date: 2023-10-01
Estimated due date: 2025-01-01

The main goal for the review is to ensure consistency with the requirements document: https://dcc.ligo.org/LIGO-T2000740.

During O4a, the main focus of the review was establishing instances where the requirements document deviated from current performance. The main goal of O4b should be to bring the requirments document into alignment with reality, as well as suggest areas of the lowest hanging fruit for improvement.

Motivation and goals

Review serves many goals, including maximizing reliability and best practices amongst the alert system.

Expected products and/or outcomes

Achieve review signoff on the low latency alert system for O4b.

Required inputs

ACTIVITY OPS-10.7-A-**INFRAOPS**: LOW LATENCY REVIEW AND TESTING

TASK OPS-10.7-A(i)-**INFRAOPS**: LOW LATENCY DOCUMENTS REVIEW

Review the design and implementation documents of the low latency alerts system and the "User Guide of the alerts" for the non-LVK community.

TASK OPS-10.7-A(ii)-**INFRAOPS**: REVIEW OF MAIN LOW LATENCY SOFTWARE STACK OF O4 SYSTEM

The review will also include the execution of extensive stress test of the whole infrastructure including the GraceDB / igwn alert system that will be deployed for the O4 operations.

TASK OPS-10.7-A(iii)-**INFRAOPS**: PRODUCTION LOW LATENCY ALERT SYSTEM REVIEW

Continuous review an testing maintenance and updates of the production alert (GWCelery) system.

OPS-10.8 Interfaces with IGWN working groups

Start date: 2023-10-01
Estimated due date: 2025-01-01

The low latency group provides both technical infrastructure and science analyses specific to searches, all of which are required in order to communicate transient detections as public alerts.

Motivation and goals

The interfaces between the low latency and other groups are considerable, including how search groups interact with the alert system. The low latency group maintains value-added data products such as ligo.skymap, embright, and others.

Expected products and/or outcomes

The low latency group runs the Mock Data Challenges, upon which acceptance testing relies, in addition to aids in the assessment and development of alert data products. It also has membership in two CBC task forces, one focused on SSM and the other on mass information.

Required inputs

ACTIVITY OPS-10.8-A-**INFRAOPS**: COARSE-GRAINED MASS INFORMATION IN ALERT
Upgrade coarse grained classifications to include HasSSM. Improve and revise mass information in alerts (in collaboration with the CBC group). Develop EM-bright to provide HasSSM classification and other improvements to alert products.

ACTIVITY OPS-10.8-B-**INFRAOPS**: INCORPORATION OF MULTIPLE PIPELINE INFORMATION IN LOW LATENCY ALERT PRODUCTS
Better understand the redundancy and complementarity among multiple search pipelines contributing to low-latency alerts, including through the use of quantitative metrics derived from the mock data challenges.

OPS-11 Computing and Software

OPS-11.1 LVK.OPS.COMP.COS: Collaboration Operation Services

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work areas under this heading provide basic collaboration resources for daily business and operations such as document repositories, version control systems, membership rosters and email lists, etc.

Motivation and goals

The LIGO, Virgo and KAGRA collaborations require cyberinfrastructure in order to conduct basic daily operations. Typically without these services and systems collaboration business would immediately cease either broadly or across topical areas.

Expected products and/or outcomes

Generally this work produces and maintains document systems, version control, meeting platforms, mailing lists and membership information among other things.

Relationships to other projects

LVK.OPS.COMP.IAM, LVK.OPS.COMP.SEC

ACTIVITY OPS-11.1-A-**INFRAOPS**: LVK.OPS.COMP.COS.DBDOC: DOCUMENT DATABASES
Maintain, operate and develop a database and its interface for collaboration documents and meeting agendas.

ACTIVITY OPS-11.1-B-**INFRAOPS**: LVK.OPS.COMP.COS.DOC: DOCUMENT WEB APPS
Maintenance, operations and development of document web apps not otherwise mentioned such as Google Docs and electronic notebooks (alogs).

ACTIVITY OPS-11.1-C-**INFRAOPS**: LVK.OPS.COMP.COS.GIT: GITLAB
Maintain, operate and develop a collaboration wide Gitlab instance used for document and code version control, project management and help desk functions.

ACTIVITY OPS-11.1-D-**INFRAOPS**: LVK.OPS.COMP.COS.HELP: HELP DESK
Maintenance, operations and development of tutorials and documentation about IAM, IGWN computing, security, etc.

ACTIVITY OPS-11.1-E-**INFRAOPS**: LVK.OPS.COMP.COS.MAIL: COLLABORATION MAIL
Maintenance, operations and development of email lists, e.g., sympa.ligo.org., and transfer agents.

ACTIVITY OPS-11.1-F-**INFRAOPS**: LVK.OPS.COMP.COS.MEM: MEMBERSHIP SERVICES
Maintain, operate and develop several sites and tools used for managing collaboration membership. Some examples include membership rosters, address books, group management services, MOU infrastructure, election systems and publication databases.

ACTIVITY OPS-11.1-G-**INFRAOPS**: LVK.OPS.COMP.COS.RMTM: REMOTE MEETINGS
Maintenance, operations and development of remote meeting platforms such as Mattermost and TeamSpeak.

ACTIVITY OPS-11.1-H-**INFRAOPS**: LVK.OPS.COMP.COS.WEB: COLLABORATION WEB SITES
Maintain, operate and develop websites and webapps that are useful for collaboration activities but are not otherwise accounted for in the WBS, e.g., the stochastic group ALOG and the EPO website.

ACTIVITY OPS-11.1-I-**INFRAOPS**: LVK.OPS.COMP.COS.WIKI: WIKI
Maintain, operate and develop a Foswiki instance used for collaboration documentation.

OPS-11.2 LVK.OPS.COMP.DAS: Data Analysis Services

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work areas under this heading provide services for data analysis. Excluded are services dealing with data handling, which has its own project "Data Handling Services"

Motivation and goals

Although data analysis is under the control of the Observational Science Division (OBS), data scientists in LIGO, Virgo and KAGRA rely on key services to be provided in order to conduct analysis.

Expected products and/or outcomes

This work produces web based analysis platforms, grid computing connectivity and a host of low latency analysis services that aid in the distribution of public gravitational wave alerts.

Relationships to other projects

LVK.OPS.COMP.IAM, LVK.OPS.COMP.SEC, LVK.OPS.COMP.DHS

ACTIVITY OPS-11.2-A-**INFRAOPS**: LVK.OPS.COMP.DAS.GDS: GLOBAL DIAGNOSTIC SYSTEM
GDS is comprised of software and services that primarily plays the role of providing a layer between the LIGO real-time control system and down stream analysts using the LIGO Data Analysis System (LDAS) environment. GDS, for example, is currently where some real-time calibration and data quality processes are managed.

ACTIVITY OPS-11.2-B-**INFRAOPS**: LVK.OPS.COMP.DAS.LL: LOW LATENCY ANALYSIS SYSTEMS
Work areas under this heading support low latency data analysis services such as data replay and simulation streaming services.

ACTIVITY OPS-11.2-C-**INFRAOPS**: LVK.OPS.COMP.DAS.OSG: OPEN SCIENCE GRID
Work areas under this heading directly support grid computing using open science grid software and services, for example maintaining entry points for various LIGO, Virgo and KAGRA computing facilities.

ACTIVITY OPS-11.2-D-**INFRAOPS**: LVK.OPS.COMP.DAS.WEB: WEB BASED ANALYSIS PORTALS AND FRAMEWORKS
Work areas under this heading directly support web-pased data analysis platforms such as Jupyter and Streamlit. Additionally some bespoke platforms such as the inspiral range monitor and gwistat fall under this category.

OPS-11.3 LVK.OPS.COMP.DHS: Data Handling Services

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work areas under this heading deal with the movement and storage of collaboration data internally and to the public.

Motivation and goals

Although data analysis is under the control of the Observational Science Division (OBS), data scientists in LIGO, Virgo and KAGRA rely on services to move data, access data and archive data.

Expected products and/or outcomes

This work produces candidate/results databases, data location services, internal messaging services, external alert infrastructure, grid storage solutions and more.

Relationships to other projects

LVK.OPS.COMP.IAM, LVK.OPS.COMP.SEC, LVK.OPS.COMP.DAS

ACTIVITY OPS-11.3-A-**INFRAOPS**: LVK.OPS.COMP.DHS.BULKDD: BULK DATA AGGREGATION AND DISTRIBUTION
: This project covers the operation, maintenance, and support of services that aggregate and distribute bulk detector data (hoft).

ACTIVITY OPS-11.3-B-**INFRAOPS**: LVK.OPS.COMP.DHS.CIS: CHANNEL INFORMATION SYSTEM
: The channel information system provides an updateable interface to define LIGO interferometer channels.

ACTIVITY OPS-11.3-C-**INFRAOPS**: LVK.OPS.COMP.DHS.CVMFS: CVMFS
: CERN Virtual Machine File System is used to distribute both software and data in a globally routable location that leverages http and FUSE. Work here manages providing access to LIGO data and software via CVMFS mechanisms.

ACTIVITY OPS-11.3-D-**INFRAOPS**: LVK.OPS.COMP.DHS.FMT: DATA FORMATS AND SERVICES
: Work in this area covers maintenance and development of current standards such as frame files and LIGO LW XML as well as exploring new standards.

ACTIVITY OPS-11.3-E-**INFRAOPS**: LVK.OPS.COMP.DHS.GDB: GRACEDB
: GraceDB is used both internally and by the braoder (public access) community to access gravitational wave candidate events in real-time. It is at the center of the public alert infrastructure and the creation of gravitational wave transient catalogs (GWTC)

ACTIVITY OPS-11.3-F-**INFRAOPS**: LVK.OPS.COMP.DHS.GDF: GRAVITATIONAL WAVE DATA FIND
: Gravitational wave data find allows cross-collaboration, cross site location of gravitational wave data files (frame files) as a service.

ACTIVITY OPS-11.3-G-**INFRAOPS**: LVK.OPS.COMP.DHS.IGWA: IGWN ALERT
: Based on SCIMMA HOPSKOTCH, IGWN Alert is a client library to support internal message passing to orchestrate real-time analysis.

ACTIVITY OPS-11.3-H-**INFRAOPS**: LVK.OPS.COMP.DHS.KAFK: KAFKA
: Kafka plays several roles in data transport through the collaboration including low latency strain data, analysis metric data, and real-time message passing. We have a goal of potentially reducing some of the duplication of infrastructure around kafka and to consider expanding its use to other areas.

ACTIVITY OPS-11.3-I-**INFRAOPS**: LVK.OPS.COMP.DHS.LEGDD: LEGACY DATA REPLICATION SERVICES
: These are legacy services used to replicate data to computing sites for some remaining needs.

ACTIVITY OPS-11.3-J-**INFRAOPS**: LVK.OPS.COMP.DHS.LL: LOW LATENCY DATA DISTRIBUTION
Internally gravitational wave data is streamed from all observatories across collaboration operated data centers using Kafka and some services.

ACTIVITY OPS-11.3-K-**INFRAOPS**: LVK.OPS.COMP.DHS.NDS2: NDS2
Network service for accessing data (rather than file access)

ACTIVITY OPS-11.3-L-**INFRAOPS**: LVK.OPS.COMP.DHS.OSDF: OSDF
Federated data storage in the Open Science Grid

ACTIVITY OPS-11.3-M-**INFRAOPS**: LVK.OPS.COMP.DHS.PUB: PUBLIC DATA RELEASE
Data is release to the public across several platforms including DCC, the GWOSC website, OSDF and Zenodo. This work area captures existing public release mechanisms and explores future needs.

ACTIVITY OPS-11.3-N-**INFRAOPS**: LVK.OPS.COMP.DHS.PUBA: PUBLIC ALERT INFRASTRUCTURE
The public alert infrastructure is responsible for disseminating gravitational wave discoveries quickly in an automated fashion and to facilitate further communications.

ACTIVITY OPS-11.3-O-**INFRAOPS**: LVK.OPS.COMP.DHS.RDB: RESULTS DATA BASES
Trigger and time series databases are often used internally as part of data analysis workflows and can / should be centrally managed.

ACTIVITY OPS-11.3-P-**INFRAOPS**: LVK.OPS.COMP.DHS.RUC: RUCIO
This is a new service for replicating data to computing sites.

ACTIVITY OPS-11.3-Q-**INFRAOPS**: LVK.OPS.COMP.DHS.SEGDB: SEGMENT DB
Database for storing LIGO and Virgo segments that indicate when interferometer data is available as well as its quality

OPS-11.4 LVK.OPS.COMP.IAM: Identity and Access Management

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work in this area allows the tracking of who is in IGWN, what their roles and affiliations are, and allows them to authenticate to and get authorized for services that they need to access for IGWN work.

Motivation and goals

Having centralized identity and access management allows for easy tracking of who should have access to which computing resources and provides a way for services to easily identify and grant that access.

Expected products and/or outcomes

This work provides login accounts to IGWN members, organizational management tools to IGWN administrators, and role and access information to IGWN services

Relationships to other projects

ACTIVITY OPS-11.4-A-**INFRAOPS**: LVK.OPS.COMP.IAM.ACCT: ACCOUNTS

Work in this area involves creation and management of user accounts and credentials (passwords, ssh keys, etc).

ACTIVITY OPS-11.4-B-**INFRAOPS**: LVK.OPS.COMP.IAM.CIL: CILOGON

This work relates to contract management, liason efforts, and managing priorities for our subscription to CILogon (cilogon.org).

ACTIVITY OPS-11.4-C-**INFRAOPS**: LVK.OPS.COMP.IAM.COMG: COMANAGE

This is work related to managing an identity management platform which currently is used for KAGRA members and will replace myLIGO for LIGO and Virgo members.

ACTIVITY OPS-11.4-D-**INFRAOPS**: LVK.OPS.COMP.IAM.ECP: ECP

Work in this area is releated to translating web logins into a command-line environment.

ACTIVITY OPS-11.4-E-**INFRAOPS**: LVK.OPS.COMP.IAM.INF: INFRASTRUCTURE

Work in this area relates to management of hardware and software platforms upon which IAM systems run.

ACTIVITY OPS-11.4-F-**INFRAOPS**: LVK.OPS.COMP.IAM.KRB: KERBEROS

Work in this area is related to the creation and management of LIGO.ORG credentials for user accounts and robots.

ACTIVITY OPS-11.4-G-**INFRAOPS**: LVK.OPS.COMP.IAM.MFA: MULTIFACTOR AUTHENTICATION

Work in this area relates to implementing and managing a second factor (beyond passwords) for LVK authentications.

ACTIVITY OPS-11.4-H-**INFRAOPS**: LVK.OPS.COMP.IAM.MGMT: IAM SUBGROUP MANAGEMENT

This work relates to coordinating efforts, holding meetings, and tracking efforts related to IGWN identity and access managemnt.

ACTIVITY OPS-11.4-I-**INFRAOPS**: LVK.OPS.COMP.IAM.MYLG: MYLIGO

This works relates to management of myLIGO, the identity management system for LIGO and Virgo members needing LIGO.ORG credentials.

ACTIVITY OPS-11.4-J-**INFRAOPS**: LVK.OPS.COMP.IAM.SCIT: SCITOKENS

Work in this area relates to using JSON web tokens called SciTokens to authorize robots and users to access grid computing services.

ACTIVITY OPS-11.4-K-**INFRAOPS**: LVK.OPS.COMP.IAM.SHB: SHIBBOLETH

Work in this area relates to web logins and the passing of authorization information to web services.

OPS-11.5 LVK.OPS.COMP.MGMT: Management

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work in this area contributes to the overall direction and prioritization of the IGWN Computing and Software Group. In some cases is comprises managerial tasks, in others it is providing the direction to other areas and projects contained elsewhere within Computing and Software. It also contains entire projects, such as usage accounting, that are necessary to provide data to the rest of the collaborations on how computing resources are prioritized and delivered.

Motivation and goals

A misallocation of computing resources, failure to understand the supply and demand for resources, inappropriate prioritization of the human effort supporting cyberinfrastructure, or a failure to anticipate and develop needed improvements to IGWN computing hardware, software, or cyberinfrastructure could all jeopardize the ability of the collaborations to deliver their scientific potential.

Expected products and/or outcomes

This area produces the tools that are used to monitor computing hardware and usage, the studies that guide allocation of computing resources, the workplan and organizational structure of the Computing and Software group, and the policies and procedures that guide its operation.

Relationships to other projects

ACTIVITY OPS-11.5-A-**INFRAOPS**: LVK.OPS.COMP.MGMT.ACCT: ACCOUNTING

This project develops, supports, and operates the software and infrastructure that allow measurement and recording of all IGWN and non-IGWN computing resources.

ACTIVITY OPS-11.5-B-**INFRAOPS**: LVK.OPS.COMP.MGMT.CHR: COMPSOFT CHAIR)

This Activity has been superseded by OPS-16.6-A

ACTIVITY OPS-11.5-C-**INFRAOPS**: LVK.OPS.COMP.MGMT.EXT: COMPSOFT EXTERNAL GROUP INTERACTIONS

Facilitation of external computing collaborators (such as OSG, EGI, or HTCondor) to help achieve IGWN CompSoft deliverables.

ACTIVITY OPS-11.5-D-**INFRAOPS**: LVK.OPS.COMP.MGMT.HDW: HARDWARE SUPPLY, DEMAND AND PRIORITIZATION

This project anticipates needed hardware and efficiently allocates the resources to acquire such hardware, based on the demand of the collaborations for computing resources, and enables prioritization of such resources should they be over-subscribed.

ACTIVITY OPS-11.5-E-**INFRAOPS**: LVK.OPS.COMP.MGMT.OPT: OPTIMIZATION PRIORITIZATION

Strategic identification of opportunities and priorities within IGWN computing optimization efforts.

ACTIVITY OPS-11.5-F-**INFRAOPS**: LVK.OPS.COMP.MGMT.POL: COMPSOFT POLICIES AND PROCEDURES

Creation and updating of the policies and procedures that guide the operation of the group, and tracking the implementation of such policies where required.

ACTIVITY OPS-11.5-G-**INFRAOPS**: LVK.OPS.COMP.MGMT.REV: COMPSOFT REVIEW

Internal review of software developed or maintained by the group, in accordance with standard collaboration review requirements for production readiness.

ACTIVITY OPS-11.5-H-**INFRAOPS**: LVK.OPS.COMP.MGMT.WBS: WORK BREAKDOWN STRUCTURE

Development, support, and maintenance of software tools to manage the group WBS, and review and updating of the work items and their progress within the chosen software tools.

OPS-11.6 LVK.OPS.COMP.SEC: Security

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work in this area sets information security policy and manages security operations and incident response.

Motivation and goals

Information security incidents can cause loss of data, loss of access to computing resources, and reputational damage, in some cases on scales that could jeopardize the future of IGWN, and must be mitigated to the extent possible.

Expected products and/or outcomes

This work provides guidance to computer administrator and users on securing systems and accounts and provides

Relationships to other projects

ACTIVITY OPS-11.6-A-**INFRAOPS**: LVK.OPS.COMP.SEC.INF: INFRASTRUCTURE

Work in this area relates to management of hardware and software platforms used for information security work.

ACTIVITY OPS-11.6-B-**INFRAOPS**: LVK.OPS.COMP.SEC.MGMT: SECURITY SUBGROUP MANAGEMENT

This is work to prioritize, organize and manage efforts related to IGWN information security.

OPS-11.7 LVK.OPS.COMP.SOFT: Software

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work in this area supports the use of shared software by other IGWN groups, through either the support and maintenance of shared software common to many groups, or the integration of individual groups's software into common distributions.

Motivation and goals

Much of our collabroations' work depends on either software suites that provide common tools many groups use, or consistent packaging of more specialized software into a set of supported environments. This area also covers specialized consulting to adapt the sofware other IGWN groups develop and maintain for better utilization of IGWN computing resources.

Expected products and/or outcomes

Products of this area are packages of software and the support and maintenance of shared software environments.

Relationships to other projects

ACTIVITY OPS-11.7-A-**INFRAOPS**: LVK.OPS.COMP.SOFT.FRSUP: FRAME DISTRIBUTION AND READING

The support, maintenance, and operation of software tools and libraries to distribute and read gravitational-wave frame files.

ACTIVITY OPS-11.7-B-**INFRAOPS**: LVK.OPS.COMP.SOFT.GLUE: GLUE

The support, maintenance, and operation of LSCSoft GLUE.

ACTIVITY OPS-11.7-C-**INFRAOPS**: LVK.OPS.COMP.SOFT.GSTC: GSTLAL CALIBRATION

The support, maintenance, and operation of the GstLAL calibration framework.

ACTIVITY OPS-11.7-D-**INFRAOPS**: LVK.OPS.COMP.SOFT.GWPY: GWPY

Support, maintenance, and operations of the GWPy package for access to gravitational-wave frame data.

ACTIVITY OPS-11.7-E-**INFRAOPS**: LVK.OPS.COMP.SOFT.LAL: LALSUITE MAINTENANCE AND SUPPORT

The support as well as the maintenance and operation of the LALSuite software. Development of software in LALSuite is excluded.

ACTIVITY OPS-11.7-F-**INFRAOPS**: LVK.OPS.COMP.SOFT.LDG: LDG PACKAGE

The support, maintenance, and operation of the LDG package providing a user environment for interacting with collaboration data and services

ACTIVITY OPS-11.7-G-**INFRAOPS**: LVK.OPS.COMP.SOFT.MGMT: SOFTWARE SUBGROUP MANAGEMENT

Work in this area prioritizes, organizes, and manages the other areas within the COMP.SOFT project.

ACTIVITY OPS-11.7-H-**INFRAOPS**: LVK.OPS.COMP.SOFT.OPT: SOFTWARE PERFORMANCE OPTIMIZATION

Work in this area is specialized engineering to improve the hardware performonce of other collaboration software, porting of such software to run on accelerators, and the testing and deployment of hardware-specific optimizations.

ACTIVITY OPS-11.7-I-**INFRAOPS**: LVK.OPS.COMP.SOFT.PKG: PACKAGING

The support, maintenance, and operation of IGWN designated software packaging, as well as the cyberinfrastructure and associated support, maintenance, and operation of platforms that enable IGWN users to deploy their own software. Work in this area must support an approved platform (currently conda and Rocky Linux 8).

ACTIVITY OPS-11.7-J-**INFRAOPS**: LVK.OPS.COMP.SOFT.SUP: DEVELOPMENT SUPPORT FOR ANY SOFTWARE

Supporting IGWN software developers in migrations to currently supported environments and build tools (for example, python versions).

ACTIVITY OPS-11.7-K-**INFRAOPS**: LVK.OPS.COMP.SOFT.TEST: TESTING INFRASTRUCTURE AND SUPPORT

Support, maintenance, and operation of the cyberinfrastructure and documentation that facilitates IGWN users' ability to deploy continuous integration and automated testing, as well as direct training and support of IGWN users in adapting their software to automated testing.

ACTIVITY OPS-11.7-L-**INFRAOPS**: LVK.OPS.COMP.SOFT.WRKF: WORKFLOW MANAGEMENT TOOLKIT

Work in this project develops, supports, and maintains a general-purpose workflow management tool, or facilitates the migration of existing IGWN pipelines to use standard IGWN HTCondor interfaces and environments.

OPS-11.8 LVK.OPS.COMP.SYS: Computing systems)

Start date: 2024-01-01
Estimated due date: 2025-01-01

Work under this area deals with procuring, maintaining and operating computing resources for collaboration data analysis and other activities.

Motivation and goals

The LIGO Virgo and KAGRA collaborations require computing infrastructure for dedicated, real-time data analysis and so-called "offline" analysis, which processes data at a higher latency. Computing systems are provided by a combination of the observatory labs, collaboration members and national facilities / partnerships within the member countries.

Expected products and/or outcomes

This work produces usuable interoperable computing systems across the LIGO, Virgo and KAGRA collaboration as well as contributes to an interoperable national infrastructure.

Relationships to other projects

ACTIVITY OPS-11.8-A-**INFRAOPS**: LVK.OPS.COMP.SYS.COND: HTCONDOR

Work in this area deals with operating and maintaining an HTCondor scheduling system

Activity OPS-11.8-B-**InfraOps**: LVK.OPS.COMP.SYS.EDG: European data grid user services and infrastructure

Work in this area provides a consistent and useful user environment in European computing

Activity OPS-11.8-C-**InfraOps**: LVK.OPS.COMP.SYS.HDW: Hardware

Work in this area focuses on operating, maintaining and planning for new compute capacity to support collaboration data analysis.

Activity OPS-11.8-D-**InfraOps**: LVK.OPS.COMP.SYS.IDG: Indian computing user services and infrastructure

Work in this area provides a consistent and useful user environment in LIGO India computing

Activity OPS-11.8-E-**InfraOps**: LVK.OPS.COMP.SYS.JDG: Japanese computing user services and infrastructure

Work in this area provides a consistent and useful user environment in KAGRA computing

Activity OPS-11.8-F-**InfraOps**: LVK.OPS.COMP.SYS.K8S: Kubernetes

Work in this area supports operating kubernetes infrastructure for real-time computing environments

Activity OPS-11.8-G-**InfraOps**: LVK.OPS.COMP.SYS.LDG: LDG user services and infrastructure

Work in this area provides a consistent and useful user environment in LIGO computing

Activity OPS-11.8-H-**InfraOps**: LVK.OPS.COMP.SYS.MGMT: Computing Systems Subgroup Management

Work in this area manages physical cyberinfrastructure.

Activity OPS-11.8-I-**InfraOps**: LVK.OPS.COMP.SYS.MON: Monitoring

Work in this area develops, operates and maintains monitoring infrastructure for colloboration physical cyberinfrastructure.

Activity OPS-11.8-J-**InfraOps**: LVK.OPS.COMP.SYS.NET: Network

Work in this area deals with networking - both LAN and WAN - for collaboration physical cyberinfrastructure.

Activity OPS-11.8-K-**InfraOps**: LVK.OPS.COMP.SYS.OPT: Optimization for heterogeneous computing systems

Work in this area focuses on optimizing the utilization of computing hardware accounting for highly heterogenous workflows and requirements, e.g., “online” and “offline” workflows.

Activity OPS-11.8-L-**InfraOps**: LVK.OPS.COMP.SYS.STR: Storage

Work in this area focuses on procuring, operating, maintaining and planning for new storage to support collaboration data analysis and data release.

Activity OPS-11.8-M-**InfraOps**: LVK.OPS.COMP.SYS.VMS: Virtual Machines

Work in this area supports operating and maintaining virtual machines that provide collaboration computing resources.

OPS-12 Open Data

The Open Data Working Group prepares, hosts, and maintains public releases of instrument data from the LVK collaboration. We also support public releases of analysis results, such as event catalogs.

OPS-12.1 Public Data Preparation

Start date: 2023-03-01
Estimated due date: 2025-08-23

Project Description

The O4a observing run will complete in January of 2024. At that time, we can begin preparing the O4a data release. This includes the bulk strain data release and the O4a transient catalog events. These are planned to be released August 23, 2025. In addition, we plan to write a paper describing the data release, and post it to the arXiv at the time of release.

ACTIVITY OPS-12.1-A-**INFRAOPS**: ADD O4A TRANSIENT EVENTS FROM CBC CATALOG TO GWOSC EVENT PORTAL

Astrophysical transients observed during O4a will be released in a catalog. These events will need to be added to the Event Portal database.

ACTIVITY OPS-12.1-B-**INFRAOPS**: PREPARE O4A STRAIN DATA RELEASE

Strain data from O4a will be released on August 23, 2025. We will need to prepare this data release, along with documentation and data quality segments.

ACTIVITY OPS-12.1-C-**INFRAOPS**: PREPARE O4A AUXILIARY CHANNEL RELEASE

In O3, we released all auxiliary channels used to create data quality flags and data cleaning. We need to decide if there will be a similar release for O4a.

ACTIVITY OPS-12.1-D-**INFRAOPS**: PREPARE O4A EXCEPTIONAL EVENT DATA RELEASES

Select astrophysical transients (i.e. exceptional events) may have dedicated publications, and may be published before the time of the strain data release. In these cases, our policy is to release snippets of data around the time of the event at the time of publication.

ACTIVITY OPS-12.1-E-**INFRAOPS**: PREPARE O4A DATA PAPER

We plan to write a paper describing the O4 data release. The first draft of this paper will describe only the O4a data release, and should be posted to the arXiv at the time of the data release.

OPS-12.2 GWOSC Webserver Development

Start date: 2024-01-01
Estimated due date: 2024-09-01

Project description

The GWOSC website (`gwosc.org`) is maintained by the Open Data Working Group. Several key developments are planned for this year.

As the number of events expands, we need to develop the webserver to handle larger numbers of events. For example, the current API includes nodes that return ALL events in the database. Beyond a few hundred events, this won't be feasible for simple JSON/HTTP formats. Instead, we need to develop a framework where all queries require some selection, with options to limit the number of returned results.

We are also seeking to make our webserver more robust by implementing a package known as the Django REST framework, which will allow us to limit the rate of quries from a single IP address. This is needed, as currently, our webserver can be crashed by large numbers of queries from computer clusters. This may require a redesign of our API

ACTIVITY OPS-12.2-A-**INFRAOPS**: LIMIT THE NUMBER OF EVENTS DELIVERED BY THE GWOSC API
The API currently includes some nodes that deliver all events in the Event Portal database. This should be updated to limit the number of events returned. The GWOSC python client currently relies on one such node, so it will need to be updated to handle the case of a limited number of events.

ACTIVITY OPS-12.2-B-**INFRAOPS**: REWRITE GWOSC API USING THE DJANGO REST FRAMEWORK
The django REST framework is a popular package for implementing RESTful API's in django. We hope to rewrite the GWOSC API using this framework. This will give the GWOSC website a more consistent API, and also allow us to better manage the rate of quries to the webserver. For example, we sometimes receive spikes in the rate of queries due to users on computer clusters; completing this activity will protect our server from crashes due to these bursts of activity.

ACTIVITY OPS-12.2-C-**INFRAOPS**: GWOSC WEBSERVER MAINTENANCE (LEVEL-OF-EFFORT)
The GWOSC webserver routinely requires maintenance. This includes a wide variety of tasks, such as fixing problems as they arise, organizing new releases, minor updates, bug fixes, model updates, software updates, and bug fixes.

OPS-12.3 Display Community Catalogs

Start date: 2024-01-01
Estimated due date: 2024-10-01

Project Description

A number of teams outside of the LVK have published catalogs of GW transient events found in searches of public LIGO/Virgo data. We are developing a process within the LVK to make some of these catalogs available through the Event Portal, to enable research across multiple data sets.

ACTIVITY OPS-12.3-A-**INFRAOPS**: INGEST AND RELEASE COMMUNITY CATALOGS
Add some GW catalogs produced by teams outside the LVK to the Event Portal.

OPS-12.4 Create Desktop App

Start date: 2024-01-01
Estimated due date: 2024-12-01

Project Description

Even basic interactions with a GW data file require programming skills. This project seeks to create a desktop application with a GUI for viewing the contents of a GW data file.

ACTIVITY OPS-12.4-A-**INFRAOPS**: DEVELOP AN INTERACTIVE PLOTTING SOFTWARE FOR GW DATA
We are interested in developing a desktop app, with a GUI that allows inspecting public detector data files and performing some basic analysis tasks. This will be pursued by Virgo staff with dedicated funding.

OPS-12.5 Host Open Data Workshop

Start date: 2024-01-01
Estimated due date: 2024-04-20

Project Description

The last several years, we have hosted Open Data Workshops. This activity has grown to become a hybrid online and in-person events, with multiple Study Hub locations and participants spanning the globe. This year, KAGRA will take the lead, with Lupin Lin planning an Open Data Workshop in April of 2024.

ACTIVITY OPS-12.5-A-**INFRAOPS**: PLAN OPEN DATA WORKSHOP 2024
Lead the planning of the Open Data Workshop.

ACTIVITY OPS-12.5-B-**INFRAOPS**: MENTOR AT OPEN DATA WORKSHOP 2024
The workshop is supported by a team of mentors who update the tutorials, present the lectures, host Study Hubs, answer questions, and support all content for the workshop.

OPS-13 LIGO Timing Diagnostics and Development Plans

OPS-13.1 LIGO Timing Diagnostics

Start date: 2024-01-01
Estimated due date: 2025-01-01

Traceable and closely monitored timing performance of the detectors is mission-critical for reliable interferometer operation, astrophysical data analysis and discoveries. The Advanced LIGO timing distribution system, also adopted by KAGRA, provides synchronized timing between different detectors, as well as synchronization to an absolute time measure, UTC. Additionally, the timing distribution system must provide synchronous timing to sub-systems of the detector. The timing distribution system's status is monitored continuously and is periodically tested in-depth via timing diagnostics studies.

ACTIVITY OPS-13.1-A-**INFRAOPS**: CRITICAL TIMING TASKS

TASK OPS-13.1-A(i)-**INFRAOPS**: VERIFYING TRACEABLE PERFORMANCE OF THE TIMING DISTRIBUTION SYSTEM

TASK OPS-13.1-A(ii)-**INFRAOPS**: VERIFYING THE VALIDITY AND ACCURACY OF THE RECORDED TIME-STAMP

TASK OPS-13.1-A(iii)-**INFRAOPS**: VERIFYING THE ACCURACY OF THE DISTRIBUTED TIMING SIGNALS

TASK OPS-13.1-A(iv)-**INFRAOPS**: PERFORMING IN-DEPTH TIMING DIAGNOSTICS FOR EXCEPTIONAL GW CANDIDATES (OPEN PUBLIC ALERTS AND CONFIRMED CATALOG EVENTS)

TASK OPS-13.1-A(v)-**INFRAOPS**: MEASURING AND DOCUMENTING THE TIMING PERFORMANCE

ACTIVITY OPS-13.1-B-**OTHER**: LONG-TERM TIMING TASKS

TASK OPS-13.1-B(i)-**OTHER**: EXPANDING THE CAPABILITIES OF DATA MONITORING TOOLS RELATED TO TIMING

TASK OPS-13.1-B(ii)-**OTHER**: AVAILABILITY OF TIMING DIAGNOSTICS FOR VARIOUS SUBSYSTEMS

TASK OPS-13.1-B(iii)-**OTHER**: REVIEWING THE PHYSICAL/SOFTWARE IMPLEMENTATION AND DOCUMENTATION OF THE TIMING DISTRIBUTION AND TIMING DIAGNOSTICS COMPONENTS

OPS-14 Joint Run Planning

OPS-14.1 Coordination of observing between LIGO, KAGRA, and Virgo

Start date: 2023-10-01
Estimated due date: 2025-01-01

Motivation and goals

The value of LIGO data is much greater when combined with that of other GW detectors. Furthermore, the scientific rewards to the LSC are greater when the analysis can be performed on data beyond that from the LIGO detectors. Lastly, the greater scientific community needs a definitive and uniform vision of the network's plans for observing The goal of the LSC Run Planning Committee is to ensure that the required discussions take place and that the common statement, and timeline for future observing, is maintained in a timely way.

Expected products and/or outcomes

The most visible and concrete products are text, timeline, and their posting at the web page https://observing.docs.ligo.org/pla
.

Required inputs

Input to create the text and timeline is collected from LSC, as well as KAGRA and Virgo, experts in commissioning, operations, and the collaboration/laboratory leadership of LIGO, Virgo, and KAGRA.

ACTIVITY OPS-14.1-A-**INFRAOPS**: JRPC MAINTAING THE PUBLIC OBSERVER PAGE

Maintain the public facing web page.

TASK OPS-14.1-A(i)-**INFRAOPS**: PUBLIC TEXT

Help to collect and harmonize text from the LSC/LIGO Lab, as well as from Virgo and KAGRA

TASK OPS-14.1-A(ii)-**INFRAOPS**: PUBLIC TIMELINE

Maintain the timeline, for the LSC/LIGO Lab, as well as from Virgo and KAGRA

OPS-14.2 Rapid Response Team for human vetting of low latency public alerts

Start date: 2024-01-01
Estimated due date: 2025-01-01

Rapid Response Team (RRT) is a LIGO-Virgo-KAGRA (LVK) group that provides human responses to monitor and vet gravitational wave event candidates. Vetting process ultimately leads to issuing human-readable public alerts in the form of Global Coordinate Network (GCN) circulars for each and every significant event candidate.

Motivation and goals

When a significant GW event candidate is detected, the first public alert is issued autonomously. Subsequently, RRT vets the candidate and informs the external astronomers of its findings by issuing machine-readable public alerts in several channels as well as a human readable GCN Circular. Either an Initial or a Retraction Circular is issued depending on whether or not the event is considered to be a candidate of interest by the RRT. This provides the external astronomers critical information that would be helpful for their decision to perform follow-up observation or not.

The main goal of the RRT is to provide human response for all significant public alerts with an acceptable latency for O4. Toward that goal, JRPC cooperates with working groups that take part in the RRT to define the RRT policy [63], to provide manual for responders[64], to manage the shifts for non-expert responders from wider collaboration and to provide training.

Expected products and/or outcomes

All Significant LVK public alerts in O4 will be accompanied with timely GCN circulars (either Initial or Retraction). Toward that goal, a properly trained team must be maintained without interruption for the entire O4 without over-stretching anybody in the team.

In O4, due to improved automated checks made possible by Detector Characterization working group, majority of events (e.g. BBH without external counterpart) are handled by a non-expert group called Level 0 from wider collaboration without involvement of technical experts called Level 1 experts. Since LVK collaborators are spread over the globe, each collaboration will provide 8 hours of Level 0 coverage per day, resulting in 24/7 non-expert coverage. It is expected that about 50% of non-expert shifts in US time zone will be provided by the LSC Fellows, and the remaining 50% by the wider collaboration members.

It is JRPC's job to ensure that LSC Level 0 shift will be maintained with properly trained responders without interruption for the entire O4. This is also applicable for site advocate shifts (level 1 experts who are typically run coordinators and delegates) for the LSC.

There are other RRT Level 1 shifts and rosters (Detector Characterization, astronomical analysis pipelines, low latency infrastructure, parameter estimation, calibration) but these are maintained by relevant working groups in coordination with RRT managers.

Required inputs

JRPC will work with LVK Operations chairs as well as working group chairs to draft and maintain policies as well as manuals for RRT as needed.

ACTIVITY OPS-14.2-A-**INFRAOPS**: PROVIDING LOW LATENCY HUMAN RESPONSES TO ALL SIGNIFICANT PUBLIC ALERTS

TASK OPS-14.2-A(i)-**INFRAOPS**: MAINTAINING POLICY DOCUMENTS AND SOFTWARE
1 FTE Month.
This includes policies for the collaboration as well as software pieces relevant for RRT. Most of the work was done in 2023. However, existing documents and software must be updated as necessary.

TASK OPS-14.2-A(ii)-**INFRAOPS**: ORGANIZING AND TRAINING THE RRT RESPONDERS TEAM
1 FTE Month.
Recruit and train Level 0 responders. Maintain a roster of responders as far as O4 continues. Maintain training materials and manuals.

TASK OPS-14.2-A(iii)-**INFRAOPS**: SERVICE AS THE RRT LEVEL 0 RESPONDER: LSC FELLOWS
1.5 FTE Months.
This task is used for contributions from LSC fellows. For LSC collaborators who are not LSC Fellows, use OPS-14.2-A(iv).
Note: Each shift slot requires about 0.8 hours of person power on average including the time to respond to events, assuming 1 event per week per shift time zone. This is regardless of the number of shifters per shift and regardless of the duration of each shift (8 hours per shift for Europe and US, Asia is sometimes but not always subdivided into two 4 hours shifts).

TASK OPS-14.2-A(iv)-**INFRAOPS**: SERVICE AS THE RRT LEVEL 0 RESPONDER: MEMBERS WHO ARE NOT FELLOWS
1.5 FTE Months.
This task is used for contributions from LSC collaborators who are not LSC fellows. See the note in OPS-14.2-A(iii) for calculating the contribution.

OPS-15 Support of Observatories

OPS-15.1 Collaboration between LSC Members and Observatory Staff

Start date: 2023-10-01
Estimated due date: 2025-01-01

This committee is responsible for coordinating contributions by LSC members in direct support of Observatory activities. This includes LSC Fellows, LSC members who make working visits to the sites and LSC members who collaborate with the commissioning teams at the sites.

Motivation and goals

The SO chairs serve as liaisons between the LIGO observatories and the broader LSC community. LSC members (including LIGO Lab. staff) and others who either have a need for support from the LSC for a particular investigation, or who would like to get involved in efforts to support the observatories, can contact the SO chairs for assistance in identifying and organizing efforts to satisfy the needs.

Expected products and/or outcomes

In the long-term this committee seeks to encourage ongoing in-depth collaborations between LSC groups and scientists and engineers working at the sites.

ACTIVITY OPS-15.1-A-**INFRAOPS**: PARTICIPATION IN THE LSC FELLOWS PROGRAM

LSC Fellows visit an observatory site for periods on at least three months. While on-site the Fellows work with a local mentor on various projects such as improving detector operation or noise, future upgrades, outreach, or ananlysis. During Observing runs LSC Fellows also participate in Data Qualityi(DQ) shifts and in the Level 0 response to event candidates found by search algorithms running in near real-time.

TASK OPS-15.1-A(i)-**INFRAOPS**: ACTIVITIES AS AN LSC FELLOW

LSC Fellows should be able to claim full credit for their participation. Depending on their projects they may assign some of their effort elsewhere (for example to the commissioning, calibration, or detector characterization activities). This activity can be used to account for the balance of their time, or to record all of it if a detailed accounting of their various efforts would be overly cumbersome.

TASK OPS-15.1-A(ii)-**INFRAOPS**: ON-SITE CONTACT FOR DQ SHIFTS

During O4 have regular meetings with collaborators who are taking DQ shifts. Aid in the interpretation of local events for the (usually) remote DQ shift takers. Train and staff DQ shifts.

ACTIVITY OPS-15.1-B-**OTHER**: COLLABORATION WITH LOCAL SITE STAFF ON IMPROVING DETECTOR NOISE OR DUTY CYCLE.

Activities by LSC members in support of local efforts. Activities involving Detector Characterization, Calibration, Low Latency, Computing & Software etc. should be accounted for in the relevant sections. This activity exists to capture work not otherwise categorized explicitly in the white paper. It can include efforts from LSC Fellows.

OPS-16 Leadership and Service Roles

OPS-16.1 Operations Division Leadership

Start date: ongoing
Estimated due date: ongoing

The Operations Division is responsible for coordinating, overseeing, and reviewing operations work.

ACTIVITY OPS-16.1-A-**INFRAOPS**: OPERATIONS DIVISION CHAIR
The Operations Division Chair coordinates the activities of the Division.

OPS-16.2 Calibration Working Group Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.2-A-**INFRAOPS**: SERVING AS CALIBRATION WORKING GROUP CHAIR
The Calibration Working Group is responsible for organizing, delivering, and documenting the calibration information for the detectors in the Collaboration. This Working Group has two co-chairs.

OPS-16.3 Detector Characterization Working Group Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.3-A-**INFRAOPS**: SERVING AS DETECTOR CHARACTERIZATION WORKING GROUP CHAIR
The Detector Characterization (DetChar) Working Group is responsible for organizing and documenting the Collaboration's efforts in detector characterization and the development of tools for that purpose. This Working Group has two co-chairs.

OPS-16.4 Low-latency Working Group Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.4-A-**INFRAOPS**: SERVING AS LOW-LATENCY WORKING GROUP CHAIR
The Low-latency Working Group plans, organizes and oversees analysis activities necessary to provide and disseminate low-latency event information within and outside the LSC. This Working Group has two co-chairs.

OPS-16.5 Run Planning Committee Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.5-A-**INFRAOPS**: SERVING AS RUN PLANNING COMMITTEE CHAIR

The Run Planning Committee is charged with the strategic planning of engineering and observing runs and advises the OMT on proposed observing run start dates, run duration, and other relevant activities. This Committee has one chair.

OPS-16.6 Computing and Software Working Group Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.6-A-**INFRAOPS**: SERVING AS COMPUTING AND SOFTWARE WORKING GROUP CHAIR

All of the management tasks performed by the Co-Chairs to lead the group and interface with the broader collaborations.

The Computing and Software Working Group is responsible for organizing and documenting the Collaboration's computing hardware and software infrastructure and for formulating plans for its evolution. This Working Group has two co-chairs.

OPS-16.7 Support of the Observatories Committee Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.7-A-**INFRAOPS**: SERVING AS SUPPORT OF THE OBSERVATORIES COMMITTEE CHAIR

This Committee is responsible for coordinating contributions by LSC members in direct support of Observatory activities. This Committee has two co-chairs.

OPS-16.8 Open Data Working Group Leadership

Start date: ongoing
Estimated due date: ongoing

ACTIVITY OPS-16.8-A-**INFRAOPS**: SERVING AS OPEN DATA WORKING GROUP CHAIR

The Open Data Working Group is responsible for the release of instrumental data and associated documentation to the public. This Working Group has one chair.

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