Report for External Review 2012

KAGRA detector characterization team

1. Overview

1-1. Definition and scope of the subsystem

Coordination of the activities related to detector characterization consists of two categories, interferometer-based detector characterization and data analysis-based detector characterization.

Data analysis-based detector characterization provides the environment where one enables to make confident detection or non-detection of gravitational wave signals. The data quality and veto information are produced via carful monitor of detector data and environmental sensors, coincidence analysis between detector, environmental channels as well as the gravitational wave channel. These data will be distributed to collaborators as soon as they are generated.

Interferometer-based detector characterization is performed mainly during commissioning process. During this period, the detector systems will be optimized/improved with regard to both stationary and non-stationary noise, narrow-band noise artifacts known as lines, and robustness. The detector characterization helps the identification and suppression of the noise and feed-back to the detector operation for improvement to instruments.

1-2. Importabt interface

Because the detector characterization uses channels provided from various instruments, many subsystems are interfaced. Particularly Digital control system, main interferometer, geophysics interferometer, laser, input-output optics, suspension, auxiliary optics, data analysis subsystems are closely interfaced. Figure 1. shows how the detector characterization interfaces the other subsystems. The data analysis subsystem is interfaced through the generation of veto information, data quality information, calibration accuracy. The subsystems of instruments are interfaced through physical and environmental monitors, auxiliary channels, online-monitors, diagnostics of the interferometer.

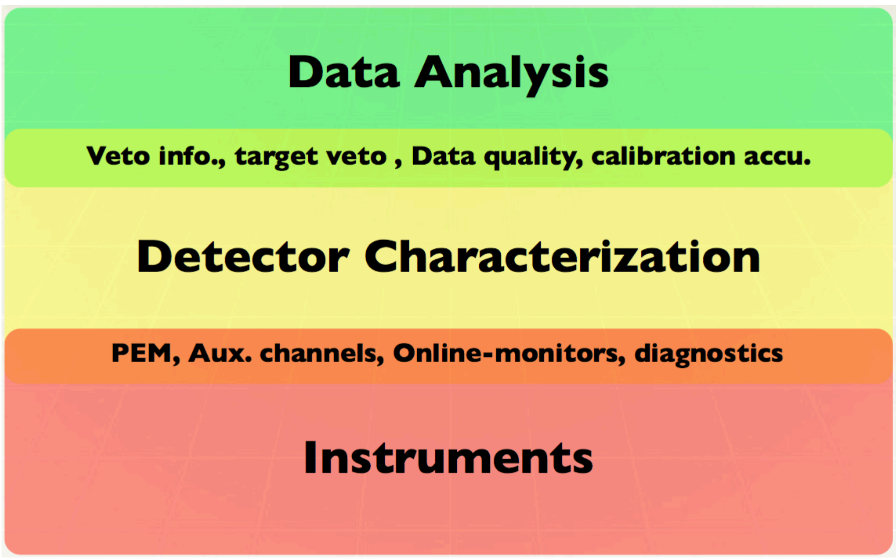

Figure 1. Interfaces of the detector characterization

1-3. Design phase

2. iKAGRA

2-1. Target specifications

- Development of the detector characterization system in a pre-process server. The computation power for performing the detector characterization is to satisfy that coincidence analyses between all combinations of 2 channels out of around 200 channels can finish in real-time.
- Identification and suppression of noise and removal of its sources. Contribution to improvement to instruments in commissioning process. Our target is the false alarm rate is 1 unidentified glitch in 3 months.
    - To check whether the specification of each channel is satisfied or not.
    - To check channel noise limit: quantization noise limit, saturation limit, dark noise limit etc.
    - Long term monitoring data streams of each channel to know statistical properties of the signals, trend etc.
    - To check correlations between channels.
    - To identify lines.
    - To identify burst-line noise (glitches).
- Generation of the data quality information and veto list, and the distribution of them to collaborations.
- Support detections or non-detections of gravitational wave signals.
- Measurement of the accuracy of calibration in terms of h-of-t production.

2-2. Final design

Figure 2 shows the final design of the detector characterization. Most of the tasks are done in the preprocess server at the Kamioka on-site.

1: Raw data in unit of ADC digitized voltage (namely the gravitational wave channel) is converted to strain data which is physical observable of gravitational wave detection, called as h-of-t. The Calibration will be done by the data analysis subsystem.
The accuracy of the reconstruction of h-of-t is evaluated through hardware injection tests.

2: Data from the physical and environmental sensors and auxiliary data of the interferometer are collected and assigned to slow channels and fast channels in the EPICS system by the digital control system subsystem.
These data are displayed via the on-line monitors and used for the detector diagnostics. A part of the tasks of the detector diagnostics done by detector characterization is to provide tools for the identification and suppression of noise sources.

3: Veto list is produced by evaluation of the data quality information and coincidence analysis between channels. (3-1):The coincidence analysis using the slow and fast channels and the gravitational wave channel is performed in order to know the noise couplings and to veto these data segments. Important channels for the veto analysis are listed in Appendix though the channels listed here are not completed yet. When non-stationary noise appears at the same time in both the gravitational wave channel and other channels, we define the channels as the important channels. (3-2):the veto lists and the data quality information of multiple detectors are used for global detector diagnostics.

4: The obtained data quality information and veto list are used for the post-processing of the event trigger generation (ETG) of the event searches.

5: The data quality information and veto lists are stored in the database on the main data analysis server at ICRR and distributed to both internal and international collaborations.

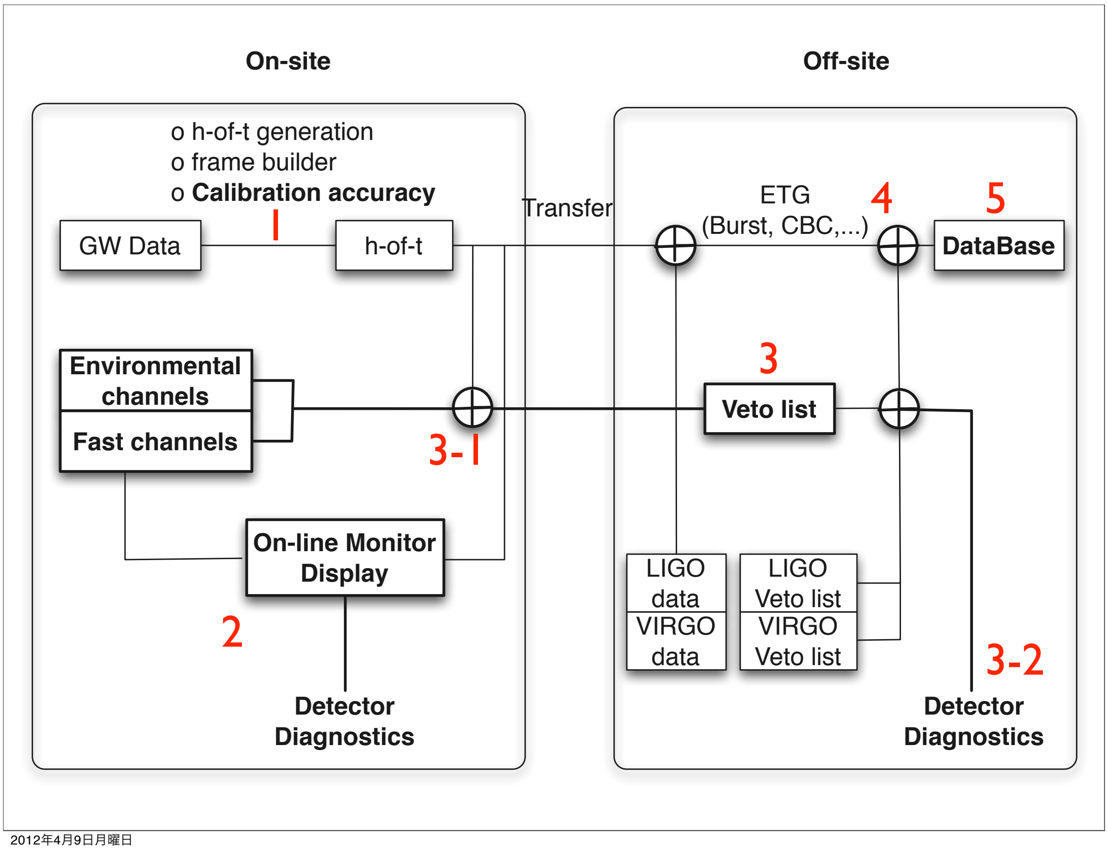

Figure 2. The final design of the detector characterization.

2-3. Schedule

1. Prototype test
- Installation test of basic detchar system at NAOJ and software development.
- Test operation of basic detchar system during CLIO operation.
- Software development

2. Computation platform
- 2Q-4Q2014: Implementation of detchar system in a pre-process server.
- 1Q-3Q2015: Installation of the pre-process server to a building.

3. Test operation
- Test operation of the detchar system when the environmental monitors start working in ~March in 2015.
- Operation of the detchar system during GIF operation from ~ June, 2015.
- Operation during iKAGRA in ~ Nov. 2015.
- Software development

4. Operation

• Operation during bKAGRA from ~ Aug. 2018.

Figure 3 shows the gunt chart of the schedule of the detector characterization.

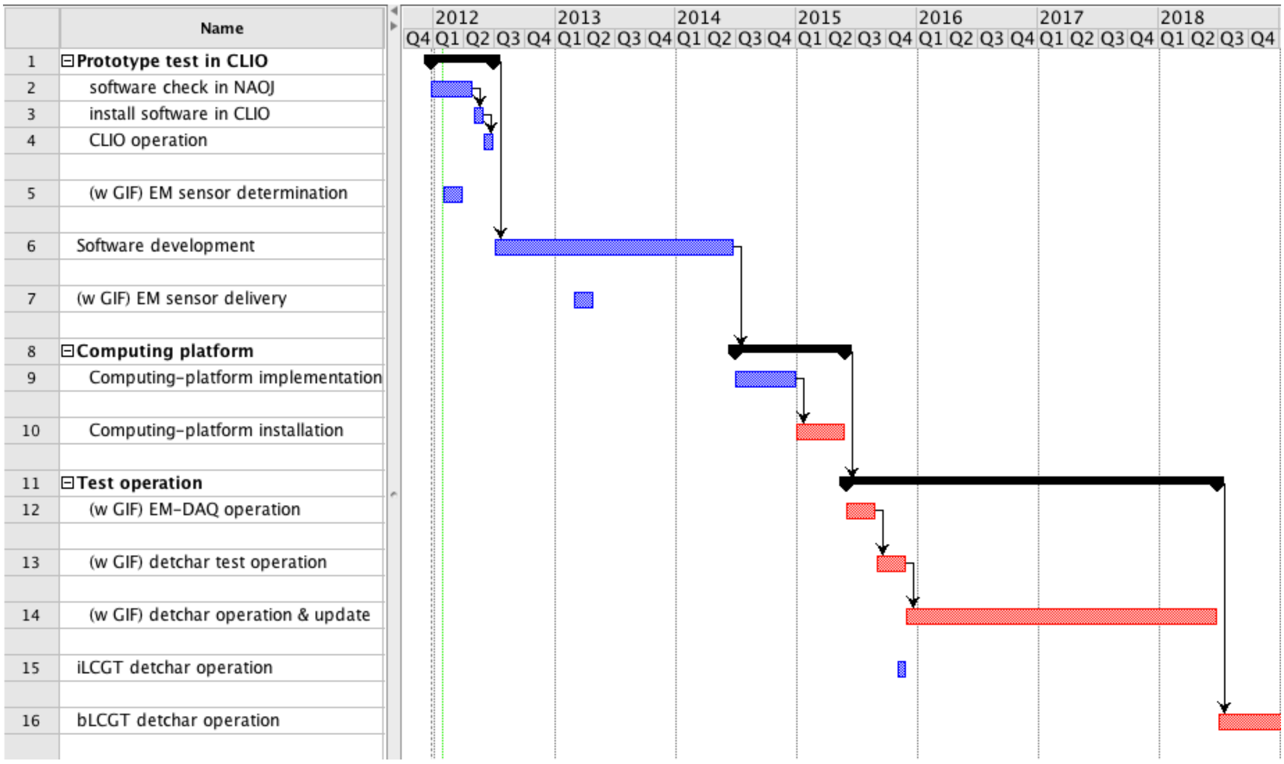

Figure 3. Gunt chart of the schedule of detector characterization

2-4. Quality assurance

Environmental monitors and the pre-process server are put in a clean environment such as a box which protects them from humidity, particles, etc.

2-5. Installation scenario

Detector characterization is mainly performed in the pre-process server at the underground of Kamioka mine or outside of Kamioka mine. If the pre-process server is put at the underground, the detector-characterization system including both hardware and software is constructed during 2Q-4Q2014 outside of Kamioka mine, and the system is installed in the underground during 1Q-3Q2015. The process and schedule of the installation need to be adjusted with the digital control system subsystem and the geophysics interferometer subsystem.

2-6. Risk management

1. We cannot get budget to have the pre-process server.

- Probability P :
  1 The probability is not large and will probably not occur. There is no substantial reason but just a problem on whether budget is obtained or not.
- The degree of seriousness S :
  3 It will result in the failure of the KAGRA project.
- R = P x S
  3 = 1 x 3

This affects the realtime event searches which are crucial for multi-messenger observation using the gravitational wave detectors including KAGRA and other astronomical telescopes.

- Back-up strategy if there is any

Solution: We have to give up the real-time detector characterization. The activity should be limited to the off-line detector characterization which will be performed on the ICRR's computation server. The off-line detector characterization will support the off-line event searches.

2. The analysis building cannot be constructed.

- Probability P :
  1 The probability is not large and will probably not occur. There is no substantial reason but just a problem on whether budget is obtained or not.
- The degree of seriousness S :
  2 It will to some degree endanger the successful completion of the project.
- R = P x S
  2 = 1 x 2
- Back-up strategy if there is any

Solution is to put the pre-process server for the detector characterization in the Kamioka mine.

3. Physical environmental monitors provided by the geophysics interferometer subsystem cannot be linked to the EPICS system.

- Probability P :
  2 The probability is around 0.5.
- The degree of seriousness S :
  2 It will to some degree endanger the successful completion of the project.
- R = P x S
  4 = 2 x 2
- Back-up strategy if there is any
  Construct detector-characterization system without using EPICS system for the physical environmental monitors.

4. Lack of man power.

- Probability P :
  3 The probability is large and will probably occur.
- The degree of seriousness S :
  2 It will to some degree affect the successful completion of the project.
- R = P x S
  6 = 3 x 2
- Back-up strategy if there is any
  Alternative solutions are
  - to employ younger researchers
  - to assign human resources in related subsystem as a person who performs detector characterization of his subsystem.

3. bKAGRA

3-1. Requirements

- Generation of veto list, evaluation of data quality
  - Online glitch detection
    - Low-latency glitch detection pipeline

        - Glitch classification
    - Online segment generation
        - Data quality information of science mode, lock, calibration,...
    - Online veto
        - Low-latency veto pipeline for ~200 channels from AOS, ...
    - Segment database
        - Generation of database of segment information
    - Triggered event database
        - Generation of database of glitches
    - Channel information system
        - Document of channels
    - Validation tools for segment
        - Check whether segment information is recorded correctly.
    - Dead channel monitor
        - Monitor whether channels are working or not.
    - Line tracking
        - Line finding tools
    - Data quality flag
    - Recording detchar-information
        - Recoding detchar-information in frame file.
    - Daily report tools
        - Publish daily report of data quality, triggered glitches, and so on.

- Partial detector diagnostics
  Provide information of data quality, non-stationary components, monitoring tools to subsystems which perform detector diagnostics.
    - Glitch detection pipeline
    - Coincidence analysis between channels, channel and h-of-t,...
        - Find correlation between channels
    - Noise floor monitor tool
    - To check channel noise limit: quantization noise limit, saturation limit, dark noise limit etc.
    - Long term monitoring data streams of each channel to know statistical properties of the signals, trend etc.
    - Line identification.

- Evaluation of calibration accuracy in terms of the parameter estimation
    - Hardware injection test
    - Waveform reconstruction

3-2. Preliminary design
See section 2-2.

3-3. Schedule
See section 2-3.

3-4. Prototype test (if any)
1. Testbed of the detector-characterization system will be developed on the digital system at NAOJ provided by the digital control subsystem. The digital system does not have any channel which links to real data. Test will be done by simulated data.
2. The detector-characterization system will be installed in CLIO and tested during CLIO operation.

3. After March in 2015, the geophysics interferometer will be in operation and will provide physical and environmental monitors. The detector-characterization system will analyse data from the monitors.
4. When iKAGRA will be inoperation, the development of the detector characterization system should be nearly finished.

3-5. Quality assurance

See section 2-4.

3-6. Installation scenario

See section 2-5.

3-7. Risk management

See section 2-6.

Appendix

A. Design changes that have been made with the suggestions in the 1st. external review (if any)

no

B. Items that have been reduced in cost (if any)

no

C. Important channels (not completed)

Physical and environmental monitor - beam splitter chamber (accerelometer)
Physical and environmental monitor - coil magnetometer located in the KAGRA Vault
Physical and environmental monitor - end X - seismometer, magnetometer
Physical and environmental monitor - end Y - seismometer, magnetometer
Physical and environmental monitor - Interferometer Sensing and Control Table accelerometer
Physical and environmental monitor - Laser and Vacuum Equipment Area
Physical and environmental monitor - Pre-Stabilized Laser
Alignment Sensing and Control - Beam Splitter
Alignment Sensing and Control - End Test Mass - X arm
Alignment Sensing and Control - End Test Mass - Y arm
Alignment Sensing and Control - Input Test Mass - X arm
Alignment Sensing and Control - Input Test Mass - Y arm
Alignment Sensing and Control - Quadrant Photo Diode at the X-end station
Alignment Sensing and Control - Quadrant Photo Diode at the Y-end station
Alignment Sensing and Control - Recycling Mirror
Alignment Sensing and Control - Wave Front Sensors
Input Output Optics - Mode Cleaner Optic
Interferometer Sensing and Control - Output Mode Cleaner
Length Sensing and Control - Anti-Symmetric
Length Sensing and Control - End Test Mass - X arm
Length Sensing and Control - End Test Mass - Y arm
Length Sensing and Control - Mode Cleaner Optic
Length Sensing and Control - Michelson cavity length
Length Sensing and Control - Power Recycling Cavity
Length Sensing and Control - Reflected Light Port on views symmetric port of interferometer
Output Mode Cleaner - Alignment Sensing and Control

Output Mode Cleaner - Piezoelectric Transducer
Output Mode Cleaner - Quadrant Photo Diode
Pre-Stabilized Laser - Frequency Stablization Servo
Seismic Isolation - Beam Splitter
Seismic Isolation - End Test Mass - X arm
Seismic Isolation - End Test Mass - Y arm
Seismic Isolation - Input Test Mass - X arm
Seismic Isolation - Input Test Mass - Y arm
Seismic Isolation - Laser and Vacuum Equipment Area
Seismic Isolation - Mode Cleaner Optic
Seismic Isolation - Recycling Mirror
Suspension - Beam Splitter
Suspension - End Test Mass - X arm
Suspension - End Test Mass - Y arm
Suspension - Input Test Mass - X arm
Suspension - Input Test Mass - Y arm
Suspension - Mode Matching Telescope
Suspension - Recycling Mirror