LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
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Data quality vetoes applied to the analysis of GW150914

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This document has been created as a supplement to LIGO-P1500238.

This document describes all the data quality (DQ) vetoes which were applied to the analysis of GW150914. For each DQ flag the definition of the veto is given, the interferometer this veto is applicable to, the category the veto was applied to the Burst and Compact Binary Coalescence (CBC) searches and the total amount of deadtime associated to each DQ veto. Deadtime in this document refers to the amount of time removed from single-detector analysis ready time for each veto individually. In the application of these DQ vetoes to the Burst and CBC searches some DQ vetoes will overlap in time and others may not be defined during coincident time. For the amount of time removed from each coincident analysis at each category please see LIGO-P1500238.

1 Data quality vetoes

1.1 Missing data veto

Purpose: This veto captures any data dropouts at either interferometer.
Definition: Customized software indicate when the recalibrated data frames were unable to be produced either due to missing raw interferometer data or data in the raw data frames that are marked as invalid.
Veto Category: Burst - 1, CBC - 1
Deadtime: LIGO-Hanford - 0%, LIGO-Livingston - 0%

1.2 Burst hardware injection veto

Purpose: This veto indicates whenever a burst hardware injection has been performed.
Definition: The times of transient hardware injections labelled as burst type are recorded by the online detector characterization (ODC) system by monitoring the state of the calibration injection model. Deadtime quoted includes the padding used in the analyses (±4 seconds).
Veto Category: Burst - 4[1], CBC - 2
Deadtime: LIGO-Hanford - 0.003%, LIGO-Livingston - 0%

1.3 CBC hardware injection veto

Purpose: This veto indicates whenever a CBC hardware injection has been performed.
Definition: The times of transient hardware injections labelled as CBC type are recorded by the ODC system by monitoring the state of the calibration injection model. Deadtime quoted includes the padding used in the analyses (±8 seconds).
Veto Category: Burst - 4, CBC - 3[2]
Deadtime: LIGO-Hanford - 0.052%, LIGO-Livingston - 0.072%

[1]Burst veto category 4 is reserved for transient hardware injections only.
[2]CBC veto category 3 is reserved for CBC hardware injections only.

1.4 DetChar hardware injection veto

Purpose: This veto indicates whenever a DetChar hardware injection has been performed.
Definition: The times of transient hardware injections labelled as DetChar type are recorded by the ODC system by monitoring the state of the calibration injection model. Deadtime quoted includes the padding used in the analyses ($\pm$16 seconds).
Veto Category: Burst - 4, CBC - 2
Deadtime: LIGO-Hanford - 0%, LIGO-Livingston - 0%

1.5 Stochastic hardware injection veto

Purpose: This veto indicates whenever a stochastic hardware injection has been performed.
Definition: The times of hardware injections labelled as stochastic type are recorded by the ODC system by monitoring the state of the calibration injection model.
Veto Category: Burst - 1, CBC - 1
Deadtime: LIGO-Hanford - 0%, LIGO-Livingston - 0%

1.6 Beckhoff hardware problems

Purpose: To capture times when the Beckhoff system (a slow control system which is used to control a subset of hardware in the interferometer) suffered a hardware failure at the LIGO-Hanford Y-end.
Definition: The veto was created by hand, where the start time was recorded as 4 seconds before excess non-stationary data started due to the hardware failure and finished 3 seconds after the interferometer dropped out of observing mode.
Veto Category: Burst - 1, CBC - 1
Deadtime: LIGO-Hanford - 1.50%

1.7 45 MHz sideband fluctuations

Purpose: This veto identifies times when the amplitude of the 45 MHz optical sideband, which is used to generate error signals for optical cavities, has excess noise. If the amplitude of the 45 MHz optical sideband fluctuates, excess noise will be injected in to the associated optical cavities which has been seen to couple to the gravitational wave channel.
Definition: An auxiliary channel which monitors amplitude fluctuations in the signal used to generate the 45 MHz optical sideband was found to be the optimum witness of non-stationary behaviour seen in the gravitational wave channel data. This veto was designed to capture long duration (on the order of one minute) non-stationary behaviour. Various thresholds on the band limited root-mean-square of this witness channel were investigated to see which threshold proved most effective (in terms of efficiency and deadtime) at removing non-stationary data. Custom software was implemented to automatically capture this behaviour over the analysis period (and throughout the first observing run).
Veto Category: Burst - 1, CBC - 1
Deadtime: LIGO-Hanford - 2.95%

1.8 Less severe 45 MHz sideband fluctuations

Purpose: See above veto, 45 MHz sideband fluctuations, for description.
Definition: This veto was designed to capture less severe, short time scale (on the order of 1 second), non-stationary data. This veto was created in a similar manner as the previous veto - a study of different thresholds on the band limited root-mean-square of the witness channel were investigated to give the optimal efficiency and deadtime. Custom software was implemented to automatically capture this behaviour over the analysis period (and throughout the first observing run).
Veto Category: Burst - not applied, CBC - 2
Deadtime: LIGO-Hanford - 0.014%

1.9 Overflows in the SUSETMY model channels

Purpose: This veto captures time when the electrostatic drive on the bottom stage of the Y-end test mass digital signal overflows. This is due to a relatively fast transient that is on the main carrier beam, and therefore directly on/at the readout, which gets amplified by the differential-arm digital filters sufficiently to cross the digital-to-analog converter limits.
Definition: This veto was created automatically by monitoring the interface between the computers and the analog electronics that they control on the Y-end test mass.
Veto Category: Burst - 2, CBC - 2
Deadtime: LIGO-Hanford - 0.067%, LIGO-Livingston - 0.021%

1.10 Overflows in the SUSETMY model channels with a SNR > 200

Purpose: See veto above - overflows in the SUSETMY model channels. This veto however is aimed specifically to identify very loud overflows.
Definition: This veto was created automatically by monitoring the interface between the computers and the analog electronics that they control on the Y-end test mass. A subset of these overflows is kept based on their severity as determined by an algorithm that is designed to witness transient power in a given signal. This veto is specific to the Burst search where ± 3 seconds of padding is applied because the overflows can exceed an integer second.
Veto Category: Burst - 2, CBC - not applied
Deadtime: LIGO-Hanford - 0.146%, LIGO-Livingston - 0.047%

1.11 Output Mode Cleaner (OMC) photodiodes analog-to-digital overflows

Purpose: This veto captures times when the signal on the OMC photodiodes exceeds the limit of the analog-to-digital converter at the interface to the computers that control the instrument.
Definition: This veto was created automatically by monitoring the interface between the OMC photodiodes analog signal and the computers.
Veto Category: Burst - 2, CBC - 2
Deadtime: LIGO-Hanford - 0.002%, LIGO-Livingston - 0.003%

1.12 Non-stationary data prior to loss of resonant power in the optical cavities

Purpose: To veto times when the data became non-stationary before the state of the interferometer reported the end of an observation segment.
Definition: These times were found by hand by monitoring an algorithm, run over the gravitational wave channel, that is designed to witness transient power.
Veto Category: Burst - 1, CBC - 1
Deadtime: LIGO-Hanford - 0.0004%, LIGO-Livingston 0.001%

1.13 Glitches due to DC power fluctuations of the photon calibrator laser

Purpose: This veto captures times when the photon calibrator has power fluctuations which exceed 20% of the nominal level.
Definition: A threshold placed on a witness channel which monitors the power levels of the photon calibrator laser was used to flag times when the power fluctuated beyond the 20% level. These times were then padded by -10 and +20 seconds to capture the full behaviour.
Veto Category: Burst - 1, CBC -1
Deadtime: LIGO-Livingston - 0.058%

1.14 Seismic transients

Purpose: This veto was created to identify times of strong excess seismic noise that coupled in to the output of the interferometer.
Definition: The 10-30 Hz band limited root-mean- square of the ground seismometer, located at the input test mass on the Y-arm, in the vertical degree of freedom was found to correlate with excess noise in the output of the interferometer. Different thresholds on this witness channel were tested to find the optimal efficiency and deadtime that captured these effects.
Veto Category: Burst - not applied, CBC - 2
Deadtime: LIGO-Hanford - 0.431%