

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
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Technical Note	LIGO-T2100150-LSC	2021/04/30
<h1>LIGO Data Quality Vetoes Applied to the Analysis of O2</h1>		
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This document describes all the LIGO data quality (DQ) vetoes which were applied to the analysis of LIGO data from the second observing run. 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 observing mode time for each veto individually. The listed deadtime does not include time removed from periods that a given detector was not in observing mode, meaning that time removed from analyses of GW170608 that used non-observing mode data is not included in these values. Flags that were designed specifically for analyses of GW170608 are noted in the definition of the flag. 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 total amount of time removed for each detector at each category and additional details on the use of data quality vetoes, please see Davis et al. (arXiv:2101.11673).

Please note that this document is currently a draft and we expect to have the final version of this document updated by the end of May 2021.

1 Data Quality Vetoes in the Second Observing Run

1.1 CBC Hardware Injection

Purpose: This veto indicates whenever a CBC hardware injection has been performed at either interferometer.

Defintion: 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 - 4¹, CBC - 3²

Deadtime: LIGO-Hanford - 0.013066%, LIGO-Livingston - 0.003567%

1.2 DetChar Hardware Injection

Purpose: This veto indicates whenever a Detector Characterization hardware injection has been performed at either interferometer.

Defintion: 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 (± 16 seconds).

Veto Category: Burst - 4, CBC - 2

Deadtime: LIGO-Livingston - 0.002430%

¹Burst veto category 4 is reserved for transient hardware injections only.

²CBC veto category 3 is reserved for CBC hardware injections only.

1.3 Stochastic Hardware Injection

Purpose: This veto indicates whenever a stochastic hardware injection has been performed at either interferometer.

Defintion: 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 - 0.005652%, LIGO-Livingston - 0.005878%

1.4 High amplitude violin modes

Purpose: This veto indicates that the fundamental suspension fiber resonances, or “violin modes”, had rung up to the point where they were causing the Ooutput Mode Cleaner (OMC) photodiodes to saturate at LIGO-Livingston.

Definition: This veto was generated by marking the first OMC photodiode saturation and removing the rest of the science mode data from that point forward. This observation stretch was eventually broken due to the high violin mode amplitude.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Livingston - 0.015674%

1.5 Fire Alarm

Purpose: Fire alarm ringing at LIGO-Hanford whilst the interfermoeter was in observing mode.

Defintion: High frequency noise was caused by the fire alarm ringing. This was noted in the LIGO-Hanford alogs³ and times for this veto were chosen by studying spectrograms of the gravitational-wave data.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.003236%

1.6 Guardian computer failure

Purpose: To capture times when a Guardian computer failure incorrectly allowed times when the interfometer was not in its nominal state in to observing time at LIGO-Livingston.

Defintion: The guardian is an automated software platform that controls the state of the interferometers. Times were chosen by recording the time of the state change away from nominal observing.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Livingston - 0.000336%

³Alogs are logbook entries that can be found at alog.ligo-wa.caltech.edu (for LIGO Hanford) or alog.ligo-la.caltech.edu (for LIGO Livingston)

1.7 ETMY Electronics Glitching

Purpose: To capture times when End Test Mass Y (ETMY) electronics chain was glitching at LIGO Hanford.

Definition: This veto was generated by studying the frequency of loud transient noise in the gravitational-wave channel. It was decided to remove 2 days of data on 18-19th Dec 2016.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.783478%

1.8 ETMY PUM Bad Calibration

Purpose: To capture times which were incorrectly calibrated due to swapped out ETMY Penultimate Mass (PUM) coil driver.

Definition: This veto was generated by hand in consultation with the LIGO calibration group, to remove times with an incorrect calibration.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.077366%

1.9 Snow plows running during Observation

Purpose: This flag indicates that a snow plow was running during observation mode, which seismically coupled into the LIGO-Hanford detector output.

Definition: This flag was defined by hand using the logbook as a guide and narrowing down the times of interested based on corner station seismometer data.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.273199%

1.10 High Parametric Instability Modes

Purpose: This veto removes times at LIGO-Hanford when the RMS of any parametric instability (PI) mode is high. Parametric Instabilities operate by transferring energy from the fundamental optical mode of the interferometer, into an interferometer optic's mechanical mode.

Definition: This flag was generated automatically by thresholding on channels which monitor the amplitude of each PI mode of each test mass.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.089079%

1.11 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.

Defintion: The last 4 seconds of an observation segment which ends suddenly due to a lock

loss, i.e. when light stops being resonant in the arms, are automatically removed.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.002200%, LIGO-Livingston - 0.004764%

1.12 Radio frequency beatnote whistles present

Purpose: This veto indicates that a radio frequency beatnote, or “whistle”, was present in the detector data.

Definition: This flag was defined by using the Hierarchical Veto algorithm, which was able to correlate whistles in the data with a photodetector used to sense an auxiliary degree of freedom.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Livingston - 0.028626%

1.13 PSL ISS glitching

Purpose: Some blip glitches in the strain channel (including some CBC loudest triggers) were found to be caused by the Pre Stabilised Laser (PSL) Intensity Stabilisation Servo (ISS) glitching.

Definition: Loud, short-duration mid/low frequency glitches in H1:PSL-ISS_PDA_REL_OUT_DQ.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.000144%

1.14 Glitching in HAM1 HEPI L4C

Purpose: Severe extended time of noise in HAM1 HEPI L4C.

Definition: Omicron trigger with SNR greater than 40 in HAM1 HEPI L4C.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.016057%

1.15 Whistles caused by bad VCO offset

Purpose: Pre Stabilized Laser (PSL) Voltage Control Oscillator (VCO) parked itself in a bad location so the background is not representative of the analysis period; there are many RF beatnote glitches also known as whistles.

Definition: This flag was defined by thresholding on a channel which controls the PSL VCO range. Within a certain range of values, the flag removes times which produce whistles.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Livingston - 0.224673%

1.16 Computer Reboot Veto

Purpose: Dramatic change in Power Spectral Density after auxiliary computer reboot.

Definition: This flag was created by hand, using information given in LIGO-Hanford alog

33756.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.022119%

1.17 Overflows in the SUSETMX model channels

Purpose: Overflows in SUSETMX model channels.

Definition: This veto was created by monitoring the interface between the computers and analog devices that they control on the X-end test mass.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.003883%

1.18 Gitches whitnessed by HAM1 HEPI L4C

Purpose: Severe extended time of noise in the Horizontal Access Moule 1 (HAM1) Hydraulic External Pre-Isolator (HEPI) seismometer.

Definition: This veto was created by thresholding on omicron triggers with an >40 which describe the behavior of the HAM1 HEPI seismometer. Omicron is an unmodelled transient detection pipeline that broadly performs a multi-Q transform given some data stream, then searches for significant clusters of tiles in time-frequency space, optimizing over the quality factor.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.003236%

1.19 Glitches caused by ETMY Optical Lever

Purpose: Glitches witnessed in the ETMY optical lever caused noise to upconvert in the LIGO-Hanford gravitational-wave channel.

Definition: This veto was created by constructing a band limited RMS (BLRMS) between 10-50 Hz of the ETMY optical lever signal and thresholding when the signal went abpve 65 (no units).

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.057951%

1.20 Severe scattered light

Purpose: This veto indicates that there was severe scattered light in the detector.

Definition: This veto was defined by combining the results of the Hierarchical veto algorithm with the overall glitch rate of the detector during times when the RMS of the microseismic band (0.1-0.3 Hz) exceeded $1 \mu m/s$.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Livingston - 0.108358%

1.21 Spikes in power mains monitor channels

Purpose: This veto captures loud transients related to spikes in the power mains that resulted in multiple seconds of excess noise.

Definition: This veto was created by placing a threshold on the 32-128 Hz band limited root-mean-square of the power mains monitor channel. The flag was then padded at the end by 2 seconds to capture the extended excess noise.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.001352%

1.22 45 MHz Sideband Severely Fluctuating

Purpose: This veto removes times at LIGO-Hanford when the the 45 MHz amplitude control glitches and couples into all vertex degrees of freedom and the gravitational-wave strain channel. This flag is a supplement to another flag which automatically tracks this noise.

Definition: This veto is created by hand to remove large periods of noise caused by the 45 MHz sideband that severely affect the transient searches ability to estimate the power spectral density.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.235368%

1.23 Elevated Violin Modes

Purpose: This veto indicates that the fundamental suspension fiber resonances, or “violin modes”, had rung up to the point where they were causing the Output Mode Cleaner (OMC) photodiodes to saturate at LIGO-Hanford.

Definition: This veto was generated by removing times when the OMC photodiode saturates.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.007723%

1.24 Anthropogenic seismic noise

Purpose: This veto indicates times when noise in the 10-30Hz seismic band is so high that this noise couples into the LIGO-Hanford gravitational-wave strain data.

Definition: This veto was created by setting a BLRMS of the output of a seismometer located in the corner station near ITMY. Whenever this BLRMS goes above 600 nm/s time is removed.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.029396%

1.25 Power fluctuations during chiller transitions

Purpose: This veto captures transients related to power fluctuations caused by switching on and off a chiller at the X-end.

Definition: A threshold was placed on the 75-100 Hz band limited root-mean-square of a magnetometer channel that was located near the chiller at the X-end.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Livingston - 0.055234%

1.26 Glitches caused by ETMX Optical Lever

Purpose: Glitches witnessed in the ETMX optical lever caused noise to upconvert in the LIGO-Hanford gravitational-wave channel.

Definition: This veto was created by constructing a band limited RMS (BLRMS) between 45-100 Hz of the ETMX optical lever signal and thresholding when the signal went above 7.5 (no units).

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.019336%

1.27 Malfunctioning ITMY Optical Lever

Purpose: This veto captures times when the IMTY optical lever was malfunctioning at LIGO-Hanford and causing glitches in the gravitational-wave strain channel

Definition: This flag was created by hand, using information from LIGO-Hanford alog 35378.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.010002%

1.28 Thunder Noise at End Y

Purpose: This veto removes times when acoustic noise related to thunderstorms at LIGO-Livingston coupled into the gravitational-wave strain channel and caused multiple seconds of excess noise.

Definition: This flag was created by taking the band limited RMS (BLRMS) of a microphone located at the Y end, and removing times when this output went above 200 (~ 40 mPa).

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Livingston - 0.014395%

1.29 Thunder Noise at Corner Station

Purpose: This veto removes times when acoustic noise related to thunderstorms at LIGO-Livingston coupled into the gravitational-wave strain channel and caused multiple seconds of excess noise.

Definition: This flag was created by taking the band limited RMS (BLRMS) of a microphone located in the corner station, and removing times when this output went above 250 (~ 50 mPa).

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Livingston - 0.009781%

1.30 Severe ETMY Scattering - Livingston

Purpose: This veto captures periods of severely scattering related to the Y-end test mass suspensions.

Definition: Based on the motion of the Y-end test mass, time periods where the 4th harmonic of scattered light light is predicted to be above 25 Hz.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Livingston - 0.028387%

1.31

Purpose: This veto captures time when there was excess glitching in the gravitational-wave strain data due to acoustic noise from a severe thunderstorm on 3rd May 2017.

Definition: This flag was created by hand and removed 5 hours of excess noise in the gravitational-wave strain channel.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Livingston - 0.134607%

1.32 Severe SRM and PRM Scattering

Purpose: This veto captures periods of severely scattering related to the power recycling and signal recycling mirror suspensions.

Definition: Based on the motion of the signal recycling mirror, time periods where the 4th harmonic of scattered light light is predicted to be above 40 Hz.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.001323%

1.33 ITMX R0 Overflow

Purpose: This veto captures times when odd ringing appeared in the LIGO-Hanford gravitational-wave strain data after actuators on ITMX R0 hit a digital overflow

Definition: This flag was created by monitoring the front end digital to analog (DAC) overflow monitors, and when all 3 actuators on IMTX R0 hit a digital limit at once was the time removed.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.000863%

1.34 Glitches in End X SUSRACK

Purpose: This veto captures times when glitching in the end X suspension rack coupled into the gravitational-wave strain data in LIGO-Hanford.

Definition: This flag was created by making a BLMRS of a magnetometer signal located at the End X and applying a Savitzky-Golay filter to normalise the trace to threshold.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.011951%

1.35 Earthquakes with Ground Motion BLRMS above 320 nm/s

Purpose: This veto removes times when earthquakes were causing extremely high ground motion at LIGO-Hanford. We created this flag based upon the output of a ground sesmometer located at the corner station.

Definition: This flag was created by taking the Band Limited RMS (BLMRS) of the output of this sesimometer in the Z direction (i.e. up and down) and created the veto whenever the BLRMS went above 320 nm/s.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.090381%

1.36 Earthquakes with Ground Motion BLRMS above 190 nm/s

Purpose: This veto removes times when earthquakes were causing extremely high ground motion at LIGO-Livingston. We created this flag based upon the output of a ground sesmometer located at the corner station.

Definition: This flag was created by taking the Band Limited RMS (BLMRS) of the output of this sesimometer in the Z direction (i.e. up and down) and created the veto whenever the BLRMS went above 190 nm/s.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Livingston - 0.094800%

1.37 45 MHz Amplitude Modulation Stabilization Issues

Purpose: This veto removes times at LIGO-Hanford when the the 45 MHz amplitude control glitches and couples into all vertex degrees of freedom and the gravitational-wave strain channel.

Definition: This veto was created by making a BLRMS of the 45 MHz amplitude modulation control signal and thresholding when this signal became too high and created glitches in the gravitational-wave strain data.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.044870%

1.38 Green Light in Arms

Purpose: This veto removes times at LIGO-Hanford when the Alignment Length Sensing (ALS) laser was left unshuttered which allowed green light to continue to resonate in the arms. The ALS laser is usually shuttered when the detector is in observing mode.

Definition: This flag was created by hand, using times indicated by a channel which monitors the power of the ALS laser in the arms. **GW170608 Analysis flag

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.000000%

1.39 Times with people walking around the LVEA, EX and EY

Purpose: This veto removes times when people were walking around the observatory corner station, EX and EY stations.

Definition: This flag was created by hand, using times indicated in the LIGO-Hanford alogs when people were known to moving around near the detector topics. **GW170608 Analysis flag

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.000000%

1.40 Glitches in End X SUSRACK in non-observing time

Purpose: This flag is a supplemental to the other End X SUSRACK flag defined in this document. This flag was created to capture times of this behavior when the interferometer was not in its nominal observing mode due to the analysis of GW170608.

Definition: This flag was made in the same way as the previously mentioned flag. The only difference is that for this flag we consider times when the detector was in a non-nominal observing mode. **GW170608 Analysis flag

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.000237%

1.41 Severe ETMY Scattering - Hanford

Purpose: This veto captures periods of severely scattering related to the Y-end test mass suspension.

Definition: Based on the motion of the Y-end test mass, time periods where the 20th harmonic of scattered light light is predicted to be above 30 Hz.

Veto Category: Burst - 2, CBC - 2

Deadtime: LIGO-Hanford - 0.018919%

1.42 Nonstandard calibration configuration

Purpose: This veto captures times when LIGO-Hanford was not in the standard O2 configuration which makes the calibration suspect.

Definition: This flag was created by hand, with times indicated by the LIGO calibration

group and the LIGO-Hanford alog 37743.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.389258%

1.43 Long Gates

Purpose: Gating is used to remove high amplitude noise transients from gravitational-wave strain data, by multiplying the data by an inverse window function. This veto removes times when a gate is longer than 3 seconds, as a gate of this length or more is known to bias estimation of the power spectral density in CBC analyses. A version of this flag covers both interferometers.

Definition: This flag was constructed by monitoring a system automatically records the gating times.

Veto Category: Burst - N/A, CBC - 2

Deadtime: LIGO-Hanford - 0.059985%, LIGO-Livingston - 0.000621%

1.44 Loud power mains transients impacting noise subtraction

Purpose: This veto was created to flag time periods where significant transients in one of the power mains monitor channels biased the estimation of transfer functions during the noise subtraction process.

Definition: Periods of significant excess noise were observed after noise subtraction which were found to be related to excess noise in the power mains. The full time duration overlapping the transients in which the noise subtraction transfer function was measured were flagged.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Livingston - 0.005302%

1.45 Transients in photon calibration laser impacting noise subtraction

Purpose: This veto was created to flag time periods where significant transients in the photon calibrator laser biased the estimation of transfer functions during the noise subtraction process.

Definition: Periods of non-physical reduction in the noise level were observed after noise subtraction which were found to be related to excess noise in the photon calibrator laser biasing the measurement of transfer functions. The full time duration overlapping the transients in which the noise subtraction transfer function was measured were flagged.

Veto Category: Burst - 1, CBC - 1

Deadtime: LIGO-Hanford - 0.002337%

1.46 Saturation in ETMX electrostatic drive control signal

Purpose: This veto indicates that the drive signal controlling the ETMX electrostatic drive has hit the limit of the digital-to-analog converter. This is typically due to a high amplitude transient amidst otherwise nominal operation.

Definition: This veto is defined by monitoring the real time diagnostics on the system that controls the digital-to-analog converter.

Veto Category: Burst - 2, CBC - not used. This flag is captured by CBC Gating Times

Deadtime: LIGO-Hanford - 0.000022%

1.47 Saturation in ETMY electrostatic drive control signal

Purpose: This veto indicates that the drive signal controlling the ETMY electrostatic drive has hit the limit of the digital-to-analog converter. This is typically due to a high amplitude transient amidst otherwise nominal operation.

Definition: This veto is defined by monitoring the real time diagnostics on the system that controls the digital-to-analog converter.

Veto Category: Burst - 2, CBC - not used. This flag is captured by CBC Gating Times

Deadtime: LIGO-Hanford - 0.095321%, LIGO-Livingston - 0.035925%

1.48 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 - not used. This flag is captured by CBC Gating Times

Deadtime: LIGO-Hanford - 0.006594%, LIGO-Livingston - 0.006147%

1.49 Smoke Alarm in corner station

Purpose: Vetoes an instance on March 16th, 2017 when a smoke alarm coupled into DARM, which produced loud triggers in the Coherent WaveBurst all-sky search.

Definition: The Use Percentage Veto (UPV) algorithm generated veto segments based on a central station microphone picking up the smoke alarm.

Veto Category: Burst - 2, CBC - not used

Deadtime: LIGO-Livingston - 0.003679%

1.50 Saturation in ITMY L2 control signal

Purpose: This veto indicates that the control signal controlling ITMY L2 has hit the limit of the digital-to-analog converter.

Definition: This veto is defined by monitoring the real time diagnostics on the system that controls the digital-to-analog converter.

Veto Category: Burst - 2, CBC - not used

Deadtime: LIGO-Hanford - 0.062020%

1.51 Thirsty raven pecking

Purpose: Vetoes low-bandwidth glitches around 94 Hz caused by thirsty ravens pecking at ice on GN2 vent lines. This is believed to couple to DARM through the P-Cal periscope.

Definition: The Use Percentage Veto (UPV) algorithm generated veto segments based on the BSC10 accelerometer.

Veto Category: Burst - 2, CBC - not used

Deadtime: LIGO-Hanford - 0.001632%