“Category 1” (CAT1) data quality vetoes applied to the analysis of the O3 run Virgo data

Version 1 -- 25 May, 2021

The Virgo DetChar team

This document describes all the Virgo data quality (DQ) vetoes which were applied to the analysis of Virgo data from the third observing run O3 (April 2019 - March 2020). All these vetoes belong to “Category 1” (CAT1), meaning that the flagged data segments are unusable and should thus be removed from all analysis -- see the O3a Data Set Technical Details and references therein for more information, in particular about the veto categories. All flags have a 1-second granularity.

For each DQ flag (defined by a name and a version number), the definition of the veto is given, together with the total amount of dead time associated with it.In this document, “deadtime” refers to the amount of time removed from Virgo SCIENCE mode, for each veto individually. Similarly, the DQ flags are not independent: they may overlap. And they only make sense when they are applied globally on the data, taking the logical OR of all the vetoes.

In the following, a GPS segment is a half-open interval [integer_GPS_low; integer_GPS_high[whose boundaries are integers.

Virgo SCIENCE mode

Virgo in SCIENCE mode means that the detector is taking data that are expected to be of a quality good enough to be included in the datasets suitable for physics analysis.

Name	Version	SCIENCE time		
V1:ITF_SCIENCE	2	O3: 21669574 s	O3a: 12057731 s	O3b: 9611843 s

Virgo CAT1 flags

Bad quality of the reconstructed strain data h(t)

Purpose: Remove from the final dataset all GPS segments, within science mode, during which the quality of the reconstructed strain data channel h(t) is labelled as bad by the h(t)

reconstruction framework. This means that input data for h(t) reconstruction may be missing or that calibration lines to estimate the cavities finesse and gain had a too low SNR, etc.

Definition: This veto is based on a quality flag channel written by the h(t) reconstruction framework and available in the frames with the h(t) channel.

Name	Version	Dead time		
V1:DQ_HREC_BAD_QUALITY	1	O3 = 15792 s (0.073%)	O3a = 4545 s (0.038%)	O3b = 11247 s (0.117%)

Reconstructed strain data h(t) consistently null

Purpose: Remove from the final dataset all GPS segments during which the reconstructed strain data channel h(t) is equal to 0.

Definition: This veto is based on the comparison of the maximum value of the absolute value of the h(t) channel computed over 1 second with a threshold much lower than the regular amplitude variations of the strain data.

Name	Version	Dead time		
V1:DQ_HREC_IS_ZERO	1	O3 = 5196 s (0.024%)	O3a = 3197 s (0.027%)	O3b = 1999 s (0.021%)

Reconstructed strain data h(t) channel missing in frames

Purpose: Remove from the final dataset all GPS segments during which the reconstructed strain data channel h(t) is missing in the h(t) frames provided online.

Definition: This veto is based on internal information provided by the Virgo DAQ and the h(t) reconstruction framework.

Name	Version	Dead time		
V1:DQ_HREC_MISSING	1	O3 = 179 s (0.001%)	O3a = 0 s (0.000%)	O3b = 179 s (0.002%)

Missing samples for the reconstructed strain data h(t) channel

Purpose: Remove from the final dataset all GPS segments during which the reconstructed strain data channel h(t) contains missing samples in the frames.

Definition: This veto is based on a close inspection of the frame contents, focusing on the h(t) channel.

Name	Version	Dead time		
V1:DQ_HREC_MISSING_V1ONLINE	3	O3 = 325 s (0.002%)	O3a = 322 s (0.003%)	O3b = 3 s (0.000%)

Removal of the last 10 seconds of data before a loss of control of the Virgo detector

Purpose: Remove from the final dataset 10 seconds of data preceding a control loss of the Virgo detector. The reconstruction of h(t) is based on 8 seconds-long sliding windows and so a control loss could potentially corrupt h(t) for up to that duration. Trimming data by chunks of 10 seconds is a conservative choice adding 2 of seconds of safety margin.

Definition: Fast channels sampled at 10 kHz allow to define accurately the moment when the control of the Virgo detector is certainly lost. Data are vetoed from 10 seconds before that time up to the end of the SCIENCE segment -- due to the internal latency of the Virgo automation system that steers the detector, the SCIENCE mode can remain enabled for a handful of seconds at most after the control has been lost.

Name	Version	Dead time		
V1:DQ_LOCK_LAST_10S	1	O3 = 6715 s (0.031%)	O3a = 4015 s (0.033%)	O3b = 2700 s (0.028%)

Saturation of the B1P_PD1 photodiode

Purpose: Remove from the final dataset all GPS segments during which the dark fringe photodiode B1P_PD1 is saturating.

Definition: Each photodiode provides several auxiliary channels allowing one to detect various transient saturation modes. These data are analyzed in real time to produce a DQ flag that is read back to define the vetoed segments.

Name	Version	Dead time		
V1:DQ_SATURATION_B1P_PD1	3	O3 = 769 s (0.004%)	O3a = 494 s (0.004%)	O3b = 275 s (0.003%)

Saturation of the B1P_PD2 photodiode

Purpose: Remove from the final dataset all GPS segments during which the dark fringe photodiode B1P_PD2 is saturating.

Definition: Each photodiode provides several auxiliary channels allowing one to detect various transient saturation modes. These data are analyzed in real time to produce a DQ flag that is read back to define the vetoed segments.

Name	Version	Dead time		
V1:DQ_SATURATION_B1P_PD2	3	O3 = 661 s (0.003%)	O3a = 379 s (0.003%)	O3b = 282 s (0.003%)

Saturation of the B1_PD1 photodiode

Purpose: Remove from the final dataset all GPS segments during which the dark fringe photodiode B1_PD1 is saturating.

Definition: Each photodiode provides several auxiliary channels allowing one to detect various transient saturation modes. These data are analyzed in real time to produce a DQ flag that is read back to define the vetoed segments.

Name	Version	Dead time		
V1:DQ_SATURATION_B1_PD1	3	O3 = 1864 s (0.009%)	O3a = 1264 s (0.010%)	O3b = 600 s (0.006%)

Saturation of the B1_PD2 photodiode

Purpose: Remove from the final dataset all GPS segments during which the dark fringe photodiode B1_PD2 is saturating.

Definition: Each photodiode provides several auxiliary channels allowing one to detect various transient saturation modes. These data are analyzed in real time to produce a DQ flag that is read back to define the vetoed segments.

Name	Version	Dead time		
V1:DQ_SATURATION_B1_PD2	3	O3 = 2037 s (0.009%)	O3a = 1419 s (0.012%)	O3b = 618 s (0.006%)

Excess rate of noise transients (glitches) in the h(t) strain channel

Purpose: Remove from the final dataset all GPS segments during which the rate of noise transient (aka “glitches”) is too high or in the presence of a very high-SNR glitch.

Definition: The glitch rate is measured by the Omicron software, running offline on the reconstructed strain data h(t). When it exceeds some threshold above which the quality of the data is certainly impacted the corresponding DQ flag is raised. Vetoed GPS segments are those during which that DQ flag is active.

Name	Version	Dead time		
V1:DQ_SATURATION_OMICRON	1	O3 = 12444 s (0.057%)	O3a = 7745 s (0.064%)	O3b = 4699 s (0.049%)

Saturation of a correction signal of a suspension of the Virgo detector

Purpose: Remove from the final dataset all GPS segments during which at least one of the feedback systems used to control the suspensions of the Virgo detector is saturating.

Definition: Each suspension feedback system of interest is monitored in real time and has its own DQ flag that becomes active when a saturation is recorded. Then the DQ flags from all suspensions are combined in a logical OR to generate the vetoed segments.

Name	Version	Dead time		
V1:DQ_SATURATION_SUSP_OR	2	O3 = 986 s (0.005%)	O3a = 533 s (0.004%)	O3b = 453 s (0.005%)

Identification of times during which the Virgo detector is not really in SCIENCE mode

Purpose: Remove from the final dataset all GPS segments during which the automation system steering the Virgo detector still has the SCIENCE mode enabled whereas the control of the instrument has already been lost.

Definition: Due to the intrinsic latency of the automation system controlling the Virgo detector, the information that the control of the instrument has been lost can take up to a few seconds to reach the top-level automation node. Therefore, during these GPS segments, the data are incorrectly flagged as good for analysis. This DQ veto fixes that problem by comparing the Virgo

automation mode (running in cycles 1 second-long each) with the actual status of the detector using information from fast channels sampled at 10 kHz.

Name	Version	Dead time		
V1:DQ_SCIENCE_FALSE	1	O3 = 2650 s (0.012%)	O3a = 950 s (0.008%)	O3b = 1700 s (0.018%)

Identification of times during which the Virgo detector was controlled in a configuration not validated for SCIENCE mode yet

Purpose: Remove from the final dataset all GPS segments during which the configuration with which the Virgo detector is controlled has not been validated for SCIENCE data taking whereas that mode has been set in the control room.

Definition: DAQ channels associated with the control of the Virgo detector allow one to infer which control configuration is in use at any given time. If that configuration is not among the nominal ones at the time it is used, the DQ flag is raised and the corresponding GPS segment vetoed.

Name	Version	Dead time		
V1:DQ_SCIENCE_INPUT_TM_LOCK	1	O3 = 3273 s (0.015%)	O3a = 3261 s (0.027%)	O3b = 12 s (0.000%)

Identification of times during which the control of the Virgo detector may not have been stable enough for SCIENCE mode

Purpose: Remove from the final dataset all GPS segments during which the control of the Virgo detector was kept while being not accurate enough to allow SCIENCE mode data taking.

Definition: During the O3 run, the global control of the Virgo detector could be lost because of a transient loss of data impacting one of the numerous feedback systems needed to maintain the instrument at its nominal working point. While waiting for an opportunity to fix the problem at the level of the hardware, a software fix was developed, allowing an automated transition to another feedback configuration, less accurate but robust against that loss of data. This saved a lot of running time (re-acquiring the global control of the instrument takes a few tens of minutes) but the data taken during the transition phases (nominal to alternative control configurations and back) and when the alternative feedback system was enabled had to be vetoed. The corresponding DQ flag is based on auxiliary data from that feedback system that detect such transitions both ways.

Name	Version	Dead time		
V1:DQ_SC_NI_MISSING_DATA	1	O3 = 2335 s (0.011%)	O3a = 0 s (0.000%)	O3b = 2335 s (0.024%)

Summary: the logical “OR” of all the CAT1 vetoes

Total dead time, computed by taking the logical OR of all the segments CAT1-vetoed by the DQ flags described above.

CAT1 vetoes logical OR	Dead time		
	O3 = 39438 s (0.182%)	O3a = 18802 s (0.156%)	O3b = 20636 s (0.215%)