

Event Data Recorder (EDR) Developed by Toyota Motor Corporation

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ABSTRACT

An event data recorder (EDR) records the vehicle status at the timing of an accident. Toyota Motor Corporation began the sequential introduction of EDRs onto its vehicles from August 2000. Currently, about 70% of all Toyota's vehicles in North America are equipped with an EDR, which is more than the average rate of EDR installation in vehicles in North America (around 50%). The U.S. has introduced regulations for EDRs. Toyota regards these as minimum requirements and also records additional data for accident analysis, including the following: (1) pre-crash data, (2) side crash data, (3) rollover data, (4) pedestrian protection pop-up hood (PUH) data, and (5) vehicle control history (VCH) data from a non-crash triggered recording system. The regulations stipulate that EDR data retrieval must be possible using a commercially available tool. The developed system uses the Crash Data Retrieval (CDR) tool manufactured by Bosch. Data from all Toyota EDRs around the world can be retrieved using the CDR tool, including in North America. Since EDR data collection and analysis are very important for real-world accident analysis, an automatic online EDR data collection system was constructed with the cooperation of Bosch. Toyota is currently developing new systems using EDR data. As an example, making effective use of crash severity ΔV and seatbelt data, the Advanced Automatic Collision Notification (AACN) system is due to start trials in Japan from November 2015. The expansion of EDR functions and system development using EDR data are likely to continue growing in importance.

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1. INTRODUCTION

Passive safety technology has made substantial advances in recent years and technology is being developed to protect occupants in a variety of crash types. Systems targeting frontal and side crashes, as well as rollovers are steadily becoming standard on vehicles. As well as various types of airbags and other occupant restraint systems, vehicles are also provided with a range of airbag control sensors that determine the optimum airbag deployment timings. It is possible to identify the type and severity of accidents by recording data from these sensors when a crash occurs. Data can also be recorded from the local area network (LAN) of the vehicle to identify the vehicle status leading up to the crash to determine the details of the vehicle before the accident.

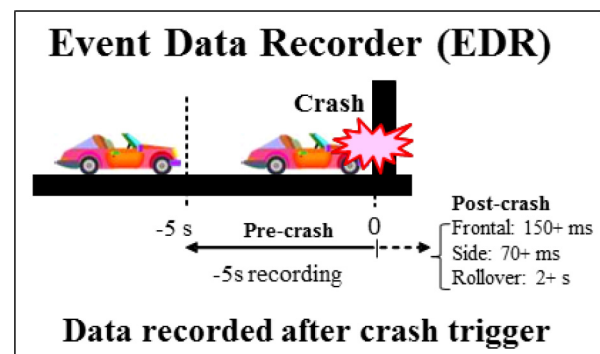


Figure 1. Event data recorder.

An event data recorder (EDR) records the vehicle status when an accident occurs.

Recording starts with the acceleration (G) at the beginning of the crash judged as almost time zero. The recorded data consists of precrash data, which details the vehicle status before the crash, and post-crash data, which details the occupant status from the start of the crash and the severity of the crash.

The pre-crash data shows the vehicle status and driving operations. Data, such as the vehicle speed, engine speed, accelerator pedal position, and brake status is recorded at 0.5 or 1-second intervals. Since these values vary in accordance with the driving operations, new data must be constantly recorded.

Post-crash data includes airbag sensor data, which indicates the type and severity of the crash, the occupant status (such as whether seatbelts are being worn), and airbag deployment data.

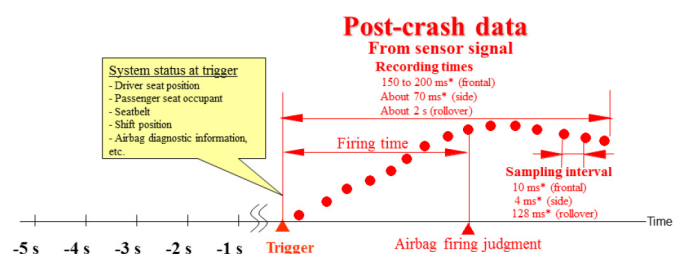
Since the recorded data describes driving and accident conditions, the property rights of EDR data belong to the owner. Therefore it is necessary to respect privacy and obtain the permission of the user before downloading data. It is important to record the most effective data for accident analysis more closely while ensuring the accuracy and reliability of the data.

2. EDRs DEVELOPED BY TOYOTA

2-1 Prior to EDR Regulations

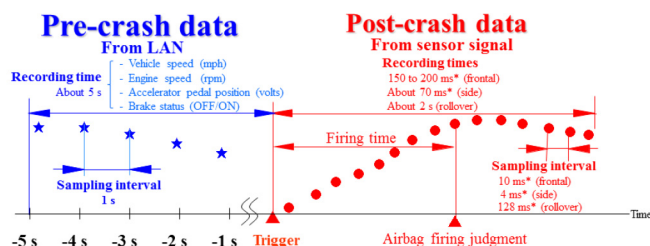
Toyota began the sequential adoption of EDRs onto its vehicles in August 2000. To obtain pre-crash data of the vehicle status from other systems, the vehicle must have a LAN. In Toyota the presence of a LAN determines whether pre-crash data can be obtained.

Toyota developed Type A and B EDRs. Type A records only post-crash data in vehicles without a LAN and Type B records both preand post-crash data.



Note 1: Frontal crash data is recorded by the Type A EDR and is available in all models. Side crash and rollover data depends on the model.

Figure 2. Type A: post-crash data only.



Note 1: The pre-crash data specifications recorded by the Type B EDR are common to all models.
Note 2: Frontal crash data is also recorded by the Type B EDR, and is available in all models. Side crash and rollover data depends on the model.

Figure 3. Type B: pre- and post-crash data.

APPENDIX A shows the year of EDR introduction for each model in North America, highlighting the timing of Type B (pre-crash data) adoption. Although the details of the recorded data differ between models, all models in North America were equipped with pre-crash data by the end of 2010.

In around 2009, more than 150 EDR data download tools (also called the read-out tools (ROTs), see section 2-3) were delivered in North America, and a thorough field investigation using EDR data was started in May of the same year. As shown in Fig. 4, the data identified cases caused by the driver mistakenly depressing the accelerator instead of the brake.

Toyota delivered a total of 230 EDR download tools around the world and began responding to inquiries from the field. At the same time, download tools were provided to the National Highway Traffic Safety Administration (NHTSA) in the U.S. for cooperation with an investigation by that agency.

The interim report issued by NHTSA on August 10, 2010, stated that EDR data was useful in around 90% of cases of possible sudden acceleration and that the main causes were mistaken pedal application and late braking (Fig. 5).

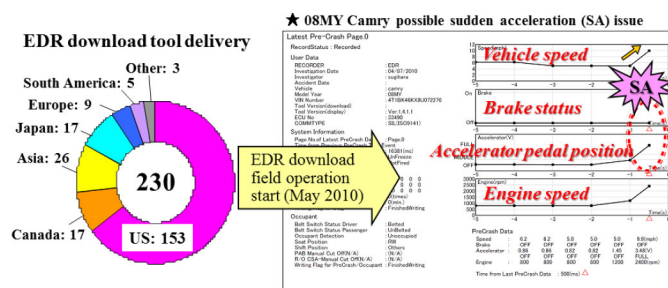


Figure 4. EDR download tool delivery.

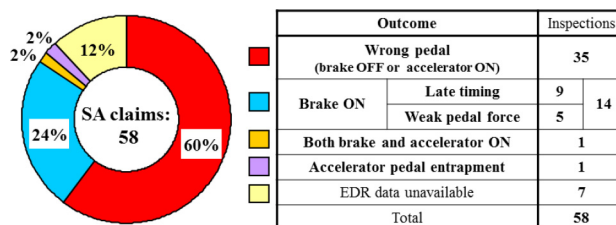


Figure 5. NHTSA investigation of possible sudden acceleration.

2-2. Compliance with EDR Regulations

Using the experience obtained from the field investigations of possible sudden acceleration, the EDR recording specifications were substantially revised to enable the recording of useful data for accident analysis. This revision coincided with the enactment of EDR regulations in the U.S. [1] Regarding these regulations as minimum requirements, it was decided to add various types of data to enable accident analysis (although this data was partially recorded prior to the enactment of the EDR regulations, the following sections describe the differences with the regulations). The regulatory-compliant EDR, called the 12EDR, was phased in starting in 2011 and was in all vehicles prior to the regulation effective date of Sept. 2012. (the two digits before "EDR" indicate the year of market launch)

2-2-1. Addition of Pre-Crash Data

The principle of data capture was revised to enable the recording and accurate identification of driver operations and the vehicle status before the crash (Fig. 6).

Previously, only the minimum amount of data was recorded, including vehicle speed, engine speed, accelerator pedal position, and brake status. The necessary data was selected after considering the driver operations and inputs relevant to the three overall vehicle states (running, stopping, and turning) and listing the vehicle state outputs changed by these inputs. The data that was added is shown by the large black circles (●) in Figure 6. Figure 7 outlines the details of the regulatory-compliant 12EDR. Major enhancements include the increased pre-crash data, and the shorter sampling time (0.5 s, reduced from 1.0 s). Excluding the frontal crash recording time, the post-crash data specifications are virtually unchanged.

- Focus on Running, Stopping, and Turning
- Record both Driver Inputs and Vehicle Status

	Driver operation/input	Vehicle status/output
Running	- Accelerator pedal position	- Vehicle speed
	- Shift position	- Engine speed
Stopping	● Cruise control (ON/OFF), drive mode switch	● Throttle angle
	- Brake status (ON/OFF)	● Low longitudinal acceleration (Gx)
Turning	● Master cylinder pressure	● Yaw rate
	● Steering angle	

— : Data required by Part 563 regulations

● : Toyota enhanced data (from 06EDR)

Figure 6. Pre-crash data capture principle.

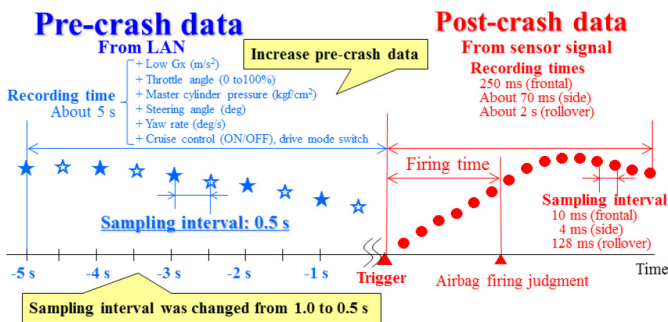


Figure 7. 12EDR implementation.

The following test demonstrates the enhancement in recording accuracy achieved by 12EDR. Figure 8 shows an example of the data recorded by 12EDR for a short accelerator ON operation (less than 1 s) after changing the sampling time.

- ◆ Test: short accelerator ON
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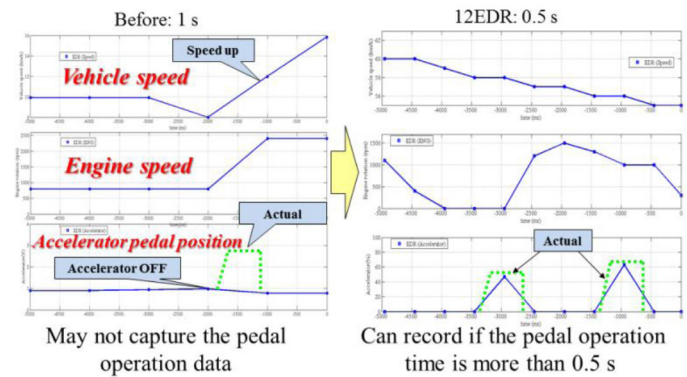


Figure 8. Sampling time change.

Figure 9 shows a recording of the operation of the brake override system (BOS), which reduces the throttle angle and decreases the vehicle speed when the accelerator and brake pedals are depressed simultaneously.

- ◆ Test: both pedals applied

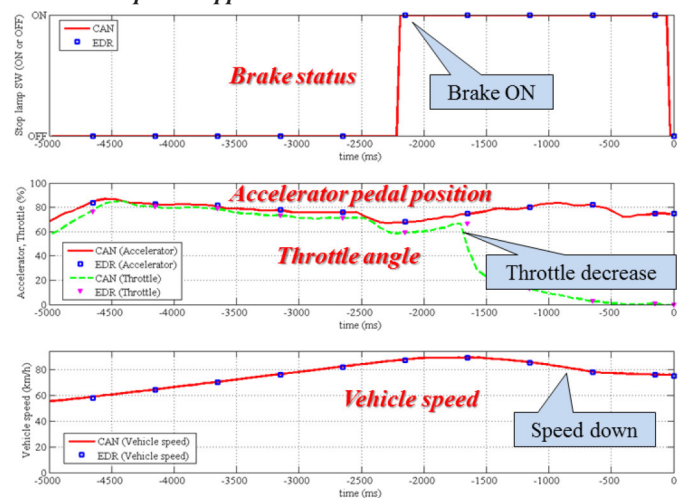


Figure 9. BOS recording.

2-2-2. Post-Crash Data Required for Crash Reconstruction

Frontal Crash

The change in longitudinal velocity (also called “delta-V, longitudinal,” or ΔV_x) is recorded in accordance with the requirements for continuously running algorithms described in the regulations.

To identify ΔV_x more precisely, the recorded value is calculated using the moving average of the value sampled from the longitudinal acceleration (Gx) sensor 20 times over a period of 10 ms at an interval of 0.5 ms (Fig. 10).

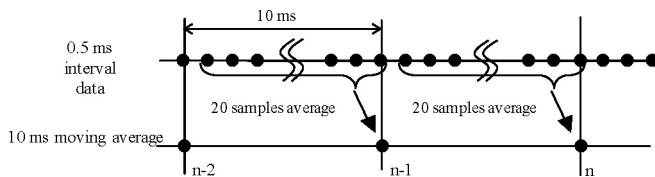


Figure 10. Frontal crash recorded data.

The calculated ΔV_x is recorded every 10 ms over a period of 250 ms.

Recording is ended when the “end of event” conditions are satisfied. The purpose of this process is to end recording when the crash is over and to prepare for the next recording. It enables the accurate identification of severe crashes such as multiple impacts (Fig. 11).

Since the data length depends on the end of event timing, the number of the recorded data is also recorded. If ΔV_x or the data number cannot be recorded because the crash has disconnected the battery, the state of the ignition power source (i.e., the battery state) is attached to the front part of each data item to clarify the effective range of the recorded data. This is for more severe crash than FMVSS208. The CDR tool reports ON/OFF state in the delta V time series table.

To prevent unnecessary recording triggered by rough roads, slight crashes, and the like, the regulations require an integral guard value (trigger threshold: moving average over 150 ms (V150) ≥ 8 km/h) to be set.

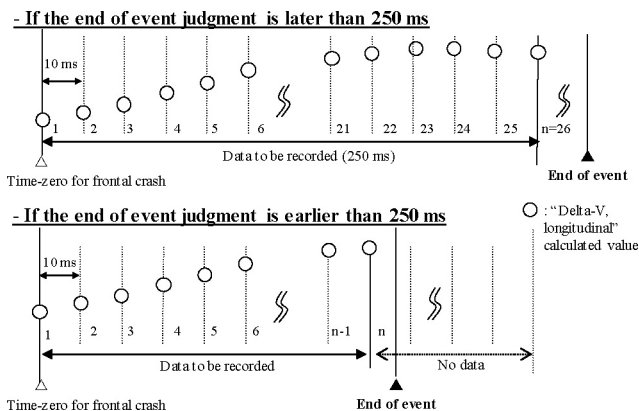


Figure 11. Frontal crash buffer data.

2-2-2-2 Additional Side Crash Data Recording

In a side crash, the values from the lateral acceleration (G_y) sensors installed at the B-pillar, C-pillar, and airbag electronic control unit (ECU) are recorded (Fig. 12). Figure 13 analyzes a rear-seat pole side crash at 29 km/h. Because large rotational movement is generated in the vehicle, the airbag ECU G_y sensor can only detect an integral change in lateral velocity (“delta- v , lateral,” or ΔV_y) of half that value. The regulations only require the recording of ΔV_y inside the airbag ECU. However, it was concluded that the EDR should also record the B- and C- pillar data in the event of a crash outside the center of gravity of the vehicle [2,3].

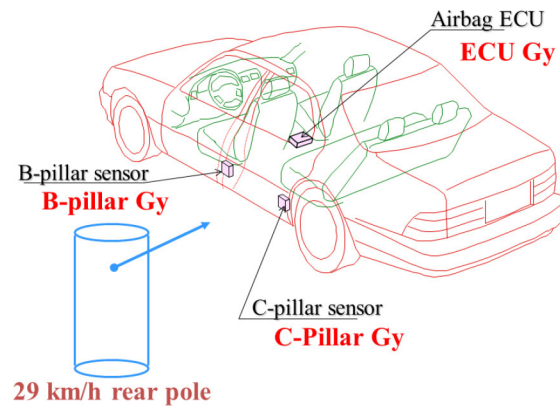


Figure 12. Side airbag sensing system.

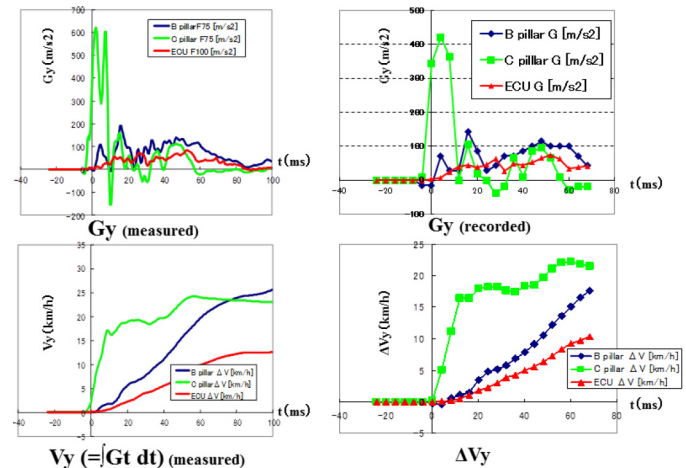


Figure 13. 29 km/h rear pole.

To identify the ECU G_y , B-pillar G_y , and C-pillar G_y more precisely, the recorded values are calculated using the moving average of each G_y sensor value sampled 8 times over a period of 4 ms at an interval of 0.5 ms (Fig. 14).

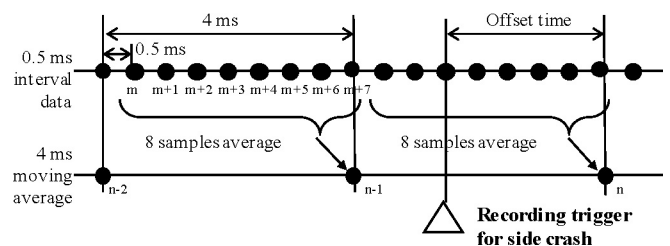


Figure 14. Additional side crash recorded data.

G_y is recorded over a period of 96 ms at an interval of 4 ms.

The side crash judgment trigger is performed using the signals from each sensor. However, since the longitudinal position of each sensor differs, the start-up timing of each crash G_y also changes. Therefore, the fastest data is used as the side crash trigger data. Since the location and trigger threshold of each sensor differ, it is necessary to record the G_y before the trigger. The G_y of each side crash sensor is then recorded over a period from -24 ms to 72 ms based on the fastest trigger.

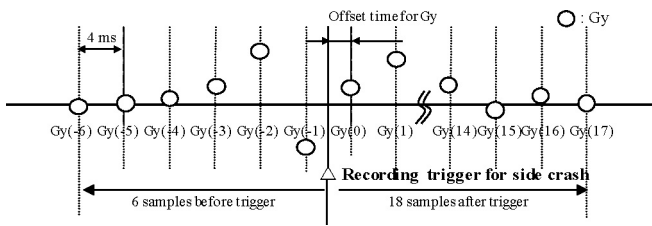


Figure 15. Additional side buffer data (for ECU Gy, B-pillar Gy, and C-pillar Gy).

It should also be noted that the same recording as for the B-pillar sensor is carried out if a front door G sensor is provided in addition to the side crash B-pillar sensor.

Rollover Record

There are two main categories of rollover events, with and without a crash (Fig. 16) [2,3].

The non-crash type tends to be a slow screwing rollover in which the rotation of the vehicle follows an inclined surface. The crash type tends to involve the vehicle tripping over a curb, causing the vehicle to move sideways and rotate quickly.

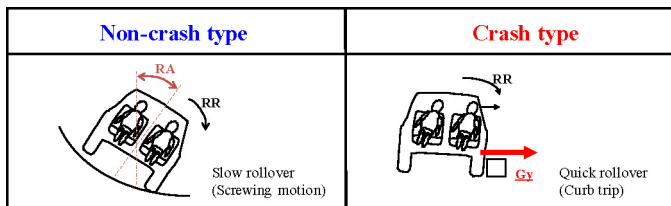


Figure 16. Rollover event types.

The rollover judgment trigger is a roll rate (RR) over 43 deg/s or a roll angle (RA) of over 26 deg, as calculated by the roll rate sensor in the airbag ECU.

Figure 17 shows the RA and Gy values calculated from this sensor in a screwing non-crash type rollover. At the beginning of the event, Gy is generated when the RA increases and reaches approximately 90 deg. In other words, the angle of the surface causes the roll to start. The vehicle then rolls over and Gy is generated when the side of the vehicle impacts the road.

Similarly, Fig. 18 shows a crash type rollover involving a curb trip. Around time-zero when the trigger is generated, RA begins to increase after a sudden spike in Gy. The vehicle starts rolling with the origin of rotation located at the tire, in accordance with the strength of the impact between the tire (the side of the vehicle) and the curb. The initial sudden Gy peak must be accurately identified to determine whether the vehicle will roll over.

Therefore, it is necessary to make separate records for slow non-crash types and sudden crash types of rollover.

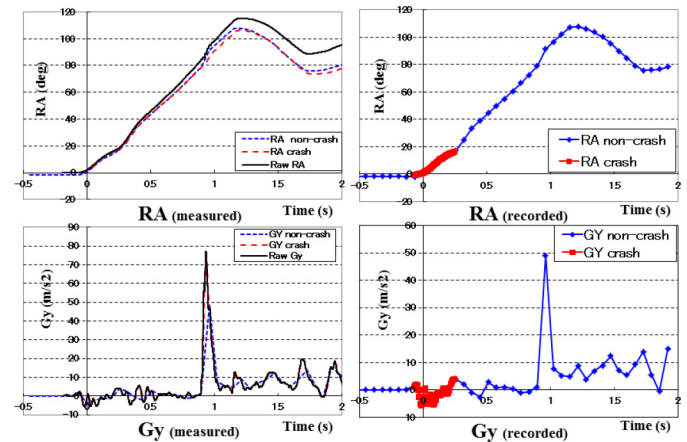


Figure 17. Non-crash type: screwing rollover.

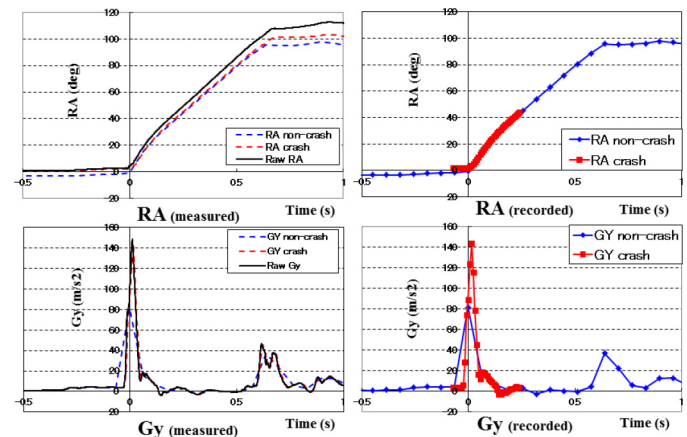


Figure 18. Crash type: rollover after curb trip.

The moving average calculation duration of the recorded data was optimized to record crash and non-crash type rollovers accurately. Results of analysis found that the duration for crash type rollovers should be 8 ms and the duration for non-crash type rollovers should be 64 ms. After optimizing the recording time and amount of recorded data, the number of data samples was set to 40 with a recording time range from -80 ms to 240 ms for crash type rollovers and from -640 ms to 1920 ms for non-crash type rollovers. Judgment whether a rollover is a crash or non-crash type is performed based on the airbag deployment time after the trigger (Table 1).

Table 1. Explanation of buffer data.

Event type	Time to deploy	Data	Number of samples
Crash type	< 240 ms	8 ms moving average	40
Non-crash type	>= 240 ms or OFF	64 ms moving average	10: pre-triggered 30: on/post-triggered