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Automated Vehicle Safety Consortium™ Best Practice

AVSC Best Practice for Data Collection for Automated Driving System-Dedicated Vehicles (ADS-DVs) to Support Event Analysis

Rationale

Data recording is important to crash reconstruction, system performance investigations, and event analysis to identify lessons learned to enable industry-wide improvements in automated driving systems (ADS) safety. The *Best Practice for Data Collection for Automated Driving System Dedicated Vehicles (ADS-DVs) to Support Event Analysis* provides an initial version of what is expected to be an evolving set of best practices and standards for event data recording as ADS technology matures. This best practice specifically addresses data collection for event analysis capable of producing lessons learned (i.e., about what an ADS "saw" and what actions it took) from critical driving scenarios. The ability to efficiently and consistently identify and address safety issues for deployed vehicles is important to gaining the trust and confidence of the public.

Preface

The Automated Vehicle Safety Consortium™ (AVSC) is an industry program of SAE Industry Technologies Consortia (SAE ITC®) working to quickly publish best practices that will inform and lead to industry-wide standards advancing the safe deployment of automated driving systems (ADSs). The members of this consortium have decades of accumulated experience focused on safe, reliable, and high-quality transportation. They are committed to applying those principles to SAE level 4 and 5 automated vehicles so that communities, government entities, and the public can be confident that these vehicles will be deployed safely.

The Consortium recognizes the need to establish best practices for the safe operation of ADS-dedicated vehicles (ADS-DVs). These technology-neutral practices are key considerations for safely deploying ADS-DVs on public roads. Members of the AVSC intend to support the published principles and best practices in an effort to establish a suggested level for other industry participants to meet. These best practices will serve as a basis to enhance and expedite the formal industry standards development process through SAE International and other global standards development bodies. Effectively implementing these principles can help inform the development of sound and effective ADS regulations and safety assurance testing protocols that will engender public confidence in the efficacy of ADS-DVs.

Comment and open discussion on the topics are welcome in appropriate industry forums. As discussion unfolds, AVSC documents will be revised as significant information and/or new approaches come to light that would increase public trust.

Introduction

Historically, open industry standards for data collection have benefited from initial efforts like this and lessons learned following deployment of the technologies across vehicle fleets. Data recording was first introduced to vehicles in the 1980s. SAE International took a first step at standardizing data recording practices with the Recommended Practice SAE J1698 in 2003. This led to the National Highway Traffic Safety Administration (NHTSA) publishing a notice of proposed rulemaking (NPRM) in June 2004 [1], publishing a final rule for 49 CFR Part 563 in 2006 [2], issuing amendments 2008 [3], 2011 [4], and 2012 [5], and began implementing 49 CFR Part 563 [6] enforcement starting in September of 2012.

As technology and functionality of vehicle systems change, so do data recording needs. In place of a human driver, an ADS provides the functionality of perceiving the environment and handling vehicle motion control, i.e., the dynamic driving task (DDT), as described in SAE J3016. This best practice addresses a technology that is still evolving and may continue to evolve for many years. Data collection practices are expected to mature, and eventually stabilize, as ADS technologies do. This best practice is a proactive step toward harmonized data collection requirements for ADS-DV event analysis to identify lessons learned. The data elements and recording durations described herein are expected to provide the types of data most useful to event analysts.

For event analysis, the primary differences between ADS-operated vehicles and conventional human operated vehicles are a different set of technology-related factors that may contribute to an event. This best practice seeks to achieve two goals that support identification of lessons learned for ADS-DVs: (1) provide information about what the ADS “saw” and “did” and (2) help identify the technology-relevant factors that contributed to the event. When an ADS takes the place of the human driver, new factors such as issues with sensing, processing, and control systems, become potentially important issues in event analysis. It is important to note that event analysis may use data from many sources to determine key factors associated with the event. Other sources of data may include event data recorder (EDR) data, human eyewitnesses, and scene analysis. In many cases, event reconstruction practices used today (for human driven vehicles) may be sufficient to determine performance-related factors for ADS-DVs without the need for additional data (e.g., collision factors such as speed or obscured vision). However, for example, existing methods used to determine human inattention, disobeyed traffic control devices, and attempted avoidance maneuvers may be insufficient to determine factors related to ADS control systems and determination of saliency. This best practice recommends data collection practices (including data elements, recording interval, and recording frequency) to support analysis related to ADS sensing, determination of saliency, and vehicle motion control in the event of a collision. The following set of scenarios describes example collision factors that may be determined through the recommended data collection practices:

Scenario A: Salient object not detected – If an ADS fails to detect a salient object or event prior to a collision, then collecting salient object and visual representation data can help identify lessons learned from this scenario. The recommended recording interval (5 seconds) and frequency (2 samples per second) for these data is expected to be sufficient to determine when the ADS should have determined saliency of an object. This best practice is consistent with current collision reconstruction practices, in which reaction to hazard detection (e.g., evasive vehicle maneuvers) for human drivers are recorded up to 5 seconds prior to the triggering event.

Scenario B: Salient object detected, but not acted upon by the ADS – If an ADS correctly detects objects and events prior to a collision but fails to take the correct course of action, then collecting salient object and ADS action data can help identify lessons learned from this scenario. The recommended recording interval (5 seconds) and frequency (2 samples per second for salient object, 5 samples per second for ADS actions, 4 samples per second for ADS requested gear) for these data is expected to be sufficient to assess the effectiveness and timing of the evasive maneuver the ADS requested. This best practice is consistent with current collision reconstruction practices, in which evasive vehicle maneuvers for human drivers are recorded up to 5 seconds prior to the triggering event.

Scenario C: ADS response commanded, but loss of control – If an ADS correctly detects objects and events, and requests an evasive maneuver, but the ADS-DV control system fails to actuate or actuated commands are ineffective in avoiding a collision (e.g., via lateral and longitudinal vehicle motion control), then collecting ADS commanded and actual vehicle indicated motion control data can help identify lessons learned from this scenario. The recommended recording interval (5 seconds) and frequency (5 samples per second for vehicle motion control data) for these data is expected to be sufficient to assess the effectiveness of the control system actuation. This best practice is consistent with current collision reconstruction practices, in which vehicle control outputs are recorded up to 5 seconds prior to the triggering event.

Additionally, the traveling public, law enforcement, or government agencies may expect more data for collisions involving ADS-equipped vehicles, for example due to the absence of a human to serve as an eyewitness. In an effort to better understand ADS-DV performance, the data collection described in this best practice includes data elements and recording triggers that go beyond other current crash reconstruction recommendations and regulations. Human eyewitness testimony is limited by field of view, memory bias, and attention, and has been shown to be imperfect and incomplete [7]. By contrast, data elements recorded by ADS developers and manufacturers provide an objective and reliable account of ADS-performance-relevant factors leading up to an event that may help engender public trust.

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1. Scope

This Automated Vehicle Safety Consortium (AVSC) ***Best Practice for Data Collection for Automated Driving System Dedicated Vehicles (ADS-DVs) to Support Event Analysis*** (***AVSC0004202009)*** makes recommendations for uniform collection, storage, and retrievability of onboard motor vehicle ADS event data. It addresses the definition of event and related concepts, definition of ADS-related data elements, recording interval and frequency, retrievability, considerations for survivability, storage, and traceability. The document is not intended to be all-inclusive and work will continue beyond its initial publication to add and refine items and definitions. This best practice only applies to SAE J3016 level 4 and level 5 automation fleet-operated vehicles that would not be sold or leased to private individuals. This document only pertains to ADS-dedicated vehicles.

This best practice complements current motor vehicle event data collection guidance for crash reconstruction in the pursuit of identifying ADS-DV-relevant lessons learned in critical driving scenarios. This complements crash recon-struction guidance, including 49 CFR Volume 6 Part 563 and the SAE event reconstruction standards, including J1698, J1698-1, J1698-2, J1698-3, and J3197. Part 563 supports “effective crash investigations and for analysis of safety equipment performance” [6] but does not consider ADS-equipped vehicles. SAE J1698-1 specifies data collection “useful for analyzing vehicle crash and crash-like events.” SAE J1698-1 specifically recommends data elements for ADS-equipped vehicles that capture ADS mode, control actions, and fallback-ready user intervention, but these are insufficient for crash reconstruction. To further address the needs of crash reconstruction for ADS-equipped vehicles, SAE J3197 provides guidance on additional data elements for helping determine what ADS sensors saw and ADS requested vehicle motion control. None of these documents have focused on data collection for ADS developers and manufacturers to identify lessons learned in critical driving scenarios. Furthermore, J3197 applies to all ADS-equipped vehicles, whereas this document is tailored to fleet operated ADS-DVs that are subject to narrower set of considerations[1]. In comparison to the other data collection guidance, the focus on lessons learned and the application only to fleet-operated ADS-DVs results in a broader definition of event, a more extensive list of data elements, and a tailored discussion of data prioritization, retrievability, survivability, storage, and traceability considerations not found in other documents.

This best practice further contributes to data collection guidance by offering recommendations that pertain specifically to fleet-operated ADS-DVs and collecting additional data elements in support of better characterizing elements of the driving scenario and the ADS response. The additional data elements recommended in this best practice will help identify lessons learned across ADS developers and manufactures and improve industry-wide safety knowledge and resilience. Lessons learned enable information sharing with other ADS developers and manufacturers. This best practice also provides guidance relating to data prioritization, availability, and processing not found in the other referenced documents.

This best practice has been developed to support event analysis in the determination of what the ADS thought was important (e.g., objects and environment), how the ADS commanded the vehicle (e.g., longitudinal and lateral control), and how the vehicle control systems responded. The data may be valuable for identification of lessons learned about ADS-specific driving hazards, and ultimately lead to improved ADS design by providing a better understanding of the circumstances and actions that create hazards in critical driving scenarios.

1.1 Purpose

The guidance provided in this document is intended for use by the technical community (developers, manufacturers, testers, etc.) and event analysts, as well as safety researchers, municipalities, and infrastructure owner-operators (IOOs), and the general public.

Industry is motivated to learn from collision events involving ADS equipped vehicles, and through this document the AVSC seeks to anticipate the types of data collection practices that will enable learning and improving ADS safety performance. Common approaches to data collection are increasingly important as technology readiness level increases. This best practice is applicable at higher levels of technology readiness, including commercial

[1] Fleet operated ADS-DVs may differ from other ADS-equipped vehicles in several ways, including types of use cases supported, DDT fallback roles (i.e., ADS performs DDT fallback instead of a human), and vehicle ownership models.

deployments and testing of mature technologies on public roads prior to commercial deployment. It is important to note that ADS technology is still in development, and this document is expected to evolve as technology matures and more data becomes available. Stakeholders can compare the best practices identified against their procedures or use them as a benchmark. ADS developers and manufacturers should follow the spirit of these best practices, but it is recognized that each system developer may need to tailor the application of best practices to their particular implementations.

The document describes data elements that may be used to establish what the ADS thought was important (e.g., objects detected), establish when it sensed it or them, visually represent these data for event analysis, and help determine ADS-related collision factors. It is important to note that event analysis uses many sources of information to determine collision factors, including EDR data, human eyewitness accounts, geometric analysis, and scene analysis. As such, ADS-related data can supplement a full reconstruction of the events.

2. References

2.1 Applicable Documents

The following publications were referenced during the development of this document. Where appropriate documents are cited.

2.1.1 SAE Publications

AVSC00002202004	AVSC Best Practice for Describing an Operational Design Domain: Conceptual Framework and Lexicon
AVSC00003202006	AVSC Best Practice Passenger-Initiated Emergency Trip Interruption
ISO/SAE DIS 21434	Road Vehicles – Cybersecurity (unapproved draft published 2020-02-12)
SAE J670_200801	Vehicle Dynamics Terminology
SAE J1698_201703	Event Data Recorder
SAE J1698-1_201805	Event Data Recorder – Output Data Definition
SAE J1698-2_201803	Event Data Recorder – Retrieval Tool Protocol
SAE J1698-3_201512	Event Data Recorder – Compliance Assessment
SAE J3016_201806	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
SAE J3018_201909	Safety Relevant Guidance for On-Road Testing of SAE level 3,4,5 Prototype Automated Driving System (ADS)-Operated Vehicles
SAE J3061_201601	Cybersecurity Guidebook for Cyber-Physical Vehicle Systems
SAE J3197_202004	Automated Driving System Data Logger

Unless otherwise indicated, the latest issue of SAE publications apply. Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

2.1.2 Other Documents

[1] Federal Register, "Notice of proposed rulemaking, Docket No. NHTSA-2004-18029," 2004. [Online]. Available: https://www.federalregister.gov/documents/2004/06/14/04-13241/event-data-recorders.

[2] Federal Register, "Final rule, Docket No. NHTSA-2006-25666," 2006. [Online]. Available: https://www.federalregister.gov/documents/2006/08/28/06-7094/event-data-recorders.

[3] Federal Register, "'Final rule; response to petitions for reconsideration, Docket No. NHTSA–2008–0004," 2008. [Online]. Available: https://www.federalregister.gov/documents/2008/01/14/E8-407/event-data-recorders.

[4] Federal Register, "Final rule; response to petitions for reconsideration, Docket No. NHTSA–2011–0106," 2011. [Online]. Available: https://www.federalregister.gov/documents/2011/08/05/2011-19214/event-data-recorders.

[5] Federal Register, "Final rule; response to petitions for reconsideration, Docket No. NHTSA-2012-0099," 2012. [Online]. Available: https://www.federalregister.gov/documents/2012/08/09/2012-19580/event-data-recorders.

[6] US Code, "49 CFR Part 563, Event Data Recorders," [Online]. Available: https://www.govinfo.gov/content/pkg/CFR-2019-title49-vol6/xml/CFR-2019-title49-vol6-part563.xml.

[7] M. L. Howe and L. M. Knott, "The fallibility of memory in judicial processes: Lessons from the past and their modern consequences.," *Memory*, Vol. 23 no. 5 p. 633–656, 2015.

[8] AAA, "Accident Reporting," 2020. [Online]. Available: https://drivinglaws.aaa.com/tag/accident-reporting/.

[9] J. Stewart, "Why People Keep Rear-Ending Self-Driving Cars," October 2018. [Online]. Available: https://www.wired.com/story/self-driving-car-crashes-rear-endings-why-charts-statistics/.

[10] European Union, "General Data Protection Regulation, OJ L 119, 04.05.2016; cor. OJ L 127, 23.5.2018," May 2018. [Online]. Available: https://gdpr-info.eu/.

[11] California, "California Consumer Privacy Act, Title 1.81.5," 2019. [Online]. Available: https://www.oag.ca.gov/privacy/ccpa.

[12] European Automobile Manufacturers Association, "Articulated Pedestrian Target Specifications, V1.0," 2015. [Online]. Available: https://www.acea.be/uploads/publications/Articulated_Pedestrian_Target_Specifications_version_1.0.pdf.

[13] European New Car Assessment Program, "Test Protocol - AEB VRU systems, Version 3.0.2," July 2019. [Online]. Available: https://cdn.euroncap.com/media/53153/euro-ncap-aeb-vru-test-protocol-v302.pdf.

[14] European Automobile Manufacturers Association, "Bicyclist target ACEA specifications Version 1.0," November 2018. [Online]. Available: https://www.acea.be/uploads/publications/Bicyclist_target-ACEA_specifications.pdf.

3. Definitions

3.1 ADS-DEDICATED VEHICLE (ADS-DV) (SAE_J3016_201806)

A vehicle designed to be operated exclusively by an SAE level 4 or level 5 ADS for all trips within its given operational design domain (ODD) limitations (if any).

3.2 DATA RETRIEVAL TOOL

The device or system that extracts the recorded data from storage and provides the data to the Data Access Tool.

3.3 DATA ACCESS TOOL

The device or system that processes and displays data in a usable form for authorized users.

NOTE: Data retrieval and access tools may be packaged in the same tool or separately. These tools may not require access to the vehicle if, for example, data is stored in a cloud repository. These tools may be software based if data is stored in a cloud repository and provided electronically to authorized users.

3.4 DYNAMIC DRIVING TASK (DDT) (SAE_J3016_201806)

All of the real-time operational and tactical functions required to operate a vehicle in on-road traffic, excluding the strategic functions such as trip scheduling and selection of destinations and waypoints, and including without limitation:

Lateral vehicle motion control via steering (operational);

Longitudinal vehicle motion control via acceleration and deceleration (operational);

Monitoring the driving environment via object and event detection, recognition, classification, and response preparation (operational and tactical);

Object and event response execution (operational and tactical);

Maneuver planning (tactical); and

Enhancing conspicuity via lighting, signaling and gesturing, etc. (tactical).

3.5 DYNAMIC DRIVING TASK (DDT) FALLBACK (SAE_J3016_201806)

The response by the *user* to either perform the *DDT* or achieve a *minimal risk condition* after occurrence of a *DDT performance-relevant system failure(s)* or upon *operational design domain* (*ODD*) exit, or the response by an *ADS* to achieve *minimal risk condition*, given the same circumstances.

NOTE 4: At levels 4 and 5, the *ADS* must be capable of performing the *DDT fallback* and achieving a *minimal risk condition*. Level 4 and 5 *ADS*-equipped *vehicles* that are designed to also accommodate *operation* by a *driver* (whether *conventional* or *remote*) may allow a *user* to perform the *DDT fallback* if s/he chooses to do so. However, a level 4 or 5 *ADS* need not be designed to allow a *user* to perform *DDT fallback* and, indeed, may be designed to disallow it in order to reduce crash risk (see 8.9 in SAE_J3016_201806).

NOTE 5: While a level 4 or 5 *ADS* is performing the *DDT fallback*, it may be limited by design in speed and/or range of *lateral* and/or *longitudinal vehicle motion control* (i.e., it may enter so-called “limp-home mode”).

3.6 SALIENT [OBJECT/EVENT DETECTED]

An object, event, or factor relevant for performance of the dynamic driving task.

NOTE: In the case of an event, salient objects may be located at any position relative to the vehicle, including forward, rearward, and to the side.

4. Definition of Event

The definition of an event should account for the intent and needs of event analysis and safety research (improved safety), as well as the intended ADS functionality (i.e., fleet-operated ADS-DV performing the DDT and DDT fallback within a specific ODD). For the purposes of this document, *event* is defined as a collision or collision-like situation. Note that the words *crash* and *collision* are used interchangeably for the purposes of this document. A notable challenge is the lack of consensus for what constitutes a collision for event reporting purposes. Collision reporting requirements vary by state, for example, criteria may be described in terms of dollar value or impact with domesticated but not undomesticated animals [8]. Differentiating among these requirements may be challenging for an ADS to determine. The remainder of this document provides clarity and consistency for determining an event (collision).

The definition of an impact event for electronic data recording (EDR) is currently based on triggers, including a velocity change (see SAE J1698 Table 1) and the deployment of any non-reversible deployable protection device, such as an airbag, deployable knee bolster, or rollover event. This threshold is no longer sufficient to capture all collisions in ADS-DVs that might otherwise be detected by a human. Example events highlighting the difference between a triggering event and a human driver's ability to determine if a collision occurred include some collisions involving vulnerable road users (VRU) which may not be detectable within current restraints sensor capability. Other examples might include actions taken by the ADS-equipped vehicle, such as recording data, pulling over, ceasing ADS operation, and facilitating investigation of the collision. It is important to note that not all events that result in an impact will meet the conditions for event reporting and data recording, for example, a small rock hitting the windshield.

There may be other events of interest for ADS-DV event analysis, for example "near-miss" events that do not result in a collision. "Near miss" events are beyond the scope of this best practice, because there is not yet a clear definition. As the understanding of event types that are of interest to ADS developers and manufacturers matures, and definitions agreed, this best practice may be updated to reflect this understanding.

4.1 Conditions for Event Data Recording

This best practice recommends using all triggering conditions specified in the SAE J1698 family of standards and additional triggering conditions set forth in this section for consideration. Data recording occurs if the ADS has been engaged at any point during the 5 seconds prior to the triggering condition being met. Triggering conditions include:

- (from SAE J1698) Event resulting in the deployment of a non-reversible restraint, such as airbags
- (from SAE J1698) Event resulting in a change in vehicle velocity that equals or exceeds 8 km/h within a 150 ms interval
- Events causing failures that result in the ADS performing DDT fallback
- "Other events" - ADS developers and manufacturers should address other types of impacts not covered by SAE J1698 or NHTSA 49 CFR Part 563 [6] including events for which a human-operated vehicle would be required to stop as governed by road regulations (e.g., VRU collisions)

"Other events," pose technical challenges associated with light-impact detection and classification, such as object classification, the nature of the impact, and the availability of standard testing methods and equipment.[2] Not all cases of contact between the ADS-operated vehicle and other objects could cause injury to persons or negatively influence ADS functionality. Extreme examples where contact with an ADS would not cause harm are: if a pedestrian places their hand on the front of nearby vehicles as they cross a crowded crosswalk, or an event where a wheel strikes a curb. Certain road regulations reference criteria such as damage dollar amounts and distinctions between domesticated and undomesticated animals, which can be challenging to objectively quantify or determine using ADS-DV on-board systems. The definition of data collection triggering is rapidly evolving to consider new data elements as they become available in order to meet the needs of ADS event analysis.

5. Data Elements

Data elements are prioritized based on their anticipated value to event analysis activities. As ADS technologies are deployed and experience is gained, it is possible that this list of data elements will evolve.

A total of 39 data elements have been identified to support various aspects of event analysis and should be recorded where such information (or features) is already a part of the intended functionality. For the purpose of this document,

[2] Existing test procedures and test targets for pedestrian detection (e.g., European New Car Assessment Program (Euro NCAP) testing of Automatic Emergency Braking (AEB) systems [13] supported by European Automobile Manufacturers Association (ACEA) specifications [12] [14]) do not fully support the needs of detecting triggering events for ADS light-impact event detection and analysis. These test targets were developed for forward vision- and radar-based detection. They do not accurately represent many characteristics of road users such as mass, detailed physical attributes, and behavior. As technology matures, new event classification schemes and the equipment to execute them may need to be developed to support detection of light-impact triggering events for ADS event analysis.

data elements have been organized into four categories based on their contribution to event analysis: (1) Vehicle Control ("What the ADS did"), (2) Saliency ("What the ADS thought was important"), (3) Sensing ("What the sensors saw"), and (4) General Parameters.

Please note that definitions for data elements are provided in Section 5.2.

Vehicle Control ("What the ADS did")

- ADS Action – ADS Requested Gear (from SAE J3197)
- ADS Action – ADS Requested Hazard Flasher
- ADS Action – ADS Requested Headlights
- ADS Action – ADS Requested Lateral Vehicle Motion Control (adapted from SAE J3197)
- ADS Action – ADS Requested Longitudinal Vehicle Motion Control (adapted from SAE J3197)
- ADS Action – ADS Requested Pedestrian Communication Device
- ADS Action – ADS Requested Turn Signals
- ADS Determined – Reference Vehicle Speed (adapted from SAE J1698-1)
- ADS Determined – Reference Vehicle Steering Position
- ADS Mode (adapted from SAE J1698-1)
- Failure Mitigation Strategy Activated (from SAE J1698-1)
- Vehicle Indicated – Brake Delivered Effort Actual (adapted from SAE J1698-1)
- Vehicle Indicated – Gear Position (from SAE J1698-1)
- Vehicle Indicated – Hazard Flasher Status (from SAE J1698-1)
- Vehicle Indicated – Headlight Status (adapted from SAE J1698-1)
- Vehicle Indicated – Powertrain Delivered Effort Actual (adapted from SAE J1698-1)
- Vehicle Indicated – Steering Position Actual (adapted from SAE J1698-1)
- Vehicle Indicated – Speed (adapted from SAE J1698-1)
- Vehicle Indicated – Turn Signal Status (from SAE J1698-1)

Saliency ("What the ADS thought was important")

- Salient Object(s) Detected – Classification
- Salient Object(s) Detected – Identification Number (ID)
- Salient Object(s) Detected – Lane Delineation and Channelization
- Salient Object(s) Detected – Relative Position (from SAE J3197)
- Salient Object(s) Detected – Relative Velocity (adapted from SAE J3197)
- Salient Object(s) Detected – Traffic Control Device State (adapted from SAE J3197)
- Salient Object(s) Detected – Vehicle Backup Light Status
- Salient Object(s) Detected – Vehicle Brake Lights Status
- Salient Object(s) Detected – Vehicle Emergency Light Status
- Salient Object(s) Detected – Vehicle Hazard Flasher Status
- Salient Object(s) Detected – Vehicle Turn Signal Status
- Salient Emergency Vehicle Warning(s) Detected (from SAE J3197)

Sensing ("What the sensors saw")

- Visual Representation (adapted from SAE J3197)
- Other Sensor and Input Data

General Parameters

- ADS Relevant Health Status (adapted from SAE J1698-1)
- Data Record Trigger Type (adapted from SAE J3197)
- Passenger-Initiated Emergency Trip Interruption Activation (adapted from SAE J3197)
- Time of day (adapted from SAE J3197)
- Vehicle Location (adapted from SAE J3197)
- Vehicle Identification Number (VIN) (from SAE J1698-1)

5.1 Data Element Prioritization

Vehicle design, including vehicle architecture, data collection systems, and power systems should be developed in a way to prioritize collection and availability of these elements post-collision for the purposes of event analysis. Data elements are prioritized into three tiers based on anticipated value to event analysis. Each data element contributes to a better understanding of the circumstances leading up to an event. This is a framework for ADS developers and manufacturers to prioritize recording data elements among limited resources and data recording considerations. ADS developers and manufacturers may choose to prioritize any data elements into the top tier at their discretion.

Recognizing that each ADS is unique and each collision is different, there may be system-specific or collision-specific factors that render certain data elements high priority. For example, if an ADS has determined that there is a blocked sensor and it is operating in a degraded mode but still functional, recording the sensor data may be prioritized as it may help explain system performance. In another example, a vehicle power grid failure that will result in fault code logging may lead to no data element recoding capability. All data elements are recorded on an as-applicable and as-available basis.

Priority 1 - These are data elements considered likely to be most relevant to ADS-related event analysis. As such, these data elements are most important to recover from a vehicle.

Priority 2 - These are data elements considered to offer secondary value to ADS-related event analysis. As such, these data elements are important to recover from a vehicle, as long as recording of Priority 1 data elements is not negatively impacted.

Priority 3 - These are data elements considered to offer tertiary value to ADS-related event analysis. As such, these data elements are important to recover, as long as recording of Priority 1 and 2 data elements is not negatively impacted.

The priority for each data element is specified in the definitions in Section 5.2.

5.2 Data Element Definitions

5.2.1 ADS Action – ADS Requested Gear

From SAE J3197. The transmission gear commanded by the ADS. This data element relates to the Vehicle Indicated – Gear Position (5.2.32) data element.

Unit	Not Applicable
Minimum Resolution	As applicable per transmission (typical values are Drive, Park, Reverse, Neutral, etc.)
Minimum Range	N/A
Minimum Accuracy	N/A
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	4 samples / second
Priority	1

5.2.2 ADS Action – ADS Requested Hazard Flashers

Flag indicating whether the ADS has requested that the hazard lights be turned on. This data element relates to the Vehicle Indicated - Hazard Flasher Status (5.2.33) data element. Specifications are consistent with J1698-1, see Hazard Flasher Status.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.3 ADS Action – ADS Requested Headlights

Flag indicating whether the ADS has requested that the headlights be turned on. This data element relates to the Vehicle Indicated - Headlight Status (5.2.34) data element.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.4 ADS Action – ADS Requested Lateral Vehicle Motion Control

Adapted from SAE J3197, which defines this data element as the "rate of acceleration requested by the ADS with the intent of increasing or decreasing the vehicle's lateral motion. As the technology used to accelerate the vehicle may vary, the unit, minimum resolution, minimum range and minimum accuracy may be defined by the system developer." This best practice recommends a recording frequency of 5 samples per second, an increase from the 4 samples per second used in SAE J3197. Note that this document applies only to ADS-DVs, and as such the definition of lateral vehicle motion control may differ from "Steering Input" described in SAE J1698-1, which defines steering input in terms of the angular position of the steering wheel where the value of zero (0 degree) indicates its neutral position (i.e., straight). For example, ADS-DVs may not have a steering wheel. This data element relates to other lateral vehicle motion control data elements, including ADS Determined – Reference Vehicle Steering Position (5.2.9) and Vehicle Indicated – Steering Position Actual (5.2.31) data elements.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	1

5.2.5 ADS Action – ADS Requested Longitudinal Vehicle Motion Control

Adapted from SAE J3197, which defines this data element as the "rate of acceleration requested by the ADS with the intent of increasing or decreasing the vehicle's motion." This best practice recommends expressing units in torque if available, however, other units are acceptable, including force or acceleration. This document recommends a recording frequency of 5 samples per second, a slight increase from the 4 samples per second used in SAE J3197. This data element relates to other longitudinal vehicle motion control data elements, including ADS

Determined – Reference Vehicle Speed (5.2.8), Vehicle Indicated – Brake Delivered Effort Actual (5.2.28), Vehicle Indicated – Powertrain Delivered Effort Actual (5.2.29), and Vehicle Indicated – Speed (5.2.30) data elements.

Unit	Preferred Unit - Torque (Nm)
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	1

5.2.6 ADS Action – ADS Requested Pedestrian Communication Device

If the ADS controls a device for communicating with pedestrians, this data element refers to the output of this device.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.7 ADS Action – ADS Requested Turn Signals

Flag indicating whether the ADS has requested that the turn signals be turned on. This data element relates to the Vehicle Indicated – Turn Signal Status (5.2.35) data element.

Unit	Not Applicable
Minimum Resolution	Left, Right, None
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.8 ADS Determined – Reference Vehicle Speed

Adapted from SAE J1698-1. The vehicle reference speed as determined by the ADS. If the ADS determines multiple speed values, these values may be recorded separately, whereas SAE J1698-1 only specifies one value. This document recommends a recording frequency of 5 samples per second, an increase from the 2 samples per second used in SAE J1698-1. This data element relates to other longitudinal vehicle motion control data elements, including ADS Action – ADS Requested Longitudinal Vehicle Motion Control (5.2.5), Vehicle Indicated – Brake Delivered Effort Actual (5.2.28), Vehicle Indicated – Powertrain Delivered Effort Actual (5.2.29), and Vehicle Indicated – Speed (5.2.30) data elements.

Unit	km/h
Minimum Resolution	1
Minimum Range	200
Minimum Accuracy	±1
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	2

5.2.9 ADS Determined – Reference Vehicle Steering Position

The vehicle reference steering angle as determined by the ADS. If the ADS determines multiple steering position values, these values may be recorded separately. This data element relates to other lateral vehicle motion control data elements, including ADS Action – ADS Requested Lateral Vehicle Motion Control (5.2.4) and Vehicle Indicated – Steering Position Actual (5.2.31) data elements.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	2

5.2.10 ADS Mode

Adapted from SAE J1698-1, with the following clarifications:

DDT (nominal) – As defined in SAE J3016.

DDT fallback (non-nominal) – As defined in SAE J3016. Note that minimal risk maneuver (MRM) is considered a subset of potential DDT fallback states and that the value of DDT fallback is recorded only if MRM is not currently underway.

Request to intervene – Not applicable to this document; this does not preclude a vehicle having the ability for a human to control the vehicle.

Minimal risk maneuver (MRM) – The term MRM is not yet defined by SAE International. Defining this term may be considered in future revisions of this best practice. Until a definition is provided, the use and interpretation of this state is manufacturer-specific and situationally-dependent based on the ODD.

Minimal risk condition (MRC) – As defined in SAE J3016.

Dis-engaged – Vehicle is not operating in automated mode. The ADS is not engaged, for example if it is shut off while in the MRC. This is not an indication that the ADS is not able to operate. The MRC state is different from dis-engaged state because the ADS may still be engaged in some fashion while in the MRC, e.g., performing self-diagnostics or preparing to drive once issues have been addressed.

Not-operating – ADS is incapacitated, for example a condition that triggers a failure mitigation strategy would be considered a not-operating state.

Unit	Not Applicable
Minimum Resolution	DDT (nominal), DDT fallback (non-nominal), Minimal risk maneuver, Minimal risk condition, Dis-engaged, Not-operating
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.11 ADS Relevant Health Status

Adapted from SAE J1698-1, which includes operating or indicator status. This data element includes relevant fault codes or other indications of vehicle system or ADS faults.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.12 Data Record Trigger Type

Adapted from SAE J3197 with the additional trigger types defined in this best practice, i.e., “ADS Perceived Collision” and “ADS Unable to Perform DDT.” This element describes the type of trigger associated with the event record.

Unit	Not Applicable
Minimum Resolution	Deployment, Delta-V Threshold, Pedestrian Device, Rollover, ADS Perceived Collision, ADS Unable to Perform DDT
Minimum Range	N/A
Minimum Accuracy	N/A
Minimum Recording Interval	0 seconds relative to time zero
Minimum Recording Frequency	1 sample
Priority	1

5.2.13 Failure Mitigation Strategy Activated

As defined in SAE J1698-1 and SAE J3016. Note that “ADS incapacitated” may be manufacturer dependent. Figure 13 in SAE J3016 shows this state change.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.14 Other Sensor and Input Data

ADS developers and manufacturers may choose to record other sensor data not utilized in Visual Representation. Examples of other sensor data include LIDAR, RADAR, and camera data, and information communicated to the vehicle. Some examples of information communicated to the ADS can be traffic light status or work zone status via vehicle-to-everything (V2X) or cloud-based communication. ADS developers and manufacturers should describe:

- Signal processing which is applied pre-recording, e.g., amplification or adjustments for atmospheric conditions, which may be advantageous in poor lighting and weather conditions.

- Positions and tracks for detected objects.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	Manufacturer Specific
Priority	3

5.2.15 Passenger-Initiated Emergency Trip Interruption Activation

Adapted from J3197 to be consistent with AVSC Best Practice Passenger-Initiated Emergency Trip Interruption, see Passenger-Initiated Emergency Stop (PES) from J3197 for reference. May be activated by any passenger-initiated emergency trip interruption system, if equipped. It should be noted that these systems may have many stages before being activated.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.16 Salient Object(s) Detected - Classification

If the ADS classifies objects, this data element provides that classification.

Note: The ADS developers and manufacturers should define what level of classification, if any, their system utilizes.

Note: Classification is inherently a challenging task and accuracy depends on a variety of factors. Similar to human perception, there may be periods during which the system may misclassify and reclassify an object.

Example: Classification may include vehicle, bicycle, pedestrian, unclassified, static or dynamic, traffic control device, other (e.g., structure, light pole), if applicable.[3]

Unit	Manufacturer Specific
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.17 Salient Object(s) Detected – Identification Number (ID)

The identification number (ID) is used to track data associated with the same object. Only objects that the ADS is responding to should be recorded. Object salience is determined by the ADS.

[3] The *AVSC Best Practice for Describing and Operational Design Domain: Conceptual Framework and Lexicon* suggests 10 categories for other road users. This list is a good reference for classification purposes: 1. Automobile, 2. Bicyclist, 3. Pedestrian, 4. Transit vehicle, 5. Truck, 6. Motorcycles and scooters, 7. Micromobility vehicles as defined by SAE J3194_201911, 8. Wheelchairs/wheeled mobility assistance devices, 9. Emergency vehicles, and 10. Other vehicles (e.g., golf-carts, garbage trucks, postal vehicles, street sweepers, etc.)

Note: In some cases, the object ID may not be consistent across all recorded values in the time series, e.g., when the object temporarily leaves and then re-enters the ADS-DV's field-of-view.

Note: Objects within a group (e.g., number of pedestrians at crosswalk) may not be individually identified.

Unit	Manufacturer Specific
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

Salient Object Attributes

All data elements starting with the naming convention of "Salient Object…" relate to a particular Salient Object ID and should correspond to that Salient Object ID, e.g., from initial assignment through data retrieval.

5.2.18 Salient Object(s) Detected – Lane Delineation and Channelization

This data element facilitates analysis of the ADS-determined drivable surface of the road. This data element is implementation specific.

Examples of the types of lane markers that this data element relates to include white, yellow, and orange lines, dashed and solid lines, and temporary lane markers (e.g., cones, barriers). If an implementation does not use lane markings, they are not considered salient, thus this data element will not be recorded.

Lane delineation and channelization are combined into a single data element because these data elements both relate to determining where the ADS-DV may drive. For example, an ADS-DV may not be using lane markings to perform the DDT because traffic cones are arranged to create a temporary traffic pattern that is inconsistent with the lane markings.

Unit	Manufacturer Specific
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.19 Salient Object(s) Detected – Relative Position

From SAE J3197. Coordinates relative to the ADS-DV defined coordinate system, which may be system specific.

Unit	X, Y, Z Relative to manufacturer reference axis, for example vehicle axis system (X_v, Y_d, W_v). Units may be system specific, for example, feet or latitude, longitude.
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.20 Salient Object(s) Detected – Relative Velocity

Adapted from SAE J3197, which only includes heading. This document recommends heading and speed, expressed as a velocity vector. The velocity vector is defined as the first derivative of position with respect to time of the object reference point. This value may be determined by differentiating the Salient Object(s) Detected – Relative Position (5.2.19) data element over time.

Unit	V_X, V_Y, V_Z, Relative to manufacturer reference axis and point (see Salient Object(s) Detected – Relative Position (5.2.19))
Minimum Resolution	Manufacturer Specific*
Minimum Range	Manufacturer Specific*
Minimum Accuracy	Manufacturer Specific*
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

* Should be of sufficient resolution, range, and accuracy such that recorded events can be reconstructed and interpreted by a human observer.

5.2.21 Salient Object(s) Detected – Traffic Control Device State

Adapted from SAE J3197, which does not provide a definition for this parameter. This data element is implementation specific. The goal of this data element is to determine what the ADS determined to be the salient traffic control devices and the state of those traffic control devices. Examples of the types of traffic control devices that this data element may include are active traffic control device signals, passive traffic control devices, and others from the Manual of Uniform Traffic Control Devices (MUTCD).

Note: Values and use of this parameter may be implementation specific.

Note: The ADS may be tracking multiple traffic lights at one time.

Note: The traffic control device that pertains to ADS right of way will be flagged as such.

Examples: Types of data that may be used include sign classification (stop sign, yield), signal state (red, yellow, green, turn arrows, not operational), pedestrian signals (e.g., walk, don't walk), and temporary traffic control devices identified (examples may include flagmen).

Unit	Manufacturer Specific Description of Traffic Control Device Type and State
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.22 Salient Object(s) Detected – Vehicle Backup Light Status

Flag indicating whether a salient vehicle's backup lights are activated.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.23 Salient Object(s) Detected – Vehicle Brake Light Status

Flag indicating whether a salient vehicle's brake lights are activated.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.24 Salient Object(s) Detected – Vehicle Emergency Light Status

Flag indicating that an emergency vehicle has been detected in an emergency mode. This differs from Salient Emergency Vehicle Warning(s) Detected (5.2.27) in that this data element applies to a salient object.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.25 Salient Object(s) Detected – Vehicle Hazard Flasher Status

Flag indicating whether a salient vehicle's hazard lights are activated.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.26 Salient Object(s) Detected – Vehicle Turn Signal Status

Flag indicating whether a salient vehicle's turn lights are activated.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.27 Salient Emergency Vehicle Warning(s) Detected

From SAE J3197, see Environmental Input – Emergency Vehicle Warning Flag. This flag indicates that an emergency vehicle has been detected in an emergency mode whose presence is relevant to performance of the DDT by the ADS. In comparison to Salient Object(s) Detected – Vehicle Emergency Light Status (5.2.24), this data element does not have to be associated with a specific detected object and is flexible to accommodate non-visual means of detection, e.g., sound based. For example, this flag may be positive even if the emergency vehicle is occluded around the corner of a building.

Unit	Not Applicable
Minimum Resolution	Vision, Sound, V2X or other communications, Other (may include combinations of detection methods if multiple are valid)
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.28 Vehicle Indicated – Brake Delivered Effort Actual

Adapted from SAE J1698-1, see Brake System Internal Pressure. This data element is intended to capture the degree of deceleration effort undertaken by the vehicle, not just whether the brakes are applied as SAE J1698-1 specifies. The interpretation of the data may depend on vehicle architecture, for example it may include application of brakes and other deceleration actions such as regenerative braking. This data element relates to other longitudinal vehicle motion control data elements, including ADS Action – ADS Requested Longitudinal Vehicle Motion Control (5.2.5), ADS Determined – Reference Vehicle Speed (5.2.8), Vehicle Indicated – Powertrain Delivered Effort Actual (5.2.29), and Vehicle Indicated – Speed (5.2.30) data elements.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	1

5.2.29 Vehicle Indicated – Powertrain Delivered Effort Actual

Adapted from SAE J1698-1, see Throttle Position. This data element is intended to capture the degree of acceleration effort undertaken by the vehicle. May depend on vehicle architecture (e.g., internal combustion engines may have a torque sensor and electric drivetrains may use current at the motor). This data element relates to other longitudinal vehicle motion control data elements, including ADS Action – ADS Requested Longitudinal Vehicle Motion Control (5.2.5), ADS Determined – Reference Vehicle Speed (5.2.8), Vehicle Indicated – Brake Delivered Effort Actual (5.2.28), and Vehicle Indicated – Speed (5.2.30) data elements.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	1

5.2.30 Vehicle Indicated – Speed

Adapted from SAE J1698-1, see Speed, Vehicle Indicated. The speed indicated by a manufacturer-designated subsystem designed to indicate the vehicle's ground travel speed during vehicle operation. Vehicle speed may also be determined from other data elements, such as the vehicle location and time of day. This document recommends a recording frequency of 5 samples per second, an increase from the 2 samples per second used in SAE J1698-1. This data element relates to other longitudinal vehicle motion control data elements, including ADS Action – ADS Requested Longitudinal Vehicle Motion Control (5.2.5), ADS Determined – Reference Vehicle Speed (5.2.8), Vehicle Indicated – Brake Delivered Effort Actual (5.2.28), and Vehicle Indicated – Powertrain Delivered Effort (5.2.29) data elements.

Unit	km/h
Minimum Resolution	1
Minimum Range	0 to 200
Minimum Accuracy	±1
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	2

5.2.31 Vehicle Indicated – Steering Position Actual

Adapted from SAE J1698-1, see Steering Input. This data element is intended to identify changes to lateral motion control relative to other data elements in event analysis. This differs from "Steering input" specified in SAE J1698-1 in that the angle is measured at the point of actuation, e.g., pinion, rather than at the steering wheel. This difference helps accommodate ADS-DVs, which may not have steering wheels. This document recommends a recording frequency of 5 samples per second, an increase from the 2 samples per second used in SAE J1698-1. This data element relates to other lateral vehicle motion control data elements, including ADS Action – ADS Requested Lateral Vehicle Motion Control (5.2.4) and ADS Determined – Reference Vehicle Steering Position (5.2.9) data elements.

Unit	Manufacturer Specific
Minimum Resolution	Manufacturer Specific
Minimum Range	Manufacturer Specific
Minimum Accuracy	Manufacturer Specific
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	5 samples / second
Priority	1

5.2.32 Vehicle Indicated – Gear Position

From SAE J1698-1, see Gear Position. This data element relates to the ADS Action – ADS Requested Gear (5.2.1) data element.

Unit	N/A
Minimum Resolution	As applicable per transmission (typical values are Drive, Park, Reverse, Neutral, etc.)
Minimum Range	N/A
Minimum Accuracy	N/A
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.33 Vehicle Indicated – Hazard Flasher Status

From J1698-1, see Hazard Flasher Status. This data element relates to the ADS Action – ADS Requested Hazard Flashers (5.2.2) data element.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.34 Vehicle Indicated – Headlight Status

Adapted from J1698-1, see Headlight Status. This document recommends -5.0 seconds relative to time zero to start recording, differing from the -1.1 seconds recommended in SAE J1698-1; and this document recommends a minimum recording frequency of 2 samples / second, whereas SAE J1698-1 does not provide a minimum recording frequency. This data element relates to the ADS Action – ADS Requested Headlights (5.2.3) data element.

Unit	Not Applicable
Minimum Resolution	Yes or No
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.35 Vehicle Indicated – Turn Signal Status

From SAE J1698-1, see Turn Signal Status. This data element relates to the ADS Action – ADS Requested Turn Signals (5.2.7) data element.

Unit	Not Applicable
Minimum Resolution	Left, Right, None
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	2

5.2.36 Time of day

Adapted from SAE J3197, with the difference that this best practice combines 3 data elements from SAE J3197 (Hour, Minute, Second) into a single data element. This data should include date and time of day (i.e., clock time).

Unit	YYYY:MM:DD:HH:MM:SS
Minimum Resolution	1 second
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 seconds
Minimum Recording Frequency	1 sample
Priority	1

5.2.37 Vehicle Location

Adapted from SAE J3197, with the difference that this best practice combines 3 data elements from SAE J3197 (Latitude, Longitude, and Heading) into a single data element, increases the recording interval from -1.1 seconds to -5.0 seconds, and adds minimum recording frequency of 2 samples / second.

Unit	Manufacturer Specific
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	2 samples / second
Priority	1

5.2.38 Vehicle Identification Number (VIN)

From SAE J1698-1. Full VIN.

Unit	Manufacturer Specific
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	1 sample
Priority	1

5.2.39 Visual Representation

Adapted from SAE J3197. This data provides a reasonably human viewable image of the scene necessary to understand the event. Humans should be able to discern salient objects or traffic control devices and their positions, and, if directly observable from the ADS-DV's vantage point, status of turn signals, hazard lights, and headlights subject to the resolution limitations of the recorded data. ADS manufacturers and developers may collect this data through a number of mechanisms, such as cameras, LIDAR, radar, ultrasonic sensors, and other means.

Data comprising a 360-degree field of view is recommended if available. Recorded angles may be reduced if the images are deemed to be irrelevant to the event or DDT performance. Please note that 360 field of vision does not imply there are no "blind spots" for a given event field of view. There may be times where an ADS determines that it is able to discern salient objects and traffic control devices with one or more sensors temporarily disabled, or with reduced recording frequency of those sensors. In such instances a recording frequency of 4 samples per second would not be required.

The goal of this data element is not to enable recreation of events in ADS components, but to study their performance. Signal processing may be applied pre-recording, e.g., compression, transforms (lens, color correction, exposure, contrast). This signal processing may result in a sufficiently different image than the original image used by the ADS for decision-making. Signal processing techniques that alter the image such that the goal of visual representation cannot be achieved, for example, segmentation and edge detection, are not recommended.

Note: Traditional collision reconstruction techniques can determine signage and lane markings without additional data collection.

Note: Lighting and weather conditions may reduce the coverage of the viewable image.

Unit	Image File
Minimum Resolution	Not Applicable
Minimum Range	Not Applicable
Minimum Accuracy	Not Applicable
Minimum Recording Interval	-5.0 to 0 second relative to time zero
Minimum Recording Frequency	4 samples / second
Priority	2

6. Visual Representation Considerations

Visual representation of salient objects and conditions leading up to an event may assist event analysis and analysis of safety equipment performance. The use of this data differs in nature from the way SAE J1698-1 and SAE J3197 are intended to be used. SAE J1698-1 and SAE J3197 are intended to be usable by a wide range of persons, such as a crash reconstructionist that may not be familiar with the systems. By contrast, this best practice will be used by ADS developers and manufacturers who will apply their knowledge of the ADS and tools available to identify lessons learned.

All recorded data elements are based on the ADS determination of their importance. ADS should also record data from 360-degrees around the ADS-DV (subject to earlier identified constraints) that may be retrieved by ADS developers and manufacturers and represented visually in a reasonably understandable manner. This data will provide useful visualizable context that complements other ADS-DV data (i.e., vehicle control, saliency, and general parameters). This visual representation data will produce more complete and objective facts about real-world collision events and provide event analysts additional context for circumstances leading up to the event. This visual representation does not need annotations for objects since ADS developers and manufacturers are capable of overlaying the salient object data and the visual representation data.

7. Recording Considerations

7.1 Interval and Frequency

This best practice generally recommends a recording interval of 5 seconds prior to time zero. The recording interval was determined based on SAE J1698, which specifies a recording interval of 5 seconds prior to the triggering event. This interval has been sufficient for collision reconstruction of human driven vehicles. AVSC will continue to monitor data interval needs for the purposes of event analysis.

The recording frequency was determined based on the needs of event analysis, and varies between data elements. A summary of data recording frequencies is given in Table 1.

Data recorded after time zero may be of value to event analysis for certain collision types. Recording data past time zero is recommended. Data availability (9.2) may affect the ability to record past time zero.

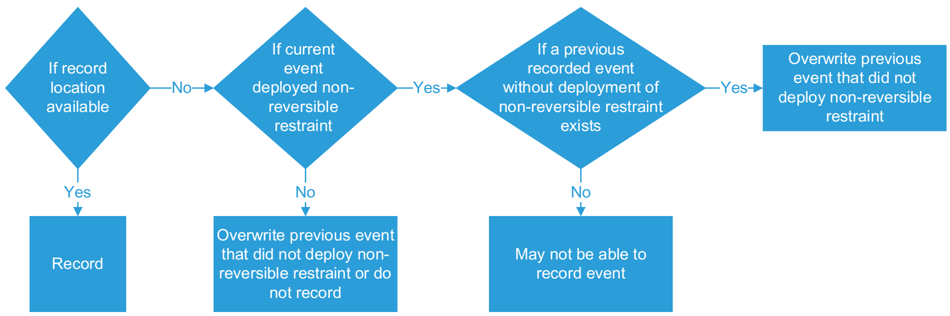
TABLE 1 Summary of data recording frequency.

Recording Frequency	Data Elements	Considerations
1 Sample	• Data Record Trigger Type • Time of day • Vehicle Identification Number	Signal not anticipated to change values during recording interval, or time series data can be determined by other means.
2 Samples per Second	• ADS Action – ADS Requested Hazard Flasher • ADS Action – ADS Requested Headlights • ADS Action – ADS Requested Pedestrian Communication Device • ADS Action – ADS Requested Turn Signals • ADS Mode • Failure Mitigation Strategy Activated • Vehicle Indicated – Gear Position • Vehicle Indicated – Hazard Flasher Status • Vehicle Indicated – Headlight Status • Vehicle Indicated – Tzurn Signal Status • Salient Object(s) Detected – Classification • Salient Object(s) Detected – Identification Number (ID) • Salient Object(s) Detected – Lane Delineation and Channelization • Salient Object(s) Detected - Relative Position • Salient Object(s) Detected - Relative Velocity • Salient Object(s) Detected - Traffic Control Device State • Salient Object(s) Detected - Vehicle Backup Light Status • Salient Object(s) Detected - Vehicle Brake Lights Status • Salient Object(s) Detected - Vehicle Emergency Light Status • Salient Object(s) Detected - Vehicle Hazard Flasher Status • Salient Object(s) Detected - Vehicle Turn Signal Status • Salient Emergency Vehicle Warning(s) Detected • ADS Relevant Health Status • Passenger Initiated Emergency Trip Interruption Activation • Vehicle Location	Consistent with related SAE J1698-1 data elements.
4 Samples per Second	• ADS Action – ADS Requested Gear • Visual Representation	Consistent with related SAE J3197 data elements. This frequency helps capture periodic signals, such as hazard lights of other vehicles.
5 Samples per Second	• ADS Action – ADS Requested Lateral Vehicle Motion Control • ADS Action – ADS Requested Longitudinal Vehicle Motion Control • ADS Determined – Reference Vehicle Speed • ADS Determined – Reference Steering Position • Vehicle Indicated – Brake Delivered Effort Actual • Vehicle Indicated – Powertrain Delivered Effort Actual • Vehicle Indicated – Speed • Vehicle Indicated – Steering Position Actual	Vehicle motion control related data may change more rapidly than other data elements during events. Therefore, a higher recording frequency is recommended.

7.2 Data Capture

The recording system should be capable of recording at least one event, subject to the conditions summarized in Figure 1.

FIGURE 1 Decision flow for recording multiple events.



7.3 Synchronization and Correlation

In order for data to be utilized for the purposes set forth in this document, there should be a method for synchronizing (i.e., aligning the data in the time domain) the event data elements recorded by multiple Electronic Control Units (ECUs). The data should align within the minimum recording frequency defined in Section 5 of this document - Data Elements. Data synchronization may utilize Zero from the EDR, global clock, etc.

Data recorded by multiple ECUs should also be correlatable, i.e., a relationship can be established among data associated with the same event, including data from EDR and ADS Data Logger. ADS data elements that may be used for correlation among data sets include odometer and ignition cycle.

8. Retrievability

8.1 Data Location

Event recorded data may be located in on-board systems, off-board systems (e.g., cloud storage), or both for storage and processing.

8.1.1 Data Retrieval and Access Tools

Tools for data retrieval and access should be available for authorized users to meet the intent of event analysis. An authorized user is an individual who has received authorization from the ADS developer or manufacturer to access data from the event.

8.1.2 Data Retrieval

Some recorded data may be retrieved in coordination with other recorded data elements, but not necessarily collected via the regulated EDR specified in 49 CFR Part 563 [6]. This data may be determined, recorded, or otherwise obtained via methods other than those specified for a regulated EDR.

8.1.3 Security and Data Integrity

The recording system should be tamper-resistant and compliant to ISO/SAE 21434 and SAE J3061 requirements for data security. The organizations should comply with industry accepted practices related to data integrity, such as ISO 9001:2015.

9. Survivability

The objective of data recording should be to reach a similar approach to survivability as described in 14 CFR Part 563.10 [6]. Currently, vehicles may not be able to meet these requirements because of limitations of current technology, e.g., distributed sensor and electronics architecture and memory capacity, which is still in development.

Data collection performance may differ between a fully-functioning vehicle and a vehicle that is operating in a degraded mode (e.g., in the process of achieving a minimal risk condition). A vehicle operating in a degraded mode may have lost certain capabilities that are necessary to effectively perform data capture, processing, and storage. For example, the availability of data may be limited by vehicle malfunction or by damage due to collision forces which prevent record completion. Record completion depends on data availability, which in turn depends on the availability of the sensing systems, communication systems, and power systems. For example, disruption to power or communications systems would limit the availability of data to be recorded. There are challenges with how data is buffered and written, which involves trade-offs between recording different data elements based on factors such as space efficiency, where data originates, and relevance to a particular event or series of events. ADS developers and manufacturers may be building ADS on top of existing vehicle architectures which can limit access to available power and communications systems and pose challenges based on the location of systems within the vehicle. It is expected that understanding of data collection needs will improve and vehicle technologies and architectures will evolve. These factors may motivate future enhancements to the approach described in this document.

9.1 Prioritized Recording of Data Elements

Data that is important to event analysis should be recorded. Data elements are prioritized in order to record as much useful data as possible for event analysis and accommodate situations where not all prioritized data can be recorded (e.g., vehicle damage due to collision forces prevents record completion). The intent is be able to determine what the ADS thought was important and how the ADS acted. Data elements are prioritized into three tiers. Within each tier, ADS developers and manufacturers may determine the best method for further prioritizing data elements.

In cases where not all data can be recorded, there may be significant variation in the interval over which data elements are recorded because of how data is buffered and written. Methods for buffering and writing data should consider trade-offs between the size, write time, and value to event analysis for each record. For example, it may take the same amount of time to record 10 records of one data element and 4 records of another data element because of the difference in size. An ADS developer and manufacturer may want to obtain a more complete record of a certain data element before recording other data elements within the same priority level because the more complete record provides more value to event analysis. The approach to prioritizing data elements may vary depending on the operational design domain and use case and may be determined by the manufacturer.

9.2 Data Availability for Sensing, Communications, and Power Systems

Completing a record involves many steps. Malfunction in, or damage to, any system responsible for completing these steps may negatively impact record completion. Data availability may depend on data being collected and processed (e.g., via a sensor and microprocessors), communicated (e.g., via a communication bus or wireless communication), and transitioned from a volatile to non-volatile state (a process that requires power systems).

Only data that has been received by the data recorder at time zero in the event recording sequence may be reliably captured and used for event analysis. Damaged systems (i.e., sensors and signal processing systems, communication systems, and vehicle power systems) may provide unreliable data or no data at all. ADS developers and manufacturers, at their discretion, to continue post-collision recording.

9.3 Survivability Considerations

As vehicles are deployed and technology evolves, there are several considerations related to data survivability.

9.3.1 Changes to Vehicle Architecture

One limitation of current ADS technology is that system developers are working with architectures that are expected to evolve.

9.3.2 Changes to Load Cases

Future survivability best practices should consider collision direction, velocity change, and relationship between collision population and ODD. For example, 6 O'clock of the ADS-DV (i.e., rear of the vehicle) may be a more frequent strike location [9]; however, current collision data is insufficient to make load case recommendations for ADS. Survivability requirements should be revisited as more data becomes available.

9.3.3 Changes to Demonstrating Compliance

It is too early to develop new survivability tests for data recording devices in ADS-DVs. ADS developers and manufacturers should use engineering judgement as to how best to ensure survivability of data. As with the type of data elements themselves, the means of demonstrating survivability requirements for recorded data are expected to evolve with ADS technology and as more data becomes available.

9.3.4 Opportunities for Improvements to Survivability

System developers should reduce disruptions that could prevent data record completion. Improvements in power systems, for example, may help when converting data from a volatile to non-volatile state. Redundant vehicle architecture that increases database transfer rates, backup power supply capacity, and memory read / write cycle durability, or decreases power demand of components is another example of opportunity for improving data survivability. Changes to vehicle systems like these will be phased in according to the automotive engineering design cycle.

10. Data Storage

Data recording may include off-board systems for storage and processing. Retention duration of recorded data is defined by the manufacturer.

11. Traceability

The ADS-DV should be uniquely identified for data traceability purposes. The industry standard and preferred method for identifying the ADS-DV is the Vehicle Identification Number (VIN). The VIN may be anonymized when the data is shared with authorized parties (e.g., eliminate the last six digits). It may be impossible to avoid identifying vehicle occupants while capturing event data. It should be noted that the recommendations in this best practice may relate to laws and regulations, e.g., European Union General Data Protection Regulation (GDPR) [10] and the California Consumer Privacy Act of 2018 [11], which are outside the scope of this document.

12. Summary

Data collection and recording enable event analysis and are important to understanding and improving the safety of ADS-DVs. This document represents a proactive step by members of industry to address data collection practices, specifically those related to data collection for the purpose of producing lessons learned (i.e., what an ADS "saw" and what actions an ADS took from critical driving scenarios that can be shared among industry to increase system-wide safety.

This document defines an event for event analysis as broader than triggering definitions for events in other existing data collection practices (including SAE J1698-1 and SAE J3197) in that it addresses other types of impacts not covered by SAE J1698-1 and events that cause failures that significantly degrade the ability of the ADS to operate safely resulting in the ADS performing fallback maneuvers to achieve a minimal risk condition.

Data elements considered to be important to event analysis are identified and defined, including units, minimum resolution, minimum range, minimum accuracy, minimum recording frequency, minimum recording interval, and prioritization tier. Data collection practices are expected to evolve with ADS-DV technology and considerations related to topics such as off-board storage, availability of vehicle subsystems (e.g., sensing, communications, and power systems), changing vehicle architectures, changing load cases, and changes to demonstrating compliance are addressed.

13. About Automated Vehicle Safety Consortium™

The objective of the Automated Vehicle Safety Consortium™ is to provide a safety framework around which automated vehicle technology can responsibly evolve in advance of the broad use of commercialized vehicles. The consortium will leverage the expertise of its current and future members and engage government and industry groups to establish safety principles and best practices. These technology-neutral principles are key considerations for deploying SAE level 4 and level 5 automated vehicles on public roads.

AVSC Vision:

Public acceptance of SAE level 4 and level 5 automated driving systems as a safe and beneficial component of transportation through industry consensus.

AVSC Mission:

The mission of the Automated Vehicle Safety Consortium™ (AVSC) is to quickly establish safety principles, common terminology, and best safety practices, leading to standards to engender public confidence in the safe operation of SAE level 4 and level 5 light-duty passenger and cargo on-road vehicles ahead of their widespread deployment.

The AVSC will:

- Develop and prioritize a roadmap of pre-competitive topics;
- Establish working groups to address each of the topics;
- Engage the expertise of external stakeholders;
- Share output/information with the global community;
- Initially focus on fleet service applications.

14. Contact Information

To learn more about the Autotmated Vehicle Safety Consortium, please visit https://avsc.sae-itc.org.

Contact: AVSCinfo@sae-itc.org.

15. Acknowledgements

The Automated Vehicle Safety Consortium™ would like to acknowledge the contributions of the member organizations during the development of this document.

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16. Abbreviations

ACEA - European Automobile Manufacturers Association
ADS - Automated Driving System
ADS-DV - Automated Driving System-dedicated vehicles
AEB - Automatic Emergency Braking
AVSC - Automated Vehicle Safety Consortium™
DDT - Dynamic Driving Task
DDTF - Dynamic Driving Task – Fallback
DV - Dedicated Vehicles
ECU - Electronic Control Unit
EDR - Event Data Recorder
Euro-NCAP - European New Car Assessment Program
GDPR - European Union General Data Protection Regulation
ID - Identification Number
IOO - Infrastructure Owner-Operator
km/h - kilometers / hour
MRC - Minimal Risk Condition
MRM - Minimal Risk Maneuver
ms - millisecond
MUTCD - Manual of Uniform Traffic Control Devices
NHTSA - National Highway Traffic Safety Administration
Nm - Newton meter
NPRM - Notice of Proposed Rulemaking
ODD - Operational Design Domain
PES - Passenger-Initiated Emergency Stop
SAE ITC® - SAE Industry Technologies Consortia
VIN - Vehicle Identification Number
VRU - Vulnerable Road User(s)

Appendix A. Best Practice Quick Look

Data Collection for Automated Driving System Dedicated Vehicles (ADS-DVs) to Support Event Analysis

Data elements (5.0). Organized into four categories to facilitate event analysis:

1. Vehicle Control ("What the ADS did")
2. Saliency ("What the ADS thought was important")
3. Sensing ("What the sensors saw")
4. General parameters (VIN, Time-of-day, trigger type, location, and passenger-initiated stop actions)

- **Data element prioritization (5.1).** Prioritize ADS data elements based on their likely importance to event analysis.
  - Priority 1 - Data elements considered likely to be most relevant to ADS-related event analysis.
  - Priority 2 - Data elements considered to offer secondary value to ADS-related event analysis.
  - Priority 3 - Data elements considered to offer tertiary value to ADS-related event analysis.
- **Data Element Definitions (5.2).** Total of 39 data elements identified to support event analysis and should be recorded where such information (or features) is already a part of the intended functionality.

Visual representation (6.0). Recording data from ADS sensors; potentially adds context to other vehicle and ADS data elements during event analysis with reasonably human viewable images of the scene.

- ADS should record data from 360-degrees around ADS-DV (subject to identified constraints).

Recording Considerations (7.0).

- **Interval and Frequency (7.1).** The interval is generally five (5) seconds prior to time zero and frequency ranges from one (1) sample per second to (5) samples per second depending on the data element. Recording data past time zero is recommended. Data availability (9.2) may affect the ability to record past time zero.
- **Data Capture (7.2).** The recording system should be capable of recording at least one event, subject to conditions summarized in Figure 1.
- **Synchronization and Correlation (7.3).** There should be a method for synchronizing (i.e., aligning the data in the time domain) the event data elements recorded by multiple ECUs.
  - The data should align within the minimum recording frequency defined in Data Elements Definitions (5.2).
  - Data recorded from multiple ECUs should be correlatable.

Retrievability (8.0). Event recorded data may be stored and processed in on-board systems, off-board systems (e.g., cloud storage), or both.

- **Data Location (8.1).** Event recorded data may be located in on-board systems, off-board systems (e.g., cloud storage), or both for storage and processing.
  - **Data Retrieval and Access Tools (8.1.1).** Tools for data retrieval and access should be available for authorized users.
  - **Data Retrieval (8.1.2).** Some recorded data may be retrieved in coordination with other recorded data elements.
  - **Security and Data Integrity (8.1.3).** The recording system must be tamper-resistant and compliant to ISO/SAE 21434 and SAE J3061 requirements for data security.

Survivability (9.0). The objective of data recording should be to reach a similar approach to survivability as described in 14 CFR Part 563.10 [6]. Currently, vehicles may not be able to meet survivability requirements as described in 14 CFR Part 563.10 due to limitations to current technologies which are still in development.

- **Prioritized Recording of Data Elements (9.1).** Data that is important to event analysis should be recorded. Data elements are prioritized in order to record as much useful data as possible for event analysis and accommodate situations where not all prioritized data can be recorded. A manufacturer may want to obtain a more complete record of a certain data element before recording other data elements within the same priority level because the more complete record provides more value to event analysis.

Data storage (10.0). Data recording may include off-board systems for storage and processing.

Traceability (11.0). The ADS-DV should be uniquely identified. The Vehicle Identification Number (VIN) should be used to uniquely identify the ADS-DV.