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Architecting the ZEV OBD System to Delight the Service Community

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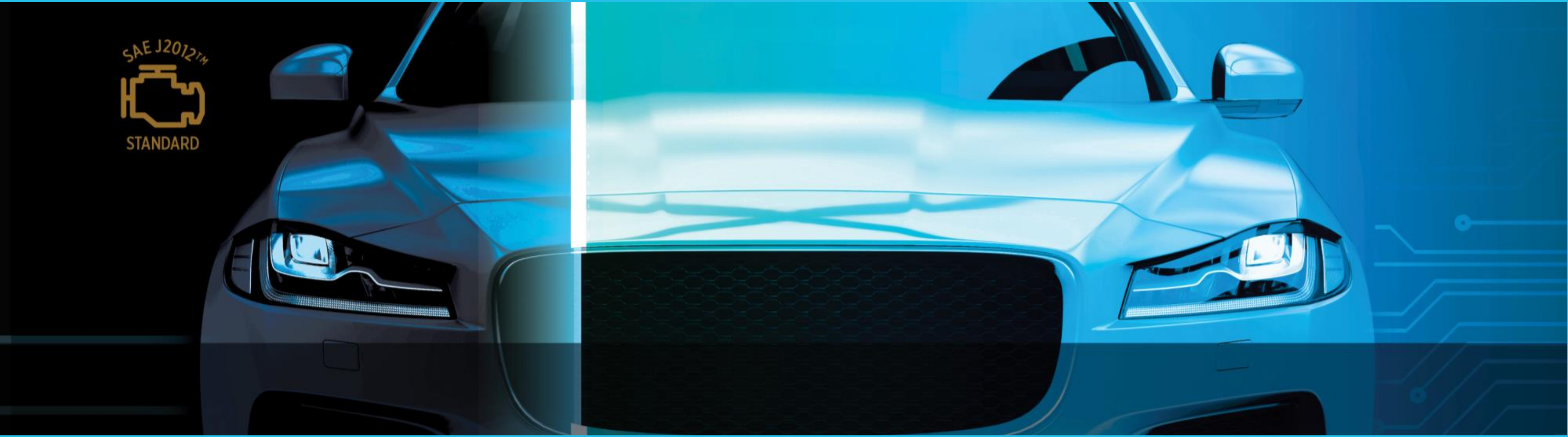
Contents

- Introduction
- Approach and Drivers
- Diagnostic Data Management System – Vehicle-Level Architecture Requirements
- Conclusion

Introduction



Review of Previous Progress

In our previous talks we have delved into:

- Dotted line ties in emerging global regulations necessitation OBD-like diagnosis of propulsion relevant components.
- Where to start designing an OBD system in the void of an OBD II-style regulation.
- Determining WHAT to diagnose and HOW to diagnose it.

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- Basic principles upon which a good OBD system must be designed.

Going deeper in this line –

Define the minimum architectural elements to include in the diagnostic data management system design.

Why?

To achieved **harmonized OBD system behavior across the vehicle** and report diagnostic data that actually makes sense.

What Do I Hope to Leave with You Today?

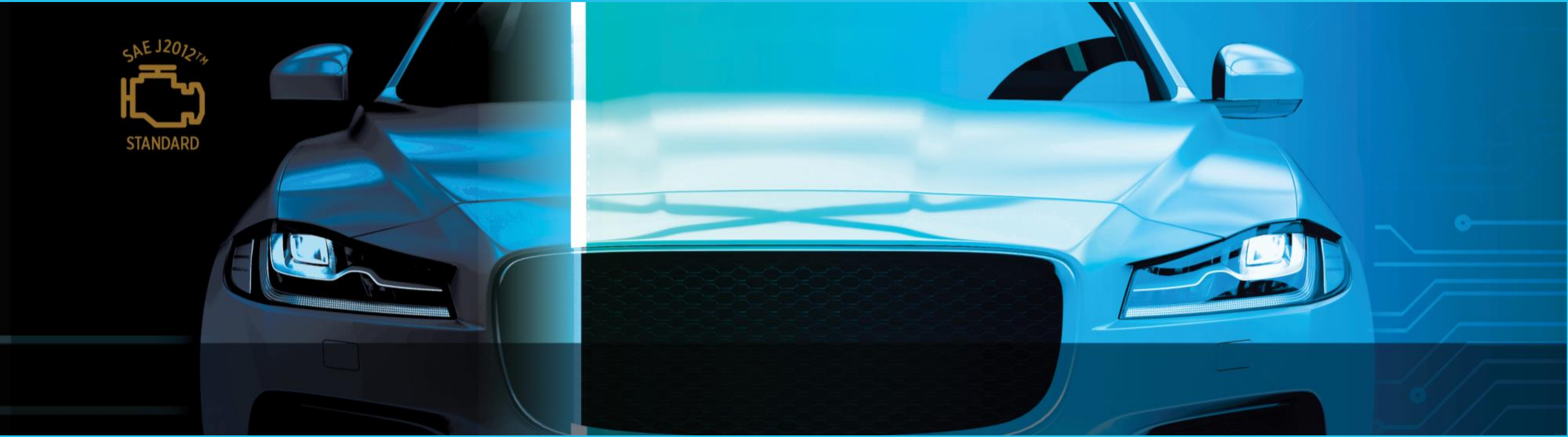
An effective OBD system “design standard” regarding more specific requirements driving the end-to-end behavior of the OBD system across the vehicle.

A Few Other Introductory Notes

- I will *not* cover detailed technical requirements dictating the fault code storage and diagnostic data management behavior.
  - (e.g., progression of a fault through the status; details on setting versus clearing of associated diagnostic data; etc.)
  - (Perhaps in a future presentation).

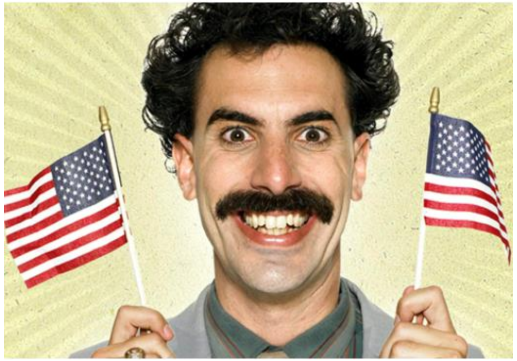
- Example of why what we are covering today is important –
  - …it provides the rules to achieve the same basic OBD system behavior across every ECU, e.g., all ECUs “turn the page” on the driving cycle at the same time.
  - …without such, each ECU may not set and heal faults, store and clear diagnostic data, according to the same cadence (frequency), according to the same “triggers”.

Approach and Drivers



Our Ultimate Design Goal

Achieve a harmonious diagnostic system that seamlessly and simultaneously complies with associated regulatory requirements and delights the service community.



Our Approach

- Take “best practices” as tried and tested through existing OBD regulations.
- Modify elements of existing OBD regulations to better serve service technicians.
- Add common-sense elements to improve OBD system design.
- Include enhancements as requested by the service technician community at large.

Our Performance Targets

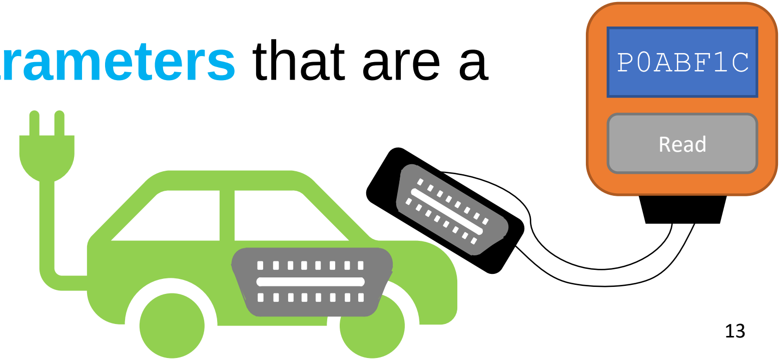
We shall define architectural requirements that facilitate creation of a an OBD system that is:

- **Viable** (functioning);
- **Useful** (to service technicians);
- **Efficient**
  - (in resultant software design, in consideration of, e.g., processing, memory, and bus-loading).

Our Design Targets

The high-level requirements guiding our design originate from new (non-OBD II) global regulations, which necessitate ability to accurately:

- Report a **DTC** and associated **DTC status**;
- Report **datastream parameters** that implicate **propulsion system active** and **clearing of diagnostic data**;
- Report **vehicle operation tracking parameters** that are a function of **vehicle state**.

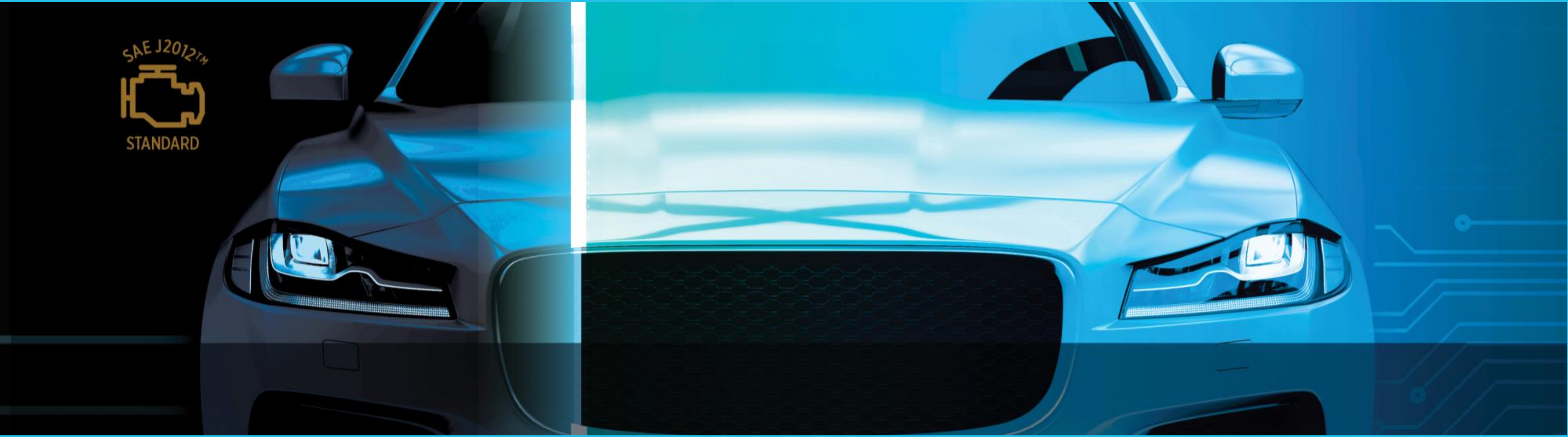


Expected Outcome

A “best architected” OBD system that synergizes with emerging regulatory requirements [for ZEVs] to:

1. Serve the service community;
2. Facilitate simple compliance with new regulatory requirements that have touch-points into OBD
   - (e.g., DTCs; regulated diagnostic data (PIDs (DIDs), ITIDs));
3. Accurately provide critical data to protect the manufacturer from malfunctioning or mis-used vehicles skewing in-use test results
   - (e.g., SOH accuracy; durability requirements).

Diagnostic Data Management System – Vehicle-Level Architecture Requirements



But First – What is the Diagnostic Data Management System?

- **It describes the logic existing on the ECU that dictates the behavior of the overall OBD system.**
  - → Performs all “accounting”.
  - → Effectively outlines high level state-machine elements resulting in the status of the associated diagnostic system elements.

- **It includes storage, management, and healing/clearing behavior of:**
  - − Diagnostic monitors;
  - − Fault codes (DTCs) (across the various possible DTC statuses);
  - − Associated diagnostic data (snapshot data, DTC extended data, readiness, test results, adaptations, etc.);
  - − Ancillary functions (default action, telltale, user messaging).

The Basic Elements

Vehicle States

- Propulsion System Active
- High Voltage System Active
- Charging System Active
- Accessory

Cycles

- Ignition Cycle
- Propulsion System Active Cycle
- Driving Cycle
- Charging Cycle
- Warm-up Cycle
- Monitoring Cycle

Diagnostic Monitor Status

- Monitor Enabled
- Monitor Complete
- Test Result Status

Inputs from External Sources / Events

- Fault Memory Clear

Notes –

- The vehicle states are not necessarily mutually exclusive, as dependent on vehicle/software design.
- The cycles are not mutually exclusive, and are dependent on vehicle/software design combined with vehicle usage.
- The diagnostic monitor status data plays with the vehicle states and cycles data for the resultant "diagnostic data management element's behavior" for the given element* (*i.e., diagnostic monitor, DTC, DID, ITID, snapshot, etc.).
- "Monitoring cycle" is applied to each specific diagnostic monitor within an ECU, but it is important to establish a generalized definition of a monitoring cycle for resultant potential uses (such as indetermination of a corollary to "readiness", or in calculation of a corollary to IUMPR).
- "Fault memory clear" trigger may originate from external or situational sources, but is critical to achieve vehicle-wide harmonized OBD system behavior, so appropriate definition is crucial.

A Note on Centralized Data Sources

- To achieve true harmonization across the vehicle, it is important that there is a centralized source of data for these Vehicle States and Cycles.

- A "centralized" source means that either originating data used to calculate the values, or the final calculated value, come from the same source.
  - Tip – it is generally best to utilize centralized resultant data (e.g., Propulsion System Active as opposed to every ECU receiving the same input values to calculate their own determination of Propulsion System Active) as it:
    1. Minimizes processing in consideration of the whole system;
    2. Minimize possibility for "fat finger"/engineering mistakes in implementation.
  - In the case that a Vehicle State has a corresponding Cycle, it can be most efficient to have a centralized source for the Vehicle State, with each ECU individually calculating Cycle.

- The centralized data shall come from the ECU with the best ability to calculate an accurate value (i.e., the ECU receiving native inputs required for the calculation).

- The centralized data shall be fully diagnosed (in an OBD II style) to ensure its integrity.

Why These Basic Elements?

These are a minimum subset to ensure data (inputs) that…

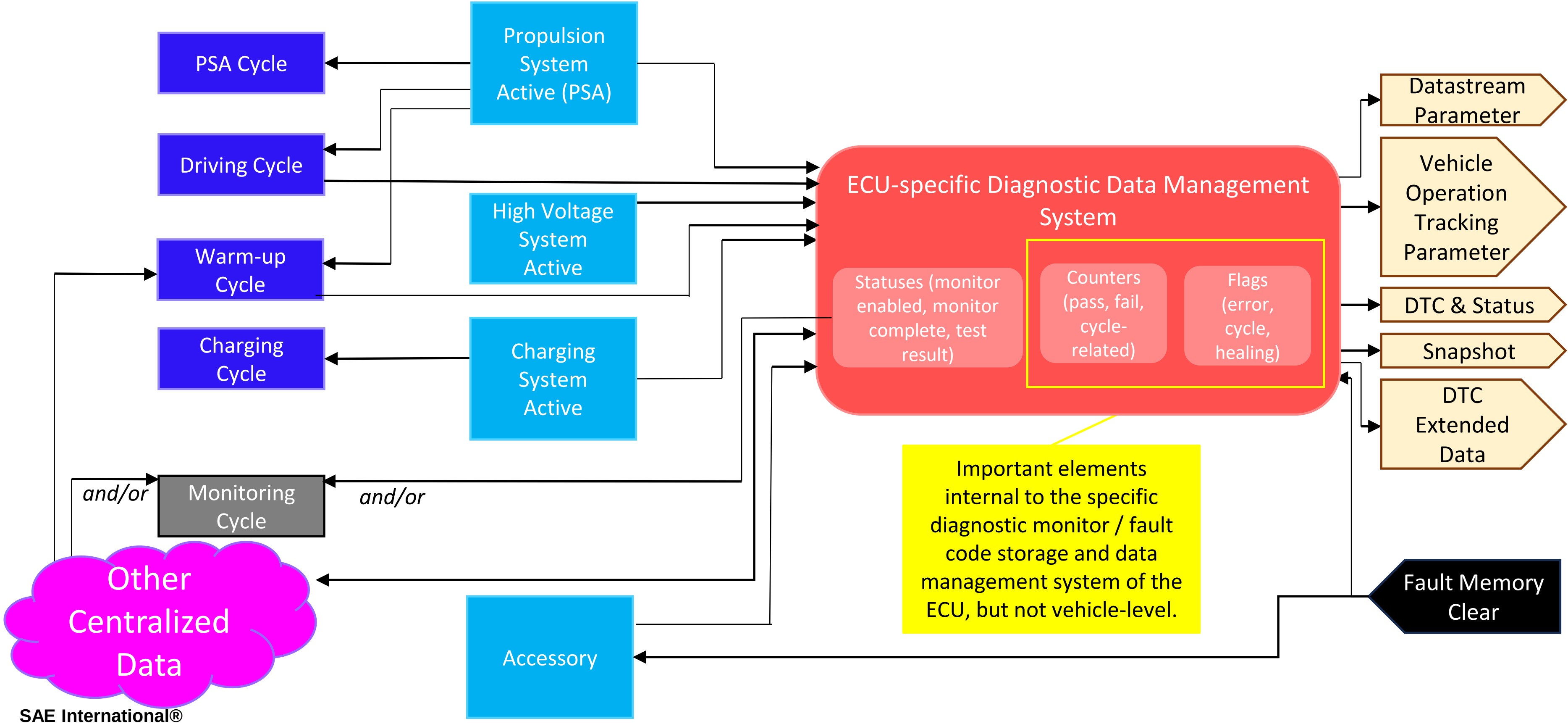
… may be used across multiple ECUs (e.g., charging system active, high voltage system active) …

and

…will be used across multiple ECUs (e.g., propulsion system active, driving cycle)…

is aligned, in order to achieved “harmonized” OBD system behavior across the vehicle.

Simplistic Representation of the Elements – “Big Picture”



Propulsion System Active (PSA)

Definition

- The state where the powertrain is enabled such that the vehicle is ready to be used to propel the vehicle or transport occupants.
  - Powertrain: electric propulsion system (e.g., HV battery, motors, and inverters).

Uses

- Denote a new driving cycle.
- [If utilized by OEM] warm-up cycle definition.
- [If utilized by OEM] IUMPR-like (or MAR-like) denominator incrementing.
- Regulated PIDs (DIDs), ITIDs (see later slide for summary of examples).

High Voltage System Active

Definition

- The state in which the high voltage energy storage system (ESS) is enabled and the PSA criteria have not been achieved.
    - Enablement may be actively by the driver, the onboard control system, or external/offboard means (such as a remote command).

Uses

- [As applicable] specific diagnostic monitors’ enablement criteria.
- [If and as applicable] specific diagnostic monitors’ denominator criteria.

Note – Though no explicitly associated regulated data, this can be critical to achieved harmonized behavior in setting and healing behavior of faults across HV-system-specific components that may be distributed across multiple ECUs.

Charging System Active

Definition

The state in which the onboard vehicle charging system is enabled for ESS charging via electric vehicle supply equipment (EVSE) or sources external to the vehicle.

Uses

- [As applicable] specific diagnostic monitors' enablement criteria.
- [If and as applicable] specific diagnostic monitors' denominator criteria.
- Regulated PIDs (DIDs), ITIDs (see later slide for summary of examples).

Accessory

Definition

The state in which the vehicle is energized but powertrain is not in a state to propel or charge the vehicle. (i.e., It has not achieved the propulsion system active definition, nor the charging system active definition.)

Uses

- The minimum required state in which diagnostic information must be able to be erased.
- Perform a bulb check upon entry to this state.

Note – there are no explicitly regulated requirements tied to the Accessory state (and bulb check is explicitly in a separate state, “key on, engine off”, for ICEs/PHEVs), however this is a reasonable standardized requirement given the need to protect for both above use cases, and given the lack of need of a corollary to “key on, engine off position” in a non-ICE application.

Propulsion System Active Cycle

Definition

The state in which the vehicle has met the PSA definition for a minimum amount of time (e.g., 2 ± 1 s).

Note – traditional OBD regulations utilize the term “Ignition Cycle”, but PSA cycle is a better generalization to extend to, e.g., ZEVs.

Uses

- [If applicable] Storage of confirmed fault codes as permanent fault codes to NVRAM before the end of the PSA cycle.
- [Generally] Transition into a new PSA cycle to be use as a key event to perform any actions that were not performed at the end of the previous PSA cycle.
- Regulated PIDs (DIDs), ITIDs (see later slide for summary of examples).

Note – though permanent fault codes are not required, it can be a useful tool for service technicians in understanding persistent problems.

Driving Cycle

Definition

A trip that consists of the propulsion system active criteria being achieved, disabled, and includes the period of time up to the next propulsion system active criteria being met.

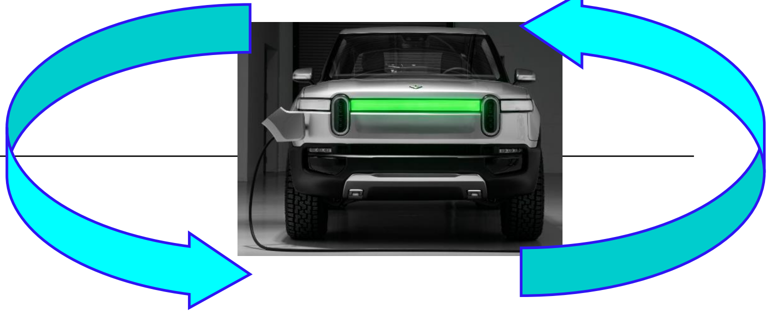
You're always in a driving cycle.

Uses

- [If and as applicable] Incrementing of monitor tracking counters (i.e., for use in corollary to IUMPR).
- [If and as applicable] Healing of a pending fault code and a permanent fault code (before the end of the driving cycle).
- [Generally] Fault code storage within the current driving cycle.

Note – Though no explicit ties to regulated requirements, the driving cycle definition is a critical part of fault code storage and healing.

Charging Cycle



Definition

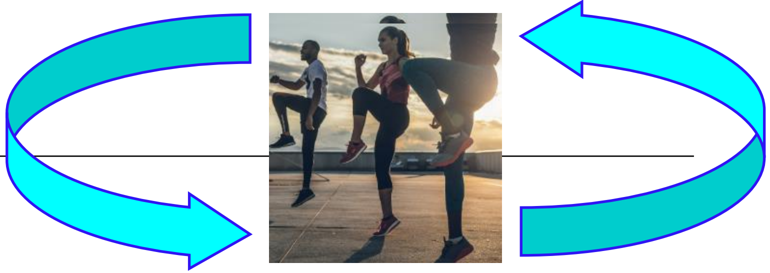
A period that consists of the charging system active criteria being met for a minimum amount of time (e.g., e.g., 2 ± 1 s).

Uses

[If and as applicable] Internally defined system tracking requirements.

Note – Though no explicit ties to regulated requirements, tracking of charging cycles could provide additional important data regarding degradation of the electric propulsion system.

Warm-up Cycle



Definition

A driving cycle in which sufficient vehicle operation has occurred to “fully exercise” the propulsion system (e.g., to allow critical systems to warm up to a specific threshold, or to encounter other minimum viable vehicle usage or operation conditions such as time at speed).

Note – Warm-up cycle is not explicitly required in any regulations, but the spirit of the warm-up cycle is important in maintaining the integrity of a confirmed fault code history. Definition should be system-specific.

Uses

- Confirmed fault code healing (historical fault healing);
- Snapshot data healing (in conjunction with confirmed fault code healing);
- [If applicable] Specific elements within DTC extended data (see next bullet);
- [If applicable] (Non-regulated) warm-up cycle based counters to provide service as may be useful as additional troubleshooting information.

Monitoring Cycle

Definition

A driving cycle in which monitoring has occurred [a PASS/FAIL decision has been made for a specific diagnostic monitor].

Note – Monitoring cycle is not explicitly required in any regulations, but concept is central to the functioning and integrity of the fault code storage and data management system.

Uses

- Pending fault code detection, storage, and erasure;
- Confirmed fault code storage;
- Snapshot data and applicable DTC extended data storage and erasure (only if that snapshot data is only associated with a pending fault code);
- Permanent fault code erasure;
- Initiation and clearing of default action and telltale/user notification.

Diagnostic Monitor Statuses –

- **Monitor Enabled Status:** All enablement criteria have been achieved, no inhibit or disablement criteria are present, such that the diagnostic monitor has all conditions physically necessary to run and make a reliable PASS/FAIL decision.
- **Monitor Complete Status:** The diagnostic monitor has run and made a PASS/FAIL decision [this driving cycle].
- **Test Result Status:** The Boolean PASS/FAIL decision most recently made by the associated diagnostic monitor.

Note – these are elements internal to the diagnostic monitor, but are critical to the ability to report relevant data to a service technician, as well as to the proper functioning of the fault code storage and data management system within the specific ECU.

Fault Memory Clear

Definition

- Fault memory is the information pertaining to malfunctions that is stored in the onboard computer including:
  - fault codes of all fault statuses;
  - stored system conditions such as Snapshot data and DTC extended data;
  - adaptations or learned parameters.
- A fault memory clear event is an external event (such as a service 0x14 code clear request, or an ECU reprogramming event), or a vehicle/situational event (such as loss of power to an ECU) resulting in the loss (clearing) of all* fault memory.

  * Design system to ensure all diagnostic data is cleared upon a fault memory clear event.

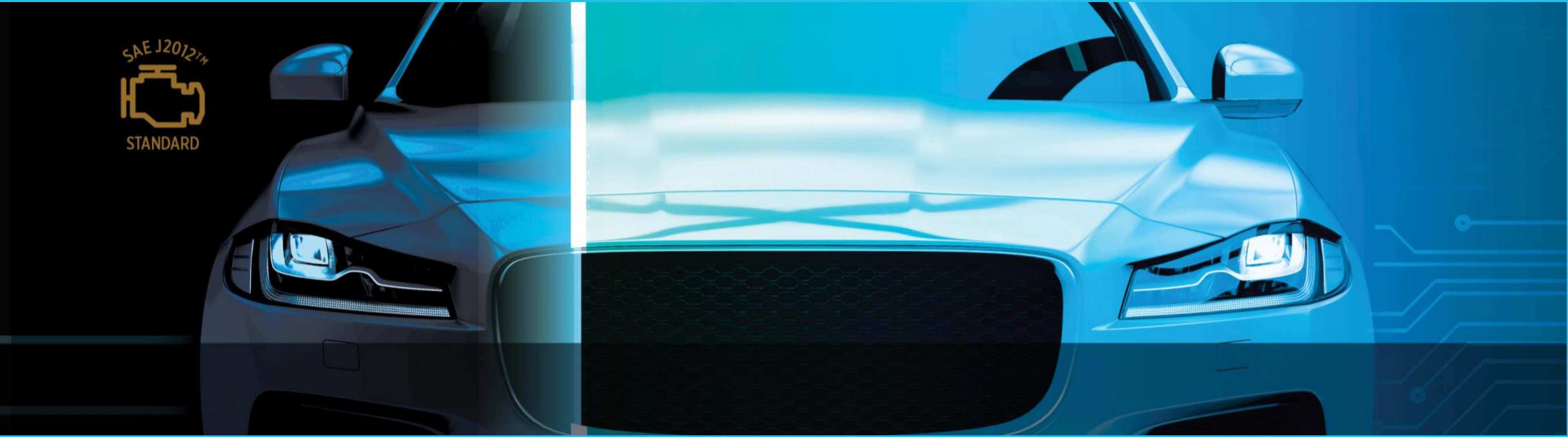
Uses

Regulated PID (see next slide for summary of example).

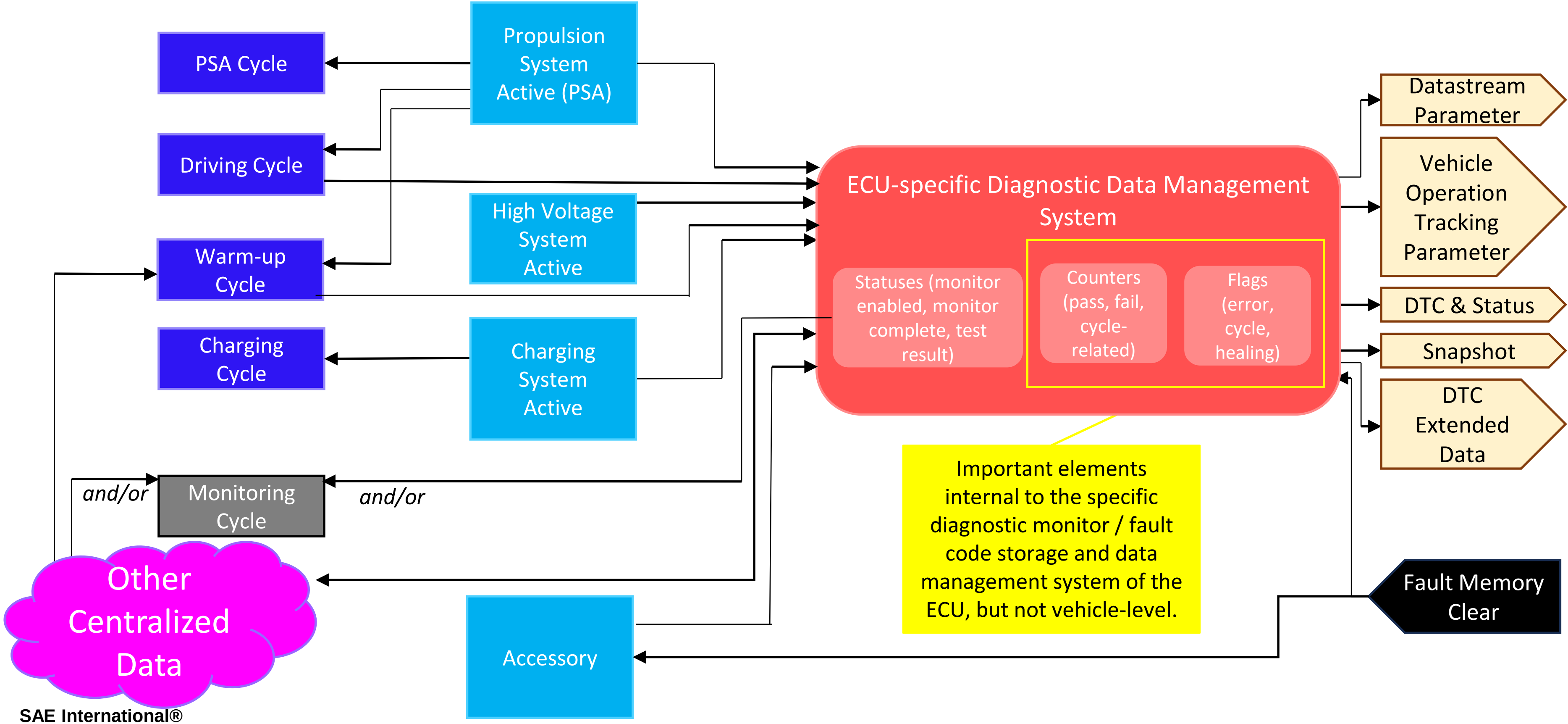
Regulated Data Related to These Elements

"Basic Element"	Regulatory Requirement Incorporating "Basic Element"	J1979-DA PID / ITID	CARB ACCII Reference
Propulsion System Active Cycle	Number of propulsion system active trips since fault memory last cleared	0xF4D6	
Propulsion System Active Cycle	Total number of propulsion system active trips	0xF896	1962.5(c)(4)(D)1.b.
Propulsion System Active	Total propulsion system active time	0xF819	1962.5 (c)(4)(D)1.e.
Propulsion System Active	Total idle propulsion system active time	0xF819	1962.5 (c)(4)(D)1.f.
Propulsion System Active	Total city propulsion system active time	0xF819	1962.5 (c)(4)(D)1.g.
Propulsion System Active	Total net battery current in the state of propulsion system active	0xF885	1962.5 (c)(4)(D)1.k.
Propulsion System Active	Total net energy consumed in the state of propulsion system active	0xF886	1962.5 (c)(4)(D)1.l.
Propulsion System Active	Total energy into the battery during the state of propulsion system active	0xF887	1962.5 (c)(4)(D)1.m.
Propulsion System Active	Total battery energy supplied to an off-board usage during the propulsion system non-active	0xF88B	1962.5 (c)(4)(D)1.q.
Propulsion System Active	Average battery temperature during propulsion system active	0xF88E	1962.5 (c)(4)(D)1.r.
Charging System Active	Total grid energy into the battery during off-board charging	0xF888	1962.5 (c)(4)(D)1.n.
Charging System Active	Total grid energy into the battery from off-board DC charging	0xF889	1962.5 (c)(4)(D)1.o.
Charging System Active	Total grid energy into the vehicle from off-board AC charging	0xF88A	1962.5 (c)(4)(D)1.p.
Charging System Active	Average battery temperature during charging	0xF88F	1962.5 (c)(4)(D)1.r.
Fault Memory Clear	distance traveled since fault memory last cleared	0xF431	1962.5 (c)(4)(A)1.a.
Potential Candidate for a "Centralized" Signal	vehicle speed	0xF40D	1962.5 (c)(4)(A)1.a.
Potential Candidate for a "Centralized" Signal	absolute accelerator pedal position	0xF449, 0xF44A, 0xF44B	1962.5 (c)(4)(A)1.a.
Potential Candidate for a "Centralized" Signal	time elapsed since start of trip	0xF41F	1962.5 (c)(4)(A)1.a.
Potential Candidate for a "Centralized" Signal	odometer reading	0xF4A6	1962.5 (c)(4)(A)1.a.

Conclusion



(In summary let's take a last look here)

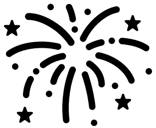


Summary

- Architecting an effective diagnostic data management system requires **consideration of OBD system design across the entire vehicle**.

- The necessary “building blocks” must include single, **centralized sources** of **all signals** that will **dictate the behavior of the fault code storage and data management system**.
  - We identified and defined each of these “building blocks”.

- This high-level architecture will “set you up for success” to achieve harmonized OBD system behavior, resulting in:
  - Efficient software design;
  - Data that makes sense for use by a service technician.



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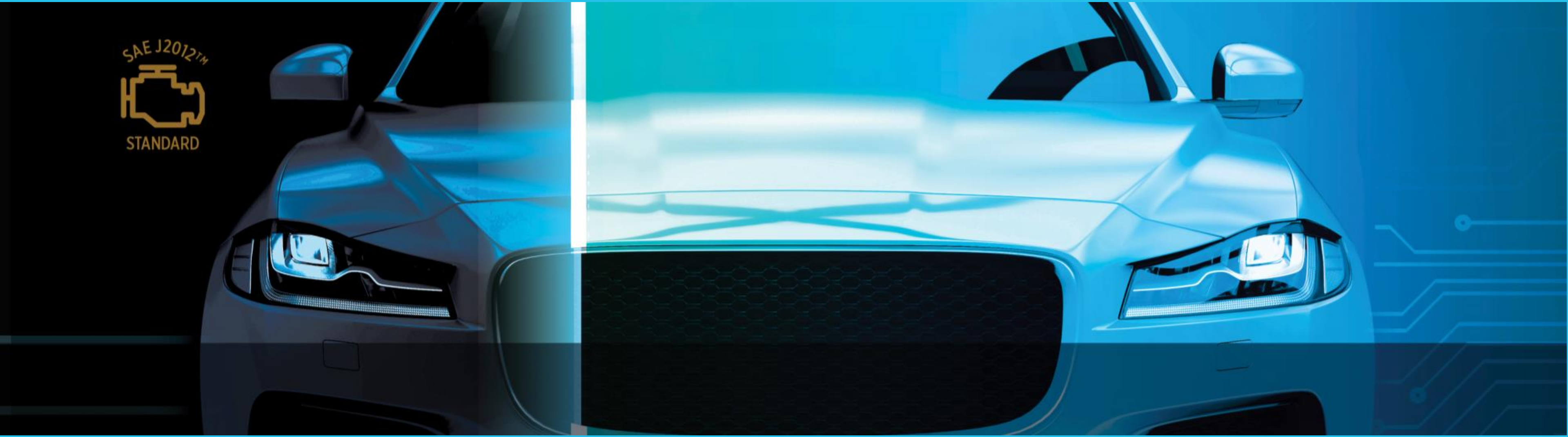

Thank You!

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