



SURFACE VEHICLE INFORMATION REPORT

J3252™

AUG2023

Issued

2023-08

Process for Developing an Interoperable Cooperative Driving Use Case Test Framework and Test Procedures

RATIONALE

Cooperative driving automation (CDA) depends on interactions between systems developed and operated by a diverse set of public and private stakeholders. During the development of a CDA Feature, these stakeholders may work independently. To ensure proper operation of the Feature and interoperability between the various stakeholder implementations, a common set of test procedures are required. This SAE Information Report provides the methodology and process for developing these test procedures.

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1. SCOPE

This report provides the process for developing a flexible test framework to support the creation of system-level cooperative driving automation (CDA) Feature test procedures, which are intended to be objective, repeatable, and transparent, and enable collaborative testing of the Feature. Utilizing a Feature's functional and logical scenario details, it provides the building blocks necessary to develop cooperative automated driving system (C-ADS)-equipped vehicle (C-ADS-V) and CDA infrastructure (CDA-I) system diagrams, identify the interfaces to and from the systems, and identify the set of functional test support components specific to the CDA Feature. Utilizing these details, along with the Feature-specific concrete scenarios, a method for developing a test scope and system level use-case-focused test procedures is provided.

NOTE: See the note following the CDA FEATURE definition in Section 3 for how capitalized "Feature" versus lowercase "feature" is used in this report.

NOTE: Some of the material developed for this report preceded the SAE J3251 and SAE J3256 feature reports. Future revisions of this report will align content and address redundancies with the CDA Feature reports.

NOTE: Throughout this report, several processes, sub-processes, components, etc., are defined which have a set guidance on the data items to be collected or defined in support of developing CDA Feature test procedures. While the rules of grammar may state otherwise, within this report, these items are capitalized to let the user of this report know to separate these from general items versus the specific ones contained in this report. It is also a way to let the reader know that a description of these items is provided in the report should they need to be referenced.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this report to the extent specified herein. Unless otherwise indicated, the latest issue of the publications shall apply.

2.1.1 SAE Publications

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.

SAE J3016	Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles
SAE J3131	Definitions for Terms Related to Automated Driving Systems Reference Architecture
SAE J3164	Ontology and Lexicon for Automated Driving System (ADS)-Operated Vehicle Behaviors and Maneuvers in Routine/Normal Operating Scenarios
SAE J3216	Taxonomy and Definitions for Terms Related to Cooperative Driving Automation for On-Road Motor Vehicles

2.1.2 IEEE Publications

Available from IEEE Operations Center, 445 and 501 Hoes Lane, Piscataway, NJ 08854-4141, Tel: 732-981-0060, www.ieee.org.

IEEE Std 1609.2	IEEE Standard for Wireless Access in Vehicular Environments - Security Services for Applications and Management Messages
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2.1.3 NHTSA Publications

Available from the National Highway Traffic Safety Administration (NHTSA), 1200 New Jersey Avenue, SE, Washington, DC 20590, Tel: 1-888-327-4236, <https://www.nhtsa.gov/>.

DOT HS 812 623 A Framework for Automated Driving System Testable Cases and Scenarios

DOT HS 813 073 An Approach for the Selection and Description of Elements Used to Define Driving Scenarios

2.1.4 FHWA Publications

Available from the Federal Highway Administration (FHWA), 1200 New Jersey Avenue, SE, Washington, DC 20590, Tel: 202-366-4000, <https://highways.dot.gov/>.

MUTCD Manual on Uniform Traffic Control Devices for Streets and Highways

2.1.5 NIST Publications

Available from NIST, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070, Tel: 301-975-6478, www.nist.gov.

NISTIR 7166 Achieving Intelligent Performance in Autonomous Driving

2.1.6 National Academies of Sciences, Engineering, and Medicine Publications

Available from the National Academies of Sciences, Engineering, and Medicine, <https://www.nationalacademies.org/>.

HCM Highway Capacity Manual 7th Edition: A Guide for Multimodal Mobility Analysis

3. DEFINITIONS

Cited below are the definitions that apply to this report.

AGREEMENT-SEEKING COOPERATION (CLASS C): Refer to SAE J3216.

AUTOMATED DRIVING SYSTEM (ADS): Refer to SAE J3016.

AUTOMATED INFRASTRUCTURE SYSTEM (AIS): The infrastructure hardware and software that are collectively capable of performing all the real-time operational and tactical functions required to operate the infrastructure system in real-time dynamic traffic environments on a sustained basis, regardless of any other design constraints

CDA FEATURE: Refer to SAE J3216.

NOTE: To avoid confusion between this use of the word “feature” and the common English definition of “feature,” within this report, capitalized “Feature” is used to indicate a CDA Feature, and lowercase “feature” is used to indicate the common English definition, except when necessary to follow rules of grammar.

CDA FEATURE RELEVANT ENTITY: A physical item in the environment external to a CDA system that plays a role in the CDA Feature’s execution in use.

NOTE: A CDA Feature relevant entity includes road users and non-road user static or moving objects (e.g., channelizing device, signs).

CDA FEATURE RELEVANT ENVIRONMENT PROPERTY: Features of the environment external to a CDA system that play a role in the CDA Feature’s execution in use.

NOTE: Examples of CDA Feature relevant environment property include weather, traffic conditions, temporary road zones, etc.

CDA INFRASTRUCTURE: Infrastructure capable of supporting CDA Feature execution.

CDA SUPPORT DATA: Additional information, specific to the CDA Feature, necessary to be possessed by a CDA system to support execution of the CDA Feature.

CDA SYSTEM: Self-contained integrated hardware and software that are collectively capable of supporting CDA Feature execution in use.

COOPERATIVE AUTOMATED DRIVING SYSTEM (C-ADS)-EQUIPPED VEHICLE: Refer to SAE J3216.

COOPERATIVE DRIVING AUTOMATION (CDA): Refer to SAE J3216.

ENTITY: See CDA FEATURE RELEVANT ENTITY.

ENVIRONMENT PROPERTY: See CDA FEATURE RELEVANT ENVIRONMENT PROPERTY.

EXTERNAL CDA INTERFACE: A connection between CDA systems and entities in which attributes and/or information is received, sensed, or transmitted.

FULL ID: A unique ID for a CDA system, CDA Feature relevant entity, and/or CDA Feature relevant environment property that includes the base category, all subcategories, and, if necessary, a number sequence added as a unique identifier.

DIRECT COMMUNICATION: Wireless message/data transmission and/or reception between two or more CDA systems or CDA Feature relevant entities using a common communications channel, and which does not require a remote set of systems or devices to relay the desired information.

INDIRECT COMMUNICATION: Wireless message/data transmission and/or reception by a CDA system or CDA Feature relevant entity using a remote set of systems or devices to relay the desired message/data.

INFRASTRUCTURE-TO-NETWORK (I2N) COMMUNICATIONS: Indirect communication between a local infrastructure and a host beyond the local infrastructure.

INTENT-SHARING COOPERATION (CLASS B): Refer to SAE J3216.

MACHINE-TO-MACHINE (M2M) COMMUNICATION: Direct or indirect communication performed by a CDA system of CDA Feature relevant entity (e.g., V2V, V2I, V2N communication).

MESSAGE NAME DESCRIPTOR: A short identifier given to a message that is being exchanged over a direct communication link.

NON-ROAD USER OBJECT: Non-road user physical items, which can be static or moving, that a C-ADS-V or CDA-I system may encounter and/or need to be aware of for proper operation of the CDA Feature.

OPERATIONAL DESIGN DOMAIN (ODD): Refer to SAE J3016.

PRESCRIPTIVE COOPERATION (CLASS D): Refer to SAE J3216.

ROAD USER: Refer to SAE J3216.

SCENE: Refer to [OPERATING] SCENE in SAE J3164.

SHORT ID: A unique ID for a CDA system, CDA Feature relevant entity, and/or CDA Feature relevant environment property that includes the base category and only the subcategories and, if necessary, a numerical value to make it unique.

STATUS-SHARING COOPERATION (CLASS A): Refer to SAE J3216.

SYSTEM OF SYSTEMS (SoS): A collection of CDA systems that interoperate to achieve the desired CDA Feature capabilities.

TRUE POSITIVE: An outcome where the system(s) correctly interprets the need for action and takes the appropriate action(s).

TRUE NEGATIVE: A outcome where the system(s) correctly interprets no need for action and thereby takes no action.

VEHICLE-TO-INFRASTRUCTURE (V2I) COMMUNICATIONS: Direct communication between local infrastructure and one or more vehicles.

NOTE: Communication can be initiated by either the vehicle or the local infrastructure.

VEHICLE-TO-NETWORK (V2N) COMMUNICATIONS: Indirect communication between a vehicle and a host beyond the local infrastructure.

VEHICLE-TO-VEHICLE (V2V) COMMUNICATIONS: Direct communication between two or more vehicles.

WAY: A road, street, path, etc., used for travelling from one place to another.

4. ABBREVIATIONS

Cited below are the abbreviations that are used in this report.

AAI	Actors, Attributes, and Interfaces
ADS	Automated Driving System
AIS	Automated Infrastructure System
C-ADS	Cooperative Automated Driving System
C-ADS-V	C-ADS-Equipped Vehicle
ConOps	Concept of Operations
CDA	Cooperative Driving Automation
CDA-I	Cooperative Driving Automation Infrastructure
HCM	Highway Capacity Manual
ID	Identifier
ISD	Individual System Diagram
I2N	Infrastructure-to-Network
LVC	Live, Virtual, Constructive
M2M	Machine-to-Machine
MUTCD	Manual on Uniform Traffic Control Devices (for Streets and Highways)
NIST	National Institute of Standards and Technology
NISTIR	NIST Internal Report
ODD	Operational Design Domain

SoS	System of Systems
SoSD	System of Systems Diagram
SSP	Service-Specific Permissions
TFD	Test Framework Development
TPD	Test Procedure Development
TSD	Test Scope Development
TSFC	Test Support Functional Component
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2V	Vehicle-to-Vehicle

5. CONCEPT OF OPERATIONS

Given that this report provides the process for developing other report material, the concept of operations (ConOps) provided is abbreviated from what is provided in a Feature requirements and design report. It retains a discussion of the current situation and issues that have led to the development of the report along with features that are to be provided by the documented process. Additional items have been added which are tailored to this being a test procedure development process document, including where this fits in the full Feature development process and the types of testing to be supported by the test procedures developed following the process provided in the report.

5.1 Current Situation and Problem Statement

Automated driving system (ADS) and CDA-I implementations control how the system processes and responds to its prescribed operational design domain (ODD), for vehicles, or other design constraints, for infrastructure. However, a C-ADS implementation needs to also rely on information obtained from other C-ADS-V and/or CDA-I implementations, which the system implementer may have no control over. For CDA to operate as required, cooperation among two or more C-ADS systems is necessary, thus necessitating the systems to be interoperable. To aid in determining the interoperability of these systems a common set of test procedures is needed.

This report provides a process for developing a common set of CDA Feature test procedures using a common nomenclature, definitions, actors, attributes, etc., to enable collaborative testing. The goal is that if multiple independent system implementors develop test procedures following the process provided in this report, those test procedures would be similar and would test a CDA Feature in a similar way. Independent system implementor validation of the CDA Feature using the test procedures will hopefully aid in a smoother transition to collaborative validation of the independently developed CDA Feature system implementations.

5.2 CDA Feature Development and Test Process Flow

Figure 1 provides an illustration of the high-level process steps, divided into three process groups, involved in going from CDA Feature development to CDA Feature test and analysis. The information developed in one process step is used by the next process step and, in some instances, other processes steps. Similarly, the information developed in one process group is used by the next. The process groups are:

1. CDA Feature Development: Shown as a blue dashed box in Figure 1. Includes the Functional, Logical, and Concrete Scenario Development process steps. This is where the Feature description, design, etc., are developed.
2. CDA Feature Use Case Test Development: Shown as a green dashed box in Figure 1. Includes the Test Framework, Test Scope, and Test Procedure Development process steps. This is where the Feature test procedures and supporting information are developed.

3. CDA Feature Use Case Testing: Shown as an orange dashed box in Figure 1. Includes the Test Planning, Test Execution, and Test Analysis and Reporting process steps. This is where the execution of the test procedures is planned and carried out and where test results analysis is performed.

The dashed boxes mentioned above mean that the Feature information developed for the process steps contained in the process group is outside the scope of this report. Figure 1 also has a solid purple box around process group CDA Feature Use Case Test Development, which indicates that this report provides the process that would be used within that process group to develop the test framework, test scope, and test procedure information for a CDA Feature. The information developed by following the process steps would go into a Feature related report and not this one.

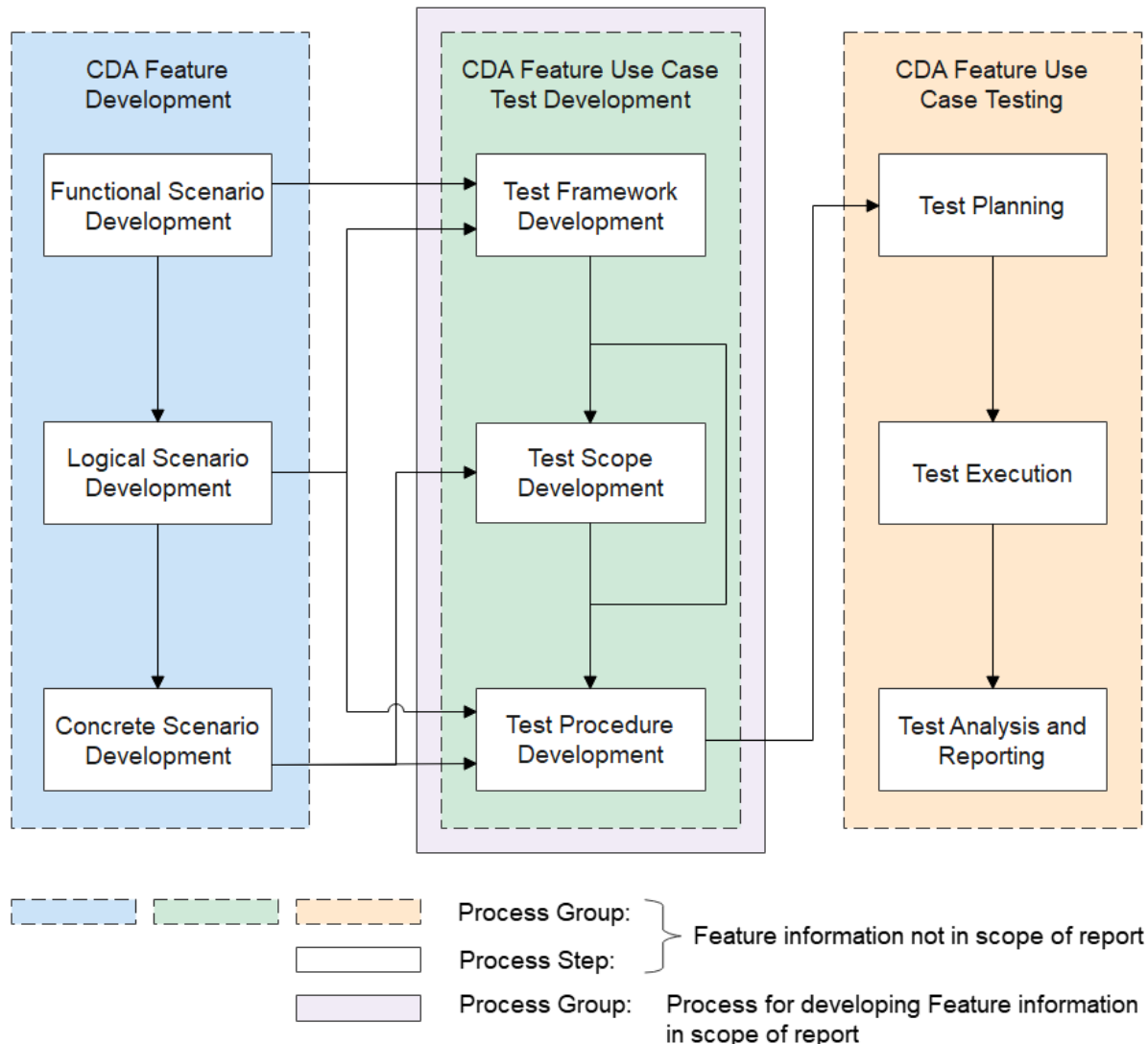


Figure 1 - CDA Feature development and test process groups/process steps dependencies flow chart

The following is a summary of what is provided in this report regarding the process for developing the information for each of the CDA Feature Use Case Test Development process steps shown in Figure 1:

- Test Framework Development (TFD): Provides the process to identify the CDA Feature systems, actors, and attributes, their interactions, as well as describe each of the individual CDA systems at a functional test support component level.
- Test Scope Development (TSD): Provides the process to identify the scope of testing including which concrete scenarios and systems that are intended to be the focus of the testing.
- Test Procedure Development (TPD): Considering a combination of the test scope, test framework, and concrete scenarios, provides the process to develop a set of CDA Feature test procedures.

The complete process to follow for each of the CDA Feature Use Case Test Development process steps described above is contained in Sections 6 through 8, respectively.

NOTE: Test Framework Development comes before the Test Scope Development because it is intended to address the Feature as a whole; i.e., all the Feature systems, entities, environment properties, and interfaces, rather than just a subset of them, should that all that be required by the test scope. This way if testing is phased, resulting in multiple test scopes over time, the test framework process will not need to be repeated each time the test scope changes. Rather, based on the scope of testing, only the aspects of the Test Framework Development relevant to the test scope will be leveraged for the testing.

5.3 Process Needs

The following are the needs required by the process provided in this report, to support the development of the test procedures for a CDA Feature. Some of these needs are provided by process groups from outside this report while others are provided by the process steps contained within this report.

- Functional scenario: From CDA Feature Development and provides a set of CDA Feature details including a description of the Feature and the systems, actors, and attributes relevant to the Feature.
- Logical scenario: From CDA Feature Development and provides more specific details regarding the Feature and the parameter space (e.g., types, ranges) for the systems, actors, and attributes that needs to be supported.
- Concrete scenario(s): From CDA Feature Development and provides a specific parameter set for the systems, actors, and attributes.
- Scope of testing: From the Test Scope Development and provides information to assist in CDA Feature Test Procedure Development.

5.4 Test Method Support

The test procedures developed using the process steps in this report are to support a variety of different testing methods, some of which are discussed in this section. DOT HS 812 623 (Chapter 5, “Findings” sub-section) provides some testing methods which, according to that report, offer “varying degrees of test control, and varying degrees of fidelity in the test environment.” The test methods include:

- Modeling and simulation.
- Closed-track testing.
- Open-road testing.

Figure 2 is an illustration of the CDA Feature development, these test methods, and their relationship with each other. It shows that, from the CDA Feature development, testing of the Feature can move to either of the three test methods even though, typically, testing starts with modeling and simulation, moves to track testing, and finally progresses to open-road testing. Depending on the results of the testing, additional CDA Feature development may be needed, or testing could progress to one of the other test methods.

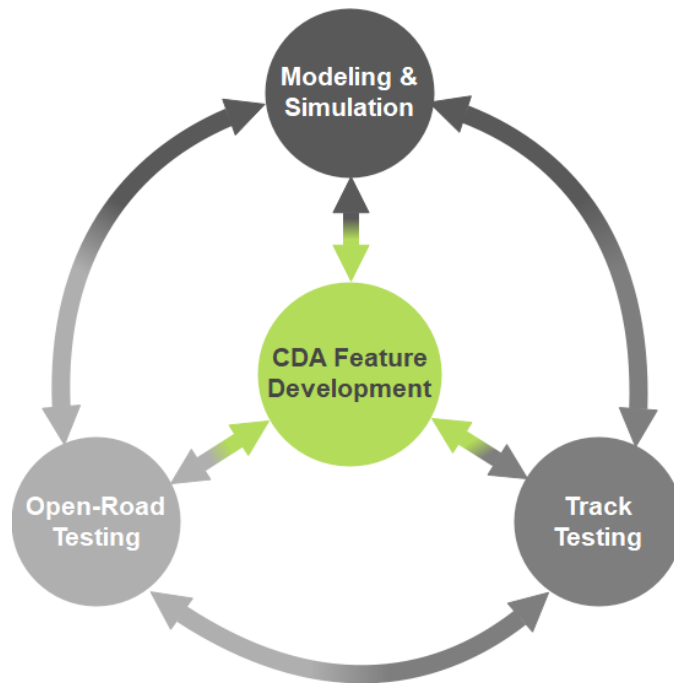


Figure 2 - CDA Feature development: use case testing methods relationship diagram

In addition to the more traditional breakdown of testing shown in Figure 2, more sophisticated testing methodologies which support combinations of testing methods are being performed within industry and academia. One such methodology is live, virtual, constructive (LVC) testing, where:

- Live testing is where real systems interact with other real systems.
- Virtual testing is where real systems interact with simulated systems.
- Constructive testing is where simulated systems interact with other simulated systems.

The LVC testing methodology does not preclude the other test methods mentioned earlier in this section. In fact, each of those test methods is supported within one of the LVC test methods.

With the LVC testing methodology, testing can comprise any one of the live, virtual, or constructive test methods by itself or may include a combination of the methods. Figure 3 provides a graphic of the LVC test methods and how they can be combined, shown by the overlap in methods, to create combinations of test methods. It also shows where each of the modeling and simulation, closed-track testing, and open-road testing methods fit with the LVC testing methodology.

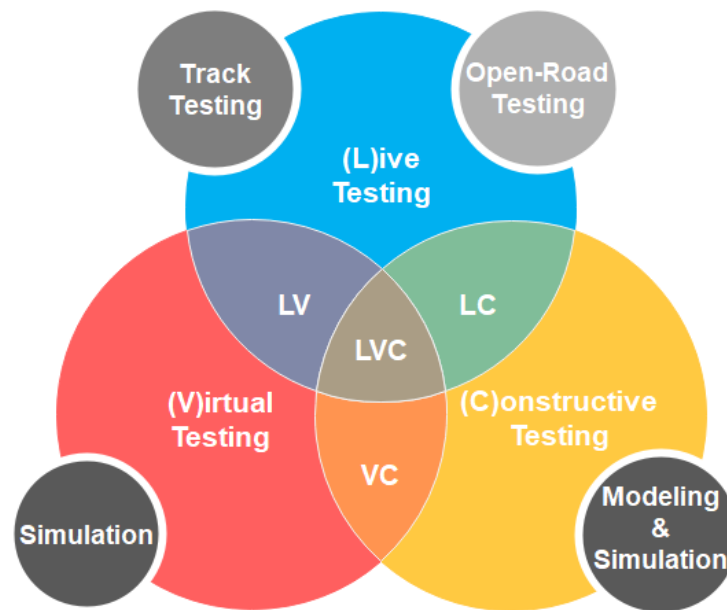


Figure 3 - Live, virtual, constructive (LVC) testing methodology graphic

5.5 Features of the Test Procedure Development

Documented within this section are the features that need to be supported by the test framework and test procedure process steps to satisfy the scope (see Section 1) and current situation and problem statement (see 5.1).

NOTE: See the note following the CDA FEATURE definition in Section 3 for how lowercase “feature” versus capitalized “Feature” is used in this report.

5.5.1 Test Development Procedure

A detailed process for developing use case test procedures needs to be provided. This is to aid in developing a comprehensive set of test procedures while reducing the time to develop them.

5.5.2 Common Terminology

Common terminology needs to be identified for referring to the actors and attributes and communication interfaces. This is to aid different stakeholders in having the same understanding of what is being referred to within the test procedure documentation.

5.5.3 External Interactions

The ability to identify all the Feature item external interactions needs to be provided. The is to ensure the none of the items (e.g., actors, attributes, interfaces) pertinent to the Feature are missed when developing test procedures.

5.5.4 Item Details

For each of the Feature item external interactions, the ability to identify the specific details of the items (e.g., different vehicle types or road conditions) needs to be provided. This is to ensure that the degree to what an item needs to be supported, via the interactions, are available when developing test procedures such that complete test coverage can be obtained if necessary.

5.5.5 Information Needs

The ability to identify the complete set of information needed to support Feature operation needs to be provided. This is to ensure that everything necessary for the Feature to perform as expected has been identified.

5.5.6 Feature Responses

The ability to identify how the Feature is expected to respond given the external interactions, item details, and information needs, needs to be provided. This is to ensure the test procedures can identify success or failure criteria for a test procedure.

5.5.7 Degree of Testing

The ability to identify the degree to which the Feature is to be tested needs to be provided. This is to aid in identifying which test procedures should be developed.

5.5.8 Test Method Support

Different test methods need to be supported by the test procedures. This is to enable testing to progress with Feature maturity while also offering a degree of reuse of the test procedures as testing progresses from one test method to the next.

6. PROCESS FOR DEVELOPING THE TEST FRAMEWORK

The aim of the CDA Feature Test Framework Development process step is to identify the CDA system interactions as well as describe each of the individual CDA systems at a functional test support component level. In doing so, the framework should be defined at such a level that it enables developing test procedures which support the different methods of testing indicated in 5.4.

NOTE: The test framework development process step involves the development of the framework for the Feature as a whole. In doing so, the framework only needs to be developed once. The test scope development process step, which comes after the test framework development process step, will determine which aspects of the Feature will be tested and leverage the appropriate framework items.

The Test Framework Development process step has five sub-processes:

1. Identify Actors, Attributes, and Interfaces.
2. Assign Unique Identifiers.
3. Develop System of Systems Diagram.
4. Develop Individual System Diagrams.
5. Develop Individual System Test Support Functional Component Diagrams and Details.

The sub-processes take as inputs one or more of the functional and logical scenario details, developed within the CDA Feature Development process group (see 5.2), reference tables and/or diagrams which are contained within this report, and in some instances the outputs from some of the other sub-processes generated via following the processes provided in this report. A summary of the complete process is provided in:

- Figure 4, which shows the sub-processes for items one to four above which are common for both a C-ADS-V system and a CDA-I system.
- Figure 5, which shows the sub-processes for item 5 above for a C-ADS-V system.
- Figure 6, which shows the sub-processes for item 5 above for a CDA-I system.

NOTE: The sub-process steps in Figure 5 and Figure 6 would be performed for each C-ADS-V and/or CDA-I system.

To make the figures more readable, within each figure, are circles with either number-number or number-letter combinations contained within. The number-number combinations indicate reference tables or diagrams, contained within this report, which are provided as inputs to the sub-process. The number-letter combinations indicate report outputs which are either generated by the sub-process or generated by another process step/sub-process within this report and used by this one. Number-number and number-letter combinations which start with a “1,” are references or outputs related to the Test Framework Development. For details on what the number-number and number-letter combinations refer to, the following are provided after Figure 6:

- Table 1 provides an item identifier, ID, and description for the sub-process outputs.
- Table 2 provides an item identifier, ID, and description for the reference tables and diagrams.

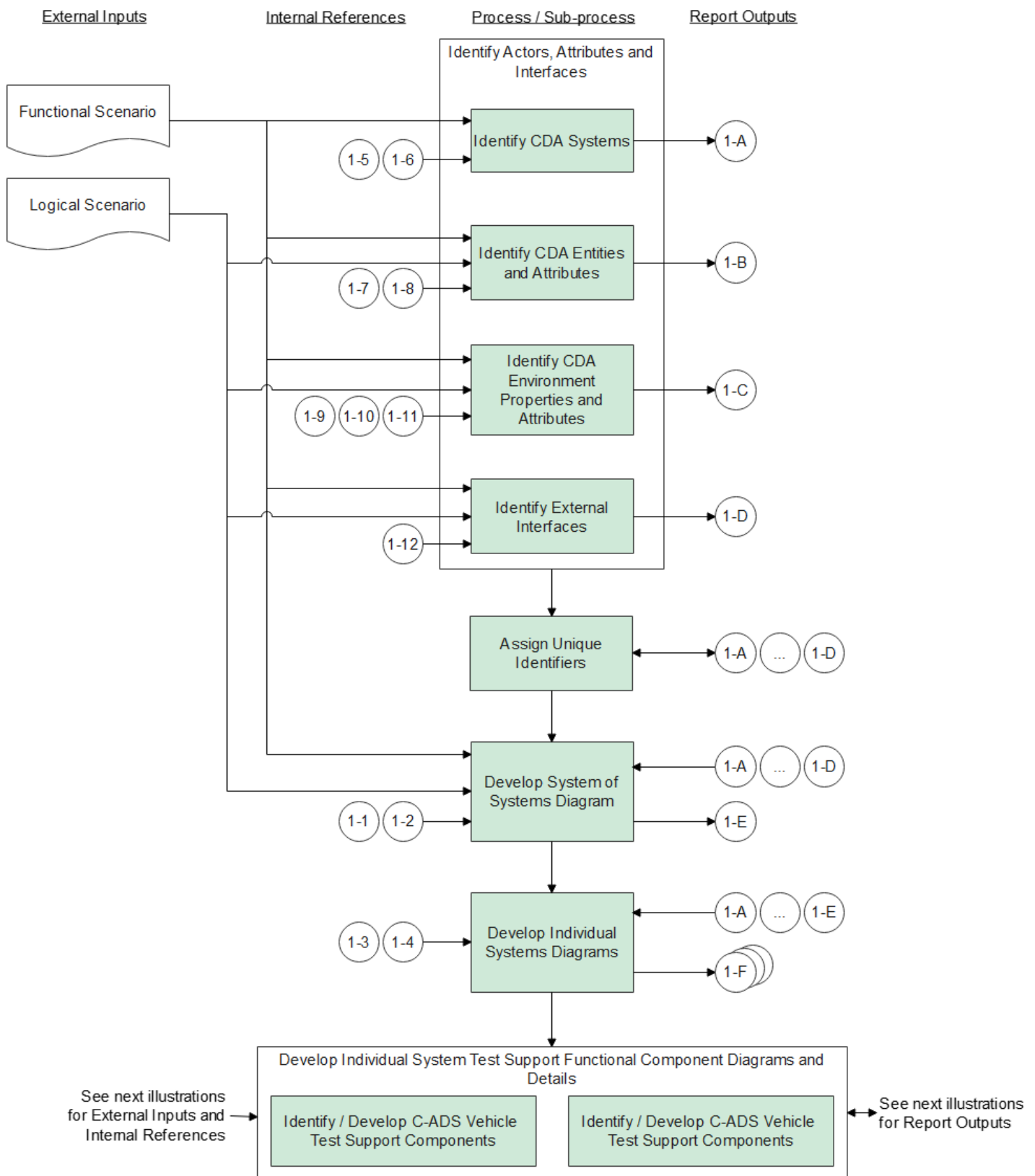


Figure 4 - Test framework development: common process steps

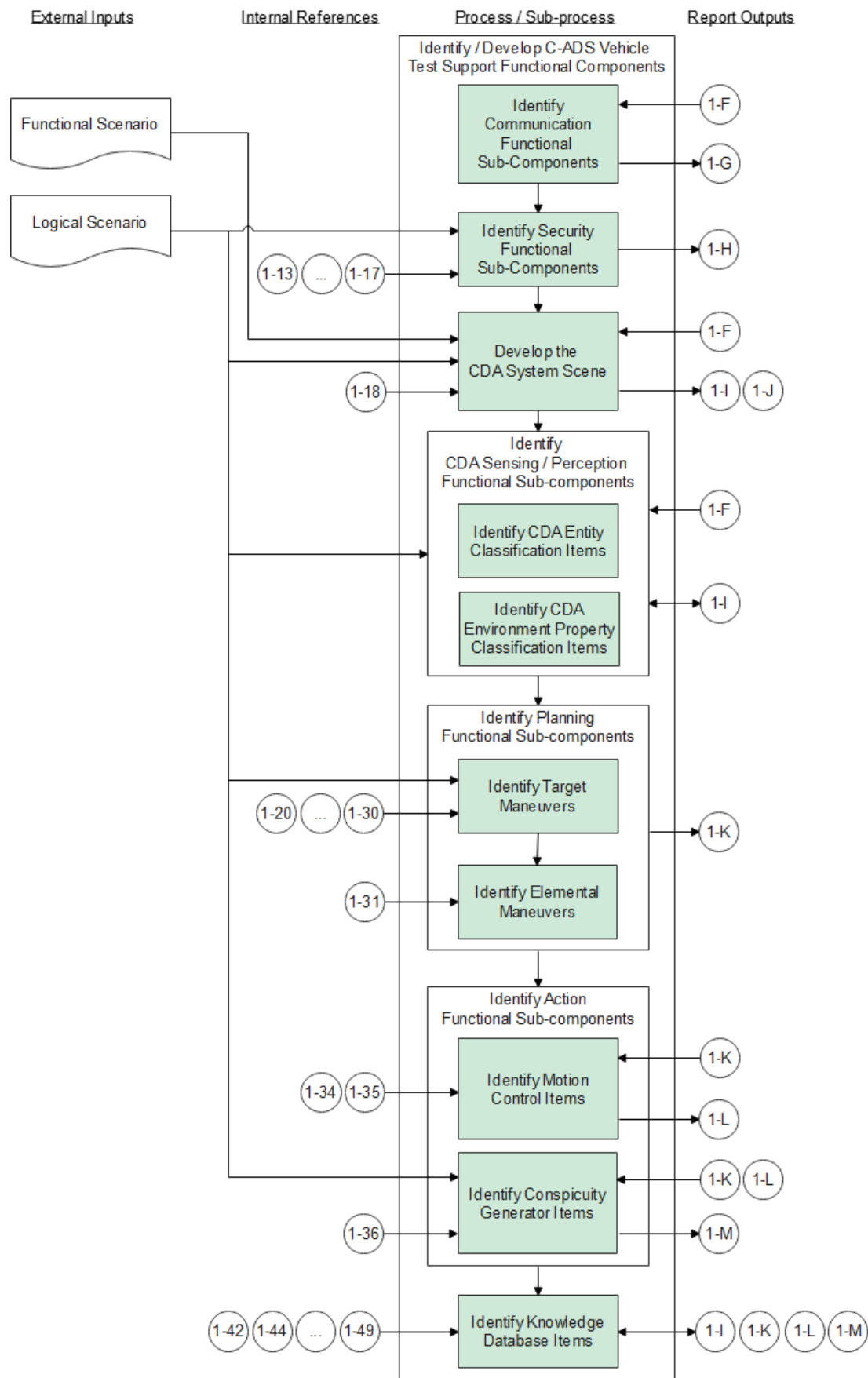


Figure 5 - Test framework development: C-ADS-V test support functional components processes

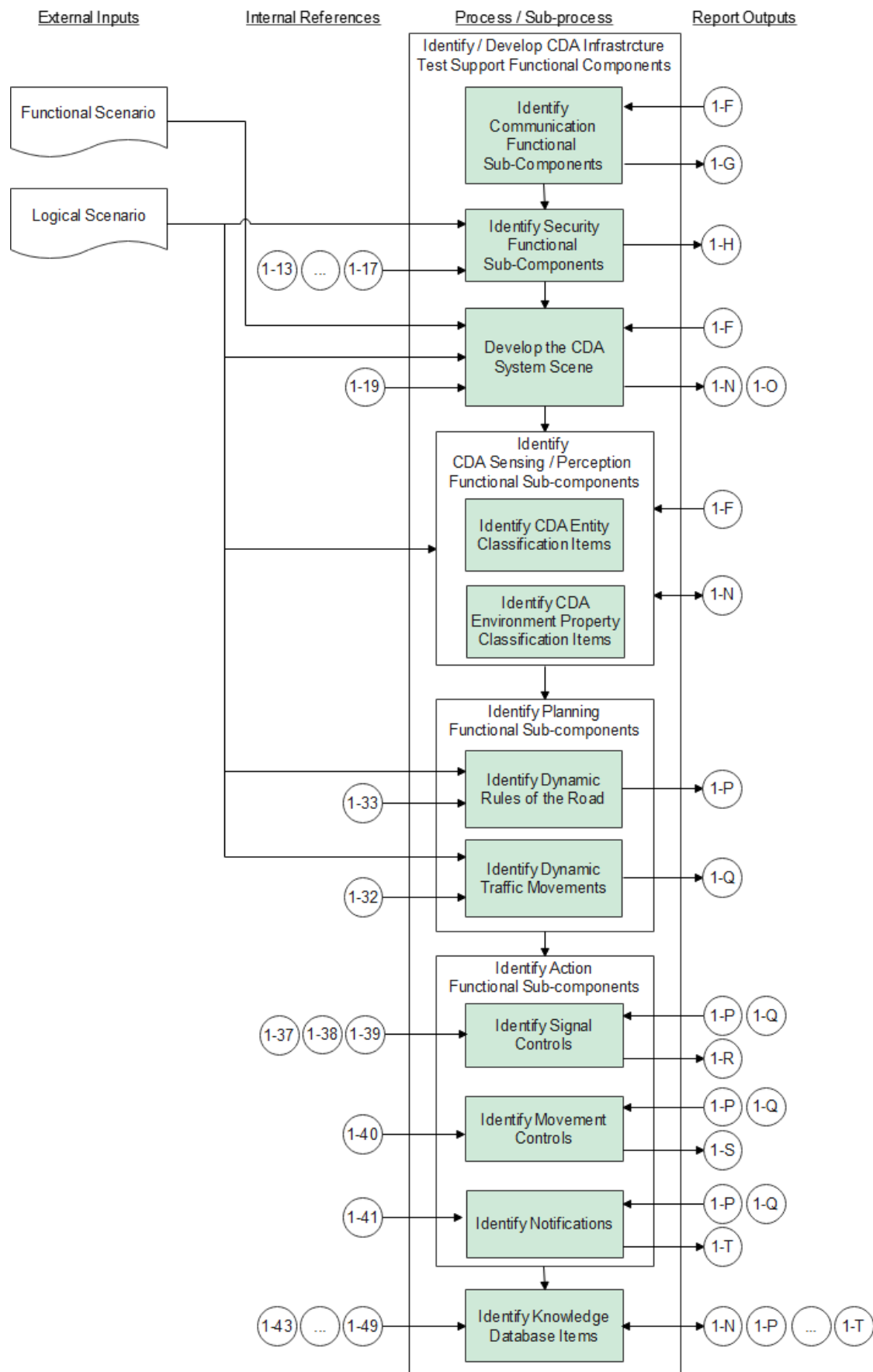


Figure 6 - Test framework development: CDA-I test support functional components processes

Table 1 - Test framework development: process outputs

Item	ID	Name
1-A	TFD-AAI-Tbl-Out-1	Systems list
1-B	TFD-AAI-Tbl-Out-2	CDA Feature relevant entities and attributes list
1-C	TFD-AAI-Tbl-Out-3	CDA Feature relevant environment properties and attributes list
1-D	TFD-AAI-Tbl-Out-4	External interfaces list
1-E	TFD-SSD-Dgrm-Out-1	System of systems diagram
1-F	TFD-ISD-Dgrm-Out-1	Individual system diagram - <CDA System>
1-G	TFD-TSFC-Tbl-Out-1	Communication sub-component details: data source and data user(s) - <CDA System>
1-H	TFD-TSFC-Tbl-Out-2	Security sub-component details - <CDA System>
1-I	TFD-TSFC-Tbl-Out-3	C-ADS-V scene information - <CDA System>
1-J	TFD-TSFC-Dgrm-Out-4	C-ADS-V scene illustration - <CDA System>
1-K	TFD-TSFC-Tbl-Out-5	Maneuver information
1-L	TFD-TSFC-Tbl-Out-6	Motion control information
1-M	TFD-TSFC-Tbl-Out-7	Conspicuity generator information
1-N	TFD-TSFC-Tbl-Out-8	CDA-I scene information - <CDA System>
1-O	TFD-TSFC-Dgrm-Out-9	CDA-I scene illustration - <CDA System>
1-P	TFD-TSFC-Tbl-Out-10	Dynamic rules of the road information
1-Q	TFD-TSFC-Tbl-Out-11	Dynamic traffic movements information
1-R	TFD-TSFC-Tbl-Out-12	Signal control information
1-S	TFD-TSFC-Tbl-Out-13	Movement control information
1-T	TFD-TSFC-Tbl-Out-14	Notifications information

Table 2 - Test framework development: process reference items

Item	ID	Name
1-1	TFD-SSD-Dgrm-Ref-1	CDA system of system diagram: illustration of possible interface connections
1-2	TFD-SSD-Dgrm-Ref-2	CDA system of systems diagram: mapping of possible system interfaces
1-3	TFD-ISD-Dgrm-Ref-1	C-ADS-V system diagram with possible interface connections
1-4	TFD-ISD-Dgrm-Ref-2	CDA-I system diagram with possible interface connections
1-5	TFD-AAI-Tbl-Ref-1	CDA system category/subcategory classifications - C-ADS-V
1-6	TFD-AAI-Tbl-Ref-2	CDA system category/subcategory classifications - CDA-I
1-7	TFD-AAI-Tbl-Ref-3	CDA Feature relevant entity category subcategory classifications and attributes - road user
1-8	TFD-AAI-Tbl-Ref-4	CDA Feature relevant entity category subcategory classifications and attributes - non-road user object
1-9	TFD-AAI-Tbl-Ref-5	CDA Feature relevant environment property category subcategory classifications and attributes - environmental conditions
1-10	TFD-AAI-Tbl-Ref-6	CDA Feature relevant environment property category subcategory classifications and attributes - road conditions
1-11	TFD-AAI-Tbl-Ref-7	CDA Feature relevant environment property category subcategory classifications and attributes - operational constraints
1-12	TFD-AAI-Tbl-Ref-8	CDA external interfaces
1-13	TFD-TSFC-Tbl-Ref-1	Security profile - profile identification
1-14	TFD-TSFC-Tbl-Ref-2	Security profile - sending
1-15	TFD-TSFC-Tbl-Ref-3	Security profile - receiving

Item	ID	Name
1-16	TFD-TSFC-Tbl-Ref-4	Security profile - security management
1-17	TFD-TSFC-Tbl-Ref-5	SSP design
1-18	TFD-TSFC-Tbl-Ref-6	C-ADS-V CDA scene zones - possible physical item relative directionalities
1-19	TFD-TSFC-Tbl-Ref-7	Way types
1-20	TFD-TSFC-Tbl-Ref-8	Target maneuver - follow road same lane maneuvers
1-21	TFD-TSFC-Tbl-Ref-9	Target maneuver - follow road different lane maneuvers
1-22	TFD-TSFC-Tbl-Ref-10	Target maneuver - intersection maneuvers
1-23	TFD-TSFC-Tbl-Ref-11	Target maneuver - turnabout maneuvers
1-24	TFD-TSFC-Tbl-Ref-12	Target maneuver - leaving road maneuvers
1-25	TFD-TSFC-Tbl-Ref-13	Target maneuver - entering road maneuvers
1-26	TFD-TSFC-Tbl-Ref-14	Target maneuver - interchange maneuvers
1-27	TFD-TSFC-Tbl-Ref-15	Target maneuver - other road user handling maneuvers
1-28	TFD-TSFC-Tbl-Ref-16	Target maneuver - special crossing maneuvers
1-29	TFD-TSFC-Tbl-Ref-17	Target maneuver - work zone maneuvers
1-30	TFD-TSFC-Tbl-Ref-18	Target maneuver - special zone maneuvers
1-31	TFD-TSFC-Tbl-Ref-19	Elemental maneuvers
1-32	TFD-TSFC-Tbl-Ref-20	Dynamic traffic movements items
1-33	TFD-TSFC-Tbl-Ref-21	Dynamic rules of the road items
1-34	TFD-TSFC-Tbl-Ref-22	Category - lateral control items
1-35	TFD-TSFC-Tbl-Ref-23	Category - longitudinal control items
1-36	TFD-TSFC-Tbl-Ref-24	Conspicuity items
1-37	TFD-TSFC-Tbl-Ref-25	Signal control - category: visual control signals
1-38	TFD-TSFC-Tbl-Ref-26	Signal control - category: non-visual control signals
1-39	TFD-TSFC-Tbl-Ref-27	Signal control - category: visual beacons
1-40	TFD-TSFC-Tbl-Ref-28	Movement control - visual indicators
1-41	TFD-TSFC-Tbl-Ref-29	Notifications - visual messages
1-42	TFD-TSFC-Tbl-Ref-30	Internal vehicle data - categories and attributes
1-43	TFD-TSFC-Tbl-Ref-31	Internal infrastructure data - categories and attributes
1-44	TFD-TSFC-Tbl-Ref-32	Localization data - data categories and attributes
1-45	TFD-TSFC-Tbl-Ref-33	Roadway data - categories and attributes
1-46	TFD-TSFC-Tbl-Ref-34	Operational constraints data - categories and attributes
1-47	TFD-TSFC-Tbl-Ref-35	Environmental conditions data - categories and attributes
1-48	TFD-TSFC-Tbl-Ref-36	Objects - categories and attributes
1-49	TFD-TSFC-Tbl-Ref-37	Special zones - categories and attributes

6.1 Identify Actors, Attributes, and Interfaces

Using the functional scenario and the logical scenario details from the CDA Feature Development process group (see 5.2), the following need to be identified for the CDA Feature (for definitions, see Section 3):

- Actors, which include the following:
 - CDA systems.
 - CDA feature relevant entities (also referred to with shorthand notation as “E(e)ntity” or “E(e)ntities”).
 - CDA feature relevant environment properties (also referred to with shorthand notation as “E(e)nvironment Property” or “E(e)nvironment Properties”).
- Attributes of each of the CDA Feature relevant entity and CDA Feature relevant environment properties.
- External CDA interfaces.

The process for identifying each of these is provided in further detail in the 6.1.1 through 6.1.4.

Within this report are tables which provide a common set of category and subcategory classifications for the actors, attributes, and interfaces (AAI), along with a corresponding abbreviation nomenclature, to use in the development of the test framework. This is to aid in removing ambiguity in which systems, entities, etc., are being referred to, regardless of the user of the CDA Feature test report.

6.1.1 Identify CDA Systems

CDA systems are the actors in the CDA Feature which are the focus of the testing. Two categories of CDA Systems have been identified:

- C-ADS vehicles.
- CDA infrastructure.

NOTE: There may be other road users (e.g., pedestrians) that are relevant to the CDA Feature but they would be considered as feature relevant entities, not CDA systems.

6.1.1.1 Template Output Table

TFD-AAI-Tbl-Out-1 provides a template which can be used for listing the details of the CDA Feature Systems.

TFD-AAI-Tbl-Out-1: Systems list

Category	Abbrev	Subcategory 1	Abbrev	Subcategory 2	Abbrev	System ID

6.1.1.2 Process

Input

- Functional scenario

Steps

Utilizing the input, identify the systems that comprise the CDA Feature and perform the following:

1. Create a systems list table (see 6.1.1.1 for a template) for documenting the details of the CDA systems.
2. See 6.1.1.3 for C-ADS-V and CDA-I systems.
3. Within the appropriate table from step 2, locate each of the systems described in the Functional Scenario (see Input).
4. For each of the systems fill out the table from step 1, which includes the:
 - a. Category classification and abbreviation.
 - b. Subcategory 1 classification and abbreviation.
 - c. If relevant, Subcategory 2 classification and abbreviation.

NOTE: This table includes a system ID. The ID will be identified following the process in 6.2.

Output

- TFD-AAI-Tbl-Out-1: Systems list

NOTE: Columns from the template table which are not used can be deleted from the output table.

6.1.1.3 Reference Tables

The reference tables for identifying the CDA system are provided in A.1.1. The following is a reference ID and link to these tables.

- TFD-AAI-Tbl-Ref-1: CDA system category/subcategory classifications - C-ADS-V
- TFD-AAI-Tbl-Ref-2: CDA system category/subcategory classifications - CDA-I

6.1.1.4 Example

See B.2.1.1 for the systems classification for an example CDA Feature use case scenario.

6.1.2 Identify CDA Feature Relevant Entities and Attributes

CDA entities are the physical actors that play a role in the CDA Feature for one of more of the CDA systems. These entities have attributes associated with them which are either being sensed or received by the CDA systems. Note that, depending on what the interaction is, some actors may play the role of both a CDA system and a CDA entity.

CDA Feature relevant entities are comprised of:

- Road users (e.g., motor vehicles, pedestrians).
- Non-road user objects (e.g., static objects like channelization devices, moving objects).
- Other CDA systems (only if being sensed).

6.1.2.1 Template Output Table

TFD-AAI-Tbl-Out-2 provides a template which can be used for listing the details of the CDA entities and their attributes.

TFD-AAI-Tbl-Out-2: CDA Feature relevant entities and attributes list

Category	Abbrev	Subcategory 1	Abbrev	Subcategory 2	Abbrev	Subcategory 3	Abbrev	CDA Feature Relevant Entity ID	Sensing/ Communication Attributes

6.1.2.2 Process

Input

- Functional scenario
- Logical scenario

Steps

Utilizing the inputs, identify the CDA Feature relevant entities and attributes that are relevant to the CDA Feature systems and perform the following:

1. Create a CDA Feature relevant entities and attributes list table (see 6.1.2.1 for a template) for documenting the details of the CDA entities and attributes.
2. See 6.1.2.3 for the CDA road user entities and CDA non-road user object entities.
3. Within the appropriate table from step 2, locate the CDA entities described in the functional and logical scenario details (see Input).
4. For each of the non-CDA system entities, fill out the table from step 1, which includes the:
 - a. Category classification and abbreviation.
 - b. Subcategory 1 classification and abbreviation.
 - c. Subcategory 2 classification and abbreviation.
 - d. If relevant, Subcategory 3 classification and abbreviation.
 - e. Attributes for the entity which are relevant to the CDA Feature that could either be sensed or obtained via M2M communications.
5. For any CDA system entities, use the same category, subcategory classifications as were used to identify the system in 6.1.1.
6. Only include the external CDA entities that are relevant to support the CDA Feature.
 - a. For example, for a C-ADS-V, do not show those entities that are germane to the base autonomous driving functionality of the C-ADS-V.

NOTE: This table includes a CDA Feature relevant entity ID. The ID will be identified following the process in 6.2.

Output

- TFD-AAI-Tbl-Out-2: CDA Feature relevant entities and attributes list

NOTE: Columns from the template table which are not used can be deleted from the output table.

6.1.2.3 Reference Tables

The reference tables for identifying the CDA entities and attributes are provided in A.1.1. The following is a reference ID and link to these tables.

- TFD-AAI-Tbl-Ref-3: CDA Feature relevant entity category subcategory classifications and attributes - road user
- TFD-AAI-Tbl-Ref-4: CDA Feature relevant entity category subcategory classifications and attributes - non-road user object

6.1.2.4 Example

See B.2.1.2 for the CDA Feature relevant entities and attributes classification for an example CDA Feature use case scenario.

6.1.3 Identify CDA Feature Relevant Environment Properties and Attributes

CDA feature relevant environment properties are actors, and the attributes associated with them, related to the environment that a system may find itself and may parallel the ODD for the C-ADS-V of the Feature.

In this revision of the report CDA Feature relevant environment properties are comprised of:

- Environmental conditions (e.g., weather conditions).
- Road conditions (e.g., environmental conditions of the road surface).
- Operational constraints (e.g., traffic levels of service).

6.1.3.1 Template Output Table

TFD-AAI-Tbl-Out-3 provides a template which can be used for listing the details of the CDA environment properties and their attributes that are relevant to the CDA Feature.

TFD-AAI-Tbl-Out-3: CDA Feature relevant environment properties and attributes list

Category	Abbrv	Subcategory 1	Abbrv	Subcategory 2	Abbrv	Subcategory 3	Abbrv	CDA Feature Relevant Environment Property ID	Attributes

6.1.3.2 Process

Input

- Functional scenario
- Logical scenario

Steps

Utilizing the inputs, identify the CDA environment properties and attributes that are relevant to the CDA Feature and perform the following:

1. Create a CDA Feature relevant environment properties and attributes list table (see 6.1.3.1 for a template) for documenting the details of the CDA systems.
2. See 6.1.3.3 for the CDA environmental conditions properties, CDA road conditions properties, and CDA operational constraints properties.
3. Within the appropriate table from step 2, locate the CDA environment properties described in the functional and logical scenario details (see Input).
4. For each of the CDA environment properties fill out the table from step 1, which includes the:
 - a. Category classification and abbreviation.
 - b. Subcategory 1 classification and abbreviation.
 - c. Subcategory 2 classification and abbreviation.
 - d. If relevant, Subcategory 3 classification and abbreviation.
 - e. Attributes for the environment property which are relevant to the CDA Feature.
5. Only include the external CDA environment properties that are relevant to support the CDA Feature.
 - a. For example, for a C-ADS-V, do not show environment properties that are germane to the base autonomous driving functionality of the C-ADS-V.

NOTE: This table includes a CDA Feature relevant environment property ID. The ID will be identified following the process in 6.2.

Output

- TFD-AAI-Tbl-Out-3: CDA Feature relevant environment properties and attributes list

NOTE: Columns from the template table which are not used can be deleted from the output table.

6.1.3.3 Reference Tables

The reference tables for identifying the CDA Feature relevant environment properties and attributes are provided in A.1.2. The following are the reference IDs and links to these tables.

- TFD-AAI-Tbl-Ref-5: CDA Feature relevant environment property category subcategory classifications and attributes - environmental conditions
- TFD-AAI-Tbl-Ref-6: CDA Feature relevant environment property category subcategory classifications and attributes - road conditions

- TFD-AAI-Tbl-Ref-7: CDA Feature relevant environment property category subcategory classifications and attributes - operational constraints

6.1.3.4 Example

The example use case contained in this report does not have any associated CDA Feature relevant environment properties; therefore, an example is not provided. However, given the content which would be identified is like the CDA Feature relevant entities and attributes content, it would be like what is provided in B.2.1.2 for the example CDA entities and attributes classification.

6.1.4 Identify CDA External Interfaces

The CDA external interfaces are how a CDA System:

- Obtains information from other CDA systems.
- Determines attributes about CDA entities and environment properties.

Since the CDA System is built on top of an ADS, only those aspects of the interfaces necessary to support the CDA Feature, beyond what is required of the ADS, are identified in this report. Given this, the two types of interfaces this report considers are:

- Communication interface.
- Sensing interface.

6.1.4.1 Template Output Table

TFD-AAI-Tbl-Out-4 provides a template which can be used for listing the details of the CDA external interfaces that are relevant to each of the CDA Feature systems. Given that the sensing interface details are provided in other tables, this table primarily addresses the communications interface.

TFD-AAI-Tbl-Out-4: External interfaces list

Category	Abbrev	Subcategory 1	Abbrev	Subcategory 2	Abbrev	Subcategory 3	Abbrev	Subcategory: Message/Data Set Descriptor Abbrev	ID
Sensing	SEN	Specific items contained in the CDA Entities and/or CDA Environment Properties Tables							
Communication	COM								
Communication	COM								
Communication	COM								

6.1.4.2 Process

Input

- Functional scenario
- Logical scenario

Steps

Utilizing the inputs, identify the CDA external interfaces that are relevant to the CDA Feature systems and perform the following:

1. Create an external interfaces list table (see 6.1.4.1 for a template) for documenting the details of the CDA Feature interfaces.
2. If any sensing interfaces are required for the CDA Feature, retain the first row of the table from step 1 with the sensing category identified; however, there is no need to list any sensing subcategories as these are already identified in the tables from 6.1.2 and 6.1.3.
3. For the communication interfaces, see 6.1.4.3 for the CDA external interfaces and identify each of communications interfaces described in the functional and logical scenario details (see Input) required to support the system and or/entity interactions
4. From the tables in step 3, for each of the communication interfaces fill out the table from step 1, which includes the:
 - a. Category classification and abbreviation.
 - b. Subcategory 1 classification and abbreviation.
 - c. Subcategory 2 classification and abbreviation.
 - d. If relevant, Subcategory 3 classification and abbreviation.
5. For each communication interface add the message or data set descriptor abbreviation, which should be included in the logical scenario details, to the table from step 1.

Output

- TFD-AAI-Tbl-Out-4: External interfaces list

NOTE: Columns from the template table which are not used can be deleted from the output table.

6.1.4.3 Reference Tables

The reference tables for the current set of subcategory classifications and abbreviations for the communications and sensing interfaces are provided in 0. The following is a reference ID and link to these tables:

- TFD-AAI-Tbl-Ref-8: CDA external interfaces

NOTE: The reference table includes machine-to-machine (M2M), vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), vehicle-to-network (V2N), and infrastructure-to-network (I2N) communications. M2M should be selected if it is clear which CDA Feature relevant entities the communication is between. The latter three should only be selected to remove ambiguity regarding which entities are involved in the communication. For example, if the communication is V2V but the infrastructure needs to process those messages, then to avoid confusing the communication as V2I it may be better to select V2V rather than M2M for the communication link between the C-ADS-V and the CDA-I.

NOTE: For the communications interface, depending on the CDA Feature, it is envisioned that potentially large as well as diverse information may be obtained or exchanged. Therefore, rather than a detailed set of attributes, it is intended that the message name descriptor or a data set descriptor be identified and used in the CDA test framework material.

NOTE: The reference table lists V2I, V2N, and I2N communications interfaces. Rather than introducing I2V, N2V, and N2I, these latter three should be considered to support communications in either direction. For example, considering V2I, it may be used to indicate communications from the vehicle to the infrastructure and/or communications from the infrastructure to the vehicle.

6.1.4.4 Example

See B.2.1.4 for the CDA external interfaces classification for an example CDA Feature use case.

6.2 Assign Unique Identifiers

Using a combination of the abbreviations, as documented in 6.1.1 through 6.1.4, along with an optional numerical value; each system, entity, environment property, and interface can be assigned a unique identifier.

There are two options for developing the IDs: a full ID or a short ID, the latter of which can be used in cases where a lower subcategory/subcategory set provides sufficient context to understand what is being referenced.

1. Option 1 - Full ID: <CATEGORY>_<Subcategory 1>_...<Subcategory N>_<Optional Numerical Value>
2. Option 2 - Short ID: <CATEGORY>_<Final Set of Unique Subcategories>_<Optional Numerical Value>

6.2.1 Process

Input

- TFD-AAI-Tbl-Out-1: Systems list
- TFD-AAI-Tbl-Out-2: CDA Feature relevant entities and attributes list
- TFD-AAI-Tbl-Out-3: CDA Feature relevant environment properties and attributes list
- TFD-AAI-Tbl-Out-4: External interfaces list

Steps

Utilizing the input tables, assign unique IDs to the systems, entities, environment properties, and interfaces by performing the following:

1. Assign a prefix which will be the category abbreviation that corresponds to the system, entity, environment property, or interface category contained in the input tables.
2. Assign a subcategory suffix: Following the prefix will be either a full ID suffix or short ID suffix. The steps for these are:
 - a. Full ID: For the full ID, concatenate the prefix from step 1 with each of the subcategory abbreviations contained in the input tables, with an underscore “_” inserted to separate the category from the subcategories and one subcategory from another.
 - b. Short ID: If a set of one or more end-level subcategories is unique and provides sufficient context to understand what is being referred to then, if desired, the full subcategory chain does not need to be included. In this case, follow the steps for 2a; however, only include the prefix and the final *N* end-level subcategories required to uniquely identify the system, entity, environment property, or interface.

NOTE: For both steps 2a and 2b, when the subcategory identified in the input table is “Any,” meaning *any* of the possible subcategory classifications is not important, then this does not need to be included in the ID.

NOTE: For communication interfaces, if M2M is identified for Subcategory 2, then the type of communication should be clear based on the CDA Feature relevant entities; therefore, M2M can be left out of the full or short ID.

NOTE: For communication interfaces the message abbreviation should be considered a subcategory and included in the ID.

NOTE: See 6.2.2 for some reference examples on creating full versus short IDs.

3. Assign an optional numerical value: When there are multiple of the same system, entity, environment property or interface, add a unique numerical ID to the suffix of the ID created in 2a or 2b with an underscore “_” inserted to separate the numerical ID with the rest of the ID.

Output

- Updated input tables

6.2.2 Reference Example IDs

For reference in creating IDs, the following are some examples for developing full versus short IDs.

Example 1: Full ID versus short ID with a unique final subcategory.

If it is desired to indicate a CDA Feature relevant entity of a police motor vehicle, per TFD-AAI-Tbl-Ref-1: CDA system category/subcategory classifications - C-ADS-V, there is only one category/subcategory chain that includes police. So, only the category and final subcategory need to be included (along with an optional numerical value if more than one police motor vehicle is involved in the CDA Feature). Considering this, the following would be the full ID and short ID options:

- Police motor vehicle full ID: RD-USR_MtrVeh_PubSaf_Police
- Police motor vehicle short ID: RD-USR_Police

Example 2: Full ID versus short ID with a non-unique final subcategory

If it is desired to indicate a CDA Feature relevant entity of a single trailer semi motor vehicle, per TFD-AAI-Tbl-Ref-1: CDA system category/subcategory classifications - C-ADS-V, a heavy truck can also have a single trailer, therefore, the final subcategory does not provide sufficient context to understand what is being referred to and, thus, additional subcategories are required. Considering this, the following would be the full ID and short ID options:

- Single trailer semi motor vehicle full ID: RD-USR_MtrVeh_Semi_SglTlr
- Single trailer semi motor vehicle short ID: RD-USR_Semi_SglTlr

6.2.3 Example

See B.2.1.1, B.2.1.2, and B.2.1.4 for the system, entity, and interface IDs for an example CDA Feature use case.

6.3 Develop System of Systems Diagram

The CDA systems, entities, environment properties, and external interfaces (6.1.1 through 6.1.4, respectively) along with the unique IDs (6.2), that pertain to the CDA Feature, will be combined to develop a system of systems (SoS) diagram (SoSD).

A SoSD provides the bigger picture of how all the systems, entities, and environment properties interact with each other and aids in:

1. Ensuring that all the interactions between the systems and between each CDA system and their relevant CDA entities and environment properties are understood and documented.
2. Supporting the development of individual CDA system diagrams.
3. Supporting efforts where the individual CDA systems may be developed by independent stakeholders, by ensuring all stakeholders understand how their system fits into the overall CDA Feature.

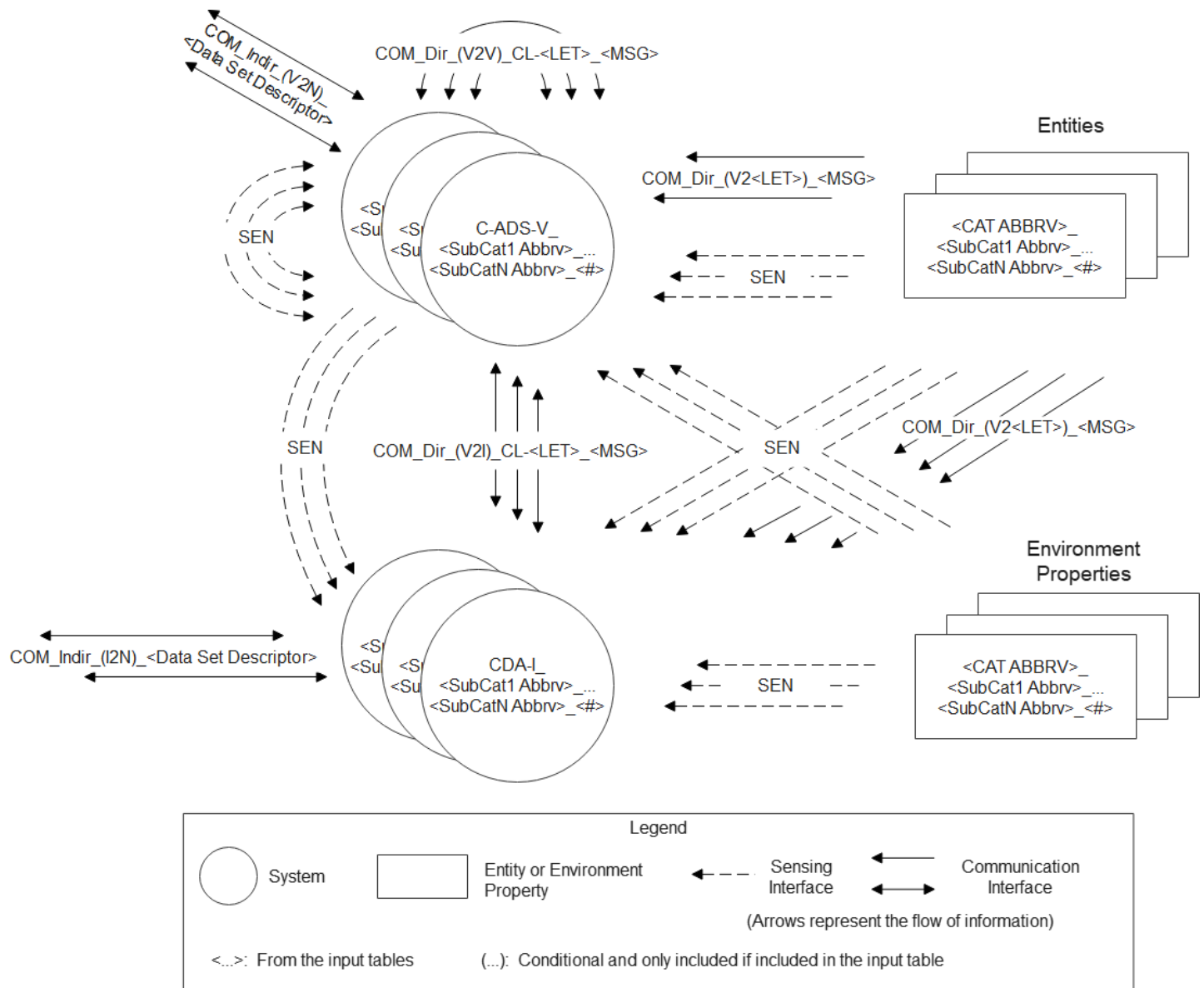
6.3.1 Template System of Systems Diagram

Before getting into the process for creating a SoSD and to better put into context what a SoSD is, TFD-SSD-Dgrm-Ref-1 below provides a template SoSD with all the possible interface connections that may exist between CDA systems, entities, and environment properties in addition to indirect communications interfaces for C-ADS-V and CDA-I systems. A CDA Feature SoSD will only include the systems, entities, environment properties, and interfaces specific to that Feature.

Like the common nomenclature that is used to identify the CDA systems, entities, interfaces, etc., for the SoSD, a common set of shapes should be used to distinguish between CDA systems and the CDA entities and environment properties they interact with:

- CDA systems are identified as circles.
- CDA Feature relevant entities and environment properties as identified rectangles.
- Communication interfaces are shown as solid lines with the arrow indicating the direction of the flow of information.
- Sensing interfaces are shown as dashed lines with the arrow indicating the direction of the flow of information.

NOTE: If a CDA system identified in 6.1.1 is also being sensed and thus is included in the CDA entities table, it should not be shown twice on the SoSD. Rather, it should be shown as a system, but with a sensing interface between it and the system by which it is being sensed.



TFD-SSD-Dgrm-Ref-1: CDA system of system diagram: illustration of possible interface connections

NOTE: In TFD-SSD-Dgrm-Ref-1, the full ID is implied; however, per 6.2, if desired and supported, short IDs could be used instead.

NOTE: In TFD-SSD-Dgrm-Ref-1, where “V2<LET>” is indicated, the “<LET>” would be replaced by the proper character from the input table if something other than “M2M” is identified for subcategory 2 for that communication link.

Referencing TFD-SSD-Dgrm-Ref-1, TFD-SSD-Dgrm-Ref-2 provides a list of the interfaces that are possible between the different CDA systems and other CDA systems, entities, environment properties, and external networks.

TFD-SSD-Dgrm-Ref-2: CDA system of systems diagram: mapping of possible system interfaces

System	Sensing Interface				Direct Communications Interface			Indirect Communications Interface
	C-ADS-V	CDA-I	Entities	Env Prop	C-ADS-V	CDA-I	Entities	External Network
C-ADS Vehicle	X		X	X	X	X	X	X
CDA Infrastructure	X		X	X	X		X	X

6.3.2 Process

Input

- Functional scenario
- Logical scenario
- TFD-SSD-Dgrm-Ref-1: CDA system of system diagram: illustration of possible interface connections
- TFD-SSD-Dgrm-Ref-2: CDA system of systems diagram: mapping of possible system interfaces
- TFD-AAI-Tbl-Out-1: Systems list
- TFD-AAI-Tbl-Out-2: CDA Feature relevant entities and attributes list
- TFD-AAI-Tbl-Out-3: CDA Feature relevant environment properties and attributes list
- TFD-AAI-Tbl-Out-4: External interfaces list

Steps

Utilizing the input tables and the nomenclature of TFD-SSD-Dgrm-Ref-1, develop a SoSD by performing the following:

1. Create shapes to represent each of the CDA Feature systems, entities, and environment properties.
2. Identify each of the systems, entities, and environment properties by their full ID or short ID.
3. For each CDA System, show the interface(s) to the:
 - a. CDA system(s) with which it interacts.
 - b. The CDA feature relevant entities with which it interacts.
 - c. The CDA feature relevant environment properties with which it interacts.
4. If a CDA system needs to sense another CDA system, ensure this sensing interface is shown as well.
5. Identify each of the interfaces by their full ID or short ID.
6. Crosscheck the input tables to ensure each of the systems, entities, environment properties, and interfaces are accounted for in the SoSD.

Output

- TFD-SSD-Dgrm-Out-1: System of systems diagram

6.3.3 Example

See B.2.1 for the SoSD for an example CDA Feature use case.

6.4 Develop Individual System Diagrams

Utilizing the SoSD, individual system diagrams (ISDs) will be developed which extract just the CDA entities, environment properties and interfaces which are relevant to that CDA system. This information is expanded upon by adding in the attribute information as well.

In addition to the aids provided by developing a SoSD discussed in 6.3, an ISD aids in:

1. Providing a double check on the system interactions to ensure none were missed.
2. Supporting the development of individual test support functional component diagrams.

6.4.1 Template Individual System Diagrams

TFD-ISD-Dgrm-Ref-1 and TFD-ISD-Dgrm-Ref-2 provide template ISDs for a C-ADS-V and CDA-I system, respectively, with all the possible interface connections that may exist between them and other CDA systems, entities, environment properties, in addition to indirect communications interfaces. An ISD will only include the systems, entities, environment properties, and interfaces specific to that system for the Feature.

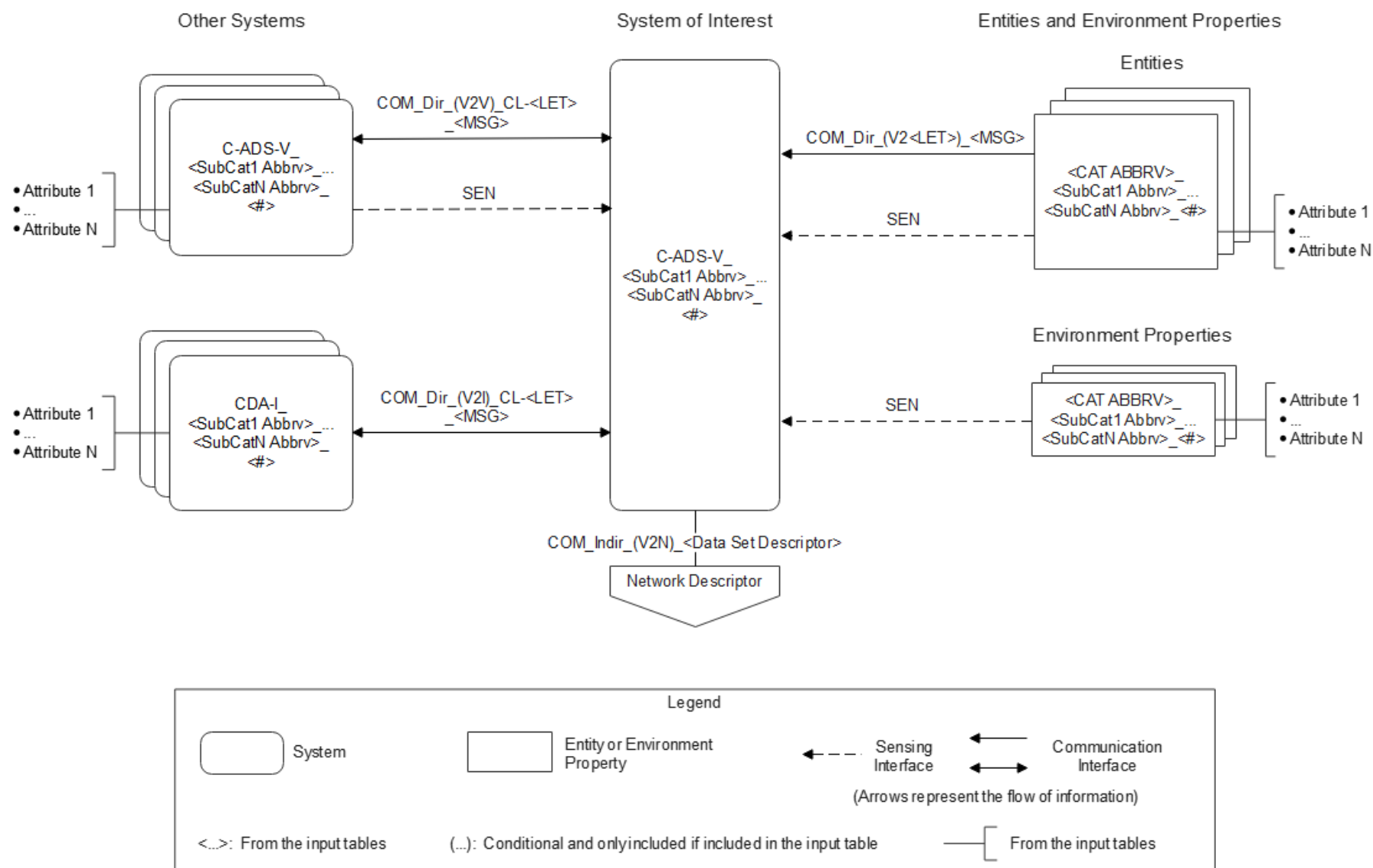
TFD-ISD-Dgrm-Ref-1 and TFD-ISD-Dgrm-Ref-2 show the same set of possible connections as exist for the SoSD presented in 6.3.1. To distinguish between CDA systems, entities, environment properties, and indirect interfaces, they show:

- The CDA system of interest in the middle as a rounded rectangle.
- The CDA systems it interacts with to the left, also as rounded rectangles.
- The CDA entities and environment properties as rectangles to the right.
- Indirect CDA interfaces as a connector to the bottom.

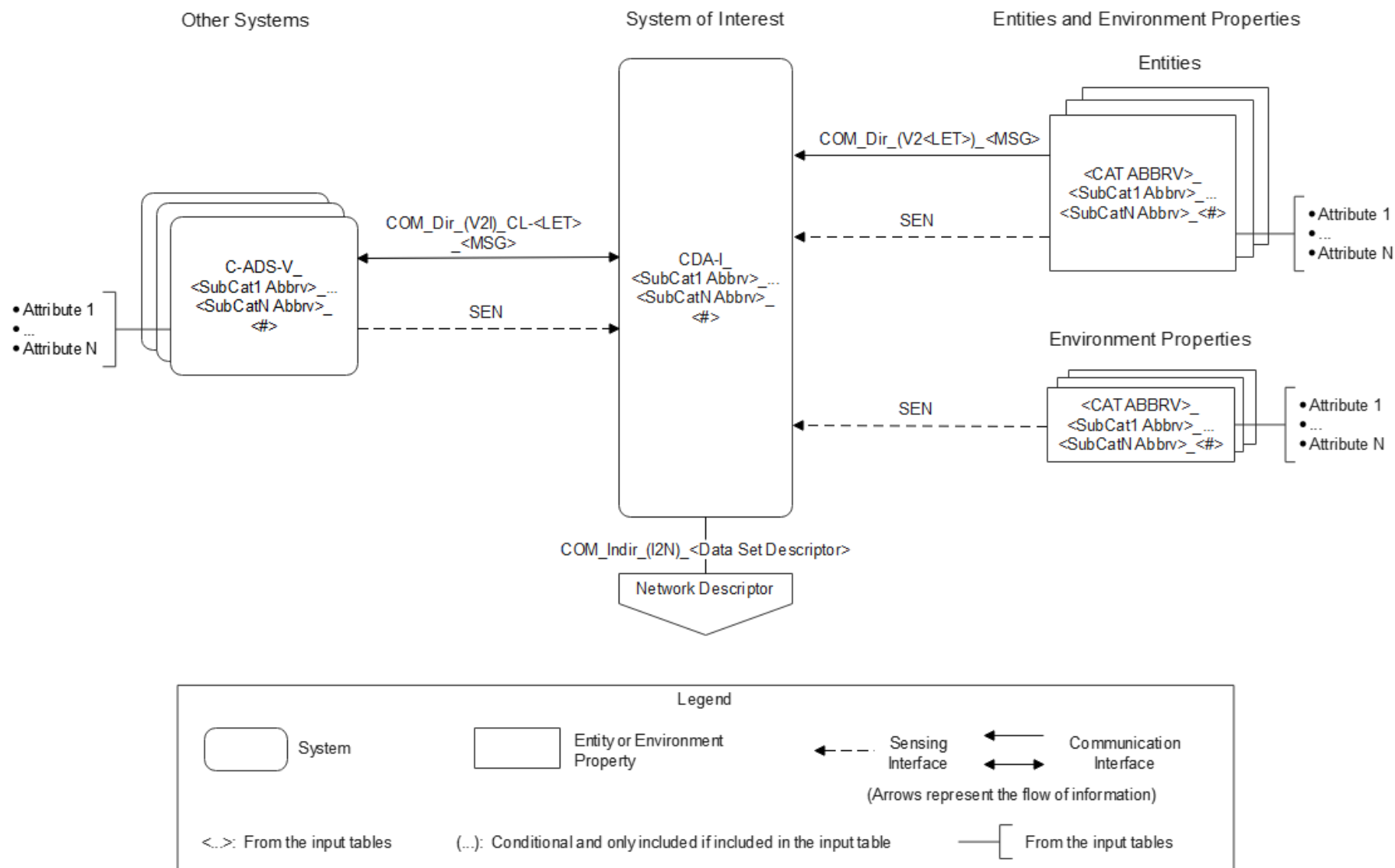
NOTE: If a CDA system is also being sensed and thus is included in the CDA entities table, it should not be shown twice on the ISD. Rather, it should be shown as a system but with a sensing interface between it and the system that it is being sensed by.

NOTE: In TFD-ISD-Dgrm-Ref-1 and TFD-ISD-Dgrm-Ref-2, the full ID is implied; however, per 6.2, if desired and supported, short IDs could be used instead. However, if short IDs were used for the SoSD, then they would be used here as well.

NOTE: In TFD-ISD-Dgrm-Ref-1 and TFD-ISD-Dgrm-Ref-2, where “V2<LET>” is indicated, the “<LET>” would be replaced by the proper character from the input table if something other than “M2M” is identified for subcategory 2 for that communication link.



TFD-ISD-Dgrm-Ref-1: C-ADS-V system diagram with possible interface connections



TFD-ISD-Dgrm-Ref-2: CDA-I system diagram with possible interface connections

6.4.2 Process

Input

- TFD-SSD-Dgrm-Out-1: System of systems diagram
- TFD-AAI-Tbl-Out-1: Systems list
- TFD-AAI-Tbl-Out-2: CDA Feature relevant entities and attributes list
- TFD-AAI-Tbl-Out-3: CDA Feature relevant environment properties and attributes list
- TFD-AAI-Tbl-Out-4: External interfaces list
- TFD-ISD-Dgrm-Ref-1: C-ADS-V system diagram with possible interface connections
- TFD-ISD-Dgrm-Ref-2: CDA-I system diagram with possible interface connections

Steps

Utilizing the input tables and the nomenclature of TFD-ISD-Dgrm-Ref-1 and TFD-ISD-Dgrm-Ref-2, develop ISDs by performing the following for each system:

1. Place the system of interest in the center.
 - a. Identify the system by its full ID or short ID.
2. Referring to the SoSD, for the CDA system from step 1, show the interface(s) to the:
 - a. CDA system(s) it interacts with to the left.
 - b. The CDA entities it interacts with to the right.
 - c. The CDA environment properties it interacts with to the right.
3. If a CDA system needs to sense another CDA system, ensure this sensing interface is shown as well.
4. Use the same ID nomenclature as was used on the SoSD (i.e., full ID or short ID) for each CDA system, entity, environment property, and interface to aid in traceability between an ISD and the SoSD.
5. For each entity, environment property, and CDA system that is being sensed, list the attributes that were identified in Section 6.1.2 and 6.1.3 and documented in the input tables.

Output

- TFD-ISD-Dgrm-Out-1: Individual system diagram - <CDA System>

NOTE: There will be an output system diagram for each of the individual CDA Feature systems.

6.4.3 Example

See B.2.2 for the individual SDs for an example CDA Feature use case.

6.5 Develop Individual System Test Support Functional Component Diagrams and Details

Given the diversity in system implementations from one implementor to the next, it is unlikely the physical system components and/or the partitioning of functionality across physical system components will be the same among implementors. For the information to be gathered by the sub-processes contained in this section, it is not important where the data items of interest physically reside within an implementation; rather, it is only important that the data items are correctly categorized. Therefore, in this report system functional components are introduced, as opposed to system physical components, to enable common functional test support data items to be identified without regard to any particular implementation.

For the systems which are having test procedures developed, individual system test support functional component (TSFC) detail needs to be identified and optionally corresponding functional component diagrams created. Having these details will aid in identifying a comprehensive set of test procedures. Seven functional components have been identified which, depending on if the system is a C-ADS-V or CDA-I, may have a distinct set of sub-components to consider. Depending on the CDA Feature, each system may not require the full set of functional components and/or sub-components. The primary functional components include:

- Communication.
- Security.
- CDA System Scene.
- CDA Sensing/Perception.
- Planning.
- Action.
- Knowledge Database.

Utilizing the inputs and working through the details of 6.5.2, which applies to both C-ADS-V and CDA-I systems; 6.5.3, which is specific to C-ADS-Vs systems; and 6.5.4, which is specific to CDA-I systems,

- Individual test support functional components and their corresponding sub-components will be identified.
- For each of the functional components or sub-components, specific details will be identified which will aid in developing the test procedures.
- Using the above and 6.5.1, test support functional component diagrams will be developed which will provide a visual representation of the functional components and sub-components required to support the planned testing of the Feature, as well as provide the relationships between the functional components.

For each of the above functional components, process information is provided for identifying the Feature-specific details of that functional component.

6.5.1 Template Test Support Functional Component Diagrams

Figure 7 and Figure 8 provide template test support functional component diagrams for an individual C-ADS-V system and CDA-I system, respectively. Within each diagram, potential relationships between functional components and sub-components are shown to assist with identifying the relevant information when executing the testing. For C-ADS-V systems, the ADS is the foundation for the CDA Features; however, CDA-I systems may or may not need the support of an automated infrastructure system (AIS) to support a CDA Feature. For both systems, only the aspects of the automated system that are expected to support the CDA Feature are considered and included in the functional component diagram, not the full set of automation that would be required to support the C-ADS-V or CDA-I capabilities.

The figures show three types of color-coding:

- In green is the Knowledge Database which is where system data, or data which may be derived from the ADS (for a C-ADS-V) or AIS (for a CDA-I), but is not CDA Feature-specific, is identified.
- In grey are functional components which would be considered part of the ADS (for a C-ADS-V) or AIS (for a CDA-I). They are separated this way to show that a C-ADS-V or CDA-I would not implement a separate sensing, planning, and acting functionality. Rather the automated system components would be leveraged to support the CDA Feature-specific items.
- In blue are functional components which are specific to CDA. It should be noted that the “CDA System Scene” is a central functional component based on SAE J3164 and is described in detail in the sections which address this functional component.

NOTE: Figure 7 and Figure 8 should not be considered as system architectures. If a system architecture is required, that will be included in the CDA Feature report. Rather these are visual representations of functionality that may exist in an architecture and that are relevant to the CDA Feature. This is done to compartmentalize the data items that need to be identified to support the testing. Since these are not architectures, they are not implying processes.

NOTE: While an ADS (for a C-ADS-V) or AIS (for a CDA-I) may need just grey and green functional components, CDA requires blue, grey, and green functional components.

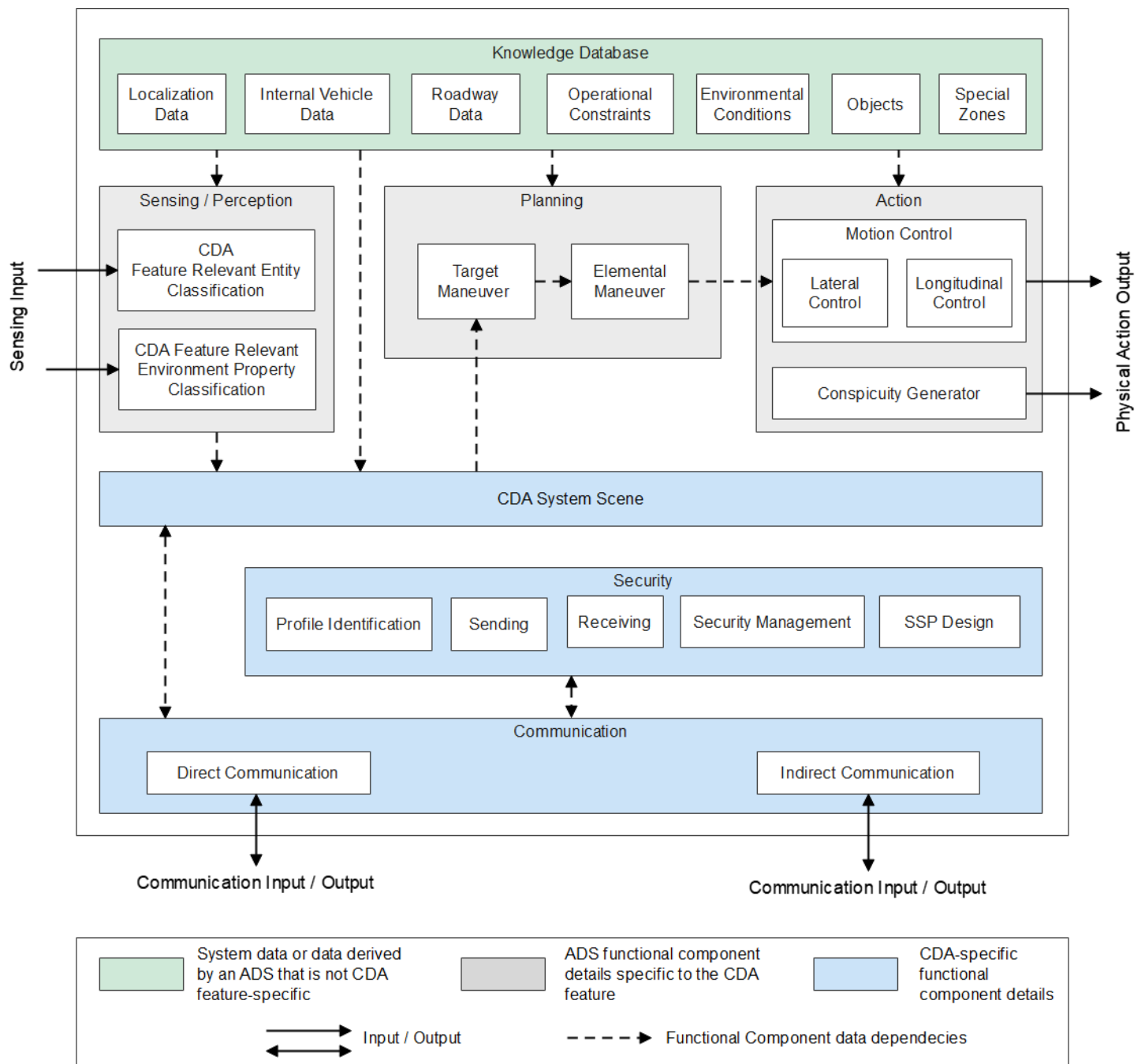


Figure 7 - C-ADS-V test support functional component diagram

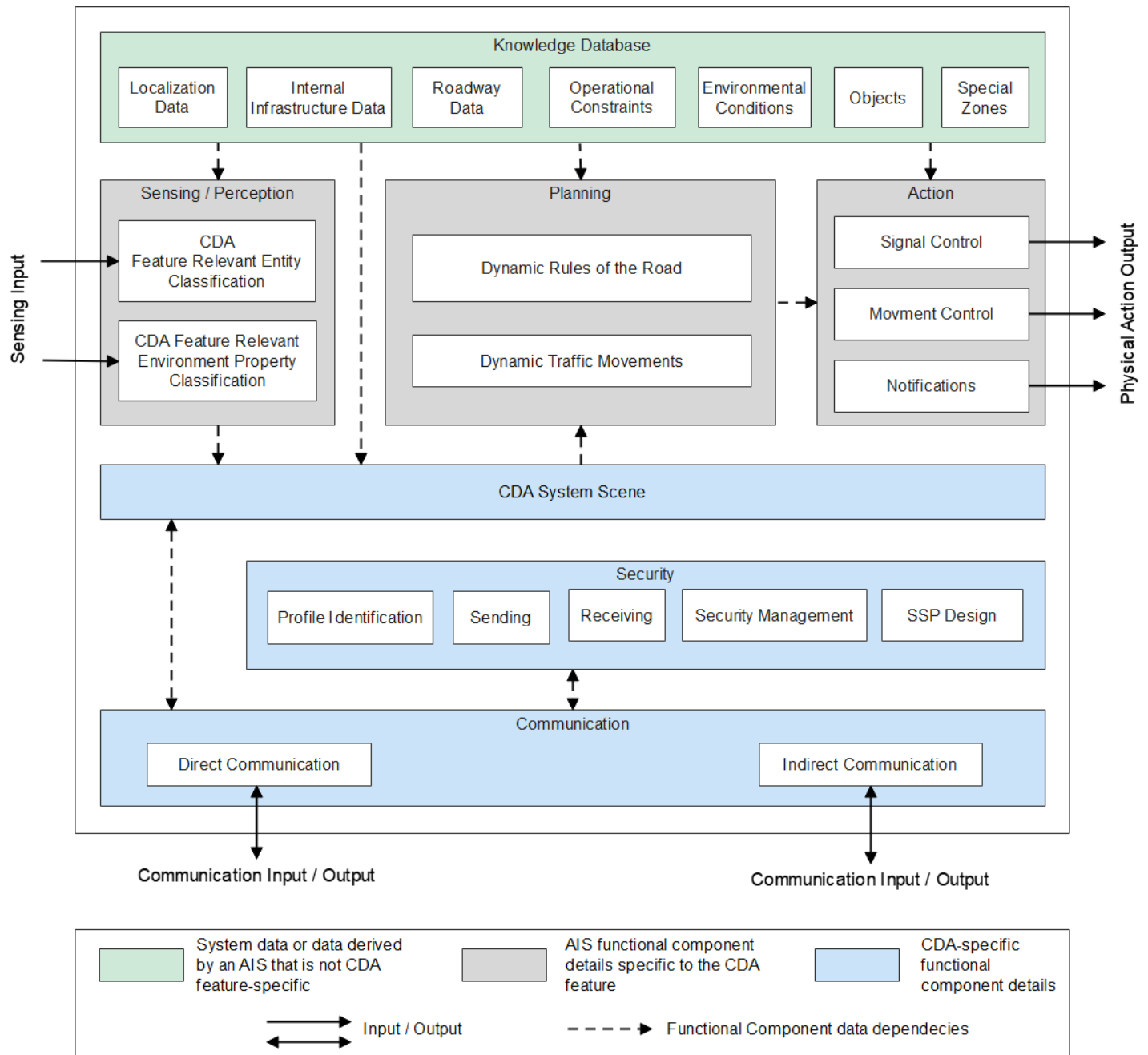


Figure 8 - CDA-I test support functional component diagram

6.5.2 Common Test Support Functional Components

The test support functional component diagrams for the C-ADS-V and CDA-I shown in Figure 7 and Figure 8 share many of the same functional components/sub-components. Thus, the process for developing the common test support functional component details for both systems is combined into this section. The template tables, inputs, process, and outputs contained in the following sub-sections should be followed for both C-ADS-V systems and CDA-I systems.

6.5.2.1 Identify Communication Sub-components

The Communication sub-components align with the subcategory 1 communications interfaces identified in 6.1.4, which are:

- Direct Communications.
- Indirect Communications.

6.5.2.1.1 Template Output Table

TFD-TSFC-Tbl-Out-1 provides a template which can be used for listing the details of the communication functional component. It will identify each of the messages along with the functional component that sources the data and the functional component(s) that use the data.

TFD-TSFC-Tbl-Out-1: Communication sub-component details: data source and data user(s) - <CDA System>

ID	Functional Component Sourcing Data	Functional Component(s) Using Data	Directionality

6.5.2.1.2 Process

Input

- TFD-ISD-Dgrm-Out-1: Individual system diagram - <CDA System>

Steps

Utilizing the individual system diagram as the input,

1. Create a communication sub-component identification and details table (see 6.5.2.1.1 for a template) for documenting the details of the Communications test support functional component.
2. For each of the communication interfaces shown on the ISD, which is provided as an input, identify the following:
 - a. The interface ID which includes the message name or descriptor and indicates which message is being exchanged.
 - b. The source and destination test support functional components for the message.
 - c. The directionality of the interface, i.e., one-way/two-way.

NOTE: For determining source and destination functional components, it is likely that the full message content of messages defined specifically to support the CDA Feature would be utilized by the test support functional components. For other messages defined to support non-CDA Features but used by the CDA Feature (e.g., Basic Safety Messages [BSMs]), only a sub-set of the message content may be needed.

Output

- TFD-TSFC-Tbl-Out-1: Communication sub-component details: data source and data user(s) - <CDA System>

6.5.2.1.3 Example

See B.2.3.1.1 (CDA-I) and B.2.3.2.1 (C-ADS-V) for the Communication functional component details for an example CDA Feature use case.

6.5.2.2 Identify Security Sub-Components

Given that the test procedures are intended to support collaborative testing of CDA Features, only those collaborative aspects of the Security sub-components should be considered. The other aspects of security would be expected to be tested as part of the internal CDA development effort. The supported security functionality is normally determined by the security profile that has been developed for the Feature, which may then inform Feature-specific security requirements. There are five different security profiles areas identified in IEEE 1609.2 which map directly to the Security sub-components that will be considered. In addition to the security profiles, during the development of the Feature, security analysis may identify service-specific permissions (SSPs) that are required to support the Feature. The inclusion of SSPs also generally involves the development of Feature-specific requirements, therefore, this is also considered in the security sub-components. The process for determining which of the security sub-components and their details is addressed below.

NOTE: While the C-ADS-V and CDA-I share the same Security sub-components, for a given CDA Feature, the security profiles for the C-ADS-V and CDA-I will likely be different.

6.5.2.2.1 Template Output Table

TFD-TSFC-Tbl-Out-2 provides a template which can be used for listing the details of the Security functional component. It will identify each of the security profiles along with the individual profile elements that will be the focus of testing.

TFD-TSFC-Tbl-Out-2: Security sub-component details - <CDA System>

Security Sub-Component	Parameter Name	Parameter Test Considerations
Security Profile: Profile Identification		
Security Profile: Sending		
Security Profile: Receiving		
Security Profile: Security Management		
SSP Design		

6.5.2.2.2 Process

Input

- Logical scenario

Steps

If the logical scenario (see Input) considers security as part of the Feature development, then perform the following:

1. Create a security sub-component details table (see 6.5.2.2.1 for a template) for documenting the details of which profiles/parameters and SSP design/parameters will be considered in the testing.
2. From the input, identify which Security sub-components are relevant to the CDA Feature.
 - a. Retain those rows in the table from step 1 and either remove or blank out the other rows.