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ITS Architecture Requirements and Features Needed to Provide for Safety-Related ITS User Services

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16. Abstract

The Intelligent Transportation System (ITS) Architecture is based on DOT requirements to provide user services in areas such as mass transit, commercial vehicle operations, traffic management, and personal vehicles, among others. The objective of this task was to assess the extent to which the ITS Architecture supports or is compatible with safety-related ITS user services of interest to the National Highway Traffic Safety Administration (NHTSA), particularly those having significant in-vehicle control and warning functionality. The task was structured to permit feedback of NHTSA needs and concerns to the architecture development teams during the process of ITS Architecture development.

The study found no major issues in the ITS Architecture that would limit or adversely impact the efforts of NHTSA to facilitate the deployment of future in-vehicle safety-related systems. To a large extent, this can be attributed to the fact that the ITS Architecture does not address in-vehicle safety systems in detail-actual deployment and design issues were considered beyond the scope of the architecture. It also assumes that these systems fall into the category of higher risk/later deployment, with most of the cost being borne by the private sector. The study did, however, identify several technical concerns and issues that were brought to the attention of NHTSA and the ITS Architecture Team during the course of the effort. While several areas of concern were addressed by the Architecture Team during the course of the study, other issues (documented in the final report) remain open.

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1. Findings and Recommendations

1.1 Summary

This report presents the results of an analysis of safety-related functions of the National Intelligent Transportation System (ITS) Architecture, currently under development by the U.S. Department of Transportation (DOT). The ITS Architecture addresses all facets of the national surface transportation infrastructure, with the overall objectives of enhancing travel efficiency, reducing congestion, improving fuel economy, reducing harmful exhaust emissions, and enhancing traveler safety. For ITS implementation, it is anticipated that a wide range of advanced electronic, computer, and communications technologies will be employed within numerous cooperating and interconnected systems and subsystems, covering local, regional, and national geographic areas.

In Phase I of this program, four contractors were chosen to independently develop candidate architectures. Two contractors (Rockwell International and Loral) were selected for Phase II, in which a single, comprehensive architecture was jointly developed. Two Interim Program Reviews (IPRs) and a Final Program Review (FPR) were conducted during Phase II. The analysis summarized in this report was performed using the architecture information provided in the final program review in Washington, DC from 2 - 4 April 1996 as well as material and findings from the two IPRs (June 1995 and October/November 1995). This report presents all findings concerning safety related services in the ITS Architecture including those first identified in previous analyses based on the two IPRs. Several issues first discussed in the previous analyses have not been resolved in the ITS Architecture as of the FPR, so they remain as issues discussed by this report.

1.2 Summary of Findings

This study found no major issues in the ITS Architecture that would limit or adversely impact the efforts of the National Highway Traffic Safety Administration (NHTSA) to facilitate the deployment of future in-vehicle safety-related systems. To a large extent, this can be attributed to the fact that the ITS Architecture does not address in-vehicle safety systems in detail-actual deployment and design issues were considered beyond the scope of the architecture. It also assumes that these systems fall into the category of higher risk/later deployment, with most of the cost being borne by the private sector.

The FPR documentation includes revisions that improve the readability and usefulness of the architecture and resolve several issues first identified in Stanford Telecom's (STel's) previous ITS Architecture analyses [Ref. 22-23]. The improvements to the traceability matrix [Ref. 10] were significant. Some relatively minor technical omissions and inaccuracies (described in detail in §4), however, remain. Key findings relevant to the current ITS Architecture follow.

- The En-route Driver Information Service provides both traffic and safety-related messages to drivers through two subservices: driver advisory (wide area messaging) and in-vehicle signage (short range messaging). The ITS Architecture as of IPR #2 did not provide for a wide-area broadcast driver advisory implementation thus precluding the possibility to provide common information to drivers over a wide region. The architecture now contains such a function. However, the architecture appears to overly emphasize the information providing function of driver advisory over the information service of in-vehicle signing. The architecture appears to equate driver advisory with the providing information function while relegating in-vehicle signing to a driver interface function. This emphasis results from the assignment of functions to these subservices in the traceability matrix and the naming of data flows and not from a deficiency of the architecture. NHTSA, however, may want to ensure that the important safety functions of in-vehicle signing are emphasized sufficiently.

- The ITS Architecture intentionally leaves the subject of in-vehicle safety-related control systems open and non-specific. Only a small fraction of the postulated communications volume relates to safety-critical in-vehicle systems, even in the twenty-year scenario. Furthermore, the data flow diagrams depicting in-vehicle safety-related functionality are rather generic and high-level; all safety-related vehicle control functions are performed by the same set of process specifications. This approach was taken to reflect the fact that most of these systems are in a very early stage of design and development, and that numerous (and likely proprietary) implementation approaches'are possible. However, previous Task 1 effort [Ref. 19] identified real-time safety-related vehicle control systems as a key area where further refinement of automotive data bus multiplexing standards may be required. As described in §4, further NHTSA coordination may be needed.

  This approach of performing all safety-related vehicle control functions with the same set of process specifications could be interpreted to imply a level of complexity and coordination that may, in practice, not be appropriate. The complex system depicted in the architecture would most likely evolve over time from a simple system with few components into a more complex system with many components, or possibly into several separate subsystems that have minimal interaction. In addition, the control of the vehicle as indicated in the architecture does not include all the possibilities. For example, future vehicles may assist in steering and braking functions by controlling suspension and transmission, two possibilities not shown by the architecture.

- The ITS Architecture provides functions (P-Spec 6.2.2, Prepare and Output In-vehicle Displays, and P-Spec 6.2.5, Provide Driver Interface) for preparing and displaying information to the driver in audio and visual formats. The complexity and quantity of processing that P-Spec 6.2.2 seems to imply may make it difficult to implement a useful and safe interface for the driver. The latency of safety-critical information must be sufficiently short to be usable by a driver. The ITS Architecture does not appear to address or to describe the needs of the (human) driver interface which are affected by the size and content of messages, both of which were assigned by the architecture. Specific human interface requirements were not assessed by this analysis, but NHTSA may wish to involve human interface experts to assess the size, content, and complexity of the ITS Architecture's proposed driver interface.

- Within the physical architecture, the subsystems, equipment packages, data flows, and interfaces defined by the physical architecture appear to be adequate for implementing advanced safety systems and should not impair the deployment of these safety systems. Although the equipment packages defined by the architecture may not correspond exactly to existing or future vehicle control and operational systems, they are sufficiently general to accommodate future implementation. The data flows <u>between</u> subsystems are sufficiently defined and general enough to handle the required information flow for future implementation. However, descriptions of data flows to systems outside the architecture were not defined or discussed-this is probably just an oversight in the preparation of the documents, but should be corrected before the National Architecture Review.

The communications interfaces were defined by the physical architecture and recommended communication methods were analyzed by the architecture. The communications appear to be adequate for efficient and safe operations, but several considerations were identified that will require attention during ITS implementation. The primary issues concerning communications and safety-related services can be summarized as:

- The communications analyses show that data loads and performance are acceptable, but the analyses do not consider such factors as voice and visual data that may dramatically increase the communications needs.
- The compatibility of data exchanged at the application layer between in-vehicle systems and ITS infrastructure needs to be ensured; standardization of message sets and the way message fields are interpreted by high level applications provides an environment for effective implementation of services.
- In-vehicle electronic interfaces should support "plug and play" with third party aftermarket ITS components. This may require two classes of data bus: a closed, possibly proprietary one for safety-related control functions, and an open, possibly standardized one for driver warning and convenience functions.
- Data messages should remain independent from communications media and lower protocol layers to ensure flexibility and the capability to route messages through different types of communications media or networks.
- The interference to wireless communications and the security of these links was not fully addressed by the architecture and should be an important consideration during the implementation of ITS services especially those services (e.g., intersection collision avoidance and automated highway systems) involving control of safety systems.
- The interfaces defined by the architecture appear acceptable for safety-related services but the implementation of the architecture should avoid the proliferation of interfaces, both vehicle-to-infrastructure and vehicle-to-driver.
- The architecture recommends that short range communications (e.g., beacons) should be used for safety-related services such as in-vehicle signing and intersection collision avoidance, but this is obscured by the unrelated, but controversial, design decision to preclude short range communications for services such as route guidance. Short range communication recommendations appear adequate for safety-related services, but the architecture does not perform any detailed analysis concerning this communication.

Finally, the ITS Architecture documentation is challenging to use and may prove inaccessible for system developers. While traceability matrices are provided to map user service requirements to data flows and functions, it is in general quite difficult to obtain an overview of any single user service from the provided documentation. As part of the effort needed to perform this task, a high level object oriented model of the safety-related user services under consideration was created to help facilitate an understanding of these services and their potential implementation. While it can be argued that our ability to extract the information needed to perform this task is proof of the quality of the documentation, existence of more accessible documentation would have greatly reduced the effort required.

One useful rendition of the architecture is the World Wide Web Site [Ref. 25] created by Rockwell International. This site provides an interactive view of the architecture that allows quick referencing of the various components of the architecture. In fact, the architecture . presentation at this site appears to be more complete and accurate than the printed version distributed for the FPR that was analyzed for this study. Several of the documentation discrepancies identified by this study do not exist in the World Wide Web site version of the architecture. It may be useful for DOT to investigate ways to make the interactive version available to developers as it may assist in the maintenance and evolution of the architecture by reducing the costly distribution associated with printed documents. This interactive view of the architecture, however, lacks a means to obtain an overview of any single user service.

DOT recognizes the difficulty for developers in understanding such a complex architecture and has begun efforts to help facilitate the implementation of the architecture. NHTSA may wish to participate in the implementation process to ensure that usable and accessible views of safety-related services are provided in any information guides of the architecture.

1.3 Recommendations

This document addresses recommendations relevant to the concerns identified within this analysis at the points within the document where the concerns are described. In particular, $4 contains many detailed concerns meriting ITS Architecture Team and/or NHTSA review and consideration. The most significant of the identified concerns meriting attention by NHTSA are summarized below.

- Lack of Detail in Definition of In-Vehicle Control Services. The ITS Architecture focuses on user services that involve interfaces external to the vehicle. While this concentration is appropriate given the desire to concentrate on communications and performance standards involving interfaces exterior to vehicles, there are significant concerns relevant to in-vehicle real-time control systems that merit NHTSA attention. As previously identified in Task 1 [Ref. 19] real-time vehicle control (e.g., longitudinal and lateral collision avoidance) severely tax the capabilities of currently defined in-vehicle communications bus standards. ITS Architecture evolution, by defining some of the requirements and capabilities of these services, will place additional constraints on their implementation. For example, defined requirements and interface capabilities for a platooning service will directly impact implementations of vehicle longitudinal control functions. While potentially out-of-scope for the ITS Architecture, a more detailed NHTSA examination of performance issues relevant to these in-vehicle control functions, in the context of the ITS Architecture, appears warranted.

- Lack of Consideration for Human Interface Requirements. As discussed in the findings section, the ITS Architecture does not appear to address or to describe the needs of the (human) driver interface. Human interfaces need to be streamlined, integrated, flexible, intuitive, and safe. These features were apparently not considered by the architecture when message size and content were assigned. The design of actual interfaces is beyond the scope of the architecture, but its features will shape possible implementations. As with in-vehicle control complexity, further examination concerning the impact of the architecture on human interfaces appears warranted. A detailed analysis is not necessary, but close scrutiny during the standardization and implementation phase is needed.

- Inaccessibility of the Architecture Documentation. While not a major issue affecting safety-related services, the difficulty in using the documentation may inhibit the development of ITS Architecture compatible safety-related systems leading to uncoordinated operations within the vehicle. If NHTSA desires to promote the evolution of the safety-related user services of the architecture, then NHTSA should consider approaches to obtaining more accessible architecture documentation for use by developers-either within the context of the ITS Architecture or as a separate activity. The current documents will not, by themselves, inhibit development of systems supporting the safety-related user services, but improved documentation could enhance ITS Architecture acceptance and promote deployment of such systems.

- Vulnerability of Wireless Interfaces. Due to the openness of wireless communications, there exists a risk in performance from interference from other systems or deliberate sabotage. Both vehicle to vehicle and vehicle to roadside communications may be degraded or "spoofed" causing potentially dangerous situations. As with many other issues, good design practices not specified by the architecture can alleviate this risk, but the architecture does not fully address this issue. These design practices, however, may place additional burdens on the ITS communications that also have not been considered. Additional examination by NHTSA appears warranted but monitoring of the ITS implementation and standardization process may be adequate at this time.

Finally, now that the ITS Architecture is essentially complete, NHTSA needs to consider its role in the maintenance and evolution of the architecture as well as its implementation. NHTSA does not need to play a major role, but it should monitor and participate in future activities to ensure that safety-related services of concern to NHTSA are not de-emphasized or adversely affected. As NHTSA develops its own systems and technologies, NHTSA should compare them with the architecture and suggest any needed changes to the architecture based on these systems and its own experience in developing them. The architecture needs to maintain pace with developments in technology. In this manner, the architecture can be kept up to date with NHTSA's needs and developments.

2. Study Overview

2.1 Background: ITS Architecture and Safety Systems

The ITS Architecture addresses all facets of the national surface transportation infrastructure, including improving safety for the traveling public. Several of the user requirements identified by the DOT for the ITS Architecture aim directly at improving the safety of drivers, transit passengers, and other travelers. These user requirements provide the focus for the assessment of the ITS Architecture summarized in this report.

This section outlines the basic objectives of the ITS Architecture assessment. This section also presents an overview of the approach and methodology used to assess the National ITS Architecture for its support and compatibility with safety-related ITS user services. Additional information about the safety services and the ITS Architecture may be found in $3.

2.1 .1 Safety-Related ITS User Services

The ITS User Services Requirements document prepared by the DOT lists 29 user services, most of which have several subservices. Of these services, nine were identified by NHTSA/OCAR as having important in-vehicle safety-related functions to be addressed in this assessment. Based on the input from several reviewers during the IPRs, an additional user service, highway-rail intersection, will be added as the thirtieth user service requirement for the ITS Architecture. This user service is clearly an important safety service, but is not analyzed in this report as it has not yet been incorporated into the ITS Architecture. Specific information concerning the nine identified user services of interest to NHTSA/OCAR is outlined in §3.

2.1.2 ITS Architecture

The ITS Architecture is not a system design nor is it a design concept. The architecture defines the various ITS functions, the physical entities which execute these functions, and the necessary interfaces and information flows between the various functions and entities of the architecture. The architecture is intended to support national and regional interoperability including the interoperability of products performing the various ITS services. The Architecture consists of various components such as a Logical Architecture and a Physical Architecture. An oven'iew of the components of the ITS Architecture as prepared for the DOT is provided in $3.

2.2 Objective of this Study

The ITS Architecture is based on DOT requirements to provide user services in areas such as mass transit, commercial vehicle operations, traffic management, and personal vehicles, among others. The objective of this task is to assess the extent to which the ITS Architecture supports or is compatible with safety-related ITS user services, particularly those having significant in-vehicle control and warning functionality. For this task, NHTSA identified nine such safety-related ITS user services:

1. En-Route Driver Information including Driver Advisory and In-vehicle Signing
2. Emergency notification and personal security
3. Emergency vehicle management
4. Longitudinal collision avoidance

5. Lateral collision avoidance
6. Intersection collision avoidance
7. Vision enhancement for collision avoidance
8. Safety readiness
9. Pre-crash restraint deployment

The assessment of how the ITS Architecture supports and is compatible with the nine safety-related user services is determined by two cooperative activities:

- A general analysis of the maturity and integrity of the overall ITS Architecture in its current stage of development; and
- Specific analyses of the ITS Architecture in support of each of the nine safety-related user services.

In addressing the second activity, it is important to realize that there are both functional and performance aspects to consider. For example, whether the architecture supports the collection, processing, and distribution of certain data required for a safety-related user service addresses only the functional aspects. However, issues such as whether the data is of the required precision and integrity, or whether the communication links have the required throughput and latency address the performance aspects of the architecture.

2.3 Approach & Methodology

2.3.1 Overview

The overall approach to performing this analysis was to use the available ITS Architecture documentation [Ref. 1- 18] as inputs to a system design process. Using the various logical and physical elements extracted from the architecture, efforts were made to define systems to correspond to each of the nine targeted user services. The resulting systems were then assessed for factors such as:

- Completeness in satisfying the relevant ITS functional requirements;
- Consistency in nomenclature and data flows;
- Compatibility and integrability with in-vehicle warning and control systems;
- Technical errors such as duplicated or omitted elements, ambiguous or erroneous definitions and specifications, incorrect data flows;
- Capability to support an evolutionary deployment strategy; and
- Adequacy of the interfaces between in-vehicle systems and other ITS Architecture elements.

Additionally, the study addresses other related factors, such as:

- Whether existing communications interface standards and protocols are adequate for the identified information flows;
- Strategies for further architecture development; and
- Technical issues that may impede the implementation and deployment of the safety-related user services.

2.3.2 Methodology

The detailed methodology followed for the analysis is depicted in Figure 2-1. The architecture defines individual functions called Process Specifications (P-Specs), groups of functions called Data Flow Diagrams (DFDs), and the data flows between them. To fully capture a given user service, all data flows directly affecting the user service must be traced from their sources to their destinations (called "sinks"), which may reside in multiple functional processes and physical subsystems. The final operational diagram for a given user service can therefore be quite complex, and its physical elements may be dispersed over many subsystems, communications links, and elements outside the architecture (called "Terminators"). In some cases, a data flow will source or sink at a terminator, and no further tracing is possible. In other cases, the source or sink will be a process specification that requires inputs from yet other process specifications to produce or utilize the given data flow. If this process specification was part of a different user service, no further tracing was performed.

The physical architecture was assessed by determining if the physical systems necessary for performing the safety services were present. This required a review of the various subsystems and equipment packages outlined by the physical architecture. The communications portion of the physical architecture and the various elements of the Communications Document [Ref. 6] were assessed to determine if the needed interfaces and data flows were present for performing the safety services. The overall communications approach was also reviewed.

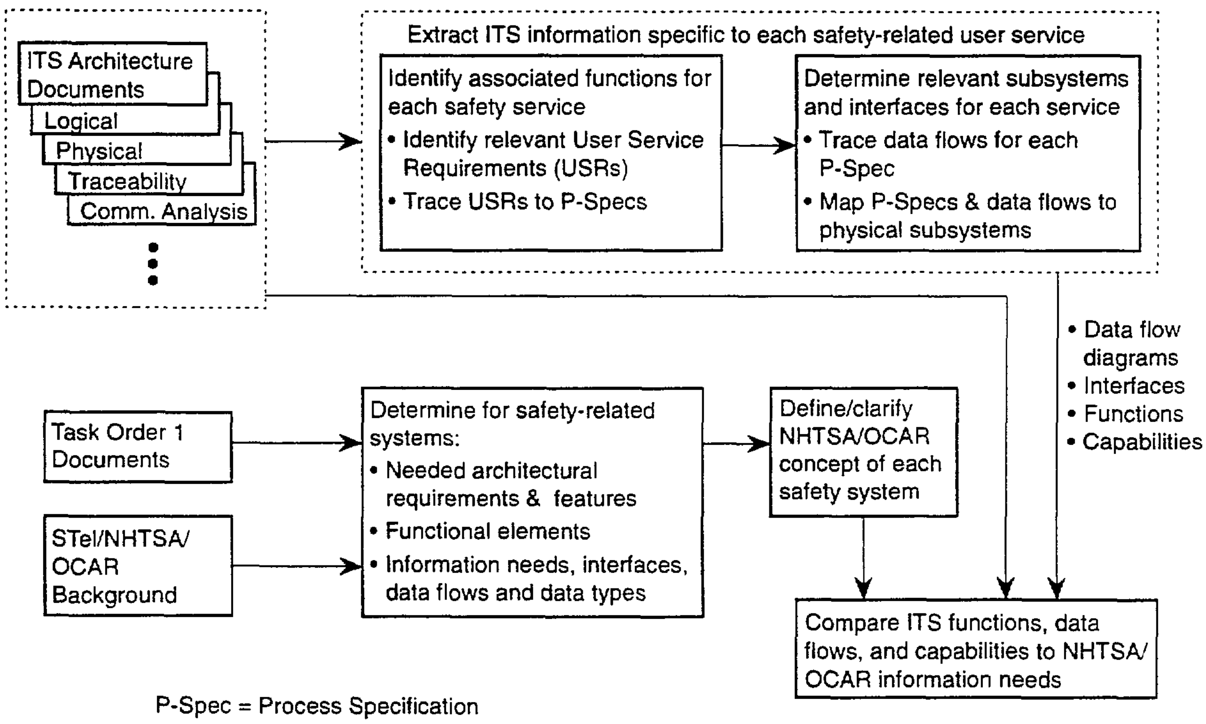


Figure 2-1 Methodology used to Analyze the FPR ITS Architecture

3. ITS Architecture

3.1 The ITS Architecture

The National ITS Architecture provides the framework for designing transportation systems that meet the user service requirements identified by the DOT. Several of the user requirements identified by the DOT for the ITS Architecture aim directly at improving the safety of the traveling public. The architecture supporting these requirements was prepared by the two Phase II contractors, Rockwell and Loral, and is presented in several documents. These documents include the logical and physical architecture, an analysis of communication requirements, and other supporting material such as recommended areas for standardization and implementation.

3.1 .1 Safety-Related ITS User Services.

The ITS User Services Requirements document lists 29 user services that are intended to enhance travel efficiency and traveler safety. NHTSA/OCAR identified nine user services as having important in-vehicle safety-related functions. The 29 individual user services are organized into 7 broad categories, three of which include the nine identified safety services, and are described below. Each user service typically has associated with it 15 to 20 separate and specific User Service Requirements (USRs). An additional user service, highway-rail intersection, will be added as the thirtieth user service requirement for the ITS Architecture. This user service is clearly an important safety service, but is not analyzed in this report as it has not yet been incorporated into the ITS Architecture.

Travel and Traffic Management

This category of services relates to a centralized management function that strives to reduce traffic congestion and pollution, and enhance travel efficiency through the use of concepts such as demand management, dynamic rerouting of traffic, and efficient use of mass transit. The following service is of interest to OCAR:

1. En-Route Driver Information, including Driver Advisory and In-vehicle Signing: provides drivers with information on optimum route selection, and near real time response to congestion. Allows drivers to obtain information on transit systems and optimal modes of transportation, and to reserve space on public transit systems. Augments road signs and provides information concerning road conditions with in-vehicle signing and assists drivers in situations with reduced visibility.

Emergency Management

This category of services provides rapid response to traffic and driver emergencies, possibly relating to accidents, vehicle breakdown, or threats to personal security and safety. It includes the following subservices:

1. Emergency notification and personal security: allows drivers to send emergency messages to the local 91l-type of service; may include vehicle location and status information, and driver conversational data.

2. Emergency vehicle management: allows emergency vehicles to be dispatched more rapidly, safely, and efficiently. Chooses optimum response strategy and vehicle routing,

allows for control of intersections and signal lights en route, or dynamic routing to avoid congestion.

Advanced Vehicle Safety Systems

This category of services relates primarily to in-vehicle control systems that enhance vehicle safety through partial or full automation of various vehicle functions. These may range from driver warning systems that operate on relatively long time constants, to real time control systems that can assist the driver in avoiding imminent collision situations.

1. Longitudinal collision avoidance: alerts driver to unsafe following distance or impending longitudinal collision; may have an automatic control capability to help avoid or lessen the severity of a collision. Intelligent cruise control function maintains safe following distance to a lead vehicle, and has a "platooning" capability that allows multiple vehicles to travel together at the same speed.

2. Lateral collision avoidance: monitors driver blind spots during lane changes; maintains lane discipline by sensing lane boundaries and warning the driver of lane departure, or automatically making steering/braking corrections.

3. Intersection collision avoidance: receives data from outside the vehicle (either from roadside infrastructure or other vehicles) warning of intersection crossing hazards from other vehicles, pedestrians, or other hazards.

4. Vision enhancement for collision avoidance: monitors the roadway environment for potential collision hazards; used primarily when conditions may limit driver vision, such as at nighttime, fog, rain, snow, etc. May provide an enhanced video display, audible alert, or other display to the driver.

5. Safety readiness: monitors the status of key vehicle systems and warns the driver that they may be malfunctioning; monitors driver performance to detect possible driver drowsiness or inebriation. May detect unsafe road conditions such as icing or standing water.

6. Pre-crash restraint deployment: controls deployment of restraint systems such as airbags, roll bars, and seat belt tensioners in response to a detected impact. May use advanced sensors and algorithms to detect various types of impacts.

3.1.2 ITS Architecture

The ITS Architecture is described in a series of documents produced by the Joint Architecture Team consisting of the two Phase II contractors, Rockwell and Loral. The following documents provided much of the direct technical detail used in this study:

1. Logical Architecture (Volumes I, II, & III): describes the system functions and information flows needed to implement the user services [Ref. l-3]

2. Physical Architecture: maps the functions and data flows from the logical architecture into physical subsystems and communications links [Ref. 4]

3. Theory of Operations: provides a narrative description of the architecture and its functionality [Ref. 13]

4. Communications Document: describes various facets of the communications needed to support the ITS Architecture and provides an assessment of the communications performance [Ref. 6]

5. Traceability Matrix: provides an "audit trail" allowing user services to be quickly traced to their corresponding functions, data flows, and physical elements [Ref. l0]

Several other ITS Architecture documents are useful for understanding and background information, but were not directly needed for the analysis. These include: Mission Definition [Ref. 12], Standards Development Plan [Ref. 8], and Implementation Strategy [Ref. 16].

The ITS Architecture derives directly from the User Service Requirements (USRs) of the ITS National Program Plan. There are 29 individual user services, organized into 7 broad categories. Each user service typically has associated with it 15 to 20 separate USRs. To facilitate the system architecture specification process based on these user requirements, the Joint Architecture Team selected the Hatley-Pirbhai methodology, which is widely utilized in the systems engineering community, and for which suitable computer-based tools exist. Hatley-Pirbhai captures several aspects of a large, real-time system: the flow of control through the system (which relates to system states, stability, and the time sequencing of events); the flow of data through the system (which relates to data management and communications link specification); and the flow of logic in the system (which relates to software/logical architecture and algorithms). Briefly, a large, complex, real-time system must have a control model, a data structure model, and a logical architecture, and these structures must be mapped into physical entities within the system.

It should be noted that the control model requires more detailed knowledge of event sequencing and timing constraints. These are not generally known in the early stages of system design, thus there is currently no control model included within the ITS Architecture. Also, the data model and the logical model are closely interrelated, and are usually captured jointly through data flow diagrams (DFDs). Another reliable principle of systems engineering is that the physical architecture should be easy for humans to grasp and interact with. Generally this means that the number of major components or subsystems should be relatively small (typically less than ten), and that the functionality of each major component should be self-contained and easily mapped to a major requirement or requirements category. For these reasons, the ITS Architecture currently comprises a logical architecture and a physical architecture, with only a very high level view of timing relationships between user services. This strategy is depicted graphically in Figure 3-l.

Logical Architecture

The ITS logical architecture consists of a series of data flow diagrams (DFDs), and their associated textual descriptions. The individual requirements (USRs) are mapped to functionality "bubbles", called process specifications or P-Specs. A DFD usually contains several process

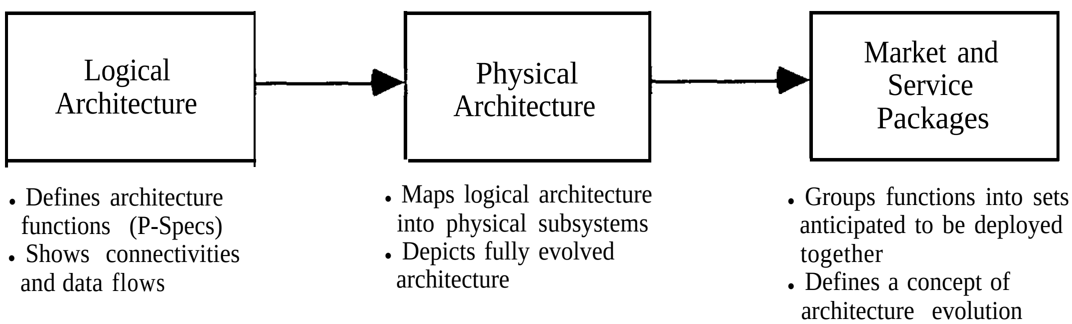


Figure 3-1 Strategy for Specifying the ITS Architecture.

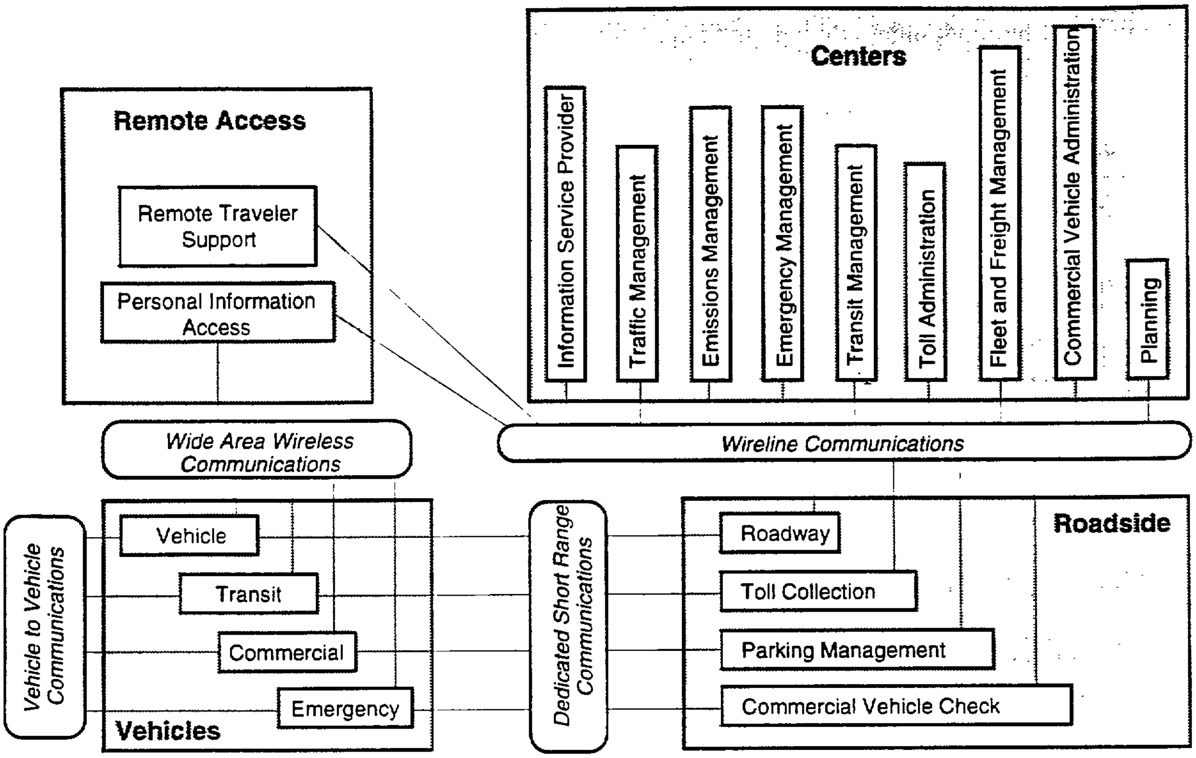


Figure 3-2 Physical Subsystems and Interfaces

specifications that act together to satisfy a higher level requirement. The process specifications are connected by arrows labeled with information types, referred to as data flows. Additional data flow arrows may connect process specifications to data stores, or to physical elements external to the system, called Terminators, that ultimately supply raw data or utilize processed data. A process specification may be decomposed into a lower level, more detailed DFD, or a DFD may be "collapsed" into a process specification on a higher level DFD, depending on the level of detail contained in the requirements and the desired level of specificity.

Physical Architecture

The physical architecture of the ITS Architecture has been partitioned into three views or "layers": transportation, communications, and institutional. The transportation layer describes the functional entities that create, process, disseminate, and use data. The transportation layer defines two entities: subsystems for those functions inside the architecture and terminators for those functions outside. The transportation layer also outlines the various physical data flows and physical interfaces that will be required for the ITS Architecture. The physical subsystems of the architecture are further defined by a set of equipment packages. These packages are a composition of process specifications from the logical architecture that define a set of functional capabilities that may be deployed together. Figure 3-2 provides an overview of the subsystems and interfaces of the physical architecture.

The communications layer describes the physical paths over which data is exchanged from the viewpoint of fixed ("wireline") and mobile ("wireless") services. While the transportation layer defines the interfaces between the subsystems of the architecture, the communications layer further refines the communications necessary for implementing these interfaces and presents reference models for the implementation of communication systems and connections. The communications layer also defines the interconnections and interfaces between the transportation layer's subsystems and terminators through a series of Architecture Interconnect Diagrams (AIDs).

The institutional layer deals with policy issues and the interrelationships of policy making bodies, service providers, and end users. Since this study was intended to deal with technical issues, the Institutional layer will not be discussed any further in this report.

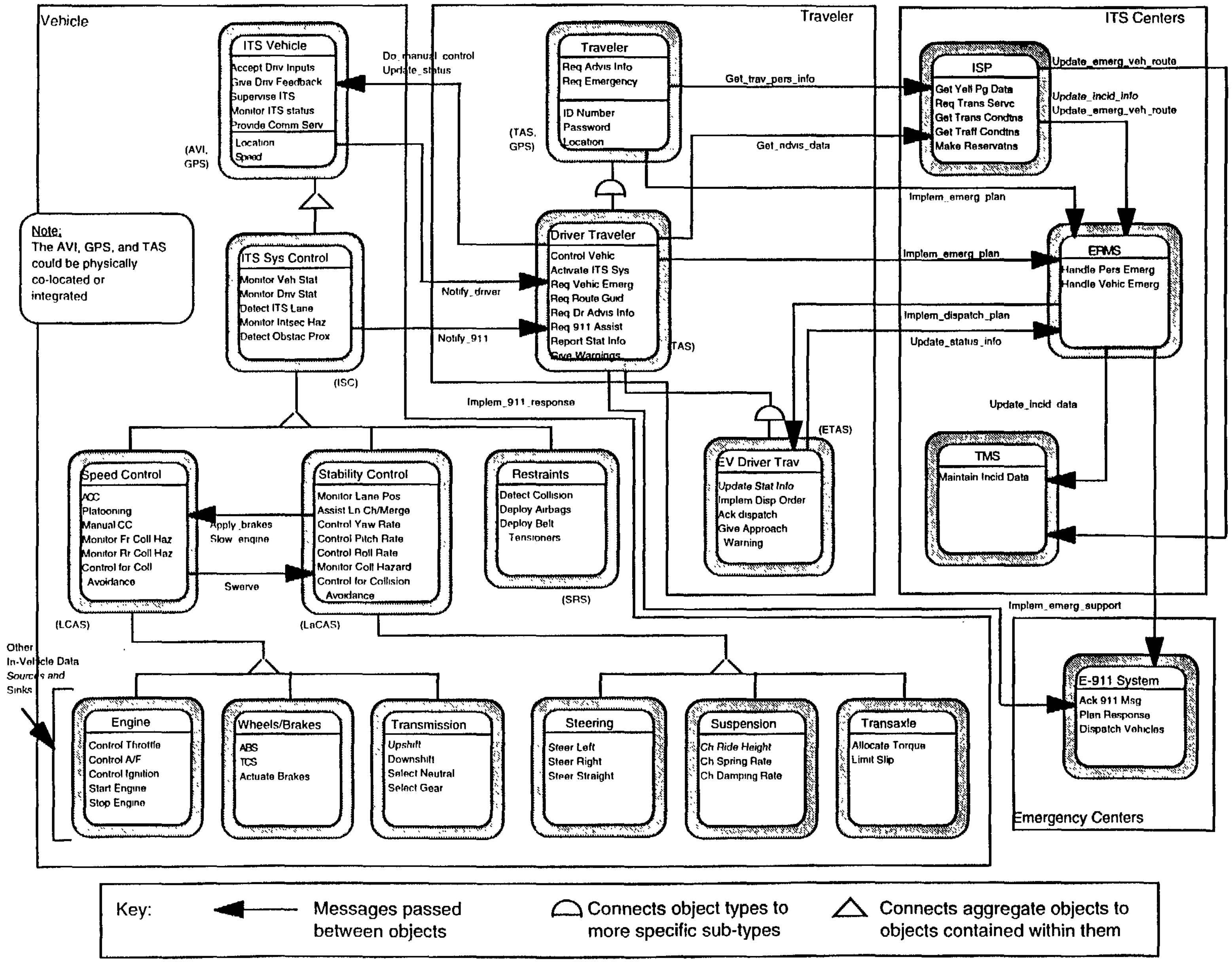
3.2 Object Oriented Model for the User Services

Several difficulties emerged when an initial attempt was made to map the User Service Requirements (USRs) into ITS architectural features. The USRs in effect represent a "wish list" of functions and services. They have been grouped according to their functional similarities and targeted user groups, as is usually the case with a top level requirements specification. The ITS Architecture maps the USRs into processing elements and data flows as a means of identifying similarities and overlaps in processing, and corresponding data requirements. However, this approach has several limitations: it does not map well to architectural features, the data flows are somewhat complex and redundant, functions and data flows cannot be readily changed, control flows and control conflicts cannot be easily visualized, and complex functions tend to become fragmented across multiple processing elements. To supplement the ITS Architecture approach, an object oriented information model was developed in this study for the nine USRs of interest to NHTSA using the methods and approaches of References 20 and 2 1. The model is shown in Figure 3-3.

An object oriented analysis provides an early foundation for mapping logical functions to physical entities, while accommodating changing or evolving requirements. It is also effective in identifying and eliminating functional overlaps and ambiguity, and simplifying interfaces. In addition, the object oriented information model was motivated by several concerns that are not fully addressed in the ITS Architecture:

- The need for unambiguous, stable control, including simple and intuitive driver interfaces.
- The need for fail-safe operation A failure of an ITS component must not result in loss of control of the vehicle or other hazardous conditions.
- The need to meet stringent timing and data integrity constraints.
- The desire for modular architectures that can be readily upgraded or modified (implies the need for simple interfaces and data flows, and optimal mapping of functions and data to architectural features).
- A desire to segregate proprietary features from standardized or open features.
- A need to provide an evolutionary implementation path that uses existing technology as a "point of departure". ITS systems introduced in the near future will either be standalone systems that can be easily installed in a vehicle, or they may be integrated with existing distributed controls within the vehicle such as the ABS and Engine Management System.
- The desire to accommodate all reasonable implementation strategies and technologies.

Figure 3-3 Object Oriented Information Model of Safety-Related ITS User Services



To achieve these objectives, the object oriented information model makes use of several key analytical concepts, such as:

- Ownership of functions and data by the objects that are most closely associated with them. Objects can only control their own functions and data, or request services from other objects.
- Hiding of functional complexity and data structures within simple, readily identifiable objects.
- Simplification of data flows between objects through the use of “service request” messages.
- Use of implied functionality. For example, it is assumed that all objects have the ability to manage their data, and process incoming and outgoing messages, without these capabilities being explicitly stated.
- Inheritance: simple objects reside in the lower niches of an inheritance structure, and represent more specialized versions or components of higher level objects Higher level objects have precedence over lower level objects.
- Persistence: objects (and their corresponding functions and data structures) do not change with respect to time or location.
- Encapsulation: any identifiable service, function, or data structure in the system is encapsulated as either an object, a class of objects, a method, or data structure.
- Abstraction: functions that apply to more than one level of an inheritance structure can be abstracted up to the highest applicable layer to eliminate redundancy and maximize reuse of hardware and software.

Based on these concepts, the following top level subject areas or domains were identified: travelers, vehicles, ITS centers, non-ITS centers, and ITS infrastructure. The vehicle and traveler domains were found to contain a significant amount of inheritance and abstraction, which reduced their complexity and eliminated much redundancy and ambiguity.

As an example, all users of ITS services can be viewed as travelers. Presumably they must all have a name, home address, account number, or some other unique form of identification to ITS. A driver is simply a more specialized version of a traveler, and inherits the top level functions and data of the traveler (e.g., the capability to request advisory information). To these top level traveler functions the driver adds driver-specific functions such as the capability to activate the vehicle’s ITS systems, and requests for vehicle emergencies. Similarly, an emergency vehicle driver can be seen as a more specialized version of a driver. Physically, the objects in the traveler domain could represent actual people, or they may represent an automated system that performs the enclosed functions on behalf of the traveler. The actual implementation would depend on customer demand (i.e., one box for all travelers/drivers, or separate but similar boxes for each), cost, and available components. Within the vehicle, the main concern of the object oriented information model is to maintain stable, unambiguous, non-overlapping control of the various ITS-related systems. Each ITS-related system must be capable of being controlled and monitored by some form of external intelligence, which may be either a human operator or a . . higher level control module.

This object oriented information model should be viewed as an initial attempt to view the ITS Architecture in a manner that may be more useful for system designers and users. It should not be considered as a replacement for the ITS Architecture documents. The DOT and specifically NHTSA may wish to incorporate this object oriented approach into their efforts to guide system developers and users.

4. Safety Services and the ITS Architecture

4.1 Safety Services and the ITS Architecture

One of the important goals of the ITS Architecture is to improve the safety of the traveling public. The nine user service requirements studied for this task provide important functions that can meet this goal. In analyzing the ITS Architecture as of the FPR, STel determined that the architecture does not prevent the deployment of future safety-related'.systems, but the limited analysis of some technical issues and some documentation inconsistencies might adversely affect development of the architecture.

This section outlines an analysis of the essential elements of the architecture: the logical architecture and the physical architecture. After a general review of issues for each of these elements (§4.2 and § 4.3), a detailed analysis organized by the three groupings of the nine user service requirements is presented (§4.4 (Travel and Traffic Management User Services), $4.5 (Emergency Management), and §4.6 (Advanced Vehicle Safety Systems)).

4.2 Logical Architecture Realization of Safety Services

Earlier STel examinations of the ITS Architecture as of IPR #l and IPR #2 [Ref. 22-23] included detailed analyses of the logical architecture and its suitability for performing the safety-related user services. These analyses determined that the logical architecture was adequate for safety services and did not impede implementation of advanced safety systems in automobiles. Several deficiencies, however, were identified and suggestions made to improve the flow of information and to reduce the complexity of processing required for safety services. In addition, several discrepancies and inconsistencies in the documentation were found. Changes within the ITS Architecture at the time of the FPR that affect these earlier assessments are discussed below.

The logical architecture [Ref. l-3] in the FPR improves upon the already adequate architecture from IPR #2 [Ref. 24]. In addition, the traceability matrix [Ref. 7] presents the information in a more useful manner than in previous versions that improves the usability of the architecture documents, especially the logical architecture and all of its data flow diagrams and process specifications. The logical architecture now includes additional process specifications that clarify the role of specific process specifications and provide useful distinctions between different process specifications. The logical architecture and the associated traceability matrix also removes some errors that were identified in STel's earlier analyses.

For example, in the IPR #2 Logical Architecture, two process specifications (6.2.5 and 6.6.3.2 [Ref. 24]) were both listed as "Process vehicle location data." This error has been corrected in the FPR documentation. STel's analyses of IPR #2 also indicated the lack of broadcast support for the Driver Advisory service. In the IPR #2 documentation, the Driver Advisory user service, as implemented with the old P-Spec 6.2.4 (Provide Advisory Data and Reservations) [Ref. 24, p. 156], relied upon a two-way information transaction between a vehicle and an Information Service Provider: a request is sent from the Personal Vehicle Subsystem to the ISP, which then provides the desired information. This implementation appeared to preclude the use of broadcast services for this function. The FPR documentation has updated the implementation of driver advisory so it now includes a broadcast message from the ISP to the vehicle. This is implemented by the new P-Spec 6.2.1.4 (Provide Traffic and Transit Broadcast Messages) [Ref. 1, p. 87].

The description of this new data flow and the supporting process specification indicates that this broadcast service is only to be provided by an ISP and not by short-range beacons-the road condition advisories from beacons support the in-vehicle signing user service. Unfortunately, the architecture appears to emphasize the information providing function of driver advisory over the information service of in-vehicle signing. This issue is further discussed in $4.4.

The complexity and quantity of processing that P-Spec 6.2.2 needs may make it difficult to implement a useful and safe interface for the driver. The latency of safety-critical information must be sufficiently short to be usable by a driver and human interfaces need to be streamlined, integrated, flexible, intuitive, and safe. The ITS Architecture does not appear to address or to describe the needs of the (human) driver interface which are affected by the size and content of messages, both of which were assigned by the architecture. These features were apparently not considered by the architecture when message size and content were assigned. The design of actual interfaces is beyond the scope of the architecture, but its features will shape possible implementations. Specific human interface requirements were not assessed by this analysis.

Another apparent limitation previously identified is that the ITS Architecture does not specify a logical function for gathering or disseminating safety-related data within the vehicle, or for communicating this data to other vehicles or to ITS infrastructure. An automated data collection system collects status information, key vehicle performance data, and sensor readings from other systems in the vehicle and stores them in a central data repository. While the ITS Architecture does have various data stores (e.g., vehicle_identity_for_collision_notification_store), the information included in these stores is limited to information such as vehicle identity. Additional data may be used for post-collision safety research or for notification during an emergency.

Other considerations raised in the previous IPR analyses, however, were not changed or discussed in the FPR documentation. Important considerations from the earlier analyses are summarized in the sections addressing the individual safety services ($4.4, $4.5, & $4.6).

4.3 Physical Architecture: Equipment Packages & interfaces for Safety Services

The physical architecture is adequate for performing the safety services and should not impede implementation of advanced safety systems in automobiles. The 107 equipment packages and the many interfaces documented by the ITS Physical Architecture provide a solid framework on which to implement the various safety services of interest to NHTSA. Difficult design and implementation considerations, however, must be resolved before actual implementation.

Several of these considerations were complicated by decisions underlying the Joint Architecture Team’s realization of the ITS Architecture in the FPR. For example, the Logical Architecture’s functional realization for advanced vehicle safety systems indicates a highly complex and integrated approach while the Physical Architecture defines equipment packages that may make a more distributed implementation possible. This apparent conceptual difference may make it difficult for determining between a coordinated approach or independent operations for the final implementation of advanced vehicle safety systems.

Subsystems and Equipment Packages

The physical architecture provides system developers with a view of the ITS Architecture that outlines specific physical subsystems that may be created. These subsystems define specific functional entities, but each cannot be viewed as a complete physical entity. For example, although there are four vehicle subsystems-vehicle, transit, commercial, and emergency-the three specialized vehicles (transit, commercial, and emergency) are different implementations of the vehicle subsystem. Functions common to each of the specialized vehicle types are contained within the vehicle subsystem from which the specialized types are derived. This form of hierarchy is natural to object oriented approaches but may create some confusion in this nonobject oriented architecture since each subsystem could mistakenly be viewed as independent physical manifestation of ITS functions.

The equipment packages are a composition of process specifications from the logical architecture that define a set of functional capabilities that may be deployed together. Different equipment packages may be independently deployed or may share physical components, such as sensors-the ITS Architecture does not define final designs. Many of the equipment packages associated with safety services (see Table 4-l) correspond to safety systems currently available or under development as outlined in the final report of Task Order 1 [Ref. 19].

Interfaces

The physical architecture also defines the data flows and interfaces between subsystems and terminators. (See Figure 4- 1.) These interfaces are further refined within the communications layer where the type of communications service most appropriate for each link is determined (e.g., wireline, wireless). The physical data flows consist of data from one or more logical data flows and indicate the data that is to be exchanged between subsystems to execute their functions as defined by the associated process specifications.

The physical data flows appear to be complete and should not inhibit the development of safety related services. The actual implementation of data flows, whether as dedicated channels or through multiplexed systems, may provide difficulties to developers. The ITS Architecture does not define the communications implementation needed for exchanging information between subsystems nor does it outline the amount or contents of data for exchanging information between equipment packages within subsystems. The ITS Architecture does, however, define the projected size (in bytes) of data flows between subsystems and assesses the required communications capacity necessary to implement the architecture. The exchange of information between equipment packages requires attention by NHTSA as various methods, including dedicated wiring or data buses as discussed in the final report of Task Order 1 [Ref. 19], may be utilized. NHTSA may consider modeling the internal communications necessary for carrying the ITS Architecture projected communications load.

The Architecture Flow Diagrams and the associated descriptions of physical data flows presented in the Physical Architecture document are useful for systems developers. Unfortunately, the Physical Architecture document, which is organized by subsystems, does not present descriptions of physical data flows from subsystems to terminators. Only data flows to subsystems are described. This deficiency appears to be a simple act of omission in creating the FPR documentation rather than a flaw in the ITS Architecture. The missing data flows are shown within the architecture flow diagrams. but are not discussed. This omission should be resolved before the National Architecture Review.

Additional insights into the interfaces and communications are presented in §5.

User Services	In-Vehicle IVHS Systems*	ITS Architecture Equipment Packages#	ITS Process Specifications
Travel and Traffic Management			
En-route driver information: driver advisory and in-vehicle signing	N/A (none assessed)	In-vehicle • Basic vehicle reception • Interactive vehicle reception • In-vehicle signing system External • Automated road signing • Basic information broadcast • Roadway in-vehicle signing • TMC input to in-vehicle signing	 6.2.5, 6.2.2 6.2.2, 6.2.5 6.2.2, 6.2.5 1.1.2.6, 1.1.7, 1.2.7.4, 1.2.7.7 1.1.4.3, etc. 1.2.7.4 1.2.4.3
Emergency Management			
Emergency notification and personal security	• Automated collision notification (ACN)	In-vehicle • Vehicle Mayday I/F	 3.3.2, 3.3.3, 6.7.1.1, 6.7.1.2
Emergency vehicle management	N/A (none assessed)	External • Emergency and Incident Management Communication • Emergency Mayday and E-911 I/F • Emergency Response Management • Emergency Vehicle Routing and communications • Vehicle Mayday I/F	 5.1.2, 5.1.3, 5.2 5.1.1, 5.1.3, 5.2 5.1.4, 5.1.5, 5.2, 5.3.1, 5.3.2, 5.3.4, 5.5 5.2, 5.3.2, 5.3.6 3.3.2, 3.3.3, 6.7.1.1, 6.7.1.2
Advanced Vehicle Safety Systems			
Longitudinal Collision Avoidance	• Proximity detection system • Headway detection system (Situation awareness) • Headway detection system (Collision warning) • Autonomous cruise control • Control for collision avoidance	In-vehicle • Vehicle longitudinal control • Vehicle longitudinal warning system	 3.2.1, 3.2.3.3, 3.2.3.4.1, 3.2.3.4..2, 3.2.3.1, 3.2.3.4.5 3.1.1
Lateral Collision Avoidance	• Road departure warning • Lane change and merging • Control for collision avoidance	In-vehicle • Vehicle lateral control • Vehicle lateral warning system	3.2.1, 3.2.3.3, 3.2.3.1, 3.2.3.4.3, 3.2.3.4.4, 3.2.3.4.5 3.1.1, 3.2.3.5
Intersection Collision Avoidance	• Intersection crash avoidance • Control for collision avoidance	In-vehicle • Vehicle intersection control • Vehicle intersection collision warning system External • Roadway intersection collision system	 3.1.1 3.1.1, 3.1.3 1.2.7.6
Vision Enhancement for Crash Avoidance	N/A (none assessed)	In-vehicle • Driver visibility improvement system	 3.4
Safety Readiness	• Automobile diagnostic system • Driver diagnostics	In-vehicle • Driver safety monitoring system • Vehicle safety monitoring system	 3.1.2, 3.1.3 3.1.2, 3.1.3
Pre-crash Restraint Deployment	• Pre-collision preparation	In-vehicle • Vehicle pre-crash safety system	 3.1.1, 3.2.3.5

* Includes in-vehicle IVHS safety systems assessed in Task Order 1 [Ref. 19]
# Equipment packages from Physical Architecture [Ref. 4] of the ITS Architecture

Table 4-1 User Services and Associated Physical Systems

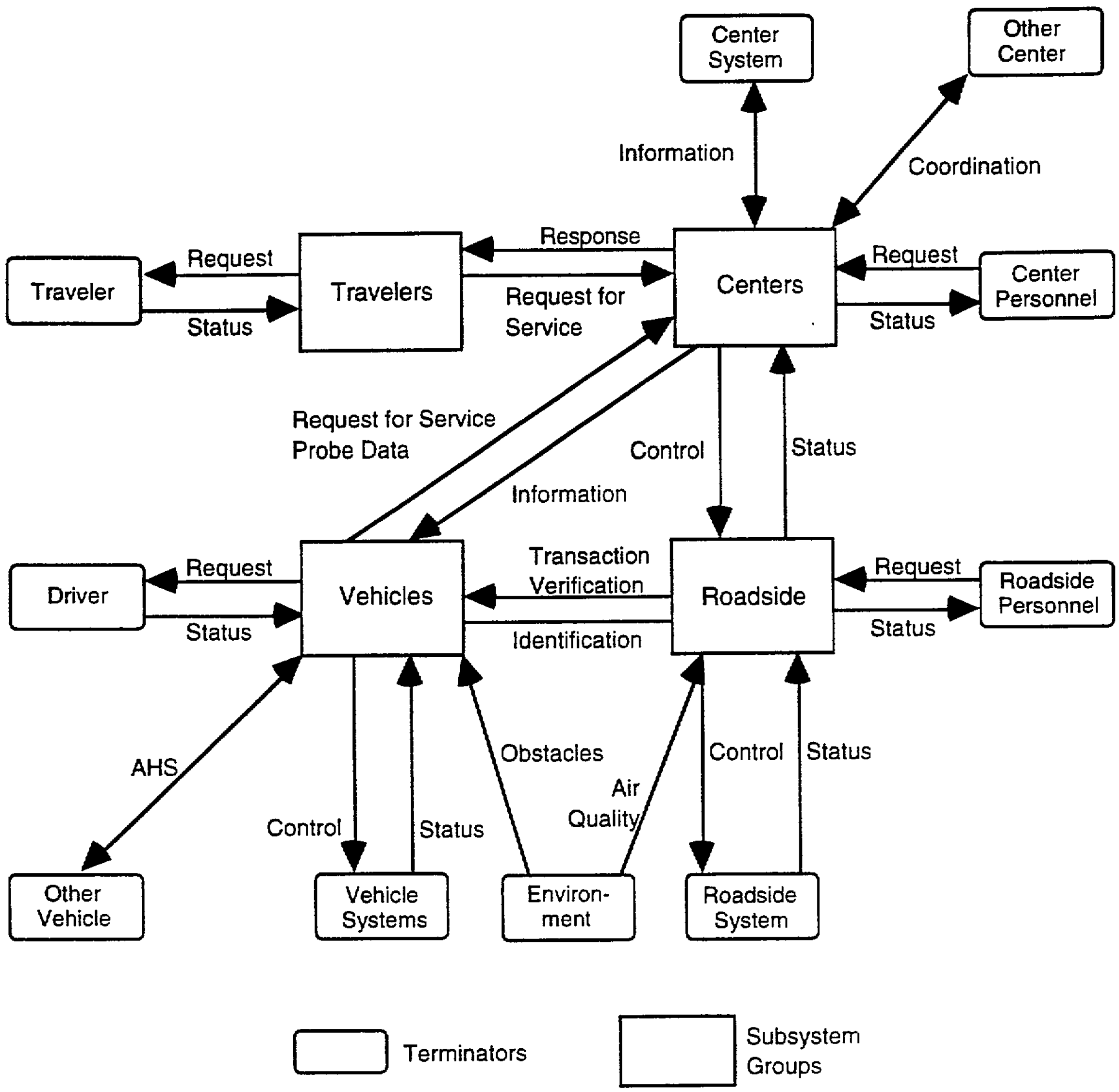


Figure 4-1 Top level Architecture Flow Diagram

4.4 Travel and Traffic Management User Services

En-route Driver Information

The En-route Driver Information user service of the Traffic and Traffic Management User Services group consists of two major functions: Driver Advisory and In-vehicle Signing. The Driver Advisory service focuses on delivering information about alternative routes to the driver while en-route. The In-vehicle Signing service provides assistance to drivers when conditions of poor visibility exist by augmenting existing signs or providing road and environmental condition information. This can be accomplished in many ways including both in-vehicle visual or auditory cues.

As discussed in the previous section, STel's analyses of the architecture as of IPR #2 identified a lack of broadcast support for the Driver Advisory service. The FPR documentation updated the implementation of driver advisory so it now includes a broadcast message from the ISP to the vehicle. This is implemented by the new P-Spec 6.2.1.4 (Provide Traffic and Transit Broadcast Messages) [Ref. 1, p. 87]. ISPs provide this broadcast service using wide area wireless communications. This broadcast service provides a capability to distribute unsolicited road or traffic condition warnings to large numbers of vehicles thus increasing the flexibility of the architecture.

What should be noted is the difference between driver advisory and in-vehicle signing communications. While driver advisory relies on wide area wireless services for both two-way and broadcast communications, in-vehicle signing uses short-range wireless communications including tags and beacons. In-vehicle signing which includes road condition or sign information for the nearby area appears to be better served by the use of beacons or other short range communications devices rather than wide area distribution.

Each of these services, driver advisory and in-vehicle signing, provide information to the driver for different purposes and through different methods. It appears, however, that the architecture as referenced in the traceability matrix considers the driver advisory as meaning assembling and transmitting the congestion data and does not include presenting the information to the driver. In addition, the matrix references show in-vehicle signing as merely displaying the information rather than as a service providing sign or roadway information such as "stop" or "fog ahead." This unexpected emphasis within the traceability matrix is seen in the assignment of process specifications to user service requirements [Ref. 10, Appendix E, p. 6-8]. For example, P-Spec 1.2.7.4 (Process In-vehicle Signage Data) and P-Spec 1.2.4.3 (Output In-vehicle Signage Data) are integral parts of the in-vehicle signage user service as it shows the infrastructure components of this service. These process specifications, however, are not referenced by the traceability matrix for this service. (Incidentally, P-Specs 1.2.7.4, 1.2.7.5, 1.2.7.6, and 1.2.7.7 are not shown in DFD 1.2.7 of the Logical Architecture [Ref. 1, p. 43].)

The implication of driver advisory as being an information providing service and in-vehicle signing as being only the in-vehicle display is further reinforced by the names assigned to the information flows between the relevant process specifications. For example, the names of the data flows to the process specification, Provide Driver Interface (P-Spec 6.2.5), are based on the names of the data flows containing the driver advisory service information from the ISP to the vehicle. Although these data flows to the Provide Driver Interface process specification also carry the in-vehicle signing information, such as roadway safety information (e.g., safety-warnings), the implication is that only driver advisory information reaches the driver. While this may be merely an inadvertent implication of the architecture, it does create some confusion.

Figures 4-2 and 4-3 as well as the figures in §4.5 and §4.6 depict the anticipated interfaces and information flows between in-vehicle safety systems as they reflect the nine safety-related ITS user services and the portions of the ITS Architecture that are external to the vehicle. The figures have been simplified to show only those system components that directly affect the flow of formatted data between logical devices within the vehicle, or to processing elements external to the vehicle, or to the driver. The system block diagrams show where sensors are attached to their control modules, but the flow of raw (i.e., analog or unformatted digital) sensor data is not shown on the physical data flow diagrams for greater clarity.

Figure 4-3 and the system block diagrams of $4.5 and $4.6 assume that some type of data multiplex network is used to connect the various in-vehicle data processing components. Elements attached to the network are assumed to be capable of running the required network access and arbitration protocols. In general, sensors and actuators do not perform these functions and would not be directly connected to such a network. The diagrams also assume that, where

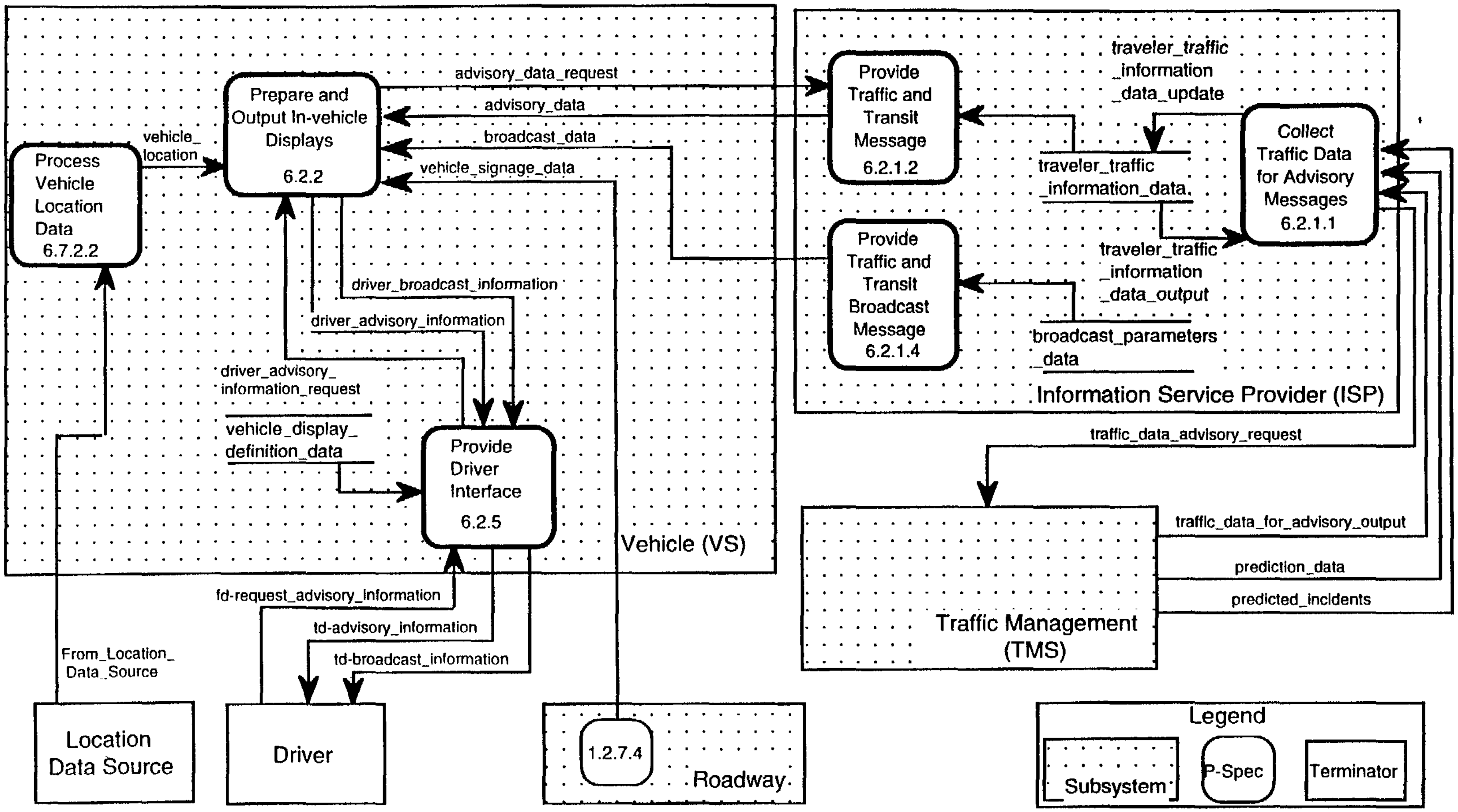


Figure 4-2 Driver Advisory and In-Vehicle Signage Logical Flow Diagram

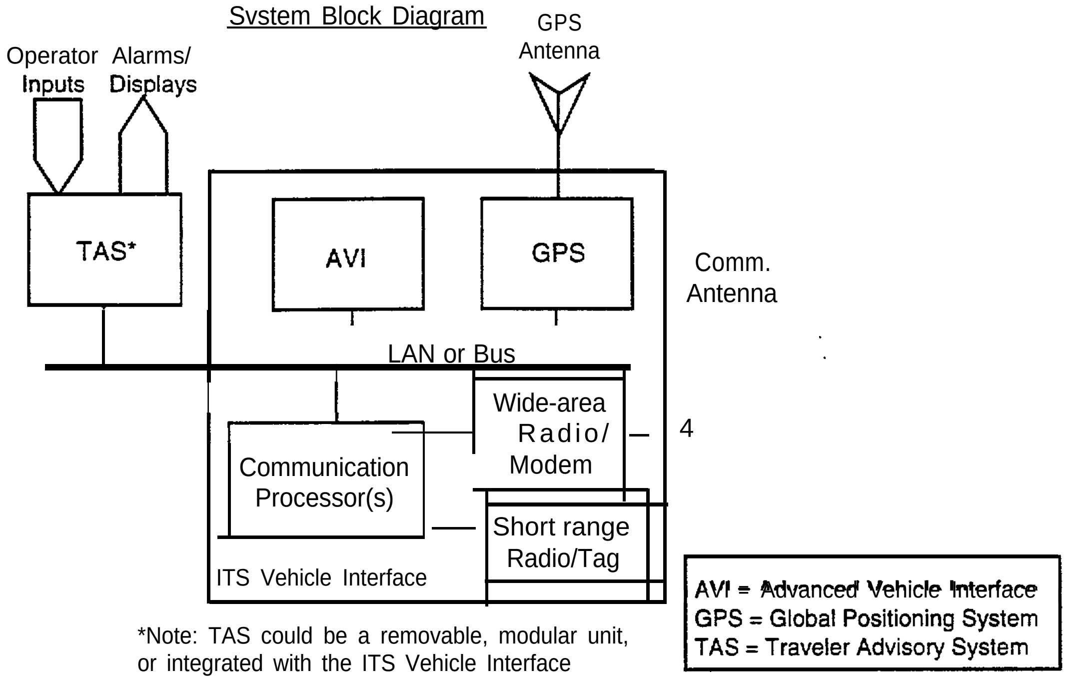


Figure 4-3 Candidate Implementation for Driver Advisory Service

suitable, existing in-vehicle controls, sensors, and actuators (e.g., anti-lock brakes, engine management system) are used to perform certain ITS, functions by employing higher level controllers to coordinate the actions of these existing lower level devices.

Based on object oriented concepts, two key types of interface objects were identified: one to serve the needs of the driver, and another to control the ITS-related functions of the vehicle. Consistent with the ITS Architecture, a functional element known as the Traveler Advisory System (TAS) was devised to provide a single interface point to the driver for interacting with the ITS in-vehicle systems and receiving information from ITS infrastructure and centers. This may include entering commands, requesting data, displaying data, and activating alerts and alarms. However, it should be understood that, depending on implementation strategies, individual in-vehicle systems could be equipped with separate, dedicated driver display and input devices, rather than a single, integrated unit.

It is likely that data outside the vehicle will exist in a format different from that of data within the vehicle. This will require some type of gateway or communications controller to serve as a buffer and translator between the in-vehicle data communications protocol and the external data link protocol. In the system block diagrams this module is referred to simply as the communications processor, and contains the functionality needed to identify, buffer, reformat, and resend data packets to and from either the internal bus or the external data link.

4.5 Emergency Management User Services

Emergency Notification and Personal Security

The Emergency Notification and Personal Security user service has two subservices. One subset-vice provides automated collision notification, corresponding to the Automatic Collision Notification (ACN) system from Task Order 1 [Ref. 19]. The other subservice is essentially a manual version of ACN, where the driver or traveler controls the composing and sending of emergency messages. The ITS Architecture defines a modular approach, with one functional element performing the geolocating, another providing the driver interface, and another performing the communication. The Architecture, however, does not constrain implementation of these functions to be either inside a single unit within the vehicle or distributed among several. Figure 4-4 depicts the processing outlined by the architecture.

As noted in STel's earlier analysis [Ref. 23], the two subservices of this user service appear to operate relatively independently--each subservice is provided a separate communications function within the architecture (P-Specs. 3.3.2 and 6.8.2.2). While the ITS Architecture does not specify whether these functions should be combined within a common unit/subsystem, some form of coordination between their operation may be necessary. In particular, without such coordination, there is the potential for an accident event to result in two independent emergency messages to the emergency management system. One message generated by the automatic collision notification system within the vehicle and a second when the driver presses his or her panic button. While it could be the intent of the ITS Architecture Team to have different types of information in these two messages or to have the emergency management system sort out the multiple messages, it would appear appropriate to have at least some coordination of the multiple emergency notification subservices occur within the vehicle subsystem. Limiting the number of messages or providing coordination information (such as a flag indicating that a previous message was sent) can improve the response of emergency management systems that already find it difficult to handle multiple messages.

The possible implementations of the functions of this service, one of which is depicted in Figure 4-5, may present problems. In general, there is a trend toward greater integration of in-vehicle subsystems through the use of multiplexed data communications. Vehicle sensors, for example, may provide data applicable to a variety of functions by distributing data via a standard bus architecture. However, for automatic collision notification, which is intended to remain operational after an accident has occurred, distributed operation through the use of in-vehicle data multiplexing could significantly decrease overall reliability (since a lengthy data bus may be more susceptible to failure than the elements connected to it). In particular, key processes such as the communications and sensor processing functions may need to be collocated within a single protected unit in order to assure very high reliability in the post-crash environment or to use highly survivable connections.

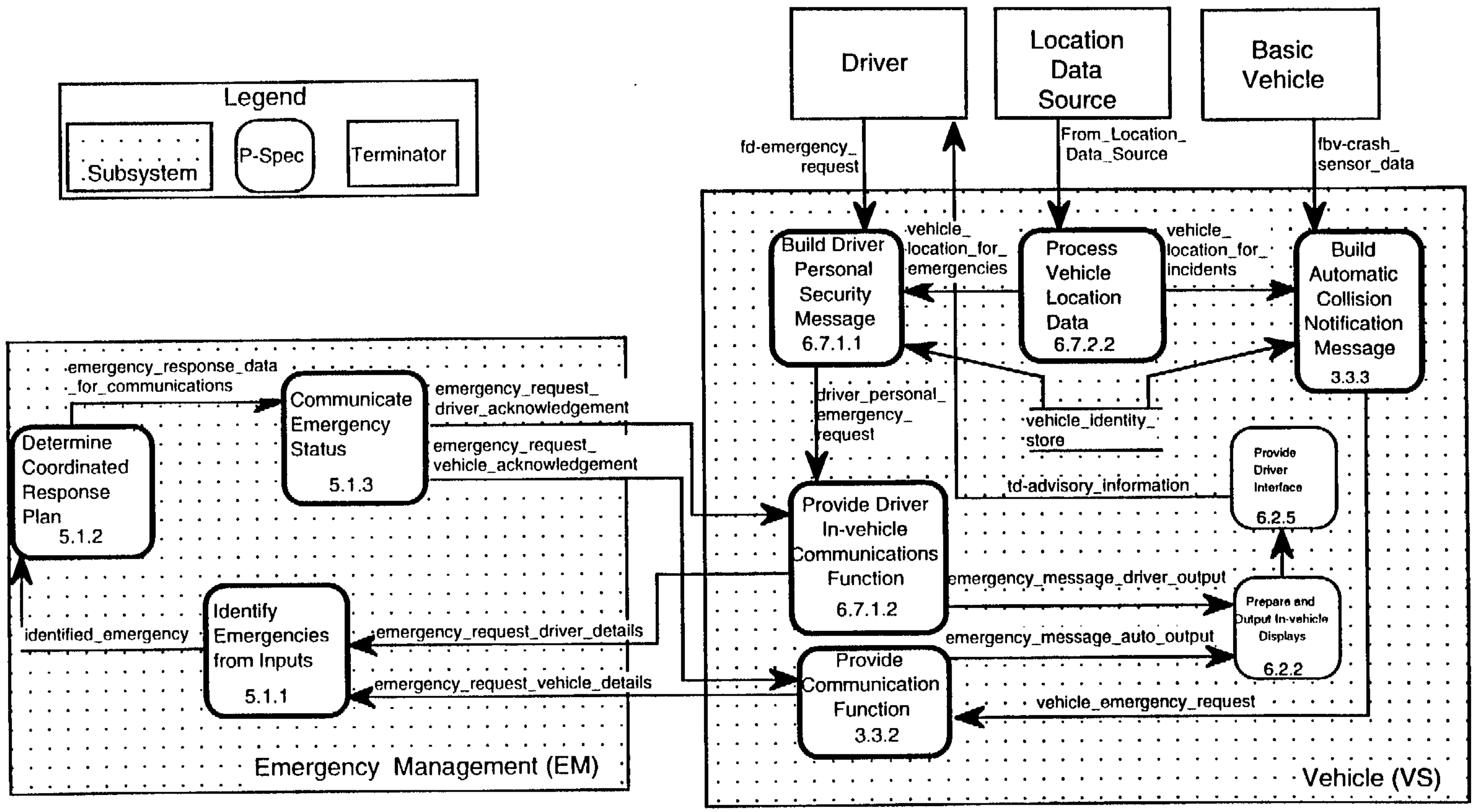


Figure 4-4 Emergency Notification and Personal Security Data Flow

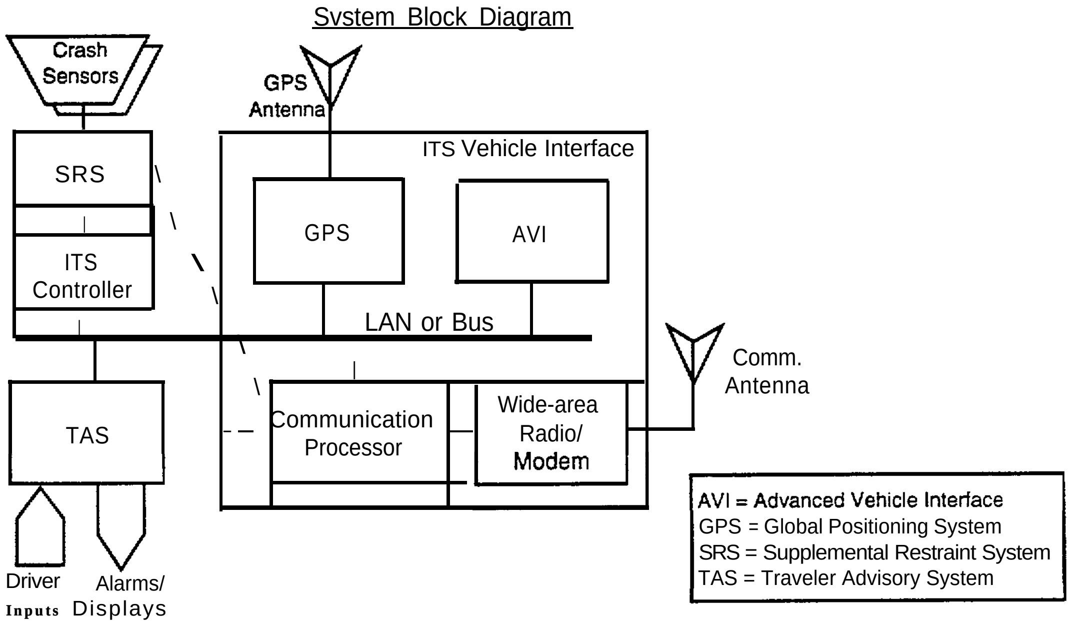


Figure 4-5 Emergency Notification and Personal Security Block Diagram

Emergency Vehicle Management

The Emergency Vehicle Management user service does not interact with any of the in-vehicle control systems, but the in-vehicle component is similar in concept to, and compatible with, the Driver Advisory user service. An input and display device allows emergency vehicle operators to send and receive data to and from an Emergency Management System (EM) for optimal control and dispatch of emergency vehicles. The EM can also control signal lights and other signage along the route.

The information flows and processes associated with this service seem essentially complete and will not impede deployment of this service. (See Figure 4-6.) Some minor improvements may help this service. As noted in STel's previous analysis [Ref. 23], the data flows associated with this user service do not explicitly show emergency vehicle route guidance and location data flowing back to the emergency vehicle or its driver. This information may be helpful to improve the coordination of emergency vehicles. It also appears desirable to have "vehicle-location" data flowing to the Traffic Management Subsystem (TMS) to facilitate more efficient control of traffic signals along the emergency vehicle route. Currently, only "emergency-vehicle-route" data is furnished to the TMS. While the route data does include an estimate of emergency vehicle arrival times at each traffic node, a more precise approach would seem to be direct delivery of accurate emergency vehicle position data to the TMS. Note also that this approach would allow the Traffic Management Subsystem to take appropriate action if the emergency vehicle should happen to deviate from the originally planned route.

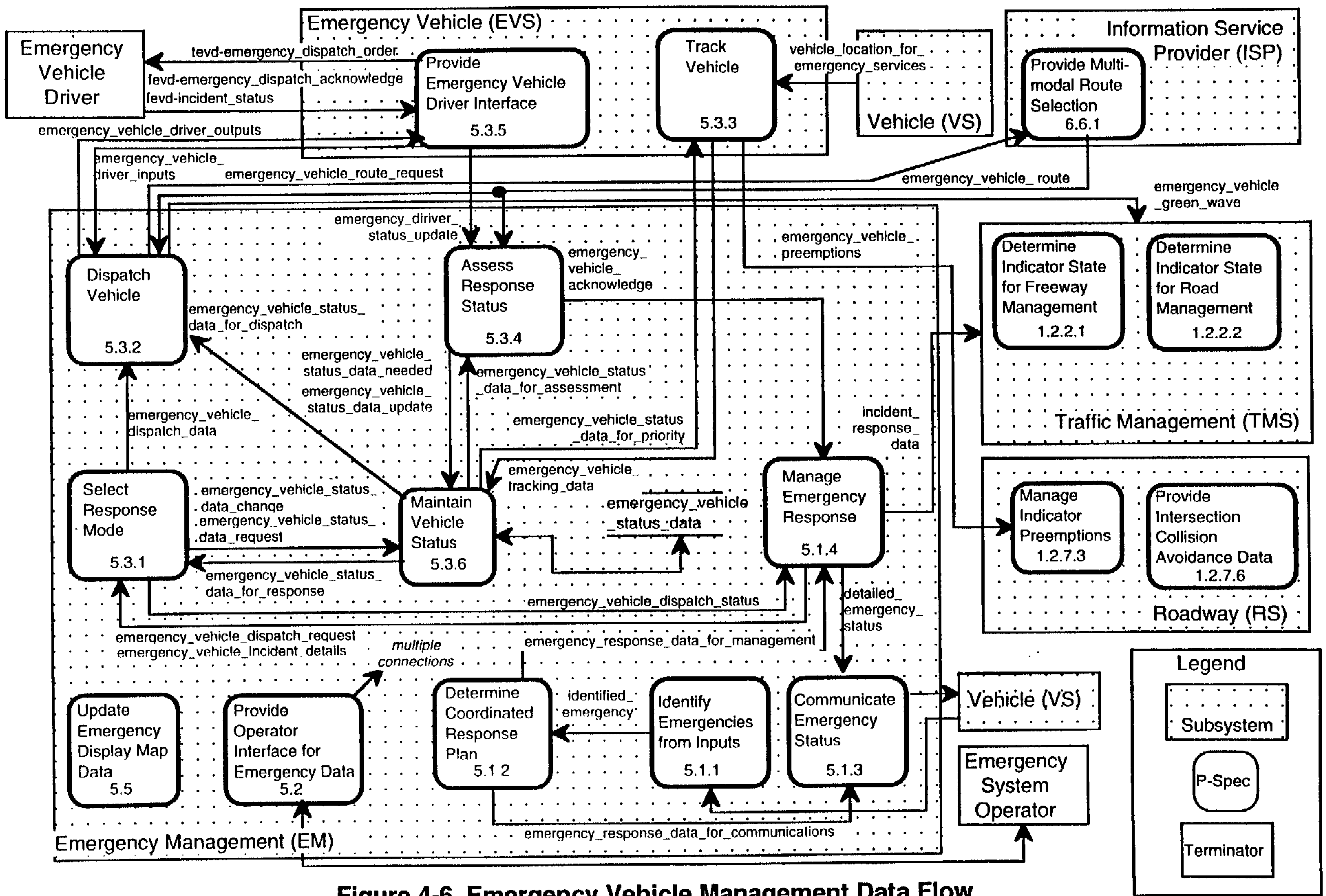


Figure 4-6 Emergency Vehicle Management Data Flow

4.6 Advanced Vehicle Safety Systems User Services

This category of services relates primarily to in-vehicle control systems that enhance vehicle safety through partial or full automation of various vehicle functions. After a general overview of these advanced vehicle safety systems, sections for each of the safety-related advanced vehicle services describe various issues resulting from the ITS Architecture.

Three of the advanced vehicle safety systems user service requirements, Longitudinal Collision Avoidance, Lateral Collision Avoidance, and Intersection Collision Avoidance use the same set of process specifications to perform their different operations. As was the case in IPR #2, the common set of process specifications (P-Spec 3.1.1, 3.1.3, 3.2.3.3, and P-Specs in DFD 3.2.3.4) perform all of the in-vehicle ITS-related control functions. This could be interpreted to mean that the same physical components will perform all of these functions and communicate over the same data flows. As seen in the Physical Architecture, the corresponding equipment packages each perform some of these process specification, but individual equipment packages do not necessarily mean that the functions will be performed separately. Thus, the functions may be shared or coordinated in some manner, thereby not necessarily reducing the complexity implied by the logical architecture.

In practice, an actual implementation, at least in early deployments, will be distributed and modular. The complex system depicted in the architecture would most likely evolve over time from a simple system with few components into a more complex system with many components, or possibly into several separate subsystems that have minimal interaction. The high-level approach of the architecture reflects the fact that most of these systems are in a very early stage of design and development, and that numerous (and likely proprietary) implementation approaches are possible. The previous Task 1 effort [Ref. 19] identified real-time safety-related vehicle control systems as a key area where further refinement of automotive data bus multiplexing standards may be required to allow future coordination between systems.

Another issue first raised in STel's previous analysis [Ref. 23] and that still remains in the FPR concerns the execution of vehicle control. The implementation of vehicle control as seen, for example, in DFD 3.2.3 (Provide Vehicle Control) and its constituent P-Spec 3.2.3.3 (Process data for Vehicle Actuators) [Ref. 1, p. 63], does not fully indicate the complexity of activities that may be used for braking and other functions. The ITS Architecture shows all vehicle control functions being implemented with throttle, brake, and steering inputs; actual systems may also control suspension, transmission, transaxle, and ignition spark. The listing of specific vehicle controllers in the architecture may not be appropriate since they may be considered design issues and thus beyond the scope of the architecture.

Longitudinal Collision Avoidance

While Figure 4-7 shows the ITS Architecture processes for longitudinal collision avoidance, Figure 4-8 depicts a candidate physical implementation of this service. The system block diagram indicates the possible integration of systems: a basic following (headway) distance monitoring system, a backing and blind spot monitoring system, an intelligent cruise control, a system that warns of impending collision and immediate need for driver intervention, and an active control system that can assist the driver in controlling the vehicle to avoid a collision. However, since these systems vary considerably in complexity and likely implementation timelines, it was assumed for Task Order 1 [Ref. 19] that they would be implemented separately as technology and demand permitted, possibly with some integration occurring in the long term.

Although the ITS Architecture indicates fully integrated functionality, several important technological trends were identified in Task Order 1 [Ref. 19] that will influence this operation. In the near term, it was found that in vehicles having multiple control systems (e.g., anti-lock

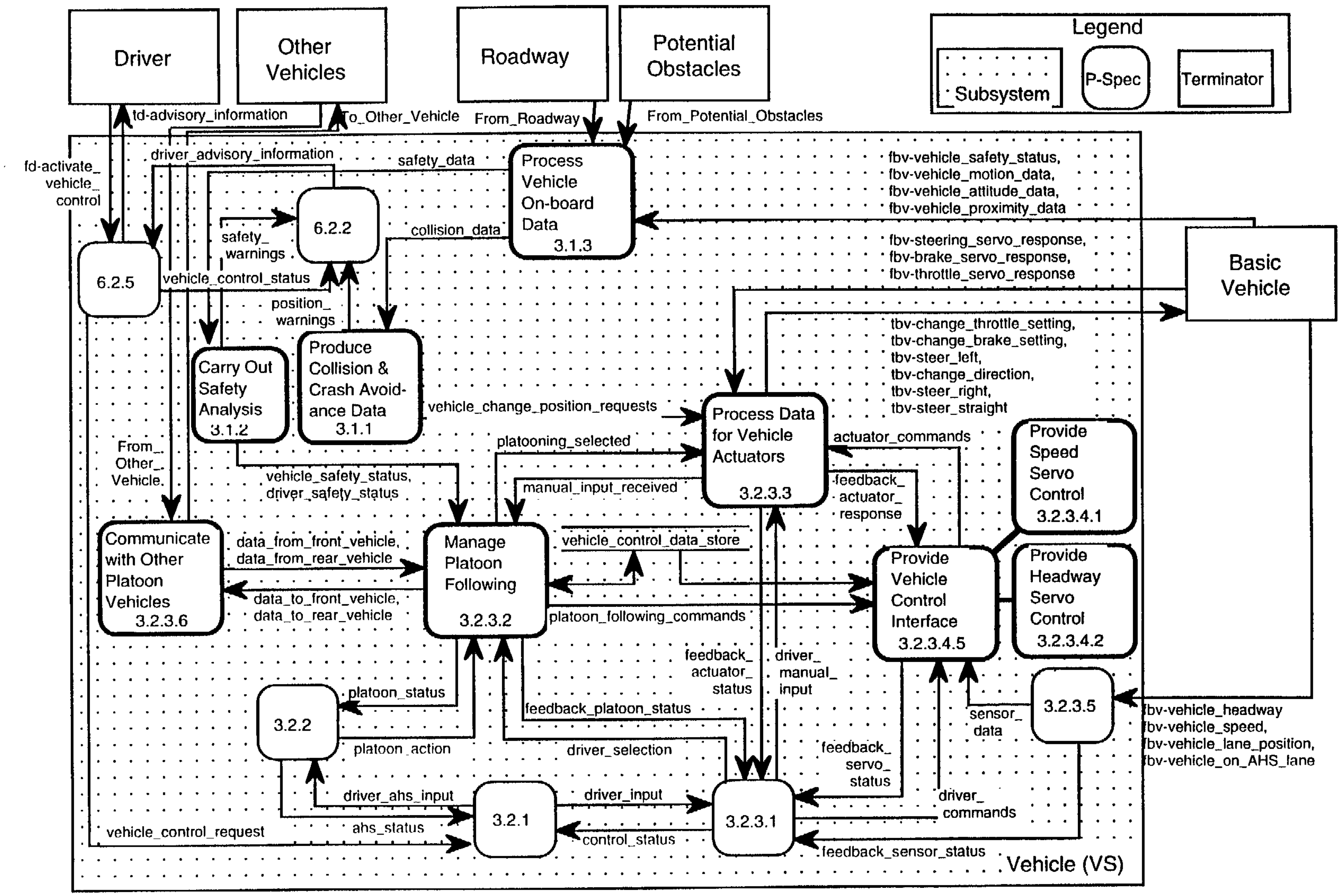


Figure 4-7 Longitudinal Collision Avoidance Data Flow

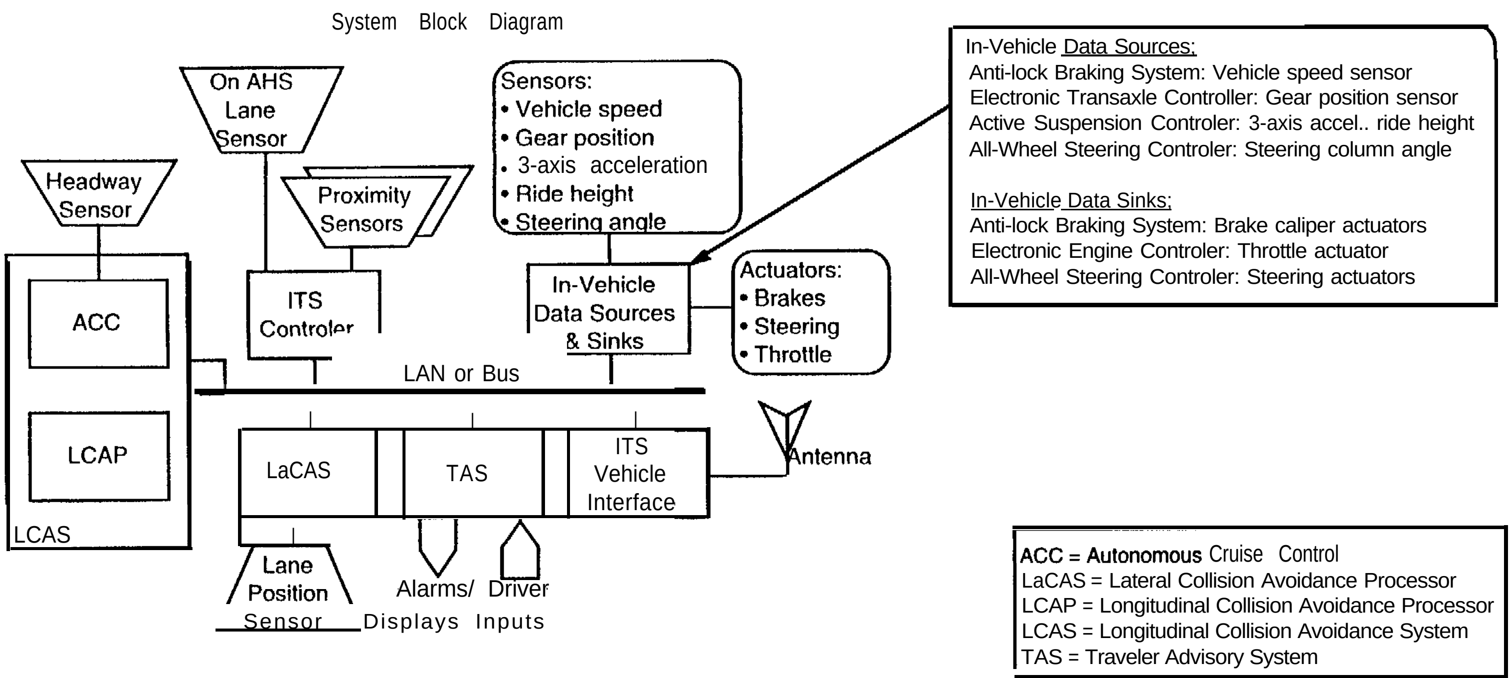


Figure 4-8 Candidate Implementation for Longitudinal Collision Avoidance

brakes, all-wheel steering, and electronic engine management), these control systems will be primarily standalone. They may share status and diagnostic data, but the actual processes of sensing vehicle performance parameters and controlling vehicle actuators is performed independently by dedicated electronic control modules. There is an emerging trend toward networking these independent control modules so that sensor data can be shared, and more sophisticated control algorithms implemented (e.g., vehicle lateral stability control). But even in these more integrated systems, actuator control will not be shared across different control modules. For example, the ABS controller will continue to actuate the brake calipers, even if another control module is capable of originating a request for braking actions. The request will be made from controller to controller. This approach simplifies the time-evolution concepts for these systems, eliminates the possibility of a massive, single point failure posed by an integrated system, and avoids the safety risks associated with multiple controllers contending for control of the same actuators.

Lateral Collision Avoidance

As with longitudinal collision avoidance, the functioning envisioned by the ITS Architecture for lateral collision avoidance (Figure 4-9) will require a complex hierarchy of control processes and integration of physical systems (Figure 4-10). Similar concerns as mentioned for longitudinal collision avoidance about coordinating the operation of these various elements also apply for lateral collision avoidance.

Intersection Collision Avoidance

The intersection collision avoidance service presents additional challenges for system developers and the ITS Architecture. Concepts for implementing intersection collision avoidance are still in a very embryonic form, requiring a highly flexible, open approach in the ITS Architecture. The implementation approaches proposed for intersection collision avoidance within the architecture involve communication between the vehicle and either roadside infrastructure or other vehicles in the vicinity of the intersection. Although the roadside to vehicle communication flow is provided in the ITS Architecture, the capability for vehicle-to-vehicle intersection communications is not present. The physical vehicle-to-vehicle data flow only contains the logical flow, from-other-vehicle, that, as written, only contains platoon operations data. NHTSA and other entities concerned with this safety service may want to review this decision to not include intersection collision avoidance data in the vehicle-to-vehicle communication path. Although it is unlikely that vehicle-to-vehicle communications will be used for effective intersection collision avoidance systems, the architecture should allow for flexible implementations that may use vehicle-to-vehicle communications in case new strategies are developed, but the ITS Architecture can be easily updated to include this information.

As with longitudinal colhsion avoidance, the functioning envisioned by the ITS Architecture for intersection collision avoidance (Figure 4-11) will require a complex hierarchy of control processes and integration of physical systems (Figure 4-12). Similar concerns as mentioned for longitudinal collision avoidance about coordinating the operation of these various elements also apply for intersection collision avoidance with the added burden of coordinating operations with other vehicles or with roadside sensors.

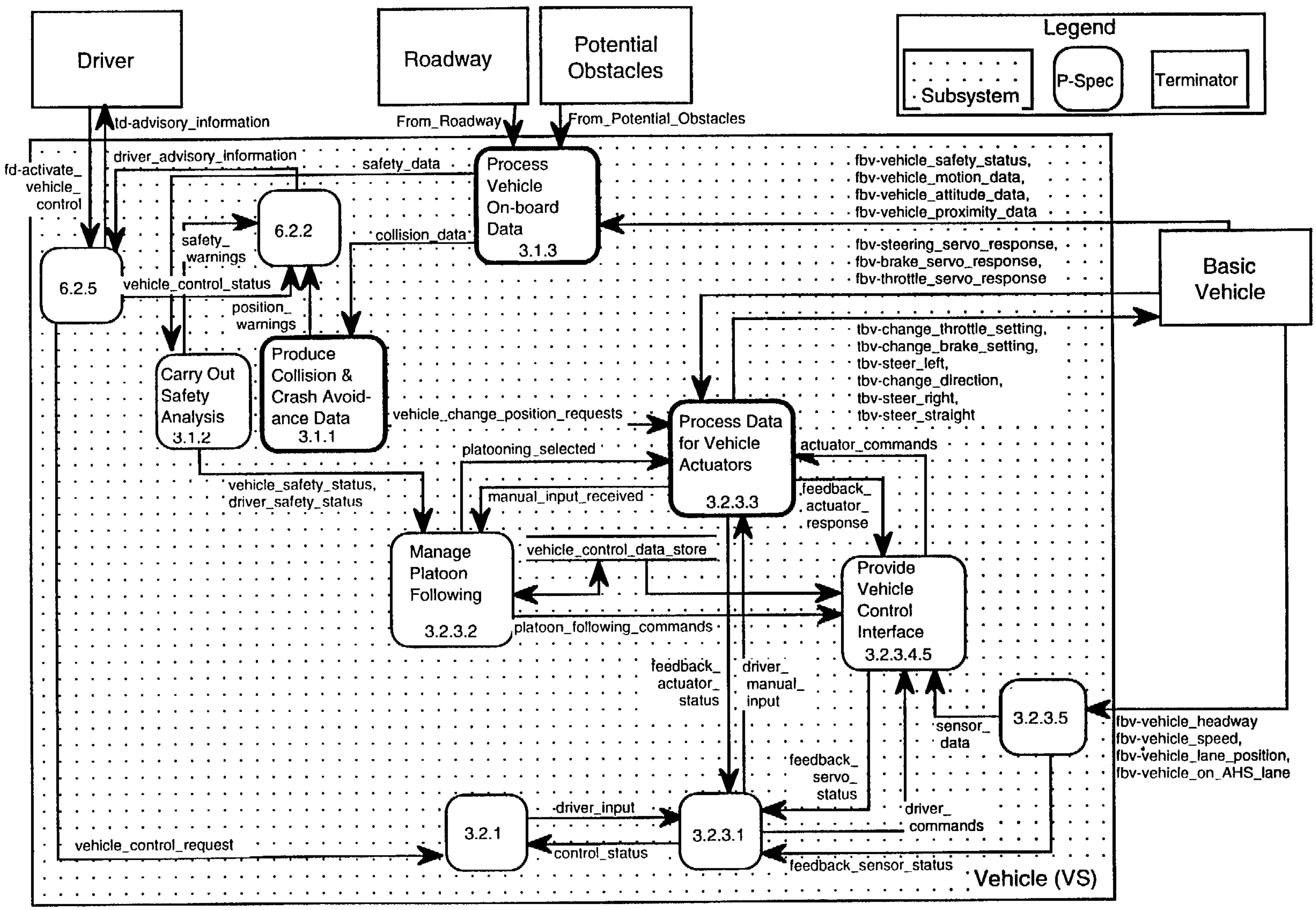


Figure 4-9 Lateral Collision Avoidance Data Flow

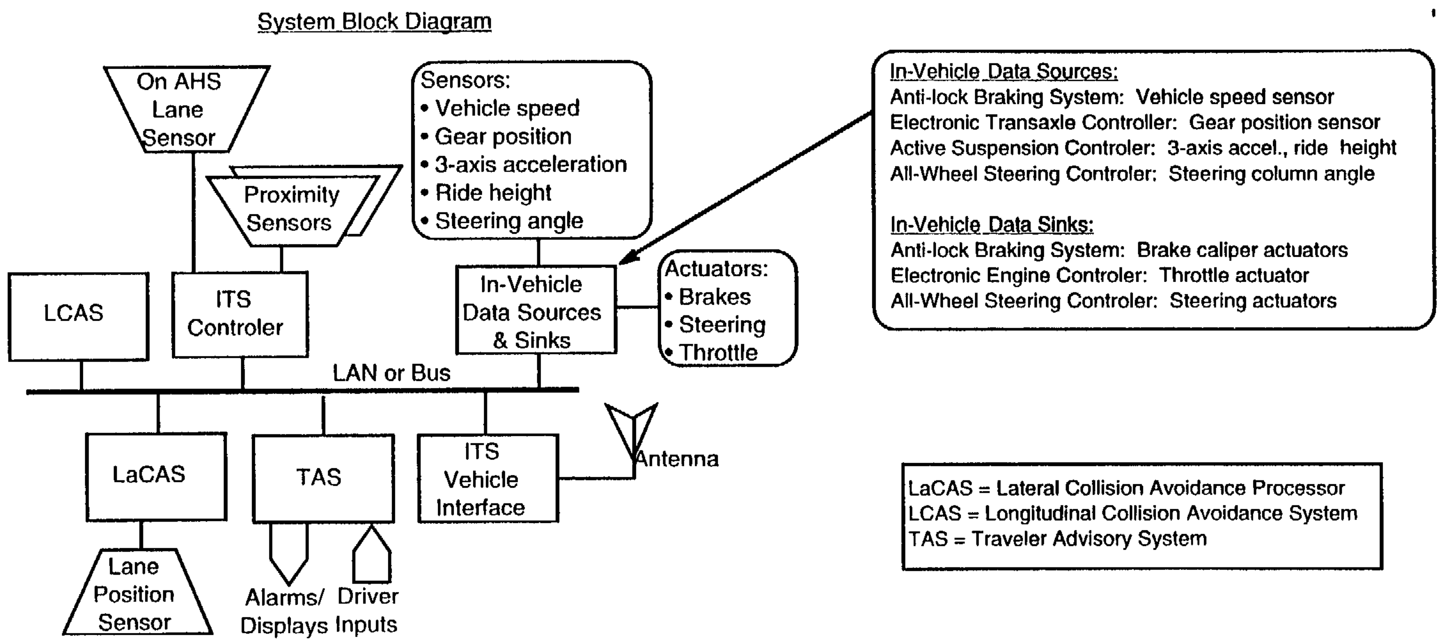


Figure 4-10 Candidate Implementation for Lateral Collision Avoidance

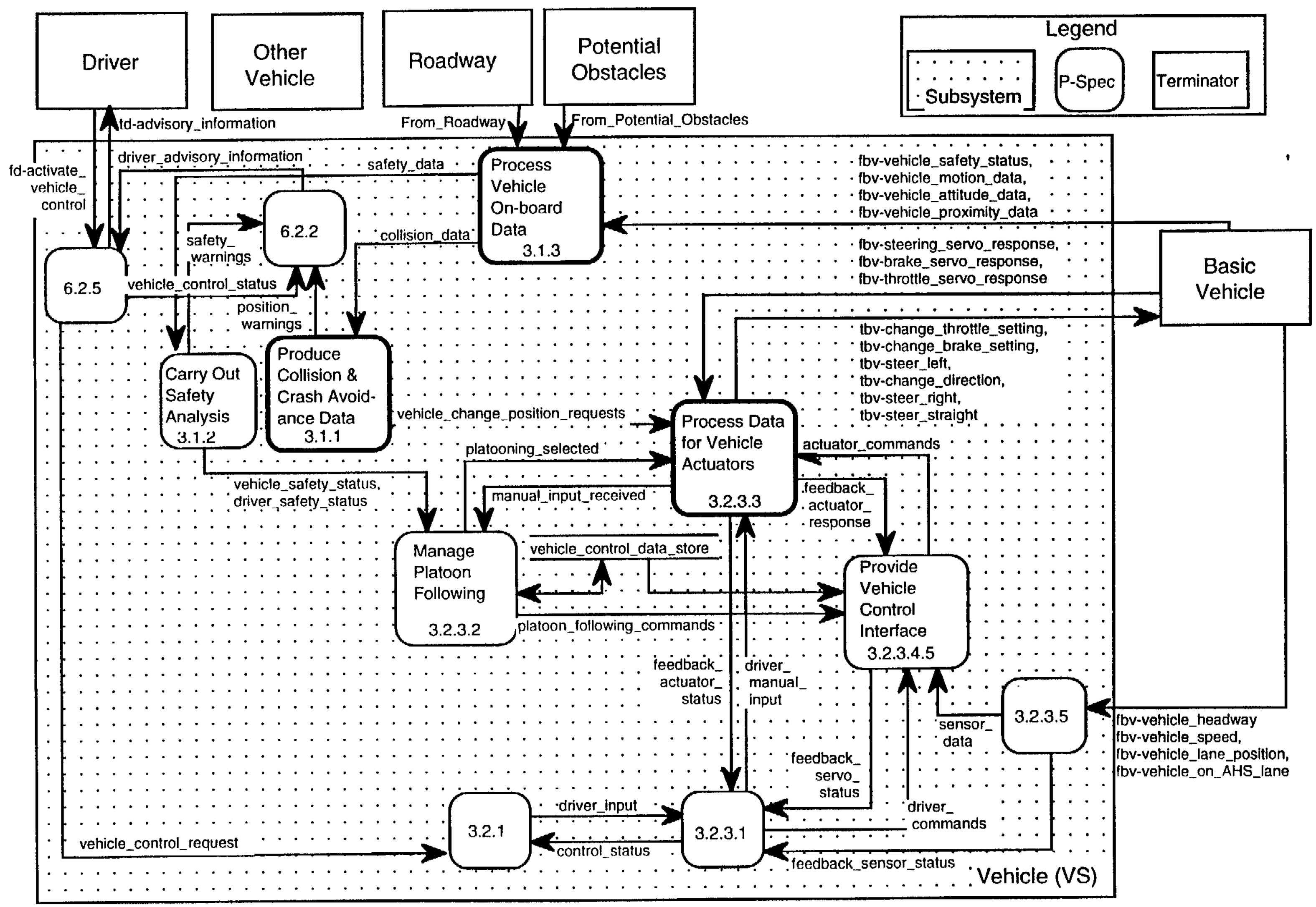


Figure 4-11 Intersection Collision Avoidance Data Flow

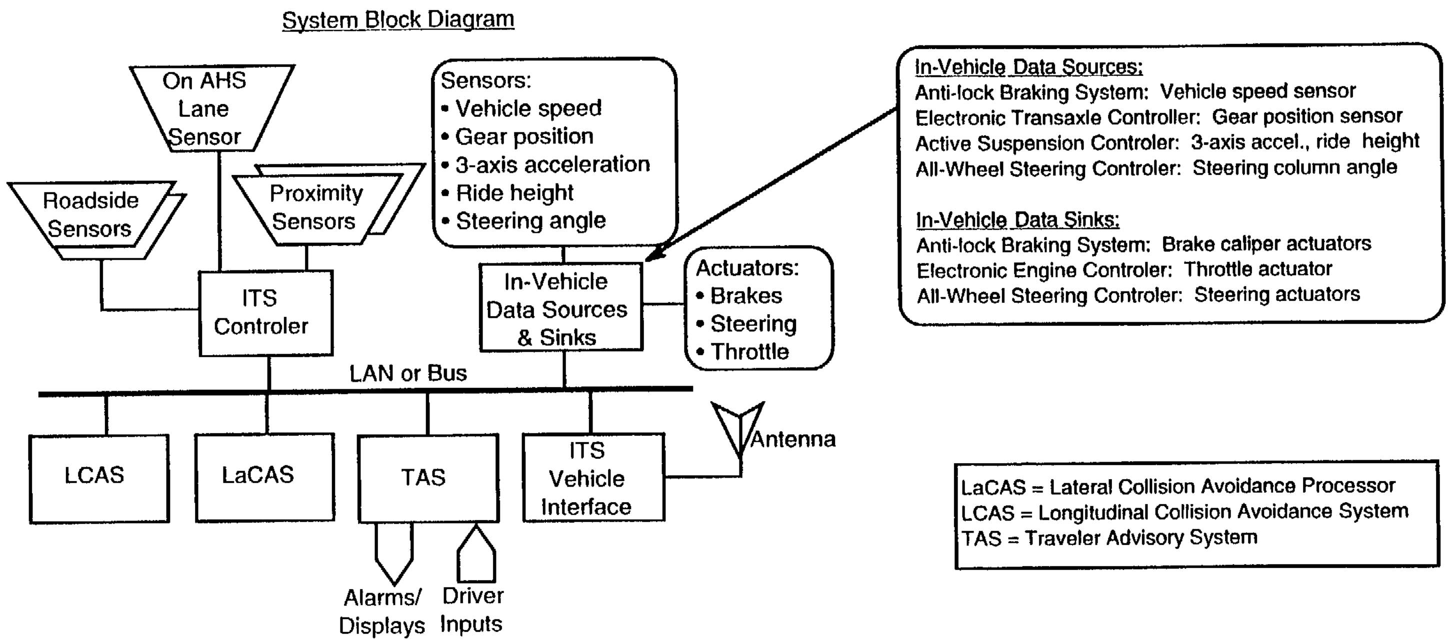


Figure 4-12 Intersection Collision Avoidance Physical Implementation

Vision Enhancement for Collision Avoidance

In terms of data flows and architectural features, this user service does not require complex processing like other safety-related services (Figure 4-13). An imaging sensor (such as a Charge Coupled Device (CCD) or infrared imager) captures data, which is typically fed directly to a processing and display device such as a LCD panel. There is no planned integration with other in-vehicle electronic systems, other than possibly a driver interface for on/off commands and status reports. It is possible, however, that the same sensor data could be shared between a vision enhancement device and a machine vision device (such as a lane position monitor). Functionally, however, the two systems would be independent.

Real time imaging data is much more bandwidth intensive than the other in-vehicle applications, and there is little benefit to be gained by sending it over a multiplexed data bus. The system depicted in the ITS Architecture appears to be acceptable, although it may be desirable to include data flows to the driver or the driver interface to accommodate driver control inputs and status reports. In addition to the more text/alarm oriented functions, a driver interface might also support imaging or graphics displays. The amount of data required for this service (2 MBytes) seems sufficient, but since this service is envisioned as an independent function the actual data size should not affect other functions within the vehicle.

Safety Readiness

The complexity of the vehicle control functions is further increased by the additional responsibility of preparing safety diagnostic data for the safety readiness service. The current ITS Architecture does not explicitly depict a standalone status monitoring and diagnostic functionality. The data flow diagram (Figure 4-14) shows roadway condition data, driver safety data, and vehicle safety data flowing directly from the roadway and the basic vehicle to the vehicle control algorithms in DFD 3.1 [Ref. 1, p. 61], where they are processed into control input data and safety reports. In practice, critical real time control functions are usually separated from less critical functions so that timing and reliability constraints can be met with a high level of

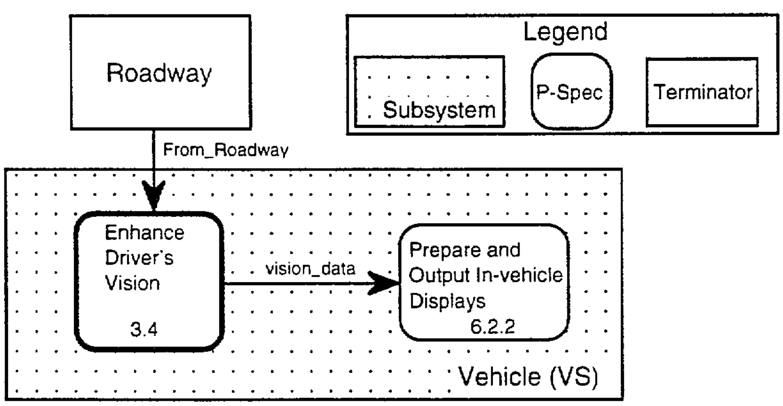


Figure 4-13 Vision Enhancement for Collision Avoidance Data Flow

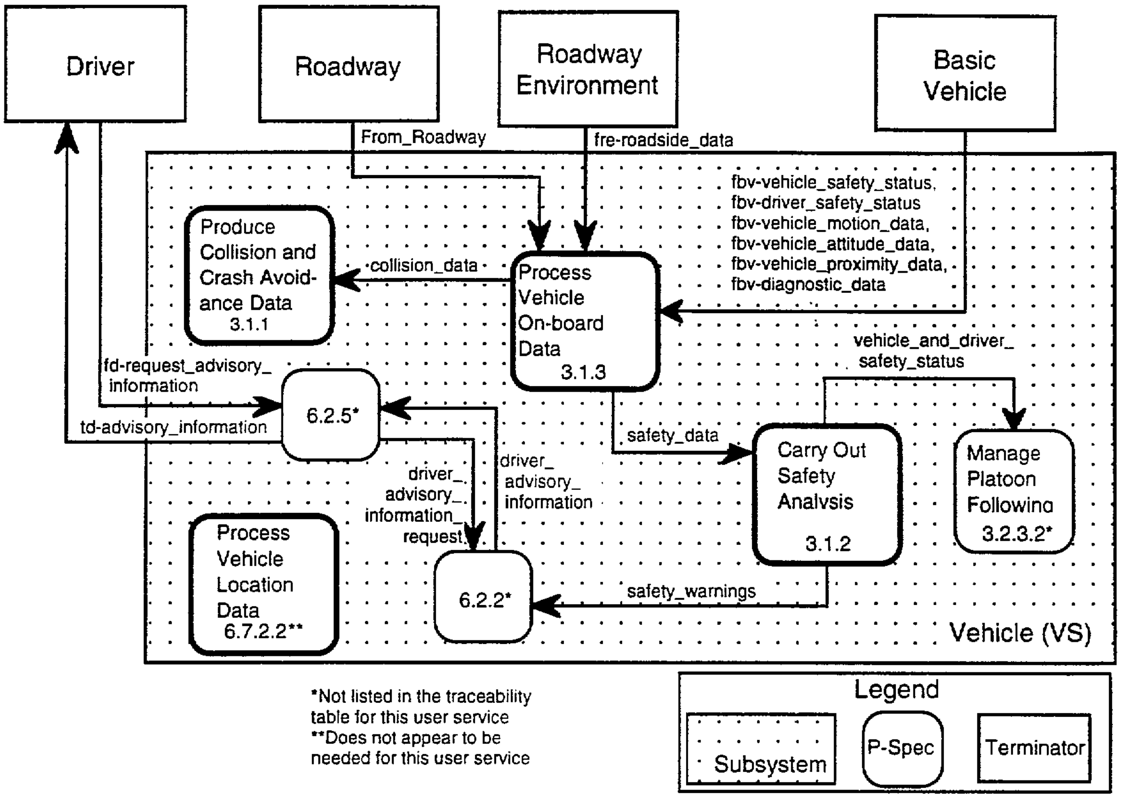


Figure 4-14 Safety Readiness Data Flow

assurance. These systems may perform internal self-diagnostic checks at periodic intervals, but do not generally process routine, ongoing status information sent from external sources.

The process as outlined by the data flows for this service in the ITS Architecture is missing a control function to counteract insufficient driver readiness. The process shows functions and data flows for assuming control of a vehicle during platoon operations if the driver is impaired, but it does not indicate control functions for non-platoon operations. Such functions as inhibiting vehicle starting if a driver is inebriated or assuming vehicle control for a driver who remains asleep in spite of warnings, do not appear in the architecture. Driver warning functions and data flows exist, but the control functions do not. A data flow from P-Spec 3.1.2 (Carry Out Safety Analysis) to the basic vehicle that would initiate an automatic response by the vehicle may be sufficient to satisfy this control function. It is important for the architecture to consider control options since driver readiness such as state of inebriation is key for safety. These functions that take control of a vehicle from a driver result in policy issues such as liability and personal freedom. These issues need to be addressed, but the ITS Architecture should include them to ensure possible future implementations once policy issues are resolved.

Emerging systems provide more sophisticated monitoring than earlier on-board diagnostic systems such as that found in engine management systems. Safety-critical real time control systems are generally capable of performing internal status checks and diagnostic routines at either pre-specified intervals, upon request, or upon engine startup. Results of these checks may be sent over a Class B data bus to a separate diagnostic module for further processing or display, System Block Diagram Using Multiplexing

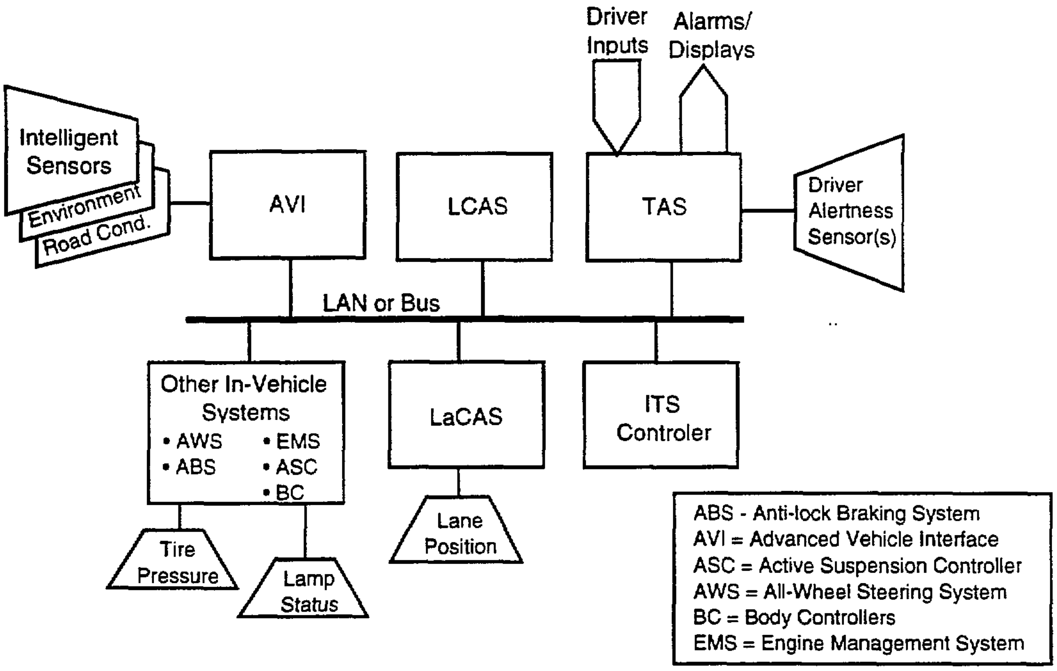


Figure 4-15 Candidate Implementation for Safety Readiness

such as is required by the OBD-II standard. (See Figure 4-15.) Faults can be presented to the driver in the form of warning lights, alarms, or alphanumeric codes.

Pre-crash Restraint Deployment

The ITS Architecture shows a rather complex method for the Pre-crash Restraint Deployment service, involving four data flow paths and three processing elements (Figure 4-16). Furthermore, the elements that perform these functions are also responsible for real time vehicle control functions. It does not seem likely that this approach would be used in practice. Restraint deployment must be done very quickly (within a few milliseconds), and with extremely high reliability. Restraints are usually triggered directly by a collision sensing device, which may sense only longitudinal forces, or may supplement this with lateral and vertical acceleration, velocity, and jerk data. In either case, it would seem more reasonable to use P-Spec 3.3.3 (Build automatic collision notification message) [Ref. 1, p. 65] for restraint deployment, since it already receives crash sensor data directly, must be highly survivable, and has a small processing burden compared to the P-Specs in DFD 3.1 [Ref. 1, p. 61]. P-Spec 3.3.3 could be renamed "Prepare for collision" to reflect these two collision-triggered functions. Another alternative would be to take advantage of the existing Supplemental Restraint System (SRS) found in most new cars today and assign it all pre-collision preparation functions. This implementation is depicted in Figure 4-17. The complex arrangement depicted by DFDs 3.1 and 3.2 [Ref. 1] seems less than optimal.

In addition, the data flows entering P-Spec 3.1.3 do not include crash sensor data (fbv-crash_sensor_data). If it is intended that P-Spec 3.1.3 initiates the control loop for deploying restraints, than this data flow should go to P-Spec 3.1.3. Also, P-Spec 3.2.1 and P-Spec 6.2.5 share the same name, Provide Driver Interface. It is unclear what the difference is between these two functions, so different names should be used or the functions combined to eliminate any confusion created by the shared name.

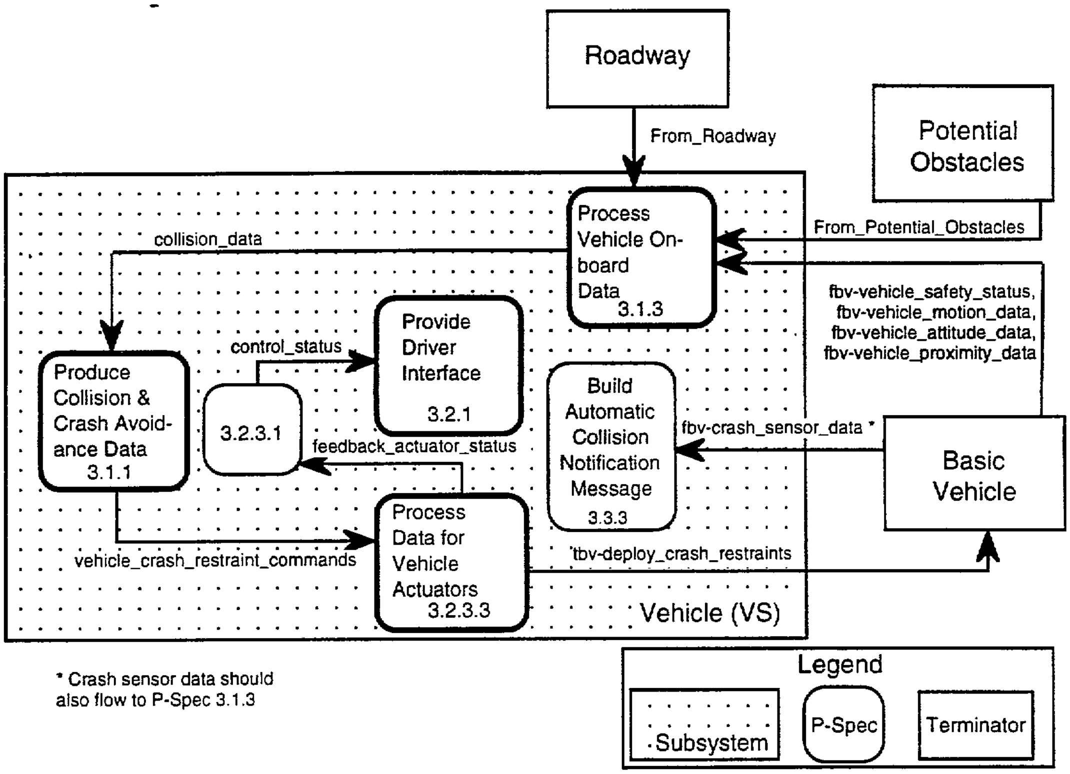


Figure 4-16 Pre-crash Restraint Deployment Data Flow

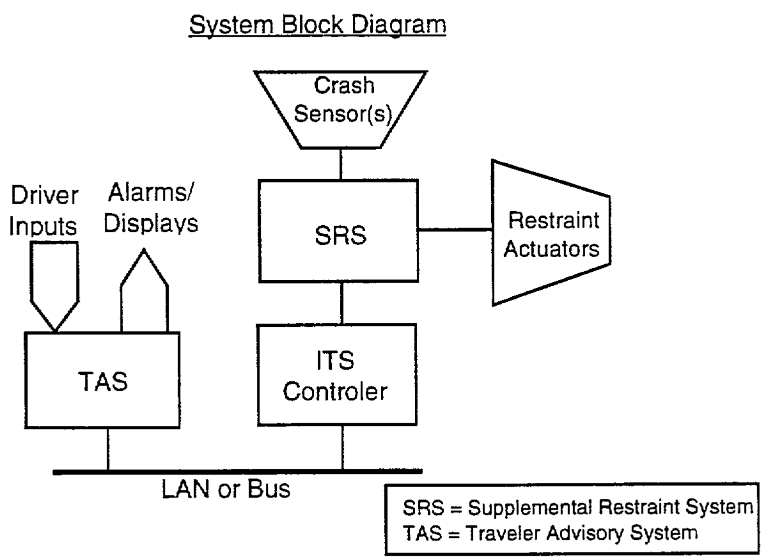


Figure 4-17 Pre-crash Restraint Deployment Physical Implementation

5. ITS Architecture Communications

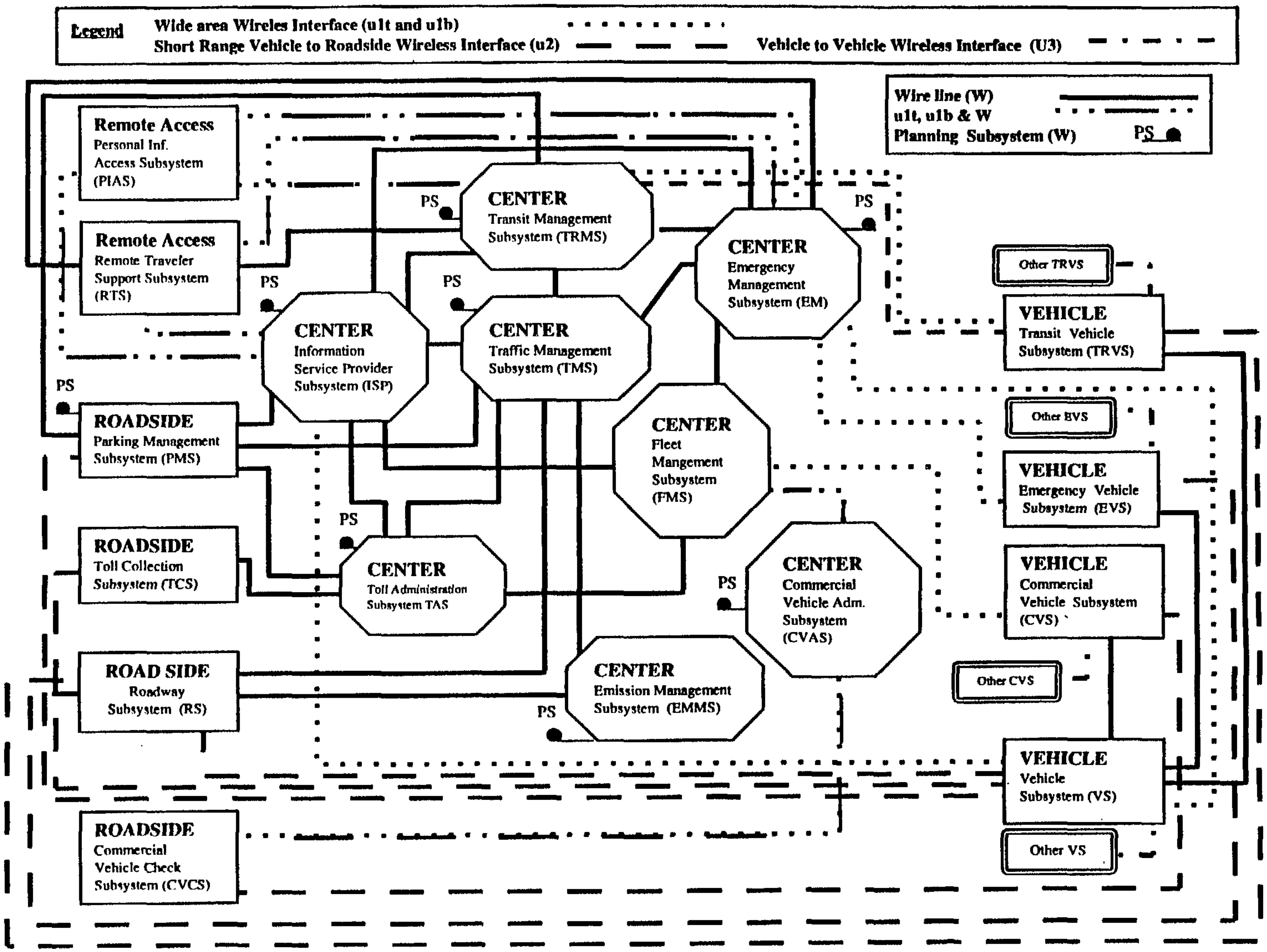
5.1 ITS Architecture Communications Overview

The ITS Architecture identifies a wide range of communications requirements, interface& and implementation options. The physical architecture and the communications document of the architecture describe the physical paths over which data is exchanged from the viewpoint of fixed (“wireline”) and mobile (“wireless”) services. The physical architecture defines both the interfaces between the subsystems of the architecture and the communications necessary for implementing these interfaces. The communications portion of the architecture also presents reference models for the implementation of communication systems and connections. The interconnections and interfaces between the transportation layer’s subsystems and terminators are defined through a series of Architecture Interconnect Diagrams (AIDs).

All of the architecture physical data flows and their corresponding physical interfaces have been assigned a form of communication best suited to meeting that flow. The architecture identified wireline and various wireless forms such as wide-area, dedicated short range, and short range vehicle to vehicle. Wireline communications are principally for fixed point to point communications typically served by fixed wireline systems such as fiber optic or coaxial cable. Fixed point to point microwave communications, however, may also meet this need. The various forms of short range wireless communications include systems using technologies such as infrared, millimeter wave, and conventional radio. Wide area wireless communications includes mobile satellite systems, cellular systems, and broadcast FM.

The communications documentation provides a good overview of possible uses of these technologies and presents results from analyses of performance. Information, however, appears to be missing. For example, a description of the vehicle to vehicle communications path is not outlined in either the data flow table (Table A.5-1 [Ref. 6, p. A-181) or the level 1 AIDS [Ref. 6, p. B-l]. This data flow is shown on the level 0 AID. The level 0 AID is a useful diagram providing developers with a visualization of all the subsystems and interfaces, but it is rendered nearly ineffectual by its poor use of graphics such as dashed lines. The lines indicating the origin and destination as well as the type of communications media are very difficult to read and should be revised to make more readable. See Figure 5- 1.

It should be reiterated that the communications portions of the FPR documentation primarily makes recommendations concerning type of communications (e.g., wireless) and presents analyses that do not prescribe requirements or design. Indeed, the communications elements of the architecture do not prescribe a design or plan for implementation of ITS systems. The communications analyses, though, do rely on design considerations such as data message sizes and specific implementations such as Cellular Digital Packet Data (CDPD). The following sections discuss issues concerning communications including operational considerations (§5.2), interfaces (§5.3), loading (§5.4), short range communications (§5.5), and performance (§5.6).



* Diagram from ITS Architecture Physical Architecture [Ref. 4, p. 3-12]

Figure 5-1 ITS Architecture Level 0 Interconnect Diagram

5.2 Operational Considerations

Several considerations concerning communications operations need to be addressed during the implementation of the ITS Architecture. These operational considerations can influence the effectiveness of safety-related ITS services. In order to provide for interoperability, the compatibility of data exchanged at the application layer between in-vehicle systems and the ITS infrastructure needs to be harmonized. This interoperability involves the standardization of message sets and the way message fields are interpreted by high level applications. The emphasis should be on logical interoperability, so systems can effectively coordinate and share information as needed. To also ensure coordinated operations, data messages should be independent from communications media and lower protocol layers. This includes the capability to route messages through different types of communications media or networks depending upon the application. The emphasis should be on cost, reliability, and meeting performance requirements.

To further facilitate interoperability, in-vehicle electronic interfaces should support "plug and play" with third party aftermarket ITS components. This may require two classes of data bus: a closed, possibly proprietary one for safety-related control functions and an open, possibly standardized, one for driver warning, in-vehicle signing, and convenience functions. The interconnections between ITS subsystems and terminators are especially important since these are the interfaces over which common data may be shared between ITS functions and safety-critical control functions. The presence of standard interfaces can only promote the availability of ITS systems.

Wireless communications are vulnerable to interference and active sabotage. The security risk is low to moderate for such operations as in-vehicle signing where the broadcasting of messages using beacons may be degraded by interference or even spoofed by saboteurs. This degradation may cause erroneous information to be received by the driver or cause messages to be missed. This error may result in un-safe conditions but do not directly affect the control of the vehicle. Reducing the risk for this problem may include the simple repeating of messages or multiple beacons along the stretch of roadway to counter the effects of interference. Other safety-related services do involve the transmission of control information that may present a high risk for security. Intersection collision avoidance and automated highway systems (including platoon communications) can be implemented with both vehicle to vehicle and vehicle to roadside communications both of which may be adversely affected by interference both unintentional and intentional. The ITS Architecture does not fully address this security risk. Although interference and security concerns are considered implementation issues beyond the scope of the architecture, the architecture itself can lead to risky situations that may be avoided through other concepts. NHTSA needs to ensure that, during the implementation phase, security issues are fully addressed. Security may also add complexity or increase message sizes affecting both processing and communications performance such as latency and throughput.

5.3 Safety-Related Communications Interfaces

It appears that all of the key interfaces that affect safety-related services and are of interest to NHTSA have been identified and defined. These interfaces include:

- Vehicle-vehicle
- Vehicle-roadside
- Vehicle-ISP
- Vehicle-Emergency Management System
- Vehicle-Traffic Management System

The first two of these interfaces require short range communications. Path lengths between transmitter and receiver are typically on the order of a few hundred meters or less, so only a few vehicles will be within range at any given time. Service may be either broadcast or point to point, and the type of information to be exchanged is usually narrowly focused on a specific function or service. The short ranges and low power requirements open the possibilities to a wide range of inexpensive technologies, such as infrared, millimeter wave, and conventional radio. This is likely to be an area where third party suppliers or OEMs develop relatively simple, low cost systems to address a specific problem, and where there is little or no requirement to integrate with a regional ITS system.

Most of the initial development in short range services is likely to occur between third party suppliers and local jurisdictions attempting to alleviate a specific traffic problem (e.g., variable in-vehicle signage, automated toll collection, etc.). The ITS Architecture does not address short range communications in detail, but it appears that in-vehicle signing, intersection collision avoidance, longitudinal collision avoidance, and lateral collision avoidance fall into this category. There is some uncertainty as to how platooning would be controlled; it may be purely vehicle-to-vehicle, or may involve a traffic management center, or some roadside system that monitors local traffic conditions. Regulatory issues such as availability of spectrum allocations and allowable power flux densities may also be significant.

The latter three of the interfaces listed above require wide area communications. The leading contenders for this service are mobile satellite systems, cellular systems, and broadcast FM using digital subcarriers. Since the user service requirements span a wide range of functional and performance needs, there is no single “best fit” communications resource. It is likely that several of these services may coexist in the future, but in the near term there is considerable market uncertainty. Cellular and broadcast FM are already in widespread use, but there is currently little support for data communication. Satellite systems are being designed specifically for digital communications applications, but there is currently no market penetration and the proposed cost of many of the systems are rather high for general use. It is reasonable to assume that some ITS communications will be provided through voice channels. Most of this voice traffic will be carried over the existing cellular telephone grid. It can be assumed that the cellular service providers will gradually increase their system capacities in response to this trend, thus no detailed analysis is needed within the architecture. What is not clear is the implementation strategy for many of the planned ITS services. The detailed communications analysis is based entirely on packet switched datagram message traffic.

The implementation of the architecture, however, should avoid the proliferation of interfaces, both vehicle-to-infrastructure and vehicle-to-driver. To avoid numerous interfaces, the implementation phase of the architecture needs to ensure standards for communications and related protocols. Dedicated short range communications may require several tags in the near future as different systems are currently being deployed, but in the long term and for wide-area communications the number of interfaces should be low. Requiring multiple communication systems may lead to multiple radios and antennas that not only will introduce complexity but will also dramatically increase the cost of ITS systems.

5.4 Communications Loading

Under the assumptions adopted by the Joint Architecture Team, data communications between the infrastructure and vehicles do not appear to be heavily stressed in terms of bandwidth or latency requirements. Little of the data is used directly by in-vehicle control systems, permitting message latencies to be on the order of several seconds or more. Combined with the low volume of data, this indicates that link data rates and propagation delay are not major design drivers. Cost, availability, and the ability to meet latency requirements are the dominant criteria and will determine the actual bit rate on the physical channels and the preferred communications media.

In the proposed datagram packet switching scenario, messages are based on templates taken from a message dictionary. Messages are composed of concatenated binary fields whose lengths and range of values are pre-defined. Typically, there is allowance for free-form alphanumeric text fields. The message dictionary must anticipate all foreseeable information needs and message types, and developers must ensure that their products conform to the defined space of message types and fields. This may be difficult to achieve with ITS, where many of the concepts have only been defined at a high level, and many competing implementations have been proposed. Real world traffic and service scenarios can also be quite complex and difficult to predict. From the end user viewpoint, it is difficult to read and input alphanumeric data, particularly when under strict time constraints or while operating a vehicle. Choosing messages through a graphical interface or list of menu options may alleviate this some, but can still be confusing and limiting.

It may prove that many of the proposed ITS services will rely extensively on circuit switched voice, which would increase the communications load significantly. For example, to initiate a platoon, it may be more efficient for a Traffic Management Center to contact a designated platoon leader by voice and receive feedback and acknowledgment by voice. It may be quite difficult to anticipate all of the message types, sequencing, and timing requirements needed to implement platooning (or other safety-critical services) with formatted datagrams.

Another situation where datagram service may have serious limitations is traveler advisory services, It may be quite difficult to anticipate what types of information a user may need, in what form it will be needed, and how the user may want it combined with other information. Voice and human interaction can be much more effective when information needs are not well defined.

The phenomenon of “information creep” should also be considered. History has shown that as communications technologies mature and become more powerful, users’ expectations and information needs will increase. Datagram service may be viewed as adequate for some period of time, but user expectations will invariably grow to possibly include graphics, voice and video annotation, and imaging. Adding any of these information types would increase the ITS communications load significantly.

The architecture assesses the data loads only over interfaces within the ITS Architecture. It does not assess the affect on systems, such as in-vehicle data buses, that are not directly a part of the architecture. The message sizes, throughput, and latency of ITS communications each has a varying affect on in-vehicle system performance. NHTSA may wish to model and assess this impact on safety-related in-vehicle systems and associated data buses.

5.5 Dedicated Short Range Communications

As at IPR #2, there was some concern by attendees at FPR concerning the use of dedicated short range communications, specifically beacons. Some attendees pointed out that beacons are being used with good success in Europe and Japan, and can be quickly and inexpensively deployed in limited geographic areas to address a specific problem. ITS information is most valuable along congested stretches of urban and interurban expressways, which can be adequately served by relatively few short range beacons. Others also pointed out that the architecture, by dictating that beacons could not be used for such services as route guidance, was in fact a design decision that should be beyond the scope of the ITS Architecture.

This concern regarding the architecture’s treatment of beacons is exacerbated by the assumptions used in the architecture analvsis. The ITS Architecture analysis assumed a single transmitter frequency for all beacons, with large “dead zones” between beacons to avoid interference. It was also assumed that beacons would be deployed uniformly over a large, two-dimensional grid, rather than linearly along more heavily used expressways and arteries. These assumptions regarding beacon usage may be unnecessarily constraining. In-vehicle receivers already exist that can rapidly scan multiple channels, thus the single frequency assumption may not be valid A multi-channel_ capability avoids the problems arising from interference between nearest neighbor beacons and the resulting need for “dead zones” or coverage gaps between beacons. Neither throughput, capacity, or latency performance appear to be significant issues with vehicle to roadside communications. A limited amount of real time control data may be transmitted over these links to support, for example, platooning. The main issue appears to be a vehicle’s “dwell time” in a beacon coverage zone, which may only be a few seconds for short range beacons. This would preclude larger data transfers and possibly the capability to exchange data with a Center or ISP.

The recommendation not to use beacons for such services as route guidance does not affect the safety-related services best served by short range communications. The architecture indicates that short range communications should be used for such safety-related services as intersection collision avoidance, in-vehicle signing, automated highway systems (“platooning”), and, when added, highway/rail crossings. Short range communications are also used for other ITS services such as toll and parking systems. What is unfortunate is that the design decision, which, may in fact, be a good decision to ensure that infrastructure-intensive implementations for some services are avoided, obscures the many uses of beacons existing in the architecture. A concern for safety-related systems is that the architecture decision against beacons may bias the implementation of services that fall in the gray area between in-vehicle signage and route guidance toward wide area communications, when an implementation based on short range communications might be appropriate. For example, a system designer needing to implement a capability to divert automobiles around an accident (with a message such as, “accident ahead, suggested alternative route is . . .“), could easily interpret this as a route guidance function. An implementation based on beacons (as a low cost alternative to the variable message boards in use today) would then not be recommended by the architecture.

5.6 Communications Performance Considerations

ITS Architecture contains performance assessments of a CDPD-based packet switching/datagram system under a number of loading scenarios. The emphasis in these analyses was on wide area communications between ITS centers and vehicles, including private, transit, and commercial vehicles. Vehicle to vehicle and vehicle to roadside communications were not assessed in detail. Based on the ITS Architecture assumptions, CDPD appears to be well-suited to ITS services that provide solicited information to drivers. Of the nine user services addressed in this study, this would include emergency notification and personal security, emergency vehicle management, and the non-broadcast elements of the driver advisory service. For these applications, the latency characteristics for CDPD are generally good for near real time requirements.

Unlike the analysis for IPR #2, the communications performance analysis of FPR now includes broadcast services for driver advisory. The rapid distribution of safety-related driver advisory data appears best implemented via broadcast services, but CDPD does not appear well suited for services needing a localized broadcast capability. While current CDPD specifications do define a broadcast type of capability, it is based on pre-definition of user groups and is not suitable for broadcasting messages to all vehicles within a particular localized area. That is, since the set of vehicles within a localized area will rapidly change, the predefined groups of CDPD broadcast service will not be adequate.

List of Acronyms

ABS	Anti-lock Braking System
ACN	Automatic Collision Notification
ADI	Advanced Driver Interface
AHS	Automated Highway System
AID	Architecture Interconnect Diagram
AM	Amplitude Modulation
bps	Bits per Second
CCD	Charge Coupled Device (imaging system)
CDPD	Cellular Digital Packet Data (communications standard)
DFD	Data Flow Diagram (within the ITS Logical Architecture)
DOT	Department of Transportation
EM	Emergency Management System
FM	Frequency Modulation
FPR	Final Program Review
GPS	Global Positioning System
IPR	Interim Program Review
ISP	Information Service Provider
ITS	Intelligent Transportation System
IVHS	Intelligent Vehicle Highway System
LCD	Liquid Crystal Display
MBytes	Mega Bytes
N/A	Not Applicable
NHTSA	National Highway Traffic Safety Administration
OBD	Onboard Diagnostics
OCAR	Office of Crash Avoidance Research
OEM	Original Equipment Manufacturer
P-Spec	Process Specification (within the ITS Logical Architecture)
PIAS	Personal Information Access Subsystem
SAE	Society of Automotive Engineers
SRS	Supplemental Restraint System
STel	Stanford Telecommunications, Inc.
TAS	Traveler Advisory System
TMC	Traffic Management Center
TMS	Traffic Management Subsystem
USR	User Service Requirement
VRC	Vehicle to Roadside Communications
v s	Vehicle Subsystem

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