## VII Data Use Analysis and Processing

# SYSTEM ARCHITECTURE DESCRIPTION

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# Abstract

The Michigan Department of Transportation (MDOT) Vehicle Infrastructure Integration (VII) Data Use Analysis and Processing (DUAP) System Architecture Description (SAD) documents the high-level view of the means of acquiring and using VII data in the management and operations of Michigan's transportation systems. The SAD provides a conceptual framework, or frame of reference, for the planning, analysis, and design of a system. The document will be used by MDOT to facilitate communications on VII and transportation operations with its stakeholders and partners, and as an architectural plan for development of prototype applications for VII data use, analysis, and processing.

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# 1 INTRODUCTION

## *1.1 Purpose*

A System Architecture provides a conceptual framework, or frame of reference, for the planning, analysis, and design of a system.

A system inhabits an environment. The environment, or context, determines the setting and circumstances of developmental, operational, political, and other influences upon that system. The environment can include other systems that interact with the system of interest, either directly via interfaces or indirectly in other ways. The environment determines the boundaries that define the scope of the system of interest relative to other systems.

A system has at least one stakeholder. Each stakeholder typically has interests in, or concerns relative to, that system. Concerns are those interests which pertain to the system's development, its operation, or any other aspects that are critical or otherwise important to the stakeholders. Concerns include system considerations such as performance, reliability, security, distribution, and growth.

A system exists to fulfill one or more missions in its environment. A mission is a use or operation for which a system is intended by one or more stakeholders to meet a set of objectives.

The framework of this System Architecture Description is organized into one or more constituents called (architectural) views. Each view addresses one or more of the concerns of the system stakeholders. The term view is used to refer to the expression of a system's architecture with respect to a particular viewpoint.

This document applies to the DUAP system. The document control number for this document is contained in the document footer and the file name for the electronic rendition of the document is recorded in the table of contents for the document.

## *1.2 Scope of This Project*

Advances in information and communications technology over recent decades have created the potential for vehicles themselves to become active participants in the management and operations of the transportation infrastructure. Whereas traditional roadway infrastructure and traffic controls are independent of the controls within a vehicle, VII initiatives are aggressively pursuing opportunities for the sensors and controls on vehicles and the roadway to work together.

Federal, state, and local agencies and private commercial stakeholders are working together to evaluate and promote the VII opportunities. To this end, the U.S. Department of Transportation (USDOT), MDOT, other state and local agencies, the Vehicle Infrastructure Integration Consortium (VIIC), and industry associations have established a network of common interests and a process of mutual investment and support intended to develop and realize the potential of VII. The efforts of these participants over the last several years have resulted in a

common vision and plan; opportunities for public information and involvement; and the beginnings of a technical (and economic) framework.

MDOT is leading the way among state agencies and has produced a *Vehicle-Infrastructure Integration Strategic and Business Plan* that lays out the vision and action plan for VII development in Michigan. The plan describes the institutional relationships, outreach, and technical developments that will be needed to develop and deploy VII. The DUAP project brings together much of the technical development called for in the plan.

The specific purpose of the DUAP project is to support MDOT and its partners in evaluating uses and benefits of VII-related data in transportation agency management and operations. As such, the project complements parallel efforts of MDOT, USDOT, VIIC, and others to design and deploy the VII network[1], vehicle equipment, and initial applications. The DUAP project builds on that foundational work to investigate how the availability of data from VII-equipped vehicles throughout the road network may impact the ways transportation agencies do business. The project will focus specifically on data uses and benefits in responding to safety concerns, managing traffic, and managing MDOT's transportation assets. The work will also support other VII activities, technology development for MDOT, and economic growth for the state.

The key tasks within the DUAP project are

- to identify uses for the VII data;
- to develop algorithms to use and process the VII data;
- to develop prototype applications and data management software; and
- to evaluate how well the data and the algorithms function in a department of transportation.

As illustrated in Figure 1, it is envisioned that a DUAP system will draw data from existing MDOT data sources and other relevant data sources to be integrated with VII data. The integrated system output could be returned to the existing MDOT applications as an enriched data stream or could be used in new applications for MDOT. Other MDOT projects may have influence on or facilitate the data integration. Applications outside MDOT could receive data through a new MDOT gateway application.

[1] Throughout this document the term "VII network" should be understood to refer to a VII network based on the USDOT's VII National System Requirements.

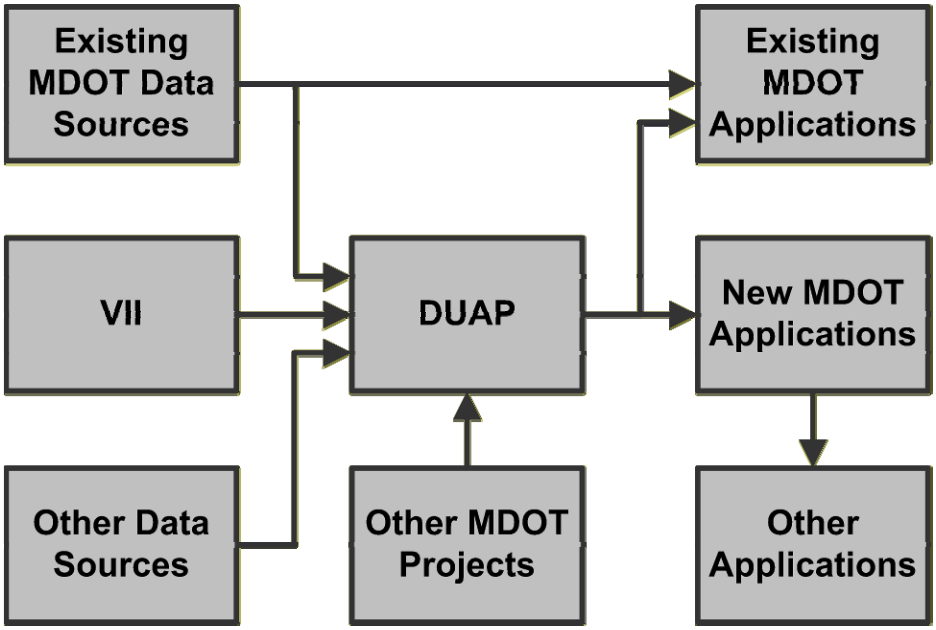


**Figure 1 – DUAP Data Flows**

## *1.3 Definitions, Acronyms, and Abbreviations*

This document may contain terms, acronyms, and abbreviations that are unfamiliar to the reader. A dictionary of these terms, acronyms, and abbreviations can be found in Appendix A.

## *1.4 References*

Full citations for the documents referenced in this System Architecture document can be found in Appendix B, which also includes documents that have not explicitly been referenced, but contain additional information relevant to the project.

## *1.5 Document Overview*

The organization and content of this System Architecture Description, and the selection of viewpoints, is based on IEEE Standard 1471-2000 and Federal Highway Administration (FHWA) requirements as expressed in 23 CFR 940.11.

The remainder of this document consists of the following sections and content:

Section 2 (**Stakeholders and Concerns**) identifies the stakeholders and their interests with regard to the system development, operation, policies, and other impacts of the system.

Section 3 (**Operational View**) provides the participating agencies with an overview of the system's purpose, scope, and functions. It also addresses policy statements about the system and policies governing the interactions between the system and external systems, agencies, and users.

Section 4 (**Information View**) provides the system developers and developers of other interfacing systems with an overview of the data interfaces, and data flows for the system.

Section 5 (**Decomposition View**) provides the system developers and developers of other interfacing systems with an overview of the computational objects (software modules), program interactions and behavior, and software interfaces that form the system.

Section 6 (**Hardware View**) provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of the planning for the hardware, communications, and operational support for the system.

Section 7 (**Technology View**) provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of what relevant technologies will be used, how industry standards and specifications will be implemented, and what technologies will be required to support testing of the system.

Section 8 (**National ITS Architecture View)** provides the Federal Highway Administration, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National Intelligent Transportation System (ITS) Architecture. This includes the system's relationship to the standard Market Packages and to the National ITS Physical and Logical Architectures.

Appendix A (**Definitions, Acronyms, and Abbreviations**) provides definitions for the terms, acronyms, and abbreviations used throughout the document.

Appendix B (**Supporting References**) identifies references with additional information relevant to this project or mentioned within this document.

# 2 STAKEHOLDERS AND CONCERNS

DUAP stakeholders include all those who develop and administer, provide data to, or use the DUAP system. Stakeholders in this case are predominantly MDOT staff but also include those who work with MDOT or who exchange data with MDOT.

MDOT operators have the objective of minimizing the impact of planned and unplanned events on the normal flow of traffic. In order to meet this objective, operators perform the following tasks:

- Review major incidents and events that impact travel
- Assess potential impact on travelers
- Determine response actions needed
- Monitor incidents and events for status changes

MDOT maintenance personnel maintain the roadways and bridges within their particular jurisdiction. They provide snow removal and pavement treatment in the winter, perform routine reactive maintenance, and clean up and repair roadway as needed in response to incidents.

MDOT asset managers and planners analyze the data and information collected about the assets in their area to determine the annual programs and projects. Their goal is a cost-effective use of resources within the agency. Planning and pavement and bridge management personnel are included in this group of stakeholders.

MDOT executives, such as the MDOT Director, MDOT Executive Bureau, and State Transportation Commission provide oversight and make final decisions on investments in Michigan's transportation infrastructure. Information from existing systems is used to guide and support the decisions made by the executives.

MDOT system administrators are part of the Michigan Department of Informational Technology (MDIT). Their goal is to have all collected data available for use by the other stakeholders. MDIT Enterprise Information Technology (IT) policies, standards, and procedures are documented to assure consistency, efficiency, and effectiveness in the delivery of information technology services that support the business functions of the state.

Local and regional transportation agencies (including transit agencies) interact with existing MDOT systems where their areas of operation interface with MDOT. Stakeholders within these agencies may include executives, managers, operators, maintainers, and system administrators. Other Departments of Transportation (DOTs) are stakeholders in the existing data where there is cooperation across state or provincial boundaries.

MDOT's Asset Management Council brings together state and local transportation agencies from across Michigan to invest more efficiently in Michigan's roads and bridges. The Council provides coordination and collaboration in asset management policies, programs, and practices among the member agencies.

The USDOT is focused on the safety, mobility, and economic impact of the nation's transportation systems. USDOT works with each state to gather quality data that are used for national statistical reporting. Often these data have an impact upon the prioritization of state projects.

International highway and transportation agencies and authorities share MDOT's interests in the development and deployment of VII technologies. As such, they are actively monitoring VII developments in Michigan, the United States, and the rest of the world, and will continue to be stakeholders throughout the development of the DUAP program.

Travelers are all the people who use the roadways, whether driving or riding in private or commercial vehicles. They obtain their trip information from various sources and use it to prepare for their daily commute or for an extended trip. The trip information may be used by the traveler for determining possible delays along desired route(s) or choosing an alternative route or mode of transportation.

Commercial fleets are those transportation vehicles which are used by businesses for economic purposes. These fleets obtain route information from the existing data in order to select the most economical route.

Commercial information service providers (ISPs) and other media outlets use data from the existing traveler information systems to redistribute information to their audiences. This information may be provided as part of a newscast (free) or as a subscription service.

Universities and the research community assist MDOT and other transportation agencies in both acquiring and analyzing traffic, environmental, and asset data.

Emergency Services are staffed with trained personnel who respond to emergency incidents or major disasters both on and off the roadway system. Their primary goal is to provide appropriate services—for example, medical, law enforcement, or hazardous materials—while protecting the public and services personnel from further injury or loss during the response. The data from the roadway system will assist them initially in getting to the incident location. While Emergency Services personnel are on-site, the data can be used to help evaluate the impact of the incident on the current traffic and help determine if additional resources are needed.

Other Michigan state and local agencies may use existing transportation systems data for planning and operational needs specific to their agency. The Michigan Economic Development Corporation (MEDC), for example, provides assistance to small and large companies in Michigan seeking to grow in a very competitive and challenging global economy. Efficient transportation systems and data are essential to those companies' operations and can catalyze further opportunities for growth.

The automobile manufacturers (or original equipment manufacturers, OEMs) and their suppliers are stakeholders in DUAP because VII data become available to transportation agencies only if those OEMs provide equipment and communication systems in their vehicles for transmitting the data to the VII

network. Many of the OEMs are members of the VIIC, which is developing the on-board equipment (OBE) and assisting the USDOT in development of applications for VII infrastructure and data. OEMs are in many cases also developing independent telematics networks from which transportation agencies might be able to obtain data similar to that provided through the USDOT/VIIC efforts.

Automotive industry research groups and associations are stakeholders in DUAP through their support of the MEDC and the automotive manufacturers. The Center for Automotive Research (CAR) and Connected Vehicle Trade Association (CVTA), for example, provide perspective and research on industry trends, policies, and methodologies. In particular, the Connected Vehicle Proving Center (CVPC) under development by CAR and CVTA will test and evaluate connected vehicle systems by integrating connected vehicles, smart roadway infrastructure, and communication technologies to showcase the potential of VII and related vehicle-communications initiatives.

The VII network (or any similar independent telematics network) introduces a network operating entity as a stakeholder to DUAP and to transportation system operations. Once the VII field infrastructure is in place, a network operating entity will be needed to operate, monitor, and maintain the flow of VII data and the infrastructure enabling it. The operating entity's responsibilities in this capacity are similar to those of a transportation agency relative to the transportation network. The operating entity's telecommunications service providers would be indirect stakeholders in DUAP.

# 3 OPERATIONAL VIEW

The Operational View provides the participating agencies with an overview of DUAP's purpose, scope, and functions. It also addresses policy statements about the system and policies governing the interactions between the system and external systems, agencies, and users.

## *3.1 Background, Objectives, and Scope*

The current state of processes and systems available to MDOT contains significant opportunities to improve safety, mobility, and efficient use of the state's transportation system. Expectations for delivery of transportation services continue to grow[2], while resources for service delivery are externally constrained. Transportation agencies are expected to satisfy greater demand for services for less cost, all the while making a net positive contribution to the state's broader economic development.

These demands are illustrated in the case for change described in Section 3 of the DUAP Concept of Operations (ConOps). The traveling public wants more real-time information about traffic and road conditions. MDOT wants more information about its assets and how they are used by the traveling public. Everyone wants to travel in complete safety. While travel demand is increasing, funding levels have not kept sufficient pace to allow meeting that demand with new pavement or bridges alone. New technologies will have to fill that capacity gap, and the integration of those new capabilities with existing applications will bridge the remainder.

To that end, a strategy is put forth in MDOT's *Vehicle-Infrastructure Integration Strategic and Business Plan* that focuses on partnering, developing, and deploying a VII infrastructure and testbeds; increasing safety and mobility; improving asset management; developing outreach programs to better expose others to VII in Michigan; justifying the need for VII; and determining creative investment funding venues for VII activities.

Within this context, the DUAP project will investigate and evaluate the utility of VII data and its integration with other transportation agency sources in enhancing safety, increasing mobility, and improving asset management. Tasks within DUAP will identify uses for the VII data, develop algorithms to use and process the VII data, develop prototype applications and data management software, and evaluate the utility of the processed data for MDOT and its partners. Data processing will require acquisition from a variety of sources, standardization and integration, storage, synthesis for particular applications, and dissemination.

[2] The American Association of State Highway and Transportation Officials (AASHTO) reports, for example, that "Interstate highway travel demand measured through vehicle miles traveled (VMT) will increase from 690 billion in 2002 to 1.3 trillion by 2026." (AASHTO 2007)

## *3.2 Operational Policies and Constraints*

Operational policies will need to be established to protect the privacy and data ownership of the data originators. While the USDOT VII program is addressing policy issues for the VII network itself, MDOT will be faced with many of the same issues as it seeks to integrate VII data into its operations.

For example, while VII probe data are "anonymized" to the extent that information is not associated directly with a particular vehicle or driver, there are inherent limitations to that anonymity. In the simplest such case, the VII-originated record of a vehicle's behavior could be uniquely correlated to a particular vehicle if it were the only such vehicle on a roadway at a particular time and had been corroborated by other observations. While this may not be a significant policy issue during system development and testing, or after every vehicle on the road is VII-enabled, it could become an issue in the transition—when some but not all vehicles are so equipped and are therefore more easily identifiable.

The question of ownership of commingled data may become an issue for DUAP-based information. MDOT and its partner transportation agencies currently subscribe to selected traffic, vehicle location, and weather information services that would be blended into the DUAP data streams. While the bulk of data will be from the VII network, other sources present opportunities for data expansion and validation that might be necessary for DUAP to succeed. Limitations on the use or redistribution of data from these third-party sources could hamper the usefulness of DUAP and will need to be considered in agreements for those services.

## *3.3 Description of the Proposed System*

When describing a system, there are many ways to represent what the system will do and how it will be implemented. Each representation has its own strengths and limitations, but all are intended to create understanding of the system's boundaries, components, and interactions. Each representation has its own set of basic units and interactions. One or more of these representations taken together describe the system architecture.

Systems similar to the DUAP system are frequently and effectively represented as sets of interacting services. Each service has one or more interfaces by which the services interact. This representation is a very natural way of approaching a potentially complex system with a basic repeatable model.

A representation based on services and interfaces inherently leads to a flexible, scalable, and maintainable design. With well-defined interfaces, it is possible to improve the functions of the system by adding services that conform to the interfaces, but provide new operations. Services do not unnecessarily constrain the physical and computational hardware to which they might be deployed. It is possible to scale the system by adding hardware to support the processing needs of new services as they are developed and deployed. Maintainability can be preserved by being able to update both hardware and software components while the system is running.

A DUAP system based on a service-oriented architecture will then be flexible, scalable, and maintainable. It will be capable of handling large amounts of continuously streaming data. It will support current and future MDOT missions and goals.

Figure 2 is a simple (but abstract) representation of the DUAP system as a set of services. As shown in the figure, the basic services provided by DUAP are input, dynamic data, computational, persistent data, output, presentation, and administrative. These basic services are common to all information systems, but will have specific implementations for DUAP to assure that the needs described earlier in the ConOps are met.

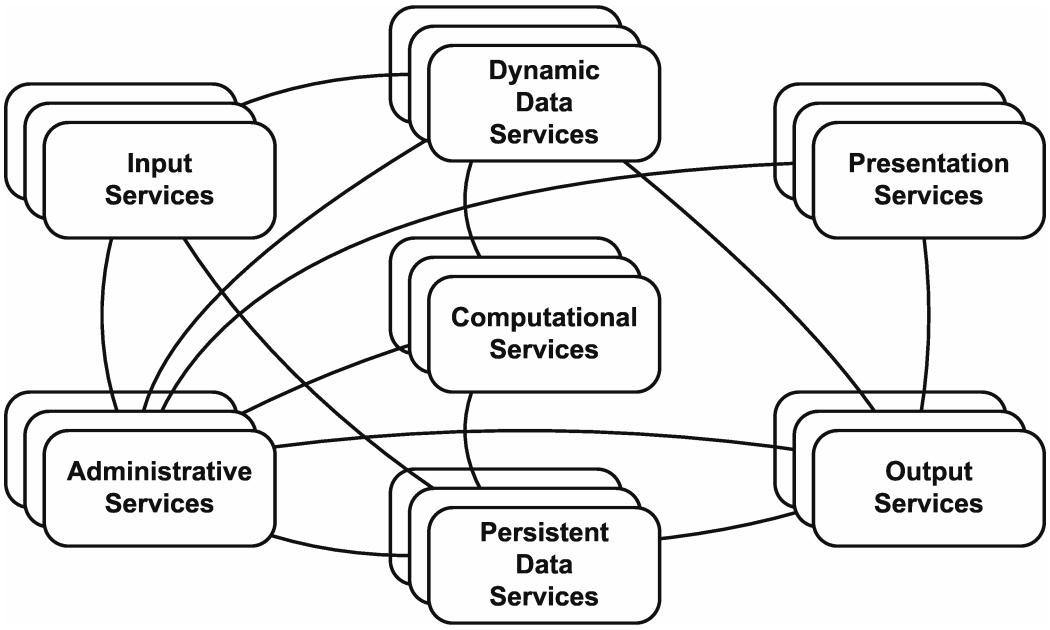


**Figure 2 – DUAP System Services**

### 3.3.1 Input Services

Input services provide the ability for DUAP to interact with any other system that might have data needed by DUAP. These other systems could include the VII proof of concept (POC), other probe data services, other transportation agency traffic management systems, commercial traffic information service providers, and weather service providers. A specific DUAP input service would be needed for each source of data.

The VII POC input services, for example, will use the X-031 Probe Data Service (PDS) interface as described by the VII Network User to Service Delivery Node Subsystem document. DUAP data input services will send a subscription request to the Probe Data Service, to be fulfilled within the VII network. As infrastructure data are collected from the vehicles by the network, the network feeds the data continuously to the subscribed DUAP services.

Input services will also receive speed, volume, and occupancy data from the Advanced Traveler Information System (ATIS) throughout the state. The Michigan Intelligent Transportation System (MITS) Center Advanced Traffic Management System (ATMS), for example, will have its own input service for collecting speed, volume, and occupancy, and may also obtain event descriptions and messages posted on changeable message signs (CMS) or dynamic message signs (DMS).

### 3.3.2 Dynamic Data Services

The Dynamic Data Services are the active memory of DUAP. Data obtained by the Input Services are stored here for use by other DUAP components. Following a pattern similar to the Input Services, the Dynamic Data Services (and other services within the DUAP system) register with the Input Services to receive copies (subscriptions) of the data for their use. The Dynamic Data Services then provide a buffering service within the DUAP system to increase the data longevity so that other more complex services will have an opportunity to process the data completely. As input data are buffered, they are immediately made available to other services.

### 3.3.3 Persistent Data Services

The Persistent Data Services are the long-term memory of DUAP. While buffering services like the Dynamic Data Services are intended to store data that are readily accessible and saved for a relatively short duration, longer-term storage will be fulfilled by Persistent Data Services. Archive services, for example, will receive vehicle data from buffering services just like other services in the DUAP system. Buffering services provide fast access to the most recent vehicle data, while archive services will organize and provide long-term storage for vehicle information to support future data analysis and management needs.

### 3.3.4 Computational Services

The purpose of the DUAP system's Computational Services is to apply logical algorithms to incoming vehicle and traffic observations in order to transform those observations into data that are directly applicable to transportation management and operations processes. Computational Services will operate on the dynamic and persistent data to perform analysis functions that derive new and useful information about what is occurring within the public infrastructure. Derived information can then be operated upon by still other Computational Services for further analysis.

Many Computational Services are possible. A list of immediately useful algorithms follows:

- Incident Detection and Location
- Queue Length
- Travel Time
- Segment Aggregation
- Weather Condition

- Road/Bridge Condition
- Pothole Locator
- Data Quality Checking

### 3.3.5 Output Services

Output Services subscribe to data within DUAP Dynamic and Persistent Data Services and structure and format it for use by other services within, and external to, the DUAP system. For example, SAE J2354 XML-formatted data can be produced as data output to other systems that provide traveler information and enhance public safety.

Data output services also format analyzed data for use by presentation services. An example of this relationship between data output and presentation services is sending information messages to a VII participating vehicle. This interaction could be achieved by preparing data according to the X-032 interface—described by VII National System Specification—to an Advisory Message Distribution Service.

### 3.3.6 Presentation Services

Presentation Services support human interpretation of DUAP data. Due to the inherent flexibility in modular service implementation, presentation services—and the data output services that support those presentation services—can be added to the system as needed.

For example, a traveler information presentation service might be expected to provide information on incidents and travel times through a Web page. Other computational services—incident detection, travel time calculation, and incident status monitoring, for example—would generate the data, and an output service would package the data. A presentation service, however, would create the user interface. Similarly, presentation services for maintenance support systems could be deployed to generate pavement segment maintenance priority lists, immediate maintenance alerts, and estimated segment roadway life expectancy from data created by other computational services.

### 3.3.7 Administrative Services

Administrative Services exist within the DUAP system to configure other services. Essentially, administrative services fulfill the role of “meta-services.” These services will be used to configure the startup and shutdown of the other services, to view logging information, and to change the operating modes of the system.

## *3.4 Modes of Operation*

Modes of operation are a way of defining and expressing sets of conditions under which a system is expected to operate. From a system user’s perspective, the modes define what can (or can’t) happen while the system is in that mode. From a system developer’s perspective, modes prescribe what the system should (or should not) do while the system is in that mode. In an automobile, for example,

the mode is driver-selected by the ignition switch, which then constrains what vehicle subsystems are enabled or disabled. The modes of operation for the DUAP software system are:

- Start – Start is the mode that tells the administrative services to start the dependent processes sequentially as defined. A system in this mode will either transition to Normal mode or to Shutdown mode.
- Normal – Normal is the desired mode for the system. In this mode, the system is ready to receive and process data as designed. From this mode, the system can either go into Abnormal mode, Diagnostic/Repair mode, or Shutdown mode.
- Abnormal – In this mode, the system is still functioning but is also experiencing a problem. From this mode, the system can either go into Diagnostic/Repair mode or Shutdown mode.
- Diagnostic/Repair – In this mode, the system runs diagnostic services in order to attempt a repair. From this mode the system can either go back into Normal Mode or go into Shutdown mode.
- Shutdown – In this mode, the system is shutting down dependent processes in a predefined sequence. When shutdown is complete, the system will be in Off mode.
- Off – In this mode, the system is completely shutdown. From this mode, the system can go only to Start mode.

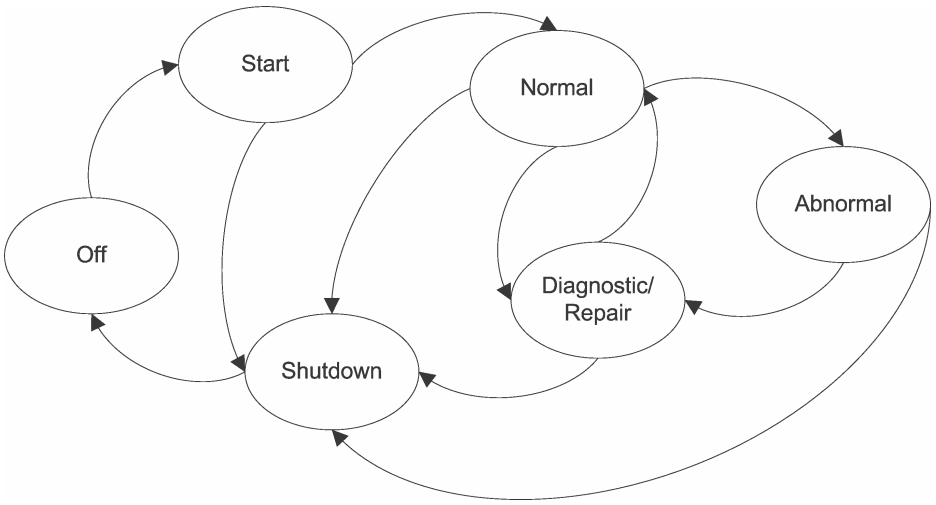


**Figure 3 – Modes of Operation**

## *3.5 User Classes and Other Involved Personnel*

### 3.5.1 Profiles of User Classes

User classes are described by the manner in which those users interact with the DUAP system. They must include all stakeholders in the system, but are grouped by their interactions, not by organizational affiliation or other attributes. User

classes may interact directly or indirectly (through a proxy) with the DUAP system. User classes relevant to DUAP include:

- Data-providing systems (provider systems)
- Data-subscribing systems (subscriber systems)
- Data-subscribing users (subscribers)
- Administrators
- Developers

The data-providing systems class consists indirectly of on-board systems in the vehicles and other telemetry systems which provide data that is ultimately collected by the DUAP system. The data includes observation from vehicles, environmental sensor stations, and other transportation-related measurement devices. This user class provides the majority of the raw data for the DUAP system. Stakeholders who belong to this user class include the automobile manufacturers and OEMs and commercial fleets.

The data-providing systems class also includes the systems that collect the data directly from the on-board and telemetry systems and publish the data for collection by the DUAP system. These systems interact directly with the DUAP system. Included in this class of systems is the USDOT's VII system.

The data-subscribing systems class consists of the systems which subscribe to the data published by DUAP to support processing by other applications. These applications take the data provided, perform analysis, and present the data to the users in the data-subscribing user class.

The data-subscribing user class consists of the actual users of the data from the DUAP system. The stakeholder groups who use the data include the following:

- MDOT maintenance personnel
- MDOT asset managers and planners
- Commercial ISPs and media
- Universities and the research community assisting MDOT
- Emergency Services personnel
- Other Michigan state and local agencies

This user class may use the data directly as subscribed or may use it in other applications.

The administrator class of users represents individuals who are responsible for maintaining the collected data and ensuring it is available for use by the other user classes. This user class assures consistency, efficiency, and effectiveness of the data collection and delivery.

The developer class of users consists of individuals who are responsible for developing applications which use the raw data. The developers may be MDOT

personnel or may be from other agencies that work with MDOT. The applications developed by this class depend on the accurate and timely delivery of consistent data.

### 3.5.2 Other Involved Personnel

There are two classes of users who do not directly interact with the system but who have an influence on, or are influenced by, the system.

The owners of provider systems are one such class. This class of users directly influences the systems from which DUAP is gathering data. Decisions made by these users in regards to transportation-related measurement devices can have a profound impact on the viability of the DUAP system. Applications which use the raw data and subscribers to the data expect that the data will be provided in a consistent manner. Coordination is necessary between the owners of provider systems and DUAP to ensure that the DUAP system data used by the applications and subscribers is both accurate and timely.

The other user class in this category is the owner/developers of subscriber systems. These users do not work directly with the DUAP system but are influenced by the output of the system. These users also must ensure that the output of their systems accurately reflects the actual environment based on the data received by their systems.

### 3.5.3 Interactions among User Classes

During the system development process, developers are active with all of the stakeholders and user classes in identifying and implementing system functional requirements. Once the system is deployed, these activities may continue as users identify opportunities to refine or supplement the system's capabilities. Since DUAP is in its prototype stage, this interaction is critical to the system's acceptance and implementation across MDOT.

Likewise, system administrators work with all of the stakeholders and user classes in assuring that the deployed system is available and operating as intended. Administrators maintain both the system and its configuration such that developers have operational context for continued development, data-providing systems are known and actively providing data, and subscribing users and systems have continued access to system interfaces.

Data-providing systems provide the essential raw information from which DUAP creates higher-value operational data, so those systems are of interest to all DUAP user classes. While all classes may be involved with the data-providing systems during system development, only DUAP administrators interact directly with those systems during normal operation.

Data-subscribing systems and users interact primarily with DUAP administrators. In this prototype stage of DUAP's lifecycle, however, users will be evaluating and offering feedback on system interfaces and functionality to system developers.

There are many interactions between the user classes described above. The major interactions are described below.

The provider system interacts with the subscriber system. A change by the provider system that affects the provided data elements will need to be coordinated with the subscriber system. It is possible that the change may require a modification to the subscriber system in order to handle the new data.

The subscriber system interacts with the subscriber. A subscriber expects the data to be provided in a consistent manner. A change in the subscriber system may require a change by the subscriber.

Administrators and developers interact with all the user classes listed. The work that the administrator performs includes hardware and software maintenance and upgrades. This work impacts the other user classes as well as is impacted by them. Developers create new applications and add additional functionality to current applications. In performing this work, the developers may affect the other user classes. The requirements for the application development will come from the other user classes.

## *3.6 Support Environment*

Support for MDOT systems and data is provided by MDIT, whose goal is to achieve a unified and more cost-effective approach for managing information technology among all the Michigan Executive Branch agencies while delivering innovative business solutions with their partners.

MDIT Enterprise IT policies, standards, and procedures (Policies & Standards 2000) are established and implemented to assure consistency, efficiency, and effectiveness in the delivery of IT services that support the business functions of the State. Generally, MDIT prefers adherence to widely available technology standards, software tools, and frameworks that have open-software interfaces and broad industry support; and hardware that historically is of outstanding build quality and high reliability.

Specific products having been identified as Enterprise IT standards for the State are reviewed, at a minimum, every two years. Currently, standard products have been defined for the desktop environment, Web tools, database software and tools, servers, network devices, and network monitoring tools.

# 4 INFORMATION VIEW

The Information View provides the system developers and developers of other interfacing systems with an overview of the data flows and data schemas for the DUAP system.

## *4.1 Data Flows*

Figure 4 shows an overview of the relationships between DUAP and other systems. Each of these connections can be associated with one or more message sets. The data elements that define the information in these data connections will in turn establish the context for the data structures that will be required to support the DUAP system services.

Data processed by the DUAP system will come from the VII PDS, the MITS center, other Traffic Operations Centers (TOCs), and MDOT's lane closure database. Probe data may also be provided by other vehicle fleets with telematics capabilities. After processing by the DUAP system, data will be provided to other systems based on the subscriptions to the system.

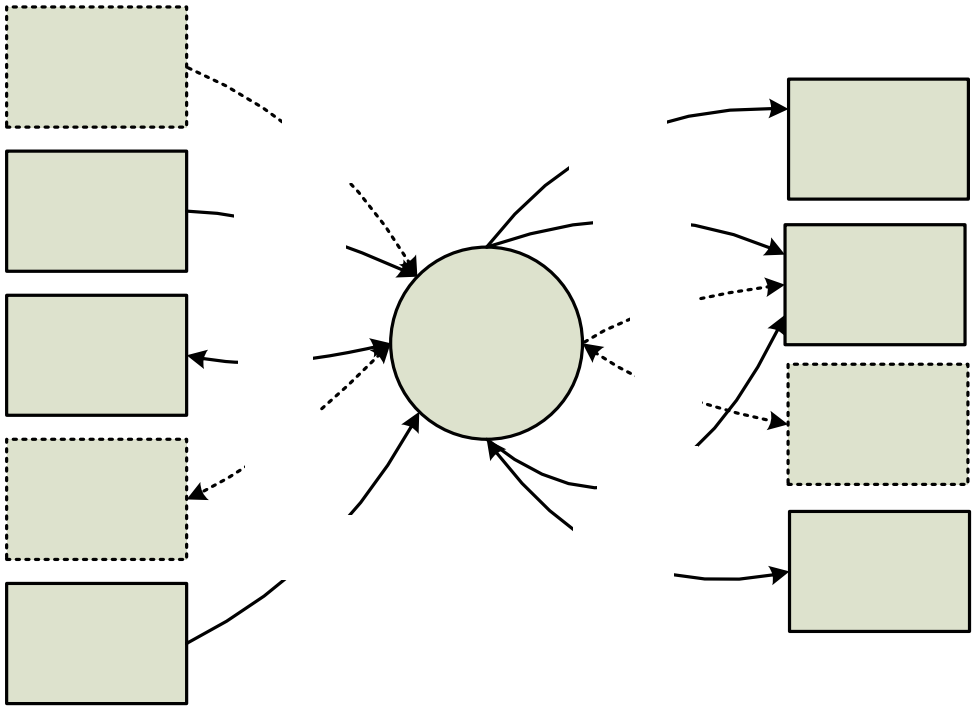

**Figure 4 – DUAP Information Overview**

Data Flow Diagrams (DFDs) and DFD descriptions are used to identify the processes and information associated with the functional requirements process model. The Figure 5 DFD begins to break down the DUAP data flows within the "Process Data" bubble in Figure 4. Each process bubble is shown with its associated input and output data flows. At this level, DUAP processing consists of four generalized processes:

- DFD:1 Collect Data

- DFD:2 Derive Data
- DFD:3 Publish Data
- DFD:4 Present Data

Each one of these processes is broken down into its component processes in subsequent sections. These processes interact with and are supported by two data stores, each with their own schema, as described in Section 4.2.

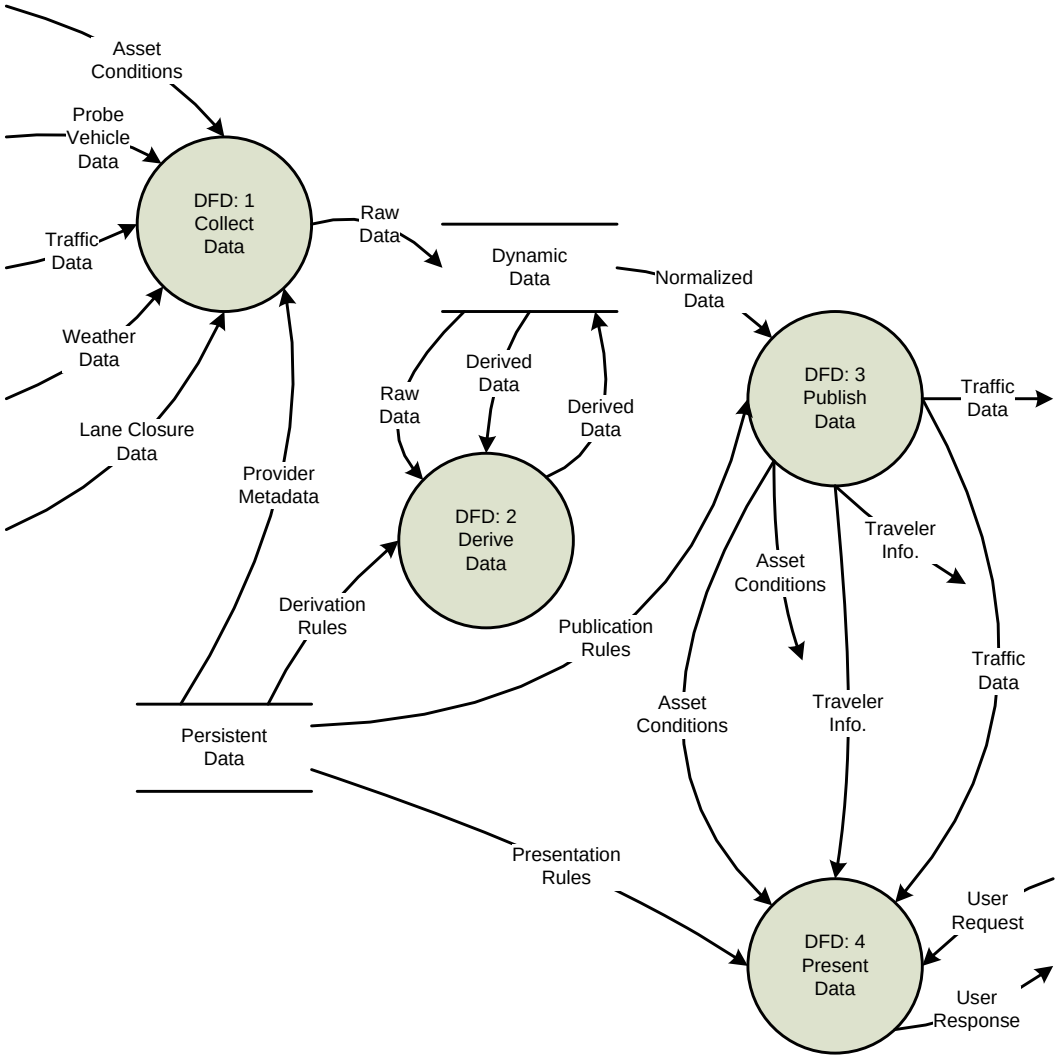


**Figure 5 – DUAP Data Flow**

### 4.1.1 Collect Data

Figure 6 shows the data flow associated with DFD:1 Collect Data. The data format, location, and interval for data collection from each source are stored as part of the system configuration in the persistent data store. This information will be used to enable the DUAP system to interface with other systems that have data needed by DUAP. Each data collection process is specialized to a particular

source and types of data, and results in those types of data being sent to the dynamic data store.

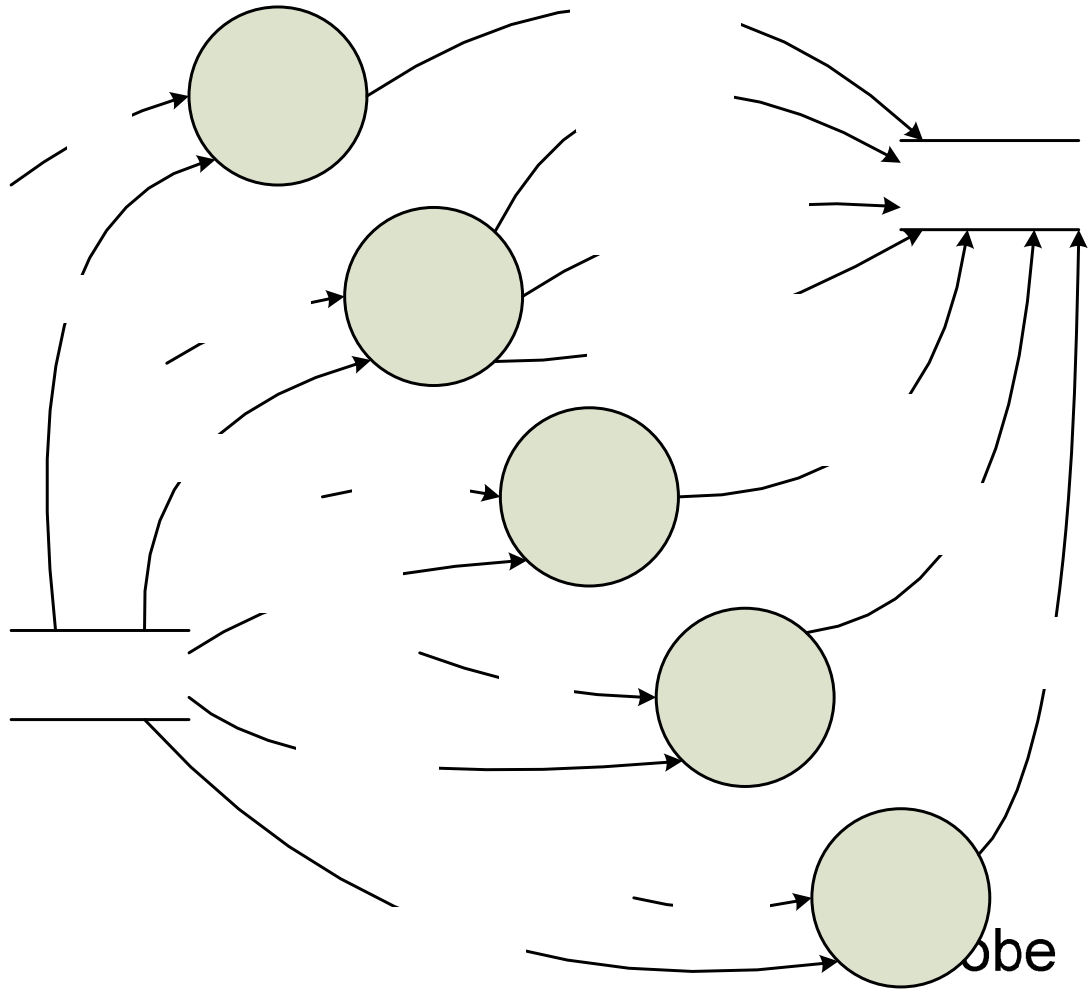

**Figure 6 – DUAP Collect Data**

### 4.1.2 Derive Data

Figure 7 shows the processes and data flows associated with DFD:2 Derive Data. Each data flow within this process involves the application of logical algorithms to derive meaningful transportation information. Some of the data will be stored in the active memory as Dynamic Data and other data will be stored for a longer term as Persistent Data.

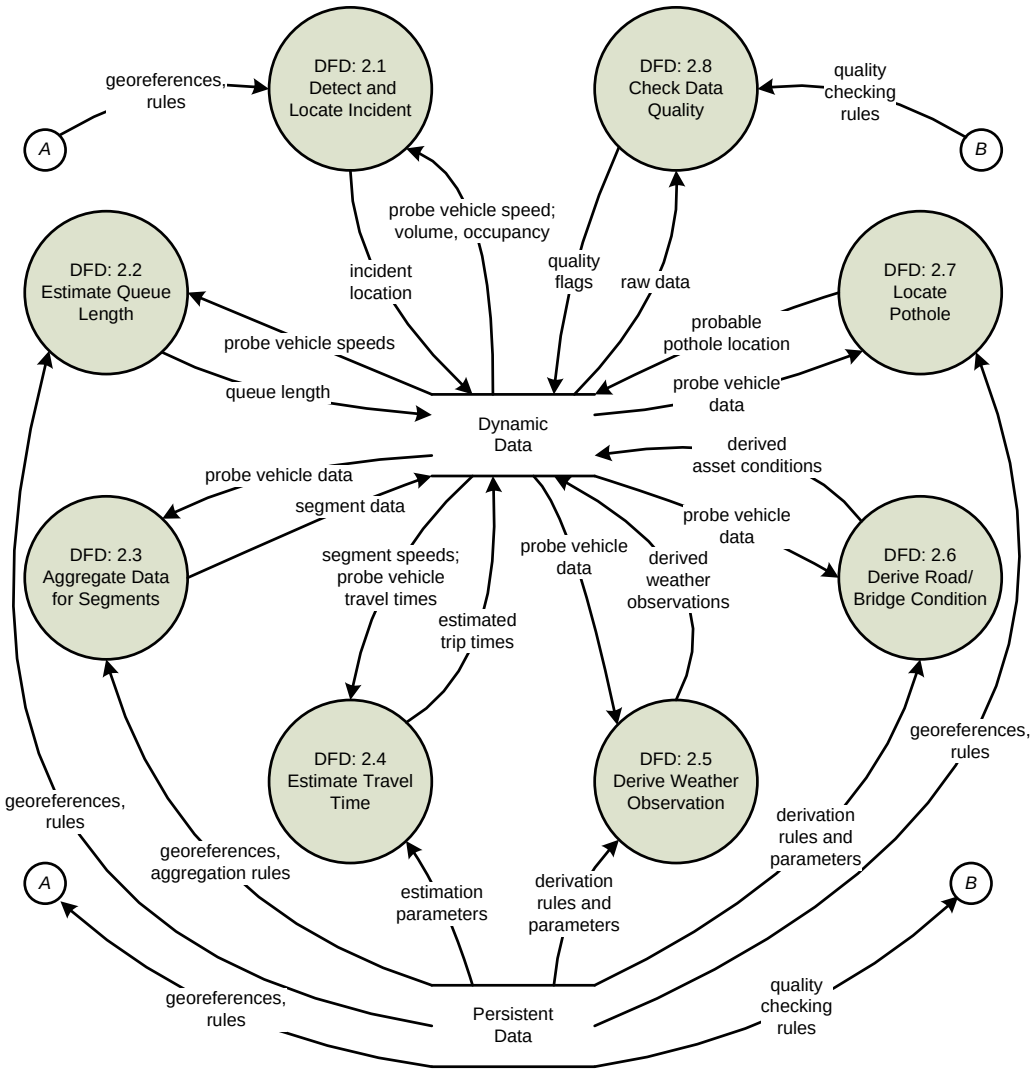


**Figure 7 – DUAP Derive Data**

### 4.1.3 Publish Data

Figure 8 shows the data flow associated with DFD:3 Publish Data. Each data flow within this process takes the configuration information contained in the Persistent Data and formats the specified data from the Dynamic Data and Persistent Data based on the configuration information.

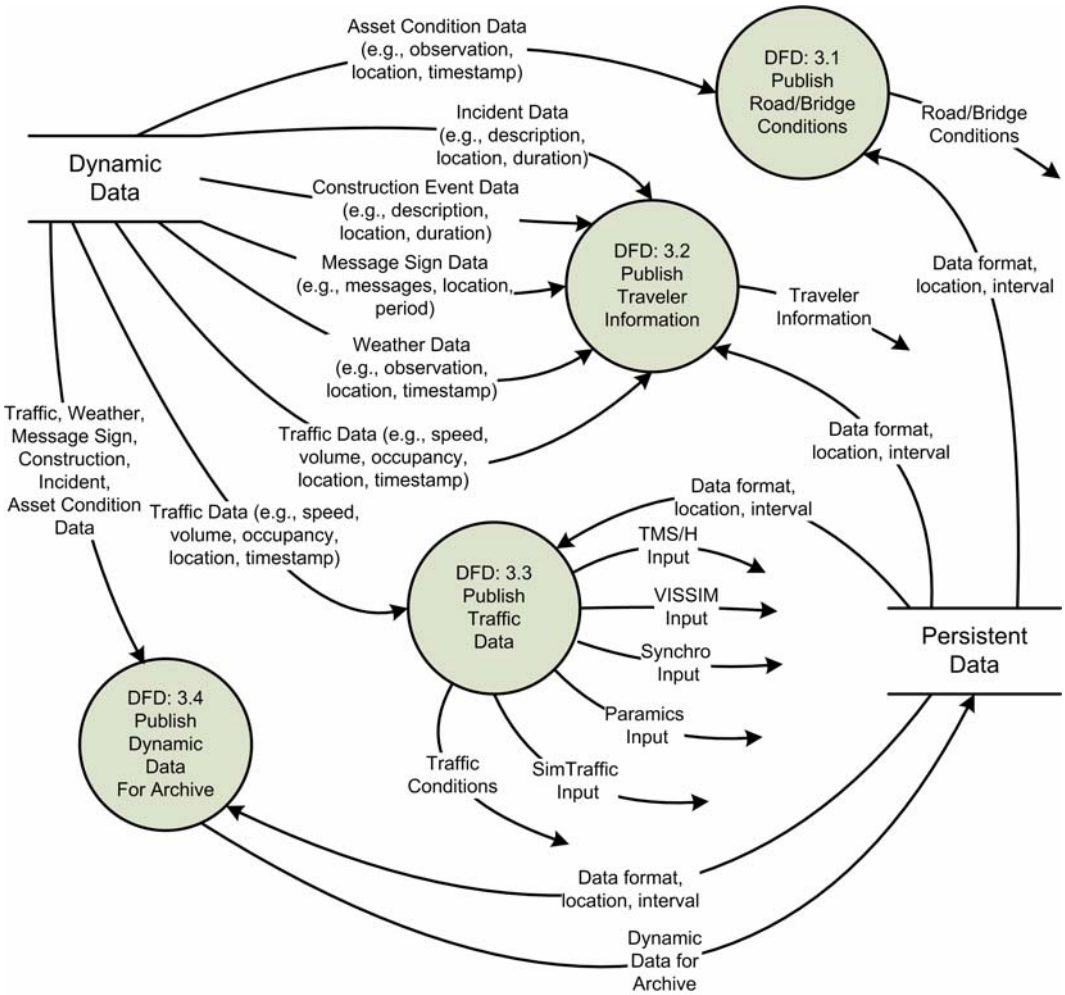


**Figure 8 – DUAP Publish Data**

### 4.1.4 Present Data

Figure 9 shows the data flow associated with DFD:4 Present Data. Each data flow within this process takes the configuration information contained in the Persistent Data and formats the data to be published for presentation to the subscriber.

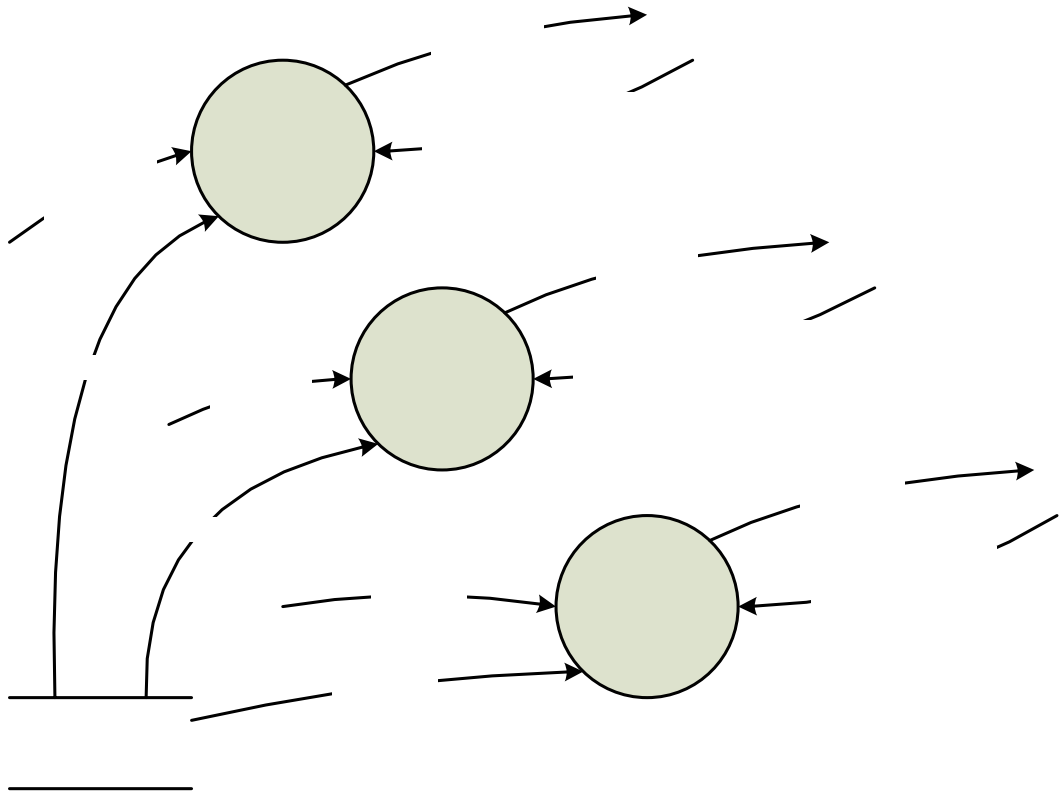

**Figure 9 – DUAP Present Data**

Published Road/Bridge Conditions

## *4.2 Data Stores*

The DUAP system uses two data stores to support its data processing. The dynamic data store, accessed through the Dynamic Data Services, is designed to provide rapid access to large collections of probe vehicle, traffic, and weather data needed for calculations. The persistent data store, accessed through the Persistent Data Services, provides access to more varied and complex schemas containing DUAP system configuration, georeferencing data, and archives of DUAP input, processing, and output data.

The dynamic data store will maintain all of the current observations of probe, traffic, weather, and event data in a simple structure that allows the data to be accessed quickly and efficiently by other DUAP services. For observations of these types, attributes would include, at a minimum

- observation type
- observation value
- location of the observation in terms of latitude, longitude, and elevation
- time at which the observation occurred
- source of the observation

Data format

The base observation types are defined in the standards appropriate to those types. For probe vehicle observations, for example, the observation types are generally

defined by the SAE J2735 specification. Traffic and weather observation types are drawn from SAE J2354 and the underlying Traffic Management Data Dictionary (TMDD). Events captured in the dynamic data store have the same basic attributes, but need a region of application rather than a specific location, and occur over an interval of time, rather than at a particular point.

The persistent data store retains both information needed by the DUAP system to maintain its own operation and information produced by DUAP. Due to the diversity of needs for persistent data, it may, in fact, be more of a data warehouse than a data store. It should not be presumed that there will be a single means of data storage that covers all of the persistent data, or that a common interface would be needed or appropriate.

DUAP system configuration data, for example, generally support system start-up and shutdown, and may not need to be accessible once the system is running. As such, configuration data need not be in the system's active memory, or even available through a persistent database connection. It may be acceptable from a performance standpoint to leave the configuration data in lower-performance media.

Georeferencing data is similar to the system configuration data in some respects. The raw georeferencing data for DUAP are drawn largely from the Michigan Geographic Framework (MGF) maintained by the Michigan Center for Geographic Information (CGI). Most of the MGF is provided in shape files and has to be mapped to global coordinates before it is useful to DUAP. Because the georeferences will be needed for many of the Computational Services, it is likely that they will need to be stored in a high-performance medium.

The DUAP system will archive input, processed data, and output. Duplication of data within the archives is a potential issue, but will be managed by specifically identifying the context of each archived data package. An observation of a vehicle's speed, for example, would be archived

- as part of the original probe data service message in which DUAP received it
- as an incremental dynamic data cache update when it is loaded to the cache
- as part of an output report of speed data along that segment.

In each case, the individual piece of data may be the same, but it is being archived in a different context.

# 5 DECOMPOSITION VIEW

The Decomposition View provides the system developers and developers of other interfacing systems with an overview of the computational objects (software modules), program interactions and behavior, and software interfaces that form the system. Test engineers will use this view to prepare the System Test Plan and the System Test Procedures for each module. System designers will use this view to design each module so that it performs the required functions.

The functional decompositions are illustrated by block diagrams of a system or component, a sub-component, an external system, and a component elsewhere within the system, as shown in Figure 10.

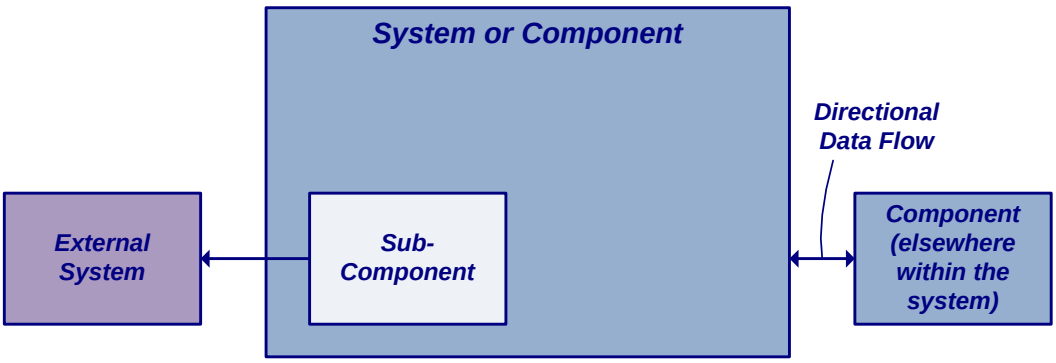


**Figure 10 – Legend for Decomposition Diagrams**

The modules identified in this view do not represent a mandatory design description. The modules are based on the functional requirements of the system. The final design may further decompose these modules into smaller components to allow for specialization of modules to specific tasks, to reuse existing software modules or code from other sources, or to optimize how the coding will be performed.

## *5.1 DUAP Functional Decomposition*

As shown in Figure 11, the DUAP system is decomposed into the following functional modules:

- Input Services
- Dynamic Data Services
- Computational Services
- Persistent Data Services
- Output Services
- Presentation Services
- Administrative Services

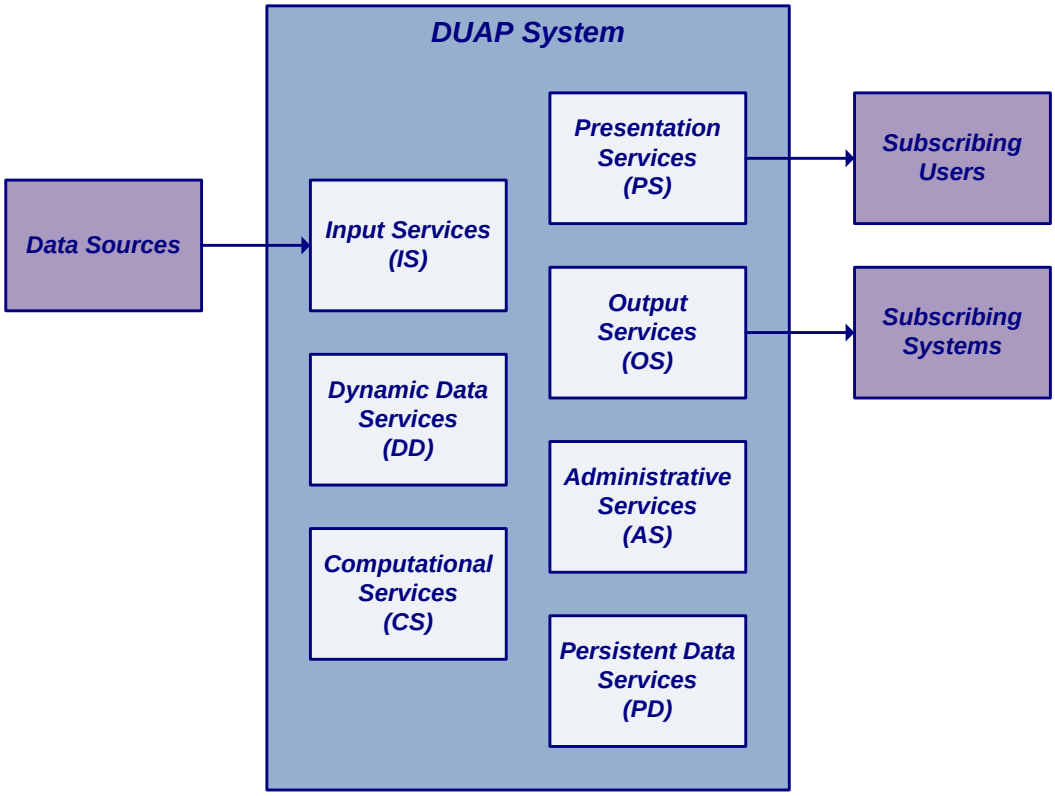


**Figure 11 – DUAP System Functional Modules Overview**

These modules and their interconnectivity will be discussed in more detail in the following subsections.

### 5.1.1 Input Services Module

The Input Services module, shown in Figure 12, will be responsible for receiving all incoming data for the system. This module provides the ability for DUAP to interact with external systems which have data needed by DUAP. The Input Services module also interacts with the Administrative Services, Dynamic Data Services and the Persistent Data Services modules.

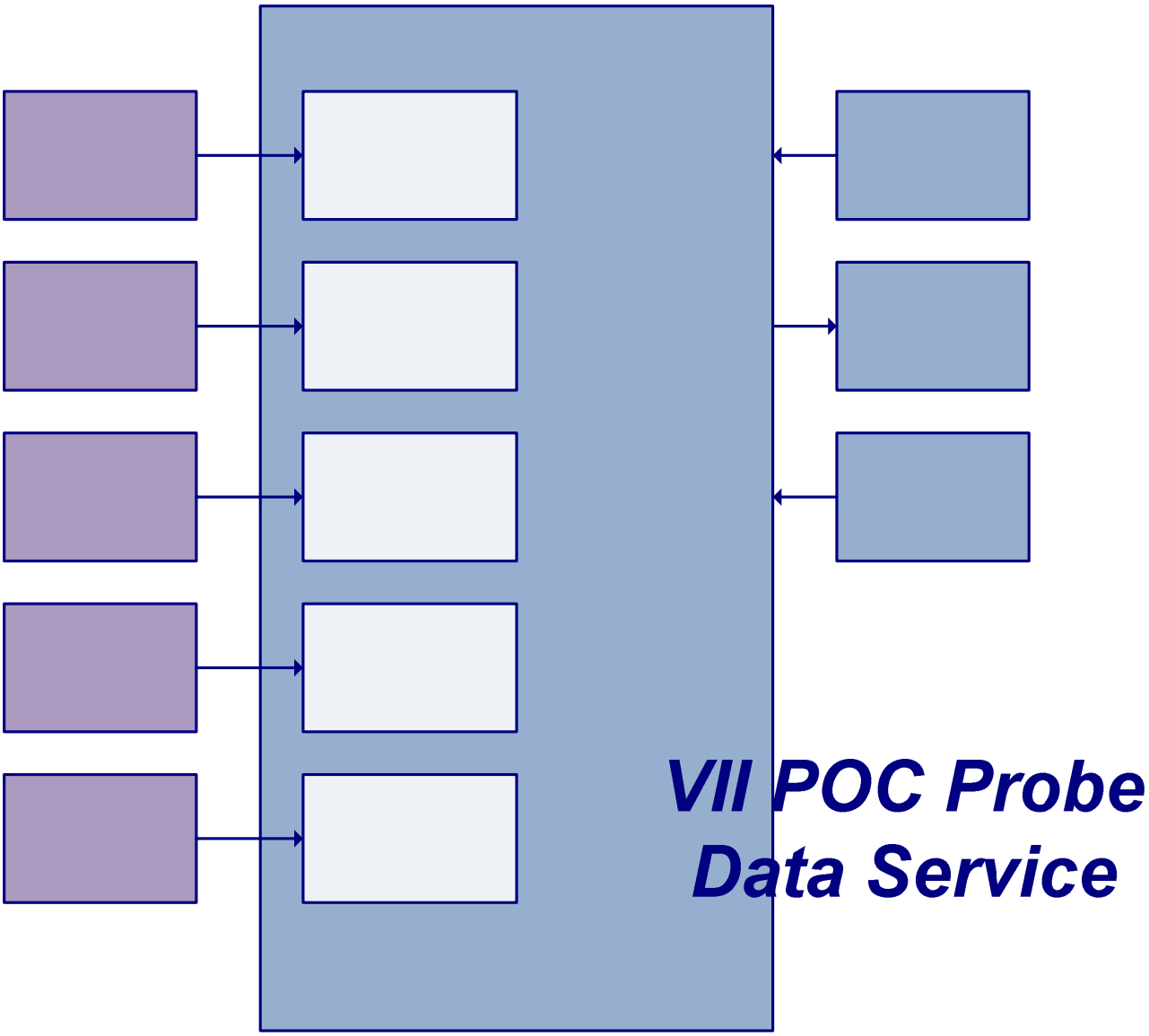


**Figure 12 – Input Services Module**

Data from each external data source will be received by an associated Input Services sub-module which will interface with the system. The external data sources and their corresponding Input Service sub-modules follow:

- VII POC Probe Data Service – VII Probe Data Input Service sub-module
- MITS Center Traffic Data – MITS Center Traffic Data Input Service(s) sub-module(s)
- Weather Data System – Weather Data Input Service sub-module
- TMS Asset Data – TMS Asset Input Service(s) sub-module(s)
- MDOT Lane Closure Database – Lane Closure Input Service sub-module

**MITS Center**

These sub-modules will parse the data and send it to the Dynamic Data Services for storage in a consistent manner. Administrative Services configure and schedule the Input Services activities with the external data sources as well as with Dynamic Data Services and Persistent Data Services. The Input Services module will use data retrieved from the Persistent Data Services module to configure the interface to the external data source.

### 5.1.2 Dynamic Data Services Module

The Dynamic Data Services module, shown in Figure 13, is responsible for maintaining the "active memory" of DUAP. This module will cache data received from the Input Services module and the Computational Services module.

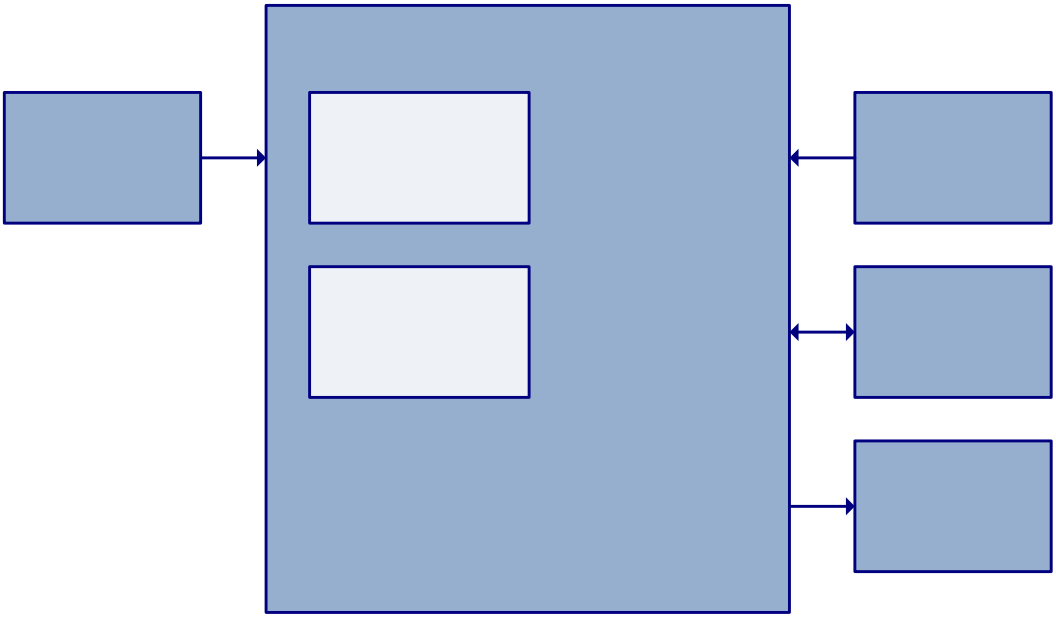

**Figure 13 – Dynamic Data Services Module**

Interfaces to the Dynamic Data Services will represent data as observations and events at particular locations and times. Data from this module will be used by the Computational Services module and the Output Services module. Administrative Services configure and schedule the Dynamic Data Services activities with Input Services, Computational Services and Output Services.

### 5.1.3 Computational Services Module

The Computational Services module, shown in Figure 14, will perform computations on data provided by the Dynamic Data Services and the Persistent Data Services to derive new observations and measures of effectiveness.

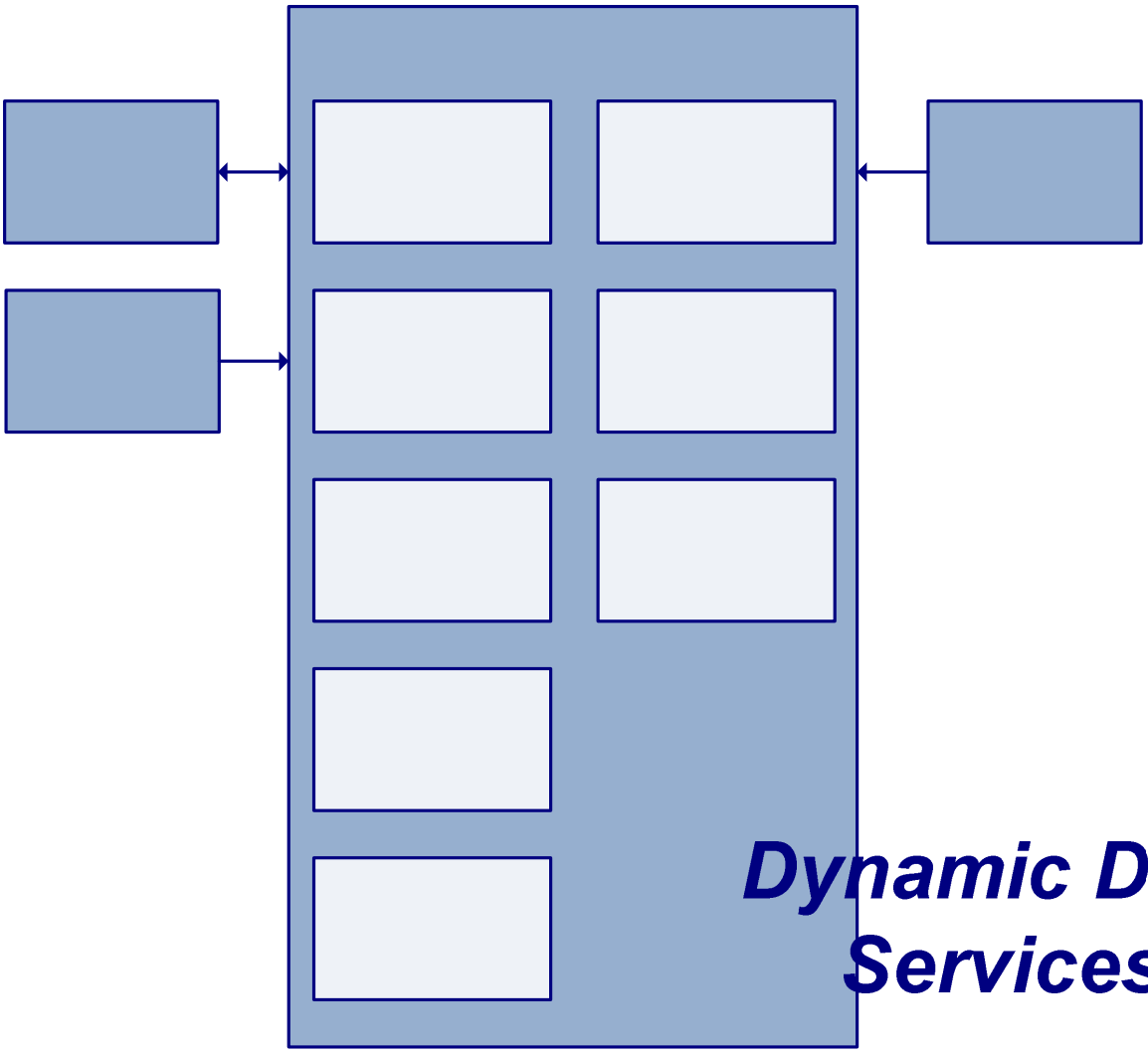

**Figure 14 – Computational Services Module**

This module applies logical algorithms to incoming data in order to transform the observations into data applicable to transportation management and operations processes. Using inputs from the Dynamic Data Services module and the Persistent Data Services module, this module will provide the following functions for the DUAP system:

- Incident Detection – Data will be analyzed to detect incidents.
- Incident Location – Data will be analyzed to determine incident location.
- Queue Length – Data will be analyzed to determine queue length.
- Travel Time – Data will be analyzed to provide travel time information.
- Segment Data Aggregation – Segment data will be aggregated.

- Weather Conditions – Data will be analyzed to provide current and predictive weather conditions.
- Road/Bridge Conditions – Data will be analyzed to determine road and bridge surface conditions.
- Pothole Location – Pothole location and severity will be determined from the data.
- Data Quality Checking – Data will be checked to maintain quality of the DUAP system.

The computed output from these functions is returned to the Dynamic Data Services for storage and subsequent access. Administrative Services configure and schedule the Computational Services activities with Dynamic Data Services and Persistent Data Services.

### 5.1.4 Persistent Data Services Module

The Persistent Data Services Module shown in Figure 15 is responsible for storing the data for the long term.

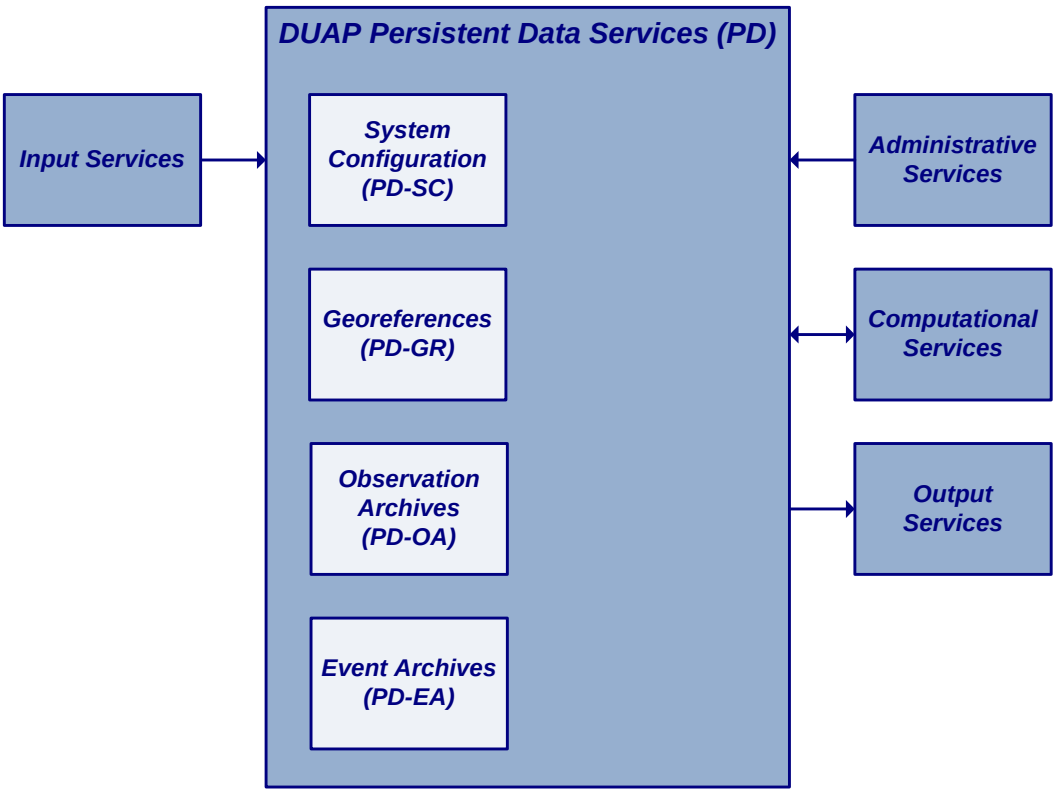


**Figure 15 – Persistent Data Services Module**

This module stores the system configuration data, the georeference data, the observation archives, and the event archives. These data are provided to the other modules as requested. The Persistent Data Services module obtains data from Input Services and Computational Services. The Output Services module receives

data from this module. Administrative Services configure and schedule the Persistent Data Services activities with Input Services, Computational Services, and Output Services.

### 5.1.5 Output Services Module

The Output Services module, as shown in Figure 16, is responsible for formatting data for use by other services both internal and external to the DUAP system.

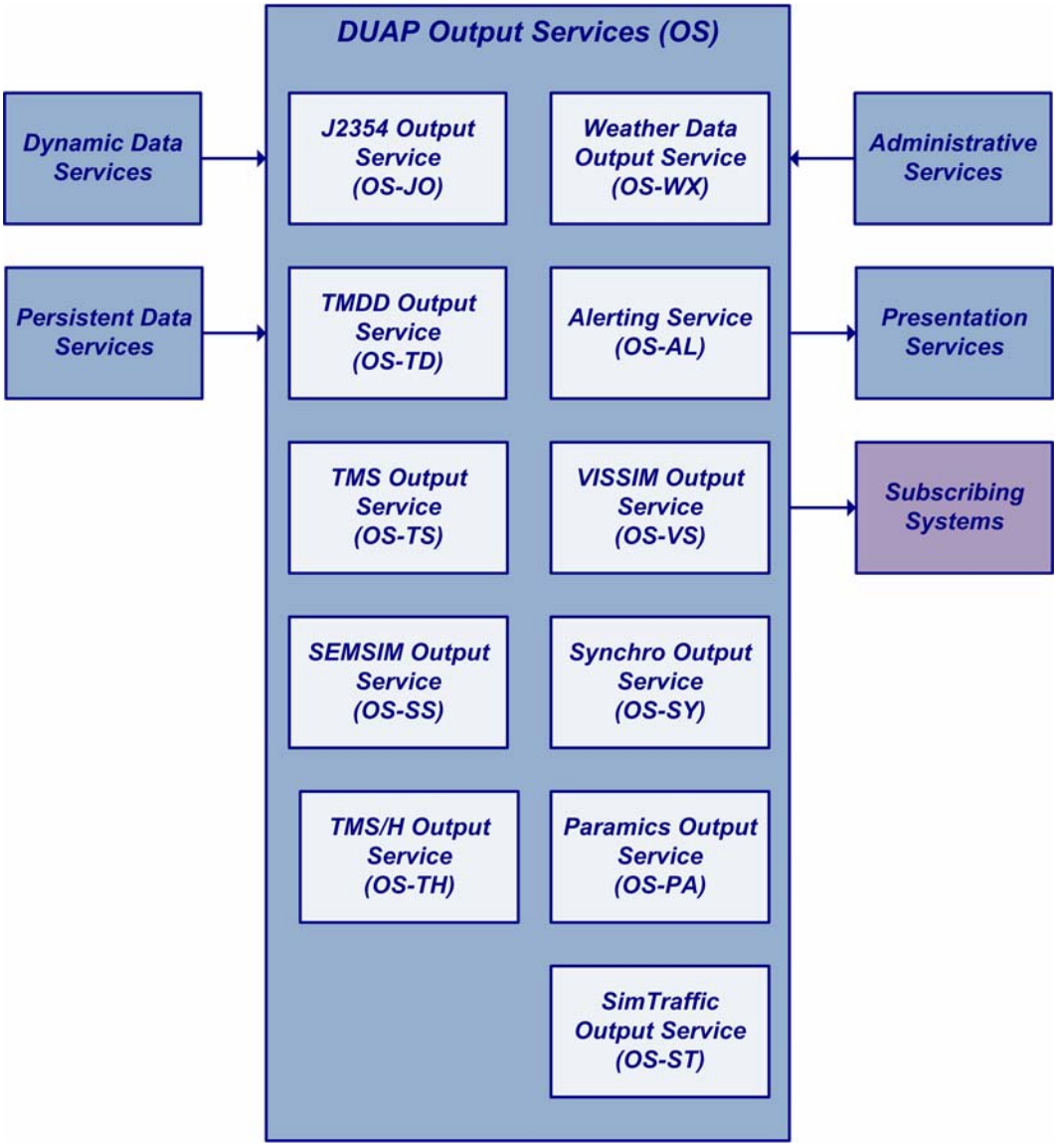


**Figure 16 – Output Services Module**

Data from the Persistent Data Services module and the Dynamic Data Services module are structured and formatted for use by the Presentation Services module and external subscribing systems. Each subscriber is associated with a sub-module that formats the data as required by that subscriber. The number and function of sub-modules depends on the requirements of the subscribing systems.

Output Services sub-modules include:

- J2354 Output Service
- Weather Data Output Service
- TMDD Output Service
- Alerting Service
- TMS Output Service
- VISSIM Output Service
- SEMSIM Output Service
- Synchro Output Service
- TMS/H Output Service
- Paramics Output Service
- SimTraffic Output Service

Administrative Services configures and schedules the Output Services activities with the Persistent Data Services and the Dynamic Data Services modules, and Presentation Services.

### 5.1.6 Presentation Services Module

The Presentation Services module, shown in Figure 17, is responsible for providing the data in a useable form for the stakeholders.

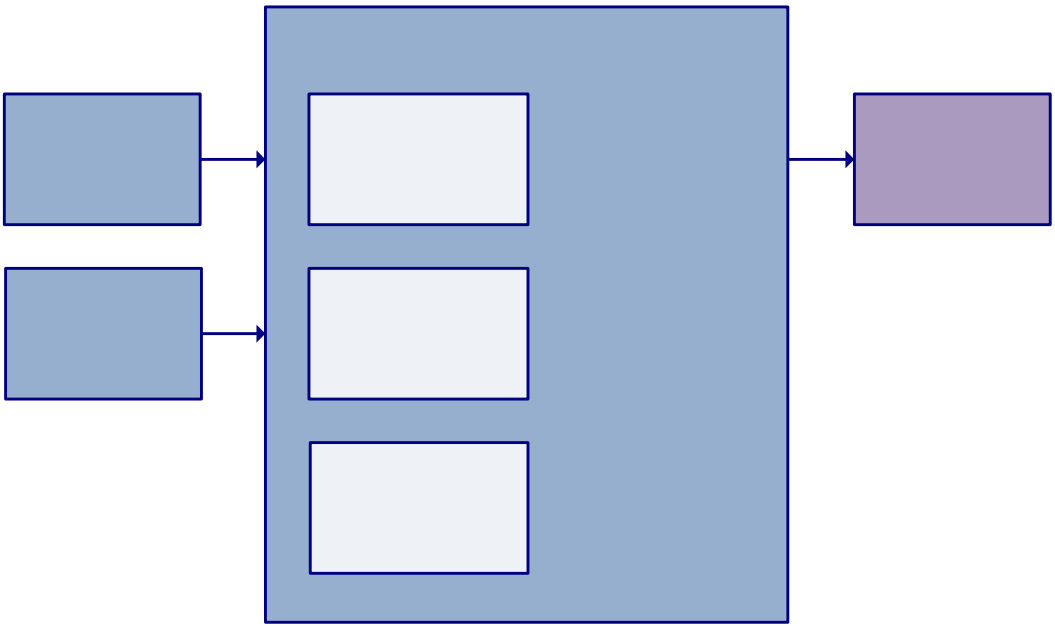

**Figure 17 – Presentation Services Module**

This module will receive data from the Output Services module. The Query Service, Tabular Data Service, and Mapping Service sub-modules will format and present the data for the subscribing users. Administrative Services configures the Presentation Services.

### 5.1.7 Administrative Services Module

The Administrative Services module provides system configuration information to each of the other modules in the DUAP system. The configuration information will provide information on input data formats, output data formats, and computational processes.

# 6 HARDWARE VIEW

The Hardware View provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of the planning for the hardware, communications, and operational support for the system.

## *6.1 Hardware Configuration*

The system's base computing hardware will consist of Sun Microsystems X4200 servers or equivalent models. Computing hardware specifications change rapidly and equivalent or better performing servers may actually be deployed. Each server will contain a minimum of two dual-core processors, equating to at least four processors per machine. Memory will be maximized according to server purpose and software needs. Sixteen (16) gigabytes (GB) of random access memory will be the installed standard for each server. Storage will consist of high-speed, 146 GB serial-attached Small Computer Systems Interface (SCSI) disk drives. Up to four disk drives per server can be installed.

Sun servers have a feature called Integrated Lights-Out Management (ILOM). Essentially there is a small computer built into the server that monitors the server health. With ILOM, it is possible to securely and remotely monitor, shut down, and restart the DUAP system when necessary.

The DUAP network hardware configuration is shown in Figure 18 – DUAP Network Diagram. A more detailed description of the hardware configuration will be provided in the System Design Description.

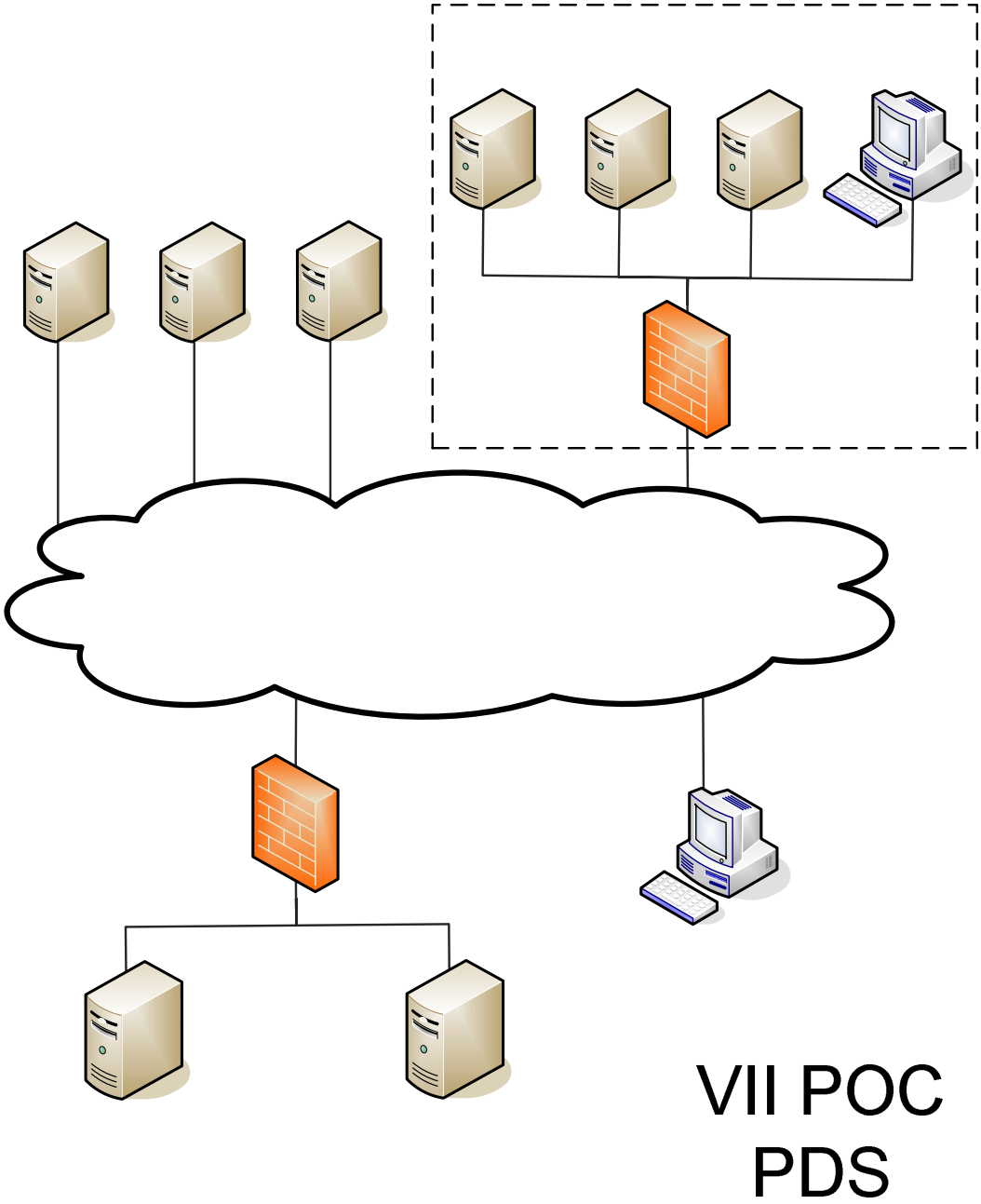


**Figure 18 – DUAP Network Diagram**

## *6.2 Power and Environmental Support*

The computer hardware will be housed in a restricted access, environmentally controlled room. The servers will be mounted in standard (42U, 19-inch) racks. Uninterruptible power supplies (UPS) will provide conditioned and continuous power for the system and will be mounted near the servers.

UPS will be able to sustain the DUAP system for 20 minutes in the event of total power failure. Power interruptions lasting more than 20 minutes will result in temporary loss of access to the DUAP demonstration system. Access to the DUAP system will be automatically restored when main power is restored.

## *6.3 Communications*

The wide area network (WAN) segment of the DUAP system is connected to the Internet and the VII network. The WAN bandwidth for the POC will be one symmetric T1 (1.536Mb/s upload/download). Additional communications needs will be determined during the system design.

Local area networks (LANs) are connected to the WAN using switches and routers. The LAN for the DUAP project will be connected using Gigabit Ethernet switches and routers. Gigabit Ethernet equipment is widely available and cost effective. Through the use of modular networking equipment, it is possible to upgrade to higher communication bandwidth by replacing computer network interface cards and switches as it becomes necessary and economical to do so.

# 7 TECHNOLOGY VIEW

The Technology View provides the system developers, communication system designers, network system designers, hardware designers, and system maintenance and support staff with an overview of what relevant technologies will be used, how industry standards and specifications will be implemented, and what technologies will be required to support testing of the system. The designers use this view to identify constraints imposed on the design by standards, specifications, and regulatory rules. Designers also use this view to identify design constraints imposed by the technologies selected for the system implementation. FHWA uses this view to verify that appropriate ITS standards are being used in compliance with FHWA regulations.

## *7.1 System Technology*

The DUAP system will be built on a Java software foundation, giving the advantage of being operating system agnostic.

Java and its related software frameworks and technologies will be used to develop the applications. Java Database Connectivity (JDBC) enables generic access to multiple vendor databases. Database information requests will be handled through standard Structured Query Language (SQL) commands.

MDOT and MDIT may have existing algorithms and software modules that can be leveraged for the DUAP project. Java modules will be directly interfaced to the DUAP system and non-Java software modules will be interfaced to the system using the Java Native Interface (JNI) where possible. Algorithms and non-interfaced software modules can be implemented using Java and will then be directly usable by the DUAP project.

The system will be configured as a set of services which adds flexibility to the system. It will be possible to re-organize service deployments across the available computing hardware. Fewer very demanding computational services can be installed on one set of servers while less demanding services can be installed on another set of servers. Processing load will be distributed more evenly across the available computing resources, minimizing information bottlenecks.

## *7.2 Standards and Specifications*

Implementation of the DUAP system will be dependent on a large body of standards. Table 1 provides a list of the applicable standards and indicates the general area where the standard may apply to the system.

**Table 1 – Standards and Specifications for the DUAP Project**

| Standard | Application Area |
|---|---|
| AASHTO-ITE TM 2.1, *Standards for Traffic Management Center-to-Center Communication*, March, 2006. | Communications |

| Standard | Application Area |
|---|---|
| APTA TCIP-S-001 3.0.0, *Standard for Transit Communications Interface Profiles (TCIP)*, American Public Transit Association, September 2006. | Communications |
| IEEE Std 1609.3-2007, *IEEE Trial-Use Standard for Wireless Access in Vehicular Environments (WAVE)-Networking Services*, Institute of Electrical and Electronics Engineers, Inc., April 20, 2007. | Communications |
| IEEE Std 802.11-2007, *IEEE Standard for Information technology-Telecommunications and information exchange between systems-Local and metropolitan area networks-Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications*, Institute of Electrical and Electronics Engineers, Inc., 2007. | Communications |
| IEEE Std P1512.2-2004, *IEEE Standard for Public Safety Traffic Incident Management Message Sets for Use by Emergency Management Centers*, Institute of Electrical and Electronics Engineers, Inc., 2004. | Communications |
| ISO 11519-1:1994, *Road vehicles -- Low-speed serial data communication -- Part 1: General and definitions*, International Organization for Standardization, 1994. | Communications |
| ISO 11519-3:1994, *Road vehicles -- Low-speed serial data communication -- Part 3: Vehicle area network (VAN)*, International Organization for Standardization, 1994. | Communications |
| ISO 11898-1:2003, *Road vehicles -- Controller area network (CAN) -- Part 1: Data link layer and physical signaling*, International Organization for Standardization, 2003. | Communications |
| ISO 11898-2:2003, *Road vehicles -- Controller area network (CAN) -- Part 2: High-speed medium access unit*, International Organization for Standardization, 2003. | Communications |
| ISO 11898-3:2003, *Road vehicles -- Controller area network (CAN) -- Part 3: Low-speed, fault-tolerant, medium-dependent interface*, International Organization for Standardization, 2003. | Communications |

| Standard | Application Area |
|---|---|
| ISO/IEC 42010:2007, *Systems and software engineering - Recommended practice for architectural description of software-intensive systems*, International Organization for Standardization, July 15, 2007. | Documentation |
| ITE/AASHTO TM 1.03, *Standards for Traffic Management Center to Center Communications*, Institute of Transportation Engineers, 2000. | Communications |
| ITE/AASHTO TM 2.01, *Message Sets for External Traffic Management Center Communications (MS/ETMC) Message Set Standard*, Institute of Transportation Engineers, 2000. | Communications |
| Michigan Department of Information Technology, Center for Geographic Information, *Michigan Geographic Framework Network*, http://www.michigan.gov/cgi/0,1607,7-158-12618-31485--,00.html, Michigan Department of Information Technology, Retrieved May 2, 2007. | Geospatial Data |
| Michigan Department of Information Technology. *Policies & Standards*. http://www.michigan.gov/dit/0,1607,7-139-34305---,00.html, Michigan Department of Information Technology, Retrieved May 11, 2007. | Technology |
| MIL-STD-810F, *Department of Defense Test Method Standard For Environmental Engineering Considerations and Laboratory Tests*, US Department of Defense, January 1, 2000. | Testing |
| NMEA-0183, *NMEA 0183 Interface Standard & 0183-HS High Speed Addendum;* National Marine Electronics Association, Inc., January 2002. | Communications |
| NTCIP 1202 v01.07d (draft), *National Transportation Communications for ITS Protocol Object Definitions for Actuated Traffic Signal Controller (ASC) Units*, National Transportation Communications for ITS Protocol, January 30, 2007. | Communications |
| NTCIP 1204 v03.03c (draft), *National Transportation Communications for ITS Protocol Environmental Sensor Station Interface Standard– Version 03*, National Transportation Communications for ITS Protocol, June 22, 2007. | Communications |

| Standard | Application Area |
|---|---|
| NTCIP 1210 v01.46c (draft), *National Transportation Communications for ITS Protocol Field Management Stations – Part 1: Object Definitions for Signal System Masters*, National Transportation Communications for ITS Protocol, August 29, 2006. | Communications |
| SAE J2266, *Location Referencing Message Specification (LMRS)*, SAE International, November 2004. | Geospatial Data |
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# 8 NATIONAL ITS ARCHITECTURE VIEW

This view provides the US Department of Transportation, participating agencies, and other interested parties with an understanding of how the proposed system fits into the National ITS Architecture. This includes the system's relationship to the standard Market Packages and to the National ITS Physical and Logical Architectures.

The Federal Highway Administration in January 2001 issued Part 940 of Chapter 23 of the Code of Federal Regulations (23 CFR 940), its final rule on conformance of ITS systems and projects to the National ITS Architecture and associated standards. This architecture viewpoint allocates the components of the DUAP system according to the structure and viewpoint of the National ITS Architecture.

System functions in the National ITS Architecture are described in three representations: market packages, a physical architecture (in terms of subsystems, terminators, and equipment packages), and a logical architecture (in terms of processes and the data flows between them). A complete description of these representations and their associated object classes can be found in the referenced National ITS Architecture documentation. The description of the National ITS Architecture herein is limited to those aspects of the architecture that are specifically related to the DUAP system.

## *8.1 Physical Architecture*

The *Physical Architecture* is comprised of transportation, communication, and institutional layers. The transportation layer includes the various transportation-related processing centers, distributed roadside equipment, vehicle equipment, and other equipment used by travelers to access ITS services. The communication layer provides for the transfer of information between the transportation layer elements. The institutional layer introduces the policies, funding incentives, working arrangements, and jurisdictional structure that support the technical layers of the Architecture.

Within the physical architecture, *subsystems* are used to describe collections of specific processing functions related to real-world transportation systems. *Terminators* are real-world users of, and objects associated with, the transportation systems; in the physical architecture, terminators interact with the subsystems, but are "outside the scope of" the transportation system itself. Terminators can be sources of information or consumers of information.

The Transportation and Communication Layers together are the *Architecture Framework* that coordinates overall system operation by defining what each major transportation system element does and how they interact to provide user services. Figure 19 shows a high-level view of the Architecture Framework. The shaded areas of the figure indicate the elements corresponding to the DUAP system.

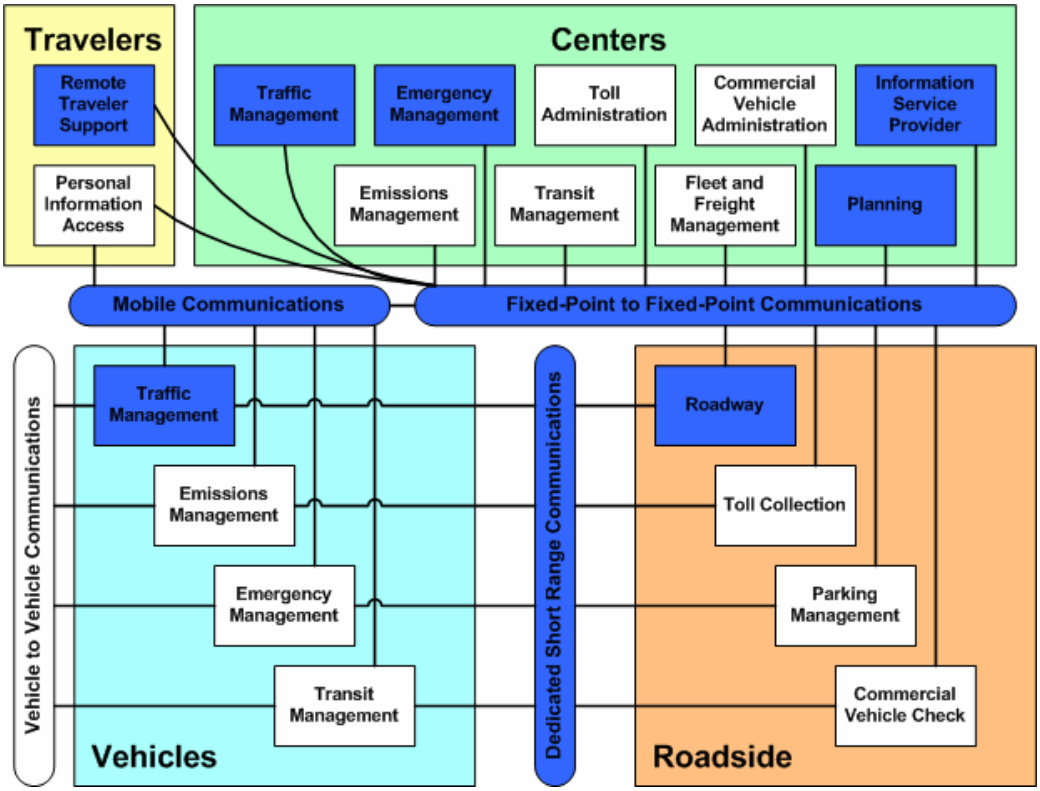


**Figure 19 – Architecture Framework**

## *8.2 Market Packages*

*Market packages* represent functional groupings within the Physical Architecture that correspond to specific services. Market packages are collections of functions (the "package") that can be used together to meet a related group of operational needs (the "market"). A market package does not necessarily correspond to a specific product or system. Version 6.0 of the National ITS Architecture describes eighty-five (85) market packages to represent the breadth of capabilities in the overall architecture. Table 2 illustrates the distribution of DUAP System components in the context of these market packages.

**Table 2 – Market Packages Relating to the DUAP System**

| Market Package | Market Package Name |
|---|---|
| ATMS02 | Traffic Probe Surveillance |
| MC11 | Environmental Probe Surveillance |
| MC12 | Infrastructure Monitoring |

Other market packages may benefit from DUAP System components and these will be identified as the project develops.

### 8.2.1 Traffic Probe Surveillance

The National ITS Architecture provides the following description of the Traffic Probe Surveillance market package:

> "This market package provides an alternative approach for surveillance of the roadway network. Two general implementation paths are supported by this market package: 1) wide-area wireless communications between the vehicle and center is used to communicate vehicle operational information and status directly to the center, and 2) dedicated short range communications between passing vehicles and the roadside is used to provide equivalent information to the center. The first approach leverages wide area communications equipment that may already be in the vehicle to support personal safety and advanced traveler information services. The second approach utilizes vehicle equipment that supports toll collection, in-vehicle signing, and other short range communications applications identified within the architecture."

The DUAP system supports the data collection described in this package. The implementation varies from the description by the following:

- DUAP will gather data using the second approach.
- DUAP has not been described in the context of toll collection and in-vehicle signing.

### 8.2.2 Environmental Probe Surveillance

The National ITS Architecture provides the following description of the Environmental Probe Surveillance market package:

> "This market package collects data from vehicles in the road network that can be used to directly measure or infer current environmental conditions. It leverages vehicle on-board systems that measure temperature, sense current weather conditions (rain and sun sensors) and also can monitor aspects of the vehicle operational status (e.g., use of headlights, wipers, and traction control system) to gather information about local environmental conditions."

The DUAP system supports the data collection described in this package. The implementation varies from the description by the following:

- The DUAP system will gather data from vehicles based on the implementation of vehicle on-board systems by automobile manufacturers.

### 8.2.3 Infrastructure Monitoring

The National ITS Architecture provides the following description of the Infrastructure Monitoring market package:

> "This market package monitors the condition of pavement, bridges, tunnels, associated hardware, and other transportation-related infrastructure (e.g., culverts) using both fixed and vehicle-based infrastructure monitoring sensors. Fixed sensors monitor vibration, stress, temperature, continuity, and other parameters and mobile sensors and data

logging devices collect information on current infrastructure condition. This market package also monitors vehicle probes for vertical acceleration data and other probe data that may be used to determine current pavement condition."

The DUAP system supports the data collection described in this package. The implementation varies from the description by the following:

- The DUAP system will gather data only from vehicle probes based on the implementation of vehicle on-board systems by automobile manufacturers.

## *8.3 Logical Architecture*

The Logical Architecture provides a functional requirements process model for ITS systems. Data Flow Diagrams and DFD descriptions are used to identify the processes and information associated with the functional requirements process model.

Within the ITS Logical Architecture volume of the National ITS architecture, DFD:1 *Manage Traffic* is the level one diagram for the Traffic Management functions. This DFD shows the processes that provide the Manage Traffic function. This function provides the facilities to manage traffic flowing in the area it serves. This functionality includes:

- DFD:1.1 *Provide Traffic Surveillance.* DFD 1.1 shows the processes that make up the Provide Traffic Surveillance facility within the Manage Traffic function. These processes collect and store traffic data collected by sensors for use in traffic management, and by the media and other ITS functions. This in turn includes the functionality of:
  - DFD:1.1.2 *Process and Store Traffic Data.* This DFD shows the processes that make up the Process Traffic Data for Storage facility within the Manage Traffic function. These processes analyze collected data; distribute it to other facilities in the function; and store the data, together with that provided by other facilities. The processes include:
    - DFD:1.1.2.6 *Process Collected Vehicle Environmental Probe Data*.
  - DFD:1.1.6 *Collect Vehicle Traffic Probe Data.*
  - DFD:1.1.7 *Collect Vehicle Environmental Probe Data.*

DFD:3 *Provide Vehicle Monitoring and Control* is the level one diagram for the vehicle monitoring. This functionality includes:

- DFD:3.1 *Monitor Vehicle Status.* The processes in this facility monitor vehicle operation, driver performance and data provided from the roadway on which the vehicle is operating.

DFD:6 *Provide Driver and Traveler Services* is the level one diagram for the Driver Interface services in the vehicle. This functionality includes:

- DFD:6.2 *Collect ISP Services Data.* This DFD collects data from other ITS functions as well as non-ITS sources to support various driver and traveler information and services applications. This includes:
  - DFD:6.2.5 *Collect Probe Data From Vehicles*

# APPENDIX A - DEFINITIONS, ACRONYMS, AND ABBREVIATIONS

The following table provides the definitions of all terms, acronyms, and abbreviations required to properly interpret this document.

| Term | Definition |
|---|---|
| AASHTO | American Association of State Highway and Transportation Officials |
| Architect | The person, team, or organization responsible for systems architecture. |
| Architecting | The activities of defining, documenting, maintaining, improving, and certifying proper implementation of an architecture. |
| Architectural description (AD) | A collection of products to document an architecture. |
| Architecture | The fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution. |
| ATIS | Advanced Traveler Information System |
| ATMS | Advanced Traffic Management System |
| CAR | Center for Automotive Research |
| CCTV | Closed-Circuit Television |
| CFR | Code of Federal Regulations |
| CGI | Center for Geographic Information |
| CMS | Changeable Message Sign |
| ConOps | Concept of Operations |
| CVPC | Connected Vehicular Proving Center |
| CVTA | Connected Vehicle Trade Association |
| DFD | Data Flow Diagram |
| DMS | Dynamic Message Sign |
| DOT | Department of Transportation |
| DSRC | Dedicated Short Range Communications |
| DUAP | Data Use Analysis and Processing |
| ESS | Environmental Sensor Station |

| | |
|---|---|
| FHWA | Federal Highway Administration |
| GB | Gigabyte(s) |
| IEEE | Institute of Electrical and Electronic Engineers |
| ILOM | Integrated Lights-Out Management |
| ISP | Information Service Provider |
| IT | Information Technology |
| ITS | Intelligent Transportation Systems |
| JDBC | Java Database Connectivity |
| JNI | Java Native Interface |
| LAN | Local Area Network |
| MDIT | Michigan Department of Information Technology |
| MDOT | Michigan Department of Transportation |
| MEDC | Michigan Economic Development Corporation |
| MITS | Michigan Intelligent Transportation Systems |
| MGF | Michigan Geographic Framework |
| OBE | On-board Equipment |
| OEM | Original Equipment Manufacturer |
| PDS | Probe Data Service |
| POC | Proof of Concept |
| SAD | System Architecture Description |
| SAE | An organization formerly known as Society of Automotive Engineers, now known as SAE International |
| SCSI | Small Computer System Interface |
| SEMSIM | Southeast Michigan Snow and Ice Management |
| SQL | Structured Query Language |
| SRS | Software Requirements Specification |
| System | A collection of components organized to accomplish a specific function of set of functions. |
| TOC | Traffic Operations Center |
| TMDD | Traffic Management Data Dictionary |
| TMS | Traffic Management System |
| TMS/H | Traffic Monitoring System for Highways |

| | |
|---|---|
| UPS | Uninterruptible Power Supply |
| USDOT | United States Department of Transportation |
| View | A representation of a whole system from the perspective of a related set of concerns. |
| Viewpoint | A specification of the conventions for constructing and using a view. A pattern or template from which to develop individual views by establishing the purposes and audience for a view and the techniques for its creation and analysis. |
| VII | Vehicle Infrastructure Integration |
| VIIC | Vehicle Infrastructure Integration Consortium |
| WAN | Wide Area Network |
| XML | eXtensible Markup Language |

# APPENDIX B - SUPPORTING REFERENCES

The following documents contain additional information pertaining to this project or have been referenced within this document:

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