Key Concepts of the National ITS Architecture

Because of the extensive geographic and functional scope of the National ITS Architecture and the requirements which drove its development, it is structured somewhat differently and uses different terminology than is typically used today in the transportation community. It was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments across the country. Accordingly, general names were given to the physical transportation system components and locations in order to accommodate a variety of local design choices and changes in technology or institutional arrangements over time. This allows the general structure of the National ITS Architecture to remain stable while still allowing flexibility and tailoring at the local implementation level. This difference in language can be easily overcome with a better understanding of how the National ITS Architecture is organized and how it relates to familiar systems of today.

> The National ITS Architecture is available as a resource for any region and will continue to be maintained by the U.S. DOT independently of any specific system design or region in the nation. It represents the work and collective thinking of a broad cross-section of the ITS community (systems engineers, transportation practitioners, technology specialists, system developers, consultants, etc.) over many years. As such, the National ITS Architecture contains material that will assist agencies in the development of regional ITS architectures, which will help region's understand how an individual project, such as a traffic signal control project, fits into a larger regional transportation management context.

As background, this paper explains the essential terminology and concepts needed to understand, navigate, and use the National ITS Architecture. The following concepts and terms are explained in this section:

- User Services and User Service Requirements
- Logical Architecture
- Physical Architecture
- Equipment Packages
- Service Packages

This discussion was originally adapted from a larger document, "Developing Traffic Signal Control Systems Using the National ITS Architecture," published by the U. S. DOT. See Report No. FHWA-JPO-98-026.

User Services and User Service Requirements

User services represent what the system will do from the perspective of the user. A user might be the public or a system operator.

Table 1 presents the 33 user services which formed the basis for the National ITS Architecture development effort, grouped into eight bundles for convenience. These user services were jointly defined by a collaborative process involving USDOT and ITS America with significant stakeholder input. Clearly, a different set could have been defined. The important point is that the concept of user services allows the process of system or project definition to begin by thinking about <u>what</u> high level services will be provided to address identified problems and needs. New or updated user services have been added to the National ITS Architecture since it was first developed, and changes to these user services may occur in the future based on changes in transportation needs.

Table 1. User Services for the National ITS Architecture

User Service Bundle	User Service
Travel and Traffic Management	Pre-Trip Travel Information En-Route Driver Information Route Guidance Ride Matching and Reservation Traveler Services Information Traffic Control Incident Management Travel Demand Management Emissions Testing and Mitigation Highway-Rail Intersection
Public Transportation Management	Public Transportation Management En-Route Transit Information Personalized Public Transit Public Travel Security
Electronic Payment	Electronic Payment Services
Commercial Vehicle Operations	Commercial Vehicle Electronic Clearance Automated Roadside Safety Inspection On-Board Safety and Security Monitoring Commercial Vehicle Administrative Processes Hazardous Material Security and Incident Response Freight Mobility
Emergency Management	Emergency Notification and Personal Security Emergency Vehicle Management Disaster Response and Evacuation
Advanced Vehicle Safety Systems	Longitudinal Collision Avoidance Lateral Collision Avoidance Intersection Collision Avoidance Vision Enhancement for Crash Avoidance Safety Readiness Pre-Crash Restraint Deployment Automated Vehicle Operation
Information Management	Archived Data Function
Maintenance and Construction Management	Maintenance and Construction Operations

A number of functions are required to accomplish each user service. To reflect this, each of the user services was broken down into successively more detailed functional statements, called *user service requirements*, which form the fundamental requirements for the National ITS Architecture development effort. For example, the traffic control user service is actually defined by over 40 "functions". The scope of the National ITS Architecture is defined by the functional requirements defined for the 33 user services. In the early versions of the National ITS Architecture these user service requirements were used as a departure point for the development of project functional requirements and system specifications, but they have been replaced for this use by the functional requirements that have been defined for each equipment package, which are defined later in this discussion.

Table 2 provides an illustration of user service requirements using an excerpt from the traffic control user service.

Table 2. User Service Requirements Example

1.6.0 ITS shall include a Traffic Control (TC) function. Traffic Control provides the capability to efficiently manage the movement of traffic on streets and highways. Four functions are provided which are (1) Traffic Flow Optimization, (2) Traffic Surveillance, (3) Control, and (4) Provide Information. This will also include control of network signal systems with eventual integration of freeway control. **1.6.1** TC shall include a Traffic Flow Optimization function to provide the capability to optimize traffic flow. **1.6.1.1** Traffic Flow Optimization shall employ control strategies that seek to maximize traffic-movement efficiency. **1.6.1.2** Traffic Flow Optimization shall include a wide area optimization capability, to include several jurisdictions. **1.6.1.2.1** Wide area optimization shall integrate the control of network signal systems with the control of freeways. **1.6.1.2.2** Wide area optimization shall include features that provide preferential treatment for transit vehicles. **1.6.2** TC shall include a Traffic Surveillance function.

Logical Architecture

A logical architecture is best described as a tool that assists in organizing complex entities and relationships. It focuses on the functional processes and information flows of a system. Developing a logical architecture helps identify the system functions and information flows, and guides development of functional requirements for new systems and improvements. A logical architecture should be independent of institutions and technology, i.e., it should not define where or by whom functions are performed in the system, nor should it identify how functions are to be implemented.

The logical architecture of the National ITS Architecture defines a set of functions (or processes) and information flows (or data flows) that respond to the user service requirements discussed above. Processes and data flows are grouped to form particular transportation management functions (e.g., manage traffic) and are represented graphically by data flow diagrams (DFDs), or bubble charts, which decompose into several levels of detail. In these diagrams, processes are represented as bubbles and data flows as arrows. Figures 1 and 2 depict simplified data flow diagrams from the National ITS Architecture documents. Note that each bubble in the logical architecture is a process that describes some logical function to be performed.

For example, as shown in Figure 1, at the highest level of the National ITS Architecture, the manage traffic process (which includes traffic signal control functions) interacts with eight other processes.

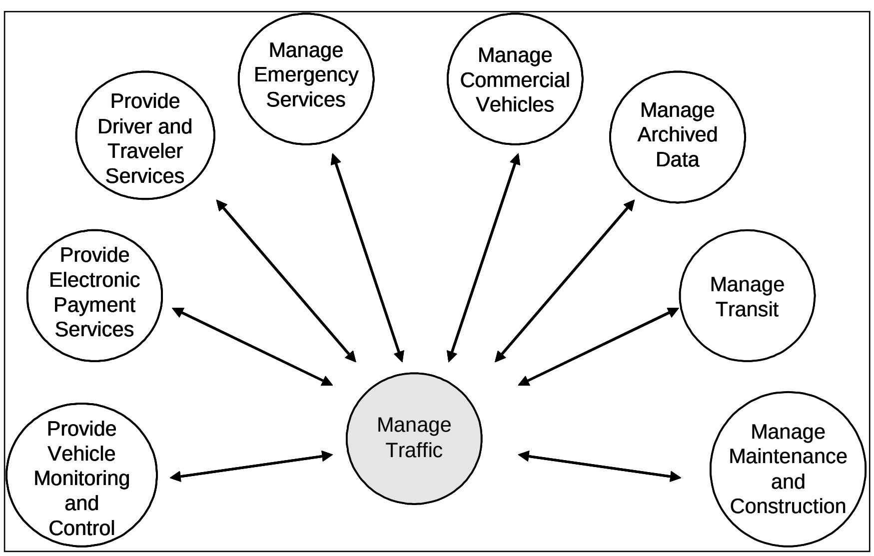

Figure 1. The Nine Major Processes within the Logical Architecture

Figure 2 illustrates how the manage traffic process is then further broken down into six sub-processes; how one of those processes, Provide Traffic Surveillance, is broken down into seven sub-processes; and so on. Each of these processes are then broken down even further so that a complete functional view of a system emerges. At the lowest level of detail in the functional hierarchy are the *process specifications* (referred to as *PSpecs* in the documentation). These process specifications can be thought of as the elemental functions to be performed in order to satisfy the user service requirements (i.e., they are not broken out any further). The information exchanges between processes and between PSpecs are called the (logical) *data flows*. Example overview descriptions of process specifications relevant to traffic signal control systems are given in Table 3.

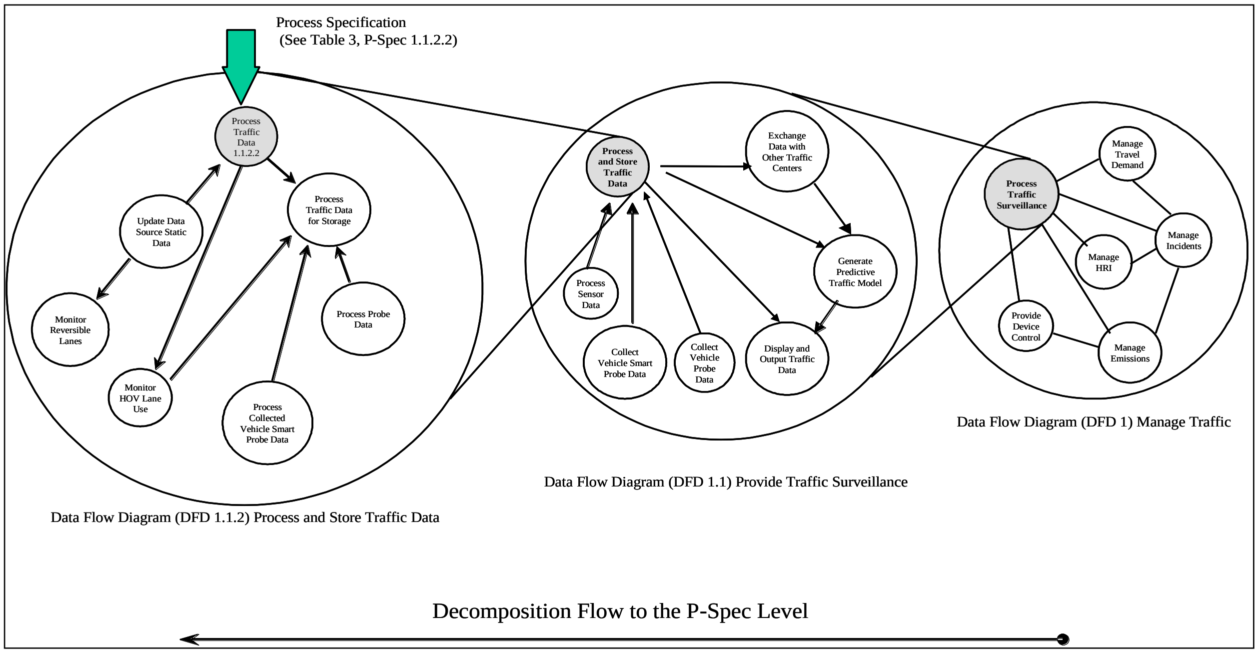

Figure 2. Example of Logical Architecture Functional Decomposition

Table 3. Process Specifications Example

Process Traffic Data (PSpec 1.1.2.2) Overview: This process shall receive and process data from sensors at the roadway. This data includes sensor and video data coming from traffic sensors as well as inputs for pedestrians, multimodal crossings, parking facilities, highway rail intersections, high-occupancy vehicle (HOV) / high-occupancy toll (HOT) and reversible lanes. The process distributes data to Provide Device Control processes that are responsible for freeway, highway rail intersections, parking lot, and surface street management. It also sends the data to another Provide Traffic Surveillance process for loading into the stores of current and long term data. Information about the various sensors to aid in this processing and distribution of data is accessed from the data store static_data_for_sensor_processing. **Select Strategy (PSpec 1.2.1)** Overview: This process shall select the appropriate traffic control strategy to be implemented over a road and/or freeway section served by the specific instance of the Manage Traffic function. The strategy shall be selected by the process from a number that are available, e.g., adaptive control, fixed time control, local operations. The selected strategy shall be passed by the process to the actual control processes for implementation according to the part of the network to which it is to be applied, i.e., surface roads, freeways (i.e., limited access roads), ramps and/or parking lots. The definition of strategy can be extended to include a strategy for the operations of sensors such as video cameras used to provide traffic surveillance data. The process shall make it possible for the current strategy selection to be modified to accommodate the effects of such things as incidents, emergency vehicle preemption, the passage of commercial vehicles with unusual loads, equipment faults and overrides from the traffic operations personnel. The strategy for control of freeways and parking lots is through use of DMS signs and lane indicators. The strategy for control of ramps is through the timing plans for ramp meters. The selected strategy shall be sent to the process within the Provide Traffic Surveillance facility responsible for maintaining the store of long term data. **Determine Indicator State for Road Management (PSpec 1.2.2.2)** Overview: This process shall implement selected traffic control strategies and transit priority on some or all of the indicators covering the road (surface street) network served by the Manage Traffic function. It shall implement the strategies only using the indicators (intersection and pedestrian controllers, reversible lane signals, etc.) that are specified in the implementation request and shall coordinate its actions with those of the processes that control the freeway network and the ramps that give access to the freeway network. **Output Control Data for Roads (PSpec 1.2.4.1)** Overview: This process shall transfer data to processes responsible for controlling equipment located at the roadside within the road (surface street) network served by the Manage Traffic function to support traffic control. This process shall also control the reversible lane facilities equipment required to change the direction of traffic flow along surface streets. Data for use by in-vehicle signage equipment shall be sent to another process for output to roadside processes. All data shall be sent to this process by processes within the Manage Traffic function. This process shall also be responsible for the monitoring of input data showing the way in which the indicators are responding to the data that they are being sent, and the reporting of any errors in their responses as faults. The reported data shall include the operational status (state of the device and configuration) from the indicator device. All output and input data shall be sent by the process to another process in the Manage Traffic function to be loaded into the store of long term data.

Physical Architecture

A physical architecture is the physical (versus functional) view of a system. A physical architecture provides agencies with a physical representation (though not a detailed design) of how the system should provide the required functionality. A physical architecture takes the processes (or PSpecs) identified in the logical architecture and assigns them to physical entities (called *subsystems* in the National ITS Architecture). In addition, the data flows (from the logical architecture) that originate from one subsystem and end at another are grouped together into (physical) *architecture flows*. In other words, one architecture flow may contain one or more detailed data flows. These architecture flows and their communication requirements define the *interfaces* required between subsystems, which form the basis for much of the ongoing standards work in the ITS program. Development of a physical architecture will identify the desired communications and interactions between different transportation management organizations.

Figure 3 depicts the relationship between the logical and physical architecture. The dashed lines in the figure highlight the relationship between functions or processes in the logical architecture to subsystems in the physical architecture and between data flows in the logical architecture to architecture flows in the physical architecture.

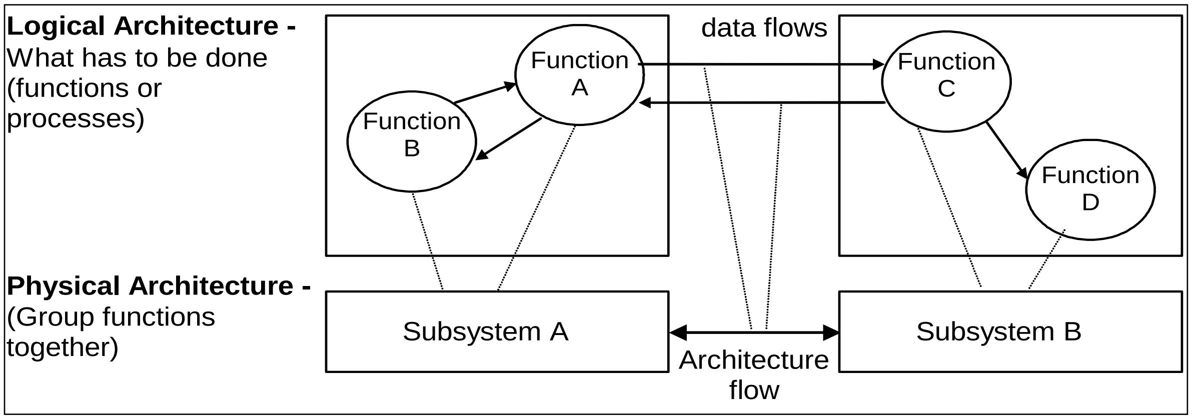

Figure 3. Representative Logical and Physical Architecture

Figure 4 from the National ITS Architecture, shows the 22 transportation subsystems (white rectangles) and the 4 general communication links (ovals) used to exchange information between subsystems. This figure represents the highest level view of the transportation and communications layers of the physical architecture. The subsystems roughly correspond to physical elements of transportation management systems and are grouped into 4 classes (larger rectangles): Centers, Field, Vehicles and Travelers.

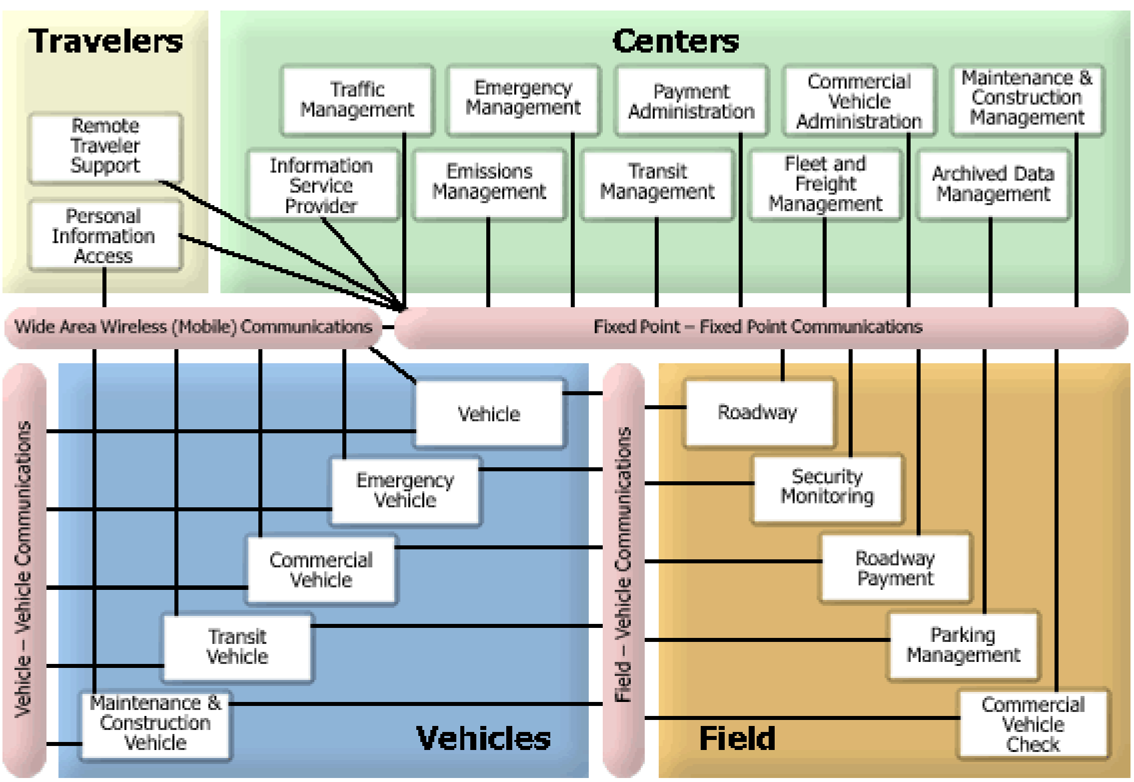

Figure 4. National ITS Architecture Subsystems and Communications

In addition to the 22 subsystems, the physical architecture defines interfaces to entities called Terminators, which represent systems that are on the boundary of the architecture. The architecture does not define functionality for the Terminators, just interfaces to them. An example of a terminator from the is the Weather Service. In addition to “systems”, terminators are used to represent the humans that operate the subsystems (e.g. Traffic Operations Personnel). The current version of the National ITS Architecture has 76 terminators defined.

As an example of how the physical architecture represents ITS implementations, consider basic traffic signal control systems, which are represented in the architecture by functions within 2 of the 22 subsystems: the Traffic Management subsystem and the Roadway subsystem. This is illustrated in figure 5, which depicts traffic signal control related elements as an overlay to the diagram just presented.

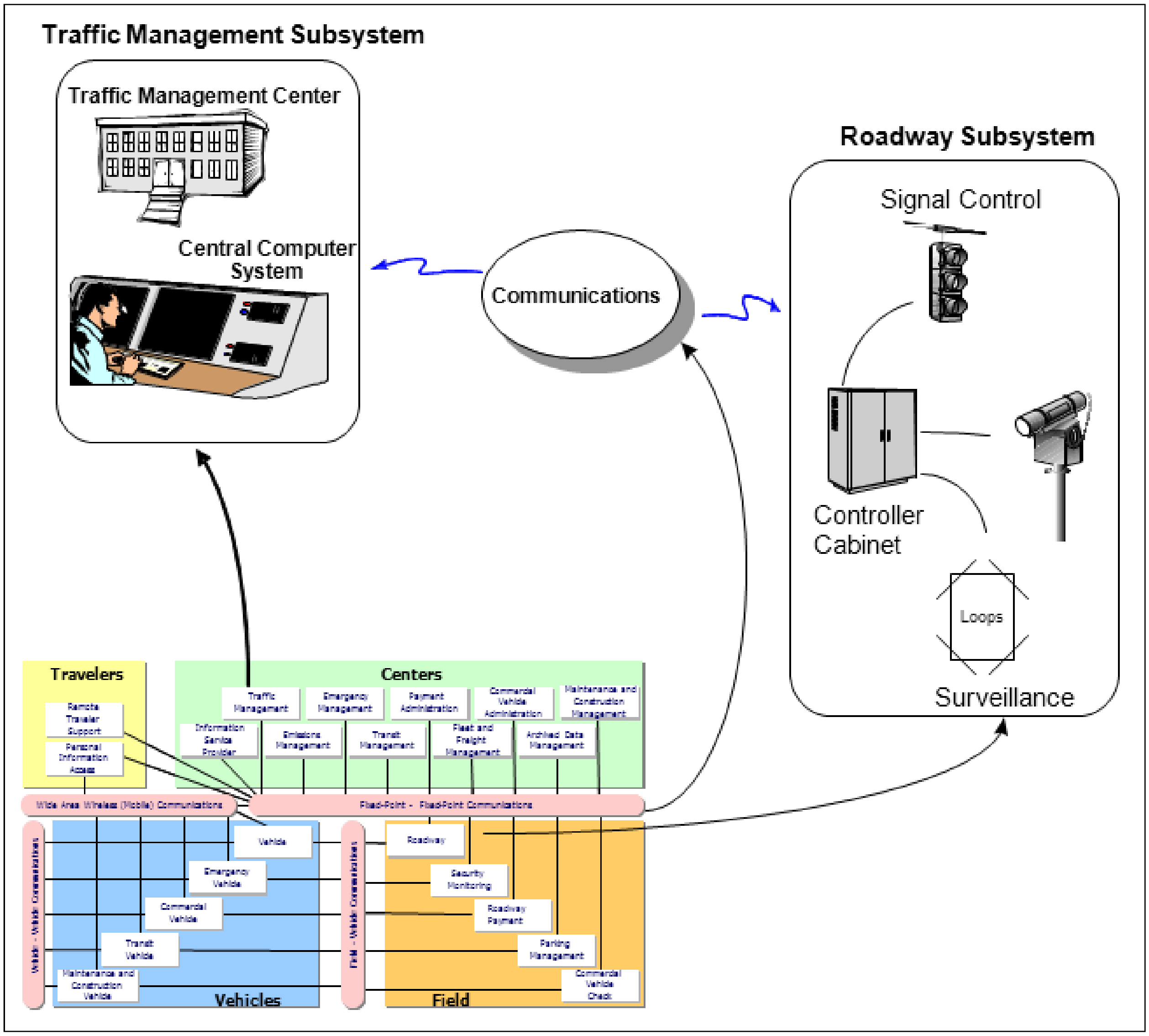

Figure 5. Basic Traffic Signal Control System Architecture Depiction

These two subsystems, together with the necessary communications (shown by the blue, curved lines) to exchange control and surveillance information, provide the following capabilities typically associated with traffic signal control systems:

- Area-wide signal coordination
- Arterial network traffic conditions
- A range of adaptive control strategies

The Traffic Management subsystem functions are implemented with central equipment typically found in traffic management centers; e.g., computers, traffic control consoles, and video switching and display systems.

The Roadway subsystem functions are implemented with equipment typically found in the field; e.g. traffic signal controllers and traffic lights, vehicle detectors (e.g., inductive loop, radar, video), and video cameras.

Fixed-Point to Fixed-Point Communications includes the equipment necessary for the various subsystems of the architecture, including the Traffic Management and Roadway subsystems, to exchange data to perform their transportation functions. These communications services may be provided by agency-owned communications plants (e.g. twisted pair, coaxial, fiber, or spread-spectrum radio), or may be leased from a communications service provider.

The Traffic Management and Roadway subsystems also provide other functions not typically associated with traffic signal control systems. These include the following transportation system functions:

Freeway Management Systems

- Monitor Freeway Conditions
- Identify Flow Impediments
- Ramp Metering/Lane Controls
- Highway Advisory Radios/Dynamic Message Signs

Incident Management Systems

- Incident Detection/Verification
- Incident Response/Clearance

Railroad Grade Crossing Systems

- Improve and automate Highway-Railroad Intersection warnings and Traffic Signal Control
- Provide advanced warning of closures
- Coordinate traffic signal control with rail movements

An important concept to understand from the physical architecture is that of support for combining subsystems together (or functionality from multiple subsystems) in an actual implementation. This is particularly important for the “center” subsystems, which should not be immediately thought of as separate buildings. In simplest terms, the center subsystems are not “brick and mortar”. Each subsystem is a cohesive set of functional definitions with required interfaces to other subsystems; subsystems are functionally defined, not physically defined. A regional implementation may include a single physical center that collocates and integrates the capabilities from several of the center subsystems. For instance, a single Transportation Management Center may include the capabilities of a Traffic Management Subsystem, Transit Management Subsystem, Emergency Management Subsystem, and Information Service Provider Subsystem. Conversely, a single subsystem may be replicated in many different physical centers in a complex metropolitan area system. For instance, the traffic management subsystem may be implemented in a traffic management center for freeway control in addition to several distinct city traffic management centers that cooperatively control the arterials and surface streets. Figure 6 provides an indication of the range of ways that center subsystems may be implemented in physical centers.

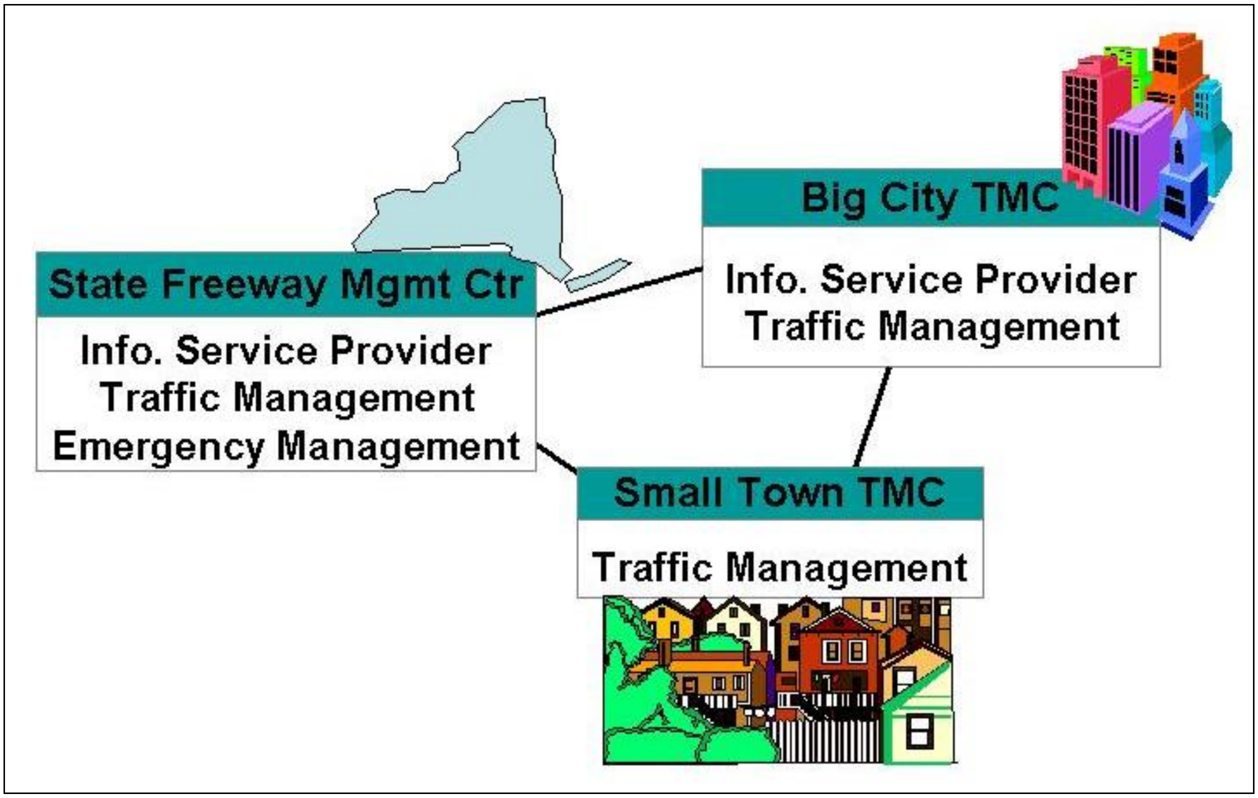

Figure 6. Center Subsystems Configuration Options

Equipment Packages

The term "*equipment package*" is used in the National ITS Architecture to group like functions (PSpecs) of a particular subsystem together into an "implementable" package of hardware and software capabilities. , The grouping of functions also takes into account the user services and the need to accommodate various levels of functionality within them. The equipment packages are associated closely with service packages (which will be discussed next) and were used in the original development of the National ITS Architecture as a basis for estimating deployment costs (as part of the evaluation that was performed). The specific set of equipment packages defined is merely illustrative and does not represent the only way to combine the functions within a subsystem. The National ITS Architecture has defined 233 equipment packages in total.

Table 4 illustrates an example of an equipment package that is relevant to traffic signal control, e.g., "TMC Signal Control", which is comprised of 5 process specifications: Process Traffic Data, Provide Traffic Operations Personnel Traffic Data Interface, Select Strategy, Determine Indicator State for Road Management, and Output Control Data for Roads.

Table 4. Equipment Package Example

TMC Signal Control Equipment Package (part of the Traffic Management Subsystem): This equipment package provides the capability for traffic managers to monitor and manage the traffic flow at signalized intersections. This capability includes analyzing and reducing the collected data from traffic surveillance equipment and developing and implementing control plans for signalized intersections. Control plans may be developed and implemented that coordinate signals at many intersections under the domain of a single traffic management subsystem and are responsive to traffic conditions and adapt to support incidents, preemption and priority requests, pedestrian crossing calls, etc. This equipment package consists of the following PSpecs: 1.1.2.2 Process Traffic Data 1.1.4.2 Provide Traffic Operations Personnel Traffic Data Interface 1.2.1 Select Strategy 1.2.2.2 Determine Indicator State for Road Management 1.2.4.1 Output Control Data for Roads 1.2.8-Collect Traffic Field Equipment Fault Data

Equipment packages are also used as the basis for defining a high level set of functional requirements which can support the definition of ITS projects through regional ITS architectures. As an example the functional requirements defined for the TMC Signal Control Equipment Package are shown in Table 5.

Table 5. Functional Requirements Example

TMC Signal Control Functional Requirements: 1. The center shall remotely control traffic signal controllers. 2. The center shall accept notifications of pedestrian calls. 3. The center shall collect traffic signal controller operational status and compare against the control information sent by the center. 4. The center shall collect traffic signal controller fault data from the field. 5. The center shall manage (define, store and modify) control plans to coordinate signalized intersections, to be engaged at the direction of center personnel or according to a daily schedule. 6. The center shall implement control plans to coordinate signalized intersections based on data from sensors. 7. The center shall manage boundaries of the control sections used within the signal system. 8. The center shall maintain traffic signal coordination including synchronizing clocks throughout the system.

Service Packages

Many of the user services are too broad in scope to be convenient in planning actual deployments. Additionally, they often don’t translate easily into existing institutional environments and don’t distinguish between major levels of functionality. In order to address these concerns (and to support the creation of service based regional ITS architectures), a finer grained set of deployment-oriented ITS service building blocks were defined from the original user services. These are called “*service packages*” in the documentation.

Service packages are defined by sets of equipment packages required to work together (typically across different subsystems) to deliver a given transportation service and the major architecture flows between them and other important external systems. *In other words, they identify the pieces of the National ITS Architecture required to implement a service*. As such, they are directly grounded in the definition of the Architecture. Most service packages are made up of equipment packages in two or more subsystems. Service packages are designed to address specific transportation problems and needs and can be related back to the user services and their more detailed requirements.

For example, the functionality of the broad user service named “traffic control” was broken up into several service packages to allow for explicit consideration of:

- basic functions (such as surveillance, which is represented by the “network surveillance” and “probe surveillance” service packages),
- institutional settings (by separating control functions typically performed by different agencies into the “surface street control” and “traffic metering” service packages), and
- functional levels of service (by including a “regional traffic management” service package that provides for coordination of control strategies across jurisdictions).

Other service packages that relate to traffic control are the “Transit Signal Priority” service package which comprises of the functionality for transit vehicle priority treatment at traffic signals and the “Emergency Routing” service package which includes the functionality for emergency vehicle preemption at traffic signals.

Table 6 provides an example of a service package related to traffic signal control, Figure 7 contains the service package diagram, and Figure 8 explains the basic elements of the service package diagrams.

Table 6. Service Package Example

Traffic Signal Control (ATMS03) This service package provides the central control and monitoring equipment, communication links, and the signal control equipment that support traffic control at signalized intersections. A range of traffic signal control systems are represented by this service package ranging from fixed-schedule control systems to fully traffic responsive systems that dynamically adjust control plans and strategies based on current traffic conditions and priority requests. This service package is generally an intra-jurisdictional package. Systems that achieve coordination across jurisdictions by using a common time base or other strategies that do not require real time coordination would also be represented by this package. Coordination of traffic signal systems using real-time communications is covered in the ATMS07-Regional Traffic Management service package. This service package is consistent with typical traffic signal control systems.

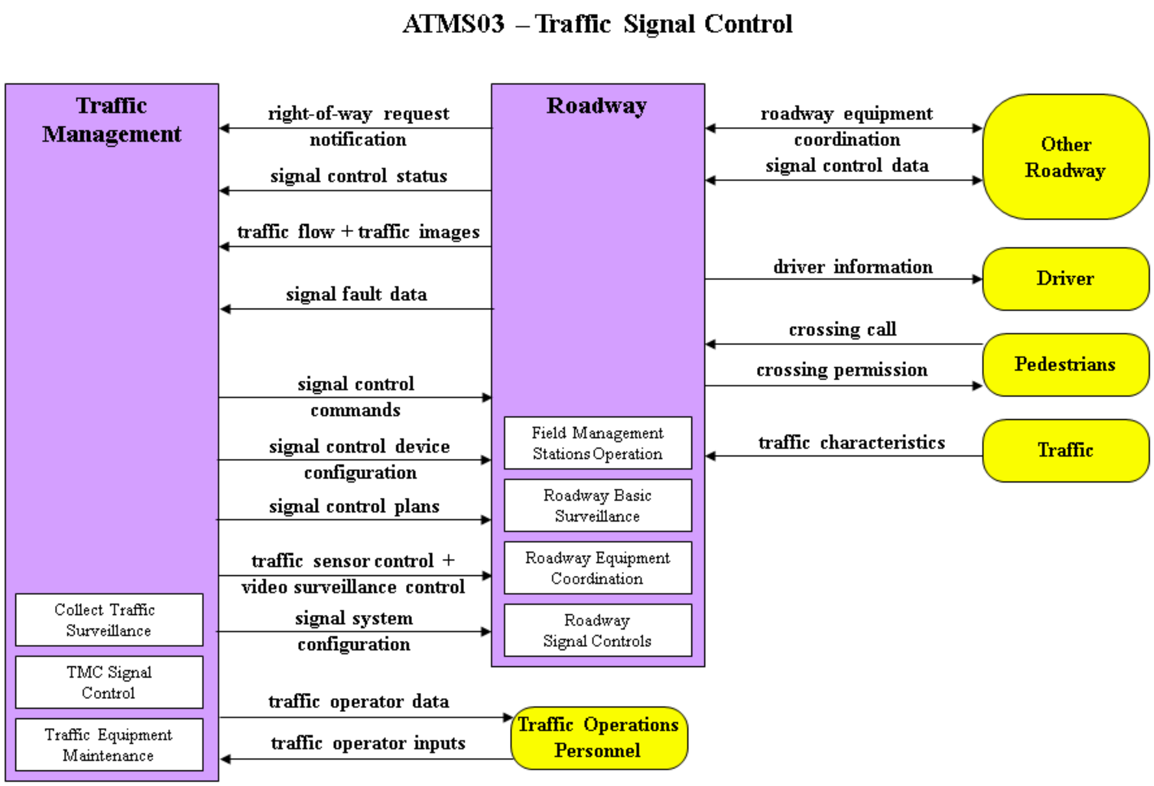

Figure 7. Traffic Signal Control Service Package Diagram

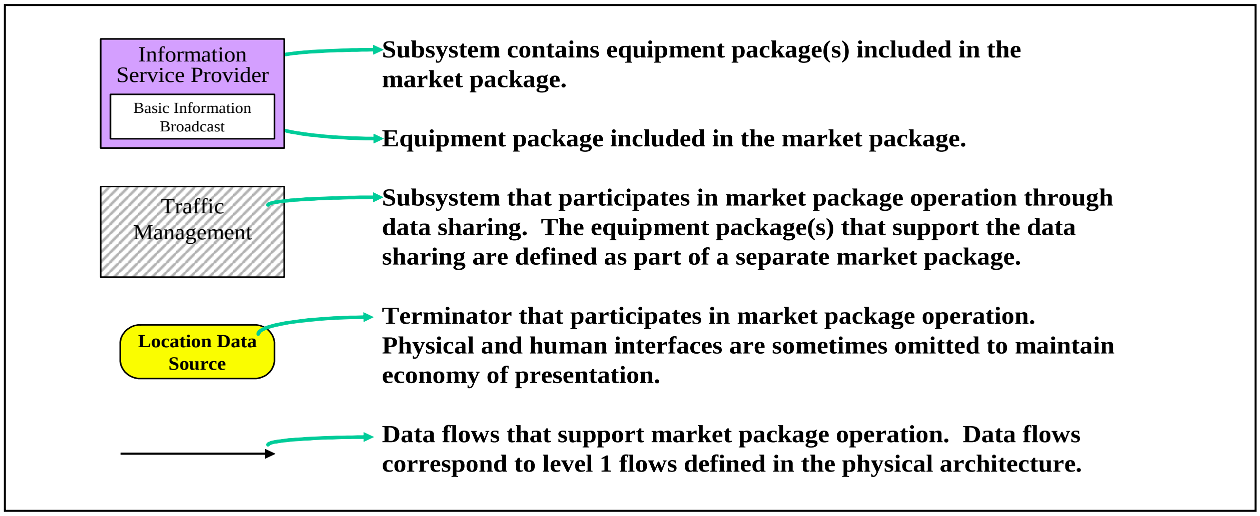

Figure 8. Service Package Elements

The National ITS Architecture identifies a total of 97 service packages that reflect the current definition of ITS and the evolving implementations of ITS. Table 7 contains a complete listing of these, grouped according to their respective major application areas. As with equipment packages, the specific set of service packages defined is merely illustrative and does not represent the only way to combine the functions and equipment in order to provide ITS services.

A given service package may provide only part of the functionality of a user service (supporting multiple service levels), but often serves as a building block by allowing more advanced packages to use its components. Service packages also allow early deployments to be separated form higher risk services and can specifically address varied regional needs..

Service packages are not intended to be tied to specific technologies, but of course depend on the current technology and product market in order to actually be implemented. As transportation needs evolve, technology advances, and new devices are developed, service packages may change and new service packages may be defined.

In short, service packages provide a key method for entering into the National ITS Architecture and can be used as a foundation for the development of regional ITS architectures. The important point to remember is that they provide a set of manageable, service-oriented views which allow the user to jump right into the physical architecture definition.

Table 7. ITS Service Packages

Service Package Group	Service Package
Traffic Management	Network Surveillance
	Probe Surveillance
	Traffic Signal Control
	Traffic Metering
	HOV Lane Management
	Traffic Information Dissemination
	Regional Traffic Management
	Traffic Incident Management System
	Traffic Decision Support and Demand Management
	Electronic Toll Collection
	Emissions Monitoring and Management
	Roadside Lighting System Control
	Standard Railroad Grade Crossing
	Advanced Railroad Grade Crossing
	Railroad Operations Coordination
	Parking Facility Management
	Regional Parking Management
	Reversible Lane Management
	Speed Warning and Enforcement
	Drawbridge Management
	Roadway Closure Management
	Variable Speed Limits
	Dynamic Lane Management and Shoulder Use
	Dynamic Roadway Warning
	VMT Road User Payment
	Mixed Use Warning Systems
Public Transportation	Transit Vehicle Tracking
	Transit Fixed-Route Operations
	Demand Response Transit Operations
	Transit Fare Collection Management
	Transit Security
	Transit Fleet Management

Service Package Group	Service Package
	Multi-modal Coordination Transit Traveler Information Transit Signal Priority Transit Passenger Counting Multimodal Connection Protection
Traveler Information	Broadcast Traveler Information Interactive Traveler Information Autonomous Route Guidance Dynamic Route Guidance ISP Based Trip Planning and Route Guidance Transportation Operations Data Sharing Travel Services Information and Reservation Dynamic Ridesharing In-Vehicle Signing Short Range Communications Traveler Information
Advanced Safety Systems	Vehicle Safety Monitoring Driver Safety Monitoring Longitudinal Safety Warning Lateral Safety Warning Intersection Safety Warning Pre-Crash Restraint Deployment Driver Visibility Improvement Advanced Vehicle Longitudinal Control Advanced Vehicle Lateral Control Intersection Collision Avoidance Automated Vehicle Operations Cooperative Vehicle Safety Systems
Commercial Vehicle Operations	Carrier Operations and Fleet Management Freight Administration Electronic Clearance CV Administrative Processes International Border Electronic Clearance Weigh-In-Motion Roadside CVO Safety On-board CVO Safety CVO Fleet Maintenance HAZMAT Management Roadside HAZMAT Security Detection and Mitigation CV Driver Security Authentication Freight Assignment Tracking
Emergency Management	Emergency Call-Taking and Dispatch Emergency Routing Mayday and Alarms Support Roadway Service Patrols Transportation Infrastructure Protection Wide-Area Alert Early Warning System Disaster Response and Recovery Evacuation and Reentry Management

Service Package Group	Service Package
	Disaster Traveler Information
Archived Data	ITS Data Mart ITS Data Warehouse ITS Virtual Data Warehouse
Maintenance & Construction Operations	Maintenance & Construction Vehicle and Equipment Tracking Maintenance & Construction Vehicle Maintenance Road Weather Data Collection Weather Information Processing and Distribution Roadway Automated Treatment Winter Maintenance Roadway Maintenance and Construction Work Zone Management Work Zone Safety Monitoring Maintenance & Construction Activity Coordination Environmental Probe Surveillance Infrastructure Monitoring

Summary

The National ITS Architecture provides a common structure for the design of ITS. It defines the functions that must be performed by components or subsystems, where these functions reside (e.g., field, traffic management center, or in-vehicle), the interfaces and information flows between subsystems, and the communications requirements for the information flows in order to address the underlying user service requirements. Since the National ITS Architecture is also the foundation for much of the ongoing ITS standards work, consideration of the interface and information exchange requirements established by the Architecture today will likely facilitate or ease the transition to incorporating standards-compliant interfaces in the future.