Executive Summary

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Prepared for:

Federal Highway Administration
US Department of Transportation
Washington, D. C. 20590

January 1997

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) OPPORTUNITY

Although the United States has one of the best surface transportation systems in the world, the mobility we as Americans prize so highly is threatened by the continuing growth in travel demand. In many areas of the country, we no longer have the option to build additional roadways to meet this increasing demand, due to the lack of suitable land to build on, limited financial resources, and environmental impact issues.

Congestion on the Nation's highways, particularly in urbanized areas and along heavily traveled inter-city corridors, is exacting a toll on our pocketbooks, our quality of life, and our environment. In a recent report published by the Texas Transportation Institute on urban mobility in 50 urbanized areas (e.g., Los Angeles, Washington, D.C., Miami, , etc.), it was estimated that for 1992, the total cost (delay plus wasted fuel) due to congestion for the areas studied was $48 billion, approximately 89 percent of that attributable to delay. This represented a nine percent increase over the economic impact of congestion calculated for 1991. Washington, D.C., had the dubious honor of ranking number one with a “congestion tax” of $820 per person and $1580 per registered vehicle. Despite the increasing delays due to congestion, of the 88 percent of all U.S. workers who drive to work, 76 percent drive alone, 12 percent use car pools, and only 5 percent use mass transit. In fact, the United States, with an average of 1.3 occupants per vehicle, has the second lowest occupants per vehicle rating in the world behind San Marino.

Safety on the nation's surface transportation system is also a concern. Preliminary 1993 estimates indicate there were 40,115 people killed and another 3 million injured in traffic accidents involving automobiles. While most accidents are urban, sixty-one percent of all fatal accidents are reported to occur in rural areas. Even though highway fatalities have leveled off in the past few years, it is astounding that we can so blithely accept the loss of so many lives when technology could save many of them.

Transportation Element	United States	Next Closest
Roads	3,904,721 miles	1,342,000 miles (India)
Registered Automobiles	146,314,000	40,772,407 (Japan)
Cargo Shipped by Road (in million ton-miles)	815,014	278,806 (China)
Cargo Shipped by Rail (in million ton-miles)	1,183,000	853,576 (China)

The United States' surface transportation system is one of the best in the world. Safe, efficient, environmentally responsible transportation is vital to the social and economic well being of the nation.

In addition to the basic problems of congestion and safety, there are the “niche” problems of inefficiency and loss of productivity. These range from a frustratingly simple one of finding a parking place, or knowing that none are available without having to look for twenty minutes, to having to stop to pay tolls. Relative to commercial vehicle operations, the productivity of trucking is eaten into by stops for weighing, for inspections, or to verify compliance with regulations. Since transportation is an integral part of nearly all of industry's productive and distributive processes, a penalty to transportation productivity is a penalty to national productivity. We should and can do better.

There is no single answer to the set of complex transportation problems that face the nation. However, new technologies in computing, sensing, and communications, commonly referred to as ITS technologies, are opening up new possibilities that collectively can go a long way. Some of these are better ways of doing old things, like traffic control, but some are entirely new, such as dynamic route guidance. Most are ideas that transportation professionals have had for a long time, but were beyond the available technology or cost too much as individual bits and pieces.

ITS technologies have been encapsulated in a collection of interrelated user services for application to the nation's surface transportation problems. To date, thirty user services have been identified, the most recent being the Highway Rail Intersection. This list of user services is neither exhaustive nor final. The user services have been bundled into six categories as shown below.

User Services Bundle	User Services
Travel and Transportation Management	• En-Route Driver Information • Route Guidance • Traveler Services Information • Traffic Control • Incident Management • Emissions Testing and Mitigation • Demand Management and Operations • Pre-trip Travel Information • Ride Matching and Reservation • Highway Rail Intersection
Public Transportation Operations	• 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 Monitoring • Commercial Vehicle Administration Processes • Hazardous Materials Incident Response • Freight Mobility
Emergency Management	• Emergency Notification and Personal Security • Emergency Vehicle Management
Advanced Vehicle Control and Safety Systems	• Longitudinal Collision Avoidance • Lateral Collision Avoidance • Intersection Collision Avoidance • Vision Enhancement for Crash Avoidance • Safety Readiness • Pre-Crash Restraint Deployment • Automated Highway System

ITS User Services

ITS presents stakeholders with a variety of options to address their transportation needs. Left without adequate guidance, stakeholders could easily develop systems solutions to their needs which were incompatible with their regional neighbors. Put another way, if City A choose to implement user services one way, and a neighboring City B another, then it is a real possibility that a motorist/traveler would find that none of the ITS equipment or services purchased for use in City A, would work in City B. To fully maximize the potential of ITS technologies, system design solutions must be compatible at the system interface level in order to share data, provide coordinated, area-wide integrated operations, and support interoperable equipment and services where appropriate. The National ITS Architecture provides this overall guidance to ensure system, product, and service compatibility/interoperability, without limiting the design options of the stakeholder.

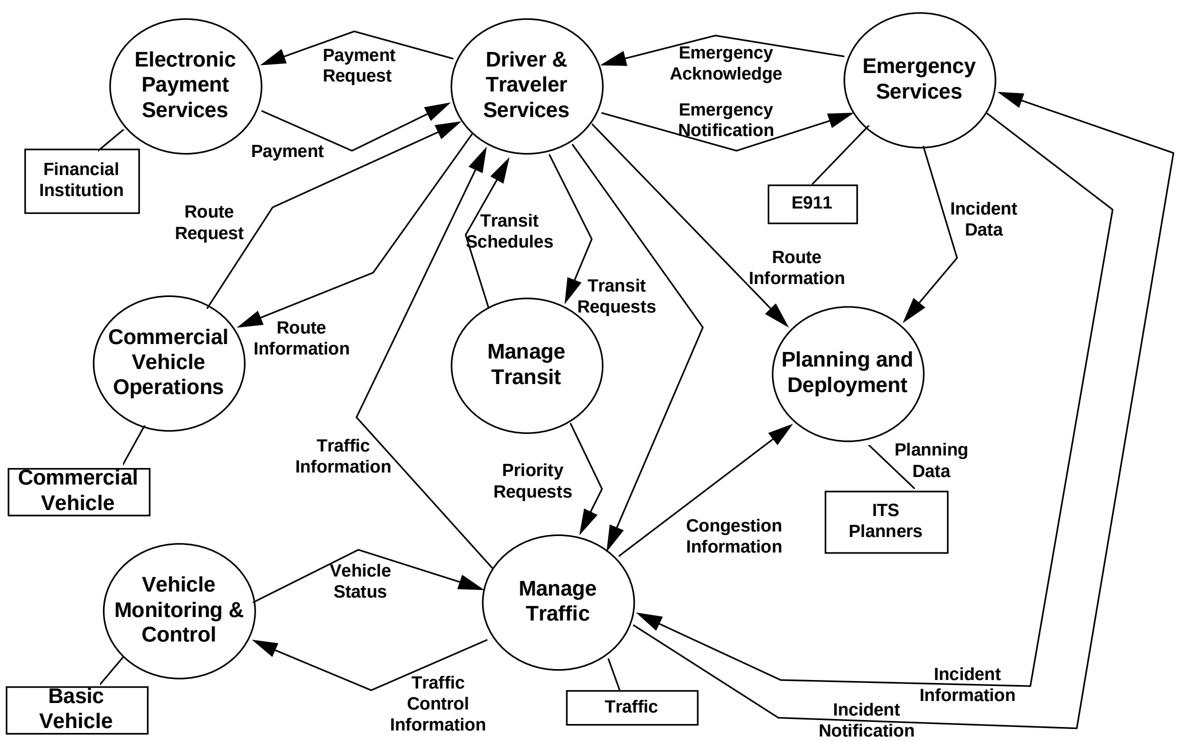
NATIONAL ITS ARCHITECTURE

The National ITS Architecture provides a common structure for the design of intelligent transportation systems. It is not a system design nor is it a design concept. What it does is define the framework around which multiple design approaches can be developed, each one specifically tailored to meet the individual needs of the user, while maintaining the benefits of a common architecture noted above. The architecture defines the functions (e.g., gather traffic information or request a route) that must be performed to implement a given user service, the physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle), the interfaces/information flows between the physical subsystems, and the communication requirements for the information flows (e.g., wireline or wireless). In addition, it identifies and specifies the requirements for the standards needed to support national and regional interoperability, as well as product standards needed to support economy of scale considerations in deployment.

Model of ITS Functions (Logical Architecture)

The *Logical Architecture* presents a functional view of the ITS user services. This perspective is divorced from likely implementations and physical interface requirements. It defines the functions or process specifications that are required to perform ITS user services, and the information or data flows that need to be exchanged between these functions. The functional decomposition process begins by defining those elements which are inside the architecture, and those which are not. For example, travelers are external to the architecture, but the equipment that they use to obtain information or provide inputs is inside. In other words, the architecture defines the functions ITS must perform in support of a traveler's requirements, not the functions of the traveler. A financial institution that processes tolls is outside of the architecture, whereas the ITS components that detect vehicles and collect tolls are inside. Existing broadcast media for the transmission of traveler information are outside of the architecture, but the elements that provide ITS traveler information to the media are inside. Communications within the rail infrastructure are outside the architecture but the support for the highway-rail interface is inside.

ITS functions are depicted using *data flow diagrams*. A simplified top level data flow diagram is presented below. In a data flow diagram, circles represent functions that are broken down into lower levels of detail on subsequent diagrams. The lowest level of decomposition is a *Process Specification*, e.g., *Detect Roadside Pollution Levels*. This process detects pollution levels present in the environment and passes the pollution measurement data on to another process, *Process Pollution Data*, where it is combined with other such detected data. Both process specifications are within the *Manage Traffic* function. Rectangles represent the external entities defined above. The lines drawn between the functions (circles), and between the functions and the external entities (rectangles), represent data flows. They are further subdivided on subsequent diagrams and are described in a data dictionary.



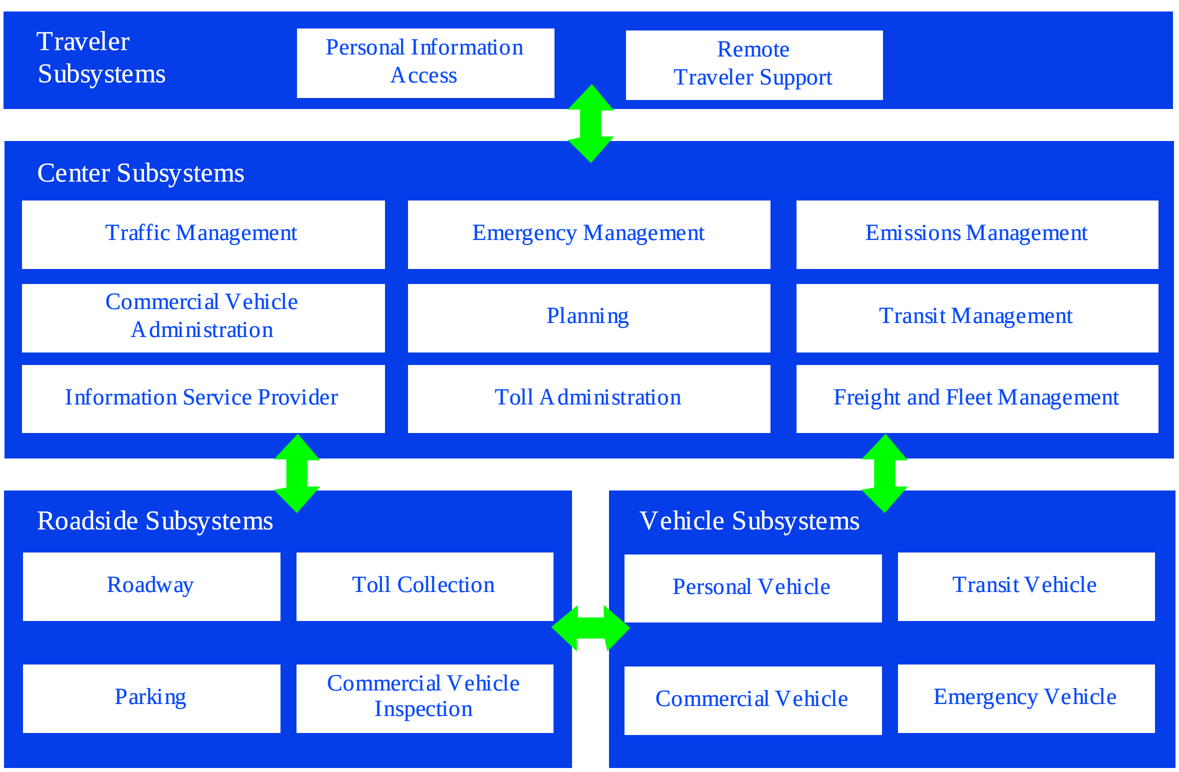
Simplified Top Level Logical Architecture

Model of ITS Physical Entities (Physical Architecture)

The *Physical Architecture* partitions the functions defined by the Logical Architecture into *systems*, and at a lower level, *subsystems*, based on the functional similarity of the process specifications and the location where the functions are being performed. A top level diagram of the physical architecture is shown on the following page.

The physical architecture defines four systems; *Traveler*, *Center*, *Roadside*, and *Vehicle*, and nineteen subsystems. The specific choice of nineteen subsystems represents a lower level of partitioning of functions that is intended to capture all anticipated subsystem boundaries for the present, and 20 years into the future. Subsystems are composed of *equipment packages* with specific functional attributes. Equipment packages are defined to support analyses and deployment, and they represent the smallest units within a subsystem that might be purchased.

In deployments, the character of a subsystem deployment is determined by the specific equipment packages chosen. For example, one municipal deployment of a *Traffic Management Subsystem* may select *Collect Traffic Surveillance* and *Basic Signal Control* equipment packages, while a state Traffic Management Center may select *Collect Traffic Surveillance* and *Freeway Control* packages. In addition, subsystems may be deployed individually or in "aggregations" or combinations that will vary by geography and time based on local deployment choices. A Traffic Management Center may include a *Traffic Management Subsystem*, *Information Provider Subsystem*, and *Emergency Management Subsystem*, all within one building, while another Traffic Management Center may concentrate only on the management of traffic with the *Traffic Management Subsystem*. A discussion of the function of each subsystem is provided on the following pages.



Architecture Systems and Subsystems

Center Subsystems

Center Subsystems deal with those functions normally assigned to public/private administrative, management, or planning agencies. The nine Center Subsystems are described below:

- ***Commercial Vehicle Administration*** - Sells credentials and administers taxes, keeps records of safety and credential check data, and participates in information exchange with other commercial vehicle administration subsystems and CVO Information Requesters.
- ***Fleet and Freight Management*** - Monitors and coordinates vehicle fleets including coordination with intermodal freight depots or shippers.
- ***Toll Administration*** - Provides general payment administration capabilities to support electronic assessment of tolls and other transportation usage fees.
- ***Transit Management*** - Collects operational data from transit vehicles and performs strategic and tactical planning for drivers and vehicles.
- ***Emergency Management*** - Coordinates response to incidents, including those involving hazardous materials (HAZMAT).
- ***Emissions Management*** - Collects and processes pollution data and provides demand management input to Traffic Management.
- ***Planning*** - Aids in optimal planning for ITS deployment. Collects and processes operational data from other Center subsystems, as well as the Parking Management Subsystem, and provides the results to Transportation Planners.
- ***Traffic Management*** - Processes traffic data and provides basic traffic and incident management services through the Roadside and other subsystems. The Traffic Management Subsystem may share traffic data with Information Service Providers. Different equipment packages provide a focus on surface streets or highways (freeways and interstates) or both. It also coordinates transit signal priority and emergency vehicle signal preemption.
- ***Information Service Provider*** - This subsystem may be deployed alone (to generally serve drivers and/or travelers) or be combined with Transit Management (to specifically benefit transit travelers), Traffic Management (to specifically benefit drivers and their passengers), Emergency Management (for emergency vehicle routing), Parking Management (for brokering parking reservations), and/or Commercial Vehicle Administration (for commercial vehicle routing) deployments. ISPs can collect and process transportation data from the aforementioned centers, and broadcast general information products (e.g., link times), or deliver personalized information products (e.g., personalized or optimized routing) in response to individual information requests. Because the ISP may know where certain vehicles are, it may use them as “probes” to help determine highway conditions, levels of congestion, and aid in the determination of travel or link times. This probe data may be shared with the Traffic Management Subsystem. The ISP is a key element of pre-trip travel information, infrastructure based route guidance, brokering demand-responsive transit and ridematching, and other traveler information services.

Roadside Subsystems

These subsystems include functions that require convenient access to a roadside location for the deployment of sensors, signals, programmable signs, or other interfaces with travelers and vehicles of all types. The four Roadside Subsystems are described below:

- ***Roadway -*** Provides traffic management surveillance, signals, and signage for traveler information. This subsystem also includes the devices at roadway intersections and multi-modal intersections to control traffic.
- ***Toll Collection -*** Interacts with vehicle toll tags to collect tolls and identify violators.
- ***Parking Management -*** Collects parking fees and manages parking lot occupancy/availability.
- ***Commercial Vehicle Check -*** Collects credential and safety data from vehicle tags, determines conformance to requirements, posts results to the driver (and in some safety exception cases, the carrier), and records the results for the Commercial Vehicle Administration Subsystem.

Vehicle Subsystems

These subsystems are installed in a vehicle. The four Vehicle Subsystems are described below:

- ***Vehicle -*** Functions that may be common across all vehicle types are located here (e.g. navigation, tolls, etc.) so that specific vehicle deployments may include aggregations of this subsystem with one of the other three specialized vehicle subsystems types. The Vehicle Subsystem includes the user services of the Advanced Vehicle Control and Safety Systems user services bundle.
- ***Transit Vehicle -*** Provides operational data to the Transit Management Center, receives transit network status, provides enroute traveler information to travelers, and provides passenger and driver security functions.
- ***Commercial Vehicle -*** Stores safety data, identification numbers (driver, vehicle, and carrier), last check event data, and supports in-vehicle signage for driver pass/pull-in messages.
- ***Emergency Vehicle -*** Provides vehicle and incident status to the Emergency Management Subsystem.

Traveler Subsystems

These subsystems represent platforms for ITS functions of interest to travelers or carriers (e.g., commercial vehicle operators) in support of multimodal traveling. They may be fixed (e.g., kiosks or home/office computers) or portable (e.g., a palm-top computer), and may be accessed by the public (e.g., through kiosks) or by individuals (e.g., through cellular phones or personal computers). The two Traveler Subsystems are described below:

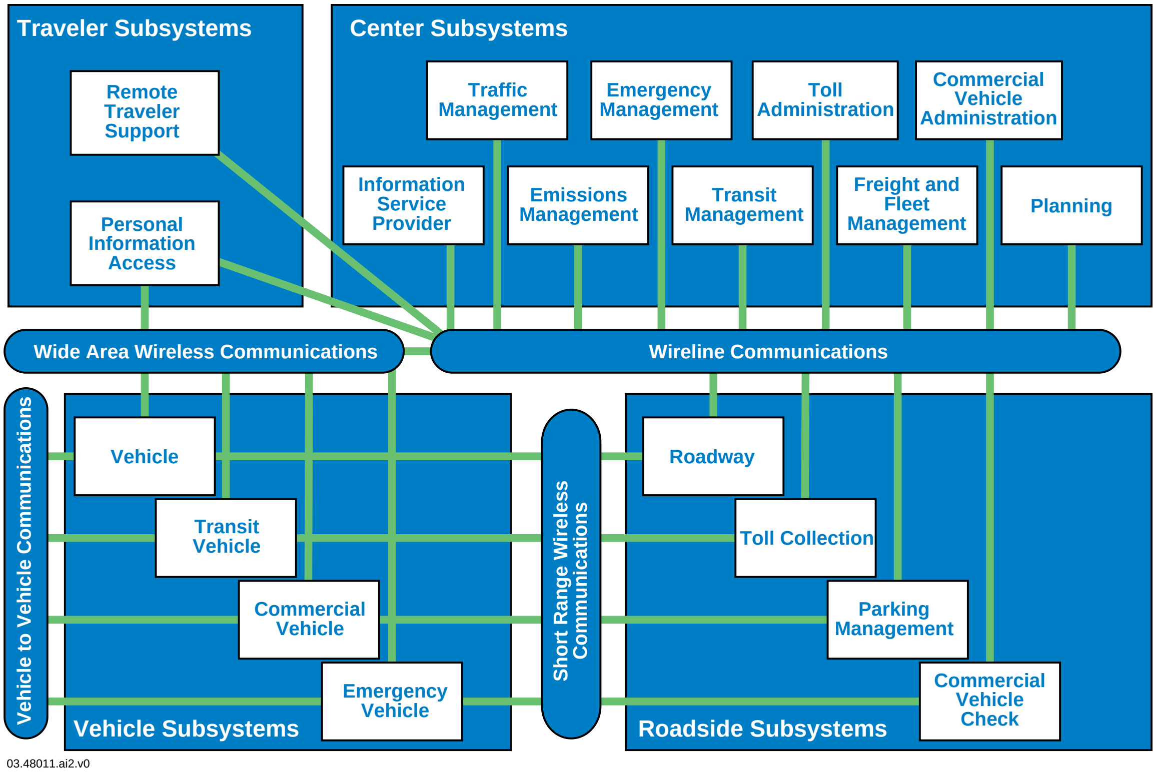
- ***Remote Traveler Support* -** Provides traveler information at public kiosks. This subsystem includes traveler security functions.
- ***Personal Information Access* -** Provides traveler information and supports emergency requests for travelers using personal computers/telecommunication equipment at the home, office, or while on travel.

Communications

The National ITS Architecture provides the framework that ties the transportation and telecommunication worlds together to enable the development and effective implementation of the broad range of ITS user services. There are multiple communications options available to the system designer. The flexibility in choosing between various options allows each implementor the ability to select the specific technology that meets the local, regional, or national needs. The architecture identifies and assesses the capabilities of candidate communications technologies, but it does not select or recommend “winning” systems and technologies.

One of the fundamental guiding philosophies in the development of the National ITS Architecture has been to leverage the existing and emerging transportation and communication infrastructures in its design. This minimizes the risk and cost of deployment, and maximizes marketplace acceptance, penetration, and early deployment.

The architecture has identified four communication media types to support the communications requirements between the nineteen subsystems. They are *wireline* (fixed-to-fixed), *wide area wireless* (fixed-to-mobile), *dedicated short range communications* (fixed-to-mobile), and *vehicle-to-vehicle* (mobile-to-mobile). A top level subsystems interconnect diagram that identifies the communications media interfaces between the architecture’s nineteen subsystems is provided on the following page.



Architecture Subsystems Interconnect Diagram

There are numerous wireline technologies to choose from for fixed-to-fixed communications requirements. For example, the Traffic Management Subsystem can use leased or owned twisted wire pairs, coaxial cable, or fiber optics to gather information and to monitor and control Roadway Subsystem equipment packages (e.g., traffic surveillance sensors, traffic signals, changeable message signs, etc.). In other applications, it may be more advantageous to use terrestrial microwave links, spread spectrum radio, or an area radio network to provide communications between a Traffic Management Center and remote controllers. Although wireless communications technologies, they are used to provide fixed-to-fixed communications in the example cited, consequently the architecture recognizes them as wireline communications media.

The architecture design links the Center Subsystems together over a wireline network. This allows each Center Subsystem to collect, integrate, and disseminate collected information to all other Center Subsystems, resulting in improved interjurisdictional communications and coordination that in turn will directly affect the efficiency and effectiveness of all Center Subsystems operations. Wireline network options include the use of private networks, public shared networks, or a mixture of the two. Private network technologies assessed by the architecture team include Ethernet, Fiber Distributed Data Interface (FDDI), Synchronous Optical NETwork (SONET), and Asynchronous Transfer Mode (ATM). Public shared network technologies assessed include leased analog lines, leased digital lines, frame relay, Integrated Services Digital

Network (ISDN), metropolitan ethernet, Internet, and Switched Multimegabit Data Service (SMDS).

The architecture identifies two distinct categories of wireless communications based on range and area of coverage. Wide area wireless (fixed-to-mobile) communications are suited for services and applications where information is disseminated to users who are not located near the source of transmission and who require seamless coverage. Wide area wireless communications are further differentiated based on whether they are one-way or two-way. An example of a one-way, broadcast transmission are the traffic reports we currently receive over AM or FM radio. A mobile traveler who requests and receives current traffic information from an Information Service Provider, is an example of two-way communications.

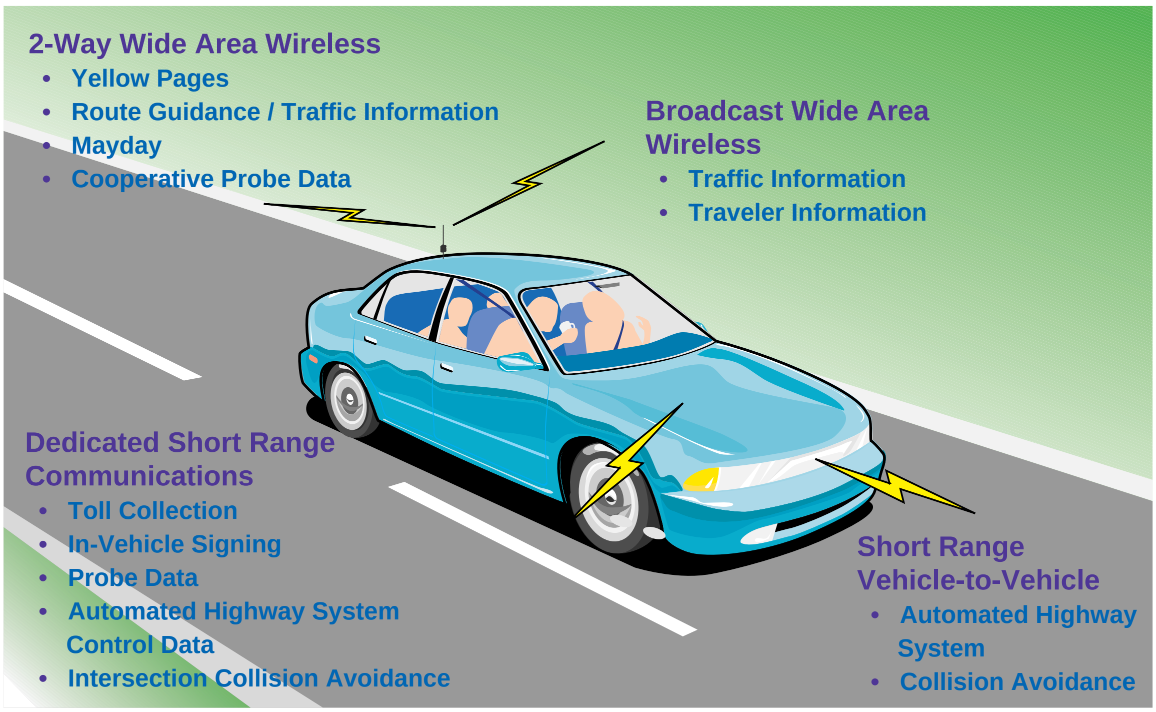
Several two-way wide area wireless technologies were assessed by the architecture team. They included Global System for Mobile Communications (GSM), Special Mobile Radio (SMR), Enhanced Special Mobile Radio (ESMR), Personal Communications System (PCS), ARDIS, RAM, Geotek, 220 Mhz, Metricom, Tetherless Access Ltd. (TAL), two-way paging, and Cellular Digital Packet Data (CDPD). Although each technology had its own strengths and weaknesses relative to addressing ITS communication requirements, all of the currently deployed systems failed to provide the ubiquitous coverage required for nationwide interoperability.

In an attempt to address the ubiquitous coverage issue, the architecture team assessed the current and emerging satellite communication technologies. Systems assessed included ORBCOMM, STARSYS, VITASAT, MSAT, Constellation, GLOBALSTAR, IRIDIUM, TELEDESIC, Ellipso, Odyssey, Skycell, VSAT, and OmniTRACS. Availability and cost of the service, coupled with the cost of the terminals, were common issues that must be addressed if satellite communication technologies are to be a viable candidate for ITS user services.

The architecture team also examined one-way, broadcast communication technologies. Technologies examined included AM subcarrier, FM subcarrier, and Highway Advisory Radio (HAR). FM subcarrier systems assessed included Mitre's Subcarrier Traffic Information Channel (STIC), NHK's Data Radio Channel (DARC), SEIKO's High Speed FM Subcarrier Data System (HSDS), RBDS, ALERT, and Modulation Sciences, Inc.'s SCA. Issues that resulted from these assessments included the limited coverage of the currently available systems and the proprietary hardware and interfaces of the high data rate systems (HSDS, STIC, and DARC). The assessment did indicate that all of the high data rate systems would meet the capacity requirements of the ITS data flows proposed for broadcast communication services.

The second category, short range wireless, is concerned with information transfer that is of a localized interest. There are two types of short range wireless communications identified by the architecture. They are vehicle-to-vehicle and Dedicated Short Range Communications (DSRC). Vehicle-to-vehicle (mobile-to-mobile) short range wireless communications are required to support the Automated Highway System (AHS), and most likely, intersection collision avoidance implementations. The architecture team has identified the required interfaces and data flows, but has not assessed available and/or emerging communication technologies, since the AHS Consortium has several ongoing studies in this area.

Appropriate applications for DSRC (fixed-to-mobile) include toll collection, parking fee collection, roadside safety inspections, credential checks, in-vehicle signing, intersection collision avoidance, and selected Automated Highway System (AHS) communications (e.g., safety checks, access authorization, and system status updates). The architecture team assessed radio frequency (RF) and Infrared (IR) short range wireless beacon/tag communications for the DSRC requirement. Key issues relative to beacons that require further analysis and study are the required coverage and who should pay for their installation, operation, and maintenance. The communication media required to provide a full range of ITS services to the passengers of a vehicle of the future are provided below.



Vehicle Communications in the Future

Some broad conclusions can be drawn from the communications assessments and analyses.

- A large set of the architecture data flows are best supported by commercially available mobile wireless data networks operated in the packet switching mode. Prominent among these today are GSM, RAM, ARDIS, and CDPD.
- Although GSM is not significantly deployed in the United States, it is extensively used in Europe and should be considered as an alternative communications service for product vendors.
- Of the new communication technologies being deployed, CDPD's technical performance has been validated through ITS-related simulation and through

operational field trials. CDPD's coverage is expected to cover the entire footprint of the cellular system, which is projected to cover 75% of the population before the end of 1997. Another version of CDPD, which extends Internet Protocol (IP) capabilities to regular AMPS cellular channels and the PSTN, called "Circuit Switched CDPD", will be used to extend CDPD service to areas that do not have the full CDPD overlay implementation. Nevertheless, some areas may never have CDPD in any form, and may transition directly to other, more advanced, cellular or PCS based packet data systems.

- RAM and ARDIS coverage is focused on the major metropolitan areas where there is significant business activity. There is little or no coverage in rural areas.
- Metropolitan area network type wireless data systems, such as systems by Metricom and TAL, can be used to access some ITS user services. One limitation is that these data systems are targeted at the non-mobile user. Because of their simplicity, these systems offer price advantages over mobile wireless data systems.
- Two-way paging (narrow band PCS) can be used for applications that are not time critical and which do not require a real time response. Particularly suitable would be messages for which a canned response would suffice.
- There are an array of satellite systems that are suitable for ITS applications. These include a variety of Little (data only) and Big (voice and data) low-earth-orbit (LEO) systems, as well as more conventional medium-earth-orbit (MEO) and geosynchronous orbit (GEO) systems. Many of these systems are not yet deployed, however they are projected to be in service within the next few years. Because of the higher costs for services and equipment, satellite systems would be most appropriately used where terrestrial alternatives are not available. Among the satellite systems, little LEO choices seem to be the most appropriate, since they are targeted specifically at short bursty data transactions.
- Service prices for two-way systems have come down in recent years, however, cost is a significant issue for the consumer, both for the communications device and the charges for service. If equipment costs were to drop to the $200 range, and more applications were to become available, a mass market could develop. This will probably take a few years. ITS is no different in this respect than other wireless data application areas. ITS applications will benefit from the developments and user acceptance trends in the broader fields of the mobile office and wireless Internet access.
- There are several broadcast media choices for one-way ITS communications. The most prominent among these are FM Subcarrier systems. A detailed quantitative assessment of the three leading high speed subcarrier systems (HSDS, DARC, and STIC) has been performed. The analysis showed that any one of them would be adequate to carry the broadcast data flows envisioned. The low speed RBDS FM subcarrier could also be used if the ITS application could live with relatively small amounts of data or long periods between updates.

- For the wide area wireless interface, the data loading results indicated that for the Urban environment in the year 2002, the largest data loads would result from the local CVO user service group, followed closely by transit and private vehicles. Private vehicle and local CVO were the largest data users, twice the rate of transit. In the inter-urban environment (suburb and inter-city), for the same time period, local CVO and transit would be the largest data users. For the inter-urban environment in 2012, local CVO remained the largest data user, followed by transit. The rural data loads were very low, with local CVO the largest user, followed by private vehicles.
- Cellular Digital Packet Data (CDPD) wireless simulation results have shown that the delay from the vehicle to the infrastructure, even in the presence of non-ITS data, and with an incident during the peak period, is very low (150 ms for ITS only; 300 ms for ITS plus non-ITS; 10% increase in the sectors affected by the incident).
- For broadcast systems, the quantitative analysis has shown that the combination of the low-rate RBDS, with the emerging high data rate FM subcarrier standard, will satisfy the ITS Architecture broadcast requirements for the foreseeable future. New broadcast techniques, including Digital Audio Broadcasting, will accommodate any long term growth.

The conclusion that can be drawn from the technology assessments and the data loading and communication system performance analyses, is that the commercially available wide area wireless (including broadcast) and wireline infrastructures, adequately meet the near term technical requirements of ITS. Deployment of ITS services will depend on these communications services being affordable. We expect that as markets evolve, existing communication technologies and infrastructure will evolve and expand to meet the growing needs.

Benefits Resulting from the Architecture

The basic benefit of the architecture is to provide a structure that supports the development of open standards. This results in the below derived benefits:

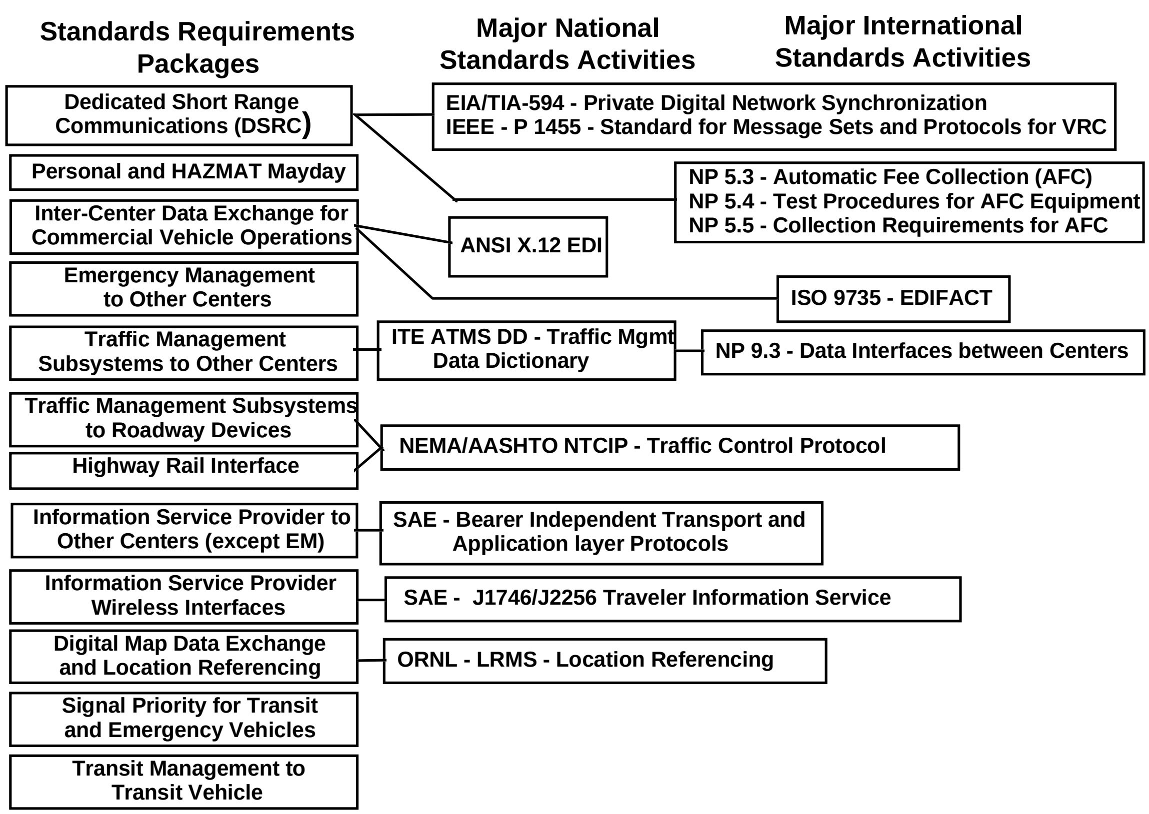
> **Integration:** The architecture makes integration of complex systems easier. This is achieved by presenting the structure around which standards can be developed. Because of improved integration, ITS services will benefit from better availability and sharing of traveler information, such as congestion information, and better utilization of shared resources, such as roadside surveillance data.
>
> **Compatibility:** The same mobile equipment will work over the entire country. Because equipment is compatible everywhere, there is a larger total market for services, resulting in more capable and cost effective products. Similarly, infrastructure systems can use standards to improve product quality and lower product costs. Future growth is enhanced by open standards being available, allowing everyone a chance to participate.

Support for Multiple Ranges of Functionality: Because the architecture does not dictate a design, standards can be developed to support a wide range of designs or levels of functionality in deployment, providing services ranging from free to pay-for-use.

Synergy: An overused concept but in this case, well suited due to the careful methodology used in development of the architecture. The methodology began with the architecture functional requirements and then mapped common requirements into specific applications. This allows developers to support a range of applications with similar functions and thereby serve larger potential markets with their products.

Standards

The architecture structure is a means through which relatively independent standards activities can proceed with harmonious results. Because the standards will be developed based on the architecture interfaces and data flows, information that cuts across standards activities is identified. This knowledge allows standards organizations to be aware of overlapping activities. It also permits the effective coordination of activities.



Standards Supporting Architecture Standards Packages

Standards development is of interest to nearly all organizations involved with the deployment of ITS. It is anticipated that product developers, communication providers, and private service providers will play an equal role in standards activities with local, regional, state, and federal public infrastructure agencies. It may be to their advantage to become involved with international activities as well, since significant efforts are underway outside the United States as indicated in the above figure. In particular, the adoption of common standards with Canada and Mexico would be beneficial to all three countries.

The architecture has identified 12 key standards areas that are relatively independent. The figure above indicates the standards packages along the left hand column and the current standards activities that are already addressing some of the key standards areas on the right. Certain areas are not currently covered by any significant activities and will require new efforts. For each of the standards packages, a detailed list of architecture data flows is provided so that standards organizations can readily apply the architecture to their efforts.

DEPLOYMENT OF ITS

The Implementation Strategy defines a series of steps that encourage efficient deployment of architecture compatible systems. These include:

- Identification of basic building blocks that apply to most ITS deployments,
- Focus on low-risk early deployments most relevant to near-term problems,
- Further encourage private sector participation in ITS deployment,
- Parallel advancements in service and system integration over time.
- Recommended Strategic Actions.

Identify ITS Building Blocks. During the course of the program, it became apparent that some of the original user services were too broad in scope to be convenient in planning actual deployments. Accordingly, a finer grained breakdown of ITS services have been defined in what are called *market packages*. These market packages listed below are tailored to fit - separately or in combination - real world transportation problems and needs. For example, Traffic Control has been broken into *Surface Street Control*, which is typically under the local jurisdiction, and *Freeway Control*, typically under State Transportation Agency control. Many market packages are also incremental so advanced packages can be efficiently implemented based on earlier deployments.

Market Packages

Traffic Management
- Network Surveillance
- Probe Surveillance
- Surface Street Control
- Freeway Control
- HOV and Reversible Lane Management
- Traffic Information Dissemination
- Regional Traffic Control
- Incident Management System
- Traffic Network Performance Evaluation
- Dynamic Toll/Parking Fee Management
- Emissions and Environmental Hazards Sensing
- Virtual TMC and Smart Probe
- Standard Speed Railroad Grade Crossing
- High Speed Railroad Grade Crossing
- Railroad Operations Coordination

Emergency Management
- Emergency Response
- Emergency Routing
- Mayday Support

Traveler Information
- Broadcast Traveler Information
- Interactive Traveler Information
- Autonomous Route Guidance
- Dynamic Route Guidance
- ISP Based Route Guidance
- Integrated Transportation Management/Route Guidance
- Yellow Pages and Reservation
- Dynamic Ridesharing
- In Vehicle Signing

Commercial Vehicles
- Fleet Administration
- Freight Administration
- Electronic Clearance
- Electronic Clearance Enrollment
- International Border Electronic Clearance
- Weigh-In-Motion
- Roadside CVO Safety
- On-board CVO Safety
- CVO Fleet Maintenance
- HAZMAT Management

Transit Management
- Transit Vehicle Tracking
- Transit Fixed-Route Operations
- Demand Response Transit Operations
- Transit Passenger and Fare Management
- Transit Security
- Transit Maintenance
- Multi-modal Coordination

Advanced Vehicles
- 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 Highway System

ITS Planning
- ITS Planning

ITS Market Packages

Recommend Early Deployments. The market packages are interrelated and are also influenced by the availability of basic supporting infrastructure, the evolution of technology, the emergence of industry standards, the institutional context of implementation, and market demand. It is difficult to predict when many of these factors will be resolved. Instead, the strategy suggests early deployments that are not dependent on technology advances or institutional change and it leaves room for a competitive environment in which to advance transportation technologies. *Early Market Packages* are the subset of market packages that appear to be early winners due to a promising combination of low risk implementation characteristics, developing public and private markets, and tangible system or user benefits. Market packages that best satisfy the above criteria include: *Surface Street Control, Freeway Control, Dynamic Toll Management, Transit Vehicle Tracking, Transit Operations, and Electronic Clearance.*

The nine elements identified by the Intelligent Transportation Infrastructure initiative further prioritize those early market packages that are oriented towards public infrastructure support for major metropolitan areas. This provides additional near-term focus for the strategy.

Encourage Private Sector Participation. An attempt has been made to structure many of the services so that the collection of user fees is practical in order to attract private capital. Where the prospect of user fee revenue is inadequate to attract this investment, the possibility of contractual arrangements with public sector agencies remains an option. The relative emphasis within the architecture on vehicle based systems, and the separation of transportation management and transportation information services, are examples of choices which preserve and enhance the opportunity for private sector participation. It is forecast that several key functions will remain a public responsibility, including traffic management and emergency management services, where direct user fee based operation is impractical.

Enable Service Integration and Extend Interoperability. The strategy begins with what we have now: "islands" of basic ITS capability that are deployed in response to local needs. New standards and the continuing communications revolution will encourage service expansion and eventual linking of these ITS islands. The implementation strategy considers the minimum level of standardization required to achieve interoperability, while preserving existing investments and the potential for innovation. This balanced view emphasizes the interfaces to vehicles and other mobile elements for standardization and leaves the other regional and sub-regional interfaces to evolve towards open standards based more on local needs than top-down national priorities.

The National ITS Architecture provides a general framework that must be adapted and elaborated for use in supporting an interoperable regional transportation system design. It is recommended that regional architectures be developed as a major output of this process, which adapts the National ITS Architecture to reflect major service, technology, and interface choices which are most appropriate for the implementing region.

Progressive Implementation of More Advanced Services. Geographic expansion and increased integration will be paralleled by technology growth resulting in new capabilities, new products, and new features. For example, early deployment of basic toll collection capabilities enables future, efficient deployment of vehicle probe data collection, which in turn enhances advanced traveler information market packages and more advanced, area-wide traffic control strategies.

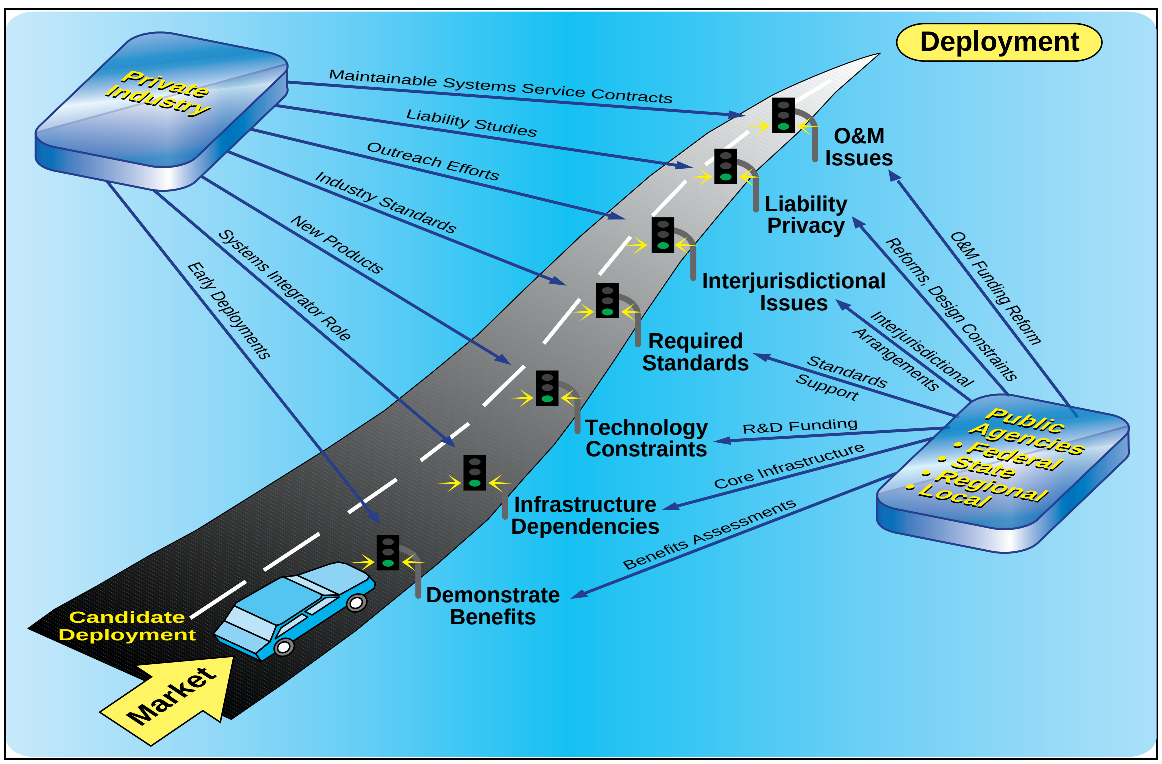
Recommended DOT Strategic Actions. The strategy culminates in a series of top-level recommendations for strategic actions that are intended to facilitate ITS deployments. These actions should lower identified barriers and otherwise enhance the prospects for efficient, interoperable ITS implementations.

> ***Facilitate National Interoperability.*** The recommendations complement the current US DOT "ITS Standards Development" activity with education programs and other forms of outreach intended to ensure active participation in, and beneficial adoption of, the standards that are developed. Legacy systems must be supported while standards adoption is encouraged in newer systems. Typically, conversion to newer, interoperable systems will occur over time in the course of normal system maintenance and upgrade. Finally, the subset of the

architecture products that directly support the evolving standards and implementation guidance efforts should be maintained.

Policy and Guidance. First, the local implementor must be equipped with sufficient information to make appropriate ITS architecture choices. Education and training programs which enlist regional field representatives as local champions and continuance of the on-going federal efforts to develop, consolidate and publish ITS benefits are positive steps to this end. Each of these programs must be supported by preparation of handbook level guidance and update of existing transportation manuals, handbooks, and publications over time.

Strategic Investment. Funding recommendations are made for projects that verify and refine integration strategies (e.g., regional architecture development), field operational tests that resolve major implementation choices (e.g., the role of probes versus roadside surveillance), and research and development activities that develop the tools (e.g., Improved ITS Benefits/Impact Models) and technologies (e.g., advanced vehicle sensor and control technologies) that support ITS implementations.



Achieving Efficient ITS Deployment Through Public and Private Sector Initiatives

Navigating the Architecture Documentation

The architecture, its goals, objectives, definition, evaluation, and deployment are documented in extensive volumes. All of the information is not of value to everyone. Information is provided for the casual reader (Vision), implementors (Implementation Strategy), designers (Architecture documents), and standards organizations (Standards documents). The figure below contains a road map through the documents and helps a reader decide which document to access for more information. The casual reader may be satisfied with the Vision and Implementation Strategy documents. Detailed information is available to architects and designers in the various architecture definition documents. Specific sets of documents address architecture objectives, evaluations, and standards. In addition to the documents, information on ITS, the Architecture, and the Standards activities is available at technical forums, and on the internet.

The *Vision* contains a magazine style description of what users can expect to see in the transportation world of the future. The document contains easy to read descriptions addressing each of the major ITS stakeholders. Also presented are vignettes of life in the years 1997, 2002 and 2012.

The *Mission Definition* ties the architecture program to the national program plan. Here, the stage is set for the architecture work. The document addresses goals, objectives, user service requirements, and expected benefits. The document also contains a communications threat analysis to remind us of the pitfalls that we should avoid.

The Architecture Definition is contained in a set of 4 volumes. The *Logical Architecture* presents a functional view of the ITS user services. This perspective is divorced from likely implementations and physical interface requirements. It presents only the functions (process specifications) that are necessary to perform ITS services and the information (data flows) that need to be exchanged between these functions. The Logical Architecture document contains diagrams showing such processes and data flows between them. The document also contains a complete data dictionary.

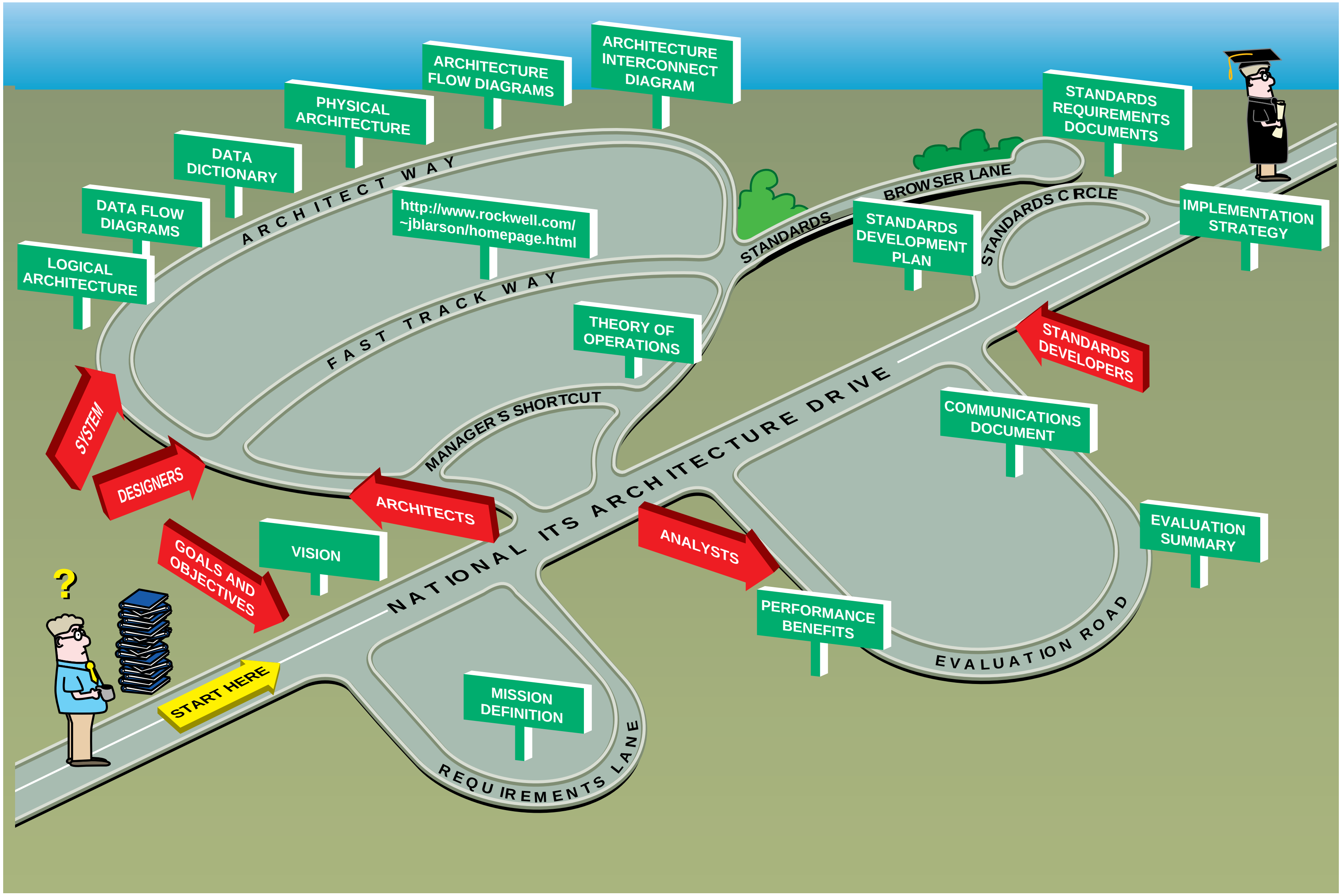
The *Physical Architecture* collects related functions together into subsystems. This document contains a collection of Architecture Flow Diagrams that show all of the data that passes between subsystems. The characteristics and constraints on the inter-subsystem data flows are also presented. The logical and physical architecture are tied together with a collection of cross-reference tables in the *Traceability Matrix*. The *Theory of Operations* provides a simple walk-through of how the architecture supports ITS implementations. This document contains easy-to-read text and diagrams that explain the operational concepts the architecture uses to implement the user services. Advantages and disadvantages of alternative operational concepts are also presented.

Several documents report the results of the numerous evaluations conducted on the architecture. Because the architecture is not something that one can directly see or touch, the evaluations are based on possible implementations. The *Communications Document* presents a thorough analysis of the communications aspects of the architecture. Analysis begins with the communications requirements resulting from analysis of the architecture data flows. Quantitative data loading requirements are proposed for a hypothetical system design whose parameters are documented in the *Evaluatory System Design*. A far reaching technology assessment is presented that covers several potential communications technology choices. These alternatives are compared with estimated ITS requirements. In particular, data loading requirements are used in a detailed simulation of one of the candidate wireless wide area communications technologies (CDPD). The document has an extensive set of appendices, each dealing with a specific communications study.

The *Risk Analysis* document assesses the risks threatening architecture deployment and suggests mitigation strategies. These strategies have been included in the overall implementation strategy for the architecture. The *Performance and Benefits Study* documents the results of a set of evaluation criteria as applied to the architecture. The results indicate that the architecture is flexible and adaptable. The document also presents an overall benefits discussion. This discussion is limited to benefits of the architecture (as opposed to benefits of ITS). ITS benefits can also be found in a number of other sources. A *Cost Analysis* document uses the same hypothetical system design used for the communication analysis, to provide a basis on which an implementor might begin to estimate the costs of deploying ITS in his jurisdiction. The evaluations are summarized in an *Evaluation Summary* document that focuses on results of the various analyses.

Support for Implementors is provided in three documents. *A Standards Development Plan* presents the steps that need to be taken to produce a collection of interface standards. The document leads a standards development organization through the architecture documents. It defines those standards that require national interoperability for nationwide deployment of ITS. Those data flows that are related to near term deployments (e.g. Intelligent Transportation Infrastructure and Commercial Vehicle Information Systems and Networks) are listed. For each deployment feature (e.g. Traffic Signal Control), either a set of existing standards activities are identified, or new standards work is recommended. In either case, architecture information should be valuable. A top level view of how to use the detailed information is presented along with a mapping from deployment features to a set of 12 standards packages. The *Standards Requirements Document* contains detailed information for each standards package. An example package is communication from the Traffic Management subsystem to the Roadside. Although NTCIP is identified as already addressing this communication link, flows exist in the architecture that are not supported by this standard.

The culmination of the architecture effort is its ultimate implementation. This is described in the *Implementation Strategy* document. The document includes sample ways in which current deployment activities can use the architecture to identify interfaces that need to be standardized. It also presents a process for rolling out ITS services. The process is part of an overall strategy that includes recommendations for future research and development, operational tests, standards activities, and training.



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Architecture Documentation Roadmap