Key Concepts of ARC-IT

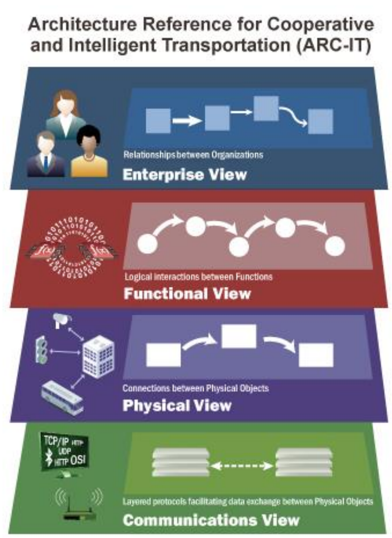
The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) provides a common framework for planning, defining, and integrating intelligent transportation systems. It is a mature product that reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.) over many years. ARC-IT, previously called the National ITS Architecture, was first developed in 1996 and has been updated many times over the years to reflect changes in technology and define new ITS services.

ARC-IT contains material that will assist agencies in the development of regional ITS architectures, which will help regions understand how an individual project fits into a larger regional transportation management context. Additionally, ARC-IT provides material facilitating the definition of projects within a regional architecture, and subsequently taking that project-focused material into systems engineering tasks such as Concept of Operations, System Requirements and System Architecture development.

ARC-IT was developed to support ITS implementations over a 20-year time period in urban, interurban, and rural environments. As a reference architecture, ARC-IT provides both the framework enabling a common language for architecture description, and the baseline material for regions to define their specific architectures; hence it uses a set of general names for the physical transportation system components in order to accommodate a variety of local design choices, changes in technology, or institutional arrangements over time. This allows the general structure of ARC-IT to remain stable while still allowing flexibility and tailoring at the local implementation level.

This paper will provide users of ARC-IT with an understanding of how ARC-IT is organized and how it relates to familiar systems of today. As background, this paper explains the essential terminology and concepts needed to understand, navigate, and use ARC-IT. The following concepts and terms are explained in this paper:

- Viewpoints and Views
- ITS Services / Service Packages
- Physical View
- Physical Objects
- Information Flows
- Functional Objects
- Functional View
- Enterprise View
- Communications View



Viewpoints and Views

ARC-IT is organized around four viewpoints, each providing a distinct perspective to understand the architecture. The approach to develop a System Architecture in this way is based on ISO/IEC/IEEE 42010:2011, a standard for "Systems and software engineering — Architecture description." This includes steps to define the full environment in which stakeholder concerns are satisfied. The figure above identifies the four Viewpoints used to describe ARC-IT: Enterprise, Functional, Physical, and Communication. This is a change from how the National ITS Architecture was originally organized at its inception in 1996, which was organized primarily around the Physical and Logical Architectures.

The viewpoints define the concepts that make up the viewpoint, together with the interrelationships between the concepts (both within a single viewpoint and between viewpoints). together with their model kinds (graphics, databases and hypertext) and interrelationships constitute ARC-IT's framework. Interrelationships describe how an element defined in a particular viewpoint relates to another element in another viewpoint. This set of 'correspondence rules' ties the ARC-IT together. This framework of viewpoints and correspondence rules provides the backdrop against which the balance of ARC-IT content is defined: For each viewpoint, there exists one view. While the viewpoint defines the rules, the view defines the content. For example, the Physical Viewpoint is organized around a set of Physical Objects and in the Physical View one of the Physical Objects is Traffic Management Center. The discussion of each View below will highlight key concepts within the view, key interrelationships between the concepts, and will draw a comparison with concepts in the previous version of the National ITS Architecture. But first the discussion will consider the scope of ITS Services considered by ARC-IT.

ITS Services/ Service Packages

The scope of ARC-IT is defined by a set of 152 ITS Services: transportation services that can be provided through the use of ITS. The range of services covered by ARC-IT is broader than the original set of 33 user services defined in earlier versions of the National ITS Architecture, incorporating all the connected vehicle applications of the Connected Vehicle Reference Implementation Architecture (CVRIA) as well as additional ITS services defined internationally.

ARC-IT uses the concept of ***Service Packages*** *to describe the portion of the architecture needed to implement the service*. Service Packages include the portions of each of the four views needed to describe the service. Details of how Service Packages are represented in the four views are given in the individual View sections below.

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. Service Packages provide a key method for entering into ARC-IT and can be used as a foundation for the development of regional and project ITS architectures.

Service Package Implementation, a subset of a service package that defines an approach for meeting the user needs of a given service package was added for Version 9.1. An implementation indicates what functions and flow triples are required, and which flows and functions may enhance the service without duplicative effort or interference. More than 50 Service Package Implementations are defined for many commonly used ARC-IT service packages.

Each Service Package has a description that addresses the scope of the service package. As shown in the example below, this description may also include reference to related Service Packages.

Table 1: Service Package Example

Traffic Signal Control (TM03) 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 TM07-Regional Traffic Management service package. This service package is consistent with typical traffic signal control systems.

Each Service Package also has an identified set of User Needs, which address the need for the service from a user (or in the parlance of ARC-IT, a stakeholder) perspective. An example of the user needs for the Traffic Signal Control Service Package are given below. Note that the need for Traffic Signal Control is expressed from the perspective of the Traffic Operations organization.

Table 2: User Needs for Traffic Signal Control

Need
Traffic Operations need to be able to remotely control traffic signals at intersections under their jurisdiction.
Traffic Operations need to be able to manage and implement control plans in order to coordinate signalized intersections.
Traffic Operations need to be able to monitor and control pedestrian crossing aspects of traffic signals in order to facilitate safe pedestrian crossings at the intersection.
Traffic Operations need to monitor the status of traffic signal control equipment.

Table 3 contains a complete list of the Service Packages, grouped by **Area of Services.** The number of Areas (12) has been expanded from the similar concept in earlier versions of the architecture in order to better highlight similar services.
Service Packages that originated outside the United States are designated with the International icon 🌐.
The term (Implementations) in the table indicates that alternative implementations have been defined for that service as a separate diagram.

Table 3: Service Packages

Area	Name
Commercial Vehicle Operations	CVO01: Carrier Operations and Fleet Management
	CVO02: Freight Administration
	CVO03: Electronic Clearance
	CVO04: CV Administrative Processes
	CVO05: Commercial Vehicle Parking
	CVO06: Freight Signal Priority
	CVO07: Roadside CVO Safety
	CVO08: Smart Roadside and Virtual WIM
	CVO09: Freight-Specific Dynamic Travel Planning
	CVO10: Road Weather Information for Freight Carriers

Area	Name
	CVO11: Freight Drayage Optimization
	CVO12: HAZMAT Management
	CVO13: Roadside HAZMAT Security Detection and Mitigation
	CVO14: CV Driver Security Authentication
	CVO15: Fleet and Freight Security
	CVO16: Electronic Work Diaries
	CVO17: Intelligent Access Program
	CVO18: Intelligent Access Program - Weight Monitoring
	CVO19: Intelligent Speed Compliance
	CVO20: International Border Registration
	CVO21: International Border Electronic Clearance
	CVO22: International Border Coordination
Data Management	DM01: ITS Data Warehouse **(Implementations)**
	DM02: Performance Monitoring **(Implementations)**
Maintenance and Construction	MC01: Maintenance and Construction Vehicle and Equipment Tracking
	MC02: Maintenance and Construction Vehicle Maintenance
	MC03: Roadway Automated Treatment
	MC04: Winter Maintenance
	MC05: Roadway Maintenance and Construction
	MC06: Work Zone Management
	MC07: Work Zone Safety Monitoring
	MC08: Maintenance and Construction Activity Coordination
	MC09: Infrastructure Monitoring
	MC10: Asset Tracking **(Implementations)**
	MC11: Maintenance and Construction Activity Coordination
Parking Management	PM01: Parking Space Management **(Implementations)**
	PM02: Smart Park and Ride System **(Implementations)**
	PM03: Parking Electronic Payment **(Implementations)**
	PM04: Regional Parking Management
	PM05: Parking Reservations
	PM06: Loading Zone Management
Public Safety	PS01: Emergency Call-Taking and Dispatch
	PS02: Emergency Response
	PS03: Emergency Vehicle Preemption **(Implementations)**
	PS04: Mayday Notification
	PS05: Vehicle Emergency Response
	PS06: Incident Scene Pre-Arrival Staging Guidance for Emergency Responders
	PS07: Incident Scene Safety Monitoring
	PS08: Roadway Service Patrols
	PS09: Transportation Infrastructure Protection
	PS10: Wide-Area Alert
	PS11: Early Warning System

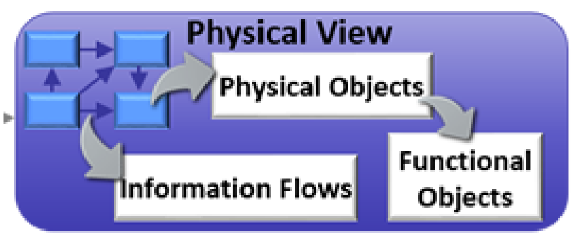
Area	Name
	PS12: Disaster Response and Recovery
	PS13: Evacuation and Reentry Management
	PS14: Disaster Traveler Information
	PS15: Stolen Vehicle Recovery
Public Transportation	PT01: Transit Vehicle Tracking
	PT02: Transit Fixed-Route Operations
	PT03: Dynamic Transit Operations
	PT04: Transit Fare Collection Management
	PT05: Transit Security
	PT06: Transit Fleet Management
	PT07: Transit Passenger Counting
	PT08: Transit Traveler Information
	PT09: Transit Signal Priority **(Implementations)**
	PT10: Intermittent Bus Lanes **(Implementations)**
	PT11: Transit Pedestrian Indication
	PT12: Transit Vehicle at Station/Stop Warnings
	PT13: Vehicle Turning Right in Front of a Transit Vehicle
	PT14: Multi-modal Coordination
	PT15: Transit Stop Request
	PT16: Route ID for the Visually Impaired
	PT17: Transit Connection Protection
	PT18: Integrated Multi-Modal Electronic Payment
Support	SU01: Connected Vehicle System Monitoring and Management
	SU02: Core Authorization
	SU03: Data Distribution
	SU04: Map Management
	SU05: Location and Time
	SU06: Object Registration and Discovery
	SU07: ITS Communications
	SU08: Security and Credentials Management
	SU09: Device Certification and Enrollment
	SU10: Center Maintenance
	SU11: Field Equipment Maintenance
	SU12: Vehicle Maintenance
	SU13: Personnel Device Maintenance
	SU14: Remote Access
Sustainable Travel	ST01: Emissions Monitoring
	ST02: Eco-Traffic Signal Timing
	ST03: Eco-Traffic Metering
	ST04: Roadside Lighting
	ST05: Electric Charging Stations Management

Area	Name
	ST06: HOV/HOT Lane Management
	ST07: Eco-Lanes Management
	ST08: Eco-Approach and Departure at Signalized Intersections **(Implementations)**
	ST09: Connected Eco-Driving
	ST10: Low Emissions Zone Management
Traffic Management	TM01: Infrastructure-Based Traffic Surveillance **(Implementations)**
	TM02: Vehicle-Based Traffic Surveillance **(Implementations)**
	TM03: Traffic Signal Control **(Implementations)**
	TM04: Connected Vehicle Traffic Signal System **(Implementations)**
	TM05: Traffic Metering
	TM06: Traffic Information Dissemination **(Implementations)**
	TM07: Regional Traffic Management
	TM08: Traffic Incident Management System
	TM09: Integrated Decision Support and Demand Management
	TM10: Electronic Toll Collection
	TM11: Road Use Charging
	TM12: Dynamic Roadway Warning
	TM13: Standard Railroad Grade Crossing
	TM14: Advanced Railroad Grade Crossing
	TM15: Railroad Operations Coordination
	TM16: Reversible Lane Management
	TM17: Speed Warning and Enforcement
	TM18: Drawbridge Management
	TM19: Roadway Closure Management
	TM20: Variable Speed Limits
	TM21: Speed Harmonization
	TM22: Dynamic Lane Management and Shoulder Use
	TM23: Border Management Systems
	TM24: Tunnel Management
	TM25: Wrong Way Vehicle Detection and Warning
	TM26: Signal Enforcement
Traveler Information	TI01: Broadcast Traveler Information **(Implementations)**
	TI02: Personalized Traveler Information
	TI03: Dynamic Route Guidance
	TI04: Infrastructure-Provided Trip Planning and Route Guidance
	TI05: Travel Services Information and Reservation
	TI06: Dynamic Ridesharing and Shared Use Transportation **(Implementations)**
	TI07: In-Vehicle Signage
Vehicle Safety	VS01: Autonomous Vehicle Safety Systems
	VS02: V2V Basic Safety
	VS03: Situational Awareness
	VS04: V2V Special Vehicle Alert

Area	Name
	VS05: Curve Speed Warning
	VS06: Stop Sign Gap Assist
	VS07: Road Weather Motorist Alert and Warning
	VS08: Queue Warning **(Implementations)**
	VS09: Reduced Speed Zone Warning / Lane Closure **(Implementations)**
	VS10: Restricted Lane Warnings
	VS11: Oversize Vehicle Warning
	VS12: Pedestrian and Cyclist Safety
	VS13: Intersection Safety Warning and Collision Avoidance
	VS14: Cooperative Adaptive Cruise Control
	VS15: Infrastructure Enhanced Cooperative Adaptive Cruise Control
	VS16: Automated Vehicle Operations
	VS17: Traffic Code Dissemination
Weather	WX01: Weather Data Collection **(Implementations)**
	WX02: Weather Information Processing and Distribution
	WX03: Spot Weather Impact Warning
	WX04: Roadway Micro-Prediction

Physical View

The Physical View describes the transportation systems and information exchanges that support ITS Services. This view is quite close in content to the Physical Architecture defined in the original version of the Architecture. In this view, the Architecture is depicted as a set of Physical Objects that interact and exchange information to support the Service Packages.



Since the Physical View is concerned with constructs in the real world, it tends to be the most approachable view from which to start. This is why when browsing Service Packages on the ARC-IT web site, users are first directed to the Physical diagram, which is representative of the portion of the Physical View that makes up the Service Package.

The Physical View is defined primarily by three constructs: Physical Objects, Information Flows and Functional Objects.

Physical Objects are defined to represent the major physical components of the ITS Architecture. Physical Objects that provide ITS functionality are referred to as subsystems, whereas those that do not provide ITS functionality are called terminators. Both types of Physical Objects exchange information in order to provide ITS services. A general "ITS" Class covers all of ITS while five more specific classes (Center, Support, Field, Vehicle, and Personal). Physical Objects in ARC-IT belong to one of 5 “classes”:

- Centers, such as a Traffic Management Center
- Field Equipment, such as a Traffic Signal Controller
- Vehicles, including specialized vehicles such as Transit Vehicles

- Personal, such as personal devices (smartphones)
- Support Systems; this class is new from previous versions and includes systems that provide non-operational use of ITS data (e.g. Archive Data Systems), and systems that provide support to a variety of services (e.g. Map Update System)

Figure 1 shows the 49 transportation subsystems of ARC-IT (organized by the 5 classes) and the general communication links used to exchange information between subsystems. This figure represents the highest-level diagram of the Physical View.

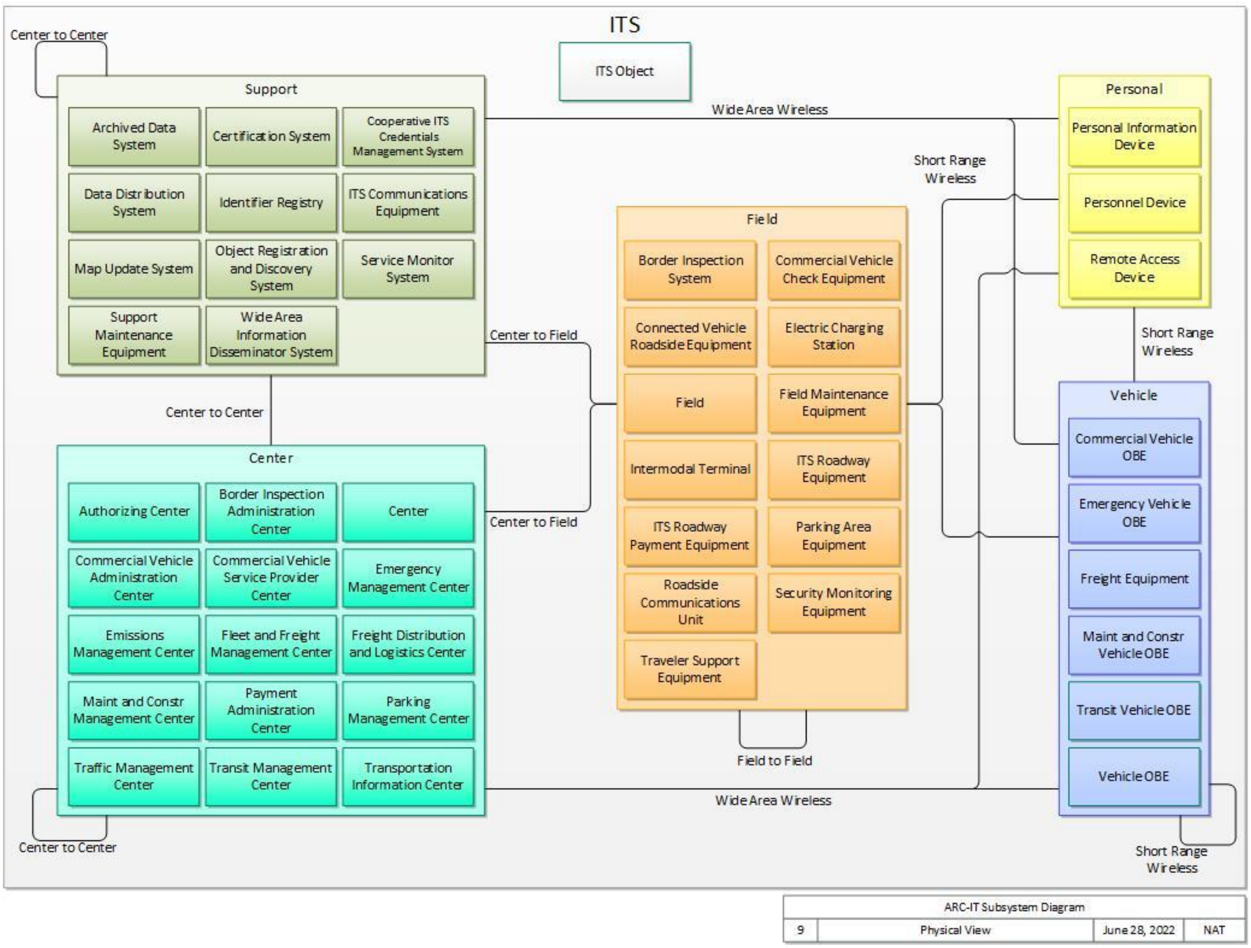


Figure 1. ARC-IT Subsystems and Communications

In addition to the 49 subsystems, the physical view defines 108 Terminators. Terminators act as "sources" or "sinks;" they provide data that can be used to provide an ITS service, or they consume data produced by an ITS service. Since a Terminator is outside the system boundary, ARC-IT does not define functionality for it. "Weather Service System" is an example of an ARC-IT Terminator. Humans that operate Subsystems (e.g. Traffic Operations Personnel) are also Terminators from the systems perspective.

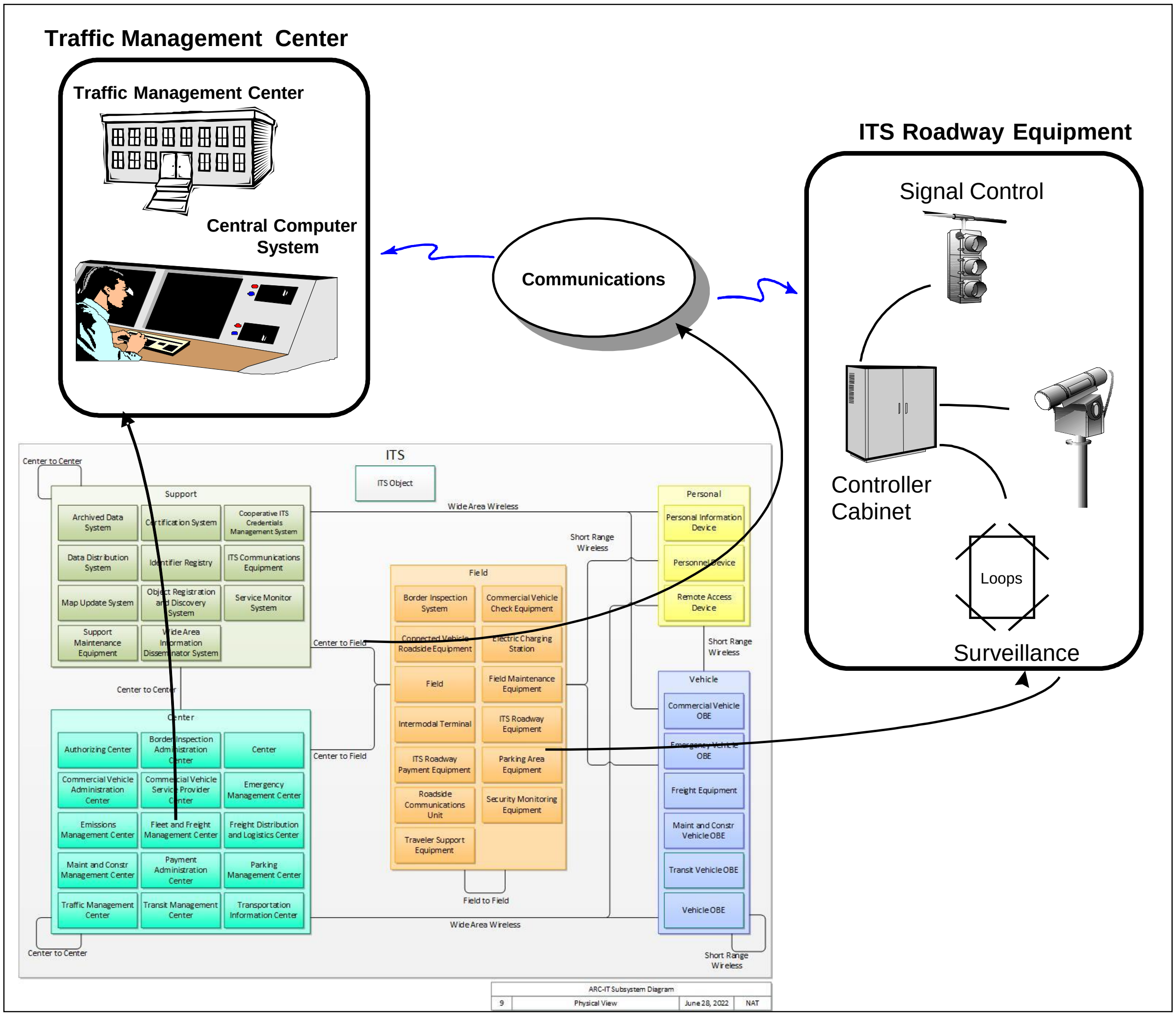


Figure 2. Basic Traffic Signal Control System Architecture Depiction

As an example of how the Physical View represents ITS implementations, consider basic traffic signal control systems, which are represented in ARC-IT by functions within 2 of the 49 subsystems: the Traffic Management Center and the ITS Roadway Equipment. This is illustrated in Figure 2, which depicts traffic signal control related elements as an overlay to the diagram just presented.

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

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

The description above is an example of an implementation of a Service Package. Figure 3 shows the ARC-IT Traffic Signal Control Service Package. The main interface shown is between the Traffic Management Center and the ITS Roadway Equipment: the eleven green and red lines between these Physical Objects are Information Flows. An Information Flow represents the flow of information from one system to another. The white rectangles in the two Subsystems are the Functional Objects, that will be further described below.

The service package includes additional interfaces to four Terminators that participate in the service (shown in the diagram as other physical objects which do not have any Functional Objects). For example, a Pedestrian can interact with the traffic signal equipment on the roadway to push a crossing request button. The color of the physical objects indicates the "class" of the object (teal for centers, orange for field equipment, blue for vehicles, green for support and yellow for personal devices).

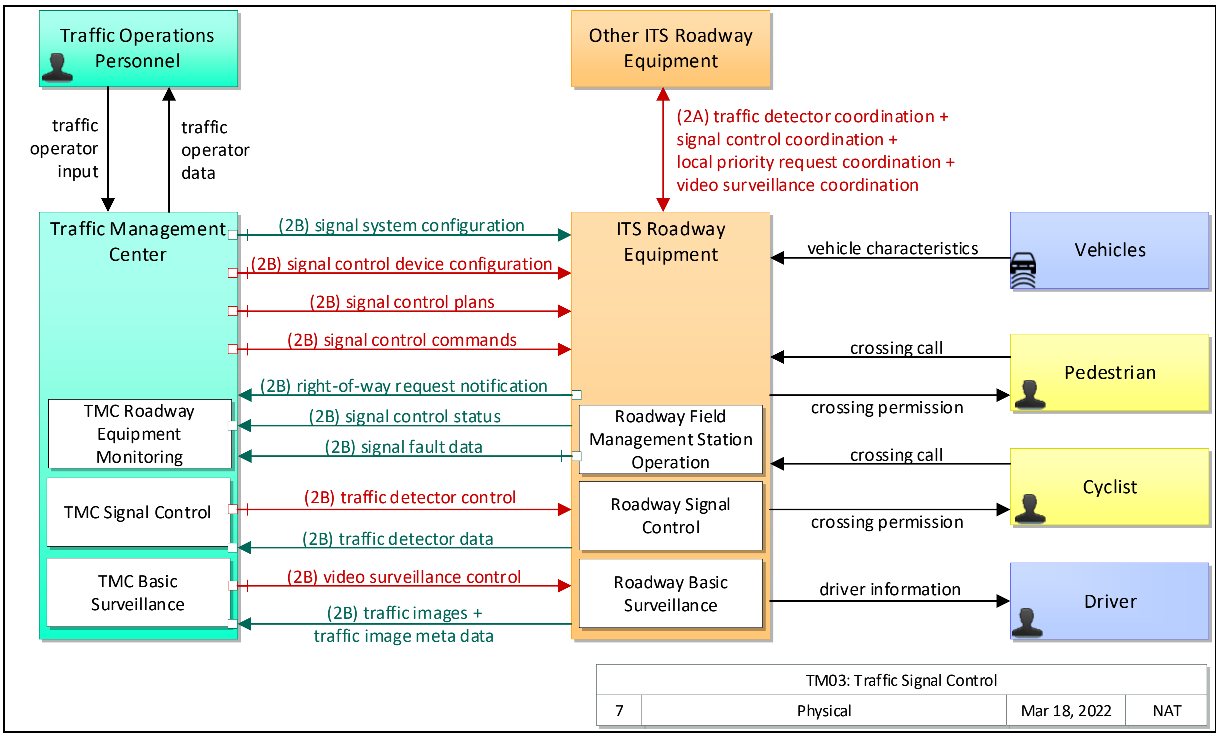


Figure 3: Traffic Signal Control Service Package Diagram

The Functional Objects are used in ARC-IT to group like functions of a particular Subsystem together into an "implementable" package of hardware and software. The grouping of functions also takes into account the scope of the service package and its defined needs. ARC-IT has defined 389 Functional Objects in total. Each Functional Object is defined by a description and is mapped to a set of functional requirements. Table 4 illustrates an example of a Functional Objects description from one of the functional objects shown in the Service Package diagram above: "TMC Signal Control".

Table 4. Functional Object Example

'TMC Signal Control' 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 Center and are responsive to traffic conditions and adapt to support incidents, preemption and priority requests, pedestrian crossing calls, etc.

Each Functional Object also includes 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 Functional object are shown in Table 5.

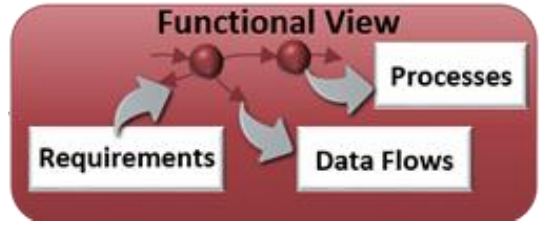
Table 5. Functional Requirements Example

TMC Signal Control Functional Requirements:
01 The center shall remotely control traffic signal controllers.
02 The center shall accept notifications of pedestrian calls.
03 The center shall collect traffic signal controller operational status and compare against the control information sent by the center.
04 The center shall collect traffic signal controller fault data from the field.
05The 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.
06 The center shall implement control plans to coordinate signalized intersections based on data from sensors.
07 The center shall manage boundaries of the control sections used within the signal system.
08 The center shall maintain traffic signal coordination including synchronizing clocks throughout the system.
09 The center shall implement control plans to coordinate signalized intersections based on data from sensors and connected vehicles.
10 The center shall adjust signal timing in respond to a signal prioritization, signal preemption, pedestrian call, multi-modal crossing activation, or other requests for right-of-way.
11 The center shall collect commercial vehicle data (e.g., characteristics, route, schedule) for intermodal freight events.
12 The center shall adjust signal timing in respond to traffic and environmental parameters at each intersection in real time and adapts so that the traffic network is optimized using available green time to serve the actual traffic demands while minimizing the environmental impact.
13 The center shall process collected traffic and environmental data from sensors and connected vehicles.
14 The center shall support requests from emergency management centers to provide responding emergency vehicles with signal preemption.
15 The center shall monitor, analyze, and store traffic sensor data (speed, volume, occupancy) collected from field elements at or near signalized intersections.
16 The center shall maintain a database of traffic sensors and associated data (including the roadway on which they are located, the type of data collected, and the ownership of each).
17 The center shall remotely control devices to detect traffic in the vicinity of traffic signals.

These functional requirements are traced to the needs defined for each Service Package. In addition, you will notice that the set of functional requirements above covers a larger scope than just the Traffic Signal Control service package. This is because Functional Objects can be included in many different Service Packages. For example, the TMC Signal Control functional object is included in the following service packages, which explains the breadth of the requirements:

- Connected Vehicle Traffic Signal System
- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Emergency Vehicle Preemption
- Freight Signal Priority
- Infrastructure Enhanced Cooperative Adaptive Cruise Control
- Intersection Safety Warning and Collision Avoidance
- Maintenance and Construction Signal Priority
- Traffic Signal Control
- Transit Signal Priority

Functional View



ARC-IT's Functional View defines a set of functions (or processes) and data flows that respond to a set of requirements. This view closely corresponds with the Logical Architecture in previous versions. The functional view includes a hierarchical set of processes and data flows that are analogous to, and based on, the processes and data flows that were included in previous versions of the National ITS Architecture and CVRIA. The processes and data flows have been extended using the structured analysis that underlies the functional view to cover all ARC-IT service packages and needs. Figure 4 shows the top-level hierarchy of the Functional View, with 10 process collections that represent the top level of the hierarchy.

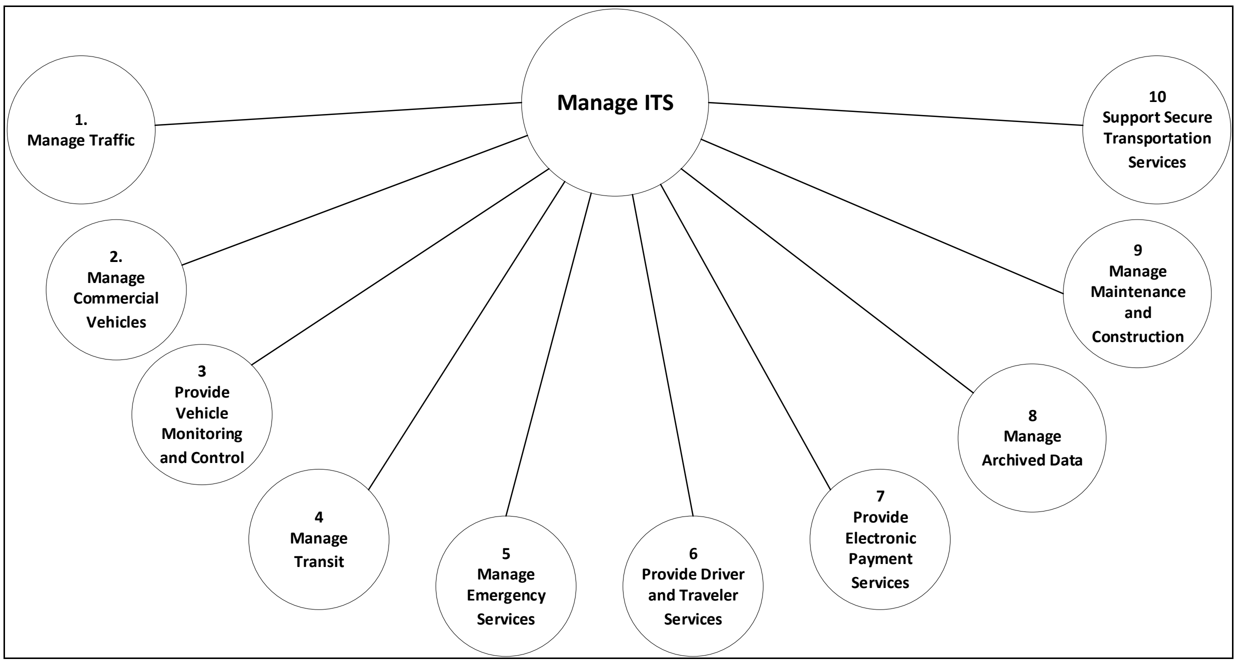


Figure 4: Functional Hierarchy

At each level of the hierarchy, if a process has additional processes below it (e.g. child processes) then the process is identified as a collection. If a process has no further processes defined below it then it is called a process specification or pspec. These pspecs can be thought of as the elemental functions to be performed in order to satisfy requirements (i.e., they are not broken out any further). The information exchanges between processes are called the data flows. Example overview descriptions of pspecs relevant to traffic signal control systems are given in Table 6 below.

The functional view is mapped to the physical view in two key ways. First, each pspec is mapped to only one physical object and one or more functional objects. For example, the pspecs shown in Table 6. Process Specifications ExampleTable 6 all map to the Traffic Management Center physical object, and within that physical object all of these pspecs map to the TMC Signal Control functional object.

Table 6. 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.

The second connection between the physical and functional views is with the mapping of data flows to information flows. Each information flow of the physical view has one or more data flows of the functional view mapped to the information flow. For example, the information flow *signal control device configuration* (which goes from the Traffic Management Center to ITS Roadway Equipment) is mapped to the data flows: *indicator_control_configuration_data_for_signal_control* and *signal_system_configuration.* This illustrates that one information flow may map to multiple data flows.

Enterprise View

The Enterprise View addresses the relationships between organizations and users, and the roles those entities play in the delivery and consumption of ITS services. Relationships between entities are dependent on the roles those entities take in the delivery of user services. A general expression of user needs (which are defined for each Service Package) serve as the overarching organizational rationale for each of the ITS services described by the Service Packages.

The building blocks of ARC-IT's Enterprise View are Enterprise Objects, which are organizations or individuals that interact with other Enterprise Objects and/or Physical Objects in order to exchange information, manage or operate systems beyond the scope of one organization. The Enterprise View focuses on the relationships between those Enterprise Objects, but also defines how Enterprise Objects interact with Physical Objects. The ARC-IT website provides the roles and relationships for the enterprise objects. These roles and relationships are defined for each service package across four phases of the systems life cycle:

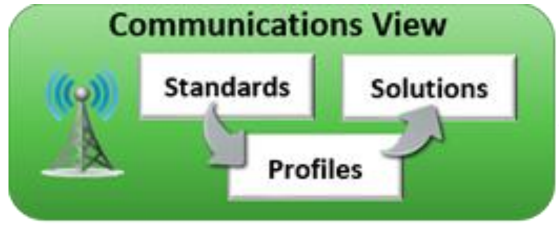
- Development
- Installation
- Operations
- Maintenance

As an example, for the Traffic Signal Control service package, Table 7 shows the Roles and Relationships defined for the Operations and Maintenance phase.

Table 7: Example of Roles and Relationships for the Operations Phase

Source	Destination	Role/Relationship
ITS Roadway Equipment Maintainer	ITS Roadway Equipment	Maintains
ITS Roadway Equipment Manager	ITS Roadway Equipment	Manages
ITS Roadway Equipment Owner	ITS Roadway Equipment Maintainer	System Maintenance Agreement
ITS Roadway Equipment Owner	ITS Roadway Equipment Manager	Operations Agreement
ITS Roadway Equipment Owner	Other ITS Roadway Equipment Owner	Information Exchange and Action Agreement
ITS Roadway Equipment Owner	Traffic Management Center Owner	Information Exchange Agreement
ITS Roadway Equipment Supplier	ITS Roadway Equipment Owner	Warranty
Other ITS Roadway Equipment Maintainer	Other ITS Roadway Equipment	Maintains
Other ITS Roadway Equipment Manager	Other ITS Roadway Equipment	Manages
Other ITS Roadway Equipment Owner	ITS Roadway Equipment Owner	Information Exchange and Action Agreement
Other ITS Roadway Equipment Owner	Other ITS Roadway Equipment Maintainer	System Maintenance Agreement
Other ITS Roadway Equipment Owner	Other ITS Roadway Equipment Manager	Operations Agreement
Other ITS Roadway Equipment Supplier	Other ITS Roadway Equipment Owner	Warranty
Traffic Management Center Maintainer	Traffic Management Center	Maintains
Traffic Management Center Manager	Traffic Management Center	Manages
Traffic Management Center Manager	Traffic Operations Personnel	System Usage Agreement
Traffic Management Center Owner	ITS Roadway Equipment Owner	Information Exchange Agreement
Traffic Management Center Owner	Traffic Management Center Maintainer	System Maintenance Agreement
Traffic Management Center Owner	Traffic Management Center Manager	Operations Agreement
Traffic Management Center Supplier	Traffic Management Center Owner	Warranty
Traffic Operations Personnel	Traffic Management Center	Operates

Communications View



The Communications View describes the protocols necessary to provide interoperability between Physical Objects in the physical view. Each triple from the Physical View (defined as source Physical Object, Information Flow, destination Physical Object) has been mapped to a set of standards or published specifications that together can be used to build an interoperable implementation. ARC-IT organizes the standards into 'Profiles' that identify complementary communications standards and specifically includes standards that will support secure ITS communications. The combination of a profile that identifies the communications stack along with ITS Application performance, message and data dictionary standards are assembled into a communication 'Solution' for each information flow triple in the physical view.

A typical communications solution is illustrated by a diagram that shows the standards in the solution, as shown in Figure 6. The diagram shows a specific communications solution, which includes the profiles or standards that provide data, management, facilities, and security for the triple. The example below shows the solution for the *signal control status* information flow from ITS Roadway Equipment to the Traffic Management Center that is part of the Traffic Signal Control Service Package.

Selected Solution

US: NTCIP Traffic Signal - SNMPv3/TLS

Solution Description

This solution is used within the U.S.. It combines standards associated with US: NTCIP Traffic Signal with those for I-F: SNMPv3/TLS. The US: NTCIP Traffic Signal standards include upper-layer standards required to implement center-to-field traffic signal communications. The I-F: SNMPv3/TLS standards include lower-layer standards that support secure center-to-field and field-to-field communications using simple network management protocol (SNMPv3); implementations are strongly encouraged to use the TLS for SNMP security option for this solution to ensure adequate security.

Figure 5. Communications Solution for NTCIP Traffic Signal - SNMPv3/TLS

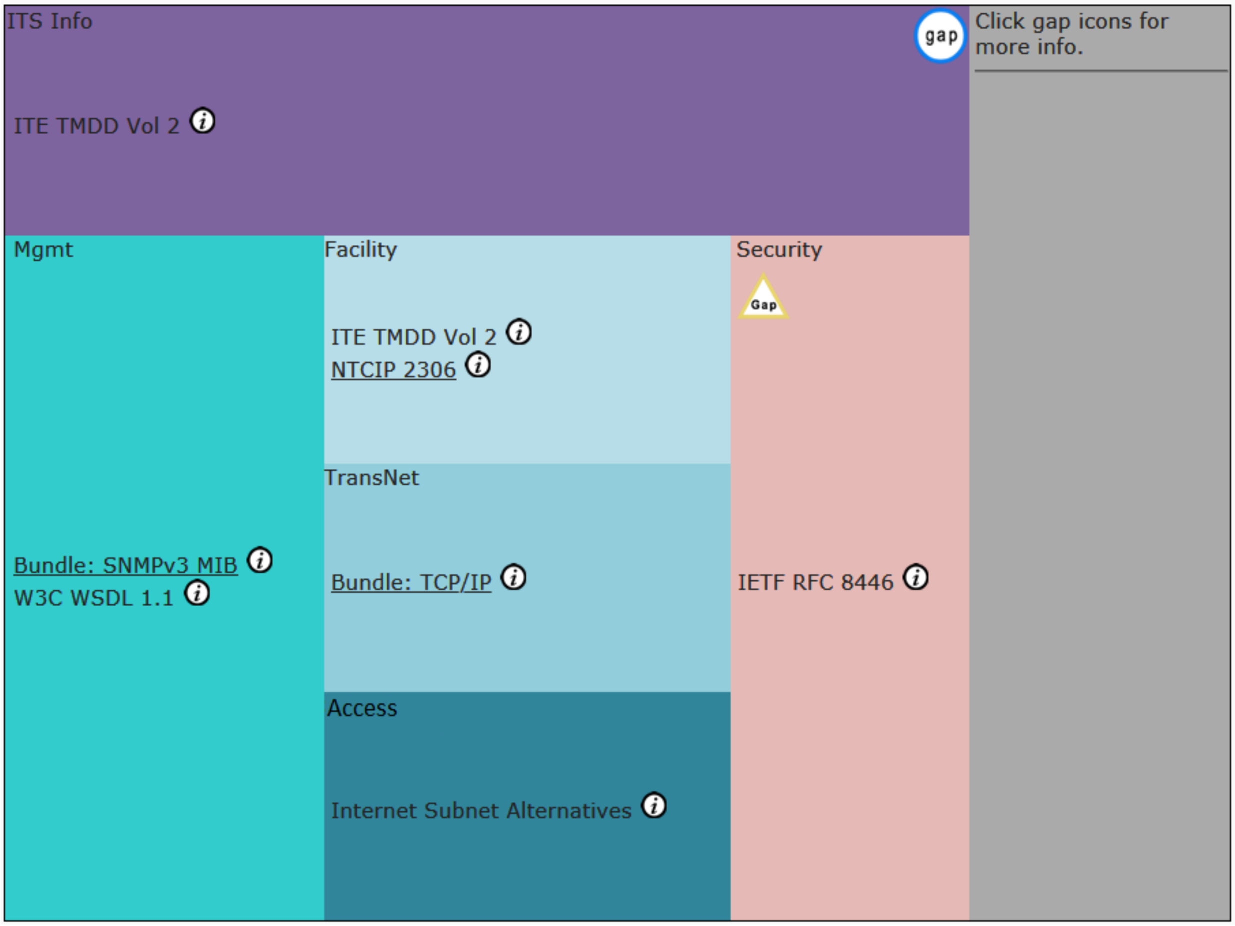


Figure 6: Example Communications Diagram

The communications view also defines issues associated with the application of a particular set of standards to satisfying an ARC-IT triple. Issues can identify a gap in a particular standard, or a mismatch between a set of standards, or a gap related to the assignment of a particular solution to a particular triple. Some solutions are assigned as a 'best effort' solution; that is, what ARC-IT thinks is the best way to implement this triple today, but issues suggest that some challenges remain. Sometimes issues take a temporal nature; for example, a set of standards might have built an ideal solution at one time, but some aspect of the technological (or other) landscape changed, and now that set of standards is no longer wholly sufficient and require additional work. Lastly, sometimes an issue is not a gap, but an overlap between two competing solutions or standards.

Summary

ARC-IT provides a framework for the description of ITS systems. It defines the functions that must be performed by the Physical Objects where these functions reside (e.g., field, traffic management center, or in-vehicle), the interfaces and information flows between the physical objects, and the communications requirements for the information flows in order to address the underlying user needs. Since ARC-IT is also the foundation for much of the ongoing ITS standards work, consideration of the interface and information exchange requirements established by ARC-IT today will likely facilitate or ease the transition to incorporating standards-compliant interfaces in the future.