Northern Virginia
Intelligent Transportation System (ITS)
Early Deployment Study

# Final Report: *Advanced Traffic Management System (ATMS) Implementation Plan*

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## DISTRIBUTION OF REPORT

This final report is a supplement to the ITS Strategic Deployment Plan for the Northern Virginia Region. It's primary purpose is to provide a tactical plan for the potential integration of traffic control systems in the Northern Virginia Region.

**Distribution of this report is being made** to **the Federal Highway Administration, the Virginia Department of Transportation, and the jurisdictions/agencies identified under this project as the primary tier of stakeholders in the advancement of traffic management in the region. Any subsequent distribution of the this report will be at the discretion of the Virginia Department of Transportation.**

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# SECTION 1.0 INTRODUCTION

## 1.1 PURPOSE OF PLAN

The Advanced Traffic Management System (ATMS) Implementation Plan for the Northern Virginia Region is intended to specifically address a growing need to integrate the advanced traffic control systems deployed or under development in the region into a true ATMS. The plan focuses on four areas including: the system functional requirement; the development of a system architecture for a region-wide ATMS; the identification of advanced technology to support the systems architecture; and recommendations for a phased plan to implement ATMS in Northern Virginia.

Preparing an implementation plan for ATMS requires that this term be defined. For the purposes of this report, ATMS is the use of technology to actively control, coordinate, and manipulate traffic flows on the regional roadway network. In order to achieve this, the system must: collect, process, and evaluate data in real-time; aid in developing and coordinating a response to demand on network operations; implement a response; and provide the users of the network with timely and accurate information concerning network status, travel options, and other decision support oriented information to aid in optimizing network operations at the highest possible level of safety, efficiency, and convenience to the users. The system should also support other regional **ITS efforts** by providing effective data exchange with the other ITS subsystems under consideration for Northern Virginia.

### 1.1.1 Regional ITS Functional Drivers

Over recent months, and in conjunction with the on-going development of an Intelligent Transportation System (ITS) Strategic Deployment Plan for the region, a User Services Plan for ITS deployment was completed as an interim report on the overall ITS deployment plan progress. Through this effort, the study team formulated local deployment objectives based on the transportation information issues, needs, and requirements as seen by the collective group of primary jurisdictions and agencies in the region. This primary tier have a vested interest in advanced technology applications to the operation of the regional network. Of the objectives defined, six are identified herein as the primary objectives, or functional drivers, for ITS deployment. These are presented in **Table I-l.**

These objectives reinforce the study team's recommendations in defining guidelines for further development of an integrated regional transportation operations concept and are particularly applicable to the requirements of a regional ATMS. Functionally, the ATMS implementation strategy is the foundation upon which cooperation and coordination of the operating transportation agencies and organizations is intended to support continuing development of the transportation infrastructure, and is to create opportunities for private sector involvement, particularly with the development of a supporting communications infrastructure.

**TABLE 1-1**
**REGIONAL ITS FUNCTIONAL DRIVERS**

- Provide a common framework for interagency communications and coordinated management of the transportation network;
- Enhance the credibility of system operations through improved information processing and dissemination to the system users;
- Establish automated inter-jurisdictional information exchange capabilities;
- Examine methods by which independent GIS development activities in the region can be integrated to reduce maintenance intensive efforts to continuously update system(s);
- Provide integrated, multi-jurisdictional database(s) as a regional resource;
- Consider the extent to which expert or predictive system(s) can be utilized to provide decision support in implementing transportation system operation plans.

## 1.2 COORDINATION WITH ITS STRATEGIC DEPLOYMENT PLAN

Given the characteristics of the transportation network in the Northern Virginia Region -- similar to other major metropolitan regions in the United States – the ATMS component of the overall ITS deployment strategy is the basic building block for advanced technology applications. This is largely due to the historical emphasis placed on improving traffic operations as the focus of enhancing mobility and safety in travel, mitigating traffic congestion, and reducing environmental impacts. This also holds true for the Northern Virginia Region.

There is, however, a growing interdependence on interfacing regional traffic operations with travel demand management, public transportation management, emergency management, and commercial vehicle operations to continually provide an acceptable level of mobility to the users of the transportation network, while optimizing safety and providing ease of system use for the end users. As a result, an effective ATMS implementation strategy for Northern Virginia needs to consider the interface requirements for traffic management with these other user service areas.

### 1.2.1 User Service Deployment Recommendations

Section 5.0 of the *Interim Report: User Services Plan* presented the study team's recommendation for region-wide ITS user service deployment by time frames. The deployment time frames were: Near-Term (1997-l 999); Mid-Term (2000-2005); and Long-Range (2006-2012). Excerpted from that analysis, in **Table** 1-2, are the user services primarily applicable to an ATMS implementation strategy.

**TABLE 1-2**

**ATMS USER SERVICE DEPLOYMENT TIME FRAMES**

| USER SERVICE | SHORT TERM (1997-1999) | MID TERM (2000-2005) | LONG RANGE (2006-2012) |
|---|---|---|---|
| **Travel & Transportation Management** | | | |
| En-Route Driver Information * | ○ | ● | |
| Route Guidance | ○ | ● | |
| Traffic Control | ○ | ● | |
| Emissions Testing and Mitigation * | | ○ | ● |
| **Travel Demand Management** | | | |
| Demand Management & Operations * | | ○ | ● |
| **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 * | ○ | ● | |
| **Emergency Management** | | | |
| Emergency Notification & Personal Security* | | ○ | ● |
| Emergency Vehicle Management | ○ | ● | |
| Incident Management | ○ | ● | |
| Hazardous Materials Identification | ○ | ● | |

0 = Partial Deployment
● = Full Deployment
* = Secondary to ATMS Deployment

The primary tier of user services identified for ATMS deployment are those directly relating to transportation management, public transportation operations, and emergency management. The user services identified in Table 1-2 with an '*' have been specifically noted to be secondary to the development of the core ATMS. The deployment of these user services is dependent on the continuing development of a strategy to fully integrate all of the surface transportation subsystems in the region to provide total transportation systems management, with seamless boundaries between the various transportation modes and the numerous independent operating systems that currently exist in the region.

### 1.2.2 Coordinated Transportation System Operations Concept

The ATMS Implementation Plan represents the tactical element of the overall ITS deployment strategy. The key element of this relationship is the concept presented with an integrated user service deployment recommendation to establish a Transportation Management Coordination Center (TMCC) for the region to provide total transportation system management coordination. With respect to transportation operations, four regional management systems were identified to provide deployment of the user services relating to network operations: traffic operations, transit operations, emergency management services, and commercial vehicle operations.

The most effective ATMS implementation strategy will require the integration of two of the proposed primary subsystems -- traffic operations and emergency management services. A third, transit operations, is also recommended for partial inclusion in the ATMS deployment strategy for the purposes of utilizing transit schedule adherence data as input to the overall operations model for determining network link travel times, where applicable, and interface with arterial traffic signal operations to implement specific control strategies such as signal preemption and prioritization schemes. A fourth key element of the ATMS implementation strategy, as it relates to the proposed overall ITS, is that the communications infrastructure required for ATMS deployment becomes the backbone communication component for a region-wide ITS.

### 1.2.3 Needed Functional Areas

From Table 1-2, and in coordination with the ITS National Program Plan (NPP), the recommended user service deployments were analyzed against the main technology functions identified in the NPP to identify the general areas of supporting technologies required for ITS user services deployment.

With either partial or full user service deployments recommended in the near-term (1997-1999), all but seven of the sixteen technology functions are required to support the ATMS/ITS implementation. The seven -- routing data processing, traffic prediction data processing, traffic surveillance, signalized traffic control, traffic control data processing, in-vehicle sensors, and restrictions traffic control -- are viewed as not fully deployable until the supporting infrastructure for coordinated transportation systems management is in place. This is not expected to occur until the end of the mid-term time frame.

**TABLE I-3**
**NEEDED FUNCTIONAL AREAS**

| TECHNOLOGY FUNCTION | SHORT TERM (1997-1999) | MID TERM (2000-2005) | LONG RANGE (2006-2012) |
|---|---|---|---|
| 1-Way Mobile Communications | ● | | |
| 2-Way Mobile Communications | ● | | |
| Data Base Processing | ● | | |
| Individual Traveler Interface | ● | | |
| Navigation | ● | | |
| Routing Data Processing | ○ | ● | |
| Stationary Communications | ● | | |
| Traffic Prediction Data Processing | ○ | ● | |
| Traffic Surveillance | ○ | ● | |
| Variable Message Displays | ● | | |
| Payment Systems | ● | | |
| Signalized Traffic Control | ○ | ● | |
| Traffic Control Data Processing | ○ | ● | |
| In-Vehicle Sensors | ○ | ● | |
| Vehicle Surveillance | ● | | |
| Restrictions Traffic Control | ○ | ● | |

0 = Partial Deployment
● = Full Deployment

While traffic surveillance is considered partially deployable in the near-term for region-wide ATMS/ITS deployment, it is to consist of technology applications that will provide wide-area traffic surveillance capabilities to monitor network operations. At present, existing systems and systems under deployment in the region rely almost totally on point-detection capabilities supported by visual surveillance and verification. It is anticipated this surveillance methodology will be prevalent in the region until it is replaced by technological advances in cost-effective satellite communications and other surveillance techniques to allow for wide-area monitoring of traffic movement within the network or until it reaches the end of its useful service life, whichever occurs first.

## 1.3 APPROACH AND METHODOLOGY

As previously stated, the ATMS Implementation Plan is the tactical element of the region-wide ITS strategic plan to deploy advanced systems to manage, coordinate, and manipulate traffic flows on the regional roadway network. With several current ITS initiatives underway in the region, developing a supporting communications infrastructure for effective and efficient exchange of information between the numerous jurisdictions and agencies involved in traffic and traffic-related operations becomes the initial focus of the ATMS tactical deployment. The primary tier of jurisdictions and transportation-oriented agencies identified for potential participation in ATMS deployment are listed in **Table 1-4** below.

**TABLE 1-4**
**PRIMARY TIER JURISDICTIONS/AGENCIES**

| **National/Federal** | **State** | **Local** (cont.) |
|---|---|---|
| - FHWA-VA Division<br>- Federal Transit Administration (FTA)<br>**Regional**<br>- Northern Virginia Transportation Commission (NVTC)<br>- Potomac and Rappahannock Transportation Commission (PRTC)<br>- Virginia Railway Express (VRE)<br>- Washington Metropolitan Area Transit Authority (WMATA)<br>- Metropolitan Washington Airport Authority (MWAA) | - VDOT-Central Offices<br>- Virginia Department of Rail & Public Transportation (VDRPT)<br>- Virginia State Police<br>**Local**<br>- City of Alexandria<br>_ City of Fairfax<br>- City of Falls Church<br>- City of Manassas<br>- City of Manassas Park<br>- Arlington County<br>- Fairfax County<br>- Loudoun County<br>- Prince William County<br>- Town of Herndon | - Town of Leesburg<br>- Town of Vienna<br>**Local Emergency**<br>- Arlington Co. Police Dept.<br>- Arlington Co. Fire Dept.<br>- Fairfax Co. Police Dept.<br>- Fairfax Co. Fire Dept.<br>- Loudoun Co. Fire & Rescue Services<br>- Prince William Co. Police Dept.<br>- Prince William Co. Fire Dept.<br>- City of Alexandria Police Department<br>- Department of Emergency Services |

While this report provides information regarding traffic management improvement needs, its primary focus is the assessment of the functional requirements, and the logical and physical architectures for information exchange improvement. In addition, it yields the definition of a recommended implementation sequencing priority to build the communications infrastructure required in the mid-term and long-range ITS deployment phases with the coordination, collaboration, and cooperation of this primary tier of jurisdictions and transportation agencies.

# SECTION 2.0 FUNCTIONAL REQUIREMENTS/ARCHITECTURE

## 2.1 INTRODUCTION

The contents of this section provide an overview of the recommended system objectives, the defined ATMS functional requirements, and the system architecture for the region. A system architecture is the framework that describes how system components interact and work together to achieve system goals. The architecture describes what the system operation is, what each component of the system does, and what information is exchanged among the components,

System architecture may be divided into two kinds: logical and physical. In a broad sense, the logical architecture describes how the information flows as well as from and to which component: while the physical architecture describes how and what technologies are used to fulfill the goals of the logical architecture. Since many alternative technologies may be used to perform the same function in the logical architecture, many alternative physical architectures can be used to fulfill the goals of the logical architecture.

The assessment of functional requirements and the architecture development effort for the NoVA ATMS includes the following:

- **Identifying System Objectives**
  Identifying specific top-level system objectives for the implementation of an ATMS in the Northern Virginia Region based on the recommendations of the User Service Plan.

- **Identifying Architecture Guiding Principles**
  Developing general principles to guide the architecture development so that it fulfills the system objectives.

- **Developing a Logical Architecture**
  Identifying the different functional processes that are required to achieve the system objectives and the data flows between these processes.

- **Defining Decision Support Systems**
  Evaluating functional requirements for the different support systems or components that are required to support the processes identified in the logical architecture.

- **Developing a Physical Architecture**
  Involves the development of the physical architecture based on the logical architecture and the support system requirements, while taking into account existing infrastructure, institutional arrangements and issues, and technological factors.

- **Evaluating the Communications infrastructure**
  Identifying the communications infrastructure requirements to support the physical architecture recommended earlier.

## 2.2 SYSTEM OBJECTIVES

The recommended specific top-level system objectives for the implementation of an ATMS in Northern Virginia are summarized in **Table 2-1.** These objectives are also supported by four principles recommended to guide the development of the NoVA ATMS Architecture. In conjunction with the system objectives, these principles include:

- Leveraging the existing and planned infrastructure to the maximum extent;
- Accommodating increasing levels of system integration in a phased deployment;
- Assuring equity in benefits and costs while splitting infrastructure elements over different agencies: and
- Promoting interjurisdictional coordination and cooperation.

**TABLE 2-1**
**ATMS SYSTEM OBJECTIVES**

| |
|---|
| ▪ Incorporate the various components currently in place into a unified system in an evolutionary manner consistent with advanced technology development: |
| ▪ Integrate a common communications platform to facilitate data sharing, coordination, and policy deployment, through out the various jurisdictions in the region; |
| ▪ Expand the existing surveillance network to include major arterials and expansion of the traveler information systems include these areas; |
| ▪ Provide an integrated environment between the arterial signal control systems and the freeway management systems; |
| ▪ Provide advanced monitoring features of system field components including controllers, detectors, communications, and other equipment: |
| ▪ Allow for future expansion to control all foreseeable traffic control devices; |

- Provide an integrated environment between the traffic control systems and emergency services;
- Provide an automated method for evaluating system performance;
- Support efficient administration of maintenance operations with the development of integrated maintenance management systems;
- Provide ability to exchange traffic flow, systems operation, maintenance information, control commands, and messages between jurisdictions and agencies;
- Provide for the management of all related system data in a format that can be easily accessed through industry standard database managers; and
- Enhance user perspective of system status with graphical user interfaces (GUI) to facilitate system management, operations, and dissemination of information.

## 2.3 LOGICAL ARCHITECTURE

The logical architecture identifies the functions required by the system to meet the user needs and to implement the associated ATMS user services (Table 1-2). In order to develop the logical architecture, it is necessary to understand the context of the system needed to fulfill the requirements of the identified ATMS-related user services. First, the primary categories of external data sources, data providers, and data users are identified. These primary categories are then further decomposed to identify specific terminators in the context of the ATMS architecture.

### 2.3.1 Context Diagram

The NoVA ATMS logical architecture context diagram, shown in **Figure 2.1,** provides a definition of the architecture boundary. It is made up of the ATMS functional process and a large number of terminators. The terminators provide the system interface information to support the user service requirements identified in the User Service Plan. Each of the terminators represents an external entity that communicates data to, or receives data from the ATMS functional process. The terminators are grouped into the following four categories: Users (Center Personnel, Roadside Personnel, Vehicle Operator or Traveler), System (Center System, Roadside System and Vehicle System), Environment, and other Subsystems (other Centers).

- **User Terminators:** These are the personnel at ATMS Center subsystems and Roadside subsystems as well as Drivers and Travelers who interact with ATMS subsystems. The primary external data

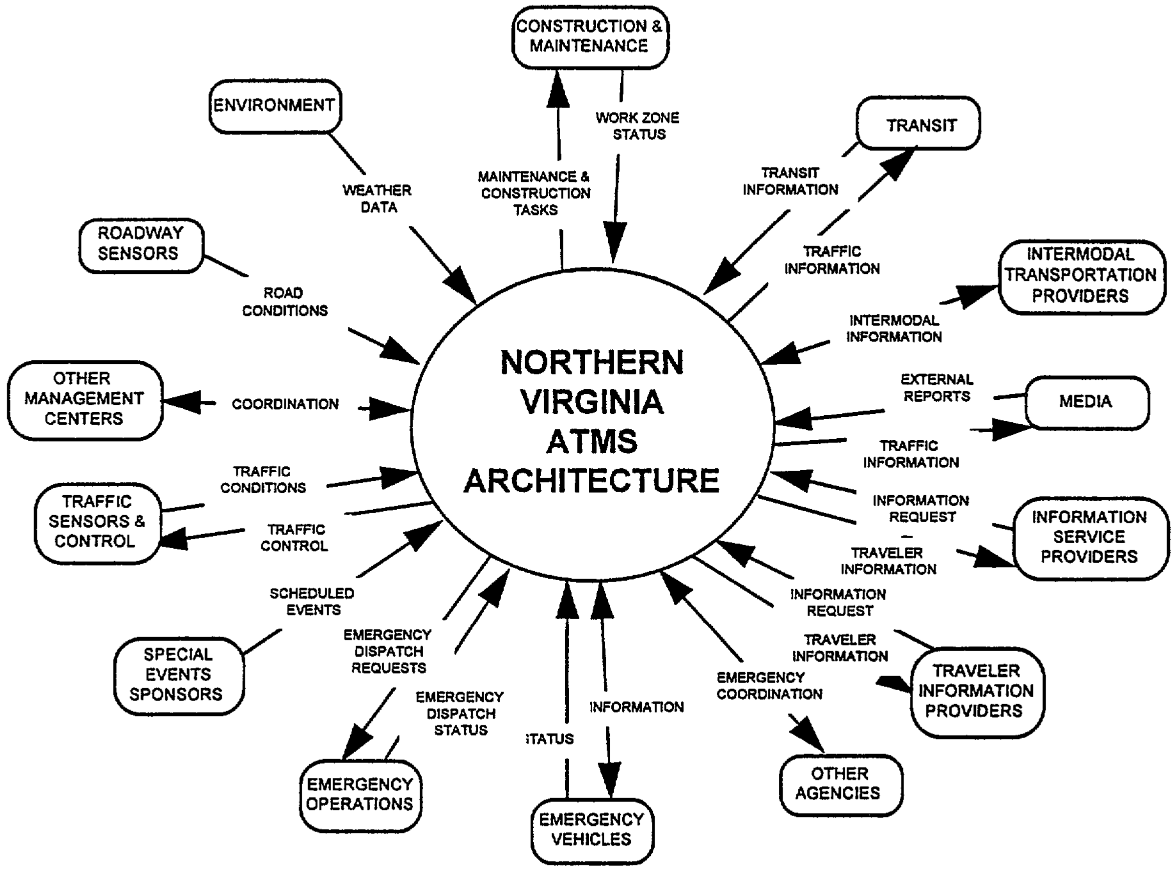


**Figure 2.1 - Logical Architecture Context Diagram**

sources, data providers, and data users in this category include:

Construction and Maintenance: Roadway maintenance personnel, roadway construction personnel, or other work crew personnel.
Media: Entities which gather or disseminate information to the public (television, radio, newspaper, traffic reporting services, etc.)
Information Service Provider: Providers of ATMS information.
Travel Information Provider: Providers of any information oriented towards the traveler.
Emergency Vehicles: Police, fire, ambulance, towing or other special response vehicles.
Emergency Operations: Emergency operations centers responsible for managing an emergency fleet (fire, police, ambulance, HAZMAT, etc.)

Other Control Centers: Other jurisdictions, agencies, and traffic management centers which interface to the architecture.

- **System Terminators:** These are the non-ATMS centers (e.g., government agencies ATMS will interact with), roadside systems (e.g., traditional signals and sensors) and vehicle systems that ATMS will interact with. Primary external sources, providers, and users of this category include:

  Other Agencies: Non-jurisdictional agencies and service providers who may be called to participate in an emergency response.

  Transit: Entity(ies) responsible for monitoring, managing, and planning the transit fleets.

  Roadway Sensors: Sensors which report roadway conditions.

  Traffic Sensors and Control: Traffic flow control and surveillance information.

- **Environment Terminators:** The environment—snow, ice, etc.—is sensed by ATMS subsystems.

  Environment: Sensors which report weather and other operations and information centers that the NoVA ATMS Architecture interacts with.

  Intermodal Transportation Providers: Non-roadway transportation providers (airplanes, ships, trains, etc.).

  Special Events Sponsors: External entities which control, manage, or organize events which may affect the roadway.

As previously noted, the context diagram – Figure 2.1 – represents the functionality required to support these external data sources, data sources, data providers, and data users associated with the Northern Virginia ATMS. The functional decomposition of the logical architecture is provided in the following section.

### 2.3.2 Functional Decomposition

The next step in developing the logical architecture is to group the functional requirements into functional processes. These processes identify the data flow needs between the ATMS Architecture and the terminators. The functions derived from the functional requirements form the basis of the logical architecture for the ATMS. This section contains the data flow diagrams for the NoVA ATMS Logical Architecture. Four processes are included in the NoVA ATMS: traffic management; emergency services; public transportation management; and traveler information services. The modular nature of this architecture allows a phased deployment of functions depending on the needs and funding availabilities of the participating jurisdictions and agencies. The functions performed by each tree of processes are described on the following pages.

#### 2.3.2.1 Traffic Management Process

This functional process includes the functionality needed for the management of traffic in the network. Included are traffic surveillance, traffic control, incident detection, demand management and emissions management functions, plus all associated capabilities. The traffic surveillance, traffic control, and incident detection facilities work closely together to both detect incidents from the traffic data and minimize the impact on the flow of traffic in the network. A link is provided to the emergency services function so that detected incidents can be reported for action by the appropriate emergency service provider.

The data flow diagram, **Figure** 2.2, identifies the primary functions and associated data flows. The functions associated with the Traffic Management Process are: Manage Incidents; Monitor Traffic Flow and Roadway Status; Control Traffic Flow; Manage Traffic Demand; and Manage Work Zones. A brief description of each of these primary functions follows:

***Manage Incidents***

It is the process and activities to manage traffic incidents on the roadway. It collects network status, traffic coordination data, signal priority requests, external reports, scheduled events, and other traffic management coordination data. The process analyzes and identifies potential or predicted incidents by comparison with historical traffic data. It promotes incident management through coordination with the Control Traffic Flow process, and interacts with Traffic Operations Personnel for presentation of incident data and acceptance of incident commands.

***Monitor Traffic Flow and Roadway Status***

This process monitors and measures the status of the traffic network. It collects data on weather conditions, road conditions, and traffic conditions. The process also collects and analyzes regional traffic flow data from other Traffic Operations Centers. It provides coordination data to the Manage Incidents Process and the Manage Traffic Demand Process, and provides traffic network status information to the Traffic Operations Personnel.

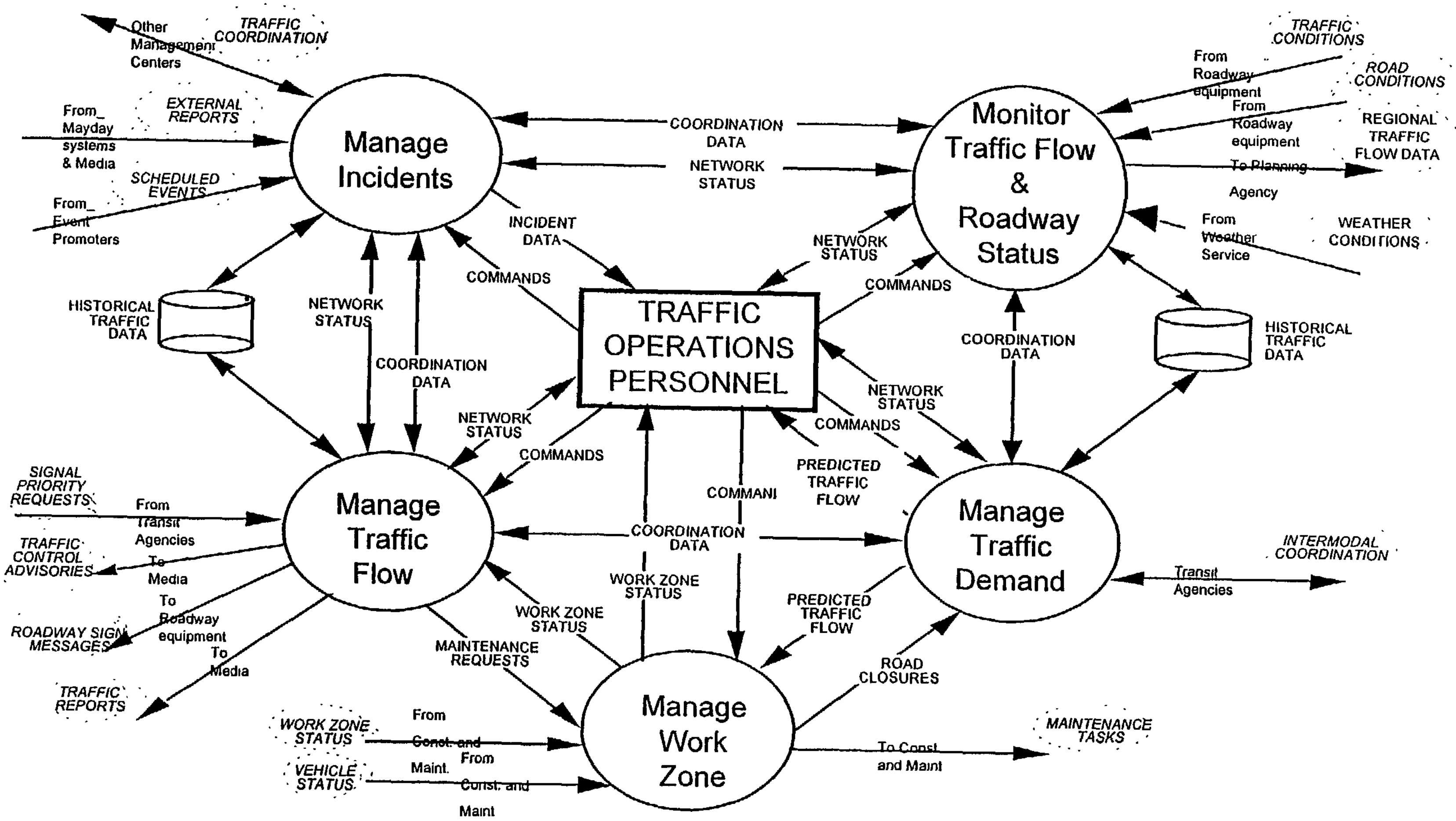


**Figure 2.2 - Traffic Management Process**

***Control Traffic Flow***

Control Traffic Flow is the process and activities to manage the control of the traffic system. It uses traffic network status, incident coordination data, work zone status, traffic coordination data and signal priority requests to provide traffic control. This process configures traffic control devices based on predictive traffic flows, actual traffic data, and requests from Traffic Operations Personnel. It provides information to travelers via roadway message displays and coordinates traffic control information with intermodal and other traffic operations centers. This process also provides traffic information and advisories concerning the traffic network to the Traveler Information Services process.

***Manage Traffic Demand***

This is the process and activities to manage traffic demand on the roadway network. It uses information on traffic conditions, historical traffic data, road closures, transit schedules, and network status to provide the prediction management and demand management strategies.

***Manage Work Zones***

It is the process to manage work zones on the traffic network. It provides status on the work zone and work zone coordination data by analyzing the work zone and construction zone effects on traffic flow. It also processes maintenance requests from the Control Traffic Flow process.

#### 2.3.2.2 Emergency Services Process

This functional process performs the management functions needed for dispatch and control of emergency services responding to incidents and the activation of law enforcement agencies. It therefore has interaction with the Manage Traffic, Manage Transit, and Provide Driver and Traveler Services functions. An interface is also provided to the Manage Traffic function for the coordination of incident management and to provide priority for emergency vehicles at signalized roadway intersections and highway ramos. The primary functions of this process include Coordinate Emergency Response and Manage Emergency Vehicles. The Emergency Services Process, **Figure** *2.3,* includes the functions required to interface with emergency services personnel.

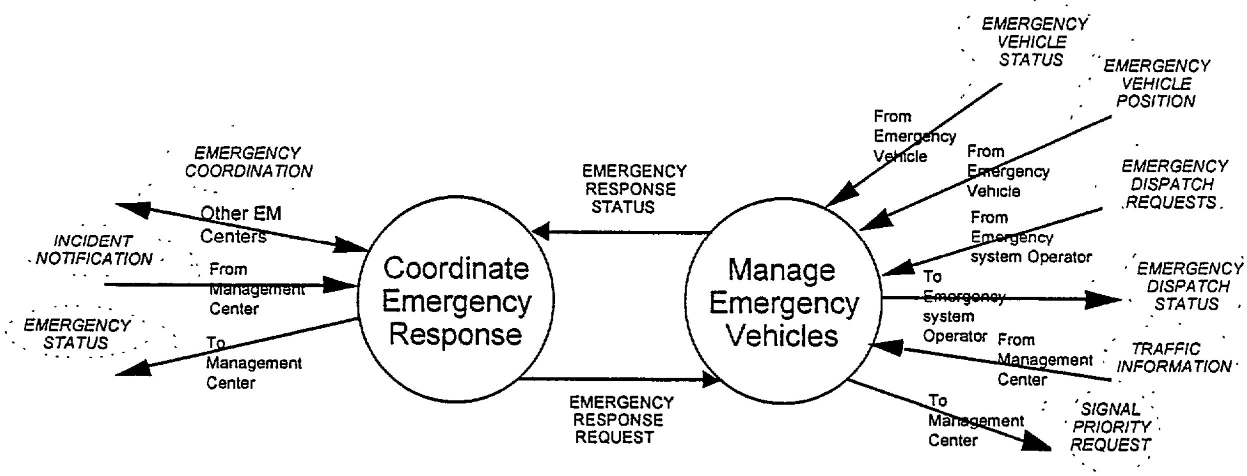


**Figure 2.3 - Emergency Services Process**

***Coordinate Emergency Response***

This process handles the requests for emergency assistance and coordinates with the Manage Emergency Vehicles process.

***Manage Emergency Vehicles***

Provides the management of emergency vehicles. This function is supported through acceptance of dispatcher inputs, status back to dispatchers, transmission of information to the emergency vehicles, and position and status of the emergency vehicles in the network.

### 2.3.2.3 Public Transportation Management Process

This functional process integrates the transit monitoring functions which apply to fixed route transit services and flexible operations and control transit systems (demand responsive transit). Transit information is provided to the transit driver and transit user directly through this function. Interaction with the Manage Traffic Function is provided to support prioritization schemes at signalized roadway intersections and highway ramps, and also to reflect the overall coordination between transit and traffic management services. The Public Transportation Management Process, **Figure 2.4**, identifies the functions required to manage both fixed and variable schedule transit vehicles and interface with the Traffic Management Process. It provides transit scheduling activities including performing fixed-route planning and scheduling, monitoring transit schedules for schedule adherence, and disseminating schedule information to travelers, operation centers, and terminals.

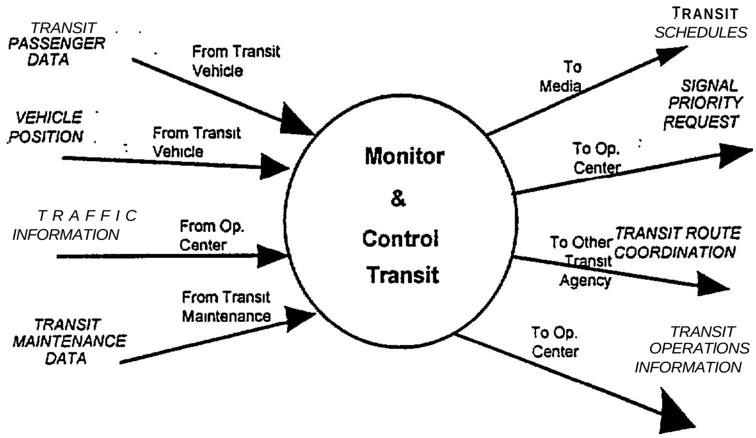


**Figure 2.4 - Public Transportation Management Process**

### 2.3.2.4 <u>Traveler Information Services Process</u>

This functional process provides the multi-modal trip planning, route guidance and advisory functions for travelers and all types of drivers. It also enables them to confirm and pay for yellow pages services and provides personal emergency notification functions (Automated Mayday). The multi-modal trip planning function enables trips to include private car and regular transit modes, plus ridesharing, demand responsive transit, and other modes. The Traveler Information Services Process, **Figure 2.5,** includes the Trip Planning, On-Board Driver Information System and Traveler Information Services functions required to interact with end users of ATMS services, principally vehicle drivers, travelers, and transit users.

***Trip Planning***

Provides the services to facilitate trip planning and route selection. It accepts, traffic information, route criteria, and transit scheduling information. The process develops route plans and instructions based on this information.

***On-Board Driver Information System***

This process provides traveler information directly to the on-route drivers. The process provides vehicle position data, travel information requests, routing instructions, weather data, intermodal information, etc.

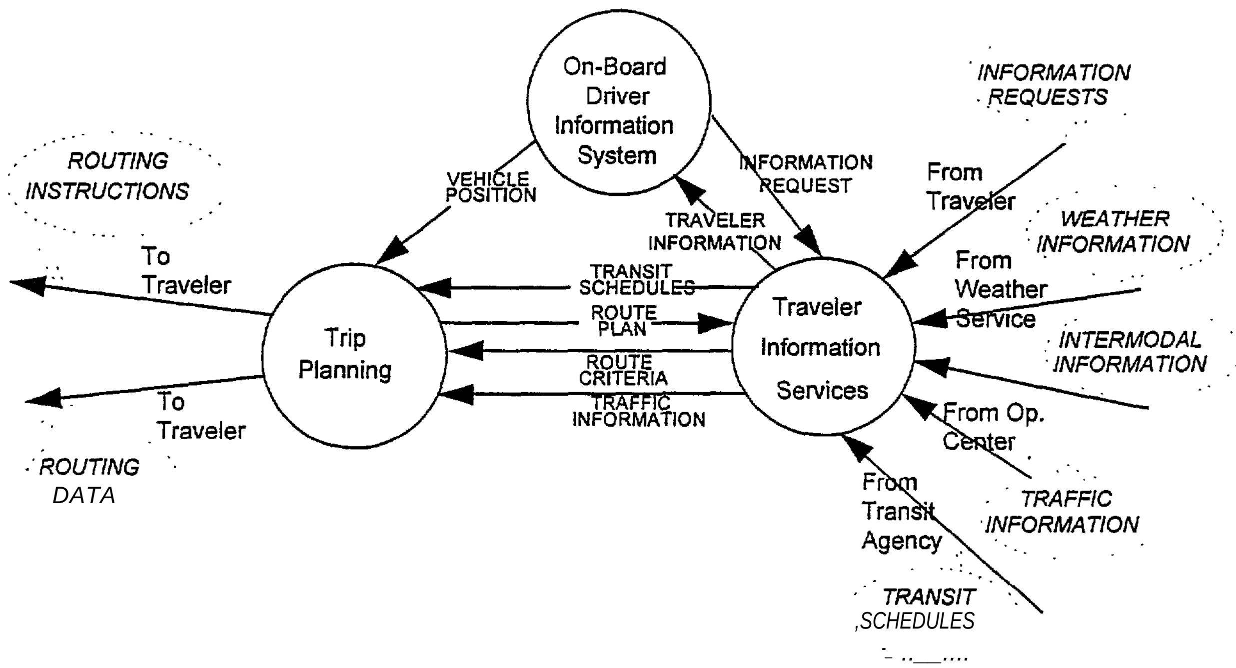


**Figure 2.5 - Traveler Information Services**

***Traveler Information Services***

This process manages and disseminates traveler information to system users. It accepts weather information, intermodal information, traffic information and transit schedules. It also services requests for information and initiates the processing of the requested information.

## 2.4 SUPPORT SYSTEMS FOR NoVA ATMS ARCHITECTURE

This section provides an overview of the various support systems recommended to support the ATMS architecture for the Northern Virginia Region. These support systems operate with the existing infrastructure and facilitate the transition from the current state-of-the-practice to the implementation vision. The following principles should be enforced:

- **Modularity** - The different agencies and jurisdictions will have unique priorities and fiscal resources over the ATMS implementation time frame. For this reason, interdependencies between the support systems must be minimized. Standard interfaces must be used so independent users have the ability to tailor the use of the support systems to their specific needs.

- **Flexibility** - Variations to system configurations will be controlled through input parameters. Object-Oriented Design (ODD) techniques should be adopted in the development of the support systems to promote flexibility in modifying input parameters.

- **Interoperability** - The support systems deployed by the different agencies must be able to work together (i.e., compatible). At a minimum, they must facilitate the free exchange of information.

- **Maintainability** - Maintainability should be promoted through modularity, high-level programming languages, state-of-the-art software engineering principles and practices, standard operating systems, and general purpose processors.

### 2.4.1 Description of Support Systems

The functionalities of the proposed transportation management coordination center (TMCC) and networked local traffic, transit, and emergency centers will be augmented by providing operations personnel with new tools for managing data, generating information on the operational status of the network, detecting and resolving incidents, controlling the traffic network, simulating real-time proposed alternatives to control and assess their impact, and facilitating the dissemination of traffic and travel information to other sources.

This section provides an overview of the categories of required support systems and addresses the demand of these functionalities to achieve the ATMS vision. Input parameters for planning ATMS or ATMS-related project deployments are also provided.

#### 2.4.1.1 Traffic Management

Control capabilities required for managing the traffic network are provided by this category. Traffic management is responsible for management of the traffic network. All traffic control is performed by the traffic operations control systems in the jurisdictions, TMS, ATSS and others [referred to as Traffic Control Systems (TCS) from here on]. Wide-Area traffic management is proactive and coordinates with the various TCSs for network-wide optimization. Wide-Area Traffic control notifies the TCS of optimization to be implemented. The TCS are responsible for implementing the optimization by directly communicating with their respective field equipment. The Traffic Management Support System category is composed of the following:

- Wide-Area Traffic Management
- Incident Management
- Traffic Control (for Surface Streets and Freeways)

***Wide-Area Traffic Management***

The Wide-Area Traffic Management Support System is responsible for providing proactive traffic management over a large traffic network consisting of one or more traffic control systems, either surface street, freeway and/or corridor. It is also responsible for the implementation of demand management policies and strategies that include the control of High Occupancy Vehicle (HOV) facilities, reversible lanes, and coordination with public transportation systems.

This support system will be deployed in the proposed TMCC and will be accessible from all the jurisdictions/agencies for data exchange. Coordination between the individual TCS will be accomplished through:

- Formulation of individual control objectives and control constraints that will support coordinated operation.
- Development of demand forecasts that anticipate traffic conditions in one control area based on observed demand and control strategies in other control areas and information from dynamic assignment and vehicle routing systems.
- Prediction of local and area wide congestion and congestion propagation in response to detected incidents and incident management plans.

Demand forecasting provides the proactive responsiveness of the Wide-Area Traffic Management Support System. Demand forecasts are based on historical travel patterns, observed origin-destination pairs from probe vehicles, assigned vehicle routes from the dynamic traffic assignment subsystem, and current traffic conditions and controls. The prediction of local- and wide-area congestion, congestion propagation in response to detected incidents, and incident management plans provide reactive responsiveness as well as coordination across several individual traffic control systems.

Another important function of the Wide-Area Traffic management support system is to provide monitoring, prediction, and control consideration as a result of environmental conditions such as rain, snow, and ice. Anticipation of increased risk associated with environmental conditions can be translated into control objective and constraint formulations to increase safety through effective traffic control. The Wide-Area Traffic Management Support System will generate specific strategies (ramp metering rates, signal timings, etc.) in the case of incidents or when the TCS fails or is not capable of generating the necessary strategy. The TCS is responsible for communicating directly with the signal and control equipment to implement the strategy.

The Wide-Area Traffic Management Support System will support operator decision making through the Graphical User Interface (GUI) where the processed surveillance and detection information, as well as the strategic controls, are presented to the operator in a format that is consistent with their view of the network operating conditions. The GUI will be used to allow operators to implement management decisions. The Wide-Area Traffic Management Support System may be deployed in the TMCC or distributed over the network.

***Incident Management***

This support system will manage incidents after their detection. An incident is any type of non-recurrent congestion as a result of accidents, visibility, weather conditions, construction, acts of god, etc. This system will ingest incident detection data, classify the incident, determine incident severity and duration, and log the incident. Then, using historical knowledge and intelligent reasoning methodologies, the system will dispatch appropriate emergency services and generate routes for emergency vehicles to provide a coordinated response to resolve the incident efficiently while preserving safety. Additional support may include notifying external agencies, such as towing organizations. This support system may be driven by an incident management expert system coupled with a GIS and deployed by the police and fire and rescue agencies with communication links to the TMCC through standard data interfaces.

***Surface Street Traffic Control***

This automated support system uses the current state-of-the-traffic network to regulate signaling patterns of surface streets. The signal controllers rely on traffic sensors that indicate current traffic conditions. This is achieved by using algorithms that can derive demand from detector data at intersections and subsequently adjust the signaling pattern for near-optimum traffic flow. These systems will also employ various Real-Time Traffic Adaptive/Responsive Control Systems to manage the traffic signal network. This support system is anticipated to be deployed by the local jurisdictions in their respective traffic control centers with communication links to the TMCC through standard data interface.

*Freeway Traffic Control*

This support system's (TMS) primary purpose is to monitor and control traffic flow along the freeway corridors in the region. It collects data through detectors on the roadway and analyses them to detect incidents and implement ramp metering strategies. It also controls the freeway control equipment such as lane usage signals and ramp meters. This system may also employ video surveillance for incident verification. This support system interfaces with the simulation model support systems (discussed later under Analysis and Modelling category) to develop strategies for freeway control.

#### 2.4.1.2 System Management

This category monitors, configures, and manages the ATMS assets. Support for planning and scheduling of construction and special events is also provided. The system management category is consists of the following support systems:

- Maintenance Management and Repair Scheduling
- Management/Operation Center Hardware and Software Monitoring
- Configuration and Inventory Management
- Event Planning and Scheduling

*Maintenance Management*

The management system is responsible for the logging and scheduling of reported failures or preventive maintenance requests. These requests will consist of various types including field surveillance equipment, failures of field control and signal equipment, failures of communications interfaces between the TMCC and TCS, roadway problems, and failures of TMCC hardware and software.

*Hardware and Software Monitoring*

This support system is responsible for monitoring the assets within the centers to detect failures. Once a failure is detected, it is reported to other support systems. The assets monitored within the center include: hardware, CPU, memory, disk, peripherals: software - o/s problems, swapped out process and down process; communication - links between hardware nodes and interfaces to external systems; and DBMS - database usage and database sizing.

### *Configuration and Inventory Management*

This management system tracks configuration changes to hardware and software assets that reside in either the field or inside the centers. For hardware assets, this system interacts with the DBMS to maintain and track hardware component locations, installation dates, service dates and history, manufacturers name, manufacturers number, dates purchased, and other technical details associated with the specific hardware component. For hardware components in the field, the system also maintains records from the DBMS that define a common network representation. The common network representation defines the communication network between controllers, detectors, signals, and the center. It also defines the state/status of each component in the network (e.g., working, requires servicing, abnormal). For software assets, this system interacts with the DBMS to maintain and track creation dates, functions performed, authors, modification dates and history, and other technical details associated with the particular software components.

### *Event Planning and Scheduling*

This system is responsible for the off-line planning and scheduling of three types of activities: planned construction events, planned special events; and incidents (contingency planning only). For planned events this support system assists the operator by providing support for:

- Manual requests
- Automatic acceptance of requests through an external communication system interface
- Event calendar schedule
- Generation of the planned event scenario (e.g., for a special event – a football game – scenario generation entails determining event attendance and spectator profiles, emergency service needs – police, fire, rescue, etc.)
- Retrieval of event plans (traffic and logistic) for past similar events
- Generation of traffic control plans
- Storage of new event plans
- Schedule of control plan implementation with the I/O manager
- Schedule of outputs to external systems and agencies with the I/O manager

Contingency planning (e.g., incidents) is supported the same way as planned events. However, requests for resources are not automatically received, and the activities of the plan are not scheduled until the time of the emergency.

### 2.4.1.3 Analysis and Modeling

This category is responsible for providing the capabilities for analyzing and modeling all aspects of the traffic network and is composed of five support systems managed by an integrated modeling manager including:

- Integrated Modeling Manager
- Origin-Destination (O-D) Processing
- Historical Data Analysis
- Traffic Simulation Models
- Dynamic Traffic Assignment Models
- Signal and Control Optimization Models

***Integrated Modeling Manager***

This support system will manage all of the models available for use in the ATMS. The essential function of the support system is two-fold:

- To provide a standardized, common entry into the analysis and modeling repository.
- To provide a layer of software on top of all existing models that will allow them to be accessed from anywhere within the ATMS - for both on-line(real-time) and off-line purposes.

The repository includes all of the various microscopic and macroscopic traffic simulation models, signal and control optimization models, and the ATMS component simulation models. To accomplish these functions, the support system must collect and format the inputs obtained from the various center databases and from the operator (via GUI) so the processed input can be used by various models. The opposite is likewise true. The support system must collect and format the outputs obtained from various models so that they are displayable and storable to the operator and the database. This support system may be deployed at the TMCC with access provided to the individual jurisdictions.

***Origin - Destination Processing***

This support system performs a key function with the Dynamic Traffic Assignment Support System in meeting the essential ATMS requirement for proactive traffic management and control. Its function is to synthesize and forecast an origin-destination matrix from observed traffic information including: real-time link volumes computed by the traffic and environmental monitoring support system, historical origin-destination data, and traffic information. The support system should have the capability to develop a partial origin-destination matrix. The support system will interface with the integrated modeling manager to transfer data to other support systems. It will have the capability to forecast the synthesized origin-destination matrix over the assignment period required by the dynamic traffic assignment and wide area traffic management support systems. Real-time and off-line evaluation support will be provided.

***Historical Data Analysis***

This support system is responsible for providing the operator with a transparent interface to the DBMS and will primarily generate necessary reports, calculate growth trends, and project future data. The reports may include both routine and ad hoc requests. An example of a routine report is the weekly traffic data summary. The ad hoc request for reports may originate whenever a need for summary data arises, especially for off-line planning purposes.

***Traffic Simulation Models***

This support system contains a repository of all traffic simulation models available for use in the ATMS. This includes both microscopic and macroscopic level models - NETSIM, NETFLO, FREFLO, FRESIM, CORFLO, TRAF, etc. More advanced models to simulate ATMS operations, that are presently under development, may also be added to this support system.

The main functions of the models available in this support system are macroscopic traffic flow simulation at network or regional level and microscopic traffic flow simulation.

***Dynamic Traffic Assignment***

This support system performs several key functions within the context of wide-area proactive traffic control. These functions include:

- In cooperation with a detailed traffic simulation program, generating measures of effectiveness (MOE) for evaluating regional and local control strategies being considered by the Wide-Area Traffic Management support system and the traffic control centers;
- Developing "System Optimal" routes in support of the Wide-Area Traffic Management Support System route diversion strategies;
- Developing 15-minute forecasts of network loads at interface points between traffic control systems based on a time dependent regional O-D. The required assignment interval is a function

of the size of the network. For small networks, a 15-minute interval is probably sufficient; for large networks, 30 minutes or longer may be required. Developing 5-minute forecasts of network link volumes using the network loads previously developed and specific control strategies being employed by the traffic control system.

***Signal and Control Optimization Models***

This support system contains a repository of all signal and control optimization models available for use in the ATMS. It is a library of traffic signal optimization programs which are under the control of the Integrated Modeling Manager. This includes both microscopic and macroscopic level models - TRANSYT, PASSER II, SIGOP III, SOAP, MAXBAND, etc. and will be used to evaluate the efficacy of candidate ATMS control strategies on-line prior to the deployment of the "best" candidate strategy. It will also be used "off-line" to evaluate new strategies to determine whether they should be introduced into the library of candidate control strategies.

#### 2.4.1.4 Monitoring

This category performs the data processing and provides the necessary controls and interfaces to the operator for monitoring the traffic network. It is consists of:

- Vehicle Tracking
- Surveillance Image Processing
- Traffic and Environmental Monitoring

***Vehicle Tracking***

This support system will track the location of vehicles equipped with automatic vehicle identification/automatic vehicle location (AVI/AVL) by displaying them on a graphical user interface superimposed on a map grid. Registered vehicles - individual and groups (or classes) of vehicles, such as transit fleets – equipped with AVI/AVL will send probe data (e.g., location, speed data, and environmental data) to the ATMS system via the input stream processing support system (which will load the DBMS with the data).

***Surveillance Image Processing***

The processing of raw image data from closed-circuit television (CCTV) cameras in the field is performed through the input stream processing support system. The primary functionality is processing the raw image from the CCTV system to compute the traffic data (volume, density, speed, queue-length, delay, traffic classifications) and detect incidents.

***Traffic and Environmental Monitoring***

The primary processing functions of this support system are:

- Process multiple traffic and environmental sensor measurements to generate link-based estimates of traffic and environmental variables for use by all other support systems
- Generate network-wide estimates of traffic and environmental conditions
- Detect and verify incidents on both freeways and surface streets
- Use additional sources of information on incident occurrences
- Detect and verify surveillance equipment failures
- Provide operator control of CCTV cameras (pan, tilt, zoom)

#### 2.4.1.5 Communications

This category provides the capabilities needed for interfacing with external ATMS entities. It receives data from external ‘electronic systems and agencies. This support system is composed of the following three support systems:

- Output Stream Processing
- Input Stream Processing
- I/O Manager

***Output Stream Processing***

The output stream processing is responsible for transmitting data to destinations external to ATMS which include: ATIS, CVO, APTS, other ATMSs; Organizational Users (e.g., MPOs); Users (e.g., the traveling public); and Emergency Services (e.g., police).

The support system will transmit analog, digital, and video data. It performs the following processing on these data streams:

- Communications protocol handling
- Data formatting and transmission

***Output Stream Processing***

The output stream processing is responsible for transmitting data to destinations external to ATMS which include: ATIS, CVO, APTS, other ATMSs; Organizational Users (e.g., MPOs); Users (e.g., the traveling public); and Emergency Services (e.g., police).

The support system will transmit analog, digital, and video data. It performs the following processing on these data streams:

- Communications protocol handling
- Data formatting and transmission

**I/O Manager**

The I/O Manager handles the scheduling of data that needs to be transmitted to other systems. Electronic requests, which consists of an event identification and time, is received to schedule output data.

Each new incoming request is inserted into a time sorted schedule or queue. The support system then processes the sorted queue and at the appropriate time activates the appropriate system.

## 2.5 PHYSICAL ARCHITECTURE

On the basis of the logical architecture and the support system requirements defined earlier, four types of physical architectures were identified. These are Fully Centralized, Peer to Peer with Decentralized Coordination, Peer to Peer with Centralized Coordination, and Peer to Peer with Permissive Control and Centralized Coordination. These were then analyzed to assess their advantages and disadvantages with respect to the existing infrastructure, institutional arrangements and issues, and technological factors involved. A summary of this analysis is presented in **Table 2-2**, with comments on the advantages and disadvantages of each alternative listed.

On the basis of the analyses utilizing the architecture guiding principles, it has been determined that the peer to peer with centralized coordination architecture best fits the overall local ATMS/ITS deployment objectives for the Northern Virginia Region.

**TABLE 2-2**
**ALTERNATIVE ARCHITECTURES ADVANTAGES/DISADVANTAGES**

| Alternative | Pros | Cons |
|---|---|---|
| Fully Centralized | ♦ Single standard communications channel to/from central facility<br>♦ Efficiency and cost of staffing<br>♦ Single standard interface to support<br>♦ Consistent user interfaces | ♦ Autonomy sacrificed<br>♦ Local TOCS become obsolete<br>♦ Susceptible to failure<br>♦ Consensus building most difficult |
| Peer-to-Peer With Decentralized Coordination | ♦ No additional facilities to operate or maintain<br>♦ Full ATMS autonomy maintained<br>♦ Peer-to-Peer communication<br>♦ Inherently fault tolerant | ♦ Regional coordination difficult<br>♦ Duplicate data processing and display equipment<br>♦ Added complexity<br>♦ Additional manpower supporting distributed operations |
| Peer-to-Peer With Centralized Coordination | ♦ Full ATMS autonomy maintained<br>♦ Consistent coordination<br>♦ Information dissemination via common standard channels and interfaces<br>♦ Inherently fault tolerant | ♦ Duplicate data processing and display equipment<br>♦ Added complexity<br>♦ Additional manpower supporting distributed operations<br>♦ Central coordination facility to operate and maintain |
| Peer-to-Peer With Permissive Control And Centralized Coordination | ♦ Full ATMS autonomy maintained<br>♦ Consistent coordination<br>♦ Information dissemination via common standard channels and interfaces<br>♦ Inherently fault tolerant<br>♦ Most conductive to regional emergencies<br>♦ Flexibility to expand and add areas/jurisdictions/user services | ♦ Duplicate data processing and display equipment<br>♦ Added complexity<br>♦ Additional manpower supporting distributed operations<br>♦ Central coordination facility to operate and maintain |

### 2.5.1 Peer to Peer with Centralized Coordination

This architecture is based on the concept that a central regional Transportation Management Coordination Center (TMCC) is established. The TMCC would be responsible for providing regional coordination between the different users and agencies associated with traffic management activities. The TMCC would be manned by representatives from critical agencies which would include VDOT, transit, and emergency services personnel. With the communications backbone providing real-time and comprehensive data from local jurisdictions/agencies and VDOT, required information would be available at the TMCC for analysis as well as decision making. The facility would be the key interface between the Northern Virginia ATMS and other regional traffic management centers including Maryland and the District of Columbia. This architecture is presented in **Figure 2.6**.

The TMCC will utilize low cost computer, data processing, and communications equipment, and would not increase the quantity of operations and maintenance personnel required for the overall system. Personnel utilization would tend to be efficient, because the personnel will be able to

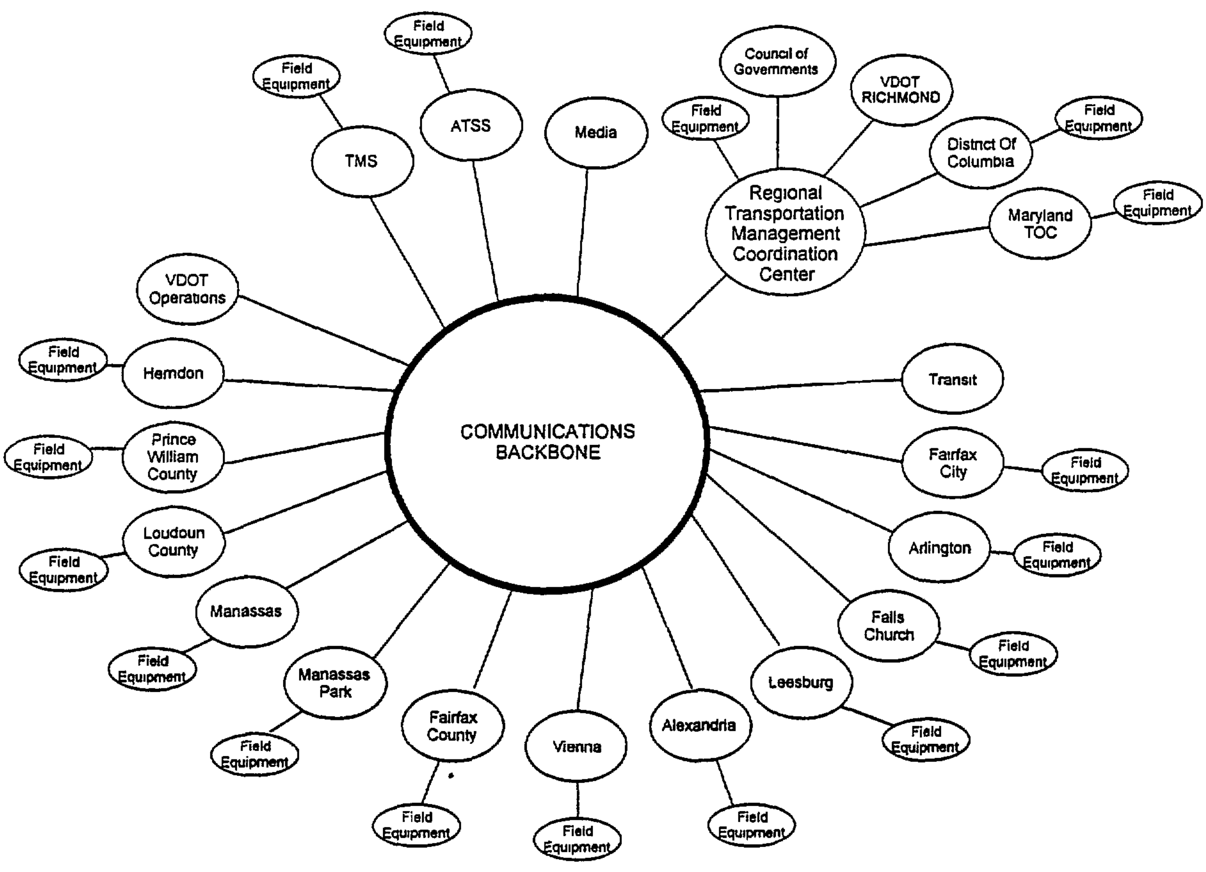


**Figure 2.6 - Peer to Peer with Centralized Coordination Architecture**

perform multiple job functions. This would be especially true during emergency situations or times of critical needs. The TMCC would have the ability for operators at the TMCC to provide "hands-off' control of field equipment normally controlled by local traffic operations centers. This would allow the local jurisdictions to maintain their autonomy, but would allow operations to continue during off-hours or other times when the primary management center is unavailable.

The TMCC would also support the centralized collection and storage of ATMS and Advanced Traveler Information System (ATIS) data. A database would be created and available for use by all users.

## 2.6 COMMUNICATIONS INFRASTRUCTURE

This section provides recommendations on communications technologies to implement the Peer to Peer with Centralized Coordination Architecture. The logical architecture in Section 2.3 presented the types of information to be transmitted in and between the four major processes associated with the Northern Virginia Region ATMS. For the analysis presented in this section, the information which will be transmitted within the ATMS Architecture requires three basic types of transmission: data, video, and voice.

For Northern Virginia, the architecture can be supported by a variety of existing and new communications systems and services. These generally fall under three basic categories: 1) communications between the elements of the infrastructure and with other supporting organizations and agencies; 2) communications between the ATMS infrastructure and vehicles; and 3) communications between vehicles. The ATMS communications infrastructure analysis presented with this report primarily focuses on the first and second categories. Deployment recommendations of a communication strategy for the third category -- between vehicles – are addressed in more detail in the ITS Strategic Deployment Plan.

The peer to peer communication strategy is based on a distributed system architecture, with processing functions and common databases resident at the TMCC and local TOCs. The configuration of the existing VDOT and other agency operations centers, maintenance centers, and agency-owned communications facilities lends itself to this approach. Phased improvements and expansion of this existing communications system will be programmed to allow for ease of future system expansion to share information such as maps, video images, and transportation system information with an unlimited number of sites.

### 2.6.1 Alternative Communications Technologies

To support the interagency links and shared information exchange requirements, the plan for the ATMS deployment requires that the communication infrastructure and supporting phased implementation program be correlated to the time frames defined for the overall ITS deployment program: near-term, mid-term, and long-range. It is recommended that the deployment of the communications infrastructure in the aforementioned three basic categories relate to the implementation time frames by the following:

| Category | Time Frame |
|---|---|
| Within infrastructure communication | Near-Term/Mid-Term |
| Vehicle to and from infrastructure | Mid-Term |
| Vehicle to vehicle | Long-Range |

Candidate technologies which are available to establish the communications infrastructure were analyzed for applicability in the near- and mid-term deployment time frames, with emphasis on the requirements to provide the backbone system for the ATMS Architecture. Important factors considered in recommending a technology for the ATMS communications backbone include:

- The technology must be nationally recognized, using an open systems architecture that is compliant with the International Standards Organizations (ISO) seven-layer architecture
- The technology must be supported by the commercial industry
- The technology must support fault-tolerance and network management
- The technology must have the ability to expand as bandwidth and interface requirements expand
- The technology must be compatible with many types of data and bandwidth requirements
- The technology must be available in hardened equipment for outdoor environments
- The technology must perform in a reliable and cost-effective manner

Presented on the following pages is a brief summary of study team's analysis relating to communication technologies to support integrated ATMS deployment.

#### 2.6.1.1 Within Infrastructure Communication

The program is recommended to cover all communications that are necessary to interconnect the various initial elements of the coordinated transportation management system and supporting the traffic management, emergency management, public transportation management, and traveler information services processes. For this basic communications category, four sub-categories are considered: landlines, microwave, radio, and satellite systems.

***Landlines***

Much of the existing infrastructure connectivity in operating traffic management, emergency management, public transportation management, and traveler information systems is provided using agency-owned, leased, or dedicated landline services. Leased lines are currently employed by VDOT for Surface Condition Analyzer (SCAN) data transmission, some variable message sign control, interagency links, etc. While the use of leased lines is advantageous, dedicated cable systems are beneficial and have the following advantages:

- VDOT and its project partners can control the quality of service;
- VDOT and its project partners can select the optimum cable routing schemes to insure adequate and a desired level of facility coverage;
- Maintenance support can be designed with consideration to budget constraints:
- Offers a control mechanism against inflationary costs nominally associated with leased facilities;
- Can be designed to provide spare capacity for use by other agencies; and
- Offers opportunities for public/private partnerships through joint use of the system, e.g., local telephone and cable television companies.

In Northern Virginia, dedicated cable systems are typically a combination of copper and fiber optic media. Fiber optic cable is state-of-the-art for dedicated systems and provides for high-capacity communications – in both data and video transmission requirements. Additionally, fiber optic cable is inherently immune to electromagnetic interference from power lines, radio signals, etc.

Leased lines offer an alternative that mitigates the liability of the initial installation costs associated with agency-owned facilities. Leased data-grade telephone lines are currently part of the Northern Virginia transportation communications infrastructure. Of the potential communications alternatives, the expansion of the leased line network is recommended. This alternative is the most viable for early deployment initiatives, however, third party reliance for services and maintenance may have affect on dependability, and thus desirability as a communications medium. In addition, lease payments tend to inflate over time beyond original price quotes.

For the visual detection component of the proposed surveillance system expansion, the use of a leased telephone line network presents additional considerations with respect to implementation. Ordinary voice-grade lines are not adequate for transmitting full-motion video signals without the use of video compression devices. In addition, higher capacity leased lines will be required than currently in use in the region with the ultimate expanded system. The alternative to compressed, full-motion video is the use of slow scan methods for dealing with video signal transmission. This technology converts the video image into a digitized format, and then transmits one scan line at a time over a standard voice-grade telephone line, similar to a FAX transmission. The time of transmission depends on the resolution of the transmitted image. Current technologies provide one frame every 1 to 20 seconds, versus 30 frames per second for full-motion video. At this rate, it becomes very difficult for the system operator to determine if traffic is moving, this is not a viable option for use in incident detection.

**Microwave**

Microwave is considered as a communications alternative for the ATMS to transmit data and video signals where landline links installation, as with agency-owned or dedicated lines, would be costly and somewhat impractical to install. This technology application is more cost effective when used in combination with relatively expensive surveillance equipment, e.g., closed circuit television. It is a high-capacity communication link alternative, however, it requires a direct line of sight path and is only suitable for carrying video over limited distances. For a system of the complexity and capacity under consideration for the Northern Virginia ATMS, obtainment of the necessary licensing may prove to be difficult, as well.

Lower capacity microwave communications systems, in the 31-33 Ghz range, have proven to be quite cost effective in applications to advanced arterial signal system deployment. These systems currently do not require licensing and provide an effective communications alternative for data transmission. They also have the ability to transmit video, however, transmission is typically limited to one camera per channel. Thus, for systems requiring video transmission for a large number of cameras within a given zone of the overall system, the cost effectiveness is reduced.

***Radio***

Radio transmission of data has been successfully used in traffic control applications, however, its implementation is most successful in relatively flat areas with low population densities. In addition, FCC regulations currently restrict frequency allocations and transmission power output for equipment used in traffic management, thus limiting its potential. Other concerns are:

- Depending on the transmitted frequency, it may require clear lines of sight between transmitters and receivers (e.g., spread spectrum), requiring the installation of costly antennas and repeaters;
- The ability to transmit video images is non-existent since the radio bandwidth is insufficient for video transmission; and
- As the initial system expands, additional licensing will be required, which will become increasingly difficult.

### *Satellite*

Satellite communications has the ability to support communications within the infrastructure without the need for landlines which may be costly under some conditions. Satellite communications is a mature technology that has been commercially available to the trucking industry for the last 4-6 years. Several type of satellite communication services are available including mobile satellite for commercial applications. Dedicated satellite communications channels can also be leased from a number of sources and are not subject to the problem of frequency licensing, as with radio systems. Additionally, this alternative does not require line-of-sight communication paths between receivers and transmitters although it does require a line-of-sight path between the ground (earth station) and the satellite.

To be economical for the Northern Virginia ATMS, the satellite communication sub-system must be designed to minimize the amount of transmission required between the receivers and transmitters. With this design alternative, the system would only transmit information when information is available or a specific control function is required. While this has application to data transmission requirements, it places considerable constraints in the cost-effective use of satellite'communications for full-motion video surveillance. The cost effectiveness of area-wide deployment in the near- and mid-term deployment time frames with this approach will be dependent on statistical analysis of actual frequency of transmissions. It is recommended that this analysis should be performed during preliminary engineering design of any project consideration for system implementation.

There are two basic types of satellite communications that require consideration: shared-use channels and leased channels. Shared use channels are less expensive than agency-owned dedicated cable systems. With this application, similar to those offered to the trucking industry, the user must purchase the remote communication equipment to be used in the field component location. Additionally, there is a one-time charge for central site software plus the cost of the telephone link to the provider's network center.

An alternative to shared use channels is leased satellite channels. Channels can be leased from organizations such as Hughes Network Systems that would be set aside for the specific use of the participating agencies in the integrated ATMS deployment. This is the preferred method for deployment of satellite communications in that it would provide for 24-hour transmission of video images, if needed. It is also more cost effective than the use of shared channels, since polled communications techniques can be used and the channel lease rates can be guaranteed for the life of the satellite, usually eight years. However, the total system installation and operations cost is high compared to other alternatives. As an example, using current rates, a single channel for continuous video transmission is approximately $25,000 per year. To reduce this cost, multiplexing techniques will require further evaluation during preliminary engineering design of system implementation.

#### 2.6.1.2 <u>Vehicle to and from Infrastructure</u>

This category includes the systems that support transmission of traffic, traveler information, safety advisories, and assistance requests from specially equipped vehicles. These functions can be provided by wide-area communications systems (satellite) or localized transmission to and from roadside devices (e.g., sign post systems). Current and emerging technologies in this area include:

- Local-Area Broadcast (Highway Advisory Radio)
- FM Subcarrier (One-Way)
- Wide-Area Radio (Two-Way)
- Cellular
- Commercial Radio
- Satellite Communications (One-Way)

With the eventual implementation of a national ITS system, satellite communications will in all probability be the predominant communications channel for vehicle to infrastructure communications. This will probably become a reality to users of the Northern Virginia ATMS by the end of the long-range deployment time frame (15+ years). Mid-term applications are recommended to focus on the communications links between the system and the region's maintenance and emergency service fleets, the Virginia State Police, and other similar agencies. This link would consist of in-vehicle or on-board computer systems linked to the TMCC and TOC centers via satellite communications. Once implemented, the real-time information processed by the TMCC/TOCs could be monitored by individual vehicles already enroute or engaged in service patrols in the region. This will provide for increased efficiency in incident and emergency response and enforcement.

The deployment of area-wide cellular communications is also anticipated during the latter part of the mid-term time period for application to secondary user services identified for the ATMS implementation. Areas of applications include personal security and emergency notification services and traveler interface with regional traveler information systems deployment.

#### 2.6.1.3 Vehicle to Vehicle

This category includes the inter-vehicle communication systems that will be needed to implement Advanced Vehicle Control Systems (AVCS) on a large scale. This technology is currently under development and its implementation will be conducted independent of the region's transportation service providers and end users needs, therefore, is not addressed in detail in this document.

### 2.6.2 Interagency Communications Recommendations

Based on the aforementioned communications alternatives, candidate technologies available to establish the network-level data, video, and voice links were analyzed for applicability to provide the backbone for the ATMS Architecture. The alternatives considered for the backbone communications include:

- Integrated Services Digital Network (ISDN)
- Proprietary Fiber Optic Links
- Fiber Data Distribution Interface
- Cable Television
- Switched Public Telephone (dial-up)
- Switched Public Telephone (leased)
- Analog (twisted pair)
- Satellite
- Synchronous Optical Network (SONET)
- Asynchronous Transfer Mode (ATM)
- Analog (RS-232, EIA 485 etc.)
- Digital (DS-0, DS-1, DS-3, etc.)
- Laser
- Microwave

- Digital Spread Spectrum Packet Radio
- Land Mobile
- Cellular Telephone
- Personnel Communications Service
- Broadcast AM/FM Radio

#### 2.6.2.1 Communications Backbone

Based on the study team's analysis, the recommended architecture for the Northern Virginia ATMS backbone is the Synchronous Optical Network (SONET). **Table 2-3** presents the most widely used SONET communications standards. By using various combinations of these standard rates, almost any combination of data, video, and voice data transmission can be made across the backbone.

**TABLE 2-3**
**SONET COMMUNICATIONS STANDARDS**

| Channel | Bit Rate | Signal Composition |
|---|---|---|
| DS-0 | 64 Kb/s | 2.4/4.8/9.6/19.2/28.8/56 Kb/s |
| DS-1 | 1.544 Mb/s | 24 DS-0 channels |
| DS-3 | 44.736 Mb/s | 28-DS-1 channels |
| OC-1 | 51.84 Mb/s | 1 DS-3 channel (equivalent capacity) |
| OC-3 | 155.52 Mb/s | 3 DS-3 channels (equivalent capacity) |
| OC-12 | 622.08 Mb/s | 12 DS-3 channels (equivalent capacity) |
| OC-48 | 2488 Mb/s | 48 DS-3 channels (equivalent capacity) |
| OC-96 | 4976 Mb/s | 96 DS-3 channels (equivalent capacity) |
| OC-192 | 9953 Mb/s | 192 DS-3 channels (equivalent capacity) |

The SONET architecture uses single-mode fiber optic cable as its communications medium. This is the most prevalent fiber technology being deployed today. Single-mode fiber is being used to replace copper, coax, and microwave links around the world. Because of the demand, single-mode fiber cable is now cheaper than copper cable, and has many manufacturers supporting the market. The bandwidth capacity of single mode fiber is very significant (over 100 GHz). Once installed, the fiber has high growth potential, and only requires higher speed communications equipment to incorporate the growth.

#### 2.6.2.2 Backbone/Local TOC Communications Laterals

**Figures 2.7 through 2.9** depict the SONET communication backbone and the various categories of local TOCs that are recommended to be connected to the backbone to fulfill the functions of the Northern Virginia ATMS. With the transportation management coordination concept adopted for the regional ATMS, three supporting communication subsystems are recommended for transportation operations coordination: traffic operations; transit operations; and emergency management. The terminators of each of these subsystem categories are shown in the figures. The probable and/or alternative communication links from the SONET backbone to each terminator is also depicted in the figures.

Based on the recommended physical architecture, the existing communications infrastructure, and the technological factors, fiber, leased lines, and wireless communications were identified as practical options for the backbone to local TOC laterals in the near- and mid-term deployment time frames. The final technology type implemented for the lateral links will be dependent upon the final number and level of participation of the primary jurisdictions and agencies (Table I-4) in the ATMS deployment. Recommendations in this regard are discussed in more detail in Section 4.0 -- Phased Implementation Plan – of this report.

#### 2.6.2.3 Life-Cycle Cost Analysis

For the purpose of providing a comparative analysis of the various communication technologies and options for the lateral communication links to accommodate the proposed architecture, a cost analysis was performed. Initial and life-cycle costs were generated.

The three technologies (fiber, leased line, and wireless) were evaluated. With the latter, wireless, two communications type alternatives were considered: microwave and satellite. For the reasons stated previously in Section 2.6.1.1 -- Within Infrastructure Communications -- area-wide satellite communications is not immediately identified for implementation in the near- and mid-term deployment time frames, and thus, is not included in this cost analysis. In lieu of satellite communications, microwave is considered as the most viable wireless technology application for within infrastructure communications in the near future.

Within each communication technology category, the alternatives were further decomposed to options available to provide data, video, and voice. These options were considered to evaluate the requirements for full video, high speed data and voice, and low speed data and voice exchange

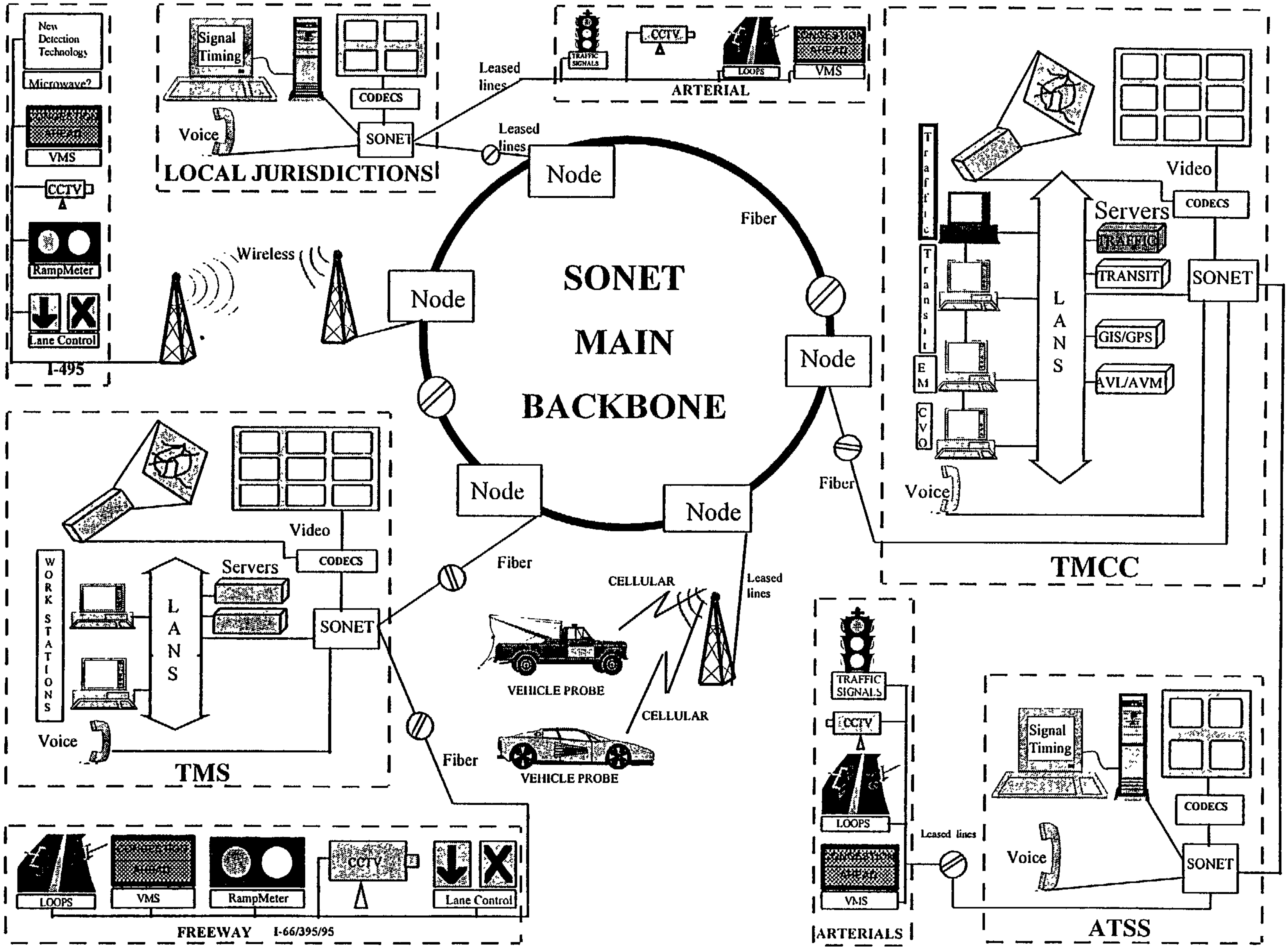


**Figure 2.7 - Traffic Operations Communications Architecture**

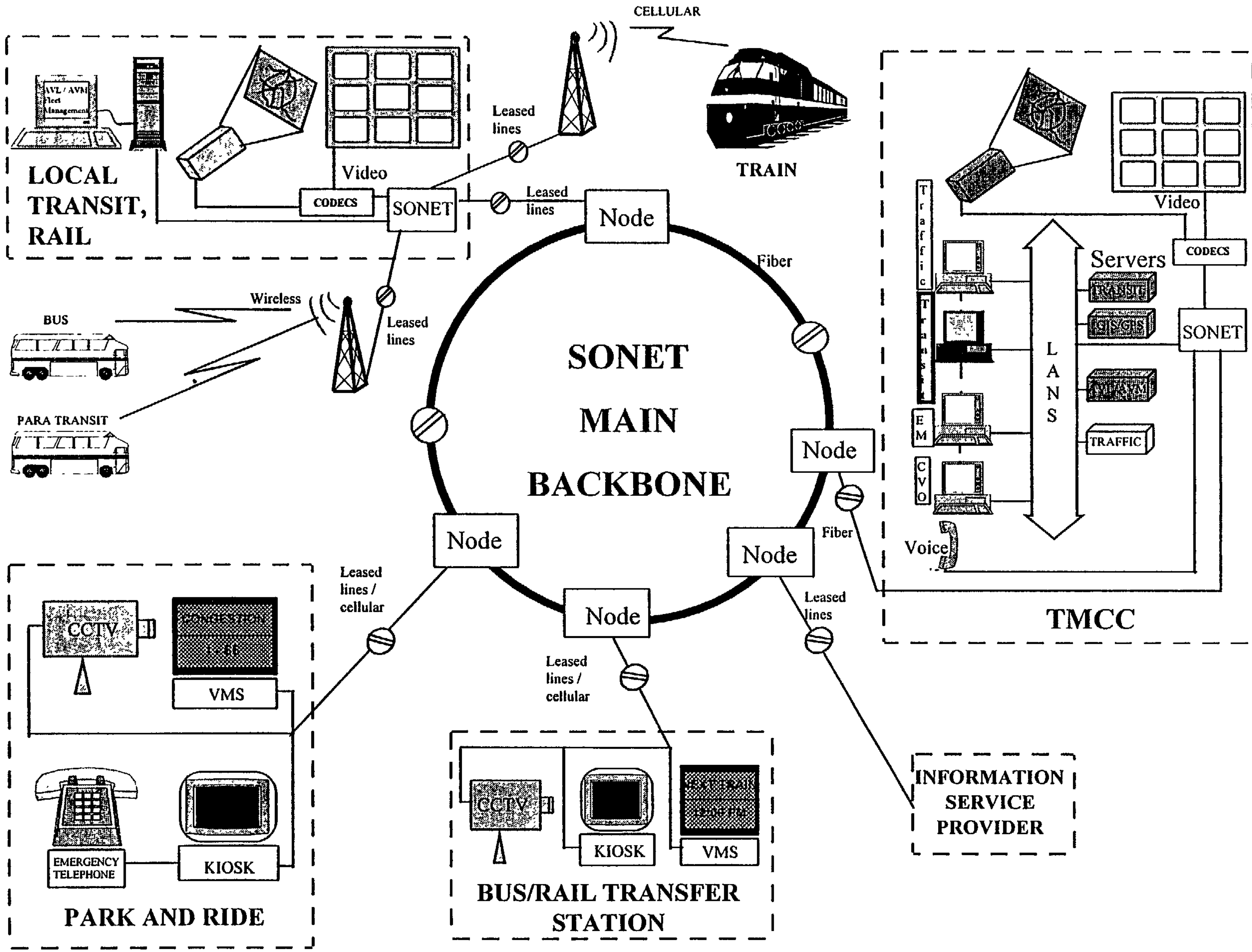


Figure 2.8 - Transit Operations Communications Architecture

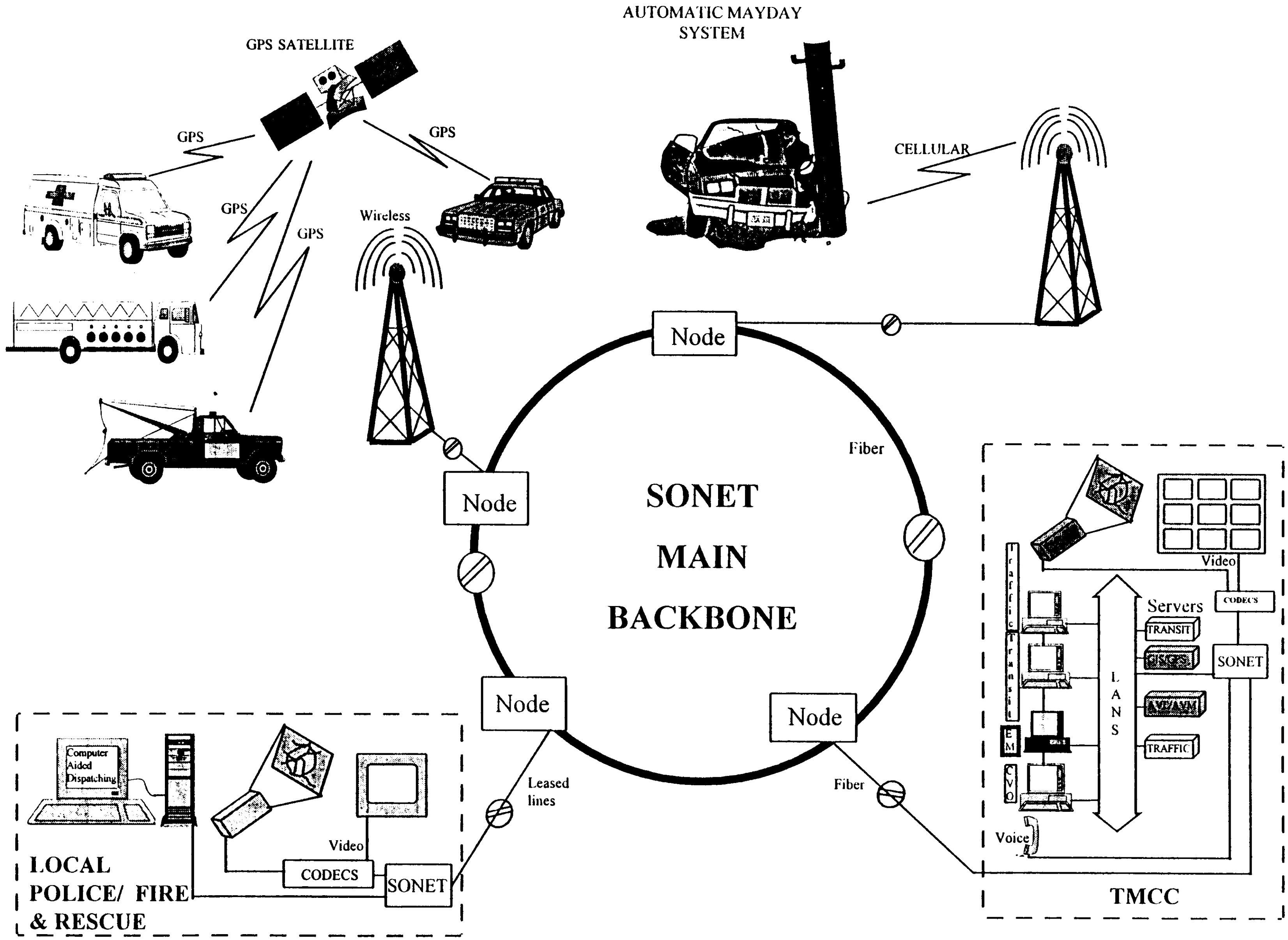


**Figure 2.9 - Emergency Management Communications Architecture**

capabilities.  Tables 2-4 and 2-5 summarize the projected initial and life-cycle costs, respectively, for the three alternatives.  It is important to note that the cost analysis are based on a homogeneous application of each technology alternative and option to compare costs.

**TABEL 2-4**
**INITIAL COSTS FOR LATERALS FROM LOCAL CENTERS TO FIBER BACKBONE**

| COMMUNICATION TECHNOLOGIES | COMMUNICATIONS OPTIONS | | |
|---|---|---|---|
| | LOW SPEED DATA & VOICE | HIGH SPEED DATA & VOICE | FULL VIDEO |
| FIBER | | $50,845,200 | $52,973,700 |
| LEASED LINES (DS-3 & DS-1) | | | $8,776,812 |
| LEASED LINES (T-1) | | $4,059,276 | |
| MICROWAVE | | $17,115,000 | $25,594,000 |
| LEASED LINES (ISDN 128-Kbs) | $267,300 | | |
| LEASED LINES (28.8-Kbs) | $205,425 | | |

Note:  An additional $28,859,332 is required for expansion of existing fiber backbone with each of the above options.  The cost figures shown in the table do not include this amount.

This analysis assumes the utilization of the existing VDOT fiber optic backbone and focuses on the options to provide lateral communication links from the backbone to the primary jurisdictions/agencies TOCs identified in Table 1-4.  It is important to note that the costs are generated on a worst-case scenario basis, with each technology application considered to be uniform for all laterals from the backbone.  The actual deployment costs will be somewhat lower, in that a hybrid system is anticipated for final deployment , due to a mix of technology types and communication options required to satisfy each independent agency's needs for data, voice, and video exchange with the TMCC.

It is assumed that over ATMS deployment period the existing fiber network will be expanded to form two rings so as to make the backbone fault tolerant, as previously described. This expansion is expected to cost $28,859,332 and is common to all options and technologies considered. The initial cost to have full video capability for the local centers utilizing the fiber communications technology is estimated at $52,973,700. To obtain the same communications capability, the initial cost for utilizing the T-1 leased lines is $25,594,000. Other communication options are as stated in the table.

**TABLE 2-5**
**20 YR LIFE-CYCLE COSTS FOR LATERALS FROM LOCAL CENTERS TO FIBER BACKBONE**

| COMMUNICATION TECNOLOGIES | COMMUNICATIONS OPTIONS | | |
|---|---|---|---|
| | LOW SPEED DATA & VOICE | HIGH SPEED DATA & VOICE | FULL VIDEO |
| FIBER | | $58,987,400 | $64,095,800 |
| LEASED LINES (DS-3 7 DS-1) | | | $82,982,460 |
| LEASED LINES (T-1) | | $10,243,080 | |
| MICROWAVE | | $62,955,900 | $86,597,400 |
| LEASED LINES (ISDN 128-Kbs) | $1,831,500 | | |
| LEASED LINES (28.8-Kbs) | $1,433,250 | | |

Note: Add $30,105,644 for expansion of existing fiber backbone with each of the above option. The cost Figures shown in the table do not include this amount.

The life-cycle costs shown above indicates fiber is the most economical option for full motion video when compared to leased lines and microwave. However, the T-1 leased lines are shown to be the most economical for high speed data and voice transmission. As different agencies will have different data needs, their lateral connections to the back bone can be any of the technologies listed. Fiber is recommended for the backbone as it supports all data communication needs.

### 2.6.3 Conclusion

The preceding analysis shows that the recommended architecture can be supported by a variety of existing and emerging technologies. Each of the alternatives has its own advantages and drawbacks. However, the choice of communications alternative would have to be in consonance with the system objectives and architecture guiding principles stated earlier. Foremost among these principles was leveraging existing infrastructure to the maximum extent. VDOT presently has fiber optic cable along the I-66 and I-395195 corridors. Also, there is fiber optic cable along the Dulles Toll Road. These are major infrastructure elements that can be utilized and cannot be ignored. Therefore, it is proposed to expand this fiber network to form two fault tolerant rings to provide the backbone for the ATMS and all future ITS deployments. The final deployed system will however be a hybrid system. It is anticipated that the various agencies will connect to the network from nodes on this backbone through a communications technology of their choice based on their individual communication needs and level of participation.

# SECTION 3.0 ADVANCED TECHNOLOGY EVALUATION

## 3.1 INTRODUCTION

In order to support the processes described in this report, the system must be flexible, scalable and expandable. The ATMS architecture accomplishes this through the modularized approach afforded by the Client-Server methodology. This relationship is temporary in nature, the roles of Client-Server can be reversed for different requests and functions. With this methodology, it is important for the architecture to be based on standards so that the inevitable equipment and software obsolescence does not limit the future capabilities of this or other systems that will receive and provide ATMS information. The application of standards to the ATMS are required, this is to provide the necessary "open" architecture so it can continue to evolve and grow as new capabilities and requirements are identified for the system.

The contents of this section describe the hardware and software required to implement the Northern Virginia ATMS. The technology recommendations are based on an evaluation of available technologies for their suitability to implement the decision support systems, physical architecture and communications infrastructure recommended in the previous section.

## 3.2 NETWORK-LEVEL HARDWARE AND SOFTWARE

The basic configuration for data collection, integration and exchange within the NoVA ATMS Architecture is based on **a** multi-database model in which the global network (i.e., TMCC) accesses and retrieves the required data from each local TOC through an external data interface then back to the local system's database. This model allows the agency's ITS based systems to be as unique as necessary to support their local requirements. It also allows for integration of existing system computers and their databases. The unified view of the regional data is provided by the global scheme at the TMCC, with each agency system making global queries through this regional level architecture.

### 3.2.1 Data Interface

The agency-specific ITS based systems collect and process data within their own databases as required to perform their specific functions. Any data that is required by the regional network is accessed by the Data Interface, converted to the form (i.e., protocol) required by the regional database and transmitted to the TMCC. When the data arrives at the global database, it becomes available to the entire network immediately. It is important to note that the regional database design does not dictate the design of the local TOC databases. Differences between the local TOC and regional TMCC database are accommodated during the conversion phase of data forwarding. As shown in **Figure 3.1,** additional hardware and software elements will be required at each agency-specific system to integrate the TOC into the regional network. A data interface will be added and connected to the central hardware platform at each TOC. As the name implies, this device will interface and communicate with the local TOC's system processor, extract the required data and process and transmit the information to the TMCC for integration into the regional database. The data interface will also receive information from the TMCC database in support of the regional workstations.

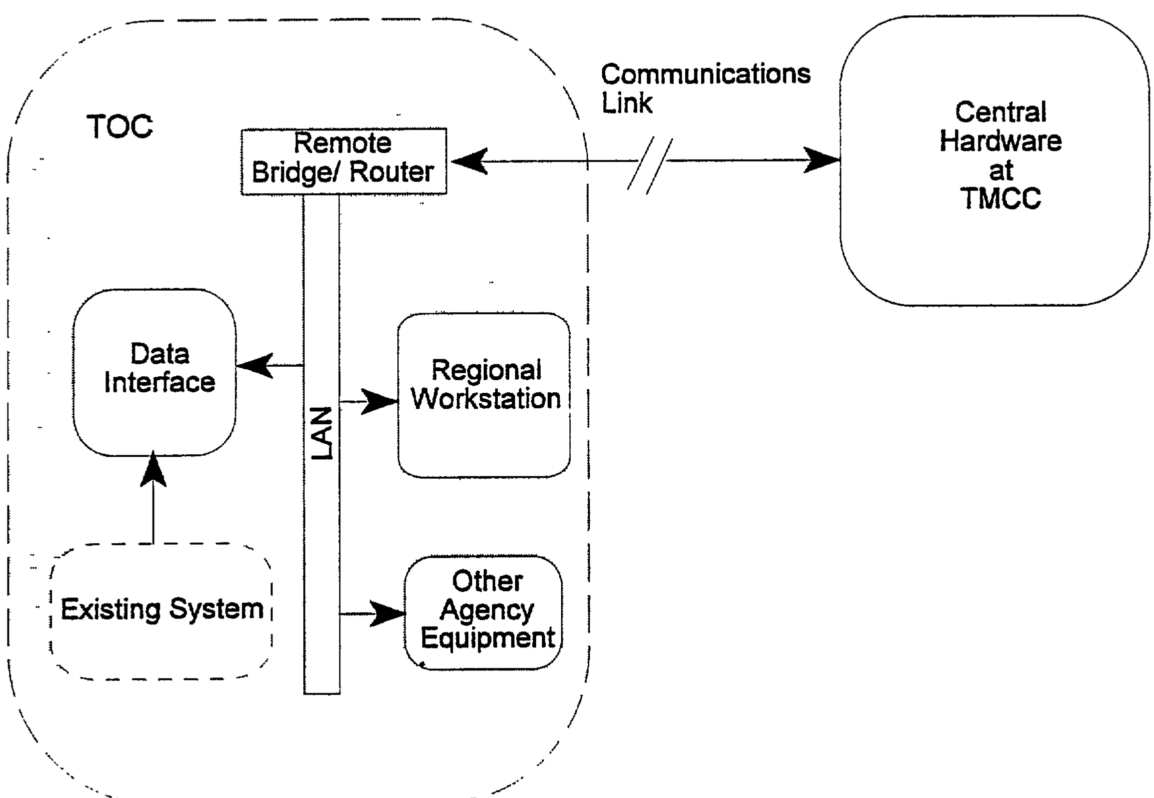


**Figure 3.1 - Basic Data Sharing Configuration**

It is imperative that the data interface device be compatible with a variety of host agency platforms and operating systems. This requirement applies not only to the integration of existing systems into the regional architecture, future systems should not be locked into using a specific platform or operating system because of the data interface requirements. The data interface will be able to interface with all of the existing systems under study and provide a gateway into the network and database. Minimum features of the proposed data interface include:

- Pentium 100 MHz with 32 MB memory
- 1 GB hard disk
- 2XCDROM
- Network interface card
- Operating system
- Network software (e.g., TCP/IP with NFS, SNMP support, DECNet/Pathworks support, Novell Client support)

### 3.2.2 Workstations

All user access to the regional network will be through workstations located at each system-level TOC and at the TMCC. The primary objectives of the operator interface are to provide an effective means for personnel to enter/log information (e.g., incident and construction events), to facilitate the interpretation of regional information (e.g., graphics displays), and to quickly develop solutions to problems (e.g., coordination support). The regional network will use an integrated workstation concept to allow common information to be shared across the multiple systems and to provide a common interface to the network. The information presented on the workstations will be displayed in a combination of formats - including graphical, textual, and video - and will include interfaces to existing and future agency - specific systems. Through the use of standardized graphical user interfaces (GUI) and support products, these various kinds of information can be presented in an integrated fashion. Features and mechanisms common to most GUI environments include moveable and/or re-sizable windows with scrollable content regions and lists, multiple fonts, and intermixed graphics on high resolution displays. Operator input and selection is provided via mouse and keyboard devices.

Many different windows can be made available to the user. Detailed requirements will be defined through the coordinated effort of the participating agencies to reach consensus on an ATMS Operations Plan and standards for a Regional TOC Information Exchange Network. Some examples of these include:

- Status windows to present real-time text and value-based status on attributes of either a single entity or an "object" within the system. Objects may include roadway and transit links/nodes (e.g., identification, lanes, current volume and speed, system elements on the link, headways), routes (combinations of links and nodes), and/or individual system components (e.g., VMS). Attributes will change over time due to data collection cycles, operator input, and event-driven modifications.

- CCTV video window to display live video images from selected cameras. A portion of the window may include a video selection panel for identifying the available video channels in the network and selecting the desired one. This panel may also be configured to provide camera control.

Several GUI packages have emerged as industry standards. In the PC environment, packages include Microsoft Windows, IBM Presentation Manager, and HP NewWave. In the UNIX and networking environments, the X Windows system has become the defacto standard. The X Windows system is designed to operate in a network environment and uses a client-server model to communicate between the display application and the display device. Another standard that is under development is the IEEE 1201.2 Drivability Recommended Practice. This standard will address the window system and GUI functions.

The workstations will be a high-speed microprocessor-based computer system functioning under a multi-tasking operating system. The system should support an industry standard window environment with access to third party support software such as e-mail, spreadsheets, and statistical packages. The workstations must also support the selected LAN networking protocol and database management system (DBMS). Peripherals will include keyboard, mouse, and high resolution color monitor.

### 3.2.3 Remote Workstations

Several agencies will not be providing automated data to the TMCC but may regardless be interested in receiving the information. Remote workstations will be used to accomplish this receive-only function. They are simply wide-area network extensions of the TMCC/TOC network. A remote workstation will be loaded-with workstation and communications software that support the receipt of data from a TMCC regional server.

### 3.2.4 Remote Bridges/Routers

Electrical devices called brouters are used to link two local area networks, and connect their respective network traffic on separate LANs. Remote brouters are used to tie together separate

LANs connected by a point-to-point communications such as a telephone line. In this case, the remote brouters connects the LAN at the agency TOC with the LAN at the TMCC.

### 3.2.5 Software

Each data interface will require specialized software to interface properly with the host system. This software will accomplish the following functions:

- Access the host systems database and retrieve the necessary information.
- Process these data as required. As an example, most roadway links in the regional network will have multiple sensors. Moreover, these sensors will transmit data to the system TOC at intervals more frequent than the regional cycle time (i.e., 20-seconds to l-minute as compared to 5-minutes). The data interface will take the data from multiple sensors over multiple time periods, and convert the information into wide values covering the entire 5 minutes.
- Perform initial error checking of the processed information. For example, the current 5-minute value might be compared with historical information for the same period as a validity check. The error checking function may also include identifying the status of each individual detector within a link as provided by the host machine, eliminating any failed detectors from the link calculations.
- Convert the aggregated data into the regional protocol for transmission to the TMCC.
- Access the regional database (at the TMCC) and retrieve the necessary information.
- Support video selection, coordination support, real-time graphic displays, database access, and communication functions.

The data interface will connect to existing systems using standard communications software and protocols where available. The data interface will perform its translation function processes on both the existing member agency's system and the TMCC regional database server. A process on the data interface will request data from a 'data provider' on the existing system via interprocess communications. Interprocess communications allow software processes on the same system or different systems to communicate with each other. Examples of interprocess communications include sockets (TCP/IP) and mailboxes (VMS, DECnet). In the case where no off-the-shelf software is available to facilitate interprocess communications between the data interface and the existing systems, custom serial communications software will be developed.

After a native data stream is received from the existing system's data provider process, it will be sent to a translator and normalization process (also on the data interface) that will convert the data from the system's native format to the TMCC standard common access format and relate the data to the regional transportation network links. As a final step, the data interface will send the data to the TMCC regional database server which will make the data available to the regional database and to all agency workstations. The communications protocol to the regional server will be TCP/IP. The interprocess communications standard that will support the data interchange between the data interface and the TMCC regional servers will be TCPAP sockets. The data interface will have the ability to connect to various kinds of existing and future systems, and support a variety of communications protocols as summarized in **Table 3-1.**

TABLE 3-1

OPERATING SYSTEMS AND COMMUNICATIONS PROTOCOLS

| System Type | Communications Protocol | Inter Process Communication Option |
|---|---|---|
| UNIX | TCPAP | Sockets |
| VAX/VMS | DECnet<br>TCP/IP<br>LAT<br>Serial | Mailboxes and Sockets<br>Sockets<br>LAT<br>Custom |
| OS/2 | Netbios<br>TCP/IP | Netbios/Named Pipes<br>Sockets |
| NT | TCP/IP | Sockets |
| DOS | Connection to native DOS systems may require an upgrade of the system to the OS/2 or NT platforms. The DOS application will then be run under new environment and then use Netbios or TCPAP and sockets as communications protocols and interprocess communications links. | |

### 3.2.6 System-Specific Requirements

The data interface software will include elements that allow the data interface to communicate and gather data from an existing system. The design of the data interface is such that the impacts on existing systems will be minimized. Nonetheless, an agency's existing system will require the development of custom software that aggregates and sends data in the system's native format to the data interface. Custom communications software may also be required for both the data interface and the agency's existing system that will allow a process on the existing system to communicate with a process on the data interface. Custom software on the data interface will also be needed to convert between the system's native format and the TMCC common access format. The cost of this custom software will vary, depending on each specific system's plafform and operating system, applications program language, and file structure.

It is noted that future local TOC systems may incorporate the necessary files, processing functions, protocols, etc. into their central hardware/software design, thereby eliminating the need for a data interface. Integrating this functionality directly onto the host platform does create some potential drawbacks. One of the functions of the data interface is to serve as a 'gateway' between a TOC and the TMCC permitting the central hardware at each location to automatically exchange information regardless of their respective specifications and compatibilities Eliminating this gateway in future system designs will require these systems to use TCP/IP, and essentially be an extension of the TMCC configuration. Video selection may also prove difficult.

Another concern is the additional burden placed on the host computer in terms of processing and communications, particularly when most networks are being developed in a distributed environment. Therefore future upgrades should be designed so that the TOC systems maintain their independence and the peer-to-peer with centralized coordination architecture is preserved.

## 3.3 TMCC HARDWARE AND SOFTWARE

The proposed hardware configuration at the TMCC is shown in **Figure 3.2.** At the heart of the regional TMCC architecture is a network of servers. This central processing hardware will manage the large real-time database,. provide fast response to the multiple users (i.e., agencies) who will often access the regional network simultaneously, store data to support the graphical user interface and coordination support mechanisms, and generally other system functions. Each server will perform specific tasks or processes assigned.

### 3.3.1 TMCC Architecture

As mentioned earlier, the ATMS architecture will be based on the client-server model. The TMCC architecture will also be developed using this medel. The benefits of this approach for ATMS are a scalable, expandable, flexible and open architecture. Scalable means that as the ATMS grows, the architecture will not have to be redesigned. Expandable means that as new functions are

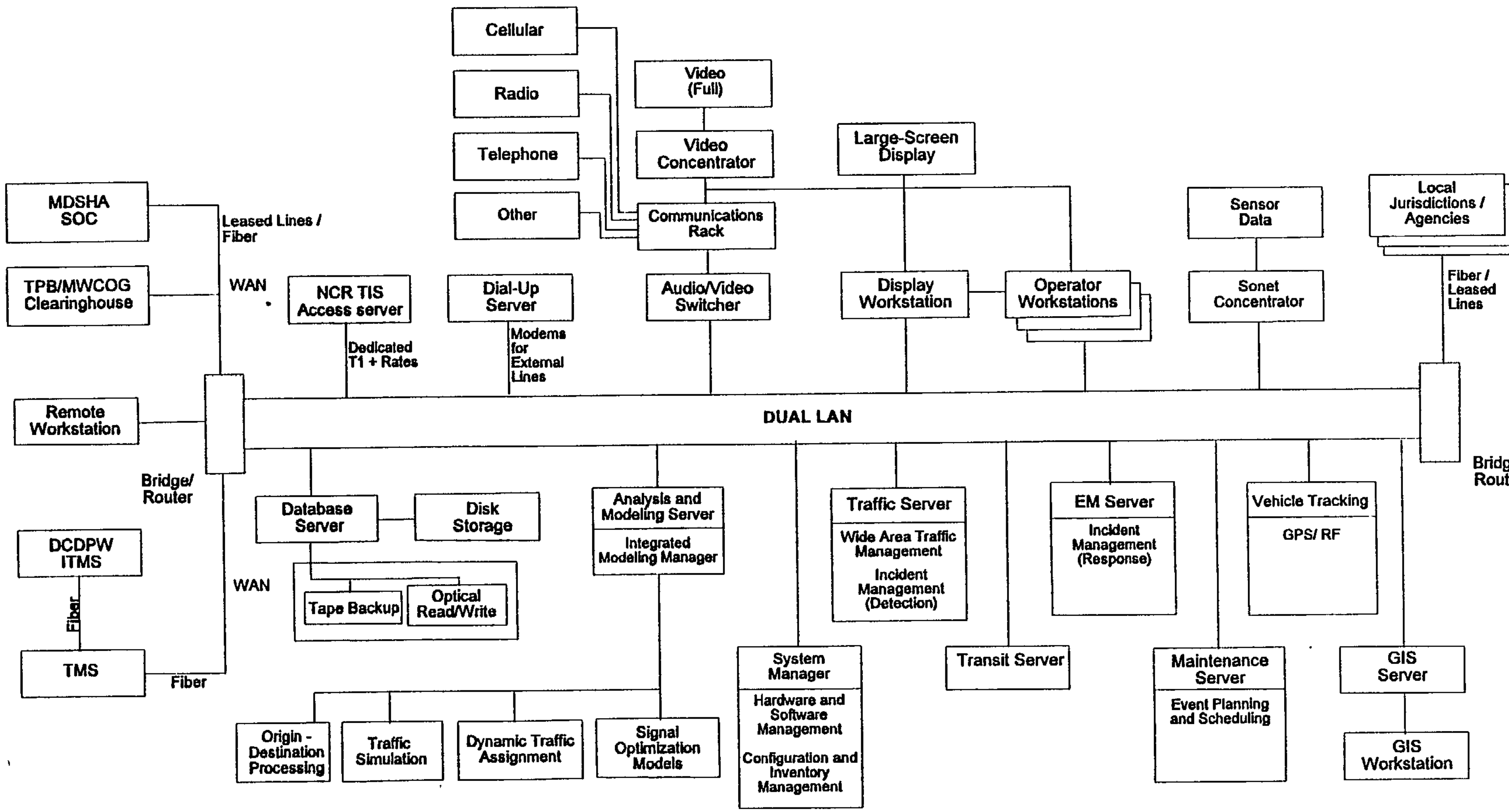


**Figure 3.2 - Recommended TMCC Configuration**

added, providing additional or more powerful processors will be all that is needed to continue operations. Flexible indicates that the functions and processes can migrate across platforms of varying power or networks without failing.

#### 3.3.1.1 Local Area Network

The dual LAN will be fiber based and support both TCP/IP and Ethernet protocols. Network technology is rapidly advancing, it is expected that at the time of initial ATMS delivery Ethernet technology will be capable of transmitting data at 100 Mbits per second. The dual network is provided to ensure high availability of the TMCC .

#### 3.3.1.2 Audio/Video Switch

This small dedicated processor will control the telephone, radio and video switching functions at the TMCC. The switching commands will come from operational computer processes, direct operator controls (dialing and switching), or operator directed computer based controls (pointing at locations and options on the GIS-based display).

#### 3.3.1.3 Display Workstation

This dedicated computer controls the signals that provide projection to the large display screen(s). The two types of signals that can be displayed are from the CCTV, computer generated images (GIS and/or graphics display) or a combination of the two. This display computers Control, like the audio/video switch, can come from direct operator commands, operational computer processes, or ‘point and click’ interfaces.

#### 3.3.1.4 Operator Workstations

To provide commonalty in the look and feel of the operators interface at the TMCC, three integrated operator workstations will be provided to serve traffic, transit and emergency management functions. Each workstation will consist of a computer, two 19” or larger high resolution color displays, a module consisting of four minimum 12” color monitors with three “quad” converters (allowing for 4 separate video per monitor), a keyboard and pointer input device (mouse, trackball,

#### 3.3.1.5 NCR TIS and Dial-up Servers

These information servers will provide the proposed National Capital Region Transportation Information Showcase system and the public access to the available TMCC traffic and transportation information. These servers provide security functions to ensure that unauthorized access to important operational information is not jeopardized. They also relief processing functions from the real-time operational TMCC computers. The number of access ports for each of these servers is expandable so when more people want TMCC provided information, more (in number or power) servers and/or ports can be added.

#### 3.3.1.6 Database Server

This high availability dedicated server will be accessed by most TMCC and ATMS related processing. It will be the central repository for the on-line transactions related to incoming traffic, transit, and emergency services conditions.

#### 3.3.1.7 Geographic Information System Server

Given the large amounts of data that will be input to the regional database from multiple sources (i.e., TOCs), coupled with the large area of coverage and the need to disseminate the information using a common reference, it is imperative that the database be organized using a GIS referencing system. Other subsystems will then access the information and perform spatial comparisons (e.g., developing travel time for alternative routes and modes between two nodes). A geographic information system (GIS) is defined as a computer hardware and software system designed to collect, manage, manipulate, analyze, and display spatially referenced data. The spatially referenced indexing used with a GIS provides a common foundation for the integrating and sharing of aggregate information within and across multiple transportation agencies.

The information collected and integrated by the TMCC into the regional database on the GIS server will be shared with other agencies (e.g., graphic displays) regardless of whether they have GIS. The regional architecture will also accommodate the integration of other agencies' GIS, just as it provides for the integration and information sharing. This will require the development of a regional standard for static data interchange. Such a standard will provide a detailed description of these data elements and their relationships, thereby allowing the import and export of information from the GIS to other agencies' GIS. One possibility in this regard is to use the proposed National Spatial Data Transfer Standard (SDTS).

#### 3.3.1.8 Application Servier(s)

These computers will contain majority of the processes required to carry out the ATMS functions at the TMCC. They must be at high availability since they support the TMCC operational requirements which are expected to be operated 7 days a week, 24 hours a day, and 365 days a year with minimum "down" time.

#### 3.3.1.9 Traffic Server

This server will provide the platform for deploying the Wide-Area Traffic Management and Incident Management (Detection) support systems discussed in section 2.4.1. Software that assists TMCC personnel in developing demand management strategies such as control of HOV facilities and freeway ramp metering will be available on this server. Software on this server also assists in developing coordinated strategies for responding to congestion predicted through Origin-Destination and Historical data analysis. It will also ingest incident data, classify, determine severity and expected duration, log the incident and suggest the most suitable incident management plan from a predefined set of ATMS strategies.

#### 3.3.1.10 Emeraency Management Sewer

This server will provide for coordination of incident response after an incident has been detected. Together with the incident management software on the traffic server, it fulfills the incident management support system requirements.

#### 3.3.1.11 Maintenance Server

This server will provide for maintenance management, repair scheduling and special event planning and scheduling.

#### 3.3.1. 12 System Management Sewer

This server will perform system administration functions such as management/operation center hardware and software monitoring, configuration and inventory management, granting user access to users and monitoring usage, etc.

#### 3.3.1.13 Analysis and Modeling Server

This server provides the platform for deploying the software for the integrated modeling manager support system described in 2.4.1.3. Software for Origin-Destination processing, Historical Data Analysis, Traffic simulation, etc., may be deployed on individual PCs configured to support those software and linked to this server.

#### 3.3.1.14 Vehicle Tracking

This server collects location information from transit and probe vehicles in the system. It processes location information from vehicles using different types of location systems such as GPS, Cellular, and Dead Reckoning and interfaces with the GIS server to provide location information on a map.

#### 3.3.1.15 Transit Server

This server coordinates the operations of the various transit agencies in the region. It serves as the focal point for information exchange between the various transit agencies. It also disseminates transit information to the NCRTIS project and other information providers. It coordinates with traffic management to ensure schedule adherence.

### 3.3.2 Database Management System

As previously defined, the regional network will require the use of Database Management Systems (DBMS) in the heterogenous network environment. Consistent interfaces between network TOCs and the TMCC servers will be required, allowing these architecture levels to exist on different platforms. Data interchange services will also be required to handle the exchange of data between different platforms.

Basic database services include the ability to access data and to perform searches based on potentially complex sets of conditions. Other operations include inserting, deleting, and updating records. The DBMS must also provide facilities to ensure data integrity. Facilities must exist to translate between data representation across platforms.

One potential standard is the SQL standard (IS0 9075:1982). Many database products support the standard SQL interface. A variety of other products include the SQL interface to allow data to be imported from databases. SQL should enable the use of many available software packages for database interaction. Even in a worst case scenario, where two DBMSs will not interact, the SQL user interface may be used as a bridge between the DBMSs.

### 3.3.3 Other Software Issues

In addition to the operating systems and third party software previously mentioned, the regional architecture for data exchange will require the development and integration of applications software at the TMCC to provide the necessary functionality. This will include the following:

- Protocols for two-way data transmissions between the TMCC and system-level TOCs
- Processing of all the data received from the TOCs, integration of the automated data with manual information, routing of the processed information to the appropriate devices, and storage
- Processing and support for the map interface, incident log, and construction log
- Coordination support processing, including real-time development and storage of response plans based on operator actions and inputs, and calculation of associated measures of effectiveness
- Graphical user interfaces and the associated screen layouts and graphic displays for the operator workstations at the system-level TOCs and at the TMCC
- Management of the information exchange network, including routing of channels between TOCs, identifying which channels are available to the network, ensuring that available communications bandwidth is not exceeded, etc.
- Processing (i.e., filtering) of the information for subsequent dissemination to the media and other private entities

## 3.4 SOFTWARE

An open systems environment is recommended to provide a complete environment for the development and implementation of computing systems based on a publicly available set of interfaces, protocols, services and supporting formats. The basic objectives of an open systems environment is to provide portability, scalability and interoperability. Portability provides the ability to move source code between diverse architectures. Scalability furnishes the ability to run software on machines of varying power and complexity. Interoperability supplies the ability for diverse systems to share and exchange data. All of these objectives must be fulfilled in order to provide the necessary functionality of the ATMS. These are necessary due to the heterogeneous set of hardware and software suites that are currently being used by the state, county, cities, towns, and other jurisdictions/agencies with which the ATMS must interface. An open system can:

- "Interoperate" on an integrated network.
- Encourage the development of "portable software applications".
- Protect investment in applications software.
- Enhance the productivity of knowledgeable workers.
- Reduce dependence on a single source of supply for technology.
- Enable the ATMS to distribute computing power throughout a network.
- Provide a stable base for the evolutionary development of large complex systems.
- Reduce training costs for developers and users.

An open system will also provide a wider selection of cost-competitive, reusable components and a wider selection of hardware and software options. It will also reduce dependence on a single vendor's product (e.g. UNIX vs. VMS) and standardize communication mechanisms between products which will allow the ATMS to evolve, rather than become obsolete.

### 3.4.1 Operational COTS Software

The Northern Virginia ATMS will be based on an open systems environment and extensive use of Commercial-Off-the-Shelf **(COTS)** products, where applicable.

#### 3.4.1.1 Standards

Three Government Profiles for standards need to be considered. The profiles will include the National Institute of Standards and Technology (NIST) standards, Defense Information Systems Agency (DISA) Technical Reference Model, and X/Open.

NIST has published the Application Portability Profile (APP) which defines a common tailored environment and refers to standards-and Federal Information Processing Standards (FIPS). The Technical Reference Model, under control of the Defense Information Systems Agency, tailors and expands the APP and works closely with NIST. The X/Open is an International Certification Group.

The Applications Portability Profile (APP) provides **a** reference used by agencies of the federal government defining open systems. It ties together the various ISO, FIPS, ANSI, NIST, IEEE and other standards, but it itself is not a standard. The APP is constructed from seven services:

Operating system, User interface, Programming, Data management, Data interchange, Graphics, and Network management. These services implement the programming and data interfaces defined in the various standards that are utilized to provide an applications portability profile. The system software managers will use the APP to define a single logical machine that will be used in multiple and different ways.

The DISA Technical Reference Model for information management is an important element in the Corporate Information Management (CIM) Initiative. It provides a common architecture and standards for all infrastructure programs within the DoD, and defines a common vocabulary and set of basic standards for the infrastructure systems. Its key goals include improving: user productivity, development efficiency, portability and scalability, Interoperability, vendor independence, life-cycle cost, and security. The DISA Technical Reference Model is derived from the APP and is closely aligned with IEEE POSIX 1003.0 Draft Guide. POSIX stands for Portable Open Systems Interface for UNIX.

X/Open is a worldwide organization dedicated to specifying an open Common Applications Environment (CAE) based on de facto and international standards. The X/Open Portability Guide contains a list of standards meant to ensure source code portability. The CAE lists standards for applications to interface with: Operating systems, User interfaces, Data management systems, Networking and Languages. X/Open is broader than NIST in its selection of applicable standards and is playing a leading role in object-oriented approaches to software design and development. In summary, the ATMS will adhere to all of these standards as they are accepted and supported by COTS vendors.

#### 3.4.1.2 Environment

With client-server computing, the ATMS will have the choice of a broad range of industry standards and PCs, workstations and servers that are high quality, competitively priced, and optimized for network operations. This allows the project to more effectively use the existing desktop systems with leading desktop applications and software to integrate applications from key COTS vendors.

The NoVA ATMS project will contain a heterogeneous and loosely-coupled workstation/PC-based environment and not a mainframe or cluster environment. This distributed architecture improves user productivity by making data access faster and easier, and the emergence of commercial-quality open systems now gives users an even more economical and powerful alternative.

The cost benefit in staying away from a VAX-cluster environment and moving towards a client-server environment are of importance. For example, hardware costs of new equipment are significantly less than in a VAX-cluster environment. The initial cost estimates for supporting an open system development platform vs. a VAX development platform have been approximated at cost ratios of 30 to 1. Additional savings can be found in lower cost for peripherals (particularly disks) and reduced recurring maintenance costs. Also, reduction in facilities costs are anticipated due to floor space requirements, elimination of costly air/humidity handling equipment, reduced investment in electrical power conditioning and UPS equipment. Of particular savings is the leverage in existing investment in PCs. MS/Windows machines can become functional clients through use of Windows GUI software, XI 1 windowing software, and/or NFS networking.

Software costs for open systems operating system software (e.g. UNIX, NT) are an order of magnitude lower than VMS or other proprietary systems. Pricing of COTS software products are lower due to competition in the open systems market and recurring software maintenance dollars are less due to lower initial investment.

Staffing costs will also be less expensive with an open system architecture. The trend is towards fewer individuals and more complex tasks. Open system workstations have become a critical necessity where productivity is an issue. Also, software specialists {for proprietary products) within VDOT, local jurisdictions, and agencies are a scarce commodity. This is in direct contrast with the number of UNIX knowledgeable specialists currently in the workforce.

It is recommended that the NoVA ATMS use an open system architecture. The ATMS software architecture will also be a layered and open. Layering is an approach that isolates functionality and services with well-defined interfaces and will allow application developers to be isolated from lower-level systems. This supports openness, interoperabiiity, portability, and standards. Layering will take place at many levels: between service layers and within services. In the layering design, standards can be imposed. These standards will describe interfaces and functionality and not the implementations. Layering also isolates functionality details and machine dependencies. An example of this layering is the IS0 Open Reference Model.

### 3.4.2 Operating System

The operating system should be able to perform all of the previously mention functions without significantly slowing down the computer or requiring extensive additional hardware (processors, and memory, both permanent and temporary). It should be capable of running on PCs, and at least communicating with workstations. It must provide the ability to connect any number of computers together in a LAN configuration.

The operating system should provide a simple and user-friendly graphical user interface and extensive on-line help for new and advanced users. It must also be multi-tasking and multi-threaded. The multi-tasking so that more than one program can be resident in memory and operational at any time; the multi-threaded so that a single program can perform multiple tasks at the same time. Further, the operating system must provide a large and flat memory model so that programs and data of unlimited size can be reliably and safely accessed and executed. This memory must be protected so that errors in a single program do not crash the system as a whole. Finally, It is recommended that the operating system be one of the standard packages in common use in today's market so that extensive software and support is readily available.

#### 3.4.2.1 Operating Svstem Alternatives

There are a variety of operating systems that are available on today's market The following provides a brief overview of the features of the more common operating systems.

***DOS (Disk Operating System)***

Although DOS does not satisfy the requirements previously mentioned, it is important to include it because for many years it was the standard for operating systems, and nearly all subsequent operating systems have been based upon it. DOS is entirely driven by commands entered at a prompt and is very rudimentary. DOS is not multi-tasking, and applications have direct access to only 640 Kilobytes of memory. In addition, it is only an eight bit operating system, which means it moves data around in eight bit increments, relatively slow by modern standards.

***Windows***

Windows is not really an operating system on its own, but it is an addition to DOS. It provides a graphical user interface, some multi-tasking abilities, and effectively eliminates the 640 KB DOS memory barrier. It also provides rudimentary facilities for networking multiple computers together. It is a sixteen bit operating platform, and therefore considerably faster than DOS on its own, but slower than more recent operating systems.

### *Windows NT*

Windows NT is not just an extension of DOS but is a full-fledged operating system in its own right because it does not depend on DOS and it is free from many of the DOS limitations. To the user it will look and work very much like a DOS version of windows. It is a multi-tasking, multi-threaded, 32 bit operating system, and provides sufficient capabilities for networking a number of computers together. It is a brand new and untested operating system, which is a note worthy drawback.

### *OS/2*

OS/2 has been around for a number of years. The initial versions were severely limited but OS/2 version 2.x has overcome many of the early defects. OS/2 provides its own user graphical interface, and has the capability to switch to a DOS or Windows mode. The majority of DOS and Windows programs will run in OS/2. It is a multi-tasking, multi-threaded, 32 bit operating system, and provides sufficient capabilities for networking a number of computers together. Having been around for a number of years, OS/2 is well tested.

### *UNIX*

UNIX was originally designed for large mainframes and minicomputers, but versions of it are now available for all computers. It provides multi-user capabilities so that several users can use the same computer at once, from different terminals. It is multi-tasking, has recently become multi-threaded, and provides fully sufficient capabilities for networking a number of computers together. In addition, it can be integrated into an OS/2 network, so that a computer running UNIX can fully communicate with computers running OS/2. Whether or not it can be integrated into a Windows NT network remains to be seen. The disadvantage of a UNIX operating system is that it requires large amounts of memory and disk space, and is expensive. It is usually considered impractical for a small computer.

### *Macintosh/System 7*

The most recent operating system for the Macintosh is called System 7.x. Macintoshes have very rarely been considered for systems such as this which are intended to be flexible and fully compatible with existing systems. Support for the Macintosh has steadily increased over the years. Software (such as PCSoft), and hardware (such as the PowerPC), have bridged most of the communications gaps between other PCs and the Macintosh. A Macintosh can be integrated into most other networks. Apple and Macintosh computers have a very strong history of being fully equipped, and easy to use. The traditionally high cost of the Macintosh has been decreasing. It is important not to ignore the possibility of a system based on Macintoshes, but their use is still limited in the general computer industry.

**OS/32**

OS/32 has been around for a number of years. In fact, it was OS/32 that was first used for the UTCS systems in the early 1970's. Unfortunately, because it never became a major standard in the PC industry, current versions of OS/32 still have limited features compared to more mainstream operating systems. A primary limitation to this-operating system is that it requires a minicomputer on which to operate. In addition, due to its limited use, adequate system support may be difficult to obtain. OS/32 does not provide its **own** graphical user interface. Some software packages have developed a basic graphical environment, but these generally lack the capability of windowing and do not provide many of the standard user-friendly features (e.g., menu bars and on-line help). Further, it only supports applications written for the OS/32 environment.

***VMS***

VAX Management System is a proprietary operating system of the Digital Equipment Corporation and has been in existence since the early 1980s. It was an important operating system for real-time computing applications, but has been experiencing a downward sales trend in recent years. Of its weaknesses, the most significant to ITS applications is poor software driver support for equipment from third party vendors and its excessive utilization of computing resources. VMS provides its own user graphical interface (DecWindows), but MOTIF applications can be developed. It is a multi-tasking, 32 bit operating system, and provides sufficient capabilities for networking a number of computers. It does not provide built-in support for threads. . VMS software is free when purchasing appropriate DEC hardware.

### 3.4.2.2 <u>Operating System Recommendations</u>

The ATMS TMCC operating system is recommended to be UNIX, which will provide a superior environment for rapid prototyping and application development. It facilitates program modularity and reusable code, which lowers software costs, speeds development and improves maintainability. UNIX supports the best solutions for client-server computing. No other environment supports the range of applications, systems, networking and tools required to harness the full power of client-server computing.

The initial traffic control applications software for the NoVA ATSS is based on the Management Information System for Traffic (MIST). The product is written in the C language and requires the IBM OS/2 operating system on a PC type platform. OS/2 2.0 is a high performance operating system that performs multiple tasks simultaneously (a requirement for the traffic control system). OS/2 has the ability to run MS-DOS and Windows 3.0 applications as well as those written specifically for 16- and 32-bit OS/2 (OS/2 is already a 32-bit operating system). OS/2 2.1 enhancements will provide a 32-bit graphics engine, the ability to run Windows 3.1 applications, and more support for printer and display drivers (a weakness in version 2.0).

Currently, the MIST TCS product is using OS/2's Presentation Manager for the GUI to its traffic control services. This is acceptable for the present applications using MIST. But these GUI services are out of date. Today, most of OS/2s interoperability features are focused on the Workplace Shell, a GUI designed to replace OS/2's original GUI Presentation Manager. The Workplace Shell helps users integrate information across different servers by manipulating on-screen icons. However, in addition to the Workplace Shell, OS/2 users need “requester” software that will communicate with the network operating system running at every server. Requesters let different application programming interfaces be loaded or unloaded as needed. The recommendation would be for this product to be written using X Windows (which currently supports such functionalities) or use Windows NT with its proposed network GUI architecture.

Another operating system that is an unknown, as regards to functionality and ruggedness, is Microsoft’s new Windows NT. If Windows NT provides the “hyped” functionality as has been marketed, it could be the choice for the ‘PC-based’ software of the future.

### 3.4.3 Languages

All new software to be developed and or integrated with the existing MIST product capabilities, will be written in the C language and operate under the UNIX operating system. This is especially true of the interfaces to the relational database management system and GIS software. The main programming language will be C and ANSI X3.1 59-1989 compliant with bindings to POSIX 1003.x. This is the defacto standard for most UNIX programming and tool building and provides interfaces with POSIX defined in terms of C. This project will use integrated software engineering environments and CASE tools. These tools and environments will contain Program editors, Code generators, Design Analyzers, Test data generators, Compilers and loaders.

All new development will be done with the C programming language. The MIST TCS product is currently coded in C and will continue to be updated with C. All software in the COMPASS FTMS package will use C and UNIX. All TMCC/TOC software will use the chosen integrated software engineering environments, CASE tools and Software Methodology described in Section 4.5. Eventually all C programming code will be translated to C++.

# SECTION 4.0 PHASED IMPLEMENTATION PLAN

## 4.1 VISION

Simply stated, the vision for the NoVA ATMS is total traffic management capability. This vision is to be achieved through the application of a client-server methodology for information exchange. For Northern Virginia, this methodology is supported by a systems architecture that provides peer to peer information exchange with centralized management coordination.

The vision for the NoVA ATMS is also multi-modal in appearance with respect to information processing requirements. The functional decomposition for traffic management in Section 2.3.2 includes process integration for traffic management, emergency services, public transportation management, and traveler information services. The emphasis with this approach needs to be placed on the data interfaces between numerous existing "legacy" systems currently operating in the region to establish network data exchange and communication protocols. In addition, these existing systems currently operate under an equal number of organizational structures. And, these structures have independently evolved to generate varying requirements for internal information processing and reporting formats with respect to operations and maintenance. Therefore, data recording and data reporting formats will also require further attention as system implementation progresses.

### 4.1.1 Interagency Operations

The analysis of the communication system requirements identifies a need to establish a wide-area-network (WAN) interconnecting the existing operations centers in the region for peer to peer information exchange. It is proposed that the network level management function be performed by centralized coordination through a regional Transportation Management Coordination Center (TMCC). The use of the term "center" here relates to the functionality of the total traffic management system, only.

#### 4.1.1.1 Management Process Distribution

The architecture recommended for the NoVA ATMS provides for distributed data processing and control, therefore, management responsibilities can be similarly distributed on the WAN to any number of operating entities. The ultimate control of the individual agency systems remains with that agency. To maximize the efficiency of the process, however, the degree of management process distribution will need to be coordinated and mutually agreed upon by the jurisdictions and agencies involved through collective and comprehensive agreements. While many similar agreements are already in place among the various jurisdictions and transportation agencies in the region, it is expected that some minor adjustments to the terms may be required. This is largely due to the need to minimize overlapping functions of the individual agency systems, when integrated, to maximize regional system efficiency. With the implementation vision, this process can also exist in a dynamic state, i.e., as experience indicates through actual day-to-day operations once the regional network is implemented, the level of participation of the jurisdictions and agencies can be adjusted to accommodate the particular needs of any one individual party, without significantly affecting overall efficiency of regional information exchange and system management.

#### 4.1.1.2 Interagency Communications System

The vision also maximizes the utilization of the existing, available communication infrastructure for the backbone interagency communications system. The fiber optic (FO) communications backbone currently owned and maintained by VDOT will require some expansion and ultimately is recommended to have fault tolerant capability to ensure continuous real-time data exchange between the majority of the agencies on the network, in the event of a communications failure along any segment of the backbone. The current system utilizes, in part, a collapsed-ring topology which cannot provide the degree of protection and re-routing capabilities required in the event of spot failure on the backbone. A systematic program for this expansion is included in the vision to provide self-healing capability to the network.

Through the expanded system, the various operations centers will be linked on the WAN via direct FO or wireless communication links, either through owned facilities or those facilities owned and maintained by independent service providers (ISPs). The facility utilized for a particular link is determined by its cost effectiveness at that particular time frame in the ATMS deployment strategy.

### 4.1.2 Individual Agency Operations

The vision provides for each individual agency to maintain its current level of autonomy, unless otherwise agreed upon for a particular need or circumstance. Implementation of integrated operations, however, will require each agency to actively participate in developing an internal plan to consider the NoVA ATMS implementation requirements in their current facility maintenance programs and existing or planned system(s) expansion. This consideration is crucial for success in improving traffic management in the region. As the recommended deployment projects in Section 3.2.2 suggest, opportunities for public/public and public/private cost sharing will be an integral part of any particular project deployment, particularly in the emergency management and traveler information services.

The vision also offers opportunity for each agency to maximize its benefit in actively participating through economies of scale. The natural evolution of technology will make these opportunities apparent when they come into existence - and they should not be overlooked. Privatization, government decentralization, and general downsizing trends in the public sector will further influence future decisions regarding agency coordination and collaboration. As region-wide ATMS and other advanced transportation systems evolve with the economic environment and business culture of the region, numerous co-location and resource sharing opportunities are anticipated with respect to traffic control and public transportation management services. This trend is currently being experienced in the region and activities in this area are expected to accelerate over the near-term (l-3 year) time frame. The implementation strategy, systems architecture, and supporting elements are configured to address these trends. Most importantly, it provides a resource to the individual agency and will present opportunities to reduce annual operating expenses while providing enhanced transportation services to the users in their jurisdiction.

## 4.2 DEPLOYMENT RECOMMENDATIONS

As the functional decomposition of the ATMS Architecture identifies, there are numerous functional requirements that the NoVA ATMS must meet. The deployment recommendations are intended to address ail requirements under each project, as applicable, in its early planning stages. it is recommended that any traffic improvement project under consideration, in addition to the system-oriented projects recommended with this report, perform an evaluation to identify those functions that may have particular application to that project. This will serve to facilitate the implementation of ATMS and the supporting ATMS infrastructure through a uniform evaluation process.

Through this study's user interviews and inventories, documented in the *Interim Report*: User Services *P/an,* overcoming credibility problems with existing operations and improving public image of the primary transportation service providers through improved service reliability were noted as the key factors to a successful regional deployment. Among the jurisdictions and agencies, a universal preference was indicated for initial service deployments that focused on operations rather than the benefit of ITS user services to the end user, such as traveler information services.

As a result, and consistent with the functional decomposition for the NoVA ATMS, the project recommendations presented herein are operations oriented with a primary focus on expanding and enhancing traffic control and emergency management. Secondary consideration is given to the ATMS deployment strategy with respect to interfaces with public transportation operations and traveler information services deployment. These are addressed in more detail in the ITS Strategic Deployment Plan.

### 4.2.1 Sequencing Priorities

Deployment priorities are established by evaluating the ranking of user service deployment needs against the ATMS system objectives and functions presented in this report. **Table 4-1** identifies which user services represent priority needs for the system improvements.

A total of 16 user services are included in the ATMS implementation sequence. Of these, 7 are recommended as primary deployment targets and 9 are considered secondary to ATMS deployment. The primary deployment of these secondary user services is through other service areas such as travel demand management and public transportation operations. They are considered here in accordance with the process areas identified in the ATMS Architecture functional decomposition in Section 2.0.

The data flows identified in the primary process areas of Traffic Management, Emergency Services, Public Transportation Management, and Traveler Information Services also play a key role in developing sequencing priorities and specific project elements for ATMS deployment. Analysis of the data flow diagrams show that primary early deployment (near-term) drivers for the Northern Virginia Region include:

- Need for diverse data collection and real-time database capabilities
- Interjurisdictional coordination, cooperation, and cost sharing
- Local agencies need real-time information on freeway traffic conditions and incident management operations
- VDOT needs expanded real-time information on arterial traffic conditions and arterial control systems status
- Access to regional databases is needed that contain arterial and freeway information, timing plans and schedules, current and planned construction and maintenance activity, and traffic volume data

**TABLE 4-1**
**IMPLEMENTATION SEQUENCING PRIORITIES BY USER SERVICE**

| Priority No. | User Service/Description |
|---|---|
| 1 | Incident Management |
| 2 | Traffic Control |
| 3 | Emergency Vehicle Management |
| 4 | En-Route Driver Information * |
| 5 | Electronic Payment Services |
| 6 | Emergency Notification & Personal Security * |
| 7 | Public Transportation Management |
| 8 | Route Guidance |
| 9 | En-Route Transit Information * |
| 10 | Public Travel Security * |
| 11 | Demand Management & Operations * |
| 12 | Personalized Public Transit * |
| 13 | Commercial Vehicle Electronic Clearance |
| 14 | On-Board Safety Monitoring * |
| 15 | Emissions Testing & Mitigation * |
| 16 | Automated Roadside Safety Inspection * |

* Secondary service

These considerations are given particular attention with the project deployment recommendations in the near-term (1-3 year) deployment time frame.

These priorities are recommended to be addressed over the next 18 year time frame. The end of this time frame is coincident with the end of the mid-term (2000-2005) deployment window and is consistent with the migration paths foreseen in the industry for the availability of supporting technologies and functions that will enable total integrated transportation system management implementation for the year 2006 and beyond.

The identified secondary services and those primary services pertaining to Commercial Vehicle Operations – Commercial Vehicle Electronic Clearance and Automated Roadside Inspection – while interdependent on ATMS deployment, are proposed to be implemented under other ITS deployment areas. Deployment recommendations for these services are addressed in detail in the ITS Strategic Deployment Plan.

### 4.2.2 Project Descriptions

Presented on the following pages are general descriptions of recommended deployment projects for the primary ATMS services. These represent major elements of the deployment strategy in achieving the system objectives and follows the general sequence of deployment priorities presented in the previous section. The projects are summarized in **Table 4-2.** The target deployment time frame is also identified by project. It is important to note that the project deployment recommendations in some cases may represent a “family” of potential smaller projects. The final project size and extent of ATMS coverage for the region will be dependent upon the final number and level of participation of the jurisdictions and agencies in any one project area. The potential projects identified herein are regional in scope, i.e., considered when deployed to be of regional significance in improving operations. They are also considered as such for the purpose of guiding the development of conceptual cost estimates for region-wide deployment.

**TABLE 4-2**
**ATMS IMPLEMENTATION PROJECT SUMMARY**

| **Proj. No.** | **Project Name** | **Near –Term** (1997-1999) | **Mid-Term** (2000-2005) |
|---|---|---|---|
| 1 | Regional TOC Information Exchange Network | ● | |
| 2 | Regional Signal Systems Integration – PHASE I | ● | |
| 3 | Capital Beltway (VA) ATMS | ● | |
| 4 | ATMS Operations Plan | ● | |
| 5 | Alternate Traffic Routing/Diversion Pilot Project | ● | |
| 6 | FO Communications Backbone Expansion-PHASE I | ● | |
| 7 | Emergency Services Integration | ● | |
| 8 | I-395/66 TMS FO Tie-In/Upgrades | | ● |
| 9 | Transportation Management Coordination Center | | ● |
| 10 | Traffic/Transit Data Exchange | | ● |
| 11 | Regional Signal System Integration – Phase II | | ● |
| 12 | FO Communications Backbone Expansion–Phase II | | ● |

## PHASED IMPLEMENTATION PLAN

**Number:** 1

**Name:** Regional TOC Information Exchange Network (IEN)

**Primary User Service(s):** Incident Management, Traffic Control

**Description:** Establish an initial electronic information system to interconnect the primary operations and information centers at both regional and inter-regional levels. Regional centers for this phase include the existing NoVA District TOC, the VA State Police (Fairfax), and the TMS. Interregional centers include the MD State Operations Center (SOC), the near-future District of Columbia integrated Transportation Management System (ITMS) center, and MWCOG's Regional Clearinghouse.

This initial system will include one work station per agency with full GIS capabilities to display region-wide operational information. The system will facilitate information exchange – both data and video. Communications between the NoVA TOC and VA State Police regional centers will be provided by lateral communication links to the SONET compliant fiber optic (FO) backbone of the NoVA TMS Expansion Project, when complete. Short-term interregional center connections to the regional network will be accomplished via dial-up or dedicated line access. The system will allow for full voice, data, and video exchange capabilities, with compression technologies utilized for interregional video transmission.

The system will facilitate advanced traffic management, initial enhancements to emergency (incident) management services, and support area-wide traveler information services deployment initiatives such as the anticipated National Capital Region Traveler Information Showcase project. The IEN project will also define the initial protocols for inter-center information exchange and perform a detailed assessment of independent **agency** specific systems relating to software integration requirements to support direct transfer of operational and historical data recommended to be implemented under subsequent operations improvement projects.

**Objective:** Initial enhancement of regional and interregional traffic operations and incident management processes.

**Scheduled Start:** **Year 1**

**Participants:** VDOT, VA State Police, MDSHA, DCDPW, MWCOG as primary tier participants. Secondary tier to include Arlington County and City of Alexandria for coordination data exchange requirements with other projects underway.

**Number:** 2

**Name:** Regional Signal Systems Integration - PHASE I

**Primary User Service(s):** Traffic Control

**Description:** The initial element of this first phase project is "study-oriented" and will perform a detailed requirements analysis and preliminary engineering for the integration of regional arterial signal operations. This project will focus on system modeling to optimize arterial traffic flow across the region. It will also determine independent system data interface requirements to standardize data and communication protocols to interface with Project 1. Current independent signal systems to be considered are the NoVA ATSS, Arlington County, and City of Alexandria systems.

The preliminary engineering element of the project will examine local controller and other field equipment upgrade requirements and evaluate the addition of a supporting CCTV subsystem(s) for arterial surveillance. Preliminary plans and functional specifications will be developed for all project elements.

Implementation of this project will facilitate "real-time" data exchange between the NoVA ATSS, Arlington County, and City of Alexandria signal systems.

**Objective:** Provide an integrated environment between the primary arterial signal control systems, provide advanced monitoring features of system field components, and expand the existing surveillance network.

**Scheduled Start:** Year 1

**Participants:** FHWA; VDOT; Counties of Arlington, Fairfax, and Prince William; Cities of Alexandria, Fairfax, Falls Church, Manassas, and Manassas Park; Towns of Dumfries, Herndon, Leesburg, and Vienna; MWCOG.

**Number:** *3*

**Name:** Capital Beltway (VA) ATMS

**Primary User Service(s):** Incident Management, Traffic Control, Route Guidance

**Description:** Perform a detailed requirements analysis, conceptual design and preliminary engineering for the expansion of the NoVA TMS. This project will focus on system needs in the area of surveillance requirements/technology and closely interface with the I-95 Corridor Coalition efforts to examine advanced and new technology applications for wide-area surveillance.

The requirements analysis and conceptual design elements of this project are recommended to be linked to Project 2, to evaluate the integration of freeway and arterial systems traffic modeling for the purpose of examining alternatives to traditional ramp metering strategies.

Final design and implementation of a motorist information variable message signing (VMS) system on I-495 to interface with the MDSHA CHART Program and area-wide traveler information services initiatives are recommended under this project for early implementation. Expanded CCTV surveillance and a pilot program for demonstration of wide-area surveillance and detection techniques are recommended under this project as well. The latter will require close coordination with Project No. 2.

The project will also "showcase" a wireless communications subsystem for I-495, interconnected to the VDOT-owned FO backbone through system nodes at the I-495/1-66 and I-495/I-95/I-395 interchanges. It will also serve as the "prototype" for future upgrades (mid-term) of detection technologies and other field equipment in the existing freeway management system (I-395, I-66, I-95) .

**Objective:** Expand the existing surveillance network and provide an integrated environment between the arterial control systems and freeway management systems.

**Scheduled Start:** Year 2

**Participants:** FHWA; VDOT; Counties of Fairfax and Prince William; City of Alexandria; Town of Vienna

**Number:** 4

**Name:** ATMS Operations Plan

**Primary User Service(s):** n/a

**Description:** Address the initial requirements for an ATMS Operations Plan with concentration on jurisdiction and/or agency data exchange and operations protocols with respect to integrated freeway and arterial signal operations.

Coordinated with Project 1, this project will facilitate the development of a uniform approach to future ATMS deployment through agency consensus. It will also serve to establish guidelines for the development of decision support system and software interface requirements for the future expansion of the Regional Traffic Operations Network to other jurisdictional and/or agency centers not included in Project 1.

Operating guidelines will be developed for integrated traffic management, emergency services, and public transportation management. Interface guidelines for exchange of operations data with traveler information services will also be established.

**Objective:** Incorporate the various components currently in place into a unified system in an evolutionary manner consistent with advanced technology development.

**Scheduled Start:** Year 1-2

**Participants:** FHWA; FTA; VDOT; VDRPT; Counties of Arlington, Fairfax, and Prince William: Cities of Alexandria: Fairfax, Falls Church, Manassas, and Manassas Park; Towns of Dumfires Herndon, Leesburg, and Vienna; MWCOG; NVTC; PRTC; VA State Police: City of Alexandria; Arlington, Fairfax, and Prince William County Police; City of Alexandria Police; Fairfax, Loudoun, and Prince William County Fire and Rescue; and Department of Emergency Services.

## PHASED IMPLEMENTATION PLAN

**Number:** 5

**Name:** Freeway Alternate Routing/Diversion Pilot Project

**Primary User Service(s):** Incident Management, Traffic Control, Emergency Vehicle Management, Electronic Payment Services

**Description:** Guidelines will be developed for a pilot project to demonstrate the efficiency and effectiveness of integrating freeway and arterial system operations in the I-95 Corridor (U.S. Route I), I-66 Corridor (U.S. Routes 50,29) and the Dulles Toll Road Corridor (VA Route 7) to enhance traffic flow during traffic emergencies and critical peak-period congestion. The latter is recommended to include the development of a congestion-pricing strategy for the Dulles Toll Road/Rte. 7 Corridor as alternative routing options to alleviate recurring congestion on Rte. 7.

Implementation of this project will build upon Projects 1, 2, and 3 (in part) for the definition of supporting infrastructure and management systems to effect interagency information exchange, data interfaces, and the determination of specific control strategies.

**Objective:** Demonstrate the feasibility and benefits of an integrated environment between the traffic control systems, emergency management, and emergency services.

**Scheduled Start:** Year 2-3

**Participants:** FHWA; VDOT; Counties of Fairfax and Prince William; City of Alexandria; Towns of Vienna and Dumfries.

**Number:** 6

**Name:** FO Communications Backbone Expansion - PHASE I

**Primary User Service(s):** Traffic Control

**Description:** Perform preliminary engineering, final design, and implement an initial expansion of the TMS fiber optic backbone to interface with the Dulles Toll Road fiber backbone from I-495 to VA Route 28/Dulles Airport. Project will also examine FO expansion along the Dulles Greenway to Leesburg and to VA Route 234 along I-66.

A detailed requirements analysis for integrating MWAA airport information and access management system into the regional center network (Project 1) is recommended to be included as part of the infrastructure requirements analysis. Communications links between the TMS FO system along I-395 to National Airport will also be considered.

**Objective:** Integrate a common communications platform to facilitate data sharing, coordination, and policy deployment.

**Scheduled Start:** Year 2

**Participants:** FHWA; FAA; VDOT; MWAA; Rebuild, Inc.; Counties of Arlington, Fairfax, and Prince William; City of Alexandria; Towns of Leesburg, and Vienna.

## PHASED IMPLEMENTATION PLAN

**Number:** 7

**Name:** Emergency Services Integration

**Primary User Service(s):** Incident Management, Emergency Vehicle Management

**Description:** This project will focus on continuing the development of the communications infrastructure to provide for the partial integration of freeway, arterial signal and emergency management operations. It assumes that the NoVA ATSS is operational and controlled from the NoVA District TOC. The project will include final alternatives analysis of communication alternatives, preliminary engineering, final design and implementation.

Lateral communication links from the fiber optic (FO) backbone to all local Emergency Service Providers (ESPs) are recommended and include: Arlington, Fairfax, and Prince William County Police; city of Alexandria Police; and Fairfax, Loudoun, and Prince William County Fire and Rescue. GIS-based workstations will be provided to interface with the regional center network initiated under Project 1.

This project will provide integrated traffic and emergency management real-time data exchange between the expanded TMS, NoVA ATSS, Arlington County, and City of Alexandria signal systems and the primary tier of ESPs and the Virginia State Police. Workstations for voice, data, and video exchange will also be provided at all primary ESP center locations. Dial-up or dedicated line access with other major interregional centers (MWCOG Regional Clearinghouse, MDSOC, DCITMS) will continue. Fleet management system(s) will become operational for the ESPs under this project.

**Objective:** Provide an integrated environment between traffic control systems and emergency services.

**Scheduled Start:** Year 2-3

**Participants:** FHWA; VDOT; Counties of Arlington, Fairfax, and Prince William: City of Alexandria; Arlington, Fairfax, and Prince William County Police; City of Alexandria Police; and Fairfax, Loudoun, and Prince William County Fire and Rescue; Department of Emergency Services.

**Number:** **8**

**Name:** I-395/66 TMS FO Tie-In/Upgrades

**Primary User Service(s):** Traffic Control

**Description:** This project will focus on upgrading the existing Coaxial/Twisted-Wire Pair communications backbone along I-395 and I-66 inside the Capital Beltway to FO. It will also identify selected field equipment upgrades (local controllers, communications field equipment, etc.). Upgrades to existing communication links between VDOT (TMS) and Arlington County and the City of Alexandria operations centers for full voice, data, and video exchange will be included.

Evaluation of including a direct FO link to the proposed District of Columbia Integrated Transportation Management System (ITMS) center is recommended to interface NoVA ATSS, Arlington County, City of Alexandria, and NoVA TMS systems to the new D.C. signal and expanded freeway management system. This link would facilitate enhanced traffic operations at both the regional and inter-regional levels and provide owned facilities for continuous "real-time" data exchange between major regional centers and integrated interregional signal and freeway operations capabilities.

**Objective:** Provide the ability to exchange real-time traffic flow, systems operations, maintenance information, control commands, and messages between jurisdictions and agencies at an interregional level in a cost effective manner.

**Scheduled Start:** **Year 4-5**

**Participants:** FHWA; VDOT; **DCDPW;** Arlington and Fairfax Counties: City of Alexandria; National Park Service.

## PHASED IMPLEMENTATION PLAN

**Number:** 9

**Name:** Transportation Management Coordination Center

**Primary User Service(s):** Incident Management, Traffic Control, Emergency Vehicle Management, Public Transportation Management, Demand Management & Operations

**Description:** This project will focus on developing the central hardware, software and facilities for the TMCC. It will initiate the trafficlemergency management operations coordination through enhancement of the NoVA District TOC and establish real-time data and video links with all media and independent service providers (ISPs) for traveler information services.

The short-term dial-up access communication links with other major centers (MWCOG Regional Clearinghouse, MDSHA SOC, etc) are recommended for upgrades under this project to leased lines or wireless communications.

Emphasis will be placed on developing the integrated, multi-modal network status monitoring modeling and decision support structure for ATMS. Traffic and emergency management operations will be facilitated with dedicated servers, with the core TMCC configured for near-future expansion to include the transit, maintenance management, and CVO interfaces on the network.

**Objective:** Provide the ability to exchange real-time traffic flow, systems operations, maintenance information, control commands, and messages between jurisdictions and agencies at an interregional level in a cost effective manner.

**Scheduled Start:** Year 4-5

**Participants:** FHWA; FTA; VDOT; VDRPT; Counties of Arlington, Fairfax, and Prince William; Cities of Alexandria; Fairfax, Falls Church, Manassas, and Manassas Park: Towns of Dumfires Herndon, Leesburg, and Vienna; MWCOG; NVTC; PRTC; VA State Police: City of Alexandria; Arlington, Fairfax, and Prince William County Police; City of Alexandria Police: Fairfax, Loudoun, and Prince William County Fire and Rescue; and Department of Emergency Services.

**Number:** 10

**Name:** Traffic/Transit Data Exchange

**Primary User Service(s):** Traffic Control, Public Transportation Management

**Description:** This project will establish real-time data exchange with transit systems to monitor schedule adherence, system status, and coordinate emergency operations. Laterals from the FO backbone communications system will be provided to interregional (WMATA, VRE, AMTRAK) and local (Alexandria DASH, Arlington Trolley, City of Fairfax CUE, Fairfax Connector, PRTC Commuter ride, and Tyson Shuttle) transit operations centers.

The regional signal optimization modeling performed under Project 2 will be revisited under this project to incorporate the transit system input parameters. Full implementation of AVI/AVL technologies for fleet management capabilities with the existing regional and interregional transit systems will be required to maximize the benefit of this project.

**Objective:** Provide the ability to exchange real-time traffic flow, systems operations, maintenance information, control commands, and messages between jurisdictions and agencies at an interregional level in a cost effective manner.

**Scheduled Start:** Year 5-6

**Participants:** FHWA; FTA; VDOT; VDRPT; NVTC; PRTC; WMATA; VRE; Counties of Arlington and Fairfax; Cities of Alexandria and Fairfax.

## PHASED IMPLEMENTATION PLAN

**Number:** 11

**Name:** Regional Signal System Integration- PHASE II

**Primary User Service(s):** Traffic Control

**Description:** This second phase project is implementation oriented and will perform the final design and proceed with implementing the final phase of the NoVA Integrated Regional Signal System. The implementation builds from Projects 2 and 5 and incorporates the remaining jurisdictions (Cities of Fairfax, Falls Church, Manassas, and Manassas Park: Towns of Vienna, Herndon, Leesburg) with lateral communication links to the FO backbone system for voice, data, and video.

This project will also provide “central system” status for those jurisdictions that currently do not have central systems in place to access/exchange data with the Interim TMCC.

**Objective:** Complete a fully functional integrated regional signal system.

**Scheduled Start:** Year 6

**Participants:** FHWA; FTA; VDOT; VDRPT; Counties of Arlington, Fairfax, and Prince William; Cities of Alexandria; Fairfax, Falls Church, Manassas, and Manassas Park; Towns of Dumfires Herndon, Leesburg, and Vienna: MWCOG; NVTC; PRTC; VA State Police: City of Alexandria; Arlington, Fairfax, and Prince William County Police; City of Alexandria Police; Fairfax, Loudoun, and Prince William County Fire and Rescue; and Department of Emergency Services.

**Number:** 12

**Name:** FO Communications Backbone Expansion - PHASE II

**Primary User Service(s):** Traffic Control

**Description:** This project will complete the ring topology for the FO communications backbone with design and implementation in the VA Route 234 Corridor between I-95 and I-66; and U.S. 15 Corridor between I-66 and Leesburg. Additional fiber will be installed along mainline I-66 to compete the full ring topology.

Depending on the need for ATMS expansion to the western portions of the NoVA District at the time of this project, nodes may be established on the FO expansion in these corridors for wireless center-to-center (future) or center-to-vehicle communication links to the perimeter and outer reaches of the region.

**Objective:** Integrate a common communications platform to facilitate data sharing, coordination, and policy deployment.

**Schedule:** Year 7-8

**Participants:** FHWA; VDOT; Counties of Fairfax and Prince William: Cities of Alexandria; Towns of Leesburg, and Vienna.

# SECTION 5.0 FUNDING REQUIREMENTS

## 5.1 INTRODUCTION

This section provides an overview of the procurement and implementation options for the Northern Virginia ATMS, and an order of magnitude ATMS implementation cost. In addition, a preliminary deployment schedule, identifying the key project deployment activities such as project development, design, implementation, and operations over the proposed 1-8 year implementation period is also included.

Operations is considered in the deployment schedule. This is due to the extended final system acceptance testing and the initial operations periods anticipated for projects of this complexity and the potential warrant/operate options, in the likely event that a design/build procurement approach is taken with some of the deployment recommendations.

## 5.2 PROCUREMENT OPTIONS

The procurement of system elements can occur through several different options, due to the number of agencies and transportation modes considered under this plan. The regional system may be implemented using the following:

- Procurement of system elements through the independent efforts of individual agencies
- Procurement of system elements through a cooperative effort of all agencies identified as project participants
- Institution of a State Procurement Contract

### 5.2.1 Independent Efforts of Individual Agencies

Due to the complexity and the multi-modal approach being considered for the Northern Virginia ATMS, the procurement of system elements through independent efforts of individual agencies is not recommended. This approach will perpetuate the problems of the past with respect to advanced systems deployment by continuing individual system(s) expansion using incompatible equipment, potentially have significant impact on the proposed regional ATMS deployment schedule, and result in increased administrative costs.

### 5.2.2 Cooperative Effort of All Agencies

Procurement through a cooperative effort of the participating agencies would allow for phased delivery dates, identical equipment, and reduced costs (through bulk purchase of the system components). The cooperative effort option, however, may be restricted due to budget allocations and internal organizational preferences of the participating agencies. The consideration of public/private partnership opportunities under this option provides a potential to reduce budgetary constraints for the regional ATMS deployment.

### 5.2.3 State Procurement Contract

Through the institution of a State Procurement Contract, equipment could be procured by requesting a bid for a given system component (e.g., CCTV cameras). Once the contract is awarded to a specific vendor, the State and any participating agency(ies) within the State would purchase the equipment under an agreement at a specified price. Each agency could standardize on a specific make and model of item and thereby obtain identical systems.

Given that “out-of-state” entities provide transportation services in the region, this approach would require compact or multi-agency agreements that satisfies all relevant state regulations, and could become quite burdensome to implement. This approach is also time sensitive. Existing and near-term system expansion is already underway in Northern Virginia along with other areas of the State. As a result, large-scale procurement would not be cost-effective at this time

### 5.2.4 Recommendation

For the Northern Virginia ATMS implementation, the second option -- procurement through the cooperative efforts of all participating agencies -- is recommended (to the extent practical.) Agency restrictions in deployment participation resulting from current and near-term budget allocations could be lessened through multi-agency cost sharing, this is defined by inter-agency comprehensive agreements.

The adoption of the tenets of this ATMS Implementation Plan by the primary tier of jurisdictions/agencies (Table 1-4) will result in overcoming individual agency preferences with respect to system improvements. This recommendation is selected purely under the perspective of a qualified region-wide system and does not limit the uniqueness of each jurisdiction/agency.

## 5.3 IMPLEMENTATION APPROACHES

There are four basic categories of deployment approaches to be considered for the deployment of the Northern Virginia ATMS. These include:

- Engineer/Contractor
- System Manager
- Program Manager
- Design/Build

The fourth category - Design/Build - is also considered under the ATMS deployment program as a potential sub-category under the System or Program Manager approach. This category, along with each of the others, is explained and summarized in more detail in the following sections.

### 5.3.1 Engineer/Contractor

Traditionally, this procurement approach has been used by most of the transportation agencies in the region for the implementation of transportation improvement projects. Typically, the Engineer prepares a single set of Plans, Specifications, and Estimates (PS&E) for the project. The PS&E then constitutes the contract documents. The contract documents are then advertised, bids are received from contractors, and the project is awarded to the lowest responsive bidder. The successful bidder is responsible for providing a complete and fully operational system, including furnishing and installing all hardware and any required software, system integration, training and documentation. Depending on the specific project requirements, contractor development of implementation and operations plans may be included as the contractor's responsibilities.

The engineer, typically a consultant to the client/owner (administering agent), continues involvement in the project after contract award by participating in reviews of contractor submittals, system tests (factory demonstration, stand-alone, integration, final acceptance testing), and development of system operations-plans if not performed by the contractor. The client/owner generally retains the primary responsibility for ensuring conformance of the work with bid documents and for testing and accepting system elements. The client/owner is also generally responsible for coordination between contractors working on various phases of the program. Considerations in project implementation with this approach include the following:

- Generally there is one large contract to prepare
- No single contractor possesses the required experience and qualifications to fulfill all the work

- Project success is dependent on prime contractor's ability to coordinate and manage a large number of subcontractors
- It is difficult to administer multiple layers of subcontractors and suppliers
- Prime contractor will depend principally on bid price for selecting subcontractors and will place specification adherence responsibility on the subcontractor and ultimately with the client/owner

The Northern Virginia ATMS implementation will involve state-of-the-art hardware and software and include a wide range of technology applications, equipment, construction techniques, and related services. It will undoubtedly become an issue as to what type of contractor should be the prime. Since interaction between the contracting agency and the contractor(s) is very important to the project success, this has proven to be a problem for a few transportation agencies in past procurement activities.

Typically, the administering agency relies on the knowledge of the prime contractor to select the appropriate or qualified contractors, with the criterion being lowest cost. Experience with advanced technology applications to transportation systems in recent decades has left many transportation agencies with systems that are proprietary, maintenance-intensive, and prone to routine failures.

### 5.3.2 System Manager

With this approach, responsibility for administering the project(s) is typically shared between the client/owner and the System Manager. Each parties' level of involvement is negotiated. The activities of the System Manager include preliminary engineering, preparation of specifications, supervision of final design preparation, construction engineering, and construction inspection or supervision of others performing these services, development of required software, system integration, and training. Typically, early project activities at the client/owner level including developing the concept for a program, group of projects, or a single project are completed prior to procuring the System Manager.

The System Manager shares in administering the contracts with the client/owner and is primarily responsible for integrating the various subsystems into an operating system. Assistance is also provided to the client/owner in overall program management and quality control, however, primary responsibility for the overall program remains with the client/owner.

Depending on the negotiated terms of the agreement between the client/owner and the System Manager, the final PS&Es for all or portions of the work may be included as the System Manager's responsibilities.

### 5.3.3 Program Manager

This approach is similar to the system manager approach, except that the Program Manager becomes the responsible entity -- having single point responsibility. Unlike the system manager approach, the Program Manager would have responsibility for contract administration and conceptual development of the deployment initiatives by project or sub-program. The contracting agency would only manage the Program Manager firm. The Program Manager would then have responsibility for managing the work of all subcontractors and construction contractors. Services of the Program Manager may continue into the operations phase of any deployment activity with oversight and/or staffing responsibilities, depending on the negotiated terms of agreement between the client/owner and the program manager.

Again, similar to the system management approach, the design elements may be performed by the Program Manager or others. A design/build approach for some segments may be more applicable (e.g., fiber optic backbone expansion) and should be considered. With the design/build option, the Program Manager may serve as the prime contractor or administer all work relating to a design/build segment.

### 5.3.4 Design/Build

A turn-key method, the design/build approach would provide single point responsibility for all work associated with the deployment of the system. Similar to the program manager approach, the agency's role is in monitoring the activity of the design builder. The design/builder performs all design work, contracts and/or constructs system elements, commissions the system, and eventually turns it over to the operating agency. A major sub-option to this approach includes extended operations period responsibility for the design/builder (design/build/operate/transfer) or continued operations over an extended period of time (design/build/operate). The latter is of particular importance to the Northern Virginia ATMS deployment in light of the recent enactment of the Public-Private Transportation Act of 1995. Privatization initiatives and public/private partnership potentials will represent key factors in the evaluation of the design/build opportunities.

Unlike the program management approach, design/build places a burden of supervision on the contracting agency to insure that quality is maintained. With this approach, the design/builder is usually provided a conceptual design and functional specification for the implementation activity. This level of documentation is provided by the client/owner and it is either prepared internally or prepared under contract by an independent firm.

### 5.3.5 Recommendation

Trends in decentralization and downsizing of government services, and privatization of transportation services suggest that the Northern Virginia ATMS procurement and implementation approach focus on softening the current level of administrative burden on the region's jurisdictions/agencies for transportation system operations while maximizing the quality, effectiveness, and reliability of system deployment. To reach this, two required approaches are: the procurement approach that maximizes the cost sharing potentials among the participating agencies; and the implementation approach that ensures quality, provides the needed enhancements (to the region's transportation system) in a timely manner, and produces reliable systems.

For the Northern Virginia ATMS, this translates to a multi-agency participation in all applicable procurement activities. The deployment process should use a System Manager or Program Manager approach for the overall program, supported by smaller implementation projects using a traditional engineering/contractor approach or design/build initiatives. Either approach is recommended to consider the design/build options for some work segments.

## 5.4 DEPLOYMENT COST ESTIMATES

This section outlines the costs involved in the establishment and operation of the Northern Virginia ATMS. These costs are presented in **a** range, conceptual, and based on the regional ATMS projects presented in Section 4.2.2. They are also based on the system management approach for implementation, per Section 53.5. Three categories of cost are considered: capital, operating, and maintenance. These categories and defined parameters for each are summarized on the following pages. Costs are summarized by project in Section 5.4.4, **Table 5-1**, and Section 5.4.5, **Tables 5-2** and **5-3** for the overall recommended ATMS.

### 5.4.1 Capital Costs

Capital costs for ATMS deployment are defined as costs associated with engineering, furnishing, installing, and testing (EFIT) subsystems; engineering contingencies; construction services; system manager fees; etc. For the purpose of the benefit-cost analysis to be performed under this study, annualized costs are also considered for comparison to the existing system financial information, characteristics, and performance measures. The overall system benefit-cost analysis for the ATMS deployment recommendations is provided in the ITS Strategic Deployment Plan.

The costs presented in Table 5-1 were derived with the following assumptions: the base year is 1995; the construction start year is 1997; and the overall system service life is 15 years. Annualized costs are shown in Tables 5-2 and 5-3 and assume an annual interest rate of 6%.

In general, the service life of a/an surveillance, guidance, and information systems is generally estimated to span 10-20 years, depending on the funding level committed to annual maintenance and other factors. An average system life of 15 years is used in this cost analysis to arrive at a conservative cost to be used for the benefit-cost analysis.

### 5.4.2 Operating Costs

This category includes salaries, wages, benefits, materials and supplies, and other expenses. For the Northern Virginia ATMS cost estimates, a conservative estimate of annual operating cost is calculated at 4%-5% of the base capital costs by project. While each control center will require specialized staff, the potential to share resources among the participating agencies will serve to minimize any additional staff requirements and, in fact, may result in a reduction of staff needs for agencies that currently have operating systems.

It is expected, however, that some staff replacements/training will be required to provide expertise for some agencies with the following positions: system supervisor; system operators; communication specialist; software specialist; and hardware specialist. Specific needs by agency in these positions will require further evaluation with each phase of the ATMS deployment and will be dependent on the level of participation of each agency in the overall system operations.

### 5.4.3 Maintenance Costs

Software and maintenance fees are included in this category on an annual basis. Costs are derived based on a percentage of total estimated capital cost by project. Typically, the following factors are used: equipment and software.

The elements under the equipment factor are communications infrastructure, field equipment, and central equipment. The software maintenance elements include maintenance fees and support services. A conservative estimate in the range of 10% was used to arrive at the listed cost estimates.

### 5.4.4 Estimated Project Costs

Presented in Table 5-1 is a summary of estimated ATMS implementation capital costs by projects, as identified in Section 4.2.2. The costs are presented in 1995 dollars. Two costs are shown in the table, lower-limit and upper-limit. The total indicates that a full ATMS implementation can be accomplished in the ranges of $119,830,000 to $177,296,000. These limits relate to the range of conceptual deployment costs derived through the supporting communications infrastructure analysis for the communication options to link the local TOCs to the proposed SONET communications backbone. Final deployment costs for the ATMs will be dependent on the extent of coverage and the number of jurisdiction/agencies participating in any one given deployment activity. The costs identified in this section represent a region-wide deployment.

**TABLE 5-1**
**ESTIMATED ATMS IMPLEMENTATION CAPITAL COSTS**

| **Proj. No.** | **Project Name** | **Lower-Limit Cost** (x 1000) | **Upper-Limit Cost** (x 1000) |
|---|---|---|---|
| 1 | Regional TOC Information Exchange Network | 6,632 | 27,705 |
| 2 | Regional Signal Systems Integration – Phase I | 3,700 | 6,427 |
| 3 | Capital Beltway (VA) ATMS | 15,909 | 15,909 |
| 4 | ATMS Operations Plan | 623 | 623 |
| 5 | Alternate Traffic Routing/Diversion Pilot Project | 1,058 | 1,058 |
| 6 | FO Communications Backbone Expansion-Phase I | 11,527 | 11,527 |
| 7 | Emergency Services Integration | 9,691 | 25,124 |
| 8 | I-395/66 TMS FO Tie-In/Upgrades | 6,691 | 6,691 |
| 9 | Transportation Management Coordination Center | 4,419 | 5,284 |
| 10 | Traffic/Transit Data Exchange | 23,584 | 29,834 |
| 11 | Regional Signal System Integration – Phase II | 5,984 | 17,102 |
| 12 | FO Communications Backbone Expansion-Phase II | 30,012 | 30,012 |
| **Total** | | $119,830 | $177,296 |

### 5.4.5 Estimated Annual Costs

The program's estimated annual cost is the total of the annual recovery and the annual operation and maintenance cost. With the estimates based on an upper- and a lower-limit, the range of the limits is between $2,439,000 and $29,706,000. This range has a margin of $8,267,000. The cost for the twelve deployment projects are presented in **Tables 5-2** and **5-3**.

**TABLE 5-2**
**ESTIMATED ATMS IMPLEMENTATION ANNUAL COSTS**
**(Based on Lower-Limit Costs)**

| **Proj. No.** | **Project Name** | **Lower – Limit Cost** (x1000) | **Annual Cap Rcvy Cost** (x1000) | **Annual O & M Cost** (x 1000) |
|---|---|---|---|---|
| 1 | Regional TOC Information Exchange Network | 6,632 | 683 | 435 |
| 2 | Regional Signal Systems Integration – Phase I | 3,700 | 381 | 166 |
| 3 | Capital Beltway (VA) ATMS | 15,909 | 1,638 | 1,209 |
| 4 | ATMS Operations Plan | 623 | 64 | 0 |
| 5 | Alternate Traffic Routing/Diversion Pilot Project | 1,058 | 109 | 0 |
| 6 | FO Communications Backbone Expansion-Ph. I | 11,527 | 1,187 | 945 |
| 7 | Emergency Services Integration | 9,691 | 998 | 807 |
| 8 | I-395/66 TMS FO Tie-In/Upgrades | 6,691 | 689 | 548 |
| 9 | Transportation Management Coordination Center | 4,419 | 455 | 214 |
| 10 | Traffic/Transit Data Exchange | 23,584 | 2,428 | 1,879 |
| 11 | Regional Signal System Integration – Phase II | 5,984 | 616 | 438 |
| 12 | FO Communications Backbone Expansion-Ph. II | 30,012 | 3,090 | 2,460 |
| **Subtotal** | | $119,830 | $12,338 | $9,101 |
| **Estimated Annual Cost** | | | | $21,439 |

**TABLE 5-3**
**ESTIMATED ATMS IMPLEMENTATAION ANNUAL COSTS**
**(Based on Upper-Limit Costs)**

| **Proj. No.** | **Project Name** | **Upper-Limit Cost** (x 1000) | **Annual Cap Rcvy Cost** (x 1000) | **Annual O & M Cost** (x 1000) |
|---|---|---|---|---|
| 1 | Regional TOC Information Exchange Network | 27,705 | 2,852 | 1,299 |
| 2 | Regional Signal Systems Integration-Phase I | 6,427 | 662 | 278 |
| 3 | Capital Beltway (VA) ATMS | 15,909 | 1,638 | 1,209 |
| 4 | ATMS Operations Plan | 623 | 64 | 0 |
| 5 | Alternate Traffic Routing/Diversion Pilot Project | 1,058 | 109 | 0 |
| 6 | FO Communications Backbone Expansion-Ph. I | 11,527 | 1,187 | 945 |
| 7 | Emergency Services Integration | 25,124 | 2,587 | 1,440 |
| 8 | I-395/66 TMS FO Tie-In/Upgrades | 6,691 | 689 | 548 |
| 9 | Transportation Management Coordination Center | 5,284 | 544 | 249 |
| 10 | Traffic/Transit Data Exchange | 29,834 | 3,072 | 2,135 |
| 11 | Regional Signal System Integration-Phase II | 17,102 | 1,761 | 888 |
| 12 | FO Communications Backbone Expansion-Ph. II | 30,012 | 3,090 | 2,460 |
| **Subtotal** | | $177,296 | $18,255 | $11,451 |
| **Estimated Annual Cost** | | | | $29,706 |

### 5.4.6 Preliminary Deployment Schedule

Presented on the last page is a preliminary schedule for ATMS implementation. The schedule provides for the 1-8 year deployment time frame recommended in Section 3.2.1 for the twelve deployment projects to implement the primary ATMS services. A two-year overall system operation and evaluation period is included after the completion of all initial deployment activities, bringing the total program duration to a minimum of ten years. Other elements of the schedule are self explanatory.

The schedule also identifies four major operational phases over the initial deployment period. Phase 1 is bound by the completion of the ATMS Operations Plan and continues through the completion of emergency services integration and the expanded TMS to include the Virginia portion of the Capital Beltway (I-495). During this Phase 1 period, inital integrated operations established with the Regional TOC Information Exchange Network Project and the first phase of integrated regional signal operations will be phased in.

Phase 2 will be the first phase of region-wide integrated traffic and emergency management operations. During this phase the TMCC will be implemented. Phase 3 will begin with the completion of the TMCC and continue through the end of the last recommended deployment project, Phase II of the fiber communications backbone expansion.

The beginning of Phase 4 will provide fully integrated traffic, transit, and emergency operations and will remain in operation during the 2-year system operations/evaluation. It is expected that unless the systems operations/evaluation identifies major areas of recommended change, Phase 4 operations will be the predominant operational strategy for the region.

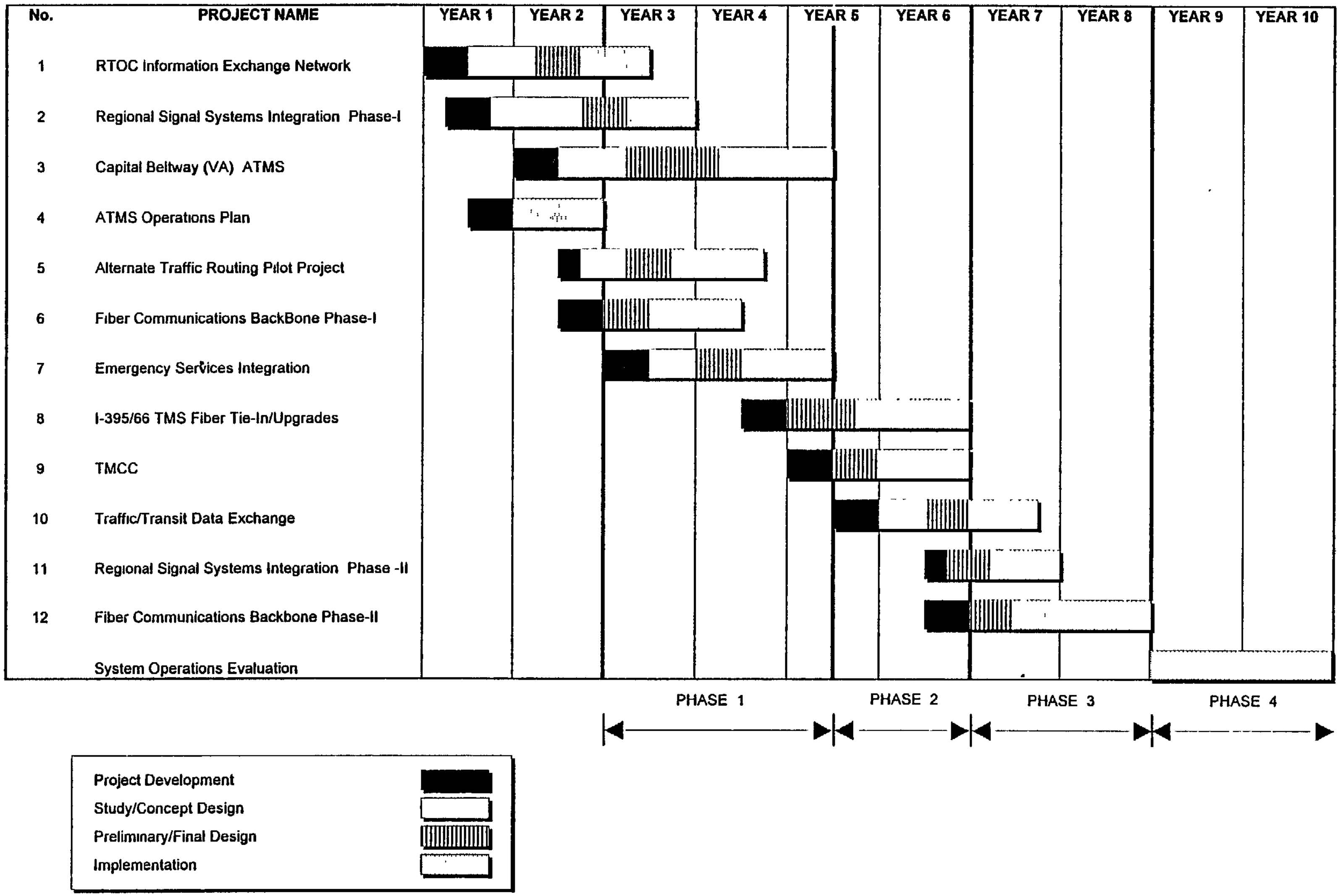


**Figure 5.1 - Preliminary Deployment Schedule**

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# APPENDIX COMMUNICATIONS INFRASTRUCTURE COST ANALYSES WORKSHEETS

Presented herein is the summary data for the initial and life-cycle cost analyses performed for the communications infrastructure to support the ATMS Architecture. The summary data includes cost analyses for full video, high speed data & voice, and low speed data & voice. The referenced phases of the analysis correlate to the ATMS deployment recommendations (project numbers) by the following:

| Phase | Corresponding ATMS Project No. | Phase Description |
|---|---|---|
| 1 | 1 | Initial Regional Center Network |
| 2 | 6 | Phase I FO Backbone Expansion |
| 3 | 7 | Initial Arterial Signal/Emergency Services Providers (ESP) integration |
| 4 | 9 | Transportation Management Coordination Center |
| 5 | 10 | Initial Transit Data Exchange |
| 6 | 11 | Additional Arterial Signal Integration |
| 7 | 12 | Phase II FO Backbone Expansion |

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## APPENDIX COMMUNICATIONS INFRASTRUCTURE COST ANALYSES WORKSHEETS - LOW SPEED DATA & VOICE

| Communications Options<br>Low Speed Data & Voice | | | | Lease Lines (ISDN 128-kbs) | | Lease Lines (28.8-kbs) | |
|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| **PHASE 1** | | | | | | | |
| TOC<br>3975 Fair Ridge Dr<br>Fairfax | Node 66-2 | Site | 2.10 | $8,100 | $55,500 | $6,225 | $42,225 |
| Va. State Police<br>9801 Braddock Rd<br>Fairfax | Node 66-2 | Site | 6.88 | $8,100 | $55,500 | $6,225 | $42,225 |
| Dept. Of Emergency Serv.<br>1519 Davis Ford Road<br>Woodbridge | Node 95-3 | Site | 1.35 | $8,100 | $55,500 | $6,225 | $42,225 |
| | | | **Phase 1 Totals** | **$24,300** | **$166,500** | **$18,675** | **$166,500** |
| **PHASE 2** | | | | | | | |
| Interface Dulles Toll Road (DTR) with Fiber Back Bone | Node 66-1 | DTR & I-66 Inter | 2.75 | | | | |
| Extend Fiber From Dulles Toll Road to Leesburg | Future Node 267-1 | Future Node 267-2 | 14.02 | | | | |
| Extend Fiber along I-66 to Route 234 | Node 66-3 | Future Node 66-4 | 5.34 | | | | |
| | | | **Phase 2 Totals** | **$7,468,668** | **$8,074,356** | **$7,468,668** | **$8,074,356** |
| **PHASE 3** | | | | | | | |
| Alexandria City<br>Trans. & Env. Serv.<br>City Hall, Alexandria | Node 95-1 | Site | 3.21 | $8,100 | $55,500 | $6,225 | $42,225 |

| Communications Options<br>Low Speed Data & Voice | | | | Lease Lines (ISDN 128-kbs) | | Lease Lines (28.8-kbs) | |
|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Alexandria City Fire Dept<br>900 Second St<br>Station 54, Alexandria | Node 95-1 | Site | 3.76 | $8,100 | $55,500 | $6,225 | $42,225 |
| Alexandria City Police<br>2003 Mill Rd<br>Alexandria | Node 95-1 | Site | 3.69 | $8,100 | $55,500 | $6,225 | $42,225 |
| Arlington Co. DPW<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.93 | $8,100 | $55,500 | $6,225 | $42,225 |
| Arlington Co. Police<br>2100 15th Street<br>Arlington | Node at TMS | Site | 2.99 | $8,100 | $55,500 | $6,225 | $42,225 |
| Arlington Co. Fire<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.92 | $8,100 | $55,500 | $6,225 | $42,225 |
| Fairfax Co. OOT<br>12055 Gov't. Center Pkwy<br>Fairfax | Node 66-2 | Site | 0.62 | $8,100 | $55,500 | $6,225 | $42,225 |
| Fairfax Co. Fire & Resuce<br>4100 Chainbridge Rd.<br>Fairfax | Node 66-2 | Site | 3.34 | $8,100 | $55,500 | $6,225 | $42,225 |
| Fairfax Co. Police<br>3911 Woodburn Rd<br>Annandale | Node 66-1 | Site | 3.81 | $8,100 | $55,500 | $6,225 | $42,225 |
| Loudon Co. DPW<br>750 Miller Drive<br>Leesburg | Future Node 267-2 | Site | 1.78 | $8,100 | $55,500 | $6,225 | $42,225 |
| Loudon Co. Fire & Rescue<br>16600 Courage Ct<br>Leesburg | Future Node 267-2 | Site | 0.4 | $8,100 | $55,500 | $6,225 | $42,225 |

| Communications Options<br>Low Speed Data & Voice | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | Lease Lines (ISDN 128-kbs) | | Lease Lines (28.8-kbs) | |
| Location | From | To | Distance (Miles) | Initial | 20 Yr. L.C. | Initial | 20 Yr. L.C. |
| Prince William Co. DPW<br>4379 Ridgewood Cntr Dr.<br>Woodbridge | Node 95-3 | Site | 4.73 | $8,100 | $55,500 | $6,225 | $42,225 |
| Prince William Co. DPW<br>One County Complex Ct.<br>Prince William | Node 95-3 | Site | 6.85 | $8,100 | $55,500 | $6,225 | $42,225 |
| | | | **Phase 3 Totals** | **$105,300** | **$721,500** | **$80,925** | **$548,925** |
| **PHASE 4** | | | | | | | |
| MWCOG<br>777 N. Capital St.<br>Washington, DC | Node at TMS | Site | 7 | $8,100 | $55,500 | $6,225 | $42,225 |
| MD SHA - SOC<br>7491 Connelley Dr.<br>Hanover | Node @I-95, 395, & 495 | Site | 30 | $8,100 | $55,500 | $6,225 | $42,225 |
| DC DPW<br>2000 14th St, NW<br>Washington, DC | Node at TMS | Site | 6 | $8,100 | $55,500 | $6,225 | $42,225 |
| | | | **Phase 4 Totals** | **$24,300** | **$166,500** | **$18,675** | **$126,675** |
| **PHASE 5** | | | | | | | |
| Alexandria Dash<br>116 S. Quaker Lane<br>Alexandria | Node 95-1 | Site | 1.85 | $8,100 | $55,500 | $6,225 | $42,225 |
| Arlington Trolley<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.18 | $8,100 | $55,500 | $6,225 | $42,225 |
| Fairfax City CUE<br>10455 Armstrong St.<br>Fairfax | Node 66-2 | Site | 3.97 | $8,100 | $55,500 | $6,225 | $42,225 |

| Communications Options<br>Low Speed Data & Voice | | | | Lease Lines (ISDN 128-kbs) | | Lease Lines (28.8-kbs) | |
|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Fairfax Connect<br>12055 Gov't. Cntr. Pkwy<br>Fairfax | Node 66-2 | Site | 0.62 | $8,100 | $55,500 | $6,225 | $42,225 |
| PRTC<br>1519 Davis Ford Rd.<br>Woodbridge | Node 95-3 | Site | 1.35 | $8,100 | $55,500 | $6,225 | $42,225 |
| VRE<br>6800 Verser Center<br>Springfield | Node 95-2 | Site | 1.53 | $8,100 | $55,500 | $6,225 | $42,225 |
| WMATA<br>600 5th St. NW<br>Washington | Node at TMS | Site | 5.15 | $8,100 | $55,500 | $6,225 | $42,225 |
| | | | **Phase 5 Totals** | **$56,700** | **$388,500** | **$43,575** | **$295,575** |
| **PHASE 6** | | | | | | | |
| Falls Church DPW<br>300 Park Ave<br>Falls Church | Node 66-1 | Site | 3.63 | $8,100 | $55,500 | $6,225 | $42,225 |
| Fairfax City DPW<br>10455 Armstrong St.<br>Fairfax | Node 66-2 | Site | 3.17 | $8,100 | $55,500 | $6,225 | $42,225 |
| Herndon DPW | Future Node 267-1 | Site | 3.40 | $8,100 | $55,500 | $6,225 | $42,225 |
| Leesburg DPW<br>25 W. Market St.<br>Leesburg | Future Node 267-2 | Site | 1.78 | $8,100 | $55,500 | $6,225 | $42,225 |
| Manassas DPW | Future Node 66-4 | Site | 6.15 | $8,100 | $55,500 | $6,225 | $42,225 |

| Communications Options<br>Low Speed Data & Voice | | | | Lease Lines (ISDN 128-kbs) | | Lease Lines (28.8-kbs) | |
|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Manassas Park DPW<br>1 Park Center Ct.<br>Manassas Park | Future Node 66-4 | Site | 7.31 | $8,100 | $55,500 | $6,225 | $42,225 |
| Vienna DPW<br>127 Center St South<br>Vienna | Node 66-1 | Site | 3.48 | $8,100 | $55,500 | $6,225 | $42,225 |
| | | | **Phase 6 Totals** | **$56,700** | **$388,500** | **$43,575** | **$295,575** |
| PHASE 7 | | | | | | | |
| Extend Fiber along Rte. 234 | Node 95-4 | Future Node 66-4 | 22.31 | | | | |
| Extend Fiber along Rte. 15 | Future Node 66-4 | Future Node 267-2 | 26.30 | | | | |
| Complete second loop on I-66 | Future Node 66-4 | Node 66-1 | 17.17 | | | | |
| | | | **Phase 7 Totals** | **$21,390,664** | **$22,031,288** | **$21,390,664** | **$22,031,288** |
| | | | **Phase 1 Through Phase 7 Totals** | **$29,126,632** | **$31,937,144** | **$29,064,757** | **$31,538,894** |

# APPENDIX COMMUNICATIONS INFRASTRUCTURE COST ANALYSES WORKSHEETS - HIGH SPEED DATA & VOICE

| Communications Options<br>High Speed Data & Voice | | | | Fiber | | Lease Lines (T-l) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| Location | From | To | Distance (Miles) | Initial | 20 Yr. L.C. | Initial | 20 Yr. L.C. | Initial | 20 Yr. L.C. |
| **PHASE 1** | | | | | | | | | |
| **TOC**<br>3975 Fair Ridge Dr<br>Fairfax | Node 66-2 | Site | 2.10 | $884,480 | $1,187,160 | $15,968 | $171,440 | $501,500 | $1,841,750 |
| Va. State Police<br>9801 Braddock Rd<br>Fairfax | Node 66-2 | Site | 6.88 | $2,348,344 | $2,570,848 | $17,384 | $284,720 | $501,500 | $1,841,750 |
| Dept. Of Emergency Serv.<br>1519 Davis Ford Road<br>Woodbridge | Node 95-3 | Site | 1.35 | $585,380 | $803,460 | $15,638 | $145,040 | $501,500 | $1,841,750 |
| **Phase 1 Totals** | | | | **$3,818,204** | **$4,561,468** | **$48,990** | **$601,200** | **$1,504,500** | **$5,525,250** |
| **PHASE 2** | | | | | | | | | |
| Interface Dulles Toll Road (DTR) with Fiber Back Bone | Node 66-1 | DTR & I-66 Inter | 2.75 | $1,016,700 | $1,214,900 | | | | |
| Extend Fiber From Dulles Toll Road to Leesburg | Future Node 267-l | Future Node 267-2 | 14.02 | $4,609,576 | $4,816,792 | | | | |
| Extend Fiber along I-66 to Route 234 | Node 66-3 | Future Node 66-4 | 5.34 | $1,842,392 | $2,042,664 | | | | |
| **Phase 2 Totals** | | | | **$7,468,668** | **$8,074,356** | **$7,468,668** | **$8,074,356** | **$7,468,668** | **$8,074,356** |
| **PHASE 3** | | | | | | | | | |
| Alexandria City<br>Trans. & Env. Serv.<br>City Hall, Alexandria | Node 95-l | Site | **3.21** | $1,178,348 | $1,397,916 | $16,298 | $197,840 | $501,500 | $1,841,750 |

| Communications Options<br>High Speed Data & Voice | | | | Fiber | | Lease Lines (T-l) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Alexandria City Fire Dept<br>900 Second St<br>Station 54, Alexandria | Node 95-I | Site | 3.76 | $1,353,688 | $1,573,696 | $16,298 | $197,840 | $501,500 | $1,841,750 |
| Alexandria City Police<br>2003 Mill Rd<br>Alexandria | Node 95-I | Site | 3.69 | $1,331,372 | $1,551,324 | $16,298 | $197,840 | $501,500 | $1,841,750 |
| Arlington Co. DPW<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.93 | $1,089,084 | $1,308,428 | $15,968 | $171,440 | $501,500 | $1,841,750 |
| Arlington Co. Police<br>2100 15th Street<br>Arlington | Node at TMS | Site | 2.99 | $1,108,212 | $1,327,604 | $15,968 | $171,440 | $501,500 | $1,841,750 |
| Arlington Co. Fire<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.92 | $1,085,896 | $1,305,232 | $15,968 | $171,440 | $501,500 | $1,841,750 |
| Fairfax Co. OOT<br>12055 Gov't. Center Pkwy<br>Fairfax | Node 66-2 | Site | 0.62 | $352,656 | $570,152 | $15,260 | $114,800 | $501,500 | $1,841,750 |
| Fairfax Co. Fire & Resuce<br>4100 Chainbridge Rd.<br>Fairfax | Node 66-2 | Site | 3.34 | $1,219,792 | $1,439,464 | $16,298 | $197,840 | $501,500 | $1,841,750 |
| Fairfax Co. Police<br>3911 Woodburn Rd<br>Annandale | Node 66-I | Site | 3.81 | $1,369,628 | $1,589,676 | $16,298 | $197,840 | $501,500 | $1,841,750 |
| Loudon Co. DPW<br>750 Miller Drive<br>Leesburg | Future Node 267-2 | Site | 1.78 | $722,464 | $940,888 | $15,638 | $145,040 | $501,500 | $1,841,750 |
| Loudon Co. Fire & Rescue<br>16600 Courage Ct<br>Leesburg | Future Node 267-2 | Site | 0.4 | $282,520 | $499,840 | $15,260 | $114,800 | $501,500 | $1,841,750 |

| Communications Options High Speed Data & Voice | | | | Fiber | | Lease Lines (T-l) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | 20 **Yr. L.C.** | **Initial** | 20 **Yr. L.C.** | **Initial** | 20 **Yr. L.C.** |
| Prince William Co. DPW<br>4379 Ridgewood Cntr Dr.<br>Woodbridge | Node 95-3 | Site | 4.73 | $1,662,924 | $1,883,708 | $16,628 | $224,240 | $501,500 | $1,841,750 |
| Prince William Co. DPW<br>One County Complex Ct.<br>Prince William | Node 95-3 | Site | 6.85 | $2,338,780 | $2,561,260 | $17,384 | $284,720 | $501,500 | $1,841,750 |
| | | | **Phase 3 Totals** | **$15,095,364** | **$17,949,188** | **$209,564** | **$2,387,120** | **$6,519,500** | **$23,942,750** |
| **PHASE 4** | | | | | | | | | |
| MWCOG<br>777 N. Capital St.<br>Washington, DC | Node at TMS | Site | **7** | **$2,526,600** | **$2,945,200** | **$224,900** | **$533,000** | $371,000 | $1,339,100 |
| MD SHA - SOC<br>7491 Connelley Dr.<br>Hanover | Node @I-95, 395,& 495 | Site | **30** | **$9,999,000** | **$10,632,000** | **$225,500** | $581,000 | $1,371,500 | $5,192,750 |
| DC DPW<br>2000 14th St, NW<br>Washington, DC | Node at TMS | Site | **6** | **$2,207,800** | **$2,625,600** | **$224,384** | $491,720 | **$327,500** | $1,171,550 |
| | | | **Phase 4 Totals** | **$14,733,400** | **$16,202,800** | **$674,784** | **$1,605,720** | **$2,070,000** | **$7,703,400** |
| **PHASE 5** | | | | | | | | | |
| Alexandria Dash<br>116 S. Quaker Lane<br>Alexandria | Node 95-l | Site | 1.85 | $990,256 | $1,209,352 | $222,968 | $378,440 | $501,500 | $1,841,750 |
| Arlington Trolley<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.18 | $849,984 | $1,068,728 | $222,968 | $378,440 | $501,500 | $1,841,750 |
| Fairfax City CUE<br>10455 Armstrong St.<br>Fairfax | Node **66-2** | Site | 3.97 | $1,420,636 | $1,640,812 | $223,298 | $404,840 | $501,500 | $1,841,750 |

| Communications Options<br>High Speed Data & Voice | | | | Fiber | | Lease Lines (T-l) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | 20 **Yr. L.C.** | **Initial** | 20 **Yr. L.C.** | **Initial** | 20 **Yr. L.C.** |
| Fairfax Connect<br>12055 Gov't. Cntr. Pkwy<br>Fairfax | Node 66-2 | Site | 0.62 | $352,656 | $570,152 | $222,260 | $321,800 | $501,500 | $1,841,750 |
| PRTC<br>1519 Davis Ford Rd.<br>Woodbridge | Node 95-3 | Site | 1.35 | $585,380 | $803,460 | $222,638 | $352,040 | $501,500 | $1,841,750 |
| VRE<br>6800 Verser Center<br>Springfield | Node 95-2 | Site | 1.53 | $642,764 | $860,988 | $222,638 | $352,040 | $501,500 | $1,841,750 |
| WMATA<br>600 5th St. NW<br>Washington | Node at TMS | Siie | 5.15 | $1,796,820 | $2,017,940 | $224,054 | $465,320 | $501,500 | $1,841,750 |
| | | | **Phase 5 Totals** | **$6,638,496** | $8,171,432 | $1,560,824 | $2,652,920 | $3,510,500 | **$12,892,250** |
| **PHASE 6** | | | | | | | | | |
| Falls Church DPW<br>300 Park Ave<br>Falls Church | Node 66-1 | Site | 3.63 | $1,312,244 | $1,532,148 | **$223,298** | $404,840 | $501,500 | $1,841,750 |
| Fairfax City DPW<br>10455 Armstrong St.<br>Fairfax | Node 66-2 | Site | 3.17 | $1,420,636 | $1,640,812 | **$223,298** | $404,840 | $501,500 | $1,841,750 |
| Herndon DPW | Future Node 267-l | Site | 3.40 | **$1,238,920** | $1,458,640 | **$223,298** | $404,840 | $501,500 | $1,841,750 |
| Leesburg DPW<br>25 W. Market St.<br>Leesburg | Future Node 267-2 | Site | 1.78 | $722,464 | **$940,888** | $222,638 | $352,040 | $501,500 | $1,841,750 |
| Manassas DPW | Future Node 66-4 | Site | 6.15 | $2,115,620 | $2,337,540 | $224,384 | **$491,720** | $501,500 | $1,841,750 |

| Communications Options<br>High Speed Data & Voice | | | | Fiber | | Lease Lines (T-I) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | 20 **Yr. L.C.** | **Initial** | 20 **Yr. L.C.** | **Initial** | 20 **Yr. L.C.** |
| Manassas Park DPW<br>1 Park Center Ct.<br>Manassas Park | Future Node 66-4 | Site | 7.31 | $2,485,428 | $2,708,276 | $224,900 | $533,000 | $501,500 | $1,841,750 |
| Vienna DPW<br>127 Center St South<br>Vienna | Node 66-1 | Site | 3.48 | $1,264,424 | $1,484,208 | $223,298 | $404,840 | $501,500 | $1,841,750 |
| **Phase 6 Totals** | | | | **$10,559,736** | **$12,102,512** | **$1,565,114** | **$2,996,120** | **$3,510,500** | **$12,892,250** |
| **PHASE 7** | | | | | | | | | |
| Extend Fiber along Rte. 234 | Node 95-4 | Future Node **66-4** | 22.31 | $7,252,428 | **$7,466,276** | | | | |
| Extend Fiber along Rte. 15 | Future Node **66-4** | Future Node **267-2** | 26.30 | $8,524,440 | **$8,741,480** | | | | |
| Complete second loop on I-66 | Future Node **66-4** | Node **66-1** | 17.17 | $5,613,796 | **$5,823,532** | | | | |
| **Phase 7 Totals** | | | | **$21,390,664** | $22,031,288 | **$21,390,664** | **$22,031,288** | **$21,390,664** | **$22,031,288** |
| **Phase 1 Through Phase 7 Totals** | | | | **$79,704,532** | **$89,093,044** | **$32,918,608** | **$40,348,724** | **$45,974,332** | **$93,061,544** |

# APPENDIX COMMUNICATIONS INFRASTRUCTURE COST ANALYSES WORKSHEETS - FULL VIDEO

| Communications Options<br>Full Video | | | | Fiber | | Lease Lines (DS-3 & DS-1) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| **PHASE 1** | | | | | | | | | |
| **TOC**<br>3975 Fair Ridge Dr<br>Fairfax | Node 66-2 | Site | 2.10 | $948,980 | $1,341,960 | $261,116 | $2,126,780 | $754,500 | $2554,250 |
| Va. State Police<br>9801 Braddock Rd<br>Fairfax | Node 66-2 | Site | 6.88 | $2,412,844 | $2,725,648 | $278,108 | $3,486,140 | $754,500 | $2,554,250 |
| Dept. Of Emergency Serv.<br>1519 Davis Ford Road<br>Woodbridge | Node 95-3 | Site | .35 | **$649,880** | **$958,260** | $257,156 | $1,809,980 | $754,500 | $2,554,250 |
| | | | **Phase 1 Totals** | **$4,011,704** | **$5,025,868** | **$796,380** | **$7,422,900** | **$2,263,500** | **$7,662,750** |
| **PHASE 2** | | | | | | | | | |
| Interface Dulles Toll Road (DTR) with Fiber Back Bone | Node 66-1 | DTR & I-66 Inter | 2.75 | $1,016,700 | **$1,214,900** | | | | |
| Extend Fiber From Dulles Toll Road to Leesburg | Future Node 267-1 | Future Node 267-2 | 14.02 | $4,609,576 | **$4,816,792** | | | | |
| Extend Fiber along I-66 to Route 234 | Node 66-3 | Future Node 66-4 | 5.34 | $1,842,392 | **$2,042,664** | | | | |
| | | | **Phase 2 Totals** | **$7,468,668** | **$8,074,356** | **$7,468,668** | **$8,074,356** | **$7,468,668** | **$8,074,356** |
| **PHASE 3** | | | | | | | | | |
| Alexandria City<br>Trans. & Env. Serv.<br>City Hall, Alexandria | Node 95-1 | Site | 3.21 | $1,242,848 | $1,552,716 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |

| Communications Options<br>Full Video | | | | Fiber | | Lease Lines (DS-3 & DS-1) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| Location | From | To | Distance (Miles) | Initial | 20 Yr. L.C. | Initial | 20 Yr. L.C. | Initial | 20 Yr. L.C. |
| Prince William Co. DPW<br>4379 Ridgewood Cntr Dr.<br>Woodbridge | Node 95-3 | Site | 4.73 | $1,727,424 | $2,038,508 | $269,036 | $2,760,380 | $754,500 | $2,554,250 |
| Prince William Co. DPW<br>One County Complex Ct.<br>Prince William | Node 95-3 | Site | 6.85 | $2,403,280 | $2,716,060 | $278,108 | $3,486,140 | $754,500 | $2,554,250 |
| | | | **Phase 3 Totals** | **$15,933,864** | **$19,961,588** | **$3,418,268** | **$29,548,940** | **$9,808,500** | **$33,205,250** |
| PHASE 4 | | | | | | | | | |
| MWCOG<br>777 N. Capital St.<br>Washington, DC | Node at TMS | Site | 7 | $2,591,100 | $3,100,000 | $284,300 | $3,981,500 | $594,000 | $1,952,600 |
| MD SHA - SOC<br>7491 Connelley Dr.<br>Hanover | Node @I-95, 395,& 495 | Site | 30 | $10,063,500 | $10,786,800 | $291,500 | $4,557,500 | $1,824,500 | $6,565,250 |
| DC DPW<br>2000 14th St, NW<br>Washington, DC | Node at TMS | Site | 6 | $2,272,300 | $2,780,400 | $278,108 | $3,486,140 | $540,500 | $1,752,050 |
| | | | **Phase 4 Totals** | **$14,926,900** | **$16,667,200** | **$853,908** | **$12,025,140** | **$2,959,000** | **$10,269,900** |
| PHASE 5 | | | | | | | | | |
| Alexandria Dash<br>116 S. Quaker Lane<br>Alexandria | Node 95-1 | Site | 1.85 | $1,054,756 | $1,364,152 | $261,116 | $2,126,780 | $754,500 | $2,554,250 |
| Arlington Trolley<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.18 | $914,484 | $1,223,528 | $261,116 | $2,126,780 | $754,500 | $2,554,250 |
| Fairfax City CUE<br>10455 Armstrong St.<br>Fairfax | Node 66-2 | Site | 3.97 | $1,485,136 | $1,795,612 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |

| Communications Options Full Video | | | | Fiber | | Lease Lines (DS-3 & DS-1) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Alexandria City Fire Dept<br>900 Second St<br>Station 54, Alexandria | Node 95-1 | Site | 3.76 | $1,418,188 | $1,728,496 | $265,076 | $2,443,580 | $754,500 | $2554,250 |
| Alexandria City Police<br>2003 Mill Rd<br>Alexandria | Node 95-1 | Site | 3.69 | $1,395,872 | $1,706,124 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |
| Arlington Co. DPW<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.93 | $1,153,584 | $1,463,228 | $261,116 | $2,126,780 | $754,500 | $2,554,250 |
| Arlington Co. Police<br>2100 15th Street<br>Arlington | Node at TMS | Site | 2.99 | $1,172,712 | $1,482,404 | $261,116 | $2,126,780 | $754,500 | $2,554,250 |
| Arlington Co. Fire<br>2100 Clarendon Blvd<br>Arlington | Node at TMS | Site | 2.92 | $1,150,396 | $1,460,032 | $261,116 | $2,126,780 | $754,500 | $2,554,250 |
| Fairfax Co. OOT<br>12055 Gov't. Center Pkwy<br>Fairfax | Node 66-2 | Site | 0.62 | $417,156 | $724,952 | $252,620 | $1,447,100 | $754,500 | $2,554,250 |
| Fairfax Co. Fire & Resuce<br>4100 Chainbridge Rd.<br>Fairfax | Node 66-2 | Site | 3.34 | $1,284,292 | $1,594,264 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |
| Fairfax Co. Police<br>3911 Wodburn Rd<br>Annandale | Node 66-1 | Site | 3.81 | $1,434,128 | $1,744,476 | $265,076 | $2,443,580 | $754,500 | $2‘554,250 |
| Loudon Co. DPW<br>750 Miller Drive<br>Leesburg | Future Node 267-2 | Site | 1.78 | $786,964 | $1,095,688 | $257,156 | $1,809,980 | $754,500 | $2,554,250 |
| Loudon Co. Fire & Rescue<br>16600 Courage Ct<br>Leesburg | Future Node 267-2 | Site | 0.4 | $347,020 | $654,640 | $252,620 | $1,447,100 | $754,500 | $2,554,250 |

| Communications Options Full Video | | | | Fiber | | Lease Lines (DS-3 & DS-1) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Fairfax Connect<br>12055 Gov't. Cntr. Pkwy<br>Fairfax | Node 66-2 | Site | 0.62 | $417,156 | $724,952 | $252,620 | $1,447,100 | $754,500 | $2,554,25C |
| PRTC<br>1519 Davis Ford Rd.<br>Woodbridge | Node 95-3 | Site | 1.35 | $649,880 | $958,260 | $257,156 | $1,809,980 | $754,500 | $2,554,250 |
| VRE<br>6800 Verser Center<br>Springfield | Node 95-2 | Site | 1.53 | $707,264 | $1,015,788 | $257,156 | $1,809,980 | $754,500 | $2,554,250 |
| WMATA<br>600 5th St. NW<br>Washington | Node at TMS | Site | 5.15 | $1,861,320 | $2,172,740 | $274,148 | $3,169,340 | $754,500 | $2,554,250 |
| | | | **Phase 5 Totals** | **$7,089,996** | **$9,255,032** | **$1,828,388** | **$14,933,540** | **$5,281,500** | **$17,879,750** |
| **PHASE 6** | | | | | | | | | |
| Falls Church DPW<br>300 Park Ave<br>Falls Church | Node 66-1 | Site | 3.63 | $1,376,744 | $1,686,948 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |
| Fairfax City DPW<br>10455 Armstrong St.<br>Fairfax | Node 66-2 | Site | 3.17 | $1,485,136 | $1,795,612 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |
| Herndon DPW | Future Node 267-1 | Site | 3.40 | $1,303,420 | $1,613,440 | $265,076 | $2,443,580 | $754,500 | $2,554,250 |
| Leesburg DPW<br>25 W. Market St.<br>Leesburg | Future Node 267-2 | Site | 1.78 | $786,964 | $1,095,688 | $257,156 | $1,809,980 | $754,500 | $2,554,250 |
| Manassas DPW | Future Node 66-4 | Site | 6.15 | $2,180,120 | $2,492,340 | $278,108 | $3,486,140 | $754,500 | $2,554,250 |

| Communications Options Full Video | | | | Fiber | | Lease Lines (DS-3 & DS-1) | | Microwave | |
|---|---|---|---|---|---|---|---|---|---|
| **Location** | **From** | **To** | **Distance (Miles)** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** | **Initial** | **20 Yr. L.C.** |
| Manassas Park DPW<br>1 Park Center Ct.<br>Manassas Park | Future Node 66-4 | Site | 7.31 | $2,549,928 | $2,863,076 | $284,300 | $3,981,500 | $754,500 | $2,554,250 |
| Vienna DPW<br>127 Center St South<br>Vienna | Node 66-1 | Site | 3.48 | $1,328,924 | $1,639,008 | $265,076 | $2,443,580 | $754,500 | $2,254,250 |
| | | | **Phase 6 Totals** | **$11,011,236** | **$13,186,112** | **$1,879,868** | **$19,051,940** | **$5,281,500** | **$17,579,750** |
| **PHASE 7** | | | | | | | | | |
| Extend Fiber along Rte. 234 | Node 95-4 | Future Node 66-4 | 22.31 | $7,252,428 | $7,466,276 | | | | |
| Extend Fiber along Rte. 15 | Future Node 66-4 | Future Node 267-2 | 26.30 | $8,524,440 | $8,741,480 | | | | |
| Complete second loop on I-66 | Future Node 66-4 | Node 66-1 | 17.17 | $5,613,796 | $5,823,532 | | | | |
| | | | **Phase 7 Totals** | **$21,390,664** | **$22,031,288** | **$21,390,664** | **$22,031,288** | **$21,390,664** | **$22,031,288** |
| | | | **Phase 1 Through Phase 7 Totals** | **$81,833,032** | **$94,201,444** | **$37,636,144** | **$113,088,104** | **$54,453,332** | **$116,703,044** |