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Newport News Signal System Feasibility Study and ITS Master Plan Volume 1 of 2

FEASIBILITY STUDY - Final

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Executive Summary

The Feasibility Study was conducted as part of a pre-design evaluation for the upgrade of the citywide traffic signal system in Newport News. The findings that follow establish a plan to guide the City through the design and construction phases of the project. It was determined that the City will pursue a multiyear development of a Citywide Signal System Upgrade. It is essential that this citywide signal system upgrade project move forward now because the existing signal infrastructure has exceeded its 20 year life expectancy and must be replaced with an expandable system to meet future transportation needs. The primary objective of this project is defined in the mission statement as follows:

The mission purpose and need of the project is to design and implement an advanced transportation management system for citywide control of highway and local traffic in Newport News utilizing signals, warning devices, and incorporating Intelligent Transportation System (ITS) components. The focus of design will be to develop a system, which safely and efficiently moves people and goods within the City and between surrounding jurisdictions and is responsive to the dynamic demands of coordinated traffic operations. Components of the system will form a flexible architecture that allows for expandability, is easily maintained, is interoperable within the regional vision/architecture, and supports a phased plan of implementation.

The Feasibility Study is comprised of two volumes. Volume 1 presents the analysis and findings of the review of signal system upgrades. Volume 2 presents the ITS Master Plan for use in expanding the traffic signal system capabilities.

Technical Summary

The primary objective of developing the Newport News Signal System Feasibility Study is to establish a plan to guide the City through the design and construction phases of the project. The Feasibility Study contributes to long range planning by offering policies and strategies for implementation in the City's "Framework for the Future" document based upon operational, technological, and economic analysis. The Feasibility Study focuses on the functional requirements for traffic signal system components that are regionally and locally significant, as well as addresses the specific needs of staff and steering committee members.

Kimley-Horn and Associates, Inc., under subcontract to Wilbur Smith Associates, was retained under the VDOT ITS On-Call contract, to prepare the City of Newport News' Signal System Feasibility Study. When combined with the Intelligent Transportation Systems (ITS) Master Plan, the Signal System Feasibility study provides a comprehensive document to serve as the basis for the development of plans and specifications for an Advanced Traffic Management System (ATMS). The Signal System Feasibility Study is a compilation of the following seven technical documents:

- System Inventory Baseline
- Mission Statement and Draft Operational Concepts
- System Evaluation Criteria
- Technology Evaluation and Recommendations
- Proposed Communication System Upgrades
- Proposed System Functional Requirements
- Proposed System Architecture

The system inventory baseline identified that the current 254 signalized intersections operate in 27 coordinated signal systems with a few isolated operations. The inventory summarized controller type, location, and operational characteristics for each intersection. In addition, the baseline inventory reviewed current staffing levels and determined that the City currently operates and maintains all existing controller equipment and communications infrastructure.

During the early stages of this study, the project team worked with the steering committee to establish a mission statement to help guide the decision-making process throughout subsequent activities. The identified mission statement is as follows:

The mission purpose and need of the project is to design and implement an advanced transportation management system for citywide control of highway and local traffic in Newport News utilizing signals, warning devices, and incorporating Intelligent Transportation System (ITS) components. The focus of design will be to develop a system, which safely and efficiently moves people and goods within the City and between surrounding jurisdictions and is responsive to the dynamic demands of coordinated traffic operations. Components of the system will form a flexible architecture that allows for expandability, is easily maintained, is interoperable within the regional vision/architecture, and supports a phased plan of implementation.

To ensure the development of a comprehensive study that addresses the City's needs, a two-day workshop was held to gain input from key stakeholders that would ultimately benefit from the future ATMS. The stakeholders were divided into two categories: 1) Public Transportation & Public Safety, and 2) Institutional & Operations. Several issues were identified during the two-day workshop as well as through the surveys received from participants.

Vital functions identified through stakeholder outreach include the following:

- *Providing wireless remote access to facilitate uploading/downloading timing changes and status monitoring*
- *Supporting a minimum of seven timing plans per intersection*
- *Automated reporting of controller, detector, and communication failures*
- *Automated reporting of special event schedules and road closures*

In addition to the features of the system, the workshop also addressed current and future operating arrangements between the City and other agencies. Based on the request to share data with other City agencies, emergency operations personnel, as well as non-City stakeholders, a proposed architecture was recommended that identified the City of Newport News Engineering Division as the clearing house of information between the City and the Virginia Department of Transportation (VDOT) regarding transportation specific issues. VDOT will provide the City with regional information for the interstate system, bridges, and tunnels, which will be dispersed to other City divisions such as public works, schools, and emergency operations. Conversely, the City will provide information such as road closures, detours, and incidents along the major arterials to VDOT. During the design phases, detailed protocols and formats will be developed to stream-line this process.

After determining the focus areas and desired functions, the next step involved evaluating current technologies available to support the three elements of an ATMS:

- Signal Controllers
- Signal Cabinets
- Central Systems

The technology evaluation included the NEMA and 170/2070 environments, both of which have the ability to provide the requested functionality. The City is already comfortable with the NEMA environment, and the ability to transition new controllers into existing cabinets provides the flexibility for phased construction.

However, with the NEMA environment the selection of a hardware vendor also establishes the software functionality for the central system. Nonetheless, given the current NEMA market there are several vendors capable of supplying the functionality the City is seeking, and therefore there is a competitive environment in which to obtain a cost effective system.

In addition to reviewing the hardware elements of the system, the feasibility study also evaluated communications media alternatives ranging from a twisted pair environment to wireless networks to an all fiber backbone. After evaluating the existing twisted pair communication infrastructure and opportunities to share the existing Citywide IT fiber infrastructure, it was determined that an all fiber network would be optimal for providing access to real-time traffic data as well as accommodating the needs of the ITS elements, which are discussed in a separate document.

Based upon input received through the steering committee and stakeholders input process, the following recommendations should be considered as detailed design plans and specifications are developed to construct the Newport News Advanced Traffic Management System.

- Design an ATMS to accommodate a NEMA environment cabinet, controller, and central system
- Design the system to include TS-2 controllers Citywide to provide current equipment and provide for maintenance and replacement parts at all signalized locations
- Design for TS-2 cabinets in locations requiring additional functionality such as multiple phase signal operations and traffic responsive mode
- Design the system to accommodate two redundant traffic control centers
- Design an all fiber communication network that maximizes the use of the existing Citywide IT network but minimizes the number of new connection points
- Design the communications system to operate in an Ethernet environment to control the ATMS function and proposed ITS functions identified in a separate document

1.0 Introduction

The purpose of Subtask B of the Newport News Signal System ATMS Feasibility Study and ITS Master Plan is to prepare the functional requirements that will become the basis for the City's planned system upgrades. The Feasibility Study reviews operations and technology alternatives that will enhance existing operations within the City as well as with surrounding jurisdictions by expanding traffic management.

The primary objective of developing the Feasibility Study is to establish policies and strategies for implementation in the City's "Framework for the Future" based upon operational, technological, and economic analysis. The Feasibility Study focuses on the functional requirements for traffic signal system components that are regionally and locally significant, as well as addressing the specific needs of staff and steering committee members.

1.1 Document Organization

This document is divided into 8 sections. Section 1 provides an introductory project overview, document organization, and mission statement. Section 2 summarizes the system inventory baseline. Section 3 provides the evaluation criteria for proposed system alternatives. Section 4 describes the existing and proposed concept of operations. Section 5 reviews the evaluation of technologies and traffic control strategies. Section 6 analyzes communication upgrade alternatives and resource sharing opportunities. Section 7 provides the culmination of the findings into a series of functional requirements for the proposed system. In Section 8, a summary of the feasibility study and a conclusion will be provided.

1.2 Project Overview

The City of Newport News is developing a detailed Signal System Feasibility Study and Intelligent Transportation Systems (ITS) Master Plan that when combined will provide a comprehensive document to serve as the basis for the development of plans and specifications for an Advanced Traffic Management System (ATMS). Kimley-Horn and Associates, Inc., under subcontract to Wilbur Smith Associates, is preparing these documents within the VDOT ITS On-Call contract.

The ATMS Feasibility Study is a compilation of seven technical documents, submitted previously in draft versions, which have been combined into this final report. Under a separate phase of this effort, an ITS Master Plan is also being developed to account for elements beyond the scope of traditional traffic signal system deployment. The seven technical documents represented within this ATMS Feasibility Study are:

- System Inventory Baseline
- Mission Statement and Draft Operational Concepts
- System Evaluation Criteria
- Technology Evaluation and Recommendations
- Proposed Communication System Upgrades
- Proposed System Functional Requirements
- Proposed System Architecture

1.3 Mission Statement

During the early stages of this project, the project team worked with the steering committee to establish a mission statement to help guide the decision-making throughout subsequent activities. The identified mission statement is as follows:

The mission purpose and need of the project is to design and implement an advanced transportation management system for citywide control of highway and local traffic in Newport News utilizing signals, warning devices, and incorporating Intelligent Transportation System (ITS) components. The focus of design will be to develop a system, which safely and efficiently moves people and goods within the City and between surrounding jurisdictions and is responsive to the dynamic demands of coordinated traffic operations. Components of the system will form a flexible architecture that allows for expandability, is easily maintained, is interoperable within the regional vision/architecture, and supports a phased plan of implementation.

2.0 System Inventory Baseline

The following information has been compiled from GIS data and signal design plans supplied by the City, and supplemented with field investigations and interviews with the City's staff. The existing system information has been divided into three subsections: central system, communications, and field equipment. The data gathered has been consolidated into the GIS database. The contents of the GIS data fields, illustrated on the base map, are explained in this section.

2.1 Central System

The software used to communicate with the field hardware described in the subsequent section is the LM System Software (Rev. 6.3A/1996) provided by Traffic Control Technologies. The LM100 Software used in Newport News can supervise up to 32 field masters on two system servers: Server "C" and Server "D" shown in **Figure 1**. Server "C" manages the south end of Newport News, while Server "D" manages the north end. The software has the capability to communicate with the master in a closed-loop system. In the Newport News architecture, all communications with local controllers are via the field masters, and 24 local intersections can be communicated with simultaneously if they are connected to the same master. Two masters can communicate with one another to extend the system boundaries beyond the local controller capacity limitations. Some isolated intersections are operating as a stand-alone master controller, but are not currently connected/monitored by the central system. These isolated intersections are only accessible by technicians in the field or by dial-up from vendor software. There are 27 master controllers within the Newport News Signal System. The J Clyde Morris Boulevard & Old Oyster Point Road system is not part of the LM System. This system currently has Eagle equipment and does not report to the LM System. **Table 1** shows the existing master controller locations that are currently connected to the central system servers.

Table 1: Master Controller Locations and System Report-In Times

CITYWIDE SYSTEM	"C" Server	TIME
75TH-WARWICK	A - 1	0200-0230
42ND-HUNTINGTON	B - 2	0230-0300
39TH-HUNTINGTON	C - 3	0300-0330
16TH-MARSHALL	D - 4	0330-0400
26TH-MARSHALL	E - 5	0400-0430
27TH-WICKHAM	F - 6	0430-0500
39TH-MARSHALL	G - 7	0500-0530
36TH-MARSHALL	H - 8	0530-0600
BRIARFIELD-MARSHALL	I - 9	0600-0630
25TH - JEFFERSON	J - 10	0630-0700
CANON-MIDDLEGROUND	No Communication	
SAUNDERS-DAPHIA	L - 12	0130-0200
CITYWIDE SYSTEM	"D" Server	
YORKTOWN-JEFFERSON	No Communication	
FT EUSTIS-JEFFERSON	B - 2	0005-0030
LUCAS CREEK-DENBIGH	C - 3	0030-0100
COLONY-WARWICK	D - 4	0100-0130
WARWICK-ELMHURST	E - 5	0830-0930
MAIN-WARWICK	F - 6	0200-0230
LOGAN-WARWICK	G - 7	0230-0300
OPERATIONS-JEFFERSON	H - 8	0300-0330
JEFFERSON-HOGAN	I - 9	0330-0400
CENTER-JEFFERSON	J - 10	0400-0430
MAXWELL-WARWICK	K - 11	0430-0500
TURNBERRY-JEFFERSON	L - 12	0500-0530
J C MORRIS -THIMBLE SHOALS	M - 13	0530-0600
J C MORRIS – OLD OYSTER POINT	N - 14	0600-0630
MARRY OAKS-WARWICK	O - 15	0630-0700

2.2 Communications

Within the Newport News traffic signal system there are two central communication lines that are used to communicate with the 27 master controllers throughout the system. The master controllers, in turn, communicate with the 250+ attached local controllers. The two communication lines are plain old telephone system (POTS) lines that operate on the Verizon public telephone network. There are currently no agency-owned communication lines in operation between the central system and the masters. Data is transmitted on these dial-up communication lines via low bandwidth data modems operating at 300 bits per second (bps) data rates.

A 300 bps communications rate is less than ideal by today's standards, let alone the increasing demand for bandwidth by advanced signal controllers. These slow data transfer rates inhibit the upload and download rate at which data is transferred. The master

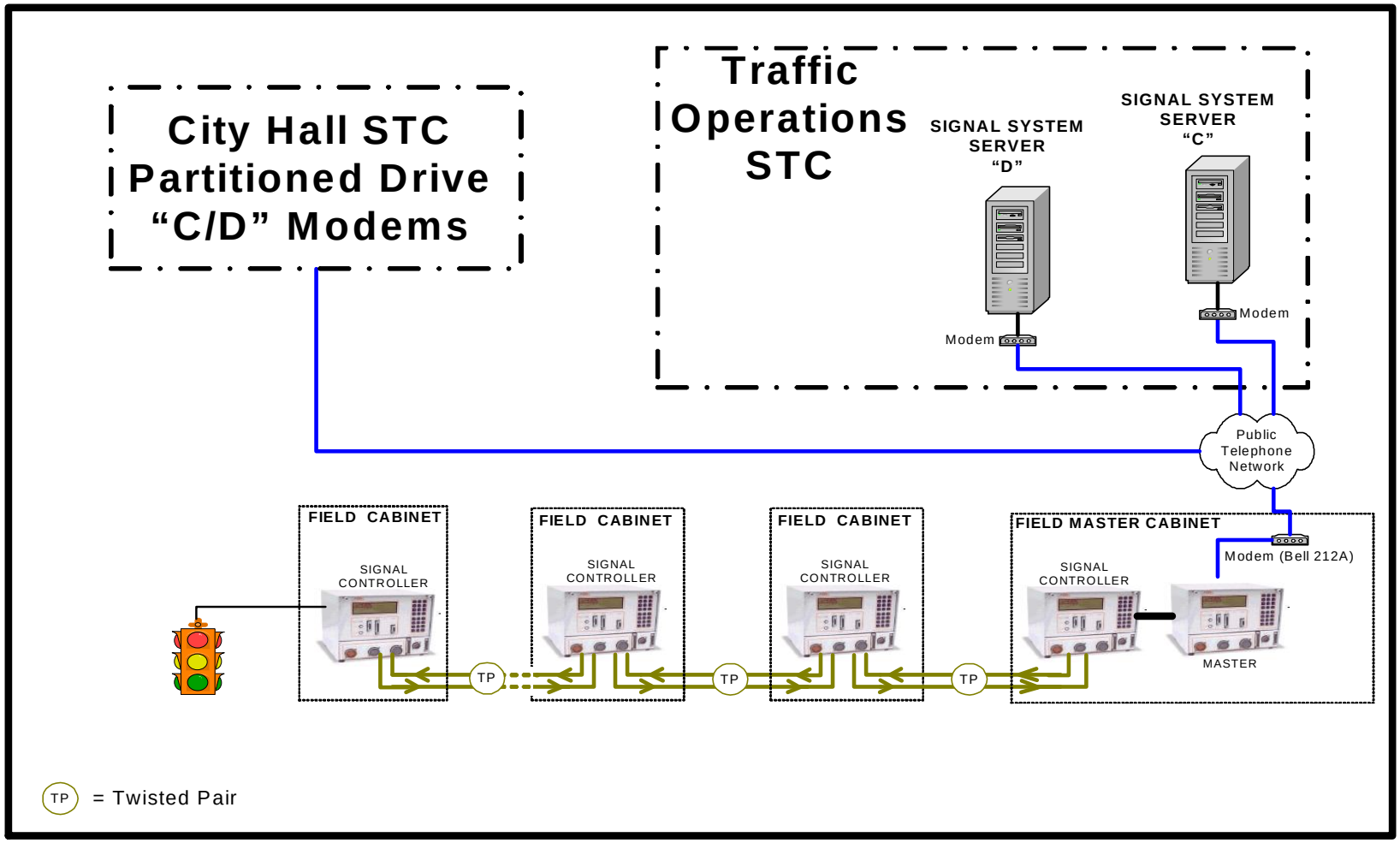
controller communicates with the local controllers by using internal modems within the controller to communicate over City-owned twisted pair cables. The communications architecture is illustrated in **Figure 1** below. There is a mixture of 6-pair and 12-pair size 19-AWG twisted pair cable throughout the system.

As seen on the base map (**Figure 2**), there are gaps within the current system that do not allow for complete connectivity between the closed loop systems nor directly with the operations centers without using the dial-up public telephone network.

A further limitation on the existing communication network is that the dial-up field modems at the master cabinet locations are no longer produced. These Bell 212A-style modems, once manufactured by UDS/Motorola, are currently being repaired by staff when possible. If modems are not repaired, adjacent systems are being chained in order to share the modem at the master controller and remotely communicate with central operations. In order to maintain remote operations prior to the ultimate replacement of the system, it may be necessary to obtain and test alternative vendor modems for compatibility with the current system. Two vendors worth noting are GDI and ARC Electronics, both of which manufacture a field-hardened Bell-212 compatible modem.

(http://www.sgdi.com/pdf_files/GDI%20SM336SA.pdf; and http://www.arcelect.com/ARC_IM_Modem_24_manual.html

Figure 1 - Existing Central/Communication Architecture



2.3 Field Equipment

The Newport News Signal System consists of several styles of field equipment. The equipment can be broken into several categories and are listed in the database that is included in this document as an appendix.

Each signal in the database is identified by intersection location and a controller number. Other contributing descriptive factors are whether the signal is existing or future, a master or local controller, actuation or fixed-timed operations, video or loop detection, pedestrian push-button actuation for pedestrian cross-walks, pre-emption for emergency vehicles, signal span type (span wire or mast arm), physical cabinet location (ground or pole mount), cabinet type, controller type, and controller size.

Controller Number: Each signal is listed in the database with a controller number. A "0" is representative of a future signal and therefore no controller number has been assigned.

Location: This is the intersection location where the signal is installed or planned to be installed.

Existing or Future: Many of the signals listed in the database are currently installed and in operation. The database identifies the signal type with a "Y" for yes in this data field column, either existing or future.

Master: There are 27 master controllers within the Newport News Signal System. These master controllers are the central control and communication points for the sub-systems. Typically, one master control cabinet communicates and controls several other local controllers (no more than 24 per master). A "Y" for yes is used in the database for identifying the master controller locations.

Actuation: Each traffic signal is either a fixed time signal or an actuated signal. A "Y" is used to identify an actuated signal, while a blank cell is used to show that the signal operates under a fixed time-based.

Video Detection: Actuated traffic signals are split into two categories, inductive-loop detection or video detection. If the signal is actuated by video detection a "Y" for yes will be present in the appropriate cell of the database.

Pedestrian Actuation: There are 39 signal locations that have pedestrian cross walks with pedestrian push-buttons and pedestrian signals. These signals are listed as having pedestrian-actuation and are identified in the database with a "Y" for yes. Typically, these signals are in high pedestrian areas, and this feature helps with the safe movement of pedestrians across roadways.

Pre-emption: There are 68 signals that are equipped with emergency vehicle pre-emption. In the Newport News Signal System, pre-emption is the device that signals the controller to immediately service an emergency vehicle. As an emergency vehicle approaches the intersection (in an emergency situation, i.e. with emergency lights on) the controller interrupts its normal phasing cycle to service the approach actuated by the emergency vehicle, allowing the vehicle to pass through the intersection with little delay. A "Y" for yes is used to identify a signal location with emergency vehicle pre-emption.

Span Type: There are two primary methods used to install signal heads across an intersection, either by a mast arm or span-wire installation. In some locations (mainly large intersections and intersections underneath overpasses) a third method is used that places the signal heads on top of a pedestal pole at a height that is typically less than that of a span wire or mast arm height.

Cabinet Location: The cabinet location is listed in the database as either ground mounted or pole-mounted.

C*abinet Type*: The cabinet type used throughout the system is the TS-1. This data field is used to differentiate with other cabinet types (i.e. TS-2, 170/2070 style, ITS, etc.).

Controller Type: The controller type identifies the controller as "Flasher", "LC", or "LMD." "Flasher" represents locations where either dedicated school flashers or non-signalized intersection warning flashers are used. "LC" and "LMD" represent locations where there are traffic signal controllers from Traffic Controller Technologies or PEEK. Additionally, there are three "EAGLE" controller locations along J. Clyde Morris, which are coordinated with the VDOT Hampton Roads District traffic signals along that corridor.

Cabinet Classification: The existing cabinet sizes have been placed into six categories with a separate category for flasher controls. The sizes are listed below in **Table 2**. Please note that these sizes are approximate.

Table 2: Cabinet Size and Classification

Cabinet Sizes and Classification for Newport News Signal System	
Cabinet Classification	Approximate Size of Cabinet
NN1	48" x 30" x 18"
NN2	48" x 36" x 24"
NN3	48" x 48" x 30"
NN4	48" x 48" x 18"
NN5	48" x 48" x 24"
NN6	60" x 48" x 30"
FL	12" x 12" x 12"

System Detectors: The existing system detector locations are noted in the database with the direction of travel and lanes covered. Currently, all system detectors are using inductive loops. Systems loops that are within closed-loop system boundaries provide data for supporting traffic responsive operations for that system. **Table 3** summarizes the existing system detector locations. Lane descriptions include L for Left, C for Center and R for Right lanes.

Table 3: System Detector Locations

LOCATION	DIRECTION	LANES
Jefferson between Ivy Farms and Dresden	NB	L,C,R
Jefferson between Harpersville and Winston	SB	L,C,R
Mercury between Newmarket and Jefferson	EB	L,C,R
Jefferson between Hemlock and Lyliston	NB	L,C,R
Jefferson between Ivy Farms and Dresden	SB	L,C,R
Jefferson between Harpersville and Winston	NB	L,C,R
Mercury between Newmarket and Hampton City Limits	WB	L,C,R
Warwick between 75th St. and Mercury	NB	L,C,R
Warwick between 75th St. and Mercury	SB	L,C,R
Mercury between JRB and River	EB	L
Mercury between Warwick and River	WB	L
39th St. between Marshall and Roanoke	EB	L,R
39th St. between Marshall and Roanoke	WB	L,R
Warwick between Cedar and Logan	NB	L,C,R
Warwick between Cedar and Logan	SB	L,R
Warwick SBLT at Ridgeway	SB	L
Jefferson between Clair La. and Operations Dr.	SB	L,C,R
Oyster Point b/w Criston - Village Green (system)	EB	L,C,R
Oyster Point b/w Criston - Jefferson (system)	WB	L,C,R
Oyster Point b/w Canon - Village Green (system)	WB	L,C,R
Jefferson between Oyster Point and HQ Way	NB	L,C,R
Jefferson between Oyster Point and Hogan	NB	L,C,R
Jefferson between Muller La. and Hogan	SB	L,C,R
Jefferson between Thimble Shoals and Pilot House	SB	L,C,R
Jefferson between J.Clyde and Pilot House	NB	L,C,R
Denbigh east of McManus	WB	L,R
Denbigh west of McManus	EB	L,R
Jefferson Ave between Turnberry and Bland	SB	L,C,R
Jefferson Ave b/w Turnberry and Denbigh Crossing	NB	L,C,R
Jefferson Ave between Bland and Habersham	SB	L,C,R
Jefferson Ave between Bland and Turnberry	NB	L,C,R
Jefferson between Habersham and Brick Kiln	NB	L,C,R
Jefferson between Richneck and Buchanan	SB	L,C,R

2.4 Overview Base Map and Database

Using the geographic information system (GIS) database from the City as a baseline, the information gathered from signal design plans, Operations' spreadsheets, and field reviews have been consolidated onto the GIS database. **Figure 2** depicts the existing City-wide signal system element locations and some identified future locations. The base map also includes City IT fiber network access points that are described further in Table 22 in Section 7.2. **Appendix A: Newport News Signal System Baseline Database** provides the output of entries for each field location based upon the database fields described in Section 2.3 above. Some data is missing, particularly for locations that have been implemented relatively recently. However, since it is anticipated that the whole system will be upgraded, this information is not critical to subsequent analysis.

Figure 2 - Newport News Signal System Baseline Overview Map

2.5 Existing Staffing and Operations

Within the City of Newport News, decisions about the operations and maintenance of the signal system are influenced by two distinct divisions within the Department of Engineering. Current staffing conditions and responsibilities are discussed in this section.

2.5.1 Existing Staffing

Within the Department of Engineering there are two divisions, Transportation and Traffic Operations, which are responsible for maintaining the traffic signal infrastructure in the City. Between the two divisions, full-time staff members collectively operate and maintain the existing system. The Traffic Operations is located at the City Operations Center along Operations Drive. The Traffic Operations staff includes: an operations superintendent and seven traffic signal technicians and one traffic counter. This staff is supervised by the Assistant Director of Engineering. The staff is also responsible for maintaining City-owned street lighting fixtures.

The Transportation Division is located in City Hall on Washington Avenue as is also a division of the Engineering Department. In the Transportation Division, there are three staff members that coordinate closely with the Traffic Operations staff to maintain the signal system. The Transportation staff includes an Engineer III and two engineering technicians. The staff members are responsible for plan reviews, traffic studies, and they coordinate closely with Traffic Operations staff regarding issues relevant to the design, maintenance, and operations of the traffic signal infrastructure, street lights, and railroad crossing preemption. The Transportation Engineering staff also fields complaints from the public, prepares and implements updated signal timing plans, and prepares and implements new signal designs.

Transportation Division staffing has been routinely supplemented by the Congestion Mitigation Air Quality (CMAQ) On-Call contract for over a decade. On average over the last three years, the Transportation Division has utilized (consultant resources) the equivalent of approximately one and a half additional staff members in order to maintain optimized signal timing plans that are responsive to changes in traffic patterns. One of the City's transportation goals is to update every coordinated signal system on a three year cycle. Given their current workload, the task of maintain optimized signal timings on a three year cycle is beyond the capacity of current staffing.

2.5.2 Existing Operations and Maintenance

The current signal system operates 254 signalized intersections and 61 flashing warning devices. These signals are completely operated and maintained by the City of Newport News Traffic Operations staff.

The system logs data from signalized intersection onto the two central computers. The message logs are reviewed daily to verify if each system is operating under the

intended cycle, split and offset. Reports of free operation are further investigated to identify the cause of the lapse in coordination.

The message logs also report loss of communication, as well as when the signal system returned to programmed operations. The message logs are also reviewed to verify that the master controllers are communicating with the local intersection controllers.

Repair calls are classified as either a standard or emergency response. When a movement with a single signal head indication shows that a bulb is out (red, yellow, or green), this is considered an emergency response call even under an on-call time period.

Standard response calls include communication problems, bulb out on approaches with dual signal indications, and loss of communications between two master controllers, which allows for expanded system boundaries for certain times of the day.

Routine maintenance is performed on every signal on a semi-annual basis. Routine maintenance includes a thorough evaluation of the signal cabinet, vacuuming the inside of the cabinet, changing the filter, testing signal loops to ensure proper operation, cleaning all signalized heads, and (changing the bulbs) on a two year cycle.

New mast arm signal poles are manufactured with a stainless steel brushed finished. Old installations and Special area City Center poles are painted in green. While it is the intent to maintain the appearance of the poles on a routine basis, due to time limitations, there is no regular schedule for re-painting.

2.5.3 Span of Operation

The existing traffic signal system operates 254 signalized intersections along the major arterials within the City of Newport News including systems along Jefferson Avenue, Warwick Boulevard, Huntington Avenue, Washington Avenue, Mercury Boulevard, Harpersville Road/Hampton Road Center Parkway, J. Clyde Morris Boulevard, Oyster Point Road, Bland Boulevard, Denbigh Boulevard, and several blocks in the downtown area.

Engineering Transportation staff hours are 8:00 AM until 5:00 PM. The City's Operations Division operates weekdays from 7:00 AM until 4:00 PM, Monday through Friday with an on-call schedule with consideration for staff on a rotational basis. Evening hours and weekend calls are handled by the six signal technicians in the Traffic Operations division, who rotate over a two-week period. Each technician is on-call once every three months. When technicians are on call, they have to respond to emergency repair calls within a half hour.

2.5.4 Incident and Emergency Management

The City of Newport News operates its signal system on either time-based coordination or using traffic responsive thresholds. The major commuter corridors that provide access to Interstate 64 primarily operate under traffic responsive mode. Under this condition, the system loops in the pavement collect volume-data in 10-minute increments and compare this information against pre-determined thresholds, which then operate a specific timing plan. When field data for a specific loop exceeds the peak condition, pre-developed incident management plans are downloaded from the timing library. There are corridors, where the system loops are not properly placed or they are malfunctioning such that the system only operates in a time-based mode. Under these conditions, incident management plans can only be implemented by manually downloading them.

The City of Newport News also operates special plans within school zones. Based on known operating hours, certain signals that service a school entrance or major intersection are allowed to run in free operation for a period of approximately 15 minutes to allow bus traffic associated with adjacent schools to enter the system quickly. These plans are implemented on a time-of-day basis at specific intersections. When natural disasters or winter storms cause a delay in school schedules, often times the flasher schedules cannot be updated in time, since a manual download must be initiated to each individual local controller or flasher controller.

Given the significant growth in retail activity along certain corridors (Jefferson Avenue; immediately north and south of I-64), the City has also developed holiday plans during the late evening and weekend periods. These plans are implemented on a time-of-day basis and re-evaluated every one to three years.

2.5.5 Timing Plans

Currently the City operates most of its system with a library of seven timing plans that are implemented by either time-based coordination or traffic-responsive thresholds. The seven plans include the following plans:

1. Transitional Plan
   The transitional plan usually operates at the lowest acceptable cycle length and is developed to address the minimum volume of traffic that warrants coordination. It is usually the first and last plan run prior to allowing the system to operate in a free capacity.
2. AM Plan
   The AM plan is developed to meet the needs of the morning commuters.
3. Off-Peak / Pre-PM Plan
   The off peak plan is usually implemented in residential areas where the AM volumes spikes and then drops off allowing for a lower cycle length between the morning and noon periods.
   The Pre-PM plan is implemented in commercial areas where volumes consistently rise throughout the day and though the cycle length may not vary there is a shift in the time allocated (i.e. splits) between the mainline and side street.

4. Noon Plan
   The Noon plan is developed to meet the needs of the “lunch” time patrons as well as commercial uses and businesses, when there is a more balance in green time between side street demand and mainline progression.
5. PM Plan
   The PM peak emphasizes mainline progression for the commuter returning home, but must also balance the demand of the commercial needs in heavy retail areas.
6. Incident Management Inbound Plan
   This plan is developed if there is an incident on the interstate and traffic is diverted into the City. The inbound direction (northbound or southbound) varies depending on where the system falls relative to the interstate.
7. Incident Management Outbound Plan
   This plan is developed to evacuate the local streets onto the interstate system. The outbound direction (northbound or southbound) varies depending on where the system falls relative to the interstate.

Plan development is further complicated by the limitations of the older PEEK equipment that only allows the use of four different cycle lengths, four different splits, and three different offsets.

For the systems with primarily two phased intersections, the number of timing plans is reduced based on a lower volume demand and a reduced need for varying timing plans.

3.0 System Evaluation Criteria

The objective of this section is to compile and document relevant system evaluation criteria for subsequent ATMS review and technology analysis. The evaluation criteria, builds upon the input and information gathered during the development of the previous two reports in preparation for ultimately identifying the functional requirements for the proposed system upgrades. The prioritization of user needs and functional requirements is analyzed and summarized within this section.

In this section, proposed system functional needs and features were surveyed from a variety of stakeholders both in a written survey and during a 2-day workshop environment. An existing system inventory was provided by the City of Newport News and verified by Kimley-Horn in a windshield survey to determine how future functions can be implemented. Survey results were documented and analyzed based on guidance from the steering committee and detailed results are provided in **Appendix B**. Priority is recommended to be given to providing the basic function of uploading and downloading a minimum of seven timing plans from a remote location and communicating key road closure and incident information to other City Departments and VDOT to help response times within the City limits.

3.1 Proposed System Functional Needs/Features

In order to clearly understand the functional needs of all the stakeholders, a functional survey was developed and distributed prior to the two-day workshop. This process allowed each organizations representative to seek additional feedback and more accurately summarize the needs of the organizations they represented.

The fifteen question survey, which included an extensive list of sub-questions, was divided into four focus categories dealing with Public Transportation/Transit, Public Safety, Institutional/IT, and a Traffic Operations.

The survey was distributed to the following stakeholders:

- √ Newport News Transportation
- √ Newport News Traffic Operations
- √ Newport News GIS
- √ Newport News Citywide IT
- √ Newport News Fire/Rescue
- × Newport News Police
- √ Newport News School Transportation
- √ Newport News Public Works
- √ Newport News Emergency Operations Center (Office of Emergency Management)
- √ City of Hampton Traffic Engineering

- √ VDOT Hampton Roads STC
- √ VDOT Hampton Roads District
- × VDOT Hampton Roads Tunnels
- √ FHWA
- √ Hampton Roads Planning District Commission
- √ Hampton Roads Transit
- × Newport News-Williamsburg Airport Authority
- × Amtrak
- × CSX
- × Virginia Department of Rail and Public Transportation

Of the 20 stakeholders, 14 responded to the survey and are indicated with a check by their organization. This information has been compiled in a matrix and illustrated in the **Table 4**.

3.2 System Elements Inventory Summary

Given the age of the existing equipment and lack of current vendor support, during the scoping phase of this project it was assumed that the existing system hardware at a local level and central level would be completely replaced with new technology. Therefore, it was determined that a detailed intersection by intersection inventory would be very labor intensive and was not the best use of the overall project budget. Therefore, a more comprehensive "windshield" inventory was performed to validate existing conditions.
The City provided a detailed list of signalized intersection information with the following attributes:

- Signal Operations (Existing, Future, or Master)
- Actuation Type (vehicle, pedestrian, video)
- Cabinet information (mounting, cabinet type, foundation size and controller type)

Kimley-Horn took this data in the field to verify information in addition to performing a visual evaluation of the following elements:

- Controller ID Number
- Signal Type (Span Wire or Mast Arm)
- Cabinet Type (Pole Mount or Ground Mount)
- Cabinet Size (approximate for possible future re-use)
- Cabinet Color (for maintenance requirements)
- Actuation Type (Loops or Video)

- Pedestrian Actuation (yes or no)
- Pre-Emption (yes or no)
- Communication (aerial or underground)
- Flasher Type (school or other)

Given the assumption that the central and local hardware is obsolete, there is still an opportunity to salvage some infrastructure. Therefore, as part of the field inventory, cabinet size and mounting types were noted in order to evaluate if various types of controllers can be mounted into existing cabinets.

While there is a cost saving by using existing cabinets, consideration must also be given to operational constraints and what is required to maintain current signalized control during the upgrades (i.e. minimize downtime).

The system inventory elements verified in the field are indicated by a legend symbol on the City Wide Base Map prepared as part of Task B.2 System Inventory Database and Base Map. The additional detailed information is included in tabular format and is included in an attachment.

3.3 Weighted Evaluation Criteria Matrix

The values presented in this matrix represent the results of a sequential process to gain insight and consensus along the way. This process began with surveys provided to stakeholder representative to answer specific question that helped guide the development of the general needs of their organizations as it relates to the City of Newport News Signal System Operations. Not all questions were answered due to the fact that not all the questions were relevant to each of the stakeholders.

The fifteen question survey was divided into four focus categories

- Public Transportation/Transit
- Public Safety
- Institutional/IT
- Traffic Operations

Each question was further broken down into detailed functions and features of specific applications. Some of the questions pertain to the stakeholders' desire to maintain existing functionality, while others focus more on new functionality. The results are summarized and sorted by total merit in the attached matrix (**Table 4**).

From the survey responses, factors and priority rankings were applied to each response based on:

- the importance of the functionality;
- the strength of need; and

- the criticality (or rank/priority) of the focus category.

To clarify the step by step process used to develop the total merit of each function, an alphabetical sequence from A through I was assigned to each step in the process and is labeled in the attached matrix.

Columns A through C simply identify the raw results of those who responded to the survey questions. The functionality description, as well as those who responded, is identified in the following two columns.

Columns D through F establish a weighted value based upon the importance of the functionality to those who responded. Column G provides the rank/priority of the focus category. Column H identifies the degree of interest for each function. Column I provides the combined total merit by multiplying the weighted importance by the focus category priority as seen in the following column headings from **Table 4**, and described in further detail below.

	Priority	Importance Ranking			Survey Question	Who needs it?
	G	A	B	C		
		1	2	3		
1	OP1.1	5	1		Wireless remote access connectivity with central to upload/download timing changes	NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT

Weighted Importance			Rank/Priority	% Responded	Total Merit
D	E	F	G	H	I
A*10+B*5+C*1	A / (A+B+C)	D*E	G	(A+B+C)/respondents	F*G*H
Importance	Strength	Weighted Importance			

The stakeholders were given three options to rank the importance of each question. Questions ranged from a variety of topics from “How and when do organizations communicate?” to “What do they do with the information received?” The functions were ranked 1, 2 or 3 with the following understanding:

#1 – Must have it (column A)

#2 – Would be nice to have (column B)

#3 – Don’t need/not a priority (column C)

The overall importance (column D) was calculated by multiplying the amount of respondents with an answer from options 1, 2, or 3 with an associated multiplier of 10, 5, or 1 respectively.

The overall strength (Column E) was calculated by multiplying the total importance by the percentage of the respondents prioritizing a function #1 (Must have) and then dividing by the percentage of the total responses.

The importance and strength are combined to an initial weighting of the functions (column F – Weighted Importance). Several topics in the four categories may

have received an equal weighting since some stakeholders did not respond to every topic.

Therefore, it was determined that each of the four categories would be further ranked relative to the overall needs and functions of an ATMS. Based on direction from the steering committee, the following ranking was applied to the four focus areas, with four being the most important attribute (column G – Rank/Priority).

1 - Institutional/IT (IT)

2 - Public Safety (PS)

3 - ATMS functionality (ATMS)

4 - Traffic Operations functionality (OP)

An overall importance factor was calculated similar to Column E (Strength). However, in Column H the number of responses (A+B+C) is divided by the overall importance by the total number of respondents (e.g. 13). This gives a representation of the degree of interest for the functionality, in comparison to Column E where the calculation was based only on the number of responses to each function/question.

The weighted importance value (Column F) is then multiplied by the focus priority ranking (Column G) and by the percentage of total respondents (Column H) to determine the Total Merit (column I).

This step by step evaluation generated Total Merit values ranging from 3 to 85 for the 76 survey questions. Table 5 is sorted by Total Merit in descending order.

Nearly half of the questions resulted in a Total Merit greater than 50, with only seven functions receiving values in the 80s.

Based on the information provided by the stakeholders and direction provided by the steering committee, the following functionalities are recommended to be given top priority as the City-wide signal system moves from study into design.

- Provide wireless remote access to upload and download timing changes
- Support a minimum of seven timing plans
- Report controller, detector, and communication failures
- Report special event schedule and road closures.

All of the functions have a direct impact on the way services are provided (police, fire, HRT, school and VDOT) within the City roadway network. Accurate and reliable information focus on these topics identified above will allow each organization to adjust their own operations and maximize the efficiency to their particular users.

The information is summarized in **Table 4** to illustrate the importance and merit of interest the stakeholders have for each function.

Table 4: Newport News Survey Summary

		14	Respondents		NN Ops	NN Emerg. Mgmt						
					NN Publ Works	NN IT						
					NN Fire	NN Public Schools					**Priority (1=Low to 4 = High)**	
	Value				HRPDC	FHWA			PS	=Transportation information for Public Safety	2	
	10	*1 = Must have it;*			NN GIS	HRTransit			IT	= Institutional/IT	1	
	5	*2 = Would be nice to have;*			VDOT District	VDOT HRSTC			OP	= Traffic Operations functionality	4	
	1	*3 = Don't need/not a priority*			Hampton Traf Engineering	NN Transp./Engineering			ATMS	= ATMS functionality	3	
	Priority	**Importance Ranking**					**Weighted Importance**			**Rank/Priority**	**% Responded**	**Total Merit**
	G	**A**	**B**	**C**			**D**	**E**	**F**	**G**	**H**	**I**
		1	**2**	**3**	**Survey Question**	**Who needs it?**	A*10+B*5+C*1	A / (A+B+C)	D*E	G	(A+B+C)/respondents	F*G*H
							Importance	**Strength**	**Weighted Importance**			
1	OP1.2	6	1		· Support 7+ time of day plans	NNTE, NNOPS, NNOEM(2), NNPS, FHWA, NNGIS, VDOT	55	86%	48	4	50.0%	96
2	ATMS1.44	7			- Controller Failure Report	NNTE,NNOPS, NNOEM, NNPS, FHWA, NNGIS, VDOT	60	100%	60	3	50.0%	90
3	ATMS1.45	7			- Detector Failure Report	NNTE,NNOPS, NNOEM, NNPS, FHWA, NNGIS, VDOT	60	100%	60	3	50.0%	90
4	ATMS1.46	7			- Communication Failure Report (Type and Frequency)	NNTE,NNOPS, NNOEM, NNPS, FHWA, NNGIS, VDOT	60	100%	60	3	50.0%	90
5	PS1.1	8	1		· Special event schedules?	NNTE, FD, NNPS, HRPDC, NNOPS, NNGIS, VDOT, HRT(2), NNEM	75	89%	67	2	64.3%	87
6	PS1.2	8	1		· Road closure notification?	NNTE, FD, NNPS, HRPDC, NNOPS(2), NNGIS, VDOT, HRT, NNEM	75	89%	67	2	64.3%	87
7	OP1.1	5	2		Wireless remote access connectivity with central to upload/download timing changes	NNOPS, NNOEM, NNPS, NNTE(2), FHWA(2), NNGIS, VDOT	55	71%	40	4	50.0%	80
8	ATMS1.27	6	2		· Paging system for alerts and/or alarm levels?	NNTE, NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT, HRT(2)	60	75%	45	3	57.1%	78
9	ATMS1.28	6	2		· Transit/emergency vehicle priority system functionality?	NNTE, NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT, HRT(2)	60	75%	45	3	57.1%	78
10	ATMS1.03	6	1		· Vehicle count data acquisition?	NNTE, NNOPS(2), NNPS, HRPDC, FHWA, NNGIS, VDOT	55	86%	48	3	50.0%	72
11	ATMS1.04	6	1		- For use with congestion management plan?	NNOPS(2), NNPS, HRPDC, FHWA, NNGIS, VDOT	55	86%	48	3	50.0%	72
12	ATMS1.26	6	1		· Modification or regrouping of intersections into different subgroups for timing control boundaries by time of day, scheduler initiation, or user intervention?	NNTE, NNOPS, NNOEM, NNPS, FHWA, NNGIS, VDOT(2)	55	86%	48	3	50.0%	72
13	ATMS1.30	6	1		· Traffic responsive/adaptive operations?	NNTE, NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT	55	86%	48	3	50.0%	72
14	ATMS1.31	6	1		· Pedestrian crossing equipment – countdown, audible, etc.?	NNTE, NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT	55	86%	48	3	50.0%	72
15	ATMS1.43	6	1		- Intersections On-Line Status	NNTE, NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT	55	86%	48	3	50.0%	72
16	PS1.3	7	2		· Construction activities/schedules?	NNTE, FD, NNPS, HRPDC, NNOPS(2), NNGIS, VDOT, HRT(2), NNEM	70	78%	55	2	64.3%	71
17	OP1.3	5	1	1	· Maintain at least two operation centers	NNTE, NNOPS, NNOEM(2), NNPS, FHWA(3), NNGIS, VDOT	46	71%	33	4	50.0%	66
18	OP1.4	5	1		· Emergency pre-emption	NNTE, NNOPS, NNPS, FHWA(2), NNGIS, VDOT	45	83%	38	4	42.9%	66
19	ATMS1.14	5	2		· Expanded traffic signal system coverage?	NNOPS, NNOEM, NNPS, NNTE(2), FHWA(2), NNGIS, VDOT	55	71%	40	3	50.0%	60
20	ATMS1.25	5	2		· Ability to visually verify reported equipment malfunctions?	NNOPS, NNTE(2), NNOEM, NNPS, FHWA(2), NNGIS, VDOT	55	71%	40	3	50.0%	60
21	ATMS1.29	5	3		· Central system open interfaces for exchanging information with other agencies? (i.e. VDOT, 511, Hampton, etc.)	NNTE, NNOPS(2), NNOEM, NNPS(2), FHWA, NNGIS, VDOT, HRT(2)	55	63%	35	3	57.1%	60
22	ATMS1.39	5	2		- System Delay	NNOPS, NNOEM, NNPS, HRPDC, NNTE(2), FHWA(2), NNGIS,	55	71%	40	3	50.0%	60
23	PS1.5	6	3		· Congestion alerts?	NNTE, NNPS, FD(2), HRPDC, NNOPS(2), NNGIS, VDOT, NNEM, HRT(2)	65	67%	44	2	64.3%	57
24	ATMS1.11	5		1	· GIS-based map?	NNOPS, NNOEM, NNPW, NNPS, FHWA(3), VDOT	51	83%	43	3	42.9%	56
25	ATMS1.34	5	1	1	· Reduced equipment maintenance costs?	NNOPS, NNTE(2), NNOEM, NNPS, FHWA(3), NNGIS, VDOT	51	71%	37	3	50.0%	56

Table 4 Continued: Newport News Survey Summary

	Priority	Importance Ranking			Survey Question	Who needs it?	Weighted Importance			Rank/Priority	% Responded	Total Merit
	G	A	B	C			D	E	F	G	H	I
		1	2	3			A*10+B*5+C*1	A / (A+B+C)	D*E	G	(A+B+C)/respondents	F*G*H
							Importance	Strength	Weighted Importance			
26	ATMS1.29	4	3		· Central system open interfaces for exchanging information with other agencies? (i.e. VDOT, 511, Hampton, etc.)	NNOPS(2), NNOEM, NNPS(2), FHWA, NNGIS, VDOT, HRT(2)	55	57%	32	3	53.8%	52
27	ATMS1.6	4	3	1	· Replace in-pavement loop detectors with video or other non-intrusive detectors?	NNOPS, NNOEM, NNPW(2), NNPS, HRPDC(2), FHWA(2), NNGIS, VDOT(3)	56	50%	28	3	61.5%	52
28	PS1.5	5	3		· Congestion alerts?	NNPS, FD(2), HRPDC, NNOPS(2), NNGIS, VDOT, NNEM, HRT(2)	65	63%	41	2	61.5%	51
29	ATMS1.35	4	2		· More efficient use of available operations and maintenance staff?	NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT(2)	50	67%	34	3	46.2%	48
30	ATMS1.37	4	2		- Phase Utilization	NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT(2)	50	67%	34	3	46.2%	48
31	ATMS1.38	4	2		- # of Stops	NNOPS, NNOEM NNPS, FHWA(2), NNGIS, VDOT(2)	50	67%	34	3	46.2%	48
32	ATMS1.42	4	2		- Current Pattern/Performance Level Report	NNOPS, NNOEM(2), NNPS, FHWA(2), NNGIS, VDOT	50	67%	34	3	46.2%	48
33	ATMS1.47	4	2		- Software emulation of graphic display of field controller front panel diagnostics?	NNOPS, NNOEM(2), NNPS, FHWA(2), NNGIS, VDOT	50	67%	34	3	46.2%	48
34	ATMS1.7	4	2		· Traffic surveillance capability?	NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT(2)	50	67%	34	3	46.2%	48
35	ATMS1.8	4	2		· Integration with local police Computer-Aided-Dispatch (CAD) data?	NNOPS, NNOEM, NNPS, FHWA(2), NNGIS, VDOT(2)	50	67%	34	3	46.2%	48
36	PS1.6	5	2	1	· Emergency maintenance notification?	FD, NNPS, HRPDC, NNOPS(2), NNGIS, VDOT, HRT(2), NNEM(3)	61	63%	39	2	61.5%	48
37	ATMS1.10	4	1	1	· Better graphical user interface?	NNOPS, NNOEM, NNPS, FHWA(3), NNGIS, VDOT(2)	46	67%	31	3	46.2%	43
38	ATMS1.51	4	1		o Communication infrastructure/equipment	NNOPS, NNPS, FHWA(2), NNGIS, VDOT	45	80%	36	3	38.5%	42
39	ATMS1.52	4	1		o Local controller	NNOPS, NNPS, FHWA(2), NNGIS, VDOT	45	80%	36	3	38.5%	42
40	ATMS1.53	4	1		o Master controller	NNOPS, NNPS, FHWA(2), NNGIS, VDOT	45	80%	36	3	38.5%	42
41	ATMS1.54	4	1		o Communication systems/technologies	NNOPS, NNPS, FHWA(2), NNGIS, VDOT	45	80%	36	3	38.5%	42
42	ATMS1.58	4	1		o Conflict Monitor Alarm	NNOPS, NNPS, FHWA(2), NNGIS, VDOT	45	80%	36	3	38.5%	42
43	ATMS1.33	4		2	· Reduced dependency on any leased line operational costs?	NNOPS(3), NNOEM, NNPS, FHWA(3), NNGIS, VDOT	42	67%	28	3	46.2%	39
44	ATMS1.5	4			- For use with highway performance monitoring system?	NNPS, HRPDC, FHWA, NNGIS, VDOT	40	100%	40	3	30.8%	37
45	IT1.3	6	4		· Emergency pre-emption operational guidelines and equipment maintenance/funding requirements?	NNOPS(2), NNOEM, STC(2), NNIT, NNPS, HRPDC(2), FHWA(2), NNGIS, VDOT, HRT	80	60%	48	1	76.9%	37
46	IT1.5	6	4		· Various levels of security clearance?	NNOPS, NNOEM, STC, NNIT(2), NNPS, HRPDC(2), FHWA(2), NNGIS, VDOT, HRT(2)	80	60%	48	1	76.9%	37
47	PS1.4	4	3	1	· Incidents in other neighboring localities?	FD(2), NNPS(2), HRPDC, NNOPS(3), NNGIS, VDOT, HRT(2), NNEM	56	50%	28	2	61.5%	35
48	ATMS1.9	3	3	1	· Integrated flood/weather detection?	NNOPS(3), NNOEM, NNPW(2), NNPS, FHWA(2), NNGIS, VDOT(2)	46	43%	20	3	53.8%	33
49	ATMS1.17	3	3		· Integrated timing coordination with adjacent agencies?	NNOPS(2), NNOEM, NNPS(2), FHWA(2), NNGIS, VDOT	45	50%	23	3	46.2%	32

Table 4 Continued: Newport News Survey Summary

	Priority	Importance Ranking			Survey Question	Who needs it?	Weighted Importance			Rank/Priority	% Responded	Total Merit
	G	A	B	C			D	E	F	G	H	I
		1	2	3			A*10+B*5+C*1	A / (A+B+C)	D*E	G	(A+B+C)/respondents	F*G*H
							Importance	Strength	Weighted Importance			
50	ATMS1.21	3	3		· Importance of single controller cabinet family throughout the City?	NNOPS, NNOEM(2), NNPS, FHWA(2), NNGIS, VDOT(2)	45	50%	23	3	46.2%	32
51	ATMS1.23	3	3		· Enhanced login security credential system (i.e. security FOB)	NNOPS(2), NNOEM, NNPS, FHWA(2), NNGIS, VDOT(2)	45	50%	23	3	46.2%	32
52	ATMS1.24	3	3		· Support GPS unit inputs for local time-based coordination?	NNOPS(2), NNOEM, NNPS, FHWA(2), NNGIS, VDOT(2)	45	50%	23	3	46.2%	32
53	ATMS1.1	3	2	1	· Increase number of time-of-day plans?	NNOPS(2), NNOEM, NNPS, FHWA(2), NNGIS, VDOT(3)	41	50%	21	3	46.2%	30
54	ATMS1.18	3	2	1	· TOC center-to-center, or field controller-to-field controller coordination between agencies?	NNOPS(3), NNOEM, NNPS(2), FHWA(2), NNGIS, VDOT	41	50%	21	3	46.2%	30
55	ATMS1.15	3	2		· Upload/download to/from controllers with Synchro?	NNOPS, NNPS, FHWA(2), NNGIS, VDOT(2)	40	60%	24	3	38.5%	28
56	ATMS1.16	3	2		· Upload/download to/from independent count boards?	NNOPS, NNPS, FHWA(2), NNGIS, VDOT(2)	40	60%	24	3	38.5%	28
57	ATMS1.22	3	2		· Capability to monitor signal heads? (i.e. lamp or LEDs are burnt out)	NNOPS(2), NNPS, FHWA(2), NNGIS, VDOT	40	60%	24	3	38.5%	28
58	ATMS1.49	3	2		- Local controller	NNOPS, NNPS(2), FHWA(2), NNGIS, VDOT	40	60%	24	3	38.5%	28
59	ATMS1.50	3	2		- Master controller	NNOPS, NNPS(2), FHWA(2), NNGIS, VDOT	40	60%	24	3	38.5%	28
60	ATMS1.57	3	2		-Faulty Detectors	NNOPS, NNPS, FHWA(2), NNGIS, VDOT(2)	40	60%	24	3	38.5%	28
61	ATMS1.32	3	1	2	· Parking Management system?	NNOPS(3), NNOEM(2), NNPS, FHWA(3), NNGIS, VDOT	37	50%	19	3	46.2%	27
62	IT1.1	5	3	1	· Shared funding agreements between agencies?	NNOEM, STC(2), NNIT(2), NNPS, NNPDC, FHWA(2), NNNGIS, HRT, NNOPS(3)	66	56%	37	1	69.2%	26
63	ATMS1.36	3	1		· Measures of effectiveness	NNOEM, NNPS, NNGIS, VDOT(2)	35	75%	27	3	30.8%	25
64	ATMS1.55	3	1		- Controller Hang-Up Test	NNOPS, NNPS, FHWA(2), NNGIS	35	75%	27	3	30.8%	25
65	ATMS1.56	3	1		- Out-of-Step Test	NNOPS, NNPS, FHWA(2), NNGIS	35	75%	27	3	30.8%	25
66	ATMS1.59	3	1		- Database Verification	NNOPS, NNPS, FHWA(2), NNGIS	35	75%	27	3	30.8%	25
67	ATMS1.40	3			- Others?	NNPS(Time delays: pedestrian and bicycle use), HRPDC(volumes/peaks), NNGIS	30	100%	30	3	23.1%	21
68	ATMS1.41	3			· Reporting	NNOEM, NNPS, NNGIS	30	100%	30	3	23.1%	21
69	ATMS1.19	2	4	1	· Importance of having a single vendor controller platform throughout the City vs. matching other agencies' equipment?	NNOPS(3), NNOEM, NNPS(2), FHWA(2), NNGIS, VDOT(2), HRT(2)	41	29%	12	3	53.8%	20
70	ATMS1.20	2	3		· Replacement of existing controller cabinets?	NNOPS, NNPS(2), FHWA(2), NNGIS, VDOT(2)	35	40%	14	3	38.5%	17
71	ATMS1.2	2	2	2	· Support school flashers?	NNOPS(2), NNOEM(2), NNPS, FHWA(3), NNGIS, VDOT(3)	32	33%	11	3	46.2%	16
72	ATMS1.12	2			- ESRI-based?	NNPW, NNGIS	20	100%	20	3	15.4%	10
73	IT1.4	2	4	2	· Shared maintenance agreements?	NNOPS(3), NNOEM, STC(3), NNPS, HRPDC, FHWA(2), NNGIS, HRT(2)	42	25%	11	1	61.5%	7
75	ATMS1.48	1			- Other Reports --- Please List	NNGIS	10	100%	10	3	7.7%	3
76	ATMS1.60	1			· Others?	NNOPS(request comm cable connection between Jefferson and Warwick for alternate access if cable is broken)	10	100%	10	3	7.7%	3

4.0 Proposed System Concept of Operations

Using the mission statement and the regional Intelligent Transportation Systems (ITS) vision as guidelines, a system concept was developed to satisfy the identified needs for ATMS deployments in the City of Newport News. The City currently has the ability to manage traffic operations from two separate locations: City Hall, and the Traffic Operations facility off of Oyster Point Road and Operations Drive. Redundant operations capabilities are envisioned to remain in effect with the proposed system upgrades.

With the addition of approximately 5 to 10 new traffic signals per year, by the year 2010, it is anticipated that the current number of signals that the city will be responsible for maintaining will increase from 254 to approximately 280 intersections. This includes locations where signals do not currently exist but are expected to be constructed and in operation by the time the system is completed.

A new traffic signal central system with expanded capabilities and peripheral ITS components will serve to meet the needs of the City as well as the region. Expanded capabilities will focus on the replacement of outdated field controllers along with the addition of equipment to support additional planned ITS elements. With the Emergency Operation Center's (EOC) close proximity to the Traffic Operations facility, integration with public safety can be more easily accomplished. This will be especially useful since the survey results indicate a significant desire for sharing information with public safety staff regarding construction activities/schedules, road closures, special event schedules, and visual verification of incidents. The system infrastructure and operations will be expected to support regional incident management functions.

Overall, the primary scope of responsibilities for the signal and system management staff at the city will not change dramatically. However, between "coming up to speed" on new equipment, being responsible for an expanded geographic coverage, and being involved in an increasingly active coordinated incident response program, the training and operations for the new system will require some changes and learning for the staff.

Deployment of additional ITS devices will support the City's ITS goals. For example, CCTV cameras can provide improved congestion information and incident verification allowing traffic management and public safety staff to make more informed traffic management and public safety responses. Strategically deployed dynamic message signs (DMS) can relay information to the public about the state of the transportation network. Flood detection and road closure systems allow for automated road closures due to high water on roadways that are prone to periodic flooding. ITS elements will be discussed in further details within the subsequent ITS Master Plan reports.

4.1 Proposed Operations

Stakeholders in the City of Newport News identified operational goals for their traffic management system. Some of these operational requirements will drive

specific staffing needs for the system. The specific set of functions desired by the City of Newport News includes:

- Traffic signals and traffic control;
- Enhanced traffic and system monitoring;
- Enhanced reporting and alarm alerting;
- Incident management;
- Special event management;
- Coordination and collaboration with other agencies; and
- Information gathering and dissemination.

A key operational characteristic that affects each of these functions is the hours of operation of the system. While many large urban freeway operations centers are staffed 24 hours per day seven days per week, it is not envisioned that continuous operations are needed in Newport News at this time. However, given the current employment centers within the City, the peak hours are naturally extending. Early peak period traffic volumes are generated by Northrop Grumman shipbuilding at the southern end of the City and Fort Eustis Army Facility at the northern City limits. Furthermore, more dense office developments are occurring in the City Center and Denbigh areas of the City, which causes expanded peak periods for the normal 8-5 commuter. An evaluation of key major intersection including Jefferson Avenue at Fort Eustis Boulevard, Oyster Point Road, J. Clyde Morris Boulevard, Mercury Boulevard and Warwick Boulevard at Denbigh Boulevard, Bland Boulevard and Mercury Boulevard identified the A.M. peak hour from 7:00 to 8:00 A.M and the PM peak hour from 4:30 to 5:30 P.M. If these peak hour represent the highest demand period at 100% the adjacent half hour periods form a bell curve around both peak periods. Currently the hours of operation cover all periods with a 65% range of the peak period. Given these trends, consideration is recommended to be given to expanding hours for traffic operations in the form of shifts. One option could be that certain employees work 7:00 a.m. to 4:00 p.m. and others work 9:00 a.m. to 6:00 p.m., which expands the coverage of operations by two hours without adding to the overall staff. As traffic demands lengthen even more in the future demands in excess of 80% if the peak period occur beyond standard operating hours, shifts should be adjusted by ½ to one hour increments to allow greater coverage.

If the City of Newport News' STC becomes a more integral part of the emergency operations center/911 dispatch that operates 24 hours per day, it may be reasonable at that time to have a traffic representative present at all times or for extended hours in the morning and evening. This person could respond to incidents by modifying traffic control schemes and disseminating information to the public and media during off-hours based upon pre-arranged standard operating procedures. At a minimum, the Transportation Division is envisioned to be a clearinghouse for local incident data and construction/ maintenance/special event schedules for other City departments. The culmination of this flow of information is documented in the System Architecture in Section 5.0.

Supplementing this information with regional incident data from VDOT's Hampton Roads STC, the Transportation Division is envisioned to supply this information to the City EOC and Public Safety dispatch center, Newport News Public Schools Pupil Transporation, and the Public Works departments. Direct access to HRT and Newport News Public School is envisioned to provide access to AVL information provided from the respective buses. HRT, in accordance with the Regional ITS Architecture, will receive incident data from the VDOT HRSTC. Therefore, a separate dedicated link is not envisioned to supply this information to HRT, but instead to make it available to all by submitting it to the VDOT HRSTC. Incident data will be shared internally with Public Schools and Public Safety, and may be posted via the City GIS mapping division.

Through a series of signal projects that will upgrade the controller units, restructure communication links, and establish flexible boundaries of existing and new systems, the City of Newport News will improve signal coordination and traffic progression.

Coordination projects with VDOT's Hampton Roads Smart Traffic Center in conjunction with the Monitor-Merrimac Memorial Bridge Tunnel operations will enable the City of Newport News to better control and manage traffic taking alternate/diversion routes through the city.

Dynamic message signs can be deployed to alert and advise motorists whether to stay on the interstate or exit onto arterial diversion routes and other key decision points throughout the city. CCTV cameras installed in the area will allow City STC staff to visually verify congestion conditions and provide improved traveler information, particularly associated with known high accident locations and interstate diversion plan (IDP) routes.

CCTV and DMS positioned around the city will facilitate incident management as well as special event management. With improved incident detection and monitoring capabilities more accurate information can be provided to travelers. Improved signal system communications will provide the opportunity to adjust signal timing plans remotely for a severe incident and especially for special event management because advance notice can ensure a structured implementation of alternate timing plans. Additional communication infrastructure will also allow current system boundaries to be extended and extend diversion route to key decision points rather than be limited based on the current system limitations.

The existing City Hall STC is already capable of receiving video feeds from VDOT's Hampton Roads STC, and it is anticipated that the planned CCTV cameras within the City of Newport News will be shared with the VDOT STC and emergency services so that dispatchers can make more informed decisions about the most appropriate equipment to route to the scene of an incident, where video is available.

4.2 Proposed Staffing

Based on conversations with the steering committee, it is not anticipated that the city will hire additional staff to operate and maintain the system immediately. Therefore, it will be important that the new system be capable of enhancing user productivity and reducing maintenance issues. Although no new positions will be allocated initially, following recommendations are offered related to future staffing and staff responsibilities:

- Plan to hire one or more signal technicians over the next 5 years. Typically, a ratio of 30:1 for the number of signals maintained by one traffic technician is considered to be good, as stated in the *ITE Traffic Installation and Maintenance Manual* (1989).[1] Currently, the city is operating in a range of about a 35:1 ratio. Given the projected rate of increase in number of intersections added to the city inventory, one additional technician will allow the city to maintain its current ratio. If the position is not filled, this ratio will rise to about 40:1. If the staff was expanded by two technicians, the future operating ratio would be closer to 31:1 within five years.
- Plan to hire one engineer and two engineering technicians over the next 5 years. CMAQ on-call consultants are currently supplying an annual equivalent of 1 1/2 engineers to update the signal timings within a three year cycle. Furthermore, the expanded signal system coverage and distributed system will allow for greater flexibility in timing plan development along with additional efforts to coordinate with neighboring Cities and Counties. In addition, there will be an added demand for implementing ITS device locations and functioning as the city clearing house for incident data for other city agencies will place an additional load on existing staff.
- A back-up staffing option is recommended to be created to fill in for times when the signal system analyst is not available. With remote access options in this day and age, times are rare when a staff member is completely unavailable; however, these times are not entirely impossible. When a staff member is unavailable and an incident or emergency situation arises, it would be beneficial for someone else to be capable of implementing system changes to response to public needs. It is recommended that training and role assignments be put in place so a city or VDOT staff person may have adequate knowledge of the system functionality to perform tasks that would be useful in an incident situation, such as implementing pre-planned timing plans.

4.3 Proposed Training

The most significant short term training needs for implementation of the new system will be as follows:

- Staff training to enable the signal crew, the operations supervisor, and the traffic engineers and technicians to operate and maintain the new controller hardware and software.

[1] Institute of Transportation Engineers, *ITE Traffic Instillation & Maintenance Ma*nual, Washington, D.C., U.S. Printing Office, 1989.

- Staff training to enable the City of Newport News operations and maintenance staff to maintain and repair future fiber-optic communications cable plant.
- Staff training to enable the traffic engineer, engineering technicians, the traffic operations supervisor and technicians, and appropriate VDOT Hampton Roads STC staff to operate the new system traffic control software.
- Staff training to enable the signal crew, and the signal system supervisor to maintain and repair the ITS field equipment proposed for use in this system (i.e. CCTV, DMS, flood sensor/warning systems, etc.).
- Staff training to enable the engineering technicians, the traffic operations supervisor, the traffic engineer, appropriate VDOT Hampton Roads STC staff to operate the new CCTV subsystem.
- Staff training to enable the signal system analyst and appropriate city information technology staff to operate and maintain the local area network (LAN) access points that will be used to support interconnection of some portions of the signal system.

Based on current discussions among the steering committee, it is anticipated that the City of Newport News Traffic Operations staff will be responsible for maintenance of the proposed communications plant with the aforementioned training.

4.4 Proposed Inter-Agency Coordination

As proposed based on input from steering members and stakeholders, the City of Newport News will be charged with maintaining all signals within their city limits. To improve signal coordination across boundaries with the City of Hampton and VDOT-administered county roads, the proposed signal system upgrades would allow agencies to share timing plan changes with one another in real-time. Additionally, based upon the regional *Interstate Diversion Plan* report prepared for the Hampton Roads Smart Traffic Center, pre-existing routes through the City of Newport News have been identified by interstate segment (i.e. between interchanges) to re-route motorists in the event of major incidents and/or interstate closures along I-64 and I-664. Upon notification from the State Police via the Hampton Roads STC, the proposed system would allow timing plans to be applied across traditional closed-loop system boundaries, and become seamless to the motorist. This allows the arterial streets to handle the abnormal congestion condition more effectively.

Similarly, Newport News Computer-Aided-Dispatch (CAD) would notify the Department of Engineering, other Departments including Public Schools and Public Works, the VDOT STC, and Hampton Roads Transit of managed incidents in progress. This will minimize the amount of time each agency spends on the phone providing or obtaining situation updates. 911 CAD dispatchers would have access to CCTV video images, particularly for diversion corridors and high accident locations to assist in verifying incidents and the severity.

4.5 Proposed Incident and Emergency Management

In support of the regional ITS architecture, as updated within the *Hampton Roads – ITS Strategic Plan 2004 (by PB Farradyne)*, the proposed system shall facilitate a higher level of coordination to respond to incidents, both local and regional in nature.[2] A key area of need identified by many of the stakeholder respondents involves visual verification of incidents, congestion, and special event conditions. From an operations standpoint, the CCTV subsystem will aid in this effort. CCTV viewing should be available to City staff within both operations facilities (City Hall STC and Traffic Operations STC), as well as VDOT STC staff, City of Hampton Traffic Engineering, and the Newport News EOC/911 dispatch center staff. In addition, as part of the regional traffic management operations, viewing or still-frame capabilities may be extended to other groups/agencies through a third-party provider such as VDOT's Statewide Video Distribution System contractor, or by way of the city's own website. Control of the CCTV will be limited to City staff within both operations facilities (City Hall STC and Traffic Operations STC).

In addition, it is recommended that remote access to the signal system from the City of Hampton STC be available in at least a view only mode, allowing incident managers from the Hampton STC to be aware of the actual timing plans in operation during an incident or special event. This will entail some level of staff training for Hampton STC staff in order to be able to perform cursory functions to view the system graphics and timing plan in effect. This will be particularly useful along key interconnecting corridors such as J. Clyde Morris, Harpersville/ Hampton Roads Center Parkway, and Mercury Boulevard.

No-notice events may call upon many of the same aspects of evacuation and incident management planning, but under much different circumstances. A no-notice event, such as a terrorist attack or sudden disaster (e.g. reservoir break or tunnel flooding), may call upon the need to allow the City of Hampton STC to have full-access to the City of Newport News signal system in the event that both the City Hall STC and the Traffic Operations STC are incapacitated, or simply disconnected from portions of the field communication network. The City of Newport News would need to provide approval to allow the City of Hampton to have full-access.

Due to limited staff and hours of operation (not 24x7x365), it is envisioned that the city would enter into an agreement with the VDOT Hampton Roads STC to allow operation of dynamic message signs throughout the city under established circumstances, provided that appropriate staff at the City are also notified of the incident during normal hours of operation, or first thing the morning after an overnight incident.

[2] PB Farradyne, *ITS Strategic Plan*, Virginia Department of Transportation - Hampton Roads Planning District Commission, April/May 2004.

4.6 Maintenance

In addition to the staff training needs discussed above, the new system will include two additional changes that will impact maintenance. One will be the likely inclusion of fiber optic communications cables in addition to, or in place of, the existing twisted pair cables. With the potential for acquiring some fiber capacity from the Citywide Information Technology access points that have been made available through arrangements with the Newport News Public Schools (NNPS), it may also be possible to outsource fiber cable maintenance to a common contractor for both NNPS and Department of Engineering's cables. Access and maintenance protocols are recommended to be developed in accordance with other agreements that have been commenced between City departments and are recommended to be referenced as part of any new municipal agreements developed for this project.

A second change involves the increased reporting capability of the vast majority of advanced traffic signal system software packages. With the added reporting capabilities, "repair" phone calls between Operations and Engineering in establishing a daily or weekly punch-list of repairs can be significantly reduced, if not avoided altogether. Routine maintenance is not anticipated to greatly change with the proposed system upgrades. Over a period of time, it is proposed to replace existing painted signal poles and cabinets with the stainless steel brushed-finished installations to match more recent intersection deployments, which will alleviate the need to keep up with any re-painting activities once completed.

4.7 Traveler Information

Currently, VDOT has an internet site for traveler information. The www.511virginia.org website provides travelers with information regarding construction and incidents on state roads. As part of the system upgrade, it is recommended that protocols and/or training be put in place so that incidents identified by City of Newport News staff can be reported to the VDOT Hampton Roads STC staff for upload into the 511 database or that Newport News staff directly post information to this site. The VDOT Hampton Roads STC (HRSTC) has been deemed the repository for the Regional Multi-Modal information System (RMMS). Currently, the Virginia Operational Information System (VOIS) platform is the data entry system for documenting road conditions and incidents on VDOT-managed roads.

This information could be further enhanced by integrating the local police, fire and rescue computer-aided-dispatch (CAD) system to export incident data for use in populating many of the fields that provide incident data to the public by way of the RMMS and the VDOT HRSTC. It is envisioned that, similar to the current manual filtering process by STC staff for data from the Virginia State Police (VSP), the local CAD data would be filtered by HRSTC staff prior to populating the VOIS database for subsequent inclusion into the 511 database. VDOT currently performs automated filtering based upon VSP "10 codes", which are used to quickly distinguish for example between freeway incidents versus robberies, domestic incidents, and other issues that typically do not affect transportation networks. A

similar integration is envisioned to reduce the amount of manual filtering necessary to supply useful information to 511 and the traveling public.

Additionally, traveler information consists of congestion information. With more robust information supplied by an upgraded signal system, the city will be able to estimate travel times along key corridors (Jefferson Avenue and Warwick Boulevard) with system detectors as well as with automatic vehicle location (AVL) information supplied by Newport News Public School buses, Hampton Roads Transit (HRT) buses, as well as local police/fire/rescue vehicles throughout the city.

5.0 System Architecture

The Transportation Division is one of eight operating units within the Department of Engineering. Transportation works closely with the divisions within the Department of Engineering as well as other City Departments and agencies. Within the Department of Engineering, the highest level of coordination with the Transportation Division occurs with Traffic Operations (daily basis), as well as frequent interaction with the Mapping Division.

Beyond intra-department coordination, the Transportation Division must coordinate with other departments such as Public Works, Information Technology, Codes Compliance Development, Planning, Schools, Police, Fire, and Emergency Management.

The frequency and type of coordination required with these external departments varies based on external factors such as emergency situations, predetermined policies and procedures, staff constraints, and the ease of coordination (i.e. manual process/phone call vs. email/data transfer, etc.).

Figure 3 illustrates the Transportation Division's proposed system architecture of operational relationships with other City and public agencies and depicts the three basic methods of coordination including:

1. The coordination process exists today and is automatically initiated.

   The most obvious automated process occurs within the public safety operations of the City among the Police, Fire and Rescue and the Emergency Operations Center. Information is easily shared among all three agencies via computer-aided dispatch (CAD). This information, compiled in a CAD format, is also shared with the Department of Engineering Mapping division and downloaded into the geographic information systems (GIS). From the GIS Mapping division, the information is then passed along to the Transportation and Traffic Operations divisions.

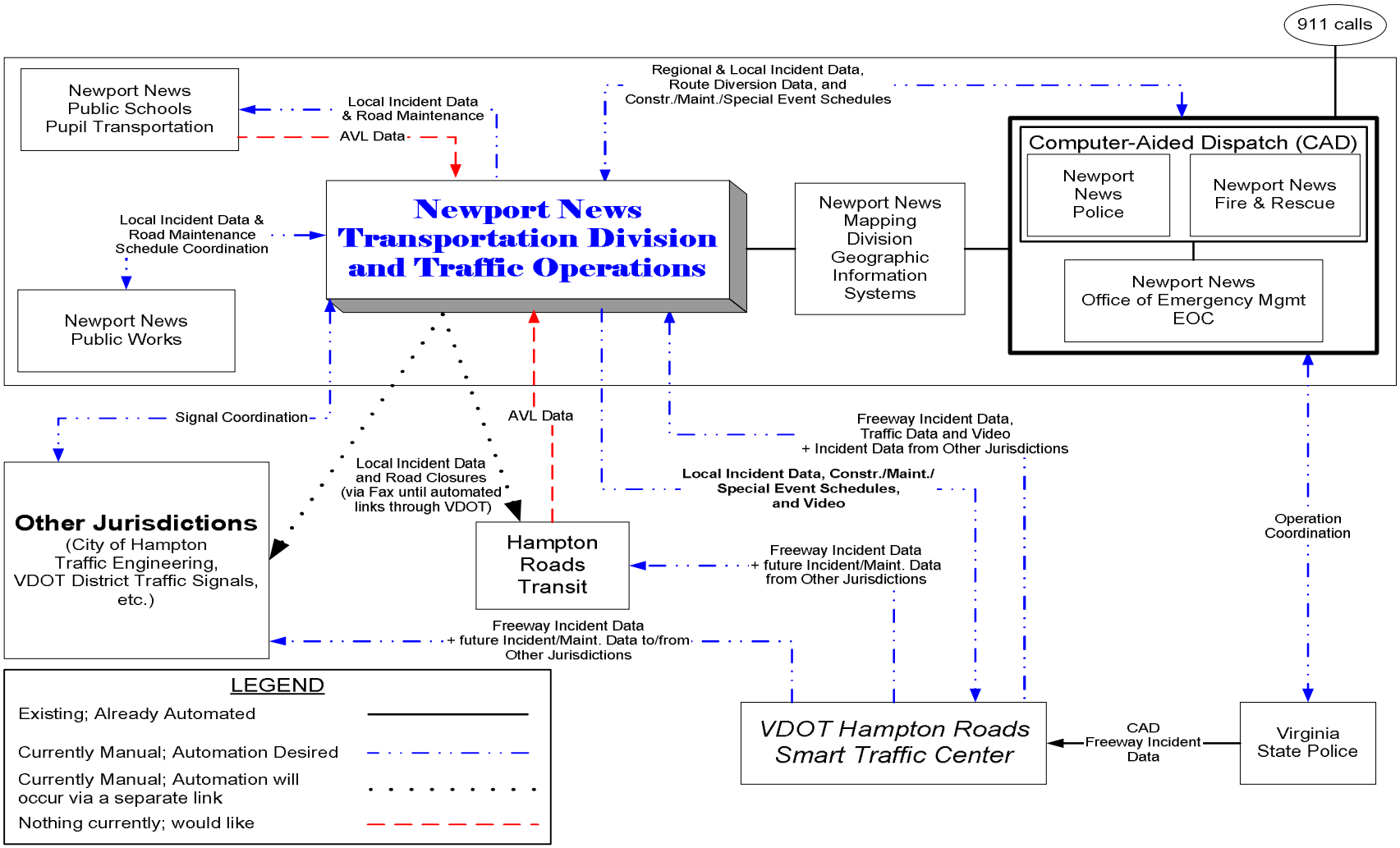
2. The coordination process is manual, but automation would be preferable.

   This type of coordination is primarily communication via telephone conversation. As illustrated in **Figure 3**, this is the primary mode of operation between most agencies. Given the demand on staff, and message interpretation, this method is not ideal especially under emergency situations when time is critical and constrained and accuracy of information is of highest importance.

3. There is no coordination procedure currently in place, but direct information access is desired.

   Hampton Roads Transit (HRT) noted that they have no existing coordination, but would like to receive direct/automated information from the City of Newport News Department of Engineering for traffic-related information.

Figure 3 - Newport News Transportation Division System Architecture



6.0 Technology Evaluation and Recommendations

6.1 Traffic Control Strategies

The basic traffic control modes are common across all signal system platforms and vendors. There are subtle differences between vendors in the way coordination is implemented, which has made standardization of these parameters difficult, but from a traffic engineering standpoint they function similarly. Larger differences arise in the implementation of more advanced features such as traffic-responsive and traffic adaptive control. This section describes the six main operational modes of traffic controllers: flash, manual, free operation, time base control, traffic-responsive and traffic adaptive.

6.1.1 Flash

An intersection on flash can operate as an all-way stop (all directions flash red) or a stop on side streets only (side streets flash red, main streets flash yellow). This makes the signal act as an all-way or two-way stop. Flash operation is often used in remote or low traffic areas during non-peak periods. New signal installations also employ flash for a period of time to allow motorists to safely adjust to the presence of a signal.

6.1.2 Manual

Under this mode, a single timing plan with fixed green times and clearance intervals is used unless manually changed by an operator. Manual mode is typically used under specific event conditions particularly adjacent to parking areas.

6.1.3 Free Operation

Also known as non-coordinated, under free mode each intersection runs independently, without a fixed cycle length, as each movement responds to demand. An intersection must be fully actuated or semi-actuated (side street and left-turn lanes) to operate in free mode. This is most appropriate for isolated intersections where arrivals are essentially random or where volume is low.

6.1.4 Time Base Control

In time base control (TBC), each intersection in a group operates on a common cycle length with offsets set relative to a common time base to allow for coordination. Group timing plans are generated using historical traffic counts to differentiate variations in traffic patterns throughout the day. This is also known as time-of-day/day-of-week control as separate timing plans are typically generated and applied for morning and afternoon peak periods, off-peak weekdays, and weekends and holidays. Within TBC, additional green time during the cycle can be reallocated to actuated non-coordinated phases. Various types of software determine which phases receive this additional green time. This may include skipping or shortening protected left turns or side street green time in a given cycle.

Before the advent of closed-loop systems, intersections would lose their synchronization over time as their internal clocks drifted. On-street master controllers served to keep a

group of intersections on a common time base. In modern systems, central software can serve this purpose by broadcasting the correct time to all controllers at regular intervals.

6.1.5 Traffic Responsive

Traffic Responsive Plan Selection (TRPS) originated in the US in the 1970's as part of the Federal Highway Administration (FHWA) Urban Traffic Control System (UTCS) software. There are variations between vendors in how this is implemented, but the basic premise is that the system selects from a library of available timing plans based on a pattern-matching algorithm from system detector volume and occupancy measurements ($v+k \cdot o$, where k is a parameter to be set). TRPS has the potential to be responsive to prevailing traffic patterns if they deviate from historical patterns while always running off-line developed, agency-approved timing plans. However, the difficulties are in setting up the algorithm to select the appropriate timing plans from the appropriate system detector measurements and in being responsive to traffic patterns while not being overly volatile. In order to achieve this, the sampling period over which detector measurements are taken has to be short enough to be responsive to traffic but long enough so as not to respond to random events that will have passed by the time a new timing plan is initiated. In addition, it is well understood that delays are often imposed by transitions between timing plans so it is important that any timing plan change be warranted in order to justify the coordination deficiency during the transition period. Currently, Newport News transitions between four and eight times between depending on the system. Given the capabilities of the new ATMS with system detectors and additional cycle lengths, it is anticipated that traffic responsive plans may transition between five and fifteen times a day depending on the demand of the system.

There are two ways that traffic responsive operation could be implemented. It could be an insurance policy against significant temporary shifts in demand. For example, if an incident on the freeway shifts traffic to signalized streets, the typical time of day plan could be inappropriate. In these cases, traffic-responsive control could potentially act more quickly than traffic engineers to select an appropriate timing plan.

Another way traffic responsive operation could be implemented is as a proactive measure to transition between time-of-day plans at the appropriate time. For example, if there is a sudden change in the weather or some other event that causes a shortened work day or school closings, traffic-responsive control could prompt a transition from an off-peak timing plan to a peak period timing plan sooner than normal. Or, if school is delayed due to weather or a power outage, the morning peak could last longer than normal. As stated previously, the difficulty with this approach is in being responsive without being overly volatile (It must be noted that TRPS implementations have features that limit the amount of switching between timing plans). Furthermore, agencies have reported that for robustness, it is best to maintain a limited number of timing plans from which a traffic responsive algorithm can choose.[3]

[3] Abbas, M., et al., Methodology for Determination of Optimal Traffic Responsive Plan Selection Control Parameters, Texas Department of Transportation, Report 0-4421-1, February 2004.

For each of these applications, however, the effectiveness of traffic-responsive operation is dependent upon the number and location of system detectors, the reliability of those detectors, and the way in which the pattern matching criteria are set. Setting parameters is typically done in an ad hoc way or through traffic simulation software.

Unfortunately, based on the references consulted for this report, there are no known methodologies for conducting cost-benefit analyses of traffic-responsive operation over time base control.[4]

6.1.6 Traffic Adaptive

Traffic adaptive is not a standardized term in the industry and can mean different things to different people. Usually, however, it has been used to refer to more specialized and advanced systems that use algorithms to make near-continual real-time signal timing adjustments in response to demand. In contrast to TBC or TRPS, adaptive control algorithms do not have timing plans, per se. Rather they continually "adapt" to traffic patterns in finer increments by redistributing green times between the phases at individual intersections, switching offsets at multiple intersections to reverse the direction of progression along an arterial, or raising or lowering the group cycle time in response to changes in demand. At any given time, the "timing plan" in effect is unique and able to change at any time. As a result, they are not prone to the effects of timing plan "ageing." In order to maintain coordination between intersections, cycle time and offset determinations are made for an entire group rather than for individual intersections.

Examples of adaptive systems of this type are SCOOT, which was developed in the UK and is sold by Siemens in the US; RHODES, developed by the University of Arizona and Gardner Transportation Systems and subsequently a Siemens product after its purchase of Gardner a few years ago; SCATS, which was developed in Australia and is sold by Transcore in the US; and the RT-TRACS family of systems which includes OPAC and RTACL, which are sold by PB Farradyne as add-ons to its MIST system.

While detector needs vary among systems, they typically require detectors 10-15 seconds of drive time upstream of the stop bar at every approach to estimate queue lengths. These detectors typically require low bandwidth second-by-second communication with the central software to continually optimize signal timings. By FHWA estimates, for US-based adaptive systems (RHODES, OPAC, RTACL), costs for the controller, communication and detection components costs between $10,000 to $40,000 per intersection, depending on the field configuration. Maintenance costs are estimated at $1,000 per year per intersection compared with $5,000 per intersection for retiming every three years.[5]

Traffic adaptive systems are far more common in Europe and Australia than in the US. This is probably due mostly to the fact that they originated there. For many years, even while SCOOT and SCATS—the most mature systems—were sold in the US, the expertise

[4] Gordon, R., Systems Engineering Processes for Developing Traffic Signal Systems, NCHRP Synthesis 307, Transportation Research Board, Washington, D.C., 2003.
[5] Adaptive Control Software, Federal Highway Administration, Publication HRTS-04-037. 2004.

to install, maintain and fine-tune these systems still resided many time zones away, adding to their initial and ongoing costs. The US entry to the adaptive market was initiated by the research arm of the US DOT in the 1990's with RT-TRACS. These systems have been deployed in pilot projects, and found to improve upon optimized fixed time plans, but have not been deployed in large numbers. SCOOT and SCATS have been thoroughly studied in simulations and in the field and have been shown to provide benefits over good time base plans in many different environments. However, adaptive control has not been widely accepted by the traffic engineering community in the US for a number of reasons. Among the more widely cited reasons are:

- Training, staffing, maintenance, and expertise needs are higher, and more than agencies can typically provide
- Adaptive systems are risky because they are non-conventional and likely to be scrutinized
- Measured benefits do not justify the added initial and operating expense
- The technology is still not widely understood and support can usually only come from the vendor
- In many instances, it is believed that adaptive control is not well suited to the specific site or application given the predictable nature of the traffic patterns of the surround land uses.

In short, it comes down to a belief that the benefits do not justify the higher costs—both capital and operations costs. System calibration is expensive and time consuming, and more detectors are needed, which need to be kept in good working order. Furthermore, there is a good deal of risk to an agency that chooses to go against conventional practices as there is likely to be additional scrutiny from public officials. Facing these barriers, most agencies that have considered adaptive control have concluded that their resources are better spent on fine tuning time-of-day plans and retiming signals more often.

6.2 Traffic signal controller and cabinet options

For an agency upgrading its traffic signal system, the selection of traffic signal controller and cabinet technology is the foundation for the rest of the system. Historically, cabinet standards were developed in conjunction with controller standards, but there are cases where controllers are backward compatible with older cabinet standards. This section will present the main features of the four main controller platform standards:

- NEMA TS-1
- 170 (Caltrans/NYSDOT)
- NEMA TS-2 Types 1 and 2
- 2070 (multiple varieties)

Table 5 lists the different cabinet standards and their compatible controllers

Table 5 - Compatible Controllers and Cabinets Pairings

Controller	Cabinet(s)
NEMA TS-1	NEMA TS-1
NEMA TS-2 Type 1	NEMA TS-2
NEMA TS-2 Type 2	NEMA TS-1
170	Caltrans 33x (e.g., 332, 334, 336)
2070	All of the above ITS cabinet

The NEMA TS-1 standard has been replaced by the TS-2 standard, but many agencies still have TS-1 cabinets and can opt to purchase a more modern controller that is backward compatible to avoid the expense of replacing the cabinets. Note that the 2070 can be mated with any cabinet type. In this section, each of these controller platforms is presented.

6.2.1 NEMA TS-1

In 1976, the NEMA developed the TS-1 standard for solid state, actuated traffic signal controllers. The controller, a self-contained unit housing both hardware and software produced by a single manufacturer, specifies the pins on three connections – the A, B and C connectors – and allows manufacturers to add an additional feature on a fourth D connector. The TS-1 standard also laid out a universally-accepted nomenclature for actuated controllers, defined the functionality of cabinet components, and set a standard for interchangeability of cabinet components between manufacturers. A TS-1 cabinet has shelf-mounted components (a power supply, detector amplifiers, and a conflict monitor) and connections to field units that terminate at a back plane with plug-in load switches. **Figure 4** identifies the base layout of a NEMA TS-1 cabinet **Figure 5** is a photograph of a TS-1 cabinet.

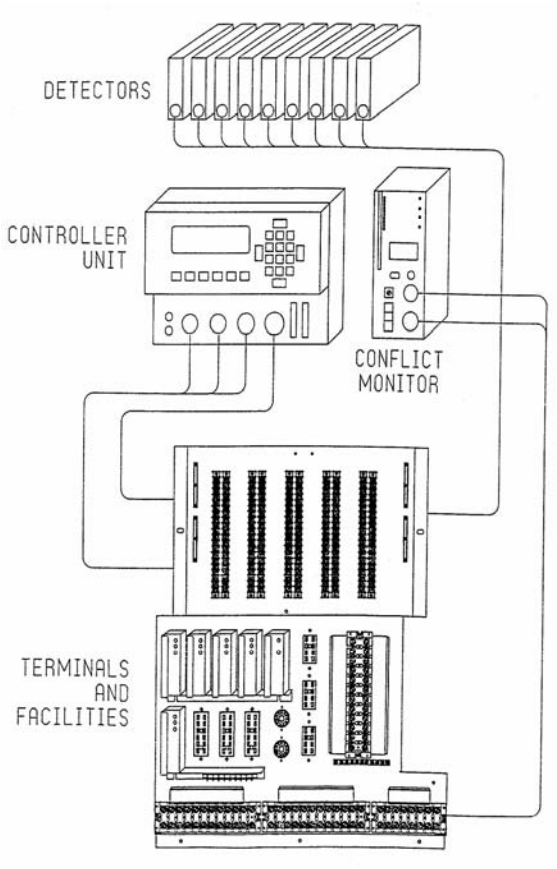


Figure 4 - NEMA TS-1 Layout

Figure 5 - Photograph of TS-1 Cabinet

6.2.2 Model 170

The model 170 family of controllers is based on a specification originally developed by FHWA and the California and New York Departments of Transportation (Caltrans and NYSDOT, respectively) around the same time as the development of the NEMA TS-1 standard. This specification provides a rigid definition of controller, cabinet, and cabinet components, including materials, form factors, and functionality. The 2002 Transportation Electrical Equipment Specification (TEES) has become the de facto standard for the 170 family of equipment, although many jurisdictions have modified the specifications to better suit their needs. Multiple vendors exist for Model 170 controllers, cabinets and components, several of which make both specification equipment and equipment with enhanced, albeit proprietary, functionality. Both Caltrans and NYSDOT maintain a Qualified Products List (QPL) for traffic signal equipment, which provides a reference of hardware that has been found to be compliant with Caltrans or NYSDOT 170 specifications, respectively.

A key distinction between the 170 family of equipment and the NEMA family is that the controller firmware is provided separately from the hardware. The firmware is supplied either on a memory chip to be installed on the CPU module or on a removable PROM module, and only needs to adhere to the hardware constraints (memory addressing, communication port addressing, pin addressing, etc.) in order to drive the equipment connected to a 170 cabinet. Firmware for 170 controllers is provided by two vendors: BI Tran Systems and Wapiti. Caltrans, the City of Los Angeles and NYSDOT have in-house developed firmware as well.

A cabinet specification was developed to house the 170 controller. The components of these cabinets are rack-mounted in a 19” equipment rack and include a 170 controller, a power supply, a conflict monitor, an input file (plug-in rack chassis for the installation of detector amplifiers and/or other field input peripherals), and an output file (a plug chassis for switch packs to drive signal heads). The 1992 TEES includes specifications for three standard cabinet sizes: 332, 334 and 336. These vary by their size and the number of inputs and outputs, which limits the number of vehicle and pedestrian phases they can accommodate. Cabinet inputs and outputs are mapped via software and not hard-wired.

Motorola has ceased production of the 8-bit chip from the 6800 family that was originally used in the CPU of the 170 controller. However, vendors have replaced the 6800 chip with the HC-11 chip and made the necessary modifications to their hardware and software. This has allowed the 170 to remain on the market. The end of the life of the 170 line has been anticipated for many years though many large agencies continue to use it. Controllers with this new chip are referred to as 170E controllers.

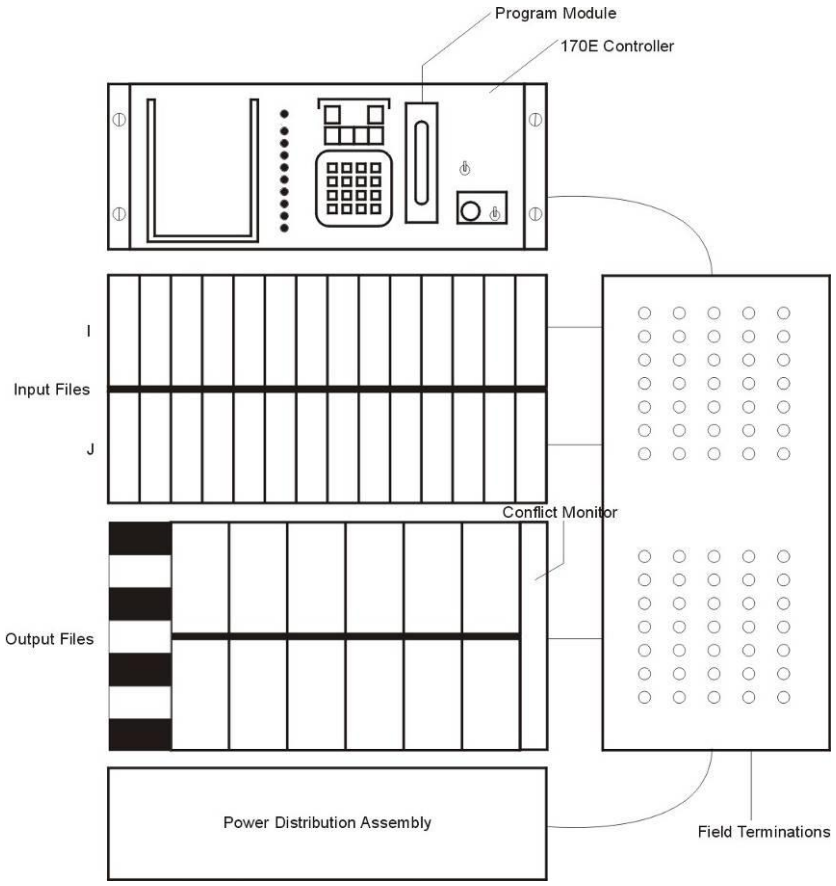


Figure 6 - Model 170 Cabinet Architecture

Figure 7 - Model 170 Cabinet Configurations (Source: 1989 Caltrans TSCES)

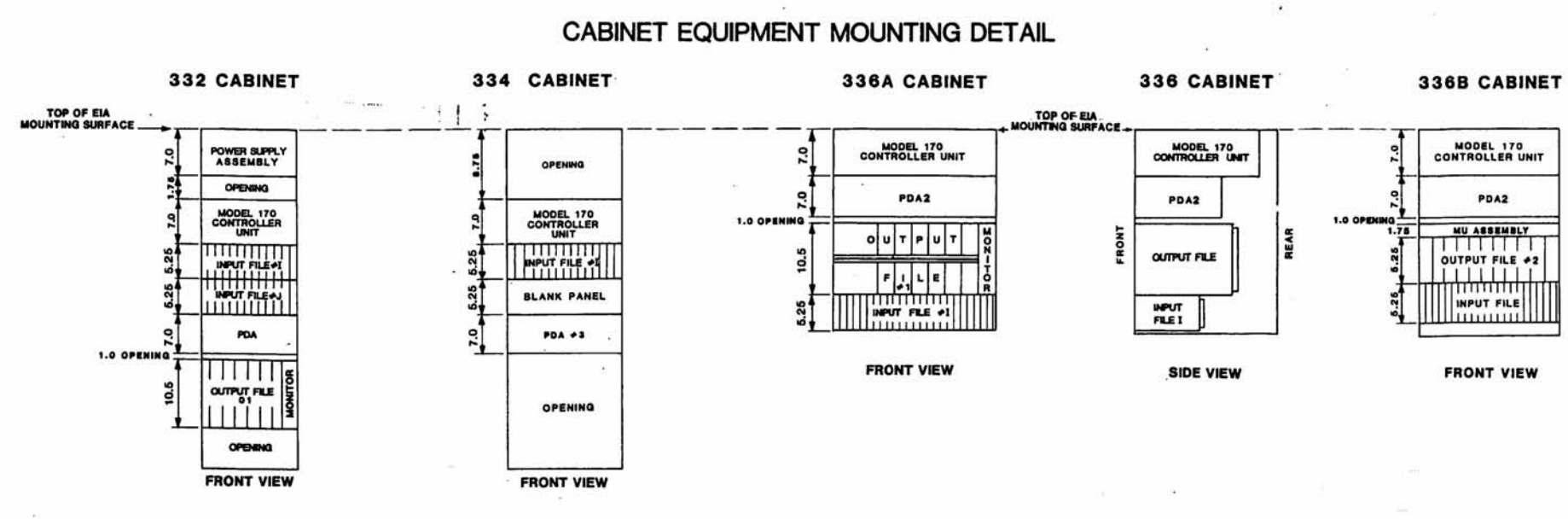


Figure 8 - Model 170 Cabinet and Controller (Source: Safetran)

6.2.3 NEMA TS-2

The NEMA TS-2 specification was published in 1992 to improve upon the TS-1. The NEMA TS-2 incorporates more modern technology to improve redundancy, diagnostics and interchangeability between vendors. This section highlights some of the more important improvements of the TS-2 over the TS-1.

- **Updated technology and improved simplicity.** The most noticeable difference is the replacement of the A, B, C and D connectors with a single serial data link connector (SDLC). This provides greater flexibility to communicate with cabinet components. The four connectors on the TS-1 were pin-based, meaning each pin served a specific limited function. Any additional functionality had to be provided through a manufacturer-specific D connector, which limited interchangeability. The SDLC connector provides two-way communication with cabinet components simplifies cabinet wiring and eliminates the manufacturer-specific D connector, improving interchangeability. Detectors in TS-2 cabinets are rack-mounted, which provides a single interface with the cabinet for the entire rack. Simplification also results in improved reliably and diagnostics.

- **Improved standardization.** The TS-2 specifies coordination, preemption, time base control and automatic flash operation more fully than TS-1. Removal of the D connector improves standardization of cabinet connections.

- **Improved redundancy.** In TS-1 cabinets, a conflict monitor served to ensure no two conflicting phases showed green at the same time. The TS-2 standard replaces this with a malfunction management unit (MMU), which is more advanced and improves redundancy. The MMU communicates continuously with the controller and either device can put an intersection into flash mode if there are any discrepancies.

- **Improved diagnostics.** The improved wiring simplicity through the use of serial connections improves cabinet diagnostics and troubleshooting. In addition, the TS-2 specifies self-test routines and verification of load switch performance for the controller and MMU. Furthermore, detector health is also continuously monitored by the controller by checking for no activity, maximum presence and erratic output. When detectors fail in a TS-2 cabinet, the controller can place a constant call (as if a vehicle were always present) and log the failure, preventing “entrapment” where an actuated phase is never served even when a vehicle is waiting.

- **Backward compatibility.** TS-2 Type 1 controllers are designed to use the SDLC connector to interface with a TS-2 cabinet. Controllers conforming to another specification called TS-2 Type 2 have the TS-1 type A, B, C and D connectors to interface with a TS-1 cabinet. Of course, this limits the enhanced functionality of the TS-2 specification, but makes for backward compatibility with existing TS-1 cabinets.

The NEMA TS-2 Type 1 cabinet is shown in **Figure 9** and the configuration is identified in **Figure 10**. **Figure 10** also illustrates the Type 2 configuration.

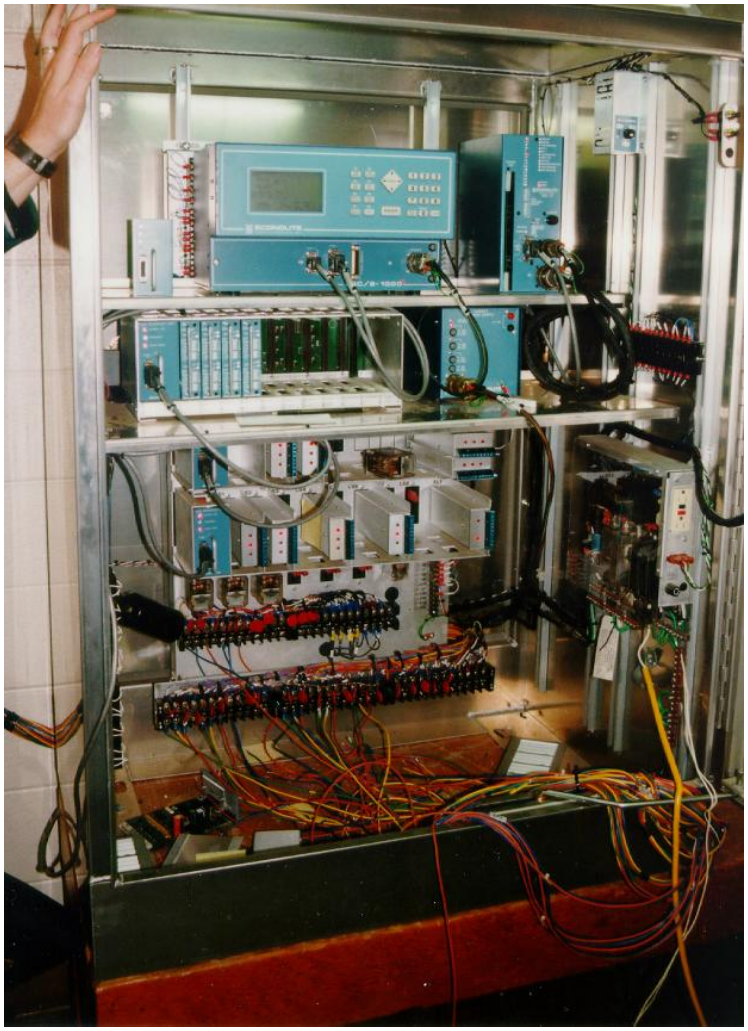


Figure 9 - NEMA TS-2 Type 1 Cabinet

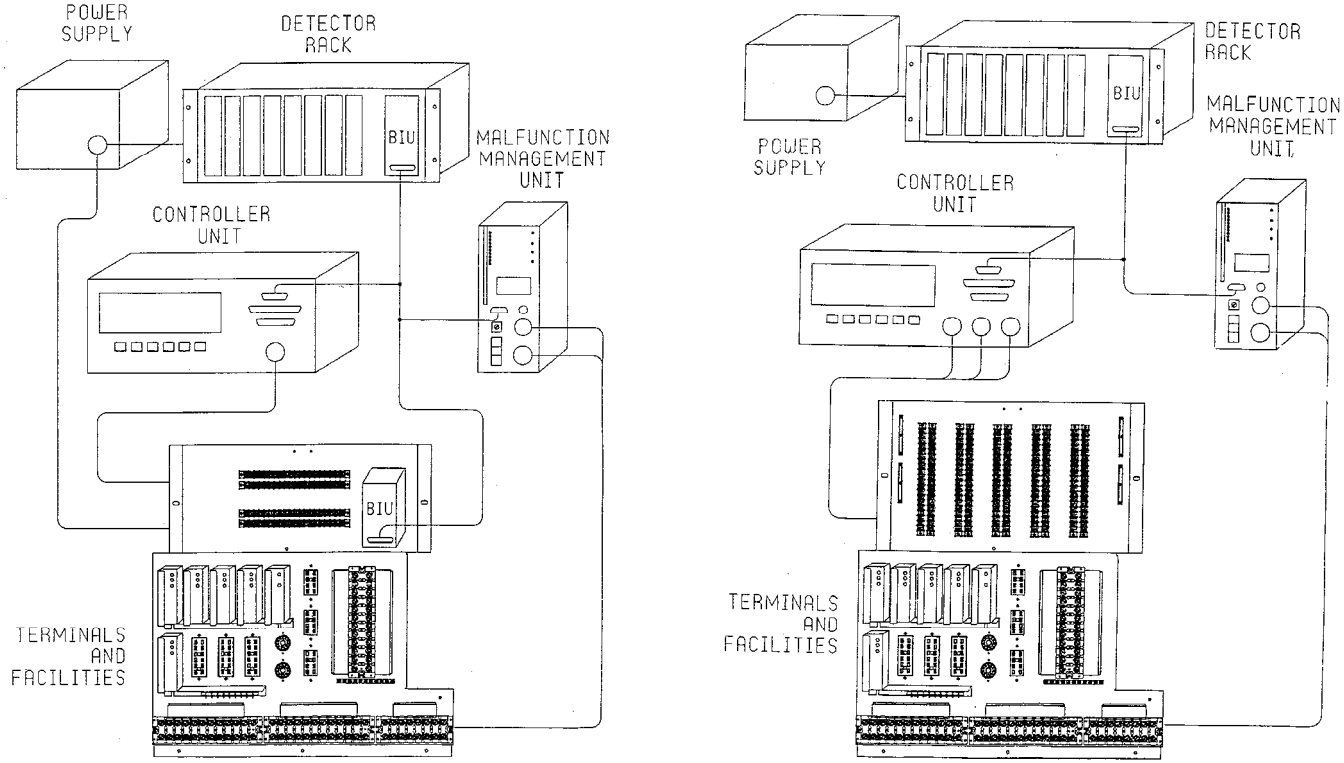


Figure 10 - NEMA TS-2 Type 1 (Left) and Type 2 (Right)

(Source: Econolite)

6.2.4 Caltrans 2070

By the late 1980s and early 1990s, Caltrans began development of a controller platform to succeed the 170. At the same time, FHWA began development of the National Transportation Communications for ITS Protocol (NTCIP), a common Intelligent Transportation Systems (ITS) communications protocol to promote interchangeability and interoperability between field devices and traffic management centers. The emergence of ITS created the need for a controller with more power and applications than existing standards afforded.

The result was the model 2070 controller, a diagram of which is shown in **Figure 11**. The 2070 utilizes a 32-bit processor, five high speed communications ports and a real-time multitasking operating system (OS-9). The 2070 is a hardware specification only so it shares the primary benefit of the 170—that the software can be purchased separately from the hardware—thus avoiding vendor lock-in for hardware. The 2070 improves upon the 170 by allowing enhanced processing power, the ability to program in higher level languages such as C, multiple high speed communications ports, and compatibility with NEMA TS-1, NEMA TS-2 and 170-style cabinets.

The 2070 controller is highly modular. Different capabilities can be provided by the appropriate selection of modules as seen in **Table 7**. The standard ensures any module can be replaced with the same module from another manufacturer. A main chassis holds a processor card, a communications module, a field I/O unit and a power supply. A NEMA interface with A, B, C and D connectors can be used to retrofit 2070s into NEMA TS-1 cabinets. An SDLC module can be included to interface with NEMA TS-2 cabinets. Tables 2 and 3 present the different modules and configurations defined by Caltrans for the 2070. As with the 170, Caltrans maintains a QPL for 2070 controllers and modules.

A VME bus chassis can be added to accommodate the installation of multiple field devices in a single controller. VME stands for Versa-Module Europe, and is based on the old Motorola VersaBus design, as standardized by the Institute of Electrical and Electronic Engineers (IEEE). Siemens uses an additional processor to implement the RHODES adaptive signal control software. Originally, that additional processor was based on an Intel Pentium, which meant that the Motorola 68360 chip and the Pentium were able to share the same memory and other resources. An additional processor might also be used for video detection, for example. However, the VME bus chassis is an expensive component, adding as much as $1000 to the cost of the controller as it also requires a more powerful (2070-1A) primary processor and power supply (2070-4A). Because its application is limited to multiprocessing, it is an option in the 2070 specification. A 2070 without the VME bus chassis is called a 2070 Lite, or 2070L. The variety of controller configurations is listed in **Table 6**.

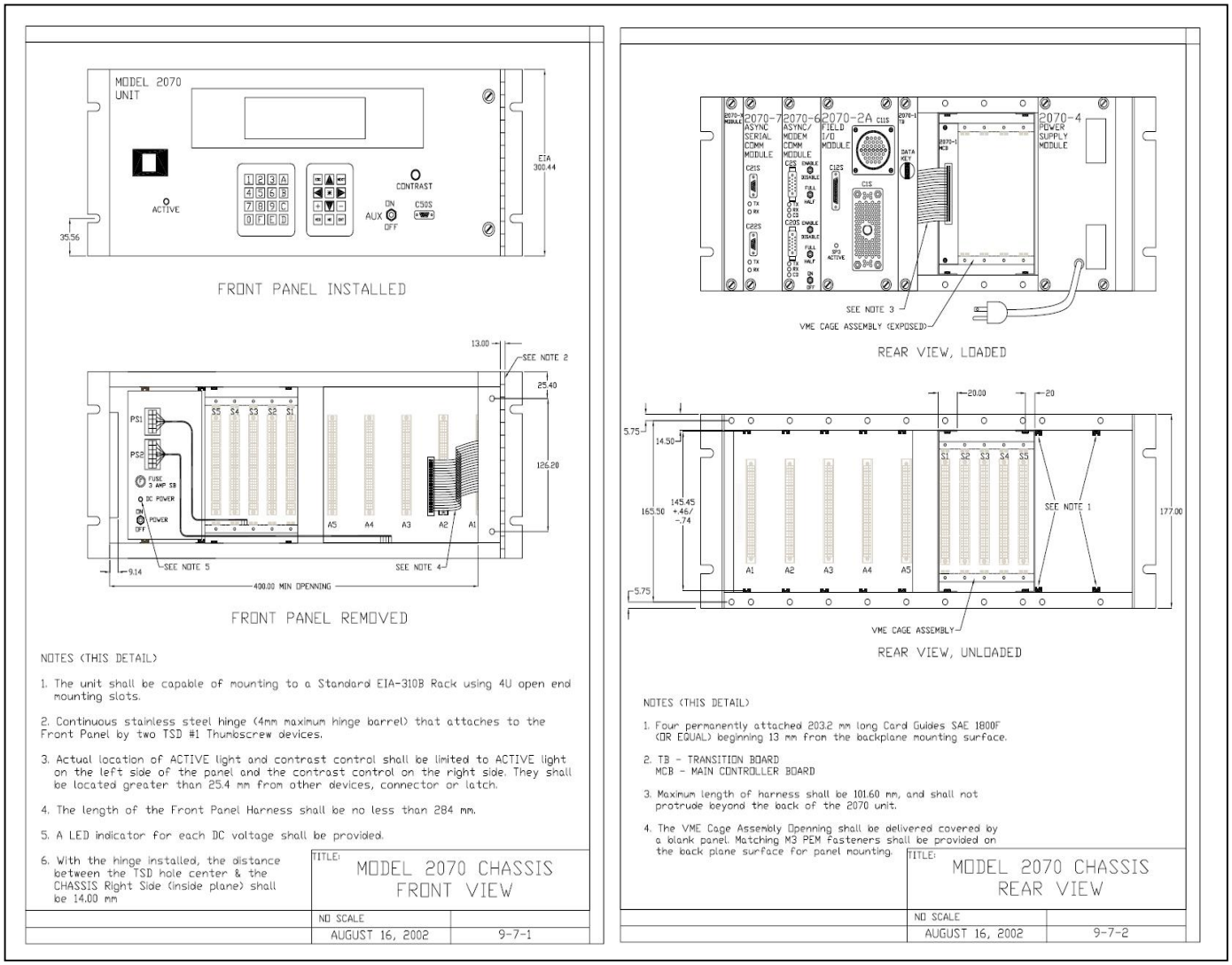


Figure 11 - 2070 Chassis Front and Rear View (Source: TEES, August 16, 2002)

Table 6 - 2070 ATC Varieties (Source: Caltrans 2002 TEES)

Unit Version	Description
2070V	With VME Chassis. Mates to 170 and ITS cabinets
2070L	LITE Unit. Mates to 170 and ITS cabinets
2070LC	LITE Unit. Mates to ITS cabinets only
2070V N1	With VME Chassis. Mates to TS-1 cabinets
2070V N2	With VME Chassis. Mates to TS-2 Type 1 cabinets
2070L N1	LITE Unit. Mates to TS-1 cabinets
2070L N2	LITE Unit. Mates to TS-2 Type 1 cabinets

Table 7 - 2070 ATC Controller Configurations (Source: Caltrans 2002 TEES)

Module	Description	2070V	2070L	2070LC	2070(V/L) N1	2070(V/L) N2
Unit Chassis		X	X	X	X	X
2070-1A	Two Board CPU	X			X[a]	X[a]
2070-1B	One Board CPU		X	X	X[a]	X[a]
2070-2A	Field I/O for 170 Cabinet	X	X[b]			
2070-2B	Field I/O for ITS Cabinet/NEMA TS-2		X[b]	X	X	
2070-N	Field I/O Module					X
2070-3A	4x40 Front Panel Display	X				
2070-3B	8x40 Front Panel Display		X		X	X
2070-3C	Blank Front Panel			X		X
2070-4A	10 Amp Power Supply	X	X[c]	X[c]		
2070-4B	3.5 Amp Power Supply		X[c]	X[c]		
2070-4N (A or B)	NEMA TS-1/TS-2 Power Supply				X	X
2070-5	VME Cage Assembly	X			X[d]	X[d]
2070-8	Field I/O Module				X	

[a] - 2070V N1 and N2 have the 2070-1A CPU Module, 2070L N1 and N2 have the 2070-1B CPU Module
[b] - 2070L has 2070-2A if mated with 170 cabinet, 2070-2B if mated with ITS or NEMA cabinet
[c] - 2070-4B if mated with ITS cabinet
[d] - 2070-5 VME Cage Assembly needed for 2070V N1 or N2

One criticism of the 2070 specification is that it is still undergoing modification. However, it appears to have stabilized over the past several years and early adopters have worked out some of the problems with different vendor interpretations of unspecified portions of the standard. Currently, the latest-referenced Caltrans specification is the August 16, 2002 TEES available on the following website: http://www.dot.ca.gov/hq/traffops/elecsys/reports/TEES.pdf.

An ITS cabinet has been developed for the 2070 and future Advanced Traffic Controller (ATC), which is planned to be its successor when the standard is completed. While the ATC and corresponding application programming interface (API) specifications are still in the early development stage, the ITS cabinet is in use in a few jurisdictions. Though the ITS cabinet standard may yet undergo

changes before it is finalized, the Caltrans TEES has a specification for it and Caltrans lists two vendors on the QPL. The ITS cabinet combines the diagnostic and serial bus features of the TS-2 cabinet with the rack-mount structure of 170-style 33x cabinets. It comes in three different sizes at present, the largest of which is as tall as a 33x cabinet, but twice as wide with two racks side-by-side.

The following figures show the 2070 in various configurations. **Figure 12** shows the empty main chassis, with optional VME chassis inside. **Figure 13** shows the 2070 with NEMA interface for mating with a TS-1 cabinet. As can be seen in the picture on the right, the chassis gets its power from the NEMA "A" connector via a duplex receptacle mounted on the NEMA module. Note also the connection between the NEMA interface and the 2070-2B Field I/O Module. **Figure 14** shows the 2070 without the NEMA interface. This variation has a VME bus as indicated by the inclusion of the more powerful 2070-1A VME processor. It also is designed to interface with a 170-style cabinet as indicated by a 2070-2A Field I/O module.

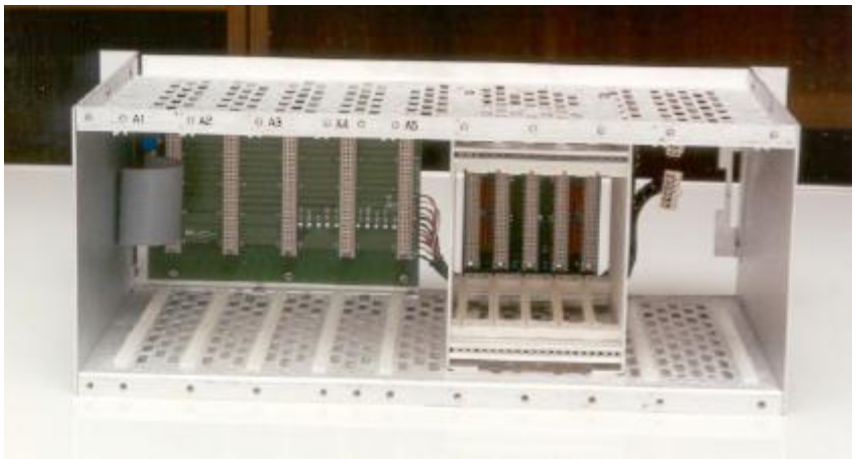


Figure 12 - Empty 2070 with VME chassis (rear view)

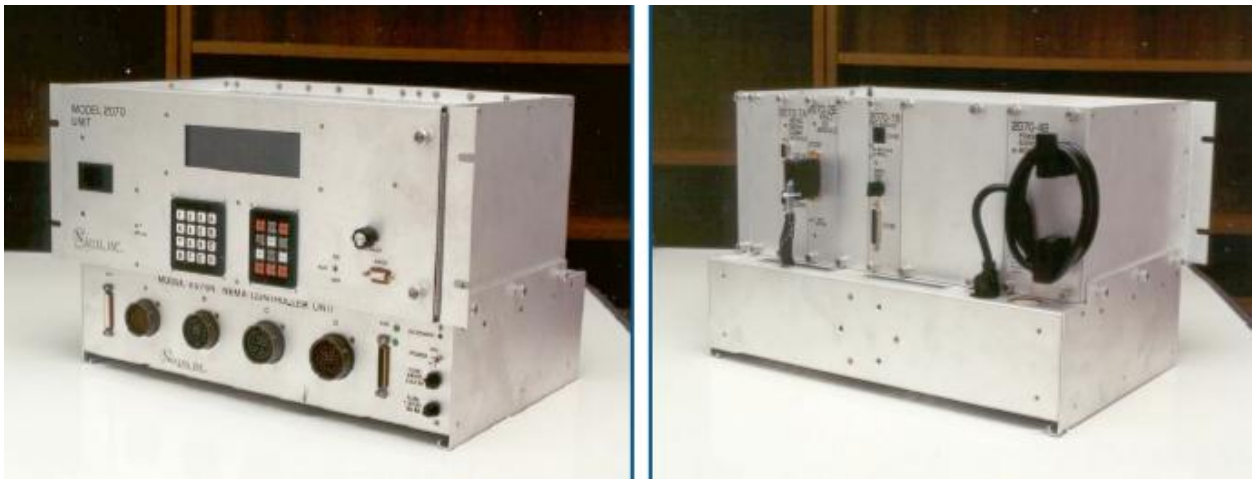


Figure 13 - 2070L N1, front (Left) and rear (Right) view

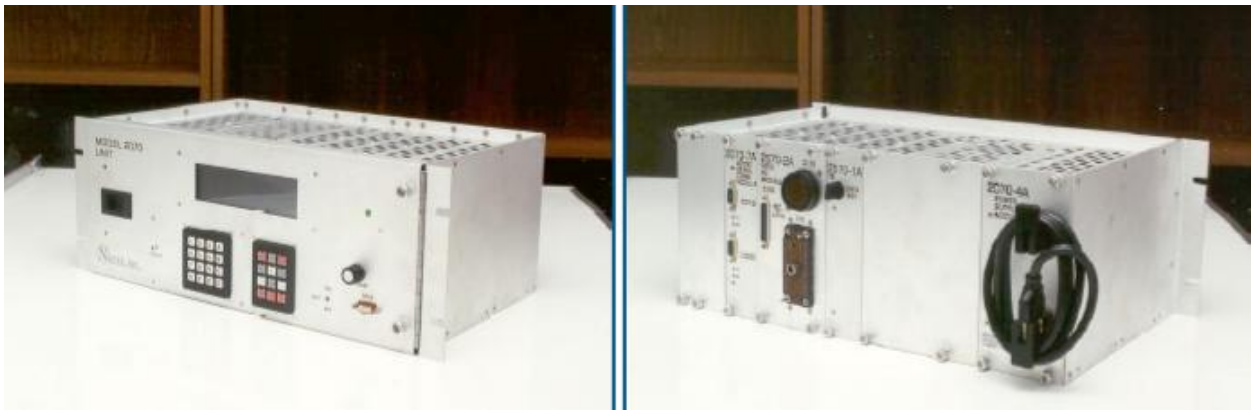


Figure 14 - 2070 with VME bus, front (Left) and rear (Right) view

6.2.5 Platform Comparison

Table 8 below compares and contrasts key features of the previously described cabinet and controller equipment. All prices are budgetary in nature and are presented primarily for comparison purposes.

Table 8 - Comparison of Controller Platform Features

NEMA TS-1	**Model 170**
Shelf-mounted components	Rack-mounted components
Controller hardware and software bundled	Controller hardware and software separate
Latitude in specifications allows manufacturer innovation (e.g., menu driven LCD displays)	Rigid hardware specification including 8 bit processor
A, B, and C connector pins defined	
Conflict monitor	
Environmental specifications of cabinet and equipment specified	Environmental specifications of cabinet and equipment specified
Cabinets delivered preconfigured to customer ordered phasing and actuation requirements	Cabinet hardware modular
Inputs and outputs hardwired	Cabinet inputs and hardware configured in software
Controller: $1,200-$1,400	Controller (including software): $1,000-$1,300
Cabinet: $4,800-$7,600	Cabinet: $4,500-$7,000
NEMA TS-2	**2070**
Shelf-mounted components, rack-mounted detectors	Rack-mounted components
Controller hardware and software bundled	Controller hardware and software separate
Latitude in specifications allows manufacturer innovation (e.g., menu driven LCD displays)	Rigid hardware specification including 32 bit processor
Serial communications via SDLC port	Communications adaptable to cabinet selected
Malfunction Management Unit	
Environmental specifications of cabinet and equipment specified	Environmental specifications of cabinet and equipment specified
Cabinet hardware modular	Cabinet hardware depends on cabinet selected
Inputs and outputs configured in software	Inputs and outputs depend on cabinet selected
Controller: $1,400-$1,800 (Type 2) $1,500-$1,800 (Type 1)	Controller (including software): $3,000-$4,000 (Lite) $4,500-$7,000 (Full)
Cabinet/Controller: $5,500-$8,200	ITS Cabinet: $10,000 (ITS)

Planning Cost Estimates

Platform	Controller	Cabinet
NEMA TS-1	$1,200-$1,400	$4,800-$7,600
Model 170	$1,000-$1,300	$4,500-$7,000
NEMA TS-2	$1,400-$1,800 (Type 2) $1,500-$1,800 (Type 1)	$5,500-$8,200
2070	$3,000-$4,000 (Lite) $4,500-$7,000 (Full)	See above $10,000 (ITS)

6.3 Other ITS Technologies

In addition to controller technologies, other Intelligent Transportation Systems (ITS) technologies are sometimes used for arterial traffic control. These technologies can be used to provide traveler information or to support real-time traffic operations. Unlike freeway ITS applications, traffic signal operators have much more ability to influence traffic patterns to respond to incidents and non-recurrent congestion. Some of the more commonly used ITS technologies are Closed Circuit Television (CCTV) cameras, Dynamic Message Signs (DMS) and traffic sensors used as “system detectors” in traffic control parlance.

6.3.1 Closed Circuit Television (CCTV) Cameras

Field equipment for a CCTV installation generally consists of a camera, motorized zoom lens, environmental enclosure, pan/tilt mechanism, local camera controller for field control, encoder, pole or other mounting structure, lightning and surge suppression devices, and a cabinet to house the ground-mounted equipment. Cameras on the market today include the lens, enclosure, and pan/tilt mechanism in a single unit.

CCTV components housed in the cabinet generally include the following:

- Camera Control Receiver (CCR): In cameras on the market today, CCRs are integrated into the pan-tilt-zoom unit. However, for some older cameras, CCRs are designed to be installed in the cabinet and can be rack mounted or shelf mounted. Under both circumstances the central system hardware and software must be compatible to communicate using the same protocol.
- Communication device: A device is needed to convert the video signal and pan-tilt-zoom control commands for transmission over communications lines. Clearly, this depends on the communications architecture. Typical communication devices are a modem for wire type communications, a video optical transceiver for analog communications over fiber, a wireless modem for radio control applications, or an Internet Protocol (IP) video encoder for Ethernet communications to the cabinet.
- Cabinet grounding system
- Backup power system/Uninterruptible Power Supplies
- Power service interface

- Surge and lightning protection for all conductors entering the cabinet including electric service, communications, video and control signals.
- Transformers (if required) may also reside in the cabinet in order to convert to voltages required for the CCTV equipment.

Figure 15 shows a photo of a sample cabinet with a local camera controller. The 170E controller and input cards above are for two loop detectors and are unrelated to the camera. The local camera controller is the black box. Below that is the power interface and below that is the fiber interface.

Figure 15 - A sample 170 cabinet with local camera controller.

Three prominent manufacturers of CCTV cameras for traffic monitoring are Cohu, Pelco, and Vicon. These three vendors have supplied cameras to major traffic management centers nationwide including VDOT Northern Virginia District, Minnesota Guidestar, and San Antonio Transguide, just to name a few. Due to the competitive nature of the marketplace, the main features of their latest vendor offerings are very comparable. Each of these manufacturers offers the capability to communicate via a competitor's proprietary protocol, either by setting a Dual In-line Package (DIP) switch on the camera or with an optional translator card. This discussion of features draws heavily from what is currently on the market. Any camera that meets or exceeds these specifications is acceptable:

- Digital signal processing (DSP) technology
- 22x optical zoom and 10x digital zoom, with automatic or manual focus
- Resolution of 470 Horizontal Television Lines (HTVL)
- Ability to see in low light conditions
- Positioning to 0.1° accuracy
- 360° continuous rotation
- Up to 64 user-defined preset positions, each with a 24-character title
- Eight programmable tours with 32 steps per tour
- Programmable privacy zones
- NEMA-TS2 temperature and power compliance
- Multi-manufacturer protocol control

Until a few years ago, most cameras were analog, producing good quality images at an affordable price. However, the introduction of Digital Signal Processing (DSP) has increased both the flexibility of using cameras while enhancing the quality of the color images produced. At the heart of DSP lies computer microchips, or "chip sets" which have replaced the conventional integrated circuits in the camera head. This enables DSP camera manufacturers to offer installer friendly, feature-rich products. DSP cameras generally offer more consistent picture quality than their analog counterparts, operating over a wider range of lighting conditions. They also may include features such as remote set-up and control using a serial data link, built-in character generator and on-screen menus.

For transportation applications, enclosures are typically sealed and pressurized with dry nitrogen to keep moisture and contaminants out of the housing and prevent condensation from appearing on the lens and interior of the housing faceplate. Many cameras have built-in pressure sensors that can generate alerts if the pressure falls below a certain threshold. Other optional environmental features of cameras are internal heaters to keep the window clear and free from condensation or ice, sunshields to keep sun glare, rain, and snow off the enclosure face plate, and wipers to clear the lens of moisture.

Cameras can be dome or barrel style as seen in **Figure 16**. Dome cameras enclose the pan/tilt/zoom mechanism and camera inside a sealed and pressurized dome enclosure. This provides greater protection from the elements and fewer moving

parts but limits the field of vision, i.e., they can not look up. For freeway applications, this is rarely an issue, but may be a consideration where site limitations require a low mounting height and the need to monitor a high flyover. Domes can be surface mounted or pendant mounted. Surface mounted domes can be mounted on the underside of structures while pendant mounted domes (shown below) can be mounted on a pole or vertical surface. Barrel style cameras can be mounted atop a horizontal mounting surface (or a pole) or off of a vertical mounting surface.

Figure 16 - Dome and Barrel Style Cameras

The pan/tilt mechanism on the barrel style camera, though separate from the camera itself, is typically sold with the camera as a single unit.

The selection of camera is not dependent on the communications infrastructure. Any camera, whether analog or DSP, interfaces with the communications infrastructure via an interface device in the cabinet. For an Ethernet IP-based communications infrastructure, for example, this would be an IP video encoder. While the marketplace is trending toward cameras with embedded encoders, most cameras on the market today leave the encoder as a separate device. Benefits to keeping the encoder separate from the camera are:

- It makes the camera simpler and easier to troubleshoot
- Encoding/decoding technology is changing far more quickly than camera technology.
- Although video compression technologies conform to standards (e.g., MPEG-2, MPEG-4), compatibility problems may arise between different encoder/decoder manufacturers. If this happens, it is easier to swap out an encoder than an entire camera.
- It takes a point of failure out of the camera and puts it on the ground where it is easier to service.

Compatibility with the National Transportation Communications for ITS Protocol (NTCIP) is available as an option with cameras on the market today, though it typically requires additional hardware or a custom order with a more powerful chip. Chips that can handle the overhead that accompanies NTCIP will likely be standard be with the next generation of cameras set to be introduced in the next

year. That being said, cameras on the market today are able to communicate using competitors' protocols using translators. As a result, the benefits of vendor interchangeability promised by NTCIP are already realized.

6.3.2 Dynamic Message Signs (DMS)

For DMS, light-emitting diode (LED) display technology has become the industry standard for new installations. These displays have good visibility, dimming capabilities, are reliable and have few moving parts, which reduces the amount of maintenance needed. There are three typical types of matrix displays: character, line, and full. **Figure 17** shows the differences between the matrix types. In character matrix displays, each character is displayed in its own distinct space in a grid format. Line matrix displays have no physical separation between characters within a line of text, but each line is distinct. This allows a narrower font to be used to fit additional characters on a line, if needed, though this reduces readability. Full matrix displays have no physical separations between individual characters or lines in the message. A message can be shown at any size and location as long as it is within the display space. In addition, full matrix displays can show icons or graphics for enhanced readability. **Figure 18** shows two examples of full-matrix displays. However, these are typically larger signs and more suitable for freeways where speeds are higher as opposed to arterials.

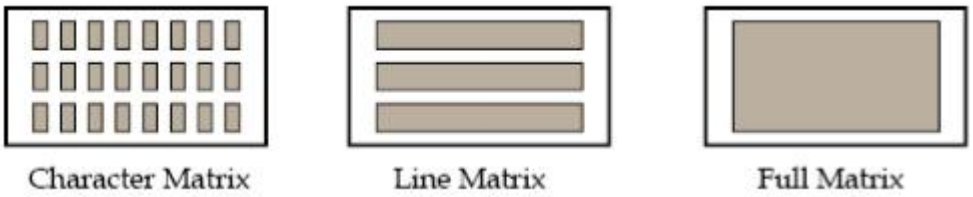


Figure 17 - DMS Matrix Display Types
(Source: Wisconsin DOT ITS Design Manual)

Figure 18 - Examples of full-matrix displays with graphics

In terms of maintenance, walk-in enclosures help protect technicians from the elements. A DMS of this type, designed for freeway applications, can cost anywhere from $105,000 to $165,000 depending on the complexities of the location, specific characteristics of the sign, and type of installation. Signs for arterials could be cheaper as they typically have fewer lines and smaller text size.

6.3.3 System detector technologies

There are a number of different types of detector technologies that could be used in a traffic signal system as system detectors. While inductive loop detectors have been the dominant type for many years, they are slowly giving way to non-intrusive detectors, which are loosely defined as detectors that cause minimal disruption to traffic and installation can be done more safely than normal conventional methods. Given the ubiquity of loops, vendors of non-intrusive detectors invariably offer loop emulators as options. As the name implies, these convert the measurements of the detector to the contact closure type interface used by loops, enabling them to mate with any controller or cabinet.

Historically, the most common type of sensor has been the inductive loop detector though this is rapidly changing as technology progresses. A loop refers to a copper wire embedded in the pavement with a current that creates a magnetic field in the space above the loop so that when a large metal object (i.e., a vehicle) occupies this field, a change in the inductance in the wire signifies a vehicle is present. The loop resides in a rectangular or circular saw cut, typically wound three times to boost signal strength, covered by a sealant to keep out moisture. Loops are typically 6 feet square and one is required for each lane. Loops can measure occupancy (the percentage of time the space inside the loop is occupied by a vehicle) and volume. If two loops are placed adjacently in the same lane in a “trap” configuration, they can also measure speed. Single loop configurations can not measure speed directly, but if an average vehicle length is assumed, speed can be estimated. For locations still installing loops, paired-loop configurations are standard.

An inductive loop detector site includes the following:

In the ground:

- Loops
- Junction/pull box
- Conduit
- Lead-in cable.

On the roadside:

- Cabinet
- Loop detector amplifiers
- Controller
- Modem

A schematic of a typical loop detector site is shown in **Figure 19**.

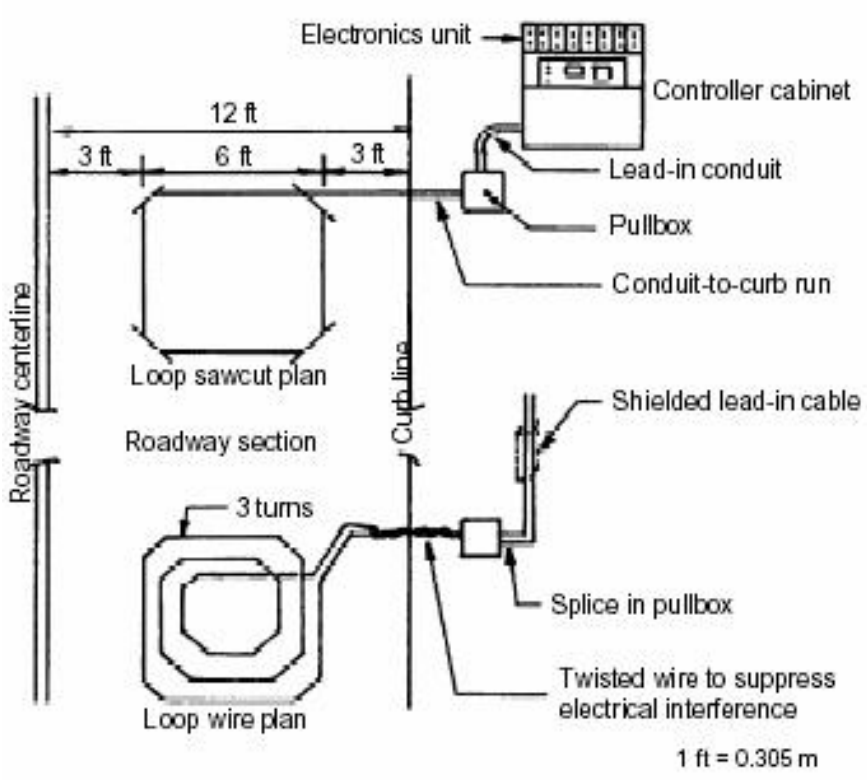


Figure 19 - Loop detector schematic

Loop detectors have well-known problems, most notably a short life span. Loops typically only last three to four years. Pavement freeze-thaw cycles can wreak havoc on loops, especially when they are not installed properly and moisture is allowed to infiltrate the seal. In addition, resurfacing always requires loop replacement and maintenance requires a lane closure. Loops also shorten the life of the pavement in which they are installed. Despite these problems, they are still the most common form of vehicle detection because they are a mature technology, they are a known quantity for transportation departments, and they work well when installed properly.

In the past ten years or so, non-intrusive detectors have slowly gained traction in the marketplace as technology has matured. While they present their own set of difficulties, they solve some of the most pressing problems that plague loops. They are not destroyed during repaving, require minimal disruption to traffic to install or service, and last longer. Non-intrusive detectors are typically mounted on a pole or overpass, either in a side fire configuration where one detector can cover multiple lanes, or in a straight-on configuration where each lane requires its own device. Except in tunnels or other locations where space is constrained, devices that can cover multiple lanes are preferable because of the cost savings. Though loops are still far more common at intersections, non-intrusive detection is the current state of the practice for new freeway installations.

Examples of non-intrusive detection technology include:

- Passive Infrared
- Active Infrared
- Magnetic
- Microwave
- Passive Acoustic
- Ultrasonic
- Passive Infrared / Ultrasonic
- Passive Infrared / Ultrasonic / Doppler Radar
- Video

While it is not possible to provide a detailed assessment of each of these technologies in this document, extensive field evaluations have been done comparing each of these. As of this writing, the best reference is *NIT Phase II: Evaluation of Non-Intrusive Technologies for Traffic Detection*, a comprehensive study done by the Minnesota Department of Transportation and completed in September 2002. It is freely downloadable from the following web site: http://www.dot.state.mn.us/guidestar/projects/nitd.html. In the State of Virginia, Trichord is using non-intrusive detection systems that operation on wireless technologies with solar energy and battery back-up power.

A typical non-intrusive detector site would include the following components:

- Sensor
- Mounting bracket
- Pole
- RS-232/422/485 cable from sensor to cabinet
- Pole-mounted cabinet with transformer
- Fiber modem

A sample schematic of a pole-mounted non-intrusive detector is shown in **Figure 20**. **Figure 21** shows pictures of two sensors currently on VDOT right of way.

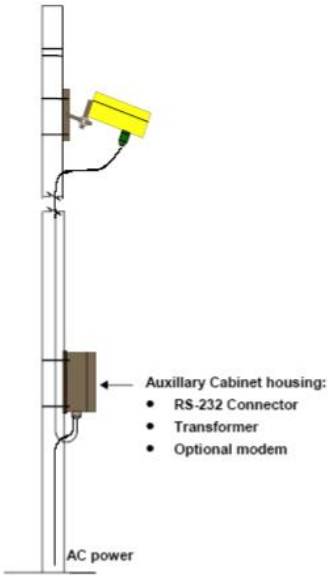


Figure 20 - Sample Non-intrusive Detector (RTMS Microwave Radar)

Figure 21 - SmarTek SAS-1 Acoustic Sensor (left) and SpeedInfo DVSS-100 Doppler Sensor (right)

6.4 Central system alternatives

In the world of traffic signal systems, there is a great deal of similarity between vendors in terms of the features offered. This is largely due to the nature of the bid process, which is often low-bid. As a result, vendors add missing features as they appear in RFPs in order to meet the requirements. In order to save costs, agencies will typically tend toward non-customized system software, which leads them to select from available known features. The combination of these factors leads to a convergence of feature sets across the vendors that compete widely for signal projects. The major software packages on the market today are:

- Siemens Actra
- Siemens i2TMS
- Naztec Streetwise
- Econolite icons
- Econolite Pyramids
- PB Farradyne MIST
- Kimley-Horn KITS

It is often difficult to separate the capabilities of the central system with that of the controllers. Central systems are distributed in nature, which means that the controllers are self sufficient and run internally stored timing plans—they do not need the central system to operate normally. Rather, in addition to polling the controllers for logs and detector data, displaying real-time status information upon request and enabling upload and download of controller parameters, they perform such central traffic control functions as traffic-responsive timing plan selection and traffic adaptive algorithms.

That being said, the main differences in system software are in the hardware they support. Therefore, as stated at the outset, the first and most important decision is the selection of cabinet/controller architecture. With that decided, there are central software options within each subset. These options are presented in **Table 9**.

Table 9 - Pairing of Central Software with Cabinet/Controller Architecture

Controller Platform	Central Software	Controller Software
NEMA (TS-2)	Siemens Actra Econolite icons Naztec Streetwise PB Farradyne MIST	Corresponding vendor firmware
170	Siemens i2TMS Econolite Pyramids PB Farradyne MIST Kimley-Horn KITS	Wapiti Wapiti BI Tran, Wapiti BI Tran, Wapiti
2070	Siemens Actra Siemens i2TMS Econolite icons Econolite Pyramids Naztec Streetwise	SEPAC NextPhase ASC OASIS Apogee

Appendix F provides a table comparing the features of each of the major software packages.

6.5 Peer ATMS Review

The purpose of the peer review was to gain insight and knowledge into state-of-practice for implementing new signal system components and technologies. The peer review enables the City of Newport News to learn lessons from peers on their recent deployments.

From an initial list of six (6) agencies, the City of Newport News chose the following four (4) peer agencies who had recently implemented new signal systems to interview:

- The Cities of Burlington-Graham, North Carolina
- The City of Charlotte, North Carolina
- The City of Clarksville, Tennessee
- The County of Okaloosa, Florida

A signal system questionnaire was developed for each agency to complete. (See Appendix A for a copy of the questionnaire.) The questionnaire asked for general information and contained questions in five (5) categories: System Information, System Operation, On-Street Features, Management and Maintenance. A copy of the completed questionnaire from each agency is included in Appendix C, along with a table summarizing the answers. **Table 10** below highlights answers to several of the key questions.

Table 10 - Summary of Peer Review Questions

Question	Burlington-Graham, NC	Charlotte, NC	Clarksville, TN	Okaloosa Co., FL
Number of Signals	165	650 Approximately 175 signals on the centralized system. It was originally just the CBD Center City Area. There are an additional 35 remote dial-up closed loop locations that are being brought into the centralized system as fiber optic cable projects are completed.	84	103 signals 56 school beacons 24 flashing beacons 7 emergency signals
Number of Staff	2 Engineers 4 Technicians	4 Engineers 3 Technicians	1 Engineer 6 Technicians	1 Engineer 5 Technicians
Controller Type(s)	2070L 170	Traconex 390 controllers in TS-1 cabinets for most of the dial-up arterials. Econolite ASC/2 2100 controllers in TS-2 for CBD area. In the process of replacing Traconex controllers with Eagle 2070 controllers using NextPhase firmware in TS-2 cabinets.	Eagle (M52)	2070 lite controller 2070L and 2070LN controllers Peek 3000 NEMA

Question	Burlington-Graham, NC	Charlotte, NC	Clarksville, TN	Okaloosa Co., FL
Communication System	Single Mode Fiber w/IFS modems	A mixture. The majority of it is still serial communications on twisted pair copper cable. Use time-division multiplexing in the CBD to the controllers from the central communications server. In the process of adding fiber optic cable all the way back to the comm servers. The dial-up arterials are also a mix. The older ones use copper and the newer ones have fiber. Both are serial communication. Just about complete with a system that will use Ethernet communications on fiber, but have not connected this yet.	Fiber (Gigabit Ethernet)	Fiber
Software System	Actra	Siemens ITS I2 software for the centralized system and Traconet software for the dial-up arterials	Actra	BiTrans QuicNet/4

Question	Burlington-Graham, NC	Charlotte, NC	Clarksville, TN	Okaloosa Co., FL
ITS Elements	CCTV - 10	No DMS signs. Now have 50 to 60 CCTV cameras in the field. The hurdles were getting the fiber installed, learning the equipment and maintaining the equipment.	No ITS elements	CCTV and VMS – they are stand alone systems.
Remote Control	Yes, via laptops	We have the ability to access our arterials remotely since they are dial-up. We currently do not have remote access to our central system except from our systems workroom.	Yes, but do not use it	The system has the capability, but hasn't been implemented.
Coordination with others	Neighboring city, Graham has read-only central software access and full CCTV access	The main TMC has recently been expanded to allow the Police to have an area with their own console and video monitors. Worked on this project jointly and now share one large video switcher. All of our cameras as well as theirs go to one place and are available to each other. This video is sent to the Law Enforcement Center, our offices and the NCDOT Incident Management Control Center . We also receive video feeds from NCDOT.	Do not coordinate with other jurisdictions.	Okaloosa does the O&M for all the cities in the county except one, which will come online soon. FDOT has the capability to view and make changes to the system as well.

Question	Burlington-Graham, NC	Charlotte, NC	Clarksville, TN	Okaloosa Co., FL
Problems with System	CCTV software problems, some lightning surge problems, and remote communications with signal monitors is intermittent at best	Had many problems in the past with lightning damage, and then changed our installation procedures for grounding to be much more aggressive. Still have some damage, but not like in the past. Have not had a problem with software crashes.	Experienced some hardware failures that caused the system to crash in the beginning, but since then, there have been no real problems.	There are problems with the controller firmware: no conditional left-turn function, no TOD exclusive ped function, lagging left turns are not functional, in mainline green a protected left-turn call will not be recognized unless a side street call exists. Central software references the old addressing of 170 programming. There is no help to speak of, and the windows development is not a true GUI.

The peer ATMS review revealed valuable information from four agencies who recently implemented new signal systems. Although each system differed in scope and technology, several concepts were linear across the responses. The following is a summary of the information that is most relevant to the City of Newport News.

The agencies interviewed implemented systems ranging from 84 to 650 signals. Approach to system management varied slightly with most employing 1-2 engineers and 4-6 technicians directly involved with system operation. System size did not have a direct correlation to staffing numbers however the larger systems staffed more engineers and fewer technicians.

A wide variety of controllers including NEMA and 2070 equipment were used by the localities. Three of the four agencies are currently running with mixed field equipment including Okaloosa County and Charlotte which are operating both NEMA and 2070 systems. The availability of spare parts was indicated as a major weakness when running mixed equipment. Traffic adaptive technologies were not used by any of the agencies, and with Charlotte was the only locality implementing limited traffic responsive systems.

Fiber was indicated as the predominant and preferred communications medium. Underground and overhead fiber was specified with Clarksville using leased lines. The City of Charlotte is currently working with a mixed communication system including 25 year old twisted pair copper interconnect, and recently deployed fiber cable. Fiber provided high reliability for all agencies, but damage due to construction and degrading fiber splices noted as the top maintenance concerns.

Siemens was the predominant supplier of central system software. Burlington and Clarksville are running Actra while Charlotte uses ITS I2. Siemens was indicated as having a positive track record, ability to adapt to shifting technology, and sufficient staff. Burlington indicated that Actra provided proven field software that matched well with the central system. Okaloosa County is running BiTrans QuicNet, which address 170 programming (i.e. backward compatibility). The County indicated that the system does not operate on a true graphical user interface (GUI).

The limitations of system procurement under low bid state regulations was listed as a concern by agencies interviewed. Three of the four agencies used low bid methods to secure their systems, and Burlington was the only locality going over budget. Frustration was indicated in terms of lengthy decision making due to state and federal approval. Charlotte had a piecemeal implementation with controllers, central servers, and fiber being installed by different projects. Sole source and all inclusive procurement were listed as methods to improve system procurement.

ITS elements were implemented by three agencies with CCTV being the first priority followed by DMS. Okaloosa indicated that these systems were stand alone. Charlotte experienced issues with learning and maintaining the equipment,

which included approximately 60 CCTV cameras. Additional cameras were listed as potential expansion priorities for two of the interviewed agencies.

Most agencies responded that they coordinate with State DOTs for information sharing particularly video images. Sharing system data with law enforcement was also indicated. Coordinating signal timings across jurisdictional boundaries was not done in the two independent cities interviewed (Charlotte and Clarksville).

Remote access capabilities are available on all four systems, but limited use was indicated. Burlington provides each engineer and technician with a laptop equipped to remotely access the system.

System problems were minimal for most agencies. Lightning surges were listed by both Burlington and Charlotte as their top concerns. Revised grounding procedures reduced the level of damage experienced during surges. Okaloosa indicated controller firmware problems with the 2070L and 2070LN controllers including conditional left-turn functions and pedestrian functions. Limited technical support was provided by the vendor to correct these problems. CCTV issues included learning curves for operation and maintenance as well as software integration and configuration problems.

The four agencies interviewed successfully implemented new signal systems with varying size and complexity. Although the technologies differed, the desired functionality was achieved in each locality.

Based on the inputs received from the Peer Review the following policies are recommended to be considered for the City of Newport News.

- Select a Citywide cabinet and controller. While this limits the city's ability to negotiate equipment cost, it will provide a greater flexibility for procuring and/or acquiring spare parts and allow easier maintenance for the Operations staff on a daily basis.

- Consider an alternative design / construction procedure, which would allow the city to procure the equipment from a sole source. This alternative suggests that a minimum of three vendors develop a test bed environment and allow the city to have a hands on evaluation process, prior to selecting a particular hardware/software platform

6.6 Preliminary Technology Recommendations

6.6.1 A Note Regarding On-Street Master Controllers

Currently, Newport News has 27 on-street master controllers for its deployment of 250+ intersection controllers. Master controllers serve to monitor groups of intersections providing status monitoring, data collection, time synchronization and traffic-responsive control for the intersections in the group.

Central systems on the market today serve the same purposes as the on-street masters. However, in addition to the obvious user interface benefits of PC-based software, central systems offer flexibility in how intersections are assigned to groups since it is done in software and independent of communications channels. This allows system boundaries to be changed by time of day to adapt to prevailing traffic conditions. In addition, the quantity of field equipment is reduced by eliminating on-street masters thereby reducing capital and operating costs. Therefore, provided all intersections have communications with the central system, on-street masters will not be required as part of the ATMS.

6.6.2 A Note Regarding Interchangeability

Interchangeability has largely been an elusive goal for the traffic signal industry. NEMA controllers have long had proprietary features to set them apart from competitors and have communicated using proprietary protocols. As a result, vendors were able to lock-in customers to their products. This has also been true with central software packages used to manage signal systems. With few exceptions, these software packages require controllers by the same vendor to realize their full functionality. The 170 and 2070 standards have separated controller software from the controller hardware, but the central software vendor still needs to be paired with the controller software vendor for full functionality.

The National Transportation Communications for ITS Protocol (NTCIP) effort sought to provide true interchangeability. The hope of the NTCIP was to ensure all NEMA controllers were interchangeable, helping agencies to avoid the vendor lock-in that was common in the industry. However, the development of the NTCIP has been rife with challenges and to date, even with a second version approved in March 2005, only a subset of controller features are mandatory by the protocol, the communications overhead stretches the limits of low bandwidth deployments, and many in the industry believe it has not yet achieved the objectives for which it was developed. For a new system, it is far better to pair controllers and software that can realize all the features of the controllers. For the most part, this means pairing controllers and software from the same manufacturer, although there are some central systems that work with multiple controller types. These include Siemens' Actra and PB Farradyne's MIST system, which can be paired with Eagle and Econolite controllers without the NTCIP.

6.6.3 Scenario A: Retain Existing Cabinets and Upgrade Controllers

All of the cabinets and controllers in Newport News are NEMA TS-1, a standard which was succeeded by the TS-2 in 1992 for the reasons mentioned previously. The cheapest and simplest option for Newport News would be to retain all existing cabinets and upgrade the TS-1 controllers to TS-2 Type 2 models. This option would afford some of the benefits of the TS-2 standard, including the redundancy and monitoring capabilities of the MMU, but the phasing assignments are hard-wired in the cabinet. From a maintenance standpoint, technicians are familiar with the existing TS-1 cabinets, but future cabinets would have to be TS-2, which would create a heterogeneous system. Not only would this require technicians to be able to troubleshoot both types of cabinets, spare parts for both cabinet types would be needed.

Based on an estimate of 275 controllers at $1,800 each, the total hardware cost for this option is $495,000. The pros and cons of this approach are summarized in **Table 11**. The costs are listed in
Table 12.

Table 11 - Scenario A Pros and Cons

Pros	Cons
Significant cost savings	Intersection phasing assignments are hard-wired in the cabinet
Allows gradual migration to TS-2	More difficult to diagnose problems than TS-2
Some benefits of TS-2 could be realized (use of MMU for redundancy)	Future intersections would have TS-2 cabinets, which would introduce two different cabinet configurations and the problems this introduces (more maintenance expertise needed, larger spare parts inventory, etc.)
	The TS-1 standard is already out of date
	Growth/expansion for other ITS (CCTV, etc.) limited by the cabinet size

Table 12 - Scenario A Estimated Costs

	Count	Unit Cost	Cost
Controllers	275	$1,800	$495,000
Cabinets	0	-	-
Total			$495,000

6.6.4 Scenario B: Replace Cabinets and Upgrade Controllers (NEMA)

Another option is to replace all controllers and cabinets with TS-2. This option would provide the full benefits of the TS-2 standard over the TS-1 described previously.

The total cost of this scenario is $2,750,000. The pros and cons of this approach are listed in **Table 13** and the cost breakdown is in **Table 14**.

The pros and cons to this approach are:

Table 13 - Scenario B Pros and Cons

Pros	Cons
Configurable intersection phasing assignments	More expensive than TS-1 option
Full diagnostic and redundancy benefits of TS-2 standard	BIUs are subject to failure (lightning strikes)
All cabinet configurations would be the same, even with system expansion (easier maintenance, small spare parts inventory)	Susceptible to vendor lock-in

Table 14 - Scenario B Estimated Costs

	Count	Unit Cost	Cost
Controllers	275	$1,800	$495,000
Cabinets	275	$8,200	$2,255,000
Total			$2,750,000

6.6.5 Scenario C: Replace Cabinets and Upgrade Controllers (2070L)

A third option, presented as Scenario C, is to upgrade the controllers to 2070L and cabinets to TS-2. While the 2070 standard had initial problems, the specification appears to be stabilizing and a number of agencies have successfully deployed them. With the most processing power and interchangeability between vendors, 2070s afford the most versatility and expandability for the future. Its operating system can multitask allowing multiple applications to run on the same controller, if needed. For traffic control applications, 2070L types are sufficient as a VME bus is not needed. While the 2070 can interface with any cabinet, it is recommended that the cabinets be upgraded to TS-2. Other cabinet options that could be selected for the 2070 controller, such as the 33x or ITS cabinet, are not recommended over NEMA TS-2 since they would require a costly adapter to mount on existing NEMA concrete bases.

The total cost of this scenario is $3,217,500. The pros and cons of this approach are listed in **Table 15** and the cost breakdown is in **Table 16**.

Table 15 - Scenario C Pros and Cons

Pros	Cons
Open architecture hardware can be purchased competitively apart from software	Most expensive option
The controller/cabinet can be used for control of other ITS devices (CCTV, DMS)	2070 standard may be succeeded in the future by a new ATC controller now in development
Multiple vendors available for hardware and software	

Table 16 - Scenario C Estimated Costs

	Count	Unit Cost	Cost
Controllers	275	$3,500	$962,500
Cabinets	275	$8,200	$2,255,000
Total			$3,217,500

6.7 Technology Evaluation Summary

Traffic control strategies range from “flashing” to “traffic adaptive”. The city is currently employing several different traffic control strategies and has a clear vision to include further use of traffic responsive strategies, which are not nearly as complex as traffic adaptive, but offer significant improvements over simple time-of-day strategies. Furthermore, the complexity and the shear volume of system detectors required to properly operate and maintain a viable traffic adaptive system far exceeds the benefits. Traffic responsive can achieve comparable results when coupled with routinely updating traffic counts and timing plans.

Traffic signal controller and cabinet options present a comparison between the city’s existing TS-1 platform, and other platforms including TS-2, 170-based, and 2070-based. The biggest investment that will be made with respect to technology upgrades falls within the cabinet choice. There are several advantages to migrating the city’s platform up to either a 2070 controller or a TS-2 controller. However, both can be accommodated within a TS-2 cabinet environment. The 2070 platform does afford more flexibility to procure the central software and the controller firmware separately from a low-bid environment for the controllers. Many vendors have ported TS-2 firmware to the 2070 controllers to provide compatibility and marketability on new installation bids nationwide. However, the cost of the hardware is still higher than the equivalent TS-2 systems on the market and 2070 controllers cannot be deployed within the city’s existing TS-1 cabinets. Recognizing that either controller choice (2070L or TS-2) are both viable options, to afford the most flexibility and build upon the in-house NEMA experience, it is recommended that Scenario B (upgrading all cabinets to TS-2 along with new TS-2 controllers) be deployed for the City of Newport News.

ITS technologies including cameras, variable message signs, and system detectors are explored for use in the City of Newport News. These technologies can provide more effective tools for managing local and regional incidents throughout the boundaries of the city. DSP-based cameras with external digital video encoders are recommended for use at key locations to be identified throughout the city as a part of the ITS Masterplan. While freeways typically strive for 100% coverage using CCTV, it is recommended that key arterial intersections be the first focus of coverage, particularly at known high accident locations. On a corridor basis, the Jefferson Avenue and Warwick Boulevard corridors are recommended to be largely covered as they are primary alternate routes when diversions from I-64 occur. Likewise, strategically placed portable VMS are recommended to be staged at key decision points with the ability to relocate them to other parts of the city during an extended incident management situation. Non-intrusive system detectors are recommended for overall deployment of actuated signals throughout the city.

7.0 Communication Media and Infrastructure Evaluation

The objective of this section is to compile and document relevant communication media technologies and infrastructure options that can be used for subsequent alternatives analysis within the ITS Master Plan.

7.1 Communication Media Evaluation

There are three primary candidate communications modes applicable for use in ATMS applications: leased telephone lines, wireless media, and fiber optic cables. Fiber optic cables are recognized industry-wide to provide the highest capacity along with the most flexibility to deploy multiple ITS applications/devices. However, fiber deployments, particularly underground installations, can sometimes be cost prohibitive. This section reviews the technical and cost implications of these communication media options for potential use in the City of Newport News' ATMS plans. Each media is evaluated based upon attributes such as: scalability, interoperability, security, and cost.

Definitions for common telecommunication terms can be found in **Appendix D** to assist with understanding concepts presented in this section.

7.1.1 Leased Telephone Lines

The use of existing public telephone networks to carry traffic control information results in low initial capital costs, but there are recurring monthly charges for this service. Accordingly, the installation of a leased telephone line consists of both non-recurring and recurring costs. Non-recurring costs include the one-time charge for installing the service (e.g. a hookup fee). Recurring costs consist of termination charges, distance charges, and optional charges such as line conditioning. As with other lease costs (vehicles, for instance), these recurring monthly costs must be accounted for in an agency's operating budget. The fact that a third party is responsible for operating and maintaining the network is both an advantage and a disadvantage. On the positive side, the telephone service provider provides technical staff, spare equipment, and 24-hour/7-days-a-week monitoring. However, agencies are constrained by their contract agreement with the service provider when problems do occur. If it is a long-term contract, this means that an agency cannot terminate service without paying a penalty for early withdrawal from a contract. If the contract does not stipulate the response times (e.g. 4 hours or less) during outages, then an agency may go without service for an extended period if the service provider has a higher priority. The monthly costs of leased line telephone services can increase unpredictably. Accordingly, long-term contracts can be structured to control the escalation of monthly costs. Member agencies may also be able to use State contracts and negotiate better rates than currently available through standard public tariffs.

There are a host of services available through service providers in the Hampton Roads region. Some of these services and typical monthly costs (without government discounted rates) are described below.

- *Analog Plain Old Telephone Service (POTS)*: Low bandwidth analog services for standard voice telecommunications and dial-up modem circuits. These services are the same as typical residential telephone service, which provide support for analog dial-up modem throughput up to a maximum of 56kbps provided the end-user equipment (i.e. traffic controllers) can also support that data rate. Typical dial-up phone service in the region is approximately $30/month.
- *DSL(Digital Subscriber Line)*: There are different variations of DSL including Asynchronous DSL (ADSL), Synchronous DSL (SDSL), and Rate Adaptive DSL (RADSL), to name a few. As a service category, these will be collectively referred to as xDSL. xDSL provides medium bandwidth data services, which is typically offered for Internet access with relatively high download data rates (768 kbps) and a moderate upload rate (384 kbps). xDSL circuits are generally less expensive than T-1s but are limited to a three-mile range from the nearest telecommunications provider Central Office (CO). Typical business class DSL circuits rated for 768kbps (bi-directional throughput) average around $150 per month.
- *T-1/DS-1*: Medium bandwidth services offered for point-to-point telecommunications up to 1.544 Mbps. T-1s can be constructed to deliver 24 voice channels, all data, or a mixture of voice and date between two or more facilities. Unlike DSL, T-1s are not distance limited, but providers charge users for extended mileage (i.e. it costs more for a T-1 from Newport News to New York than for one from Newport News to Hampton). The average cost for a typical T-1 circuit in the local area is approximately $500 to $700 per month. The disadvantage with point-to-point circuits is that redundancy can only be achieved by procuring a second T-1 circuit to an alternate location (i.e. one for Operations Center, and one for City Hall), which becomes very expensive to maintain across multiple sites. For this reason, point-to-point T-1s are not envisioned for the Newport News ATMS.
- *T-3/DS-3*: High bandwidth services for up to 44.736 Mbps or 28 T-1 circuits. Service providers generally combine multiple T-1 circuits from several locations into a single T-3 for delivery to a headquarters location instead of terminating multiple sets of T-1s. The average cost for a typical frame-relay T-3 circuit in the local area is approximately $3,000 to $4,000 per month depending on the desired/allocated bandwidth from the service provider. Unless the city chooses to deploy a large number of cameras on frame-relay or ATM circuits (see below), then T-3 circuits will not likely be warranted for the ATMS.
- *Frame Relay*: A packet technology designed specifically for delivering data services between multiple (geographically separate) locations over a common circuit. Frame Relay services generally use T-1, T-3, or fractions thereof, to provide WAN connectivity between routers on a private corporate/government

network. Unlike point-to-point T-1s, frame-relay circuits can have "virtual circuit" connections to multiple destinations thereby increasing the reliability/redundancy without paying for additional circuits to alternate destinations. Frame Relay circuits are generally less expensive than conventional T-1/T-3 circuits. The average cost for a typical frame-relay T-1 circuit (768k to 1.5Mbps) in the local area is approximately $450 to $600 per month. Frame-relay services can be provided with a private network address (i.e. City Internet Protocol (IP) addresses) accessible only by the city, or with a public IP address accessible over the Internet.

- *Asynchronous Transfer Mode (ATM)*: This is similar to Frame Relay in that it relies upon T-1 and T-3 circuits for physical transport. ATM uses much smaller packets called cells and has Quality of Service (QoS) standards that create a real-time environment for voice and video telecommunications. While data transmissions do not have the same real-time requirements as voice and video, QoS can also, for example, be applied to protect mission-critical applications from Internet traffic. ATM circuits are generally more expensive than Frame Relay and conventional T-1/T-3 circuits. The average cost for a typical ATM T-1 circuit (768k to 1.5Mbps) in the local area is approximately $600 to $800 per month.

Table 17 provides a comparative summary of advantages and disadvantages for leased line communications. Leased-line technologies share the following attributes:

- *Scalability and Backward Compatibility*: This is an advantage of leased line networks because additional telephone lines can always be added. The public telephone network is designed for scalability from analog telephone lines (Digital Signal 0 (DS-0)) to DS-1, DS-3, on up to and above Optical Carrier-48 (OC-48) channels. As new telephone standards have been established, such as SONET, they have typically maintained the ability to interconnect with previous standards (i.e. T-1, T-3, etc.). With leased lines, agencies operate on a "pay-as-you-go" mindset. Agencies can use analog dial-up lines for a few years until a need for higher bandwidth need (i.e. camera video) warrants upgrading to a T-1/DS-1 or above.
- *Interoperability*: Historically, this is an advantage of the public telephone network since different carriers must work together.
- *Security*: The traditional T-3, T-1, and DS-0 (standard telephone line) line offerings are highly secure because they are dedicated to, and only accessible by, the leasing agency. However, other types of services like frame relay and dial-up analog lines can potentially be intercepted/breached, particularly the latter where an errant telephone connection by a would-be hacker could potentially endanger a portion of the system.
- *Cost*: Initial installation cost of leased lines is low. As discussed above, the recurring operating costs are high and would need to be accounted for in the city's operating budget for portions of the system using this communications media.

Table 17:Advantages and Disadvantages of Leased Lines

Advantages	Disadvantages
n Low capital cost to deploy	n Recurring monthly operating fees
n Limited obligation; use for temporary installations and disconnect when done	n Available bandwidth usually limited
n Low maintenance because it is maintained by the telephone company	n Dependent upon telephone company for maintaining service (longer time to repair than for agency-owned system)
n Extensive trenching is not required.	n High-bandwidth services not available in all locations.
n Line-of-sight is not required.	

7.1.2 Wireless Modes

Wireless telecommunications is an alternative for the design of regional telecommunications networks. Wireless data transmission does not require trenching, attaching, or boring to install conduit for fiber optic or twisted-pair cable. This can be advantageous in rugged terrain, over bodies of water, in environmentally sensitive areas, where the cost of right-of-way (ROW) acquisition is high, where there is a lack of ROW, or in temporary installations. Wireless telecommunications can be described in terms of low bandwidth multi-point systems and high bandwidth point-to-point systems. Multi-point systems have the ability to communicate with multiple locations/devices from a single master modem, similar to the fiber ring topology. Point-to-point systems can only communicate with one location/device from a signal modem.

Regional data networks often demand high bandwidth and bi-directional telecommunications, which places limits on the wireless telecommunications format selected. For instance, low-frequency radio systems cannot effectively carry full-motion video over extended distances. Such a wireless signal would not be expected to be sent more than a few miles over a low-power, unlicensed medium without a reduction in bandwidth capacity along with an increase in potential interference.

In cases where security, exclusivity, and long-term reliability are an issue, a licensed radio system is the preferred type of radio system. The owner receives a frequency by the Federal Communications Commission (FCC) and theoretically should never experience problems with radio emissions from other systems. The downsides of the licensed format are acquisition and study costs, as well as a lengthy licensing process. Frequency searches must be performed, and preliminary notices filed before the FCC license is issued. However, licensed wireless systems have a long history of success. For years, point-to-point microwave systems have

been the medium of choice for phone companies, cable TV companies, utilities, railways, paging companies and public sector agencies, and they will continue to be an important part of the national telecommunications infrastructure.

There are several key wireless technologies available for consideration for the City Smart Traffic Center (STC) communications. These technologies include:

- *Microwave*: Microwave systems offer capacity up to 622 Mbps, though systems above 155 Mbps are generally much more costly. The largest expense of wireless systems has traditionally been the network of towers required to establish a line-of-sight between the various destinations. Microwave range is dependent upon radio frequency and signal strength and typically varies from approximately 1 to 25 miles under ideal conditions. Adverse weather conditions can have a significant affect on system performance, particularly if the system was designed for ideal conditions. Microwave network architectures include daisy-chain/repeater, ring, and central hub/relay configurations. Microwave equipment is available in both licensed and unlicensed frequency bands.
- *Spread-Spectrum Radio (SSR) for low-speed data*: Several unlicensed frequency bands (902-928 MHz, 2.4-2.4835 Gigahertz (GHz), and 5.725-5.85 GHz) are available in the United States for general public usage. Many of these frequencies have become quite overcrowded, making them unsuitable for high-capacity connections. SSR applications are commonly used in remote areas. Yet, system operators' experience has shown that even in remote areas and with close proximity between the antennas, interference can still be a problem. The advantage of the SSR system is that no license is required, and there are no fees; therefore the system may go online immediately. Lower bands of SSR are less susceptible to weather attenuation than the higher bands. Conservative distance limits are recommended to be used in order to compensate for adverse weather.
- *Wireless LAN*: IEEE (Institute of Electrical and Electronic Engineers) standards 802.11a, 802.11b, and 802.11g, aka Wi-Fi, address wireless LAN technologies over the 5.8 GHz and 2.4 GHz license-free bands, respectively. Table 18 shows the available bandwidth and relative transmission range comparisons between the three bands. The 5.8 GHz band generally experiences less conflict/interference.

Table 18 – Wireless Local Area Networks – ISM Bands

	915-MHz Band	**2.4-GHz Band**	**5.8-GHz Band**
Available Frequency Range	26 MHz	83.5 MHz	125 MHz
Approximate Throughput (Bandwidth)	11 Mbps	36 Mbps	54 Mbps
Transmission Range	Longest (power dependent)	95% of 915 MHz	80% of 915 MHz (with antenna gain)

Although the distance from the access point at which wireless networks can operate is limited, wireless signals can be received at distances of several hundred feet beyond the physical perimeter of a facility. This presents a security concern because unauthorized users outside of the facility have the opportunity to compromise network security and gain access to the network, which warrants additional measures to secure wireless LANs (WLANs). One key issue when developing a WLAN is the difficulty presented by the wired equivalency protocol (WEP). To overcome this issue, security standards were developed by IEEE giving detailed specifications to enhance the security features provided in WLAN systems.

The original 802.11 specification was developed using Service Set Identifier (SSID), Media Access Control (MAC) Address Filtering, and WEP to protect the WLAN. The SSID is a broadcast that identifies/distinguishes each WLAN. Once the network is configured, the SSID broadcast can be turned off to prevent its presences from being widely known. MAC is the technology that restricts WLAN access to only specified computers. WEP is an encryption scheme, with known security flaws, that provides minimal protection of WLAN data streams between clients and access points specified by the 802.11 standards.

The IEEE 802.11i, implemented in June 2004, is the security standard for Wi-Fi networks that upgrades former wireless network security standards (i.e. WEP). The newest standard features 128-bit Advanced Encryption Standard (AES) for data encryption, along with other enhancements. Unfortunately 802.11i has generated reports stating that WEP was easily “cracked” by those with the right tools and enough patience, while being rather hard to implement. Therefore many users, particularly residential users, do not turn on the security feature.

In 2002, during the time 802.11i was being developed, the industry consortium Wi-Fi Alliance of manufacturers introduced Wi-Fi Protected Access (WPA) as an interim security improvement over WEP. WPA is a subset of the abilities of 802.11i said to include better encryption and an easier setup. WPA comes in two packages, one for the home user and one for enterprises. Most vendors are now including WPA as a standard feature in WLAN products, or at least making it available for download.

Since Wi-Fi/WLAN uses the same frequency bands as unlicensed spread-spectrum radios, the same susceptibility to weather attenuation and interference from other systems applies.

Worldwide Interoperability for Microwave Access (WiMAX) is the IEEE standard for wireless broadband access for both portable/mobile and fixed point-to-point and point-to-multipoint applications. IEEE 802.16 was originally specified for the frequency range between 10 to 60 GHz (see Millimeter Band discussion), but was later modified to support frequencies from 2 to 11 GHz in version 802.16a.

WiMAX provides better security and increased bandwidth in comparison with Wi-Fi standards. While the standards also call for provisions for non-line-of-sight conditions, particularly for the 5 to 6 GHz band, the performance of links under those conditions is not yet well known.

WiMAX systems can deliver up to 75 Mbps per channel for fixed and portable access applications. Current market trends reflect that WiMAX technology will begin showing up in new laptops and personal digital assistants (PDAs) as early as 2006. Wireless service providers are already in the planning and design stages for establishing wireless broadband overlay networks using existing cellular towers.

- *Millimeter Band*: The existing 60 GHz band as well as the pending bands in the 71-76, 81-85, and 92-95 GHz ranges support applications such as high-speed LAN connections, broadband Internet access, point-to-point telecommunications, and point-to-multipoint telecommunications. These bands allow many broadband users to establish metropolitan area networks (MANs) with little risk of interference due to the narrow beam width of this spectrum. Millimeter band transceivers have a nominal range from 0.6 miles up to one mile with a clear line-of-sight, which already compensates for weather attenuation. Due to this distance limit between transceivers, millimeter equipment is generally not as cost effective as microwave for establishing a WAN over long distances, nor is it cost effective for distribution.

  There are many benefits and factors that make the use of a spectrum in the 60 GHz range for unlicensed wireless communication very appealing. Although, wireless systems at this frequency have been used by the intelligence and military community, this spectrum has yet to be used for commercial wireless applications on a wide scale basis. In addition to this opportunity, benefits to the usage of this spectrum include high security, high frequency re-use, and low interference, particularly with 60GHz links.

  The oxygen absorption at 60 GHz occurs at a greater degree than at lower frequencies such as 2.4 GHz and 5.8 GHz. Therefore, the transmitted signal from one link to its destination will drop down at much shorter distances than a link operating at a lower frequency. Most designers plan for distances no greater than one mile between transceivers.

  Frequencies used in other unlicensed wireless systems, 2.4 GHz and 5.8 GHz, which are not affected as greatly by oxygen absorption will continue on for a greater distance, interfering with other signals at the same frequency. Operating at 60 GHz will result in a narrower beam width and more focused antennae than at lower frequencies. The beam width is inversely proportionate to the frequency. Compared to the degrees of radiation at the 2.4 GHz (117 degrees) and 24 GHz (12 degrees) links, the 60 GHz (4.7 degrees) is exceptionally small and precise. The limited range and beam width of the 60 GHz links reduces the concern of interference or security implications.

Table 19 provides a comparative summary of advantages and disadvantages for wireless communications. Wireless technologies share the following attributes:

- *Scalability and Backward Compatibility*: Wireless networks are not generally scalable. The equipment/transceivers are configured for a specific bandwidth capacity and application and rarely allow for upgrades other than replacement. Capacity-wise, the allocated spectrum in the unlicensed bands varies dramatically, which heavily impacts the scalability of a wireless network. The 2.4GHz band can realistically provide 10Mbps capacity on most links, for 5.8GHz and 24GHz it is closer to 100Mbps, whereas the 60GHz band can provide upwards of 1.25 Gbps. Any consideration for wireless as a backbone is recommended to be focused on using the 60 GHz band.
- *Interoperability* in the WLAN environment is well established through IEEE standards-based equipment. However, in the backbone environment, microwave and millimeter band equipment is largely proprietary over the wireless interface, which currently requires each link to be configured with matching equipment. This situation is anticipated to be addressed by the Wi-Max standards, but equipment is not widely available at present.
- *Security*: WLAN wireless telecommunications is not very secure due to the wide availability of Ethernet monitoring tools and wireless WLAN transceivers. On the other hand, security of microwave and millimeter band transmissions is high because they are much more directional, require sophisticated equipment, and require a direct line-of-sight to intercept transmissions.
- *Cost*: Initial installation cost of spread-spectrum low-speed data networks is fairly low in comparison to fiber and leased lines, averaging about $3,000 to $5,000 per link. Installation cost of microwave and millimeter link are high and largely depend upon the associated cost of towers in specific locations to achieve line-of-sight. Millimeter equipment (without poles/towers) is currently ranging between $20,000 and $30,000 per pair. Recurring costs for wireless networks are moderate, as they require more frequent maintenance than fiber optics.

Table 19 - Advantages and Disadvantages of Wireless

Advantages	Disadvantages
n Can transmit data and a limited number of full motion video channels	n Higher lifecycle cost to deploy
n Can use both analog and digital transmission standards	n Requires line-of-sight for millimeter and microwave backbone
n More economical than underground infrastructure for rural/remote applications	n Some jurisdictions may have difficulty gaining approval for new towers where line-of-sight is limited by vertical obstructions (i.e. trees, buildings, etc.)
n Rapid deployment	n Susceptibility to security breaches, particularly for omni-directional Wi-Fi systems
n No land line interconnect required	n Susceptibility to weather and EMI/RFI interference
n Potential for short-range connections of traffic control system applications to a backbone (i.e. fiber, leased line)	n Backbone would require 60GHz equipment to serve the video bandwidth needs of the city
n May prove effective for temporary or interim installations	n Backbone is not scalable without significant equipment replacement
	n Unprotected channel space/shared with other users
	n Requires more sophisticated equipment and specialized technicians to operate and maintain the system

7.1.3 Fiber Optic Communication Systems

Fiber optic cables coupled with fiber optic transceivers provide digital high-speed capability for voice, data, and video transmission. There are two primary factors to consider when choosing fiber optic systems: 1) the type of cable (single-mode vs. multi-mode) and 2) the technology/optical equipment that will be used with the cable.

7.1.3.1 Fiber Optic Cables

Two types of cables are generally used for fiber optic applications: single-mode and multi-mode. Single mode fiber has significantly less signal attenuation, which permits transmission over greater distances. It does not have a bandwidth distance attenuation characteristic compared to multi-mode fiber, which means the bandwidth decreases the further it is transmitted (See **Appendix D** for further definition of single-mode and multi-mode). Because of these factors, single-mode fiber has greater opportunity for expansion. The

benefit of single-mode fiber versus multi-mode fiber is that it is two to five times less expensive. The optical modems and fiber connections are more expensive for single-mode, but the fiber cable cost savings generally negate this difference. For example, over a two-mile span of 12-fiber cable, a single-mode cable costs approximately $0.60/foot plus $2,500 for each optical modem (spaced one mile apart), totaling approximately $11,500. In comparison, a multi-mode cable costs about $1.80/foot and $1,500 for each optical modem, totaling approximately $22,000 for the same two-mile installation. The capacity (both bandwidth and distance) and flexibility provided by fiber optic cables far exceeds the slightly higher cost of installing fiber optic cable versus other media (e.g. copper twisted-pair).

7.1.3.2 Fiber Optic Technologies

Once the physical cable is installed, there are several fiber optic technologies suitable for the City Hall STC to manage information transfers over the cable. These technologies vary in the way they manage the use of the cable, as well as the method for packaging/transferring the information between the field cabinet and the STC. These technologies include Synchronous Optical Networks (SONET), Wave Division Multiplexing (WDM), Gigabit/10 Gigabit Ethernet (GigE and 10GigE), and Passive Optical Networks (PONs).

- *SONET* defines interface standards at the physical layer of the Open System Interconnection (OSI) seven-layer model. SONET was designed to replace its twisted-pair predecessors with much more capacity, increased flexibility to administer changes, and increased capability to manage the network from one location. SONET standards provide both forward-compatibility with future equipment as well as backward-compatibility with existing telephone carrier equipment, protecting long-term capital investment. The standard defines a hierarchy of interface rates that allow data streams at different rates to be multiplexed. SONET establishes Optical Carrier (OC) levels from 51.8 Mbps (about the same as a T-3 line) to 10 Gbps. SONET architectures are capable of efficiently handling large amounts of bandwidth for multiple carriers and customers. SONET's bandwidth characteristics are described in terms of optical carriers (e.g. OC-X) with capacities as shown in **Table 20**.

  When higher capacity SONET equipment is introduced to the market, the opportunity to upgrade is always available by either swapping out modules or adding new optical shelves to increase the system capacity. The increased availability of wave division multiplexing (WDM) further protects fiber investment by providing virtually unlimited capacity if utilized in a regional network). WDMs provide the ability to multiplex multiple optical signals across one fiber <u>without</u> degrading the transported data.

Table 20 – Bandwidth Table

Digital/Optical Signaling Level	Line Rate (Transmission Speed) in Mbps
DS-0	0.064
DS-1/T-1	1.544
OC-1 (equivalent to DS-3/T-3)	51.84
OC-3 (equiv. to three DS-3s)	155.52
OC-12 (equiv. to 12 DS-3s)	622.08
OC-48 (equiv. to 48 DS-3s)	2488.32
OC-192 (equiv. to 192 DS-3s)	9953.28

SONET establishes fixed bandwidth channels (e.g. DS-0s and DS-1s) that can be terminated anywhere around the ring. Since each channel is dedicated for a specific purpose, when it is not in use other channels cannot take advantage of the unused capacity. SONET was designed to accommodate all of the prevalent legacy telecommunications circuits such as analog voice circuits (DS-0s) and digital T-1 circuits (DS-1s).

The use of DS-1 (T-1) interfaces allows agencies to communicate between legacy voice telecommunications equipment such as a between two private branch exchange (PBX) telephone systems. However, if a small remote office location only has conventional analog telephone lines, ISDN, or something less than T-1 speed capabilities, a T-1 channel bank would be required in order to provide 56 kbps/64 kbps voice telecommunications circuits for up to 24 simultaneous users.

Even with the evolution of lower cost technologies such as Gigabit Ethernet, backbone providers still install SONET for four primary reasons: reliability, interoperability, compatibility with legacy communication standards, and network management. Reliability of SONET networks provides the ability to restore/re-route around a failed component or fiber in less than 200 milliseconds. Industry interoperability standards allow owners/providers to interconnect with other owners/providers without requiring the use of the same vendor's equipment and without sacrificing security within their network. SONET network management is well defined, extending beyond alarm/failure monitoring into network provisioning (setting up and removing circuits/capacity from one location to another). However, network provisioning for SONET and ATM (Asynchronous Transfer Mode) equipment is much more complex than the Ethernet networks that most IT departments are accustomed to operating.

- *Coarse or Dense WDM (CWDM or DWDM)*: In a WDM system, each wavelength operates as an entirely separate carrier channel. Wavelength is

the inverse of frequency, and WDM is, in essence, the optical equivalent to Frequency Division Multiplexing (FDM). Each wavelength can run at a different rate than the others. In the recent past, there were two primary ways to increase backbone capacity. The first was to replace the optical carrier equipment with higher capacity equipment or optical transceivers (e.g. OC-12 to OC-48). The second involved using more fibers to run a separate ring and distribute the load across two or more networks. CWDM and DWDM allow the latter to occur without any additional fiber strands on the backbone.

WDM systems can transmit SONET OC-48 on some wavelengths, while others are simultaneously transmitting one or 10 Gigabit Ethernet, or even proprietary/ specialty multiplexers without interference between channels/wavelengths.

WDM uses tunable lasers that emit light at different wavelengths. Each wavelength is transmitted through a separate window onto a single optical fiber. Light detectors at the receiving end detect their respective wavelength. International Telegraphic Union (ITU) has adopted a standard set of grid wavelengths to allow the industry to produce standard optical amplifiers instead of proprietary amplifiers specific to each WDM manufacturer. ITU Grid-compliance also enables the use of small-form factor optical add/drop filters to be inserted into the network without requiring a complete multiplexer if only one type of service (i.e. data) is required at a given drop location.

- DWDM contains a dense amount of wavelengths and therefore requires precise temperature control of transmitter lasers to prevent "drift" off a very narrow center wavelength. CWDM systems require less precision in regards to the transmitter lasers due to a less dense amount of wavelengths on the fiber. As of 2003, CWDM devices have dropped in price to the point where they are similar in price to end-user equipment such as Ethernet switches. DWDM systems are significantly more expensive than CWDM because the laser transmitters need to be significantly more stable than those needed for CWDM. DWDM systems are better suited for applications needing a fast connection over longer distances (i.e. long-distance telephone carriers).

  WDM can be deployed in a star, mesh, or even a ring-based topology. Star and mesh configurations generally require a separate pair of WDMs for each link. A detailed discussion on network topologies and communications is presented in the ITS Master Plan. If one site needs to communicate with three others, three separate WDM pairs would be required. On the other hand, in a ring configuration, it is necessary to introduce an additional function known as optical add/drop multiplexing (OADM) commonly found in SONET equipment. This functionality allows

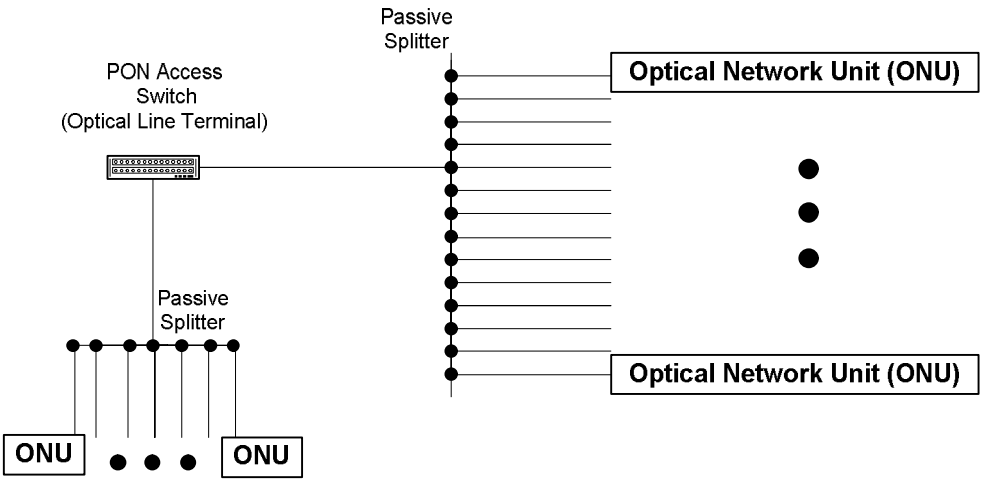
the optical network to use a single multiplexer to receive from one path and transmit/forward to the next path without dropping all wavelengths and regenerating every carrier signal.

In terms of cost, an eight lambda (i.e. eight wavelengths) WDM system with add/drop functionality and 14 DS-1 circuits, two Gigabit Ethernet uplinks, and one OC-48 SONET uplink would range between $90,000 to $120,000, depending upon manufacturer and other configuration options. The cost continues to grow as additional wavelengths are used and optical interface cards are incorporated.

- *Passive Optical Network* (PON) is an optical system that has active electronics only at the endpoints: an office, traffic operations center or field cabinet/device. Between endpoints, the network consists only of passive components including fiber optic cabling, optical splitters/combiners, and splice enclosures. There are no active electronics or metal components/connectors to power, corrode, degrade from heat, or weaken/fail over time.

  A PON generally consists of one or two shared optical fibers connecting a service provider (or head-end) to a fan-out device located near customers or field devices, along with dedicated optical fibers between the fan-out device and each field device. For a PON serving N field devices or drop locations, the fan-out device is either a 1-to-N optical power splitter or a 1-to-N wavelength-division demultiplexer (or a combination of both). This results in a 1-to-N (or N-to-1 for the return path) topology over an optical path as shown in **Figure 22**. It is "transparent" to bit rate, modulation format (e.g., digital or analog), and protocol (e.g., SONET, Asynchronous Transfer Mode (ATM), Ethernet), which allows services to be mixed or economically upgraded in the future as needed. New services and/or field devices can be added by changing equipment only at the ends of the network and only for the affected field devices rather than visiting all cabinets on a daisy-chain or fiber ring. Such flexibility is not generally the case in most of today's other network architectures.

Figure 22 - Typical PON Topology



The PON technology uses a passive splitter between the head-end's optical line terminal (OLT) and the optical network units (ONU) at the remote end. The splitter divides the downstream signal from the OLT into several identical signals that are broadcast to the ONUs. Each ONU is responsible for determining what data is intended for it and ignoring everything else. Upstream signals are handled by time-division multiplexing (TDM) in which ONU transmitters operate in burst mode. The main obstacle for reducing the deployment cost is due to the ONU at the remote end, which typically would be associated with a residence or business. Industry analysts have targeted ONU costs of $1,000 per ONU for wide-scale deployment. ONU manufacturers are developing efficiencies within the production environment and working with researchers to lower the ONU costs over the next several years.

There are currently three prominent varieties of PON: ATM PON (APON), Ethernet PON (EPON), and Gigabit PON (GPON). In its current state, PON is not the most favorable technology to deploy for the City of Newport News when compared to the other alternatives mentioned in this document. This is because the deployment of an entirely new OLT, passive splitters and ONU is required to increase the speed of a subscriber terminal from 155 Mbps to 622 Mbps. 155Mbps is not anticipated to be adequate to serve the long-range camera deployment plans for the city. In addition, connections between the OLT and ONU are not compatible with equipment compliant with the IEEE 802.3 Ethernet standard and few vendors currently offer products supporting Gigabit PON.

It should be noted that this technology is recommended considered as a viable alternative to pursue should fiber demands exceed the current technology offerings at the time. This technology shows a lot of promise for potential field distribution upgrades in the future, particularly for distributing data networks such as Gigabit Ethernet, 10 Gigabit Ethernet, and ATM directly to field devices using relatively few fibers.

- *Gigabit and 10-Gig* Ethernet (GigE) Gigabit Ethernet is an extension of the 10 Mbps (10Base-T) Ethernet and 100 Mbps (100Base-T) Fast Ethernet standards for network connectivity. Ethernet itself is a local area network (LAN) protocol standardized to allow multiple users to access a common a logical bus structure. IEEE approved the Gigabit version of the Ethernet standard, 802.3z, in June 1998.

  In the past, one potential issue in dealing with Ethernet has been the deployment of video/multimedia applications, whereby few guarantees could be made for the quality of image transmission because it was treated the same way as any other Ethernet data connection. Standards bodies have since addressed these concerns and issues by adapting Quality of Service (QoS) priorities for use in managing voice and video traffic. Video and voice services are classified with the highest QoS priority since they require real-time transmission characteristics. Data, on the other hand, can be characterized to obtain the remaining available bandwidth as the network permits. Video and voice traffic require encoding devices to convert analog inputs to digital streams for transmission across the network. A typical MPEG2/MPEG4 video codec would cost approximately $2,000 to $4,000 each for a standalone device that can be remotely managed. For a typical signal system application, each field cabinet's communication equipment would be comprised of an Ethernet switch with optical and copper connections, an Ethernet video codec (only at camera locations), and a serial port terminal server (only for signal controllers or other devices that do not currently support Ethernet communications).

  Gigabit Ethernet has a transmission range of 5 km (3.1 miles) over single-mode fibers using standard transceivers; although some manufacturers have managed to exceed the standard by an increased transmission range of 10 km (6.2 miles). Extended range transceivers are available from most manufacturers upwards of 70 km (43.5 miles). However, they must be closely matched to ensure both ends maintain equivalent optical link characteristics. The distance that single-mode transceivers can obtain is equivalent to Gigabit Ethernet (GigE) at 5 km (3.1 miles). In June of 2002, 10 Gigabit Ethernet (10GigE) was ratified as the IEEE 802.3 standard. 10GigE combines multigigabit bandwidth and intelligent services to achieve scaled, intelligent, multigigabit networks with network links that range from 10 Mbps to 10,000 Mbps. With this technology, Ethernet will run at 10 Gigabits per second, serve as a LAN connection, work in

metropolitan-area networks (MANs) and wide-area networks (WANs). One big advantage to 10GigE is that it can fit neatly within (map directly to) a SONET OC-192 channel with little waste, whereas GigE wastes 60% of an OC-48 channel and is 40 percent larger than an OC-12.

With both GigE and 10GigE standards, ring-based, mesh-based, or star topologies can be deployed, provided that some form of Equal Cost Multipath Routing (ECMR) is used to effectively manage the redundant links. Ethernet is a well-known standard among Information Technology departments and companies. Therefore, it is easier to identify resources equipped to configure, administer, and troubleshoot networks designed around Ethernet standards.

Gigabit Ethernet backbone solutions are much less expensive for data applications than SONET or WDM. A typical Open System Interconnect (OSI) layer 3 router/switch with redundant power, 32 ports of 10/100 Ethernet, and two Gigabit Ethernet fiber ports, can range from $10,000 for a fixed configuration up to $60,000 for a modular configuration. Two fibers are required for each Gigabit Ethernet backbone link unless WDM technologies are used in conjunction with the Ethernet platform. WDM adds approximately $80,000 per network link that provides 8 wavelengths of additional capacity (e.g. 8 Gbps).

7.1.4 Other Networking Technologies

The following technologies are not immediately worth considering for the City of Newport News, but may have future value as the system expands and these standards mature.

- *IEEE 802.17 Resilient Packet Ring (RPR) over Gigabit and 10 Gigabit Ethernet*: RPR and the earlier proprietary Cisco implementation Spatial Reuse Protocol (SRP) provide metropolitan area networks with the reliability, management, and real-time voice/video benefits of SONET, with the lower overhead and provisioning flexibility of Ethernet. Future upgrades to the standard include different physical layers and elegant ways of bridging between rings. Due to rings not being multivendor, interoperability is not currently a key issue with RPR. However, in the future it is possible interoperability will enable service providers to extend functionality from one ring to another. RPR appears to be a technology worth following for future implementation, but in its current form this technology is not an ideal solution for the intentions of this project due to the proprietary nature of the currently available equipment.
- *Hot Standby Router Protocol (HSRP)*: This proprietary protocol is designed for use over a Cisco-based multi-access, multicast or broadcast capable LANs (e.g., Ethernet). Using HSRP, a set of routers work in concert to present the illusion of a single virtual router to the hosts on the LAN. This set is known as an HSRP group or a standby group. A single router elected from the group is responsible for forwarding the packets that hosts send to the virtual router.

This router is known as the active router. Another router is elected as the standby router. In the event that the active router fails, the standby assumes the packet forwarding duties of the active router. Although an arbitrary number of routers may run HSRP, only the active router forwards the packets sent to the virtual router. To minimize network traffic, only the active and the standby routers send periodic HSRP messages once the protocol has completed the election process. If the active router fails, the standby router takes over as the active router. If the standby router becomes the active router, another router is elected as the standby router. This reduces the impact of a single component failure dramatically affecting the rest of the network/system.

- *Virtual Router Redundancy Protocol (VRRP)*: This open standard protocol eliminates the single point of failure inherent in the static default LAN/WAN/MAN routed environments by specifying an election protocol that dynamically assigns responsibility for a virtual router to one of the VPN (Virtual Private Network) concentrators on a network. The functionality is equivalent to Cisco's proprietary HSRP. The concentrator that controls the IP address(es) associated with a virtual router is called the Master, and forwards packets sent to those IP addresses. When the Master becomes unavailable, a backup concentrator takes the place of the Master. The advantage gained from using VRRP is a higher availability default path without requiring configuration of dynamic routing or router discovery protocols on every end-host.

7.1.5 Attributes of Fiber Optic Technologies

Fiber optic technologies share the following attributes:

- *Scalability and Backward Compatibility*: These are salient features of fiber optic networks because single mode fibers have yet to reach a quantifiable limit in bandwidth capacity. Standards such as SONET and Ethernet continue to migrate to higher bandwidths while maintaining backward compatibility. Likewise, CWDM and DWDM manufacturers continue to increase the number of wavelengths that can be carried over a single pair of fibers.
- *Interoperability*: The backbone environment is available for fiber optic networking equipment. Multi-manufacturer interoperability tests have been performed in independent labs for SONET and Ethernet equipment. Basic network management is accommodated between multiple vendors, but configuration and circuit provisioning generally must be performed using each vendor's proprietary tools.
- *Security*: In general, fiber optic telecommunications is highly secure. However, the level of security depends largely upon the technologies deployed on the fiber optic cable network (i.e. SONET is inherently more secure than Ethernet due to the dedicated bandwidth/channels allocated to each user group, as well as the out-of-band administration of those channel assignments).
- *Cost*: Initial installation cost of agency-owned fiber networks is moderate, but the recurring operating costs are relatively low. Typical fiber optic cable deployments range from $100,000 per mile for aerial cable routes, to $150,000

per mile for suburban underground conduit installations. Urban environments with concrete encased duct banks are even higher.

New installation techniques such as micro-tubing are providing additional options to agencies to re-use existing conduit by "jetting" micro-tube innerducts within spare capacity of existing conduits. These micro-tubes can then be used to jet new fiber optic cables into the micro-tubes at a cost much less than installing all new conduit systems.

Table 21 lists the advantages and disadvantages of the fiber optic medium.

Table 21 - Advantages and Disadvantages of an Agency-Owned Fiber Optic Network

Advantages	Disadvantages
n Ability to carry full-motion video, high-speed data, and voice telecommunications	n Higher cost to deploy infrastructure
n Fault tolerance capabilities	n Longer time to deploy
n High bandwidth capacity	n Requires physical path to all elements
n Not susceptible to EMI/RFI interference	
n Long distances supported	
n No monthly operational fees	
n Low maintenance costs	

7.1.6 Media Evaluation Conclusions

While a fiber optic architecture certainly satisfies the majority of the key attributes that are desired for the ATMS, the cost of such a network cannot be ignored. For instance, there will be locations that do not warrant installation of $500,000 (i.e. roughly 5 miles) of cable system to connect one site/device that only needs less than 2 Mbps network access. There will also be occasions when it will be more costly than $100,000/mile to install cable/conduit/accessories due to geographical or other constraints. For this reason, the recommended telecommunications architecture needs to support a hybrid of communication media instead of solely depending on one medium.

Fiber optic cable can provide the City of Newport News with a foundation for the growth of the ATMS over the next 20 years and beyond. As the Department of Engineering deploys new fiber cable segments with spare capacity, other city departments will begin to reap the reward of sharing the existing Citywide IT/NNPS fiber resources rather than relying on each Department to deploy individual cables on the same routes. Fiber optic systems are notable for their ability to carry full-motion video, high-speed data, and voice telecommunications, flexible technology options, fault-tolerance capabilities, network security, high

bandwidth capacity, the lack of susceptibility to electromagnetic and radio frequency (EMI/RFI) interference, and the scalability for future applications. However, fiber systems due require a longer time to deploy along with a higher initial capital cost than leased lines and wireless systems. The fiber optic medium is still the recognized as the best medium that the communications industry currently has to offer, particularly for a network backbone.

Leased lines and wireless alternatives will still play an important part in the city's proposed ATMS upgrades. Wireless is not a likely candidate for the city's communication backbone due to its higher lifecycle cost (compared with fiber optics), and the current lack of widely available vendors with interoperable broadband wireless equipment. Additionally, the line-of-sight requirements for such a backbone would require a network of towers that may be difficult to gain approval from other City staff and the public constituents. However, there is a potential for short-range connections of traffic control system applications to a backbone (i.e. fiber, leased line) using spread-spectrum technologies in the unlicensed frequency bands. Such systems can be deployed rapidly for areas where fiber optic expansion would be cost prohibitive, or simply for connecting temporary traffic signals or cameras to a nearby backbone.

Likewise, leased lines such as frame-relay T-1s can be considered for isolated camera locations that cannot be served effectively by fiber optics or wireless media. Traffic signal locations that are too far from the backbone, may be better served by a dial-up telephone line for occasional/periodic communications with the central system, or a dedicated leased line such as DSL or a low-speed frame-relay service for nearly constant communications.

By establishing technology standards that support all three media types, devices with disparate bandwidth needs (low, moderate, high) and different densities of devices (1 or 2/mile vs. 6 to 10/mile) can better utilize their resources to gain access to the aggregation hubs of the Citywide IT, Newport News Public Schools, and/or Department of Engineering fiber network. Low device densities may be better suited to wireless and/or leased line installations, while higher density installations will be able to spread the cost of the infrastructure across many devices/sites. It is recommended that the city's communications network for transportation be based on Ethernet standards (IEEE 802 set of standards), which is the most effective set of technology standards achieving availability across all three media types.

7.2 Existing Infrastructure Resources

The objective of this section is to compile and document relevant infrastructure opportunities for use by the proposed ATMS to achieve reduced cost, system redundancy, and/or integration with other transportation operations centers.

7.2.1 Newport News Public Schools (NNPS) and Citywide IT

7.2.1.1 Current/Existing Resources

The City of Newport News Public School (NNPS) system has a fiber optic system with approximately 300+/- fibers in use for connecting schools, and a majority of the police and fire/rescue facilities. When surveyed they did not specify how many, if any, spare fibers they currently have or if they would be willing to share/trade with other departments such as Transportation. Currently, Citywide IT has a total of 96 total fibers on the NNPS fiber optic system, and have indicated they have 30 spare fibers and are interested in sharing/trading fibers with other Departments (i.e. Transportation and Traffic Operations) to create redundancy. The Citywide IT network connects the majority of police, fire, and rescue facilities, as well as several satellite offices throughout the City.

The NNPS cables form three rings within the City using Jefferson Avenue and Warwick Avenue as the primary north/south routes, and cross-connecting routes near City Hall to the south, J. Clyde Morris Boulevard, Bland Boulevard, and Yorktown Road. Citywide IT has access to 48 fibers on two of the three rings for a total of 96 fibers. Fire Station #8 located at J. Clyde Morris and Kingstowne Drive is the primary access point for the Citywide IT portion of the infrastructure. Gigabit Ethernet optical equipment is currently being used by both Citywide IT and NNPS to light their respective fibers.

The entire NNPS cabling infrastructure is run through underground conduit with splice vaults located approximately 2,000-3,000 feet apart. Spare conduits were not installed. The NNPS data center (Warwick/Wellesley) is the termination for all three of the fiber rings. As new facilities (schools, police/fire stations, etc.) have been spliced into the backbone, the cost of each connection is averaging $5,000 to $10,000 per location. Most connections to date have been within 300 feet of existing routes.

NNPS also indicated a regional collaboration effort is currently under way to establish connectivity between all of the Hampton Roads School Districts for remote classroom distance-learning initiatives. NNPS expressed interest in collaboration of fiber infrastructure for connecting with the City of Hampton as well as VDOT in support of this initiative.

Citywide IT access points are shown in **Table 22**. **Figure 23** shows the major NNPS fiber routes within the City.

Table 22: Citywide IT Fiber Network Access Points

• City Hall (Washington Avenue/25th Street)
• City Center (Jefferson Avenue/Thimble Shoals Boulevard)
• City Warehouse Facilities (Jefferson Avenue/Briarfield Road)
• Operations Center (Jefferson Avenue/Operations Drive)
• Emergency Operations Center (Jefferson Avenue/Operations Drive)
• Newport News Waterworks (Warwick Boulevard/Industrial Park Drive)
• Commissioner of the Revenue Satellite Office (Jefferson Avenue/Richneck Road)
• Main Street Library/Fire Station #3 (Warwick Boulevard/Main Street)
• Fire Station #5 (Warwick Boulevard/Curtis Drive)
• Fire Station #8 (J. Clyde Morris Boulevard/Kingstowne Drive)
• Grisom Library/Fire Station #9/Police Station (Warwick Boulevard/Denbigh Boulevard)
• Future Proposed City Police Headquarters (Jefferson Avenue/Woodfin Road)

During steering committee meetings and subsequent follow-up with Citywide IT, it was also determined that the City is deploying 802.11 wireless (Wi-Fi) hot spots. Approximately 20 hot spots have been installed thus far. These 20 sites are dedicated for City staff to access internal City networks as well as the Internet through the City's firewall. **Table 23** illustrates the general locations where Wi-Fi hot spots have been deployed to date. There are requests from Parks and Recreation, Codes Compliance, and Engineering to make more hot spots available at other city facilities such as fire stations, park facilities, police station locations, and satellite City Offices, such as the City Center. Each hot spot has approximately a 300 foot radius of accessibility. Network authentication keys are used to prevent unauthorized access.

Table 23: Wi-Fi Hot Spots

•	City Hall - Second through the tenth floors
•	City Center - Second and fourth floors
•	City Center - One mounted on the roof
•	Inside Fire Station #8
•	Outside the Waterworks Lee Hall complex
•	Inside the EOC Operations Room
•	Inside and outside the Radio Shop at the Operations Center (Operations Drive at Jefferson)

7.2.1.2 Potential Uses

Potential uses for the existing IT fiber infrastructure involve:

- By using the City access points there will be a cost reduction in the backbone/trunk communications. In addition, Transportation and Traffic Operations can connect signal system distribution cables to the nearest IT access point in **Table 22** to build distribution from these points and offer redundancy to Citywide IT along alternate paths. *Two of the City's 30 spare fibers could be used to establish a backbone dedicated for the Advanced Traffic Management System (ATMS), two additional fibers (for a total of four) would be desirable to provide separate distribution strands to connect field equipment and support redundant paths along some routes.* This would allow Engineering to separate distribution to ATMS elements from the general Citywide IT network. With the use of a small fraction of the 30 fibers, additional access points could be established along Jefferson Avenue and Warwick Boulevard for distribution to field cabinets along these two critical corridors.
- Wireless remote access from Citywide Wi-Fi hotspots would reduce travel and cellular phone charges by allowing Transportion and Operations staff to remotely connect to the proposed ATMS central system servers from various existing hot spots around the City (**Table 23**) as well as future/planned locations. Available data transfer rates would be much higher with Wi-Fi than with cellular remote access connections.
- System monitoring access and digital video distribution to/from all of the IT access points throughout the City.

An existing maintenance agreement is in place with the NNPS fiber cable installer. This agreement provides a menu of options for varying response times. With the redundant network topology that is envisioned for this initiative, a rapid response times is not anticipated to be necessary for the majority of fiber-cut events that would typically occur.

Resource sharing agreements will need to be established to clearly define the time to respond to network outages, shared funding conditions (i.e. trading fibers one for one on different routes vs. a set cost for shared usage), and maintenance responsibilities of both groups.

7.2.2 City of Hampton Traffic Engineering Infrastructure

7.2.2.1 Current/Existing Resources

The City of Hampton has fiber optic systems in use for traffic operation and has indicated an interest in sharing/trading fibers for redundancy with other agencies, particularly Newport News, due to a number of major arterials that are influenced by two separate signal systems. The City of Hampton has conduit links to the Newport News city line along Mercury Boulevard and

Hampton Roads Center Parkway. In addition, along Mercury Boulevard twisted pair copper is in place between the two nearest signal cabinets. The City of Hampton has overhead (aerial) fiber optic cables on Pembroke Avenue and Todds Lane. Although there is no conduit along these routes, the city has identified these as good opportunities to tie-in with the Newport News System along 39th Street and Main Street /Willow Drive, respectively. The City of Hampton is willing to sit down with the City of Newport News to map out potential paths for communications sharing.

The City of Hampton has a coordinated signal system and remote operating capabilities to control timing plans, as well as emergency incident management plans that can be shared for regional coordination. Hampton's current system has limited capabilities to communicate with other vendor platforms. The City of Hampton has an Arterial ITS Master plan which includes CCTV cameras, arterial changeable message signs, system detectors/count stations, parking management systems, emergency vehicle priority corridors, and transit vehicle priority corridors. They are willing, and intend, to share video images with other agencies in the region.

7.2.2.2 Potential Uses

Potential uses for the City of Hampton infrastructure involves:

- Signal coordination/connection along the 39th Street / Pembroke Avenue corridor by interconnecting both agencies' systems.
- Signal coordination/connection along the Main Street / Todds Lane corridor by interconnecting both agencies' systems.
- Signal coordination/connection along the Mercury Boulevard corridor by interconnecting both agencies' systems.
- Signal coordination/connection along the Harpersville Road / Hampton Roads Center Parkway corridor by interconnecting both agencies' systems.
- Potential mutual redundancy for creating a fiber ring from J. Clyde Morris Boulevard to Harpersville Road/Saunders Road which connect to Hampton's proposed Commander Shepard Boulevard Extension to Magruder Boulevard to Hampton Roads Center Parkway and then back to Harpersville Road /Jefferson Avenue to J. Clyde Morris Boulevard. This linkage would also afford direct center-to-center communications as well.
- Potential mutual redundancy by connecting Briarfield Avenue to Aberdeen Road to Pembroke Avenue and then interconnect with proposed Newport News infrastructure along 39th Street and Chestnut Avenue to complete a ring.
- Potential mutual redundancy along the Main Street/ Todds Lane corridor using Newport News infrastructure on Jefferson Avenue to connect with Harpersville Road, and Hampton infrastructure from Hampton Roads Center Parkway to Big Bethel Road back to Todds Lane.

Approximately 2 fibers would be needed by each agency to complete each ring. Resource sharing agreements will need to be established to clearly define the time to respond to network outages, shared funding conditions (i.e. trading fibers one for one on different routes vs. a set cost for shared usage), and maintenance responsibilities of both Cities. The possible connections with the City of Hampton for redundant fiber routes are depicted in **Figure 23**.

7.2.3 Virginia Department of Transportation (VDOT) Hampton Roads Smart Traffic Center Infrastructure

7.2.3.1 Current/Existing Resources

The VDOT Hampton Roads Smart Traffic Center (HRSTC) has fibers, which have been set aside for the City of Newport News Engineering, originating from J. Clyde Morris Boulevard at an arterial changeable message sign (ACMS). There are eight fibers in total; four (4) fibers that traverse west, and four (4) fibers that traverse east. This connection route is depicted in **Figure 23**.

Additionally, there is currently a microwave link between the Newport News City Hall and the VDOT HRSTC. This covers a line-of-sight distance of approximately 20 miles. The Proxim Tsunami wireless link provides up to 100 Mbps (full-duplex) for Ethernet using the unlicensed 5.3-5.8 GHz frequency band, in addition to T-1 connections for voice or data. This wireless bridge has the ability to provide point-to-point communications from less than 1 mile to more than 15 miles. At the VDOT HRSTC, the wireless bridge is connected to a Cisco Ethernet switch, via single-mode fiber optic cable. In turn, this switch is connected to the VDOT internal network switch, the iMPath MPEG Video Encoder chassis, and in turn the analog video switch. At the Newport News City Hall location, the wireless bridge is connected to another Cisco Ethernet switch along with an iMPath Video Decoder Chassis and a Dell workstation. This workstation is a remote computer on the VDOT HRSTC network allowing access to incident and traffic information, along with video selection via the attached encoder/decoder pairs. The decoders at City Hall are attached to large-screen plasma monitors for visual traffic monitoring of VDOT cameras along the interstates and the bridge-tunnels.

Figure 23 - Inter-Agency Connection and Proposed Fiber Expansion Map

7.2.4 Potential Uses

Potential uses for the VDOT STC fiber infrastructure involve:

- Communication redundancy for the Jefferson Avenue corridor between J. Clyde Morris Boulevard and Ft. Eustis Boulevard.
- Secondary access to VDOT over fiber infrastructure instead of, or in addition to, the current wireless connection with City Hall.
- Connect with other municipalities across the regional multi-modal system (RMMS) portion of the VDOT backbone via the Ft. Eustis VDOT STC communication hub.
- Potential use of RMMS, or trading fibers with VDOT, to provide redundancy between the city's two operations locations (Operations Drive and City Hall) by way of the VDOT Ft. Eustis and the 664/23rd Street communication hubs. VDOT could benefit from redundancy along the I-664 and I-64 corridor, from a City constructed fiber route along Jefferson Avenue.
- Accessing the RMMS also provides the City with access to real-time Bridge/Tunnel information, interstate diversion plan alerts, and other freeway incident notifications.

Resource sharing agreements will need to be established if the city and VDOT decide to trade fibers, along with the maintenance responsibilities of infrastructure provided by both groups.

7.2.5 Other Service Providers

There are incumbent and competitive local exchange carriers (ILEC and CLECs) that have existing fiber networks or are continually expanding/upgrading these networks. Verizon, Cox Communications, and KMC Telecommunications, among others, were contacted regarding opportunities to share a fiber network installment. These three entities have already installed the majority of their infrastructures within the City of Newport News and do not see substantial opportunities in the foreseeable future.

While Verizon, the area wide ILEC, has a standing policy against the approach of selling dark fibers, CLECs have a proven track record of partnering with municipalities to offer fibers in exchange for right-of-way. This affords the ability to share the installation cost of such a communication network deployment by two or more entities. However, such an endeavor requires a set of ground rules to be established between all parties involved. If the opportunity arises when approached by a CLEC or other fiber optic installation group, the following rules/guidelines should include at a minimum:

- Department/entity responsible for maintaining the fibers
- Department/entity responsible for operating and maintaining any associated network equipment
- Department/entity responsible for making repairs to damaged facilities
- Leasing/purchasing arrangements for the fiber facilities
- Number of fibers available to each department or firm

- Department/entity responsible for performing any necessary splices or connectivity modifications

7.3 Communications Expansion Routes

Based on the assumption that agreements are being formalized between the Newport News Department of Engineering and the Citywide IT/ Newport News Public Schools (NNPS), this arrangement will allow for communication infrastructure sharing along, or parallel to, the key corridors of Jefferson Avenue and Warwick Boulevard will be achieved by the existing infrastructure. The quantity of fibers that are made available for use by the Department of Engineering will have an impact on the types of technologies that can be deployed without installing all new cable infrastructure in parallel to the NNPS systems.

To improve the reliability of the entire system as well as to expand the communication coverage beyond these two primary corridors, additional fiber optic communication routes are recommended. These proposed communication routes will provide greater resistance to failure (fault tolerance) and provide the necessary bandwidth required to effectively handle proposed video surveillance as well as resource sharing with other Newport News agencies and adjacent jurisdictions (i.e. City of Hampton, VDOT, etc.). The routes that have been identified typically correspond to high accident locations as well as interstate diversion routes/corridors. The following list identifies the locations of the proposed communication routes that are shown on **Figure 23** as dashed lines. In order to gain the most benefit from these expansion corridors, the routes are recommended to be grouped to establish physical rings as follows. The groups are not in order of priority.

<u>For redundancy along the northern Jefferson/Warwick corridors</u>

- Along Fort Eustis Blvd., between Warwick Blvd. and Jefferson Ave.
- Along Warwick/Yorktown Rd., between Curtis Drive. and Jefferson Ave.

<u>For redundancy in the Central Business District</u>

- Along Oyster Point/Victory, from Jefferson Ave. to City Limits
- Along Thimble Shoals Blvd., between Jefferson Ave. and Diligence Dr.

<u>For redundancy in the Central Business District and connection with Hampton and York County (VDOT)</u>

- Along J. Clyde Morris Blvd., between Jefferson Ave. and Woods Rd.
- Along J. Clyde Morris Blvd., between Interstate 64 overpass and City Limits

<u>For interconnection with Hampton</u>

- Along Harpersville Rd., from J. Clyde Morris Blvd. to Saunders Rd.
- Along Saunders Rd., from Harpersville Rd. to City Limits
- Along Hampton Roads Center Pkwy., between Harpersville Rd. and City Limits

For redundancy in the Mercury/Briarfield area east of Jefferson

- Along Mercury Blvd., between the James River Bridge and Roanoke Ave.
- Along Briarfield Rd., between Marshall Ave. and City Limits
- Along Chestnut Ave., between City Limits and Briarfield Rd.

For redundancy east of Jefferson between Briarfield and 41st

- Along Chestnut Ave., between Briarfield Rd. and 41st St.

For redundancy east of Jefferson between 48th and 40th

- Along Jefferson Ave. between 48th and 40th

For redundancy east of Jefferson between 25th and 16th

- Along 25th St., between Jefferson Ave. and Madison Ave.
- Along Jefferson Ave., between 25th St. and 19th St.
- Along Chestnut Ave., between 18th St. and 16th St.

For resource sharing initiatives and interconnection with Hampton

- Along 25th St., between Chestnut Ave. and City Limits
- Along 39th St., between Chestnut Ave. and City Limits
- Along Briarfield Rd., between Chestnut Ave. and City Limits

8.0 Proposed System Functional Requirements

The objective of this section is to present the system functional requirements for use by the proposed ATMS to achieve the desired software, hardware, communication, and the remaining associated system upgrades.

8.1 Platform/Architecture & System Administration Requirements

8.1.1 High Level System Description

These requirements describe an arterial traffic management system that purchased as part of the ATMS following the preparation of design plans and specifications. It includes the necessary central system hardware and software to monitor and control approximately 500 traffic signal controllers, 500 system detectors, 50 closed circuit television (CCTV) surveillance cameras, and 20 portable dynamic message signs (DMS) in an Ethernet network over city-owned fiber optic cables. Newport News will have two fully functional traffic management center locations having the same functionality—one at the Operations Center and one at City Hall. The system shall be sufficiently stable to run continuously (i.e. 24/7) and unattended outside of standard hours.

The proposed system shall have a central architecture, where the central system will communicate directly with each local traffic signal to provide signal controller upload and download database capabilities (i.e. no field master locations). The system shall be designed for a turn-key implementation in which a single contractor will supply, construct, install, fully integrate all hardware, software, and other equipment, and provide training for a complete and operational ATMS.

The system shall have a client-server architecture and be Microsoft Windows-based, with an intuitive graphical user interface (GUI), mapping and display functionality, and seamless cutting and pasting between standard Windows applications such as Microsoft Office Word and Excel. All system information shall be stored in a centralized multi-user database. It shall monitor system components and alert operators of unexpected conditions, log all important activity, provide device status displays on command, and allow the creation of a variety of reports to help operators manage system performance.

The system shall include centralized traffic control functionality such as traffic responsive plan selection, and allow intersections to dynamically move from one control group to another. However, control should be distributed and should an intersection lose communications with the central system, it should revert to its local time base coordination plan. The system shall accommodate the future application of transit vehicle priority and existing and future emergency vehicle preemption.

The system shall support polling, viewing, and controlling CCTV cameras. It shall also support polling portable DMS, viewing the current message, and updating messages. It shall also send alarms for predetermine weather sensor thresholds.

During the construction phase of the system upgrades, field controller locations shall be upgraded on a “closed-loop system” by “closed-loop system” basis to minimize system downtime. The existing primary system servers are located in the Operations Center off of Operations Drive. The location of the proposed primary servers will be initially located at City Hall. As new controllers/systems are transitioned to the proposed system they will then be released from/no longer monitored by the existing central system. Fiber optic communication upgrades will need to be established to each associated “closed-loop system” group of intersections prior to each transition. Once all existing intersections have been transitioned to the proposed system, a backup set of servers can be deployed in the Operations Center.

8.1.2 System Architecture

Modern traffic management systems are typically designed around a computer cluster acting as server(s) to a constellation of operator workstations acting as client(s). This is typically described as a “client-server” architecture. The server(s) manage field communications (center to field device), and collect and process field device data into traffic information. The system provides traffic information to human operators through the operator workstations. It also makes available historical information through reports generated from a database. The system shall have a client-server architecture that accommodates multiple concurrent users.

8.1.2.1 Operating System (OS)

The operating system for servers shall be Microsoft Windows 2003 Server Standard Edition (or the equivalent of a later version if available). The operating system for client workstations and laptops shall be Microsoft Windows XP Professional (or the equivalent version of Vista if available).

8.1.2.2 Local Area Network (LAN)

The LAN shall be gigabit Ethernet. Hardware shall be provided to connect servers, workstations, printers and other devices. A switch shall be provided at each field cabinet, traffic management center, and access point locations that can accommodate all LAN devices with 25% spare capacity. The network shall be based on a Gigabit Ethernet platform over single-mode fiber optic cabling configured in a ring topology to field devices. Where possible based upon available diversified cable routes, physical rings shall be established to provide reliable communications between field devices and the central system. The ATMS Gigabit Ethernet network shall be segmented so that it is not a part of the Citywide IT network in order to minimize data latency and bandwidth conflicts associated with distributing digital video across the ATMS network.

A multi-point serial concentrator shall be provided for connectivity to dial-up remote access modems or a video wall controller.

Layer-3 network switches shall be provided to connect LANs at the Operations Center and Newport News City Hall traffic management center locations as well as field device locations.

Firewalls shall be provided and be appropriately configured for proper security for interfaces with other City departments, external organizations, and/or the Internet.

8.1.2.3 Servers and Workstations

Performance of server and workstation hardware is a continual and rapidly changing environment. The following section provides general guidelines for the performance of proposed servers and workstations to support the Newport News ATMS deployment. These guidelines should be re-visited prior to final procurement of central system equipment to provide the City with the optimum configurations that are on the market at the time of purchase.

- *Application/file/database server*

An application server shall be provided to run the central system software, house the database and be a central storage location for system files. It shall meet the following minimum requirements:

- Rack-mount server configuration consuming no more than 3 rack units (RU) (5.25”H x 19”W x 24”D)
- Support for dual processors (i.e. 32-bit Intel processors at 3.0 GHz/2 MB Cache, 800 MHz FSB (or performance equivalent)
- At least three 10,000 rpm hard drives configured in a RAID 5 operation mode with sufficient capacity (see Section 8.2: System Capacity), and 100% spare storage capacity.
- 4 GB of Double-Data Rate (DDR2) Synchronous Dynamic Random Access Memory (SDRAM)
- Dual-port 10/100/1000 Mbps Ethernet network interface adapter
- DVD+/-RW burner and CD/DVD-ROM reader combination drive
- Redundant power supplies
- Redundant cooling fans
- 1RU rack-mount keyboard, monitor, and mouse drawer equipped with a 15” LCD monitor rated for a minimum of 1024x768 pixel resolution
- Keyboard/video/mouse (KVM) switch accommodating at inputs from at least 8 servers/workstations, and at least two outputs including the keyboard, monitor, and mouse drawer

The servers shall come with the following software installed:

- Microsoft Windows 2003 Server Standard Edition Operating System
- Standard database formats (i.e. SQL, Oracle, etc.)

For system redundancy, primary servers shall be installed at City Hall with a standby backup set of servers installed at the Operations Center. The servers shall support file synchronization/mirroring at least once a day to minimize data loss in the event of primary server outage. Engineering/IT will backup server data from the existing IT Network Attached Storage (NAS) devices.

- *Port server*

A port server shall be provided to manage communications with field devices. It shall have the same specifications as the application/file/database server. The system shall be configured to have the port server automatically take over for the application/file/database server should communications with the primary server fail for a user-specified number of attempts.

- *Workstations*

Eight (8) client workstations shall be provided for operators to use the system. Two (2) shall be located at the Operations Center, five (5) at City Hall and one (1) at the Emergency Operations Center (EOC). They shall have identical specifications and shall meet the following minimum requirements:

- 32-bit processor system (i.e. Intel Pentium D processor at 3.0 GHz/2 MB Cache, 800 MHz FSB (or performance equivalent)
- 2 GB DDR2-SDRAM
- 120 GB hard drive
- 10/100/1000 Mbps Ethernet network adapter
- DVD+/-RW burner and CD/DVD-ROM reader combination drive
- Dual 19” LCD flat panel monitors, 1280x1024 pixel resolution
- Keyboard, mouse

The workstations shall come with the following other software installed:

- Microsoft Windows XP Professional SP2 Operating System (or the equivalent version of Vista if available)
- Microsoft Office 2003 Standard Edition (or equivalent if a newer version is available)

- *Laptops*

Seven (7) laptops shall be provided to access the system remotely or from the field. Four (4) shall be for field technicians, two (2) shall be for city traffic engineers, and one (1) shall be for a technician at City Hall. They shall have identical specifications and shall meet the following minimum requirements:

- 32-bit processor system (i.e. Pentium M processor at 2.0 GHz (or performance equivalent)
- 1 GB DDR2-SDRAM
- 60 GB hard drive
- DVD+/-RW burner and CD/DVD-ROM reader combination drive
- Internal 56k dial-up modem
- 802.11a/b/g wireless networking card
- Secondary battery
- Carrying case

The laptops shall come with the following other software installed:

- Microsoft Windows XP Professional SP2 Operating System (or the equivalent version of Vista if available)

- Microsoft Office 2003 Standard Edition (or equivalent if a newer version is available)

Five licenses of Synchro Professional (version 6.0 or the most current version at the time the equipment is purchased) shall be provided for installation on five of the laptops or workstations.

Optional cellular/PCS PC cards and service plans can be shared for use by one or more technician laptops to augment City Wi-Fi and Internet remote access.

8.1.3 GPS Clock

A Network Time Protocol (NTP) clock using Global Positioning Systems (GPS) to maintain accurate time shall be provided. It shall be the NTP server on the LAN from which all devices obtain their time. A secondary/backup time server shall be established for the system using either publicly available NTP servers over the Internet, or via the City's intranet.

8.1.4 Video Wall Display

The video system shall support the display of simultaneous video streams on either the workstation monitor or video wall displays at the Traffic Operations STC and City Hall STC. The video wall display system shall support the receipt of Ethernet encapsulated MPEG-2 and MPEG-4 video stream formats from video encoders located in field cabinets. The network switches at both centers will provide access to the remote digital video streams, and providing distribution to the workstations and central display monitors. The video system shall allow the users/operators to select the video streams to be displayed and then display simultaneous video streams on either the workstation monitors or wall monitors. Up to 10 simultaneous video streams shall be displayed on each monitor. The video system shall provide drag-and-drop camera selection, user management, and pan/tilt/zoom control of field cameras using NTCIP or compatible camera-vendor protocols through a GUI.

8.1.5 Printers and Plotters

Two identical color laser printers, one for each traffic management center, shall be provided that are networked to the LAN and meet the following minimum requirements:

- 10/100 Ethernet interface port
- 15 pages per minute
- 600 x 600 dpi
- 350 sheet paper tray
- Support 11"x17" (Tabloid), 8-½"x11" (Letter), and 8-½"x14" (Legal) paper trays

Two color plotters, one for each traffic management center, shall be provided that are networked on the LAN and that meet the following minimum requirements:

- 10/100 Ethernet port
- Support 42”W paper rolls
- 1200 x 600 dpi

8.1.6 Uninterruptible Power Supplies (UPS)

Uninterruptible Power Supplies shall be included that can support all central system components—including workstations—running without disruption for at least the first 30 minutes of a power outage. The UPS shall initiate an orderly shutdown of all operating systems prior to loss of UPS power. At least two rack-mount UPS’ shall be provided for the central servers. Each UPS shall be no larger than 3RU high and shall have the server loads distributed between them. Dual power supply cords from each server shall be divided between two UPS devices. UPS power management software shall be provided for connected servers to fail over to the secondary UPS in the event the other UPS fails or is taken off-line for maintenance, exchanging batteries, etc. The software shall provide the functionality to automatically shut-down the attached servers only if both of the UPS devices lose primary power.

8.1.7 Multiple Site Access

The system shall allow multiple users from one or more locations (i.e. both traffic management centers, field network locations, etc.) to access the system concurrently over an Ethernet-attached network interface, virtual private network (VPN) over the Internet, or via dial-up remote access telephone lines.

8.1.8 Data Backups

Hard drive images for each server and workstation shall be provided on DVD that can restore all computers to their settings at system acceptance, i.e., including all installed software and all database configurations.

Engineering/IT will backup the ATMS server(s) from City Hall as part of normal backup routines for remaining IT application servers.

8.2 System Capacity

The system shall accommodate at least 500 controllers.

The system shall accommodate at least 100 ITS field devices.

The system shall accommodate at least 50 control groups (i.e. coordinated systems).

The system shall accommodate at least 500 system detectors.

The system shall accommodate at least 10 concurrent users, including remote users.

8.3 Security/Reliability

8.3.1 Start-up and Shutdown

At initial startup, the system shall begin normal operation with no prior state information.

The system shall save all data and end all processes in an orderly manner at user-initiated system shutdown.

The system shall save all data and end all processes in an orderly manner upon shutdown of the operating system.

Startup and shutdown operations shall be logged and/or initiate a user-defined alarm, where possible.

8.3.2 User Access Permissions

The system shall recognize different levels of user permissions that allow user-configurable read and/or write access to various system functions. Three permissions levels to which users can be assigned shall be pre-configured:

- Administrator (full access)
- User (full access with the exception of low-level OS and system administration functions not needed on a daily basis such as setting user permissions, adding or removing system devices, etc.)
- Limited user (read-only access)

All login and logout activity shall be logged.

8.3.3 Remote Access

Users shall be able to access the system remotely via dial-up or VPN over the Internet. Web browser-based remote access shall also be supported.

8.3.4 Paging

The system shall have the ability to send pages. The system shall be configurable to page numbers at user-defined alarm conditions. The system shall allow the user to configure which number(s) are paged for different alarm conditions. The system shall be configurable to page different numbers at different times of day and day of the week.

8.3.5 Clock Synchronization

The system shall be able to broadcast time to servers, workstations, field controllers, and field devices at user defined intervals. Servers shall keep their system time synchronized with the NTP server at all times. Workstations shall synchronize their clocks to the NTP server at login.

8.4 System Feature Requirements

8.4.1 Graphical User Interface

The graphical user interface (GUI) shall be the primary means to access system features and displays. It shall conform to Microsoft Windows standards and be consistent, intuitive and easy-to-navigate. It shall make use of menus, dialog boxes and icons, to minimize reliance on a manual for most tasks.

Keyboard shortcuts shall be provided for common system functions.

The system shall use traffic engineering terminology throughout.

Displays shall not affect system performance.

8.4.2 System Map

The system shall support the display of a system map of the City of Newport News with icons denoting system devices and various status levels for different devices. The map will be dynamic in nature such that the background can be updated without reconfiguring the system device icons.

System maps shall support a variety of vector and raster graphics formats as the background. Supported vector formats shall include:

- ESRI shape files
- CAD drawings (.dwg, .dxf, .dgn)
- Spatial database engine (SDE) layers

Supported raster file formats shall include:

- Bitmap (.bmp)
- JPEG (.jpg)
- Tagged Image File Format (TIFF) (.tif)

8.4.3 Panning, Zooming, and Layers

The system map shall support panning and zooming.

The system map shall support multiple layers so that different types of background information can be turned on and off as desired. Panning and zooming shall not cause layers to misalign. For ESRI shape file layers, the user shall have the ability to change colors, fonts and line weights. The user shall be able to re-order layers without removing and re-adding.

The user shall be able to set a minimum zoom level for each layer and system device on the map. This shall be the zoom level beyond which the layer or device is not viewable. This controls the level of detail/information shown when viewing a wide geographic area.

Map icons shall be user-selectable and change in size commensurate with the zoom level.

The system shall allow the user to define saved map views that can be selected later. For instance, users should be able to select a saved map view to quickly zoom to a particular control group or geographic area of the city.

8.4.4 Adding and Modifying Devices or Objects

These devices shall be selectable from the map so the user can view status and properties, or edit parameters or settings. These icons shall update in real-time at a refresh rate of once per second to show high-level status such as the mode of operation at an intersection.

The user shall be able to assign system detectors to directional links to show congestion levels based on the measurements of those system detectors and user-defined thresholds. Link congestion status shall be updated a minimum of once per second.

The map GUI shall provide a straightforward means to add devices to the map, remove devices from the map, or move devices on the map.

The map shall support display of a user-editable legend defining icons.

The user shall be able to assign hyperlinks to icons on the map so that clicking on the hyperlink automatically opens a web browser window to the specified URL (e.g. Intranet/Internet address).

8.5 Intersection Monitoring

The system shall provide the user the ability to monitor individual intersections to view their operation and status in real-time.

8.5.1 Intersection Maps

The system shall provide the ability to view static and dynamic intersection information in real-time. At a minimum, static information shall include intersection geometry (number of lanes, turn lane lengths, cabinet locations, pole locations, detector locations/zones, and ITS devices). Dynamic information shall include current plan, phase status, coordination status, alarm status (if any), pedestrian activity, and preemption/priority status. The refresh rate shall be once per second.

8.5.2 Time-Space Diagrams

The system shall include a time-space diagram viewer for a selected series of intersections that shows “green bands” for coordinated phase green times and offsets. The time-space diagrams shall also show the actual green usage for the previous cycle.

8.6 Traffic Control

8.6.1 Distributed Control

The system shall be distributed. The central software shall make the most use of the memory, processing and programming capabilities of the local controllers,

storing timing plans and parameters in the local controller to the extent possible. However, the system shall have centralized traffic control functions, effectively acting as a master controller over multiple groups of intersections, where those group assignments can be changed by time-of-day or other traffic responsive thresholds.

8.6.2 Manual Control

The system shall allow the user to manually override the current program in effect for any intersection or group. The manual override should be programmable to allow for override for a specified time period.

8.6.3 Central Flash

The system shall allow the user to place an intersection or control group in flash mode by time-of-day and day-of-week.

8.6.4 Time-Based Control

The system shall include a scheduler that allows the user to program time-of-day, day-of-week, and day-of-year schedules for each control group. Keeping with the principle of distributed control, the timing plans should be stored locally to the extent possible.

8.6.5 Traffic-Responsive Plan Selection

The system shall provide a traffic-responsive plan selection (TRPS) algorithm that can initiate transition to a new timing plan based on user-defined thresholds of system detector measurements over a user-defined interval. The thresholds should allow for various inputs by time-of-day and evaluate data in increments of 10 for 15 minute intervals.

The TRPS algorithm shall limit the amount of switching between plans that is allowed.

8.6.6 Dynamic Grouping

The system shall be able to dynamically move intersections from one group to another by time of day, TRPS, or operator intervention.

8.6.7 Transit Vehicle Priority/Emergency Vehicle Preemption

To accommodate future needs, the system shall be able to interface with local bus priority and emergency vehicle preemption functions. All priority and preemption activity shall be logged and easily reportable.

8.7 Database Features

All system data shall be stored in a database management system (DBMS) back-end. The DBMS shall support common data exchanges with other databases using Open Database Connectivity (ODBC) or similar open exchange formats. All DBMS entries shall be checked for data type and allowable range to ensure data integrity.

8.7.1 Intersection Controller Data

Users with appropriate access permissions shall be able to upload or download each controller's database to the DBMS. Uploads and downloads shall not interrupt normal operation of the controller, unless a download involves changes that require the controller to reinitialize. The system shall ensure an upload or download is done in full or not at all.

The system shall allow the local controller database to be compared with the DBMS with discrepancies logged. The user shall be able to select which database to apply to resolve the discrepancy. A system-wide discrepancy report will be generated on a daily basis and automatically stored on the primary system servers.

The system shall allow a user to make a copy of a controller database while removing site specific information (e.g., cross streets, identification number).

8.7.2 Import/Export of Timing Plans in Synchro File Format

The system shall allow the user to import and export timing plans to Synchro 6.0 or the most current version at the time the equipment is purchased.

8.7.3 System Detector Data

The system shall be able to download and store system detector data for off-line analysis. It shall store all data up to a user-specified time, overwriting older data.

8.8 Status Monitoring

The system shall monitor all field devices and log activity such as:

- Communication errors
- Controller failure
- Flash condition
- Local and system detector status
- Cabinet door open
- Conflict monitor status
- Pedestrian actuation
- Conflicting local controller and system data
- Local preemption
- Local manual control

8.8.1 Status Displays

The system shall provide real-time status displays, refreshed once per second, with detailed information on the following:

- Controller status (e.g., mode, green phase(s), ring status)
- Coordination status
- Preemption status
- Time base status
- Detector status
- Malfunction Management Unit (MMU) status (for TS-2 Type 1 cabinets)

- Group status

8.8.2 Alarms/Paging

The system shall be configurable to page numbers at user-defined alarm conditions. The system shall allow the user to configure which number(s) are paged for different alarm conditions. The system shall be configurable to page different numbers at different times of day and day of the week. The system shall support distribution to at least 50 different paging numbers, or provide an email-to-paging interface.

8.9 Reporting

8.9.1 Predefined Reports

The system shall produce a variety of predefined reports to help users manage system performance. Reports shall include a high level of detail and be professional in appearance in order to not require substantial formatting before being distributed to stakeholders. Predefined reports shall include, at a minimum, for either intersections or control groups:

- Measures of effectiveness
- Intersection detector volumes
- System detector volume and occupancy
- Communication faults
- Detector faults
- Local alarms
- MMU faults
- Group reports
- Group traffic-responsive plan changes
- Traffic-responsive system detector parameters and threshold comparisons

8.9.2 Custom Reports

The system shall allow users to define custom reports from any database entry either from scratch or based on a predefined report.

8.9.3 Event Log

An event log shall record system activity by date and time. It shall be viewable, sortable, filterable and printable.

8.10 Other ITS Devices

8.10.1 CCTV Subsystem

The system shall support a closed-circuit television (CCTV) camera interface.

- The CCTV subsystem shall be able to support 50 cameras (36 planned with room for future expansion).

- The CCTV video distribution system shall be digital, with field encoders and central office decoders. It shall support MPEG-2 and MPEG-4 video compression standards.
- The CCTV subsystem shall share the same user interface as, and be integrated with, the central system software.
- The CCTV subsystem shall allow the user to view 10 full-motion video feeds simultaneously.
- Video and control shall be shared between the Newport News Operations Center, Newport News City Hall, the Emergency Operations Center (EOC) the VDOT Hampton Roads Smart Traffic Center, and shall provide room for expansion.
- The CCTV subsystem shall include logic for a control hierarchy. Higher priority users (based on login identification) shall be able to assume pan/tilt/zoom control over a lower priority user. Once assuming control of a camera, a user should be able to lock out lower priority users. After a user-configurable length of time of inactivity, the lock should end allowing any user to assume control. The interface shall indicate which login has control. After a predetermined period of inactivity, the CCTV subsystem shall support automatically returning to a default preset position.

8.10.2 DMS Subsystem

The system shall support a dynamic message sign (DMS) subsystem.

- The system shall be able to support the use of 20 portable DMS simultaneously that will communicate with the central system via a cellular modem.
- The signs shall support NTCIP standard.
- The central software shall communicate with the signs via NTCIP standard.
- The DMS subsystem shall share the same user interface as, and be integrated with, the central system software.
- The user interface shall show the current message as shown on the sign and allow the user to select a message from a library for a given sign.
- The system shall poll for status and diagnostic information per the NTCIP standard and log errors and raise system alarms.

8.11 Local Intersection Functional Requirements

This section describes local intersection requirements, which are based on the Technology Review portion of the feasibility study. The Newport News traffic signal system may have some combination of intersections with:

- NEMA TS-1 cabinets (re-use existing) and NEMA TS-2 Type 2 controllers (new)
- NEMA TS-2 cabinets (new) and NEMA TS-2 Type 1 controllers (new)

All existing cabinets are TS-1. The majority, if not all, will be upgraded to TS-2, with the possible exception of a number of pole-mounted cabinets in the

downtown and southeast community. The functional requirements listed below apply to all controllers.

Controllers shall be fully actuated. They shall be fully compatible with the central software and allow block upload and download of all timing plan parameters. They shall meet the minimum specifications described below.

8.12 Hardware

- Shall meet NEMA TS-2 standards for traffic controllers.
- Shall have a front panel multi-line alphanumeric backlit display to show all operational parameters and states.
- Shall have an alphanumeric keypad to allow the controller to be programmed without requiring a laptop.
- Shall store all timing and control parameters in flash memory. Settings shall not be lost during power outages.
- Surge protection shall be provided for all hardware.

8.13 Communications

- The software shall be updatable from a computer or laptop via serial or Ethernet connections.
- Built-in 10-Base T Ethernet and Infrared ports.
- Shall be able to receive time broadcasts from the central system software or a Network Time Protocol (NTP) server to update internal clocks.

8.14 Traffic Control Features

- 16 Vehicle Phases
- 16 Pedestrian Phases
- 4 Timing Rings
- 16 Overlaps
- 64 Detectors
- 16 System Detectors, each with up to 10 different traffic response thresholds
- 120 coordination plans, each with its own cycle length, offset and split

8.15 Time-Base Control

- 200 Events
- 99 Day Programs
- 10 Week Programs
- 36 Exception Day Programs that can override normal day programs

8.16 Preemption/Priority

- 6 Preemption Routines
- 6 Priority Routines

8.17 Logs

- Local Alarm Log
- Communications Fault Log
- Detector Fault Log
- System Detector Log
- Measures of Effectiveness (MOE) Log
- Detector Volume Count Log
- Cycle MOE Log
- Malfunction Management Unit (MMU) Fault Log (for NEMA TS-2 cabinets)

8.18 Diagnostics & Status Displays

- Monitor Compatibility Diagnostics
- Monitor Field Status Diagnostics
- Cycling Diagnostics
- Detector Diagnostics
- Port Message and Communication Status Displays
- Hardware I/O Status Display
- MMU Status Display

8.19 Communications

8.19.1 Communications with On-Street Equipment

The system shall communicate with all on-street equipment at a minimum of once-per-minute to monitor status. Should communication between the central system and a controller fail, the controller shall revert to its local TBC settings.

8.19.2 Media

The system shall support Ethernet communications with field devices over fiber optic cable or twisted pair copper wire.

8.19.3 NTCIP Compliance

The system shall comply with the following National Communications for ITS Protocol (NTCIP) standards (including all applicable base standards referenced therein):

- NTCIP 1202: Object Definitions for Actuated Signal Control (ASC)
- NTCIP 1203: Object Definitions for Dynamic Message Signs (DMS)

8.19.4 Traveler Information Interfaces

In support of regional traffic/incident management and information sharing between agencies, the City's upgraded ATMS platform will enable better use of available staff by automating the distribution/delivery of information to other partnering traffic management agencies.

VDOT's primary traveler information system is centered on the Virginia Operational Information System (VOIS) and the 511 telephone system. VDOT's VOIS platform is undergoing major upgrades, which are slated to be completed in late 2006. Many of these upgrades have not been sufficiently documented to a level that will allow for the City of Newport News to define an interface with VDOT and the City's proposed ATMS platform. Therefore, once both systems (e.g. the City's ATMS and VDOT's VOIS2) are operational a formal interface specification should be developed for sharing information, or directly entering information, between the two agencies. At a minimum, the selected ATMS platform shall provide:

- The ability to store and catalog video image snapshots for each City camera location on a periodic basis (i.e. once per minute) for the purpose of sharing with regional traveler information systems.
- The ability to track and update local construction, lane closures, and planned special event schedules to supplement 511 and other traveler information services.
- The ability to track and update local detours (traffic or weather/flood related).
- Exchangeable data formats (i.e. XML, GIS shape files, etc.)

9.0 Summary

9.1 Framework for the Future Policies

Within the City of Newport News' Framework for the Future, there are 8 key goals within the Transportation section (Chapter 4). These goals are as follows:

GOAL 1	Plan and develop a balanced transportation system to reduce congestion and support the city's future growth and development.
GOAL 2	Improve bus service in the city.
GOAL 3	Improve the city's streets to accommodate existing and projected traffic.
GOAL 4	Reduce the impact of traffic on residential neighborhoods.
GOAL 5	Increase public awareness and involvement in transportation planning.
GOAL 6	Obtain alternative funding sources for transportation projects and improvements.
GOAL 7	Reduce the number of vehicle trips with special emphasis on reducing single occupancy trips by car.
GOAL 8	Develop the city's Airport and Seaport as quality facilities.

This section sets forth the following recommendations for additional goals, policies, strategies, and implementation for the advanced traffic management system in order to enhance the existing Framework for the Future.

Transportation GOAL 9: Plan and implement a "responsive" advanced traffic management system to optimize the efficiency of traffic flow along City streets.

POLICY 9.1: Develop an advanced traffic management system that can be implemented with a "phased" approach of compatible modular components.

Strategy 9.1.1: Consider alternative procurement processes for advanced traffic management system to allow for integration of components.

Strategy 9.1.2: Clearly define and hold firm the requirements that the system is to be maintainable, flexible to accept component modifications and constructible within funding schedules.

IMPLEMENTATION 9.1:

9.1.1: City to define their needs through development of a "Signal System Feasibility Study" and an Intelligent Transportation System (ITS) "Master Plan".

9.1.2: Provide the opportunity for system equipment vendors to develop a "test-bed" environment allowing competitive evaluation and bidding process prior to the selection of the traffic signal controller hardware and software.

POLICY 9.2: Develop a system that is capable of being expanded through the traditional signal system life cycle and can incorporate new technologies.

Strategy 9.2.1: Provide for system expansion with new development and roadway improvement projects including fiber, ITS field devices, signal upgrades, etc.

Strategy 9.2.2: Review current transportation management technologies on a regular basis to determine system benefits of upgrade.

IMPLEMENTATION 9.2:

9.2.1: Facilitate staff evaluation of new hardware and software and field technologies and update the "Signal System Feasibility Study" and Intelligent Transportation "Master Plan" as needed for phased implementation.

POLICY 9.3: Evaluate reliable communications alternatives and develop an infrastructure capable of linking traffic signals components (field and central) and intelligent transportation systems as integrated components.

Strategy 9.3.1: Develop a comprehensive communications backbone (City-owned not leased) to be accessible by other City departments.

Strategy 9.3.2: Provide supporting resources to troubleshoot and maintain the integrity/reliability of a responsive communication infrastructure.

IMPLEMENTATION 9.3:

9.3.1: Coordinate the resources of Newport News Public Schools and the City's Department of Information Technology for strategic use of existing fiber infrastructure and expansion routes to minimize deployment costs.

9.3.2: The Signal System Feasibility Study will be formatted to consider communications alternatives to evaluate the cost-effectiveness of expanding the City's existing traffic management capabilities and communication resources.

POLICY 9.4: Provide Intelligent Transportation System devices at key intersection, along with programmable traffic signal control to allow for monitoring, responding, and information dissemination.

Strategy 9.4.1: Regionally coordinate coverage locations with adjacent transportation management agencies to minimize unnecessary overlap and allow for sharing information with other agencies.

Strategy 9.4.2: Develop Memorandum of Understanding (MOU) with Virginia Department of Transportation Smart Traffic Center for regional traffic incident management support.

IMPLEMENTATION 9.4:

9.4.1: Install cameras for remotely monitoring traffic conditions, verification of incidents, and for support of regional incident management strategies.

9.4.2: Procure and deploy portable dynamic message signs for use in alerting motorists to short- and long-term road/lane closures, special event routing, and extended diversion routes.

9.4.3: Develop prioritized deployment list based on locations recommended in the ITS Master Plan.

9.4.4: Procure and deploy over-height vehicle detection/warning systems, flood detection/warning systems, and other devices to provide safer travel conditions for motorists.

Transportation GOAL 10: Provide for interagency coordination via the ATMS to optimize efficiency and enhance capabilities of emergency operations center (EOC).

POLICY 10.1: Develop standard procedures for coordinating information between the ATMS and the EOC.

Strategy 10.1: Develop data sharing guidelines and MOUs for conveying and receiving emergency situations.

IMPLEMENTATION 10.1:

10.1.1: Identify specific data to share with EOC.

10.1.2: Code data in readable format and identify events that require implementation plans.

10.1.3: Develop action plan for responding to data received between EOC and Department of Engineering.

10.1.4: Develop action plan for automated data sharing associated with emergency information for 511 traveler information.

10.1.5: Develop an action plan to integrate the City's EOC with the regional evacuation and emergency response systems.