Deliverable For:

Gateway Cities Traffic Signal Synchronization and Bus Speed Improvement Project

I-5/Telegraph Road Corridor

Deliverable 3.6

Requirements Analysis

FINAL

Version 1

Submitted To:

Los Angeles County

Department of Public Works

Submitted By:

Siemens Energy & Automation, Inc.

Gardner Transportation Systems Business Unit

April 8, 2002

Revision History

Version	Date Submitted	Comments
Draft Version 1a	August 29, 2001	Partial submission: ATMS section
Draft Version 1b	August 30, 2001	Addition of requirements table
Draft Version 1c	September 6, 2001	Full submission
Final Version 1	April 8, 2002	Communication Requirements and Agency Comments Incorporated

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1 INTRODUCTION

1.1 Background

The County of Los Angeles Department of Public Works Traffic Signal Synchronization, Operation and Maintenance (SOM) has proven successful in creating an institutional infrastructure to coordinate the activities of the agencies responsible for traffic signal operations in the County. A key feature of this infrastructure is the Forums - groups of bordering agencies created to encourage and promote inter-agency cooperation. These Forums have enabled funding to be targeted at infrastructure improvements along arterial and arterial/freeway corridors in the County's Sub-Regions. Such projects are a critical part of what will eventually be a network of integrated ITS systems in Los Angeles County and in Southern California.

The I-5/Telegraph Road Corridor is one such project which will result in arterial infrastructure improvements along Telegraph Road in the Gateway Cities (South-East LA County) Forum. The Project area contains 39 intersections in 8 different jurisdictions, comprising 6 cities, the County and Caltrans.

The objective of this Project is to design, develop and deploy traffic control systems in the corridor so that the signals along I-5/Telegraph Road can be synchronized across the jurisdictional boundaries. This Project concentrates on the needs of the agencies in this Corridor with respect to signal synchronization along Telegraph Road and recommends improvements to field infrastructure (including controllers, loops, detectors, and communications) and central traffic control systems to meet those needs.

When successfully completed, each of the agencies responsible for traffic signal operations in the I-5/Telegraph Road Corridor will have full access to an Advanced Traffic Management System (ATMS) that monitors and controls the traffic signals under their jurisdiction. Agencies will be able to synchronize their signals with neighboring agencies, and exchange traffic information in real-time.

Agencies will also be able to exchange data with other agencies in the Gateway Cities region. This will allow the agencies to respond to recurrent and non-recurrent congestion in a coordinated fashion across the jurisdictional boundaries. The traffic control systems therefore form part of a larger, regional approach supporting multi-agency traffic signal operations.

1.2 Requirements Process Overview

The User Requirements document represents the first layer of requirements for the Gateway Cities I-105 Corridor Project. The User Requirements document specifies the capabilities of the system in terms a user can understand. This will generate a common understanding of the systems for both the users as well as developers.

Once the User Requirements document has identified the capabilities of the system, the second layer of requirements is the development of the Functional Requirements. The Functional Requirements document identifies the elements of the system that are required to implement the User Requirements. This procedure enables a systematic approach to the first level of system architecture.

The Functional Requirements document describes the major system functions for each of the system components. In addition, all required system capabilities are be expressed using “shall” statements.

Use Case Diagrams depict the Functional Requirements of the I-105 Corridor Project. At the highest level, Use Case Diagrams help capture the externally required functionality for a given aspect of a system. These diagrams are intended to allow user and technical audiences to gain mutual understanding of a system’s operational characteristics.

Use Case Diagrams are composed of actors (stick figures), use cases, as well as links (connecting lines/arrows). The Use Case Diagram provides a mechanism to graphically show how actors play out their role in relationship to the use cases. The actors/users in the Use Case Diagram represent the external interactions with the system, and the use cases represent the transactions that occur within the system.

The Functional Requirements presented in this report comprise a combination of the requirements for the agencies in the Project area. Preparing the requirements for a specific system would comprise the selection of the relevant requirements based upon the information contained in the User Requirements detailing agency specific features.

Based upon the definition of User Requirements a series of Functional Requirement reports have been developed. Deliverable 3.2.1 addresses the Functional Requirements for the ATMS and Local City Control (LCC) sites in the I-5/Telegraph Road Corridor. This was complemented by two other Functional Requirements analyses. Deliverable 3.5.1 examines the interface between these ATMS and the higher-level systems that support the Corridor and regional operations, by defining Integration System Functional Requirements. Deliverable 3.6.1 derives the communications requirements both from the ATMS to field devices and also for ATMS to other ATMS in the Corridor.

This report presents the combined ATMS, LCC and communications requirements in one document.

1.3 Purpose of Document

This document is being presented for the purpose of compiling the Functional Requirements for the I-5 Telegraph Road Corridor Project. These Functional Requirements defined are for Advanced Traffic Management Systems to be used by the signal operating agencies for traffic signal control and monitoring. The Functional Requirements carry forward the User Requirements and Use Cases (Deliverable 3.1.2).

This document is organized into the following Sections:

Section 1: Introduction

Presents the Project background and introduces the document.

Section 2: System Overview

Describes the CAMS architecture and the relationship between this and other projects.

Section 3: Concept of Operations

Describes the enhancements to operations within the corridor to be brought about by the project and examines how the systems will support intra and inter agency operations, traveler information and system security.

Section 4: National Standards

Identifies applicable national standards and examines consistency with the National ITS Architecture.

Section 5: Use Case Analysis

Provides the Use Cases, which the Functional Requirements address.

Section 6: ATMS Functional Requirements

Presents the Functional Requirements as derived from User Requirements and Use Cases developed previously. Each Section of the Functional Requirements includes a subsection that repeats the User Requirements from the previous deliverable. These Functional Requirements and the User Requirements are categorized by Use Case.

Section 7: Detection Technologies

Examines currently available detection technologies and identifies technologies applicable to the Project area.

Section 8: Local Traffic Control Center Considerations

Identifies requirements for the individual city's control centers and identifies typical equipment and its attributes.

Section 9: Communications Requirements

Presents the requirements for the communications system derived from the above User and Functional Requirements for field-to-center and center-to-center communications system requirements.

Section 10: Requirements Traceability

Describes the requirements tracking process and the foundations of the Traceability Matrix. Functional Requirements are traced to User Requirements and Use Cases.

1.4 Regional Area and Agencies Involved

The I-5/Telegraph Road Corridor Project spans many jurisdictional boundaries. It will be integrated, or have the ability to integrate, with many other projects and existing systems in the region. The following cities and agencies are involved in the Project:

- Commerce
- Downey
- La Mirada
- Montebello

- Pico Rivera
- Santa Fe Springs
- Los Angeles County Department of Public Works
- Caltrans District 7

1.5 Referenced Documents

The following documents have been used as reference material in the preparation of this report:

- I-5/Telegraph Road Corridor Project
    - Deliverable 3.1.2:Advanced Traffic Management System (ATMS) User Requirements
    - Deliverable 3.6.1: Communications Requirements
- I-105 Corridor Project
    - TSMACS User Requirements Report (Final)
    - Functional Requirements Report (Draft)
- San Gabriel Valley Pilot Project
    - System Design Report, Final Version 1.0
- South Bay Traffic Signal Synchronization and Bus Speed Improvement Plan –Part III
    - Deliverable 2.2.4: Final Local Traffic Control Center(s) Facility and Computer System Requirements

2 SYSTEM OVERVIEW

2.1 The Information Exchange Network Architecture

The County DPW has developed a system architecture for integrating Advanced Traffic Management Systems (ATMS) for arterial traffic control systems into a regional framework to support the above operational goals. This is the Information Exchange Network architecture (IEN) represented in Figure 2.1. This is the architecture that will be followed in the design of the I-5 Telegraph Road Project.

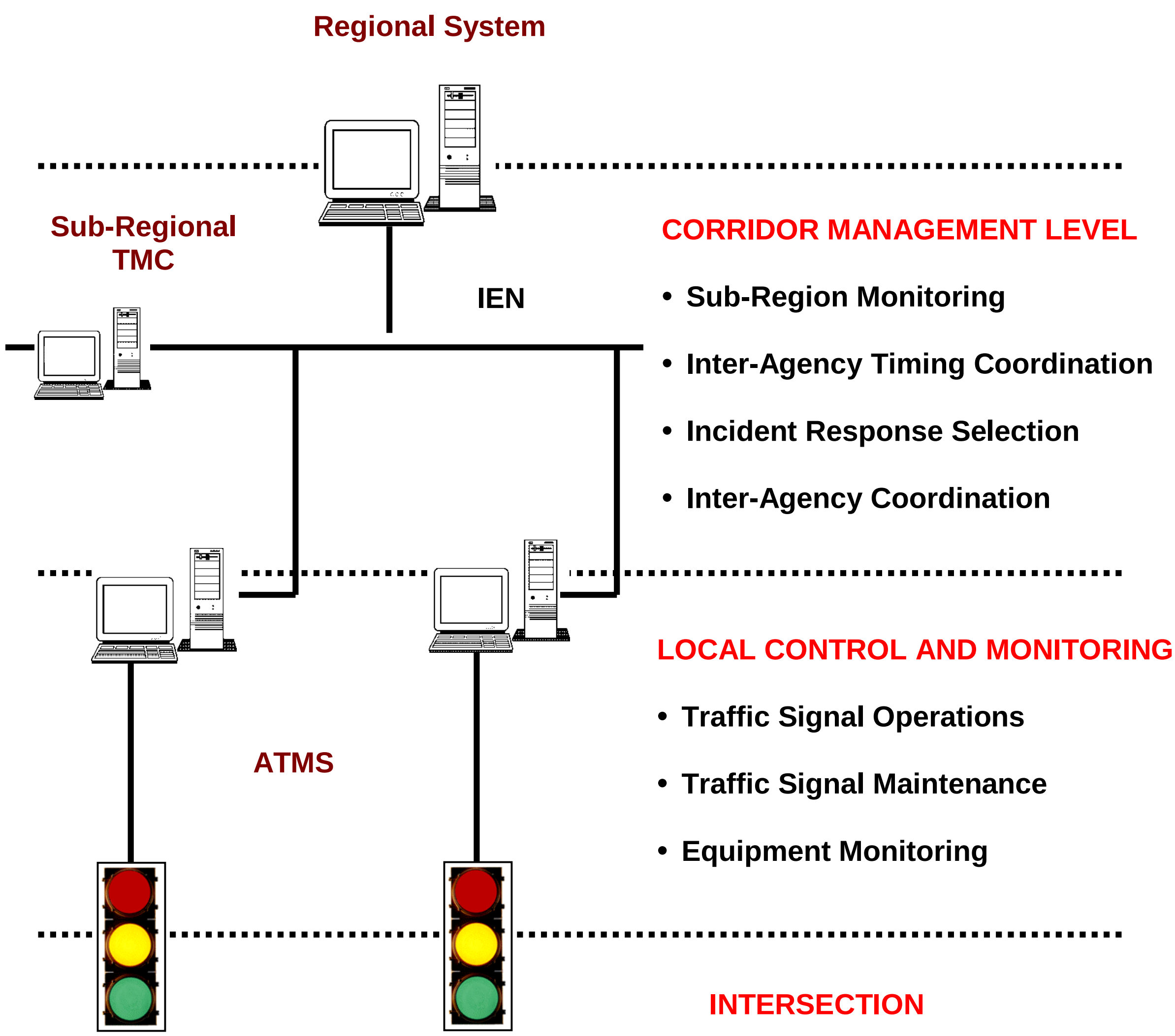


Figure 2.1: The Information Exchange Network Architecture (IEN)

The IEN architecture supports traffic signal operations in three levels. The local level comprises the day-to-day, traffic signal operations carried out by the individual agency – signal timing, maintenance and response to local traffic conditions and events. The Corridor level supports inter-agency coordination and joint signal operations – coordination across jurisdictional boundaries, exchange of local traffic data, and joint response to traffic conditions and events that affect more than one jurisdiction. The final level is the regional level. This permits the arterials of regional significance to be monitored and managed as a single entity (as Caltrans does with the freeway system). Multi-agency, cross-corridor data exchange is supported permitting a countywide response to traffic conditions and major events.

The physical elements of the architecture are ATMSs, interfaces between the ATMS and the regional system, workstations to display shared data (which may or may not be combined with the ATMS), and servers for the collection/transfer of data and to support corridor and regional functions. These components are connected via a communications network known as the Information Exchange Network (IEN). The design of the IEN is being developed as part of the East San Gabriel Valley (ESGV) Pilot Project. The initial application of this structure in the Gateway Cities region is being done under the auspices of the I-105 Corridor Project which has jurisdictions in common with the I-5/Telegraph Road Project.

2.2 IEN Implementation Projects

2.2.1 <u>ESGV IEN Project</u>

The County has undertaken a project to develop the IEN as part of the East San Gabriel Valley (ESGV) Pilot Project. The IEN is focused on providing real-time second-by-second data to partner agencies from multiple traffic signal control systems. As well as developing the IEN communications software, the Project is also developing the following applications that will run on the (?) workstations on the IEN (see Figure 2.2):

- Incident Tracking
- Incident Management
- Planned Events (Scenario) Management
- Data Archiving
- Alarm Distribution
- Reporting

From the aspect of the I5/Telegraph Road Project, these Functional Requirements for integrating systems must reflect the support of these functions.

2.2.2 <u>I–105 Corridor Project</u>

The I–105 Corridor Project will build a “Corridor System” over existing and future integrated ATMS’s that will be housed in a Sub-Regional TMC. The Corridor system’s purpose is to collect data from the individual local city control sites (that house local ATMS), share this data with other agencies within the system and disseminate information to public. The main goal of the corridor concept is to provide a mechanism for the local systems to act in a coordinated fashion to improve synchronization and traffic flow. Figure 2.2 illustrates the relationships between the local ATMS’s and the Corridor system.

The I-105 Corridor Project will have a "Corridor Server" located at the Sub-Regional TMC to facilitate sharing data among local city control sites and County TMC. A single "County Server" at the County TMC will manage information obtained from all the Corridor Servers including the I-105 Corridor.

The Sub-Regional TMC will act as clearinghouse for information and recommended actions to be implemented by each local city control site. The Sub-Regional TMC will recommend specific plans of action from its library of response plans that are created during inter-jurisdictional planning/coordination. A Command Data Interface (CDI) will allow each ATMS to communicate with the Sub-Regional TMC. CDI's will be used to interface the ATMS's to the Information Exchange Network (IEN) and translate existing data into the IEN format for sharing with the Corridor member cities/agencies and ultimately with the County. The architecture provides:

- CDI Definition
- Information Exchange Network (IEN)
- Corridor Server
- County Server

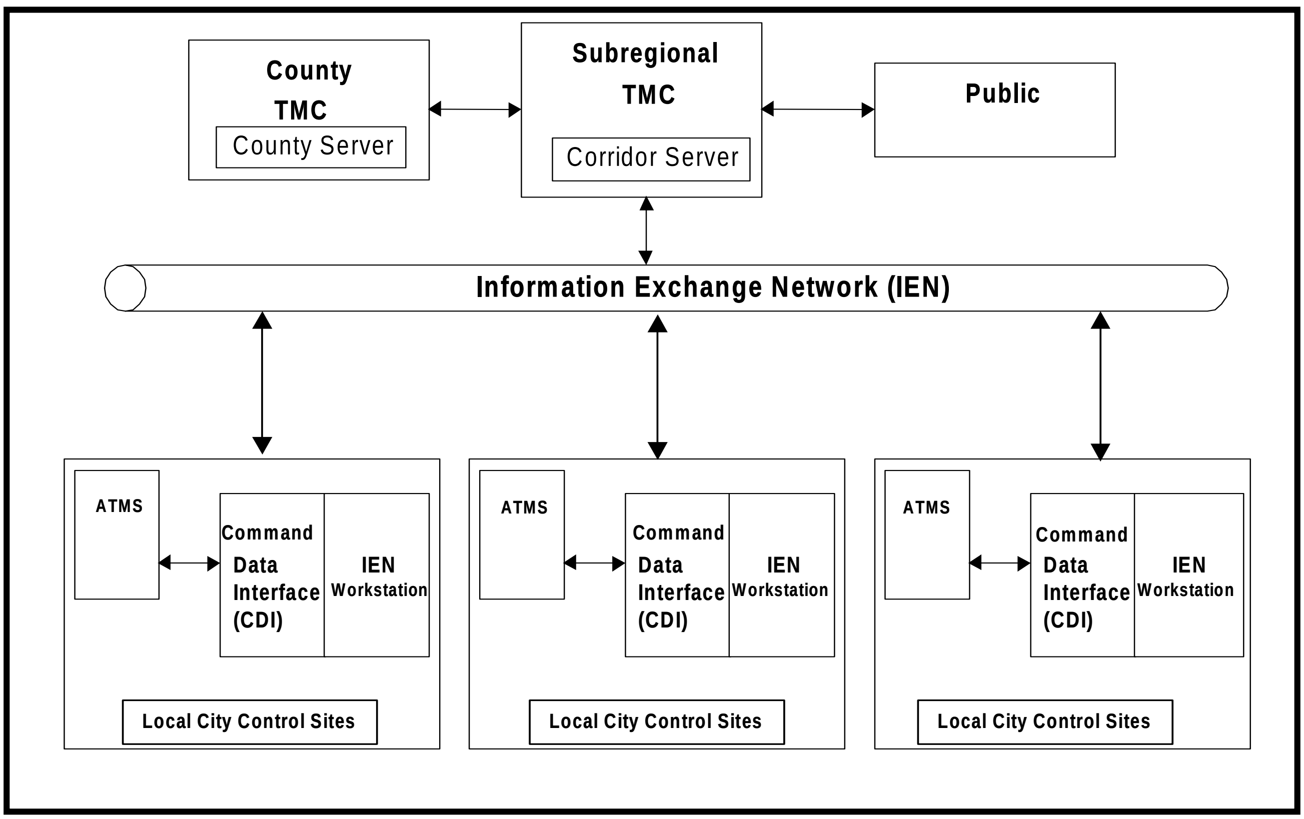


Figure 2.2: I-105 Corridor System Relations

Corridor management and control activities will be coordinated in order for traffic to move efficiently and safely between jurisdictions. This is achieved by the complementary selection of timing plans on adjacent ATMSs. The Corridor will have a WWV Clock serving as the time reference for each ATMS. The local WWV Clock at each ATMS, which, under regular operation is synced to the Corridor clock, will act as a back-up in the event that the Corridor clock is not available.

2.2.3 I-5/Telegraph Road Project

The I-5/Telegraph Road Project assumes the availability of the IEN at the Corridor and Regional levels as provided by the I-105 Corridor Project. The I-5/Telegraph Road focuses upon the selection and integration of multiple ATMSs (for the Cities included in the I-5/Telegraph Road Corridor Project) using the IEN.

The eventual design will include IEN workstations at the local level and the CDI's for the individual ATMSs. These are initially being defined and implemented as part of the ESGV Pilot Project. Additional functionality supporting the Corridor Management Level tasks will be incorporated as part of the I-105 Corridor Project.

The System Integration Functional Requirements for the I-5/Telegraph Road Project takes into account the interface of the ATMS to the IEN (i.e. the CDI) at the local level (see Figure 2.3)

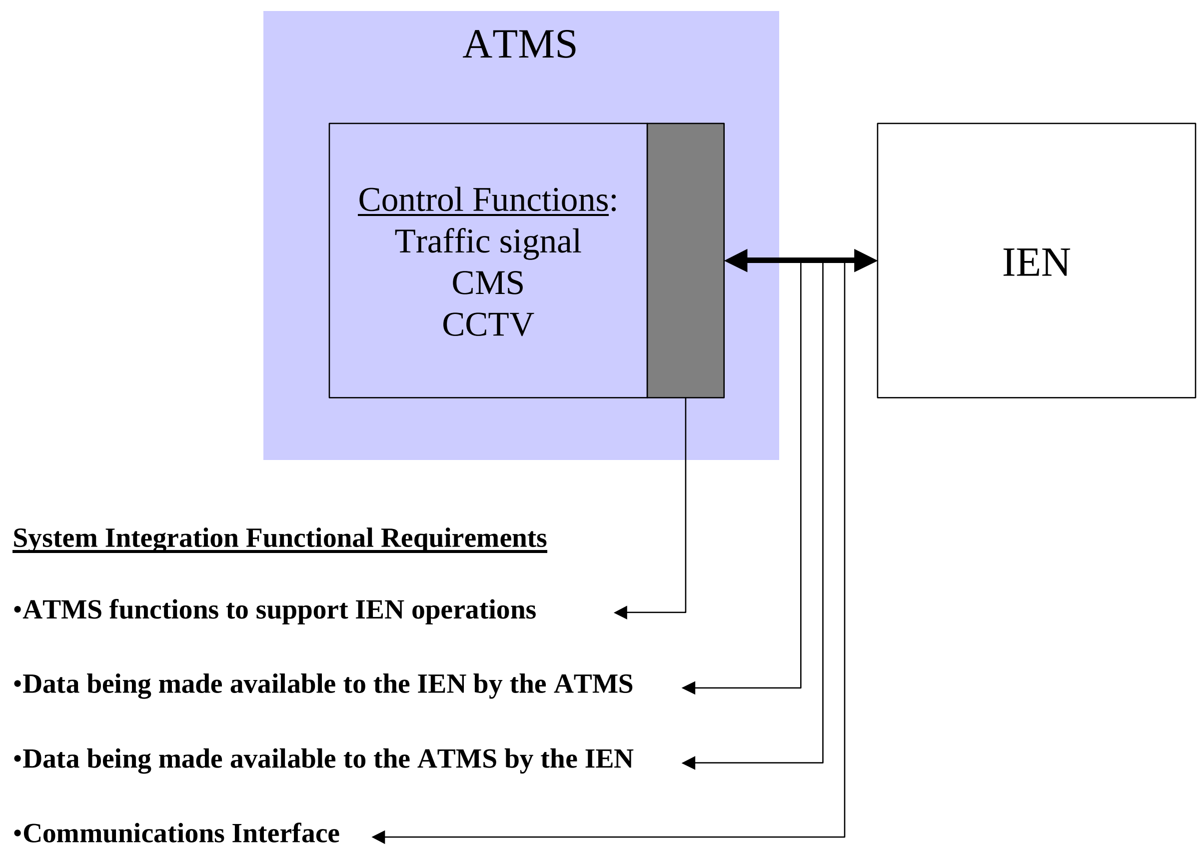


Figure 2.3: ATMS to IEN Interface

3 CONCEPT OF OPERATIONS

3.1 Operational Enhancements

The I-5/Telegraph Road Corridor System will introduce the following operational enhancements into this part of the Gateway Cities area:

- A traffic signal operations and management capability for all participating agencies.

  This will be achieved through the implementation of one or more ATMSs in the Corridor providing a centralized capability to support signal timing plan generation, implementation and management (fine tuning and other modifications), equipment monitoring and reporting, traffic conditions monitoring and reporting, response to incidents and response to equipment failures.

- Coordinated traffic signal management operations among participating agencies.

  The overall objective is to distribute demand among all roadways of the Corridor so as to achieve minimum overall delay and optimum system utilization. This is particularly useful in managing incidents where the reduced capacity on one roadway is handled efficiently through increased throughput on other arterials.

- Exchanging traffic information (link volume, occupancy, incidents, delays, etc.) between the local cities, regional agencies, TMC's, and the public.

  The exchange of information will enable system managers to select proper control strategies and coordinate signals so as to achieve minimum overall delay throughout the entire Corridor. The demand can be controlled through informing the public of traffic conditions and advising them of alternate arterials within the corridor. This will redistribute the demand proportionately in accordance with available freeway and arterial capacity.

- The ability to respond to Caltrans freeway management system incident data.

  This will permit the local agencies to be pro-active in managing the impact of incidents on the arterials by implementing pre-determined multi-jurisdictional coordinated signal timing.

3.2 Operational Concepts

The multi-city and agency participation in the IEN, dictate the consideration of two types of operations centers; a local city control center (LCC) and a Sub-Regional TMC. At this stage of the project, final decision of the configuration of the Sub-Regional TMC has not been reached. For the purpose of the I-5 Telegraph Road Project, the focus is on the LCC.

The potential functions that could be provided by at such a location can be divided into two categories:

- **Internal Functions.** These are functions that relate to the operation of system components within the jurisdiction of a specific city or agency. Examples include the operation of local traffic signal systems, local congestion, incident and event management using CCTV, system detection, CMS, etc. A full range of maintenance activities is also covered such as monitoring central, field and communications equipment and responding to alarms and equipment failures.

- **External Functions.** This includes the exchange of data, information, and/or video with outside users such as other cities, Caltrans, and the general public. The type of data/information exchanged with other agencies typically depends on multi-agency/city agreements and understandings that govern items such as type of data/information exchange, level of access/control, and permissions. For the general public, a key function of the ATMS is to provide information to the Sub-Regional TMC about roadway conditions, congestion, incidents, events, etc. The Local TCC may also receive information about signal problems, accidents, and other items from call-ins by the public.

These functions are illustrated in Figure 3.1 below. External Functions are enabled by the integration of ATMS through the IEN and so form the focus of the Integration Systems Requirements Definition. They are described in the following subsection.

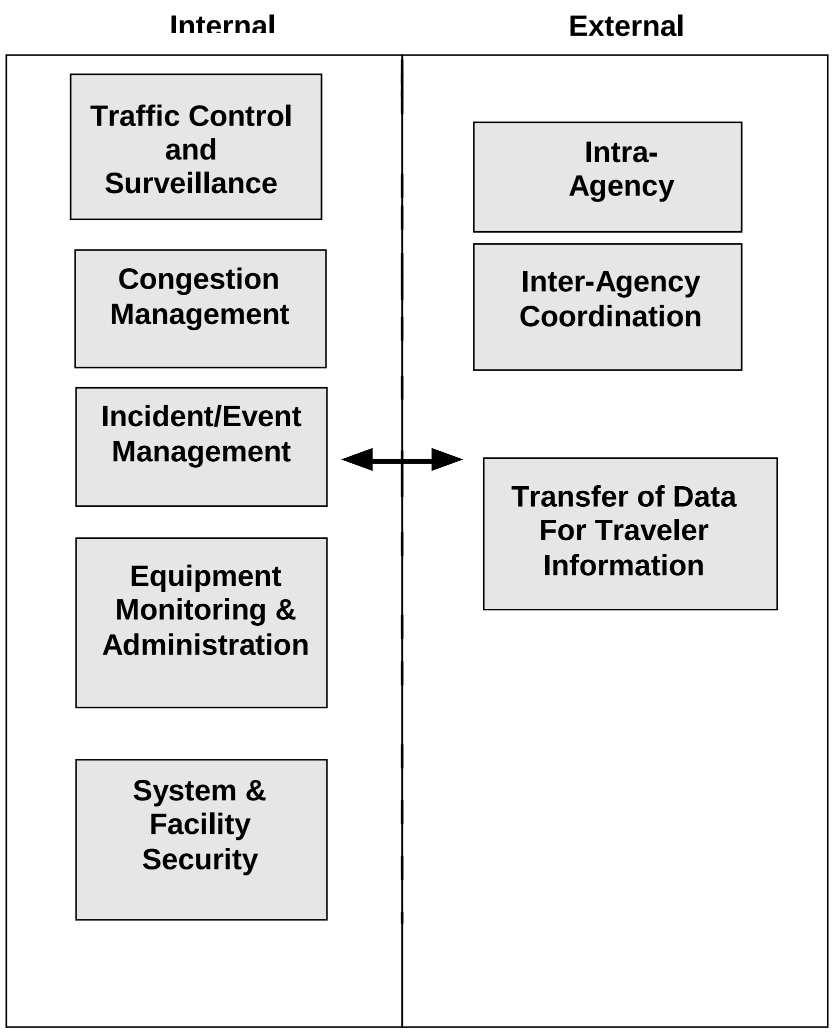


Figure 3.1 ATMS Functions

3.3 External TMC Functions

3.3.1 Intra-Agency Coordination.

The traffic-engineering department of an agency typically works closely with other internal departments such as public works, planning, maintenance and emergency services. Public works may provide input on planned roadway construction activity, unplanned events such as a water main break, and other information related to the street and utility infrastructure. Operations staff uses this information to update or create new response plans. In return, the public works department may be advised of infrastructure-related problems detected by the LCC.

System detector data provides a valuable source of traffic information for planning departments. Long term changes in urban development, and the street network, etc. impacts response plans and potentially the configuration/operation of field devices.

Maintenance staff may or may not be co-located at the LCC (more typically they are off-site at a maintenance yard or other location). An important function of the control site is to advise maintenance staff of field device malfunctions or routine maintenance functions. This may be pre-scheduled and/or the control site may have a direct dispatch facility.

Subject to the policies of the agency, there are typically links to local police, fire and other emergency services for the purpose of detecting and responding to incidents or events. Incidents detected by the system can be reported to emergency services, and they (particularly the police) may report accidents or other problems that impact traffic to the LCC.

For smaller agencies, the link with emergency services is usually by telephone or intercom. Larger TMC's (e.g. Caltrans District 7) may include an officer co-located in their Local TMC facility.

3.3.2 Inter-Agency Coordination

A key function of the IEN is to facilitate coordination with other agencies through the exchange of data and information. Data will flow between LCC's, Sub-Regional TMC's and the County TMC. Rules for the sharing of data and information may be created on a bi-party basis, or through group agreement, depending on the organizational structure and policies of the participating agencies. The following illustrates the kind of information that *may* be shared between agencies, but is not intended as a recommendation or as a statement of policy. Specific rules and permissions for information sharing will need to be developed by the participating agencies as the project progresses.

Possible types of information sharing include:

- Exchange of signal timing and other response plans to facilitate coordination at jurisdictional boundaries, or along major arterials that cross multiple jurisdictions.
- Real-time exchange of system detector data to allow one agency to implement local timing and response plans in response to changing traffic conditions in an adjacent jurisdiction.
- Sharing of CCTV video images, potentially with access control to manage who has access to what images and under what conditions.

Inter-agency coordination also extends into the area of control, under which agencies can coordinate operations to ensure that signal timings best meet the current traffic conditions, this can be:

- On a planned basis, to cope with events as diverse as sporting venues and road closures. The timing of the event is known, the impact can be anticipated and so mitigation plans can be drawn-up and programmed into the system to be implemented at the correct time.
- Automatically, on a real-time basis, using, for example, traffic responsive plan selection over a multi-jurisdictional area. This allows an ATMS to use traffic data from another agency for plan selection.
- Manually, so that an operator can request a plan for an intersection/section of an adjacent ATMS to address a particular traffic situation identified by the operator.

A specific example of this is coordinated response to freeway incidents. Freeway incident information will be received at the sub-regional TMC where it is evaluated. Should a match be found with pre-defined scenarios, and should a multi-agency response be required (e.g. the changing of arterial signal timings or displaying a dynamic message sign) then the request will be sent to the relevant systems to implement the response. The responses will be pre-defined and agreed between the agencies.

The incident information will also be passed on to the ATMS's for analysis and response. This is necessary in the event that a coordinated, multi-agency response is not required but the local agency has decided that under such conditions a response by that agency is necessary.

It should also be noted that the incident information is made available at the IEN workstations located in the agency facilities. Individual and multi-agency responses can be initiated from these workstations given the necessary access privilege.

Finally, there exists the opportunity to share control of field devices within a sub-region covered by two or more agencies for the purpose of implementing regional responses, or to allow agencies to share staffing resources, or simply to permit one agency to view the CCTV images of another and control the other agency's camera.

Specific agreements may be required for all the above types of information and control sharing, and may be subject to various operational restrictions such as time of day/hours of operation.

3.3.3 Transfer of Data for Traveler Information

The Local ATMS collects traffic data such as volume and occupancy from field devices, aggregates the data and deduces congestion parameters such as travel times and speeds. These parameters provide a measure of mobility status on roadways that can be a useful part of an Advanced Traveler information System (ATIS). An ATIS is a means to distribute real-time information on road and traffic conditions to travelers for pre-trip planning and en-route guidance. The effectiveness of an ATIS system increases with area of coverage both geographically and functionally (across different modes). For this reason the traveler information function is typically performed at the Sub-Regional TMC or regional TMC level where data from LCC's is aggregated. Hence, the local systems provide the data to the Sub-Regional and/or Regional TMC.

3.3.4 Security

The multi-jurisdictional nature of the overall system requires that additional security measures be put in place. These go beyond the common ATMS access requirements, and extend to remote users. The local agencies will maintain the ability to define access to their own systems by remote users. This access will be definable by function, by equipment and by time of day.

4 NATIONAL STANDARDS

4.1 Conformance with the National ITS Architecture

Conformance with the National ITS Architecture is addressed in Deliverable 3.1.2: ATMS User Requirements. The deployed systems will be in conformance with the National ITS Architecture through compatibility with the Information Exchange Network (IEN).

4.2 Applicable ITS Standards

During the process of development of the requirements, applicable ITS Standards are identified. A brief discussion of the standard and its potential applicability is included below based upon the ATMS requirements definition. The observations are included in the relevant sections of the Integration System Requirements.

4.2.1 Communications Protocols

A major ITS communications standardization activity is under way in the form of the development of the National Transportation Communications Protocol for ITS (NTCIP).

At the time of writing, the NTCIP has not yet been adopted as a National Standard, so it is not necessary to specify the NTCIP in order to maintain compliance with the National ITS Architecture. However, it would be prudent to accommodate the NTCIP.

Center-to-Center Communications

The NTCIP Center-to-Center protocols are relevant to the I-5 Telegraph Road Project in that they will allow agencies to exchange information, monitor conditions in other agencies' systems, and to implement coordinated responses to incidents and other changes in field conditions when needed. Such data exchange and coordinated response can be implemented either manually or automatically. One agency can monitor, and issue basic commands to (if authorized) field devices operated by another agency, even though those devices may be from a different vendor than those used by the monitoring agency.

Potential applications of interagency coordination include coordinating traffic signals across jurisdictional boundaries, providing traffic signal priority for selected (e.g., behind schedule) transit vehicles, providing real-time information to a shared traveler information center, monitoring traffic volumes on another agency's roadway, coordinating the operation of a freeway ramp meter with an adjacent traffic signal, or posting a warning message on another agency's dynamic message sign.

NTCIP Center-to-Center is covered by two standards: Datex ASN and CORBA. In addition, Message Sets for External TMC Communications is being developed. The Southern California Regional Architecture, as well as the County's IEN, is based upon the CORBA standard. This should be specified for use on this Project.

4.2.2 Incident Management

Arterial incident management has been identified as a requirement by at least one of the project agencies to date. In addition, the ATMS must be capable of being part of the detection and management of incidents on a corridor and regional basis.

The latter is addressed by the I-105 Corridor Project design. Work has already been carried out as part of the SHOWCASE Early Start Projects, which has addressed certain aspects of incident management on freeways and the distribution of incident information. The I-105 design should, therefore, follow the SHOWCASE approach, which provides freeway incident information to other systems to enable them to decide on a suitable response. The Concept of Operations permits both a multi-agency response, coordinated at the Corridor Server/Sub-Regional TMC, and a response by an individual ATMS, should that ATMS have the capability. Therefore, if it is required that a single agency provides response to freeway incidents, that agency's ATMS should be compatible with the SHOWCASE approach to freeway incident management and response.

This leaves the need for the ATMS requirements to accommodate arterial incident management. This has been addressed by the IEN development through inclusion in the Scenario Management functionality of the IEN. It is important that the Gateway Cities Projects (I-105 Corridor and I-5/Telegraph Road Corridor) are compatible with Scenario Management of the IEN. The ATMS should support the IEN Scenario Management functionality.

Incident Management is covered by three standards depending on the point of view of the user.

1. The ITE/AASHTO Advanced Traffic Management Data Dictionary (TMDD) tracks an incident from start to finish and is typically applicable to a Department of Transportation that is tracking an incident on one of its facilities. Data elements for Special Events and Roadway Construction are also defined. The relevant parts of the TMDD should be used by this Project.

2. The IEEE P1512 Message Sets for Incident Management Suite of Standards enables Emergency Management Centers to track in great detail the on-site management of an incident. This is not relevant to the Project.

3. NTCIP 1402 Transit Communications Interface Protocol - Incident Management (IM) Business Area Standard tracks an incident from the point of view – and needs – of the transit agency. This is not relevant to the Project.

These incident management standards have been harmonized through the ITS Data Registry process which should be used as a resource for the system design.

4.2.3 Location Referencing

The Society of Automotive Engineers SAE J2374 – Location Referencing Message Specification Information Report, also known as LRMS, defines a standard mechanism for the exchange of geographic location. These include:

- Address
- Cross Streets
- LinkID
- Longitude, Latitude
- Linear Reference (e.g. Milepost)

The IEN has adopted the message profiles as specified by the SAE's Location Referencing Message Specification Information Report, so this should be specified for use on the I-5 Telegraph Road Project.

5 USE CASE ANALYSIS

As described in Section 3, the User Requirements specify the capabilities of the system in terms that a user can understand. The Use Case analysis, on the other hand, captures users' expectations of the functionality of the system and expresses them clearly in terms that system developers can follow. The User Case model, which expresses top-level Functional Requirements, is the central part of a Requirements Document for the object-oriented development approach[1].

The Use Case model emphasizes interfaces and end-to-end functionality within the "system" by systematically identifying all "system users" and actions they might take. Each "User Case" describes how a "System User" or an "actor" would use the system in each particular "Case". That is, each Use Case describes a particular and observable system behavior. These "behaviors" can be traced back to each identified User Requirement in Section 3. These statements must be easily understood by end users (I-5/Telegraph Road Corridor agencies) and system developers.

The following initial Use Cases are intended to be informal, and will become better defined and more complete through an iterative review process. This document does not intend to explore the Use Case model and analysis in great details.

5.1 System Users

Use Cases are guaranteed to be observable by the fact that they must be connected to one or more "actors". In the I-5/Telegraph Road Corridor System, actors (system users) are the ones who operate various levels of traffic control systems; contribute, access and manipulate traffic data; and disseminate relevant traffic information to other agencies or public motorists. Multiple agencies will be able to coordinate their traffic signals, share real-time traffic information, respond to the Caltrans Freeway Management System and ultimately improve travel speeds along the arterial.

System User/ Use Case Actor	**Description**
Caltrans Freeway System	Caltrans computer system that manages freeway data. It provides selected data to outside agencies through a defined interface.
Sub-Regional Operator	A System Operator who is responsible for managing the Sub-Region. The Sub-Regional Operator function is normally performed at the Sub-Regional TMC, but operators at other locations may also assume this role.

[1] "Developing Object-Oriented Software - An Experience-Based Approach", By Kenneth S. Rubin, IBM Object-Oriented Technology Center, 1997.

System User/ Use Case Actor	Description
County Operator	An Operator who is responsible for monitoring congestion and traffic signal operations across the entire County (the entire system). The County operator function is normally performed at the County TMC, but operators at other locations may also assume this role.
External ATMS	An ATMS (Traffic Signal Management And Control System) which is not part of nor directly compatible with the I-5/Telegraph Road Corridor System.
Field Technician	Technical person within signals group who can make physical repairs to the signals and network hardware.
Intersection Controller	The Intersection Controller is the interface from the overall system to the vehicles on the street.
Local Operator	The Local Operator function is normally performed at a local agency TMC, but Operators at other locations can assume this role if they have the correct security access privileges. Note County also acts as a Local Operator.
Maintenance Operator	An Operator responsible for monitoring the system for equipment problems.
Off-line Operator	The Off-line Operator function is usually performed by a Traffic Engineer and can be performed from any workstation on the network.
System Operator	The System Operator manages the system for others use. This Operator sets up users accounts, equipment configuration, and so forth.
Vehicle Detector	The Vehicle Detector is the system's primary input from the street. Vehicle Detectors include, but not limited to, inductive loops or video detectors.
WWV Clock	The WWV Clock object is the system's interface to a WWV time reference. It provides accurate time information to permit time-based traffic signal coordination between geographically separated intersections within the system.

5.2 Use Cases

The following "cases" intend to capture every type of interaction that the system will have with the "outside" world, based on the User Requirements. These "cases" do not represent the design of the I-5/Telegraph Road Corridor ATMS system. They only describe the interfaces to the system and are used to verify that all requirements for the system have been identified, and all identified requirements have been addressed. The objects identified in the Use Case analysis will be carried forward for to subsequence steps of the object-oriented design process.

5.2.1 Control Traffic

Controlling traffic consists of determining what plan to run, what mode to run the controller in, implementing it via communications, and verifying its correct operation via communications.

5.2.2 Operate Signals

The Local Operator is responsible for operating all traffic signals within the local agency's jurisdiction, such as manually changing timing plans on control modes.

5.2.3 Monitor Signals

The Local Operator monitors signal operation and congestion within the local agency's jurisdiction using status screens, maps and alarms.

5.2.4 Maintain Signals

The Local Operator receives maintenance events and alarms for signals within the local agency's jurisdiction, for purposes of maintaining correct operation of the signals. The Local Operator may make database adjustments or dispatch field technicians in order to correct the problems detected.

5.2.5 Synchronize Clocks

The computers in the system synchronize all their clocks to on or more WWV Clocks.

5.2.6 Generate Timing Plans

Off-line Operator creates and edits timing plans and schedules in order to optimize traffic flow through the system.

5.2.7 Manage Timing Plans

The Local or Off-line Operator can edit signal timing plans and schedules for controllers in the local agency's jurisdiction in order to optimize flow.

5.2.8 Schedule Operations

The off-line Operator sets up scheduled plan changes and other time-of-day operations.

5.2.9 Exchange Coordination Data

External ATMS system exchanges coordinated information with the system through a Control/Data Interface (CDI). Data exchanged includes equipment status, operating modes, traffic levels, events, and plan implementation commands.

5.2.10 Data Archiving

The System stores data regularly for off-line analysis including documenting system performance.

5.2.11 Monitor Congestion

The System monitors congestion and reports it to the Local, Sub-Regional or County Operator via status screens, maps and alarms.

5.2.12 Analyze Data

The Operator can record, review and analyze signal timings and traffic data.

5.2.13 Measure Traffic

Vehicle detectors provide data (e.g. volume and occupancy) to the system. Other parameters or MOES (e.g. vehicle speed, stops, delays, queue length) are calculated by the system based on the collected data.

5.2.14 Monitor Events and Alarms

The Maintenance Operator receives maintenance events and alarms for the system or signals within the local agency's jurisdiction for purposes of maintaining correct operation of the signals. The Maintenance Operator dispatches Field Technicians or contacts a System Operator in order to correct the detected problem.

5.2.15 Generate Maintenance Log Reports

The Maintenance Operator can generate reports of historical data from the logs of events and alarms.

5.2.16 Log Event Details

The system logs events. The Maintenance Operator may enter additional details of field events into the event log database, which will appear when system maintenance reports are printed.

5.2.17 Repair Equipment

The Field Technician is responsible for correcting or repairing problems that occur with field hardware. When the repair is complete the technician notifies the System or a Local Operator that the equipment is operational. If a controller was replaced in the field, then the technician may request a download of timing sheet data to the controller.

5.2.18 Configure Operations

The Off-line Operator configures all traffic control aspects of the system, such as intersection, detector, and group geometry, traffic responsive operation, and connections to traffic data from other jurisdictions.

5.2.19 Configure System

The System Operator manages hardware and software configuration issues, such as file and directory location, database backup and replication and jurisdictional partitioning.

5.2.20 Manage Network

The System Operator performs overall network management on the local area network (LANs) in the system using COTS software packages. Different System Operators may have responsibilities for different paths of the physical network.

5.2.21 Manage Resources

The System Operator manages access to system resources. This includes setting the rights or privileges necessary to access a resource, and resolving dynamic conflicts involving resource locking.

5.2.22 Manage Users

The System Operator adds, modifies, and deletes authorized users and the privileges assigned to each of them.

5.3 The Use Case Diagram

Having defining the actors and the use cases, it is now possible to relate them together. This is illustrated in Figure 5.1, the Common ATMS Use Case Diagram, which depicts those use cases that have been identified as common to all ATMS.

Figures 5.2 through to 5.5 show additional use cases derived from the interviews with the agencies in the I-5/Telegraph Road Corridor. These are described in the following Sections.

Note that in Figure 5.2, a new Operator has been defined for the City of Commerce – that of Police Operator.

5.3.1 View CCTV Image

The Operator can select a camera and view its image on the ATMS workstation. This may also involve control of the camera movement (pan, tilt and zoom) and selection of monitor or display device other than the ATMS workstation.

5.3.2 Control City Camera

The ATMS can control the movement of a CCTV camera within the agency's jurisdiction.

5.3.3 Select Caltrans Camera

The ATMS can request a CCTV image from the Caltrans CCTV system for display on ATMS workstations.

5.3.4 Manage Signs

This comprises the management and monitoring of dynamic message signs. This involves the composition of messages, downloading of messages to the sign and determination of messages to be shown.

5.3.5 Control Signs

This comprises the control of the sign for the selection of messages to be displayed and monitoring of the sign for correct operation.

5.3.6 Response to Incidents

The ATMS can respond to incidents on the freeways and so mitigate the impact on the arterials adjacent to the affected freeway. The ATMS can also respond to incidents on arterials to mitigate their impact. This includes the development and implementation of suitable traffic management strategies.

5.3.7 Priority to Transit

The ATMS can accommodate the modification of signal timings so as to give preferential treatment to transit vehicles in the network. This involves detection of the bus, determination of need for priority, implementation of the chosen control strategy (e.g. modifications of phasing or timing), monitoring of the action and removal of the priority treatment.

5.3.8 Priority to Emergency Vehicles

The ATMS can accommodate the pre-emption of signal timings so as to give preferential treatment to emergency vehicles in the network.

5.3.9 Manage Incidents

Having detected an incident in the network, or having been notified of an incident (such as a special event), this provides the Operator with tools to monitor the incident, record changes in status, and implement suitable mitigation actions. This may also include automated up-dates of the status of the incident based on data from external sources.

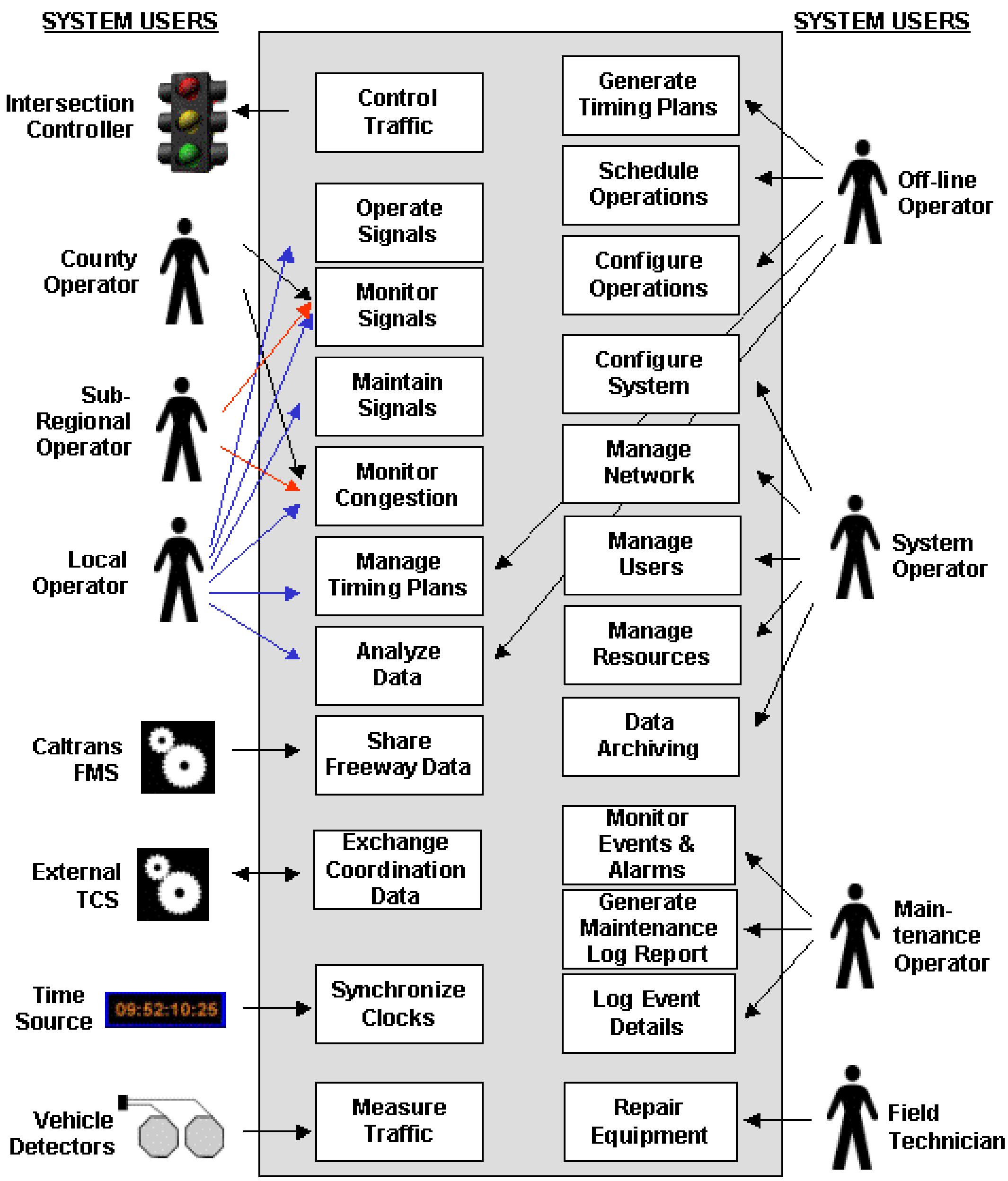


Figure 5.1: Common ATMS Use Cases

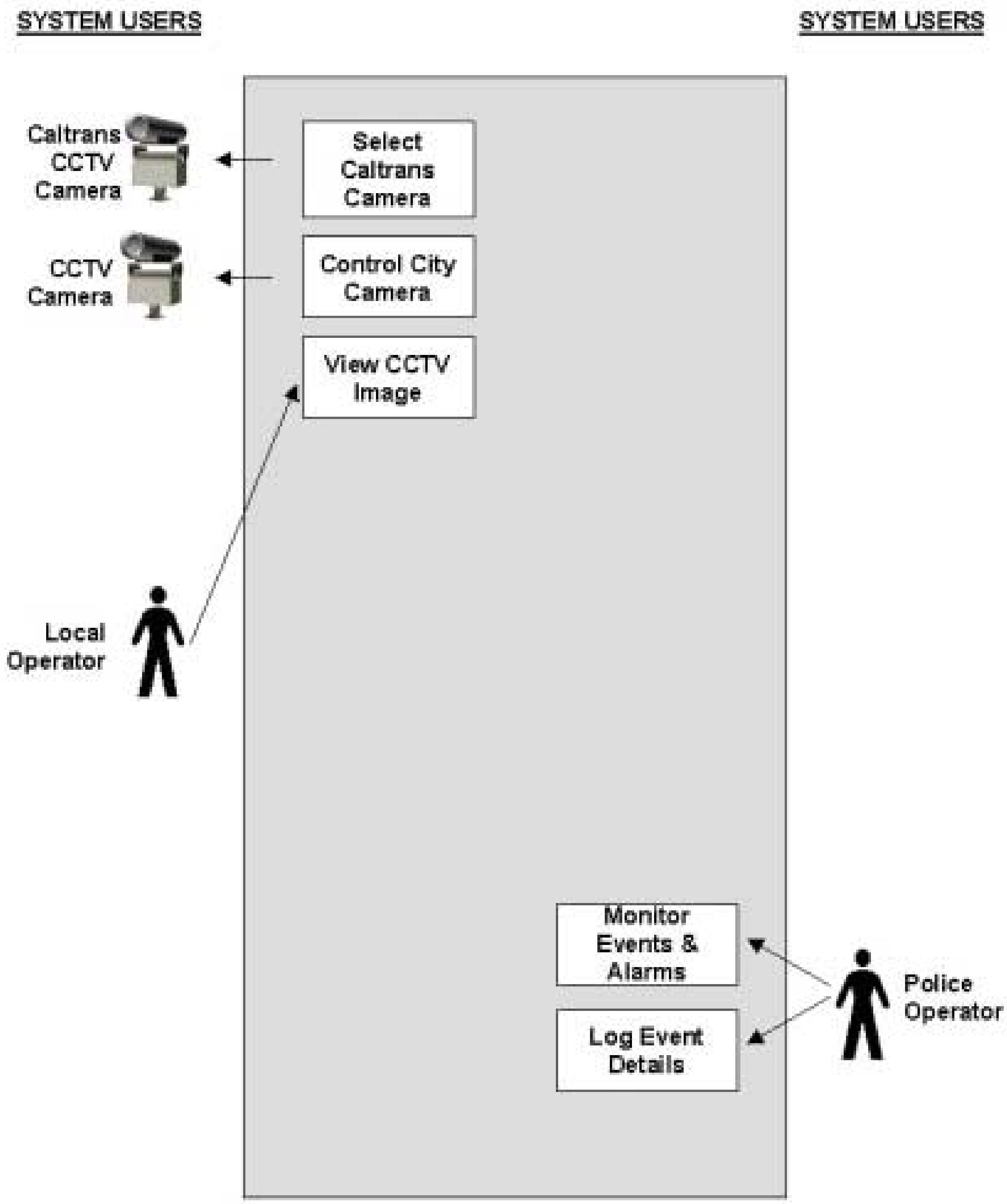


Figure 5.2: Additional Use Cases – City of Commerce

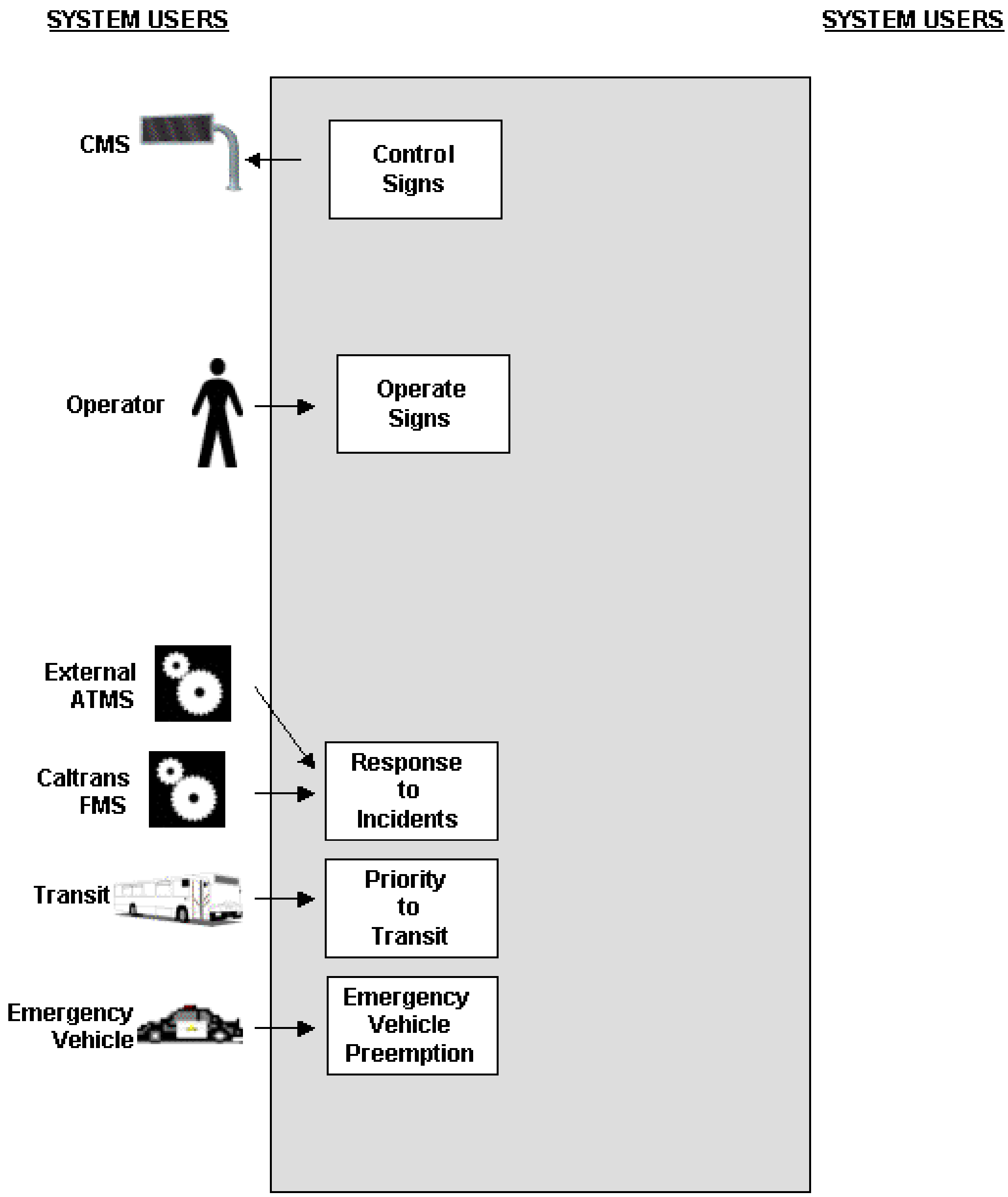


Figure 5.3: Additional Use Cases – City of Santa Fe Springs

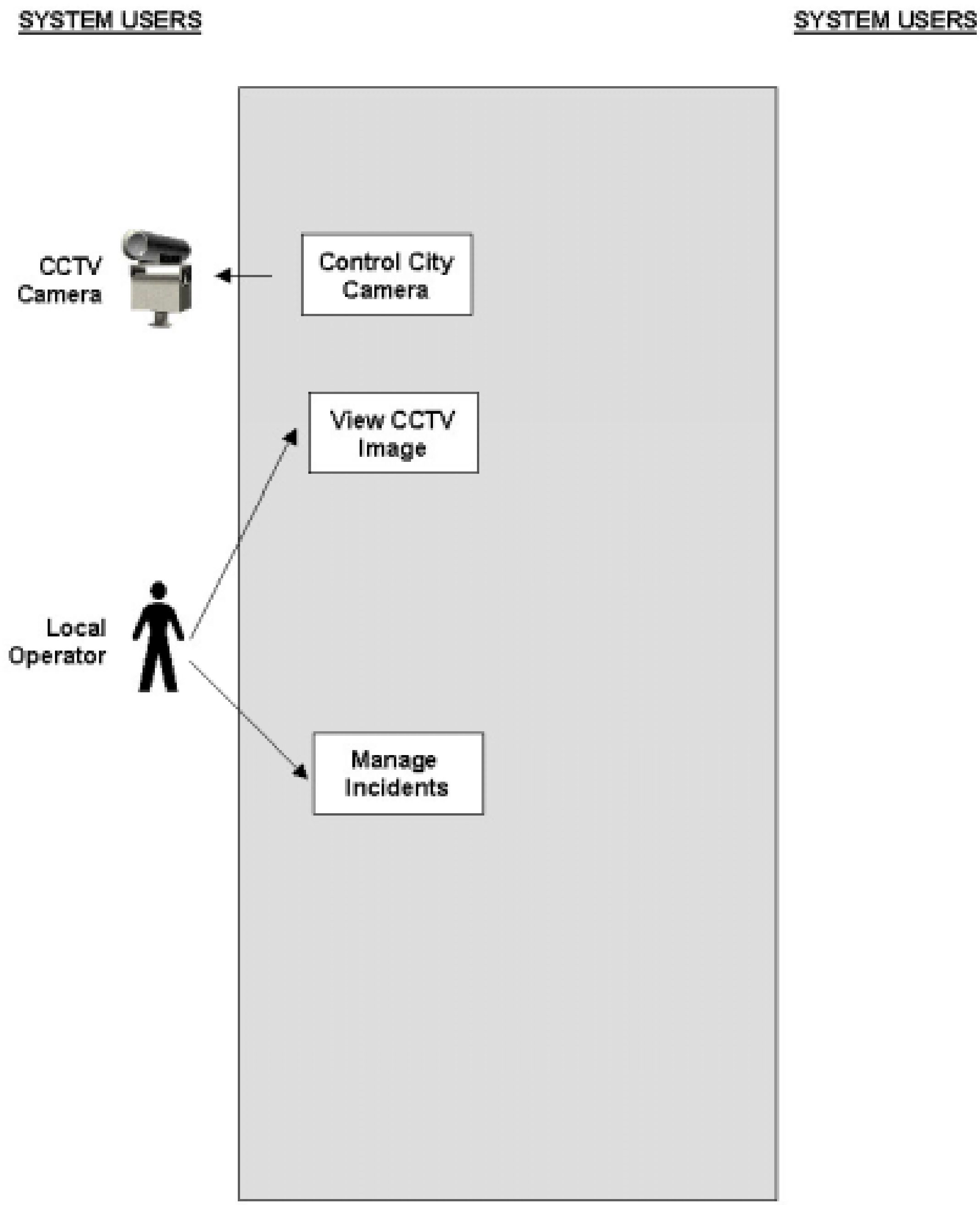


Figure 5.4: Additional Use Cases – City of Downey

6 ATMS FUNCTIONAL REQUIREMENTS

In the following statements, "the system" and "ATMS" are interchangeable. The following sub-sections identify the key Functional Requirements for achieving traffic signal synchronization within the Project area. The sub-sections below represent the Functional Requirements. These sub-categories were defined in the User Requirements Report (Deliverable 3.1.1) and were used to derive the User Requirements and Use Cases.

Each sub-section is made up of relevant User Requirements and derived Functional Requirements. Functional Requirements have been derived from the East San Gabriel Valley Pilot Project, the I-105 Corridor Project, and current industry standards.

The General Requirements sub-section groups together functionality and system characteristics that do not apply to a specific use case. The remaining sub-sections are use-case based.

6.1 General Requirements

6.1.1 System Philosophy

User Requirements

UR TS.1 ATMS will implement a download/plan select, distributed control philosophy (The term distributed control philosophy refers to current established practice of plans being developed and stored centrally, and implemented locally after being downloaded to the controller – this allows the system to be less susceptible to communications errors)

6.1.2 Inter-Jurisdictional Coordination

UR TS.4 The system shall provide seamless traffic flow between jurisdictions

UR TS.5 ATMS shall provide inter-agency plan selection capability

UR TS.6 The system shall be capable of corridor wide monitoring and traffic conditions

UR TS.7 One agency will be able to request/implement plan changes in other agencies to accommodate emergency operations and/or non-recurrent congestion situations

UR TS.8 Each agency's ATMS shall have the ability to reference plans and traffic conditions in the Corridor

Additional Functional Requirements are derived in the use-case based sections following this.

6.1.3 Agencies Involved

LA County Department of Public Works (LACDPW)

UR TS.9 LACDPW shall have operational control of signals within its jurisdiction

UR TS.10 LACDPW shall be able to perform operational monitoring (refers to phase displays and real time plan data) of all signals in the region

UR TS.11 LACDPW shall be able to perform functional monitoring (refers to alarms and faults) of all signals that it maintains

Caltrans

UR TS.12 Caltrans shall have operational control of arterial signals within its jurisdiction

UR TS.13 Caltrans shall be able to perform operational monitoring of arterial signals in the region

LACMTA

UR TS.14 LACMTA shall be able to perform operational monitoring of arterial signals in the region

6.1.4 Local Cities Involved

UR TS.15 Local Cities shall have operational control of signals within their jurisdictions

UR TS.16 Local Cities shall be able to monitor all signals within their jurisdictions

UR TS.17 Local Cities shall be able to monitor the operation of signals Corridor wide

UR TS.18 Local Cities shall be able to perform functional monitoring of controllers for maintenance purpose

UR TS.19 Local Cities shall be able to redirect control to alternate agencies

Additional Functional Requirements are derived in the use-case based sections following this.

6.1.5 System Architecture

User Requirements

UR TS.20 The ATMS shall be consistent with the County's IEN Architecture

UR TS.21 The ATMS shall be consistent with the National ITS Architecture

UR TS.22 The system shall be modular and scaleable

UR TS.23 ATMS hardware shall have networking capability

UR TS.24 The ATMS shall be based upon a client-server architecture

UR TS.25 Industry standard processors and network components shall be used

Functional Requirements

Open Architecture

FR TS.1 The system shall use the latest version of Microsoft's multi-tasking operating system for Intel-architecture PC-based servers in a client-server architecture.

FR TS.2 System workstations shall use the latest version of Microsoft's multi-tasking operating system for Intel-architecture PC-based clients in a client-server architecture.

FR TS.3 The Supplier shall place the source code for all such restrictive software that has been placed under configuration management and control (i.e. all software required to edit or alter the source code and successfully recompile and operate the software, including operating systems, libraries, tools and utilities, data base structures and code, and compilers, including a list of all software documentation tools) in a software escrow account, accompanied by detailed source code documentation, including a list of applicable software development tools.

FR TS.4 Such escrow account shall be updated with respect to all source code in the account at least annually, or earlier, if the Supplier issues an update that contains substantial revisions to the software then retained in escrow.

FR TS.5 The cost of maintaining such escrow shall be included in the contract price.

FR TS.6 The escrow account will be released in the event that the Supplier is unable to deliver services (including warranty services, maintenance, upgrades, bug fixes, and expanded features).

FR TS.7 Upon release of the escrow account under these terms, the Client shall have a royalty-free, non-transferable, nonexclusive license to use, for the Client's traffic management system purposes only, the machine-readable/executable software.

Scalability

FR TS.8 The central signal system software shall be capable of handling a minimum of up to twice the number of intersection currently under the control of the agency.

FR TS.9 Detector data shall be collected and stored in the database for up to *n* detectors (n is equal to 8 times the number of intersections supported by the system).

FR TS.10 These detectors can be any combination of local or system detectors.

FR TS.11 The delivered system shall support up to x simultaneous operators on the local area network (x is equal to the number of intersection supported by the system divided by 25).

FR TS.12 The delivered equipment shall be sized to support XX local Operators initially, with expansion requiring the addition of operator workstations only. (XX is dependent upon the specific system.)

6.1.6 User Interface

User Requirements

UR TS.39 All user accessible software shall use a Graphical User Interface (GUI)

UR TS.40 The GUI shall allow the use of a mouse

UR TS.41 The GUI shall provide users with drop-down menus for commands to the system

UR TS.42 The GUI shall provide context sensitive on-line help

Functional Requirements

General Ease of Use

FR TS.13 The GUI software shall provide the Operator with a graphical operating environment of the type commonly found on today's desktop computers.

FR TS.14 The GUI shall allow the Operator to select objects on the screen by point-and-click manipulation with the mouse, thereby minimizing typing and the need to memorize lengthy commands.

FR TS.15 It shall be possible to add or delete an intersection from a section through point-and-click manipulation of the intersections on the GUI.

FR TS.16 The GUI shall include standard Windows ™ printer interfaces and utilize standard Windows ™ printer drivers.

FR TS.17 All windows in the central signal system software shall support a mouse with a right button, a left button and a wheel.

FR TS.18 The GUI shall incorporate the following:

(1) Pop-up multiple display objects and windows;

(2) Menu icons and controls;

(3) Dialog boxes;

(4) Push button and other active commands;

(5) Visual and audio alarms; and

(6) Use of object characteristics such as colors, highlighting, and flashing to inform Operators of status changes.

FR TS.19 The GUI shall be oriented around graphic tools and based on the principle of direct manipulation.

FR TS.20 Several windows may be active at the same time and may overlap on the screen; however, the Operator shall be able to interact with only one window at a time.

FR TS.21 The Operator shall be able to easily switch from one window to another, such as by pointing with the mouse cursor to the uncovered part of another window.

FR TS.22 The Operator shall be able to move any window on the screen, to change window size, and to collapse a window to an icon.

Multi-User Capability

FR TS.23 The Supplier-furnished operating system and software shall support a multi-terminal, multi-user interface and the software shall allow access to multiple levels of the central signal system software simultaneously.

FR TS.24 Common icons shall be used as much as possible for all display levels.

FR TS.25 All colors shall be selectable by the Operator.

FR TS.26 A list of the Operators that are currently logged onto the central signal system software shall be available to be viewed by a user-defined set of Operators.

Integrity

FR TS.27 Validity checking shall be incorporated in all forms.

FR TS.28 Range error checking shall be performed at each control, if possible.

FR TS.29 Consistency error checking shall be performed before the data on a form is saved to the database.

Confirmation

FR TS.30 The User shall be asked to confirm any action that would result in data being modified or deleted in the database.

Special Editing Facilities

FR TS.31 Cut, Copy and Paste functions shall be provided to the User for all appropriate data entry tasks.

FR TS.32 Drag and drop facilities shall be provided to the User where appropriate.

Help Facilities

FR TS.33 The Help facility shall include an on-line version of the User Guide.

FR TS.34 A List of Contents shall be provided.

FR TS.35 A Keyword search facility shall be provided.

FR TS.36 Printing of Help topics shall be provided.

FR TS.37 Help on using Help shall be provided.

FR TS.38 Navigation through Help topics using hypertext links shall be provided.

FR TS.39 Context sensitive Help shall be provided for all screens.

FR TS.40 The software version of each application or optional module shall be displayed in the Help | About dialog.

Progress Indicator

FR TS.41 If the User is required to wait for the completion of an operation, where the wait time exceeds the time specified in the Timings Section, then a progress indicator shall be shown.

FR TS.42 In particular, a progress indicator shall be given for the generation of reports where the specified wait time is exceeded.

FR TS.43 The progress indicator shall graphically represent the completion status of the operation as a percentage.

FR TS.44 If a progress indicator is shown, the User shall be given the option of canceling the current function.

FR TS.45 Where the User is able to initiate several operations simultaneously, a separate progress indicator shall be given for each operation as required.

Tool Bar

FR TS.46 A tool bar shall be provided for the commonly used menu items.

FR TS.47 Standard icons shall be used wherever possible.

FR TS.48 Tool tips shall be provided for all icons.

Status Bar

FR TS.49 A status bar shall be provided to show information on the object currently selected.

FR TS.50 In particular, a description of the currently highlighted menu shall be shown.

FR TS.51 The status bar shall be divided into separate panels, as required, to separate various types of information.

FR TS.52 A list of status message types shall be specified in the documentation provided to the User.

Operator Error Messages

FR TS.53 Operator error messages shall be displayed in a consistent format.

FR TS.54 All operator error messages shall be specified in the documentation provided to the User, with corresponding indexing, and appropriate grouping of error message types.

FR TS.55 The text in an operator error message shall not imply that the User is at fault.

FR TS.56 The text in an operator error message shall give the User guidance regarding the corrective action to be taken.

FR TS.57 The text in an operator error message shall be free from technical jargon, as far as possible.

System Error Messages

FR TS.58 All Software or Hardware related exceptions shall be trapped and displayed to the User as system error messages, if possible.

FR TS.59 These shall also be logged to the Event Log.

FR TS.60 System error messages shall be displayed in a consistent format.

FR TS.61 All system error messages shall be specified in the documentation provided to the User, with corresponding indexing, and appropriate grouping of error message types.

FR TS.62 The text in a system error message shall refer the User to the Windows Application Event log, if applicable.

Multi-Tasking and Multi-Threading

FR TS.63 Several User Interface applications shall be able to be accessed concurrently by a User, up to a maximum specified.

FR TS.64 Within a single User Interface application, and where applicable, the User shall be able to initiate several operations that may execute concurrently (such as report generation).

Concurrent Users

FR TS.65 The system shall allow all Users to view any specified data concurrently.

FR TS.66 The system shall prevent a User from modifying or deleting data that is currently being modified or deleted by another User.

FR TS.67 User profiles shall be able to be stored and subsequently restored when that User logs on again.

6.1.7 System Control

User Requirements

UR TS.43 Operators will be able to manipulate intersection controllers if they have the proper privileges

UR TS.44 Local agencies will be able to delegate control authority to another agency

UR TS.45 Operator shall be able to log in from a remote location and be able to operate the system

Functional Requirements

Additional Functional Requirements are derived in the use-case based sections following this.

6.1.8 System Status

User Requirements

UR TS.46 The ATMS shall display status of system controllers

UR TS.47 The ATMS shall log and alarm equipment faults and errors

UR TS.48 The ATMS shall report events which is not faults or errors such as a cabinet door is open

Functional Requirements

Additional Functional Requirements are derived in the use-case based sections following this.

6.1.9 Map Display and Real-time Displays

User Requirements

UR TS.49 The user interface shall provide geographically accurate maps in the Project region

UR TS.50 Users shall be able to zoom and pan maps to provide more detail views, through the use of a mouse

UR TS.51 ATMS maps will allow the display of arterial incidents

UR TS.52 Operators with proper access level shall be able to edit maps

Functional Requirements

System Graphics

FR TS.68 The GUI shall incorporate a system map that covers the entire limits of the controlled area.

FR TS.69 When maximized, graphical views shall return to the scale at which they were displayed immediately prior to being minimized.

FR TS.70 Clicking on areas of the system map shall select more detailed views of controlled areas (area maps).

FR TS.71 The system shall provide the capability to draw map and graphic displays.

FR TS.72 The system shall provide the capability to import map displays from a Geographic Information System.

FR TS.73 The system shall provide the capability to import graphics in the following formats:

- .bmp
- .wmf

FR TS.74 The dynamic mapping shall incorporate full pan/zoom capability on system and area maps.

FR TS.75 The Operator shall be able to set up both dynamic and static informational layers that are displayed at different view scale levels by defining the view scale levels in a zoom level set-up configuration database table.

FR TS.76 Different layers shall be enabled as a default at different zoom levels.

FR TS.77 By setting the zoom scale range and appropriately enabled/disabled layers, the Operator shall be able to control which layers display at different zoom scales. For example, at the region-wide scale level the Operator might enable roadway centerlines (static information) as well as a communication status indication (dynamic information) for each intersection controller in the system.

FR TS.78 Display of freeway incidents is a function of the IEN and not the TCS. Arterial incidents will be displayed.

Intersection Displays

FR TS.79 The central signal system software shall allow Operators to view real-time intersection status and detector (volume, occupancy, and speed) data overlaid on maps and graphic displays showing the layout of the intersection.

FR TS.80 The Operator shall be able to double-click on a section of the main map area to maximize the previously minimized intersection graphics.

FR TS.81 The intersection graphics shall fill the entire screen when commanded by the Operator. In all menu selections, the central signal system software shall include a list of intersections by standard name and number.

FR TS.82 When an intersection graphics window is minimized, it shall be possible to maximize the window by selecting the same intersection from the menus.

Intersection Displays

FR TS.83 Intersection displays, which shall depict roadway curb lines and lane lines and shall include static displays of the following (as a minimum):

- Street names,
- Intersection number,
- Phase numbering,
- Special function definition; and
- North arrow.

FR TS.84 The intersection display shall also include dynamic indicators. The intersection display shall indicate the status of the following (as a minimum):

- Controller operational mode (TOD/DOW, traffic responsive, manual, free, free/flash, police flash, technician flash);
- Controller status (offset transition, preempted, type of preemption, conflict flash, etc.);
- The intersection display shall indicate the difference between the programmed offset and the actual timed offset;
- Communications status (e.g., on-line, bad communication, or no communication);
- Cabinet door status;
- Timing parameters currently in effect (e.g., control mode, transition status, control section assignment, timing plan number, cycle length, offset, and split values);
- Color status of all vehicular phases and overlaps (including the circular red, yellow, and green indications and all arrows);
- Status of pedestrian push-buttons;
- Color status of all pedestrian phases (including walk, flashing don't walk, and steady don't walk);
- Actuation status of all local detectors (vehicular and pedestrian) and all system detectors associated with the intersection;
- Preemption in effect, and what preemption mode;
- Special function status;
- Indication of failure, and type of failure;
- Count-up of cycle clock; and
- Count-up of the number of seconds for the split of the phase in service.

FR TS.85 The intersection graphics window shall include a window header with the standard intersection name and number in it.

Detector Displays

FR TS.86 The detector status for a given intersection shall be displayed on the screen with the intersection graphics.

FR TS.87 Traffic detector information (volume, occupancy, speed, congestion level quantities) shall be displayed.

FR TS.88 Link detector information (volume, occupancy, speed, congestion level quantities) shall be displayed as colored links.

FR TS.89 It shall be possible for the Operator to select the relevant quality for display via the GUI.

FR TS.90 V+kO values will be displayed per detector.

FR TS.91 New data types available from existing or new controllers will be able to be displayed by the system. Once the new data is configured, it will be available to the rest of the ATMS without further configuration.

6.1.10 Report Generation

User Requirements

Functional Requirements

FR TS.92 The central signal system software shall generate reports for logged events, detector data, measures of effectiveness, alarms (triggered by traffic condition) and communications statistics.

FR TS.93 The reports shall be generated on a system-wide, section or intersection basis.

FR TS.94 The Operator shall be able to generate custom reports using COTS software.

FR TS.95 It shall be possible to schedule automatic report generation via the TOD scheduler.

FR TS.96 The system shall provide routine pre-formatted reports.

FR TS.97 The User shall be able to print reports.

FR TS.98 Database reports shall be exported on command from this utility in the following formats:

- text comma-delimited
- text space-delimited
- text tab-delimited.

FR TS.99 When a report is generated, the default mode of report output shall be to the screen.

FR TS.100 When displayed, reports shall appear in a window that can be resized by the User.

FR TS.101 Multiple reports shall be able to be displayed simultaneously on the User's screen.

FR TS.102 Once a report is displayed on screen, the User shall be able to print the report.

Equipment Reports

FR TS.103 The central signal system software shall permit the Operator to view the status of equipment on a filtered basis.

FR TS.104 The following elements shall be selectable basis for use as filters in the display of system, communications, or equipment status:

(a) System, section, intersection or individual detector

(b) Status

(c) Fault

(d) Time and date (limits)

Communication Reports

FR TS.105 The central signal system software shall have a display/report that shall show the communications throughput.

FR TS.106 The display shall include number of communication attempts, number of successes, number of failures, and percentage of successful communications per intersection, per channel, and per system.

FR TS.107 The communications status views shall include a reference to the standard intersection name and number.

Detector Fault Reporting

FR TS.108 The detector feedback from the field from loop detectors and video detectors shall be continuously monitored for proper operation.

FR TS.109 Detectors shall be classified as acceptable, marginal, disabled, and failed.

FR TS.110 Detector failures shall be reported to the system log and the system workstation.

FR TS.111 The system shall be able to generate reports on detector % available at detector, intersection, or area level.

FR TS.112 The central signal system software shall have user-definable failure filters that define the thresholds that a detector must exceed to be considered failed.

FR TS.113 The filter values shall be selectable on a time of day basis.

FR TS.114 The following failure types shall be provided at a minimum:

- Maximum Presence: If an active detector exhibits continuous detection for a program entered period (0-255 minutes in one minute increments);
- No Activity: If an active detector does not exhibit an actuation during a program period (0-255 minutes in one minute increments);
- Erratic Output: If an active detector exhibits excessive actuation (program entered maximum counts per minute 0-255 in increments of one); and
- Bad communication.

Detector Reports

FR TS.115 The system shall print formatted reports from logged VOS data.

FR TS.116 The system shall provide a report on "Monthly Delay Average" per intersection.

FR TS.117 The system shall provide the following graphical and tabular reports for a detector:

- Speed Reports
- V+kO Reports
- Volume Reports
- Occupancy

FR TS.118 Raw and smoothed volume shall be displayed in user-defined intervals.

FR TS.119 The system shall provide the following graphical and tabular reports for a link:

- Speed Reports
- V+kO Reports
- Volume Reports
- Occupancy

FR TS.120 The system shall provide a report computing Seasonal Volume Coefficients.

FR TS.121 The system shall provide a report of Historical Traffic Flow Reports (1-year).

FR TS.122 An Operator shall be able to select the time period for traffic counting reports.

FR TS.123 An Operator shall be able to select the destination for traffic counting reports.

FR TS.124 An Operator shall be able to schedule automatic report generation via the TOD scheduler.

6.1.11 Database Editing

User Requirements

UR TS.59 The system shall provide mechanisms for auto-upload and auto-compare

UR TS.60 The system shall provide on-screen display and editing of controller parameters

UR TS.61 The system shall be capable of printing reports

Functional Requirements

FR TS.125 The system shall utilize a multi-user, commercial database software product.

FR TS.126 The database shall be used to store, retrieve, and maintain system data and parameter files.

FR TS.127 The system shall provide a database interface for display and editing controller databases, which shall be integrated into the central signal system software to provide seamless operation for the Operator.

FR TS.128 The database editor shall be accessible directly from the intersection display.

FR TS.129 The resulting combination of central signal system software and database software shall provide for off-line and online database generation and maintenance.

FR TS.130 This shall include loading, modifying, examining, copying, and retrieving the data used to operate the central signal system software. These data include traffic system configuration, timing plans, TOD/DOW schedules, operator databases, and alarm databases.

FR TS.131 The central signal system software shall provide the means to keep multiple intersection database windows open simultaneously to facilitate comparison and data manipulation.

FR TS.132 It shall be possible to drag-and-drop these windows throughout the entire monitor screen.

FR TS.133 Any database changes shall be achievable without having to restart the central signal system software.

FR TS.134 All tables in the database shall be printable in the same form as shown on the computer screen for use by the traffic engineers and maintenance technicians in the field.

FR TS.135 When an Operator attempts to open a controller database that is in use, the central signal system software shall display a message explaining to the Operator that the database is already open.

FR TS.136 Editing of the controller database entries shall be via a tabular format.

FR TS.137 The ATMS database will be a RDBMS, allowing SQL based queries as data collected by the ATMS.

FR TS.138 The ATMS will support of the format at the agency specific controllers.

Database Recovery

FR TS.139 All database backup and recovery shall be through the use of Commercial-Off-the-Shelf (COTS) Software. This COTS software shall be able to do the following:

- Automatically compress and back-up the database on a user-specified time-of-day setting or upon user command; and
- Restore the back-up copy of the database to the database.

FR TS.140 Static database back-ups shall be performed using a DAT tape back-up or writeable CD-ROM drive.

6.1.12 System Security

User Requirements

UR TS.62 Local agencies shall retain control authority

UR TS.63 ATMS shall recognize groups of operators to which access privileges are allocated

UR TS.64 ATMS shall have different access levels

UR TS.65 Access levels shall control access to functions

UR TS.66 Access levels shall control access to equipment

UR TS.67 The system shall allow multiple simultaneous operators to monitor controller behavior

Functional Requirements

FR TS.141 The central signal system software shall provide and maintain a security system to prevent unauthorized access to the system.

FR TS.142 Operator privileges shall be definable on a functional level.

FR TS.143 The security levels shall include, at a minimum: no access, view only, upload only, download only, and full access).

FR TS.144 Each Operator shall have a privilege level mask defined by the System Administrator.

FR TS.145 The mask shall define the specific functions that the particular Operator is authorized to perform. For example, a particular Operator may be given the ability to view all reports, but not to modify some or all levels of the database.

FR TS.146 This (the mask) shall allow for any number of different levels of operator access capability.

FR TS.147 The System Administrator level shall have full access to the system as well as the responsibility for maintaining account passwords and privilege level masks.

FR TS.148 Each Operator shall have a unique, Operator-definable password used to gain access to the system.

FR TS.149 Passwords shall be stored in the database in an encrypted format.

FR TS.150 Before gaining access to the system, the Operator shall be required to enter an operator identification code.

FR TS.151 The central signal system software shall validate the code against an encrypted database of authorized operators.

FR TS.152 Successful completion of the login shall result in execution of a session start-up procedure.

FR TS.153 The start-up procedure shall establish the privileges, object menu options, windows, and tools the Operator may utilize.

FR TS.154 Any functions that a particular Operator is not authorized to access shall either not be shown or shall be “grayed out” so that the Operator can easily distinguish the functions to which he/she has access.

FR TS.155 LAN access shall be limited to those activities that support the central signal system software.

FR TS.156 Unsuccessful login attempts shall be logged to the central signal system software log.

6.1.13 Communications

FR TS.157 The ATMS shall support different baud rates for communications channels to the controllers.

FR TS.158 The ATMS shall support different baud rates for communications channels to the Local Operator Interfaces.

FR TS.159 The ATMS shall support controllers using the AB3418 protocol.

FR TS.160 The central signal system software shall include communications support for the NTCIP protocol (Level 1 conformance).

FR TS.161 The ATMS will communicate with each intersection once per second.

FR TS.162 The TCS will support multiple communications protocols as needed by the specific installation.

6.2 Control Traffic (Control Modes)

User Requirements

The system shall support the following modes of operation:

UR TS.26 Central Coordinated: The controllers operate according to a pre-determined coordinated timing plan schedule that is stored in the central database

UR TS.27 Local Coordinated: The controllers operate according to a pre-determined coordinated timing plan schedule that is stored locally in the individual controllers

UR TS.28 Local Isolated (Free operation): The controller is not being commanded for on-line operation by a Master System

UR TS.29 Manual: The controller responds to system commands for plan selection issued from the central control using manual override

UR TS.30 Traffic responsive: The controller responds to system commands for plan selection issued from the central control based on the traffic-responsive algorithm

UR TS.31 Flashing: The controller is put on flash either manually by the central or at the cabinet. This also includes tripped conflict monitor at the local intersection

UR TS.32 Pre-empted: The controller is pre-empted by an external system to provide priority to fire or police vehicles

Functional Requirements

FR TS.163 An operator may delegate control authority to an operator at another agency.

FR TS.164 It shall be possible to delegate control authority to another agency by time of day.

Coordinated Modes

FR TS.165 The central signal system software shall operate in a distributed mode issuing plan and mode changes to local controllers.

FR TS.166 The central signal system software shall upload and download to intelligent local controllers the timing plans, time-of-day/day-of-week (TOD/DOW) schedules, and all other parameters required to operate the local intersection.

FR TS.167 All intersection controllers shall be monitored on a real-time basis by the central signal system software.

FR TS.168 The central signal system software shall support communication with the field controllers at rates from 1.2kbps to 38.4kbps.

FR TS.169 Upon system startup, the central signal system software shall establish communications with all intersection controllers and begin real-time monitoring.

FR TS.170 The central signal system software shall start to process both incoming data and Operator requests.

FR TS.171 Any upload, download, or time/date requests shall take precedence over real-time monitoring.

FR TS.172 The central signal system software shall be designed for unattended operation twenty-four (24) hours per day, seven (7) days a week, without requiring an Operator to be logged into the system.

FR TS.173 The central signal system software shall provide system control by coordinating intersection operation on an individual, section, or system-wide basis.

FR TS.174 Control modes shall be Operator-selectable from the Graphical Use Interface (GUI).

FR TS.175 For commanding an intersection to a timing plan different than the TOD/DOW, either by manual override or through the traffic-responsive algorithm, the controller shall be commanded to the appropriate plan.

FR TS.176 In the event that, while in software-commanded override, a controller does not receive a valid timing plan number from the central signal system software within an operator-defined time frame, it shall revert back to its local TOD/DOW schedule.

FR TS.177 Central override shall be allowable on an intersection, section, or system-wide basis.

FR TS.178 In the event of a failure other than power failure or the severing of communications between the central signal system software and the controller, the Operator shall have manual control over the intersection.

Upload/Download

FR TS.179 The System shall allow download on a system-wide, section, or intersection basis. Upload shall be provided on an intersection basis.

FR TS.180 Upload/download commands shall be executed immediately upon command at a communication rate of 1.2kbps to 38.4kbps between the central signal system software and the field controllers.

FR TS.181 The central signal system software shall upload and download the following data, at a minimum:

- Intersection timing parameters
- Detector data from at least 32 detectors per intersection controller
- Controller and cabinet alarm data
- Event data
- Controller date and time

FR TS.182 The central signal system software shall highlight errors or missing data in timing plans prior to permitting download of the timing plans to a controller.

FR TS.183 The central signal system software shall generate a comparison report listing all data discrepancies between the database and controller.

FR TS.184 The central signal system software shall write this report to a text file for printing or editing.

FR TS.185 It shall be possible to schedule uploads and compares by TOD (auto-compare).

FR TS.186 The results of the auto-compare will be logged and made available for Operator review.

FR TS.187 It shall be possible to request a download from the field without the need for central operator support (remote download request).

FR TS.188 Local isolated.

FR TS.189 It shall be possible to place controllers in a local isolated mode on system-wide, section, or intersection basis.

FR TS.190 The Operator shall be able to disable these components through the user interface.

FR TS.191 When disabled, the central signal system software shall not communicate with the component and the component shall run its local TOD/DOW schedule.

FR TS.192 The Operator shall have the ability to reactivate disabled, or off-line, intersections via the central signal system software.

FR TS.193 The central signal system software shall recognize the release of an intersection from communications into stand-by mode without displaying the status as a communications failure.

FR TS.194 The Operator shall be able to monitor the intersection components through the central signal system software, even while not commanding it. Flash and Free/Flash.

FR TS.195 In the flash mode, the controller shall run uncoordinated and will not provide green time to any movements at the intersection.

FR TS.196 To initiate flashing operation remotely, the controller shall be commanded to flash from the central signal system software.

FR TS.197 If the controller has been commanded to be in flash mode and remains on-line, it shall be shown as being in flash mode in the GUI.

FR TS.198 If the intersection is in flash mode because it is off-line, it shall be shown as being in free/flash mode.

Traffic Responsive

FR TS.199 In the traffic-responsive mode of operation, the central signal system software shall select the timing plan that is best suited to the existing traffic conditions as measured by the system detectors and analyzed by the system's traffic-responsive process.

FR TS.200 Once the traffic-responsive process has selected the appropriate timing plan, the plan number shall be commanded to the intersections on a continuous basis until the traffic-responsive process recognizes, based on sufficient change in traffic conditions, the need to command a different timing plan.

FR TS.201 The traffic-responsive algorithm shall be based on the UTCS algorithm or other approved traffic-responsive algorithm.

FR TS.202 In order to enhance traffic responsive operation, the following traffic-responsive process points shall be implemented:

- Each section shall be associated with zero to a maximum of ten (10) other sections.
- One section shall be designated as the master section.
- When traffic conditions warrant a traffic-responsive timing plan change for the master section, the central signal system software shall automatically change the timing plans for the other associated sections.
- If no other sections are associated with a section, only that section shall change timing plans.

FR TS.203 The Operator shall be able to define a single detector station as a section.

FR TS.204 When the traffic-responsive process detects that this detector station has exceeded operator-defined thresholds, the associated sections shall automatically change to the appropriate traffic-responsive plan. This process is intended for use in conjunction with special events (such as to detect and respond to a surge of traffic leaving the parking facility of a stadium or arena following the end of a sporting event).

FR TS.205 It shall be possible to group commands together by device or section.

6.3 Operate Signals (Manual Control)

FR TS.206 The Operator shall be able to invoke manual override of the plan currently in effect for the entire system, for a subsection of the system, or for individual intersections (system-wide, section, or intersection basis).

FR TS.207 Manual selection of timing plans shall have a higher priority than all other modes of timing plan selection.

FR TS.208 The Operator shall have two options for implementing manual override:

- Setting the manual override and later releasing the override manually; and

- Setting the manual override with a specified time frame for automatic termination.

FR TS.209 Under the second option, the manual override shall terminate automatically at the end of the specified time.

FR TS.210 When manual override is terminated, each affected controller shall revert to its previous mode of operation.

6.4 Monitor Signals

FR TS.211 The central signal system software shall monitor the traffic signal controllers on a second-by-second basis.

FR TS.212 If polling rates are restricted by elements of the field communications infrastructure, the central signal system software shall monitor the traffic signal controllers at the most frequent rate possible, up to second-by-second rates where possible.

FR TS.213 At startup, the central signal system software shall establish communications with all intersection controllers via the central communication system and begin second-by-second monitoring.

FR TS.214 The central signal system software shall process both incoming data and User requests.

6.5 Maintain Signals

Paging

FR TS.215 The central signal system software shall have the capability to automatically send alphanumeric messages to maintenance personnel upon detecting critical problems with the central signal system software.

FR TS.216 Upon detection of the critical event, which triggers a system event, the designated phone number shall be dialed and the message presented.

FR TS.217 This feature (critical event triggers) shall be fully programmable allowing designation of TOD/DOW, phone number, and which critical event to trigger.

6.6 Synchronize Clocks

User Requirements

UR TS.2 Time bases in each ATMS shall be synchronized

UR TS.3 The time reference clocks of each local ATMS shall be synchronized with the entire system to enable area-wide coordination

UR TS.37 The ATMS shall synchronize ATMS clocks based on an external, universal time reference time

Functional Requirements

FR TS.218 The Supplier shall provide the means by which the central signal system software's time clock is automatically synchronized with universal time through the WWV radio broadcast or WWV Internet source.

FR TS.219 Such automatic synchronization shall occur at least once per hour.

FR TS.220 The capability shall also be provided for the Operator to disable and re-enable this function.

FR TS.221 The central signal system software shall provide for the automatic downloading of clock updates to each field controller.

FR TS.222 The frequency of such updates shall be Operator-programmable within the range of once-per-minute to once-per-day.

FR TS.223 The central signal system software shall also permit the controller clock to be updated when a controller is brought on line.

6.7 Generate Timing Plans

FR TS.224 It shall be possible to export data to SYNCHRO.

FR TS.225 It shall be possible to import timings generated by SYNCHRO.

FR TS.226 The Operator must approve imported timings before inputting SYNCHRO generated timings into the controller database.

6.8 Manage Timing Plans

FR TS.227 The central signal system software shall permit the Operator to switch from the stored database to an uploaded controller database without either database closing or losing changes.

FR TS.228 The number of timing plans, timing plan pages, and coordination plan pages that can be stored by the central signal system software shall only be limited by the physical storage capabilities of the hardware.

FR TS.229 Each timing plan shall include uniquely programmable values for cycle length and offset, a uniquely programmable phase sequence, and uniquely programmable split values.

FR TS.230 The central signal system software shall provide the automatic calculation of permissive periods (based on splits values).

FR TS.231 The central signal system software shall also provide the capability to handle special signal and/or timing plans to accommodate unusual traffic flow patterns during special events.

FR TS.232 The central signal system software shall copy the timing plans, tables and coordination tables from one controller to another when commanded by the Operator.

6.9 Schedule Operations

Time of Day/Day of Week

FR TS.233 TOD/DOW mode shall be used for controlling traffic conditions that occur regularly.

FR TS.234 In this mode, each controller shall automatically select and implement traffic signal timing plans in accordance with the defined schedule, locally stored, on a TOD/DOW basis.

FR TS.235 TOD/DOW plans shall be downloadable from the central signal system software to the controller in the field.

FR TS.236 The Operator shall be able to schedule any plan or mode change command for execution at any time.

FR TS.237 The System Administrator shall be able to inhibit user access to the event scheduler.

FR TS.238 The entries in the event scheduler shall be automatically sequenced in ascending order by TOD/DOW, regardless of the order in which the entries were made.

FR TS.239 Operator commands shall have priority over scheduled entries in the event scheduler.

FR TS.240 The Operator shall be able to make entries into the event scheduler for up to a minimum of one year in advance.

FR TS.241 Up to 1000 entries shall be permitted.

FR TS.242 The scheduler shall have the capability to load multiple commands for the same time .

FR TS.243 For events scheduled at the same time, the execution shall occur simultaneously.

Temporary and Permanent Commands

FR TS.244 Commands entered into the event scheduler shall be of two types, permanent and temporary.

FR TS.245 Permanent commands shall be performed every time the matching of time parameters occurs.

FR TS.246 Temporary commands shall be performed once and then be deleted from the scheduler database.

FR TS.247 The Operator shall be able to enter the following permanent and temporary command times as a minimum:

- Permanent commands:
    - Every day basis (i.e., every day of the year);
    - Every week basis (i.e., on a given day or days of every week);
    - Every time span basis (i.e., every hour);
    - Every weekday (i.e., given weekday from Monday through Friday); and
    - Every weekend (i.e., given weekend day such as Saturday or Sunday).
- Temporary commands:
    - Specific date basis (e.g., December 25, 2000);
    - Specific time basis (e.g., at 2:00 PM or 1400 hours); and
    - Specific date/time basis (e.g., on 4/15/2001 at 11:00 AM).

FR TS.248 Fixed and “floating” holiday exception tables will be provided.

FR TS.249 Holidays will override the standard TOD/DOW control tables.

6.10 Exchange Coordination Data

User Requirements

UR TS.76 It shall be possible to share real-time detector data (at a minimum, Volume, Occupancy, Speed) among various jurisdictions in I-5/Telegraph Road Corridor

UR TS.4 The system shall provide seamless traffic flow between jurisdictions

UR TS.5 ATMS shall provide inter-agency plan selection capability

UR TS.6 The system shall be capable of corridor wide monitoring and traffic conditions

UR TS.7 One agency will be able to request/implement plan changes in other agencies to accommodate emergency operations and/or non-recurrent congestion situations

UR TS.8 Each agency's ATMS shall have the ability to reference plans and traffic conditions in the Corridor

Functional Requirements

FR TS.250 Data exchange between systems shall conform with the NTCIP Center-to-Center Specification.

FR TS.251 The NTCIP CORBA specification shall be supported.

FR TS.252 The IEN shall be supported.

FR TS.253 The ATMS shall accept external plan change commands.

6.11 Data Archiving

Collection and Retrieval

FR TS.254 The central signal system software shall automatically record detector data in the database.

FR TS.255 Detector data shall be stored in memory on a five minutes basis.

FR TS.256 If bad data or no data is received from the detector loops during any or all of the five-minute collection time, the data will be tagged as questionable or not available in the database.

FR TS.257 Each five-minute block shall be date and time-tagged.

FR TS.258 The User shall have the ability to enable or disable the detector data collection feature.

FR TS.259 Every twenty-four (24) hours the five-minute detector data shall be automatically compressed and written to the storage media.

FR TS.260 Detector data shall be retrievable from the storage media for use with the relational database or traffic modeling packages.

6.12 Monitor Congestion

User Requirements

Unnumbered: The ATMS should be capable of providing congestion monitoring with associated alarms.

Functional Requirements

FR TS.261 The system shall provide a means for detecting recurrent and non-recurrent congestion.

FR TS.262 System shall provide methods in the user interface to show levels of congestion for intersections including:

- Level of Service
- Detector Volumes, Occupancy, Average Speed
- Aggregate Intersection Detector Volumes, Occupancy, and Average Speed

6.13 Analyze Data

FR TS.263 The system shall provide a mechanism to export any data detector that is entered or archived in the central database for the purposes of analysis. Specific requirements are included in the appropriate sections included in these Functional Requirements.

FR TS.264 Delay simulations based on proposed timings with real-time volumes shall be carried out by exporting data to SYNCHRO.

FR TS.265 Travel time simulations, based on proposed timings with real time volumes, shall be carried out by exporting data to SYNCHRO.

Time/Space Diagrams

FR TS.266 The central signal system software shall have the ability to generate time-space diagrams from both real-time data and from programmed data contained in the database and to display such time-space diagrams on-screen.

FR TS.267 The Operator should then be able to perform “on-screen fine-tuning”, using click and drag methods to adjust the offsets, with the resulting changes in the widths of the progression bands being displayed.

Split Monitor

FR TS.268 The system software shall have the ability to provide a graphical display/report showing split times for a past period for an intersection.

FR TS.269 The split time report shall be selectable as:

- Between specific times (on a given date)
- Plan number

6.14 Measure Traffic

User Requirements

UR TS.33	The ATMS shall provide the capability of collecting and maintaining all data required for monitoring, and confirmation of displays from all intersections concurrently
UR TS.34	If the intersection is not running coordinated, data shall be continue to be collected
UR TS.36	ATMS will be capable of exporting signal timing and volume information for off-line timing generation (Off-line Timing Generation)
UR TS.38	Data collected by the ATMS shall be capable of being aggregated to peak hour volume as used to satisfy the LACMTA Congestion Management Plan highway monitoring requirements
UR TS.70	At a minimum, per lane volume and occupancy between all major intersections (mid-block) shall be collected
UR TS.71	Above data will be used for planning purpose, timing plan generation, and as input into incident detection and adaptive traffic control algorithms
UR TS.72	Detection technology shall be reliable and provide accurate data on a per lane basis
UR TS.73	Detection technology shall be cost-effective on a life-cycle cast basis
UR TS.74	Detection technology may be permanent or temporary
UR TS.75	Detection technology shall perform in all weather conditions

Functional Requirements

FR TS.270	The central signal system software shall process detector data every one (1) minute for traffic responsive operation.
FR TS.271	The central signal system software shall re-evaluate the traffic responsive data every five (5) minutes to determine the appropriateness of the timing and make changes.
FR TS.272	The field hardware shall include both system and local detectors that shall be used for both traffic counting and traffic-responsive operation.
FR TS.273	The central signal system software shall process and maintain detector count and occupancy data on a continuous basis to be used for various traffic control strategies and/or reporting tasks.
FR TS.274	Detector feedback shall be obtained on a user definable time frame.
FR TS.275	The time frame shall not be less than once per minute.
FR TS.276	The central signal system software shall recognize, process and display detector information including traffic volume, occupancy and speed.
FR TS.277	Volume shall be defined as: The number of vehicles counted in an interval of time.
FR TS.278	Occupancy shall be defined as the percentage of time the detector loop is occupied.

FR TS.279	Speed shall be calculated if based on the output from detector loops.
FR TS.280	If calculated and not measured directly, the system shall calculate a speed value for links based on an assumed vehicle length and loop size.
FR TS.281	Assumed vehicle length and loop size shall be shall be user definable system-wide parameters.
FR TS.281.a	The system shall detect a stopped vehicle or vehicles.

6.15 Monitor Events and Alarms

Alarms

FR TS.282	Malfunction detection and diagnosis and automatic status logging shall be provided to minimize the time-to-repair of critical components of the central signal system software.
FR TS.283	The system shall detect controller power failure and recovery.
FR TS.284	The system shall support as alarms any failures reported by the controller to the central.
FR TS.285	Upon failure, the central signal system software shall log the event and also display a visual alarm to the Operator.
FR TS.286	The occurrence of each such alarm shall be recorded in the system log.
FR TS.287	Alarms shall have at least two priority levels.
FR TS.288	Alarm priority level shall be user selectable. The central signal system software log shall include a reference to the intersection name and number with which any given event is associated.
FR TS.289	The event log shall include the central signal system software time that the alarm is recorded.
FR TS.290	The central signal system software shall continue to attempt communication with the failed component.
FR TS.291	If the failed component communicates successfully for an operator-specified amount of time, the component shall be considered operational.
FR TS.292	This event shall also be logged, along with the clearing of the alarm for the failed component.
FR TS.293	Alarms shall be displayed in the active window on the central signal system software screen.
FR TS.294	The alarm window shall be intrusive (preempt or interfere with the Operator's editing tasks).
FR TS.295	Alarms shall be automatically recorded in an alarm log.
FR TS.296	Alarms shall be automatically time stamped and routed to a specified Operator station.
FR TS.297	It shall be possible to change alarm routing to different Operator stations by time of day.
FR TS.298	Alarms: Immediate display of alarms taking into account the data latency of the system.

FR TS.299 Alarms shall be user selectable ignore by specific device.

FR TS.300 It shall be possible to specify that a given alarm must occur a user specifiable number of times before it is reported.

FR TS.301 It shall be possible to print the alarm log.

FR TS.302 The TCS shall monitor the controller to verify that the controller is operating under selected timing plan.

6.16 Generate Maintenance Log Reports

User Requirements

UR TS.53 The system shall be capable of generating maintenance reports

Functional Requirements

FR TS.303 The central signal system software shall generate information every 24 hours indicated device/system failures. A maintenance report suitable for in-house or contracted signal control maintenance shall be generated.

FR TS.304 A 24-hour maintenance report shall indicate type of device, failed device, and type and severity of failure, and responsibility for maintenance for the past 24 hours.

FR TS.305 It shall be possible to route maintenance reports to city operations staff.

FR TS.306 It shall be possible to route maintenance reports to city maintenance staff.

FR TS.307 It shall be possible to route maintenance reports to a signal maintenance contractor.

FR TS.308 It shall be possible to route maintenance information to LA County DPW.

FR TS.309 User will be able to schedule the printing and choose printer for traffic counting reports.

Preventive Maintenance

FR TS.310 For each traffic control device in the system, the central software shall track dates for preventive maintenance. This may include visual inspection, replacement of parts.

FR TS.311 Warranty for all traffic control devices shall also be maintained with each traffic signal.

6.17 Log Event Details

User Requirements

UR TS.55 The system shall record actions taken and changes of status

UR TS.56 The system shall record operator actions in a system log

UR TS.57 The operator shall be able to add comments to the system event log

UR TS.58 The ATMS shall record when timing plan changes have occurred

Functional Requirements

FR TS.312 The system event log shall record changes in the status of all traffic control devices and subsystems (E.g. Traffic Signals, DMS, HAR, CCTV, etc.).

FR TS.313 All database modifications, uploads/downloads, alarms, and system commands shall be logged in the system log.

FR TS.314 System logins and logouts shall be logged (with time and date stamp) and shall be accessible to the System Administrator.

FR TS.315 The event log shall be searchable by device type (or subsystem), specific device, User/Operator, and severity of error.

FR TS.316 Reports from the event log from the searchable event log viewer shall be printable.

6.18 Repair Equipment

FR TS.317 As noted in requirements Section 3.3.15, "the central signal system software shall generate a 24-hour maintenance report…" Based on information from the 24-hour Maintenance Report, the system shall track the status of maintenance including:

- Failure Date
- Maintenance Personnel/Contractor Contact Date
- Name of Maintenance Personnel/Contractor Contacted
- Scheduled time/Estimated time for Repair
- Actual Date of Failure Repaired
- Comments

6.19 Configure Operations

FR TS.318 The system shall enable the Operator to define a minimum of **Y** control sections, or subsystems where y is equal to the maximum number of intersections supported by the system.

FR TS.319 Each (control section) shall be completely independent of the connection of any particular intersection to the communications network.

FR TS.320 The number of intersections in a particular subsystem shall be programmable from a minimum of one to a maximum of the total number of intersections in the system.

6.20 Configure System

To be further defined

6.21 Manage Network (Network Administration)

FR TS.321 Using tools provided with the Windows operating system, the System Administrator or Network Administrator shall have the capability to monitor the network, including:

- Which users are logged into the system
- The status of any system firewalls
- The status of system servers

6.22 Manage Resources (System Administration)

Recovery

FR TS.322 The central signal system software shall automatically recover from a power failure.

FR TS.323 The central signal system software shall automatically begin communications with all field equipment via the central communications system.

FR TS.324 If the central signal system software detects a non-fatal error within one or more of its processes, it shall log a message to the system log.

FR TS.325 The system shall continue to operate in a degraded state.

Archiving

FR TS.326 Every twenty-four hours the five-minute detector data shall be automatically compressed and written to the system disk.

FR TS.327 Each twenty-four hour history shall be date tagged.

FR TS.328 The User shall have the ability to enable or disable the detector data archival feature.

FR TS.329 Operators may select periodic archiving of certain dynamic data from the database to an archive file.

6.23 Manage Users

FR TS.330 The system shall provide a full range of security and administration functions. The types of functions shall include:

- Login, Logout and Exit
- Security - ID/Password Combination
- Add and Delete Users
- Specification of User’s Rights on a menu-by-menu basis (User profile)
- System Administrator’s ability to Change User’s Password
- Operators ability to change their Own Password

FR TS.331 The System Administrator shall assign user rights.

FR TS.332 The User’s profile shall be accessible from any Operator workstation on the system.

FR TS.333 The system shall provide secure access to the signal control system.

FR TS.334 Operator access will be by function and specific equipment.

FR TS.335 For access definition, equipment may be grouped together.

FR TS.336 Each User must log into the system Operator Interface (OI) with a username and password.

FR TS.337 These two identifiers shall be used by the system to determine if the requester is permitted on the system and what rights that individual will have.

FR TS.338 The System Administrator shall have the ability to limit user rights down to a specific menu level.

FR TS.339 Menus and functions to which the Operator has access will be in dark letters while restricted menus or command options will be grayed out.

FR TS.340 Remote Users shall be required to provide a user name and password to connect to the network and then a separate login to the central software.

FR TS.341 The rights of the remote User will be determined and set up in the same manner as a local User.

6.24 View CCTV Image

FR TS.342 View CCTV Image - The system shall allow Operators to use their workstations to assign input from any camera to any port on the bank of monitors in the Operations Center, or to the Operator workstation itself.

FR TS.343 The system shall display the images in views that can be minimized or maximized.

6.25 Control City Camera

FR TS.344 The system shall provide Operators with the capability to carry out all camera control functions from the Operator workstation.

FR TS.345 An individual camera may be chosen by clicking on the camera icon from the zoomed in map, or by selecting the CCTV button from the toolbar.

FR TS.346 From the CCTV menu, the Operator shall be able to select preset scenes by choosing the sample view that represents the scene they desire.

FR TS.347 The system shall enable Operators to create and store preset scenes for each camera in the database.

FR TS.348 The scene shall comprise camera position (pan and tilt), zoom, focus, and/or other controller selection options.

FR TS.349 Each preset scene shall allow an associated text phrase.

FR TS.350 Sample views of the preset scenes available for each camera shall be shown and the Operator shall be able to easily "activate" the desired preset sample image.

FR TS.351 It shall be possible to establish an initial set of preset scenes for each camera.

FR TS.352 The system shall support panning, tilting, and zooming CCTV cameras.

FR TS.353 Administrators will assign a unique name to each user.

6.26 Select Caltrans Camera

FR TS.354 Operators shall be able to select a Caltrans Camera from a list or form the map and view a camera image.

FR TS.355 If an agency prefers, the Caltrans Camera will display in the same viewers as their own cameras except with the control portions of the User Interface grayed out.

6.27 Manage Signs General

Message Development

FR TS.356 The software shall support the Operator in creating and editing sign messages.

FR TS.357 The system shall assist the Operator in configuring the message for the given sign format. The system shall be able to handle all ASCII symbols, centering, justifying, and alternating messages in the same way that the sign controllers do.

FR TS.358 The system shall display the new message on the screen just as it would appear on the sign.

FR TS.359 The system shall support flashing, with user-defined on and off times.

FR TS.360 Enable the User to create one or two phase messages.

FR TS.361 Remove the "Message Duration" field from this window and put it in the window(s) used to post messages on signs.

Sign Plans

FR TS.362 The system shall provide a way to develop sign plans. Sign plans are groups of signs with an associated message. The message may be a library message or one entered by the Operator.

Scheduling

FR TS.363 The system shall: Facilitate the creation of new sign schedules for the schedule library or edit schedules previously stored.

FR TS.364 Be able to schedule messages on signs for a given period of time.

FR TS.365 Be able to schedule sign plans.

FR TS.366 Create, modify, suspend, or cancel a schedule of commands for the sign system to issue to each sign controller at the times specified in the schedule. An Operator shall not be able to schedule any command that he does not have the privilege to execute directly.

FR TS.367 If the Operator chooses to apply the schedule to multiple signs, the software shall present the Operator with a list of all signs (of the proper type), so that the Operator can select to which signs the new schedule goes. Using a single command, the Operator shall be able to cause the newly created schedule to be stored for all the signs selected, replacing the previously stored schedules.

Message Library

FR TS.368 The system shall be able to store a library of messages in the central database.

FR TS.369 In addition to the message text, a message entry in the library shall contain all the control codes, timing data, and other information needed for a sign to properly display the message.

FR TS.370 The library should be easily searchable (e.g., keyword search) to facilitate the selection of appropriate messages.

6.28 Control Signs

FR TS.371 The system shall control the sign in response to instructions from Operators and/or a schedule.

FR TS.372 Sign control functions to be supported include replacing or blanking the current display.

FR TS.373 Sign control functions to be supported include replacing or deleting the schedule for a VMS.

FR TS.374 The system shall poll each sign at regular intervals (this parameter shall be re-configurable) to verify the message currently being displayed. Operators shall have the ability to select certain sign units to be left out of the polling cycle.

FR TS.375 If the Operator chooses to send the message to one or more signs, the software shall present the Operator with a list of all signs (of the proper type), so that the Operator can select to which signs the new message goes.

FR TS.376 The Operator may designate signs by clicking on their icons on the system map.

FR TS.377 Using a single command, the Operator shall be able to cause the newly created message to be stored in all the signs he specified and, if desired, to be displayed on each of those signs.

6.29 Response to Incidents

FR TS.378 The system shall track the resources used to respond to an incident including regardless of agency that is responding or contributing resources to the response: Resources shall include:

- Vehicles (e.g. Emergency Vehicles, DOT Vehicles, TOW)
- Equipment (e.g. DMS, HAR, Signal Plans)
- Personnel
- Operations Center

FR TS.379 Changes in response status shall be communicated with other agencies via a notification.

FR TS.380 The system shall also provide for tracking of special events and roadway construction.

FR TS.381 The incident tracking system shall provide for automatic generation of response plans.

FR TS.382 Response plans shall be customizable by the Operator.

FR TS.383 Incidents shall be displayed on the system map displays.

6.30 Priority to Transit

FR TS.384 The system shall support transit priority consistent with the approach adopted by the LACMTA for countywide deployment.

6.31 Priority to Emergency Vehicles

FR TS.385 The central signal system software shall recognize the occurrence of locally initiated preemption for emergency vehicles and thereby not erroneously diagnose a coordination failure because the local controller has been preempted.

FR TS.386 The beginning and ending times of all preemption events shall be recorded in the system log.

FR TS.387 The central signal system shall include reports and displays that show the beginning and ending times (or alternately, the beginning time and duration) of all preemption events for a selected time period.

FR TS.388 Vehicle preemptions shall be reported by intersection approach.

6.32 Manage Incidents

FR TS.389 The system shall track the location and status of an incident from start to finish.

FR TS.390 Data elements used in the incident tracking system shall be compatible with the Advanced Traffic Management Data Dictionary Standard.

FR TS.391 The incident tracking system shall track incident and be able to compute incident duration.

FR TS.392 The incident tracking system shall track incident status.

FR TS.393 The incident tracking system shall include provisions for special events and roadway construction.

FR TS.394 The incident tracking system shall provide a mechanism for exchange with other agencies.

FR TS.395 The incident tracking system shall be able to receive various notification alarms.

FR TS.396 The incident tracking system shall include a mechanism to track receipt of information sent from one agency to another.

FR TS.397 The incident tracking system shall include a contacts and inventory of equipment available for incident response.

FR TS.398 The incident tracking system shall provide for automatic geocoding of incident location on the GIS-based map.

6.33 System Performance Criteria

The central signal system software shall meet the performance criteria outlined in Table 6.1.

Category	Performance Measure	Criteria
Central Workstations	(1) System start-up or re-boot time	10 minutes
	(2) Data latency	3 seconds
	(3) Display intersection graphic fully drawn and updated with dynamic attributes	10 seconds
	(4) Refresh rates: Largest map All other displays	 1 second 1 second
	(5) Time for user to monitor, display and access any control interface	3 seconds
	(6) Display of detail list views	3 seconds
	(7) Controller commands to occur	3 seconds
	(8) Number of intersections supported	2000
	(9) Number of system detectors (not only those for local actuation) supported	5000
	(10) Minimum number of simultaneous users	limited only by network
Dial-up access (telephone or cellular)	(11) Remote computer system start-up	5 minutes
	(12) Monitor and control any signal controller	15 seconds
	(13) Controller commands to occur	5 seconds
	(14) Display intersection graphics and status view, fully updated with dynamic attributes	15 seconds
	(15) Data latency	3 seconds

Table 6.1: Performance Criteria

7 DETECTION TECHNOLOGIES

7.1 Current Situation

In order to meet the objective of the Projects; i.e., to deploy traffic control systems in the Corridor so that the signals along I-5/Telegraph Road can be synchronized across the jurisdictional boundaries, it is necessary to provide system detection. System detectors are not used for direct intersection control, but for the collection of traffic data to enable a broader view of the network conditions to be taken into account in selecting signal timings. These devices typically collect volume, occupancy and speed data per each lane. System detectors are connected to a central system and are located in strategic sections where there is little chance of traffic conditions affecting the operation of the detectors (e.g. to avoid queuing over a loop detector, loops are located 250’ to 300’ from the stop-bar).

The installation of system detectors will allow for the collection of real-time traffic information that will present the system with a picture of current, up-to-the-second conditions on the Corridor. This information will then allow agencies to synchronize their signals with neighboring agencies, and exchange traffic information in real-time. Agencies will also be able to exchange data with other agencies. This will allow the agencies to respond to recurrent and non-recurrent congestion in a coordinated fashion across the jurisdictional boundaries.

Currently, no such detection is deployed within the Project area. So this detection analysis is aimed at identifying recommendations for deployment of system detectors rather than upgrading existing detection equipment.

7.2 Confirmation of Requirements

Previous efforts on this Project have identified User and Functional Requirements that necessitate system detection. Requirements fall under the following use cases:

Use Case: Monitor Congestion:

FR TS.261 The system shall provide a means for detecting recurrent and non-recurrent congestion.

Use Case: Measure Traffic

User Requirements

UR TS.33 The ATMS shall provide the capability of collecting and maintaining all data required for monitoring, and confirmation of displays from all intersections concurrently

UR TS.34 If the intersection is not running coordinated, data shall continue to be collected

UR TS.38 Data collected by the ATMS shall be capable of being aggregated to peak hour volume as used to satisfy the LACMTA Congestion Management Plan highway monitoring requirements

UR TS.70 At a minimum, per lane volume and occupancy between all major intersections (mid-block) shall be collected

UR TS.71	Above data will be used for planning purpose, timing plan generation, and as input into incident detection and adaptive traffic control algorithms
UR TS.72	Detection technology shall provide accurate data on a per lane basis
UR TS.73	UR TS.72 Detection technology shall be reliable
UR TS.74	Detection technology shall be cost-effective on a life-cycle basis
UR TS.75	Detection technology may be permanent or temporary
UR TS.76	Detection technology shall perform in all weather conditions

Functional Requirements

FR TS.272	The field hardware is expected to include both system and local detectors that shall be used for both traffic counting and traffic-responsive operation.
FR TS.273	The central signal system software shall process and maintain detector count and occupancy data on a continuous basis to be used for various traffic control strategies and/or reporting tasks.
FR TS.274	Detector feedback shall be obtained on a user definable time frame.
FR TS.275	The time frame shall not be less than once per minute.
FR TS.276	The central signal system software shall recognize, process and display detector information including traffic volume, occupancy and speed.
FR TS.277	Volume shall be defined as: The number of vehicles counted in an interval of time.
FR TS.278	Occupancy shall be defined as the percentage of time the detector loop is occupied.
FR TS.279	Speed shall be calculated if based on the output from detector loops.
FR TS.281.a	The system shall detect a stopped vehicle or vehicles.

7.3 Comparison of Appropriate Technologies

7.3.1 <u>Introduction</u>

In the past, the primary roadway surveillance technologies included roadway inductive loop detectors, pneumatic road tubes, temporary manual counts for both real-time and historical traffic data collection. However with technological innovations, several new designs of different types have been developed and are being field tested in operational tests. This Section provides information regarding roadway-oriented detection technologies. These technologies include In-Pavement sensors (inductive loop detectors, magnetic detectors/magnetometers, and self-powered vehicle detector), and overhead mounted and/or side-fired detectors (microwave, ultrasonic, infrared, passive acoustic, and Video Detection/Image Processing (VIDs).

The effectiveness of roadway oriented technologies depends on collecting, processing, and managing information on the transportation network. This data may be a combination of speed, volume, density, travel time, queue length, and vehicle identification information or a collection of all. This data are used in making real-time traffic management decisions, selecting traveler information displays and messages, and implementing the appropriate control strategies to improve traffic flow throughout a corridor. Data may also be stored for planning and historical analysis.

7.3.2 Background and Issues

The importance of an accurate and reliable detection system cannot be overstated. The following Sections discuss issues that are critical to defining a surveillance system. The flow of traffic along a segment of roadway can be described in terms of the following parameters:

- Volume - a measure of traffic demand. The number of vehicles passing a point during a specific period of time.
- Occupancy - a measure of traffic density. The percentage of time that vehicles are present in the detection zone.
- Speed - a measure of the rate of motion of the vehicles. Speed may be measured on a per vehicle basis or the average speed of all vehicles passing through the detection zone may be measured on a macroscopic basis.

A system can utilize these measures of effectiveness to determine demand levels, the utilization of capacity, potential incident and/or bottleneck locations, and the level of service or performance of network segments. Although a system that provides all possible traffic flow parameters at each detection location would be desirable, few surveillance technologies provide this capability, and those that do are relatively expensive, untested, and/or difficult to maintain.

Detector Spacing and Data Processing

The amount of data processing required is dependent upon the type of detection device(s) used. While some detection devices can measure speed, volume, occupancy and average vehicle length, others can only provide one or two of the aforementioned functions and/or presence information that requires additional processing for further determinations. This data can be analyzed using algorithms to determine the additional needs of the system. However, the amount of additional processing necessary to determine the necessary information may impact the time of receipt of the processed data thereby not making it as current as if the system had more sophisticated detector(s) that automatically process the information upon detection.

Relative Cost

The specific application must be defined to compare the relative costs of alternative technologies. In comparing costs, the following should be considered:

- Required Coverage - Several technologies (e.g., Video Image Processing (VIPs) and side-mounted microwave) provide coverage of multiple lanes, while other technologies (e.g., loops, magnetometers, and passive infrared) provide single lane coverage. Though the cost of using a technology that provides multiple lane coverage may be several times that of a detector providing single lane coverage, if multiple lane coverage is required, the overall cost may favor the multi-lane detector.

- Communication – The data collected needs to be transferred back to the central system. This can be considered as independent of the type of detection technology as various wireline and wireless communications media can be used with each candidate detection technology.
- Physical Installation - An overhead structure is required to mount overhead detectors. When a suitable structure does not exist, the cost of the structure must be included in the cost analysis. For In-Pavement detectors, the cost is reduced if installation occurs during the construction or reconstruction of the facility obviating the need for lane closures and the concomitant cost of maintenance and protection of traffic.
- Maintenance - Less costly for devices that can be maintained without disrupting traffic.
- Data Requirements - Several technologies (e.g., VIPs, and microwave) provide speed, occupancy, and volume from a single unit; while technologies such as loops, magnetometers, and passive infrared only provide presence information. To obtain speed data from these presence detectors, two units and additional data processing are required. Thus, when only presence is required, the cost of the latter technologies may be less. When speed data is required, however, the cost of the two units and additional processing may reduce or negate the cost advantage.

7.3.3 Criteria

On the basis of the requirements stated above, the following criteria can be derived for use in comparing the candidate detection technologies:

- Ability to collect data needed by the ATMS:
- Volume
- Occupancy
- Speed
- Incident Detection (for non-recurring congestion)
- Installation cost (three lane section)
- Reliability
- Maintenance Cost
- Ability to re-locate
- Ability to operate in all weather conditions

7.4 Candidate Detection Technologies

7.4.1 In-Pavement Detectors

As the name implies, the detection element of these surveillance technologies is embedded in the roadway pavement sensing the presence of vehicles as they pass over the detection zone.

Inductive Loop Detectors

The inductive loop detector has been the dominant form of surveillance technology used in traffic management systems. An inductive loop detector consists of a loop or loops of wire buried in the roadway. The loop, connected to a detector amplifier via a lead-in cable, is stimulated by a signal at a frequency ranging from 10 kHz to 200 kHz. The loop functions as an inductive element in the detection circuitry, with the loop's inductance decreasing when a vehicle stops on or passes over the loop. The output of the loop amplifier changes state to indicate vehicle presence when it senses the decrease in inductance. This presence indication is then processed to provide measurements of volume and occupancy. Speed and classification information may also be provided by connecting the loops in pairs (i.e., "speed-traps").

A major concern with loops is poor reliability, and the maintenance effort and disruption of traffic required to affect a repair (i.e., re-cutting). Most loop detector problems resulting from wear and tear are due to such factors as poor design, improper installation techniques, insufficient inspection, poor roadbed, or some combination thereof, and not an inherent deficiency in the technology itself. In newer installations, loop reliability has been dramatically improved by encasing the loop wire in plastic tubing, using better sealant, and embedding pre-formed loops (consisting of loop wires in PVC conduit) into the roadbed. Loops are traditionally cheaper to install, without the need for an overhead structure, however, the costs of maintenance and protection of traffic (MPT) offset these cheaper capital costs, especially maintenance costs.

Magnetic Detectors

Magnetic detectors indicate the presence of a metallic object (such as a vehicle) by the disruption caused in an induced or natural magnetic field. These devices may be active, such as magnetometers, excited by an electrical current in windings around a magnetic core material; or they may be passive, such as magnetic detectors, sensing perturbations in the earth's magnetic field produced when a vehicle passes over the detection zone. Like loops, the magnetic detector's probe is connected via lead-in cable to an electronic unit that contains the detection circuitry.

Magnetometer probes (i.e., active magnetic devices) are cylinders, no larger than 2 inches in diameter or more than 4.25 inches in length, installed vertically 6 to 18 inches below the pavement surface. The detection zone for a magnetometer is a point rather than the larger area encompassed by a loop. Magnetometers detect vehicle presence. The presence information can be processed to provide volume and occupancy measurements, and speed and length if installed in a paired configuration. Magnetometers may be effective for use on bridge structures (the probes can be attached to the underside of the bridge), and along roadway segments with chronically poor pavement surfaces, conditions generally not suitable for the installation of loops.

Passive magnetic detectors require a minimum vehicle speed, usually 3 to 5 mph, and therefore cannot be used to detect presence. Two types of magnetic detectors exist, with the primary difference being their installation and size. The first type is installed by tunneling under the roadway and inserting the sensing probe, approximately 2 inches in diameter by 20 inches long, into a non-ferrous conduit. The second type, approximately 3 inches by 5 inches by 20 inches long, is encased in an aluminum housing that is mounted flush with the roadway. Since passive magnetic detectors sense changes in the earth's magnetic field over a wide area, they have a detection zone covering up to three lanes. Recent application of new digital processing technology to magnetic anomaly detection promises to significantly improve the performance of these detectors with the possibility of tracking multiple vehicles in a multi-lane scenario.

Like loops, magnetometers are relatively inexpensive, but the cheaper capital costs are offset by the costs for installation and maintenance.

Self-Powered Vehicle Detector

The self-powered vehicle detector (SPVD), developed with FHWA support, consists of an in-road sensor containing a transducer, an RF transmitter with antenna, a battery, and a controller housed in a cabinet along the side of the road. The in-road sensor operates on the same principle as the magnetometer sensor. It is powered, however, by an internal lithium battery with a service life of 5-7 years. Data are transmitted from the in-road sensor to a roadside processor via a spread-spectrum radio link, obviating the need for lead-in or interconnecting cable. Along with providing volume, occupancy, speed (bins), and classification (bins) this unit also provides data regarding pavement temperature.

7.4.2 Overhead Mounted Detectors

Installation of the detection unit above or to the side of the roadway permits maintenance activities to be performed with minimal disruption to the traffic flow. Moreover, these overhead-mounted detectors can generally remain operational during roadway reconstruction and rehabilitation activities that usually destroy loops and other In-Pavement devices. One potential drawback with these technologies is that their optimum placement is generally directly over the travel lane(s); and for such an installation to be cost-effective, an existing overhead structure (e.g., overpass, sign support) is required. The location, spacing, and placement of these existing structures can impact the effectiveness of the surveillance subsystem. Moreover, many DOT's require a lane closure whenever personnel are working on a structure above the roadway. Like the I-5 / Telegraph Road Corridor, over-the-road structures do not exist for strategically placed detection. Side-mounted detectors are easier to deploy, as only a pole located at the side of the roadway is required.

Several of these overhead technologies have not been completely proven in terms of accuracy or long-term reliability through operational testing. It is anticipated, however, that current operational tests involving many of these surveillance technologies, and an FHWA-sponsored research effort to field test and evaluate these technologies, will demonstrate the viability of many of these detectors for ITS-based systems.

Microwave Radar Detectors

Microwave radar detectors direct low power microwave energy toward a roadway. As vehicles pass through the beam, a portion of the energy is reflected back (i.e., backscattered) toward the detector where presence and speed can be measured. Some microwave detectors measure the range between the detector and the vehicle, and thus provide presence information. Other types of microwave detectors measure speed and detect vehicles using the Doppler effect. Each type is discussed below.

- Doppler - The beam width of a microwave radar detector, often referred to as just a "radar" detector, can be wide or narrow.
- Wide Beam - These units are installed at locations where only the general speed of the roadway flow is required. They can be mounted over the center of the roadway or to the side. Whenever a vehicle enters the beam, its speed is measured. If multiple vehicles enter the beam within the same one-second interval, the speed of the largest vehicle is typically recorded.

- Narrow Beam - These units are installed at locations where lane-specific traffic volumes and individual speed measurements are required. An individual detector is mounted over the center of each lane.
- Long Range Detector - This unit is a variation of the wide beam detector. The design of the wide beam detector is such that, while it can be mounted on the side of the roadway, it needs to be adjacent to the roadway it is detecting. As its name implies, the long range detector projects its radar beam over a greater distance so that it can be set further back from the roadway, or on the opposite side of the roadway than the direction it is detecting. This greater distance makes this detector useful in construction zones where it can be installed away from the work area and still provide traffic flow information. This type of detector is not recommended for incident detection due to the long detection zone. A long detection zone can result in the detection of the same vehicle multiple times.

Because the measured speed depends on the angle between the direction of travel of the vehicle and the direction of propagation of the radar energy, the mounting angle is critical. These detectors can only detect vehicles moving at speeds greater than 2-3 mph. Therefore, they are not true presence detectors.

Outputs of several radar detectors (e.g., narrow-beam units installed over each lane) may be multiplexed together to conserve data recording hardware. In this case, a one-second sample rate for polling the detector outputs in each lane may not be adequate to detect each vehicle when traffic volumes and speeds are high. This configuration can be useful, however, when macroscopic speed measurements are of interest.

Side-Fired Operation

Installation of the microwave detector at the side of the roadway, at a 20-30 foot height and with no greater than a 50° angle to the vertical, provides lane specific volume and occupancy data. Speed and classification information can also be obtained if 2 side-mounted detectors are installed next to one another emulating a loop-based trap. A presence microwave detector has been developed by EIS (Electronic Integrated Systems) in concert with the Toronto Freeway Traffic Management System. The EIS "Remote Traffic Microwave Sensor" (RTMS) provides up to 8 detection zones of user-defined length (in 7-foot increments) along the antenna ground footprint within a range of 200 feet. This detector transmits a frequency modulated continuous wave (FMCW) such that the transmitted frequency is increasing or decreasing with respect to time. By comparing the frequency of the reflected signal with the signal currently being transmitted, the range can be calculated. Though this detector primarily functions as a presence detector, it can be used to measure speed by dividing the footprint of the transmitted signal on the roadway into zones of detection emulating a speed trap.

A detector installed on the side of the roadway enhances maintenance activities (i.e., lane closures are not required). The potential drawback of the side-mounted configuration is that large vehicles passing through the beam in the lanes nearest the detector may reduce the unit's effectiveness in detecting vehicles that are concurrently present in the lanes farther from the detector. This phenomenon is known as occlusion. The impact depends on the number of large vehicles in the nearest lanes and the required accuracy.

Forward Looking Operation

By mounting detector units over the roadway, the problem of interference from large vehicles is eliminated. This configuration provides two (or more) detection zones for measuring volume, occupancy, speed, and classification. To obtain this information on a lane-specific basis, a detector must be installed over each lane, increasing the costs as compared to a side-fired installation.

Ultrasonic Detectors

Ultrasonic vehicle detectors can be designed to receive range or Doppler speed data, the same information measured by the microwave radar detectors. Ultrasonic detectors transmit sound waves, at a selected frequency between 20 and 65 kHz, from forward-looking or side-viewing transducers into an area defined by the beam width pattern. A portion of the energy is backscattered or reflected from the road surface or a vehicle in the field of view. The preferred mounting positions for range-measuring (presence) ultrasonic detectors are forward and side viewing. The speed-measuring ultrasonic detector is mounted overhead facing approaching traffic. The transducers in both the presence and speed-measuring ultrasonic devices convert the received sonic energy into electrical energy that is fed to signal processing electronics either co-located with the transducer or located in a roadside controller.

Infrared Detectors

Infrared detectors consist of both active and passive models. In the active system, detection zones are illuminated with low power infrared energy supplied by light emitting diodes (LEDs) or laser diodes. The infrared energy reflected from vehicles traveling through the zone is focused by an optical system onto a detector matrix mounted on the focal plane of the optics. Real-time signal processing techniques are used to analyze the received signals and to determine the presence of a vehicle. Changes in received signal levels caused by environmental effects, such as weather, shadows, and thermal heating, can be automatically corrected by the processing.

Passive infrared detectors provide presence information. They use an energy sensitive detector element to measure, without transmitting any energy of their own, the change in energy emitted when a vehicle enters its field of view. The source of this energy is blackbody radiation produced by the non-zero temperature of emissive objects. Eltec manufactures a passive infrared detector that uses a lens, which provides 3 to 7 degree-wide detection zones that change as a function of focal length. The zone may extend up to 300 feet from the unit. The use of a long focal length lens eliminates adjacent lane detection that may occur when detecting vehicles over 100 feet from the unit.

Several disadvantages of infrared detectors are often cited. Changes in atmospheric water content (as manifested in fog, haze, and rain) and pollutant levels can cause scatter and absorption of the infrared beam and received energy. These problems may be mitigated by using a detector operating at the longer wavelengths of the infrared spectrum. Infrared detectors are used in England for both vehicle signal control and in pedestrian crosswalks.

Passive Acoustic Detectors

Passive acoustic detectors "listen" for vehicles as they pass through a detection zone. This detector technology uses arrays of microphones to detect and identify the unique acoustical signatures of engine noises and the interaction of tires with the pavement and processes them to provide spatial directivity. The size and shape of the detection zone are determined by the sensor aperture size, the processing frequency band, and the installation geometry. When a vehicle passes through the detection zone, an increase in sound energy is detected by the signal processing that is part of the acoustic array and a vehicle presence signal is generated. When the vehicle leaves the detection zone, the sound energy level drops below the detection threshold and the vehicle presence signal is terminated. Due to sound reverberation from the walls and ceiling, passive acoustic detection is not suitable for tunnels.

Video Detection/Image Processing (VIDS)

Video Detection/Image Processing (VID), developed from machine vision technology, extracts real-time traffic flow data (e.g., volume, occupancy, speed, length) by using microprocessor-based hardware and software to analyze video images of the roadway. Current VID systems (e.g., Autoscope by Econolite) use a variety of signal processing algorithms to gather traffic flow data. These systems rely on user-defined detection zones (i.e., "pseudo-detectors") within the camera's field-of-vision. Each time a vehicle enters or crosses this zone, a presence signal is generated that can be processed to provide volume, speed, classification, and occupancy measurements. Multiple detection zones can be located within the image and can be configured to suit the road geometry.

Newer VID systems identify edges on an object (such as a vehicle) and track these unique edges through the camera's field of view. TraffiCam by Rockwell identifies images in user-specified detector zones to collect data. The persistence of individual tracks is used to determine vehicle volume and type, and can reveal data on events such as sudden lane changes, vehicles traveling the wrong direction, and stationary vehicles. Information available at the control center may also include icon representations of traffic flow within the camera's field-of-view (where a different colored/shaped icon represents a different vehicle type moving against a graphical display of the roadway), and low-bandwidth "snap-shot" pictures of the video image itself.

VIDs offers certain advantages as they do not require installation in the pavement, and several lanes can be monitored using a single camera. Potential concerns and design issues with VIDs include:

- Data requirements - As noted, some VID systems provide volume, occupancy, speed, and classification data by emulating an In-Pavement detector, while others track vehicles to provide more qualitative information on the traffic flow conditions. Moreover, those systems that emulate loops typically utilize different algorithms for day conditions (identifying the entire vehicle) and night conditions (identifying the movement of head/tail lights). While the latter method provides accurate volume and speed information, it precludes the processing of occupancy and classification data. In order to obtain this presence-driven information during the hours of darkness, it is necessary to utilize low-light sensitive cameras (e.g., minimum usable illumination at scene of 2 foot-candles), and install the cameras along roadway segments with adequate lighting.

- Accuracy - The accuracy of VIDs is very sensitive to camera placement. The optimum situation is to have the cameras mounted as high as possible (at least 25 feet), and be centered over the roadway with a steep vertical angle, though an oblique angle may be tolerated if the camera is mounted at least 45 feet high. Conditions that vary from this optimum placement typically result in an increase in vehicle speed measuring errors, which are proportional to the vehicle's height divided by the camera's mounting height. Inclement weather such as fog, rain and snow, day-to-night transition, and vehicle shadows are weaknesses of this technology. A major design concern with camera placement and VIDs is occlusion, when the image of one vehicle partially or completely masks the image of an adjacent vehicle. Positioning the camera well above the center of the roadway will resolve most occlusion problems, but this may not always be feasible. Even with this type of arrangement, densely-packed or congested traffic may still cause occlusion.
- Mounting - The camera needs to be mounted on a stable platform. Camera movement caused by the wind or vibration may introduce measurement errors.
- Dedicated Camera - Using the same camera to provide both VID imaging and closed circuit television (CCTV) surveillance is usually not feasible. Every time the camera is panned, tilted, or zoomed to view an incident or other congestion, a fairly common occurrence in most systems, the VID detection zones are lost. Though it is technically feasible to reposition the camera at the previously established detection zones after it has been moved, special pan/tilt units and processing hardware are required. Moreover, for a camera to operate properly in the VID application, the automatic gain, iris, and sensitivity limits must be adjusted to prevent blooming during night hours.

Processing of upstream or downstream images influences VID performance. The primary advantage of upstream viewing is that traffic incidents are not blocked by the resulting traffic queues. Tall trucks, however, may block the line of sight; and blooming from headlights may occur. Downstream viewing offers advantages of camera concealment that does not alter driver behavior, easier identification and tracking of vehicles using information contained in the tail lights, and better acquisition of vehicle tracks because the vehicles are closer to the camera at initial lock-on.

7.4.3 Advantages and Disadvantages of Roadway-Oriented Technologies

Selection of the appropriate surveillance technology is a complex task that includes consideration of many factors. In addition to the availability and demonstrated capability of the detectors, several other criteria must be met by the selected detectors, including:

- Reliability
- Cost
- Flexibility
- Installation requirements
- Operational environmental and maintenance requirements
- Data requirements
- Representative of current technology

Exhibit 7.1 summarizes detector technologies by providing a list of detector technologies, how they are mounted, the parameters that may be detected, advantages and disadvantages, reliability, and approximate costs as well as the current status of each technology. Costs, where available, are based upon a three-lane section in order to normalize the technologies, and are presented in an order-of-magnitude level.

Exhibit 7.2 summarizes the detector technologies against the Project's requirements. It serves to subjectively rate the merits of each technology against the requirements in the Corridor.

Technology		Mounting	Obs	Detection Area	Advantages	Disadvantages	Reliability	Status	Approx. Cost (3-lane section)
Loop		In pavement	V,O, S*,L*	Size of loop	-Low/unit cost -Large experience base	-Not suitable for use on bridge decks, overpasses, poor roadbeds -Traffic interrupted for repair and installation -Susceptible to damage by heavy vehicles, road repairs, utilities	High for loop when installed properly	Operational	$3000
Magnetometer		Under Bridge Decks or in pavement	V,O, S*,L*	Point	-Small vehicle or obstacle (bike) detection -Magnetic - multi-lane coverage	-Traffic interruption for installation and repair when installed in pavement	Moderate	Operational	$3600
Microwave Radar (Doppler)	Wide Beam	Side or overhead	S	Depends on distance	-Direct measurement of speed -Inst. /maint. may not require lane closure	-Only provides speed data	High	Operational	$1000
	Narrow Beam	Overhead	S						
Microwave Radar (Presence)	Fwd looking	Overhead	V,O, S,L	Minimum 7-foot length	-Installation/maintenance may not require lane closure	-Side mounted may have masking of vehicles	Moderate	Operational	$4500
	Side Mnt	Side (paired units)	V,O, S*,L*						$3000

Technology		Mounting	Obs	Detection Area	Advantages	Disadvantages	Reliability	Status	Approx. Cost (3-lane section)
Ultrasonic		Overhead (downward)	V,O, S*,L*	Depends on distance and beam width	-Compact size -Installation/maintenance may not require lane closure -Large base in Japan	-Accuracy may be affected by variations in air temp and water concentration -One per lane required	High	Used in Japan	$3000
Infrared	Passive	Overhead (downward)	V,O	Depends on distance and beam width	-Installation/maintenance may not require lane closure -Compact size	-Susceptibility to ran, fog, haze, and other atmospheric obscurants	Moderate	Used in Europe	$4500
	Active	Overhead	V,S, O,L						$10000 – $20000
Passive Acoustic Array	Overhead or side		V,O, S,L	User defined	-Installation/maintenance may not require lane closure	-Not suitable for installation in tunnels -Signal processor required to identify vehicle	Moderate	In development	$4500 - $6000
Video Image Detection (VIDs)	Overhead or side		V,O, S,L	User defined	-Installation/maintenance may not require lane closure -Multiple lanes observed -Detect. Zone user defined	-Accuracy sensitive to camera placement (occlusion) -Susceptible to adverse weather -Roadway lighting required for accurate nighttime data	Moderate	Operational	$17,000 - $25,000

Technology	Mounting	Obs	Detection Area	Advantages	Disadvantages	Reliability	Status	Approx. Cost (3-lane section)

Obs = Observable parameter

S = Speed

V = Volume

O = Occupancy

L = Length

* = Parameter can be measured in a paired-configuration (i.e. two units needed)

"Overhead" implies both forward- or back-looking, except as noted.

Exhibit 7.1: Detector Technologies

Project Requirements	Loop	Magnetometer	Microwave Radar - Doppler	Microwave Radar – Presence	Ultrasonic	Infrared	Passive-Acoustic	Video Incident Detection
Ability to collect data needed by the ATMS:								
Volume	+	+	-	+	+	+	+	+
Occupancy	+	+	-	+	+	+	+	+
Speed	+	+	+	+	+	-	+	+
Incident Detection (for non-recurring congestion)	Central Function	Central Function	Central Function	Central Function	Central Function	Central Function	Central Function	+
Installation cost (three lane section)	+	+						
Reliability (accuracy and availability)	+		+		-[2]	-[3]		-[2]

[2] Accuracy is high in good weather conditions, but susceptible to adverse weather conditions

[3] Accuracy is moderate in good weather conditions, but susceptible to adverse weather conditions

Project Requirements	Loop	Magnetometer	Microwave Radar - Doppler	Microwave Radar – Presence	Ultrasonic	Infrared	Passive-Acoustic	Video Incident Detection
Maintenance Cost	+	-	+	+	+	+	+	+
Ability to operate in all weather conditions	+	+	+	+	-	-	+	-

Key: + = Meets or exceeds requirement

- = Does not meet requirement or performance meets requirement, but with poor results

(blank) = For Installation Cost, is dependent upon existing structure to be "+". If structure is needed, costs are high, resulting in a "-" rating. For Reliability, blank signifies moderate results, or as noted with footnotes, other factors affect reliability (e.g., weather) In all cases, proper installation and location is assumed.

Exhibit 7.2: Compliance Matrix of Detector Technologies to Project User Requirements

7.5 Analysis

As previously discussed, a number of factors affect the selection of an appropriate detection technology. Further, the requirements defined by the users, to a greater extent, will justify a certain technology approach or approaches. The following is a summary of how each technology fares in relation to the requirements, and to other factors that affect reliable implementation. This Section is followed with technology recommendations.

Loops

Loops meet all of the requirements of the Project. They are the most mature technology, and history shows that if installed correctly, are as reliable and accurate as any other technology on the market. Loops remain an inexpensive technology to install and maintain, due in part to the fact that there are numerous vendors who can install and supply them. Since they are an In-Pavement technology, additional costs are required for maintenance and protection of traffic (MPT) when installing or maintaining, however, if installed at off-peak times, these costs can be kept to a minimum. In addition, loops are already in use along the Corridor, all of which make this a viable option for the Project. A disadvantage of the loop technology is the high cost of replacement of the loop, which requires lane closures and correspond to a complete reinstall.

Magnetometers

Like loops, magnetometers meet all of the Project requirements except portability. They, too, are a mature technology, and while having some installation location restrictions, should not have any restrictions being installed in the Corridor. Their reliability, however, is not as high as loops or some of the other technologies. Magnetometers are not as common as loops (and are not in use along the Corridor), and as a result, installation and maintenance costs are higher.

Microwave Radar

Microwave Radar – Doppler –meets critical project requirements of collecting volume occupancy and speed on a per-lane basis. However, this is achieved only in the presence mode, where reliability (accuracy) is only moderate. This is a result of the occlusion affect, and if truck percentages are low, this is an attractive alternative. While higher in cost than loops, the savings in MPT can offset some of the additional cost.

Ultrasonic, Infrared, Passive Acoustic and Overhead Self-Powered Vehicle Detector (OSPVD)

These technologies are either in-development (passive acoustic) or not deployed in this country. While the fact that a technology hasn't been deployed in this country shouldn't necessarily be a deterrent to its implementation, further research should be conducted on those showing promise to determine the costs to deploy in this country and the level vendor supply and support. This pertains only to the OSPVD, as the Ultrasonic and Infrared detectors have reliability problems in adverse weather conditions.

Video Incident Detection System (VIDs)

VIDs has been implemented for a decade, and is the most expensive of the technologies. However, where cost savings can be made by using the video for incident verification and diagnosis, it has proven worthwhile. Since it is video based, though, adverse weather such as fog and heavy air has an adverse impact on the accuracy of the data collected.

In summary, the only technologies that meet all of the non-subjective requirements are Microwave Radar (presence) and Passive Acoustic. Microwave Radar has shown only moderate reliability. The passive acoustic has not been implemented in this country. Loops and magnetometers meet all of the requirements VIDs, Infrared and Ultrasonic detectors are adversely affected with inclement weather Microwave Radar (Doppler) and Infrared detectors do not measure volume, occupancy and speed, a requirement that is non-negotiable for incident detection and planning purposes.

7.6 Recommendations

Since the Corridor is comprised of multiple agencies, and as such, multiple maintainers, no one technology may be suitable, or desirable, across the Corridor. It has been previously noted that loops exist in most of the jurisdictions, and with the exception of The City of Santa Fe Springs, the agencies has not precluded their use. The City Santa Fe Springs has required non-In-Pavement technologies, and the City of Downey has requested VIDs specifically

In examining the technologies against the requirements, it is apparent that some of the technologies are not suitable. Ultrasonic, and Infrared for instance, are adversely affected by inclement weather. Further, Infrared does not collect speed data. The Passive Acoustic array does not have sufficient maturity to be considered in this deployment. Magnetometers, while a mature technology has only moderate reliability, and when compared to loops, which has better reliability and is cheaper, becomes unsuitable for the Corridor.

To that end, loops, Microwave Radar –presence – (such as the RTMS detector),and VIDs become the most applicable technologies for the Corridor, and are recommended for implementation. Loops are commonplace, reliable, cheap to install and maintain (if installed properly), non-proprietary, and provide all of the required data for the Corridor. It is not anticipated that pavement problems, resulting from truck traffic, will be experienced in these deployments since the detectors will be installed mid-block. Microwave Radar provides a proven alternative for off-the-roadway implementations such as that required by The City of Santa Fe Springs. The RTMS detector by EIS has shown increasing promise in providing more accurate, reliable information. VIDs has a proven history of providing real-time detection and surveillance.

8 LOCAL CITY CONTROL SITE CONSIDERATIONS

8.1 Introduction

The I-105 Corridor Project has provided an analysis of requirements for the Sub-Regional TMC and local city control center sites. The County of Los Angeles DPW has a separate activity addressing the County's traffic management center needs. This Section of the Functional Requirements report applies the I-105 Corridor Project local city control (LCC) site analysis to the I-5/Telegraph Road Project agencies: Commerce, Montebello, and Pico Rivera.

This Section identifies relevant User and Functional Requirements from the I-105 Corridor Project in order to derive typical requirements for the I-5/Telegraph Road Project agencies. Agency specific requirements have been developed as part of this Project. Additional material has been drawn from the South Bay Traffic Signal Synchronization and Bus Speed Improvement Plan (Part III) – Deliverable 2.2.4 : Final Local Traffic Control Center(s) Facility and Computer Systems Requirements.

8.2 Types of TMC

Located in Southern California are a range of traffic operations and management centers in use by local agencies. Examples are:

- City of Anaheim
- City of Irvine
- City of Inglewood
- City of Long Beach
- City of Los Angeles
- City of Pasadena
- City of Santa Ana

These are all examples of self-contained, purpose built facilities, sometimes occupying several thousand square feet. This has been dictated by the intensive, staff oriented nature of the operations of these systems. However, not all operations centers need to be on such a scale. Tailoring the control center, or LCC, to the City's needs is a critical aspect of the LCC's design.

The East San Gabriel Valley Pilot Project introduced the concepts of smaller scale traffic management centers, requiring less space, but still self-contained. These would address the needs of the city that wished to have an operational focus without the costs associated with a sophisticated, dedicated facility. A typical LCC for an agency that wished to have multiple operators and the ability to view CCTV images would likely involve two rooms: the control room, where the workstations are located, and the equipment room which houses the servers and communications equipment.

Figure 8.1: Example of the Control Area of an LCC

(Courtesy of the Spokane Region Transportation Management Center)

Figure 8.1 shows an example of what can be achieved in a relatively small area with such an arrangement. The photograph shows the control room of the Spokane Regional Transportation Management Center. This is a 20' by 30' room (600 sq. ft.). Behind the large screen display lies the equipment room which is 20' by 14' (280 sq.ft.) for a total of 880 sq. ft. This is providing ample space for three full operator workstations. (Note the use of the flat screen displays, which are discussed below).

The example is a relatively comprehensive traffic control facility. In relation to the I-5/Telegraph Road Project this would represent one of the larger LCCs. For example, at a city which houses a traffic control system shared by several agencies, or even where the Sub-Regional TMC is located at a city.

In addition, the ESGV Pilot Project introduced the concept of the desktop traffic management center which took advantage of the use of PC-based equipment for the ATMS. This would be simply an area set-aside within an existing work area, such as a cubicle, where the ATMS equipment would be located. This would satisfy the need of the agency that wished to operate its own system, but kept the central equipment down to the minimum required. This would also be the LCC for an agency that simply used a workstation on a remotely located ATMS.

Figure 8.2 shows an example of an equivalent arrangement being used at the City of Englewood, Colorado. This system controls approximately 80 intersections.

Figure 8.2: Example of the Control Area of an LCC

Both the self-contained LCC and the desktop LCC are considered appropriate for consideration under this Project.

8.3 User Requirements

8.3.1 General

UR LCC 1. Local City Control Sites need to support the core ATMS, detection stations and communications system functionality.

UR LCC 2. The LCC must accommodate communications infrastructure enabling the ATMS located at that LCC to download information to, and upload information from, the Sub-Regional TMC.

UR LCC 3. LCC sites may be staffed as needed. Depending on the specific scope of a facility, a full staff contingent may not be necessary.

UR LCC 4. Sharing staff with another co-located non-TMC function (i.e., accident analysis) may also be a viable option. In this case, the space requirements for the local city control site are considerably reduced.

UR LCC 5. A minimum LLC sites would be considered as housing one or two workstations in a control area and a hardware area that contains communications equipment, modems, servers, etc. It is estimated that such a site may require as little as 200 to 500 sq. ft of space.

UR LCC 6. LCC's shall be developed on a cost-effective site. This shall take into account considerations such as agency preference, development cost, and communication cost to the field devices.

UR LCC 7. When applicable, the LCC will be capable of displaying local CCTV system video images onto large video monitors, individual operator's workstations, and selected TMC offices and conference rooms.

UR LCC 8. The LCC shall have back-up power, water, and other utilities systems so operations can be continued during interruptions of normal utility service.

UR LCC 9. The LCC shall be sized to accommodate agency's operations staff and administrative support staff, the computer systems, and video display systems.

UR LCC 10. The LCC shall employ means to protect from and detect unauthorized access, tampering, and destruction of critical system information and components.

UR LCC 11. The LCC shall make use of the existing infrastructure in the Project area to the extent possible.

8.3.2 City of Commerce

UR LCC 12. The City of Commerce shall deploy ATMS workstations located at three sites: the Police Command Center, Community Section Division and Engineering Department.

UR LCC 13. The City of Commerce LCC shall be located at the Engineering Department at City Hall.

UR LCC 14. The City of Commerce LCC shall accommodate a complete ATMS.

UR LCC 15. The City of Commerce LCC shall accommodate the display of video images.

UR LCC 16. The City of Commerce LCC shall comprise self-contained rooms comprising an operations room and an equipment room.

8.3.3 City of Montebello

UR LCC 17. The City of Montebello LCC shall be located at the Engineering Department at City Hall.

UR LCC 18. The City of Montebello LCC shall accommodate a complete ATMS.

UR LCC 19. The City of Montebello LCC may comprise a defined area within the Public Works/Engineering Department or a self-contained room(s).

8.3.4 City of Pico Rivera

UR LCC 20. The City of Pico Rivera LCC shall be located at the Engineering Department at City Hall.

UR LCC 21. The City of Pico Rivera LCC will comprise a defined area within the Public Works/Engineering Department.

UR LCC 22. The City of Pico Rivera LCC will require minimal construction work.

8.4 Functional Requirements

The following are Functional Requirements for a typical LCC. Not all requirements are applicable when the TMC is not a self-contained room or rooms, but simply a defined work area (e.g. a cubicle) of an existing facility.

FR LCC 1. The specific layout of each room/area shall be configured on the basis of: staff allocation; equipment allocation; ergonomic interaction among various staff and equipment.

FR LCC 2. The LCC shall provide existing/new computer workstations and consoles/desks for the maximum number of operators expected to occupy the control room/area at one time.

FR LCC 3. In addition, a supervisor workstation and console/desk shall be provided, if required.

FR LCC 4. Ergonomically designed consoles/desks shall accommodate the surface equipment used by the operator (e.g., computer workstation components, telephone(s), detail monitor(s), etc.) allowing the operator to access the equipment easily and efficiently, while not blocking views of the other equipment and activities in the room/area.

FR LCC 5. Space for free paper work shall also be provided.

FR LCC 6. The TMC shall provide a desktop/console cable management system that allows easy reconfiguration for console monitoring.

FR LCC 7. The TMC shall provide glare control (positioning and/or filters) for workstations.

FR LCC 8. The TMC shall provide dedicated video monitors with CCTV capabilities that are designed for extended viewing (adequate separation, high contrast background, etc.) for displays.

FR LCC 9. The camera-input-to-monitor ratio shall be 4:1 or less.

FR LCC 10. Adequate space, wall clearance and access space shall be provided for visual display equipment (i.e., CCTV monitor banks, large screen display) and other stand-alone equipment, such as printers.

FR LCC 11. The layout of the equipment shall support the overall functionality of the equipment and room/area.

FR LCC 12. Sight lines to visual display equipment shall be based on acceptable horizontal and vertical viewing angles from the work position of each staff member working in the control room/area.

FR LCC 13. The visual displays shall be located to minimize glare.

FR LCC 14. Equipment shall be placed near those accessing it most frequently.

FR LCC 15. If the control room/area has more than one workstation, desks/consoles shall be within close visual and communications distance of each other, to allow for consultation, giving of advice and coordination of response.

FR LCC 16. If a supervisor function exists in the control room/area, the position of the supervisor station shall enable viewing of all accountable staff and equipment, as well as the stand-alone visual display equipment.

FR LCC 17. The control room/area shall be provided with an effective lighting design, including variable overhead lighting (i.e., dimmable and/or with zone switching) to allow operators to adjust ambient light depending upon the circumstances.

FR LCC 18. The lighting shall be arranged so that there is no direct glare on the various terminals monitors and displays.

FR LCC 19. Good task lighting shall be provided for the operators.

FR LCC 20. Walls shall be colored so as to minimize glare on terminals, monitors and displays.

FR LCC 21. Natural light through windows shall be provided, with filters or blinds for illumination and glare control.

FR LCC 22. Storage space shall be provided for manuals and files, equipment accessories (e.g. printer paper), and for the belongings of staff who do not have office space elsewhere in the building.

FR LCC 23. A raised or lowered floor shall be provided to facilitate cable routing between operator consoles, and to/from the computer/communications room/area.

FR LCC 24. Proper air-conditioned environment shall be provided for the comfort of the operators and the operating requirements of the equipment.

FR LCC 25. The TMC shall provide noise abatement (e.g., carpeted floor/tiles, textured wall materials, ceiling baffles) for sound control.

FR LCC 26. The layout of equipment shall allow for logical circulation paths within the room/area.

FR LCC 27. The control room/area and the computer/communications room/area shall be located in close proximity and preferably adjacent to each other.

FR LCC 28. Proper security shall be provided (e.g., swipe card, combination punch lock, etc.) to prevent unauthorized access to the control room/area.

FR LCC 29. A computer/communications room/area shall house the computer and communications equipment, such as CPUs, system consoles, circuit termination cabinets, modem racks, video receivers, video switchers, etc.

FR LCC 30. The layout of this room/area shall be organized according to the specific computer and communications equipment used.

FR LCC 31. Adequate floor and rack space, wall clearance and access room/area shall be provided, based on the requirements of the specific computer/communications equipment used.

FR LCC 32. In addition, temporary maintenance workspace for computer and communications staff shall be provided.

FR LCC 33. The room/area shall be provided with a raised or lowered floor, for cable routing to/from the control room/area.

FR LCC 34. A separate air-conditioning and humidifying system with back up shall be provided, if required for the specific equipment in the room/area.

FR LCC 35. The electrical power shall be regulated and air conditioner drains shall be provided for moisture.

FR LCC 36. The TMC shall provide an uninterrupted power supply (UPS) with adequate capacity to allow organized system shutdown or short term operation for the electrical system.

FR LCC 37. If ongoing TMC operation during a power outage is required, the TMC shall have a back-up generator.

FR LCC 38. Flood and fire detection and other protection equipment shall be provided in the room/area.

FR LCC 39. To minimize equipment damage, the extinguishing system shall be linked to a power shut-off so that the power is shut off prior to activating the extinguishing system.

FR LCC 40. The layout of equipment shall allow for logical circulation paths within the room/area.

FR LCC 41. The TMC shall provide typical office environment conditions (e.g., temperature, humidity, lighting, etc.).

FR LCC 42. Receptacles shall be supplied for LAN access, so that telephones, faxes, modems, etc. can all be run simultaneously.

FR LCC 43. Outlets shall be provided in logical locations or based on user preference.

FR LCC 44. Main Entrance/Reception - For security purposes, all visitors shall enter and exit the building through a single main entrance.

FR LCC 45. Other building access points shall be controlled (e.g., swipe card, combination punch lock, key) to prevent unauthorized access.

FR LCC 46. The TMC shall provide a service panel adequate to handle the demands of projected workloads for the electrical system (e.g., future upgrades and additions).

FR LCC 47. All power supply to electronics and computer equipment shall be properly conditioned to avoid voltage fluctuations and power surges.

FR LCC 48. The TMC shall provide emergency lighting for the secured areas (to supplement for all areas as per the building code in effect).

FR LCC 49. The TMC shall provide an adequate number of standard duplex convenience outlets.

FR LCC 50. Outlets shall be supplied with single phase unconditioned power appropriate for the selected equipment.

FR LCC 51. Electrical systems for the computer/communications room/area and the control room/area shall address the following factors: design according to local standards and codes; nominal voltage; circuits for each computer; circuits for the computer peripherals and electronics equipment; maximum voltage variation from nominal; frequency and allowable harmonic distortion; 5 wire (4 wire plus ground) connection; duplex receptacles located beneath equipment bays.

FR LCC 52. With the exception of the control room/area and the computer/communications room/area regular office temperature and humidity values and ranges shall be provided throughout the TMC for the comfort of the operators and to ensure proper operation of the equipment.

FR LCC 53. HVAC requirements shall be sized individually for heat loading of control room/area and computer/communications room/area requirements.

FR LCC 54. The TMC shall provide physical separation for climate control purposes of the control room/area and the computer/communications room/area, along with providing separate control for each.

FR LCC 55. Noise levels for the TMC shall be limited to 55dBA.

FR LCC 56. Insulated wall construction (floor to ceiling) shall be provided in the control room/area and the computer/communications room/area.

FR LCC 57. The TMC shall provide noise abatement (e.g., carpeted floor/tiles, textured wall materials, ceiling baffles) for sound control in the control room/area.

FR LCC 58. The TMC shall provide a fire suppression system suitable for electronic equipment areas per codes.

FR LCC 59. The TMC shall provide central fire alarm notification for fire suppression.

FR LCC 60. The TMC shall provide for automatic shutdown of all electronic equipment prior to extinguishing operation.

FR LCC 61. The TMC shall provide water protection as per applicable building code requirements.

FR LCC 62. Structural design and update of the TMC shall meet local building code requirements.

FR LCC 63. The raised/lowered flooring system shall be capable of sustaining the required loads, including point loading of heavy equipment.

8.5 Local City Control Site Equipment Requirements

8.5.1 Equipment Considerations

The ATMS Functional Requirements identifies equipment and devices that are needed to support regional traffic management functions and to provide the Local City Control Sites with access to traffic control and information within the Corridor. Relevant requirements are:

UR TS.24 The ATMS shall be based upon a client-server architecture or web

UR TS.25 Industry standard processors and network components shall be used

FR TS.1 The system shall use the latest version of Microsoft's multi-tasking operating system for Intel-architecture PC-based servers in a client-server architecture.

FR TS.2 System workstations shall use the latest version of Microsoft's multi-tasking operating system for Intel-architecture PC-based clients in a client-server architecture.

The requirements point to the use of standard, PC-based equipment.

As described above, for a self-contained facility it is recommended that the equipment be housed in two functional areas:

- Control Room/Area
- Computer/Communications Room/Area

Within the Local City Control Site, the Control Area and the Computer/Communications Area can either share the same space or be located in adjacent rooms depending on the space available at each Control Site location. This Section describes needed equipment for each space, and characterizes approximate dimensions, weight, power, and HVAC requirements of the devices.

8.5.2 Control Room/Area

Each Local City Control Site will likely house a single operator workstation. A workstation is comprised of a CPU, keyboard, mouse, and other computer accessories. The workstation will use two 19-inch high-resolution color monitors. The two monitors will be used for traffic management and control functions, as well as system maintenance functions. For example, operators will be able to enter data, monitor traffic and have access to incident information on system maps and informational windows. The monitors will also be capable of displaying the CCTV video images via the CCTV manager. For space reasons, it is recommended that flat screen monitors are used.

The operator workstation will be located either on a flat desk, or within a console (these options are discussed in Section 8.6). Other operator items that need to be located on a desk/console include a telephone, and possibly a radio for communications.

Some space for storage should also be provided for manuals, equipment, accessories, and staff belongings, especially for staff that do not have office space elsewhere in the building.

8.5.3 Computer/Communications Room/Area

The backend equipment for each Local City Control Site will vary for each site, depending on the capabilities of individual sites. It is estimated that a maximum of three equipment racks will be necessary. Local City Control Sites requiring no video will require fewer racks. Adequate floor space will need to be allocated for each equipment rack and for easy access to the equipment. The racks should be accessible from at least two sides. Some of the equipment to be stored on the racks includes all servers, distribution subsystems, routers, firewall, CCTV switch, video receivers, and UPS. The need for a telecom area is also necessary in this area**.** This will likely include a wall panel that has been estimated to require a 4-foot by 3-foot area for the installation of patch panels and WAN access hardware. The ability to use existing building telecom areas should also be considered depending on space available and ease of expansion.

If the Computer/Communications Area is housed in a separate room, the provision for a work area should also be considered. This could be as simple as including a desk, chair, and telephone.

8.5.4 Shared Areas

Other equipment that is necessary for operations includes a printer, fax machine, and photocopier. These items do not need to be exclusively for Local City Control Site use, but should be available to be shared with other department employees.

8.5.5 Summary

The following Table provides approximate quantities, dimensions, weight, and power consumption as well as HVAC requirements. The Table also provides a break down of rack space distribution.

Table 8.1: Local City Control Site Equipment Requirements

Room	Equipment	Quantity	Dimensions H x W x D	Weight	Power Consumption (Watts)	HVAC Requirements (Tons of Refrigeration per device)	Total (Tons of Refrigeration)
Control	CPU & Accessories	1	17”x7”x17”	30	400	0.114	0.114
	Monitors	2	18”x18”x10”	50	70	0.22	0.044
	Telephone	1	4”x10”x9”	4	6	0.002	0.002
	Task Lighting	1	NA	NA	75	0.021	0.021
Computer/ Comm	ATMS Server	1	.5 Rack	250*	500	0.142	0.142
	Video Switch / CODEC WAN	1	.5 Rack	250*	200	0.057	0.057
	Router / Firewall / CSU / DSU	1	.5 Rack	250*	500	0.142	0.142
	Local Signal Modems	1	.25Rack	250*	500	0.142	0.142
	Local T-1 Video / DSU / CSU / CODEC	1	.25 Rack	500*	1000	0.028	0.028
	Telephone	1	4”x10”x9”	4	6	0.002	0.002
* Includes weight of equipment’s portion of rack.					Approximate Total		**0.694**

8.6 Console Versus Desk Analysis

A major design consideration in the development of a Local City Control Site Control Area is the placement of operator equipment and devices. Factors such as workability, accessibility, space availability, and physical constraints must be examined. Conceptually there are two major options for arranging operator devices: a console design and a flat desk design. Each option has advantages and disadvantages, as well as unique requirements. This discussion addresses space requirements, access, lighting, and cable management factors for both options.

8.6.1 Equipment Requirements

Each option will have the same equipment/device requirements in order to meet the Functional Requirements of the TMC. Each operator will have a workstation at his/her desk or console. Both options will also be provided with task lighting, desk space for other work, and possibly a control system board, if not integrated into the workstation. These equipment/devices must be arranged in a way that provides accessibility, visibility, and ergonomic comfort to the operator.

Console Design

A console design “builds in” equipment such as monitors, and cables to provide an operator with a clean and attractive work area. Consoles can be custom made, or can be commercially available modular furniture. Typically a workstation requires approximately six (6) square feet of surface area. This may be higher in a console design depending on how monitors are oriented, and how much space is provided between viewing surfaces. An additional two to three (2-3) square feet should be provided for general work activities (i.e. paper work). Once a console design is determined, spatial concerns may become somewhat inflexible, as the re-arrangement of equipment and devices will be limited. This could hinder adding monitors or increasing monitor sizes if not accounted for.

Console designs have the advantage of providing cable management within the furniture itself. This allows for a clean, unobstructed area around the console with a limited amount of external or additional cable management devices. This is especially efficient with the use of a raised floor. The consoles can be placed on top of power and communication floor outlets, or against wall outlets, to provide for a system with no exposed cables. Typically each workstation will have its own dedicated power circuit and LAN outlet. In the event of an overhead cabling system it should be a goal to minimize any surface cable runs as cables switch from overhead to the floor. Also, placing workstations near walls or columns can create transfer points for cables. Any exposed cabling should be properly protected and meet applicable ADA standards.

In cases where neither raised floors or false ceilings are existing or feasible, other means of cable management will be necessary. This may reduce the appeal of using a console design, as external management methods will be required anyway. Typically console options are more expensive than flat desk solutions. Figure 8.3 shows a potential console layout. Note that an alternative is also shown in Figure 8.1.

Figure 8.3: Example Console Layout

8.6.2 Flat Desk Design

A flat desk design places equipment such as monitors onto a flat surface desk. This allows for good flexibility in arranging equipment and allows for expansion (i.e. upgrading to larger monitors). The use of a flat desk still requires the same equipment, but may require slightly less space, as equipment may be placed more closely together. Desks such as these are commercially available at reasonable cost, and can easily be reconfigured and expanded (added onto) as required to meet not only current, but future system needs as well. Many facilities may also already have extra tables/desks that could be used for this application.

A flat desk design does not have a built in cable management function as with the console design. This option requires additional cable management techniques such as cable trays and embedded conduits/ladders under the desk surface to allow for a clean and functional installation. Skirts should be provided or other means of hiding wiring, the back of computers, etc. from view. Like the console design, this application works well with a raised floor management system. Floor outlets should be provided for both power, and communications. In the case of overhead cabling, any exposed cables should be properly protected and meet ADA requirements. Some manufacturers however also provide a hybrid solution that allows for a flat desk design with built-in cable management methods. This option allows for the flexibility of re-arranging or adding additional equipment to a workstation, while still providing solid cable management methods.

Figure 8.4 shows a potential flat desk layout.

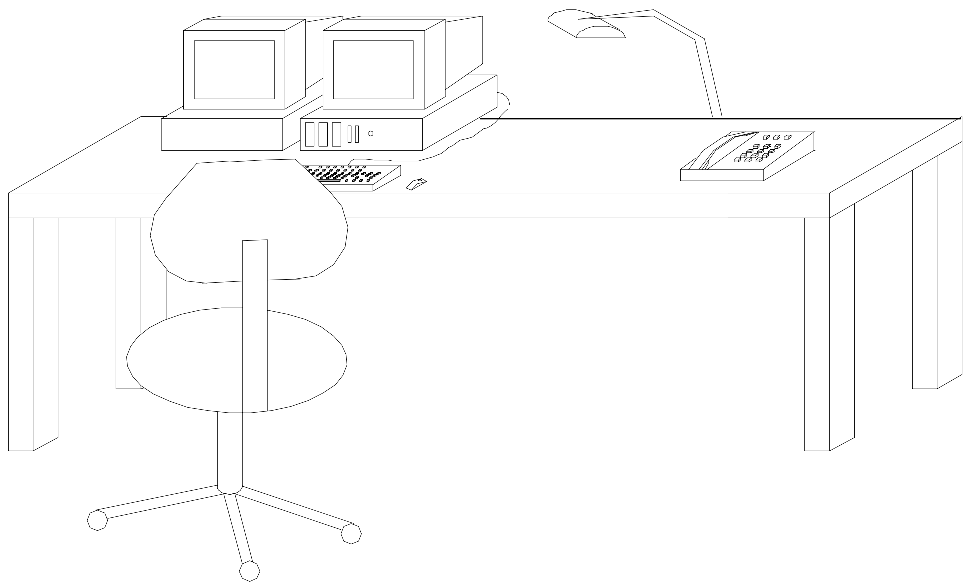


Figure 8.4: Flat Desk Layout

8.6.3 Summary

Both console and desk options have positive and negative features, and will likely be recommended on a site-by-site basis. Recommendations will be based on whether the sites have an existing desk or table that can be used or modified for this application. Also spatial concerns should be addressed. Since a console is likely to take up slightly more space, it maybe advantageous in tight locations to use a flat desk. Ideally it is recommended that a flat desk be used, with built-in cable management. This will allow for flexible equipment arrangement, and good cable management.

9 COMMUNICATION REQUIREMENTS

9.1 Relevant Requirements

9.1.1 ATMS

UR TS 3.3.5.1	The ATMS shall be consistent with the County's CAMS and IEN Architecture
FR TS 1.13.3	The ATMS shall support controllers using the AB3418 protocol.
FR TS 1.13.4	The central signal system software shall include communications support for the NTCIP protocol (Level 1 conformance).
FR TS 1.13.5	The ATMS will communicate with each intersection once per second.
FR TS 2.1.6	The central signal system software shall support communication with the field controllers at rates from 1.2kbps to 38.4kbps.
FR TS 2.1.8	Upload/download commands shall be executed immediately upon command at a communication rate of 1.2kbps to 38.4kbps between the central signal system software and the field controllers.
FR 4.1.1	The central signal system software shall monitor the traffic signal controllers on a second-by-second basis.
FR TS 21.1.1	Using tools provided with the Windows operating system, the System Administrator or Network Administrator shall have the capability to monitor the network, including: • Which users are logged into the system • The status of any system firewalls • The status of system servers
FR TS 25.1.9	The system shall support panning, tilting and zooming CCTV cameras.

9.1.2 LCC

None

9.1.3 Integration System

UR IS 11	The ATMS shall make available CCTV video images for viewing at other remote locations both in the Corridor and elsewhere.
UR IS 12	It shall be possible to view video images from CCTV cameras in other jurisdictions.
FR IS 27	The ATMS shall provide remote access via the IEN.
UR IS 30	At a minimum, the ATMS should have demonstrated the ability to support the relevant NTCIP protocol.
UR IS 31	Here there is a high degree of commitment or reasonable degree of use of the NTCIP protocol, then it should be specified for use.
FR IS 39	All system components of the I5/Telegraph Road Project will communicate via the IEN.

FR IS 43	Access to the IEN shall required on a 24 hours per day, 7 days per week basis (excluding an acceptable down time for system maintenance, backup, etc).

9.1.4 Other Forum Projects

From SGV Pilot:

- Data must arrive at the destinations at the same rate it is introduced to the network.
- A high percentage of data (99.95%) must reach the workstations (over the IEN).
- The system must work over a 384 Kbps LAN for up to 2000 detectors, 20 workstations with 50 requests each.

From I-105 Corridor Project:

Functional Requirements

- FRD429: Existing communications infrastructure shall be used wherever feasible.
- FRD430: The communications system shall support the ability to monitor and download traffic signal timing plans to controller.
- FRD431: The communications system shall support the ability to view and control CCTV cameras.
- FRD432: The communications system shall support the ability to monitor and control CMS.
- FRD433: The communications system shall support the ability to monitor and control HAR.
- FRD434: If HAR are not deployed with this Project, bandwidth capacity for future HAR installations shall be provided.
- FRD435: The communications system shall support the ability to monitor and control HAT.
- FRD436: If HAT is not deployed with this Project, bandwidth capacity for future HAT installations shall be provided.
- FRD437: The communications system shall support communications to kiosks.
- FRD438: If kiosks are not deployed with this Project, bandwidth for future kiosk installations shall be provided.
- FRD439: The communications system shall support communications to Internet web pages.
- FRD440: If Internet web pages are not deployed with this Project, bandwidth for future Internet web page installations shall be provided.
- FRD441: The agency owned cable-based communications system shall be sized with a minimum of 50% spare capacity (as standard practice), if used.
- FRD442: The communications system between the Local TMCs, Sub-Regional TMC and County TMC shall be sized to accommodate 50 simultaneous intersections sending second by second status information.

- FRD443: The communications system shall have diverse routing options where feasible.
- FRD444: Communications rates utilized shall be telephony standards.

  HLD Definitions and Recommendations

  - Camera control communications is considered low speed "bursty" and a 9600 bps asynchronous circuit is suggested.
  - The result (for CMS) is low speed "bursty" communications (and) a 9600 bps asynchronous circuit is suggested.
  - The Highway advisory radios use dial-up telephone facilities to interface with the control center. The typical controller uses dual-tone, multi-frequency (DTMF) signals for control. The messages are sent from the TMC/Control Center to the transmitter over the analog voice channel.
  - (For kiosks) a data rate of 56kps is expected to be more than adequate

9.2 Communication System Requirements

The Communications System Requirements are derived, in part, from the requirements listed in the previous Section and grouped into the following categories:

- City work stations/control sites
- Integration System Requirements
- Non-transportation related issues
- Public relations issues
- O&M issues
- Expandability
- Bandwidth requirements
- Reliability
- Redundancy
- Diversity
- Performance requirements
- Communications system access points
- Potential bottlenecks and weak links

These categories are defined for the IEN and the center–to-field communications links.

9.2.1 IEN Communications Requirements

City Work Stations/Control Sites

None

Integration System Requirements

UR TS 3.3.5.1 The ATMS shall be consistent with the County's CAMS and IEN Architecture

FR IS 27 The ATMS shall provide remote access via the IEN.

FR IS 39 All system components of the I5/Telegraph Road Project will communicate via the IEN.

Non-Transportation Related Issues

FR CS 1. Evaluation of the cost of the communications network shall consider a 10-Year Life Cycle cost analysis.

Public Relations Issues

None

O&M Issues

FR TS 21.1.1 Using tools provided with the Windows operating system, the System Administrator or Network Administrator shall have the capability to monitor the network, including:

- The status of any system firewalls

FR TS 21.1.2 The communications technology should be easy to operate and maintain.

FR TS 21.1.3 If new technology (to the Agency) is deployed, the agency staff should be provided training in maintenance and trouble shooting of the equipment.

FR TS 21.1.4 Tools should be provided to the agencies for automatic checking of the communication equipment and media.

Expandability

FR CS 2. (FRD441): The agency owned cable-based communications system shall be sized with a minimum of 50% spare capacity (as standard practice), if used.

FR CS 3. (FRD435): The communications system shall support the ability to monitor and control HAT.

FR CS 4. (FRD436): If HAT is not deployed with this Project, bandwidth capacity for future HAT installations shall be provided.

FR CS 5. (FRD439): The communications system shall support communications to Internet web pages.

FR CS 6. (FRD440): If Internet web pages are not deployed with this Project, bandwidth for future Internet web page installations shall be provided.

Bandwidth Requirements

FR CS 7. (FRD444): Communications rates utilized shall be telephony standards.

UR IS 11 The ATMS shall make available CCTV video images for viewing at other remote locations both in the Corridor and elsewhere.

UR IS 12 It shall be possible to view video images from CCTV cameras in other jurisdictions.

FR CS 8. The system must work over a 384 Kbps LAN for up to 2000 detectors, 20 workstations with 50 requests each (excluding CCTV video transfer).

FR CS 9. (FRD429) Existing communications infrastructure shall be used wherever feasible.

Reliability

FR IS 43 Access to the IEN shall be required on a 24 hours per day, 7 days per week basis (excluding an acceptable down time for system maintenance, backup, etc).

Redundancy

FR CS 10. (FRD443): The communications system shall have diverse routing options where feasible.

Diversity

FR CS 11. (FRD429): Existing communications infrastructure shall be used wherever feasible.

Performance Requirements

FR CS 12. The IEN shall be continuously available and not require an application to request connection.

FR CS 13. Data must arrive at the destinations at the same rate it is introduced to the network.

FR CS 14. A high percentage of data (99.95%) must reach the workstations (over the IEN).

FR CS 15. (FRD442): The communications system between the Local TMCs, Sub-Regional TMC and County TMC shall be sized to accommodate 50 simultaneous intersections sending second by second status information.

Communications System Access Points

FR IS 27 The ATMS shall provide remote access via the IEN.

Potential Bottlenecks and Weak Links

See redundancy.

9.2.2 Center-to-Field Communications

City Work Stations/Control Sites

Not applicable

Integration System Requirements

Not Applicable

Non-Transportation Related Issues

FR CS 16. Evaluation of the cost of the communications network shall consider a 10-Year Life Cycle cost analysis.

Public Relations Issues

Not applicable

O&M Issues

FR TS 21.1.2 The communications technology should be easy to operate and maintain.

FR TS 21.1.3 If new technology (to the Agency) is deployed, the agency staff should be provided training in maintenance and trouble shooting of the equipment.

FR TS 21.1.4 Tools should be provided to the agencies for automatic checking of the communication equipment and media.

Expandability

FR CS 17. (FRD441): The agency owned cable-based communications system shall be sized with a minimum of 50% spare capacity (as standard practice), if used.

FR CS 18. (FRD433): The communications system shall support the ability to monitor and control HAR.

FR CS 19. (FRD434): If HAR are not deployed with this Project, bandwidth capacity for future HAR installations shall be provided.

FR CS 20. The Highway advisory radios use dial-up telephone facilities to interface with the control center. The typical controller uses dual-tone, multi-frequency (DTMF) signals for control. The messages are sent from the TMC/Control Center to the transmitter over the analog voice channel.

FR CS 21. (FRD437): The communications system shall support communications to kiosks.

FR CS 22. (FRD438): If kiosks are not deployed with this Project, bandwidth for future kiosk installations shall be provided.

FR CS 23. (For kiosks) a data rate of 56kps is expected to be more than adequate.

Bandwidth Requirements

UR IS 30 At a minimum, the ATMS should have demonstrated the ability to support the relevant NTCIP protocol.

UR IS 31 If here there is a high degree of commitment or reasonable degree of use of the NTCIP protocol, then it should be specified for use.

FR TS 1.13.4 The central signal system software shall include communications support for the NTCIP protocol (Level 1 conformance).

Traffic Signals

FR TS 1.13.3 The ATMS shall support controllers using the AB3418 protocol.

FR TS 1.13.5 The ATMS will communicate with each intersection once per second.

FR TS 2.1.6 The central signal system software shall support communication with the field controllers at rates from 1.2kbps to 38.4kbps.

FR CS 24. (FRD430): The communications system shall support the ability to monitor and download traffic signal timing plans to controller.

FR TS 2.1.8 Upload/download commands shall be executed immediately upon command at a communication rate of 1.2kbps to 38.4kbps between the central signal system software and the field controllers.

FR 4.1.1 The central signal system software shall monitor the traffic signal controllers on a second-by-second basis.

Appendix A contains an analysis of the NTCIP and AB3418 protocols. The resultant bandwidth requirements are as follows:

FR CS 25. At 9600bd per channel the following shall be the minimum number of traffic signal controllers per 9600 bd circuit:

- AB3418 (no overlap) 5 controllers per circuit
- AB3418 (with overlaps) 6 controllers per circuit
- NTCIP (no overlap) 5 controllers per circuit
- NTCIP (with overlaps) 6 controllers per circuit

CCTV

FR TS 25.1.9 The system shall support panning, tilting and zooming CCTV cameras.

FR CS 26. (FRD431): The communications system shall support the ability to view and control CCTV cameras.

<u>Analog</u>

FR CS 27. The communications system shall accommodate the standard NTSC bandwidth for video of 4.2 MHz based on a 6 MHz channel spacing for video signals.

Digital

FR CS 28. Either motion JPEG or MPEG formats should be used.

Control

FR CS 29. Each camera will also require a camera control signal to control camera functions such as pan, tilt, zoom, etc.

FR CS 30. This control signal, ranging from 300 bps to 9600 bps will be accommodated over a common channel in a multi-dropped environment.

FR CS 31. In a twisted pair network, one pair can be used to address multiple cameras.

CMS

FR CS 32. FRD432: The communications system shall support the ability to monitor and control CMS.

FR CS 33. The result (for CMS) is low speed “bursty” communications (and) a 9600 bps asynchronous circuit is suggested.

Reliability

FR CS 34. The field-to-center communications shall have 99.5% availability.

Redundancy

FR CS 35. (FRD443): The communications system shall have diverse routing options where feasible.

Diversity

FR CS 36. FRD429: Existing communications infrastructure shall be used wherever feasible.

Performance Requirements

FR CS 37. The field-to-center communications shall be continuously available and not require an application to request connection.

FR CS 38. Data must arrive at the destinations at the same rate it is introduced to the network.

Communications System Access Points

Not Applicable

Potential Bottlenecks and Weak Links

See Redundancy.

10 REQUIREMENTS TRACEABILITY

The previous report "ATMS User Requirements" defined the need for tracking or tracing of requirements. Incorporated in that report was a Traceability Matrix for User Requirements to the Use Cases.

Section 5 of this report is organized to provide a mapping of the Use Cases to both the User Requirements and Functional Requirements. This is, in effect, an extension of the traceability matrix with each statement having an identifying requirement number (user – UR or functional - FR).

Two previous Functional Requirement activities have been taken into account in deriving the Functional Requirements; the East San Gabriel Valley (ESGV) Pilot Project and the I-105 Corridor Project. Additional Functional Requirements have been added reflecting current industry standards.

The ESGV Pilot Project is significant because it has formed the basis for the County's current assessment of traffic signal systems. For this reason, a tabulation of ESGV requirements against the I-5 Telegraph Road requirements have been made and is presented in the following pages.

The following codes apply in the table:

UR - User Requirement

FR - Functional Requirement

NA – Not Applicable

Review – Requires review with the County for continued relevance

Table 10.1: ESGV Requirements and I-5/Telegraph Road Requirements

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
1.	**Overview**			
1.01	Local Agencies have limited resources	Local agencies involved desire local control of their intersections, but have limited resources to accomplish this.	Constraint	NA
1.02	Open Systems	Open hardware and software systems will be used wherever possible.	Goal	UR TS.20 UR TS.21
1.03	Fully Actuated operation	Fully actuated operation under coordination will be supported where possible.	Goal	UR TS.27
1.04	Maintenance Capabilities	Enhanced maintenance capabilities are desired.	Goal	FR Sections: 5.5 5.15 5.16 5.18
1.05	County-wide solution	The system used for the Pilot Project will be scaleable to the entire County.	Goal	NA
1.06	Regional Arterial Progression	Progression on arterials of regional significance will be emphasized.	Goal	NA
1.07	Incident Management Support	See Section 4.4.		
1.1.	**System Components**			
1.1.1.	Time bases in each TCS will be synchronized	The time reference clocks of each local TCS will be synchronized with the entire system to enable adjacent intersections in different jurisdictions to be coordinated.	Requirement	UR TS.78 UR TS.79 FR TS.218 to FR TS.223
1.1.2.	TCS's can monitor neighboring agency's plans and traffic conditions	Each agency's TCS can reference plans and traffic conditions in neighboring agencies in order to select suitable plans.	Requirement	UR TS.87

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
1.2.	**Inter-Jurisdictional Coordination**			
1.2.1.	Seamless Boundaries	The objective of inter-jurisdictional coordination is to achieve seamless traffic flow between jurisdictions.	Goal	UR TS.83
1.2.2.	Joint Agency Planning is critical	The system will provide methods to facilitate joint agency planning.	Goal	UR TS.85
1.2.3.	Communication between TCSs to enable automatic plan changes	TCSs will be able to reference data from other TCSs as part of their plan selection decisions.	Goal	UR TS.87
1.2.4.	Inter-agency plan selection	One agency will be able to request plan changes in other agencies to accommodate non-recurrent congestion situations.	Goal	UR TS.84
1.3.	**Agencies Involved**			
1.3.1.	**Regional Agencies**			
1.3.1.1.	**Los Angeles County Department of Public Works**			
1.3.1.1.1.	Operational Control	LACDPW will have operational control of signals within its jurisdiction (from the Fremont facility).	Requirement	UR TS.9
1.3.1.1.2.	Operational Monitoring	LACDPW will be able to monitor all signals in the region. (Fremont facility)	Requirement	UR TS.10
1.3.1.1.3.	Functional Monitoring	LACDPW will be able to perform functional monitoring of all signals that it maintains. (Alcazar facility)	Requirement	UR TS.11
1.3.1.2.	**Metropolitan Transit Authority**			

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
1.3.1.2.1.	Operational Monitoring	MTA will be able to monitor all signals in the region.	Requirement	UR TS.14
1.3.2.	**Local Agencies**			
1.3.2.1.	Local Operation Control	Local Agencies will have operational control of signals within their jurisdiction.	Requirement	UR TS.15
1.3.2.2.	Local Operations Monitoring	Local Agencies will be able to monitor signals within their jurisdiction.	Requirement	UR TS.16
1.3.2.3.	Adjacent Operations Monitoring	Local Agencies will be able to monitor operation of signals in adjacent jurisdictions.	Requirement	UR TS.17
1.3.2.4.	Functional Monitoring	Local Agencies will be able to monitor functioning of controllers for maintenance purposes.	Requirement	UR TS.18
1.3.2.5.	Functional Monitoring Delegation	Local Agencies will be able to redirect functional monitoring to alternate locations.	Requirement	UR TS.19
1.3.2.6.	**Pasadena**			
1.3.2.6.1.	CDI	Add CDI for regional system.	Requirement	NA
1.3.2.7.	Arcadia, Azusa, Covina, Duarte, Irwindale, Monrovia, San Dimas	New Systems to be installed.	Requirement	NA
2.	**Traffic Control System (TCS)**			
2.1.	**System Architecture**			
2.1.1.	**Software Configuration**			
2.1.1.1.	Software Structure	TCS software will be modular and scaleable.	Goal	UR TS.22

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.1.2.	**Hardware Configuration**			
2.1.2.1.	Server Hardware	TCS, Corridor, and County servers will be Intel x86 machines running Windows NT Server.	Requirement	UR TS.25
2.1.2.2.	Workstation Hardware	Operator Interface Workstations will be Pentium machines running Windows NT Workstation.	Requirement	UR TS.25
2.1.3.	**Network Architecture**			
2.1.3.1.	Frame Relay	All sites within the system connected using a Frame Relay network.	Constraint	NA
2.1.3.2.	Intranet	Private intranet using PVCs to connect FRADs at local sites to a Frame Relay Router (FRR) at the County TOC.	Constraint	NA
2.1.3.3.	Security	Workstations on this net will not be connected to office or other networks.	Constraint	NA
2.2.	**Database Services (DS)**			
2.2.1.	**Static Data**			
2.2.1.1.	RDBMS	All static data will be maintained using an off-the-shelf Relational Database Management System (RDBMS) accessible via SQL.	Requirement	FR TS.139
2.2.1.2.	Backups	Static database backups may be performed onto a DAT tape backup or writeable CD-ROM drive.	Requirement	FR TS.140
2.2.1.3.	Approved plans	Libraries of approved timing plans will be available to assign to intersection controllers.	Requirement	UR 3.3.1.1
2.2.2.	**Dynamic Data**			

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.2.2.1.	Dynamic Data Availability	All data required for local, corridor and regional display and monitoring will be maintained to permit high-speed access. Dynamic data will be available to LOI and County server.	Requirement	UR TS.20
2.2.3.	**Object Broker**			
2.2.3.1.	Object Structure	The structure of the objects will be designed to be similar to the standard MIB database structure for an NTCIP traffic controller.	Goal	NA
2.2.4.	**Data Archiving**			
2.2.4.1.	Periodic archiving	Operators may select periodic archiving of certain dynamic data into the static database or onto a backup medium such as magnetic tape or CD.	Requirement	FR TS.329 FR 1.11.11
2.3.	**Traffic Applications Services (TAS)**			
2.3.1.	**Control and Coordination Modes**			
2.3.1.1.	Coordinate fully actuated controllers	Fully actuated intersection operation under a coordinated background cycle.	Requirement	UR TS.26 UR TS.27
2.3.1.2.	Support 9 or more plans	Timing plans, 9 or more per intersection.	Requirement	FR TS.228
2.3.1.3.	TRSP based plan selection	V+kO, w/ “anti-hunting” algorithm. TRSP table modification via TOD commands.	Requirement	FR TS.197 to FR TS.203
2.3.1.4.	Operator plan selection	Manual plan selection, overrides TOD/TRSP, by system, group, intersection.	Requirement	FR TS.206 to FR TS.210
2.3.1.5.	Coordination between groups	Time reference and plan selection to sync groups (within same TCS and across TCS boundaries).	Requirement	UR 3.3.1.2

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.2.	**Data Collection**			
2.3.2.1.	**Real-Time Data**			
2.3.2.1.1.	Real-time data collection	The TCS will collect and maintain all data required for once-per-second monitoring and displays from all intersections at all times.	Requirement	FR TS.211
2.3.2.2.	**Cyclic Data**			
2.3.2.2.1.	Cyclic Data Collection	The TCS will collect and maintain all data required for once-per-cycle monitoring and displays from all intersections at all times. If the intersection is not running coordination, data will be collected once per minute.	Requirement	FR TS.211 and FR TS.212
2.3.2.3.	**Detector Data**			
2.3.2.3.1.	Data from any detector w/o interfering w/ local usage	Detectors to gather VOS data independent of local actuation and detection functions. (removes the distinction between "system" and "local" detectors).	Requirement	FR TS.272
2.3.2.3.2.	Sampling period selectable by TOD	The TCS will collect data from intersections on a once-per-cycle or once-per-minute period and aggregate data within the TCS.	Requirement	FR TS.18
2.3.2.3.3.	Count Uploading	The detector data collected by the TCS will include volume, occupancy, and speed (as available at the controller).	Requirement	UR TS.70
2.3.2.4.	**Events**			
2.3.2.4.1.	Intersection-generated events	The TCS will collect events from the intersections on a once-per-second and/or once-per-cycle basis, depending on the event type.	Requirement	FR TS.211

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.2.4.2.	Communications Server Events	The TCS will collect events from the communications server regarding intersection communications status as they occur.	Requirement	FR TS.212
2.3.3.	**Command and Data Distribution**			
2.3.3.1.	Plan and Mode Changes	Issue plan and mode changes to local controller.	Requirement	FR 2.1.1
2.3.3.2.	Download Plan Data	Download plan data to local controller.	Requirement	FR 2.1.2
2.3.3.3.	Upload/Download Services	Provide services to upload and download local controller data bases.	Requirement	FR 2.1.2
2.3.4.	**Event Logging**			
2.3.4.1.	**Events Logged**			
2.3.4.1.1.	Alarm: Conflict Flash	Alarm: controller in Conflict Flash.	Requirement	FR TS.282
2.3.4.1.2.	Alarm: Power fail/Recovery	Alarm: controller power failure or recovery.	Requirement	FR TS.283
2.3.4.1.3.	Alarm: Detector Constant Call	Alarm: detectors experiencing constant calls for user-set time period.	Requirement	FR TS.284
2.3.4.1.4.	Alarm: Detector No Calls	Alarm: detectors experiencing no calls for user-set time period.	Requirement	FR TS.284
2.3.4.1.5.	Alarm: Detector Over counting	Alarm: detectors experiencing excessive calls (user set).	Requirement	FR TS.284
2.3.4.1.6.	Detector % Availability reports	Able to generate reports on detector % available at detector, intersection, or area level.	Requirement	FR TS.110
2.3.4.1.7.	Alarm: Tipped Cabinet	Alarm: tipped cabinet detected by controller.	Requirement	FR TS.284
2.3.4.1.8.	Alarm: Cabinet Door Open	Alarm: cabinet door open detected by controller.	Requirement	FR TS.284

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.4.1.9.	Alarm: Police Panel Open	Alarm: police panel door open detected by controller.	Requirement	FR TS.284
2.3.4.1.10.	Alarm: Pedestrian Indication Out	Alarm: controller detects pedestrian indication out.	Requirement	FR TS.284
2.3.4.1.11.	Alarm: Vehicle Indication out	Alarm: controller detects vehicle indication out.	Requirement	FR TS.284
2.3.4.1.12.	Alarm: Timing Sheet Data Changed	Alarm: Controller reports local database changed.	Requirement	FR TS.284
2.3.4.1.13.	Alarm: Controller Status	Alarm: Controller reports operating status change (+COI).	Requirement	FR TS.284
2.3.4.2.	**Event Notification**			
2.3.4.2.1.	Alarms: 2 levels	Alarms will have 2 priority levels.	Requirement	FR TS.287
2.3.4.2.2.	Alarms: user-selectable priority for each alarm	Alarms: user-selectable priority for each possible type of alarm.	Requirement	FR TS.288
2.3.4.2.3.	Alarms: Immediate Reporting	Alarms: Immediate display of alarms as they occur.	Requirement	Review FR TS.298 Changed to "Alarms: Immediate display of alarms taking into account the data latency of the system" by LA County, March 2002.
2.3.4.2.4.	Alarms: logging	Alarms: placed in log file.	Requirement	FR TS.286 and FR TS.295

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.4.2.5.	Alarms: ignore	Alarms shall be user-selectable Ignore by alarm type.	Requirement	Review FR TS.299 Changed to “Alarms shall be user selectable ignore by specific device” b LA County, March 2002.
2.3.4.2.6.	Alarms: User-selectable delay	Alarms shall be user-selectable Delay by alarm type.	Requirement	Review FR TS.300 Changed to “It shall be possible to specify that a given alarm must occur a user specifiable number of times before it is reported” by LA County, March 2002.
2.3.4.2.7.	Alarms: Printing	Alarms shall automatic print on designated log printer.	Requirement	Review FR TS.301 Changed to “It shall be possible to print the alarm log” by LA County, March 2002
2.3.4.2.8.	Alarms: Disk Storage	Alarms shall be automatically archived on disk.	Requirement	FR 295
2.3.4.2.9.	Alarms: Automatic Routing and time stamping	Alarms shall be automatically time stamped and routed to specified operator station.	Requirement	FR 296

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.4.2.10.	Alarm Routing by Time of Day	It shall be possible to change alarm routing to different operator stations by time of day.	Requirement	FR 297
2.3.4.2.11.	Alarms: Add New Alarms or Events	It will be possible to add new alarms or events to one component of the system without rebuilding any other part of the system.	Requirement	Review Removed by LA County, March 2002
2.3.4.2.12.	Alarm Routing	Administrators may configure the system to deliver various alarms to multiple destinations.	Requirement	FR TS.305 to FR TS.308
2.3.4.2.13.	Configurable alarm level	Alarms may be configured as having one of two levels.	Requirement	Repeated
2.3.4.2.14.	Configurable priority	Users may select priorities for each alarm.	Requirement	Repeated
2.3.4.2.15.	Configurable alarm delay	Users may configure individual delays for alarms.	Requirement	Repeated
2.3.4.2.16.	Configurable alarm routing	Users may route alarms to multiple destinations.	Requirement	Repeated
2.3.5.	**Real-Time Data Monitoring**			
2.3.5.1.	Plan compliance monitor	The TCS will monitor intersection operation to verify compliance with the selected timing plan.	Requirement	Review (Controller Function) FR TS.302 Changed to "The TCS shall monitor the controller to verify that the controller is operating under selected timing plan" by LA County, March 2002.

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.6.	**Command Scheduling**			
2.3.6.1.	TOD/DOW Tables	TOD/DOW Control by TCS (control via system-wide, group, and individual intersection, w/command hierarchy).	Requirement	FR 2.1.9
2.3.6.2.	Holiday Exception Tables	Fixed and “floating” holiday exception tables will be provided. Holidays will override the standard TOD/DOW control tables.	Requirement	FR TS.248 and FR TS.249
2.3.7.	**Traffic Analysis**			
2.3.7.1.	PASSER II Interface	Export to PASSER, Import resulting timing sheets.	Requirement	FR TS.224 Review “SYNCHRO acceptable as traffic analysis software” by LA County, March 2002.
2.3.7.2.	Transyt-7F Interface	Export to Transyt, Import resulting timing sheets.	Requirement	FR TS.224 Review “SYNCHRO acceptable as traffic analysis software” by LA County, March 2002.
2.3.7.3.	Delay Simulations	Delay simulations based on proposed timings with real-time volumes. This will be done through export to Transyt-7F.	Requirement	FR TS.224 Review “SYNCHRO acceptable as traffic analysis software” by LA County, March 2002.

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.7.4.	Travel Time Simulations	Travel time simulations based on proposed timings with real-time volumes. Assume can do this with export to Transyt-7F.	Requirement	FR TS.224 Review “SYNCHRO acceptable as traffic analysis software” by LA County, March 2002.
2.3.7.5.	Time/Space Diagrams: Display	Based on current intersection/timing plan database, display green-band time-space display on OI.	Requirement	FR TS.266
2.3.7.6.	Time/Space Diagrams: On-Screen Editing	Allow OI to modify a subset of the intersection timing plan database items (offset, green times) via TSP Diagram Editor.	Requirement	FR TS.267
2.3.7.7.	Time/Space Diagrams: Printing	Printout of diagram, either to graphics printer or text printer in “Transyt” type text format.	Requirement	Review FR TS.224 “SYNCHRO acceptable as traffic analysis software” by LA County, March 2002.
2.3.7.8.	Time/Space Diagrams: AutoCAD Export	Ability to save TSP diagram in AutoCAD format. The exact format of the AutoCAD TSP diagram file is to be determined during software implementation phase.	Requirement	Review FR TS.224 “SYNCHRO acceptable as traffic analysis software” by LA County, March 2002.
2.3.8.	**Time Synchronization**			
2.3.8.1.	WWV Time Reference	Local time first, remote time if local not available.	Requirement	Controller Function

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.3.8.2.	Controller Time/Date Set	TMC will maintain time for system. Local controller time will serve as back up if communication is lost.	Requirement	Controller Function
2.3.9.	**Scenario Management**			
2.3.9.1.	Scenario Response	The TCS will translate Scenario Response Plans from the Corridor system into the correct set of local plan changes.	Requirement	System Integration Requirement
2.3.9.2.	Each local agency can confirm, reject, or amend System Response Plans.	In order to maintain local authority, each local agency will have the ability to confirm, reject, or amend actions within its jurisdiction caused by the implementation of a Scenario Response Plan from another agency.	Requirement	System Integration Requirement
2.3.10.	**External Data Interfaces**			
2.3.10.1.	External NTCIP or CORBA	The TCS will accept commands from and provide data to external systems via an NTCIP port or CORBA interface.	Requirement	FR TS.250 FR TS.251
2.4.	**Communications Server (CS)**			
2.4.1.	Baud Rate Adjustable Interfaces - Controller	The TCS will support different baud rates for communications channels to the controllers.	Requirement	FR TS.157
2.4.2.	Baud Rate Adjustable Interfaces - Local Level	The TCS will support different baud rates for communications channels to the Local Operator Interfaces.	Requirement	FR TS.158
2.4.4.	NTCIP - Intersection Controller	The TCSs will support controllers using the NTCIP protocol.	Requirement	FR TS.160
2.4.5.	1/Sec Communications	The TCSs will communicate with each intersection once per second.	Requirement	FR TS.161

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.4.6.	Each LOI will have local access to its controllers	Communications to local controllers within a local TOC will not depend on access to a remote shared TCS. This implies local connections from the LOI to the Data Concentrators.	Requirement	NA
2.4.7.	Field Data Concentrators will be used to reduce connections to the TCS	Data Concentrators will be used to demultiplex 56Kbps links from the shared TCS to 9600 or 1200 bps links to 170 controllers. The Data Concentrators may be located in 170 field cabinets, or in the TOCs.	Requirement	NA
2.4.8.	Support existing 170 Controllers	The CS will need to support communication protocols for the following 170 software packages: BITrans 222 LACO-IV		FR 162 Review (Agency specific) Changed to "The TCS will support multiple communications protocols as needed by the specific installation.
2.5.	**User Interface**			
2.5.1.	Graphical user interface	All user accessible software will use a common graphical user interface (GUI).	Requirement	UR TS.39 FR TS.13 *et seq.*
2.5.2.	Mouse support	The GUI will allow the use of a mouse.	Requirement	UR TS.40 FR TS.14
2.5.3.	Screen resolution	Minimum screen resolution of 1600x1200x16 colors for operator workstations (higher recommended).	Requirement	Hardware Requirement
2.5.4.	Menus	The GUI will provide users with menus for giving all important commands to the system.	Requirement	UR TS.41 FR TS.18

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.5.	Help	The GUI will provide context-sensitive help for all windows and dialog boxes.	Requirement	UR TS.42 FR TS.33 *et seq.*
2.5.6.	Printing of screens	Operator workstations will be able to print a useful copy of the screen on paper.	Requirement	Operating System Function
2.5.7.	GUI workstation	The GUI will run on a PC-compatible workstation.	Requirement	FR TS.2
2.5.8.	GUI operating system	The GUI will run on a workstation running Windows NT.	Requirement	FR TS.2 and Review Replaced by "System workstations shall use the latest version of Microsoft's multi-tasking operating system for Intel-architecture PC-based clients in a client-server architecture" by LA County, March 2002.
2.5.9.	Multiple workstations	The system will support a variable number of operator workstations for the system as a whole and at individual TOC's.	Requirement	FR TS.23 *et seq.*
2.5.10.	Geographical distribution of workstations	Users at any system workstation will have the ability to control any intersection in the system if they have been granted that privilege.	Requirement	FR TS.23
2.5.11.	**System Status**			

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.11.1.	System component status	L/C/ROI: show current system functionality, including all TCS/CDI components, County and Corridor server status, and complete network status.	Requirement	NA
2.5.12.	**System Control**			
2.5.12.1.	Controller manipulation	Operators will be able to manipulate intersection controllers if they have the proper privileges.	Requirement	UR 3.1.15.3 FR TS.141 *et seq.*
2.5.12.2.	Delegation of Control Authority	Local agencies that do not have full-time staff may wish to delegate control authority to another agency by time of day.	Requirement	UR TS.19 FR TS.164
2.5.13.	**Maps and Real-Time Displays**			
2.5.13.1.	**Wide-Area Map Displays**			
2.5.13.1.1.	Geographic map displays	The user interface will provide geographically accurate maps of LA County, corridors in the County, and cities in corridors.	Requirement	UR TS.49
2.5.13.1.2.	Map zooming and panning	Users may zoom maps to more detailed views. This will take less than 5 seconds. Once zoomed, they may pan the view through different areas of the map.	Requirement	FR TS.74 Section 5.33
2.5.13.1.3.	Clickable map areas	Clickable areas on the maps will allow switching to more detailed views of the County, corridors, jurisdictions, sections, or intersections.	Requirement	FR TS.70

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.1.4.	Incident display	Maps will allow the display of freeway and arterial incidents.	Goal	Review FR TS.78 Display of freeway incidents is a function of the IEN an not the TCS. Arterial incidents will be displayed.
2.5.13.1.5.	Map Display: Decluttering	Objects on the map can be programmed to turn on or off at different zoom levels.	Requirement	FR TS.75 to FR TS.77
2.5.13.1.6.	Map Display: Editable	An operator with the correct security privileges can edit the base map displays, and textual or graphical information in them.	Requirement	UR TS.52
2.5.13.1.7.	County map freeway equipment display	The County map will display significant freeway ramp meter and CMS status information, subject to the availability of the Caltrans data.	Requirement	NA
2.5.13.1.8.	County map freeway ramp meter display	The County map will display freeway ramp meter status (on/off/failed) at all times.	Requirement	NA
2.5.13.1.9.	County map freeway ramp meter rate display	The County map will provide means to view freeway ramp metering rates with extra user effort.	Requirement	
2.5.13.1.10.	County map freeway CMS display	The County map will display freeway CMS equipment status (on/blank/failed) at all times.	Requirement	NA
2.5.13.1.11.	County map freeway CMS message display	The County map will provide means to view freeway CMS messages with extra user effort.	Requirement	NA
2.5.13.1.12.	County map arterial links	The County map will display significant arterial segments with congestion information.	Requirement	NA

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.1.13.	County map arterial link information	The County map will provide means to view more detailed arterial link information with extra user effort.	Requirement	NA
2.5.13.1.14.	County map arterial equipment status	The County map will display status of all relevant arterial equipment.	Requirement	NA
2.5.13.1.15.	County map arterial controller information	The County map will provide a means to display current timing plan information (cycle/split/offset) for arterial controllers with extra user effort.	Requirement	NA
2.5.13.1.16.	County map intersection monitoring	The County map will provide a means to display once-per-second information about at least one intersection controller anywhere in the County, or more as WAN bandwidth allows.	Requirement	NA
2.5.13.1.17.	County map corridor boundaries	The County map will display the boundaries of individual corridors it contains.	Requirement	NA
2.5.13.1.18.	County map background graphics	The County map will provide the display of useful background graphics on the County map.	Requirement	NA
2.5.13.1.19.	County map availability	The County map will be available at all workstations in the system.	Requirement	NA
2.5.13.1.20.	County Map Display: 30 second update rate	The data on the County map display will be updated at least once every 30 seconds.	Requirement	NA
2.5.13.1.21.	Corridor map displays	Corridor maps will display everything visible on county maps.	Requirement	
2.5.13.1.22.	Corridor and local map arterial link displays	The Corridor and local maps will display volume, occupancy, speed, and V+kO data directly as well as congestion data.	Requirement	NA
2.5.13.1.23.	Corridor and local map intersection display	The Corridor and local maps will display main and side-street green returns for intersection controllers.	Requirement	See Integration System Requirement

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.1.24.	Corridor and local map Display: 15 second update rate	The data on the Corridor and local displays will be updated at least once every 15 seconds.	Requirement	Section 5.33
2.5.13.2.	**Presentation Display (LOI/COI)**			
2.5.13.2.1.	Display. Vehicle Indications	Displays intersection phase color indications.	Requirement	FR TS.79 *et seq.*
2.5.13.2.2.	Display. Pedestrian Indications	Displays intersection pedestrian indications (Walk/Don't Walk).	Requirement	FR TS.79 *et seq.*
2.5.13.2.3.	Display. PPB calls	Displays Pedestrian Push Button calls.	Requirement	FR TS.79 *et seq.*
2.5.13.2.4.	Display. Vehicle Detector calls	Displays vehicle detector calls.	Requirement	FR TS.79 *et seq.*
2.5.13.2.5.	Display Link Congestion Indication	Displays link congestion indication - metric to be determined.	Requirement	FR TS.88
2.5.13.2.6.	Display Timing Intervals	Displays indication of which interval currently timing on each controller.	Requirement	FR TS.79 *et seq.*
2.5.13.2.7.	Display Coordination Status	Displays status of coordination at each controller.	Requirement	FR TS.79 *et seq.*
2.5.13.2.8.	Display Coordination Details	Displays details of coordination at a controller: coordination timers.	Requirement	FR TS.79 *et seq.*
2.5.13.2.9.	Display Conflict Monitor Status	Displays status of conflict monitor.	Requirement	Controller Dependent
2.5.13.2.10.	All intersection displays on multiple workstations concurrently	The LOI program can be run on multiple workstations and each can display data from the same or different intersections simultaneously.	Requirement	FR TS.23
2.5.13.2.11.	Display Volume	Display detector volume counts.	Requirement	FR TS.87
2.5.13.2.12.	Display Occupancy	Display detector occupancy (%).	Requirement	FR TS.87

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.2.13.	Display Speed	Display average speed over detector.	Requirement	FR TS.87
2.5.13.2.14.	Display V+kO	Display V+kO value for each detector.	Requirement	FR TS.90
2.5.13.2.15.	Field configuration of new data types	New data types available from existing or new controllers will be able to be displayed by the system without code recompilation. Once the new data is configured on the local TCS, it will be available to the rest of the system without further configuration. (via NTCIP MIB)	Goal	Review FR TS.91 Changed to "New data types available from existing or new controllers will be able to be displayed by the system. Once the new data is configured, it will be available to the rest of the ATMS without further configuration.
2.5.13.2.16.	Intersection Display data updated once/sec	All required intersection display data will be updated at least once per second.	Requirement	Section 5.33
2.5.13.3.	**Display Performance**			
2.5.13.3.1.	Display Draw Rates	Displays will draw and update within times by Table 1-1.	Requirement	Section 5.33
2.5.13.4.	**Report Generator**			
2.5.13.4.1.	Tabular Count Reports	Print formatted reports from logged VOS data.	Requirement	FR TS.115
2.5.13.4.2.	Intersection Delay Reports (monthly average)	Provide report on "Monthly Delay Average".	Requirement	FR TS.116

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.4.3.	Regional Delay Reports (monthly average)	See Intersection Delay Report above.	Requirement	NA
2.5.13.4.4.	Link Speed Reports	Report using COTS tool.	Requirement	FR TS.117
2.5.13.4.5.	Link V+kO Reports	Report using COTS tool.	Requirement	FR TS.117
2.5.13.4.6.	Link Volume Reports	Report using COTS tool.	Requirement	FR TS.117
2.5.13.4.7.	Link Occupancy Reports	Report using COTS tool.	Requirement	FR TS.117
2.5.13.4.8.	Compute Seasonal Volume Coefficients	Provide report on seasonal volume coefficients.	Requirement	FR TS.120
2.5.13.4.9.	Compute Daily Volume Coefficients	See Seasonal Volume Coefficient above.	Requirement	Review
2.5.13.4.10.	Historical Traffic Flow Reports (1-year)	See Seasonal Volume Coefficient above.	Requirement	FR TS.121
2.5.13.4.11.	Custom User-Defined/Generated Reports	Provide report generator tool. All above reports and exports will be developed using the same tool.	Requirement	FR TS.94
2.5.13.4.12.	TOD-scheduled reports	Ability to schedule automatic report generation via the TOD scheduler.	Requirement	FR TS.95
2.5.13.4.13.	Alarm-based report	Report generation based on alarms, such as link congestion or traffic condition.	Requirement	Review FR TS.92 Changed to “Traffic conditions shall trigger an alarm” by LA County, March 2002.
2.5.13.4.14.	Maintenance information routing	Jurisdictions will be able to route maintenance reports to one or more destinations.	Requirement	FR TS.305 to FR TS.308

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.4.15.	Maintenance information to operations staff	Route maintenance reports to city operations staff.	Requirement	FR TS.305
2.5.13.4.16.	Maintenance information to maintenance staff	Route maintenance reports to city maintenance staff.	Requirement	FR TS.306
2.5.13.4.17.	Maintenance information to signal maintenance contractor	Route maintenance information to signal maintenance contractor.	Requirement	FR TS.307
2.5.13.4.18.	Maintenance information to LA County	Route maintenance information to LA County DPW.	Requirement	FR TS.308
2.5.13.4.19.	Traffic counting	Users will be able to select timing and destinations for traffic counting reports.	Requirement	Review FR TS.309 (Conflicts with COTS) Changed to "User will be able to schedule the printing and choose printer for traffic counting reports" by LA County, March 2002.
2.5.13.5.	**Logs**			
2.5.13.5.1.	Alarm reporting	The operator interface will provide a means of reporting system alarms to users.	Requirement	FR TS.284
2.5.13.5.2.	Event Creation	The operator can add informational events to the system event log.	Requirement	UR 3.13.3
2.5.13.6.	**Database Editing**			
2.5.13.6.1.	On-Screen Display	Full GUI screens.	Requirement	FR TS.127

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.6.2.	On-Screen Editing	Forms-based editor.	Requirement	Review FR TS.136 Changed to “Editing of the controller database entries shall be via a tabular format” by LA County, March 2002.
2.5.13.6.3.	Printing (user selectable # of copies)	Formatted printouts - not “print-screens”. Will be able to print out full or partial database with “clean” layout.	Requirement	FR TS.134
2.5.13.6.4.	Upload/Download/ Compare	Will provide mechanism for auto-upload, auto-compare by TOD.	Requirement	FR TS.176
2.5.13.6.5.	Initiate download from field	Built in communications protocol from intersection to initiate transfer. Used when tech replaces controller, etc.	Requirement	FR 2.1.23
2.5.13.6.6.	Query/search by field	Local data base will be stored in an RDBMS, allowing SQL based queries.	Requirement	Review FR TS.137 Changed to “The ATMS database will be a RDBMS, allowing SQL based queries as data collected by the ATMS” by LA County, March 2002.
2.5.13.6.7.	LACO Format	System will support LACO-IV and NTCIP.	Requirement	Review

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.6.8.	BI Tran 222 Format	Supported by ultimate system.	Requirement	Review FR TS.138 Changed to "The ATMS will support the format at the agency specific controllers" by the LA County, March 2002.
2.5.13.6.9.	5,000 intersection capability	Database scaleable to 5,000 intersections.	Requirement	NA
2.5.13.7.	**Security**			
2.5.13.7.1.	Local Agencies retain control authority	Final authority (and responsibility) for control of signal operations will remain under the jurisdiction of the local agencies.	Requirement	UR TS.15
2.5.13.7.2.	User profile administration	Administrators and users will create and maintain profiles of information and capabilities for each user.	Requirement	FR TS.330
2.5.13.7.3.	User name	Administrators will assign a unique name to each user. User name will be unique across county-wide system.	Requirement	Review FR TS.354 Changed to "Administrators will assign a unique name to each user" by LA County, March 2002.
2.5.13.7.4.	User password	Each user on the system will have an individual password.	Requirement	FR TS.336
2.5.13.7.5.	User access level	Each user will be assigned an access level for each system resource.	Requirement	FR TS.338

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.7.7.	Password protection for users	No user will gain access to the system without entering a valid user name and password.	Requirement	FR TS.337
2.5.13.7.8.	Multiple levels of access	Administrators may grant different users different levels of access to the system.	Requirement	FR TS.338
2.5.13.7.9.	Read access to County data	All users will have read access to equipment status and congestion data in the County server.	Requirement	NA
2.5.13.7.10.	Read access to corridor data	All users within a corridor will have read access to all equipment status and congestion data in the Corridor server.	Requirement	NA
2.5.13.7.11.	Remote access to controller data	Jurisdictions may grant certain outside users or locations monitoring and control access to some or all of the jurisdiction's intersection controllers.	Requirement	FR TS.341
2.5.13.7.12.	Plan selection access to controller	Authorized users may select the timing plan in use on certain intersection controllers.	Requirement	FR TS.206
2.5.13.7.13.	Plan modification access to controller	Authorized users may modify timing plans stored in a traffic control system.	Requirement	FR TS.130
2.5.13.7.14.	Intersection timing modification access	Authorized users may modify intersection timing on certain intersection controllers.	Requirement	FR TS.130
2.5.13.7.15.	Modify safety timings at intersections	Authorized users may modify yellow and red clearance intervals for certain intersection controllers.	Requirement	FR TS.130
2.5.13.7.16.	Supervisor access	Authorized users may arbitrate conflicting requests for write access to particular intersection controllers (by terminating access if by no other means).	Requirement	FR TS.135
2.5.13.7.17.	Administrator access	Authorized users may create new users and add new pieces of equipment to the system.	Requirement	FR TS.330

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.7.18.	Intersection group protection	Jurisdictions may define intersection groups and grant access to a group in a single operation.	Requirement	FR TS.334
2.5.13.7.19.	Multi-user data access	The system will allow multiple simultaneous operators to monitor controller behavior.	Requirement	FR TS.65
2.5.13.7.20.	Multiple read access	Multiple users may monitor the same data item if they have been granted read access to that data item.	Requirement	FR TS.65
2.5.13.7.21.	Single write access	Only one user at a time may modify behavior of an intersection controller.	Requirement	Review FR TS.66 Changed to "Only one user at a time may modify database of an intersection controller" by LA County, March 2002.
2.5.13.7.23.	User access logging	The system will log all user actions that modify its behavior. The log entry will include user name, action, time, and date of action.	Requirement	UR TS.56

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.13.7.24.	Critical function warnings	The system will warn users when they perform actions that might harm the operation of an entire TOC.	Requirement	Review FR TS.30 Changed to " The ATMS will warn user when they are about to perform actions which may affect signal operations such as timing changes, controller mode changes and downloading databases" by LA County, March 2002.
2.5.13.8.	**Scenario Management**			
2.5.13.8.1.	Inter-jurisdictional plan requests	The user interface will allow jurisdictions to request neighboring agencies to implement certain plans.	Requirement	NA
2.5.13.8.2.	Scenario response to incident support	The user interface will allow designated lead agencies to implement scenario response plans which cross jurisdictional boundaries.	Requirement	NA
2.5.13.8.3.	Inter-agency message exchange	The user interface will provide means for agencies to send electronic mail to other agencies.		NA
2.5.14.	**Network Management**			

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
2.5.14.1.	Network Management Systems - Local Level	Off-the-shelf Network Management software will be provided to manage the local TCS LANs.	Requirement	Review
2.5.14.2.	Network Management Systems - Regional Level	Off-the-shelf Network Management software will be provided to manage the Corridor and County WANs.	Requirement	NA
2.5.15.	**System Backup**			
2.5.15.1.1.	System Backup	Operators will be able to copy enough of each major system component (TCS, Corridor server, County server) to a backup medium to restore that component after a system failure.	Requirement	FR TS.139
3.	**Regional Servers**			
3.1.	**Corridor servers**			
3.1.1.	SGV Corridor server Capacity	The SGV Corridor server will need to support approximately 350 intersections within the Corridor.	Requirement	NA
3.1.2.	**Control Interface**			
3.1.2.1.	Configuration Manager	A “system configuration manager” tool will be provided to allow modification to system setup, including new TCS/CDI components, system layout, etc.	Requirement	NA
3.1.3.	**Data Available**			
3.1.3.1.	Real-time data	Status, main-street greens, and cycle timer data for corridor-level maps and displays will be collected by the Corridor server once per second.	Requirement	NA
3.1.3.2.	Cyclic data	Detector, congestion, and offset/split data for corridor-level maps and displays will be collected by the Corridor server once per cycle (if not running a cycle timer, will be collected once per minute).	Requirement	NA

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
3.1.3.3.	On-demand data	More detailed data will be collected by the Corridor server on an "as needed" basis.	Requirement	NA
3.1.3.4.	Static data	The Corridor server will collect aggregate detector data and TCS events/alarms and maintain the information in its static database.	Requirement	NA
3.1.4.	**Scenario Plan Library**			
3.1.4.1.	Libraries of plans available to all agencies	Libraries of plans will be maintained so that local agencies can match plans with neighboring agencies when regional efforts are in process.	Requirement	NA
3.1.4.2.	Scenario response plans	The Corridor server will maintain a list of "Scenario Response Plans" that may be implemented from the Corridor level as the result of incident response.	Requirement	NA
3.1.5.	**Event Notification**			
3.1.5.1.	Event Notification	The Corridor server can relay TCS and Corridor events to corridor-level operators.	Requirement	NA
3.1.6.	**External Interface**			
3.1.6.1.	External Interface	The Corridor servers will be able to provide data to external interfaces.	Requirement	NA
3.1.6.2.	Standard	A standard protocol (such as CORBA or NTCIP) will be used for external interfaces.	Goal	
3.1.6.3.	Caltrans interface	The system will be able to receive and process freeway data from the Caltrans intertie system.	Requirement	NA
3.2.	**County Server**			

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
3.2.1.	LA County Server Capacity	The County server will need capacity to support at least 1,520 intersections when all the corridors in LA County are connected to the system.	Requirement	NA
3.2.2.	**Control Interface**			
3.2.2.1.	Configuration Manager	A "system configuration manager" tool will be provided to allow modification to system setup, including new TCS/CDI components, system layout, etc.	Requirement	NA
3.2.3.	**Data Available**			
3.2.3.1.	Per-second Data From Corridor server	Main and side street green indications Coordination information: Cycle timer, cycle length, splits. Controller operational status: Plan number, operating mode, communications status.	Requirement	NA
3.2.3.2.	Per-minute Data From Corridor server	Latest VOS data from controller Detector fault status. Link Congestion	Requirement	NA
3.2.3.3.	Data from Caltrans Server	Traffic Counters Ramp Meters CMS	Requirement	NA
3.2.4.	**External Interface**			
3.2.4.1.	External Interface	The County server will be able to provide data to external interfaces.	Requirement	NA
3.2.4.2.	Standard	A standard protocol (such as CORBA or NTCIP) will be used for external interfaces.	Goal	NA
3.2.5.	**Information Exchange Network (IEN)**			

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
3.2.5.1.	Information Exchange Network (IEN)	All system components of the SGV Pilot Project will communicate via the IEN. Protocol definitions will be documented to assist in future component additions.	Requirement	NA
3.2.5.2.	IEN	The IEN will be implemented using a standard interface.	Goal	NA
4.	**Regional Operator Interface**	**ROI operational requirements are covered as part 2.5 requirement specification.**		NA
4.1.	Data Display	Refer to 2.5.3 requirement specification.		NA
4.2.	**Report Generation**	**Refer to 2.5.4 requirement specification.**		NA
4.2.1.	Region Report Generation	Operators at regional sites will be able to generate reports from data and events stored on the Corridor and County servers.	Requirement	NA
4.3.	**Event Notification**			
4.3.1.	Event Notification	The Corridor server can relay TCS and Corridor events to corridor-level operators.	Requirement	NA
4.4.	**Incident Management**			
4.4.1.	Incident declaration	Regional level operators will be able to declare an incident, which then becomes visible on L/C/ROI displays.	Requirement	System Integration
4.4.2.	Incident response	Regional level operators will be able to respond to incidents via “Scenario Response Plans".	Requirement	NA
4.4.3.	Incident Detection (Future)	The Corridor server will be designed to support future “smart” incident detection and management implementations.	Goal	NA
5.	**Command/Data Interface**			

ESGV Requirements	Name	Description	Type	I-5/Telegraph Road Requirements
5.1.	Command/Data Interface	CDIs will be used to interface existing Traffic Control Systems to the IEN, and will emulate the new Project TCS to the extent possible.	Requirement	NA
5.2.	**Functions Supported**			
5.2.1.	Functions Supported	Data and Control interfaces are subject to the capabilities of the existing Traffic Control Systems.	Constraint	NA
5.2.2.	**Local Data Access**			
5.2.2.1.	Local Data Access	CDI will translate existing TCS data into IEN format, available to all other TCS's in the Corridor.	Requirement	NA
5.2.3.	**Corridor Data Access**			
5.2.3.1.	Corridor Data Access	CDI will translate existing TCS data into IEN format, available to the Corridor server.	Requirement	NA
5.2.4.	**System Command Implementation**			
5.2.4.1.	System Command Implementation	CDI will translate "Scenario Response Plan" requests into TCS-specific commands and plans.	Requirement	NA
5.2.5.	**System Traffic Responsive Control**			
5.2.5.1.	CDI Traffic Responsive	If the client system is unable to use Corridor Data Access in its Traffic Responsive Algorithms, the CDI will run the traffic-responsive portion of the TAS and apply external plan change commands to the client system. (Future Enhancement, not required)	Goal	NA
5.2.6.	**Corridor Event/ Alarm Generation**			

ESGV Require ments	Name	Description	Type	I-5/Telegraph Road Requirements
5.2.6.1.	Corridor Event/ Alarm Generation	CDI will translate and interpret TCS-specific events and alarms, and will generate standard events and alarms to the IEN and Corridor server.	Requirement	NA
5.3.	**Systems Supported**			
5.3.1.	Series 2000		Requirement	NA
5.3.2.	**Caltrans ATMS**	**See 3.1.6.3 for Caltrans ATMS interface**		
5.3.2.1.	Freeway Status Information available to all agencies	Freeway status information from Caltrans is to be made available to all agencies in the system for purposes of incident detection and/or monitoring.	Requirement	NA

APPENDIX A

STANDARDS FOR FIELD-TO-CENTER COMMUNICATIONS

AB3418 and NTCIP

Overview

The essence of electronic communications can be described as having three essential attributes: Data Elements, Messages, and Protocols. We can think of Data Elements in much the same way that we think about words in our language. In a manner similar to the spelling, pronunciation, and definition of words, Data Elements contain an object name, syntax for use, and a description of how the data is defined. We can assemble Data Elements into Messages in much the same manner that we assemble words to form a sentence. A Message is an assemblage of Data Elements that carry a specific meaning. An example of a Message might be ***vehicle location*** consisting of individual Data Elements for ***vehicle ID***, ***altitude***, ***longitude***, and ***latitude***. Protocols are essentially sets of rules for how we move data from one place to another. One might think of an example like a two-way telephone conversation whereby I speak in a way that solicits a response, you then speak when I finish asking the question by providing the appropriate response, and then I speak again when you are finished acknowledging the response.

Two examples of communications protocols in the traffic signal and Intelligent Transportation Systems (ITS) community are AB3418E and the National Transportation Communications for ITS Protocol (NTCP). These protocols are described in the following Sections.

AB3418E

California Assembly Bill No. 3418 (AB 3418) became law on January 1, 1995. The bill requires all new or upgraded traffic signal controllers installed in California after January 1, 1996, to incorporate a standard communications protocol. As the State agency responsible for implementation of the bill, Caltrans has published a specification document entitled *Standard Communications Protocol for Traffic Signals in California* for use by developers of traffic signal controller software and by California users of traffic signal controllers.

The document states that the purpose of AB 3418 is to facilitate improved coordination and management of traffic signals in situations where adjacent signals are operated by different agencies. The protocol specified allows basic communication messages to be sent to and from multiple traffic signal controllers on the same communications channel, even if the controllers are of different types or utilize different software.

While AB3418 is intended to facilitate the coordination of traffic signals operated by different jurisdictions, the following are the key elements and repercussions of the legislation for agencies operating traffic signals in California.

- AB3418 establishes a means by which traffic signal controllers installed after January 1, 1996, can be communicated with through a non-proprietary, equipment independent, communications protocol (i.e. a standard protocol).

- There is no requirement to replace or retrofit existing controllers that are not being upgraded or replaced for other reasons.
- The AB3418 standard protocol supports remote control and monitoring functions only. The control function is to enable the maintenance of signal coordination with adjacent intersections. The monitoring function is to allow verification of controller operation.
- The AB3418 standard protocol does not provide comprehensive support of all control functions, including uploading and downloading.
- The AB3418 standard protocol does not replace or supersede existing communications protocols.
- The AB3418 standard protocol may coexist in a controller with any proprietary or otherwise non-standard protocol.

The AB3418 protocol is specifically intended for use at TRAFFIC SIGNALS that require remote operation, coordination, or monitoring. AB3418 requires provision of the standard protocol in all new and upgraded controllers. The controller may use the protocol to communicate with another controller, with a field master, or with a remote computer. Such other controller, master, or computer may be owned or operated by the same or a different agency.

A controller containing a communications protocol which otherwise meets all requirements of the AB3418 specification, may incorporate, within that protocol, additional capabilities, providing such additional features are not necessary for, nor impair, use of the basic features required by the specification. A protocol may, for example, provide additional messages. In this way, the standard protocol may be a subset of a more comprehensive, and possibly proprietary, protocol. The messages added to the base protocol for specific users needs may ultimately become candidates for adoption into the protocol standard at some later date.

It should be noted that AB3418 consists of a series of predefined messages that are exchanged using a protocol based upon an early draft of NTCIP. Unfortunately, a minor change was made in the NTCIP protocol, a minor change in a single protocol header parameter. As such, this subtle change prevents AB3418 and NTCIP from exchanging messages.

NTCIP

The NTCIP is a family of standards that provides both the rules for communicating (called protocols) and the vocabulary (called data elements or data objects) necessary to allow electronic traffic control equipment from different manufacturers to operate with each other as a system. The NTCIP is the first set of standards for the transportation industry that allows traffic control systems to be built using a "mix and match" approach with equipment from different manufacturers. Therefore, NTCIP standards reduce the need for reliance on specific equipment vendors and customized one-of-a-kind software. To assure both manufacturer and user community support, NTCIP is a joint product of the National Electronics Manufacturers Association (NEMA), the American Association of State Highway and Transportation Officials (AASHTO), and the Institute of Transportation Engineers (ITE). The NTCIP originated as the National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP) and is part of a larger effort to develop a family of ITS standards for use in all aspects of implementing the National ITS Architecture.

NTCIP standards are arranged in the form of Data Dictionaries, Message Sets, and Protocol Standards. Data Dictionaries describe the individual data elements that are exchanged between Centers and Field Devices. Message Set standards are generally used to describe how data elements are combined to form pre-defined messages to be exchanged. Message Set standards are typically used in Center-to-Center exchanges. Center-to-Field applications within NTCIP typically use a dynamic arrangement of messages as described in *Transportation Management Protocol*. For use in NTCIP, Protocol Standards have borrowed heavily from existing Internet Standards. Many of the existing Internet Standards are being applied directly for use within the ITS world.

NTCIP standards are developed in such a manner as to allow for flexibility and extension so that innovation can continue without restriction. The most readily observable method of extension is in the use of manufacturer's specific data elements that are created in a similar context to the standard. In practice, we find that all devices will have two sides to their Management Information Base (MIB), the underlying database structure within the device, consisting of the Standardized side and the Manufacturer's Specific side. The Standardized side of the MIB represents that core functionality essential to promoting interoperability and interchangeability. The Manufacturer's Specific side of the MIB represents functions that are beyond that defined in the standard. Such extensions may result from functions that are unique to specific manufacturers, agencies, or projects.

The key to successful implementation and long-term deployment of NTCIP rests in documentation. This is particularly important when referencing project critical functions that are beyond those standardized in the NTCIP documents. The importance of detailed documentation of MIBs, Data Elements, Messages, and Protocols used within a project will be recognized as invaluable when the time comes to expand the system.

Bandwidth Requirements

The following Table shows an example of how AB3418 compares to NTCIP using STMP when considering the number of drops per communications channel. As previously mentioned, AB3418 and NTCIP are quite similar in design and one would expect that an analysis would yield similar results when considering a similar message length. The Table shows this to be true when NTCIP uses STMP to implement dynamic objects with message content that is similar to that of AB3418. It is important to note that if STMP is not used the results for NTCIP will be dramatically lower.

Field Communications Analysis				
Parameter	AB3418 Status8 NoOvlap FullDup	AB3418 Status8 Overlap FullDup	NTCIP STMP Example NoOvlap FullDup	NTCIP STMP Exampl e Overlap FullDup
Transmission speed (bits per second)	9600	9600	9600	9600
Bits per byte	10	10	10	10
Primary Station:				
Ave bytes in non-overlapped part of normal polling message	6	1	8	1
Ave bytes in non-overlapped part of abnormal polling message	9	1	9	9
Proportion of polling messages abnormal	10%	10%	33%	33%
Proportion of bytes requiring mask byte	0%	0%	0%	0%
Time quiet (after last response) before start RTS	0	0	0	0
Time from start of RTS to start of CTS	0	0	0	0
Delay time from CTS to start sending polling message	10	5	9	5
Time from end of polling message to end of RTS	0	0	0	0
Time from end of RTS to quiet	0	0	1	1
Time (ms) to transmit polling message on average	7	1	9	4
Modem time before and after transmission of poll message (average)	10	5	10	6
Total time for each poll message on average	17	6	19	10
Reserve time at end of round	0	0	0	0
Secondary:				
Bytes in normal response message	24	24	18	18
Bytes in average abnormal response message	39	39	11	11
Proportion of response messages abnormal	10%	10%	33%	33%
Proportion of bytes requiring mask byte	1%	1%	1%	1%

Propagation delay	0	0	0	0
Normal response preparation time (end of poll message to start of RTS)	30	30	50	50
Abnormal response preparation time	50	50	50	50
Time from start of RTS to start of CTS	10	10	9	9
Delay from CTS to start sending response message	0	0	0	0
Time from end of response message to end of RTS	0	0	0	0
Time from end of RTS to quiet	1	1	1	1
Time to send response message on average	27	27	17	17
Modem and other delay times, per response message	43	43	60	60
Total time per response message (normal & abnormal)	70	70	77	77
10.1.1.398.1.1.1 One Second Round:				
Maximum number of secondary devices on channel	11.6	13.2	10.5	11.6
Rounded down	11	13	10	11
Design Number of devices per pair (TWP cable)	5	6	5	5

Note: Overlapping is a communication transmission technique that allows the Center to transmit its next message prior to the receipt of the response from the previously sent message.

APPENDIX B

How to Specify NTCIP

(Extracted from the NTCIP User Guide)

Introduction

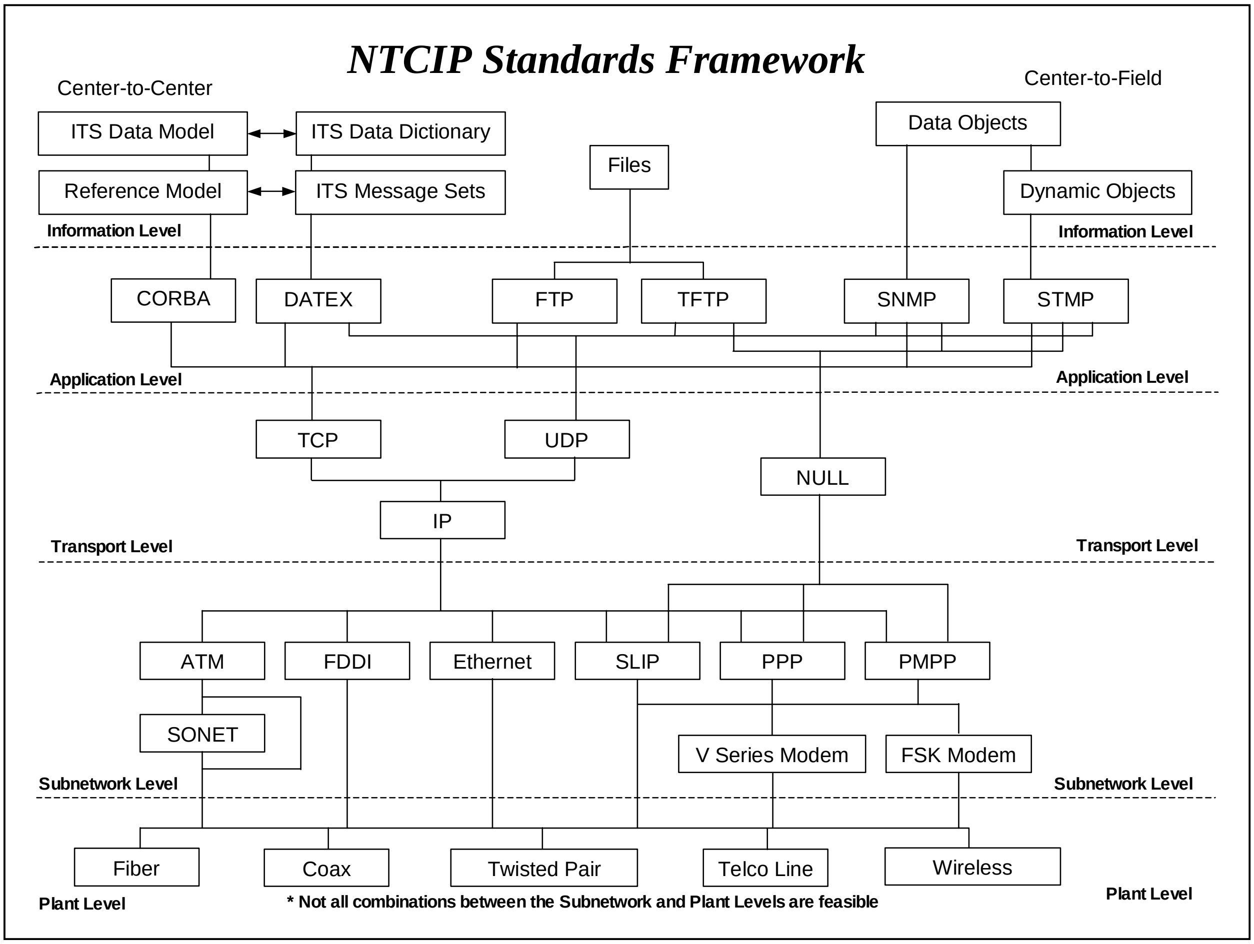
Developing successful procurement specifications is largely no different than developing procurement specifications for any other system component. The key to developing successful procurement specifications rests in having a good understanding of the Functional Requirements that the system must satisfy, and thoroughly documenting those requirements. Then, using a process such as that established in the *NTCIP Guide*, NTCIP requirements could be added to complete the procurement specifications. While it is not sufficient to simply state in our procurement specifications "the system shall be NTCIP compliant," much of the rigorous details can be left to systems integrator/manufacturer proposal submittals so long as good documentation procedures are observed.

Resources

Once we have determined and documented the Functional Requirements that the system must satisfy, we can turn our attention to documenting the NTCIP requirements. In order to do this, we must consult our NTCIP references. Reference resources are available in the library on the NTCIP website (www.ntcip.org) and include the *NTCIP Guide*, Case Studies documents, and the standards themselves. It is important to note that draft versions of emerging NTCIP standards that are nearing completion of the approval process (once user comments are solicited) can be found on the NTCIP website. Once the standards have been published, they are then only available through the Standards Development Organizations of AASHTO, ITE, and NEMA.

NTCIP Framework

One might consider it a daunting task to identify the standards needed in any single project when confronted with a family of more than 60 NTCIP documents. Recognizing the need to quickly home in on the documents needed for procurement specifications, a Framework was developed to aid those designing and specifying systems. The NTCIP Framework is the Figure shown below.



The Framework groups the associated NTCIP standards at each LEVEL. Starting at the bottom, let us review these levels:

- Plant Level – The Plant Level is shown in the NTCIP Framework as a means of providing a point of reference to those learning about NTCIP. The Plant Level includes the communications infrastructure over which NTCIP communications are intended. The NTCIP standards do not prescribe any one media type over another. In most cases, we will have a good idea as to what communications media we will be using in our system implementation.
- Subnetwork Level – Subnetwork Profiles define the rules and procedures for exchanging data between two 'adjacent' devices over some communications media. This is equivalent to the rules used by the telephone company to exchange data over a cellular link versus the rules used to exchange data over a twisted pair copper wire.
- Transport Level – Transport Profiles define the rules and procedures for exchanging the Application data between point 'A' and point 'X' on a network. This includes any necessary routing, message disassembly/re-assembly and network management functions. This is similar to the rules and procedures used by the telephone company to connect two remotely located phones.

- Application Level – Application Profiles define the rules and procedures for exchanging information data. The rules may include definitions of proper grammar and syntax of a single statement as well as the sequence of allowed statements. This is similar to combining words and phrases to form a sentence or a complete thought and defining the rules for greeting each other and exchanging information. These standards are equivalent to the Session, Presentation and Application Layers of the ISO seven layer stack.
- Information Level – Information Profiles define the meaning of data and messages and generally deal with ITS information (rather than information about the communications network). This is similar to defining a dictionary and phrase list within a language. These standards are above the traditional ISO seven-layer stack. This level represents the functionality of the system to be implemented.

Framework Path Selection Using the NTCIP Framework is simply a matter of identifying a path of connectivity through the diagram by connecting the Plant Level (bottom) to the Information Level (top). We typically use the Plant Level and Information Level as benchmarks from which to begin our navigation through the framework diagram because these two levels are readily known to us in most cases. At the Information Level we typically know what our application will be before we begin to develop our communications requirements. Remember that we documented the Functional Requirements of our system before we began to look at communication requirements. In many cases the Plant Level is also known to us either from the fact that we are handed an existing communications infrastructure to work with, or our budget constraints have led us to a particular media selection as we considered the Functional Requirements of the system.

Now that we have identified the Plant Level and the Information Level, we must begin to traverse the NTCIP Framework by asking ourselves a series of questions. First and foremost of these questions are whether our system will be one that communicates from one Center to another Center or from a Center out to Field devices. For Center-to-Center communications we will confine our selections to the left side of the NTCIP Framework. For Center-to-Field communications we will largely work with the right side of the NTCIP Framework, wandering to the left side as project requirements dictate.

Whether you begin at the top of the NTCIP Framework and work your way down or at the bottom and work your way up is a matter of preference and knowledge of NTCIP. Many find that it is easier to work from the bottom of the framework to the top because this approach more closely relates to readily identifiable project requirements. So, at the Subnetwork Level we must ask how our system will connect to the Plant Level? In the case of Center to Center, we will be using some high bandwidth approach that may even be proprietary along some segments. In the case of Center-to-Field, we must ask the same question but in a little different context. Will our Center-to-Field connectivity be through Point-to-Point (Center talking to individual Field device on a single channel), or Point-to-Multi-Point (Center talking to more than one Field Device on a single channel)? And, we must ask if our Center-to-Field communications system will use a Dial-Up approach or Direct Connect approach? Once we have answered these questions, our selections are then readily apparent.

At the Transport Level, the fundamental question is whether or not the system will need to support the routing of messages through intermediate devices or not? A subordinate question to ask if it is determined that routing is needed, is whether the connection established needs to be connection oriented (specified recipient with assurance of message receipt) or connectionless (broadcast with no assurance of message receipt)? In the case of

Center-to-Center, the common selections are TCP/IP. In the case of Center-to-Field to selections tend to vary depending on how the questions are answered. When using a direct connect approach, the Null Transport Level will be selected because no routing is likely required. When using a dial-up approach, then the typical selection is UDP/IP. Now, it really gets interesting when you have a system that uses a dial-up approach to connect to a Field Master and then a direct connect approach from the Field Master to subordinate devices. In this latter case, the dial-up side would use UDP/IP to connect to a Telco Line using a Point-to-Point V Series Modem and the direct connect side would typically use a Null Transport Level to connect to an agency owned Twisted Wire cable using a Point-to-Multi-Point FSK Modem.

At the Application Level, Center-to-Center questions diverge significantly from Center-to-Field questions. In the case of Center-to-Center, we must ask what protocol approaches our regional partners can buy into? CORBA (Common Object Request Broker Architecture) is an object-oriented approach where the data and methods of operation travel together. CORBA requires a data model that describes the data and pertinent associations. DATEX (Data Exchange) is a fixed message approach that uses a subscriber/publisher paradigm. The selection of either approach should be made on a regional basis. In the case of Center-to-Field, we must ask the question of whether we have any bandwidth constraints or not? That is, will we be attempting to pump a lot of data through a very small communications pipe in our Project? If we are using Twisted Wire then the answer is definitely 'yes' for transferring traffic signal controller data. The answer might be 'maybe' for dynamic message signs that use a dial-up connection. Nonetheless, our question really resolves to whether or not we have a need for a more bandwidth efficient version of the Center-to-Field protocol (SNMP) selected for our industry? If we do need a more efficient version of the protocol, or if we want the ability to support dynamic objects (messages), then our selection would be STMP (which also requires the support of SNMP to setup the dynamic objects).

Conformance Groups

Now that we have identified a path through the NTCIP Framework and made the appropriate selections at each Level, we must now gather the current version of the various NTCIP standards that relate to our selections. These standards will be referenced in our procurement specifications. Our next step will be go off and examine these standards for specific Conformance Requirements and selection of Optional Conformance Groups, selection of Optional Data Elements within each selected conformance group, and Range Values for data elements where such information is appropriate. To aid us in this effort, newer versions of the NTCIP standards are now using a PICS (Profile Implementation Conformance Statement) as a means of easily presenting conformance information. The PICS is really nothing more than a glorified checklist of all the Conformance Groups and Data Elements, showing their Range Values as appropriate.

Each of the NTCIP field device Data Dictionaries are setup in such a manner that all of the data elements are organized into various Conformance Groups. These Conformance Groups provide significant groupings for communicating functionality. Conformance Groups are designated as either Mandatory or Optional depending on device needs. We must select Optional Conformance Groups as necessary for communicating specific device functionality. It is important to understand that field devices may not support all of the Optional Conformance Groups.

Data Elements

Data Elements (referred to as 'objects' in older documents) are assigned to a conformance group and can be either Mandatory or Optional, depending on the need of the conformance group. Again, it is important to understand that field devices may not support all of the Optional Data Elements. Further, some of the Data Elements may depict distinctly opposite functionality. So, we must be careful to avoid simply asking for all of the optional data elements (or 'objects' as they are sometimes referred). We must carefully review the Data Elements, oftentimes in consultation with systems integrators and manufacturers, to determine which elements should be specified in our Project to obtain the desired functionality. It should be noted that some agencies have actually developed their own set of Data Elements that must be supported in field devices when used in their agency. These Agency Specific Data Elements that are outside the published standards would be treated in the same manner as Manufacturer Specific Data Elements (extensions to the standard).

Range Values

It is also important to consider appropriate Range Values to meet the needs of the intended implementation. Specifying the entire Range Value might be inappropriate. For example the Maximum Number of Phases data element in the NTCIP 1202 – *NTCIP Objects for Actuated Signal Controller* data dictionary has a maximum range of 0 to 255, however, no manufacturer has a controller with 255 phases…yet. The *NEMA TS2 Traffic Controller Assemblies with NTCIP Requirements* has recommended a minimum range value of 8 for the Maximum Number of Phases data element. Field device data dictionaries might reference other standards and these should be carefully reviewed for inclusion into procurement specifications. One example is that many of the common field device data elements have been captured in the *NTCIP 1201 – Global Object Definitions*.

Manufacturer Specific Extensions

The field device functionality covered in many of the standards represent some minimum level of functionality to be communicated. Manufacturers often develop special features to support their users and these data elements would need to be referenced as Manufacturer Specific Data Elements. Discussions with manufacturers regarding Manufacturer Specific Data Elements would be appropriate when preparing our procurement specifications.

PICS

The easiest way to get to a successful long-term implementation of NTCIP is to work with the systems integrator or equipment manufacturer(s) to arrive at a well document PICS for not only what is in the standard, but also for what will ultimately be implemented in the Project. This will also include any manufacturer specific extensions required for your Project implementation. During the bid solicitation or proposal process, a PICS can be required showing area covered by the NTCIP standards and specifically highlighting functional areas that are outside of the standards. The bid documents or proposal submittals should also include a relative order of magnitude of new development work required to implement any Project specific functionality, along with agency access to the communications data required for Project support.

Specification Development

At this point we are ready to assemble our procurement specifications. The boilerplate, format, and introductory information will be left to individual agency requirements. A detailed description of the Functional Requirements should be cited. The NTCIP requirements could show the NTCIP Framework diagram highlighting the path that we have chose for our Project and references to the appropriate NTCIP standards that we have selected to support the path diagramed. We would also include a PICS showing the minimum requirements for our Project implementation and a blank column for the systems integrator or manufacturer(s) to show compliance. Next, we would include language that requires the systems integrator or manufacturer(s) to respond to any Project specific requirements that require manufacturer specific data elements. Lastly, we would include our documentation, training, warranty and licensing requirements.

Earlier it was mentioned that good thorough documentation is a key to the successful long-term implementation of NTCIP. We should ensure that our procurement specifications request the following items, at a minimum:

- An electronic copy of the entire NTCIP Management Information Base (MIB) that includes both standardized data elements and required manufacturer specific data elements;
- An AS-BUILT Profile Implementation Statement (PICS) that reflects the Field Device conformance to all relevant NTCIP standards and manufacturer specific extensions;
- Documentation of the range values for all data elements supported by the Field Device in the PICS; and
- Documentation of all relevant dialogs, data associations, sequences, and other information necessary to ensure interoperability.

Finally, we should not forget that this might only be the first in a series of many projects where the Field Devices purchased today will need to communicate with devices from other manufacturers in the future. Our procurement specifications must set the stage for systems integrator(s) and manufacturer(s) to understand the reality of making our Project a long-term success. To this end, we will need to work out some arrangement for perpetuating the manufacturer specific data elements required for our Project to other projects and other systems integrators/manufacturers in the future. The specifics of what can be done in this regard will tend to vary from agency to agency.